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Working Program for Deep Borehole Investigations

- HDB-6,7,8 borehole-

August 2003

Horonobe Underground Research Center
Japan Nuclear Cycle Development Institute

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

1 INTRODUCTION

In the Horonobe Underground Research Laboratory project, a wide range of geoscientific research and development activities are planned to be performed in three phases, Surface-based Investigations (Phase I), Construction (Phase II) and Operations (Phase III), over a period of 20 years. Surface-based investigations have been conducted since 2000.

Main goals of the Horonobe project are:

- To establish comprehensive techniques for investigating the geological environment, and
- To develop a range of engineering techniques for deep underground applications.

The specific goals of the surface-based investigations are,

- To construct geological models of the geological environment based on the surface-based investigations and develop an understanding of the deep geological environment (undisturbed, initial conditions) before excavation of the shaft and experimental drifts
- To formulate detailed design and plans for the construction of the shaft and experimental drifts, and
- To plan scientific investigations during the construction phase.

Field investigations during the surface-based investigations phase are planned for completion by the end of 2005, with excavation of the main shaft, Phase 2 construction, planned to start in 2005. The diameter of the main shafts has provisionally been set at 6.5 meters and the proposed depth is 500 meters. Details of the geometry and depth of specific underground facilities, including the main shaft, the ventilation shaft and the drifts, will be defined using data on the geological environment obtained during the surface-based investigation phase.
As part of the surface-based investigations, geological, geophysical, hydrogeological, hydrochemical and rock mechanical investigations were carried out. Deep borehole investigations started in 2000 in order to characterize the sedimentary rocks.

Taking into account the status of the investigations as of April 2003 and the remaining time (*i.e.,* three years) for the surface-based investigations, an optimized program for deep borehole (HDB-6, 7, 8) investigations has been drawn-up. This program addresses the general issues and provides input to the subsequent investigation programs and design for the shaft and experimental drifts.

This document mainly describes the planned working program for the HDB-6,7,8 borehole investigations including associated laboratory programs during and after drilling. The working program is divided into the following investigation fields: borehole drilling, geology, geophysics, hydrogeology, hydrochemistry, rock mechanics and long-term monitoring. Post-HDB borehole investigations; a VSP (Vertical Seismic Profiling) survey are planned in the surface-based investigations phase.

2 AIMS OF THE HDB-6,7,8 BOREHOLE INVESTIGATIONS

Through consideration of the overall investigation program and the remaining key issues to be addressed in the surface-based investigations including needed information on and hypotheses of the geological environment, the overall goals of the HDB-6,7,8 borehole investigations were established as below:

- Characterization of the geological environment from the top to 600m depth in the sedimentary formations (Yuchi, Koetoi and Wakkanai Formations).
- Understanding the dstribution of Ohmagari Fault.
- Establishment of baseline conditions before excavation of the shaft and drifts.
- Provide deep boreholes for observation of hydrogeological responses during excavation of the shaft/drifts and experiments in the drifts during the construction and operation phases.

In particular, specific aims have been derived as follows:

- Identification and classification of potential water conducting features and detailed geological and hydrogeological characterization of water conducting features and rocks from the top to 600m depth in the sedimentary formations.
- Establishment of geological stratigraphy including consideration of biostratigraphy and tephrostratigraphy.
- Hydrochemical characterization of groundwater from the top to 600m depth in the sedimentary formations..
- Acquisition of rock mechanical data f for supplementing the existing geotechnical data set.
- Establishment of the basis for design of the long-term hydraulic monitoring system in order to observe the undisturbed hydraulic head distributions before excavation of the shafts and drifts.
- Observation of hydrogeological responses in peripheral boreholes during HDB-6,7,8 borehole investigations in order to assess hydraulic significance of water conducting features.
- Input to the development and assessment of techniques for predicting and modeling the geology, hydrogeology, hydrochemistry and geomechanical properties of the deep geological environment.
- Assessment of the applicability and effectiveness of a wide range of investigation techniques in addressing the key aspects of site characterization.

Details of the aims in each investigation field are discussed in Sections 5.1 to 5.7.

3 LOCATION AND LAYOUT OF THE HDB-6,7,8 BOREHOLES

The following restrictions and requirements were considered during the planning of the location and layout of boreholes (Figure 1).

Restrictions
- Budget for three vertical holes should be less than 700 M yen.
- Total drilling length is approximately 1500m.
- Obstruction to the facility construction work should be avoided.
- Borehole must be within the Horonobe-cho and cannot cross the boundary at any depth.

Requirements:
- Attempt to reduce the alternative for the distribution of the Ohmagari faults..
- The vertical depth must be over 500m to acquire information on the deep geological environment .
- It is easy to get a permission for the execution of the borehole investigations.
- Good access in winter is essential for drilling work.

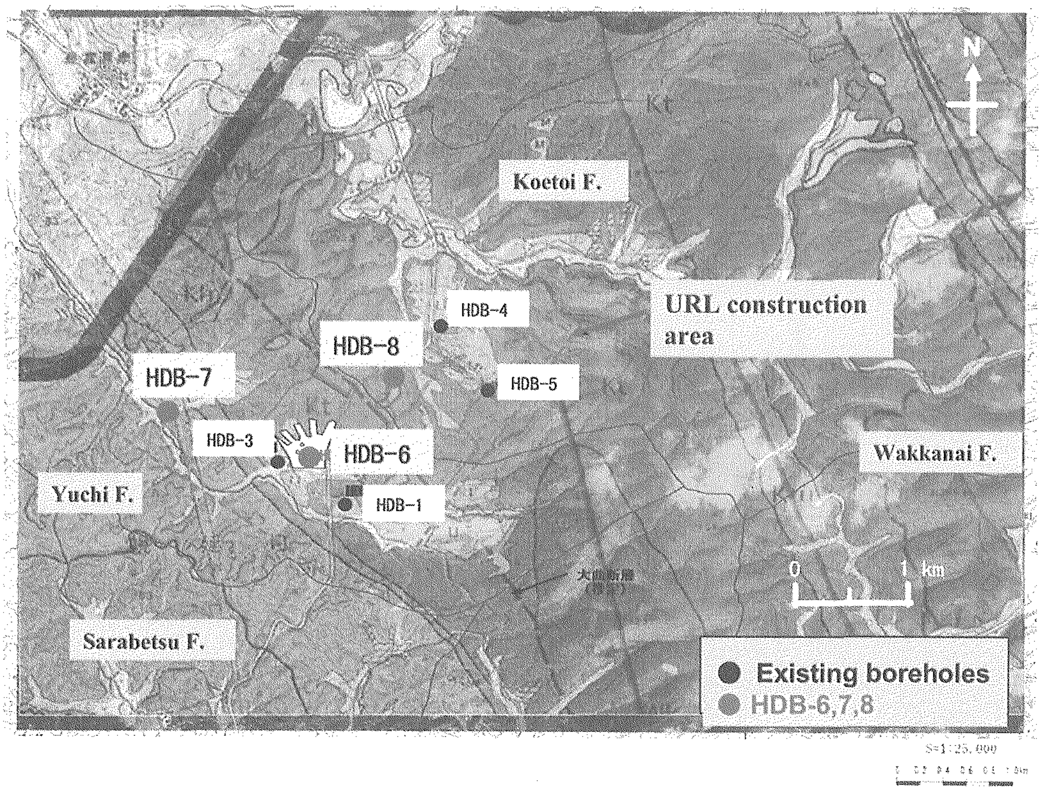


Figure1 Location of the HDB-6, 7, 8 boreholes

4 BACKGROUND INFORMATION AND PREDICTED CONDITIONS FOR PLANNING OF THE HDB-6,7,8 BOREHOLE INVESTIGATIONS

JNC has obtained some information on the geology, hydrogeology, hydrochemistry and rock mechanical properties in the Horonobe area through the execution of surface investigation (geological, geophysical, hydrogeological investigations) and borehole investigations. The information is useful in characterizing the geological environment. Based on compilation and interpretation of the data, summarized information related to the geological environment in the Horonobe area and predicted conditions in the HDB-6,7,8 boreholes are presented here:

Topography

- Topographical features around the construction site consist of mountains, hills, terrace surfaces, and alluvial low ground generally ranging in altitude from 0 to 200 meters.
- Many of drainage systems consist of rivers which flow west. The main rivers at or near the site are the Tesio and Ebekorobetsu Rivers, and together with their branches. The drainage divide of these rivers is present at southwestern side of the site. Main rivers at the site are the Penkeebekorobetsu and Shimizu Rivers.

Geology

Stratigraphy

- In the surrounding region of the construction site which occupies the eastern part of the Neogene basin (The Tesio Basin), the Miocene-Pliocene sediments (Soya coal-bearing Formation, Masuporo Formation, Wakkanai Formation, Koetoi Formation, Yuchi Formation and Sarabetsu Formation) overlie the Cretaceous-Paleogene basement (Figure 2). The Wakkanai Formation and the Koetoi formation which are diatomaceous siliceous sediments with thickness over 500 m at the construction site are distinguished based mainly on lithology : the former is composed mainly of hard shale containing opal-CT, while the latter mainly of diatomaceous mudstone not containing opal-CT.
- The detailed lithological characteristics of the Wakkanai Formation and the Koetoi Formation were obtained from petrography, X-ray diffraction analysis, geophygical characteristic tests, and organic geochemical measurement (Table 1, Figure 4, 5). These analyses confirmed that the Koetoi Formation composed of diatomaceous mudstone was indurated to the Wakkanai Formation composed of hard shale during progressive burial diagenesis of silica minerals.
- The biostratigraphical correlation among HDB-1, 2, 3, 4 and 5 boreholes was established with the microfossils (diatoms, dinoflagellates, pollen, radiolarian and foraminifera) (Figure 6). The biostratigraphic boundaries is harmony-like as the lithological formation boundary between the Wakkanai Formation and the Koetoi Formation. The diatom fossils that occurred in the Koetoi Formation in the HDB-1, 3 and 4 boreholes indicate the period of 5.5 to 3.5 Ma.

Geological structure

- Bordering on the Omagari Fault, the Wakkanai Formation and the Koetoi Formation are distributed over the east side, and the Koetoi Formation, the Yuchi Formation, and the Sarabetsu Formation are distributed over the west side. In the east side, the axes of folds which intersect the strike of the Omagari Fault, NNW-SSE trending, a little aslant and which have the N-S trending is presumed from the distribution and the inclination directions of the Wakkanai Formation and the Koetoi Formation. In the west side, the Koetoi Formation, the Yuchi Formation and the Sarabetsu Formation are distributed from the Omagari Fault in order to west, and their strikes are parallel to the strike of the Omagari Fault. Their inclinations show a 60-80 degree west inclination near the Omagari Fault and become loose as they separate from the Omagari Fault, and the Sarabetsu Formation shows a 30-50 degree west inclination.

Omagari Fault

- From the prior investigations (reconnaissance survey, reflection seismic surveys, HDB-1,2,3,4,5 borehole investigations), distribution, geometry, and activity of the Omagari Fault are not identified clearly yet (Figure 7,8).

Prediction of the geology in the HDB-6,7,8 boreholes

- Based on the compilation and interpretation of the previous studied, predicted geological columns in the HDB-6,7,8 boreholes are produced (Figure 9). The columns show the expected formation boundaries between the Wakkanai Formation and the Koetoi Formation, and between the Koetoi Formation and the Yuchi Formaiton.

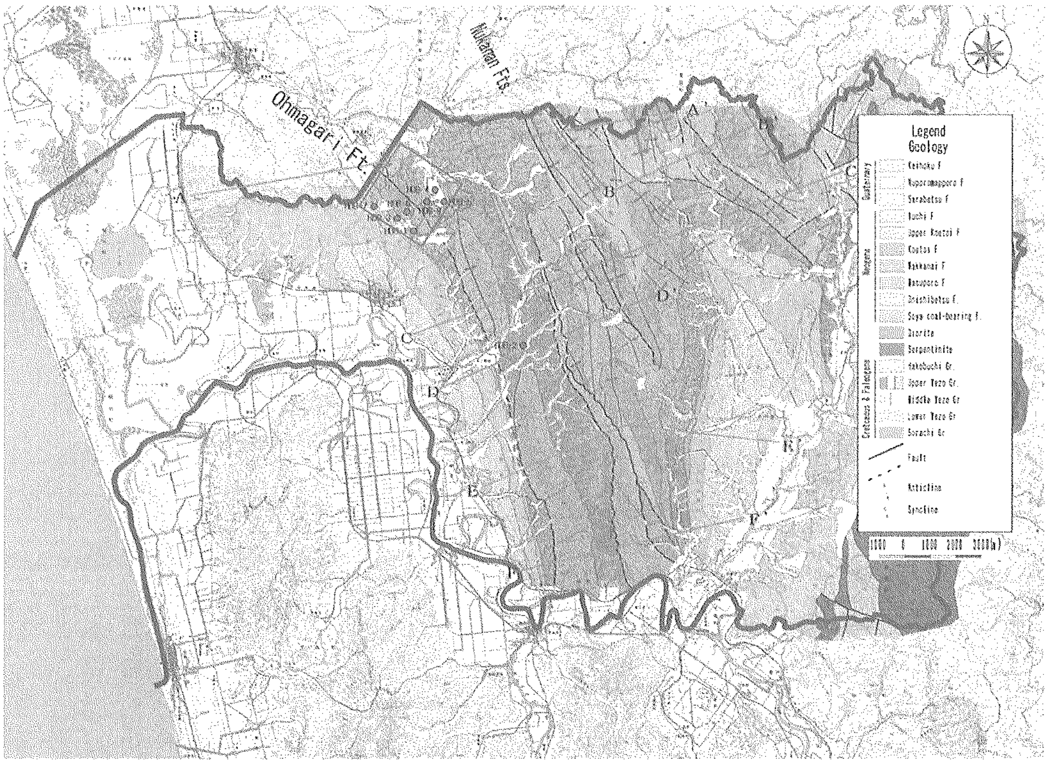


Figure 2 Geological map

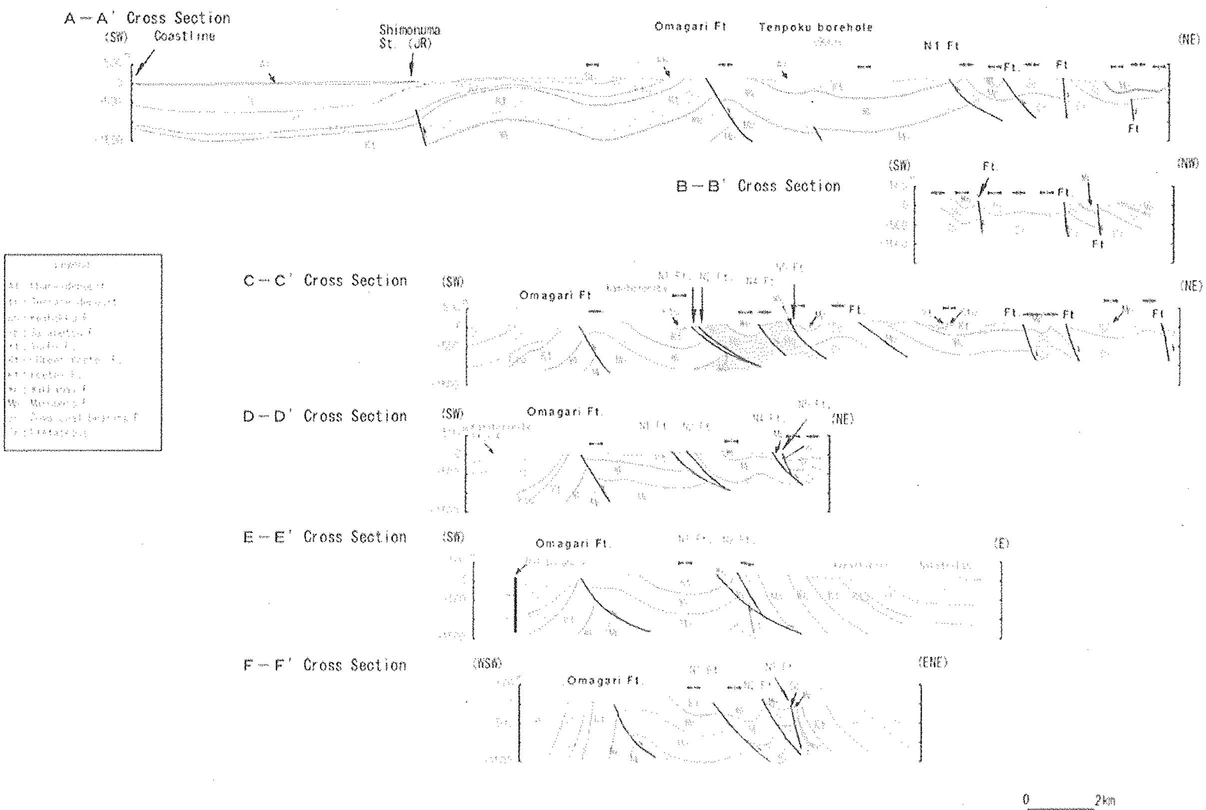


Figure 3 Cross sections

Table 1 Characteristics of Wakkanai Formation and Koetoi Formation

Formation name	Wakkanai Formation	Koetoi Formation
Rock name	Hard shale	Diatomaceous mudstone
Diatom fossil content	No – poor (fragment of diatom)	Abundant
Crystal structure of silica	Opal-CT Quartz index >1	Opal-A Quartz index <1
Porosity	35%	65%
Bulk density	18kN/m^3	15 kN/m ^{3}
Hardness (L)	500	350
Color (L*)	<30	>30
Organic geochemical composition	Streranes > = Sterenes Increased C28 Sterane (algae origin)	Streranes <Sterenes Low C28 Sterane

