ENVIRONMENTAL RECONNAISSANCE REPORT

MEAGER CREEK GEOTHERMAL AREA

Prepared for

British Columbia Hydro and Power Authority
555 West Hastings Street
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by

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in association with
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CONTENTS

CONTENTS (continued)

CONTENTS (continued)

CONTENTS (continued)

CONTENTS (continued)

CONTENTS (continued)

LIST OF TABLES

LIST OF FIGURES

ENVIRONMENTAL RECONNAISSANCE REPORT SUMMARY

This Environmental Reconnaissance Report presents an overview of a possible geothermal development at the Meager Creek area about 50 km west of Pemberton in southwest British Columbia. The report outlines the potential effects of the proposed development upon the existing environmental setting and discusses potential environmental constraints to project development. It also identifies those areas where impact prediction is not possible due to existing data and project layout and design deficiencies, and makes recommendations on studies to be conducted to fill these data gaps. It should be emphasized that the project, as described in this report, is based upon a limited amount of information, and some of the concepts are speculative.

The extent of this resource is as yet unknown, but may be of a magnitude similar to The Geysers in northern California. This is based upon geologic investigations which indicate two or perhaps three geothermal reservoirs are present, each of several square kilometres in area, subjacent to the north and south flanks of of the Meager Mountain complex. This report addresses the south portion of the resource.

For development purposes, a 55 Mw pilot plant is proposed. The term "pilot plant" implies that this initial commercial facility would enable the testing and experimentation necessary to accommodate reservoir characteristics and efficient plant design for the future. The primary concern of this report is with the impacts to the existing environmental setting, which could be generated by exploration, development and operational activities associated with the pilot plant.

The entire system to support a 55 Mw facility would utilize approximately 12 ha of land along Meager Creek, and many of the impacts from development of the proposed project would occur within this relatively

confined area. The two primary exceptions to this would be socio-economic, due to the flow of personnel and goods and services between Vancouver, Pemberton and the project area. In addition, impacts to ground and surface water which could occur outside of the immediate project area may need to be considered.

Investigations conducted during the course of this study did not disclose the presence of unique environmental conditions which would preclude development of the project. Certain constraints were identified, however, which would affect the project planning process and which could require special controls or mitigation measures. Primary among these concerns are the issues of: 1) slope stability; 2) potential surface water degradation and implications to the downstream fisheries resource of the area, and 3) effects upon wildlife in the area, especially moose and grizzly bear.

Investigations have also revealed that available environmental and project-related data are insufficient for purposes of developing a quantitative analysis of potential impacts. Therefore, additional field investigations would be necessary to provide essential baseline data. These investigations must occur prior to facilities (wells and power plant) location and siting, selection of design alternatives and final project scheduling. In addition, environmental monitoring efforts are needed to supplement existing data and document the character of the project area. This information could then be utilized to quantify impact predictions. In addition, the requirements for monitoring programs, which would provide an on-going assessment of the impacts of the project activities upon the existing environmental setting, could be more precisely designed.

Chapter I

Introduction

CHAPTER I

INTRODUCTION

1.0 AUTHORIZATION AND PURPOSE

This study was authorized by the B.C. Hydro and Power Authority (B.C. Hydro) as part of its overall responsibility in the development of the geothermal resource at Meager Creek, located about 160 km north of Vancouver. The location is depicted in Figure I-1, Regional Location Map. The proposed project is on Crown Lands under lease to B.C. Hydro for geothermal exploration.

It is the wish of B.C. Hydro that electrical generation projects be developed in an environmentally acceptable manner; thus the need for this preliminary Environmental Reconnaissance Report. The purpose of this report is to address the environmental concerns surrounding this geothermal exploration and possible future development. Official authorization to proceed was conferred by B.C. Hydro on July 10, 1978, by Purchase Order 848-732.

This environmental reconnaissance report constitutes one element of the investigative program being conducted by B.C. Hydro to assist them in determining the technical, economic and environmental feasibility of developing the geothermal resource at Meager Creek in southwest British Columbia. The geothermal program is being conducted by B.C. Hydro, subject to the Geothermal Resources Act of 1973, which stipulates that geothermal resources of 121°C or greater are to be held for the Crown (Nevin Sadlier-Brown Goodbrand Ltd. [NSBG] 1977). Authority vested in B.C. Hydro, to pursue activities which are intended to culminate in the production of electrical energy, is conferred by the British Columbia Hydro and Power Authority Act of 1964.

Regional Location Map

Meager Creek Geothermal Project

FIGURE I-1

2.0 OBJECTIVES

The basic objectives of this report are fourfold: 1) to identify existing or potential future environmental conditions which might affect or otherwise influence the proposed project and to indicate those actions which may be appropriate to alleviate such concerns; 2) to determine the existence of significant environmental constraints which might materially influence and/or delay the geothermal development as contemplated for the project area; 3) to determine the nature of related environmental programs which it may be advisable to conduct in order to gain public acceptance of the project and assure successful completion of the various tasks which must be completed before development can begin; and 4) to identify other areas of uncertainty which might affect the planning/implementation process and/or possibly indicate the need for special controls or mitigation measures. Of particular concern in this study is the fact that the proposed project would be the first in Canada to produce electricity from a geothermal resource.

3.0 SCOPE OF STUDY

The study area discussed herein concentrates on Meager Creek, which overlies the south arm of a potential geothermal reservoir. The north arm of the reservoir lies within the Lillooet drainage above Pebble Creek, but is less firm in its potential at the time of writing. This report is a case study to identify the types of environmental considerations relevant to a geothermal project. The report specifically discusses that portion of the B.C. Hydro Project Area which is likely to be affected by a geothermal development such as that conceptualized for Meager Creek. In order to accomplish this, a project scenario was conceptually placed within that environment, and then impacts were assessed. In some instances, where data on the existing environment were insufficient, impacts could not be predicted. These areas have been identified as data deficiencies, and programs which would "fill in" these data gaps are discussed in Chapter V.

For this report, it was necessary to make certain assumptions, as there is currently a lack of information regarding the geochemical and physical parameters of the reservoir at Meager Creek. These assumptions are based upon that limited amount of preliminary information which is available, and from typical characteristics which are exhibited by geothermal resources and development activities from other areas potentially similar to those assumed for Meager Creek. For these reasons, much of the material presented herein is necessarily of a general or "typical" nature. As more information becomes available from on-going exploration activities, it will be possible to make the necessary refinements in the data base and derive more site-specific project characteristics.

It should be noted that the Assumed Project Description presented in Chapter II, and the Project-Generated Impacts discussed in Chapter III are typical of a geothermal project of a type currently envisioned for Meager Creek. As more data are continually made available, it is possible to refine these project-related parameters. This refinement process is one which would continue throughout the entire project and affect a fine-tuning of various aspects of the project design (see Chapter II) and a modification of the potential impacts (see Chapter III). Additional data (see Chapter V) would enable these elements to be described with more precision than is currently possible, given the existing base of information.

Preparation of this reconnaissance report involved research of the library files of public and private institutions, personal interviews and telephone conversations with federal, provincial, regional and local agencies and individuals, and preliminary field reconnaissance. Additional valuable data and assistance were provided by B.C. Hydro's project staff and by the exploration staff of Nevin Sadlier-Brown Goodbrand Ltd. These contributions were significant to this study and are hereby gratefully acknowledged.

4.0 REPORT FORMAT

The various elements of this report are presented in an order which is intended to facilitate an understanding of the type of assumed project and the related effects upon the existing environmental setting. To this end, a project as currently envisioned is discussed in Chapter II, An Assumed Project Description. A discussion of the Existing Environmental Setting and Preliminary Assessment of Impacts which the assumed project would have upon this existing environment are presented as Chapter III. Constraints to development are presented in Chapter IV.

The material in Chapter V, Data Deficiencies and Study Recommendations, contains the basic conclusions reached from analyses of the data base and has two areas of focus. The first is a discussion of environmental data which are not in existence, but which would be necessary in order to fully characterize the existing environment and, therefore, to accurately predict the impacts of the project upon the environment. The second area of discussion is a recommendation of the types of investigations which are recommended in order to fill these data gaps.

The Study Recommendations presented are for purposes of providing data which would be necessary for one or more of the following purposes: 1) to support project planning and design activities; 2) to satisfy approval requirements; 3) to serve as a reference base for operational monitoring programs, and 4) to provide desirable documentation which would enhance public understanding of the project, as well as decisions by the project proponent, agencies and the public.

It should be noted that the material presented in Chapters III, IV and V is presented by discipline and that there is parallel organization. For example, Geology is Section 2.0 in all three chapters, Land Use is Section 8.0, and so forth.

Chapter VI presents a list of Persons and Agencies Consulted during the course of investigation and report preparation, and Chapter VII cites the Literature Reviewed during the study effort.

Chapter II

An Assumed Project Description

CHAPTER II

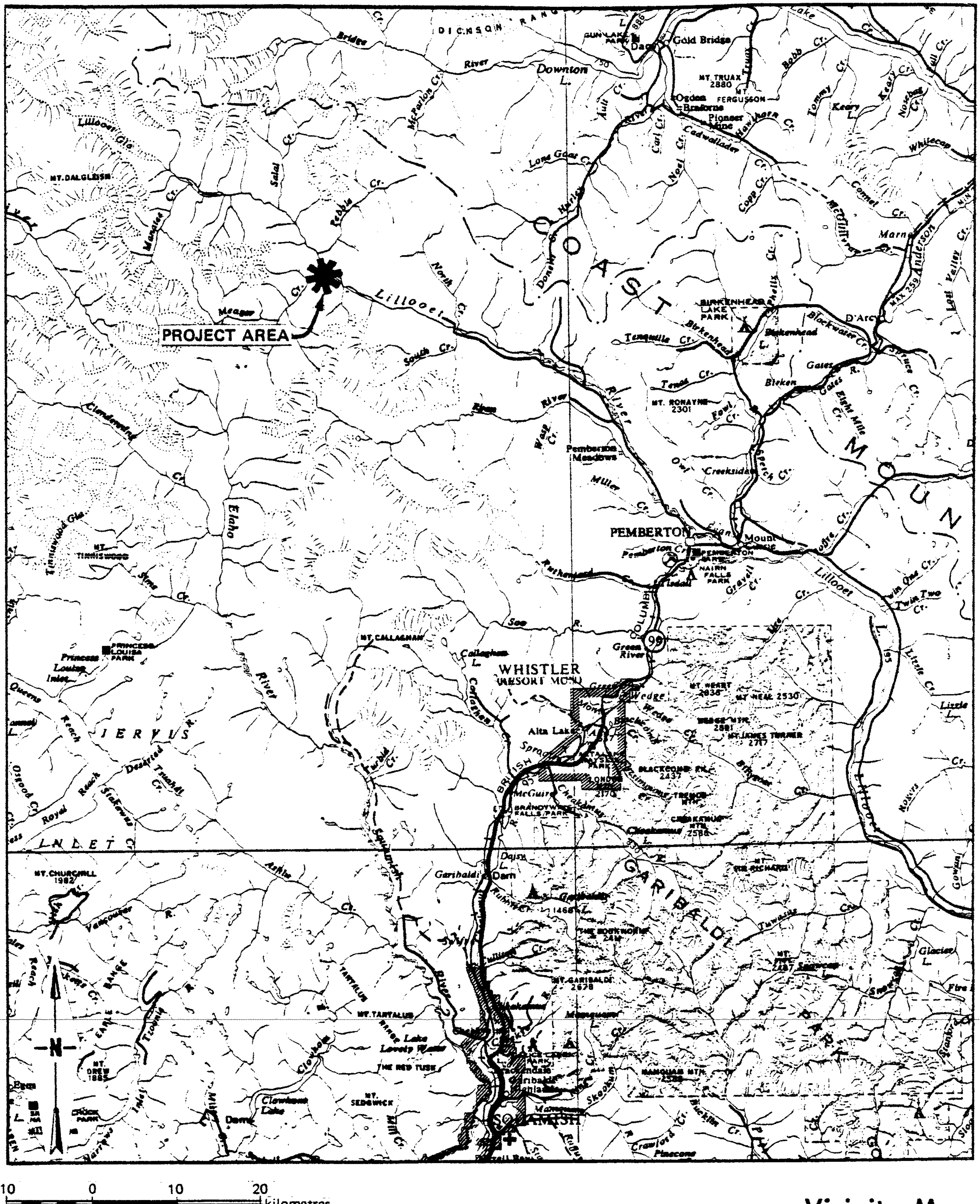
AN ASSUMED PROJECT DESCRIPTION

1.0 INTRODUCTION

This chapter discusses the basic aspects of developing a geothermal resource for electrical power generation and tentatively applies these procedures to the proposed development at Meager Creek. It incorporates existing knowledge about such processes with information currently available on the Meager Creek resource and the surrounding environment. Since much of the information on the Meager Creek resource has yet to be developed, the details of the project are at this time unknown. Therefore, this project description is "assumed," to the extent that specific elements cannot be described until further data are available regarding the nature and extent of the geothermal resource.

The Meager Creek project is located in the Coast Range, about 50 km northwest of Pemberton, as shown on the Vicinity Map (Figure II-1). The study area is within the narrow Meager Creek Valley, to the southwest of the confluence of Meager Creek and the Lillooet River. Situated at the foot of the Meager Creek Volcanic Complex, the geothermal study area is one of rugged topography and glacial slopes. Elevations generally range from about 450 m to 2600 m.

The anticipated Meager Creek Geothermal Project would consist of the procedures necessary to develop a 55 Mw geothermal power plant at Meager Creek. This project may represent the first step in the possible development of the geothermal field, which might ultimately be capable of supporting the generation of 1000 Mw of electricity (NSBG 1976). That portion of the geothermal reservoir to be tapped for the Meager Creek Project may be part of a larger system which extends along the Lillooet Valley.



Vicinity Map

Meager Creek Geothermal Project

FIGURE II-1

The basis for this conclusion lies in the geotechnical investigations conducted to date, and in the two deep temperature gradient holes drilled during October and November 1978 north of the Lillooet River Falls and on the south flank of the complex. In order to confirm this and to fully delineate the magnitude and characteristics of the geothermal field, additional surface and subsurface investigations would be conducted during the 1979 field studies. These activities would likely culminate with the drilling of the first deep exploratory well during the fall of 1979. Further activities would depend upon information gained from this well.

A typical geothermal development, such as that envisioned for Meager Creek, consists of a series of phased activities which, if successful, culminates in the production of electricity. It is important to note, however, that the sequential phases of the program are interdependent, as the conduct of each successive activity relies upon the successful completion of the previous one. Therefore, the success of Phase I, initial well-field activities, determines the timing and extent of Phase II, the design and construction program. This, in turn, affects the timing and conduct of Phase III operations. In addition, the activities within each phase are interrelated, as any one cannot occur unless the preceding or concurrent activity occurs successfully. These phases and activities are discussed more fully in Section 3.0, Geothermal Exploration and Development.

The rest of this chapter discusses those activities which comprise the development of a geothermal resource for electric power production. An overview of geothermal energy is presented in Section 2.0. The basic activities necessary to succesfully conduct a geothermal exploration and development program are discussed in Section 3.0. The status of the exploration activities at Meager Creek is presented in Section 4.0.

2.0 GEOTHERMAL ENERGY: AN OVERVIEW

2.1 Explanation

Geothermal energy is produced by heat from magma or molten rock which has migrated along fissures in the earth's crust. Sources of geothermal energy are particularly common along the world's fault zones, where earth movements and fractures of the earth's crust are common, thereby bringing the heat source closer to the earth's surface. In some places the magma is transmitted to the earth's surface, where it erupts as volcanoes. In other areas where large quantities of water have been trapped beneath the surface, the water may erupt in fountains of steam and water, or geysers, such as in Yellowstone National Park in the United States. More commonly, where surface indications of an underground geothermal reservoir are present, they consist of hot water, small geysers or fumaroles, or hotsprings. Such is the case at The Geysers in northern California, and at Meager Creek, the site of the proposed project.

The use of geothermal energy for the production of electrical power is currently the most sought-after use of the resource. This use is accomplished by transporting the steam or hot water to the surface through wells, much the same as in the oil and gas industry. The heat from this steam or hot water resource is then utilized to spin turbogenerators to produce electricity. There are currently dry steam geothermal developments producing electricity in The Geysers in northern California, Lardarello, Italy, and Matsukawa, Japan. Hot water resources being utilized for commercial scale electric power production are located in Cerro Prieto, Mexico, and Wairakei, New Zealand.

2.2 Types of Geothermal Power Production

There are three basic processes of utilizing geothermal energy for the production of electrical power. These are dry steam, flash and binary.

The method which is used for a particular resource depends upon the nature of the underlying geothermal reservoir, that is, whether it is dry steam, hot water or a mixture of steam and hot water.

2.2.1 Dry Steam

In a dry steam field, the turbine is powered directly by the steam which has been piped from the well to the power plant. It should be noted that dry steam fields are relatively rare.

2.2.2 Flash System

Where the resource is a mixture of steam and hot water, a "flash" process is utilized. That is, the hot fluid/steam mixture is transported under pressure through pipes from the well to the power plant. The pressure is then reduced, causing the liquid to vaporize, or flash to steam. This flashed steam is then used to spin the electric generating turbine. In some instances, a double flash system may be utilized. This type of production involves two separate flashing processes, one for the high pressure geothermal resource from the wells, and a second for the remaining low pressure fluid. This double flash process is utilized when the resource is of sufficient pressure and temperature that the geothermal fluid may be flashed twice in order to maximize utilization of heat from the resource.

2.2.3 Binary Cycle

This electric production system is utilized when the resource consists of water of such a low temperature that, when flashed, it would produce steam of insufficient quality and quantity to drive a turbine for commercial electric power production. For this type of electric power production, the geothermal water is piped to the power plant under pressure. Here it is passed through a heat exchanger where its heat is transferred to a second "working" fluid, such as isobutane, which then vaporizes and drives the turbine.

2.3 Geothermal Production Facilities

Certain elements are common to all methods of developing geothermal energy for electric power production. These include the production wells for bringing the resource to the surface, the power plant where the electricity is generated, and the pipeline which transports the resource between the wells and the power plant. Many developments also have injection wells, which are utilized to return the spent geothermal fluid to the subsurface.

For each power plant, there may be about five to ten wells which are used to bring the geothermal resource from the reservoir to the surface, usually from a depth of about 1800 m. In addition, there may be about five injection wells for the purpose of returning the spent geothermal fluid to the subsurface. The power plant facility typically consists of two structures. The power plant itself houses the turbine and generator, and the second structure is the cooling tower. Here the steam condensate from the flashed geothermal resource is cooled and recirculated for use in the power plant.

The power plant is located in proximity to the wells. This is because, unlike oil and gas, the geothermal resource is not transportable without loss of heat and thus must be converted to energy near the source. The distance the geothermal resource can be transported to the power plant is usually limited to about 1500 m. Beyond this distance, the heat and pressure losses incurred adversely affect the economic electrical generation process. For this reason, a geothermal power plant is built within the geothermal field.

2.4 Assumed Meager Creek Geothermal Development

Preliminary indications are that the resource in the Meager Creek Geothermal Area consists of a mixture of steam and hot water. Based upon available information, it is anticipated that the resource is of sufficient pressure and temperature to economically utilize a double flash system. It is further anticipated that the pilot power plant would produce 55 Mw of electricity from a generator powered by a single turbine, the configuration considered to be the most economical method of commercially producing electricity. The Meager Creek project would consist of the production and injection wells, power plant and cooling tower, and pipeline system, as discussed previously in Section 2.2.

3.0 GEOTHERMAL EXPLORATION AND DEVELOPMENT

The production of electricity from a geothermal power plant such as that envisioned for Meager Creek consists of the successful completion of a series of phased exploration and development activities. It is important to note that the sequential phases of the geothermal development program are interdependent. The conduct of each successive activity relies upon the successful completion of both concurrent and previous ones. In addition, the data gathered during the various activities are continually evaluated in order to determine whether continuance to the next phase is warranted.

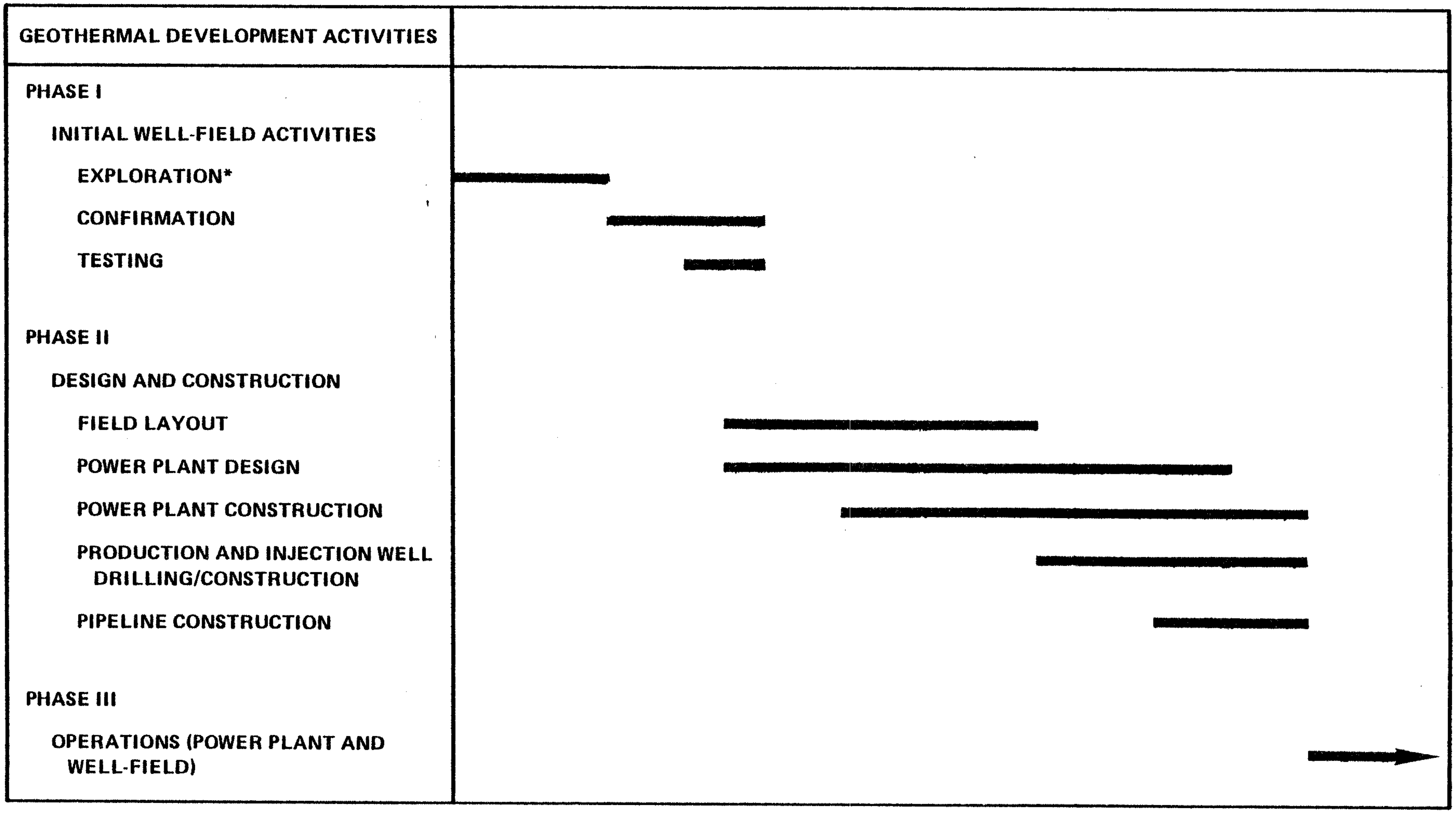
For purposes of discussion, geothermal activities which culminate in the production of electricity may be divided into three successive and interrelated phases of activity. These phases may be described as Phase I--Initial Well-field Activities, Phase II--Design and Construction, and Phase III--Operations. Within each phase, there are specific activities which may be identified for purposes of overall orientation, scheduling and evaluation. These phases and activities are differentiated below, and their relationship to one-another in time is shown on Figure II-2.

