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OPERATIONS PLAN FOR THE KATMAI DRILLING PROJECT

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ABSTRACT

This document describes the operations, logistics, and permitting requirements for constructing three scientific core holes in the Valley of Ten Thousand Smokes in Katmai National Park, Alaska. Two of the core holes will be located close to Novarupta Dome near the center of the historic volcanic eruption of 1912. One core hole near the dome will be drilled vertically to approximately 4,000 ft. The other core hole will be deviated 30 degrees from the vertical hole and will reach a depth of approximately 3,300 ft. The third core hole will be remote from the dome site, will also be deviated 30 degrees, and will reach a depth of approximately 660 ft. The objectives of the proposed core holes are to determine the chemical and physical behavior of magma in its host rock during eruption and intrusion, to determine the source, mechanism, and conditions of metals transport, and to measure the current subsurface temperature distribution to test models for the cooling of igneous systems.

The well designs include a riser and conductor pipes, surface casing, and a full blowout preventer system. The drilling and coring operations will occur over two summer seasons with a shutdown during the intervening winter. Because of the remoteness of the field site, the operation must be mobilized, supplied, and demobilized by helicopter and supported by a camp near the dome. Baseline data provided for the area include descriptions of

the geology, geochemistry, hydrology, climatology, air quality, and impact on flora and fauna. Environmental safeguards and operational safety are emphasized. The discussion of environmental safeguards includes procedures for environmental preservation and plans for fluid management, spill prevention, monitoring, and site restoration. The discussion of operational safety includes professional conduct standards, well control, helicopter safety, and emergency training. The project will be conducted in a manner that has negligible long-term impact on the environment.

The Interagency Coordinating Group (ICG) is responsible for the planning and funding of this project as well as for consequent scientific studies. The ICG consists of representatives from the U.S. Department of Energy/Office of Basic Energy Sciences (DOE/OBES), the U.S. Geological Survey, and the National Science Foundation. The drilling and coring will be funded principally through the DOE/OBES. The ICG has requested a permit from the National Park Services (NPS) to conduct the operation. The project will also require permitting by other federal agencies and the State of Alaska. The NPS will consider the ICG permit request through the National Environmental Policy Act (NEPA) process. This document is a requirement of the NEPA process.

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ACRONYMS

ADEC	Alaska Division of Environmental Conservation
COE	U.S Army Core of Engineers
CPR	Cardiopulmonary Resusitation
DOE	U.S. Department of Energy
DOE/OBES	U.S. Department of Energy/Office of Basic Energy Sciences
DOI	U.S. Department of the Interior
EIS	Environmental Impact Statement
EMS	Emergency Medical Service
EPA	U.S Environmental Protection Agency
GRDO	Geoscience Research Drilling Office
ICG	Interagency Coordinating Group
NAS	National Academy of Science
NEPA	National Environmental Policy Act
NOAA	National Oceanographic and Atmospheric Administration
NPS	National Parks Service
NSF	National Science Foundation
OSHA	State of Alaska Occupational Health and Safety Administration
SCBA	Self-Contained Breathing Apparatus
USGS	U.S. Geological Survey

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 measurements of the 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) that 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, "Direct Observation of a Young Igenous System: A Science Plan for Research Drilling in Katmai National Park, Alaska" (Eichelberger et al., 1989; Simon et al., 1988), outlines and describes the core drilling and scientific research necessary to investigate active volcanic processes at Katmai, Alaska. Katmai is the site of the historic volcanic eruption in 1912. Primary objectives of the project are the following:

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

2. to investigate geochemical profiles of the deposits not yet degraded by weathering or alteration to determine the process in which metals contained in the magma were transported and concentrated by gases following the eruption; and

3. to identify the processes and speed of the cooling of igneous rock by the 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 eruption in 1912 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 Science (NAS) (NAS, 1989).

This drilling project will extract core continuously. The project will perform down-hole scientific measurements in 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

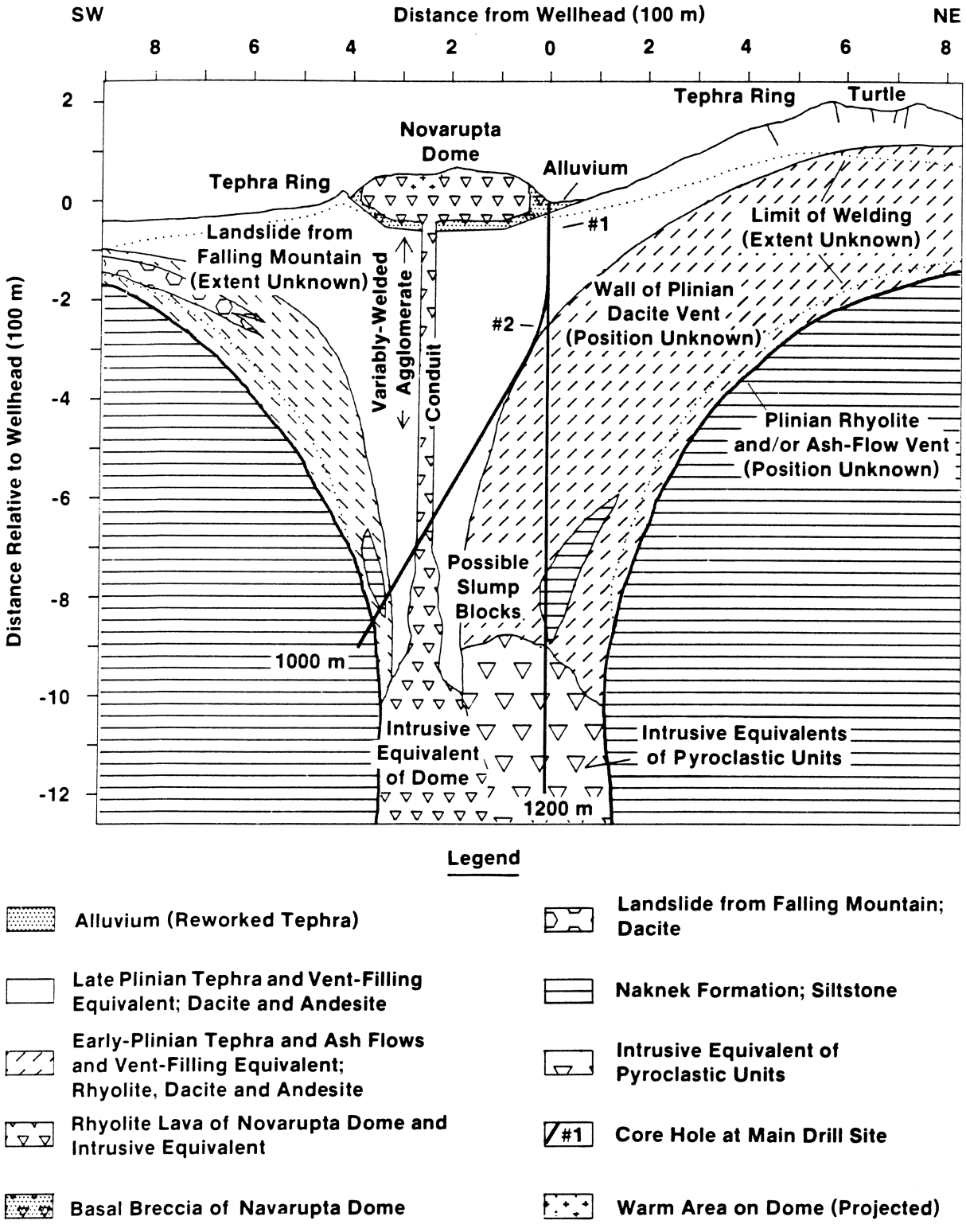


Figure 1-1. Illustration of the Geologic Objectives of the Proposed Core Holes. The schematic cross section of the vent shows the two wells at Novarupta Dome.

stratigraphy and temperature regimes of the vent. The other core hole at the vent side- tracked 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 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. Remote from the dome site, the third core hole will be drilled at a 60-degree angle from the surface to approximately 660 ft (200 m) 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). This consortium is presently conducting an integrated geologic and geophysics 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. 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. The surface-based geologic and geophysical portions of this program are nearing completion and data are being analyzed. A more comprehensive permit application is necessary for drilling and this Operations Plan is a part of this 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 behavior of the planet. Results from the scientific research at the Katmai site will find application in evaluating the hazards of explosive volcanoes and should be applicable elsewhere in finding and utilizing ore deposits and geothermal energy.

Ultimate responsibility for planning and funding the project lies with the Interagency Coordinating Group (ICG) and its constituent agencies: the U.S. Department of Energy/Office of Basic Energy Sciences (DOE/OBES), the USGS and the NSF. The USGS Branch of Alaska Geology 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 for the Katmai Drilling Project. 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 goals set by the Science Plan are 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 will be a significant logistical effort operating within stringent safety and environmental constraints. Due to the remoteness of the site, the operation will be supported by helicopter

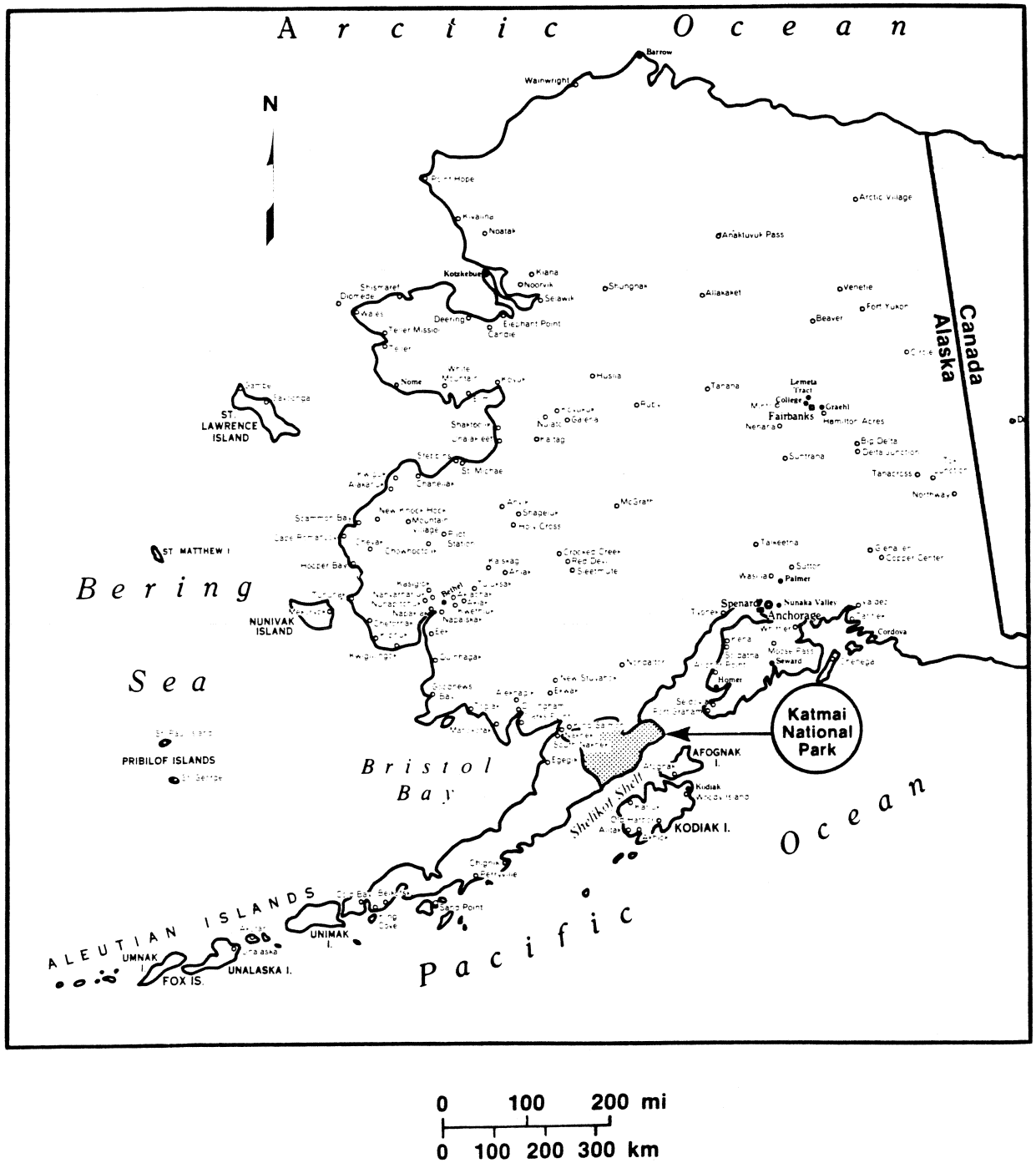


Figure 1-2. Map Including Katmai National Park; the Bristol Bay Area; Naknek, King Salmon; and the Anchorage Area

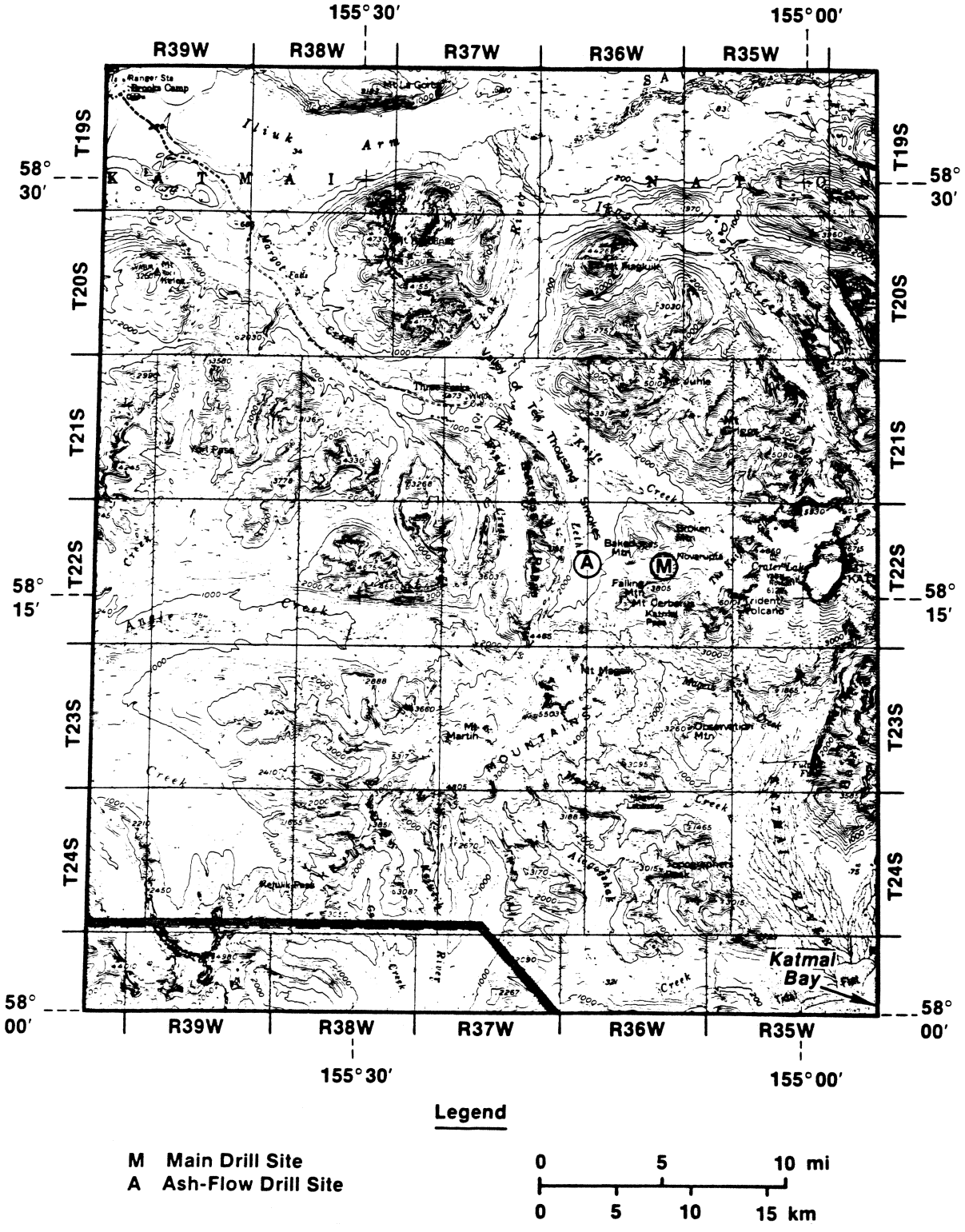


Figure 1-3. Map Showing the Location of Novarupta Dome Within Katmai National Park; Brooks Camp, the Valley of Ten Thousand Smokes, Katmai Pass, and Katmai Bay Tidal Flats on the Pacific Ocean

Table 1-1

Summary of Proposed Core 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 Mid-distance Sampling Fissure Fumarolic Deposits	Distance from Vent Distribution of Fumarolic Deposits "Sand-Line" Development

flights and a camp. The equipment for this project could be mobilized and barged from the Seattle and Anchorage areas.

The site is environmentally sensitive because it is within both a national park and a wilderness area; however, other drilling operations have been successfully completed in sensitive areas. Because of the recent volcanism in the area, high drilling temperatures may be encountered and current drilling technology will be exercised to the fullest extent. The NPS and the State of Alaska (among others) will monitor all phases of the operation. Informal discussions with permitting agencies are currently taking place (Chapter 2.0). Some of these agencies have reviewed the draft version of this Operations Plan: the Alaska Regional Office of the National Park Service in Anchorage; the Katmai Park Office of the NPS in King Salmon; the Water Resources Division of the NPS in Fort Collins and Denver; the U.S. Bureau of Land Management in Anchorage; the U.S. Environmental Protection Agency (EPA) in Anchorage; the Division of Governmental Coordination of the State of Alaska; and various divisions in

both the Alaska Department of Environmental Conservation and the Department of Natural Resources in Anchorage.

Government monitoring will continue during the permitting process and will include the physical presence of authorities during actual drilling operations. Numerous government agencies will have permitting jurisdiction.

This Operations Plan provides a detailed description of the proposed operations essential to the successful commencement and completion of the project. Also, this document provides drilling information to permitting agencies. It is anticipated that as a result of the permitting process and discussions with personnel from permitting agencies, minimal impact on the environment will be ensured.

One purpose of this document is to initiate the National Environmental Policy Act (NEPA) process. Other supporting documents are the statement issued by the NAS discussing the uniqueness of the Katmai site (NAS, 1989), and a letter of intent from the ICG. (In addition to the review by the NAS, the Katmai Science Plan has been reviewed by (1) individual experts under contract to the DOE/OBES and the NSF, (2) the DOE/OBES Continental Scientific Drilling Program Review Group, (3) the NSF Science Advisory Committee, and (4) the ICG Katmai Science Experiments Panel.) As part of the NEPA process, the NPS began a formal review and evaluation of the drilling project and will manage preparation of 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 content of this document is structured to conform to specific requirements from the NPS in accordance with 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 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 to the environment (State of Alaska, 1986). Both the NPS and the State of Alaska share concern and permitting authority over all environmental aspects of the proposed operation.

The proposed management of the project is discussed in Chapter 2.0. Chapter 3.0 describes the permitting and compliance requirements in detail, along with approaches to solutions concerning legal issues. Chapter 4.0 provides a general description of the area, its geology, geochemistry, and hydrology with appropriate maps, drill site layouts, and camp layouts.

The core hole design and planned drilling operations are based on the geological site description provided in Chapter 5.0. The scientific goals and drilling objectives of the project are included in Chapter 6.0. Preliminary core hole designs and the drilling operations are described in detail in Chapters 7.0 and 8.0. These hole designs and drilling procedures were prepared in part with data from a recent scoping that was performed jointly by the GRDO and Tonto Drilling Services. Chapter 8.0 discusses proposed drilling fluids, lost circulation, fluid management, and the

advanced engineering that will be performed prior to fielding. A broad overview of major safety issues is provided in Chapter 9.0.

Chapter 10.0 describes 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 also included. A spill prevention and a containment plan concerning petroleum products, drilling fluids, and drilling fluid additives is provided.

Helicopter and camp operations to support the project are discussed in Chapter 11.0. Chapter 12.0 includes plans for field camp operations. Helicopter and camp operations have been planned to comply with environmental health, safety, and economic constraints. Transportation information has been gathered from detailed discussions with helicopter, camp, and barge companies operating in Alaska and the Department of Interior Office of Aircraft Services in Anchorage. Site support functions that will take place in King Salmon are discussed in Chapter 13.0. A site restoration policy and plan is provided in Chapter 14.0. Benefits to the park as a result of the project are suggested with reference to cultural resource, social, economic, and environmental consequences. Data evaluating the impact to the meteorology, climatology, air quality, fauna, and flora of the area are provided in Chapter 15.0.

The ICG agencies will conduct the project in accordance with professional and federal and state environmental and safety standards. The scientific goals of the Katmai Drilling Project must be attained in a manner that has a negligible long-term effect on the environment.

This document gives the scope and magnitude of Katmai Drilling Project operations. Plans were developed based on the experience of the GRDO, industry advisors, experienced consultants, Alaska-based experts in the drilling industry, the permitting agencies, and industry personnel experienced in drilling and coring at high temperatures. In certain instances, exact details must await the hiring of contractors for drilling, helicopter, camp, environmental, and other operations. A team of project and contractor personnel will make these final decisions, with critical input provided by the permitting agencies and the actual permitting process.

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 with representation from the three federal agencies that are major sponsors of the Continental Scientific Drilling Program: the DOE, USGS, and NSF. An Interagency Accord for Continental Scientific Drilling was reached between these sponsoring agencies constituting the ICG, which was formed to coordinate scientific drilling efforts within these agencies. The ICG constituency consists of academia, the USGS, and national laboratories, with occasional input from foreign scientists. The Principal Investigators of this drilling project are John C. Eichelberger at Sandia National Laboratories, Wes Hildreth at USGS, and James J. Papike at the University of New Mexico. Thomas P. Miller and Christina Neal of the USGS Branch of Alaska Geology in Anchorage serve as a liaisons 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 NPS will have ultimate and full authority over the conduct of the operation. The USGS will provide a liaison between the NPS and the operator. The DOE will be the legal operator with the Sandia National Laboratories GRDO as the agent. Thus the USGS will transmit all NPS directives to the GRDO for implementation, and the USGS will be accountable to the NPS for the implementation of those directives. The GRDO 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. The 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.

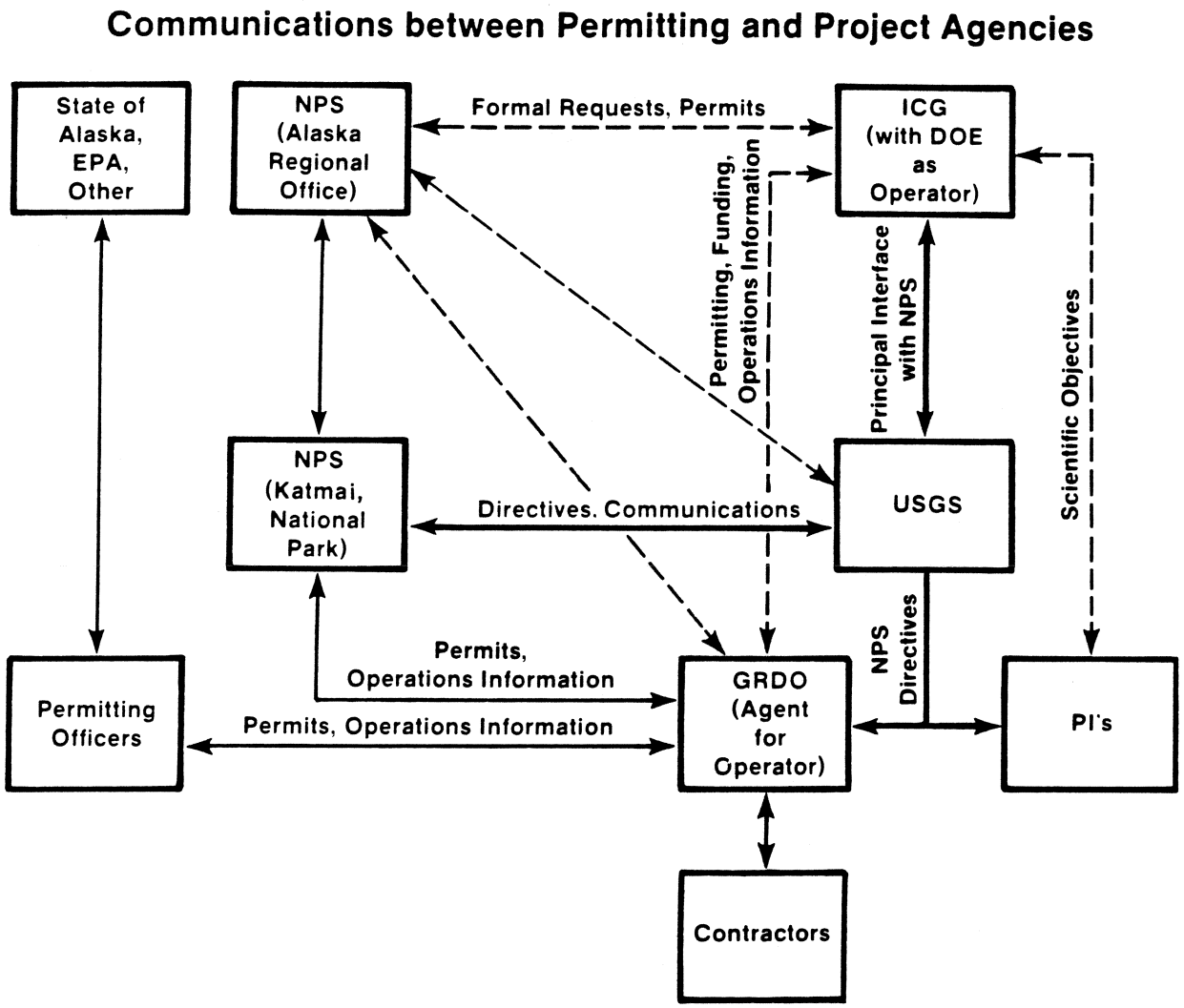


Figure 2-1. Diagram of Communications Between the Project and Permitting Agencies Such as the NPS and the State of Alaska

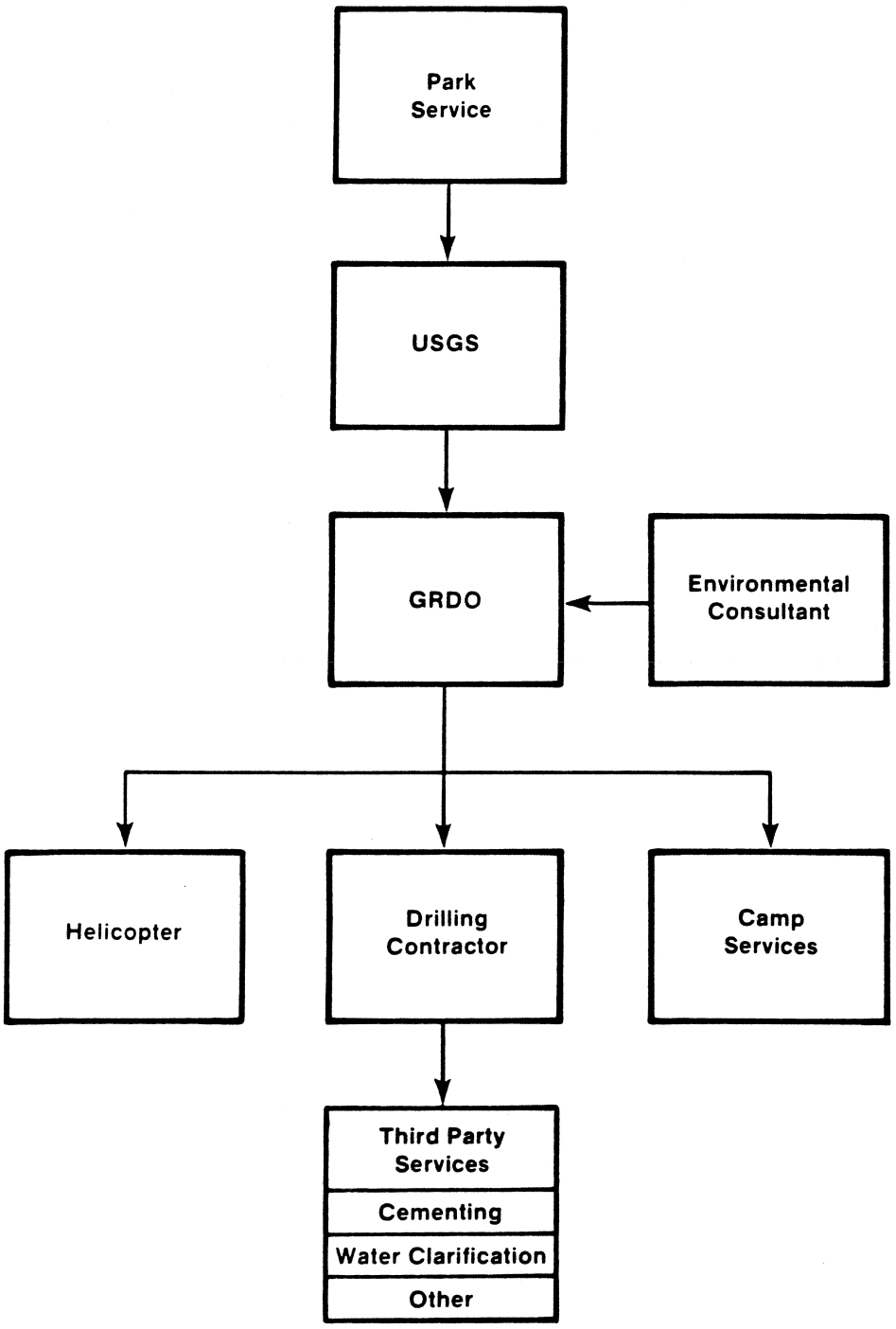


Figure 2-2. Diagram of the Principal Fielding Agencies and the Principal Contractors

3.0 PERMITTING COMPLIANCE AND LEGAL ISSUES

The ICG has formally requested a permit from the NPS to conduct the Katmai Drilling Project. The NPS will take steps under the NEPA to consider the request. A Notice of Intent will be filed stating that the NPS will consider the request for a permit. The NPS will issue a Request for Quotations for a contractor to conduct the EIS. The EIS and the public hearings attendant to its publication will be major factors influencing the NPS decision to issue a permit.