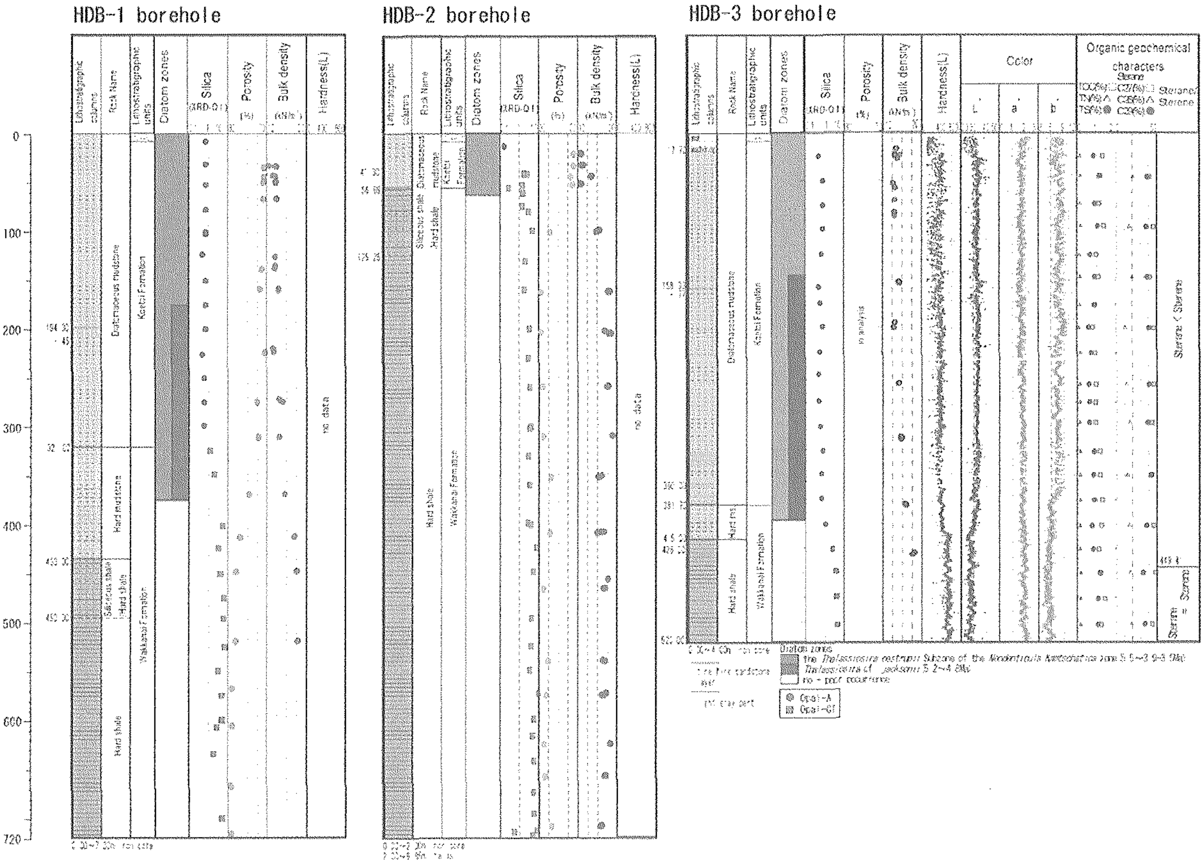


Figure 4 Lithological columns in the HDB- 1, 2, 3 boreholes

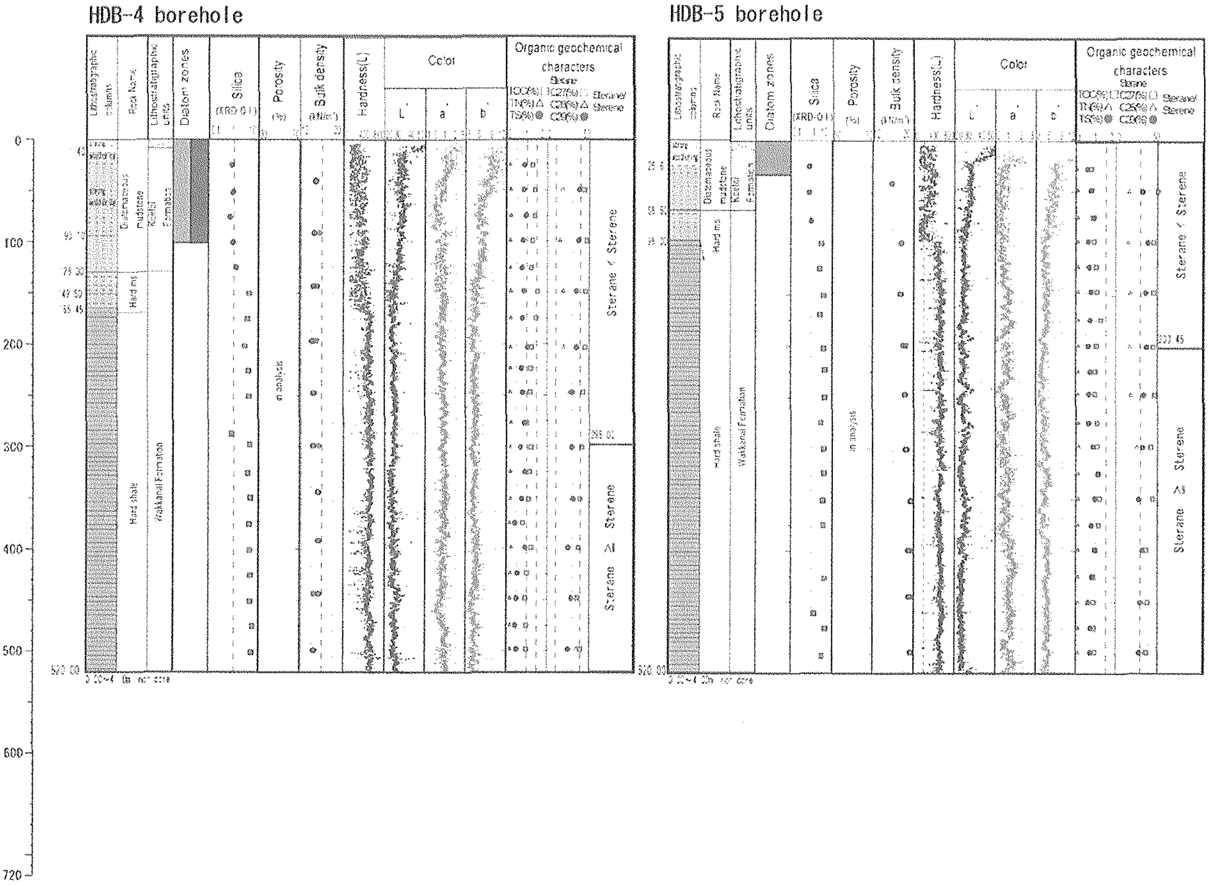


Figure 5 Lithological columns in the HDB-4, 5 boreholes

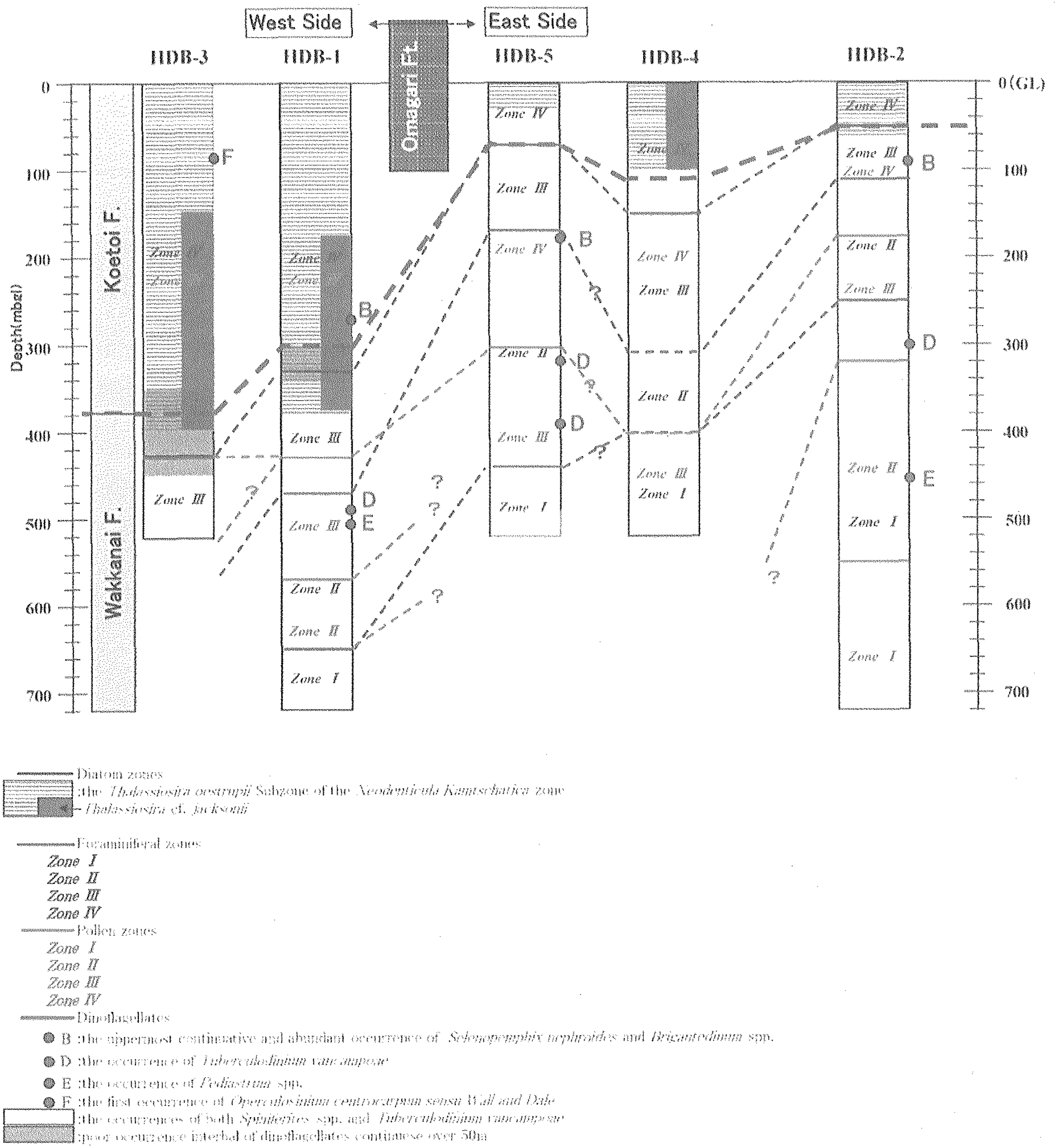


Figure 6 Biostratigraphical columns in the HDB-1, 2, 3, 4, 5 boreholes

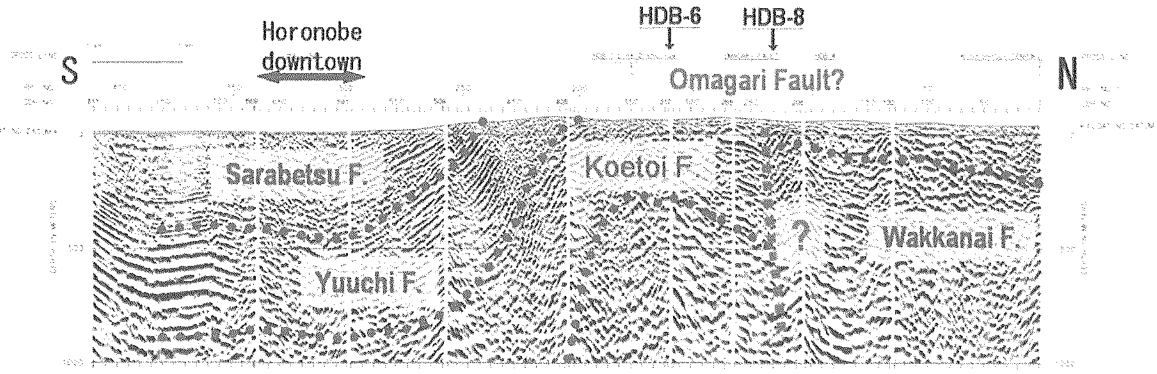


Figure 7 Reflection seismic data around the URL construction site

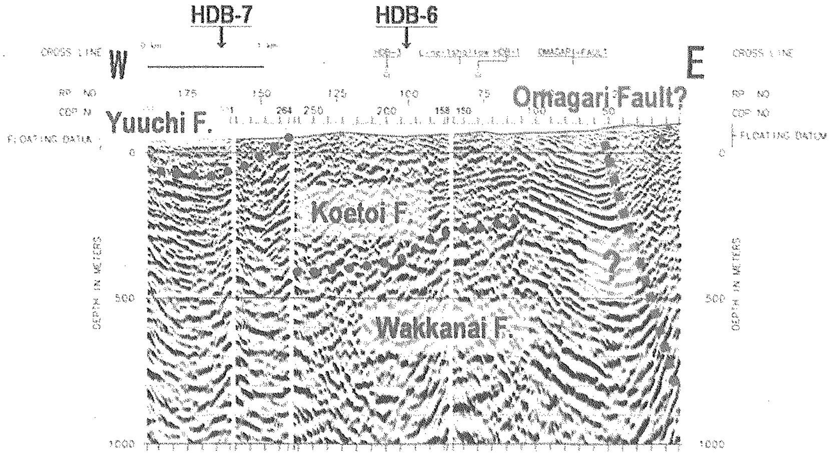


Figure 8 Reflection seismic data around the URL construction site

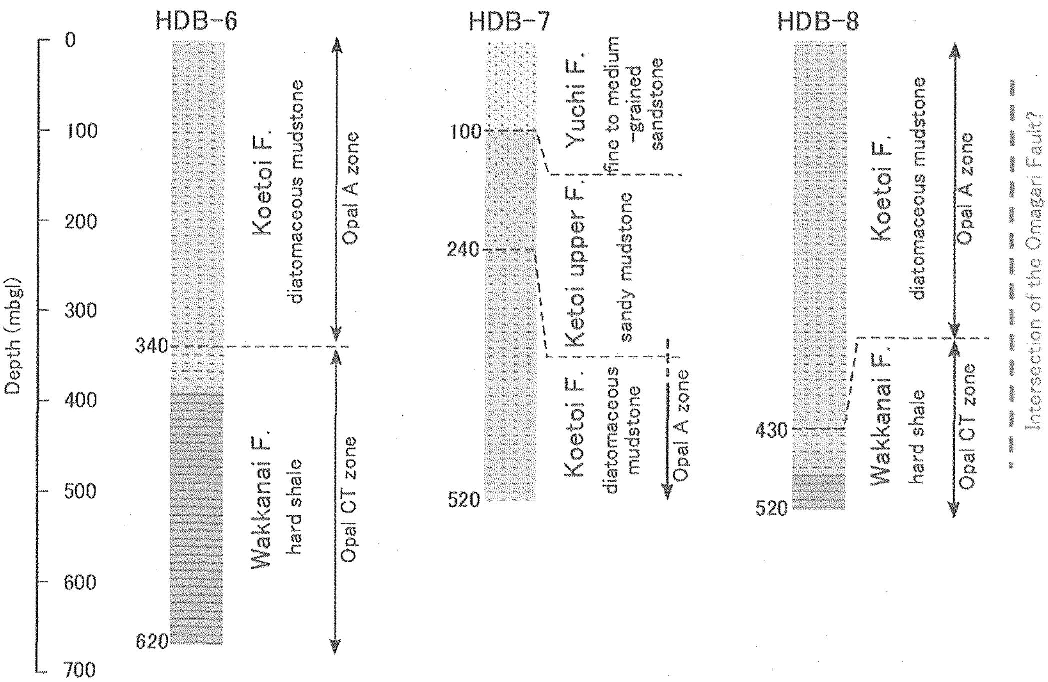


Figure 9 Predicted geological columns in the HDB-6, 7, 8 boreholes

Hydrogeology

Hydraulic properties in Hokushin Aria (HDB-1,3,4,5)

- The hydraulic conductivities in the west side of Omagari Fault (HDB-1and HDB-3) are distributed from 10^{-7} to 10^{-10}m/s order (Figure 10).
- The hydraulic conductivities in the east side of Omagari Fault (HDB-4 and HDB-5) are distributed from 10^{-6} to 10^{-8}m/s order (Figure 11).
- Hydraulic conductivity profiles for HDB-1,3,4,5 boreholes show decrease in conductivity with depth (Figure 10,11).
- The major drilling fluid loss (more than 30 litters/min) tend to occur in shallow depth at the east side of Omagari Fault (from 200 to 250 mbgl in HDB-4, 95 mbgl in HDB-5).
- Head profiles in HDB-1,3,4 show almost hydrostatistic conditions with heads around ground level and head profile in HDB-5 shows little artesian condition with a head around 10m above ground level (Figure 12).
- Dissolved gas exists in ground water in Hokushin aria.
- The volumetric gas-water ratio under the atmospheric pressure condition differs in the west side of Omagari Fault and the east side of Omagari Fault. The ratios in HDB-3 are almost same with depth. The other hand, the ratios in HDB-4 and 5 are different depend on depth (shallow section is small, deep section is large) (Figure 13).

