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Horonobe Underground Research Laboratory Project Investigation Program for the 2007 Fiscal Year (Translated Document)

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As part of the research and development program on the geological disposal of high-level radioactive waste (HLW), the Horonobe Underground Research Center, a division of the Japan Atomic Energy Agency (JAEA), is implementing the Horonobe Underground Research Laboratory Project (Horonobe URL Project) with the aim at investigating sedimentary rock formations.

According to the research plan described in the Midterm Plan of JAEA, geological investigations are to be carried out during the drilling of a shaft down to intermediate depth, while research and development in the areas of engineering technology and safety assessment are to be promoted by collaboration with other research organizations. The results of the R&D activities will be systematized as a "knowledge base" that supports a wide range of arguments related to the safety of geological disposal.

The Horonobe URL Project is planned to extend over a period of 20 years. The investigations will be conducted in three phases, namely "Phase 1: Surface-based investigations", "Phase 2: Construction phase" (investigations during construction of the underground facilities) and "Phase 3: Operation phase" (research in the underground facilities). This report summarizes the investigation program for the 2007 fiscal year (2007/2008), the third year of the Phase 2 investigations.

In the 2007 fiscal year, investigations in "geoscientific research", including "development of techniques for investigating the geological environment", "development of techniques for use in the deep underground environment" and "studies on the long-term stability of the geological environment", is continuously carried out. Investigations in "research and development on geological disposal technology", including "improving the reliability of disposal technologies" and "enhancement of safety assessment methodologies", are also continuously carried out.

Construction of the underground facilities is ongoing at the Ventilation Shaft and the East Shaft. Pre-boring close to the Ventilation Shaft is also carried out.

Regarding the surface facilities, construction of the Public Information House and preparation for the exhibits are still continuing and will be completed in May 2007. The Public Information House is scheduled to open in this summer. A detailed design will be drawn up for the International Communication House.

Keywords: *Horonobe URL Project, High-level Radioactive Waste, Geological Disposal Technology, Geoscientific Research*

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幌延深地層研究計画 平成19年度調査研究計画
(翻訳資料)

日本原子力研究開発機構
地層処分研究開発部門 幌延深地層研究ユニット
(編) 松井 裕哉+, 中山 雅, 真田 祐幸, 山口 雄大※

(2008年6月12日受理)

本計画は、独立行政法人日本原子力研究開発機構が堆積岩を対象に北海道幌延町で実施しているものです。

日本原子力研究開発機構の中期目標では、深地層の研究計画について、中間的な深度までの坑道掘削時の調査研究を進めるとともに、工学技術や安全評価に関する研究開発を他の研究開発機関と連携して実施し、これらの成果を地層処分の安全性に係る一連の論拠を支える知識ベースとして体系化することとしています。

本計画は、調査研究の開始から調査研究の終了まで20年程度の計画とし、「地上からの調査研究段階（第1段階)」、「坑道掘削（地下施設建設）時の調査研究段階（第2段階)」、「地下施設での調査研究段階（第3段階)」の3つの段階に分けて実施することとしており、平成19年度は第2段階の3年目にあたります。

平成19年度は、地層科学研究として、地質環境調査技術開発、地質環境モニタリング技術開発、深地層における工学的技術の基礎の開発および地質環境の長期安定性に関する研究を、地層処分研究開発として、処分技術の信頼性向上および安全評価手法の高度化についての調査研究を継続します。

また、地下施設の建設については、換気立坑と東立坑の掘削を継続するとともに、先行ボーリング調査を実施します。

地上施設については、平成18年度に引き続き、PR施設の建設工事および展示物の製作を行い、平成19年5月末に竣工、夏頃に開館する予定です。また、国際交流施設については、実施設計を行います。

本報告書は、日本原子力研究開発機構 研究開発報告書「幌延深地層研究計画 平成19年度調査研究計画」(JAEA-Research 2007-048) を英訳したものである。
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1. Introduction

As part of the research and development program on geological disposal of high-level radioactive waste (HLW), the Horonobe Underground Research Center, a division of the Japan Atomic Energy Agency (JAEA), is implementing the Horonobe Underground Research Laboratory (URL) Project.

The Horonobe URL, in which deep sedimentary rock will be investigated, is one of the underground research laboratories mentioned in the "Framework for Nuclear Energy Policy" published by the Japan Atomic Energy Commission (AEC, 2005).

In the "Framework for Nuclear Energy Policy", the following statement is described:

"Research and development institutions, led by the Japan Atomic Energy Agency, through utilization of underground research facilities, should rigorously continue to conduct scientific research on underground geology, basic research and development toward the improvement of reliability of geological disposal technology and safety assessment methods, and research and development for safety regulations."

In the plan for meeting the midterm goal (Midterm Plan) (October 1st 2005 to March 31st 2010) drawn up by the Japan Atomic Energy Agency on the basis of the goals specified by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) and the Ministry of Economy, Trade and Industry (METI) in October 2005 (MEXT and METI, 2005), the R&D activities on processing and disposal technology for high-level waste are described as follows:

"The Agency will designate two areas, R&D on geological disposal and scientific research on underground geology. It will carry out R&D in collaboration with other R&D institution, use the outcomes of that to form a "knowledge base" that supports a variety of arguments related to the view and evaluation on ensuring the safety of geological disposal and systematize it. The outcomes of R&D during the midterm goal period will be compiled, through review of expert in Japan and abroad, as a comprehensive report and knowledge base that ensure a set level of technological quality."

"In consideration of scientific and engineering factors depending on depth and the requirement set forth in the Specified Radioactive Waste Final Disposal Act (FY 2000 Law No. 117) (depth of 300 meters underground or more), research will be conducted when a shaft is excavated to an intermediate depth (about 500 meters underground in Mizunami City; about 300 meters underground in Horonobe-cho)".

The Horonobe URL Project is planned to extend over a period of 20 years. The investigations will be conducted in three phases, namely "Phase 1: Surface-based investigations", "Phase 2: Construction phase" (investigations during construction of the underground facilities) and "Phase 3: Operation phase" (investigations in the underground facilities). This report summarizes the investigation program for the 2007 fiscal year (2007/2008), the third year of the Phase 2 investigations and also the third year of the Midterm Plan.

In 2007/2008, at the URL Area (mainly Hokushin Area) and its surroundings, investigations from the previous year are continued. In addition, at the URL Site, construction of the underground facilities using an excavation tower and Phase 2 investigations from the previous fiscal year are continued.