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 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) will be provided through an Operations Plan. Subsequently, the NPS requires that an EIS is prepared and that additional drilling requirements are met. Information requirements for oil, gas, and other drilling activities are contained in 36 CFR 9(B). Largely, this Operations 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 resources, and environmental consequences. Information involving some of the latter categories will also be included in the EIS.

The Division of Oil and Gas of the Alaska Department of Natural Resources 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 (State of Alaska, 1986). These geothermal drilling regulations cover the administrative and technical issues 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 National Parks Service (NPS)

An oil spill prevention plan is required by the EPA and 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 permit from the COE. The Bureau of Land Management has no formal permitting requirements, but has requested that they be provided with all technical information.

Table 3-1

List of Permitting Agencies

National Park Service, Regional Office, Anchorage, Alaska	Requires a general use permit and water permit.
National Park Service, Katmai National Park Office, King Salmon	Manages and enforces all conditions of the general use permit.
National Park Service, Water Resources Division, Denver and Fort Collins, Colorado	Reviews the Operations Plan, advises the regional park offices on various aspects of the operation.
U.S. EPA, Water Quality Control Section, Anchorage, Alaska	Informally communicates with project activities and is updated on project activities.
U.S. EPA, Seattle, Washington	Requires a waste generators permit (and a possibly others).
U.S. Army Corps of Engineers, Regulatory Branch, Anchorage, Alaska	Requires a wetlands determination (and a possible permit to take the core).
U.S. BLM, Branch of Mineral Operations, Anchorage, Alaska	Informally communicates with project personnel and is updated on project activities.
U.S. Fish and Wildlife Service, Alaska Peninsula/Becharof National Wildlife Refuge, King Salmon, Alaska	Informally communicates with project personnel and is updated on project activities.
Alaska Division of Governmental Coordination, Anchorage, Alaska	Informally communicates with project personnel and is updated on project activities.
Alaska Department of Environmental Conservation, Division of Environmental Health, Anchorage, Alaska	Requires permits for the camp (food service, etc.), water supplies, and disposal of grey water.
Alaska Department of Environmental Conservation, Division of Environmental Quality, Anchorage, Alaska	Requires permits for liquid waste from drilling, wastewater from camp, and solid waste. An optional oil spill contingency plan will be filed. Coordinates the EPA waste generator permit for the state. Requires a permit to burn, a burn plan, and possibly a permit to run generators.

Table 3-1

List of Permitting Agencies (Concluded)

Alaska Department of Natural Resources, Division of Oil and Gas, Anchorage, Alaska	Requires a drilling permit.
Alaska Department of Natural Resources, Division of Land and Water Management, Anchorage, Alaska	Requires a water use permit.
Alaska Department of Fish and Game, Habitat Division, Anchorage, Alaska	Informally communicates with project personnel and is updated on project activities.
Alaska Department of Fish and Game, Game Division, King Salmon, Alaska	Informally communicates with project personnel and is updated on project activities.
Alaska Department of Labor, Division of Labor Standards and Safety	Enforces compliance with Alaska/Federal OSHA standards and regulations.
Lake and Peninsula Borough	Has not identified requirements; is currently organizing.

3.3 Permitting for the State of Alaska

The following issues will require surveillance by the State of Alaska. (The NPS and the State of Alaska will share authority over the majority of these items, because the NPS concerned with the entire operation.)

- Water Use Water use will require a permit from the Water Management Section of the Alaska Department of Natural Resources and the NPS. The state 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 600 kW (800 kW when heating is required for the waterline). There will be similar concerns for waste incineration (mainly paper and wood products, but no hazardous materials). Concerns for waste incineration include optimal combustion of any burned material, proper training of any project personnel for conducting the combustion, and visibility of resulting

smoke. A burn plan will be filed with the NPS and the state (Appendix A). A monitoring program will be in place to monitor for evidence of any hydrogen sulfide produced from this operation (Section 10.4, Appendix B).

- 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 600 kW power generated at the site, but noise abatement procedures may be requested by the NPS when 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 to maintain the operation for 10 days. For example, the drilling rig and the camp will consume less than 500 gal of diesel fuel per day. There will be up to 7,500 gal of diesel fuel stored onsite. Up to 100 gal will be needed at pumping and heating stations for lifting the water from the source to the drill rig. Another 400 gal of diesel fuel will be needed at these sites if the water must be heated to prevent freezing. Also, approximately 500 gal of gasoline will be stored onsite for pumps supporting the drill rig. Finally, approximately 2,000 gal of jet fuel will be stored onsite to refuel helicopters in an emergency. A contingency plan to mitigate spills is required by the NPS. The ADEC Division of Environmental Quality requires such a plan only if the amount of fuel involved is 10,000 bbl (42,000 gal) or more. A contingency plan is contained in this document, which will be on file with the Division of Environmental Quality. (The required EPA spill prevention plan outlined in 40 CFR 112 and the contingency plan for spills outlined in 18 AAC 75 are in Chapter 10.0 and Appendix C.)

- Hazardous Materials Permits will be required for hazardous materials from the ADEC Division of Environmental Quality and the EPA. Drilling fluid additives in concentrated form may require permitting. However, no hazardous materials will be employed or stored onsite. Mixed and used drilling fluids are nonhazardous. While no toxic materials will be brought onsite, there is small chance that connate fluids or solids (cuttings) brought up during drilling could be toxic. Therefore, the project will apply for an EPA (small quantity) Waste Generator number to allow the project to properly handle this material in the unlikely event that handling such material is necessary. Both the EPA and ADEC Division of Environmental Quality will be involved.

- 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 8.0.

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

- Affected Animal Life The U.S. Fish and Wildlife Service and the Habitat Division of the Alaska Department of Fish and Game have at this time no formal permitting requirements for the operation, although they may be called in by the NPS, the COE, or other permitting agencies. The U.S. Fish and Wildlife Service and the Alaska Department of Fish and Game have requested to be informed of project proceedings and will 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. Waterfoul will be minimally affected by the operation. Snow buntings nest around Novarupta Dome in the summer. Careful selection of helicopter routes can minimize the impact on mammals and waterfowl.

- 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. A grey water drain field will require permitting by the ADEC Division of Environmental Health.

- Cultural Artifacts The Office of History and Archaeology of the Division of Parks and Outdoor Recreation 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.

- Coastal Zone The Alaska Division of Governmental Coordination has informed the project that the activities centered at the proposed drill sites are outside of the coastal zone.

Separate permits are not presently required for the excavation of cellar, pits, and sumps, but are included in the drilling permit from the NPS and the State of Alaska. The project will contract with an independent environmental contractor to ensure 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

The DOE/OBES is the operator for the project. The GRDO at Sandia National Laboratories has been designated by the operator to carry out all field activities on behalf of the operator under a contractual agreement with the DOE.

The operator will be held responsible for the Katmai Drilling Project's compliance with existing statutes and regulations concerning the actual

drilling, coring, logging, monitoring, and associated logistical support operations. The operator will be responsible for all project activities regarding the protection of the environment and compliance with safety laws, regulations, and professional standards.

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. 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 NPS and the State of Alaska have asked the GRDO for bonds to ensure that funds will be available to clean up accidents and to properly abandon the site. The GRDO, the DOE/OBES, and the USGS are currently reviewing various alternatives to bonding that will provide these assurances. As a first step the project proposes to reserve $100,000 for accident mitigation and reserve sufficient funds for a two- to three-year monitoring program.

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 eruption in 1912. 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 covered 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 a 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 in places 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 in actively alluviating areas as much as possible. In fact, all project activities will be confined to bare pumice where possible.

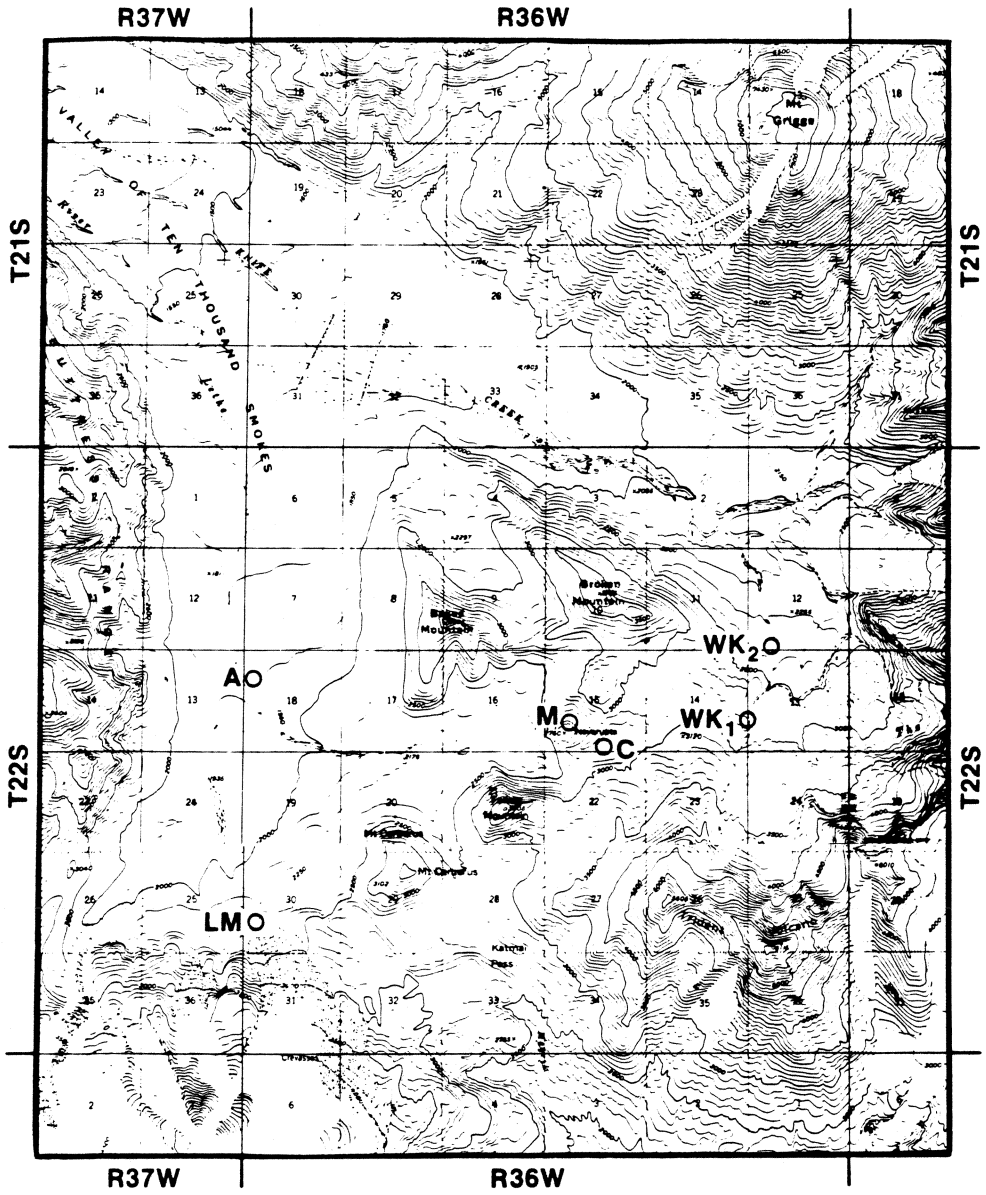
The target of the core hole at the ash-flow site is the ash-flow sheet. The vicinity has low relief; normally dry channels connect with the River Lethe. The surface material is primarily reworked pumice and ash. There is little vegetation.

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 Figures 4-2 and 4-3.

4.3 Drilling Site Layouts

The proposed drill pad at the Novarupta Dome site is in a suitable level area, which is east of the dome and 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. Thus the vegetated areas within the dome will generally remain undisturbed. Figure 4-5 shows typical coarse pumice at the proposed drill pad site.



Legend

C Camp	WK Knife Creek Water Source
M Main Drill Site	LM Lake Mageik Water Source
A Ash-Flow Drill Site	

0 1 2 3 mi

0 1 2 3 4 km

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

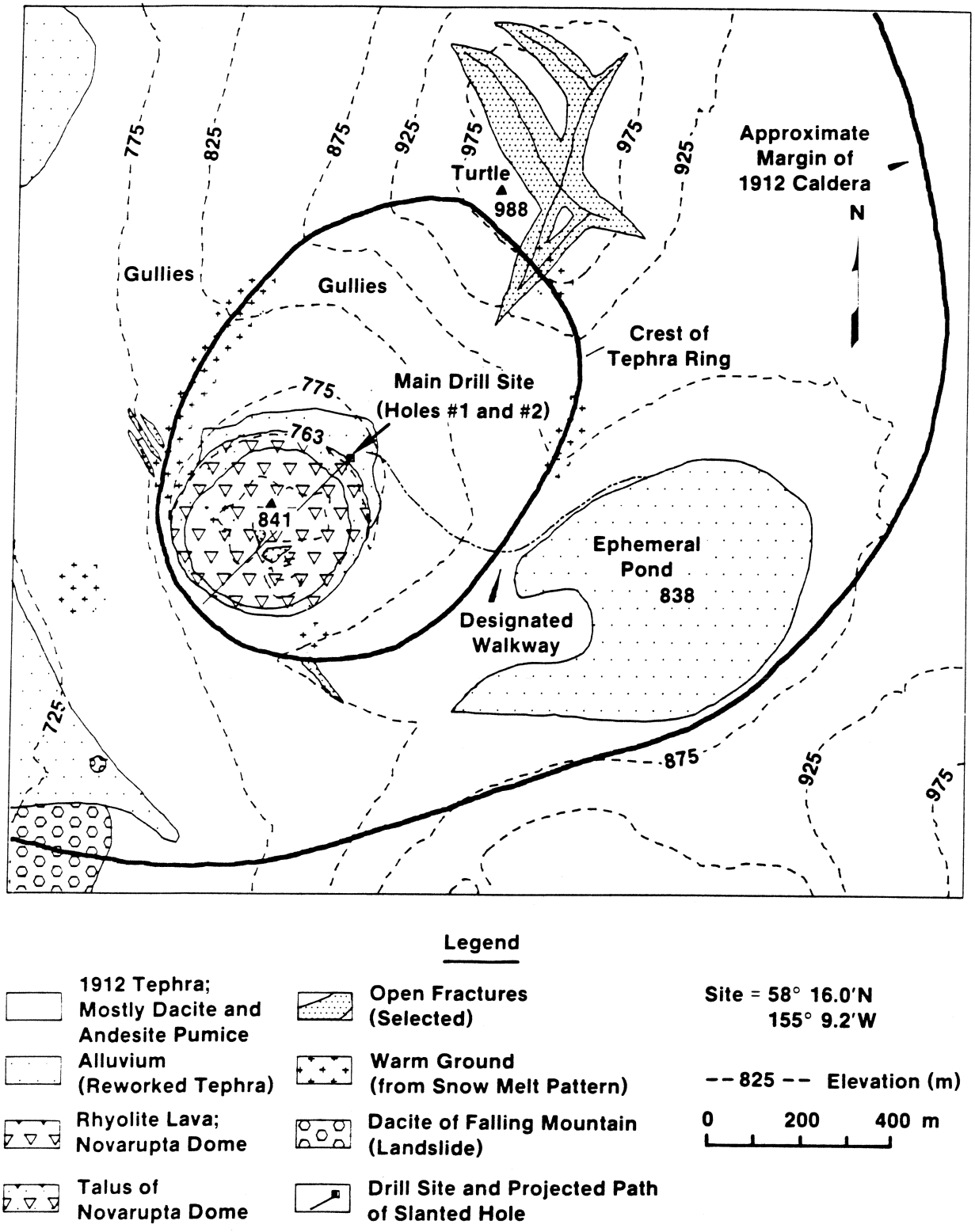


Figure 4-2. Locations of the Drill Site and Possible Campsite Near the Dome

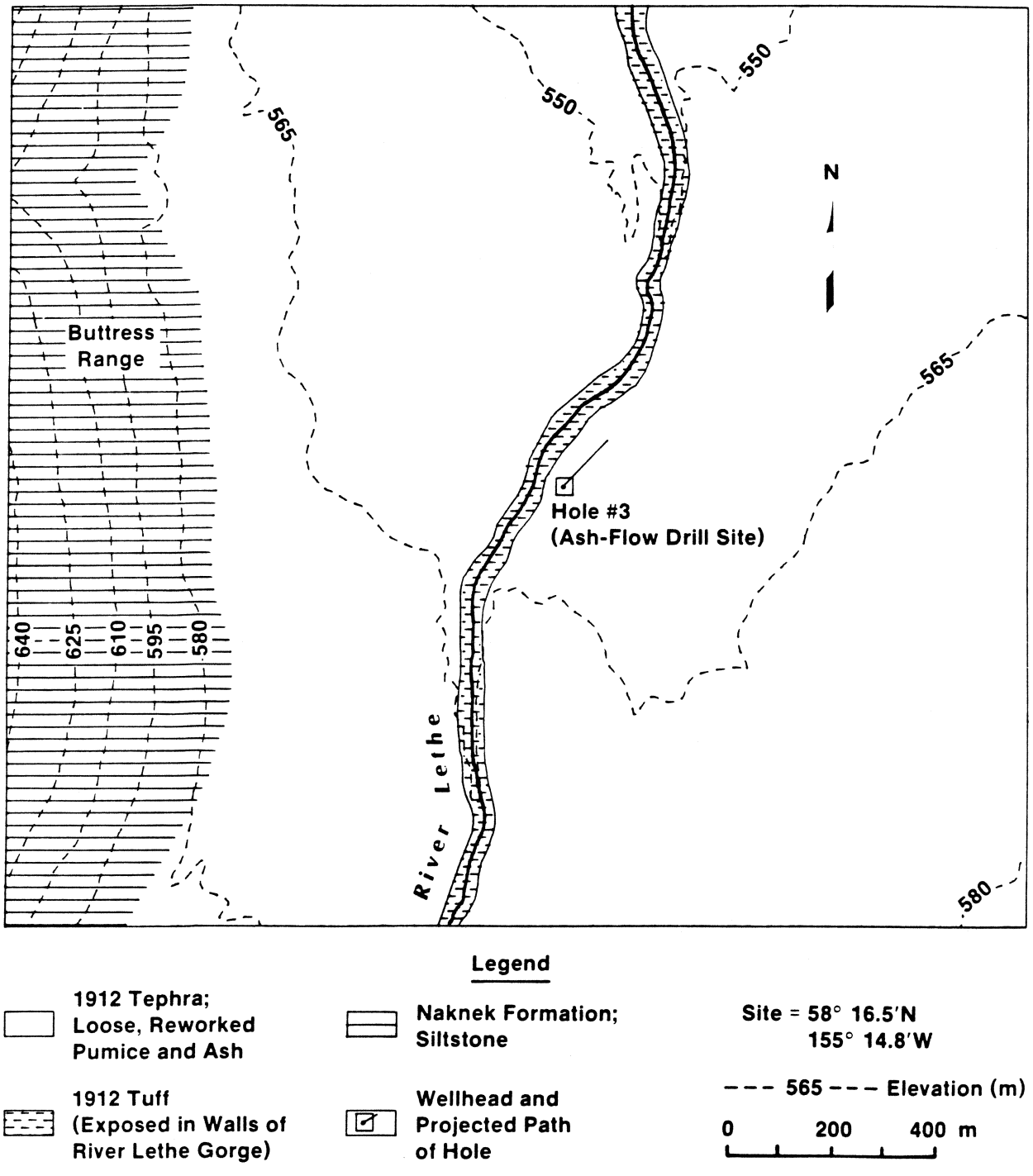


Figure 4-3. Location of the Ash-Flow Site

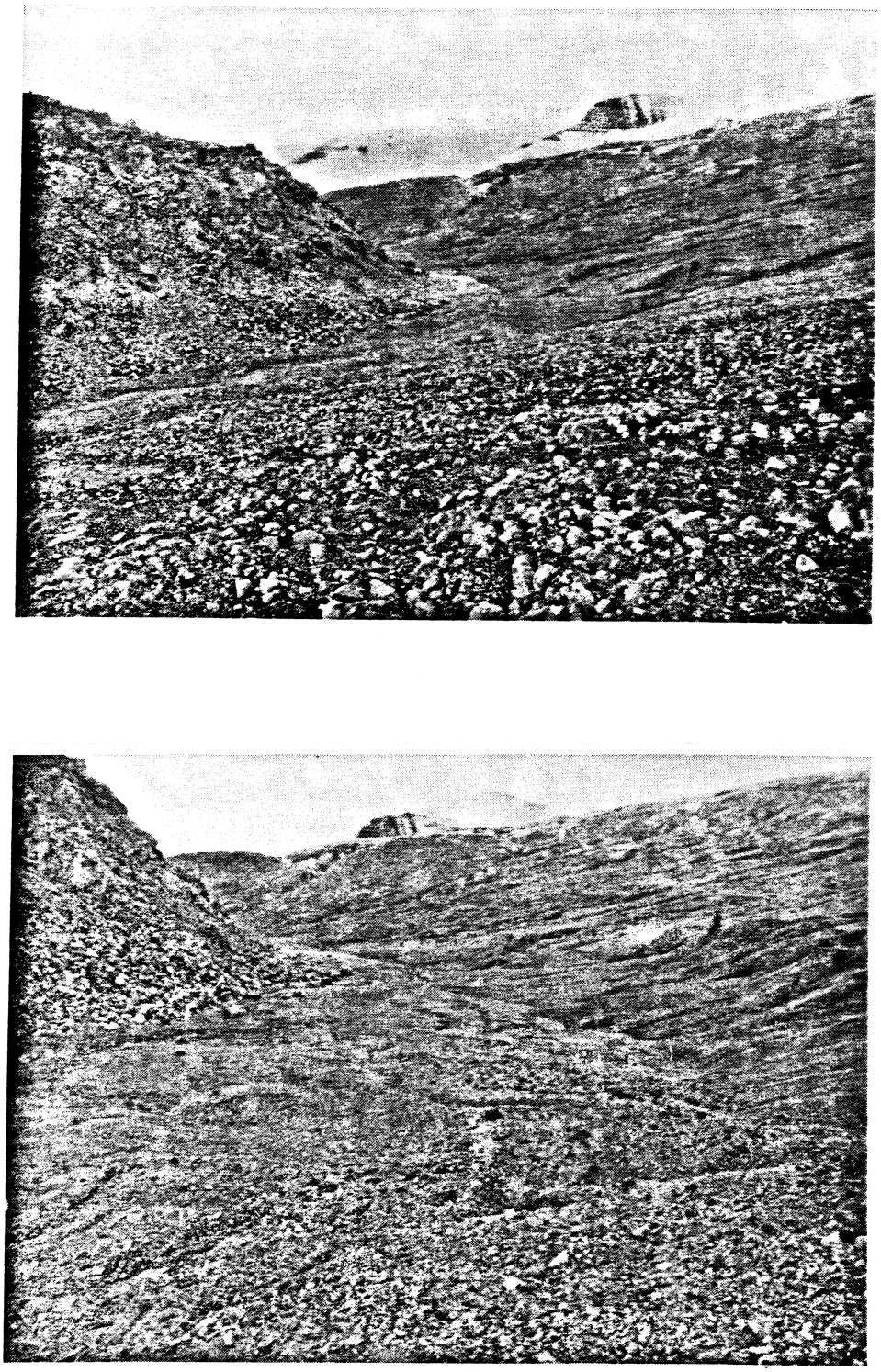


Figure 4-4. Views of the Proposed Drill Pad From the Top of the Tephra Ring and Halfway Down the Tephra Ring

The ash-flow drill site in the valley is shown in Figure 4-6. The River Lethe is in the background. Fumaroles are on both sides of the riverbank.

Preliminary site layouts required to support the operation are provided in Figures 4-7 and 4-8 and are detailed in Chapter 8.0. While it is too early for more detailed site designs, the elements of a drill site that are necessary to accomplish the drilling and coring of the core holes are provided. Drilling and coring is discussed in Chapter 8.0.

4.4 Field Camp Layout

A proposed field camp layout required to support the operation is given in Figure 4-9 and is discussed further in Chapter 12.0. Details of the campsite may change, but the essential elements of the camp and their approximate dimensions are provided.

4.5 Discussion of Access Routes

There will be controlled pedestrian access between the main drill pad and the field camp outside the tephra ring. The access over the tephra ring must be carefully designed to prevent damage to the moss (cryptogam) which is present over portions of the ring [Figures 4-4 and 4-10 (top)]. Decking material such as wooden planks or cinder blocks will be used to minimize disturbance to contours and to the cryptogam. A single pathway will be used for maintainance of the waterline that will be constructed on top of reworked pumice.

Vegetation transects will be established under NPS supervision to determine the impacts to the site and recovery in later years. Operational access routes will be limited between the camp, the dome drill site, and within the dome and ash-flow drill sites.