Prediction of hydrogeology in the HDB-6,7,8

- Permeability in the HDB-6,7,8 are middle to low, however there are the major drilling fluid loss zone in HDB-8.
- Head profiles in the HDB-6 and HDB-7 are subartesian and/or little artesian condition.
- Head profile in the HDB-8 is little artesian condition.
- Dissolved gas is existence along HDB-6 and HDB-7.
- In shallow part of HDB-8, there is little dissolved gas and the dissolved gas increases with depth.

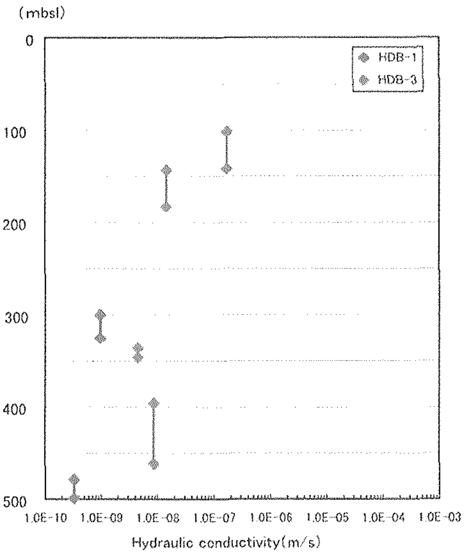


Figure 10 Hydraulic conductivity profiles in the west side of Omagari Fault (HDB-1,3)

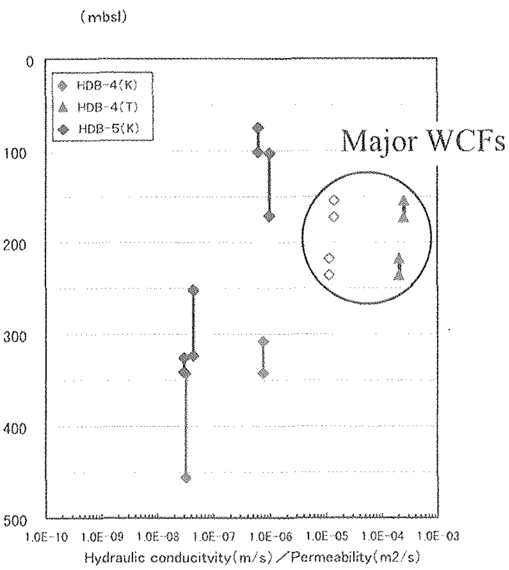
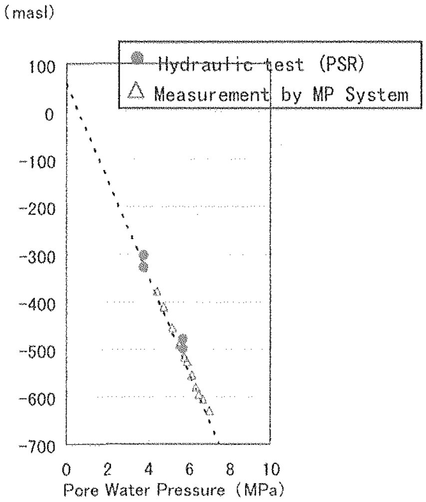
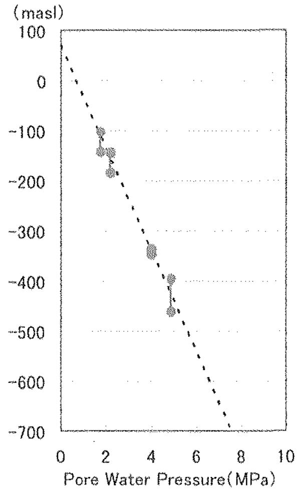


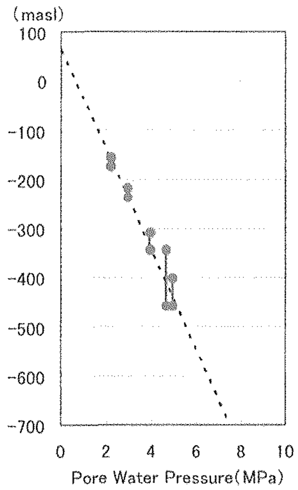
Figure 11 Hydraulic conductivity profiles in the east side of Omagari Fault (HDB-4,5)



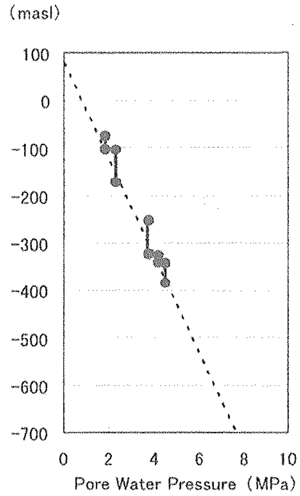
(a)HDB-1



(b)HDB-3



(c)HDB-4



(d)HDB-5

Figure 12 Hydraulic head profiles in HDB-1,3,4,5

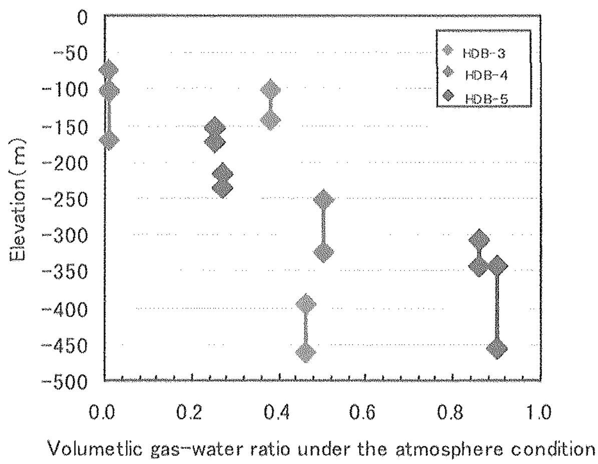


Figure 13 Volumetric gas-water ratio in HDB-3,4,5

Hydrochemistry

Groundwater type and redox condition

- Based on the analytical data of pumped groundwater in the Horonobe town, the fresh groundwaters are distributed in the shallower part of the sedimentary rocks (100-300 mbgl). The saline groundwaters are observed in the deeper part of the sedimentary rocks (300-500 mbgl) (Fig 14).
- The transition depth from the fresh groundwater to saline groundwater is different in HDB-3 borehole from HDB-4,5 boreholes.
- A possible reason is that the Ohmagari Fault could affect the distribution of groundwater chemistry.
- The porewater chemistry also shows the same tendency as the pumped groundwater (Fig 14).
- The reliable redox data has not been obtained during previous deep borehole investigations.

Origin and residence time of groundwater

- The fresh groundwater in the shallower part of the sedimentary rocks shows meteoric origin based on stable oxygen and hydrogen isotopes (Fig 15). The origin of the saline groundwater could not be clearly defined.

Prediction of hydrochemistry in the MIZ-1 borehole

- Based on the existing information, low-salinity groundwater (Na-Ca-HCO3 and Na-HCO3 type) in the upper parts of the sedimentary rocks and higher-salinity groundwater (Na-Cl type) in deep parts of the sedimentary rocks.

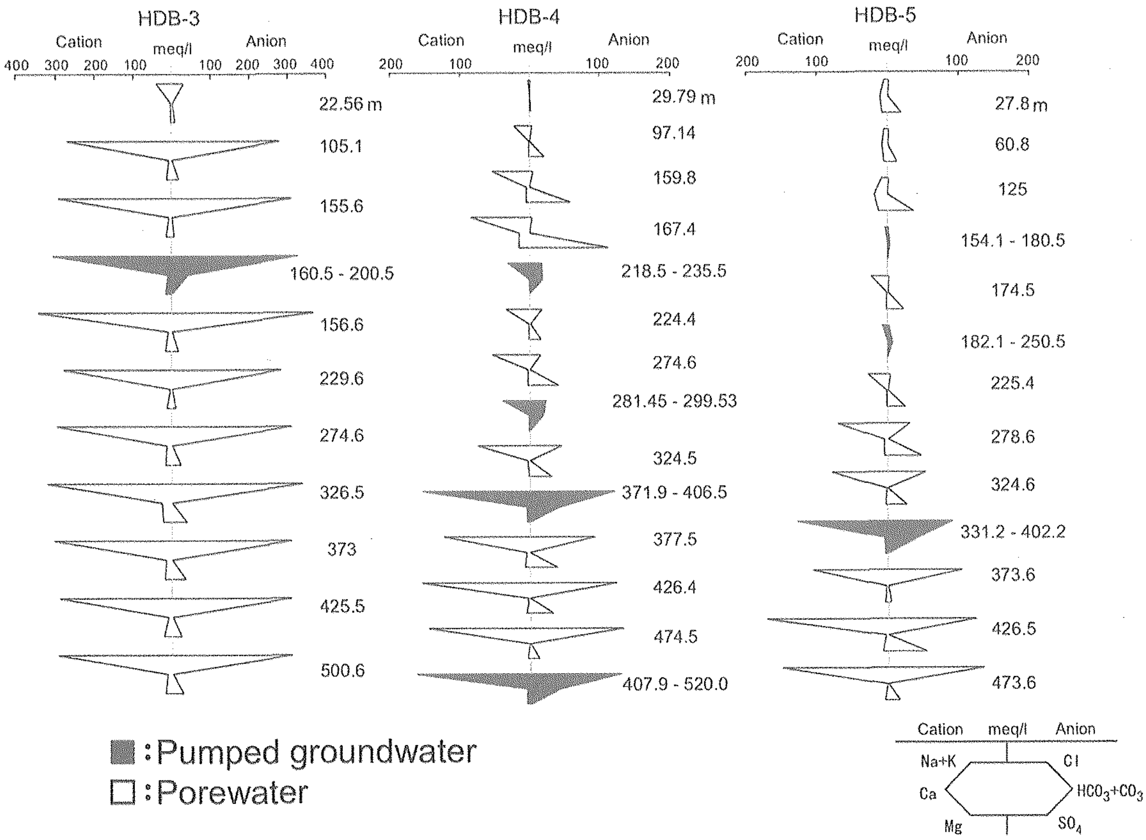


Figure 14 Groundwater chemistry of pumped groundwater and porewater

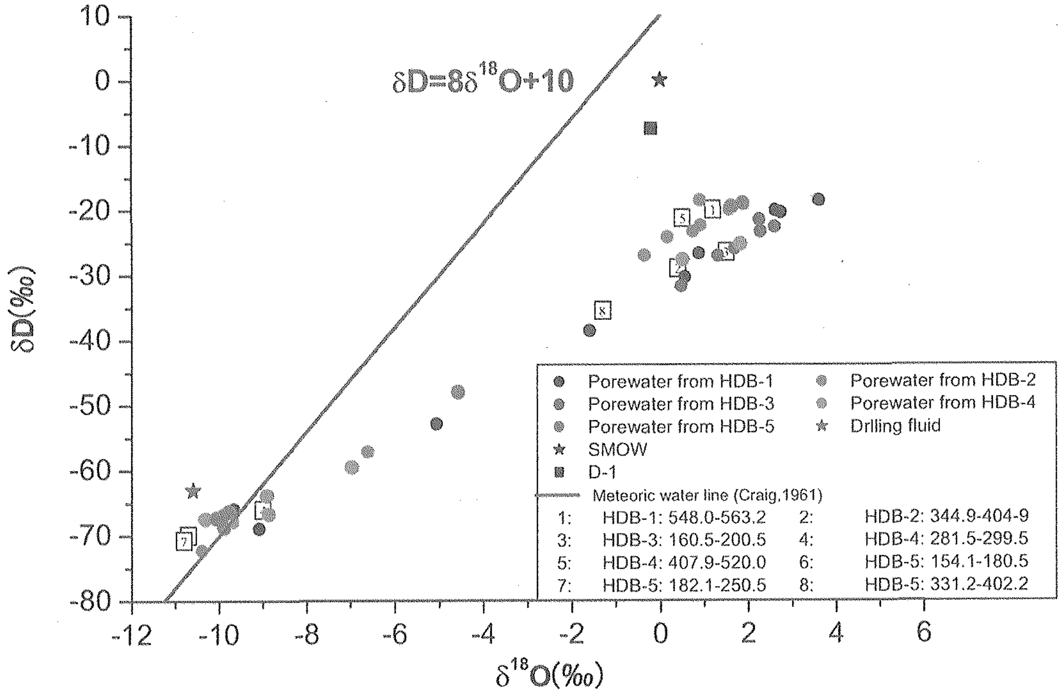


Figure 15 δ D- δ ^{18}O diagram of pumped groundwater and porewater

Rock mechanics

Properties of rock and Rock mass (Figure 16)

- The distribution of the mechanical and physical properties on cores are correspond with rock type (Koetoi formation/Diatomaseous mudstone, Wakkanai formation/hard shalel, transition layer)
- The rock properties in Koetoi Formation and transition layer are varied with depth. Especially, the properties change in transition layer is continuous at Koetoi and Wakkanai formations, but large and with precipitation.
- The rock in Koetoi Formation was classified with sedimentary soft rock ($\sigma c \leqq$ 10MPa). Average σc in Wakkanai Formation was around 20MPa, but there are many fractures relatively.

In-situ stress state (Figure 17)

- In Wast side , the directions of maximum horizontal principal stress were almost N-S and no change was observed with depth based on stress measurements and the directions of borehole break out. In East side, the directions changes were infered more complex.
- The magnitudes of minimum horizontal principal stresses may be close to overburden in both side of Ohmagari fault. The magnitudes of maximum horizontal principal stresses were no feature because of very little measurements and different measurement and analysis system between HDB-1 and others.

Based on above results, the distribution of the rock properties for prediction can be estimate if geological structure is known and it is independent with borehole location.

The position of underground laboratory is already desided in west side of Ohmagari fault. The first conceptual rock mechanical model constructed based on above results was shown in Figure 18. The data of rock properties and the conceptual model can provide for design of URL at present as well. However, the magnitude of the horizontal maximum principal stresses with depth still has large uncertanty in west side and east side of Ohmagari fault.