2. Outline of the investigation program for the 2007 fiscal year

The outlines of the investigations being conducted in 2007 fiscal year are described below.

Geoscientific research: As part of the development of techniques for investigating the geological environment, investigations will be carried out on geological structure, hydrogeology, geochemistry and rock mechanics during construction of the underground facilities and Pre-boring investigation. The resulting geoscientific data will be used to confirm the reliability of the models (geological structure, hydrogeology, geochemistry and rock mechanics) of the geological environment that were constructed based on data obtained during the Phase 1 surface-based investigations, and to improve and refine these models. In addition, newly a detailed geological structure model in the vicinity of the tunnel is constructed.

Development of investigation techniques and equipment for use in the limited space conditions of the underground facilities is continuously conducted. And examination on applicability of the controlled drilling techniques which were initiated in Phase 1, and specific resistivity monitoring from ground surface, are also continuously conducted. In addition, development of techniques for investigating the boundary of saline and fresh water is initiated.

As part of the developing techniques for monitoring the geological environment, observations of groundwater pressure/geochemistry are ongoing using long-term monitoring systems installed until 2006. For the remotely operated monitoring system, a long-term observation by the monitoring system equipped until the 2005 fiscal year is continued, and processing and the analysis of the data obtained are tried. In addition, how change in the geological environment during construction of the underground facilities is expressed on the analyzed result.

As part of the development of engineering techniques for use in the deep underground environment, measurement instrument systems on rock displacement and stress are installed with shaft excavation. The validity of tunnel design and tunnel lining techniques is confirmed based on these acquired data. In parallel, based on the results of the model experiments on the fire disaster in the underground facilities, an analysis method of the behavior of smoke-filled air is developed.

Research and development on geological disposal technology: In the studies on the long-term stability of the geological environment including investigations of fault activity and analyses of rock samples, continuous measurements are being carried out using equipments such as GPS (Global Positioning System) points, instruments for electromagnetic surveys (magnetotelluric method)[1] and seismographs installed at ground surface and in the boreholes. In addition, newly GPS measurement points for the purpose of analyzing the crustal movements are equipped around the URL area.

Research and development on geological disposal technology: As part of the improving the reliability of disposal technologies, laboratory tests on the workability of materials such as low-alkaline concrete are being conducted, to provide input for detailed planning of in-situ tests to be performed in the underground facilities in Phase 2. Information and conditions are organized for confirming the applicability of

[1] The changes in natural electromagnetic field originating from sunspot activity generate inductive current reflected the geological structure in the underground. On the magnetotelluric method, new changes in the electromagnetic field originated by electric current are measured. And these results are used to estimate sub-surface geological structures.

engineered barrier system (EBS). Using the data and the knowledge acquired until 2006 fiscal year, information and conditions are organized for confirming the applicability of EBS design methods and for evaluation of the long-term integrity.

As part of the enhancement of safety assessment methodologies, accumulation of basic data related to the mass transport is continued. In addition, based on the results of groundwater flow analyses and mass transport analyses on a regional scale (15 km×30 km) and on a site scale (10 km×10 km) (both including the URL area), geological environmental features and kind/precision of the parameters that affect the groundwater flow and mass transport are examined.

Classification of the investigations outlined above and brief explanations are provided in Table 1. The locations of the investigations and the observation points in Horonobe-cho, including the URL site, are shown in Fig. 1.

Construction of the underground facilities: The ventilation shaft and the east access shaft are still being excavated. In addition, expansion of land for a surplus soil (muck) dumping yard is conducted. In addition, the borehole investigation in the vicinity of the ventilation shaft is being conducted to deal with spring water predicted on tunnel excavation. The main aims of this investigation are to pinpoint places and to estimate amount and water property of the spring water. The results of this investigation are reflected for the drainage treatment plan decision, for the detailed execution scheme decision for spring water reduction at pinpointed place and for the geoscientific research. Surplus soil (muck) is transported to the permanent dumping yard. The drainage water produced in the underground facilities is released to the Teshio River by drainage pipes after appropriate treatment at the drainage treatment facility. The adjustment design of the URL is planned.

Construction of the surface facilities: Construction of the Public Information House including fabrication of its exhibits is continued, and is completed at the end of May 2007. The Public Information House will be open in the summer of 2007. An execution design has also been developed for the International Communication House.

Environmental monitoring: Relevant parameters such as noise, vibration, water properties, flora and fauna are monitored regularly in the area around the URL site; the properties of the drainage water produced by constructing the underground facilities are also investigated.

Collaboration with other research organizations: The studies on deep sedimentary rock formations conducted as part of the Horonobe URL project are relevant to wide range of geoscientific disciplines and also contribute to various areas of academic research. JAEA therefore intends to proceed with the project by collaborating widely with experts from domestic and overseas research organizations.

3. Geoscientific research

3.1 Development of techniques for investigating the geological environment

The main objectives of the Phase 2 investigations are 1) to confirm the result of the Phase 1 investigations, especially the reliability of models of the geological environment (mainly covering several of kilometers square include URL facilities) and the applicability of investigation techniques and analysis methods, 2) to understand changes in the conditions of the geological environment and 3) to construct models of the geological environment covering an area of several meters to several tens of meters square around the underground facilities, based on data obtained during excavation. The acquisition of geoscientific data, confirmation of the reliability of the investigation techniques and the analysis methods developed in Phasel, modeling of the geological environment and development of investigation techniques/equipment for use in the underground facilities are described below.

3.1.1 Acquisition of geoscientific data

(1) Geological structure

In the Phase 2 investigations, the aim is to confirm the reliability and to revise geological structure model around the URL facilities. The geological mapping at the shafts is carried out to understand three-dimensional geological distribution and fracture continuity.

In the 2007 fiscal year, the following investigations are carried out at the shafts wall, on the borehole investigation in the vicinity of the ventilation shaft (hereinafter called Pre-boring) and at the URL area and its surroundings: geological mapping, chemical and petrological/mineralogical analyses using rock samples[2]. Observations of gas concentrations and gas analyses in shallow boreholes of several meters to several tens of meters deep drilled during FY 2003-2005 are also carried out.

(2) Hydrogeology

In the Phase 2 investigations, data for confirming the predictions of hydraulic conductivity distribution and groundwater pressure distribution in the sedimentary rock and for revising are acquired using boreholes drilled in Phase 1, meteorological observation system and the URL facilities.

In the 2007 fiscal year, data collections will be continued by using the meteorological observation system (precipitation, temperature, humidity, wind velocity, wind direction and evapotranspiration rate) and the river flux observation system.