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

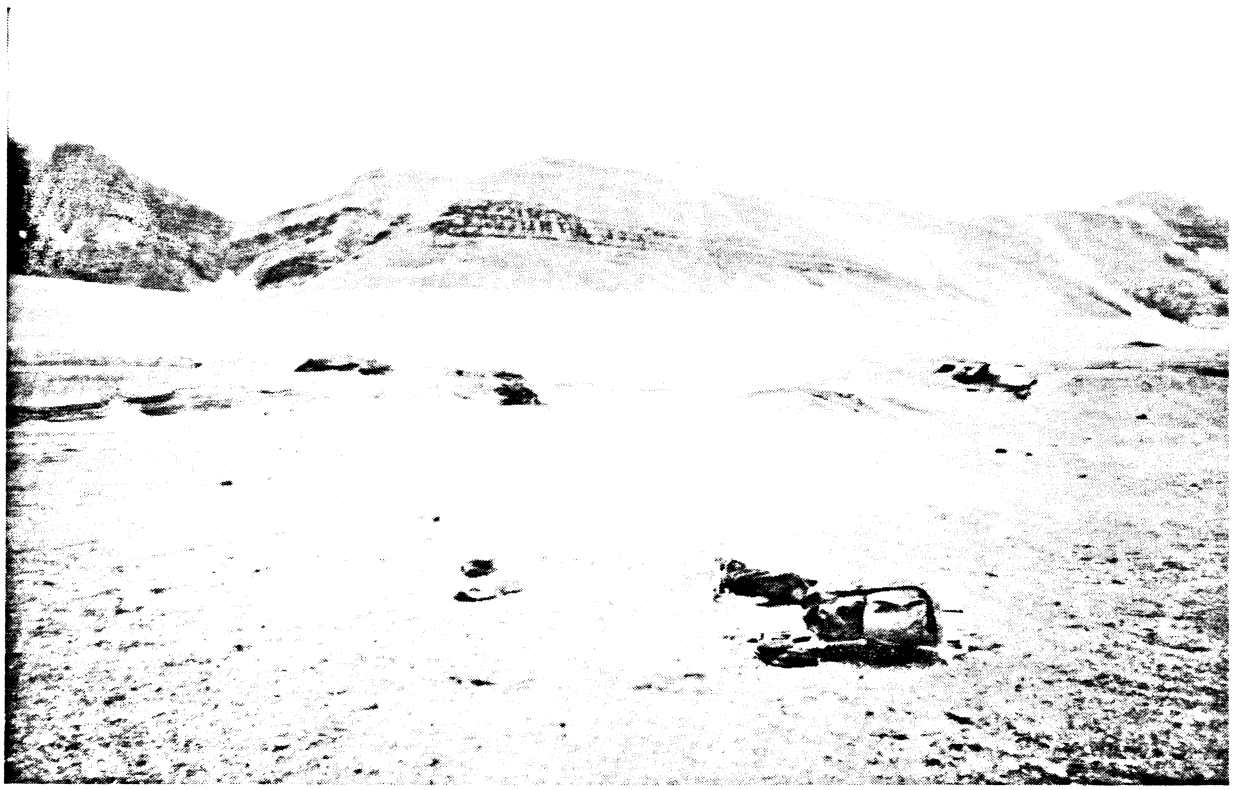


Figure 4-6. Location of the Ash-Flow Drill Site. Fumaroles are on both sides of the River Lethe.

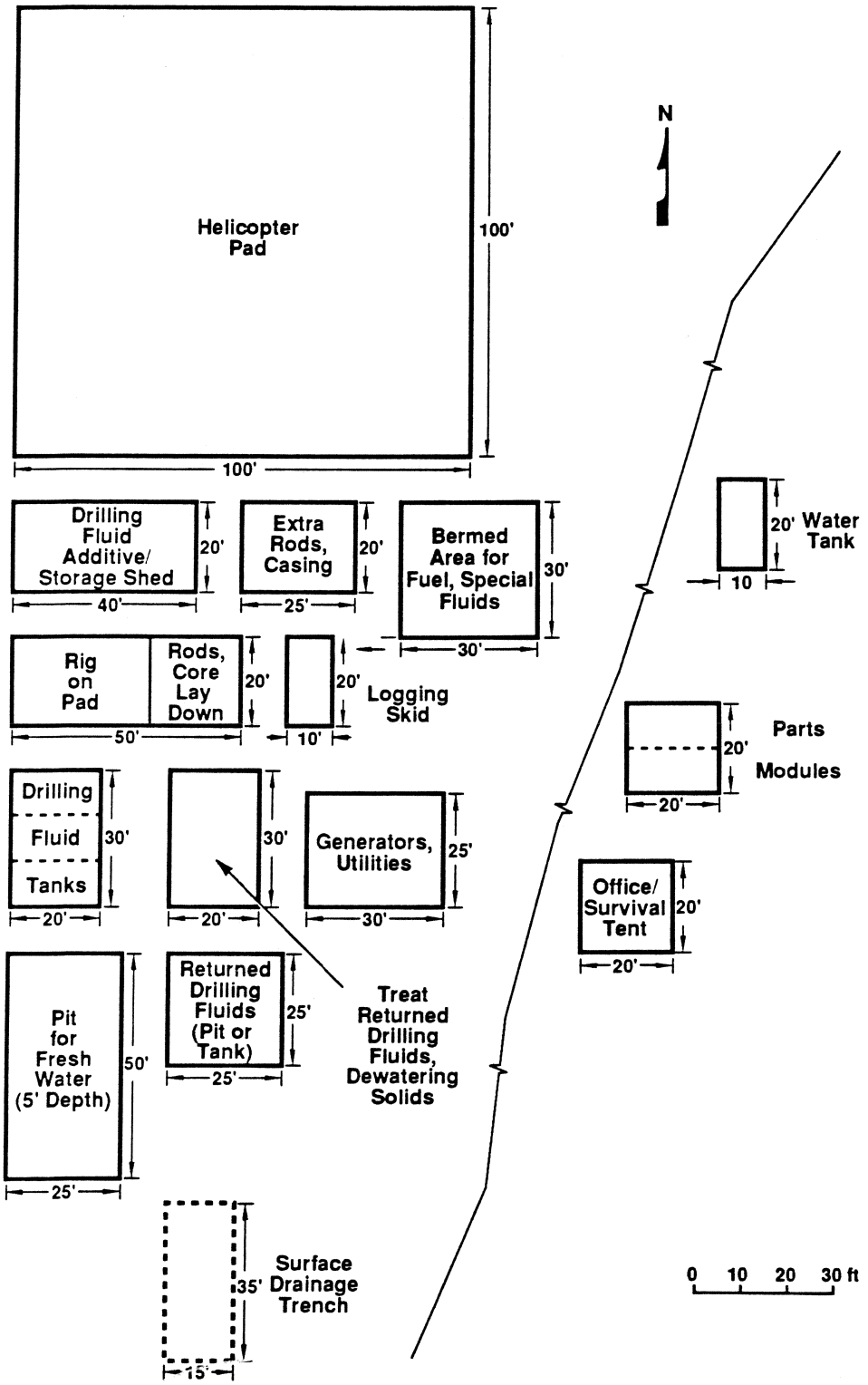


Figure 4-7. Proposed Layout of the Main Drill Site at the Dome

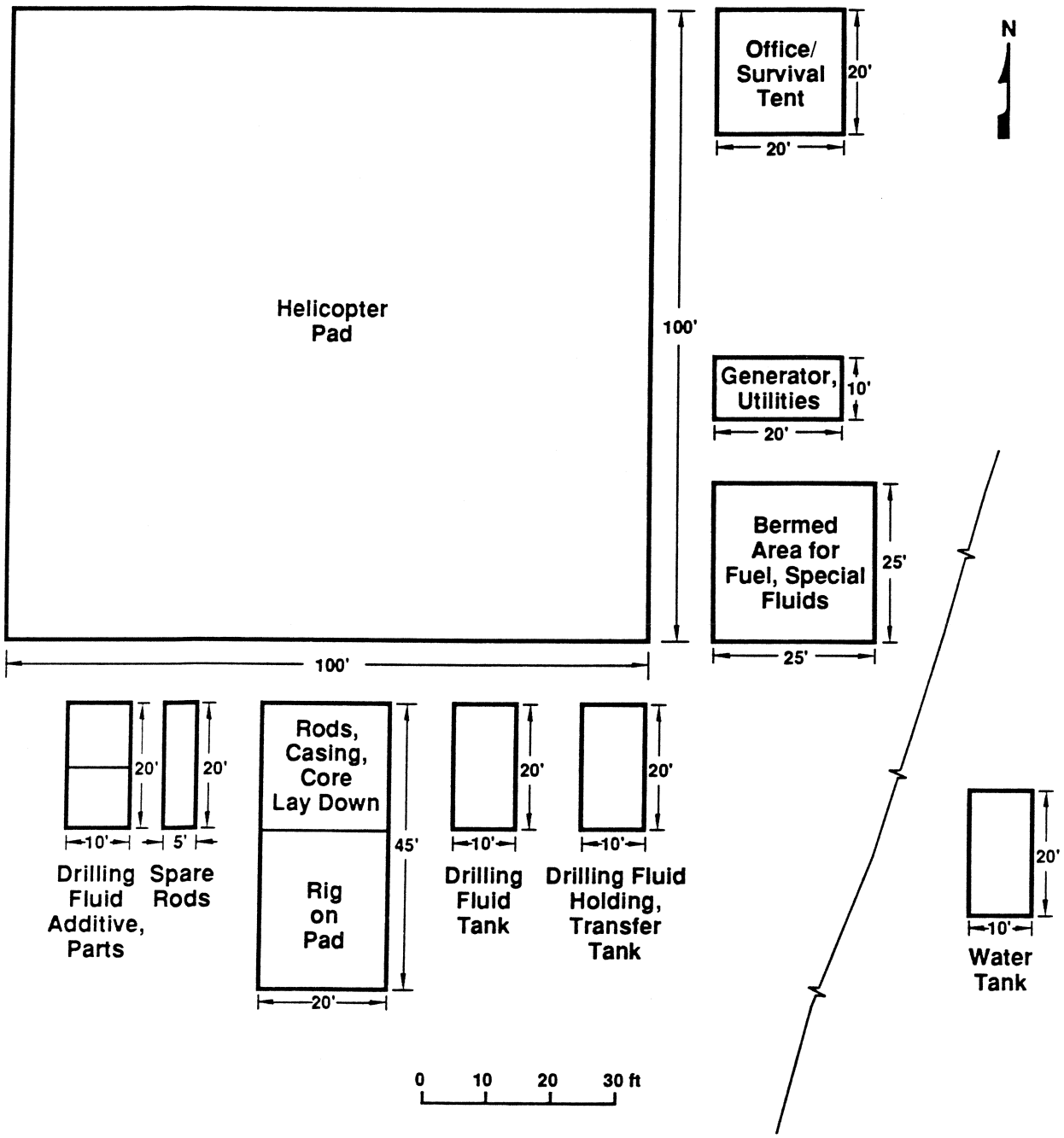


Figure 4-8. Proposed Layout of the Remote Ash-Flow Drill Site

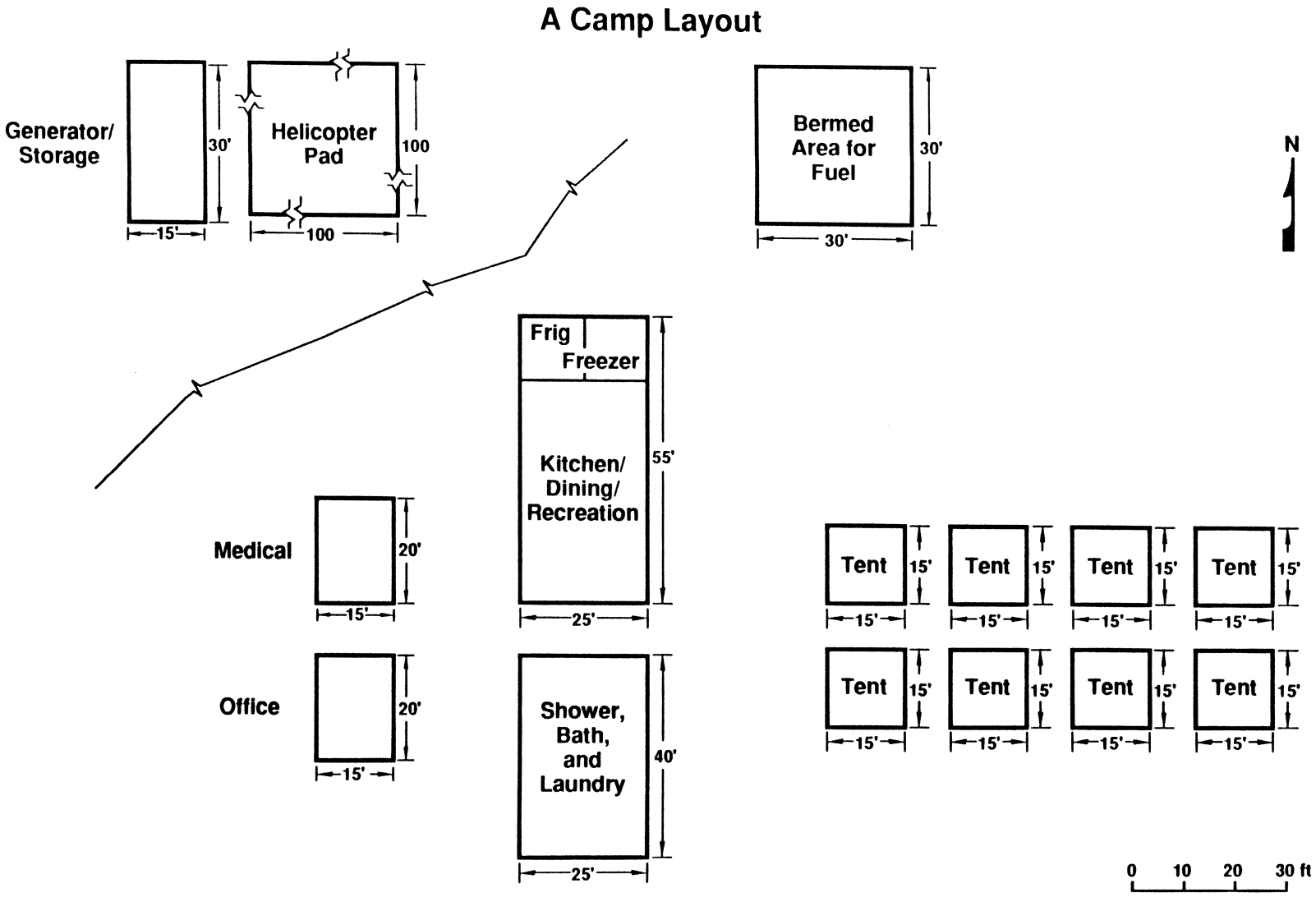


Figure 4-9. Proposed Layout of the Field Camp



Figure 4-10. View of Mossy and Reworked Pumice Areas on the Tephra Ring

5.0 GEOLOGICAL SITE DESCRIPTION

5.1 Vent Drill Site

To study the eruption in 1912, the drilling of two core holes has been planned. These core holes would be used to penetrate and sample the interior of the vent.

5.1.1 Vent Structure

Surface structures representing the three eruptive stages are concentrically arrayed. The volumes decrease with time in order-of-magnitude; therefore, 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 an 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, which is 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 appear funnel-like. Lithology of ejected wall rock fragments limits the excavated volume to within the 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 that 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). This indicates 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 that is a few tens of meters thick and is expected to be located directly beneath extensional features on the dome's surface. This expectation is based on the examination of 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 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 and will consist 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 material that is soft, friable, and permeable, to void-free glass or its finely crystalline equivalent. Unless completely unwelded or highly altered material is encountered, the vent fill will 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, continuing to greater than or equal to 300 ft (≥100 m) into the wall will be desirable to ensure that the basement rock which is 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. The vent region holes extend 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, specific targets are 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 associated with the lava dome, 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 and 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 or 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 (Figure 4-2).

5.2 Valley Drill Site

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 ash-flow sheet from the eruption in 1912, which filled a glacial valley to form the Valley of Ten Thousand Smokes.

5.2.1 Expected Sections

The target formation is the ash-flow sheet. It is covered by a veneer of variably eroded, late dacitic air-fall tephra, and it probably conceals a thin layer of early rhyolitic air-fall tephra (Figure 5-1). These eruptive products from the eruption in 1912, 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 topographic estimate 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 that followed 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. A section of conductor pipe will be set to facilitate penetration through this unstable layer (Chapter 7.0). Drilling may be difficult and the hole may be unstable in the glacial and fluvial debris of unknown thickness underlying the sheet. An effort will be made to reach greater than or equal to 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, which are roughly

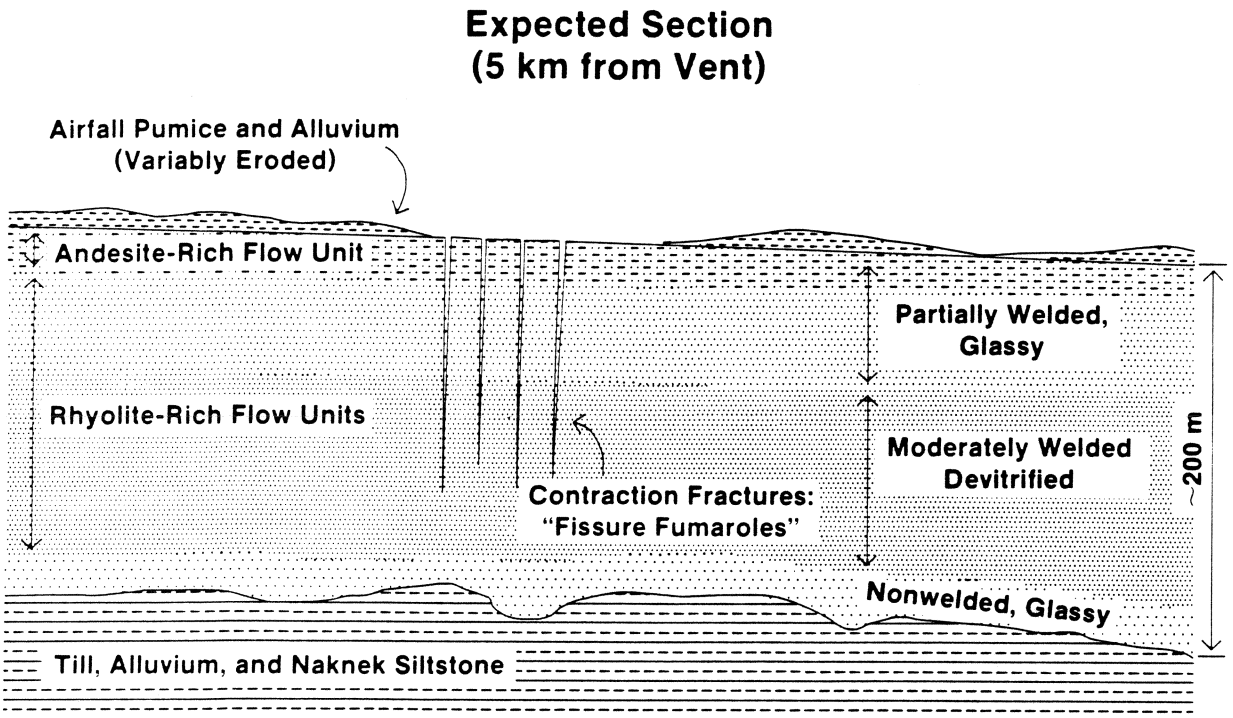


Figure 5-1. Section at the Ash-Flow Sheet

perpendicular to the valley axis. Based on exposures cut by the River Lethe, these are interpreted as the tops of deep vertical fractures that 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. This will facilitate study of metal release, transport, and disposition through the vertical extent of the vapor-transport system. Water is present at the River Lethe 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. Figure 5-2 shows fumaroles and vertical fractures in the immediate vicinity of the ash-fall drill site in the valley.

5.3 Geochemistry and Hydrology

5.3.1 Element Analysis of Typical Rock Samples From the Eruption in 1912

Table 5-1 gives chemical analyses of rocks from Falling Mountain, Mt. Cerebus; from various portions of the eruption in 1912; and from Novarupta Dome. These rock types reflect the three stages of the Katmai eruption that should be encountered while drilling the proposed wells. They are considered typical of many expected sections of the two wells described in Sections 4.1, 5.1, and 5.2 and in Figures 1-1 and 5-1. Thus this table includes analysis of rock from the early basal (rhyolitic) air fall; the early pyroclastic basal (rhyolitic) ash flow; the later, topmost (more dacitic, andesitic) ash flow; two later dacitic air-fall layers; and lava-like rock from Novarupta Dome (Hildreth, 1983; Curtis, 1968). These analyses of rock samples from the stages of the Katmai eruption do not presuppose the composition of samples to be found at depth. Rather, they provide an estimate of the elemental concentrations that may be found in various strata.

Similarly, Table 5-2 provides the ranges of trace element data for rhyolitic, dacitic, and andesitic pumice that may be found in many of the sections of the two wells described in Sections 4.1, 5.1, and 5.2 and Figures 1-1 and 5-1. Devitrification and fumarolic deposition can alter these ranges (Hildreth, 1987; Keith, in preparation), and data from this drilling project will show the extent of these alterations with depth.

5.3.2 Hydrology

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 5-1), 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 5-3). Some of these springs contain a weak thermal component, so it is possible that the interior of the sheet is still warm, though not above boiling.

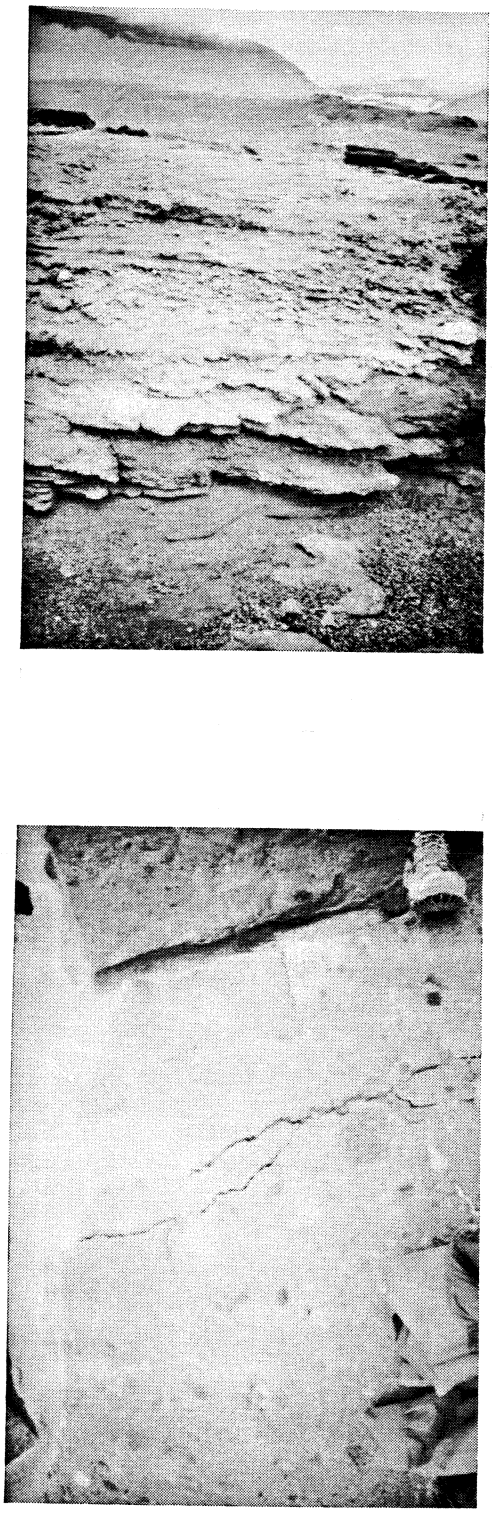
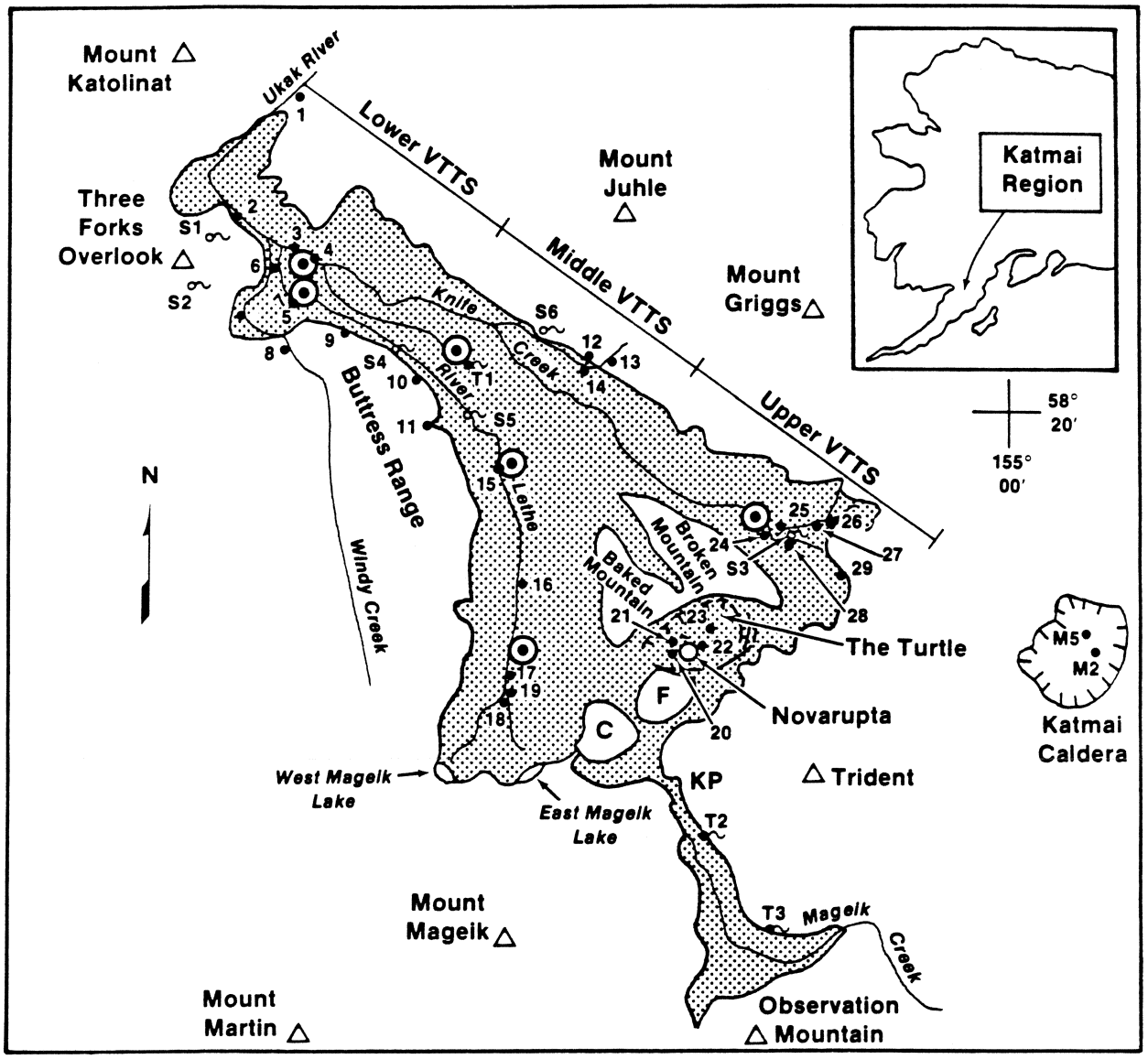


Figure 5-2. Approximately 4-Ft-High Fumaroles at the Top and a Contraction Fracture in the Vicinity of the Ash-Flow Site at the Bottom



Legend

- 1912 Ash-Flow Sheet
- Water Sample Site
- Thermal Springs
- Cold Springs
- Recommended Monitoring Sites

0 1 2 3 4 mi
0 2 4 6 km

Figure 5-3. Earlier Water-Sampling Locations and Proposed Monitoring Locations

Table 5-1*

Chemical Analyses of Rock Types From the Three Stages of the Katmai Event (ppm)

	Pre-1912 Domes		1912 Ejecta					Novarupta Dome		
	Falling Mtn.	Mt. Cerberus	Base of Rhyolitic Air Fall	Basal ash flow	Topmost ash flow	Top of Early Dacitic Air Fall	Top of Late Dacitic Air Fall	Purest rhyolite	Crystal-poor band	Crystal-rich band
SiO_2	64.2	64.0	77.4	77.3	58.6	64.6	62.9	76.9	76.6	65.1
TiO_2	0.62	0.63	0.17	0.17	0.71	0.71	0.72	0.17	0.23	0.71
Al_2O_3	16.2	16.2	12.4	12.35	16.9	15.65	16.2	12.5	12.55	15.5
Fe_2O_3	2.59	2.33	0.39	0.44	2.96	1.97	2.00	0.55	0.48	1.91
FeO	2.72	3.03	0.85	0.81	4.16	3.44	3.78	0.89	1.04	3.50
(FeO*)	5.05	5.13	1.20	1.21	6.83	5.21	5.58	1.39	1.47	5.22
MnO	0.10	0.10	0.05	0.05	0.14	0.12	0.13	0.05	0.06	0.12
MgO	2.20	2.34	0.11	0.09	3.80	2.14	2.65	0.02	0.08	1.95
CaO	5.15	5.22	0.87	0.93	7.31	4.97	5.67	0.95	1.13	4.85
Na_2O	4.19	4.13	4.25	4.21	3.54	4.20	4.01	4.36	4.36	4.21
K_2O	1.60	1.56	3.20	3.25	1.29	1.74	1.57	3.22	3.10	1.68
P_2O_5	0.13	0.14	0.03	0.03	0.13	0.135	0.13	0.02	0.04	0.15
F	-	-	500	500	400	400	-	500	-	-
Cl	20	<10	1375	800	800	700	630	1125	950	500
S	<10	<10	<10	80	140	150	240	60	10	180
Sr	303	320	40	47	327	237	240	52	58	215
Ba	595	575	990	1025	410	600	530	960	950	550
V	112	105	<2	<2	175	105	120	<2	4	102
Y	28	26	46	42	7	24	15	48	40	13
Zr	117	110	158	157	113	151	145	157	146	165
La	12	12		18.5	11	13.5	12		18.5	13
Ce	25	26		41.5	24	29	28		42	30
Nd	14	15		23.5	14	16	16		23	17
Sm	3.5	3.5		5.6	3.8	4.25	4.2		5.7	4.4
Eu	0.90	0.91		1.01	0.97	1.24	1.26		1.0	1.3
Tb	0.64	0.64		1.03	0.62	0.76	0.75		1.05	0.82
Yb	3.0	3.0		4.7	2.8	3.45	3.3		4.8	3.5
Lu	0.46	0.45		0.61	0.42	0.54	0.50		0.64	0.54

*All samples of 1912 ejecta were pumice blocks, the Novarupta samples microvesicular vitrophyres, and the two precaldera samples nonvesicular vitrophyres. Major elements and Cl through Zr were analyzed by XRF, USGS laboratories at Menlo Park; FeO by titration; F by specific-ion electrode; REE and lower list (Rb through Zn) by INAA at Lawrence Berkeley Laboratory by methods of Perlman and Asaro (1969). All data are normalized to 100%, H_2O-free; major elements in wt%, others in ppm. Total H_2O contents by Penfield analysis are given at the bottom.