Phase I--Initial Well-field Activities
- Exploration
- Confirmation
- Testing

Phase II--Design and Construction
- Field layout and power plant design
- Power plant construction
- Production and injection well drilling/construction
- Pipeline construction

Phase III--Operations
- Power plant operation
- Well-field operation

CONCEPTUAL PROJECT PHASES
MEAGER CREEK GEOTHERMAL DEVELOPMENT



*Geologic investigations, geophysical studies, temperature probes complete.

Source: VTN, 1978.

FIGURE II-2

3.1 Phase I--Initial Well-field Activities

3.1.1 Exploration

Activities associated with exploring for a geothermal resource are conducted for purposes of locating a heat anomaly, determining its potential temperature, and producing a geothermal resource through a well. The heat anomaly is located by surface activities including geologic investigations and geophysical studies such as magnetotelluric and resistivity studies. Sub-surface activities conducted to identify a heat anomaly consist primarily of drilling shallow (about 150 m) and deep (about 500 m) temperature gradient holes. The next step, to produce a resource, involves drilling a deep (about 1800 m) exploratory well into the identified resource. Depending upon the results of this well, one or more additional exploratory wells may be drilled. If a resource of sufficient potential is produced, confirmation activities are begun.

3.1.2 Confirmation

The purpose of these activities is to drill and test additional wells to locate other areas of the reservoir from which a geothermal resource could be produced, plus areas which would receive fluids and are thus acceptable for injection purposes. Illustrative diagrams of typical geothermal well drilling components are shown in Appendix A.

3.1.3 Testing

The purpose of testing each well is to acquire data regarding the geochemical properties and physical characteristics of the reservoir in order to make further evaluations regarding the commercial viability of the resource. Various short-term tests are administered at each well in order to gather data on pressure, temperature and chemical composition of the geothermal fluid. The most significant test is the long-term flow test, during which a well is flowed into an injection well for a period of about six months to one year. The purpose of this test is to gain further performance data on the reservoir and to make further determinations regarding the reservoir size and estimated potential for power generation.

3.2 Phase II--Design and Construction

This phase consists of those activities associated with designing and constructing the various elements of an operating geothermal field and power plant.

3.2.1 Field Layout and Power Plant Design

The purpose of these tasks is to optimize generating capability of the geothermal field. The field layout tasks include proper placement of the wells and power plant to optimize recovery of the resource, well design, and appropriate pipeline placement and design. Appendix B contains diagrams of three proposed geothermal field layouts for developments at The Geysers and Imperial Valley, California, and Roosevelt Hot Springs, Utah.

The size and type of power plant would be determined after sufficient well testing had been accomplished, although specific design parameters relative to the characteristics of the Meager Creek resource and the physical environment would not be established until a later time. The designated power plant turbine/ generator components would be located within the field to accommodate the specific Meager Creek resource and its location. It is also important to note that refinements, particularly in power plant design, would be made throughout the first two phases of the project, in response to additional reservoir data obtained as each well is drilled. Schematic illustrations of a typical double flash geothermal power plant, such as that envisioned for Meager Creek, and a hydrogen sulphide scrubbing system are presented in Appendix C.

3.2.2 Power Plant Construction

The construction of the power plant and associated cooling tower is the largest single activity which occurs with the development of a geothermal field, in terms of both time and manpower requirements. It is scheduled to be completed at about the same time as the following two activities, Well Construction and Pipeline Construction.

3.2.3 Well Construction

This activity involves drilling, casing and preparing for operation the production and injection wells which would be necessary to support the power plant. It is estimated that five to ten production wells and three to seven injection wells would support a 55 Mw power plant. In addition, one or two replacement wells would initially be required in the event it becomes necessary to shut down one of the other wells.

3.2.4 Pipeline Construction

The purpose of the pipeline system is to transport the geothermal resource from the production wells to the power plant and from the power plant to the injection wells. The potential for heat and pressure loss limits the distance for transporting a geothermal resource to about 1500 m. The pipeline system is typically constructed above ground.

3.3 Phase III--Operations

3.3.1 Power Plant Operation

Geothermal power plants provide baseload electrical power generation. This is because the nature of a geothermal resource precludes intermittent production. The resource, therefore, is produced to the power plant on a constant basis. Thus, a geothermal power plant is not feasible as a supplier of peaking power. The power plant envisioned for the Meager Creek project would generate 55 Mw of electrical output, with parasitic loads consuming approximately 5 Mw. Net output would then be approximately 50 Mw.

3.3.2 Well-field Operation

The primary purpose of this activity is to support the continuous operation of the power plant by supplying a constant quantity of geothermal fluid. This activity also entails transporting the spent geothermal fluid to the injection wells for appropriate return to the sub-surface. Large fluctuations in fluid supply could result in shut-down of the power plant.

4.0 STATUS OF MEAGER CREEK EXPLORATION ACTIVITIES

In 1974, B.C. Hydro commissioned the firm of Nevin Sadlier-Brown Goodbrand, Ltd. to begin geophysical investigations of the Meager Creek area which have continued until the present. In addition to the NSBG investigations, several federally sponsored analyses have also been conducted in the study area, including the Canadian Department of Energy, Mines and Resources, Earth Physics Branch, and the Geological Survey of Canada. Studies conducted involved those concerned with geologic mapping, temperature gradient and heat flows, microearthquakes, magnetotellurics, electrical resistivity and shallow and intermediate exploratory drilling.

4.1 Previous Exploration

4.1.1 1974-1975 Studies

According to NSBG (1975), the primary investigations conducted during the 1974-1975 season were resistivity surveys and shallow temperature gradient holes. The main area of investigation was along Meager Creek and on the east and south banks of the volcanic complex. Two separate electrical resistivity surveys were conducted, and four research wells were drilled and logged for temperature profiles, geology, water pressures and flows. In addition, refraction seismic surveys were conducted at or near the drill holes. Concurrent with the second resistivity survey, a self-potential (SP) survey was conducted.

4.1.2 1976 Studies

Two major projects were conducted during 1976. Geophysical surveys were conducted on the north and northeast flanks of the Meager Mountain area, and geologic mapping of the core of the volcanic complex was completed (NSBG 1977). The geophysical surveys conducted in the Lillooet River Valley north and northeast of the volcanic complex included electrical SP profiles and electrical resistivity soundings.

Studies conducted in the Affliction Creek valley included geological examinations and water samples, taken to assess the presence of H_2S. The Federal Department of Energy, Mines and Resources continued their geological mapping program and magnetotelluric survey, and made a geochemical study of spring waters.

4.1.3 1977-1978 Studies

Geophysical investigations were conducted in several parts of the Meager Mountain area during the 1977-1978 period (NSBG 1978). Resistivity surveys were carried out near the confluence of Meager Creek and the Lillooet River, and in the vicinity of the 1976 studies on the Lillooet River. In addition, geologic mapping of most of the volcanic complex was finished, and core sampling was begun.

4.2 Proposed Activities

In addition to the continuation of the on-going geophysical surveys and mapping programs, the activities proposed for the future include the drilling of approximately six 450 m to 600 m exploratory test holes early in summer 1979 and the initial slim exploratory well, to approximately 1500 m--potentially during the fall of 1979. Location of this well would be a function of the findings of the six wells previously drilled.

4.3 Preliminary Reservoir Location and Characteristics

Geologic investigations have provided data that indicate the presence of one or more potentially large geothermal convection cells in the area. These investigations indicate that a possible arc-shape geothermal reservoir, approximately 19 km in length, exists under the south, east, and north flanks of the Meager Mountain complex. To date the exact location and extent of the reservoir have not been clearly established.

Indications are that the heat source for the reservoir is probably a residual chamber of molten or semi-clastic magma located under the volcanic complex. The most recent studies indicate that this heat source is probably closer to the northern portion of the complex than the south, since the most recent volcanic eruptions occurred toward the north side of the complex.

Interpretation of aerial photos indicates that the quartz diorite reservoir is controlled by a wide fracture zone, trending in an east-west direction. Although the reservoir rock has no inherent porosity, it is "probable . . . that vertical pipes under the volcanic complex or sub-horizontal fragmental units at the base of the volcanic pile provide highly permeable conduits and play an important role" (NSBG 1975). The degree of permeability determines how freely the fluid flows through the reservoir and, ultimately, to the well. This then is an important consideration in determining the well production rate.

That portion of the reservoir which is probably feeding the high volume Meager Creek Hotsprings is approximately 5 km^2 in area, 3600 m east-west, 1.6 km north-south, and dips down northward toward the heat source. The dip may range between 15° and 35°. The top of the reservoir may be as close as 300 m to the surface. The depth of the reservoir below is estimated to extend to about 2100 m below the surface (Nevin 1978).

Chapter III

Existing Environmental Setting/ Preliminary Assessment of Impacts

CHAPTER III

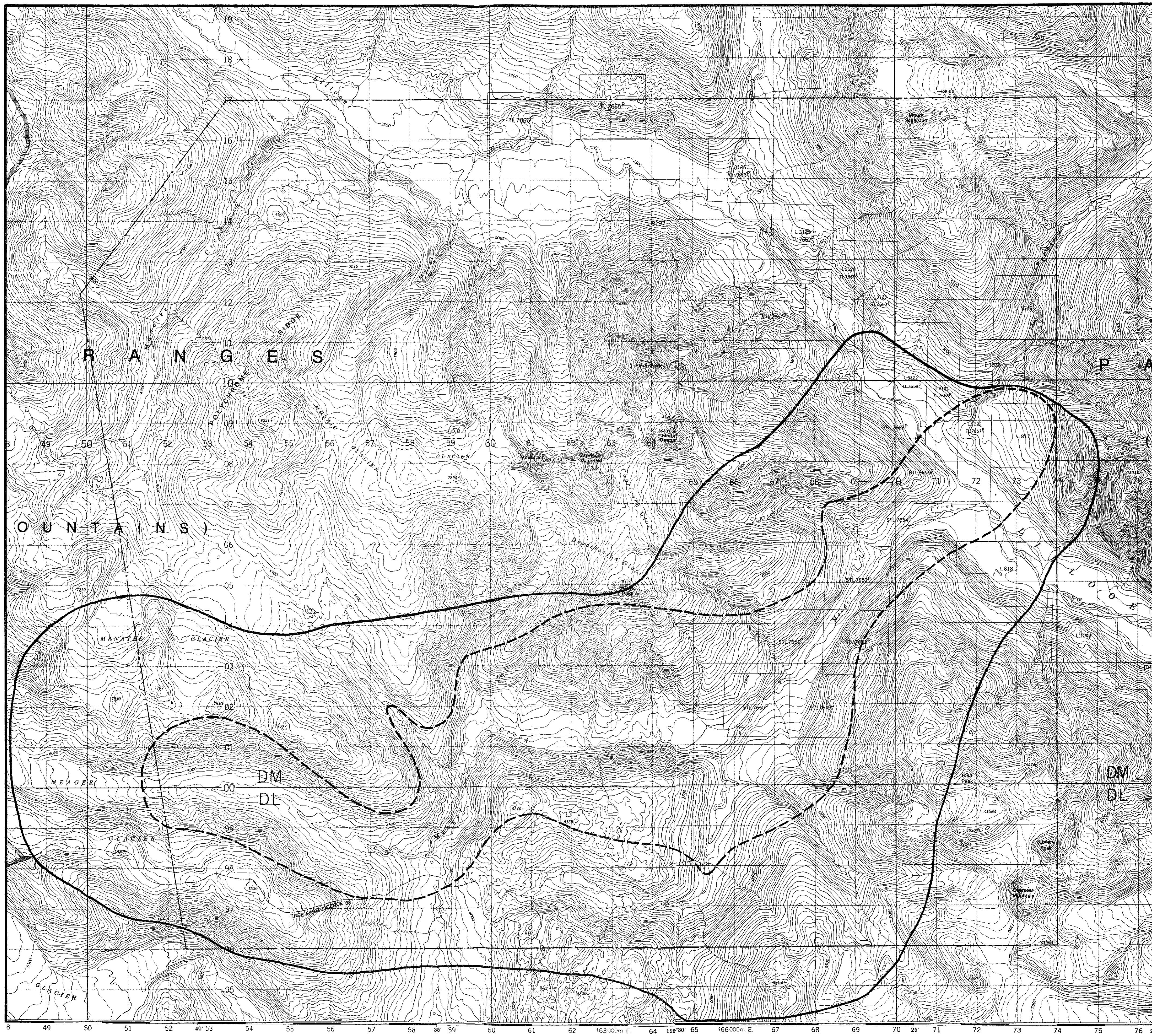
EXISTING ENVIRONMENTAL SETTING AND PRELIMINARY ASSESSMENT OF IMPACTS

1.0 INTRODUCTION

This chapter discusses both the existing environmental setting and the impacts induced by the type of development foreseen for the Meager Creek area. For purposes of this study, the land areas to be discussed have been defined and are referred to as the Meager Creek Primary and Secondary Study Areas (Figure III-1) and the area which likely would be influenced by development of the proposed project (area of project influence). Both the Primary and Secondary Study Areas, plus the B.C. Hydro Project Area, are shown in Figure III-1.

The Primary Study Area is that portion of the project area which would directly affect, or be affected by, the proposed geothermal project. This area includes the land where the geothermal exploration and production facilities would be located, plus roads and temporary drilling/construction camps. Lands and waterways which may have an effect upon or be affected by the geothermal development activities are included within the Primary Study Area. The larger Secondary Study Area is that portion of the project area which may peripherally affect or be affected by the geothermal activities which occur within the Primary Study Area. Examples of such interaction include receiving water from points of generation within the Primary Study Area; interaction with the Primary Area for fish migration; receiving wind drift, and sharing animal migration routes.

For purposes of this report, the area of project influence includes the Village of Pemberton and surrounding area, plus the transportation route connecting Pemberton to the Primary Study Area. Although most of



MEAGER CREEK
GEOTHERMAL AREA

N

scale

1000 0 1000 2000 metres

Environmental
Reconnaissance Report

B.C. Hydro and Power Authority
Vancouver, British Columbia

legend

- - - Primary Study Area

——— Secondary Study Area

-·-·- Approximate Limits of B.C. Hydro Project Area

STUDY AREA BOUNDARIES

FIGURE III-1

the physical environment discussed in this report is within the Primary and Secondary Study Areas, the economic environment directly affected by the project would be Pemberton, as it is the services center nearest to the project and most accessible to project personnel.

The existing environmental setting and projected impacts discussed herein are addressed by discipline, and the same organization is continued in Chapter IV, Potential Constraints to Project Development, and Chapter V, Data Deficiencies and Study Recommendations.

Preliminary investigations of the Study Areas and area of project influence were conducted to: 1) determine the existing environmental conditions of the surface area which overlies the geothermal reservoir; 2) identify potential environmental problems which could affect the proposed development, and 3) screen data sources regarding their availability and applicability to satisfy future project needs. The information obtained regarding the existing environment, together with knowledge of the potential project and the processes involved, were utilized in the determination and discussion of potential impacts of the proposed project.

The information also has been used as a basis for determining the types of pre-operational and on-going monitoring programs which would be necessary in order to more completely characterize the existing environment for purposes of: 1) determining in a quantitative manner the impacts which the proposed project will have upon that environment; and 2) enable investigators to determine whether environmental changes which occur during the conduct of project-related activities have been caused by the geothermal project or are the result of other activities which also occur within the area, such as those associated with logging operations or those generated by natural forces (see Chapter V), or whether the identified impacts result from a combination of factors.

2.0 GEOLOGY

2.1 Existing Environment

2.1.1 Topography

The Meager Creek area is topographically very rugged, with relief of more than 1800 m. At higher altitudes, above 2000 m, the rocks are partially coverd by glaciers and permanent snowfields, while at lower altitudes they are mantled by glacial outwash, colluvium and slide debris, and dense forests (Nevin, Stauder 1975).

The geothermal anomaly centered on Meager Creek is located immediately southwest of the Lillooet River. Access to the area was greatly improved by construction of a bridge which spans the Lillooet River just north of the confluence with Meager Creek, and a network of logging roads is currently being extended into the area.

2.1.2 Geologic Setting

Meager Creek is located in the Coast Range of British Columbia, about 160 km north of Vancouver, B.C. The geology at Meager Creek is a Pliocene to Recent volcanic complex, which marks the northern end of the Garibaldi Volcanic Belt. The area lies in an acute angle formed by the intersection of the Coast Range Mesozoic plutonic rocks and the Garibaldi Volcanic Belt, both of which trend to the north. This area is at the apparent termination of the Garibaldi Volcanic Belt and is also the termination of a line of hotsprings which are parallel to the trend of the Coast Range for a distance of 240 km from the International Border to the Meager Creek area (Read 1978).

Ten volcanic units of the Garibaldi Group form the Meager Creek volcanic complex, which intruded the Coast mountains in this area. Pliocene to post glacial andesite and dacite flows and volcano clastic deposits predominate (Read 1977). The last known volcanic event was the eruption of an ash unit dated at 2400 $\pm$ 140 years B.P. (Nasmith, et al. 1967).

A series of widely spaced northwest and northeast trending faults, with minor displacements, cut both basement and volcanic rocks (Nevin, Sadlier-Brown 1975). Hot springs, probably related to the evolution of the Quaternary volcanic complex, issue from these fractured basement rocks (Read 1977).

2.1.3 Seismicity

The Canadian Cordillera is seismically quiet, compared with other parts of the Pacific margin. Most earthquake epicenters are located along a northwest-trending zone on or near the continental slope, while the remainder are scattered throughout the western and central Cordillera in an apparently random fashion, with no obvious relationship to surface geology. There are no records of earthquakes around the Meager Creek area (Souther 1970).

A micro-earthquake study was carried out at Meager Creek during the winter of 1974-75 for a total useable recording time of 730 hours. Of this time, only 35 hours contained micro-earthquakes. These events may be due to the winter freezing-thawing cycle, as a similar micro-earthquake study, in the summer of 1975, recorded no distinct micro-earthquakes. It would appear that the Meager Creek geothermal system is not associated with microseismic activity, and that earthquakes do not constitute a serious hazard (Roger 1975).

2.1.4 Subsidence

An examination of literature on the area revealed no record of subsidence. It is considered to be highly unlikely that any has occurred, due to the nature of the underlying rocks known to be present in the area. Also, the fracture reservoir is in crystalline rocks, which are not susceptible to subsidence.

2.2 Impact Assessment

2.2.1 Topography

The nature of the proposed geothermal development is such that massive earth movements which would impact the existing topography would not be necessary. Topographic impacts within the Primary Study Area would be limited to leveling activities necessary to construct road, drill pad and power plant sites during the Phase I and early-on Phase II activities (see Chapter II-3.0).

2.2.2 Seismicity and Subsidence

Discussions of geologic impacts induced by the development of a geothermal resource typically center on the issues of subsidence and seismicity. The issue of subsidence arises from concern that the withdrawal of geothermal fluids from the reservoir would reduce ground support and induce slumping, or subsidence, of the overlying area. The concern regarding seismicity stems from both the fluid withdrawal process, plus the practice of injecting the geothermal fluid into the reservoir once it has been utilized for power production. However, these concerns are governed less by the processes of withdrawing and injecting the geothermal fluid, than by the relationship of withdrawal/injection to the underlying rock formations and physical characteristics of the reservoir. Subsidence and/or seismicity may occur if fluid is withdrawn from, but not replaced in, an area underlain by unconsolidated or unstable formations. In addition, seismicity may be induced by injecting fluid at greater pressure than that within the underlying resource.

Neither of these impacts is considered to be of significance for the proposed project. As previously discussed, the Meager Creek geothermal system lies within a seismically quiet area of the Canadian Cordillera and is not associated with microseismic activity. In addition, the Primary Study Area is located on igneous rock, and the potential geothermal reservoir is anticipated to be a fracture reservoir within crystalline rock (Sadlier-Brown 1978). It is therefore unlikely that development of the Meager Creek geothermal field would be accompanied by generalized subsidence, although localized incidents might occur in areas underlain by volcanic rock (Sadlier-Brown 1978).

3.0 SOILS

3.1 Existing Environment

The soils in the Primary Study Area are predominantly lithic soils, including bare rock and accumulations of Ferro-Humic Podzols and Folisols, with ice fields (nonsoil) at higher elevations.

Ferro-Humic Podzols are moist to wet over most of the year, but rarely freeze to any significant depth. In general, they are subject to continuous seepage which is associated with their high content of organic matter. Common parent material is colluvium, which is often in shallow veneers overlying bedrock, morainal deposits and gravelly fluvial materials. The soils have low trace saturation levels, low pH values, high organic carbon, and high Al, Cu, and Fe contents.

Folisols are organic soils that consist of shallow organic material overlying bedrock. These soils are not continuous or extensive, but occur as a minor associate in the Ferro-Humic Podzol landscape.