Groundwater level and soil moisture observation will also be continued by using existing boreholes. Based on data from these observations and the results of water chemistry for river water and precipitation, groundwater flow in the shallower part of the underground environment can be roughly understood and the recharge rate from ground surface to deep underground can be estimated. Groundwater pressures are continuously monitored and any influences due to the construction of the underground facilities are confirmed.

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[2] Chemical and Petrological/mineralogical analyses are research on microfossil in the geological formations and constituent mineral of rock sample by microscopic observation and X-ray diffraction method, respectively.

In the underground facilities, information on hydrogeological structures including the properties of water-conducting features and the inflow rate from the surrounding rock, are acquired in parallel with the shaft and drift excavation. Also on the Pre-boring investigations, information on hydraulic conductivity and hydrogeological structures are also acquired. In addition, laboratory experiments using rock samples obtained in the shafts are also conducted to investigate hydraulic properties.

(3) Groundwater chemistry

In Phase 2, investigations aimed at understanding the influence of the shaft and drift excavation on the groundwater chemistry are being conducted.

In the 2007 fiscal year, water is being sampled by squeezing drillcores and by collection from the muck of excavation, from the Pre-boring investigation and from the shaft wall, and chemically analyzed. The water sampling and analysis from the existing boreholes such as HDB-1 - 11, and from shallow boreholes, are also conducted. Sampling and chemical analyses of river water and precipitation are also conducted.

(4) Rock mechanics

In the Phase 2 investigations, the distribution of mechanical properties of the sedimentary rock measured in Phase 1 are confirmed as excavating the shafts and the drifts and the influence of excavation damage on the mechanical properties of the surrounding rock is investigated.

In the 2007 fiscal year, laboratory tests aimed at confirming the validity of rock mechanical models developed in the Phase 1 investigations are conducted by using drillcores obtained in the Pre-boring investigation.

3.1.2 Evaluation of methodologies for investigation/analysis and for modeling of the geological environment

In the Phase 2 investigations, the validity of models of the geological environment developed in Phase 1 is confirmed and they are improved as needed. Based on data on the geological environment acquired during construction of the underground facility, the modeling of geological environment around several meters to several tens meters square is carried out. Then the geological environment estimation of drifts excavated in Phase 2 is conducted. These models contribute as basic information to plan the in-situ investigations in Phase 3.

In addition, the consistency of models in different disciplines, such as groundwater flow and groundwater chemistry, is examined. The applicability of the design approach and the safety assessment methodology developed so far is examined using models and data relevant to the geological environment at Horonobe.

In the 2007 fiscal year, the applicability of models of the geological environment developed in Phase 1 is confirmed and they are improved based on data on the geological environment acquired during construction of the underground facilities and the Pre-boring investigations. This allows methodologies of investigation, analysis and modeling to be systematized and models of the geological environment

covering an area of several meters to several tens meters square around the underground facilities to be newly developed.

The data of the geological environment acquired by the 2006 fiscal year are also registered to the database.

In addition, as a part of organizing information such as know-how and knowledge based on actual experience into usage format for research and evaluation on in-situ geological environment, grounds of the technical descriptions in plans and reports through the Horonobe URL Project are extracted and ordered.

(1) Geological structure modeling

In the Phase 2 investigations, the applicability of models of the geological environment developed in Phase 1 is confirmed and they are improved based on data on the geological mappings. Also the detailed models of the geological environment in the vicinity of the shafts are constructed.

In the 2007 fiscal year, the existing geological structure model describing the distribution and geometry of geological features, including lithofacies, faults, fracture zones and folds, is being evaluated and improved, based on the information on the distribution of geological formation and fracture and the results of geophysical, geological and borehole investigations conducted in Phase 1.

(2) Hydrogeological modeling

In the Phase 2 investigations, the hydrogeological model developed in Phase 1 is confirmed and they are improved based on data obtained newly. In addition, the hydrogeological model covering an area of several meters to several tens of meters square around the underground facilities is being constructed.

In the 2007 fiscal year, the hydrogeological model covering the URL and in the vicinity is being improved based on the geological mappings, hydraulic conductivity obtained from Pre-boring investigation and the results of investigation until the 2006 fiscal year. Using this model, predictions are made of the inflow from the surrounding rock into the underground facilities and the changes in groundwater pressure during construction of the underground facilities. In addition, groundwater flow analyses considering different water densities, including fresh water, saline water and dissolved gas, are being conducted; the consistency of the models in the different disciplines is also examined.

In order to evaluate the reliability of the hydrogeological model above-described and groundwater flow analyses, the predicted results are compared with observed data on inflow rate from the surrounding rock into the underground facilities, measured groundwater pressures in the deep boreholes, groundwater level in the shallow boreholes, etc.. A hydrogeological model on surrounding of the underground facilities is also being developed based on data acquired during the construction of the underground facilities.

(3) Geochemical groundwater modeling

In the Phase 2 investigations, through the investigations on construction of the underground facilities, the reliability of these predictions and the methods developed in Phase 1 are evaluated. Results of the

predictions and the methods using geochemical groundwater model developed in Phase 1 are confirmed its validity.

In the 2007 fiscal year, the geochemical model is being improved using the data acquired in investigations conducted in the underground facilities and in the Pre-boring investigation.

(4) Rock mechanical modeling

In the Phase 2 investigations, the mechanical model developed in Phase 1 will be evaluated and refined. In addition, a model which is able to reproduce the changes in the properties of the surrounding rock is being developed.

In the 2007 fiscal year, based on the results of laboratory tests using drillcores obtained in the Pre-boring investigation, the validity of rock mechanical models developed in the Phase 1 investigations is confirmed and the rock mechanical models are improved if necessary. In addition, from the results of displacement measurements at the tunnel wall etc., applicability evaluations on the predictive analysis techniques for deformation and stress change of the surrounding rock caused by excavation, are conducted.

3.1.3 Development of investigation techniques and equipment

In the Phase 2 investigations, the investigation techniques developed taking the characteristics of the sedimentary rock and the groundwater in the underground environment at Horonobe into consideration, is applied for actual investigation during construction of the underground facility. And the validity of these techniques is confirmed

In the 2006 fiscal year, through the summarization of the Phase 1 investigations, procedure and technical know-how of surface-based investigation/analysis/evaluation on the sedimentary rock were organized. In addition, knowledge of the applicability on each investigation technique and technical issues were organized.