Table 5-1* (Concluded)

Chemical Analyses of Rock Types From the Three States of the Katmai Event (ppm)

	Pre-1912 Domes		1912 Ejecta					Novarupta Dome		
	Falling Mtn.	Mt. Cerberus	Base of Rhyolitic Air Fall	Basal ash flow	Topmost ash flow	Top of Early Dacitic Air Fall	Top of Late Dacitic Air Fall	Purest rhyolite	Crystal-poor band	Crystal-rich band
Rb	29	29		71	20	38	-		71	29
Cs	0.7	0.5		3.6	1.2	1.5	1.5		2.8	1.4
Ba	550	570		975	440	625	580		995	600
Th	2.8	2.8		5.65	2.9	3.25	3.35		5.6	3.2
U	1.2	1.3		2.5	1.3	1.4	1.5		2.55	1.5
Hf	3.4	3.4		5.3	3.2	4.5	4.5		5.2	4.5
Ta	0.30	0.29		0.52	0.3	0.33	0.34		0.49	0.34
Sb	0.6	0.3		1.1	0.5	0.6	0.6		0.9	0.6
Sc	15.5	16.6		7.8	25.0	18.3	17.6		8.7	19.5
Cr	5.1	7.0		2	27	8	9		1.6	6
Fe%	3.85	3.99		0.91	5.27	3.95	-		1.15	4.00
Co	11.5	12.4		-	18	-	-		1.6	-
Zn	65	62		37	85	73	72		30	86
(H_2O)	0.25	0.18	2.66	2.88	0.88	2.52	1.56	0.26	0.48	0.26

*All samples of 1912 ejecta were pumice blocks, the Novarupta samples microvesicular vitrophyres, and the two precaldera samples nonvesicular vitrophyres. Major elements and Cl through Zr were analyzed by XRF, USGS laboratories at Menlo Park; FeO by titration; F by specific-ion electrode; REE and lower list (Rb through Zn) by INAA at Lawrence Berkeley Laboratory by methods of Perlman and Asaro (1969). All data are normalized to 100%, H_2O-free; major elements in wt%, others in ppm. Total H_2O contents by Penfield analysis are given at the bottom.

Table 5-2

Trace Element Data for the Major Pumice Types
in the Valley of Ten Thousand Smokes (ppm)

	Rhyolite	Dacite	Andesite
Li(AA)	33, 38	20, 21	16, 19
Li(QES)	31, 34, 43, 45, 49, 52, 56	17, 19, 21, 22, 24, 25,26	17, 20, 21
Be	1.5, 2.0	0.8, 0.5	0.6, 0.6
B	31, 36, 40, 42, 51, 54, 58	28, 35, 41, 41	<4
Cu(AA)	<10	15, 21	15, 22
Cu(QES)	3, 4, 6, 6, 7, 7, 11	14, 18, 21, 23, 31, 31, 39	26, 36, 43
Ga	12, 12, 12 15, 15, 16, 16	21, 22, 22, 23, 24, 25, 28	27, 28, 29
Nb	5.2, 5.4	5.6, 4.8	4.6, 4.9
Mo	2.8, 2.9	1.6, 1.7	1.4, 1.5
Sn	1.8, 2.0	0.6, 1.0	0.9, 1.8
W	0.86, 0.98	0.40, 0.46	0.36, 0.50
Pb	13, 14	7.6, 9.0	6.3

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 5-3, Table 5-3). Conclusions from the sampling are listed below.

- Streams and Rivers Fairly high concentrations of Cl^-, F^-, SO_4^{--}, and HCO_3 that were observed at some stream and river sampling stations emanate from leaching of the ash-flow sheet rather than directly from the hydrothermal system associated with the nearby volcanoes.

  - The concentrations of the above ions depend on the volume of drained ash-flow tuff. The concentration of the ions do not depend on the temperature of the waters.

  - The concentration of these ions are low for stations where the drainage emanated from outside of the sheet (sites 8, 14, 22, Table 5-3, and Figure 5-3), or where there are a small volume of drained ash-flow tuff (sites 15 through 19, 24 through 29, Table 5-1, and Figure 5-2).

  - Concentrations of these ions are high at stations where a fairly large volume of ash-flow tuff within the sheet had been drained (sites 1 through 5, Figure 5-2).

Table 5-3

Katmai Waters

Map No.	Location	Date	Temp	Field pH	Lab pH	SiO_2	Fe	Mn	As	Ca	Mg	Sr	Ba	Na	K	Li	Rb	Cs	HCO_3	SO4	Cl	F	B	Conductivity
Upper Knife Creek																								
24	head of Knife Creek	26 Aug 89	2.9	5.3	4.06	51	38.4	0.43		23.6	5.22	0.128	0.023	6.34	0.99	0.007			0	87	3.1	0.79	<0.05	205
25	blw glaciers 4,5	26 Jul 82	5	5.4	4.18	10.6		0.12		16.6	1.87			2.85	0.5	<0.01	0.03	0.03	5	32	1.5	0.46	0.25	264
26	blw glacier 5	26 Aug 89	4.5	5.9	4.42	40.9	26.36	0.3		14.7	3.23	<0.05	<0.05	4.9	0.68	0.005			5.8	46	1.9	0.51	<0.05	120.8
27	draining glacier 4	26 Aug 89	2.6	4.2	3.98	28.6	1.36	0.39		34	2.58	0.093	<.05	6.82	0.38	0.007			0	106	1.9	1.83	<0.05	292
28a	blw glaciers 1,2,3,4	1 Aug 86	3	5.2	3.92	13.3				22.7	2.9			3.8	0.34	0.01			0	62	3.4	0.22	0.05	246
28b	blw glaciers 1,2,3,4	26 Aug 89	3.7	5.3	4.45	38.5	10.18	0.19		21.1	2.6	0.046	<.05	6.51	0.64	0.011			9.1	79	3	3.15	<0.05	187.7
29	blw glaciers 1,2,3	26 Aug 89	0.7	5.9	3.87	51.2	39	0.4		20.7	6.62	<.05	<.05	10.9	1.26	0.007			0	111	5.1	0.32	<0.05	268
S3	cold spg in up Knife Cr	6 Aug 84	10	5.7	6.27	25.7				24.1	2.15			8.1	0.5	<0.01			25	58	5	1.8	0.15	224
Lower Knife Creek																								
3a	at 3 Forks	12 Aug 82	11	5.9	7.09	28.4		0.13		56.4	11.59	0.14		42.5	2.37	0.08	0.05	0.34	55	140	57	1.6	0.3	565
3b	at 3 Forks	19 Aug 89	7.8	5.3	5.68	86.6	38.66	0.39		42	14.6	0.24	0.06	39.6	2.4	0.068			26.4	100	33.3	1.33	0.21	440
4	abv 3 Forks	6 Aug 86	6	5.5	6.78	24				44.1	9.65			31	1.1	0.07			37	104	40.6	1.35	0.19	483
Upper River Lethe																								
15	at ford	5 Aug 86	2.5	5.3	6.49	9.8				4.4	0.84			1.5	0.15	0.007			13.8	14	1.2	0.07	0.24	44.1
16	abv ford	24 Aug 89	4.7	5.6	4.82	42.9	9.68	0.09		2.1	1.04	<.05	<.05	4.24	0.87	0.003			10.3	11	1.2	0.11	<0.05	30.4
17	abv ford	4 Aug 82	7	5.7	6.49	52.4		0.09		10.1	1.83	0.05		4	1.27	<0.01	0.04	0.08	26	13	4	0.75	0.1	53.8
18	west fork	24 Aug 89	4.1	5.4	4.72	37.1	4.69	0.07		5	0.86	<.05	<.05	3.98	0.85	0.002			12.2	10	1.5	0.12	<0.05	30.1
19	east fork	24 Aug 89	5.1	5.3	4.28	36.3	16.93	0.1		10	1.45	<.05	<.05	3.44	0.76	0.002			0	40	1.2	0.11	<0.05	33.6
Lower River Lethe																								
5a	low. Lethe	13 Aug 82	13	6	7.46	27.6		0.03		25.1	8.54	0.07		35.2	2.51	0.125	0.05	0.09	82	60	40	1.65	0.4	380
5b	low. Lethe	20 Jul 82	10	5.7	7.3	26.5				28.6	9.2			34.4	1.8	0.11			67.5	71	26.7	1.2	0.4	358
5c	low. Lethe	20 Aug 89	8.4	5.48	5.9	42.5	6.78	0.09		11.5	4.47	0.14	0.1	27.1	1.81	0.069			46	26	17.1	2.33	0.06	241
Windy Creek																								
6	below ford	20 Aug 89	14.2	7.85	5.45	15	1.34	0.03		17.5	1.62	0.11	0.04	4.28	0.57	0.002			42.5	23	2.1	0.21	<0.05	124.6
7	at ford	20 Jul 86	14	5.7	6.99	10.1				14.1	2.2			3.1	0.22	0.005			24.9	21	1.5	0.06	<0.1	102

Table 5-3 (Continued)

Katmai Waters

Map No. ty	Location	Date	Temp	Field pH	Lab pH	SiO_2	Fe	Mn	As	Ca	Mg	Sr	Ba	Na	K	Li	Rb	Cs	HCO_3	SO4	Cl	F	B	Conductivi
Ukak River																								
1	at toe of ash flow	6 Aug 84	15	6.2	6.94	53.1				35.6	9.48			31.1	2.46	0.08			58	62	47	1.4	0.25	378
2a	at footbrdg	12 Aug 82	13	5.9	7.35	26.7		0.07		37.9	9.03	0.1		35.9	2.11	0.102	0.05	0.05	27	90	46	1.55	0.6	507
2b	at footbrdg	19 Jul 86	14	5.9	7.05	23.6				39.9	9.1			6.2	1.3	0.08			18.2	83	31.8	0.75	0.47	393
2c	abv foobrdg	19 Aug 89	8.4		5.51	67.9	38.66	0.39		25.9	9.17	0.17	0.03	33.4	2.08	0.066			38	101	24.9	1.4	0.13	341
Cold Springs on Three Forks Overlook Hill																								
S1a	spg on trail to Ukak R	19 Jul 82	5	5.6	7.4	19.4				16	2.98	0.03	1.53	5.26	0.5	<.01	0.02		66	20.5	2.05	0.14	0.15	140
S1b	spg on trail to Ukak R	19 Jul 86	9	5.7	7.06	19.1				18.3	3.4			4.9	0.17	0.01			46	18	2.4	0.05	<.05	128
S1c	spg on trail to Ukak R	19 Aug 89	4.8		5.39	19.2	0.11	<.01		17.3	1.89	0.041	<.05	5.19	0.52	0.004			44.7	17	2.8	0.28	<.05	125.5
S2a	spg on trail to Windy Ck	14 Aug 82	5	5.6	7.37	20.3		0.01		16.3	3.12	0.02		4.11	0.74	0.01	0.03	0.08	63	11	2.4	0.02	0.15	120
S2b	spg on trail to Windy Ck	20 Jul 86	7	5.9	6.81	19.1				14.8	3.5			4.4	0.24	0.008			48.4	21	3	0.03	0.48	120.6
S2c	spg on trail to Windy Ck	20 Aug 89	5		5.39	18.5	0.02	0.01		18.6	1.88	0.09	0.06	4.82	0.45	0.005			46.1	16	2.3	0.12	<.05	119.3
Streams Above Ash-Flow Sheet																								
8	abv ash-flow sheet	20 Aug 89	12	7.71	5.54	14.7	0.63	0.01		12.2	2.15	0.16	0.03	6.05	0.53	0.001			51.9	18	2.6	0.37	<0.05	136
9a	Fe depositing cr	13 Aug 82	12.5	5.7	7.22	20.2	1.63	0.07		11.2	2.1	0.023		4.11	0.66	<0.01	0.03	0.08	71	5	1.42	0.75	0.3	100.7
9b	Fe depositing cr	28 Aug 89	11		5.32	20.4	2.35	0.09		9.2	1.52	0.023	<0.05	4.28	0.48	0.001			46.5	5	2.3	0.17	<.05	83.6
10	stream drain Buttress	28 Aug 89	8.5	6.8	5.43	19	0.65	0.03		33.2	2.65	0.028	0.023	15.1	0.58	0.005			62	72	2.4	0.24	0.2	259
11	6 mile camp	21 Aug 89	13.1	8.06	5.41	29.5	4.85	0.08		27.3	2.36	0.17	0.1	7.03	0.62	0.005			49	35	2.2	0.22	<0.05	161
12	btw Juhle & Griggs	6 Aug 84	14	5.9	7.01	19.8				26	2.85			3.8	0.85	<0.01			58	25	2	0.19	<.1	177
13	Juhle fk stream	25 Aug 89	9.9	5.7	5.09	36.1	1.24	0.01		11.8	2.59	<0.05	<0.05	8.32	2.05	0.005			17.4	28	12	0.11	<.05	130
14	Juhle fk abv falls	25 Aug 89	6.9	5.5	4.42	97	42.35	0.59		19.7	8.15	0.089	<0.05	17.5	2.52	0.007			5.8	79	9.1	0.17	<.05	196.3
Precipitation																								
20	precip west of dome	31 Aug 89	4		4.66	2.6				0.2	0.099	<0.05	<0.05	1.08	0.09	<0.001			8.9	5	0.9	<0.1	<.05	4.5
21	Snow melt pond	28 Jul 86	14	5.2	5.44	2				0.36	0.05			0.17	<0.1	0.007			11	2	0.4	0.25	0.07	9.2
22	precip drain into dome	31 Aug 89	4		4.81	14.1				0.63	0.068	<0.05	<0.05	1.7	0.07	<0.001			10	1	1.1	<0.1	<.05	8.5
23	Snow melt on Turtle	25 Jul 82	15	5.5	5.66	0.3				0.15	0.01			1.46	<0.01	<0.01			11	<.2	0.3	0.285	0.15	7.6

Table 5-3 (Concluded)

Katmai Waters

Map No.	Location	Date	Temp	Field pH	Lab pH	SiO_2	Fe	Mn	As	Ca	Mg	Sr	Ba	Na	K	Li	Rb	Cs	HCO_3	SO4	Cl	F	B	Conductivity
Midvalley Thermal Springs																								
T1	spg mid (1)	24 Jul 87	15	5.7	6.73	55.5				89.5	17.9			73.3	2.96	0.16			105	330	69.6	3	0.66	
T1	spg north (2)	24 Jul 87	17	5.7	7.01	58.6				94	19.9			83	4.21	0.2			127	390	73.6	2.9	0.8	
T1	spg mid (3)	23 Aug 89	17.8	5.7	6.49	38.3	<.01	<.01	0.34	90.8	15.95	0.33	0.03	78.1	3.63	0.204	0.07	0.06	135	276	71	2.93	0.67	934
T1	spg mid (1)	23 Aug 89	17.8	5.9	5.89	38	<.01	<.01	0.23	89.9	15.84	0.297	0.03	80.6	3.63	0.204	0.06	0.06	132	279	68.4	2.84	0.461	917
T1	southmost spg (4)	23 Aug 89	17.6	5.7	6.32	37.3	<.01	<.01	0.52	89.8	15.77	0.225	<.05	78.4	3.41	0.188	0.06	0.05	127	280	67.6	2.42	0.4	906
Hot Springs South Side of Katmai Pass																								
T2	warm spg	3 Aug 82	15	5.7	8.05	67.5	20.1	1.16		33.5	31.12	0.4		98.9	7.92	0.038	0.09	0.05	190	93	145	0.102	1.65	
T2	warm spg	9 Aug 84	15	6	6.84	42.9	0.04	0.33	0.86	44	30	0.29		121	8.91	0.03	<.01	0.04	452	54	113	0.1	3.4	926
Thermal Springs North Side of Mageik Creek																								
T3	hot spg (1)	3 Aug 82	40	6.8	7.9	105	1.18	0.02	0.66	136	59.3	0.5		231	29	0.58	0.49	0.52	337	410	262	2.89	2.75	2080
T3	hot spg (2)	3 Aug 82	42	6.8	7.59	111	1.2	0.03	0.61	116	65.1	0.57		252	29.2	0.64	0.46	0.9	377	330	278	2.77	4.2	2280
T3	hot spg (3)	9 Aug 84	40	6.5	7.53	105	<.1	<.1	1.34	157	69.7	0.5		218	25	0.5	0.29	0.19	568	480	251	2.5	5.5	2040
Katmai Caldera Lake																								
M2	60 m depth in lake	8 Jul 75	5.5	3		120				300	51			760	90	0.92				1250	1350	0.9	12	
M5	60 m depth in upwelling	8 Jul 75	5.5	3		140				300	62			590	110	1.2				1200	1750	1.1	14	

As of March 29, 1990

- Springs These data suggested two hydrological systems. There is a rough correlation of the temperature with enhanced concentrations of the above ions. Reasons for these are the following:

  - Observations over the years suggest that the flow of the cold springs above and within the ash-flow sheet is a function of precipitation. The fresh water system flows within the somewhat porous ash-flow sheet and at the base of the ash-flow sheet, which lies above a relatively impermeable 3,300-ft-thick Naknek siltstone.

  - The cold water springs (sites S1 and S2, Table 5-3, and Figure 5-3) are relatively fresh meteoric water running directly through the Naknek siltstone. These waters may run, in part, through fractures, cracks, and joints in the siltstone. These waters are high in Ca^{++} and SiO_2, but low in Cl^-, HCO_3^-, and SO_4^{--}.

  - The midvalley thermal springs (site T1 and Figures 5-3 and 5-4) have a high ion concentration (Table 5-3). These springs appear to have a hydrothermal component. Portions of the ash-flow tuff in the midvalley could be warm. Alternately, these thermal springs may be connected to a hydrothermal system under Novarupta Basin via northwest-trending joints or fractures in otherwise impermeable Naknek siltstone. The midvalley thermal springs occur in a line of thermal springs extending over a distance of approximately 1,000 ft at a midvalley site. There are approximately 70 major orifices of these springs in the ash-flow sheet and innumerable minor orifices with an average flow of ~.33 gal/sec for each of the major orifices. Thus approximately ~25 gal/sec of saline fluid flow into Knife Creek from these springs is independent of the natural leaching process. These springs have different temperatures both as a function of the season and as a function of the individual orifice. This strongly suggests a comingling of fresh meteoric water with water from the fumarolic or active hydrothermal originating system. There may be more thermal springs of this type in the valley.

  - Thermal springs T2 and T3 (Table 5-1, and Figure 5-2) are considered hydrothermal in nature, or at least in part. The warmer spring, T3, has by far the larger concentration of ions.

- Possible drainage paths of drilling fluids from the main drill site at Novarupta Dome are the following:

  - The water drains from or near the top of the Naknek siltstone into numerous fresh water springs in lower Knife Creek at the contact with overlying ash-flow tuff;

  - The water drains into either the upper Knife Creek or River Lethe systems from within the deposits from 1912 and perhaps along the contact of these deposits and the Naknek siltstone. Seeps in the ash-flow sheet are observed along Knife Creek and may exist along the River Lethe.



Figure 5-4. Upper End of the Large Midvalley Thermal Springs

- At certain depths in the vent, the water at the vent drill site percolates into the hydrothermal system rather than the fresh water systems because the Naknek siltstone was breached.

- Drainage paths for the remote drill site near the River Lethe are the following:

  - The water drains directly into the river through fractures and welded layers of the ash flow and at the contact between these deposits from 1912 and the Naknek siltstone.

  - The water drains into the midvalley fresh water springs through the ash-flow deposits from 1912, and along the contacts of these deposits with the Naknek siltstone.

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

5.4 Summary of Surface Geology Studies in 1989

Gravity, magnetic, and electrical techniques have all identified anomalies centered near Novarupta Dome (Eichelberger et al., 1990). Results of these analysis generally support earlier descriptions of the subsurface structure that are based primarily on geology. The presence of a vent of approximately 0.6-mi (~1 km) radius has been indicated by fracture distribution, widespread thermal activity, the broad gravity anomaly, and possibly, electrical conductivity. The relatively small volume of lithic ejecta, the subtle structural and topographic characteristics of the vent, and the narrow magnetic anomaly indicate a smaller structure. Pending results of ongoing modeling, two models are consistent with these observations. The vent may have a deep welded throat within which Novarupta was 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 have been the entire vent, with the surrounding fractured basin being a zone of modest subsidence. In this case the Turtle is a high bedrock that began to slip into the open hole. In either case, the geophysics confirmed geological hypotheses: 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. (Refinements from the 1990 surface studies are not yet available.)

6.0 DRILLING OBJECTIVES AND TECHNICAL APPROACH

The results of the Katmai project will provide an in-depth understanding of one of the most interesting features in Katmai National Park, the Novarupta vent. The Novarupta vent is a unique volcanic site (NAS, 1989); 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 have occurred on the earth, the Katmai event is of a class of eruptions that was both large enough to be catastrophic in impact and 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 eruption 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, because of the age and size of the system, 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 eruption in 1912 was a single eruption of magma passing through uniform sedimentary bedrock at a site where little previous volcanic activity (none rhyolitic) had occurred. Therefore, temperature, chemical, and structural observations at depth can be directly related to the event in 1912. 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 vent structure.

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 process. Aspects of the process include fracturing of bedrock by magma; flow of

magma; growth of bubbles; expansion and breakup of the magma to ash, pumice, and gas; and excavation of the vent. This process can be divided into the behavior of magma and the behavior of the conduit system. The project will test existing theories concerning 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 the growth of the vent over time. The timing of the vent's periods of constriction, collapse, and intrusion can also be determined. The nature of the excavation of the vent can be determined by the basement fragment distribution in the vent-fill and the ash-flow sheet. The extent that the vent was formed by collapse of wall rock into magma (rather than by excavation of wall rock by erupting magma) can be determined by the identification of down-dropped blocks of basement relative to vent volume.

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(s) of the gases, which would be 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 identify the processes which occur during an explosive eruption and the processes which control whether an eruption will be explosive and ash-forming, or nonexplosive and lava-forming.

6.2 Objective 2

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

The transport of metals 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).

The conditions and mechanisms of metals migration will be determined by the subsurface mapping of metals enrichment and depletion zones, the spatial relationship of these zones, and their isotopic character. 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 to objective 2 is to describe the distribution of metals in the igneous host rock system and to interpret the means by which portions of the system reach their present chemical state.

For the igneous portion of the system, initial metal concentrations in the magma prior to eruption will be estimated by the analysis of glass inclusions from each of the three magma types. The inclusions represent samples of liquid rock encapsulated in crystals prior to eruption 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. 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 (pressure reduction) during eruption and crystallization during the cooling of metals.

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 analyzed to describe the interaction of the host rock 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 about the cause of metals transport during some eruptions but not during others. These investigations will also aid in the interpretation of the processes responsible for the formation and preservation of volcanic-rock-hosted ore deposits.

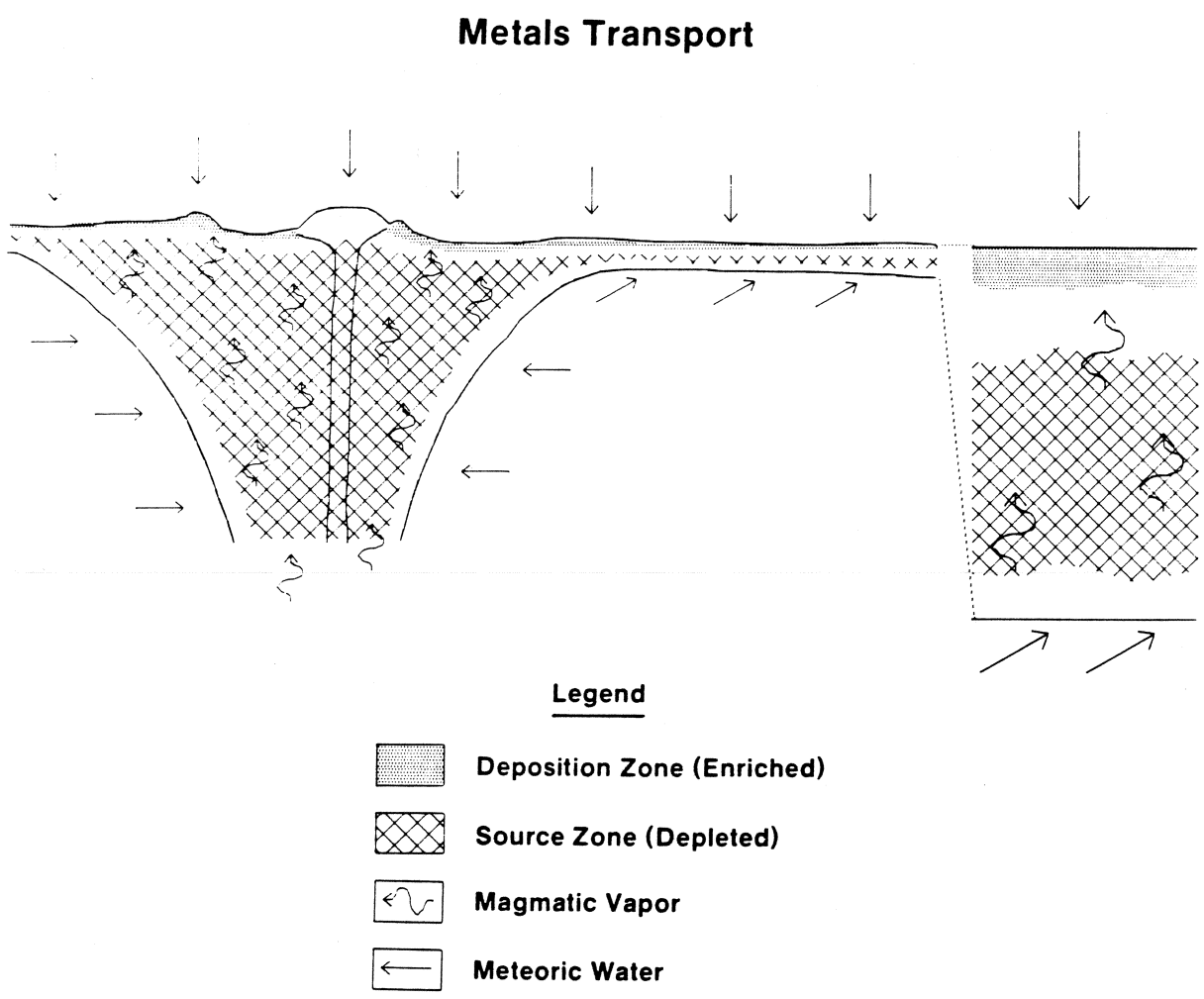


Figure 6-1. Schematic of Metals Transport

6.3 Objective 3

6.3.1 Measure the Current Subsurface Temperature Distribution and Test Models for the 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 eruption in 1912 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. Drilling into a simple, still-cooling system at a known point in time after its formation will provide fundamentally new information, such as the speed that heat travels in the Earth's crust and the rate at which 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 80 years after its formation. This is very young geologically. Magmatic temperatures of ejecta from 1912 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 8.0). 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 the isolation of radioactive waste as well as for understanding volcanism. In general, volcanoes are repeatedly intruded by pulses of magma. Results of the Katmai project 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 core hole design is provided on the basis of available data. Schematics for the 4,000-ft (~1,200-m) vertical hole, the beginning of the 3,000-ft slant hole, 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, which are discussed in Sections 8.4 and 8.7.