Soils adjacent to Meager Creek are derived from fine to gravelly fluvial materials, fine to gravelly morainal materials and fine-gravelly-rubbly or blocky colluvial materials. These occur as veneers, blankets, aprons and fans (of undetermined depth) overlying bedrock, or in some cases, overlying other deposits of moranial or colluvial material. As such, they are unconsolidated and have a high potential for landslides (Valentine, et al. 1978).

3.2 Impact Assessment

The primary soil-related impacts associated with geothermal development would result from grading for exploratory wells, access roads, pads and sumps. Additional impacts would result from site preparation for the power plant, cooling tower, and ancillary facilities.

Due to the unconsolidated and unstable nature of the colluvial, morainal, and fluvial materials which underlie the soils in the area, plus the relatively high water content of Ferro-Humic Podzols and their low base saturation level, there is high potential for erosional problems, gullying, soil creep, and failing slopes from any activities, especially those which are not carefully planned.

As a result of heavy snowfall and unstable soil conditions, the area is susceptible to avalanching. This natural tendency may be increased by logging or geothermal activities which would occur in areas of particular sensitivity. A combination of logging and geothermal activities near sensitive areas could induce avalanching. It is anticipated, however, that these potential impacts could be avoided by: 1) geologic mapping to identify sensitive areas; and 2) proper planning to avoid conducting geothermal activities in proximity to potential avalanche sites.

4.0 HYDROLOGY AND WATER QUALITY

4.1 Existing Environment

4.1.1 Surface Water Hydrology

Meager Creek is the major creek in the Primary Study Area and has a number of unnamed tributaries with limited drainages that contribute to its flow. Meager Creek originates about 40 km above its confluence with the Lillooet River. It flows into the river about 3 km below the confluence of Pebble Creek and the Lillooet River (see Figure III-2). All of the rivers and creeks in this immediate area have headwaters in the Coast Mountain Pacific Range and basically consist of runoff contributed by precipitation, snowpack and glacial melting. The major glaciers in the area are Meager, Manatee, Devastation and Capricorn glaciers.

Most of the Meager Creek stream length is below 450 m in altitude. The tributaries of Meager Creek have 50% of their stream length above 600 m. The streamflows during the fall and winter months are comprised primarily of base flows which result from ground water discharges, while streamflows during the spring and early summer are derived mainly from glacial melts or melting snow.

Based on available 1977 water year information on Place Creek (50 km southeast of Meager Creek) near Birken, mean flows range from 0.0075 m^3sec in June to 0.0189 m^3/sec in August. This information indicates the degree of variation of flow in the general area. Flow data, in terms of a stream hydrograph with discharge records, are non-existent for Meager Creek. In addition, the flow data available for Place Creek are in good part based upon estimates.

The actual size of the Meager Creek watershed which lies within the Primary Study Area, as determined from a topographic map, is approximately 120 km^2. Due to a lack of data, it is not possible to more fully characterize the watershed.

The actual contribution of precipitation to the entire water budget in the Primary Study Area is not fully known (Nevin 1978). The area closest to Meager Creek for which precipitation data are available (Pemberton Meadows) is at a distinctly lower elevation. The annual normal precipitation for a standard 30-year (1941-1971) period (Atmospheric Environment of Canada 1975) ranges from 26.7 mm in July to a high of 172.2 mm in December. These data cannot be applied to the Meager Creek area, since precipitation is expected to vary with elevation. Finally, an accurate description of the distribution of rainfall cannot be made at this time due to a lack of data characterizing the Primary Study Area. The same can be said of snowfall, i.e., there is a lack of data to determine its eventual contribution to water flow in the spring and early summer.

4.1.2 Ground Water Hydrology

Very little quantitative information is available on ground water near the Primary Study Area. The drilling that has taken place since 1974 has mainly concentrated on assessing the extent and nature of the geothermal reservoir (see Figure III-2), and these data are not considered to be of much use in defining the extent and characteristics of ground waters in the proposed project area. However, inferences regarding hydrologic characteristics have been made, based upon current geophysical explorations which are supported by field observations. One observation was that the water table is relatively high. However, aquifer and ground water characteristics in terms of levels, flow direction, flow rates, seeps and interflow with streams have yet to be determined (Nevin 1978).

Work thus far (Nevin 1975) has shown that ground water saturates all of the rocks and unconsolidated deposits in the area. The potential for

MEAGER CREEK GEOTHERMAL AREA

N

scale

1000 0 1000 2000 metres

Environmental Reconnaissance Report

B.C. Hydro and Power Authority
Vancouver, British Columbia

legend

- Primary Study Area
- Secondary Study Area
- Approximate Limits of B.C. Hydro Project Area
- Reservoir Boundary
- Undetermined Boundary
- Well Location
- Meager Creek Hotspring
- Other Hotsprings

PRELIMINARY RESERVOIR BOUNDARY

FIGURE III - 2

recharge of the underlying geothermal system is, therefore, not seen as a problem. Also, work thus far in the Meager Creek drainage system has indicated a coinciding subsurface hydrologic system which recharges and flows toward the mouth of Meager Creek. It was shown that the existing hydrologic gradient causes the geothermal waters to flow south, east and then northeast through fractured quartz diorite and alluvial gravels to the principal hotspring complex.

The present status of the whole ground water system at Meager Creek shows that the ground water basin there is saturated and has adequate water available for recharge. Geological investigation, plus past and present drilling efforts, show that permeability of the near-surface rocks allows thermo-artesian flow from wells and fluid interchange between fractured sets.

4.1.3 Water Quality

Surface Water

The proposed project lies in a remote area with very little water quality information. B.C. Hydro initiated the geothermal resource study at Meager Creek in 1974. At that time, the project was primarily concerned with the geochemistry of the resource in order to assess its magnitude (thermodynamic model), rather than the chemical constituent composition of Meager Creek. Thus, the water quality data of the surface waters of Meager Creek collected at that time were very limited (see Table III-1). A quantitative chemical analysis of a sample of Affliction Creek (the only data available), taken at the toe of Affliction Glacier, is presented in Table III-2. These data may reflect the surface water quality of Meager Creek if the general hydrologic settings are similar.

The data presented in these tables seem to suggest the existence of a chemically stable baseline which reflects the influence of the

TABLE III-1

TEMPERATURE AND MAJOR ION COMPOSITION OF MEAGER CREEK

Sample Location	Temp. (°C)	SiO_2 (ppm)	Na (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)
Water near hotspring 79-D	4	8.3	1.4	0.7	7.8	2
Water near main vent	4	9.4	5	1.1	6.8	1.8

Source: NSBG 1975.

TABLE III-2

PHYSICO-CHEMICAL COMPOSITION OF AFFLICATION CREEK
(October 1976)

QUANTITATIVE	(PPM)
T (°C)	0.0
pH (units)	6.38
SiO2	22.0
Na	7.9
K	2.9
Ca	26.0
Mg	6.0
HCO3	41.0
CO3	-0.1
SO4	44.0
Cl	0.3

STANDARDIZED SEMI-QUANTITATIVE ANALYSIS	
Sb	- *
As	-
Ba	40
Be	-
Bi	-
Bo	-
Cd	-
Cr	-
Co	-
Cu	2
Ga	-
Ge	-
Fe	1000
Pb	10
Mn	300
Mo	-
Ni	-
Nb	-
Ag	0
Sr	40
Ta	n.d.
Te	-
Th	-
Sn	140
Ti	20
V	-
Zn	-
Zr	-

'n.d.' stands for no determination
* '-' below detection limit

geothermal source via recharge into Meager Creek. A quantitative description of this phenomenon is lacking, as previously mentioned.

Ground Water

There is a lack of data on major ions and trace heavy metals, as well as on nutrients (e.g., nitrates, phosphorus) and total organic carbon which would be necessary in describing the chemistry of the existing water environment.

4.2 Impact Assessment

4.2.1 Surface Water Hydrology

The development of the geothermal resource is not expected to present any notable environmental impact to the flow regime of surface waters of the Meager Creek watershed, assuming an injection mode of geothermal development. Given the uncertainty of the composition of the geothermal resource, and thus engineering options, it is difficult to ascertain precise impacts on the existing temperature regime of Meager Creek.

There is potential for an increase in the suspended sediment load of Meager Creek, given the soil characteristics of the Primary Study Area. The existence of incipient slides or slopes subject to landslide activity could hamper the construction of roads, well sites and building sites. This would, in turn, introduce implementation of remedial methods which would require removal of expansive soils and backfilling with stable materials (soil or cement). This land alteration activity would inevitably contribute to the increase of suspended sediment load, primarily in Meager Creek and in part in the Lillooet River.

Following completion of project facilities, it may be necessary to install drainage devices in order to prevent concentrated runoff along the surfaces of cuts, fills, roads and geothermal well sites, which would otherwise present a potential problem.

4.2.2 Ground Water Hydrology

The development of the geothermal resource is not expected to significantly impact the ground water flow regime in the Primary Study Area. However, more drilling in conjunction with geophysical resource exploration needs to be done in order to ascertain potential effects which withdrawal of the geothermal resource may have upon the existing ground waters (Nevin 1978).

The potential effects of geothermal resource development on the water quality of local ground water is discussed in Section 4.3.2.

4.2.3 Water Quality

The potential impacts to the quality of surface and ground water in the Primary Study Area may be discussed in terms of liquid effluent, solid waste and human waste. The liquid effluent would consist of the geothermal resource and drilling muds. This effluent could potentially affect water quality by contributing concentrations of total dissolved solids and dissolved heavy metals. Solid waste associated with the project would consist of garbage and other materials generated by project-associated operations. Human wastes could affect water quality by increasing the ammonia and nitrate levels, and/or bacteriological count through the contribution of fecal coliforms. The potential impact which these elements could have upon water quality of the Primary Study Area are discussed below.

Surface Water

Under current practice, effluent from power plant operations is pumped to the well head of an injection well and injected via pressure. It is anticipated that this practice would be adapted in the proposed Meager Creek development. This would effectively preclude interaction of the geothermal resource with the surface waters of the Meager Creek Area, given good management practice, thus ruling out potential surface water impacts from normal operations.

It is assumed that other waste materials, including drill sump (mud pit) and drilling fluids would be conveyed to an appropriate disposal site. This would prevent escape of these deleterious substances downslope of an operating site and/or into the Meager Creek stream channel, where they would present a problem to the existing chemical regime.

In order to present a more precise outline of potential environmental impacts to the water quality of surface waters, more information is needed regarding engineering options and possible supplementary use of surface waters.

It is assumed that treatment modes for human wastes would also be developed. These would depend upon the number of people who would be living within the Primary Study Area. If there should be any effluent discharge to the existing streams, it is essential that the assimilative capacity be known, so that adequate treatment may be designed. This is not, however, considered to be a major problem.

Land alteration in the form of grading activities would accompany construction of geothermal resource facilities and would be reflected in higher suspended solids loads in Meager Creek. This impact would be coupled with elevated levels of both total dissolved solids and conductivity, which may be detrimental to the aquatic biology of Meager

Creek, depending upon the extent of such impact, both in itself and in conjunction with current logging activities.

Ground Water

Contamination of fresh ground water sources would be a possibility in any project involving major construction and drilling operations. Contamination could occur from subsurface introduction of contaminated fluids into fresh water aquifers through poorly cased wells, through percolation, and from surface mixing at springs and streams. Although unlikely, contamination of ground water could occur within the Primary Study Area as a result of leaking drill sumps, or spills of deleterious fluids on the ground surface, on banks and in drainage ditches.

It is important that ground water resources be identified at all sites of proposed development to enable implementation of proper management practices. Ground water contamination would not be a problem, given a well-planned and coordinated effort regarding well drilling, in conjunction with present geophysical exploration and ground water assessment work.

5.0 BIOLOGY

5.1 Existing Environment

5.1.1 Vegetation

Three major vegetation zones occur within the Primary Study Area. These are tundra or glacial areas, subalpine areas and coastal coniferous forest. The tundra includes primarily barren, rocky areas and glaciers and is generally present at elevations above 150 m to 200 m. The lower margin of this zone merges into subalpine forest in which Douglas Fir, Yellow Cedar, Balsam Fir, Hemlock and Western Red Cedar are found in various proportions in sparse or park-like stands.

Forest types within the forested zone vary but are primarily a mixture of stands of Douglas Fir-Yellow Cedar, Douglas Fir-Balsam (Alpine) Fir, or Hemlock-Western Red Cedar with intermediate species mixtures. Logging quality of these areas is generally poor to medium. These areas are located above Meager Creek in the higher forested portion of the Primary Study Area.

The coastal forest occurs at lower elevations in the Primary and Secondary Study Area along Meager Creek and the Lillooet River. It is primarily a mixture of wet and dry coastal western hemlock subzones. Timber stands within these subzones are primarily a mixture of Douglas Fir-Western Red Cedar, Hemlock-Douglas Fir, Hemlock-Western Red Cedar and Balsam (Alpine) Fir-Hemlock-Yellow Cedar in various proportions. Stands are generally composed of old trees, over 200 years, from about 25 m to 50 m in height with density of greater than 15 trees per ha; they are of poor to medium logging quality.

The vegetation in the Meager Creek and upper Lillooet River drainages is largely undisturbed. However, recent clear cutting has taken place along the Lillooet River near the confluence with Meager Creek and along the lower portion of Meager Creek within the Primary Study Area.

5.1.2 Wildlife

The alpine, subalpine coniferous forest area of the Meager Creek Primary Study Area is considered to be moderate priority wildlife habitat for mountain-goat, deer, and moose and is additionally utilized by brown bear, grizzly bear, mountain lion and other species.

The lower portion of the Lillooet River provides moderately high quality winter habitat for moose, which are generally uncommon in the region, and is therefore considered a high priority area by the Fish and Wildlife Branch. Animals move into and out of this area during fall and spring and depend upon forest cover to provide shelter from deep snow. Moose range extends to the lower portion of Meager Creek, and moderate quality moose habitat is found within the Primary Study Area.

The Primary Study Area encompasses deer habitat ranging from moderately low to moderate in quality, according to criteria set forth in Canada Land Inventory maps (Department of Regional Economic Expansion 1971). Winter range of moderately high quality occurs within the Lillooet River Valley below the confluence with Meager Creek. Deer numbers are not considered to be high in the area. This area also lies within moderately low quality mountain-goat summer range but does include some moderately high quality winter habitat. Populations of goat are not considered to be exceptionally high in the area. Low numbers of grizzly bear utilize that portion of the Primary Study Area along Meager Creek and the Lillooet River on an infrequent basis. The maintenance of these individuals is considered a high priority by the Fish and Wildlife Branch.

The habitat value of the Primary and Secondary Study Areas for furbearers and waterfowl is not considered to be high. The area supports relatively few waterfowl during either migration or breeding.

5.1.3 Fisheries

Meager Creek enters the Lillooet River (tributary to the Fraser River) about 64 km above Lillooet Lake. The creek consists of a mainstem about 18 km in length before splitting into three branches from 13 to 22 km in length which drain Meager, Manatee and Devastation Glaciers to the west and north. Another major tributary, the South Fork, enters from the south about 11 km above the mouth of Meager Creek. Elevations range from 390 m at the mouth, to 670 m at the South Fork confluence, to about 850 m at the confluence of the three glacier-fed tributaries.

Several lakes occur in the drainage. A small lake is present about 2 km below the South Fork on the mainstem and also about 8 km above the South Fork on the mainstem. Several occur in the headwater reaches of the South Fork.

The fisheries habitat characteristics in the mainstem of Meager Creek below the confluence of the three glacier drainages is poor, with fish present or suspected to be present. Upper Meager Creek draining the Meager and Manatee Glaciers has high water quality and fair habitat, but is of unknown value for fish. The lower South Fork has good habitat with fish present, while the upper reaches have poor habitat with fish suspected to be present. Poor habitats in the mainstem of Meager Creek are attributed to shifting channels and high water turbidity because of glacial melt and scouring, as well as erosion from the Devastation Creek slide which occurred in the summer of 1975.

The Fisheries and Marine Service and Wildlife Branch place importance on the maintenance and enhancement of the fish in the Lillooet River and on the maintenance of existing fish populations in Meager Creek.

The Lillooet River supports populations of Chinook, Coho, and sockeye salmon, and steelhead and sea-run cutthroat trout, as well as other resident species. The Lillooet River appears to be an important anadromous stream in the lower end near Pemberton, although the Meager Creek contribution is unclear. Five-year average salmon spawning escapements for the upper Lillooet River (above Lillooet Lake) are given in Table III-3. Population estimates for steelhead, sea-run cutthroat, and resident species are not available. Although the numbers of coho and sockeye that enter Meager Creek are unknown, these fishes probably do use the stream for spawning activities. Rainbow and/or steelhead trout and Dolly Varden Char are also known to exist in the mainstem and South Fork, respectively, but population estimates or important areas contributing to the success of the fishery are not available.

5.2 Impact Assessment

5.2.1 Vegetation

The primary impact on vegetation during Phase I would be vegetation clearing for well pad sites and access roads. An accidental blowout, if such occurred, could kill forest vegetation locally. Potential adverse impacts associated with well testing could result from the short-term emission of H_2S and/or hot vapors during well testing. The degree of such impact is dependent upon the water quality of the reservoir, the duration and procedures of testing, and the prevailing meteorological condition. The probability that each impact would be severe is not considered likely.

Impacts could also result from sump failure and the accidental discharge of geothermal fluids into adjacent forested areas if testing is not conducted with adequate precaution. Such discharge could result in local damage to vegetation due to the hot water temperature and/or water quality. The possibility of this is not considered likely.

TABLE III-3

SALMON SPAWNING ESCAPEMENTS

	Lillooet River		Birkenhead River*		
Period	Coho	Sockeye	Coho	Chinook	Sockeye
1940-44	6,555	7,569	5,405	1,380	62,600
1945-49	7,850	2,420	17,688	930	100,000
1950-54	6,525	870	6,445	900	84,000
1955-59	421	62	1,825	1,300	41,500
1960-64	1,478	125	3,390	750	55,500
1965-69	1,904	110	3,194	670	63,200
1970-74	3,715	250	4,100	550	67,200

*Birkenhead River, a tributary to the Lillooet River, is about 64 km (40 mi) below Meager Creek Confluence.

(Adapted from Simpson 1977, unpublished) via W. J. Schouwenburg letter, September 5, 1978

The primary impact to vegetation from power plant construction during Phase II would involve clearing areas for the plant site, additional access roads, wells and pipelines. The significance of this impact would depend upon the ultimate placement of production facilities, i.e., whether they are located in an area which has been/would be logged. Preliminary indications are that this would be the case.

Some degree of impact to vegetation could result from the emission of H_2S from the operating power plant and/or the dispersion of saline mist (salt drift) from the cooling tower. The probability and significance of these is dependent upon power plant design, the nature of the geothermal resource and operational procedures of the power plant.

5.2.2 Wildlife

The primary impacts to wildlife from exploratory drilling and testing during Phase I would be the loss of small areas of coniferous forest habitat for well sites and access roads, and noise and other disturbance from construction and traffic. The degree of these impacts, which would be influenced by possible logging operations in the area and by the final siting of roads and well pads, is not anticipated to be significant.

Potential impact to wildlife would occur during Phase II power plant construction activities. This would result from some habitat loss for plant siting, access roads and pipelines, and from noise, traffic and other activities associated with construction. The presence of the work force in the area could result in increased hunting and other forms of disturbance. Because of the moderately low quality of habitat, impacts to most forms of wildlife are not expected to be significant.

The major impact expected during Phase III operations would be disturbance of wildlife due to the presence of the work force, vehicular traffic and operational noise. This would not be expected to constitute a significant impact.

5.2.3 Fisheries

Environmental impacts potentially could occur during the Phase I exploratory drilling and well testing activities, Phase II power plant construction, or Phase III operations. Most significant impacts to the fisheries resources would probably occur from erosion during the exploratory phase, when roads would be constructed and the area clear-cut for placement of plant facilities. Siltation would potentially affect local salmonid and other resident species' spawning and rearing areas, as well as their food sources to the degree that these occur in the area. Recreational fishing in Meager Creek could also be temporarily impacted due to increased silt in the water.

Additional impacts from well water that has high concentrations of heavy metals or other toxic substances possibly could occur from surface runoff. Such impacts would probably be categorized as short-term. However, if siltation or surface water runoff occurs at a critical stage in the life cycle of salmonid species or their dependent food supplies, then a detrimental long-term impact could be expected. However, these impacts would be confined to the Meager Creek area and would not be likely to affect downstream areas in the Lillooet River.

Under anticipated operating conditions, there would be no interface of the geothermal effluent with surface water. However, in the unlikely event of an accidental release or spillage resulting in a prolonged temperature elevation of more than about 2°C, the developmental processes of salmon fry in the stream would be accelerated. This accelerated development would induce the fry to emerge early, during winter months when availability of food would be limited. This, in turn, would adversely affect survival potential for the newly-hatched fry. It should be noted, however, that this occurrence would be highly unlikely, given the distance from the project site to the areas important for salmon, downstream of Pemberton.

The proposed project is located near the mainstem area of Meager Creek, generally bounded downstream by the South Fork and upstream near the confluence of the three glacier drainages. This area, as well as downstream, is classed as poor fisheries habitat. The level of impact that could be expected with appropriate design integrated into project planning activities is considered to be small, due to the already poor habitat classification of the Primary and Secondary Study Areas of the proposed project. In addition, any impacts which might occur would likely be confined to Meager Creek and therefore would not affect the known salmonid fishery in the Lillooet River below Pemberton.

TABLE III-4

MEAN WEATHER DATA FOR PEMBERTON MEADOWS

	Average Temperature (°C)	Mean Rainfall (cm)	Mean Snowfall (cm)	Days with Frost
January	-5.8	8.61	82.04	26
February	-1.7	4.24	42.93	22
March	2.6	5.23	11.94	19
April	8.1	4.29	1.78	9
May	13.4	3.09	0.0	2
June	16.0	3.76	0.0	0
July	18.6	2.67	0.0	0
August	17.0	2.79	0.0	0
September	13.4	6.38	0.0	0
October	7.5	13.67	4.57	6
November	0.8	11.73	43.94	17
December	-3.4	7.70	95.25	25
Year	7.2	74.17	282.45	128

Source: Environment Canada (n.d.)

This complex terrain of the project area can exert a signicant influence on the meteorological factors which characterize the area's capacity to disperse air pollutants. Surface elevations of the area vary from about 800 m along Meager Creek to 2600 m at the nearby mountain peaks. The region has a high precipitation rate of about 100 cm per year at Pemberton Meadows, and the amounts are expected to be higher at higher elevations. Winds are primarily generated by air masses from the Pacific Ocean.