In the 2007 fiscal year, compiling know-how and knowledge database on the Phase 1 investigations is conducted. As part of the continuing development of surface-based investigation techniques, the applicability of drilling methods capable of controlling the angle and direction of boreholes (controlled drilling) is confirmed. The controlled drilling towards the Omagari Fault is ongoing from the 2006 fiscal year in the Kami-Horonobe area. And also in the area, for confirming the applicability of the groundwater pressure monitoring system, ca. 100-meter-length borehole is drilled and the monitoring system is installed in the borehole.

As for the investigation in the underground facility, development of the investigation techniques and equipment required for data acquisition concerning the geological environment is ongoing. Concerning hydrogeology, equipment for measuring the hydraulic conductivity in a borehole drilled from the drift wall into the surrounding rock is confirmed for its applicability. The in-situ equipments capable of monitoring the pH, redox potential (Eh), etc. of groundwater are also confirmed their applicability. In rock mechanics, optical displacement meters for stable measurement of the displacement of the sedimentary rock on the long term during shaft and drift excavation are being developed since the 2006 fiscal year. In addition, on investigation of groundwater flow, water property and mass transport focused on the boundary of saline

water and freshwater, one of the most important issues for the Horonobe URL Project, collaborative study with other research organization is started.

For the sake of monitoring changes in the geological environment of the URL area during construction of the underground facilities, changes in specific resistivity distribution related with geochemistry are examined by electrical prospecting at measurement points allocated along the lines started on the HDB-6 borehole since the 2006 fiscal year.

3.2 Development of techniques for long-term monitoring of the geological environment

3.2.1 Development of monitoring techniques in boreholes

In Phase 2, the stability of long-term monitoring systems for groundwater pressure/geochemistry is being confirmed and data on changes in the geological environment due to construction of the underground facilities are being acquired.

In the 2007 fiscal year, observations of groundwater pressure/geochemistry are ongoing using long-term monitoring systems for the sake of performance confirmation and a technique for monitoring influences originating from various investigation activities and from construction of the underground facilities are being developed. Methods for processing and analysis of the monitoring data are ongoingly developed to provide an accurate understanding of the changes in groundwater pressures.

In order to observe the microscopic rock deformation at subsurface caused by excavation, monitoring using high-precision tiltmeters and pore pressure meters installed in 2005 and 2006 is ongoing. An analysis method using these acquired data is developed.

3.2.2 Development of a remotely operated monitoring system

In Phase 2, based on monitoring data during construction of the underground facilities, the analysis method and the relevance of a remotely operated monitoring system are examined.

In the 2007 fiscal year, long-term monitoring at existing measurement points is continued. Processing and analysis of the acquired data are tried out. How the change in the geological environment caused by construction of the underground facility appears to an analytical result is examined.

3.3 Development of engineering techniques for use in the deep underground environment

In Phase 2, for confirmation of the applicability of engineering techniques for construction of the underground facilities, measurement instrument systems on rock displacement and stress are installed with shaft excavation. The validity of tunnel design and tunnel lining techniques is confirmed based on these acquired data. On the basis of these evaluations, optimization of the excavation and countermeasure work in the deeper depth are conducted.

In the 2007 fiscal year, measuring instruments such as extensometer and concrete stress meter are installed and these data are acquired. In parallel, based on the results of the model experiments on the fire disaster in the underground facilities, an analysis method of the behavior of smoke-filled air is developed.

3.4 Studies on the long-term stability of the geological environment

3.4.1 Studies on long-term changes in the geological environment

In the Phase 2 investigations, by combining the investigation method on the natural phenomena history (such as fault activity and eustasy) and the investigation/analysis method on the groundwater flow, predictive methods on changes in the geological environment caused by the future natural phenomena are developed.

In the 2007 fiscal year, investigations on topography, deformation of geological formations and fault activity and analyses of microfossils and petrology/mineralogy using rock samples obtained from outcrops and from underground facility are being conducted. Information on crustal movements and climate changes in and around Horonobe are collected and classified. The crustal movements and climate changes from the Neogene to the Quaternary in and around Horonobe are synthetically examined by combining the results of microfossil analyses, the analyzed result of geological formation and geological information acquired so far. Based on these information, information on influences of natural phenomena on the geological environment are classified.

In addition, GPS measurements at existing points are continuing and the extent of the crustal movements is being analyzed by newly equipping GPS measurement points around the URL area for the purpose of examination on fault/fold activities distributing in and around the URL area. The data on deep geological specific resistivity obtained by the electromagnetic measurements are summarized on the relevance of seismogenic process.

3.4.2 Seismological studies

In the Phase 2 investigations, seismological investigations are continuing and the influence of seismological activity on the geological environment is studied by combining data on the geological environment obtained at the surface and in the underground facilities.

In the 2007 fiscal year, observations were made of earthquakes in the Horonobe area and its surroundings using seismographs installed at ground surface and at the bottom of a 138 m-deep borehole. Based on these data, hypocenter distribution and geological structure in the deep underground are studied. In addition, information on past seismic activity in the Horonobe area is being collected and classified. Then seismogenetic area and periodicity are examined.

4. Research and development on geological disposal technology

4.1 Improving the reliability of disposal technologies

4.1.1 Verification of the engineered barrier technology

In the Phase 2 investigations, in-situ tests on, for example, the workability of low-alkaline concrete materials are being carried out.

Regarding materials for tunnel support[3] and tunnel sealing systems, laboratory tests on the workability of materials such as low-alkaline concrete are being conducted in the present fiscal year, to provide input for detailed planning of in-situ tests (specification, experimental layout, etc.) to be performed in the underground facilities in Phase 2.

4.1.2 Confirming the applicability of EBS design methods

In the Phase 2 investigations, design methods of engineered barrier system (EBS) and underground facilities are applied to determine the specifications of in-situ tests using the geological environment data acquired in Phase 1 and acquired during tunnel excavation in Phase 2.

In the 2007 fiscal year, for applying the design method described above, using the geological environment data and data based on laboratory tests using drillcores or groundwater acquired in Phases 1 and 2, information and conditions are organized for confirming the applicability of EBS design methods and for evaluation of the long-term integrity.

4.2 Enhancement of safety assessment methodologies

4.2.1 Enhancement of safety assessment model

Mass transport parameters required for safety assessment include hydraulic conductivity, porosity of rock and diffusion coefficient, etc. In the Phase 2 investigation, on confirming the applicability of safety assessment methodologies in actual geological environment, accumulation of basic data related to the mass transport, such as diffusion coefficient not acquired in Phase 1 is continued and through the understanding of the mechanism and phenomena, improvements of the reliability and precision of the data are carried out.