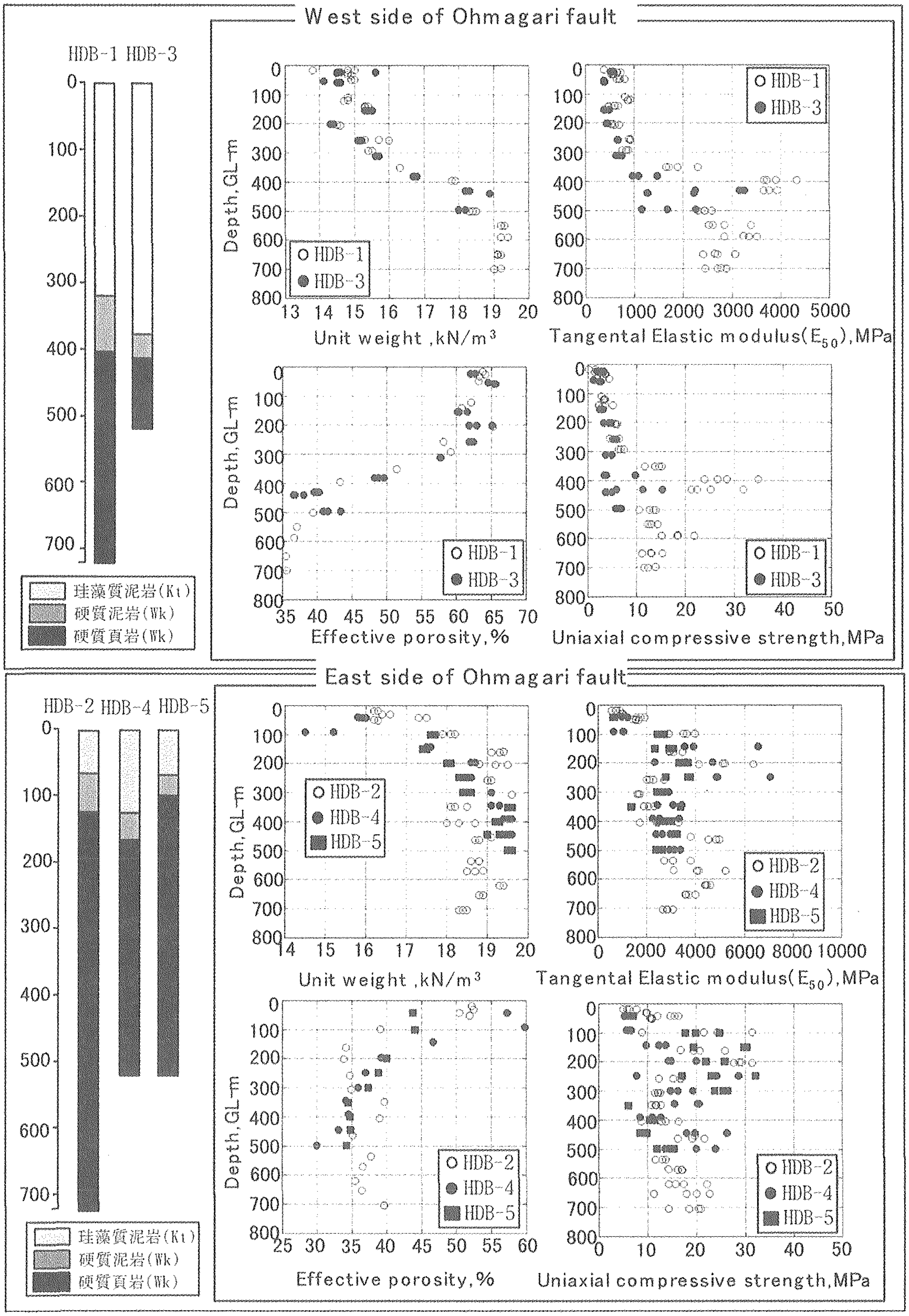
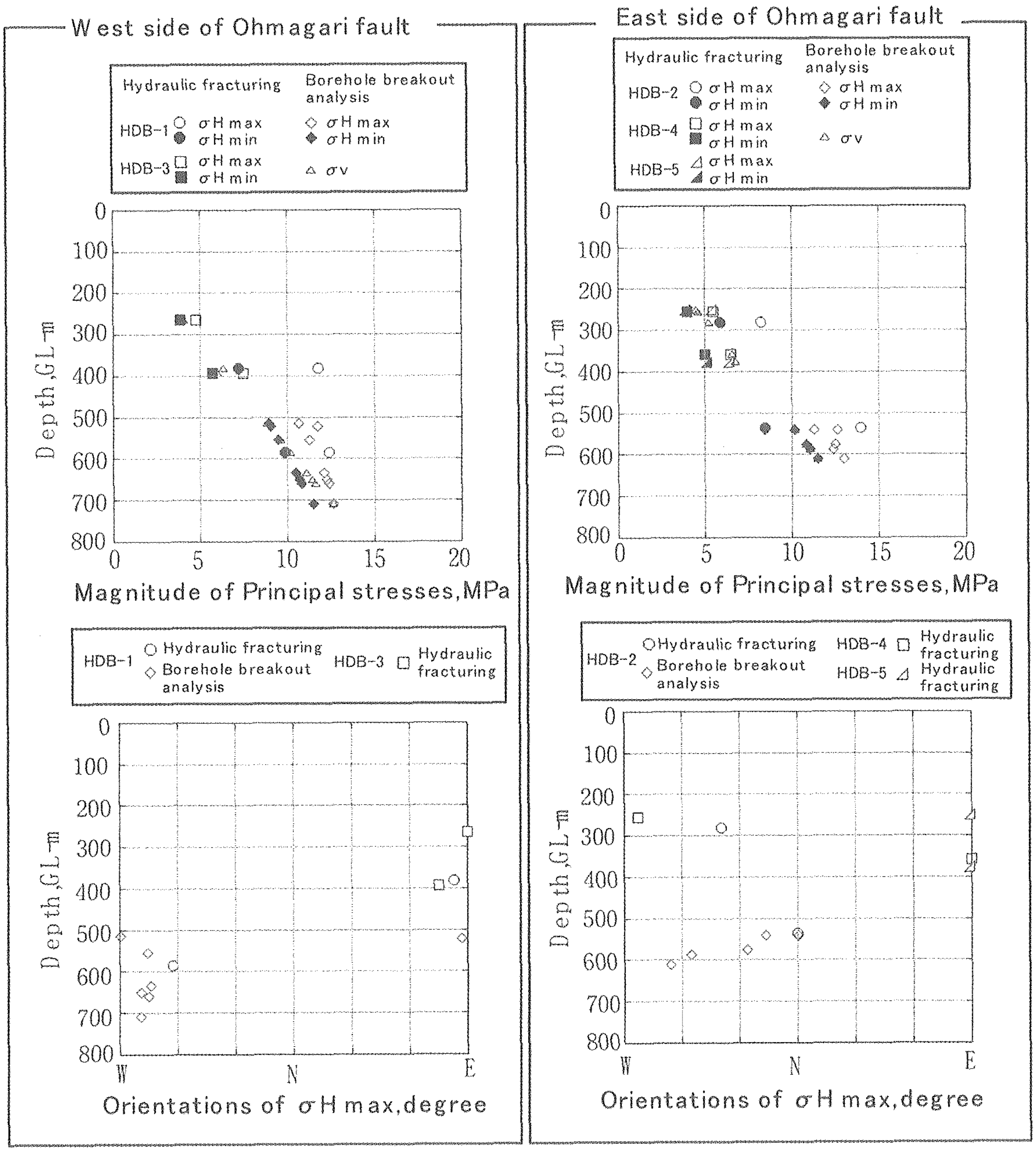


Figure 16 Distribution of the physical and mechanical properties of the rocks



*The results of HDB-3,4,5 are quick reports

Figure 17 Results on the stress measurement in HDB-1,2,3,4,5 boreholes

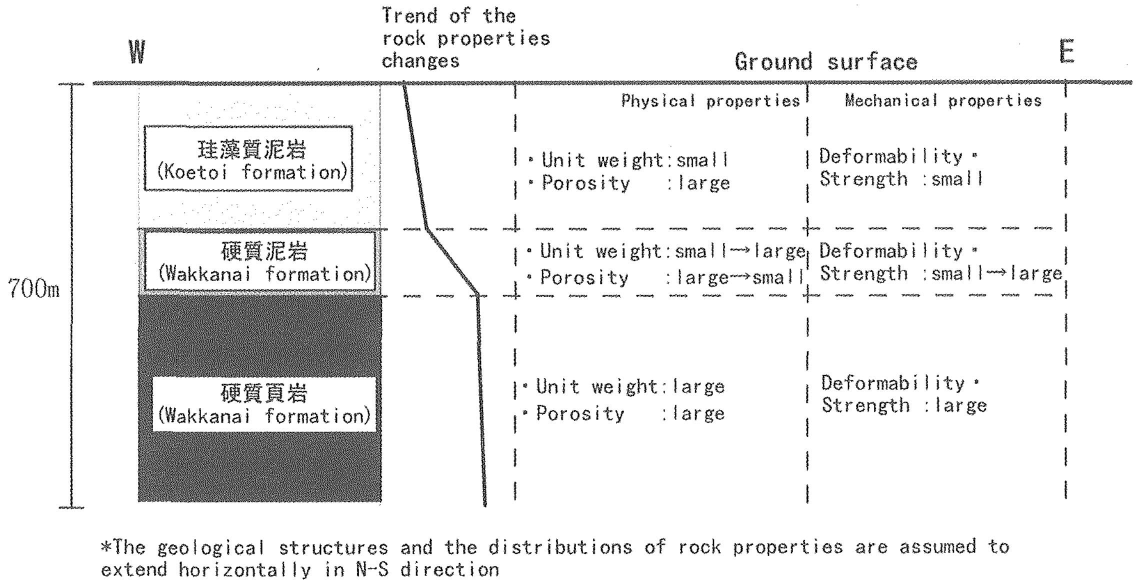


Figure 18 First conceptual model for the rock properties in west side of Ohmagari fault

5 DETAILS OF THE MIZ-1 BOREHOLE INVESTIGATIONS

In the HDB borehole investigation program, a wide range of investigations are planned (Figure 21,22,23). The following subsections (5.1 to 5.6) provide the details of the "base case" program in each investigation field. The procedure and schedule for the "base case" investigation campaign is described in Section 6.1.1, and optional cases are discussed in Section 6.1.2.

5.1 Borehole Drilling

The HDB borehole investigations comprise three deep borehole program in the Horonobe town. The main objective is to develop an understanding of the geological environment to approximately 500 mbgl, in the sedimentary formations. Full core recovery and stable borehole conditions are required for the on-site geological, hydrogeological, hydrochemical and rock mechanical investigations. A triple barrel-core recovery technique was successfully employed in the HDB-3,4,5 borehole investigations to ensure high percentage core recovery and maintain borehole integrity. It is intended to apply this method to the HDB-6,7,8 drilling program.

5.1.1 Aims

- Full core recovery for geological, hydrogeological, hydrochemical and rock mechanical investigations.
- Provide suitable locations for downhole investigations such as hydraulic tests, groundwater sampling, borehole logging hydraulic fracturing test and borehole expansion test.

5.1.2 Methodology

The three boreholes will be drilled simultaneously. Each borehole is drilled in four phases (see section 6.1.1). The following methodology will be used.

Casing and cementing
Continuous core drilling will be done to 130mbgl (HDB-7:150 mbgl). Following borehole investigations in this interval, the interval will be reamed using a tricone bit to a diameter of 12- 1/4 inch (311.2mm). Then, 9-5/8 inch (244.5mm) casing pipes will be installed and fixed by full hole cementing. Dredging and flushing of the borehole are performed after cementing. The borehole is flushed with drilling fluid tagged with fluorescent dye (see *Drilling/flushing fluid* below). Continuous core drilling will be done to approximately 300 mbgl (HDB-6: 360 mbgl, HDB-7: 320 mbgl, HDB-8: 300 mbgl). Following borehole investigations in this interval, the interval will be reamed using a tricone bit to a diameter of 8- 1/2 inch (215.9mm). Then, 7 inch (177.8mm) casing pipes will be installed and fixed by 2 stage cementing (use shoe and cementer). Dredging and flushing of the borehole are performed after cementing. The borehole is flushed with drilling fluid tagged with fluorescent dye. Continuous core drilling will be done to the final depth (HDB-6: 620 mbgl, HDB-7: 520 mbgl, HDB-8: 470 mbgl). Following borehole investigations in this interval, 4-1/2 inch casing pipes will be installed and fixed by full hole cementing (use liner hanger). Dredging and flushing of the borehole are performed after cementing. The borehole is flushed with drilling fluid tagged with fluorescent dye. Then, the perforation of the casing pipes will be carried out in order to set the monitoring sections for the pressure measurement and water sampling.

Coring
Wireline core drilling, 6-1/4 inch (158.9mm) diameter and using bentonite fluid is performed

from surface to the final depth. A triple-barrel drilling method is employed for full or high percentage core recovery. The core diameter is about 86mm.

Drilling/flushing fluid
Bentonite fluid tagged with fluorescent dye (Na-napthionate) is used for drilling. For the flushing operations, the fresh water tagged with fluorescent dye will be used. No other chemicals/additives are planned to be used in the drilling fluid.

Monitoring of the drilling
Drilling data such as rate of penetration (ROP), bit revolution, weight on bit (WOB), pumping pressure, fluid gas content, rate of water supply and return and any fluid volumes lost or gained are continuously monitored during borehole drilling to complement geological and hydrogeological investigations.

Borehole protection
In the event there is significant drilling fluid loss, plugging with LCM (Lost Circulation Material, e.g. cellulose) will be carried out. If successful, drilling will continue. However, if significant drilling fluid loss continues after plugging of the site, partial cementing of the drilling fluid loss location will be done. In case of significant borehole collapse, partial cementing will be carried out at the site where the collapse occurs. If collapse occurs even after the cementing of the location, drilling will be halted and borehole investigations (geophysics/hydraulic testing) will be performed. In all these situations, all possible on-site investigations to the site of collapse should be completed before borehole protection is implemented. After reaming with a tricon bit to the depth of collapse section is completed, casing pipes will be installed and fixed by full hole cementing to the depth of the collapse section. In the case of both drilling fluid loss and collapse occurring at same location, the borehole protection will be the same as for the borehole collapse case (see section 6.1.2).

5.1.3 Reporting

Daily report (daily at 9:00)
Status of the field work (drilling length, water level and tests performed, etc.) is reported by the contractor.

Daily report (to be supplied to JNC on the next morning)
Duration and time of drilling, personnel, activities undertaken, drilling length, tally list of drill strings and measurement or testing tools used, results of deviation surveys, bit life, details of machinery used, consumption of supplies and anything abnormal or unexpected are reported promptly.

Final report (by the end of the contract period)
A complete record of drilling is reported in detail with logs of drilling data.

5.2 Geological Investigations

The goals of geological investigations are to acquire geological and structural information, and to establish a systematic investigation technique for reliably and accurately characterizing the deep geological environment.

5.2.1 Aims

- To acquire geological and structural data on the Tertiary sedimentary rocks for the development of a geological model.
- To check and improve the existing geological model.
- To obtain data on geological and geochemical properties of the Tertiary sedimentary rocks.
- To establish methodologies to relate geological characteristics including stratigraphy and lithology.

5.2.2 Methods

A variety of geological investigations are planned on the Horonobe construction site and in the laboratory. The methods to be employed are as follows:

1. On the site

•Core description: general geological information
•Core photographing: visual geological information (*i.e.* core images)
•Core scanning: digital data on geological structures

•Core sampling: rock samples for laboratory work

2. In the laboratory

•Optical microscopy: general petrological information
•X-ray diffractometry: mineral composition
•Core scanning: biofaces and ichnofaces
•Standard chemical analyses: Biogenic silica content and chemical composition
•Hg injection porosimetry: porosity, pore-space distribution and specific surface area
•Organic geochemical analyses: organic geochemical composition
•Microfossil analyses: diatoms/dinoflagellates species

5.2.3 Planned field work

5.2.3.1 Work during drilling

On-site core description and photography (by contractor)
The cores are described completely at 1/5 scale by the contractor, using JNC's core description manual. The description includes the following items: depth, formation name, rock name, lithofacies, color, hardness, rock mass classification, weathering, fossil and trace fossil, RQD (Rock Quality Designation), core recovery, schematic section of core, fracture number, dip of fracture, fracture type, fracture shapes, striation on fracture, fault rock classification, origin of fracturing, width and coloration of altered zone along fracture, thickness of fracture fillings, types and volumes of fracture fillings. Borehole profiles, including all this information, will serve as a basis for other investigations.
Photographs of all cores are taken using a camera to preserve visual geological and structural information. All images include a scale and a color chart. Each image includes up to four, 1m long lengths of core.

Core scanning and sampling (by contractor)
Images of cores are taken with a digital scanning device using optical wavelengths for later numerical analysis of fractures. Samples for later laboratory work are then selected after the evaluation of information obtained during drilling.

5.2.3.2 Work after drilling

Core sampling (by contractor)
Samples for further laboratory work are selected based upon information obtained by previous investigations.

5.2.4 Planned laboratory work

The following laboratory work is planned. Details (*e.g.* constituents, methods and numbers of samples for analysis) are summarized in Table 2.

Petrological characterization (by contractor)
Standard optical microscopy is conducted on rock thin sections to clarify lithological characteristics of the Tertiary sedimentary rocks. Mineral compositions of the rocks are determined by XRD (X-Ray Diffraction) and conventional modal analysis (*e.g.* point-counting). In addition, heavy mineral compositions of the rocks are determined by heavy liquid separation and conventional modal analysis. Biofaces and ichnofaces of the rocks are sketched using digital images produced by core scanning. Biogenic silica content (amorphous opal content) of the rocks is measured by a absorptiometric analysis. Based on the data of these petrological analyses and on-site core description, stratigraphy and lithological characteristics of the rocks are determined for geological modeling.

Geochemical characterization (by contractor)
Major components and trace elements including REEs (Rare Earth Elements) are analyzed on rock samples by XRF, wet chemical methods and ICP-MS (Inductively Coupled Plasma-Mass Spectrometry). The aims of these analyses are to characterize the Tertiary sedimentary rocks in the Horonobe site as thoroughly as possible for geological modeling and to provide geochemical data on Horonobe site for interpreting water-rock interactions.

Microscopic pore-space characterization (by contractor)
Hg injection porosimetry, which determines open or effective porosity (*i.e.* Hg-accessible porosity), is used for intact rock materials in the HDB-6 borehole.

Organic geochemical characterization (by contractor)
TOC (Total Organic Carbon content), TN (Total Nitrogen content) and TS (Total Sulfur content) of Organic materials of the Tertiary sedimentary rocks are analyzed by CHNS Coder to clarify compositions, origin and sedimentary environment of the organic materials. Observation of visual kerogens of the rocks is performed by optical microscopy to clarify compositions, origin and maturity of the visual kerogen. Biomaker analysis (TIC, m/z57 n-alkane, m/z191 terpane, m/z215 sterene and m/z217 sterane) is performed by GC-MS(gas chromatograph–mass spectrometry) to clarify compositions, origin and maturity of biomaker.

Microfossil characterization (by contractor)
The species of diatoms/dinoflagellates of the Tertiary sedimentary rocks are identified by optical microscopy to determine the biostratigraphical ages of the rocks.

5.2.5 Reporting

5.2.5.1 Field work reports

Daily report (the evening following the day covered by the report)
A summary of lithofacies based upon the on-site core description is reported with appended description sheets providing details on the previous day's observations. Details of any anomalies and/or unexpected events encountered during drilling are described.

Summary report (within a week after each 100m of drilling has been completed)
A summary of lithofacies, fossil and trace fossil, color, hardness, weathering, rock mass classification, RQD (Rock Quality Designation), dip of fracture, origin of fracturing is reported with a geological log at 1/500 scale. All description sheets covering the interval are also submitted. Digitized numerical data are also supplied.

Final report (by the end of contract period)
A detailed geological description is reported with a full data set in a section of the final report. Full details of all methods employed, operating conditions of equipment, relevant detection limits and precision are described. Details are also given of anything unexpected that occurred during drilling.

5.2.5.2 Laboratory work reports

Prompt report (immediately after the investigation has been completed)
Raw data are reported immediately after each phase of the investigation has been completed. Data quality is then checked by JNC.