The general topography is conducive to temperature inversions, although the terrain roughness might be expected to yield moderate turbulence and hence moderate pollution dispersion in some specific areas. Details of the mesoscale/microscale mean flows and turbulence for the terrain have not yet been established.

Visibility in the project area is currently good and any potential degradation of this aesthetic factor could be of concern to the public (see Recreation, 11.0).

6.2 Impact Assessment

Meteorological impacts would occur primarily during well testing and power plant operation, and would center on the extent of dispersion of the vapors discharged to the atmosphere during these activities. Impacts created by well testing activities are considered short-term relative to those long-term impacts from a power plant with an anticipated 25- to 30-year period of operation.

The power plant would discharge water vapor from the ejectors and cooling tower. The amount of water vapor generated is a function of the size of the plant, its specific design parameters and the flow rates involved, and is expected to be considerable. The water vapor condenses to form water droplets, and a steam plume would often be seen to be emanating from the power plant. The existence and size of the steam plume would depend upon the prevailing temperature and humidity. Since cold weather is experienced throughout much of the year and high values of the relative humidity occur very frequently, the steam plume would become a fairly permanent feature of the Meager Creek valley.

7.0 AIR QUALITY

7.1 Existing Environment

At the time of this writing, there has been no air quality monitoring performed in the Meager Creek area. There are, however, no significant sources of air pollution in the region, and ambient levels of all pollutants are expected to be low. The only sources of note would be any forest fires that may occur in the region and the air pollutants generated by logging activities. If forest fires do occur, they have a short-term effect on air quality. As emissions from logging activities are limited to the summer months of May to October, their impact is minimal. Meager Creek receives an ample supply of precipitation in the form of rain or snow, and most of the area is covered by vegetation, so wind-blown dust is not a problem.

7.2 Impact Assessment

The impact of geothermal development activities and operation of the power plant on the ambient air quality depends upon the emission strengths of the pollutant of concern and the prevailing meteorological conditions. Neither of these parameters has been defined yet and so the air quality impacts cannot be quantified at this time.

Before construction of the power plant can begin, a permit may have to be obtained from the Pollution Control Branch of the Ministry of the Environment. As part of the permit application, B.C. Hydro would demonstrate compliance with applicable Pollution Control Objectives. Objectives have been set for emission rates and for ambient air quality levels. These are shown in Tables III-5 and III-6, respectively, based upon 1975 information available at the time of writing.

TABLE III-5

OBJECTIVES FOR GASEOUS AND PARTICULATE EMISSIONS FROM ALL OPERATIONS IN THE FOOD-PROCESSING AND MISCELLANEOUS INDUSTRIES

Parameter	Concentration	Monitoring Method
Total particulate	0.10 gr/scf 229 mg/m^3	Isokinetic sampling followed by gravimetric analysis
Lead as Pb, zinc as Zn	0.003 gr/scf 7 mg/m^3	Isokinetic sampling followed by absorption spectro-photometry
Sulphur dioxide as SO_2	300 ppm 798 mg/m^3	Absorption in H_2O_2 solution followed by titrimetric analysis with barium perchlorate
Nitrogen oxides as NO_2	600 ppm 1146 mg/m^3	Colourmetric analysis with phenol disulfonic acid
Hydrocarbons as methane (CH_4)	150 ppm 102 mg/m^3	Gas chromatographic analysis or equivalent
Odour	No objectionable odour outside the plant boundary.	Not listed

Source: Department of Lands, Forests, and Water Resources 1975.

TABLE III-6

AMBIENT AIR QUALITY GUIDELINES

Parameter	Period Over Which Analysis Is Averaged	Concentration	Suggested Monitoring Frequency
Sulphur dioxide	1 hour	450 μg/m^3 0.17 ppm	Continuous
	24 hours	160 μg/m^3 0.06 ppm	
	1 year	25 μg/m^3 0.01 ppm	
Carbon monoxide	1 hour	14,300 μg/m^3 13 ppm	Continuous for a two-week period once every six months
	8 hours	5,500 μg/m^3 5 ppm	
Hydrogen sulphide	1 hour	14 μg/m^3 0.01 ppm	As above
	24 hours	4 μg/m^3 0.0025 ppm	
Total suspended particulate matter	24 hours	150 μg/m^3	Continuous for a 24-hour period once a week
	1 year (geometric mean)	60 μg/m^3	
Lead	24 hours	4 μg/m^3	As above
	1 year (geometric mean)	2 μg/m^3	
Zinc	24 hours	5 μg/m^3	As Above
	1 year (geometric mean)	3 μg/m^3	
Total dustfall:			
Residential	1 month	15 tons/mi^2/mo	Monthly
Other		25 tons/mi^2/mo	

Source: Department of Lands, Forests, and Water Resources 1975.

8.0 AMBIENT NOISE

8.1 Existing Environment

Although there are no ambient noise data for the project area, noise levels are expected to be typical of rural areas where day/night sound levels (L_{dn}) generally range from 30 to 50 decibels, A-weighted (dBA).

Based upon a recent field reconnaissance, ambient sound levels in the project area presently experience noise intrusions mostly during daylight hours. These noises are generated primarily during summer months by human activities associated with logging operations and attendant truck-hauling and geothermal exploration activities (well drilling, helicopter flights, radio conversations, automobile traffic, camp generators). During winter months, much of the noise is generated by snowmobiles being utilized for recreation activities.

Other noise sources in the project area consist of naturally-occurring rock slides in glacial areas, running streams, waterfalls, and wild animals, such as whistling marmots.

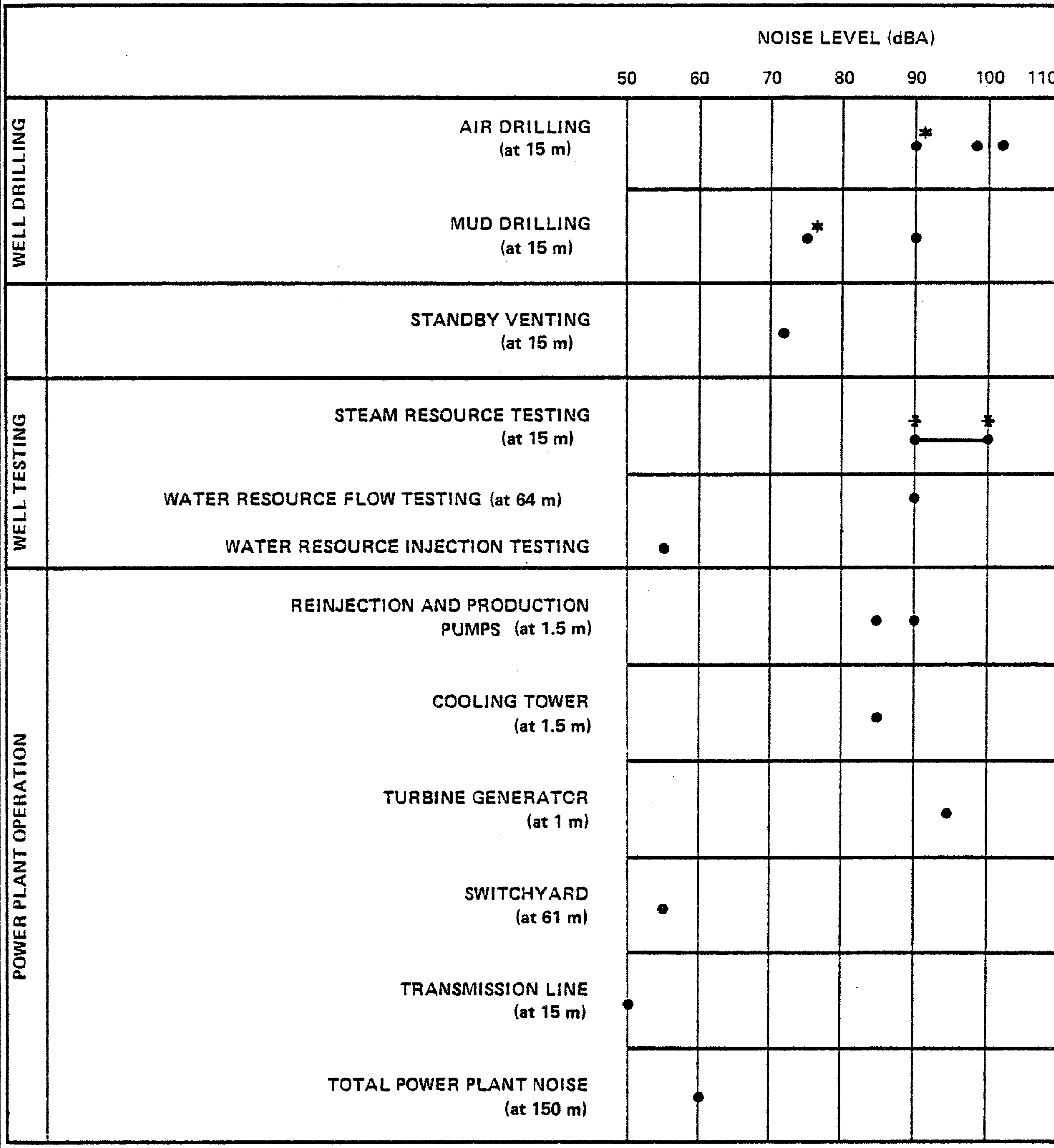
The L_{dn} is the 24-hour energy average of the sound level when the instantaneous level in decibels (dB) is measured with an A-weighting (dBA). The A-weighting makes a sound level meter "hear" in a manner similar to the human ear. Where data are available, this measure (L_{dn}) is used to evaluate the impact of noise on humans. For impact on wildlife, maximum A-weighted sound levels are used.

8.2 Impact Assessment

Due to the relative isolation of the Primary Study Area, noise generated by project activities is not expected to cause disturbance, although those persons along transportation routes may note an increase in traffic and related noise. Also, since current logging operations occur within the same transportation corridor which would be utilized for the geothermal activities, and since the Primary Study Area is currently undergoing logging operations, the noise generated by geothermal activities would be an addition to existing noise sources rather than being a new noise source in a pristine area.

Although a geothermal power plant would be expected to operate for about 25 to 30 years, the most significant noise impacts occur during Phase I and II exploration and facilities construction activities prior to the onset of power plant operation, Phase III. The operation of the power plant and transmission of electrical energy produces minimal noise levels, as graphically depicted in Figure III-3, which shows the noise values associated with the various aspects of geothermal development.

The heavy equipment that would be involved in construction activities is expected to generate noise levels on the order of 85 to 95 dBA at 15 m from the source, as indicated in Figure III-4, which follows.



● Measured Sound Level

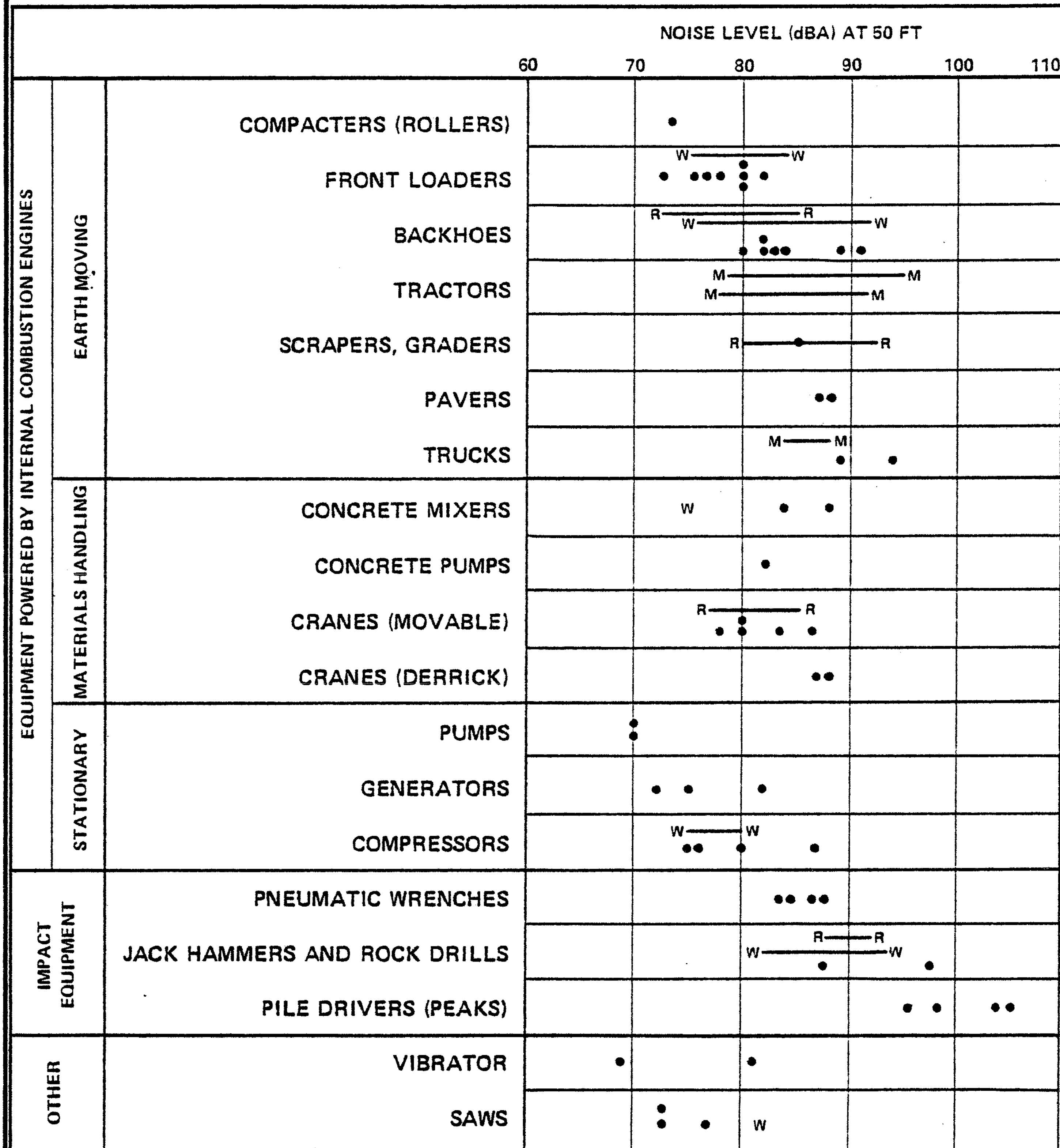
—— Range of Measured Values

* Muffled

Typical Noise Levels from Geothermal Operations

Source: Adapted from VTN 1977, and VTN Sound Level Measurements, 1978.

FIGURE III-3



- • NEW MEASUREMENTS
- W U.K. DATA
- R EUROPEAN DATA
- M MANUFACTURER'S DATA

Typical Noise Ranges from Construction Equipment

Source: Bolt, Beranek and Newman, Inc.

FIGURE III-4

9.0 LAND USE

9.1 Existing Environment

9.1.1 Location

The area of project influence lies within the Kamloops Land Registration District, as does all of the land within the designated Secondary Study Area. This area extends from the Village of Pemberton and its surrounding incorporated area, northwest along the Lillooet River to the southern extremity of the Lillooet Glacier. Most of the area discussed in this section consists of those portions of: 1) the land adjacent to Meager Creek and the Lillooet River which are accessible by motorized vehicle; 2) Pemberton Meadows (also Lillooet River valley), and 3) the Pemberton area. Due to the extreme topography surrounding Meager Creek and the upper reaches of the Lillooet River, the land most frequently utilized for human use is that which lies southeast of the confluence of Meager Creek and the Lillooet River.

9.1.2 Primary Uses

The major land uses in the area consist of logging and associated activities, agriculture, business and commercial ventures, mineral exploration, and the geothermal exploration activities being conducted by B.C. Hydro. There is also undeveloped wilderness which is used by hikers, hunters and campers (see Recreation, 11.0). These land uses are fairly distinct within the various geographic areas; business and commercial activities occur primarily within the Pemberton area; farms are located between Lillooet Lake and Pemberton Meadows, and logging activities are confined to accessible forest lands along the waterways of Meager and Pebble Creeks and the Lillooet River. Recreation activities occur in the forest areas and at the Meager Creek Hotspring, and the geothermal exploration activities are limited to the confines of the B.C. Hydro Project Area (Figure III-1).

Much of the land within the Primary Study Area has been set aside for logging and has been assigned Timber License numbers. This includes virtually all of the land adjacent to the north shore of Meager Creek, from the South Fork to the Lillooet River, and along the south shore from Capricorn Creek to the South Fork. In all, the Timber License land along Meager Creek within the Primary Study Area totals approximately 18 km^2.

Within the 440 km^2 B.C. Hydro Project Area, most of the land is undisturbed. Of that portion which is currently utilized for human purposes, most is being logged by the CRB logging company, and about 1 ha was used as B. C. Hydro's geothermal exploration camp during the summer of 1978.

It is planned that logging activities would continue in the forested areas which are adjacent to Meager and Pebble Creeks and along the Lillooet River.

There is some recreation use of the area, primarily during summer months (see Recreation, 11.0). Heavy snowfall renders the area virtually inaccessible during winter months (see Section 6.0), except for recreational snowmobile activities.

9.1.3 Ownership

Most of the land within the Secondary Study Area is Crown Land and, as such, is under the jurisdiction of the Lands Branch of the Regional District. None of it is designated Provincial Forest Reserve. The B.C. Hydro Project Area consists of Crown Land for which B. C. Hydro has been given the right to explore for the geothermal resource. The farm land within Pemberton Valley is privately owned, as is the land within the incorporated Village of Pemberton.

Logging activities are conducted under the jurisdiction of the B. C. Forest Service, on Crown lands designated as "Surveyed Timber Lease, License or Berth" (Department of Lands, Forests and Water Resources 1970, 1972).

Private land within the area of project influence is concentrated in Pemberton and on the Lillooet River floodplain, where agricultural activities are prevalent. Crown land occupies the remaining territory and the surrounding mountains.

9.2 Impact Assessment

Most of the project-generated impacts to land use would occur within the Primary Study Area, as that is where the geothermal development would be and where the drilling crews and construction workers may be housed. It should be realized, however, that much of this area would continue to be impacted by on-going logging activities, even if it were not utilized for geothermal resource development.

To date, the establishment of the B.C. Hydro Project Area for geothermal exploration and development activities has had a minor impact on land use. This has occurred to the extent that mineral prospecting activities are excluded from the area. It should be noted that, although the project area contains a few mineral prospects, no commercial mineral deposits are known (Sadlier-Brown 1978).

Impacts from geothermal activities would consist of the clearing of approximately 0.5 ha of land per well, a corridor for fluid transmission pipelines, and about 4 to 8 ha for the power plant and cooling tower. It would also be necessary to clear additional land for access roads to the wells and power plant. If the production and injection wells were clustered on "islands," less land would be needed to accommodate each well. An exploration camp would need to be constructed to accommodate drilling and construction crews.

Within the area of project influence, the existing logging road would need to be lengthened and widened, as necessary to accommodate the needs of trucks hauling drilling and construction equipment to the project site.

If the construction workers stay in the vicinity of Pemberton rather than at a Meager Creek camp, it may be necessary to create temporary housing facilities to accommodate the influx of approximately 150 workers at the peak period of construction activities. This land use impact would be year round for the duration of construction, although the workers might live there only the estimated six to nine months of the year during which construction work would occur. A permanent impact to land use in Pemberton would probably be created by a demand for permanent dwellings to house those responsible for power plant operations, about 16 people.

Impacts regarding recreation uses are discussed in Section 11.0.

10.0 SOCIOECONOMICS

10.1 Existing Environment

The purpose of this section is to provide an outline of the existing socioeconomic environment and potential project-generated impacts which would occur within the Pemberton-Lillooet Valley, which would be directly affected by the Meager Creek Geothermal Project. A more detailed socioeconomic portrayal of this area, prepared when geothermal development plans have been finalized, would enable B.C. Hydro and the Village of Pemberton to plan for facilities and services which may be necessary or desirable to accommodate the needs of the geothermal work force.

10.1.1 Demography

The population centers which would most likely be affected by the project are the Lillooet Valley and the Village of Pemberton, enumeration areas 202 and 203, within the Lillooet Electoral District. Nearby areas which may be peripherally affected are the adjacent enumeration areas of 204 and 205, the Mount Currie Indian Reserve and Creekside. For purposes of discussion, therefore, these four areas are enumerated in Tables III-7 and III-8, which follow. The first lists the population statistics for the four enumeration areas, and the second indicates the most prominent ethnic groups.

The information in Table III-7 indicates a general growth mode for the areas listed, which indicates that they are accustomed to accommodating a gradual influx of population. The table detailing the primary ethnic groups (III-8) shows that the areas are populated primarily by persons of English origin, with native Indian populations concentrated in Creekside and the Mount Currie Indian Reserve. Although not reflected in the tables, the census data show an almost even distribution of males and females.

TABLE III-7

POPULATION STATISTICS

	Pemberton	Lillooet Valley	Creekside	Mount Currie Indian Reserve
1971	155	545	420	355
1976	255	625	435	310

Sources: 1971 and 1976 Census of British Columbia.

TABLE III-8

PRIMARY ETHNIC ORIGINS
OF AFFECTED POPULATION CENTERS[1]

	British[2]	Indian-Eskimo	Netherlands	French	German	Asiatic[3]	Scandanavian	Others
Lillooet Valley								
1971	380	30	65	20	15	5	30	
1976	570	0	5	10	15	0	0	
Pemberton								
1971	95	0	0	25	5	25	15	
1976	220	0	0	5	5	10	0	
Creekside								
1971	10	390	0	0	0	0	0	
1976	375	50	0	0	0	0	0	
Mount Currie Indian Reserve								
1971	20	265	0	0	10	0	0	
1976	235	65	0	0	0	0	0	

Notes:

1) 1971 data listed by "Ethnic Groups"
1976 data listed by "Mother Tongue"
This probably accounts for the discrepancy in the British and Indian-Eskimo listings for Creekside and the Mount Currie Indian Reserve.

2) 1971 "British" is 1976 "English"

3) 1976 data show this as "Chinese and Japanese"

Sources: 1971 and 1976 Census of British Columbia.

The numbers in the tables represent trends rather than absolute quantities, as there are inconsistencies in the numbers listed in the census data from which the tables were prepared.