In the 2007 fiscal year, data acquisition using drillcores and groundwater taken from existing borehole and Pre-boring investigation is ongoing. Laboratory tests and analysis on understanding the mechanism are also ongoing.

4.2.2 Confirming the applicability of safety assessment methodologies

In Phase 2, groundwater flow and mass transport analyses on different scales, such as the regional and site scale, are being conducted and the knowledge obtained in the processes of modeling and analysis is being structured and integrated. The applicability of existing safety assessment methodologies is then examined.

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[3] Tunnel support is installed to preserve the stability of the surrounding rock and the underground voids of tunnels. The tunnel support system usually consists of rock bolts, steel arch supports and shotcrete.

In the 2007 fiscal year, based on the results of groundwater flow analyses and mass transport analyses on a regional scale of 15 km×30 km and on a site scale of 10 km×10 km (including the URL area) and based on the acquired characteristics of the geological environment, geological model and hydrogeological model are revised. In addition, the reliability of a series of method, geological environmental investigation in the Phase 1 to mass transport evaluation, is confirmed. Then this confirmation is fed back to the geological environmental investigation for the reflection to the result of safety assessment.

5. Construction of the underground facilities

In the 2007 fiscal year, the ventilation shaft and the east access shaft are still being excavated. In addition, expansion of land for a surplus soil (muck) dumping yard, the Pre-boring investigation in the vicinity of the ventilation shaft and adjustment design of the URL facilities are conducted.

Before the excavation of each shaft at the typical-section[4], temporary facilities such as excavation towers, scaffolds and hoisting devices continued from the 2006 fiscal year are constructed, and then each shaft is again excavated. Also a part of "140m depth drift", one of the horizontal drift connecting the ventilation shaft and the east access shaft, is excavated. Tunnel support is installed immediately after excavation and the stability of the surrounding rock is thus preserved as before. The type of support is selected taking into account information such as the mechanical properties of the surrounding rock. In addition, since flammable gas containing methane has been detected in and around the URL area in Horonobe, shaft excavation is carried out using explosion-proof excavation apparatus and with monitoring of the gas concentrations by way of safety management.

Surplus soil (muck) produced by tunnel excavation is stored in a temporary dumping yard which is covered by impermeable asphalt-saturated sheeting and is finally transported to the permanent dumping yard consisting of a double liner sheet structure based on an impermeable contaminant system pursuant to the Soil Contamination Countermeasures Law. In order to prevent release of natural toxic substances contained in muck, the amounts of these substances are measured periodically.

The drainage water produced in the underground facilities is released to the Teshio River by drainage pipes after appropriate treatment at the drainage water treatment facility.

The Pre-boring investigation in the vicinity of the Ventilation Shaft is being conducted to deal with spring water predicted to encounter on tunnel excavation. The main aims of this investigation are to pinpoint places and to estimate amount and water property of the spring water. The results of this investigation are reflected for the drainage treatment plan decision and the detailed execution scheme decision for spring water reduction at pinpointed place.

In addition, to reflect the result of the investigations after 2005 fiscal year in the layout of deep underground facilities, the adjustment design of the URL is conducted.

[4] Typical-section of the shafts is excavation span using excavation tower and scaffold.

6. Construction of the surface facilities

In the 2007 fiscal year, construction of a Public Information House including fabrication of its exhibits continued from the 2006 fiscal year is continued, and is completed at the end of May 2007. The Public Information House is scheduled to open in the summer of 2007. The Public Information House is composed of the first floor in the underground, the first floor on the ground and the view floor, and the height of the view tower is 50m from surface ground. Moreover, the content of the exhibition will become the one that an underground space can be experienced.

Execution design of an International Communication House is also underway following the basic design in the 2006 fiscal year.

7. Environmental monitoring

7.1 Monitoring of noise, vibration, water property, flora and fauna

Monitoring of noise, vibration, water property, flora and fauna is performed regularly in the area around the URL site.

7.2 Monitoring the construction of the underground facilities

In the 2007 fiscal year, monitoring of water properties in the URL site, the surplus soil (muck) dumping yard (and its surroundings) and the Teshio River (outlet of the drainage lines) is being carried out.

The items for analysis described in the Water Pollution Control Law and in the letter of agreement with the Kitarumoi Fishery Cooperative Association are used as the basis for monitoring water properties. Drainage water produced from construction of the underground facilities, treated water, seepage water from the surplus soil (muck) dumping yard and shallow groundwater and river water close to the surplus soil (muck) dumping yard are monitored.

8. Collaboration with other research organizations

The geoscientific studies looking at the deep underground environment in sedimentary rock that are being conducted as part of the Horonobe URL Project are relevant to wide range of areas in the geosciences and also contribute to development of academic research. JAEA is therefore proceeding with the project through collaboration with experts from domestic and overseas research organizations, including Hokkaido University and others.

8.1 Collaboration with domestic research organizations

8.1.1 Collaboration with universities

- Hokkaido University:
  - Study on transport pathways of dissolved gases and materials in compacted bentonite[5]
  - Study on organic characteristics of groundwater and rock

[5] Compacted bentonite is formed by compacting and solidifying bentonite clay powder. This is a candidate for the buffer material that forms part of the engineered barrier system (EBS).

- Saitama University:
  - Study on groundwater flow modeling
- Tsukuba University:
  - Geochemical study on rocks, minerals and groundwater
- Tokyo University:
  - Development of technology for evaluating hydrogeological models using stable isotope ratios of chlorine
- Nagoya University:
  - Development of a remotely operated monitoring system
  - Study on microbial characteristics of groundwater and rock
- Kyoto University:
  - Study on groundwater flow considering the influences of fracture zones
- Musashi Institute of Technology:
  - Study on method of radiochemical analyses in microelements
- Shizuoka University:
  - Study on microbial characteristics of groundwater and rock

8.1.2 Collaboration with other research organizations

- Central Research Institute of Electric Power Industry (CRIEPI)[6]:
  - Study for evaluating environmental characteristics relevant to geology and groundwater (including development of controlled drilling)
- Radioactive Waste Management Funding and Research Center (RWMC)[7]:
  - Study on applicability of high-accuracy geophysical investigation technologies
  - Study on applicability of investigation technologies for the geological environment
- Horonobe Research Institute for the Subsurface Environment (H-RISE)[8]:
  - Study on characteristics of sedimentary rock
- Geological Survey of Hokkaido[9]:
  - Study on change in terrain and on reconstruction of the paleo-environment
- Shimizu Corporation:
  - Study on advanced modeling technology for the geological environment
- Sumitomo Mitsui Construction Co., Ltd.
  - Development of monitoring techniques using dissolved methane gas sensor

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[6] CRIEPI is a research institute specializing in electric power technology. As part of its activities, research and development on geological disposal of high-level radioactive waste is carried out.