Final report (by the end of contract period)
All results are reported with full data sets. Full details of all methods employed, operating conditions of equipment, relevant detection limits and precision are described. Details are also given of anything unexpected that occurred during the laboratory work.

Table 2 Planned laboratory work for geological investigations

Constituents	Methods*	Sample Quantity	Laboratories
Petrological Characterization			
Petrography	Optical microscopy	60	Contractor
Mineral composition	XRD Modal analysis	50 15	Contractor
Heavy mineral composition	Modal analysis	15	Contractor
Biofaces and ichnofaces	Core scanning	30	Contractor
Biogenic Silica Content	Wet chemical analysis	150	Contractor
Geochemical Characterization			
Major components			
SiO_2, TiO_2, Al_2O_3, Fe_2O_3, FeO, MnO, MgO, CaO, Na_2O, K_2O, P_2O_5, LOI, H_2O+, H_2O-,CO_2	XRF, Wet chemical analysis	30	Contractor
Trace elements			
Li, Be, B, F, Rb, Sr, Th, U, Se, I, SO_4, TC, TN	XRF, ICP-MS, Wet chemical analysis	15	Contractor
Rare earth elements			
Y, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu	ICP-MS	15	Contractor
Microscopic Pore-space Characterization			
Porosity	Hg injection porosimetry	12 (HDB-6 only)	Contractor
Organic Geochemical Characterization			
TOC, TN, TS	CHNS Corder	60	Contractor
Visual Kerogen	Optical microscopy	60	Contractor
Biomarker	GC-MS	30	Contractor
Micro Fossil Characterization			
Diatom	Optical microscopy	66	Contractor
Dinoflagellates	Optical microscopy	70	Contractor

* Methods = XRD: X-Ray Diffractometry, XRF: X-Ray Fluorescence Spectroscopy, ICP-MS: Inductively Coupled Plasma-Mass Spectrometry, CHNS Corder: Carbon, Hydrogen, Nitrogen and Sulfur Corder, GC-MS: Gas Chromatograph--Mass Spectrometry

5.3 Geophysical Investigations

Geophysical logging and borehole TV (BTV) can provide basic information on the rock mass and structures necessary for hydrogeological and hydrochemical investigations which supplement the information from drilling reports and on-site core description. Therefore, in the HDB borehole investigation program, it is planned to conduct a series of geophysical investigations in support of the hydrogeological and hydrochemical investigations.

5.3.1 Aims

- To identify locations of potentially WCFs.
- To acquire information about the orientation and geometry of fractures and lithological boundaries.
- To acquire geophysical properties by continuous wireline logging to be used in the fracture characterization study and in the geological, hydrochemical and geomechanical modeling.
- To characterize *in situ* neutron flux production for hydrochemical interpretations.

5.3.2 Methods

A series of geophysical investigations are carried out by the following methods:

1. Petrophysical logging
   - Electrical: apparent resistivity of surrounding rock
   - Micro electrical: apparent resistivity of the borehole wall
   - Natural gamma: gamma rays from radioactive elements in the rocks
   - Temperature: measurement of ground temperature
   - Spectral gamma: content of Potassium, Uranium and Thorium
   - Neutron: thermal neutron correlated with total porosity around the borehole
   - Density: decayed gamma rays correlated with apparent density
   - Acoustic: P-wave and S-wave velocities of surrounding rock
   - Velocity: measurement of P-wave and S-wave velocities by downhole method
   - Flow meter: Electro-magnetic flow meter , temperature ,and conductivity
   - Cement bond log : indicates the degree of bonding of cement to casing and formations

2. Geotechnical logging
   - X-Y calliper: borehole diameters in orthogonal directions
   - Deviation: orientation and inclination of borehole

3. Borehole TV (BTV: digital scanning of the borehole wall)

5.3.3 Planned field work

Geophysical logging and BTV, to be performed basically in three phases, can provide information to determine test intervals for investigations such as hydraulic tests and groundwater sampling. The locations, orientations, widths, shapes and appearance of joints, faults and fractures, lithological boundaries and veins are identified as well as petrophysical properties of the rocks being characterized. The geometry of the structure system will be defined by data analysis, primarily from the digitized BTV data. Potentially WCFs may be identified by detecting anomalies on the geophysical logs and by comparing these logs with the geological and hydrogeological information.

Phase 1: surface – 130mbgl (HDB-7:150mbgl)
- Geophysical logging (and BTV only in HDB-6)

Phase 2: 130mbgl – 300mbgl (HDB-6:360mbgl, HDB-7:320mbgl, HDB-8:300mbgl)
- Geophysical logging (and BTV only in HDB-6)

Phase 3: 300 mbgl – final depth
- Geophysical logging (including borehole radar) and BTV

5.3.4 Reporting

5.3.4.1 Geophysical logging

Prompt report (1 day after the field investigation has been completed)
Each of the logs is submitted. Any anomalies and/or unexpected events encountered during the fieldwork are also reported.

Interim report (within 1 days after the field investigation has been completed)
Data records with all profiles at the same scale are submitted within 1 days of survey completion. Raw digital data in Microsoft Excel™ files are also submitted to JNC as soon as possible. Details of the anomalies and/or unexpected events are reported.

Final report (by the end of the contract period)
The report should include possible interpretations of results (including any anomalies and/or unexpected events) and the full data set. Full details of all methods employed, operating conditions of equipment, relevant detection limits and precision are described.

5.3.4.2 Borehole TV

Prompt report (1 day after the field survey has been completed)
Pictures are submitted on videotape. Digitized images in BIPS™ image files to be used for analysis by computer (Borehole Image Processing System program) are also submitted to JNC as soon as possible. Details of any anomalies and/or unexpected events encountered during fieldwork are also given.

Interim report (within 1 week after the field survey has been completed)
The locations, orientations, widths, shapes and appearance of all fracture such as faults and joints, lithological boundaries and veins are identified. The structures can be compared with those identified on the core and the two sets of data should be matched as closely as possible. Results are submitted digitally in Microsoft Excel™ files.

Final report (by the end of the contract period)
Possible interpretations of results (*e.g.* details of identified faults) and full data sets are reported. Full details of all methods employed, operating conditions of equipment, relevant detection limits and precision are described.

5.4 Hydrogeological Investigations

The investigations performed in the HDB-1 and HDB-2 boreholes in 2001 have provided the following indications on the hydrogeological characteristics of the Wakkanai Formation:
- The hydraulic conductivity in Wakkanai Formation ranged from 10^{-9} to 10^{-12} m/sec.
- No drilling fluid loss during drilling was observed.

In 2002, HDB-3,4 and 5 borehole investigations provided the following results:
- The fluid loss during drilling was observed at 220mbgl in HDB-4.
- The WCF identified from fluid logging have high transmissivities ($T \approx 10^{-4}$ m^2/sec).
- The hydraulic conductivities in the Koetoi and in Wakkannai Formations ranged from 10^{-7} to 10^{-9} m/sec.

5.4.1 Aims

- To obtain good quality data on the transmissivity, hydraulic conductivity, hydraulic head and flow model in the Yuchi, Koetoi and Wakkanai Formations as well as WCFs.

5.4.2 Methods

Fluid logging and hydraulic tests are planned. The methods to be employed are as follows:

1. Fluid logging (dynamic fluid logging, i.e. under pumping condition)
   - Electro-magnetic flowmeter logging with the measurement of electric conductivity::
     continuous measurement of flow velocity and water electric conductivity in the borehole
   - Temperature logging (conventional): continuous measurement of temperature
   - Electric conductivity logging(only first campaign at HDB-6):
     continuous measurement of electric conductivity and flow rate
2. Hydraulic tests
   - Pulse test: low to very low transmissivity
   - Slug test: average to low transmissivity
   - Pumping test: average to high transmissivity

These tests will be conducted in a sequence of test events in every specified test interval.

5.4.3 Planned field work

Fluid logging (by contractor)
Electro-magnetic flowmeter logging in undisturbed and pumping states are performed to identify inflow/outflow points and to provide a rough estimate of transmissivity. Temperature logging is performed in undisturbed state to determine the inflow/outflow points under stable pressure condition. Electric conductivity logging is performed to identify inflow/outflow points and to estimate transmissivity. These features are identified as anomalies on the profile, which in turn complement other geological and hydrogeological information, suggesting the locations of WCFs. Electro-magnetic flowmeter with the measurement of water electric conductivity in the borehole would show major to intermediate ones. The electric conductivity logging in HDB-6 is conducted to confirm the applicability of this method. The electric conductivity logging would indicate major to minor WCFs.

Hydraulic tests (by contractor)
A sequence of hydraulic test events during drilling is conducted for the purpose of obtaining hydraulic properties and sampling groundwater from WCFs. These test intervals are identified on the basis of the drilling fluid losses, rates of fluid loss and anomalies in the fluid logs and

in other geophysical logs, and the core description.
Pulse, slug and pumping (*i.e.* constant pressure or constant flow rate) test techniques are employed for very low to low, low to intermediate and intermediate to high permeability rock respectively. The most suitable method for hydraulic testing is selected on the basis of the estimated transmissivity of the test interval, the time available for the test and the applicable equipment. Initially, pulse are conducted to estimate a roughly permeability and to check the test zone compressibility due to presence of free gas. When the permeability by plus test is not very low, a slug test is conducted for deciding appropriate pumping flow rate precisely for the flow diagnostic test. The constant flow rate test or constant pressure test is carried out, when the permeability by slug test is middle to high. The subsequent pressure recovery is allowed to continue until the pressure in the test interval reaches the initial pressure or until the initial pressure can be reliably extrapolated from the recovery by the Horner plot method. Groundwater sampling takes place during the pumping test. Flow rates should be monitored continuously during groundwater sampling. Lastly, pulse tests should be conducted to check the test zone compressibility due to presence of free gas. The head difference of each test should be adjusted to 20m or less to control the generation of the gas.
It is necessary to observe and evaluate the rate of pressure recovery towards its initial state or to extrapolate to the initial state in each test. In addition to this evaluation, a flow model and boundary condition should be estimated from the pressure derivative plot.
The planned hydraulic testing program is summarized in Figure 1.

5.4.4 Reporting

Prompt reports

1. Fluid logging (within 24 hours after the field investigation has been completed)
   Results of the fluid logging are reported together with the geophysical and geological logs. Information on any anomalies and/or unexpected events along the borehole is also reported.

2. Hydraulic tests
   Before starting any hydraulic test, check sheets for the test equipment and a tally list of any equipment to be used in boreholes should be submitted to JNC staff.
   The progress of the test should be reported daily. It should include graph plots such as pressure plots and pressure derivative vs. time, and derived values of transmissivity, hydraulic conductivity, and hydraulic head with analytical methods employed etc. Test event log should also be included.

Summary report (within a week after each campaign has been completed)

A summary of the hydraulic tests performed including transmissivity and/or hydraulic conductivity and hydraulic head with depth is reported together with the geological log.
Results of the hydraulic tests are reported with the following information:

- Objectives and techniques employed
- Geology of test intervals
- Test event log
- Test interval (upper/lower/midpoint depths, length and volume of packed-off interval, pumping rate, *etc*)
- Borehole and tubing radius
- Water level in annulus (in mbgl)
- Inflation pressure of packers
- Time of test start and end

- •Test results with detection limits and precision (pressure history, final pressure plots and it's derivative of each test event, hydraulic head, data plots, analytical method used, result of curve matching, transmissivity and hydraulic conductivity taking account of the well-bore storage and skin effects etc.)
- •Short comments on the tests, including duration of pumping, rate of pressure recovery, rational for selection of diagnostic test and details of anything abnormal or unexpected

JNC staff will check the quality of the data together with the test techniques selected.

Final report (by the end of contract period)
All results are reported with full data sets. Full details of all analytical methods employed, operating conditions of equipment, relevant detection limits and precision are described. Details are also given of anything unexpected that occurred during the investigations.

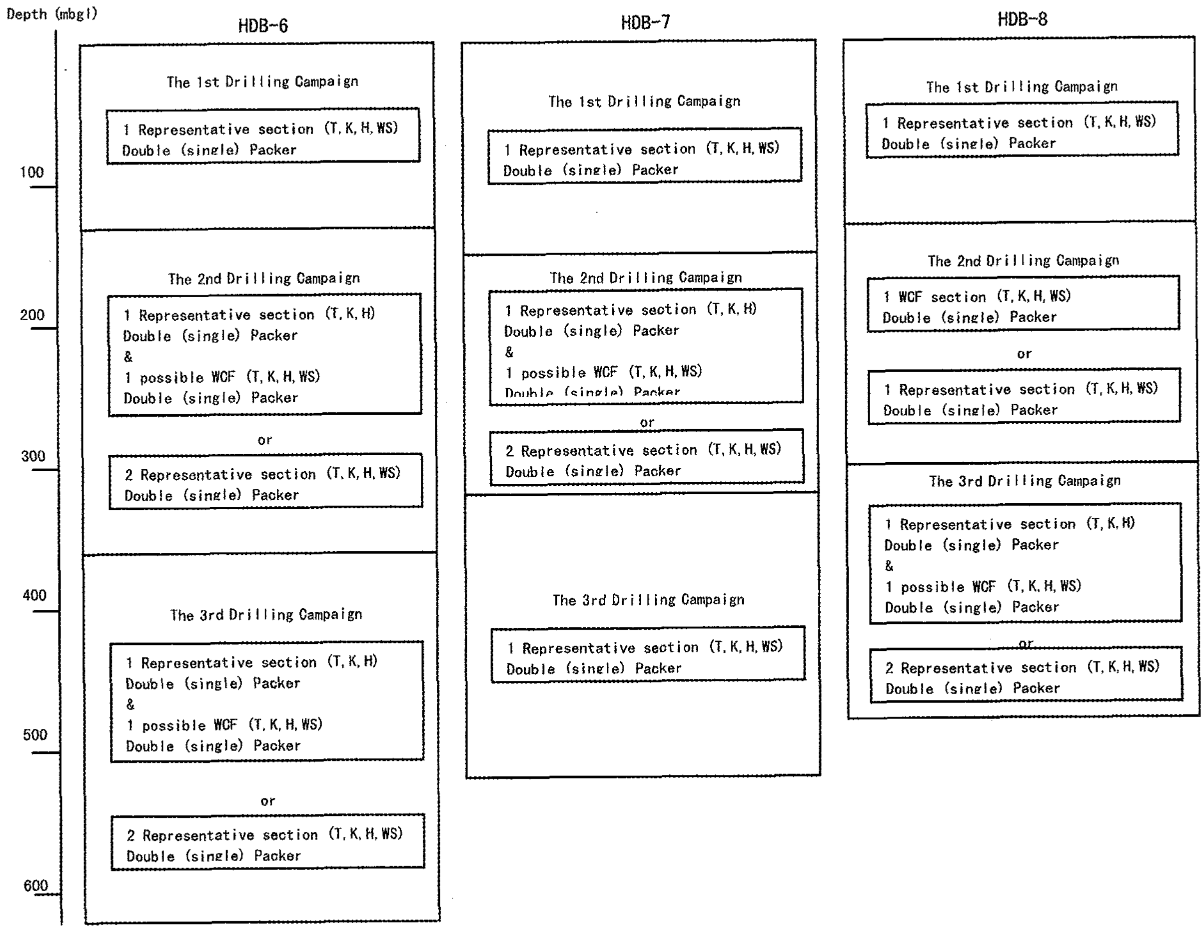


Figure 19 Summary of hydraulic test campaign

5.5 Hydrochemical Investigations

The method and procedure for groundwater sampling, combined with hydraulic packer testing, was successfully employed in the MIU-4 borehole investigations to ensure high quality hydrochemistry data (Ota et al., 2001and Kumazaki et al., 2002). It is intended to apply these method and procedure to the Horonobe deep borehole (HDB series) investigation programs.

Generally, sedimentary rocks have higher porosity. The porewater analysis should be important item for the hydrochemical investigations. The method for the porewater squeezing has been developed during t HDB-1 to 5 borehole investigations. Due to the limited amount of porewater taken from core, Na, K, Cl, Mg, Ca, SO_4, HCO_3, CO_3, oxygen and hydrogen isotopes could be analyzed. The oxidation of the core during squeezing has observed. Anaerobic squeezing procedure will be tried for the HDB-6,7,8 borehole investigations.

5.5.1 Aims

- To determine the groundwater hydrochemical profile from the top to over 500m depth in the sedimentary rock.
- To determine the boundary between fresh and saline/brackish water.
- To obtain basic information for the identification of the dominant geochemical process (e.g. water-rock-microbe interaction, mixing between saline and fresh water) and chemical buffer capacities.
- To determine the hydrochemical properties and residence time of groundwater.
- To development the methodology for taking groundwater sample by the hydraulic equipment and squeezed the core.

5.5.2 Methods

Groundwater sampling and subsequent analytical work will be performed at the Horonobe construction site and in the laboratory. The methods and objectives are as follows:

1. At the field site

- Drilling fluid preparation: drilling fluid added fluorescent dye for quantitative hydrochemical investigations
- Fluorescent dye analyses (during drilling): maintenance of fluorescent dye concentration in drilling fluid
- Fluorescent dye analyses (during pumping): to monitor degree of groundwater contamination
- Standard chemical analyses: chemistry of drilling fluid and groundwater

2. In the laboratory

- Comprehensive chemical analyses: chemistry of drilling fluid and groundwater
- Standard isotopic analyses: isotopic composition, origin and residence time of groundwater
- Gas analyses: kind and amount of dissolved gas in the groundwater
- Organic acid/microbes studies:
- Porewater chemistry: chemistry of porewater squeezed from core in the aerobic and anaerobic condition.