10.1.2 Economic Base

Economic Activities

The economic base of the area of project influence is provided by logging activities, agriculture, and trade and services. Trade and service areas are primarily located in Pemberton, which has the largest concentration of population, and there are some in Creekside. Farming, which consists largely of raising seed potatoes for export, and grains for local consumption, occurs in the Lillooet Valley, and logging is done in the mountainous areas northwest of Pemberton, along the Lillooet River and Meager Creek, a portion of which is underlain by a geothermal reservoir. Logging is currently being performed by three companies, with CRB logging the Meager Creek geothermal area. These characteristics are reflected in Table III-9, which lists experienced labour force by both industry and occupation.

Pemberton Village is a relatively complete service area, as it serves the needs of the resident rural population, plus loggers who live outside the area, some tourists, and mining and geothermal exploration activities. The transient population is mostly seasonal, as logging, tourism and geothermal exploration activities occur during the spring and summer months. Facilities in Pemberton include two motels, grocery stores, a bank, post office, restaurant, gas station, hardware and general stores, laundromat, and railway and bus station.

Employment and Income

The employment activities discussed in the previous section result in the 1970 income figures reflected in Tables III-10 and III-11. Table III-10 shows an income pattern where, within a given area, income earned by females tends to be in the lower ranges, and that earned by males tends to be in the upper ranges. It is interesting to note that in Creekside there are no females indicated as having earned any income in 1970.

The average income figures in Table III-11 show average income for males to be about four times that for females. This holds true for all areas except Creekside, which shows average income for females to be almost 30% higher than for males. This is especially interesting when compared to the Creekside data in previous table. This lists no income for females, but indicates that a maximum of five may have had earnings of less than $3,000.

The basic conclusions which may be drawn from these data are that in the four population centers represented: 1) more males than females are employed (395 to 145), and 2) on the whole, income for males is about 300% more than female income.

10.1.3 Community Infrastructure

Housing

Housing in the project area consists primarily of single-family dwelling units, either homes or trailers. Within the Village of Pemberton, in addition to single family homes, there is one apartment house, a condominium complex, and a 29-unit trailer court. In addition, there is one trailer court outside of the village.

TABLE III-9

EXPERIENCED LABOUR FORCE
IN AFFECTED POPULATION CENTERS

	Lillooet Valley	Pemberton	Mt. Currie Indian Reserve	Creekside
By Industry				
agriculture	25	0	15	10
forestry	30	10	15	55
construction	35	0	5	5
transportation	20	10	10	0
trade	15	5	0	5
service	30	20	15	10
public administration	5	0	5	10
other	20	5	40	20
By Occupation				
administration	0	5	0	5
teaching	0	0	5	0
health	0	0	0	5
social	0	0	5	5
clerical	15	5	0	0
sales	10	10	0	0
service	5	0	5	0
farming	20	5	10	5
primary	20	0	15	50
process	0	0	0	5
fabricating	5	0	0	0
construction	25	0	15	15
transport equip.	35	5	0	0
other	15	0	0	5
not stated	25	5	40	20

Source: 1971 Census of British Columbia.

TABLE III-10

1970 EMPLOYMENT INCOME
FOR INDIVIDUALS 15 YEARS AND OVER

	Lillooet Valley			Pemberton			Mt. Currie Indian Reserve			Creekside		
	M	F	T	M	F	T	M	F	T	M	F	T
Zero	5	10	15	0	10	10	5	5	10	0	0	0
Under $3,000	50	45	95	0	25	25	15	10	30*	80	0	85*
$3,000-$6,000	35	15	50	15	5	15	30	0	30	45	0	45
$6,000-$10,000	50	5	50	25	0	30*	5	0	5	5	0	5
More than $10,000	35	0	30*	10	0	5	0	0	5*	0	0	0

* Discrepancy noted

Source: 1971 Census of British Columbia.

TABLE III-11

1970 AVERAGE INCOME
FOR EMPLOYED PERSONS 15 YEARS AND OVER

	Lillooet Valley		Pemberton		Mt. Currie Indian Reserve		Creekside	
	#	$	#	$	#	$	#	$
Males	170	6,168	45	7,538	50	5,139	130	2,115
Females	75	1,649	35	1,242	25	1,112	10	3,015
Total	240	4,818	80	4,669	75	3,814	135*	2,181

* Discrepancy noted

Source: 1971 Census of British Columbia.

Plans for future housing include a 30-lot residential subdivision to be completed in 1979. The village also owns a 4 ha plot of land, a portion of which is within a B.C. Hydro right-of-way, and a best-use for the land is being studied. It may be developed as residential or commercial property, perhaps by 1979 (Dunbar 1978).

Utilities

Electricity is provided to the Village of Pemberton and outlying areas by the B.C. Hydro and Power Authority. The Primary Study Area does not have electricity. Virtually all homes utilize electricity for lighting purposes; some homes are electrically heated. Oil is the primary energy source for home heating.

Within the Village of Pemberton a new sanitary sewerage system has recently been completed, with outlying areas relying upon private systems. Potable water is in plentiful supply, as the area receives about 100 cm annual precipitation, and the Village of Pemberton has recently upgraded its water distribution system.

Community Services

There is one elementary and one high school in Pemberton, and Mount Currie also has a school system. It is generally known that some residents within the Mount Currie School District, however, send their children to Pemberton for their education.

Primary and Secondary Study Areas are patrolled by the Royal Canadian Mounted Police (RCMP), who have five policemen stationed in Pemberton to serve an area population of about 2,000 (RCMP 1978). The ratio for the area is 1 RCMP/400 population, considerably above the British Columbia average of 1 RCMP/6,000 population. The patrol area extends to the Whistler Mountain Ski Area. The Meager Creek area is now patrolled on an "as needed" basis. It was stated that construction activities might increase these patrols. There is, apparently, little problem with crime-related activities in the area.

Fire-fighting facilities consist of one fire hall and two fire trucks which are shared with the Regional District. Fire personnel consist of both permanent employees and volunteers. For large fires, the B.C. Forest Service is called in.

Medical facilities in Pemberton consist of a diagnostic center which has X-ray facilities and can treat fractures and minor medical ailments. There are one family doctor and two registered nurses, and emergency service is available 24 hours a day. There is an ambulance in Pemberton, run by the Provincial Health Service, a two-passenger commercial charter helicopter, and an Okanagan Helicopter which can accommodate stretcher cases and is available if ordered by a doctor for emergencies.

Community Attitudes

Based upon a recent field reconnaissance, investigators noted a positive attitude toward the proposed geothermal development of the Meager Creek area. Geothermal exploration personnel were well received in town, probably because their presence meant that money was spent in Pemberton (for groceries, some hardware and clothing items, laundry needs and banking services). In speaking with a Pemberton Village official, investigators learned of a new motel being planned. The developers had heard of the B.C. Hydro geothermal activities and indicated a willingness to schedule their project for completion in 1979 rather than 1980, if necessary. Investigators were also told that when controversy arises regarding development-type projects, it is usually the townspeople who disagree with those who have farming interests.

10.1.4 Transportation

The project region is served by Highway 99, the main transportation route from Vancouver to Pemberton and north to Anderson Lake. The Primary Study Area is served by a loose surface, all weather, one-lane logging road.

The Village of Pemberton is the transportation center closest to the project site and is served by both bus and railroad. The nearest commercial air transportation is available in Vancouver.

10.2 Impact Assessment

The various socioeconomic impacts discussed below and generated by project-related activities may be described as short-term and long-term. The short-term impacts would be those associated with project Phases I and II (Initial Well-field Activities and Design and Construction), while long-term impacts would be those generated during Phase III, Operations (see Chapter II). The time-frame for short-term impacts is anticipated to be from five to ten years, while the long-term operation of the power plant is usually estimated to be from 25 to 30 years.

10.2.1 Demography

Short-term demographic impacts generated by the proposed project would occur largely within the Village of Pemberton and would consist primarily of a seasonal influx of population, consisting of the drilling and construction crews. The extent of this impact would depend largely on where the drilling and construction crews were housed. It is currently anticipated that they would live near the site rather than in Pemberton or the Lillooet Valley.

Long-term demographic impacts would involve the importation of about 16 skilled workers who would be responsible for the on-going operation of the power plant. It is anticipated that these workers would move to Pemberton with their families, whereas the drilling and construction crews (Phases I and II) usually commute on weekends or other days off. The power plant operations personnel would be year-round residents of the community.

10.2.2 Economic Base

For the duration of short-term activities, the proposed project would broaden the economic base of Pemberton and the surrounding area, primarily by creating an increased demand for goods and services. In addition, it is anticipated that some of the project-generated employment would be from the local area; thus the project would serve to add an additional source of employment to the existing base of agriculture, logging, and trades and services. As with the other activities, the geothermal employment would be seasonal, peaking during the warm summer months and declining to virtually zero during the winter months.

It is not anticipated that the project-generated employment would draw large numbers of workers away from the area's established employment patterns, due primarily to the rather specialized nature of the tasks involved in geothermal drilling and construction activities. It is frequently estimated that virtually all of the drilling crews and the majority of the construction crews would be "imported," or brought from larger population centers, such as Vancouver. Some construction workers would likely be hired from the local labour force.

For the long term, the operation of the field and power plant, plus the permanent residency of power plant personnel, would create an on-going demand for both commercial and industrial goods and services.

10.2.3 Community Infrastructure

Housing

Within the area of project influence, impacts to housing are likely to be insignificant. Since the large numbers of workers who would be involved in the exploration and construction (Phases I and II) of the proposed project are likely to be housed at a camp within the Primary Study Area, it is anticipated that the primary impact to Pemberton's housing market would not occur until the estimated 16 operations personnel moved to the area for the power plant operations (Phase III). It is not anticipated that this influx of families would create undue pressures on the housing market, as the Pemberton area is currently in a growth mode and in the process of planning for and constructing new housing. By the time the project would be nearing Phase III, Operations, it is likely that the potential expansion of the Whistler Mountain Ski area would already have created a greater impact to housing in the Pemberton area than would be generated by the long-term geothermal activities.

Utilities

Since most project-related activities would occur at the project site, the impact to the utilities systems would be nil; most would occur concurrently with housing impacts.

Community Services

Community services would be impacted in varying degrees, depending on their applicability to project activities. For the short term, it is not expected that any students would be added to the schools. There are currently enough police to serve the added demand which may be created by drilling and construction crews. The project is not anticipated to generate a need for additional fire protection equipment. The demand on existing health services may increase slightly, however, due to the employment mode of the project personnel.

10.2.4 Transportation

Highway 99, the major transportation route to Pemberton, plus the road connecting Pemberton to the Primary Study Area, would receive additional traffic, consisting of both passenger cars and heavy trucks. It is anticipated that there may be increased use of B.C. Railway for the shipping of heavy manufactured equipment. This equipment may be shipped to Pemberton for truck transport to the project area.

The existing roads currently accommodate the logging trucks from the Meager Creek area, so the new traffic is not expected to create weight problems. The existing logging road would need to be widened, however, to accommodate the additional traffic.

11.0 RECREATION

11.1 Existing Environment

11.1.1 Location

The Primary and Secondary Study Areas and area of project influence are located within the Pemberton and Meager Creek Regions of the Squamish-Lillooet Outdoor Recreation Study (1976). As stated in that portion of the report which discusses the Pemberton Region, the "recreational resources focus on the Lillooet River valley with secondary resources present in the valley of the Soo and Ryan Rivers, Rutherford Creek and the alpine and lake resources of the Miller Creek area." The area is basically a mountain-forest environment, with the Lillooet River Valley providing visual variety and the "few recreational attractions" of the region (Department of Recreation and Conservation 1976).

The Meager Creek Recreation Region is comprised of the Meager and Pebble Creek drainage basins and the Lillooet drainage upstream of Meager and Pebble Creeks. Recreation opportunities focus on the narrow Lillooet and Meager valleys in the area, but there are no established recreational facilities. Several factors preclude the area's development, including: 1) distance from markets; 2) location near the end of an access route, and 3) other recreation opportunities more convenient to population centers (Department of Recreation and Conservation 1976), such as Garibaldi Park.

11.1.2 Visual and Activity Characteristics

The climate and topography of the area combine to provide a mountain-forest environment which offers views limited only by the capability of the human eye. From both the Village of Pemberton and Pemberton Valley (also called the Lillooet River Valley), there are mountain vistas in all directions. The Primary Study Area provides close-up views of steep, forested slopes, running streams and waterfalls, and glacier-covered mountain peaks. Cloud cover is frequently below the mountain peaks, providing climbers in the area with views of snow-covered peaks peering through a blanket of clouds.

The area under consideration is located within the Lillooet District of the Canada Land Inventory Land Capability for Recreation (n.d.) (Table III-12). According to this inventory, the area encompassed by the Primary Study Area has been designated as Class 5, having moderate to low capability for outdoor recreation. Within the Secondary Study Area, most of the Lillooet River and Meager and Pebble Creeks and immediately adjacent lands have been classified as having moderately low capability for outdoor recreation. However, the areas along the Lillooet River upstream of the juncture of Meager and Pebble Creeks, and downstream of South and North Creeks to Pemberton, are rated as having moderate capability for recreation.

The land along the Lillooet has been assigned the various subclass designations (Table III-13) which indicate that the area surrounding the river is accessible for fishing, affords frequent viewing opportunities, is suited to organized camping, and exhibits landscape patterns of agricultural interest. The area along Meager and Pebble Creeks is rated as having frequent viewing opportunities. The areas along the upper reaches of the Lillooet River are rated as having high to moderately high capabilities for outdoor recreation. In addition to offering organized camping potential and superior views, these areas are characterized by waterfalls and rapids and interesting rock formations.

Within the outlying portions of the Primary and Secondary Study Areas, there is low capability for outdoor recreation. The land, however, is designated as offering significant glacier view, and exhibiting variety in its land and water relationships, thereby enhancing the opportunities for aesthetic appreciation of the area (Department of the Environment n.d.).

TABLE III-12

LAND CAPABILITY FOR RECREATION

CLASS I LANDS IN THIS CLASS HAVE VERY HIGH CAPABILITY FOR OUTDOOR RECREATION

Class 1 lands have natural capability to engender and sustain very high total annual use based on one or more recreational activities of an intensive nature.

Class 1 land units should be able to generate and sustain a level of use comparable to that evident at an outstanding and large bathing beach or a nationally known ski slope.

CLASS 2 LANDS IN THIS CLASS HAVE A HIGH CAPABILITY FOR OUTDOOR RECREATION

Class 2 lands have natural capability to engender and sustain high total annual use based on one or more recreational activities of an intensive nature.

CLASS 3 LANDS IN THIS CLASS HAVE A MODERATELY HIGH CAPABILITY FOR OUTDOOR RECREATION

Class 3 lands have natural capability to engender and sustain moderately high total annual use based usually on intensive or moderately intensive activities.

CLASS 4 LANDS IN THIS CLASS HAVE MODERATE CAPABILITY FOR OUTDOOR RECREATION

Class 4 lands have natural capability to engender and sustain moderate total annual use based usually on dispersed activities.

CLASS 5 LANDS IN THIS CLASS HAVE MODERATELY LOW CAPABILITY FOR OUTDOOR RECREATION

Class 5 lands have natural capability to engender and sustain moderately low total annual use based on dispersed activities.

CLASS 6 LANDS IN THIS CLASS HAVE LOW CAPABILITY FOR OUTDOOR RECREATION

Class 6 lands lack the natural quality and significant features to rate higher, but have the natural capability to engender and sustain low total annual use based on dispersed activities.

CLASS 7 LANDS IN THIS CLASS HAVE VERY LOW CAPABILITY FOR OUTDOOR RECREATION

Class 7 lands have practically no capability for any popular types of recreation activity, but there may be some capability for very specialized activities with recreation aspects, or they may simply provide open space.

Source: Department of the Environment (n.d.)

TABLE III-13

SUBCLASSES OF RECREATION FEATURES

SUBCLASS A - Land providing access to water affording opportunity for angling or viewing of sport fish.

SUBCLASS B - Shoreland capable of supporting family beach activities. In high class units this will include family bathing. In Classes 4 and 5, the activities may be confined to dry land due to cold water or other limitations.

SUBCLASS C - Land fronting on and providing direct access to waterways with significant capability for canoe tripping.

SUBCLASS D - Shoreland with deeper inshore water suitable for swimming or boat mooring or launching.

SUBCLASS E - Land with vegetation possessing recreational value.

SUBCLASS F - Waterfall or rapids.

SUBCLASS G - Significant glacier view or experience.

SUBCLASS H - Historic or pre-historic site.

SUBCLASS J - Area offering particular opportunities for gathering and collecting items of popular interest.

SUBCLASS K - Shoreland or upland suited to organized camping, usually associated with other features.

SUBCLASS L - Interesting landform features other than rock formations.

SUBCLASS M - Frequent small water bodies or continuous streams occurring in upland areas.

SUBCLASS N - Land (usually shoreland) suited to family or other recreation lodging use.

SUBCLASS O - Land affording opportunity for viewing of upland wildlife.

SUBCLASS P - Areas exhibiting cultural landscape patterns of agricultural, industrial or social interest.

SUBCLASS Q - Areas exhibiting variety, in topography or land and water relationships, which enhances opportunities for general outdoor recreation such as hiking and nature study or for aesthetic appreciation of the area.

TABLE III-13 (continued)

SUBLCASS R - Interesting rock formations.

SUBLCASS S - A combination of slopes, snow conditions and climate providing downhill skiing opportunites.

SUBCLASS T - Thermal springs.

SUBCLASS U - Shoreland fronting water accommodating yachting or deep water boat tripping.

SUBCLASS V - A vantage point or area which offers a superior view relative to the class of the unit(s) which contain it, or a corridor or other area which provides frequent viewing opportunities.

SUBCLASS W - Land affording opportunity for viewing of wetland wildlife.

SUBCLASS X - Miscellaneous features with recreational capability.

SUBCLASS Y - Shoreland providing access to water suitable for popular forms of family boating.

SUBCLASS Z - Areas exhibiting major, permanent, non-urban man-made structures of recreational interst.

Subclasses indicate the kinds of features which provide opportunity for recreation. They are, therefore, positive aspects of land and do not indicate limitations to use. Features may be omitted from a unit, either because of the imposed three-feature limit, or because their presence was unknown or unconfirmed.

The degree to which these features are judged capable, collectively, of generating and sustaining use for recreation, determines the class. The sequence in which they are listed indicates the order of their significance. Subordinate features may be relatively insignificant and the class of a unit should not be interpreted to indicate the capability of a secondary or tertiary feature.

Source: Department of the Environment (n.d.)

11.1.3 Recreation Use

Large-scale recreation opportunities are generally not present within either the Primary or Secondary Study Areas. There is opportunity for sight-seeing, hunting, camping and fishing, with primary access being provided by the logging road. Access into most of the B.C. Hydro Project Area is by helicopter or foot. For this reason, much of this type of recreation activity is available only to those able to backpack through the area. Also, most of this activity is confined to the summer months, as heavy snowfall renders the area virtually inaccessible during the winter season, except for those who utilize the area for recreational snowmobiling.

There are several hotsprings within the project area, the largest of which is called the Meager Creek Hotspring and is accessible via a logging road. This hotspring is utilized by persons working in the area, and it attracts some automobile tourists during months when the road is open.

Large scale recreation opportunities are available outside of the Study Areas. These include water-oriented activities at Lillooet Lake, the northern shore of which is located approximately 20 km east of Pemberton. The northern boundary of Garibaldi Park is located about 15 km south of Pemberton and is accessible from Highway 99. The park offers a variety of mountain-oriented activities during both winter and summer seasons, including the facilities at Whistler Mountain Ski Area, which are about 30 km south of Pemberton.

11.2 Impact Assessment

Neither the short- nor long-term geothermal activities are expected to significantly affect recreation potential within the area of project influence or the region, as the proposed project would not generate a significant population increase. Also, the proposed expansion of the

Whistler Mountain area is planned to accommodate many times the total personnel who would be associated with the geothermal project.

11.2.1 Primary Study Area

Within the Primary Study Area, the project would have some effect upon recreation activities. The visual characteristics of the area along Meager Creek would be altered from the current patchwork of forest and clear-cut land, to a more industrial character, with the addition of the geothermal wells, pipelines, cooling tower and power plant. Also, vertical-rising steam plumes from the cooling tower and venting wells would be visible during much of the year, especially during winter months. Hunting activities may be somewhat altered, depending on the effect the geothermal-related activities have upon animal behavior (see Biology, 5.0). Some species may be driven away from the project site, while others may be attracted by the activity and/or the warm temperatures generated from the pipelines and cooling tower.

Recreation activities associated with the Meager Creek Hotspring may be enhanced if the work force at the project site make improvements (as have already occurred to some extent) in the area to enhance their enjoyment of the hotspring. Or, there may be an adverse effect if drilling activities interfere with the quantity/temperature of fluids which currently feed the spring (see Hydrology, 4.0).

Within the Primary Study Area, recreation use may be increased, as road building and/or improvements render the area more accessible. It is not expected that activities related to geothermal development would degrade the area's aesthetic quality, as the geothermal facilities would be visible only from the immediate area of the development site or from the mountaintops immediately adjacent to Meager Creek. The camp area for the drilling and construction crews would not adversely affect existing recreation use.

11.2.2 Secondary Study Area

Within the Secondary Study Area, the primary project-related impacts would consist of the establishment of an electric transmission corridor and road improvements. Previous experience indicates that animal behavior is not adversely affected by the construction of transmission towers. Therefore, recreation uses associated with fishing, hunting or photographing animals in the area are not expected to be adversely affected over the long term. The aesthetic characteristics of the corridor area would be affected to a greater or lesser extent, depending upon the size of the transmission line and the type of tower structure utilized by B. C. Hydro. As previously mentioned, road improvements may serve to increase the area's recreation use by making it more accessible.

11.2.3 Regional Area

Outside the Study Areas, but within the region, the major recreation areas of Lillooet Lake and Garibaldi Park are not expected to be significantly impacted. This is because the proposed project would not induce the influx of a large population with the time available to participate in the activities afforded by these areas (see Demography, 10.2.1).

12.0 HERITAGE CONSIDERATIONS

12.1 Existing Environment

The Primary Study Area does not contain any known or marked heritage sites/objects. It is possible that logging activities may have already obscured sites or objects of significance to the heritage of the Province, as logging is occurring in areas adjacent to Meager Creek, a natural transportation corridor for the Indians who originally inhabited the area. The same is true for the area adjacent to the Lillooet River, within the area of project influence.