Because drilling conditions are expected to be difficult, the diamond core rig chosen for this project will be one of the most 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). Rigs such as a Longyear Hydraulic 44 and a Chicago Pneumatic 50 are being considered.

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 vertical 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:

- a K55 casing riser pipe (10 3/4 in., 40 lb/ft) through loose pumice into more consolidated rock to approximately 100 ft (~33 m);
- a K55 casing conductor pipe (6 5/8 in., 24 lb/ft) 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.

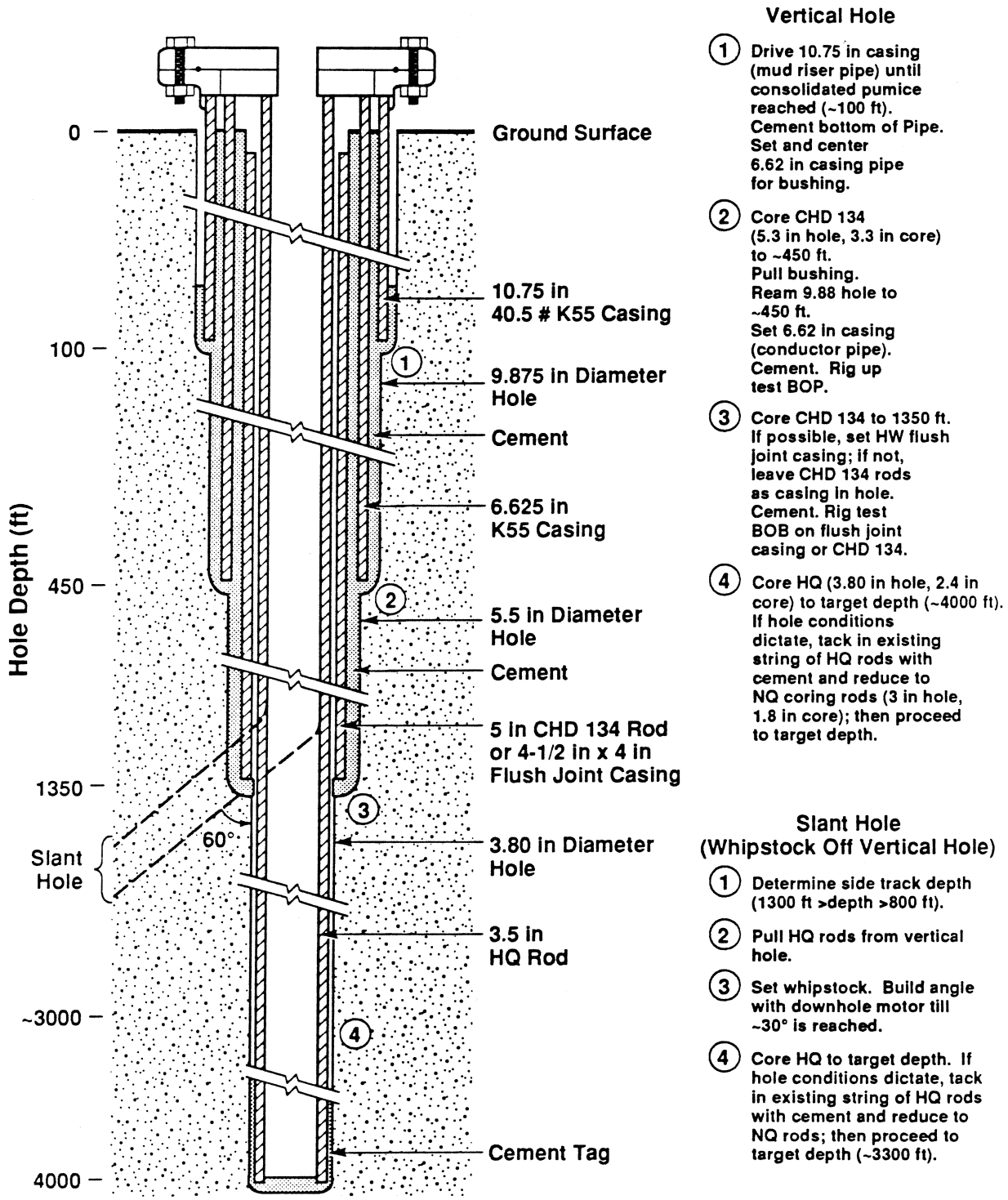


Figure 7-1. Deep Vertical Design of the Core Hole With Nested Tubulars

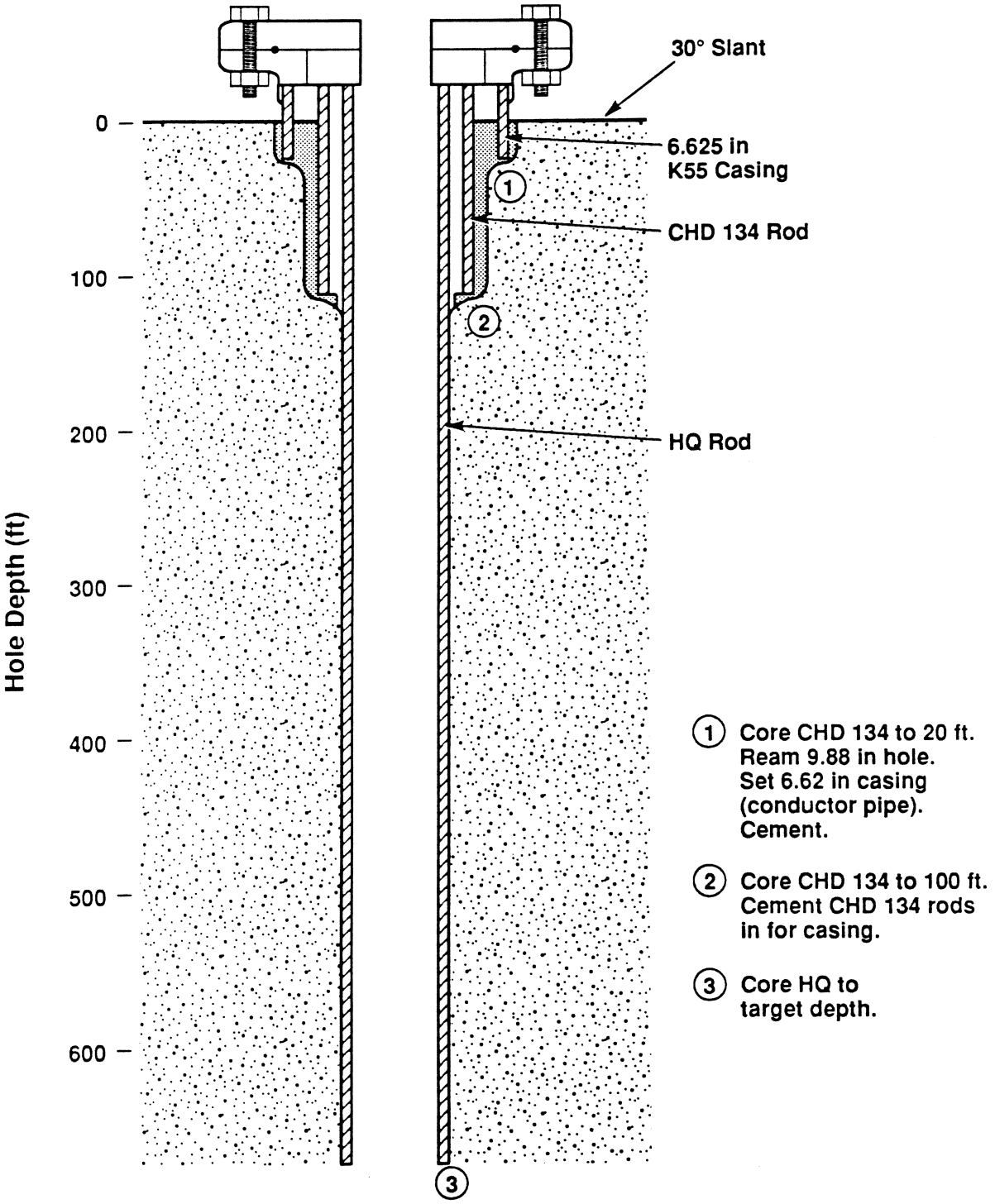


Figure 7-2. Core Hole Design for the Ash-Flow Hole

The slant hole at the ash-flow site will have the following tubulars (Figure 7-2):

- 6 7/8-in. casing and conductor pipe to approximately 40 ft (~12 m);
- CHD 134 coring rods (casing) to approximately 100 ft (~30 m); and
- HQ coring rods to 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 welded 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. A 4,000-ft vertical hole and a 3,300-ft slant hole will be drilled at the main drill site near Novarupta Dome (Section 4.3). A less extensive 650-ft slant hole will be drilled at a secondary, remote ash-flow site in the Valley of Ten Thousand Smokes, approximately 5 mi from Novarupta Dome near the River Lethe. 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 and subject to burial.

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; a logging module; fuel and water tanks and bladders; a generator; a pump; a utilities area; water storage and overflow pits; and a helicopter pad. The drill site will occupy approximately one 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 4-8) will have the same support components as the main drill site. However, due to the relatively shallow depth of the core hole at the remote drill site, all support facilities at this core hole will be on a smaller scale. The remote site will occupy approximately one-half acre and will also include an emergency survival tent and a restroom facility.

8.2 Schedule and Season of Operation

The Katmai project operations will span a 16-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 spring of 1992 when barge access to the Bristol Bay area is available and will continue through the warm season (Figure 8-1). The site will then be shut down and winterized until spring. The supply of onsite fuel, lubricants, and liquid drilling fluid additives will be drawn down as the winter shutdown approaches, and the material remaining will be transported offsite for the shutdown, if necessary. Minimal amounts of sensitive fluids will remain onsite. Liquid items and items that cannot be stored in cold weather will be removed from the site. The drill rig, pumps, and other apparatus will be properly winterized. Solid drilling fluid additives and other similar items will be stored in weatherproof, waterproof modules or in water-tight boxes.

Schedule of Operations

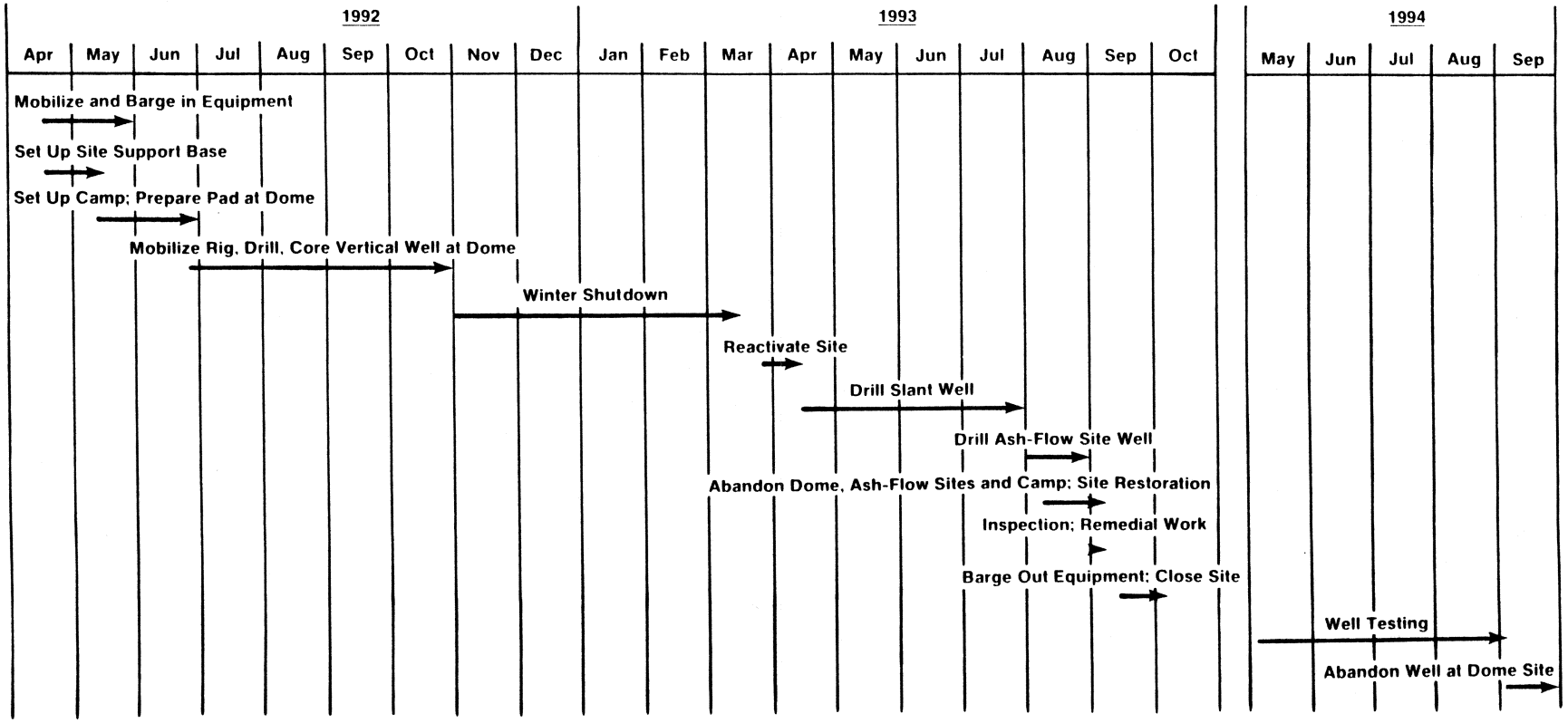


Figure 8-1. Schedule of Operations

The vertical well should be concluded before winter shutdown. The hole will not be left in an open condition. Casing and HQ rods will be in place. Choke and kill lines will be valved off. The wellhead will be affixed for the winter.

Inspections will be conducted by helicopter at approximately four- to six-week intervals during this shutdown period. The inspection party will consist of project personnel, NPS and USGS personnel, and drilling and camp contractors. If serious problems arise that cannot be handled by the inspection party, appropriate personnel will be helicoptered to the site to correct any problems during shutdown. Appropriate people will be available in the Anchorage area to respond to any emergency during the winter shutdown. One alternative is to leave a pair of caretakers to watch the wellhead, to keep snow off the camp, to remove snow at the site, etc. In this instance, the inspection flights would also serve to facilitate the change of caretaker crew.

Operations will resume in spring as soon as the weather permits and streams begin flowing. Operations 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 occur in the summer of 1994.

8.3 Operational Sequence

The following sequence of operations is planned.

- Lay out the drill and campsites during the summer before fielding. The GRDO, USGS, the drilling and camp representatives, and the NPS will perform these tasks. Permission is requested to bore 40 to 80 ft into the loose pumice using a hand auger to obtain information about pumice stability, drill pad support, and drilling conditions. Afterwards the surface area will be restored. Pumice samples will be tested for load-bearing capacity and will be analyzed by project scientists.

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

- Mobilize the main campsite and begin excavation of the pits in late May or June, as soon as snow conditions at the drill and campsite permit. Pour cement for the drill pad to accommodate both the vertical and slanted deep core holes. Pour cement into small holes for guy wires to secure the rig from wind. An all-terrain balloon-tired vehicle or a wide track D3 or D4 caterpillar tractor will be used to construct the site and to support the operation. It will be used only in the flat, unvegetated crater floor at Novarupta Dome within a 200-yd radius of the ash-flow hole and possibly at the campsite for grey water drain field construction.

- Lay waterlines from Knife Creek to the pond (Figure 8-2). Permission is requested to line a portion of the pond on the other side of the tephra ring near the campsite (Figure 4-2). This pond

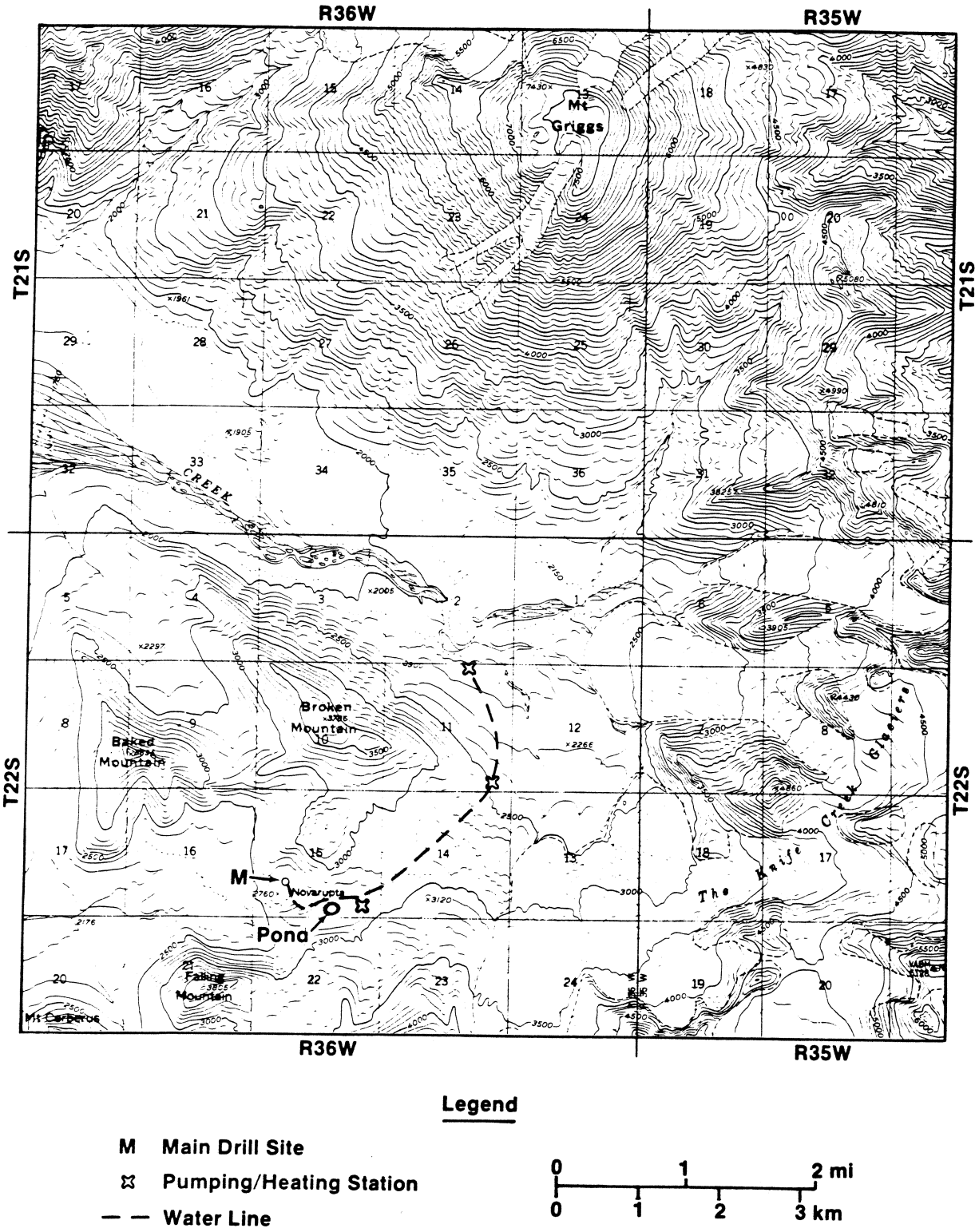


Figure 8-2. Map of the Waterline to the Knife Creek Source

will be lined to provide an additional fresh water source. The liner will consist of a high quality mat and liner assembly. Thus sources of fresh water will include the fresh water pit to be excavated, the pond, and Knife Creek. Water will be staged to provide an ample reserve for normal and emergency operations. Water will be pumped from Knife Creek directly to the dome site or the pond for further storage. Pumps and waterline heaters will be placed near the Knife Creek source, approximately halfway between Knife Creek and Novarupta Dome and at the pond near the campsite.

- Mobilize the coring rig at the main site in late May or early June 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 more consolidated rock. A casing driver or some type of hammer may be used.

- Core to the conductor pipe depth, 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. Complete the vertical hole. Operations will terminate for the winter. This will occur in October.

- Winterize 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 four to six weeks throughout the winter. Run temperature logs in the vertical well during this period.

- Begin site reactivation in early April. Commence with the slant hole.

- For sidetracking, cut HQ rods to the appropriate depth, and set the whipstock between 800 and 1,300 ft. A 50-ft cement plug will be set at the bottom of the casing and another 50-ft cement plug will be set just below the whipstock. 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. This may be performed as part of plugging and abandonment.

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

- Run a short waterline from the River Lethe and 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 rig 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 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 the 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 the camp depicted in Chapter 12.0.)

8.3.1 Operational Sequence (Initial Season of Operations, Winter Shutdown, Spring Resumption of Operations)

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 year of the split operations season, the 4,000-ft vertical hole can be completed with reasonably favorable drilling conditions.

Experience gained during the first season of drilling 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 two slant holes. 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.

The equipment mobilization by barge begins in the spring. 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 sequentially rather than simultaneously will provide advance knowledge of the drilling conditions for the second deep core hole at Novarupta Dome. To run two rigs simultaneously at the dome could result in the possibility of both rigs encountering identical serious problems simultaneously. The hole design specifies a single pad (Figure 7-1), one (not two) casing strings, and requires fewer rig days in the park and reduced helicopter support.

The project will utilize a single diamond core rig that is adequate for the difficult drilling conditions which could be encountered at Novarupta Dome. The winter shutdown also allows time to retrofit the rig, if necessary.

8.3.3 Mode of Main Mobilization

Carrying out the main mobilization and demobilization by helicopter from King Salmon is a simple, safe, and conservative approach. Support facilities are in King Salmon and materials can be stored there.

8.3.4 Daily Helicopter Support

Supporting the ongoing operation from King Salmon by means of a camp helicopter is a simple approach to transporting supplies and personnel to the remote field camp. Daily helicopter support will allow convenient air freight shipments from Anchorage and more distant areas, convenient resupply from the King Salmon area, 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 the logging of the core from the drill sites. Arrangements will be made for storage and other support facilities at King Salmon.

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 and therefore does not lift chips readily. Also, pure water 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. In addition, polymers will also be added if the rods begin to chatter in the

hole. 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, because 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. Materials and cements are employed to plug lost circulation zones and maintain circulation.

Lost circulation would normally be characterized by a drop in the flow rate of outlet fluid. There would also be a decrease in the inlet pressure reading. Fluid losses could range from 200 to greater than 5,000 gal per day. Therefore, rapid response of the drilling crew is necessary.

Remedial action in lost circulation conditions often consists of pumping plugging materials into the permeable portions of a formation (Table 8-1). 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.

Should the use of plugging materials fail, special cements will be employed. These cements set quickly; therefore, they are not a major disruption 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. If the lossy zone is thick, several cementing operations may be attempted in quick succession, each aimed at new loss zones encountered as the hole is advanced. Cementing operations will require the presence of special mixing and pumping equipment and trained crews (Section 8.7). Cementing operations also generate solid wastes that will be removed from the park (Section 8.6.3).

Sandia National Laboratories is currently developing special equipment for lost circulation problems in geothermal environments (Loepke et al., 1990). Encouraging field trials with specially selected lost circulation materials was accomplished on a recent DOE/OBES sponsored well that was engineered by the GRDO.

8.4.2 Fluid Management and Treatment of Lost Circulation

Drilling fluid additives will consist primarily of degradable polymers or clay type minerals (Table 8-1). Small amounts of rod grease and various

Table 8-1

List of Drilling Fluid Additives and Lost Circulation Materials

Operation	Drilling Fluid Additives To Be Used
Drilling through conductor pipe, low drilling temperatures, <80°C	Western sodium bentonite,* calcium carbonate, sodium, calcium, and potassium hydroxide would be used.
Drilling to main casing string depth, intermediate drilling temperatures 80°C ≤ T ≤ 150°C	Liquid anionic polymer for viscosifier and stabilizer* of finer grained sediments would be used.
Drilling beyond main casing string, high drilling temperatures >150°C	Wetting agents and detergent for clear water and low solids drilling fluids,* artificial clays,** sodium carboxylmethyl-cellulose-filtration control agent,* polyanionic celluloses,* maleic anhydride copolymer filtration control agent and viscosifier, polymeric high temperature filtration control agent, acrylamide copolymer,* liquid polymeric high temperature thinner,* lignosulfate thinners, chromium free,* and high temperature lubricants, nonhydrocarbon would be used

Lost Circulation Materials

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

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

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. 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.

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 1,200-gal tank. The lining of the pit will consist of layering to prevent pumice from piercing the lining. If necessary, the pit will be covered in a manner to prevent an overflow.

The State of Alaska requirements are to maintain circulation and to maintain annulus fluid levels within 100 ft (30 m) of the surface. This requirement will be followed until casing is set at approximately 1,300 ft (540 m) and cemented with returns to the surface (Figure 7-1). In the event of extreme lost circulation problems during this phase, the presence of a cementing crew onsite may be necessary. However, once the main (surface) casing string is successfully cemented, a waiver will be requested for the requirement to maintain the 100-ft level of drilling fluid in the annulus. The waiver will be requested for those conditions when temperature and fluid loss (actual annular fluid level) indicate it is safe to proceed. This request will be 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 scientific hole to obtain core and temperature measurements.

- 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.

- Cementing requirements for tubulars beyond the main casing string are not as critical (Section 8.7) because well control is maintained by the main casing string. The blowout preventer with the choke and kill lines on the main casing string provide well control and prevent 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 8-3. The following sequence will be employed.

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

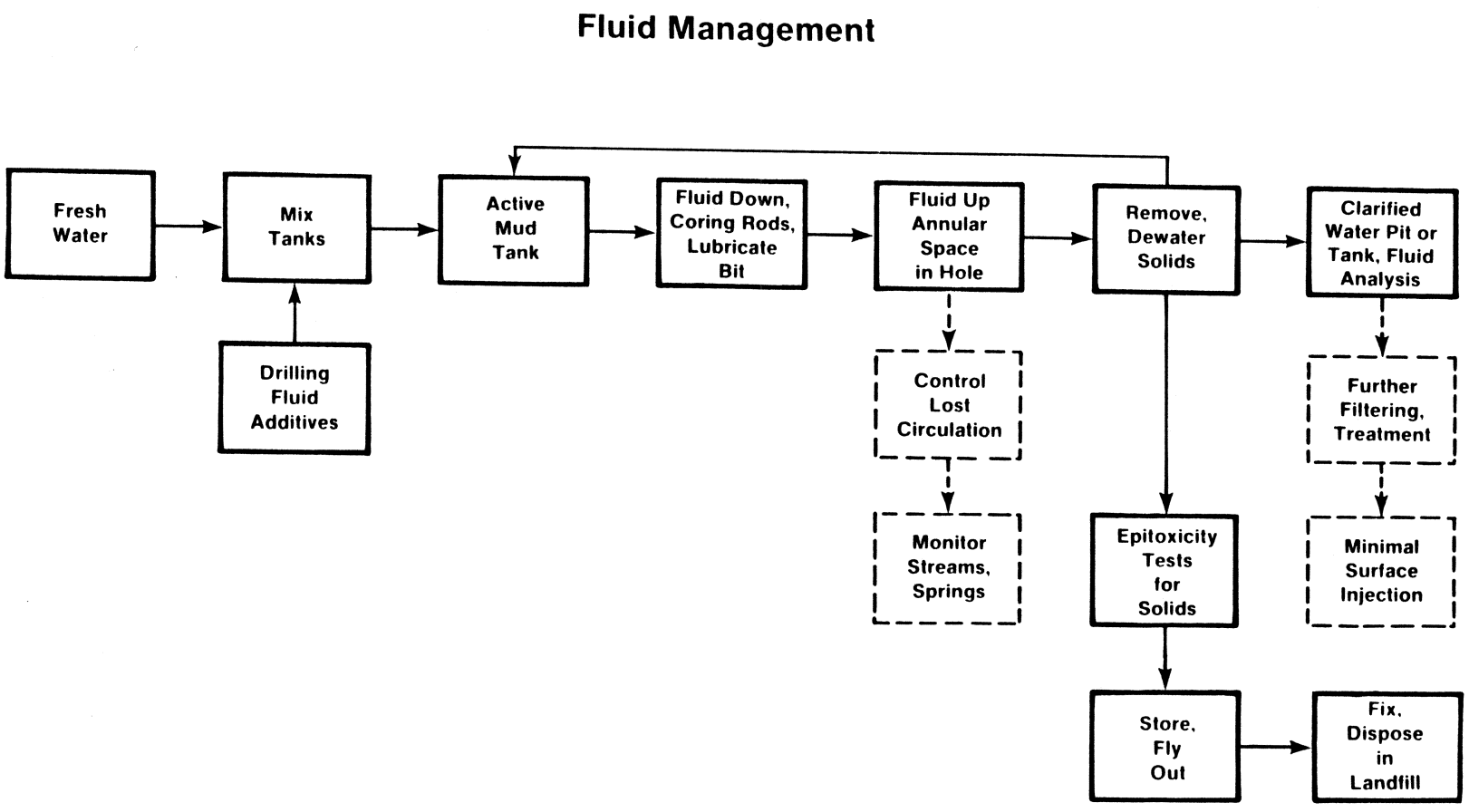


Figure 8-3. Fluid Management Flow Sheet

- 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. The drilling fluid will lubricate the coring (or reaming) bit and carry cuttings to the surface.