5.5.3 Planned field work

Drilling fluid preparation (in house)
Fluorescent dyes are added to the drilling fluid to allow the degree of contamination of groundwater samples by the drilling fluid to be determined quantitatively. The drilling fluid is made to add the fluorescent compound to fresh water controlled 10mg/l. And bentonite mud used borehole drilling is made to mix this fluid and bentonite. The fluorescent compound to be used is sodium naphthionate in sedimentary rocks. The concentrations are calculated by considering the detection limits of the fluorescent dyes and the need to identify drilling fluid contamination.

Monitoring of drilling fluid during drilling (by contractor)
The general analytical program is shown in Table 3. Physico-chemical parameters, major chemical constituents, isotopic compositions and fluorescent dye concentrations are analyzed regularly. Fluorescent dye concentrations may need to be adjusted periodically to keep the concentrations as constant as practicable. Physico-chemical parameters are continuously measured on-site. Major chemical constituents, isotopic compositions and fluorescent dye concentrations are determined at the site or in the off-site laboratory. Major chemical constituents and isotopic compositions in the original shallower water are also analyzed periodically in house.

Groundwater sampling combined with hydraulic tests (by contractor)
The hydraulic properties are very low conductivities except some part of HDB-4 and 5 around the URL contraction site. At 6 locations are planned to collect groundwater with hydraulic packer testing. The locations are planned following:

- Drilling fluid loss section during the borehole drilling
- It is necessary to measure the toxic substance in the groundwater for contracting the URL (HDB-6: about 250mabh and 500mabh)
- The hydraulic conductivity is high zone. The zone is predicted to be able to except the drilling fluid during the hydraulic pumping test.

The interval to be sampled is sealed off with a single or double packer assembly. Once the packers have been inflated, the drilling fluid should be removed, generally using a Progressing Cavity Pump Systems (PC pump), from the packed-off interval and tubing and replaced naturally by in situ groundwater.
Preparation of the drilling fluid with fluorescent dyes allows contamination of the groundwater by the drilling fluid to be estimated quantitatively. During pumping, before any groundwater samples are taken, the fluorescent dye concentration is determined regularly on the site. Several physical and chemical parameters are also measured.
As stated in the previous section, measurements are aimed at testing the applicability of mixing calculations for the estimation of groundwater chemistry. Groundwater sampling takes place when the fluorescent dye concentration is sufficiently low (*i.e.* generally below 1%). In case the fluorescent dye concentration in the isolated section does not decrease sufficiently within the time available for groundwater sampling due to large contamination of the groundwater with drilling fluid and it is judged that continued pumping will not remove sufficient drilling fluid, pumping will cease. Groundwater samples will then be taken and analyzed for major components and selected isotopes. Based on estimates of drilling fluid contamination from the tracer concentration in the samples together with the rate of tracer decrease with pumping, the in situ or initial groundwater composition will be back calculated.

5.5.4 Planned laboratory work

Some hydrochemical parameters of the drilling fluid and groundwater samples will be measured at the site. In addition, comprehensive chemical and isotopic analyses of the groundwater samples are carried out in specialized laboratories (contractor and in house) as shown in Table 3. Reference samples of drilling fluid, shallower water and groundwater are suitably pre-treated and preserved according to standard protocols, i.e., by refrigeration.

Porewater is extracted by squeezed the core in the aerobic and anaerobic condition. Comprehensive chemical and isotopic analyses of the porewater samples are carried out in the contractor and BGS laboratories as shown in Table 3. The extracted porewater is 10 ~ 20ml. So it may not be able to measure the all chemical and isotope items planed.

Table 3 Planned analytical work for hydrochemical investigations

Constituents	Sampling / Analysis Combinations*					Laboratories	Remarks
	A	B	C	D	E		
Physico-chemical Parameters							
pH	4S	3S	1S	8L	6L	Contractor	
Electrical conductivity (EC)	4S	3S	1S	8L	6L	Contractor	
Eh	–	–	1S	–	6L	Contractor	
Dissolved Oxygen (DO)	–	–	1S	–	–	Contractor	
Temperature (T)	4S	3S	1S	8L	–	Contractor	
Major Components							
Sodium (Na^+)	5L	6, 7L	–	8L	6L	Contractor	
Potassium (K^+)	5L	6, 7L	–	8L	6L	Contractor	
Ammonium (NH_4^+)	–	–	–	8L	–	Contractor	
Lithium (Li)	–	–	–	8L	6L	Contractor	
Calcium (Ca^{2+})	5L	6, 7L	–	8L	6L	Contractor	
Magnesium (Mg^{2+})	5L	6, 7L	–	8L	6L	Contractor	
Strontium (Sr^{2+})	–	–	–	8L	–	Contractor	
Selenium (Se)	–	–	–	8L	–	Contractor	
Phosphorus (P)	5L	6, 7L	–	8L	–	Contractor	
Iodine (I^-)	5L	6, 7L	–	8L	–	Contractor	
Manganese (Mn^{2+})	–	–	–	8L	–	Contractor	
Silica (H_2SiO_3)	5L	6, 7L	–	8L	–	Contractor	
Titanium (Ti)	–	–	–	8L	–	Contractor	
Iron (Fe^{3+})	5S	6, 7S	–	8S	6L	Contractor	
Iron (Fe^{2+})	5S	6, 7S	–	8S	6L	Contractor	
Iron (total Fe)	5L	6, 7L	–	8L	6L	Contractor	
Aluminium (Al)	5L	6, 7L	–	8L	–	Contractor	
Fluorine (F^-)	5L	6, 7L	–	8L	–	Contractor	
Chloride (Cl^-)	5L	6, 7L	–	8L	6L	Contractor	
Bromide (Br^-)	5L	6, 7L	–	8L	–	Contractor	
Nitrate (NO_3^-)	5L	6, 7L	–	8L	–	Contractor	
Sulphate (SO_4^{2-})	5S	6, 7S	–	8S	6L	Contractor	
Boron (B)	–	–	–	8L	–	Contractor	
Beryllium (Be)	–	–	–	8L	–	Contractor	
Chromium (Cr)	–	–	–	8L	–	Contractor	
Cobalt (Co)	–	–	–	8L	–	Contractor	
Nickel (Ni)	–	–	–	8L	–	Contractor	
Alkalinity	5S	6, 7S	–	8S	6L	Contractor	Include HCO_3 and CO_3
Total organic carbon (TOC)	5L	6, 7L	–	8L	6L	Contractor	
Total inorganic carbon (TIC)	5L	6, 7L	–	8L	6L	Contractor	
Organic acid							
Humic acid	9L	–	–	8L	–	Contractor	
Fulvic acid	9L	–	–	8L	–	Contractor	
Acetic acid	9L	–	–	8L	–	Contractor	
Formic acid	9L	–	–	8L	–	Contractor	
Isotopes							
Tritium (^3H)	9L	–	–	8L	6L	Contractor	
Chlorine-36 (^{36}Cl)	9L	–	–	8L	6L	Contractor	
Oxygen-18 (^{18}O)	9L	–	–	8L	6L	Contractor	
Deuterium (^2H)	9L	–	–	8L	–	Contractor	
Carbon-13 (^{13}C)	9L	–	–	8L	–	Contractor	
Carbon-14 (^{14}C)	9L	–	–	8L	–	JNC	
Dissolved Gas							
O_2, N_2, CO_2, Ar, CH_4, C_2H_6 C_3H_8, C_4H_{10}	–	–	–	8L	–	Contractor	
Carbon-13 (^{13}C)	–	–	–	8L	–	Contractor	
Others							
Microbes	9L	–	–	8L	–	Contractor	
Fluorescent dyes							
Sodium-naphthionate	5L		–	8L	–	Contractor	
Samples for analyses						Contractor	
Samples for storage						Contractor	

* Sampling/analysis combinations = A: Monitoring of shallow groundwater for drilling fluid
B: Monitoring of drilling fluid during drilling

C: Monitoring of outflow during pumping test
D: Groundwater (formation water) sampling
E: Porewater sampling
1: Continuously, 2: Hourly, 3: Every 2hore, 4: Daily, 5: Monthly, 6: For each 100m drilled
7: For each drilling stage, 8: At the end of hydraulic testing, 9: At the start and end of borehole drilling
S: On the site, L: In the laboratory

5.5.5 Reporting

5.5.5.1 Field work reports

Prompt report (after the field investigation has been completed)
A report to be submitted by contractors includes raw data and the following information:

1. Drilling fluid monitoring
   - Analyzed values with errors and detection limits
   - Method used, including details of equipment employed and operating conditions
   - Anything abnormal during monitoring/sampling or analysis
2. Groundwater sampling
   - pH, Eh, electrical conductivity, oxygen content and temperature during sampling
   - Any observations of color changes in water, gas bubbles, precipitation and smell
   - Amount of water sampled
   - Details of characteristics of storage containers used
   - Fluorescent dye contents
   - Alkalinity
   - Anything abnormal during sampling or analysis

Final report (by the end of contract period)
All results are compiled and reported with full data sets. The report should include analyzed values with errors and detection limits, details of method used, details of equipment employed and its operating conditions and details of anything unexpected that occurred during the monitoring/sampling and analyses.

5.5.5.2 Laboratory work report

Final report (by the end of contract period)
All results are compiled and reported with full data sets. The report should include analyzed values with errors and detection limits, details of analytical method used and its conditions and details of anything unexpected that occurred during the analyses.

5.6 Rock Mechanical Investigations

5.6.1 Aims

Aims of the geomehcanical investigations in FY 2003 are as follows,

- To evaluate the variation of the magnitude of horizontal principal stress quantitatively around position of URL
- To evaluate the mechanical properties in in-situ rock mass around position of URL
- To estimate the strain velocity dependency of rock properties and pore distribution of rock matrix.
- To confirm the correlation between rock properties and geology in selected study area

5.6.2 Methods

1 Stress measurement

Hydraulic fracturing method: The system lift up and down by the armored cable or drilling rods

2 Borehole expansion test

Packer-type measurement system: Hydrostatic Cyclic loading by oil or water

3 Laboratory test

The measurements for physical properties (Density, Unit weight, porosity, water content) : Conventional method according to JIS and ISRM suggested method, Mercury porosity measurement.

Uni-axial compressive tests, Brazillian test: Conventional method according to JIS and ISRM suggested method

Tri-axial compressive tests: CU and CD test with different strain rate

5.6.3 Planned field work

5.6.3.1 Stress measurement

In HDB-6, minimum six measurements are planned to estimate the stress variation of maximum and minimum horizontal principal stresses in each layer (Koetoi, Wakkanai formation and transition zone). The measurements in transition zone and Wakkanai formation are interest to understand the correlation between the stress variation and rock properties change. The measurements in Wakkanai formation are important to plan the in-situ experiments in third phase of Horonobe URL project. These data will use for support design of URL.

Koetoi formation : One depth (around 200mbgl)
Transition zone : Two depth (350-450mbgl)
Wakkanai formation : Three depth (450-600mbgl)

5.6.3.2 Borehole expansion tests

The measurements are planned to measure the deformability of in-situ rock mass directly in in-situ around position of URL. The data can use to estimate influence of fractures to mechanical properties of sedimentary soft rock. In detail, the calculated elastic modulus were compared to the elastic modulus evaluated by laboratory testing and geophysical logging. Therefore, the planned measurements point are selected at fractured rock part and non fractured rock part in each geological formation (Ketoi formation, Transition zone, Wakkanai formation).

Koetoi formation : Three depth (fractured part and non fractured part/ one depth)
Transition zone : Two depth (fractured part and non fractured part/ one depth)
Wakkanai formation : One depth (fractured part and non fractured part/ one depth)

5.6.4 Planned laboratory test

The physical properties(Density, unit weight, effective porosity, water content) are measured on total thirty cores with ten depth (three sample / depth) in all boreholes. Mercury porosity measurements are applied on cores taken from four depth (three depth in Koetoi formation, one depth in Wakkanai formation) to estimate the distribution of porosity dimension in HDB-6. These data supply to understand the detail structure of rock matrix.

Uni-axial compressive tests performed on total thirty cores at ten depth in all borehole to provide support data to construct three dimensional geological structure in study area.

Tri-axial compressive test(CU, CD) with different strain rate in HDB-6 are planned because the excavation progress may be different due to the excavation methods (Blasting, mechanical excavation) .

5.6.5 Reporting

5.6.5.1 Stress measurements

Prompt report (1 day after the field investigation has been completed)
The pressure-time curve and rough estimated magnitude of principal stresses and the direction is submitted. Any anomalies and/or unexpected events encountered during the fieldwork are also reported.

Final report (by the end of the contract period)
The report should include possible interpretations of results (including any anomalies and/or unexpected events) and the full data set in MS Excel format. Full details of all methods employed, operating conditions of equipment, relevant detection limits and precision are described.

5.6.5.2 Borehole expansion test

Prompt report (1 day after the field survey has been completed)
Pressure-displacement curve and rough calculated elastic modulus are submitted. Details of any anomalies and/or unexpected events encountered during fieldwork are also given.

Final report (by the end of the contract period)
Possible interpretations of results and full data sets are reported. Full details of all methods employed, operating conditions of equipment, relevant detection limits and precision are described.

5.6.5.3 Laboratory test

Interim report (After each testing has been completed)

Stress-strain curve, sketch of sample after testing and each measured parameter are submitted. Before submit, all data should be compared past data and possible interpretation will be given if abnormal data will be found. If it is impossible to interpret, re-testing should be carried out.

Final report (by the end of the contract period)
Possible interpretations of results and full data sets are reported. Full details of all methods employed, operating conditions of equipment, relevant detection limits and precision are described.

5.7 Long-term monitoring

Long-term hydraulic monitoring system has been installed in the borehole HDB-1. Long-term hydraulic monitoring systems will be installed in the boreholes HDB-3 and HDB-4. This will provide the opportunity to carry out additional investigations i.e. monitoring pressures in these boreholes before, during and after drilling the HDB-6,7,8 boreholes. These investigations are intended to provide data to evaluate connectivity between boreholes. After the HDB-6,7,8 campaign has been completed, a multi-packer system will be installed in the these boreholes for long-term monitoring before, during and after excavation of the shaft/drift.

5.7.1 Aims

-- To determine the spatial distribution and variations in hydraulic heads before the shafts/drifts construction.
- To obtain hydraulic information necessary for evaluating the groundwater flow system through the iterative process of groundwater flow simulations and refinement of concepts.

5.7.2 Methods

Long-term hydraulic monitoring in all boreholes are planned. The long-term monitoring includes monitoring of hydraulic heads.

5.7.3 Planned field work

5.7.3.1 Long-term hydraulic monitoring (by contractor)

After the HDB-6,7,8 borehole investigations have been completed, a multi-packer system that contains up to 10 packed-off intervals will be installed in each borehole. Suitable packed-off intervals for the hydraulic monitoring are selected on the basis of the geological, hydrogeological and hydrochemical investigations in the HDB-6,7,8 borehole investigations. Data on hydraulic heads are acquired hourly throughout the excavation of the shaft/drift. Information on the spatial distribution and variations in hydraulic heads with time, provided by the long-term hydraulic monitoring, is needed for evaluation of the groundwater flow system. The individual contractors will carry out all the work mentioned above except for data acquisition.

5.7.4 Reporting

5.7.4.1 Long-term hydraulic monitoring

Prompt reports

1. Installation of a multi-packer system
   The progress of the installation work should be reported every day.

2. Hydraulic monitoring (every month)
   Raw and plotted data (pressure-time), relevant detection limits and precision, details of the system set-up, measurement method employed, comments on the measurements and details of anything abnormal or unexpected are reported. Data will be provided by JNC.

Final reports (by the end of contract period)

1. Installation of a multi-packer system
   The report should clearly and accurately show packed-off intervals, inflation pressure of packers, hydraulic heads and anything abnormal that occurred during the installation of the multi-packer system. Drawings of the multi-packer system and its set-up are appended.

2. Hydraulic monitoring
All results are compiled and reported with full data sets based on the data provided by JNC. The report should contain the interpretation of the results and comments on the spatial distribution and variations in hydraulic heads with time prior to and in response to excavation of the shaft/drift.

6 INVESTIGATION PROCEDURE AND SCHEDULE

This section describes the procedure and schedule for the "base case" investigation campaign to be executed in the HDB-6,7,8 boreholes. These are summarized in Figure 21,22,23 respectively. In addition, a couple of alternative programs (optional cases) are also discussed.

6.1 Investigation Procedure

The investigation campaign will be performed in four phases during drilling and one phase after drilling. The campaign has been defined on the basis of geological, hydrogeological, hydrochemical and rock mechanical prediction, the priority of planned investigations and the time available for the investigations.
All depths are given as depth in meters from the ground level (mbgl). The actual depths at which the target features are intersected may be different from the predicted depths given below. Similarly, the proposed depths of testing and the sampling intervals are approximate and may change in light of actual geological and geophysical observations during the field investigations.

6.1.1 Base case

The following investigation procedures are described for each of the drilling phases.