Although it has been stated (Cassidy 1978) that there are no archaeological sites at Meager Creek, the Resource Map Folio produced by the Vancouver Forest District for Meager Creek does locate one historic site in the area. The folio map designated "Recreation Features Capability, Archaeological Sites" shows the historic site to be approximately 2 km south of the terminus of Devastation Slide, which occurred in 1975.

The existing environment is such that accessible areas have already been impacted, with the building of roads and bridges and clear-cut logging techniques. It is the higher elevations which remain undisturbed, but which have a lesser chance of containing heritage objects or sites, due to their relative lack of accessibility.

There is no record of archaeological sites in the area of Meager Creek, but a survey of the area has not been conducted (Cassidy 1978). Also, according to the Archaeological Sites Advisory Board, there are no archaeological sites recorded in the Lillooet valley north of Pemberton. This may be due, however, to the fact that little if any survey work has been done in the area, as the primary concerns are in proximity to Mt. Currie (Archaeological Sites Advisory Board 1978).

12.2 Impact Assessment

Within the Primary and Secondary Study Areas, any heritage sites/ objects which lie within access corridors or the sites to be developed would probably be destroyed unless preventive measures were taken.

As previously mentioned, however, the more accessible land areas have already been impacted by logging activities. Impacts which might occur due to geothermal operations would also occur in the more accessible portions of the designated study areas, and many of the impacts would therefore represent cumulative rather than original incursions into the area.

Chapter IV

Potential Constraints To Project Development

CHAPTER IV

POTENTIAL CONSTRAINTS TO PROJECT DEVELOPMENT

1.0 INTRODUCTION

In instances where project-generated impacts discussed in the previous chapter are expected to be severe, they may present certain constraints to development activities. In these cases, and in order to reduce the magnitude of these impacts, it may be necessary to alter certain of the exploration and/or development procedures, institute alternative design criteria, and/or develop mitigation measures which would either compensate for the severe impact, or rehabilitate upon cessation of the activity which generated such impact. In other cases, characteristics inherent in the existing environment may provide constraints to project activities. Such conditions would necessitate the development of special procedures, equipment, and/or the establishment of appropriate engineering design criteria to accommodate these constraints.

This chapter outlines those potential environmental constraints which could affect the development of the Meager Creek Geothermal Project. These constraints represent dual concerns. That is, they consist of impacts which the proposed project activities may have upon the existing environment, plus impacts which the existing environment may impose upon the design and conduct of project activities.

2.0 GEOLOGY

There are several serious geological hazards in the Meager Creek area. Of major concern is the instability of materials, which may cause sliding, rock creep or avalanching (Sadlier-Brown 1978). Three slides of rock, mud, water and ice mixtures, within the last 45 years, have flowed down Meager Creek. The earliest one, in 1931, began on the west flank of The Devastator and flowed down the length of Meager Valley. The origin of the slide which occurred in 1947 is not known. The recent slide of July 1975, which killed four men, originated on the southern edge of Helena Glacier just above its confluence with Devastation Glacier.

These slides were caused by failure in incompetent volcanic units. The unit that failed in the 1975 slide is particularly unstable and underlies most potential slide areas. The largest potential slide masses lie on the western flank of The Devastator, overlooking Devastation Glacier, which is receding and removing its support from the base of the slopes (NSBG 1977). Extensive mapping of the unstable unit has been done, and the 1975 slide and its cause have been studied extensively. It is believed that the unstable unit can be identified and mapped. In addition, smaller rock slides occasionally occur in fractured competent rock on the steeper slopes. These active areas are also thought to be generally identifiable (Sadlier-Brown 1978).

Occasionally, mud slides caused by water saturation in glacial or fluvio-glacial silts in the lower parts of the main valleys occur. While not as devastating as the rock slides, these should be taken into consideration when planning such facilities as roads, drill sites, pipelines and power plants. As forestry companies are beginning to log the lower slopes, these mud slides could become more common (Sadlier-Brown 1978).

Rock creep, caused by very slow, gravity-induced mass movement of large bodies of rock, is occurring in the area. This movement results in tension fractures, which are themselves hazards, within the affected rocks.

In addition to material instability, there are other hazards such as flooding and stream erosion. Flooding occurs in identifiable parts of the main river valleys. As the lower slopes are logged, the pattern and extent of flooding may be changed, so that historical data would not be as valid. Logging may also alter the very active stream erosion of the area. Changes in runoff patterns could be expected and could accelerate erosion, thus rendering certain presently stable areas subject to stream erosion (Sadlier-Brown 1978).

As noted in Chapter III-2.3, seismic activity is not considered a serious hazard in this area. Volcanism last occurred 2400 years ago on the north side of the Meager Creek Volcanic Complex, and while always possible, is not considered a serious hazard (NSBG 1977).

It is evident in the study area that avalanches are fairly common. Since such occurrences may pose a threat to project activiites and siting of facilities, and since project activities could influence the occurrence of avalanches, such impacts should be anticipated.

3.0 SOILS

The soils and underlying materials in the project area present significant constraints to the siting and building of permanent facilities such as those required in geothermal development. Several areas within the Primary Study Area have high landslide potential, a high water table, deep-seated stability problems, and poor drainage. There also exists the potential for flooding and/or channel migration during periods of high runoff. These characteristics present constraints to the alignment, construction and use of roads, and the siting of wells, pipelines and power plant. Areas which pose no engineering constraints will require exterior rock work for construction of roads or other facilities.

4.0 HYDROLOGY AND WATER QUALITY

In a series of conversations pertaining to the development of the proposed project (Nevin, Stauder, Schouwenburg 1978), it was possible to reduce the potential water impact to virtually one problem: possible temperature elevation of Meager Creek. This, however, assumes that the spent geothermal fluid would not be injected into the subsurface. It is possible that an approximate 2-3°C elevation of Meager Creek would induce premature emergence of any salmon found in this creek. The extent to which changes in temperature in Meager Creek would affect temperatures in the Lillooet River is presently uncertain. It would be anticipated, however, that changes in temperature in the Lillooet River would be minimal, as temperature decreases with time and distance from the source and is dependent on the magnitude of flow into the receiving water body.

5.0 BIOLOGY

Available information on the vegetation and wildlife resources indicate that the Meager Creek area contains timber stands of poor to medium quality and is moderate priority wildlife habitat. Based upon this information, there is no major constraint that would preclude careful project development.

There is a dearth of information available on the significance of fisheries resources of Meager Creek. Based on the classification of the habitat, however, there is no major constraint that would preclude project development.

6.0 METEOROLOGY

Meteorological considerations are not expected to present constraints to project development. They may, however, present conditions to be considered during the initial stages of project planning. Dispersion characteristics and wind drift, as yet not characterized for the Primary Study Area, would determine whether air-borne effluents disperse throughout the area or remain within the confines of the valley through which Meager Creek flows. These effluents would be those generated by project exploration and construction activities and, during power plant operation, would consist of cooling tower drift.

7.0 AIR QUALITY

It is not anticipated that air quality issues would present constraints to project development. This is due to two primary considerations. First, evidence obtained to date indicates a relatively "clean" resource, one which may be exceptionally low in H_2S, the primary nuisance pollutant associated with geothermal development. Second, the Primary Study Area is located far enough from permanent human dwellings that no related effects are anticipated.

It should be noted that the area of impact applicable to the issue of air quality has not yet been precisely determined.

8.0 AMBIENT NOISE

For various reasons, it is not anticipated that factors related to noise would affect development of the proposed project. First, the Primary Study Area is many kilometres from the nearest residence, and about 50 km from Pemberton, the nearest concentration of population. Also, due to on-going logging activities, the wild animals in the area have already been subjected to loud noises. Therefore, noise from geothermal activities would represent an additional rather than a new source of auditory disturbance.

9.0 LAND USE

Much of the land along Meager Creek within the Primary Study Area is under Timber License and either is being or will be logged. At this time there are no known heritage sites within the Primary Study Area, and it is little used for recreational purposes. For these reasons, land use is not seen as a constraint to the proposed project. The possibility exists that the CRB Logging Company might resist the proposed project on the assumption that it would interfere with their activities. This potential problem could be resolved by B. C. Hydro involving appropriate offices of CRB in the project planning stage. Arrangements could be made for CRB to log specific areas before they are cleared by B.C. Hydro, or B.C. Hydro could release the timber from the cleared area to CRB. It might be possible for B.C. Hydro and CRB to schedule logging and geothermal activities so that only areas needed by B.C. Hydro would be logged prior to CRB's existing schedule. To log the entire area prior to the onset of geothermal activities might produce soils/landslide problems. Further investigation could resolve this issue, but it could represent a constraint to project development.

10.0 SOCIOECONOMICS

The socioeconomic factors associated with the project are expected to provide an incentive for development. They are not anticipated to present constraints to project development.

11.0 RECREATION

Due to the relatively low recreation use/capability of both the Primary and Secondary Study Areas, and since the proposed project is not anticipated to significantly affect the area's existing recreation opportunities, it is not anticipated that recreation factors would offer significant constraints to the proposed project. It may, however, be desirable for B.C. Hydro to work closely with the B.C. Forest Service in order to determine the effect which the proposed project may have on the flow of the Meager Creek Hotsprings and to make appropriate plans for the future of the several springs within the Primary Study Area. These plans might involve a program to protect the aesthetic environment of the hotsprings and adjacent areas and/or facilitate their development as a regional recreation attraction. It may be feasible to combine development of the hotsprings with informational tours of the geothermal facility to create an additional recreation resource in the area. This type of program has been developed and is now operating successfuly at a geothermal field in New Zealand.

12.0 HERITAGE CONSIDERATIONS

It is not currently known whether heritage considerations would present constraints to project development. This would depend upon the results of an archaeological survey of either the Primary Study Area or the specific sites proposed for project activities, discussed in Chapter V-12.0.

Chapter V

Data Deficiencies and Study Recommendations

CHAPTER V

DATA DEFICIENCIES AND STUDY RECOMMENDATIONS

1.0 INTRODUCTION

This chapter discusses the data deficiencies which exist in the data base relative to the Meager Creek Geothermal Project, and it outlines recommended areas of study which would provide the information necessary to complete that data base. The baseline data deficiencies were identified by comparing the total anticipated project data requirements with the data base currently available from existing sources. For purposes of this study, project environmental data requirements consist of information which is necessary to satisfy permit applications, support future operational monitoring programs, and allow other related investigative, study and design efforts to proceed expeditiously while additional baseline data are being accrued.

Specifically, these data should be developed in order to provide B.C. Hydro with a data base which would enable them to complete the necessary environmental and preliminary engineering design tasks associated with the project.

The tasks for which these data are necessary include, but are not necessarily limited to, the following:

1) Fully describing those environmental conditions which exist within the defined Primary and Secondary Study Areas prior to geothermal development;

2) Identifying and determining the magnitude of those environmental considerations which are most likely to be affected by the proposed project;

3) Identifying specific environmental constraints which affect project exploration, development and facility planning activities;

4) Evaluating the suitability of, and providing a basis for, making benefit/cost comparisons of alternative facility locations and designs, environmental control equipment, and other protective, mitigative and rehabilitative measures which may be applicable, and

5) Designing on-going environmental monitoring programs, including predictive modeling techniques, sampling procedures, and data acquisition systems which would be best suited for use within the Meager Creek Primary and Secondary Study Areas.

Tasks 1 and 2 may be of special interest to B.C. Hydro in relation to the Meager Creek project. Much of the environment within the B.C. Hydro Project Area and Primary and Secondary Study Areas has been and continues to be impacted by commercial logging activities which involve clear-cutting selected parcels of land which are as large as 60 ha.

The effects of these logging activities include: degradation of the visual environment; impacts upon the biological environment due to alteration of animal habitat, cover and forage; the creation of increased opportunities for erosion and landslide in an area which is characterized by unstable soils and steep slopes, and increased potential for siltation in the area's many flowing waters, especially Meager and Pebble Creeks and the Lillooet River.

It may be important for B.C. Hydro to develop a data base which would enable them to clearly separate those environmental impacts resulting from logging activities and those which result from geothermal activities.

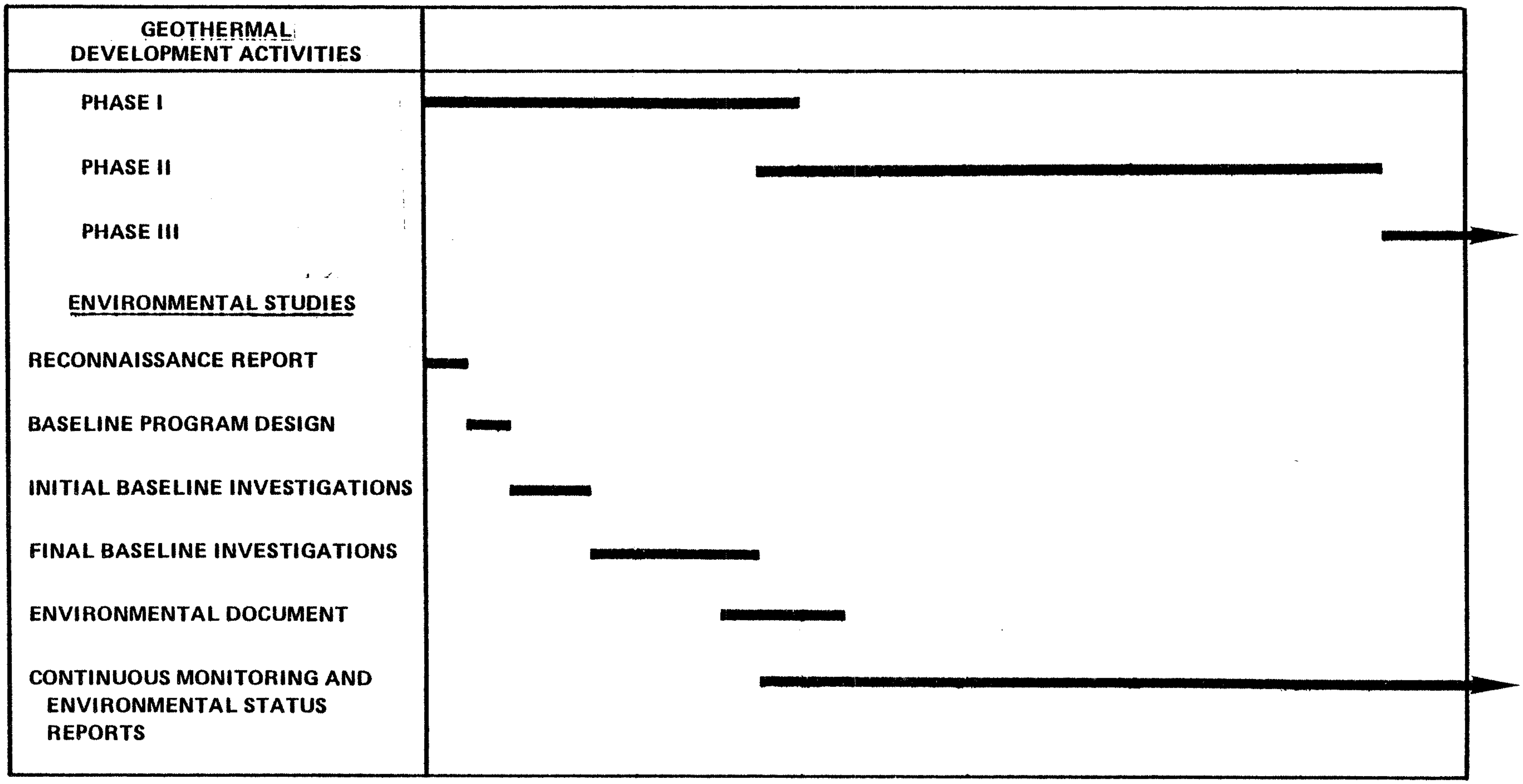
It should be noted that all of the supporting environmental data and documentation requirements cannot at this time be defined in precise terms. Data requirements are customarily developed on an individual project basis, and they vary to reflect the individual characteristics of that project, such as: the nature and complexity of the proposed development; the environmental features of the area involved; the potential impacts that may result from project implementation; the particular concerns of the agencies involved, and the public issues associated with the proposed development.

The data deficiencies identified in subsequent portions of this chapter reflect the consultant's interpretation of the probable data requirements necessary to satisfy the needs which have been discussed. However, these conclusions should be validated through specific inquiries and discussions with B.C. Hydro project personnel and with agencies, as appropriate, at the earliest feasible date.

As a result of the Ministry of the Environment's resource inventory efforts in the area, some data are available. However, most of these data are of a general nature, and site-specific data on existing ecosystems of the project area are negligible in terms of potential project requirements. The existing data base is somewhat deficient in all resource areas, and almost totally deficient in the areas of hydrology and water quality, fisheries, meteorology, air quality, ambient noise and heritage considerations.

It is important that the necessary environmental studies be coordinated with the various field activities and engineering tasks which would be involved in the development of a project as assumed for Meager Creek. In addition to this Environmental Reconnaissance Report, the proposed environmental studies would include baseline program design, initial and final baseline investigations, and an environmental document. Once the power plant is operational, continuous monitoring of key environmental elements would be part of the overall program. The proposed studies reflect the desired integration of geothermal development activities and representative environmental investigations. This integration would permit the various environmental concerns and constraints identified during environmental investigations to be incorporated into the design of the geothermal project. The following diagram (Figure V-1) shows the relationship of the various phases of project development (see Chapter II) with typical environmental activities, as discussed in the following sections of this chapter.

PROPOSED ENVIRONMENTAL STUDIES
MEAGER CREEK GEOTHERMAL DEVELOPMENT



Source: VTN, 1978.

FIGURE V-1

2.0 GEOLOGY

2.1 Data Deficiencies

Data relating the geology of the Meager Creek geothermal area to engineering considerations have not been generated. Also, mapping of all the various unstable units within the Primary Study Area is not complete, i.e., mud slides, rock creep, avalanches and flooding and stream erosion.

2.2 Study Recommendations

Due to the natural instability of the rocks of the Meager Creek area, it is recommended that an engineering-geologic study be carried out to assess the difficulties involved in developing this area for geothermal production. In addition, an extensive mapping program is recommended, in order to identify the many areas of instability within the Primary Study Area so that they may be avoided at the outset of geothermal drilling activities. A new air photo survey of the area would be required for this mapping program to be successfully performed.

It is also recommended that the results of the engineering-geologic study and the hazards mapping program be used as a basis for siting the geothermal facilities, including roads, drill pads and sumps and later, the power plant, cooling tower, and other ancillary facilities. These plans should be considered in line with current/proposed logging activities so that plans may be developed wherein logging practices do not create additional hazards which may threaten the geothermal facilities/operations at a later date.

3.0 SOILS

3.1 Data Deficiencies

There is no definitive soils information available for the Primary or Secondary Study Areas. In addition, the Meager Creek area has not been ground surveyed. Available information consists of Terrain Units and Engineering Interpretations presented in the resources folio prepared by various provincial agencies for the Lillooet Valley and Meager Mountain volcanic complex. The terrain units were mapped from aerial photographs at a large scale, and limited field checking was conducted. Therefore, engineering interpretations are for general areas and cannot be applied to specific sites without further field examinations.

3.2 Study Recommendations

It is recommended that site-specific soil investigations be conducted prior to exploratory well drilling to assist in the design, location and construction of the access road, well pad, and sump.

Further soils studies would be required but can be formulated after more specific planning has been completed.

4.0 HYDROLOGY AND WATER QUALITY

4.1 Data Deficiencies

There are considerable data deficiencies regarding the hydrologic and water quality data, as mentioned in Chapter III, primarily in terms of creek flow data, watershed data, rainfall and snowfall data, and the chemical influence of Meager Creek upon the Lillooet River. Specifically, there are no flow data for Meager Creek to indicate discharge. There are some for Place Creek, about 50 km southeast of Meager Creek, but they are based in large part upon estimates rather than recorded flows. No watershed data exist for the Meager Creek drainage area, and rainfall and snowfall data are available only for Pemberton Meadows. There have been no data generated which would enable assessment of the chemical influence of Meager Creek upon the Lillooet River.

A regular and coordinated sampling program of Meager Creek, which would also include sampling the Lillooet River both above and below the confluence of Pebble and Meager Creeks, would help in assessing the influence of the chemistry of Meager Creek on the Lillooet River. This monitoring would occur at periods of high and low flows, in order to assess the dilution effect of the waters. The frequency and extent of the monitoring program would be coordinated with the well-known aquatic biology cycles which relate primarily to the spawning of salmon and other indigenous species.

The water quality data made available by the Canadian Ministry of the Environment mostly relate to streams and rivers far from the Primary Study Area of Meager Creek. There are, in fact, no chemical data available that would accurately describe those natural phenomena that would impair or promote the growth of steelhead, sea-run cutthroat and intrinsic resident species (Schouwenburg 1978). There is concern that an accurate and reliable temperature base be obtained in Meager Creek in light of the potential effect (increased temperature) of accidental discharge or other impact of the proposed project, despite measures (primarily injection) designed to minimize this.

4.2 Study Recommendations

Several programs are recommended in order to establish a sound data base to: 1) characterize baseline conditions; 2) accurately predict project-related impacts, and 3) conduct on-going monitoring programs during various stages of the proposed project.

4.2.1 Surface Water

Streamflow Gauging Stations

Streamflow gauging stations should be installed to more fully understand the flow regimes of the Meager Creek watershed. Stations should be sited both upstream and downstream of the project area. The upstream station would provide long-term data on non-project related changes, and the downstream stations would serve to monitor project-induced impacts, in addition to providing a baseline value.

Carrying Capacity

It is recommended that evaluations be made of the carrying capacity of streams that could be affected by exploration, construction and operation activities. These would involve quantitative evaluations of sediment transport during periods of both low and high flows.

Precipitation

A coordinated system of precipitation gauges should be established at selected elevations in order to accurately record rainfall and snowfall in areas likely to be affected by the proposed project.

Water Quality Sampling

Water quality sampling stations should be established both above and below the confluence of Meager Creek and the Lillooet River. These stations should be established so that the type of sample collection and frequency of sampling would be suitable for obtaining information at least at quarterly intervals initially, and on a more intensive schedule should monitoring be required.

In addition to pH and major ion composition, it is suggested that the following water quality parameters be analyzed:

fluoride	copper	strontium
boron	iron	thallium
silver	mercury	vanadium
arsenic	manganese	zinc
barium	lead	
beryllium	rubidium	bromide
cobalt	antimony	iodide
chromium	tin	ammonium
cesium		nitrate

Knowledge of these parameters will enable B.C. Hydro to accurately characterize, relative to geothermal considerations, the existing chemical regime of waters within the Primary Study Area. This information can then be utilized to determine what, if any, effects occur as a result of on-going geothermal activities, plus the effects of any spillage or other unscheduled event which may occur.