- Fluids reaching the surface will pass through a system that serves as a tank, shaleshaker, manifold, and centrifuge. Solids will be dewatered by the on-line centrifuge (Section 8.6.1) or fluids will be returned directly to the mud tank.

- When fluids can no longer be used, the remaining solids will be removed by coagulation and deflocculation. The fluid will be run through a filter system including a carbon filter, and sent to the settling pond.

Normal water usage will be approximately 5,000 gal per day during the 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 will be approximately 1,000 gal per 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, though the hole might continue to absorb 200 to 300 gal per day. During periods of complete lost circulation, water use could increase to approximately 15,000 gal per 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. Once this unpotable water is free of drilling solids, grease, and polymer and it is PH adjusted (if necessary), it will be put in a settling pond and allowed to drain into the ground. Fresh and returned drilling fluids will be sampled for analysis. Fresh drilling fluids will be sampled whenever drilling additives are changed. Returned fluids will be monitored whenever a new formation is entered. If the water has high concentrations of toxic material brought up from the formation that cannot be removed by chemical treatment, it will be helicoptered to the Bristol Bay area for transshipment to an approved disposal site.

An average of approximately 4,000 gal per day of water is used to make drilling fluids. Approximately half of this water will be lost to the formation and half must have solids removed and must be recycled. As a result of recycling drilling fluids, the volume of treated drilling fluids sent to a settling disposal pond will be approximately 600 gal per day.

8.5.2 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). This pond will be in reworked pumice that is away from all vegetation.

Monitoring will be conducted in selected streams and rivers of the Valley of Ten Thousand Smokes to check for signs of drilling fluid from either the surface fluid or the lost circulation (Table 8-2). Monitoring will include measuring levels of salts commonly used in drilling fluids. Monitoring will also include checking for polymer from drilling fluid and polymer decomposition products. Places to be monitored will include the following (Figure 5-3):

- areas on the upper, middle, and lower River Lethe;
- areas on upper Knife Creek (including one or more places where water seeps out of the ash-flow tuff above Knife Creek) and a point on the lower Knife Creek below where fresh water springs enter; and
- the midvalley thermal springs.

Table 8-2

List of Sample Analyses

From Drilling Operations
Fresh drilling fluid
Returned drilling fluid
Cuttings and drilling sludge
From Streams, Rivers, and Springs
Headwaters of the Knife Creek and the River Lethe
Various springs and seeps in the Valley of Ten Thousand Smokes

Streams and rivers will be monitored every four to eight weeks during the drilling phase. During the subsequent well measurements phase and for one or two subsequent years, monitoring will be performed once during each summer season.

If there are severe lost circulation problems at shallow depths, nearby terrain will be examined to make certain that surface emergence of drilling fluids (a spring) has not occurred. If such a spring is created, drilling techniques will be altered and the emergence of drilling fluids will be treated as a spill to be cleaned up (Chapter 10.0 and Appendix C). The deeper the operation penetrates, the less likely it is that this will occur.

Measurements will be performed before drilling commences to establish a baseline in the streams and springs. In addition, careful water

measurements have been performed at over 30 stations in the valley (Section 5.3) (Keith et al., in preparation). If drilling fluids are found in the fresh water system of the park by monitoring or by other means, the drilling will be stopped. The problem will be corrected before drilling continues.

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. 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. Solids will be examined each time that new stratigraphy is cored. The chemical analyses in Tables 5-1 and 5-2 provide a guide for certain element concentrations.

8.6.2 Nondrilling Solid Waste

Combustible nondrilling solids will be incinerated (Appendix A), 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 less than 30 yd^3 when compacted.

8.6.3 Solids From the Cementing Operation

Most cementing operation designs include an amount of excess cement for safety. Excess cement will be removed from the park.

8.7 Cementing

The bottom of the riser pipe will be cemented into competent rock in the upper 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. High temperature cement and spherulite (to lighten cement) will be used in cementing.

The cementing of the interior rods completely to the surface is not planned nor is it technically advisable because the interior rods will be cut and removed (Section 8.3). A waiver of the State of Alaska regulations is requested regarding cementing. The State of Alaska regulations require the cementing of all strings of tubulars. It is proposed that each string of interior rods will be tacked in at the bottom. 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 crews will be flown in and

out as needed. It is expected that the needs for the cement crew will diminish after the main casing string is set.

8.8 Hole Measurements Plan

If possible, measurements in core holes will include temperature logging and monitoring; core hole deviation surveys; borehole televiewer measurements with a slim, high temperature tool; down-hole fluid samplings; and possibly, special logs provided by the Principal Investigators. The vertical hole will be logged before the slant hole is kicked off because simultaneous access to both vertical and slant holes for measurements is 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.

Principal Investigators and associated scientists will provide a continuous lithology log of the holes from the core. Many specialized measurements will be conducted later 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 or connate water aquifers, if identifiable, will be sealed off. A 50-ft plug would be set at the bottom of the casing. The core hole will be filled with a completion mud, and a cement plug will be set greater than or equal to 25 ft in length near the surface. Any protruding pipe will then be cut off and capped below ground level.

8.10 Summary of Critical Operational Problems and Operational Contingencies

Critical operational problems associated with drilling include the following:

- Water Supply and Waterlines Waterlines will be required for the water supply. The project will obtain water by running two 2-in. parallel waterlines from a location along Knife Creek (Section 4.2 and Figure 8-1) to the main drill site, which is 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 radius. The water is accessible without climbing down into the deep gullies that are prevalent in the area (Figure 8-4). A short spur line will be used from the main waterline to a recurrent pond near the campsite that is outside the tephra ring and southeast of the dome (Figures 4-2 and 8-4). Permission is requested to line this pond, which then could become a reliable secondary or possibly primary source of water. (Such a lining is easily removeable.) The lined pond at the main drill site will be kept full of water at the capacity of approximately 50,000 gal, and will be used when the waterline is down for repairs or maintenance. Other possible sources of water include the headwaters of the River Lethe and Mageik Lakes (Figure 4-1). Knife Creek has been observed flowing in

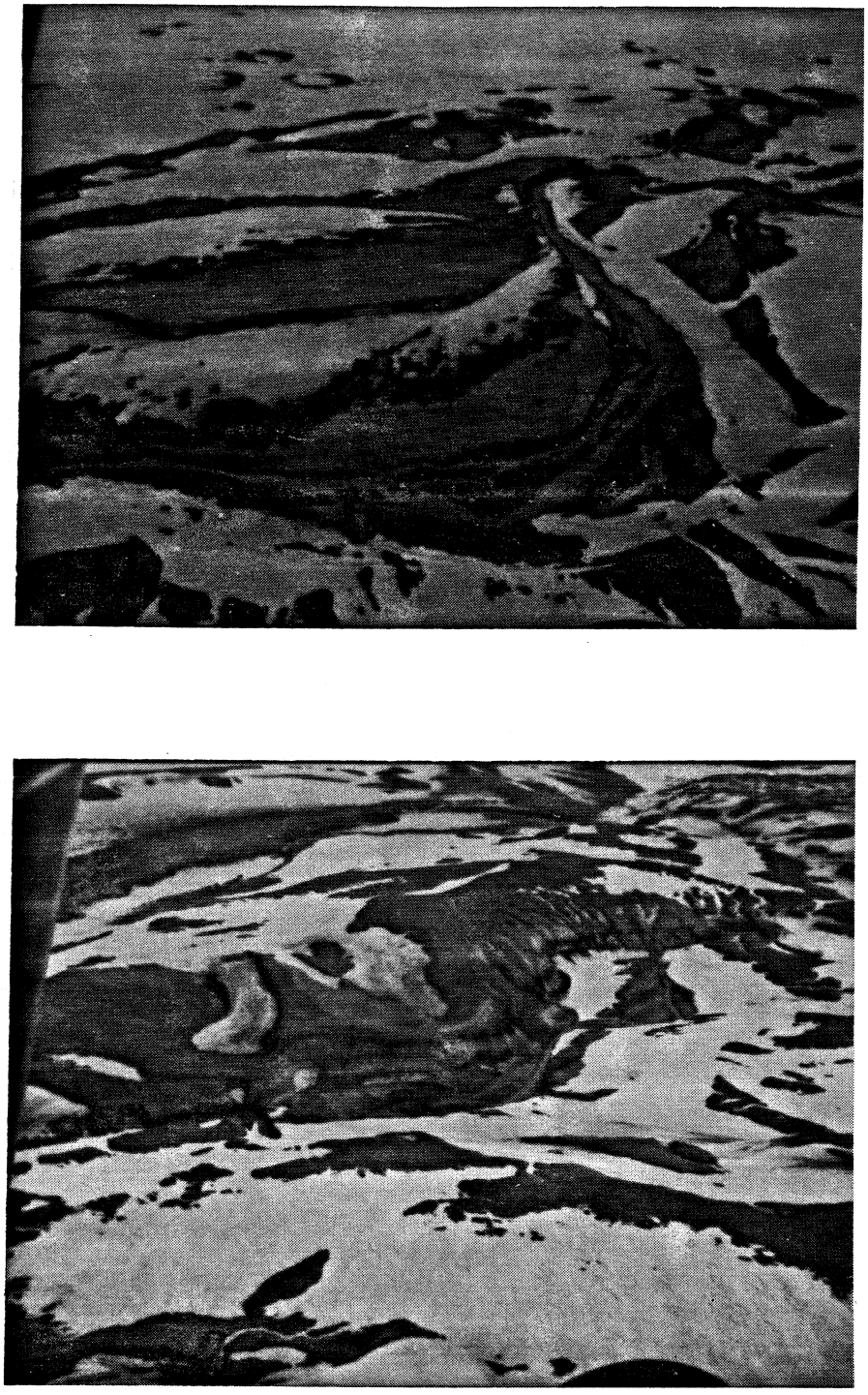


Figure 8-4. Aerial View of the Knife Creek Headwaters

early May through mid-November. A pilot from the Bristol Bay Area has observed flow year-round.

The construction of any waterline over the tephra ring will be a difficult 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. As in the completion of the drilling process, the soils under and adjacent to the waterline will be restored carefully.

Maintaining a waterline of this length by foot and helicopter is difficult; however, it is simpler to install a waterline than to drill for a water source closer to the dome site. (The waterline from the ash-flow site to the River Lethe is only 200 to 300 yd long.) The Knife Creek source is approximately 800 ft below the dome site. This creates a pressure head of approximately 350 psi. Friction losses are approximately 100 psi for a 2-in. line, depending on flow rate. To keep within pressure safety limits, it may be desirable to stage the water into an excavated, lined catch basin halfway between the Knife Creek source and the pond near the camp (although this is unlikely). Heating the waterline will be necessary in the middle to late fall and early to midspring; operating the waterline when the average temperature falls below 20 to 25°F will be difficult.

- The Effects of Loose Pumice At the main drill site, the depth where the pumice becomes consolidated is not certain, but is estimated at 100 ft (~33 m) or less. This is based on examination of the rock in gullies near the dome. Laboratory tests will be performed to determine the weight-bearing capacity of the pumice for sizing the pad.

  A riser pipe of a diameter larger than the conductor pipe (Chapter 7.0, 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 operations. Water will be used to keep pumice and dust down during dry days. Meshes or other suitable commercial product will be available to fix the pumice at the landing pad.

- High Core Hole Temperatures and Pressures (See Section 10.2.)

- Weather for Helicopter Flying 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 (Section 11.4).

- Operational Contingencies

  - During drilling and reaming, there is a possibility of twist off. It may be necessary to skid the rig over 5 or 10 ft to start a new core hole. The old well would be plugged and abandoned.

  - Slant Hole and Whipstock If drilling conditions are not satisfactory for the setting of a whipstock, the hole will be drilled from the surface from the same pad.

  - High Temperatures or Poor Drilling Conditions If high temperatures or extremely poor or unfamiliar drilling conditions are encountered, some drilling operation plans may need altering to be consistent with personnel and well safety and to protect the environment.

- Smaller Rig for Shallow Slant Core Hole It will be advisable to bring in a second smaller rig to drill the shallow slant core hole at the remote site. The work on this core hole is planned after the two deep core holes at the main dome site are completed. However, if delays arise, this rig will be flown in and work will commence on this core hole while problems at the main site are rectified.

- Disposal of Liquids and Solids from Drilling 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. Virtually all of the drilling fluid polymer and grease 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 solid material in better form for fixation. Solids will be flown out of the park and fixed at a suitable landfill.

  The drilling fluid consists of clay and polymer. The polymer will be used (and largely degraded) at higher drilling 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 natural leaching processes in the valley and the effluent from the volcanic thermal springs. These salts from natural phenomena, in turn, are carried by Knife Creek and the River Lethe systems (Table 4-1).

- Hydrologic Effects 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. Additional data were taken during the field season in 1990. 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.

8.11 Special Engineering of Drilling Operations

The GRDO is providing special engineering of certain critical items listed below for the Katmai Drilling Project. The corresponding items available from industry are either marginal or unsuitable for diamond core operations. Engineering improvements to the items below will be performed as needed. Individual components to assemble these items are available. Existing commercial equipment designs may be scaled down for a smaller operation such as this. Certain critical items necessary for the Katmai Drilling Project include the following:

- additional high-temperature drilling fluid additives that are environmentally safe. The available polymers break down at extremely high temperatures; therefore, penetration (coring rates) drop. A degree of success in development of appropriate additives will increase penetration rates, resulting in less time in the park to conduct the operation.

- continued research in optimizing lost circulation additives for diamond core drilling. The ongoing successful research in high-temperature lost circulation problems will emphasize the diamond coring mode of operation. Continued success in this work will minimize fluid loss to the formation, and in general, the potential for well control problems will be decreased.

- redesigning cement pumping and staging equipment. Much of the existing cement units have been designed for oil field applications and are bulky for this type of diamond core operations. Some service companies have "half skid" cement units that can meet the requirements for this project, but further scaling of this type of equipment is necessary to optimize it for operations.

- Instrumentation for down-hole temperature measurements during coring will be developed. This will be based on a down-hole microprocessor/memory system attached to the core tube. In this manner down-hole temperature data will be obtained each time that the core is pulled.

- separation of drilling solids from waste fluids. The technology for dewatering of drilling solids exists from the oil field industry. This process must be scaled down for this operation.

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.

All applicable State of Alaska Occupational Health and Safety Administration (OSHA) regulations will be followed. Compliance with state OSHA regulations automatically ensure compliance with federal regulations. All Mine Safety and Health Administration Regulations that apply to diamond core drilling rigs and their operations will be followed. Helicopter safety regulations and procedures will also be followed (Chapter 11.0).

A site-specific Standard Operation Procedure 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 are included in Appendix B (Wemple, 1989).

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 technician (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 Safe Operating Procedures. 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. The following communication links will be instituted:

- 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;

Table 9-1

Planning Activities Necessary for Medical Emergencies and Illness

Qualifications and Credentials Appropriate for Medical Provider at Katmai Drill Site:

Advanced cardiac life support and advanced trauma life support credentials;

Alaska licensure;

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

Certification with self-contained breathing apparatus experience in wilderness emergency medicine.

Planning Activities to Prepare for Medical Emergencies:

Decisions on equipment; communications, stabilization, cardiac monitoring, and bandaging supplies, irrigations supplies, or other supplies;

Stabilization and treatment area;

Relationship to be established with emergency medical technicians in the Bristol Bay area and Anchorage emergency physicians or family practice physicians;

Helicopter transport to be investigated under various patient conditions;

Decisions on medications to keep onsite; and

Appropriate licenses and certifications.

- 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 requested for the conduct of business and emergencies;
- an emergency communication procedure set up between the drill sites and the clinic at Naknek;

- ground radios available at each drill site and the campsite to talk to support helicopters while they are in flight; and

- ground radios (walkie-talkies) for personnel maintaining the waterline to communicate with the drill site and camp.

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

10.1 Policy for Emergency Preparedness

The policy of the fielding agencies is 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. 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. If appropriate, the depth of the annular fluid) level will be estimated at the end of each coring run and during reaming operations. An echo meter or other appropriate method will be employed.

Pressures in the vent are not known. Due to the fractured nature of volcanic vents, underpressurized fracture formations are anticipated. Higher pressures can be controlled with the blowout prevention system (Chapter 7.0), 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 inlet and outlet drilling fluid flow, pressure, and temperature (Table 10-1). All well control and choke functions will be controlled at two locations: one on the rig floor and one at a convenient location off the rig floor. Weighting materials will be onsite if needed.

In the event that well control problems occur, the following action will be taken:

- Underpressurized (fractured) Formations Venting could possibly occur if the column of water in the wellbore is diminished to a large degree by a fractured formation. The venting would occur if the wellbore pressure from the column of water falls below the

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 and 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
Waterline
Pressure
Flow rates
Inlet and Outlet temperature

boiling point corresponding to the formation temperature at a particular level in the wellbore. A first response would be to pump cold water down the wellbore to temporarily cool the formation below the stream point. Water can be pumped down the rods from the mud pump or down the annulus through the kill line. The kill line can be used even if the rods are not in the hole. If control is temporarily regained, lost circulation materials, weighting materials, and lastly, cement can be employed.

- If the well is overpressured, the influx will be circulated out through the choke line and weighting materials will be employed.

In either case the blowout preventer is available. If well control problems persist, pressurized abandonment techniques will be considered.

In the unlikely event that down-hole pressure must still be relieved, the flow could be sent through a choke line to a mud pit or a larger overflow pit, which can be made available to relieve down-hole pressure.

(This overflow pit will be used to store fresh water for drilling under normal circumstances.) Flowing the well will be performed only as a last resort. Additional reserves of fresh water will be available from the pond on the other side of the tephra ring.

It may be necessary to cool hot drilling fluid through a cooling tower or heat exchanger. Materials for such a cooling device will be stored in King Salmon (Chapter 13.0).

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

Additives for liquid drilling fluid will be stored in a lined 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 at sufficient height to contain the entire volume of the containers plus 10 percent. 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 additives and lost circulation materials 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 C. These plans will also be included in the site-specific Safe Operating Procedures. Bermed areas will be at both drill sites, the camp, and pumping and heating stations. Because the pump at the water inlet is very close to the creek, the berm at that site will have a double wall.

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 and emergencies on the drill site. Sorbent booms and a skimmer will be available for emergencies involving spills of diesel fuel or other sensitive liquids in water. A contingency contract will be executed with an Alaska firm dealing in spill control. Methods of handling the used drilling fluids are discussed in Sections 8.4 and 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 Safe Operating Procedure. (A general Safe Operating Procedure for H_2S monitoring at geotechnical field sites is included in Appendix B). The detectors will monitor locations such as the rig floor, mud pits, cellar, office areas, and camp. On windless days such gasses, if produced, could accumulate within the tempra ring.

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.

10.5 Waterline

Precautions for normal pressure safety will be exercised in operating a pressurized waterline. Appropriate regulations of the State of Alaska and OSHA will be followed. Pressures, inlet and outlet temperatures, and flow rates will be monitored.

10.6 Propane-Fired Toilets

Propane-fired toilets will be used at the camp and possibly at the dome drill site (Sections 8.1 and 12.4). Approximately three 100-lb cylinders will be used each week. Industrial safety standards for this pressurized fuel will be followed.

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 will be used primarily for mobilization and demobilization operations, and a smaller helicopter will 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 and 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 Aviation Manual of the Department of Interior Office of Airline Services 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

All primary and alternate helicopter routes will be chosen in discussion with the pilots, NPS, and State of Alaska Fish and Game personnel. The pilots will be cognizant of wildlife and visitor use areas (Chapter 14.0) and will take appropriate measures consistent with flight safety procedures to avoid or minimize disturbance to these areas.

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 and 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 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. For mobilization and demobilization, an Aerospatiale Puma or Boeing Vertol 107 helicopter is recommended. Also, a Bell 212 or an equivalent helicopter is recommended as the camp helicopter for daily support.

Table 11-1

Estimated Number of Helicopter Flights

Number of Round Trips for Mobilization/Demobilization*	
Helicopter Freight Capacity	Approximate Number of Flights
7,000 lb or	110
3,000 lb	260
Number of Round Trips by Camp Helicopter**	
3,000 lb	660

*This was derived by estimating 8 x 10^5 lb of freight mobilization/ demobilization, and 15 percent loss in sling efficiency.
**Estimating approximately nine months of actual operations.

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.

11.4 Flying Conditions

Poor flying conditions are not uncommon in the Bristol Bay area. Table 11-2 gives the flight conditions in King Salmon in 1986 (Arment, 1989). These data include flyable, marginally flyable, and not flyable weather conditions that were charted throughout the year from a fixed-wing plane flying from King Salmon to the east side of the Alaska Peninsula. These data suggest that fixed-wing flights are possible for approximately 30 percent of the time from King Salmon into the mountains on the east side of the peninsula. The weather on the east side of the peninsula is generally worse than the west side of the peninsula, where the Valley of Ten Thousand Smokes and the drill sites are located. Also, helicopters can sometimes fly under cloud cover when fixed-wing planes cannot. It is difficult to compare the experience of fixed-wing flights to the Alaska Peninsula, to helicopter capability. Based on the experience of helicopter flights during recent geophysical studies, helicopter flights are possible from King Salmon to the mountains more than 50 percent of the time. This is based on summer and early fall operations.

Table 11-2

Aviation Data for Fixed-Wing Planes Flying in the
King Salmon Vicinity in 1986

Month	Lowlands[2]			Mountain[3]			Total
	Flyable[4]	Not Flyable[5]	Marginal[6]	Fylable[4]	Not Flyable[5]	Marginal[6]	
January	16 (76%)	5 (24%)	0	5 (24%)	16 (76%)	0	21
February	10 (72%)	3 (21%)	1 (7%)	7 (50%)	6 (43%)	1 (7%)	14
March	12 (75%)	2 (12.5%)	2 (12.5%)	5 (31%)	7 (44%)	4 (25%)	16
April	12 (55%)	5 (23%)	5 (23%)	8 (36%)	13 (59%)	1 (5%)	22
May	17 (81%)	4 (19%)	0	10 (48%)	9 (43%)	2 (10%)	21
June	13 (62%)	3 (14%)	5 (24%)	5 (24%)	15 (71%)	1 (5%)	21
July	15 (68%)	5 (23%)	2 (9%)	8 (36%)	14 (64%)	0	22
August	15 (76%)	3 (14%)	2 (10%)	3 (14%)	14 (67%)	4 (19%)	21
September	17 (81%)	3 (14%)	1 (5%)	8 (38%)	12 (57%)	1 (5%)	21
October	16 (70%)	4 (17%)	3 (14%)	7 (30%)	15 (65%)	1 (4%)	23
November	6 (33%)	10 (56%)	2 (11%)	2 (11%)	15 (83%)	1 (6%)	18
December	10 (59%)	5 (29%)	2 (12%)	2 (12%)	14 (82%)	1 (6%)	17
Total	160 (68%)	52 (22%)	25 (11%)	70 (30%)	150 (63%)	17 (7%)	237
With Marginal Weather Resolved	178 (75%)	59 (25%)		78 (33%)	159 (67%)		
APPROXIMATE RATIOS	3:1			1:2			

[1]Weather checked at Flight Service Station twice each workday.
[2]West side of Alaska Peninsula (elevations of less than 500 ft).
[3]East side of Alaska Peninsula (elevations of more than 1000 ft).
[4]Y = Yes, flight can be made.
[5]N = No, flight cannot be made.
[6]M = Marginal weather, to take a "look."

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 a 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 (Table 12-1). However, the number of personnel present must always be adequate for safe response to drilling or environmental problems. The camp will have sufficient space for visitors in case of severe weather.

Table 12-1

List 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
Six drilling crew (two 3-person crews)
Drill rig mechanic/welder
Two watermen/helpers
Three camp personnel
Park Ranger
Helicopter pilot
Helicopter mechanic
Emergency medical technician (may be a member of the crew)
Chemist/Drilling Fluid Specialist
Environmental, Safety, and Health Technician
Itinerant Operating Personnel
Two to three cement crew
Contract inspectors
Special crafts
Inspectors from permitting agencies and environmental firms under contract
Other Itinerant
Science visitors (national and international)
Students
Visiting park tourists
Management from funding agencies

Because of safety and environmental considerations, the camp will be in an actively alluviating bare pumice basin, 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 reworked pumice. 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 the potential hydrogen sulfide hazard.

12.2 Access Between Drill Sites and the Main Camp

A fixed path between the campsite and Novarupta Dome will be designated (Section 4.5). Special precautions will be taken on the steep portions of the path across the tephra ring to prevent erosion and to ensure personnel safety. These precautions will include laying boards, cinder blocks, or other suitable decking material and erecting a railing. Personnel will travel back and forth from the camp to the drill site at all hours, often in severe weather. This path will be parallel and 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, the pathway will be removed, and the ground will be restored. Access to and from the camp will be restricted to this path except for emergency situations.

A survival tent will be placed close to the main drill site. Weather periods may be severe enough for short periods to preclude ready access between the campsite and the drill site. Personnel at the drill site may therefore remain at the drill site 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 survival tent and emergency food supplies 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 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 ranger will specialize or be knowledgeable in areas of resource management and biology. The helicopter pilot and mechanic will remain either at the field camp or King Salmon, as safety requirements and operational conditions 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 highly trained medical technician. A resident chemist will be necessary to treat returned drilling fluids, maintain fluid properties, and assist in controlling lost circulation. An environmental, health, and safety technician will be in residence.



Figure 12-1. Vicinity of the Campsite

Provisions will be made for itinerant 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, but weather conditions or other factors could dictate overnight stays.

Park visitors arriving at the drill sites will be briefed by the Park Ranger in residence along with USGS and GRDO site managers. If safety and operational conditions permit, they will be given a tour of the drill site.

12.4 Camp Waste and Bear-Proofing of the Camp and Drill Sites

An engineer licensed in Alaska will construct a drain field 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.

The camp will be clean and bear proof. Foods and edible trash will be stored in bear-proof containers. All necessary bear-proofing practices will be conducted by camp personnel and adhered to by all personnel at the camp. Appropriate cleaning practices will be followed at both drill sites.

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 may 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 April through the middle of October. A chartered barge or other vessel may operate in this area outside of these dates, depending on the weather. The material will be trucked to the support base at King Salmon.

13.2 Support Base at the 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.

13.3 Disposition of Core from Support Base

When the core arrives at the support facilities in the King Salmon area from the drill site, some additional logging of the core will be performed. However, the wiping, marking, and initial inspection of the well must be performed in the field by the Principal Investigator. The core will be stored as necessary and shipped from the King Salmon facility. It will be shipped to the USGS Branch of Alaska Geology in Anchorage and will be sampled for analysis by the consortium of scientists and laboratories as described in the Katmai Science Plan. The core will then be documented by the Curation Office (CO). The remaining core will be sent to the CO core facility at the DOE/United Nuclear facility in Grand Junction, Colorado.