HDB-6 borehole

During drilling

Phase I *0 – 4mbgl / Surface soil and sedimentary rocks (Koetoi Formation)*

1. Installation of 13-3/8 inch (339.7mm) casing pipes to 4mbgl and fixing by full hole cementing.

Phase II *4 – 130mbgl / Sedimentary rocks (Koetoi Formation)*

1. Begin 6 1/4 inch wireline, triple-tube, core drilling to 130 mbgl with drilling fluid I. Core recovery is done using the inner core barrel on wireline. The borehole diameter is approximately 158mm and the core diameter is approximately 86mm. Continuous monitoring of drilling parameters such as rate of penetration, bit revolution, weight on bit, pumping pressure, rate of drilling water supply and return, fluid gas content, using a suitable monitoring device, will be done to the final depth at 620mbgl. Borehole diameter will be checked every 50m drilling from the top to the final depth of the borehole.
2. Flushing the borehole to extract cuttings with drilling fluid I.
3. Extraction of 6 1/4 inch wireline tools, and drilling pipes and 7 inch temporary casing pipes.
4. Borehole TV and geophysical logging from 4 to 130mbgl.
5. Hydraulic testing and water sampling using a single or double packer assembly in the Koetoi Formation
   - Aims: transmissivity (T), hydraulic head (H), flow model (M) and water sample (W)
   - Methods: Slug, pulse and pumping
   - Structure/Lithology: transmissive zone in the Koetoi Formation.

6. Reaming by a tricone bit (12-1/4 inch, 311.2mm diameter) with drilling fluid I from 3mbgl to 130mbgl.
7. Installation 9-5/8 inch (244.5mm) casing pipes to 130mbgl and full hole cementing. Flushing the borehole to extract cuttings after dredging cement.

Phase III *130 – 360mbgl / Koetoi Formation, transition zone between Koetoi and Wakkanai Formation*

1. Continue 6 1/4 inch wireline core drilling to 360mbgl with drill fluid I.
2. Flushing the borehole to extract cuttings with drilling fluid I.
3. Extraction of 6 1/4 inch wireline tools, drilling pipes
4. Borehole TV and geophysical logging from 130 to 360mbgl (Cement bond logging: surface to 130mbgl).
5. Hydraulic testing and water sampling (2 campaigns) using a single or double packer assembly in the Koetoi Formation
   - Aims: transmissivity (T), hydraulic head (H), flow model (M) and water sample (W)
   - Methods: Slug, pulse and pumping
   - Structure/Lithology: transmissive/intact zone in the Koetoi Formation.
6. Hydraulic fracturing test (3 points) and borehole expansion test (6 points) in the Koetoi Formation.
7. Reaming by a tricone bit (8-1/2 inch, 215.9mm diameter) with drilling fluid I from 130mbgl to 360mbgl.
8. Installation 7 inch (177.8mm) casing pipes to 360mbgl and full hole cementing. Flushing the borehole to extract cuttings after dredging cement.

Phase IV *360 – 620mbgl / transition zone between Koetoi and Wakkanai Formation,* Wakkanai Formation

1. Continue 6 1/4 inch wireline core drilling to 620mbgl with drill fluid I.
2. Flushing the borehole to extract cuttings with drilling fluid I.
3. Extraction of 6 1/4 inch wireline tools, drilling pipes
4. Borehole TV and geophysical logging from 360 to 620mbgl (Cement bond logging: surface to 360mbgl).
5. Hydraulic testing and water sampling (2 campaigns) using a single or double packer assembly in the Wakkanai Formation
   - Aims: transmissivity (T), hydraulic head (H), flow model (M) and water sample (W)
   - Methods: Slug, pulse and pumping
   - Structure/Lithology: transmissive/intact zone in the Wakkanai Formation.
6. Hydraulic fracturing test (3 points) and borehole expansion test (6 points) in the

Wakkanai Formation.

7. Installation 4-1/2 inch (114.3mm) casing pipes to 310-620mbgl (use liner hanger) and full hole cementing.
8. Cement bond logging (0-620mbgl)
9. PS logging
10. Perforation of casing (max. 8 sections, 10 holes/section)

HDB-7 borehole

During drilling

Phase I 0 – 10mbgl / Surface soil and sedimentary rocks (Yuchi Formation)

1. Installation of 13-3/8 inch (339.7mm) casing pipes to 10mbgl and fixing by full hole cementing.

Phase II 10 – 150mbgl / Sedimentary rocks (Yuchi and Koetoi upper Formation)

1. Begin 6 1/4 inch wireline, triple-tube, core drilling to 150 mbgl with drilling fluid I. Core recovery is done using the inner core barrel on wireline. The borehole diameter is approximately 158mm and the core diameter is approximately 86mm. Continuous monitoring of drilling parameters such as rate of penetration, bit revolution, weight on bit, pumping pressure, rate of drilling water supply and return, fluid gas content, using a suitable monitoring device, will be done to the final depth at 520mbgl. Borehole orientation and diameter will be checked every 50m drilling from the top to the final depth of the borehole.
2. Flushing the borehole to extract cuttings with drilling fluid I.
3. Extraction of 6 1/4 inch wireline tools, and drilling pipes and 7 inch temporary casing pipes.
4. Geophysical logging from 10 to 150mbgl.
5. Hydraulic testing and water sampling using a single or double packer assembly in the Yuchi Formation
   - Aims: transmissivity (T), hydraulic head (H), flow model (M) and water sample (W)
   - Methods: Slug, pulse and pumping
   - Structure/Lithology: transmissive zone in the Yuchi Formation.
6. Reaming by a tricone bit (12-1/4 inch, 311.2mm diameter) with drilling fluid I from 10mbgl to 150mbgl.
7. Installation 9-5/8 inch (244.5mm) casing pipes to 150mbgl and full hole cementing. Flushing the borehole to extract cuttings after dredging cement.

Phase III 150 – 320mbgl / Yuch, Koetoi upper and Koetoi mainFormation

1. Continue 6 1/4 inch wireline core drilling to 320mbgl with drill fluid I.
2. Flushing the borehole to extract cuttings with drilling fluid I.
3. Extraction of 6 1/4 inch wireline tools, drilling pipes
4. Geophysical logging from 150 to 320mbgl (Cement bond logging: surface to 150mbgl).
5. Hydraulic testing and water sampling (2 campaigns) using a single or double packer assembly in the Koetoi Formation
   - Aims: transmissivity (T), hydraulic head (H), flow model (M) and water sample (W)
   - Methods: Slug, pulse and pumping

- Structure/Lithology: transmissive/intact zone in the Koetoi Formation.

7. Reaming by a tricone bit (8-1/2 inch, 215.9mm diameter) with drilling fluid I from 150mbgl to 320mbgl.
8. Installation 7 inch (177.8mm) casing pipes to 320mbgl and full hole cementing. Flushing the borehole to extract cuttings after dredging cement.

Phase IV 320 – 520mbgl / Koetoi Formation,

1. Continue 6 1/4 inch wireline core drilling to 520mbgl with drill fluid I.
2. Flushing the borehole to extract cuttings with drilling fluid I.
3. Extraction of 6 1/4 inch wireline tools, drilling pipes
4. Geophysical logging from 320 to 520mbgl (Cement bond logging: surface to 320mbgl).
5. Hydraulic testing and water sampling (2 campaigns) using a single or double packer assembly in the Koetoi Formation
   - Aims: transmissivity (T), hydraulic head (H), flow model (M) and water sample (W)
   - Methods: Slug, pulse and pumping
   - Structure/Lithology: transmissive/intact zone in the Koetoi Formation.
7. Installation 4-1/2 inch (114.3mm) casing pipes to 270-520mbgl and full hole cementing.
8. Cement bond logging (0-520mbgl)
9. PS logging
10. Perforation of casing (max. 8 sections, 10 holes/section)

HDB-8 borehole

During drilling

Phase I *0 – 4mbgl / Surface soil and sedimentary rocks (Koetoi Formation)*

1. Installation of 13-3/8 inch (339.7mm) casing pipes to 4mbgl and fixing by full hole cementing.

Phase II *4 – 130mbgl / Sedimentary rocks (Koetoi Formation)*

1. Begin 6 1/4 inch wireline, triple-tube, core drilling to 130 mbgl with drilling fluid I. Core recovery is done using the inner core barrel on wireline. The borehole diameter is approximately 158mm and the core diameter is approximately 86mm. Continuous monitoring of drilling parameters such as rate of penetration, bit revolution, weight on bit, pumping pressure, rate of drilling water supply and return, fluid gas content, using a suitable monitoring device, will be done to the final depth at 470mbgl. Borehole orientation and diameter will be checked every 50m drilling from the top to the final depth of the borehole.
2. Flushing the borehole to extract cuttings with drilling fluid I.
3. Extraction of 6 1/4 inch wireline tools, and drilling pipes and 7 inch temporary casing pipes.
4. Geophysical logging from 3 to 130mbgl.
5. Hydraulic testing and water sampling using a single or double packer assembly in the Koetoi Formation
   - Aims: transmissivity (T), hydraulic head (H), flow model (M) and water sample (W)
   - Methods: Slug, pulse and pumping
   - Structure/Lithology: transmissive zone in the Koetoi Formation.
6. Reaming by a tricone bit (12-1/4 inch, 311.2mm diameter) with drilling fluid I from 3mbgl to 130mbgl.
7. Installation 9-5/8 inch (244.5mm) casing pipes to 130mbgl and full hole cementing. Flushing the borehole to extract cuttings after dredging cement.

Phase III *130 – 300mbgl / Koetoi Formation*

1. Continue 6 1/4 inch wireline core drilling to 300mbgl with drill fluid I.
2. Flushing the borehole to extract cuttings with drilling fluid I.
3. Extraction of 6 1/4 inch wireline tools, drilling pipes
4. Geophysical logging from 130 to 300mbgl (Cement bond logging: surface to 130mbgl).
5. Hydraulic testing and water sampling (2 campaigns) using a single or double packer assembly in the Koetoi Formation
   - Aims: transmissivity (T), hydraulic head (H), flow model (M) and water sample (W)

- Methods: Slug, pulse and pumping
- Structure/Lithology: transmissive/intact zone in the Koetoi Formation.

6. Hydraulic fracturing test (1 point) in the Koetoi Formation.
7. Reaming by a tricone bit (8-1/2 inch, 215.9mm diameter) with drilling fluid I from 130mbgl to 300mbgl.
8. Installation 7 inch (177.8mm) casing pipes to 300mbgl and full hole cementing. Flushing the borehole to extract cuttings after dredging cement.

Phase IV *300 – 470mbgl / transition zone between Koetoi and Wakkanai Formation,* Wakkanai Formation

1. Continue 6 1/4 inch wireline core drilling to 470mbgl with drill fluid I.
2. Flushing the borehole to extract cuttings with drilling fluid I.
3. Extraction of 6 1/4 inch wireline tools, drilling pipes
4. Geophysical logging from 300 to 470mbgl (Cement bond logging: surface to 300mbgl).
5. Hydraulic testing and water sampling (2 campaigns) using a single or double packer assembly in the Wakkanai Formation
   - Aims: transmissivity (T), hydraulic head (H), flow model (M) and water sample (W)
   - Methods: Slug, pulse and pumping
   - Structure/Lithology: transmissive/intact zone in the Wakkanai Formation.
6. Hydraulic fracturing test (1 point) in the Koetoi Formation.
7. Installation 4-1/2 inch (114.3mm) casing pipes to 250-470mbgl and full hole cementing.
8. Cement bond logging (surface to 470mbgl)
9. PS logging
10. Perforation of casing (max. 8 sections, 10 holes/section)

6.1.2 Optional cases

Optional case #1: Loss of drilling fluid during drilling

If loss of drilling fluid occurs, all planned investigations that would have been performed during and after drilling, to the depth of the drilling fluid loss, will be executed: hydraulic testing and water sampling with a single or double packer configuration, borehole TV, geophysical and fluid logging. After these investigations have been completed, plugging or cementing is carried out at the site where the loss occurs, to reduce drilling fluid loss to the formation and drilling is resumed

Optional case #2: Borehole collapse

If it is necessary to stabilize the borehole wall where collapse occurs, all planned and feasible investigations, including all hydraulic tests, to the depth of the collapse will be executed. This section will then be partially cemented. In this case, the interval should be isolated with a single or double packer assembly, as necessary.
If collapse occurs even after the cementing of the location, re-cementing will be carried out.

Optional case #3: Drilling fluid loss and borehole collapse at the same location

In this case, all planned investigations to the location where drilling fluid loss and collapse occur are executed. After these investigations have been completed, cementing is carried out at the location and drilling is carried on.
If drilling fluid loss and/or borehole collapse occurs even after the cementing of the location, re-cementing will be carried out.

6.2 Schedule

The program is planned to start in July 2003 and take 9 months, as shown in Figure 20. Minimum time requirements for the planned field and laboratory work are as follows:

- Site preparation: 1.5 months
- Drilling/on-site investigations: 6.0 months
- Site restoration: 1.5 month
- Laboratory work: 4.0 months
- Reporting 7.0 months

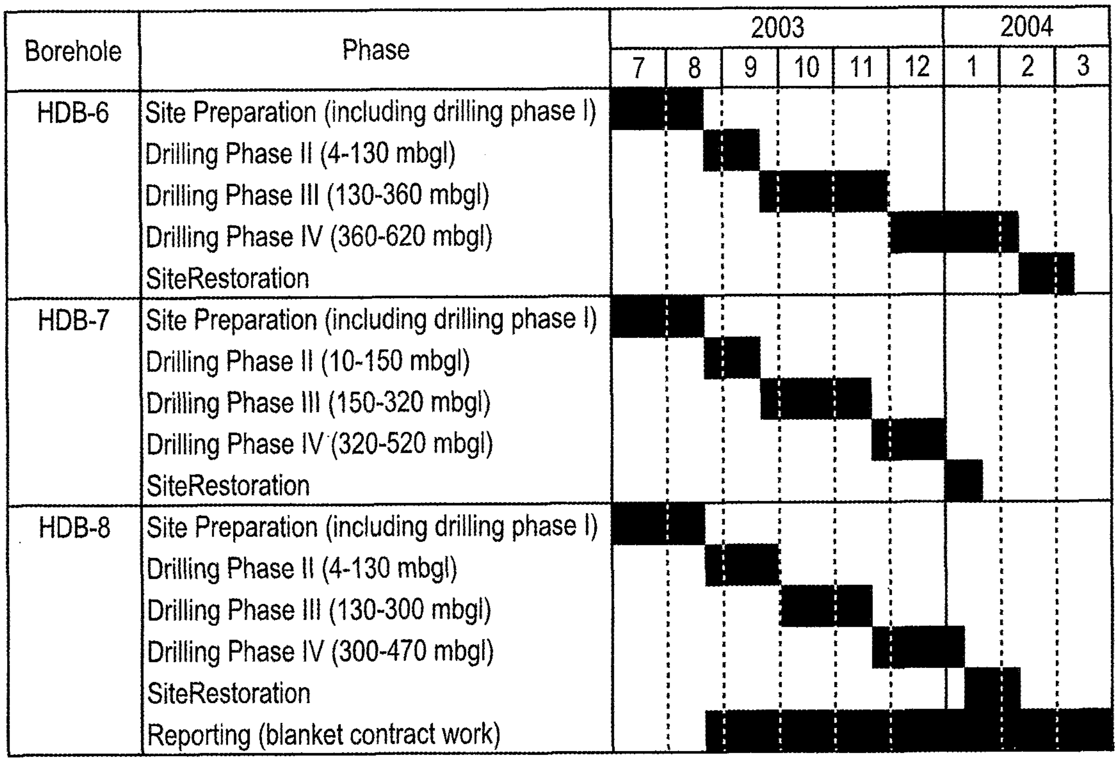


Figure 20 Timeplan of the HDB-6,7,8 borehole investigations

7 QUALITY ASSURANCE/CONTROL AND REPORTING

It is required that a quality assurance (QA) system be applied to all activities and operations carried out by contractors, which meets at least national standards.

In addition, JNC has a responsibility for the quality control (QC) of each aspect throughout the contract work and for the careful review of their deliverables as described in the preceding sections. JNC's QC system is employed to ensure that the purpose for which the work is carried out is likely to be successfully achieved. It is also intended, for the QC purpose, to have external review by experts (*e.g.* under international collaboration studies) in the particular field during the HDB borehole investigations.

8 BUDGET FOR THE MIZ-1 BOREHOLE INVESTIGATIONS

JNC plans to contract with a main contractor for the HDB borehole investigations, which will cover all of the planned fieldwork except for the long-term hydraulic monitoring. About 700 million yen has been budgeted for this blanket contract.

ACKNOWLEDGEMENT

We gratefully acknowledge Dr. Bernhard Frieg of Nagra (National Cooperative for the Disposal of Radioactive Waste) for support and review during the drawing up of this working program.