4.2.2 Ground Water

It would be necessary to first determine the existing ground water characteristics in order to adequately assess whether development of the geothermal resource would affect ground water within the Primary and Secondary Study Areas. Depending upon the physical characteristics of the reservoir, and its relationship to local ground water, potential effects of geothermal extraction may involve draw-down of local ground water and/or diminished recharge capabilities.

It is recommended that water wells be established to gather data which would aid in determining the relationship of local ground water to the geothermal resource and provide a basis for monitoring, to determine how this water could be affected by geothermal development activities. This information, in turn, would enable a more definitive characterization of the geothermal reservoir to be made through time.

Data to be gathered include:

1) An inventory of wells in the Primary Study Area and perhaps in the Secondary Study Area;

2) The quantity, occurrence, and direction of flow;

3) The elevation of the ground water table, and

4) The chemical constituent composition of the water.

5.0 BIOLOGY

5.1 Data Deficiencies

Data deficiencies occur in two areas: the nature of the resource and consequent project design; and site-specific biological information. Information on ungulate habitat values and forest cover types is preliminary and has not been finalized. Data on big game population levels, their movement patterns and specific habitat requirements are not available. The effects of recent and current logging activities on wildlife and the potential interaction between these and the proposed project are not clear.

Information on the fisheries resources of Meager Creek is generally lacking. Potential spawning or rearing areas, use of the creek by various resident and anadromous salmonids, and the significance of the stream to the overall fishery of the Lillooet River is not understood.

5.2 Study Recommendations

Recommendations are based upon available data and, as such, would be refined/expanded as more data become available. It is recommended that vegetation mapping and wildlife habitat assessment be conducted for the Primary Study Area and, as necessary, the Secondary Study Area, prior to the initiation of exploratory well drilling. Further studies could then be formulated, based upon the resource information obtained from exploration and testing and the manner in which this information could affect B.C. Hydro's decisions regarding conduct of the project.

It is recommended that a fishery habitat survey of Meager Creek and its tributaries within the Primary Study Area be conducted prior to the initiation of exploratory well drilling activities. Further investigations could be formulated after the results of well testing were known.

These studies would provide data which B.C. Hydro could utilize in the early stages of project planning in order to mitigate potential impacts to the existing biological environment. It is recommended that certain data be obtained prior to exploratory drilling in order to enable B.C. Hydro to consider environmental factors in selecting the initial drill site. In a larger sense, these data are necessary in order to determine the species, extent and habits of the fishes and wildlife which utilize the Study Area(s). Some species known to be present are considered unique, sensitive or important (e.g., moose, grizzly bear), and reduction in their numbers would be contrary to the planning and goals of the B.C. Fish and Wildlife Branch.

6.0 METEOROLOGY

6.1 Data Deficiencies

Because of the rough terrain and distance of the proposed project from existing weather stations, the available meteorological data are not adequate for complete air resources evaluation. The meteorological data which are available for the Pemberton area, therefore, are not applicable to the geothermal resource area. There are virtually no data available which would aid in determining the meteorological characteristics of the Primary Study Area.

6.2 Study Recommendations

It is recommended that a meteorological data acquisition program be conducted within the Primary Study Area in order to adequately characterize the local meteorology and ascertain the dispersive capability of the atmosphere. This would enable an accurate assessment of potential air quality impacts of project-related operations to be made. In addition, it is recommended that specific on-site meteorological data be acquired to support future efforts on the proposed project, which may include the planning of well drilling and flow testing activities, design and placement of production facilities, and operational monitoring programs. In addition, these data are requisite for climatic and microclimatic analyses particularly appropriate to Meager Creek, and for analyses related to effects of pollutant emissions on ambient air quality, soils, vegetation and visibility.

The steep terrain of the valley in which most of the Primary Study Area is located would essentially constrict the wind flow to blow either up or down the valley for most of the time, depending upon synoptic weather patterns or local effects due to differential heating or cooling. Under light wind conditions, wind flows across the valley could also occur, and since the valley floor is sheltered by relatively steep mountain slopes, the presence of calm conditions is very probable.

Due to these climatic conditions, it is recommended that the meteorological program include: 1) the installation of an instrumented meteorological tower to obtain data on winds aloft and at the surface; and 2) information on the frequency and severity of low-level temperature inversions and humidity values. Other wind stations should be installed at other locations along the valley floor and possibly on the neighbouring slopes. Field studies using pilot balloons and atmospheric tracer materials should also be undertaken to obtain a better insight into the wind profile and dispersive characteristics of the atmosphere in the valley.

Siting of the instrumentation for such a study would be critical and would be based on accessibility and how representative of the local meteorology a given site might be. There should be particular concern for the varied topography within the Primary Study Area and the meteorological consequences of locating instrumentation appropriately, with representative data being gathered, as necessary, from ridges, valleys, and flat terrain.

7.0 AIR QUALITY

7.1 Data Deficiencies

Data regarding the ambient air quality for Meager Creek and the Lillooet River Valley are virtually non-existent, as there have been no systematic data collection programs conducted in the area to date. Therefore, air quality data which are necessary in order to correctly assess impacts have not yet been collected. The deficiencies are of particular importance in the consideration of hydrogen sulphide, sulphur, and particulate matter.

7.2 Study Recommendations

It is recommended that an air monitoring program be conducted in order to characterize existing air quality, especially the current levels of hydrogen sulphide, sulphur, particulate matter, and vehicular emissions such as CO and NOx. It is suggested that an air quality monitoring program be established for the Primary Study Area to determine both variations in air quality which are due to seasonal changes and those which may occur concurrently with logging activities and may overlap seasonal time frames.

8.0 AMBIENT NOISE

8.1 Data Deficiencies

There are no noise data available for either the Primary or Secondary Study Areas. It is therefore not possible to: 1) quantify the existing un-intruded ambient noise level; 2) quantify the existing level of logging noises, or 3) determine the impact which project-generated noise would have on either the existing intruded or un-intruded environment. Due to lack of data, noise transmissivity cannot be determined, especially within the Primary Study Area, which would receive the greatest noise impact.

8.2 Study Recommendations

It is recommended that noise studies be undertaken to provide data for the purposes discussed above; and that sound level surveys be conducted within the Primary Study Area during the selected baseline period.

These surveys could be performed with a hand-held precision sound-level meter with an A-scale (human aural response) filtering and a slow response setting. Surveys would be conducted coincident with other baseline work, and would be taken quarterly to determine: 1) seasonal variations; 2) day-night variations, and 3) variations within these parameters which may be caused by current logging activities.

One one-hour reading would be taken at each of several selected sites during both day and night to cover the various source strengths and propagation conditions. Results of the noise monitoring program would be reported concurrently with the air quality and meteorological data. The measured levels at the selected sites would be presented in terms of the one-hour average sound levels in decibels (dBA) and the day-night average sound level (L_{dn}).

9.0 LAND USE

9.1 Data Deficiencies

Data on current and proposed future land use within the Primary and Secondary Areas is available for compilation and analysis. The British Columbia Forest Service has abundant data on logging activities; land ownership maps are available, and various land use documents are available from the Resource Analysis Branch, Ministry of the Environment.

9.2 Study Recommendations

It is recommended that a complete data collection program, including a search of land and mineral titles, be undertaken in order to assure that no independent generation of data is necessary for future studies.

10.0 SOCIOECONOMICS

10.1 Data Deficiencies

Generally, sufficient data exist to characterize both the existing and probable future socioeconomic environment of the area likely to be affected by the proposed project. These data have been gathered by various federal and provincial agencies, and local interests. Although much of the information is easily obtained, some is not immediately available and may take several weeks to acquire. In addition, some of the data are relatively costly to procure.

10.2 Study Recommendations

Due to the factors cited above, it is recommended that a thorough socioeconomic data search be conducted several months in advance of the anticipated need for such information. This would allow ample time for the relevant information to be obtained and, if necessary, for the preparation of original data relevant to the particular needs of the project.

11.0 RECREATION

11.1 Data Deficiencies

There is adequate information available regarding the recreation and aesthetic potential/use of the Primary and Secondary Study Areas(as well as the entire region) to enable an accurate assessment to be made of the impacts of the proposed project on the recreation/aesthetic resource. Much of this information is available from Ministry of the Environment and the B. C. Parks Branch.

11.2 Study Recommendations

It is recommended that available data be compiled to assure that there is no need to conduct a separate investigation prior to the preparation of further studies. Although some user recreation information is currently available, it may be advisable to undertake a user survey which could be utilized in a benefit/cost analysis. This user survey would also add to the data base for assessing recreation impacts of the proposed project.

12.0 HERITAGE CONSIDERATIONS

12.1 Data Deficiencies

Although there is one historic site noted on the Vancouver Forest District Folio Maps for Meager Creek, it has been stated (Cassidy 1978) that no survey has been conducted of the Meager Creek area.

12.2 Study Recommendations

It is recommended that a professional archaeologist perform a detailed archaeologic and historic site survey to assess the heritage significance of the land comprising the Primary Study Area and appropriate portions of the Secondary Study Area. it is recommended that this study be conducted prior to exploratory drilling activities in order to satisfy the requirements of: 1) the Heritage Conservation Act (August 18, 1977), Part II, Section 7; and 2) the Heritage Conservation Branch, Archaeology Division statement that, "Although the expected site density around Meager Creek is very low it is still essential to conduct a survey prior to development" (Cassidy 1978).

Chapter VI

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CHAPTER VI

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Chapter VII

Literature Reviewed

CHAPTER VII

LITERATURE REVIEWED

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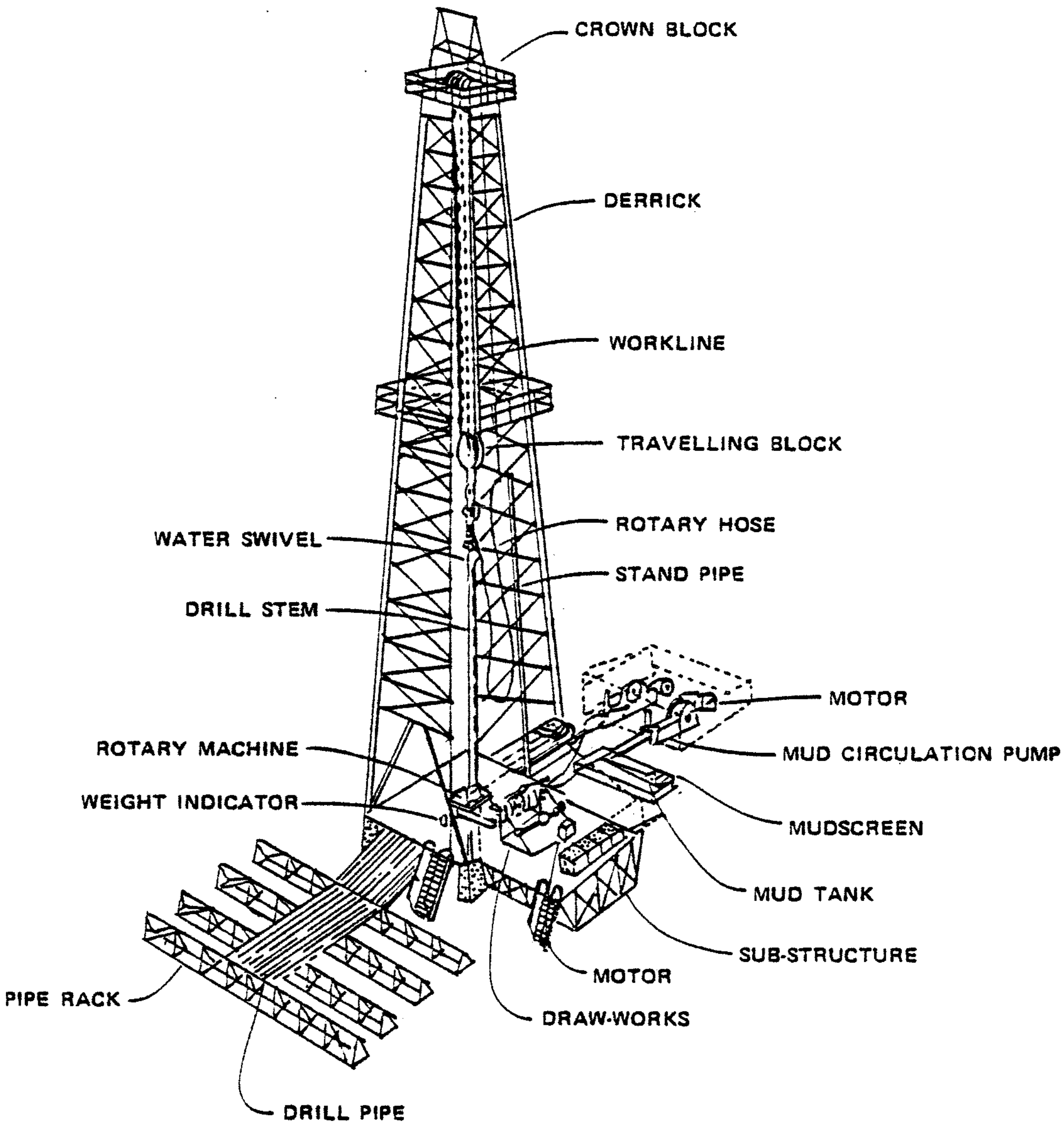
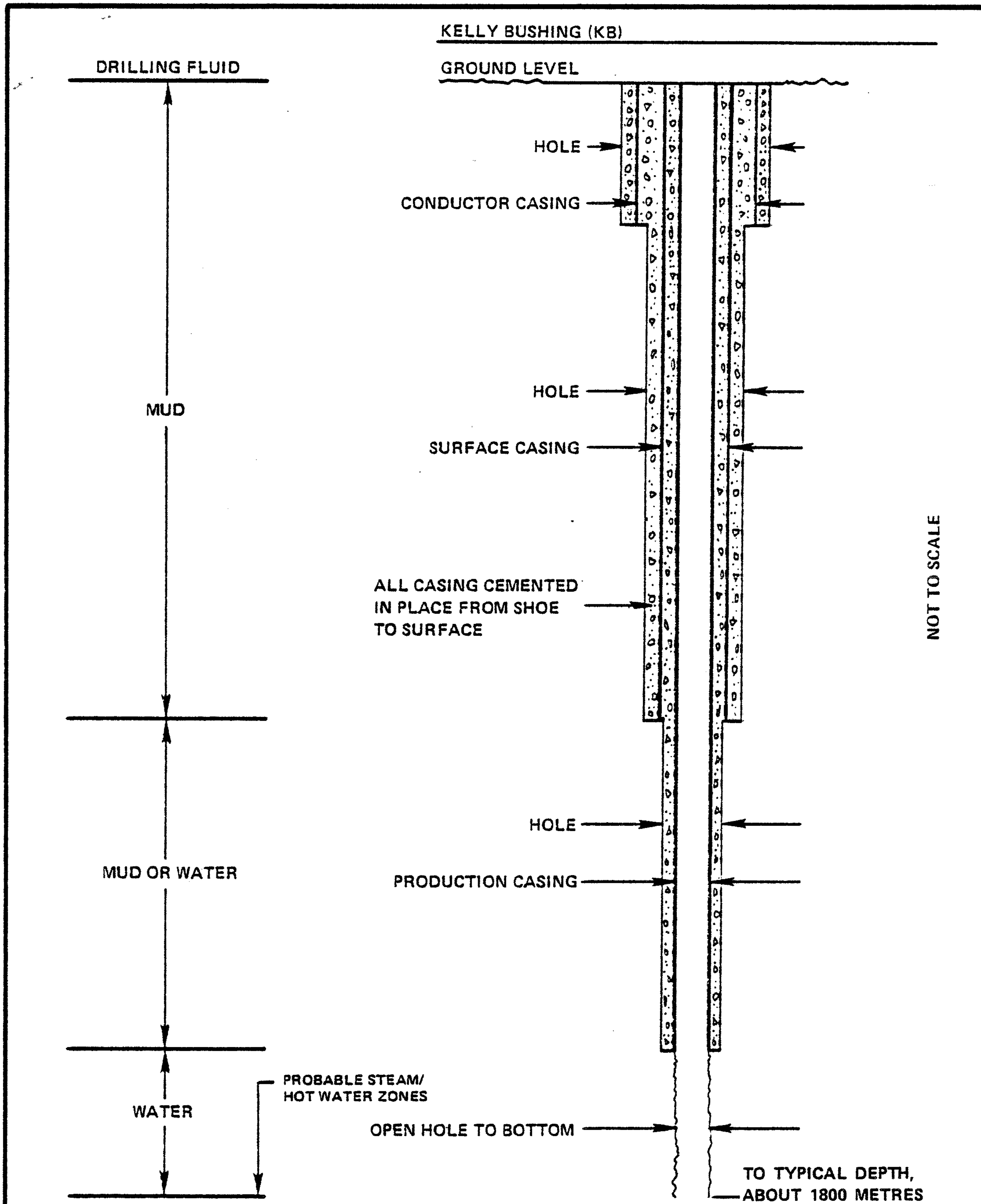
Appendices

Appendix A

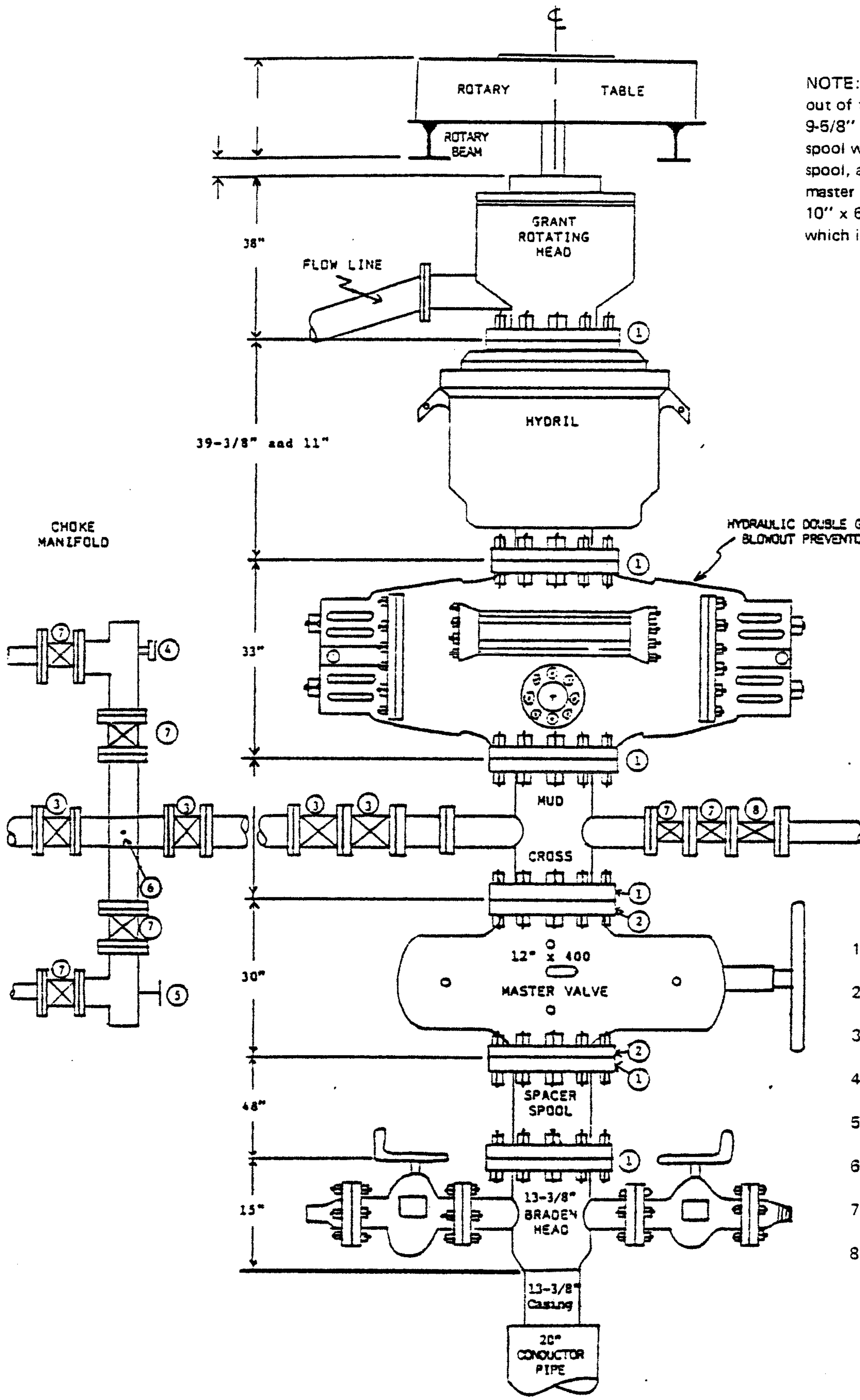


Typical Geothermal Well Drilling Rig



Typical Well and Casing Diagram

Source: Thermal Power Company



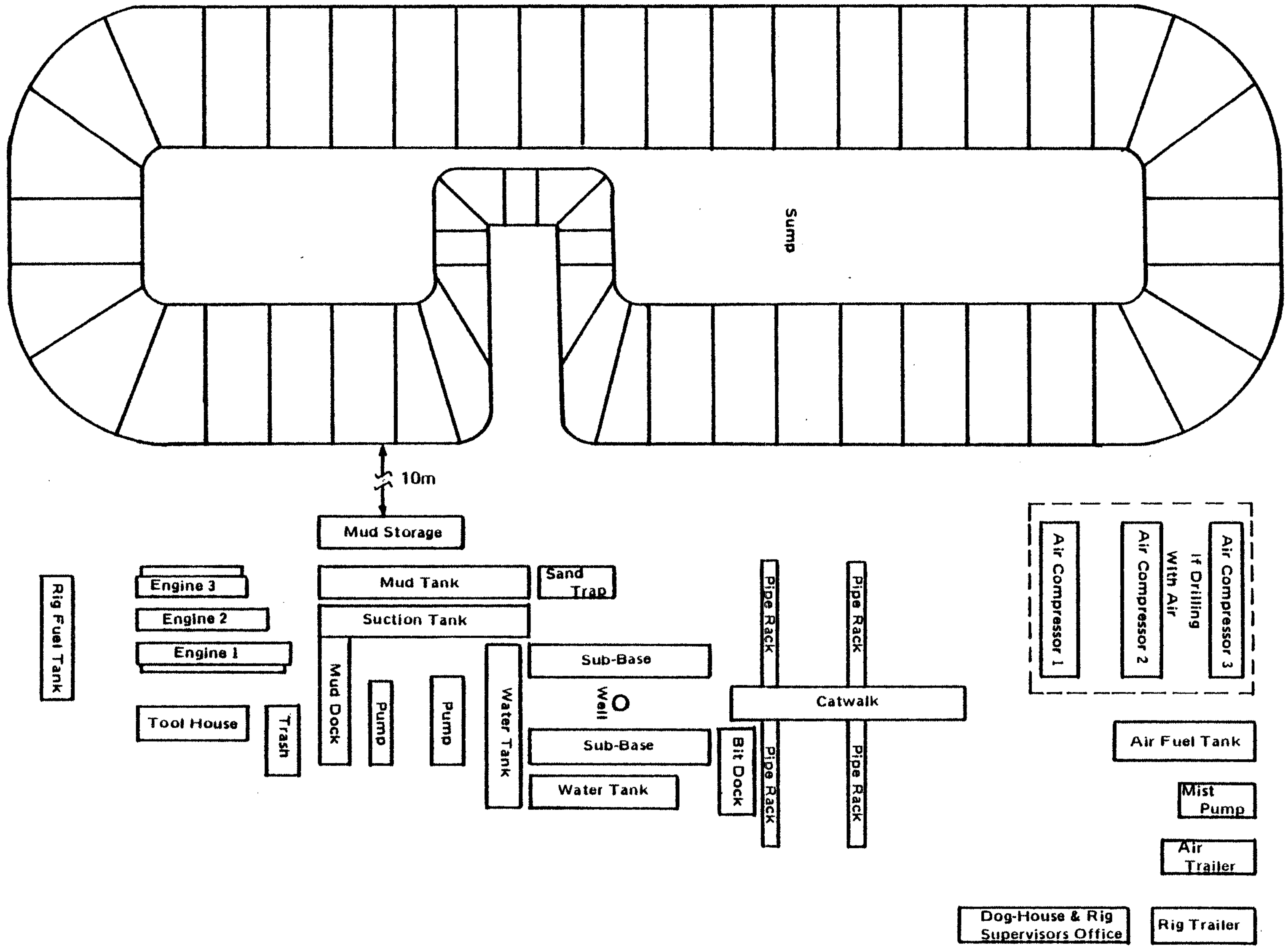
NOTE: This is the stack for drilling out of the 13-3/8" casing. When 9-5/8" casing is landed, the spacer spool will be replaced by an expansion spool, and the 12" x 400 series master valve will be replaced by a 10" x 600 series master valve, which is 31" flange to flange.