[7] RWMC was established in 1976 as a research institute for radioactive waste management. In November 2000, RWMC was designated as the organization responsible for the administration of the final disposal funds for high-level radioactive waste.

[8] H-RISE is a research institute under the Northern Advancement Center for Science and Technology (NOASTEC) established in Horonobe in 2003. Scientific research on utilization of underground space is planned.

[9] The Geological Survey of Hokkaido was established to conduct research on geology and underground resources in Hokkaido. Currently, 1) research on development, utilization and management of underground resources, 2) research on land conservation and preservation of the underground environment, 3) research on analysis and prevention of geological disasters and 4) improvement of geological information management are its main activities.

8.2 Collaboration with overseas research organizations

- Nagra[10] (Switzerland):
  - Technological study on planning of investigations in the URL project and review of annual progress
- Mont Terri Project[11] (Switzerland):
  - Test for evaluating the geochemical characteristics of pore water in impermeable sedimentary rock

In addition to the existing collaborative studies mentioned above, cooperation with Advanced Industrial Science and Technology (AIST)[12], Japan Nuclear Energy Safety Organization (JNES)[13], ANDRA[14] and other organizations is also being considered.

The project on evaluation technologies of geological environmental features at littoral region is planned by the Agency for Natural Resources and Energy (an agency of METI). Collaboration with the organization implementing this project is also carried out.

In addition, the facilities and study areas used in the Horonobe URL Project are open to domestic and overseas research organizations in the field of geological disposal.

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[10] The National Cooperative for the Disposal of Radioactive Waste (Nagra) is responsible for geological disposal research in Switzerland. A key part of its program includes in-situ investigations in domestic underground rock laboratories (e.g. Grimsel)

[11] The Mont Terri Project is an international URL project for in-situ testing in sedimentary rock relevant to research and development on geological disposal. Currently, 12 organizations from six countries, including JAEA, are participating in this project and various types of in-situ tests relevant to geological disposal have been carried out in the tunnel system in the Jura Mountains of Switzerland.

[12] AIST was reorganized in 2001 from the former Agency of Industrial Science and Technology (AIST) administered by Ministry of International Trade and Industry (MITI). AIST is the largest research institute in Japan covering a wide range of disciplines in the industrial technologies and various types of technology developments are carried out. The current disciplines covered by AIST are mainly classified into life sciences, telecommunications/electronics, nanotechnology/materials/manufacturing, environment/energy, geology and standards/measurements.

[13] JNES, an incorporated administrative agency was established in 2003. They are an expert organization with the mission to ensure safety in the use of nuclear energy in cooperation with the regulatory authority, the Nuclear and Industrial Safety Agency. Their major programs are described below: 1) inspection on nuclear power plants and nuclear facilities, etc. 2) analysis and evaluation of safety on nuclear power plants and nuclear facilities. 3) supporting activities for the nuclear emergency preparedness and response etc. 4) investigation, tests and research to ensure nuclear safety in the framework of utilizing energy. 5) collection, compilation and supply of information to ensure the safety in the framework of utilizing energy.

[14] ANDRA, the organization of radioactive waste management in France, operates the low and medium level radioactive wastes repository and plays a key role in the R&D on high-level and intermediate-level (long-lived) radioactive waste disposal. ANDRA is implementing an underground research laboratory project in sedimentary rock (same rock type as Horonobe).

Table 1 Summary of main investigations conducted in the 2007 fiscal year

Investigations		Content	Place
Development of techniques for investigate the geological environment	Geological structure	Geological mapping, Outcrop observations, Chemical and petrological/mineralogical analyses of core samples Measurements of methane and carbon dioxide at shallow boreholes	Hokushin area, Kami-Horonobe area, shaft (and drift), shallow boreholes (Hokushin, Kaishin) etc.
	Hydrogeology	Meteorological monitoring (precipitation, temperature, humidity, wind direction & velocity, evaporation), River flux monitoring, Groundwater level/soil moisture observation, Monitoring of groundwater pressure, Rock permeability test (laboratory)	Meteorological observation station (Hokushin, Horonobe, Kami-Toikan, Toikanbetsu), Hokushin evapotranspiration observation tower, P-3 - P-5, shaft and drift, URL site, shallow boreholes, HDB-1 - 11
	Groundwater chemistry	Chemical analyses of sump water from shaft wall, borehole water, river water/precipitation and water sampling by squeezing drillcores	Shaft and drift, HDB-1 - 11, shallow boreholes, P-3 - P-5, surplus soil (muck) yard
	Rock mechanics	Laboratory tests using drillcores sampled from Pre-boring investigation	URL site, etc.
	Development of investigation techniques and equipments	Examination of the controlled drilling techniques, Resistivity monitoring from ground surface, Development and trial manufacture of the investigation tools used in the boreholes in the URL., Development of techniques for investigating the boundary of saline and fresh groundwater	URL site, Kami-Horonobe, Hokushin, littoral region of Horonobe
Development of techniques for long-term monitoring of the geological environment	Development of monitoring techniques in the boreholes	Groundwater pressure observations, Installation of data transfer units, Observation using high-precision tiltmeters, pore pressure meter and dissolved methane gas sensor	HDB-1 - 11, URL site
	Development of a remotely operated monitoring system	Constant/short-term observations of geological structure/environment, Maintenance of existing observation system	URL site, HDB-3,4,5,8 area, Receiving point-Z
Development of engineering techniques for use in the deep underground environment		Installation of rock deformation/stress monitoring system, Validation of analyses method for the behavior of smoke-filled air in the underground facilities in case of fire	Shaft and drift, URL site, etc.
Studies on the long-term stability of the geological environment	Studies on long-term changes in the geological environment	Outcrop observation, Microfossils and petrological/mineralogical analyses of core samples, GPS and electromagnetic measurements	Hokushin, Kami-Horonobe, HDB-1,2,5 area, Horonobe Park observation point, Kami-Toikan observation point
	Seismological studies	Observations of earthquakes using seismographs	HDB-2, 5 area, Naka-Toikan observation point, Hokuseien observation point
Research and development on geological disposal technologies	Improving the reliability of disposal techniques	Development of low-alkaline concrete, Classification of data for application of EBS design method	URL site, etc.
	Enhancement of safety assessment methodologies	Collection of basic data for mass transport, Accuracy improvement of data based on understanding of the phenomenon, Examination of characteristics on the geological environment and parameter types/accuracies affecting mass transport, Modeling of mass transport	(No field work)
Construction of the underground facilities		Excavation of Ventilation/East Shaft and drift, Carrying out of surplus soil (muck) to the yard, Operation of drainage treatment facility, Borehole investigation in the vicinity of the Ventilation Shaft, Adjustment design of the underground facility	URL site, etc.
Construction of the surface facilities		Construction/Opening of Public Information House and preparation of the exhibits, Execution design of International Communication Facility	URL site, etc.
Environmental monitoring		Monitoring of noise, vibration, water property, flora and fauna Monitoring of drainage water from construction of URL facilities	URL site, Teshio River, Shimizu River, etc.