14.0 OPERATING STANDARDS, ENVIRONMENTAL PROTECTION, SITE RECLAMATION, AND 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 all 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. 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, if any such damage is found and is reasonably attributed to this drilling project after plugging and abandonment, 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 10.0 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 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. Cement from the guy wire anchors will be removed to a reasonable depth, and the surfaces will be restored. 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 the impact to the environment. The following reaffirms and summarizes measures to be taken to mitigate impact to 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. Photography will be accomplished in collaboration with NPS personnel.

- 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 returning and areas covered with moss and lichen.

- When necessary, access across the moss and lichen or soft soil will be facilitated by decking material, plants, etc., and will be wide enough to allow easy walking and distribution of weight to minimize disturbance to the plant growth. Vegetation transects will be established under NPS supervision to determine impacts to the site and recovery in later years.

- 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 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 or a D3 or D4 wide-track catepillar tractor will be used to move equipment and materials and will be confined to

the drill sites. 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, would require 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 wastes, if any, in an approved waste site. If necessary, drilling solids can be fixed near or on the premises of the waste site. If local arrangements cannot be made, the solids and liquids will be temporarily stored in a safe manner for shipment to a proper site for environmentally safe disposal.

- A drain field will be constructed near the campsite 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.

- Absorbent 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. The contractor will advise GRDO of any recommended remedial action. Such advice will be implemented after consulting with the NPS (through the USGS).

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

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

- An overflow pit will be available in the unlikely event of a blowout.

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

- An oil field service company with experience in geothermal cementing will be under contract to help assure a good bonding of the conductor pipe and main casing string to the formation, and to help the project of expert assistance in combating severe lost circulation problems.

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

- Funds will be reserved to combat spills and mitigate any resulting damage.

- 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 that is unrelated to the project will be removed whenever possible, and attendant damage remediated.

- Both the helicopter and camp industries in Alaska have a history of successful environmental compliance. In addition, the environmental awareness of the diamond core (minerals) drilling and coring industry that will conduct this work has vastly increased in recent years. The project will consider environmental awareness as an important criteria for contractor selection.

- Prior to fielding, engineering will be performed by the project. Critical equipment or materials will be provided when they are not available from industry.

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 responsive to that goal and employs the best, coordinated, interdisciplinary approach that current knowledge and technology permit. Because the eruption in 1912 was the central event that led to establishment of Katmai National Park, the greatly improved understanding of the eruption which 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. The Visitor Center, Overlook Cabin, and other places in the valley will have available annually updated geological displays and nontechnical literature that will reveal findings of this project. The project will develop this educational effort under the direction of the interpretive program of Katmai National Park.

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 the most dangerous type of eruption. 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 eruption in 1912 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 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 IMPACT TO FLORA AND FAUNA; CLIMATOLOGICAL, WATER FLOW, AND CULTURAL CONSIDERATIONS; AND ENVIRONMENTAL CONSEQUENCES

15.1 Flora

15.1.1 General Comments

There are two flora zones within the park: the Hudsonian and the arctic zones (Cahalane, 1959). Site areas are predominantly in the arctic zone due to elevation. The arctic zone extends from the mountain tops down to approximately 2,000 ft. Lower elevations also have this arctic zone where glaciers exert an influence. The dome site has a 2,500-ft elevation. The campsite has a 2,700-ft elevation. The ash-flow site has an approximate 1,850-ft elevation (Figures 1-3 and 4-1). Flora and fauna in the arctic zones are relatively simple. They are especially simple in the Valley of Ten Thousand Smokes due to the devastation of the eruption in 1912. Low-lying plants and small mammals characterize much of the flora and fauna, although larger mammals occasionally pass through these areas. Exposed ridges in the park are depleted of snow during the winter, and available moisture to plants is reduced. Strong winds control the availability and potential for vegetation on this pumice-like material by diminishing moisture and blowing away soil that would form. Thus much of the existing flora that has reestablished itself since the eruption in 1912 is sheltered.

15.1.2 Flora Before the Eruption in 1912

Several small areas containing flora and fauna survived the eruption in a small canyon between Mt. Katmai and Mt. Juhle (Cahalane, 1959). These provide a clue to the pre-eruption vegetation and are summarized in Table 15-1. These sites are well provided with moisture.

15.1.3 Devastation From the Eruption in 1912

During the summer of 1917, Griggs stated that

> . . . all vestiges of life were consumed by fire . . . Throughout the upper portion of the Valley of Ten Thousand Smokes and its branches not a vestige of the vegetation which must once have covered it is to be found. So complete has been the destruction that no evidence of what happened to the plants remains to tell the tale . . . We could not reasonably suppose that the area had been devoid of all vegetation before the eruption. Indeed, we knew that there were once good-sized trees far up toward Katmai Pass. On the other hand, in the light of our acquaintance with conditions on the other side of the range, we were hesitant in hypothecating destructive agencies so intense as to eradicate the very evidence of their action (Griggs, 1919).

Flora and fauna had been totally destroyed by the eruption in 1912.

Table 15-1

Species of Flora Collected From Original Plant Colonies That Survived the Eruption in 1912

Schizogonium murale (green algae)
*Philonotis fontana (moss)
Equisetum arvense (common horsetail)
Agrostis scabra var. geminata (tickle grass)
Deschampsia caespitosa, tufted hair grass
*Stellaria crispa (crisp starwort)
*Cerastium caespitosum (larger mouse-ear chickweed)
Papaver radicatum subsp. alaskanum (Arctic poppy)
*Cardamine bellidifolia (alpine cress)
*Saxifraga punctata subsp. nelsoniana (brook saxifrage)
Geranium erianthum, northern geranium
*Heuchera glabra (alpine heuchera)
*Epilobium hornemannii (Hornemann willowherb)
E. latifolium (dwarf fireweed)
*Romanzoffia sitchensis (mist maid)

*Not seen elsewhere in valley as of 1953-1954.

15.1.4 Reestablishment of Flora

The first flora that returned to the valley was algae and mosses around the fumaroles, which were observed in 1917 but died out as the fumaroles cooled. Liverworts that had formed thick heavy carpets were observed in 1930 (Griggs, 1933). However, Griggs mentions isolated clumps of grass close to Novarupta Dome in 1930. Grasses are presently established just to the north of Novarupta Dome within the tephra ring. By 1954 the liverworts had disappeared and most of the active moss and algae had retreated to the remaining warm fumaroles. Steam that was so prevalent from the many fumaroles after the eruption was no longer available to permeate the tuff, and rainwater ran off the tuff and did not remain to nurture plants.

However, by 1954 higher plants had gained footholds on the ridges between Novarupta Dome and Mt. Juhle, particularly in local depressions or washes. An example of plants reestablishing in such a depression in the pumice is given in Figure 15-1. Plants observed up to that time are listed in Table 15-2.

Plots were established in the Valley of Ten Thousand Smokes to systematically study flora (Cahalane, 1959). Two plots were in the broad flat valley west of the Baked Mountain (Figure 4-2) draining to the River Lethe. These plots are similar to sites selected for the ash-flow site and the camp. Little or no vegetation at these sites was seen. One site was on the western slope of the tephra ring surrounding Novarupta Dome. Flora was largely confined to washes.

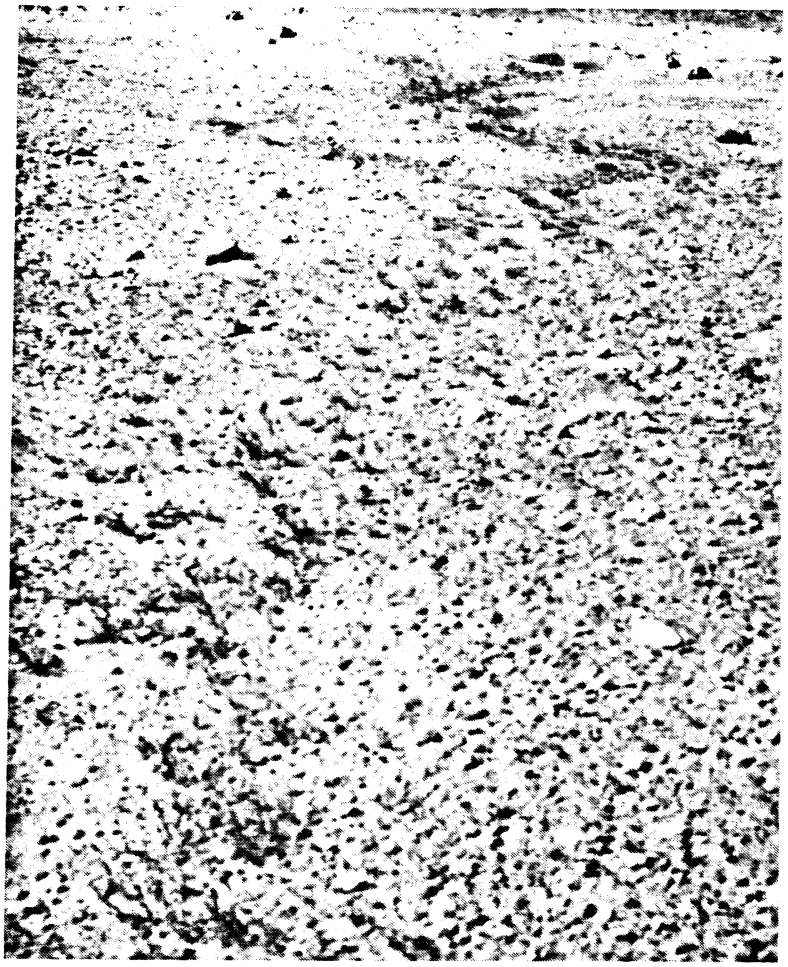


Figure 15-1. Reestablishment of Flora in Gullies in the Valley of Ten Thousand Smokes

Table 15-2

Flora Observed in the Valley of Ten Thousand Smokes in 1853 and 1854

Pogonatum alpinum (alpine pogonatum)
Polytrichum commune (hair-cap moss)
P. juniperinum (juniper hair-cap moss)
Equisetum arvense (common horsetail), 5 localities
Agrostis scabra (tickle grass)
A. scabra var. geminata (tickle grass), 2 localities
Calamagrostis canadensis (bluejoint), 5 localities
Deschampsia caespitosa (tufted hair grass)
Trisetum spicatum (downy oat grass), 2 localities
Poa arctica subsp. williamsii (Arctic blue grass), 5 localities
P. hispidula (hispid blue grass), 2 localities
P. lanata (lanate blue grass)
P. stenantha (narrow-flowered blue grass)
Eriophorum angustifolium (tall cotton grass)
E. scheuchzeri (white cotton grass)
Carex macrochaeta (Alaska long-awned sedge), 2 localities
C. mertensii (Mertens sedge), 8 localities
Luzula arcuata (alpine wood rush), 3 localities
L. parviflora (small-flowered wood rush), 2 localities
Salix alaxensis (felty-leaved willow), 4 localities
S. anglorum (willow), 2 localities
S. arbusculiodes var. glabra (willow)
S. arctica (Arctic willow), 2 localities
S. arctica var. obcordata (Arctic willow)
S. barclayi (Barclay's willow), 3 localities
S. desertorum (willow)
S. geyeriana (willow)
S. pseudomonticola (willow)
S. pulchra (beautiful willow)
S. scouleriana (willow)
Oxyria digyna (mountain sorrel), 4 localities
Sagina intermedia (snow pearlwort)
Papaver radicatum subsp. alaskanum (Arctic poppy), 2 localities
Oxytropis (sp. ?) (oxytrope)
Epilobium latifolium (dwarf fireweed), 4 localities

15.1.5 Sheltered Areas and Current Flora

There is no soil (as is commonly thought of) on these deposits or forest in the area. Sparse grasses, mosses, small plants, and trees are returning. These plants live mainly, but not exclusively, in thermal areas around Novarupta Dome and in other sheltered areas. This is especially true north of the dome within the tephra ring. There are grasses, numerous plants, and moss. Water from rainfall remains there longer than over the other reworked pumice surfaces nearby. Efforts will be made to avoid the

vegetated areas and obvious flora and fauna. Foot traffic or other project-related activity will be avoided or at least minimized in and around these areas. Temporary wooden planks, outdoor carpet, or other suitable decking material will be set up where necessary.

Numerous soft surfaces containing lichens and moss are present in the vent region and on the outer slopes of the tephra ring (Chapter 4.0). If the moss must be removed, attempts will be made to bank it for reapplication later, if feasible.

Moss and lichen (cryptogams) is the first stage in the normal process of establishing flora in the areas laid bare by the eruption in 1912. Moss and lichen stabilizes the soil, adds organic matter to the soil, and increases the moisture content of the top inch of the soil. This further stabilization of the soil may assist in the colonization of higher forms of flora mentioned above.

The sites proposed for the drill sites and camp have mainly bare pumice that may have been reworked by wind and water (Section 4.1). There is little or no vegetation at these sites, which is consistent with the earlier vegetation studies. There is flora in the proximity of the dome drill site and mosses in the vicinity of the access path between the dome site and the camp. Efforts were made to avoid vegetated areas in site selection.

15.2 Fauna

15.2.1 Birds

Bird life in the area before the eruption in 1912 was eliminated by the eruption. The resulting inhospitable environment prevented most species from returning to the Valley of Ten Thousand Smokes, and sightings of birds in the Valley is still uncommon. Table 15-3 lists observations of birds and their location in the valley.

There is little potential bird habitat at either the ash-flow site or the camp. However, snow buntings reside in the area around Novarupta Dome in the summer. Waterfowl do not inhabit the area near the drill or sites.

A southern helicopter flight route from King Salmon to the Novarupta area does not pass directly over high-density wildlife areas. The area around King Salmon airport is inhabited by waterfowl in the spring and fall seasons (Figure 15-2); flying in higher altitude mitigates this potential problem.

15.2.2 Mammals

Small burrowing animals live in some of the thermal areas around the dome. These animals may have survived in the islands of vegetation discussed above. Bears and possibly moose and caribou pass through the valley, but their incursions are rare. The habitat in the valley is not hospitable to these animals.

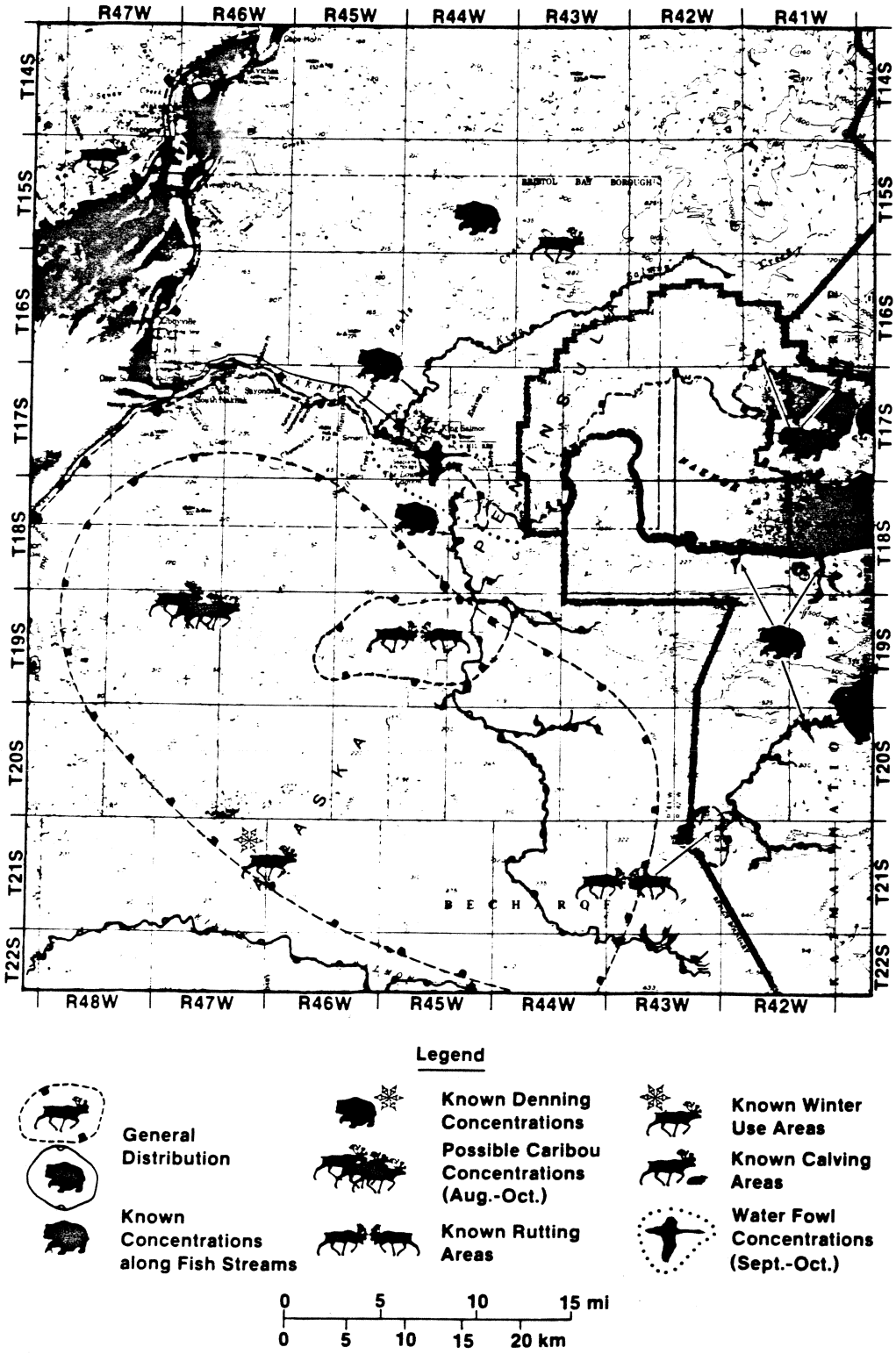


Figure 15-2. Bear and Caribou Use Areas and the Area Inhabited by Waterfowl in the Vicinity of Naknek River

Table 15-3

Observations of Birds Seen in the Valley of Ten Thousand Smokes Through 1954 (Cahalane, 1959)

Name	Place	Date
Green-winged teal	Seen at the head of the River Lethe valley	Mid-August, 1954.
American rough-legged hawk	Seen near Three Forks (lower valley)	September 14-17, 1940.
Golden eagle	Seen on the West slope of Katmai Volcano	July 4, 1954.
Northern bald eagle	Seen over the valley	Summer, 1917.
Marsh hawk	Seen at the lower end of valley	September 15, 1940.
Willow ptarmigan	Seen at the Upper Knife Creek	Early August, 1954.
Northern common raven	Seen at the Upper Knife Creek	August 15, 1954.
Western water pipit	Seen at the Upper Knife Creek	August 5, 1954.
Common redpoll	Seen over the valley	Summer, 1917.
Golden-crowned sparrow	Seen at the Head of Knife Creek	Early August, 1953.
Eastern snow bunting	Seen in the Valley and at the head of Knife Creek	Summer of 1917, and numerous occasions in July and August, 1953 and 1954. Seen regularly in the vicinity of Novarupta Dome.

The specific pattern of land use of mammals and other animals may vary over time. Usage pattern data for areas near potential helicopter flight routes can be made, however, from existing knowledge of state and federal fish and game agencies (State of Alaska, 1985; U.S. Fish and Wildlife Service, 1989).

In the warm season there are concentrations of bears along fish streams within an approximate 7- to 10-mi circle around Brook Camp. There are

known concentrations of bears along fish streams in the vicinity of King Salmon. Bear dens are in the vicinity of Mt. Katolinat, Mt. Ikaghluik, Mt. Juhle, and on the Shelikof Strait coast from the Katmai River to Kninak Bay (Figures 15-2, 15-3, and 15-4).

Caribou concentrations of the Southern Alaska Peninsula (Malchatna) herd have been found south of the Naknek River (Figures 15-2, 15-3, and 15-4) where rutting and winter use areas are known. They are distributed along both sides of the Naknek River, Lake Brooks, Naknek Lake, and both east and west of the Valley of Ten Thousand Smokes. Both the southern and northern Alaska Peninsula herds have intermingled between the Naknek River and Iliamna Lake, although the calving grounds of these respective herds are far from the King Salmon-Naknek Area or the proposed drill sites (Figure 15-4) (U.S. Fish and Wildlife Service, 1989). Helicopter routes can be chosen to avoid heavy animal use areas, and they can fly sufficiently high to minimize disturbance to these animals.

A general distribution of moose inhabit the areas between King Salmon and the Valley of Ten Thousand Smokes. There are no moose in the valley. Precautions taken to avoid disturbing bear and caribou will be adequate to avoid disturbing the moose population.

15.2.3 Fish

The rivers and streams in the Valley of Ten Thousand Smokes are not inhabited by fish. Salmon are present 2 to 3 mi up the Ukak River from Brooks Lake. Trout are seen 2 to 3 mi up Margot Creek from Brooks Lake.

15.3 Noise and Air Quality

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.

15.4 Climatological Data at King Salmon and the Proposed Drill Sites

The climate is cool and wet with limited diurnal variation. The area is subject to fog and very strong winds. There are no recorded weather data at the proposed drill sites because of their remoteness. King Salmon and (to a somewhat lesser extent) the proposed drill sites experience a predominantly marine climate with diurnal and seasonal temperatures confined within rather narrow limits. However, both King Salmon and the drill sites experience definite continental influences causing occasional strong climatic fluctuations. From December through March (months of the proposed winter shutdown) the area experiences strong winds due to passage of Aleutian lows. Winds of 50 to 90 mph are not uncommon in the King Salmon area. Strong winds are notorious in the mountains. Ice in the bay around King Salmon becomes safe to cross on foot in mid-November. The Naknek River ice becomes safe to cross on foot in approximately late November. Ice breakup on the bay is in early April, and on the Naknek River ice breakup is in approximately mid-April (NOAA, 1986). Possible

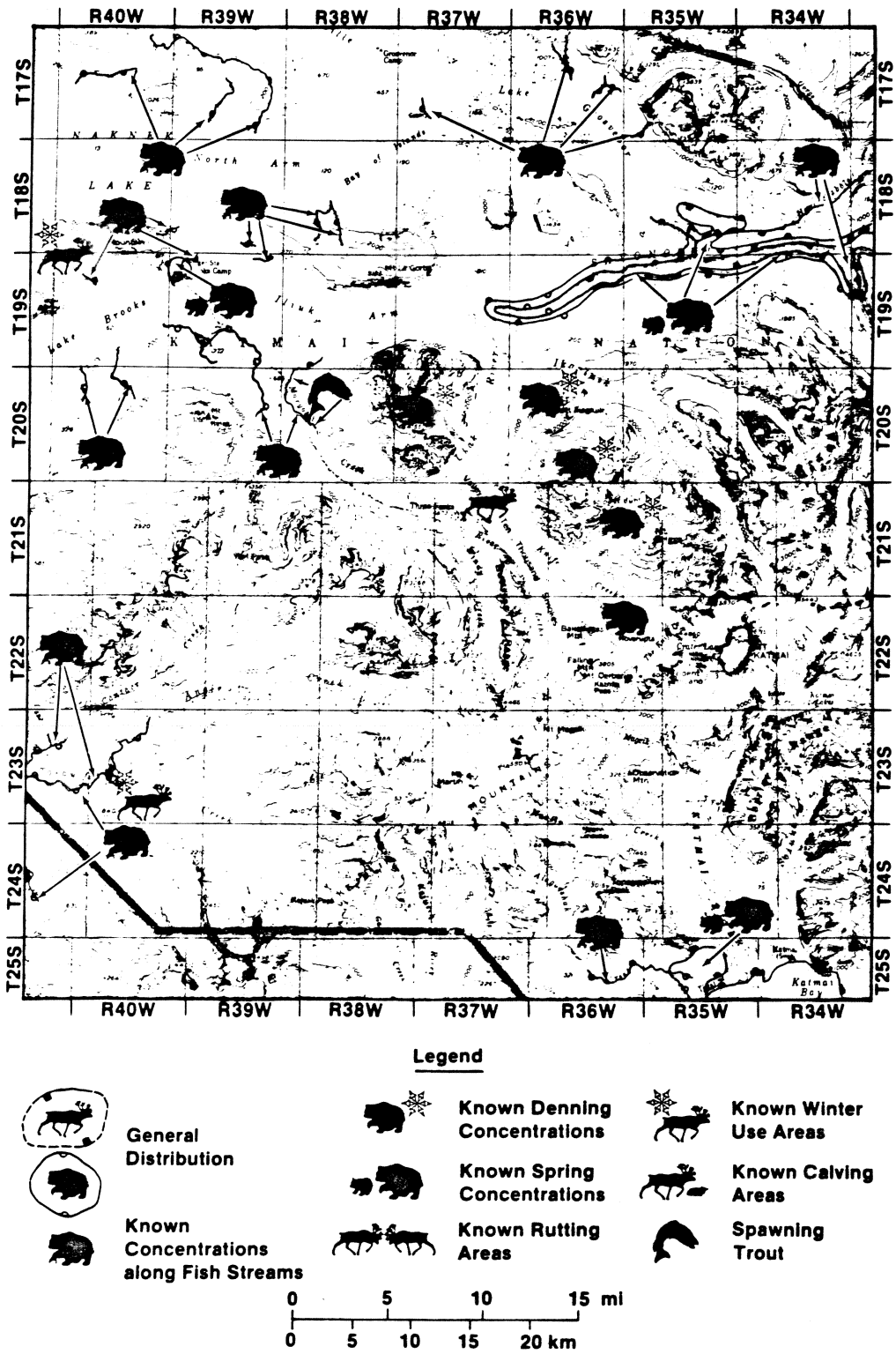
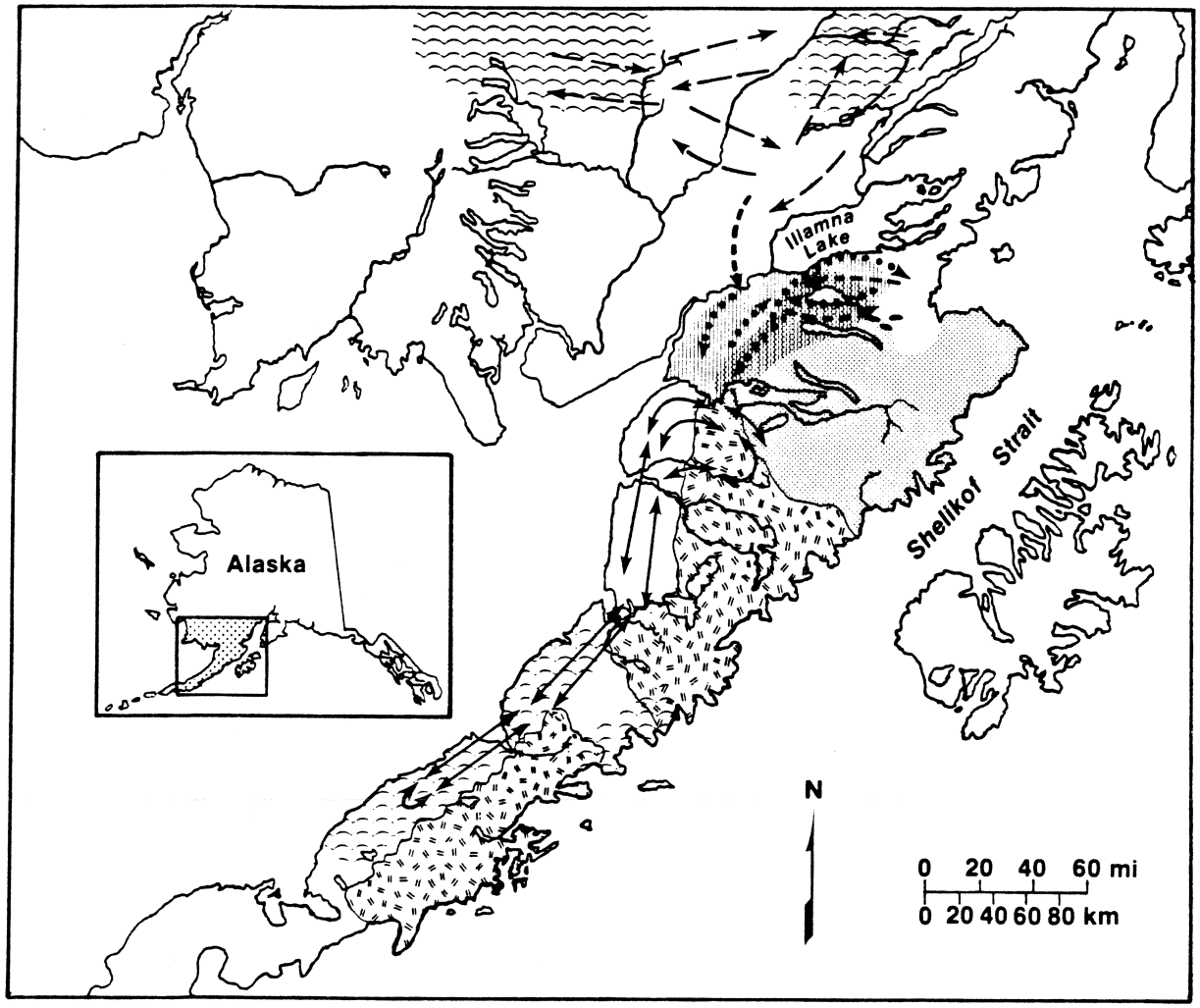


Figure 15-3. Bear and Caribou Use Areas in the Vicinity of Katmai National Park



Legend

←———	Northern Herd Migration	(Prior to 1986)
←•••••••	Northern Herd Migration Extension	(1986-1989)
←— — —	Mulchatna Herd Migration	(Prior to 1988)
←– – – –	Mulchatna Herd Migration Extension	(1988-1989)
	Winter Range Extension	(1986-1989)
	Katmai National Park	
	Alaska Peninsula/Becharof Refuges	
	Calving Grounds	

Figure 15-4. Principal Caribou Migration Paths, Range, and Calving Areas on the Alaska Peninsula

months of barge transportation would then range from approximately April into October.