LEGEND

1 12" x 900 series
2 12" x 400 series
3 4" x 900 series - 3000 lb.
4 Positive choke
5 Adjustable choke
6 Gauge
7 2" x 900 series
8 2" check valve

Typical Well Drilling Stack

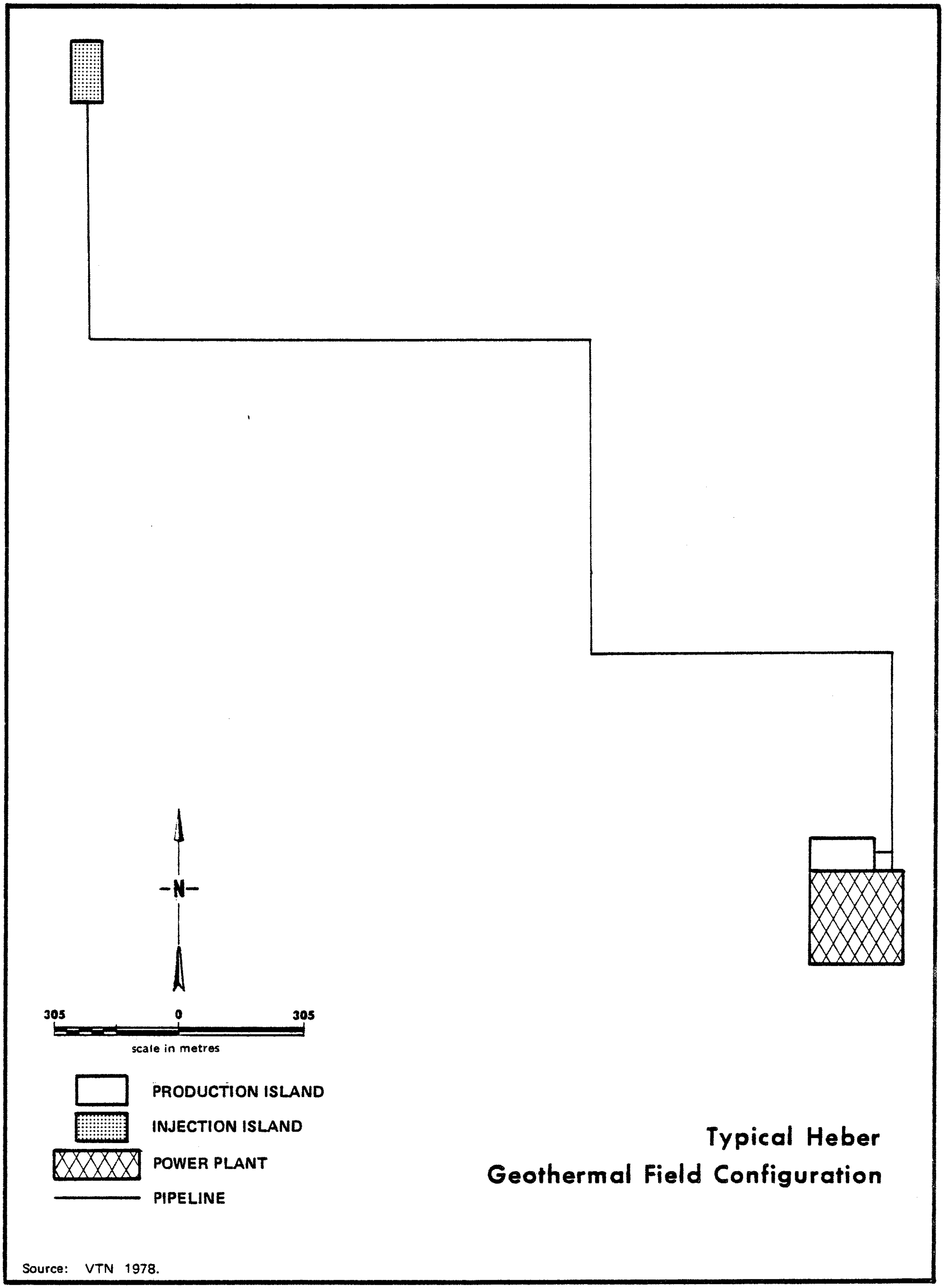
Source: Thermal Power Company



Typical Equipment Layout
Geothermal Exploration Well

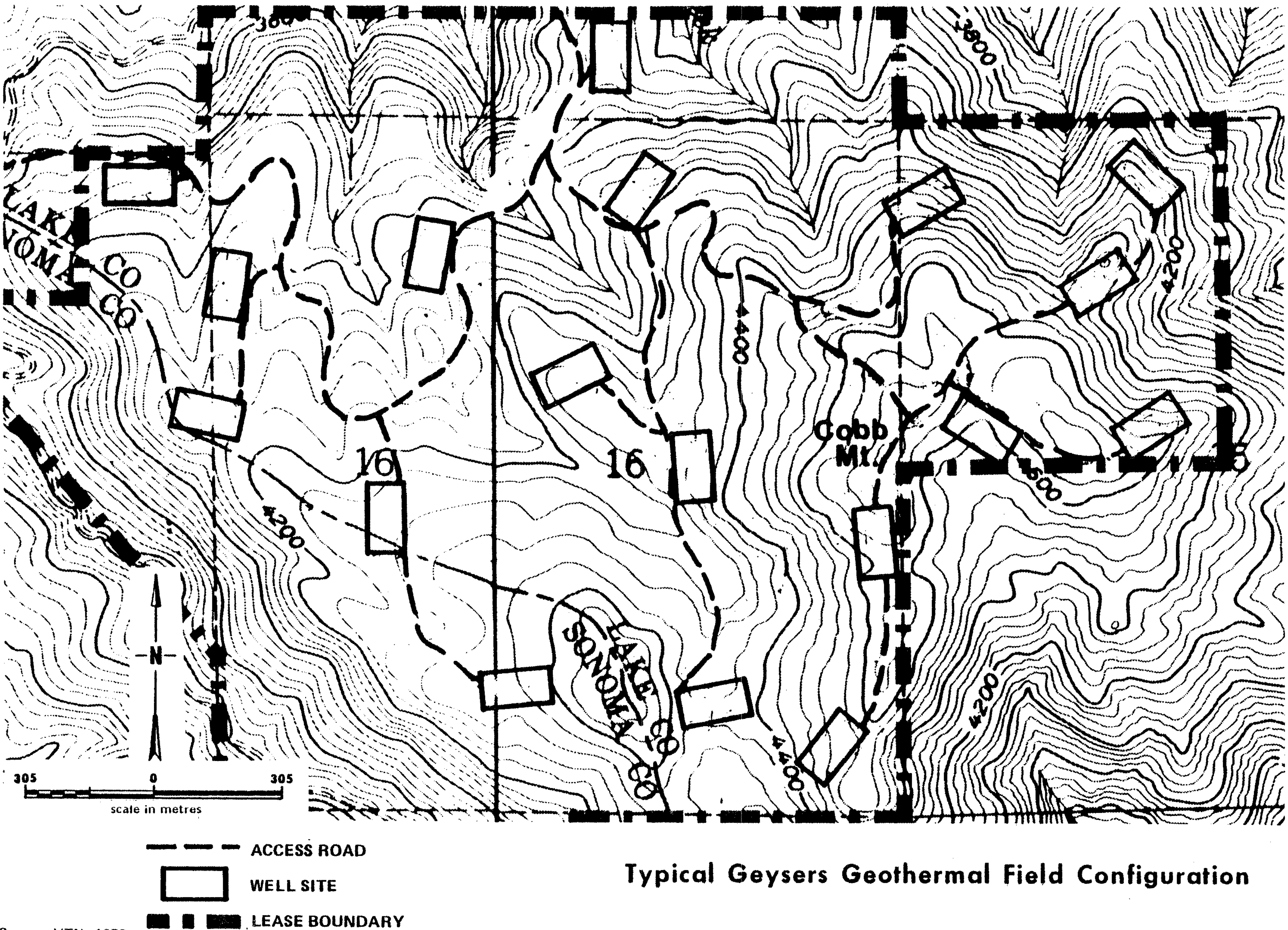
Source: Prepared by VTN 1977.

Appendix B



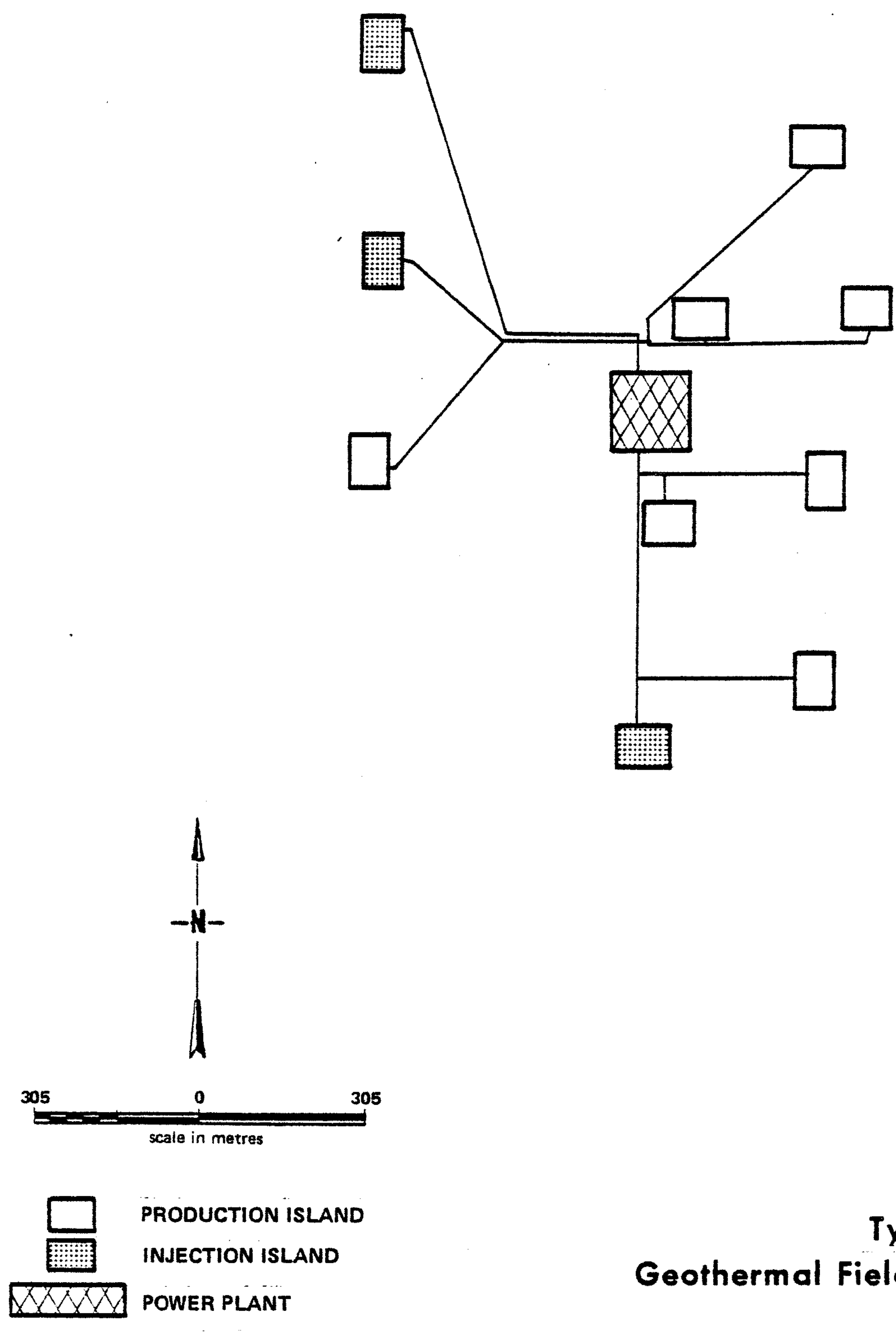
Typical Heber
Geothermal Field Configuration

Source: VTN 1978.



Typical Geysers Geothermal Field Configuration

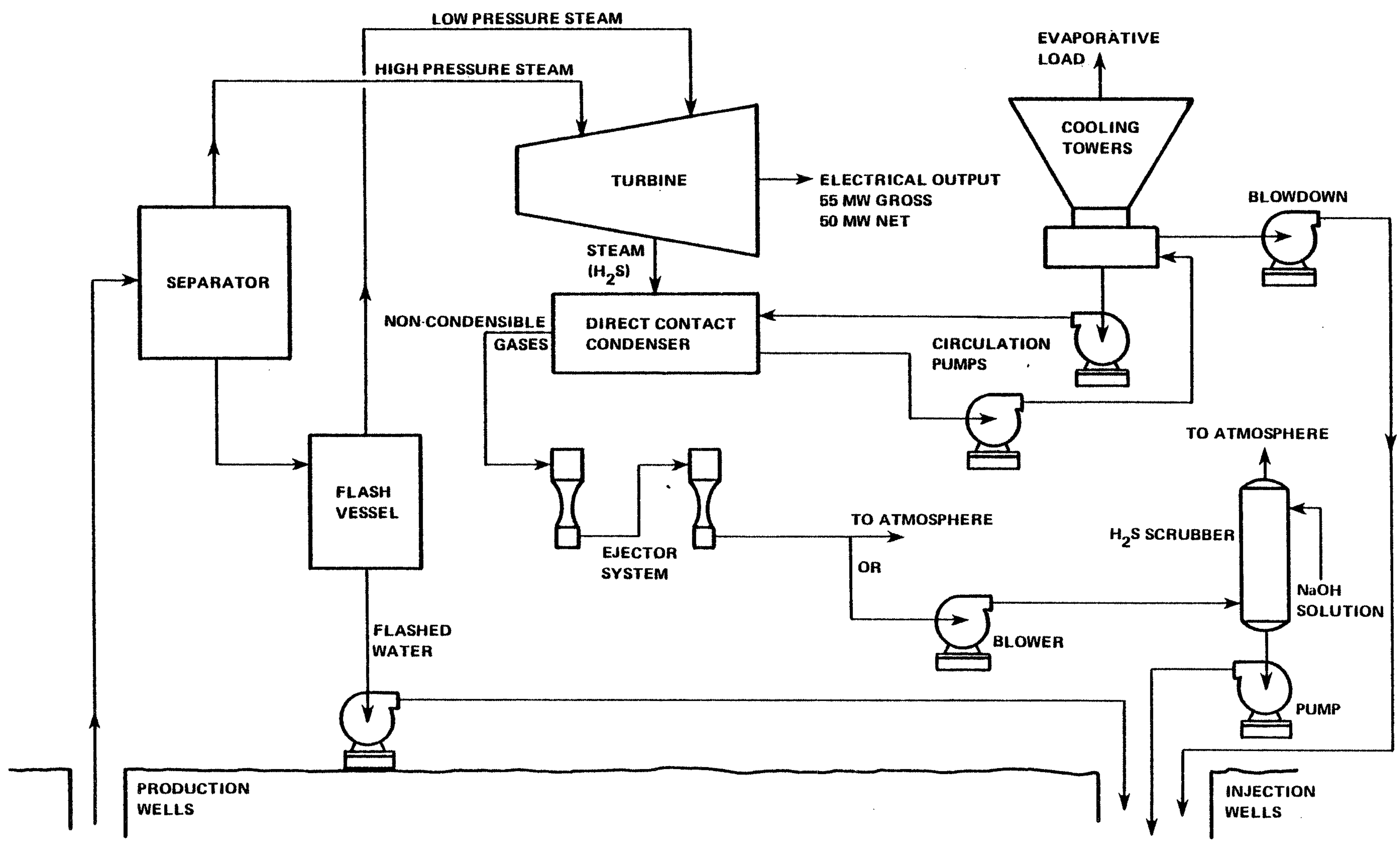
Source: VTN 1978



Typical Roosevelt Geothermal Field Configuration

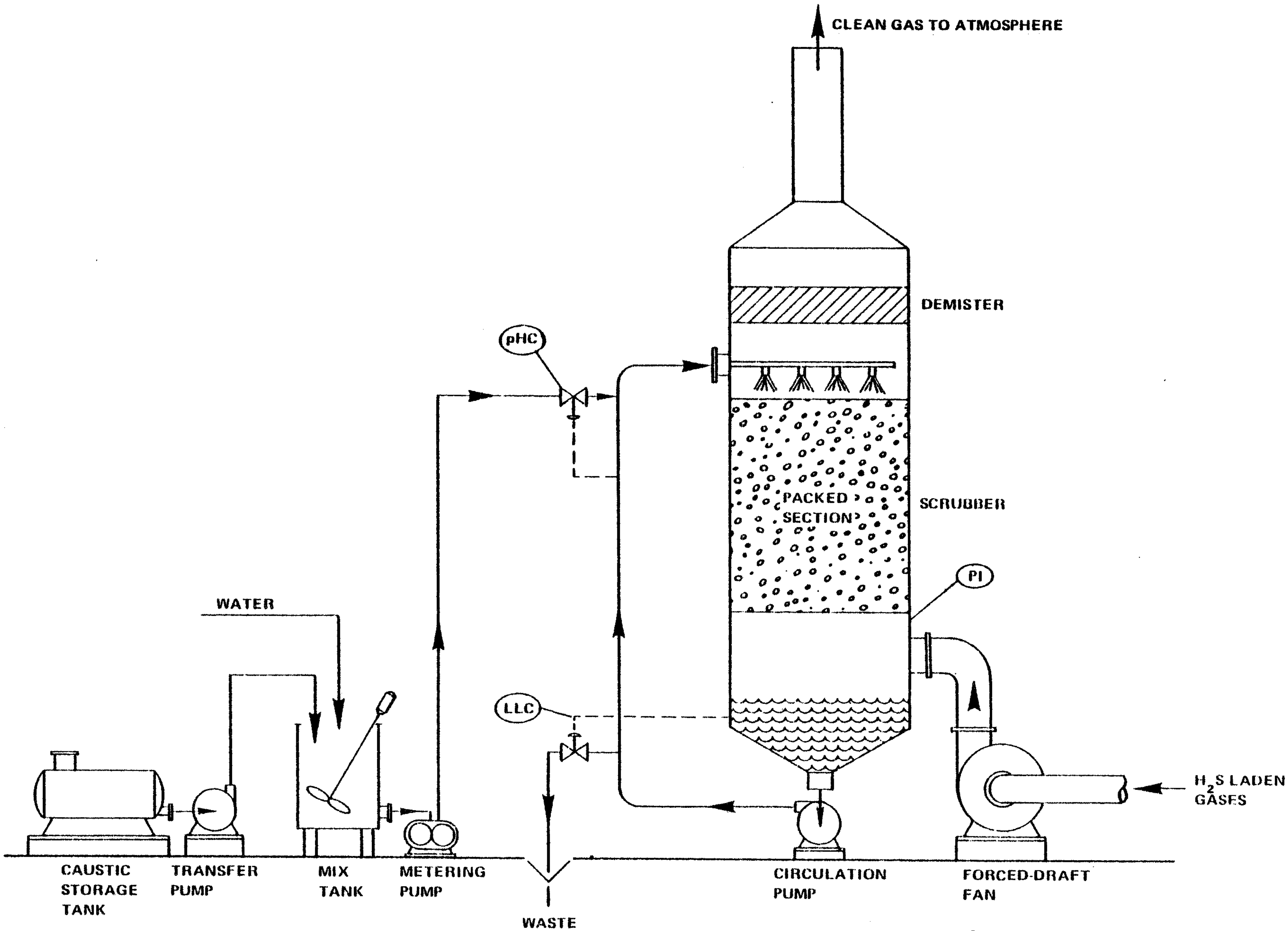
Source: VTN, 1978.

Appendix C



Typical Schematic Diagram
Double Flash Geothermal Power Plant

Source: VTN 1978.



Typical H_2S Scrubbing System

NOT TO SCALE

Source: VTN 1978.