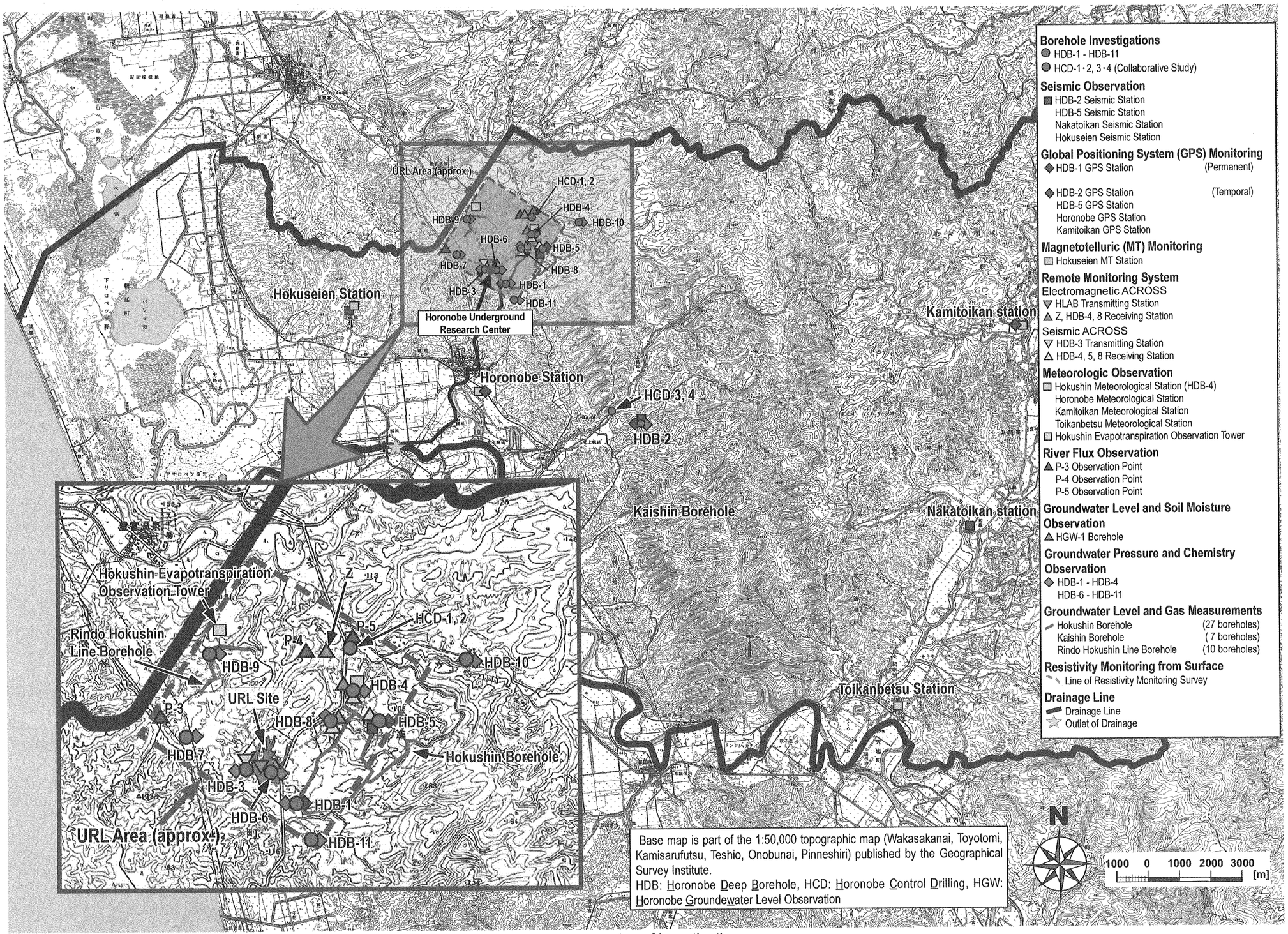

Fig.1 Location of investigations

Appendix

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Investigation schedule (2005 Fiscal Year - 2007 Fiscal Year)