REFERENCE

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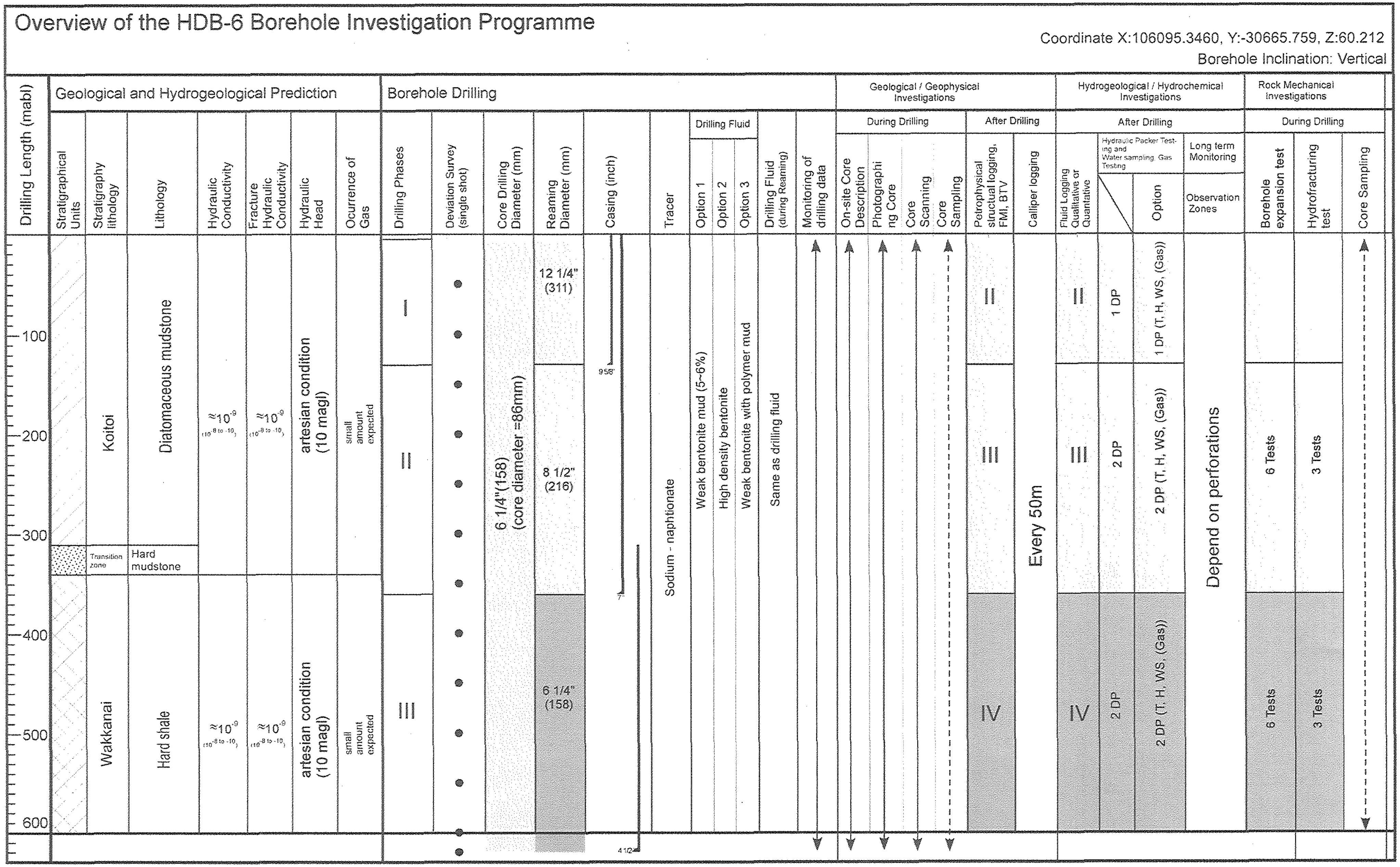
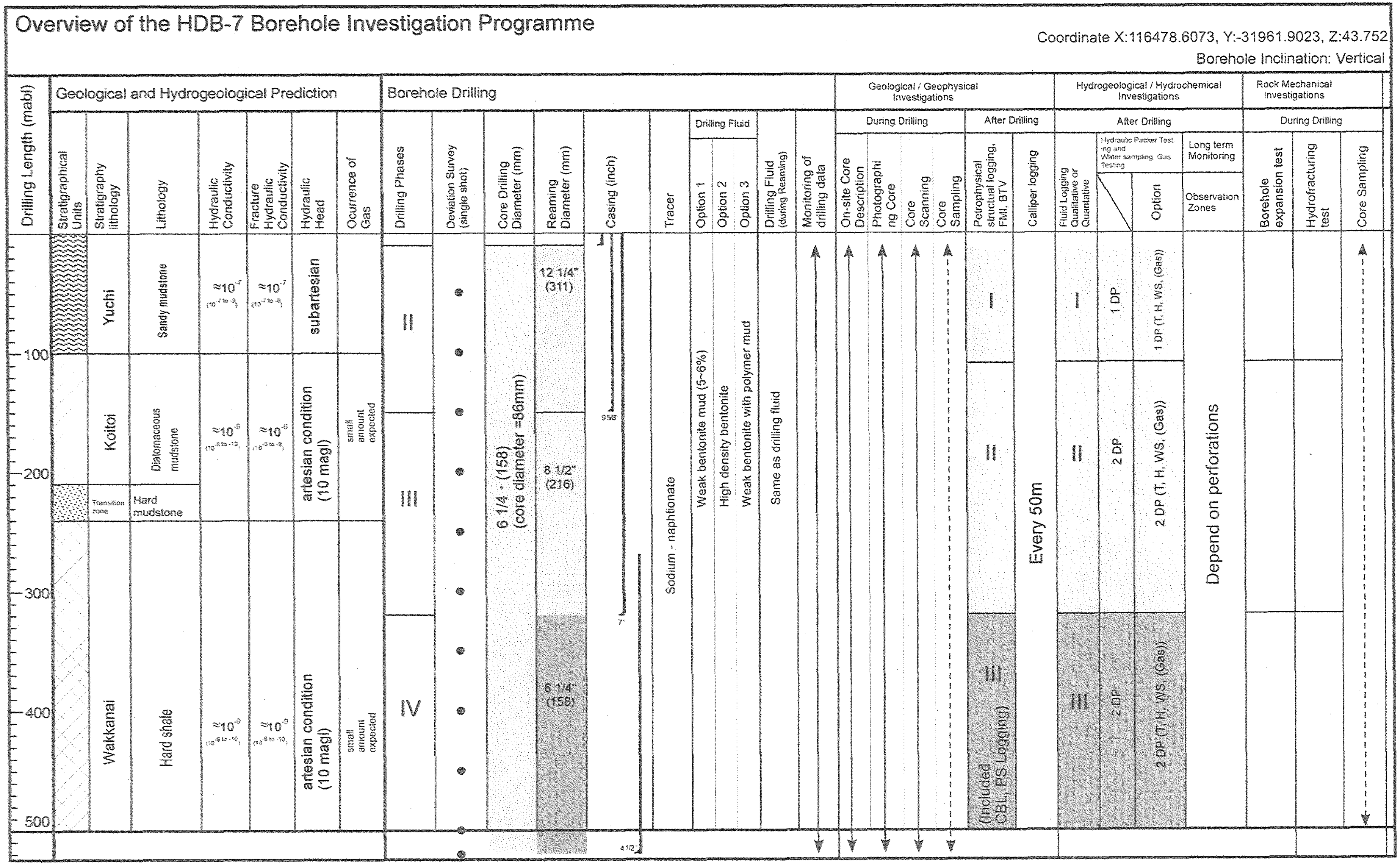


T=Transmissivity
H=Head
WS=Water Sampling

SP=Single Packer
DP=Double Packer
Gas=Gas Testing

Figure 21 Overview of the HDB-6 borehole investigation programme



T=Transmissivity
H=Head
WS=Water Sampling

SP=Single Packer
DP=Double Packer
Gas=Gas Testing

If necessary an additional CBL-Log will be made over the entire 4 1/2"-casing section after cementation

Figure 22 Overview of the HDB-7 borehole investigation programme

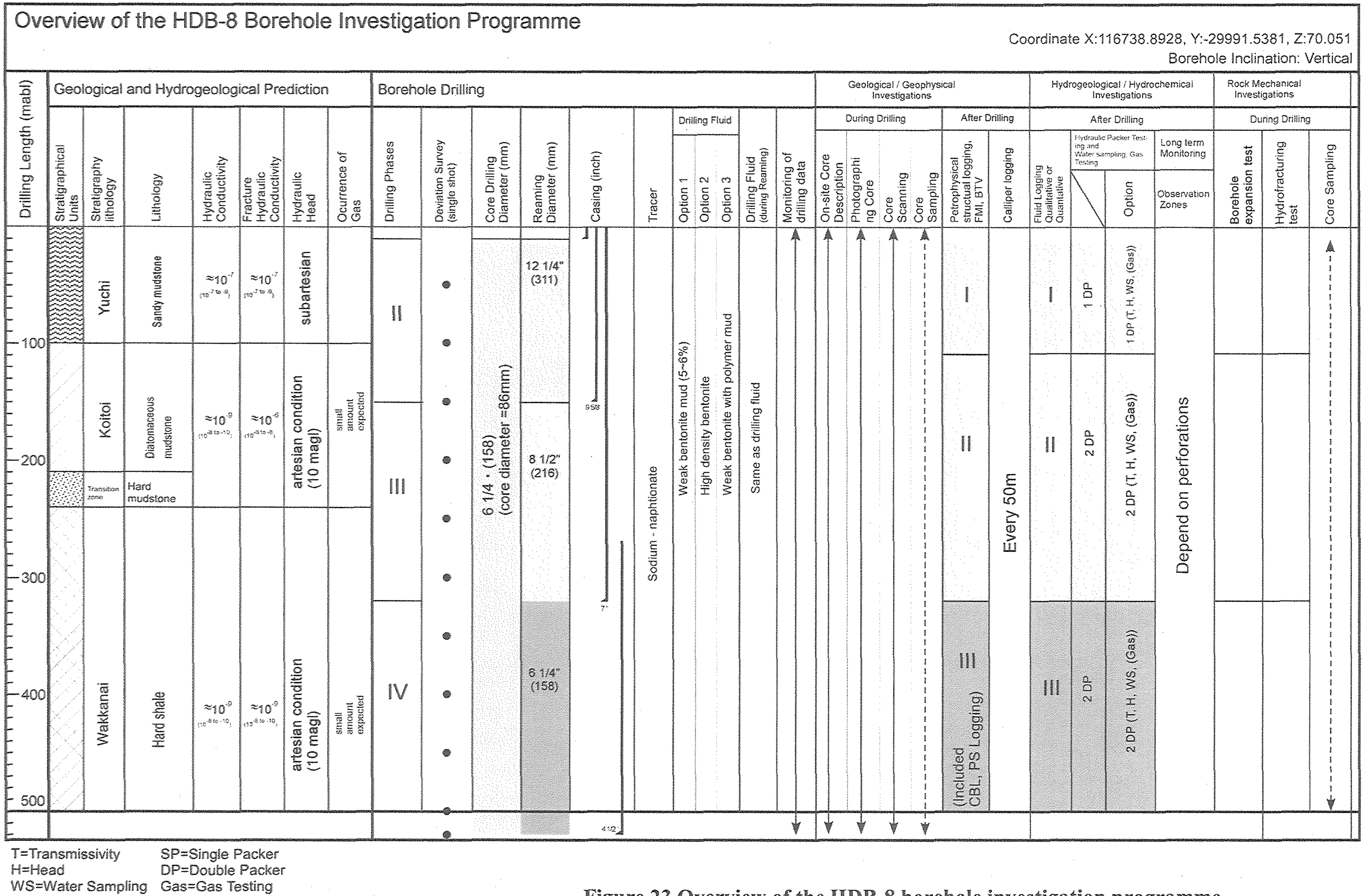


Figure 23 Overview of the HDB-8 borehole investigation programme

On-site Core Description Manual

Version: August 2003

CONTENTS

1 Depth

Fill in the depth along the borehole axis per 10 cm.

2 Formation name

Assign the rocks to one of the following units: the Wakkanai formation, the Koetoi formation, the Yuchi formation and terrace deposit(Quaternary).

3 Rock name

The sedimentary rocks are divided into hard shale, diatomaceous mudstone, tuffaceous sandstone, tuffaceouse mudstone, tuff, and conglomerate.

4 Lithofacies

Describe the sedimentary structure such as bedded/laminated, massive and so on. In addition, interval, dip angle, clear/unclear, and so on, about bedded/laminated structure.

5 Color

Describe the color tone of cores in a wet state using a color chart. In addition, describe the values of L*a*b using a colorimeter.

6 Hardness

Classify the rocks in the degree of hardness according to the following descriptors. In addition, measure the hardness value by hardness tester.

Descriptor	Criteria
H1	Can be readily indented, grooved or gouged with fingernail, or carved with a knife.
H2	Can be grooved or gouged easily by knife with light pressure, can be scratched with fingernail.
H3	Can be scratched with knife.
H4	Core cannot be scratched with knife.

(modified from USBR, 2000)

7 Rock mass classification

Classify the rocks in the degree of physical disintegration according to the following descriptors.

Descriptor	Criteria
CH	Slightly dull sound when struck with hammer and fractured by heavy hammer blow.
CM	Some dull sound when struck with hammer and fractured by hammer blow.
CL	Dull sound when struck with hammer and fractured by light hammer blow.
D	Very dull sound when struck with hammer and easily fractured by very light hammer blow.

(modified from Tanaka, 1964)

8 Weathering

Classify the rocks in the degree of weathering caused by atmospheric oxygen or surface water, according to the following descriptors.

Descriptor	Criteria
α	Fresh. No discoloration.
β	Slightly weathered. Discoloration limited to surface of, or short distance from, fractures. Minor to complete discoloration of most surface.
γ	Moderately weathered. Discoloration extends from fractures, usually throughout. All fracture surfaces are discolored.
δ	Intensely weathered. Discoloration throughout. All fracture surfaces are discolored, surfaces friable.
ε	Decomposed. Discoloration throughout. Resembles a soil.

(modified from USBR, 2000)

9 Fossil and Trace fossil

Describe the following items about fossils and trace fossils(outer diameter: >5 mm). In addition, mark the positions of the fossils and the trace fossils by the red line into core scanning image.

Fossil: types(bivalvia/gastropoda/microfossil/flora/etc.), size(diameter), form, the direction of a row.

Trace fossil: size(outer diameter and inner diameter), dip angle of long axis (if possible).

10 RQD and Core recovery

- RQD(rock quality designation) is defined by the percentage of the sum of lengths of cores longer than 10cm in the whole core length in 1m drilling.

  RQD = (sum of length of cores over 10cm) / (whole core length) x *100* [%]

- Core recovery is defined by the percentage of cored length in 1m drilling. The core length is measured at the centre of the core.

  Core recovery = (whole core length in 1m drilling) / (1m) x *100* [%]

11 Schematic section of core

Describe the schematic sections of cores about fractures excluding disking fractures. The disking fractures are tend to be level, have the plumose structure and have the form of a convex below.

12 Fracture number

Describe the number of fractures. The number is 230-5, if the fracture is the 5th-shallow fracture in 230-231 m depth. In addition, the number is 230'-2, if the fracture is the 2nd-shallow healed fracture in 230-231 m depth.

13 Dip of fracture

Describe the dip angle of fracture.

14 Fracture types

Classify the fractures according to the following descriptors.

Descriptor	Criteria
h-f	Healed fracture such as planeless fault or vein.
f	Non-healed fracture.
o-f	Open fracture. When a fracture is put together, a core does not fit in exactly.

15 Fracture Shapes

Classify the fractures according to the following descriptors.

Descriptor	Criteria
P	Planar shaped fracture.
I	Irregular shaped fracture.
C	Curved shaped fracture.
S	Stepped shaped fracture.

16 Striation on fracture

Classify fractures according to the following descriptors. In addition, describe the rake on SL and/or ST.

Descriptor	Criteria
SS	Fracture with slickenside.
SL	Fracture with slicken line (and slickenside).
ST	Fracture with slicken step (and slickenside).
-	Fracture without striation or slickenside.

17 Fault rock classification

Classify fractures according to the following descriptors. In addition, describe the thickness of fault rocks.

Descriptor	Criteria
f-b	Fracture with fault breccia. Fault breccia: incohesive, random fabric, fine matrix < 30%
f-g	Fracture with fault gouge. Fault gouge: incohesive, random fabric, fine matrix > 30%
-	Fracture without fault rock.

(after Shimamoto et al., 1996)

18 Origin of fracturing

Classify the fractures according to the following descriptors:

Descriptor	Criteria
S	Shear fracture with slicken line/slicken step/slickenside/fault rock.
T	Tension fracture with plumose structure.
U	Unknown.

19 Width and color of altered zone along fracture

Describe the widths and the colors of altered zones along fractures. The width is total length of altered zones of both-side wall rocks of a fracture.

20 Thickness of fracture fillings

Describe the thickness of fracture fillings.

21 Types and volumes of fracture fillings

Describe the types of fracture fillings in the order of relative age, using the following letter symbols.

Qtz: quartz Fe: Fe-oxyhydroxide/hydroxide Chl: chlorite Py: pyrite(euhedral)
Py: pyrite(anhedral) Cal: calcite(euhedral) Cal: calcite(anhedral) Cly: clay minerals

In addition, classify the amount of fracture fillings to the following descriptors.
Ex: Cal(3), Py (1)

Descriptor	Criteria
(1)	The smaller quantity of fracture fillings than 10% in the area ratio on the surface of fracture.
(2)	The quantity of fracture fillings of 10~50% in the area ratio on the surface of fracture.
(3)	The quantity of fracture fillings of 50~90% in the area ratio on the surface of fracture.
(4)	The larger quantity of fracture fillings than 90% in the area ratio on the surface of fracture.

22 Remarks

When there is the zone containing the master faults or the zone affected by intense fracturing, describe generally the width of the zone, the filling condition and so on, and indicate the schematic figure of the zone about fracturing. When the disking fractures progress, describe the interval of them.

Reference

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