The data showing King Salmon sites that will support helicopter flights are given in Table 15-4 and Figure 15-5. This data verifies the tenuous nature of Bristol Bay Flight weather. For example, the mean cloud cover ranges from 60 to 90 percent in any given month and often the ceiling is low, consistent with tabulated flight conditions shown in Table 11-2.

The King Salmon data in Table 15-4 is only an approximation of the weather at the proposed drill sites. Cloud and wind conditions can be quite different from that of the King Salmon area. Due to elevation, the temperatures can be 10 to 20°F colder. Maximum snow on the ground at King Salmon averages approximately 10 in. Considerably more snow could be expected at the Novarupta Dome site.

15.5 Water Flow

Much of the fresh flow is thought to be subsurface flow through the porous tephra deposits from the eruption in 1912 and above the Naknek siltstone. Fresh water springs flow more readily in rainy years. Water sampled over the duration of a decade from the Valley of Ten Thousand Smokes suggests that leaching of pumice and saline warm springs add to the salt content of the River Lethe, Knife Creek, and Ukak River system. This system can be laden with silt, ash, and pumice. Fish do not inhabit this system except for the extreme lower Ukak River. The habitat in the valley is not hospitable to these animals.

15.6 Cultural Considerations

Any evidence of cultural activities prior to the eruption in 1912 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.

Table 15-4

Local King Salmon Climatological Data Providing 10- and 20-Yr Averages

PREPARED BY: USAFETAC
AUGUST 1983

STATION NAME: KING SALMON AFS AK
LOCATION : N58 41 W156 39

PERIOD: JUNE 42-DEC 82
ELEV: 57 FT

STN LTRS:
MSC NO: AKN 70326D

AWS CLIMATIC BRIEF

MONTH	TEMPERATURE (°F) MEAN DAILY MAX	MEAN DAILY MIN	MEAN MONTHLY	EXTREME MAX	EXTREME MIN	PRECIPITATION (IN) MONTHLY MEAN	MONTHLY MAX	MONTHLY MIN	MAX 24 HRS	SNOWFALL (IN) MONTHLY MEAN	MONTHLY MAX	MAX 24 HRS
JAN	21	6	13	53	-46	1.1	3.0	.2	.9	7	19	9
FEB	23	7	15	51	-41	.9	2.8	.1	1.3	7	15	8
MAR	28	12	20	56	-42	1.2	2.4	s	1.0	8	20	11
APR	39	23	31	65	-19	1.0	3.0	s	1.2	5	16	5
MAY	51	34	43	77	4	1.1	2.4	.1	1.0	1	6	2
JUN	59	41	50	88	29	1.6	3.8	.3	.9	s	1	1
JUL	63	46	55	86	30	2.1	4.3	.3	1.1	0	0	0
AUG	61	47	54	84	28	3.2	6.4	1.1	1.4	0	0	0
SEP	55	40	47	74	16	2.9	7.3	.8	1.7	s	1	1
OCT	41	26	34	67	-11	2.1	6.5	.2	1.3	3	15	5
NOV	30	15	23	50	-26	1.4	3.0	s	1.0	6	16	9
DEC	20	4	12	48	-38	1.2	3.7	.1	.8	9	16	6
ANN	41	25	33	88	-46	19.8	7.3	s	1.7	46	20	11
EYR	41	41	41	41	41	40	40	40	40	40	37	37

MONTH	MEAN RELATIVE HUMIDITY (%) LST 04	13	MEAN VAPOR PRESSURE (IN Hg)	MEAN DEW PT (°F)	PRESSURE ALTITUDE (FT) 99.85%	SURFACE WINDS FVLG DRCTN (16 PT)	SPEED MEAN (KT)	SPEED MAX (KT) **	MEAN CLOUD COVER (?)
JAN	75	73	.08	12	1750	N	9	70	7
FEB	71	65	.06	7	1700	N	9	821	6
MAR	78	66	.09	16	1350	E	9	80	7
APR	31	61	.13	24	1300	E	9	62	8
MAY	83	56	.19	33	1100	E	10	67	8
JUN	89	61	.26	41	800	S	9	60	9
JUL	90	64	.32	47	650	S	9	65	9
AUG	89	66	.32	47	850	S	8	57	8
SEP	86	66	.25	40	1200	SSE	9	64	8
OCT	82	69	.15	27	1550	N	9	65	8
NOV	80	75	.10	18	1700	N	9	72	7
DEC	75	73	.06	8	1900	N	8	62	7
ANN	82	66	.15	27	1400	N	9	323	8
EYR	10	10	10	10	10	10	10	30	10

MONTH	MEAN NUMBER OF DATES OCCURRENCE OF: PRECIP (IN) ≥ 0.01	PRECIP (IN) ≥ 0.5	SNOWFALL (IN) ≥ 0.1	SNOWFALL (IN) ≥ 1.5	THUNDER STORMS	FOG VSBY < 7 MI	TEMPERATURE (°F) MAX ≥ 70	MAX ≥ 60	MIN ≤ 32	MIN ≤ -15
JAN	10	s	7	2	0	9	0	0	28	5
FEB	10	s	7	1	0	7	0	0	26	4
MAR	11	s	9	2	0	9	0	0	28	2
APR	10	s	6	1	0	9	0	s	26	s
MAY	11	s	1	s	s	s	s	4	11	0
JUN	13	s	s	0	s	13	2	13	1	0
JUL	15	1	0	0	s	17	6	20	s	0
AUG	18	1	0	0	s	19	3	18	s	0
SEP	16	1	s	0	s	12	s	5	5	0
OCT	14	1	3	1	s	10	0	s	21	0
NOV	12	s	7	1	s	11	0	0	26	s
DEC	12	s	9	2	s	11	0	0	28	5
ANN	152	4	49	10	s	135	11	60	201	16
EYR	40	40	37	37	37	37	41	41	41	41

*Data are not available.
sAmounts are less than is shown in the heading.
**Instantaneous peak winds.
SPercentage of calm is greater than the percentage of PLVG direction.
δBased on less than full months.

REMARKS: RUSSWO POR:
HOURLY OBS: JAN 73 - DEC 82
DAILY OBS: JUN 42 - DEC 82

Table 15-4

Local King Salmon Climatological Data Providing 10- and 20-Yr Averages (Continued)

CAV FREQ(%)	HRS LST	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	EYR
	00-02	22	17	24	27	21	32	34	34	19	24	21	26	25	
	03-05	22	17	25	31	25	41	44	43	20	25	23	23	28	
CEILING LESS	06-08	22	19	24	30	23	42	42	41	21	25	26	25	28	
THAN 3000 FT	09-11	21	19	24	28	23	36	38	36	23	26	22	24	27	
AND/OR VISIBILITY	12-14	16	17	25	26	22	25	29	30	20	28	24	23	24	
LESS THAN 3 MI	15-17	18	17	20	22	19	20	22	27	14	24	25	26	21	
	18-20	19	16	21	19	15	21	20	25	14	22	24	27	20	
	21-23	20	17	22	24	18	25	25	25	16	24	23	26	22	
	ALL HRS	20	17	23	26	21	30	32	33	18	25	24	25	25	10
	00-02	13	11	14	15	13	22	26	25	10	11	14	17	16	
	03-05	13	10	15	19	17	31	36	33	11	12	16	16	19	
CEILING LESS	06-08	12	11	16	18	15	33	34	32	12	13	16	16	19	
THAN 1500 FT	09-11	13	11	15	15	9	22	26	22	11	12	13	17	16	
AND/OR VISIBILITY	12-14	11	11	13	11	6	10	13	14	7	12	14	16	12	
LESS THAN 3 MI	15-17	11	11	12	8	4	7	8	10	4	9	15	17	10	
	18-20	13	9	13	9	6	8	8	12	5	8	14	17	10	
	21-23	13	10	12	11	10	16	14	16	6	10	15	15	12	
	ALL HRS	12	11	14	13	10	19	21	21	8	11	15	16	14	10
	00-02	10	8	9	11	10	20	22	20	8	7	11	13	12	
	03-05	10	8	8	14	14	29	32	29	8	10	11	12	15	
CEILING LESS	06-08	9	7	9	14	12	29	29	28	9	9	11	12	15	
THAN 1000 FT	09-11	10	8	10	9	6	13	17	15	6	s	10	13	10	
AND/OR VISIBILITY	12-14	9	9	9	6	3	4	5	5	4	s	10	13	7	
LESS THAN 2 MI	15-17	8	8	8	4	2	3	3	2	2	4	11	14	6	
	18-20	10	5	7	5	3	5	3	6	3	5	11	12	6	
	21-23	10	6	8	8	6	13	11	11	5	6	10	12	9	
	ALL HRS	10	7	9	9	7	15	15	15	6	7	11	13	10	10
	00-02	3	2	s	1	2	5	4	6	3	1	3	2	3	
	03-05	2	1	1	2	3	7	9	10	3	2	3	1	4	
CEILING LESS	06-08	2	1	1	2	1	2	5	8	3	2	2	1	3	
THAN 200 FT	09-11	1	1	s	s	s	0	s	s	1	1	2	3	1	
AND/OR VISIBILITY	12-14	1	2	s	0	s	0	0	0	0	s	1	1	s	
LESS THAN 1/2 MI	15-17	2	1	s	0	0	0	0	0	0	s	1	2	1	
	18-20	2	1	s	s	0	0	0	0	0	s	1	1	s	
	21-23	2	1	1	1	s	1	2	s	1	s	1	2	1	
	ALL HRS	2	1	s	1	1	2	3	3	1	1	2	2	2	10

*Data are not available.
sAmounts are less than is shown in the heading.
**Instantaneous peak winds.
$Percentage of calm is greater than the percentage of PLG direction.
ØBased on less than full months.

REMARKS: RUSSMO POR:
HOURLY OBS: JAN 73 - DEC 82
DAILY OBS: JUN 42 - DEC 82

Table 15-4

Local King Salmon Climatological Data Providing 10- and 20-Yr Averages (Continued)

AWS CLIMATIC BRIEF

Prepared by ETAC (AUG 1971)

KODIAK NS, ALASKA
N 57 45 W 152 29

PERIOD: 1946-69
ELEVATION: 81 FT

WBAN # 25501
WMO # 70350
STN LTRS: (NHB) (PANH)

	TEMPERATURE (°F)					PRECIPITATION (in)			WIND (KT)			MEAN				
MONTH	EXTREME MAXIMUM	MEAN DAILY MAXIMUM	MEAN DAILY MINIMUM	EXTREME MINIMUM	MEAN TOTAL	MAXIMUM IN 24 HOURS	MEAN SNOWFALL	MAX SNOWFALL IN 24 HOURS	PREVAILING DIRECTION	MEAN SPEED	EXTREME SPEED (PEAK GUST)	RELATIVE HUMIDITY (%) 0400	RELATIVE HUMIDITY (%) 1300	DEW POINT (°F)	VAPOR PRESSURE (in HG)	PRESSURE ALTITUDE 99.95% (Feet)
JAN	54	34	26	-5	4.7	3.2	13	11	NW	11	99	79	76	24	.13	1800
FEB	56	35	26	0	4.4	3.6	15	10	NW	10	86	79	76	24	.13	1650
MAR	57	36	27	-1	3.9	1.8	17	18	NW	10	73	78	72	24	.13	1500
APR	64	42	32	11	3.3	1.7	7	11	NW	10	84	78	69	29	.16	1500
MAY	80	47	38	20	4.3	1.9	#	4	E	8	53	83	73	36	.21	1000
JUN	86	54	45	30	4.2	2.3	#	#	E	7	61	85	76	43	.28	850
JUL	82	59	49	37	3.4	2.5	0	0	E	6	65	87	76	48	.34	650
AUG	83	60	50	36	4.3	2.2	0	0	NW	6	52	87	75	49	.35	900
SEP	71	54	45	26	6.1	2.6	#	#	NW	8	63	85	75	44	.29	1350
OCT	61	45	36	14	6.0	2.5	2	9	NW	9	72	81	71	34	.20	1700
NOV	54	39	31	6	5.6	2.3	5	14	NW	11	92	80	75	29	.16	1750
DEC	54	34	26	0	4.9	2.0	12	9	NW	11	97	76	75	23	.12	1850
ANN	86	45	36	-5	55.1	3.6	71	18	NW	9	98	82	74	34	.20	1500
EYR	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24

MEAN NUMBER OF DAYS

	PRECIP ≥0.01 in	PRECIP ≥0.5 in	SNOWFALL ≥0.1 in	SNOWFALL ≥1.5 in	THUNDER-STORMS	FOG (<7 MILES)	TEMPERATURE (°F) MAXIMUM ≥ 90	MAXIMUM ≤ 80	MINIMUM ≥ 32	MINIMUM ≥ 0	MEAN CLOUDS (TENTHS)
MONTH											
JAN	16	3	7	3	0	8	0	0	23	#	7
FEB	15	2	8	3	0	7	0	0	21	#	7
MAR	15	2	9	4	#	7	0	0	23	#	7
APR	14	2	5	2	0	6	0	0	15	0	7
MAY	16	2	#	#	#	10	0	#	3	0	8
JUN	15	2	0	0	#	14	0	#	#	0	8
JUL	14	2	0	0	#	13	0	#	0	0	8
AUG	15	2	0	0	#	12	0	#	0	0	8
SEP	17	4	#	0	0	11	0	0	1	0	7
OCT	17	4	1	#	0	7	0	0	10	0	7
NOV	17	4	3	1	0	6	0	0	17	0	7
DEC	16	3	7	3	#	7	0	0	23	#	7
ANN	187	32	40	16	#	108	0	#	136	#	7
EYR	24	24	24	24	24	24	24	24	24	24	24

REMARKS:

SMOS (NAVY) POR: Hrly and Daily Obs: Jan 46 - Dec 69

Table 15-4

Local King Salmon Climatological Data Providing 10- and 20-Yr Averages (Concluded)

NOTE: *DATA NOT AVAILABLE, #LESS THAN 0.5 DAY, 0.5 OR 0.5 INCH, OR 0.5 PERCENT (%) AS APPLICABLE.

FLYING WEATHER (% FREQ)	HOURS (LST)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	EYR
	00-02	36	38	34	36	48	44	38	34	34	31	34	34	37	
CIG	03-05	38	39	36	37	49	46	41	35	35	31	35	35	38	
less than	06-08	37	40	39	38	48	47	40	34	38	31	37	38	39	
3000 feet	09-11	38	42	37	38	48	47	39	34	37	30	36	38	39	
and/or	12-14	38	42	37	37	47	43	37	34	37	30	37	38	38	
VSBY	15-17	40	43	37	38	45	42	38	34	38	33	40	39	39	
less than	18-20	37	42	38	38	46	42	39	32	37	33	36	36	38	
3 miles	21-23	36	40	35	37	47	44	38	33	35	31	35	36	37	
	ALL HOURS	38	41	37	37	47	44	39	34	36	31	36	37	38	24
	00-02	22	24	21	19	26	29	24	22	20	14	16	18	21	
CIG	03-05	24	24	20	21	27	30	26	22	20	13	16	18	22	
less than	06-08	23	25	22	21	27	30	26	21	20	13	16	20	22	
1500 feet	09-11	22	26	21	20	25	27	22	19	19	12	17	20	21	
and/or	12-14	22	27	21	19	24	24	20	18	17	11	16	19	20	
VSBY	15-17	25	27	21	20	24	24	21	17	18	12	18	21	21	
less than	18-20	23	26	22	21	25	27	22	17	19	13	16	20	21	
3 miles	21-23	22	25	21	20	27	28	24	19	20	14	16	19	21	
	ALL HOURS	23	25	21	20	26	27	23	19	19	13	16	19	21	24
	00-02	16	16	13	14	17	23	20	17	15	8	10	11	15	
CIG	03-05	17	17	15	13	19	24	21	18	15	7	10	11	16	
less than	06-08	16	18	15	13	17	24	21	17	16	8	10	12	16	
1000 feet	09-11	16	19	15	12	16	21	17	15	14	7	10	13	15	
and/or	12-14	15	20	15	11	16	19	14	14	12	7	9	12	14	
VSBY	15-17	17	18	14	13	15	20	15	13	14	7	10	13	14	
less than	18-20	15	19	16	13	16	22	17	15	15	8	9	12	15	
2 miles	21-23	15	17	16	12	16	22	19	15	15	8	10	12	15	
	ALL HOURS	16	18	15	13	17	22	18	15	14	8	10	12	15	24
	00-02	2	2	2	1	1	4	3	3	3	1	1	1	2	
CIG	03-05	2	3	2	1	2	5	5	4	3	#	1	1	2	
less than	06-08	2	2	2	1	2	4	4	3	3	1	1	1	2	
200 feet	09-11	3	3	2	#	2	3	2	3	2	#	1	2	2	
and/or	12-14	3	3	2	1	1	3	1	1	3	#	1	1	2	
VSBY	15-17	3	4	2	1	2	2	2	2	2	#	1	2	2	
less than	18-20	3	3	2	1	2	3	3	2	2	1	1	1	2	
1/2 mile	21-23	2	2	2	1	2	4	4	3	1	1	1	1	2	
	ALL HOURS	3	3	2	1	2	4	3	3	2	1	1	1	2	24

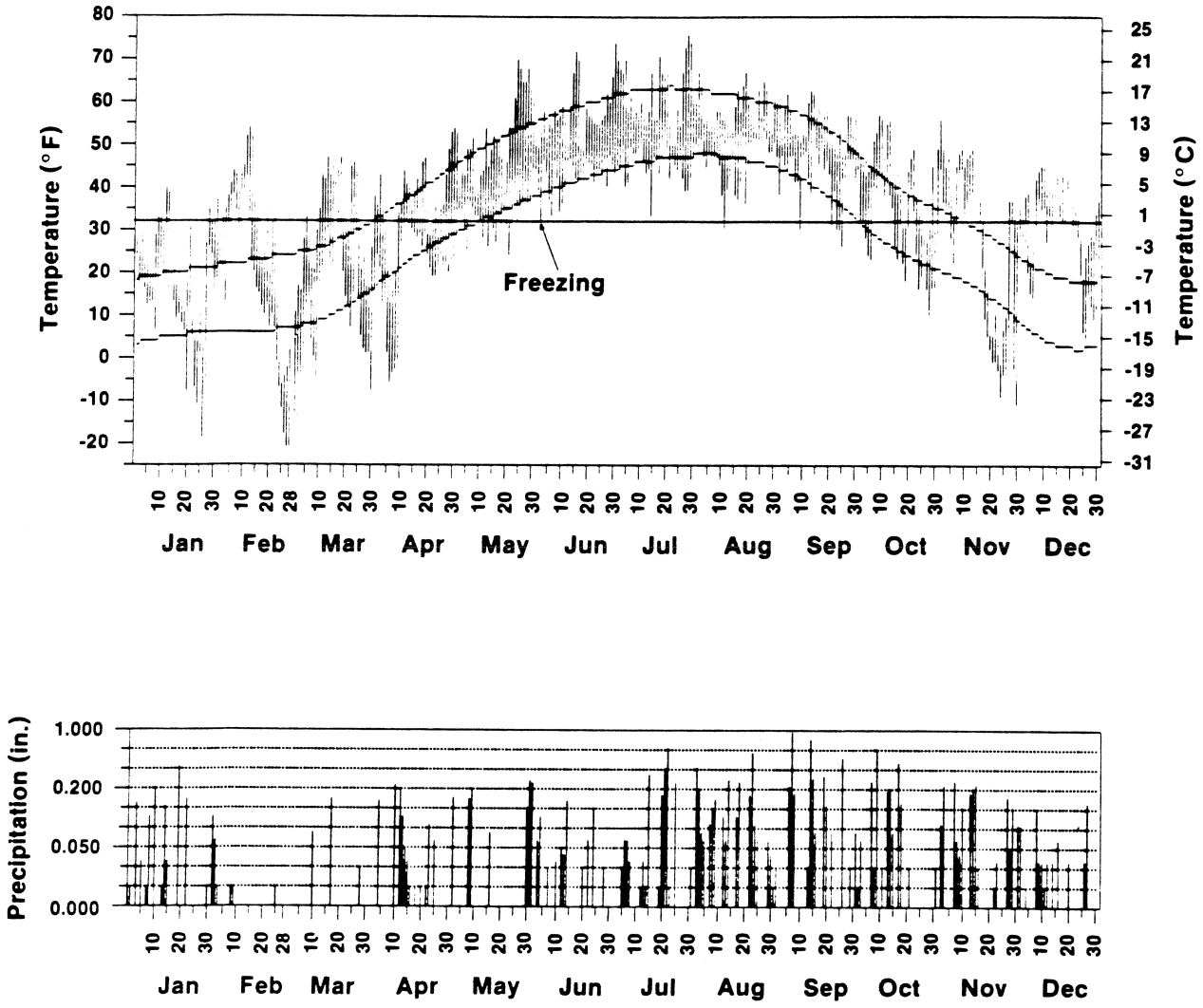


Figure 15-5. Climatological Data for King Salmon in 1986

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APPENDIX A

BURN PLAN

APPENDIX A

BURN PLAN

A permit will be requested to allow the burning of paper, paper products, and wood. Permission to burn these materials for the duration of the operation at the campsite is requested. A small incinerator will be employed that will provide adequate draft and will help ensure that the material is burned efficiently and safely.

The following procedures will be employed:

- material to be burned will be dried;
- noncombustibles will be separated from those materials to be burned;
- sufficient draft will be acquired for maximum combustion efficiency, and combustibles will not be allowed to smoulder;
- pesticides, halogenated organic compounds, and polyurethane will not be burned. No hazardous materials will be burned.
- Garbage or petroleum-based materials will not be burned in a way that emits odor or black smoke. The burning of petroleum-based fluid or petroleum-soaked pads and rags will require special permission from the NPS and the State of Alaska.
- Burning will be conducted away from camp buildings and petroleum storage areas.

Burning will occur at night or the darkest daylight hours to minimize visibility impact for any tourists. There are no population centers nearby. Weather advisories will be obtained through the camp's support helicopters and the radio nets used by the operation. Burns will not be conducted when weather conditions pose a potential hazard. The NPS and the appropriate district office of the State of Alaska will be notified on a weekly basis when burning is contemplated. Burning will occur approximately four times a week. The duration of each burn will not exceed three hours. Personnel who will conduct the burn will undergo appropriate training.

APPENDIX B

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 procedure and the development of 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 [Sandia National Laboratories (SNL), 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 must be established.

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

- Real-time field decisions on safety issues usually must 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. There must be sufficient site personnel to deal with any drilling contingency.

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 and 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 budget 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 employed 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 should be onsite 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 who must model the behavior expected from other site personnel. Appeals to common sense, basic good judgment, and teamwork in training sessions add to the shaping of attitudes. Using competent, experienced instructors in first aid, cardiopulmonary resuscitation (CPR), and self-contained breathing apparatus (SCBA) training sessions reinforces 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, the drill rig foreman always has veto power for requests for access to the rig floor. 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 employed 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 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, they are not reliable. Therefore, radios on several nets are provided. These radio nets may be established with the NPS, private landowners, a local emergency organization, or a special net established by the site personnel with communication to accommodations 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 whereas foresight is seldom 100 percent. 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 and 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 the problem cannot be diplomatically resolved; 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

Exclusion 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 delineated as clearly as possible and must 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 must be clearly identifiable. 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 is absolutely essential for Sandia National Laboratories personnel at all times while onsite and operating under the safety guidelines. 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 and unclear lines of responsibility and authority. The end result is 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 and situations identified by one person or group but not fully accepted as hazards 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 (and 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, and 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 so 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 has an unsafe concentration of H_2S to secure equipment, which 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. 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, should be required to read the SOPs, and should 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 C

SPILL PREVENTION AND MITIGATION

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SPILL PREVENTION

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

A monitoring system will be erected to warn operating personnel of any unanticipated drop in the level of a fuel tank. Monitoring devices on the main monitoring system will display 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 additives for liquid drilling fluid will be stored in a bermed area similar to the bermed area for fuels. These storage areas will be inspected on each shift. Storage areas for additives of solid drilling fluid 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, mitigation, and 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 ensure 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 follow the proper spill response and mitigation procedure determined by the severity of the spill. The GRDO Site Manager will coordinate remedial activities. A list of phone numbers of key personnel including permitting agencies (the NPS, EPA, and State of Alaska ADEC) and spill control personnel will be posted and contained in the site-specific safe operating procedure (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 with an Alaska firm will be established to effect remedial action in mitigating, containing, and cleaning 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 will provide trained manpower to combat spills and appropriate spill control equipment. If needed, this equipment would supplement spill control equipment either at the drill sites or equipment stored at the site-support facility in King Salmon.

For the containment of spills onsite, equipment that will be available to project personnel will 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.

- Oil absorbent pads that are available commercially will be used on all fuel lines, connections, etc. Oil absorbent pads will be placed generally where spills could occur from breaks in the line or leaks, such as under machinery, pumps, etc. A large number of all types of absorbent pads and materials that are sufficient to meet contingencies will be stored in reserve at the site and at the site-support facility in King Salmon. Approximately 40 empty barrels approved by the Department of Transportation will be stored at King Salmon to transport waste from a spill.

- An industrial rug or other suitable rug will be used to absorb fuel and drilling fluid in critical areas, including areas around mixing tanks and places where small spills of drilling fluid could occur.

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

- A skimmer will be used that would be suitable for a first response to a spill on water. For example, if a helicopter goes down on water or if a portion of a helicopter load is lost, a skimmer would be used to contain the spill. Helicopters will be used to transport

fuel to and from project operations. These helicopters can transport between 300 and 1,000 gal of fuel. 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 in response to a spill will be the following:

- proceed to the spill site and assess the nature of the 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 the spreading of sorbents and the formation of temporary dikes or spreading an appropriate array of sorbent boom pads on water;
- appropriate source removal with proper removal of source contents;
- cleanup and adequate decontamination;
- collecting wastes and resanding residues and placing them in proper containers; and
- proper waste disposal.

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

Minor Onsite Spills and Leaks of Fuel or Contaminants Less Than 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 Greater Than 10 Gal

Onsite Spill 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. During curtailment of the operations, the onsite crew and a spill technician (if necessary) will clean up the spill and take necessary remedial action. (It may be

necessary to maintain circulation in the well if a high temperature regime is encountered.)

Offsite Spill — 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. If possible, the 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. At least one technician will arrive as soon as possible to assist with and inspect the clean-up operation. Conformance to environmental or operational considerations may dictate the assembly of a larger clean-up crew appropriate to the magnitude of the accident.

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. Then it will be removed out of the park by helicopter for proper disposal at an approved site.

Soaked pads and absorbent booms will be helicoptered out of the park for proper disposal. For proper disposal, fluids skimmed off water will be stored in portable tanks for transport out of the park.