Investigation Phase / Item	Content	Fiscal Year 2005	2006	2007	2008	2009
		Surface-based Investigation Phase				
		Summary of the "Surface-based Investigation Phase"				
		Construction Phase				
		Establishment of Japan Atomic Energy Agency	"A plan for meeting the midterm goal (Midterm Plan)" (METI and MEXT, October 2006; Period from October 1st, 2006 to March 31st, 2010)			
3. Geoscientific research						
3.1 Development of techniques for investigating the geological environment						
3.1.1 Acquisition of geoscientific data						
(1) Geological structure	•Core sampling/analysis from underground facilities, ground surface and drillcores					
(2) Hydrogeology	•Groundwater monitoring, surface hydrogeological investigations and drillcores		Data acquisition during construction of the underground facilities / comparison with the data obtained before construction			
	•Measurements of groundwater inflow in underground facilities			Data acquisition during construction of the underground facilities		
	•Hydrogeological investigations in boreholes (permeability test, groundwater pressure, etc.)					
(3) Groundwater chemistry	•Water sampling/analysis from existing deep boreholes					
	•Water sampling/analysis from the shaft/drift wall					
	•Water sampling/analysis from boreholes drilled in the underground facilities					
(4) Rock mechanics	•Laboratory tests using drillcores from the deep boreholes					
	•Rock mechanical investigations using drillcores from boreholes drilled in the underground facilities					
3.1.2 Evaluation of methodologies for investigation/analysis and for modeling of the geological environment						
(1) Geological structure model	•Applicability confirmation/improvement of the geological structure model for an area of several hundred meters to several square kilometers					
	•Modeling the geological structure over an area of several tens of square meters					
(2) Hydrogeological model	•Analyses for predicting the inflow and the distribution of the groundwater pressure at/around the underground facilities		Predictive analysis / Comparison with actual measurements/Modeling and Updating			
	•Applicability confirmation/improvement of the hydrogeological model for an area of several hundred meters to several square kilometers					
	•Modeling the hydrogeology over an area of several tens of square meters					
(3) Geochemical model of groundwater	•Applicability confirmation/improvement of the geochemical model for an area of several hundred meters to several square kilometers					
	•Modeling the geochemistry over an area of several tens of square meters					
(4) Rock mechanical model	•Applicability confirmation/improvement of the rock mechanical model for an area of several hundred square meters					
	•Modeling in time dependence deformation					
3.1.3 Development of investigation techniques and equipment	•Development of various investigation techniques		Development and improvement of the investigation equipment		Applicaton Test / Practical Use	
	•Development of monitoring system for geological environment changes by ground geophysical survey during construction of the underground facilities		Installation of the observation system		Continuous monitoring / Data analyses (Annual)	
3.2 Development of techniques for long-term monitoring of the geological environment						
3.2.1 Development of monitoring techniques in boreholes	•Maintenance of long-term monitoring system installed in the existing boreholes			Maintenance of monitoring equipment / Management of acquired data/Data analysis		
3.2.2 Development of a remotely operated monitoring system	•Monitoring by remotely operated system using seismic and electromagnetic waves, and examination of applicability		Maintenance of observation system		Continuous monitoring / Data analyses	
3.3 Development of engineering techniques for use in the deep underground environment	•Validation of design based on various data measured during construction of the underground facilities, examination of observational construction method for sedimentary soft rock, etc.		Observational construction method		Data acquisition during construction of the underground facilities / Relevance evaluation of the preliminary design	
3.4 Study on long-term stability of the geological environment						
3.4.1 Study on long-term changes in the geological environment	•Sampling and analysis at ground surface and in the underground facilities, history of natural phenomena (such as fault activity, erosion, ridges, troughs, climate change, eustasy, etc.) and study of effects on the geological environment			Sampling and analysis, history of natural processes and events, effects on geological environment		
	•Verification of the geological environment modeling methods considered history of natural phenomena and long-term changes of the geological environment		Planning		Modeling and updating of geological environment considered long-term changes	
					Verification of methods for evaluating effects of natural phenomena	
3.4.2 Seismological studies	•Understanding earthquake activity using seismometers on the ground surface Understanding of effect of earthquake activity and tectonics on groundwater				Earthquake observation and GPS observation	
	•Understanding earthquake activity using seismometers in the underground facilities Understanding of effect of earthquake activity and tectonics on groundwater			Planning	Installation of seismometers	
4. Research and development on geological disposal technology						
4.1 Improving reliability of disposal techniques						
4.1.1 Verification of engineered barrier technology	•Studies on workability of low-alkaline concrete, feasibility of engineerad barrier system, backfilling of drifts, etc.		Understanding of basic properties in laboratory tests / Planning for in-situ tests	Low-alkaline concrete material test	In-situ test for confirmation of workability / Monitoring	
4.1.2 Applicability confirmation of EBS design methods	•Validity evaluation, Updating and enhancement of the design methods for the engineered barrier system based on "Summary in 2005FY"				preliminary survey / Planning for in-situ tests	
4.2 Enhancement of safety assessment methodologies						
4.2.1 Enhancement of safety assesment model	•Accumulation of basic data related to the mass transport, improvements of the reliability and precision of the data through the understanding of the mechanism/phenomena		Preliminary tests	Accumulation of basic data related mass transport on laboratory test/ Understanding of the mechanism and phenomena		
4.2.2 Applicability confirmation of safety assessment methodologies	•Application of safety assessment methodologies for in-situ geological environment and advancement of methodologies based on this result		Modeling and analysis of mass transport on site scale		Modeling and analysis of mass transport on regional scale	
5. Construction of the underground facilities						
- Underground Facilities	•Construction Ventilation shaft, Access shaft (East and West), 140m drift and 280m drift Borehole investigation in the vicinity of the Ventilation Shaft		Shaft excavation and construction of temporary facilities Ventilation Shaft (including Fan Shaft) Shaft excavation and construction of temporary facilities Access Shaft (East) Access Shaft (West) 140m-Drift 280m-Drift			
- Auxiliary facilities (Effluent treatment facility, Surplus soil (muck) yard, etc.)	•Construction/Operation Drainage Line, Effluent Treatment Facility and Surplus Soil (Muck) Yard		Construction of the Drainage Line Effluent Treatment Facility Discharge to Drainage Line Construction of Effluent Treatment Facility Surplus Soil (Muck) Yard Haulage Road First stage construction Second stage construction Transport to Surplus Soil (Muck) Yard		End of the first stage Third Stage Construction	
- Borehole investigation in the vicinity of the Ventilation Shaft	•Borehole drilling Investigations aimed to pinpoint places and to estimate amount/water property of the spring water			In the vicinity of the Ventilation Shaft	In the vicinity of the East Shaft	
- Adjustment design				Adjustment design		
6. Construction of the surface facilities						
- Research and Administration Facility/Test Facility	•Construction		Construction (Due for completion in May 2006)			
- Public Information House	•Construction of Public Information House			Construction	Preparation for opening / in-service	
	•Fabrication and setting of the exhibits		Execution design	Fabrication of the exhibits		
- International Communication House	•Design and construction of International Communication House		Conceptual design	Preliminary design	Execution design	Construction
7. Environmental monitoring						
7.1 Monitoring of noise, vibration, water property, flora and fauna						
- Water properties -Plants and animals	•Regular analysis of river water every three months				Monitoring	
- Noise and vibration	•Regular ecological survey in spring, summer and winter (including rare species)					
	•Regular noise monitoring every three months (around the URL site)					
7.2 Monitoring of construction of the underground facilities						
- Drainage water, seepage water from surplus soil (muck) yard and surrounding water quality survey			Background measurements		Monitoring	
- Teshio River			Background measurements		Monitoring	
8. Collaboration with other research organization						
8.1Collaboration with domestic research organizations						
8.1.1 Collaboration with universities	•Research cooperation				Advanced basic research, collaborative research	
8.1.2 Collaboration with other research organizations	•Research cooperation on the basis of agreements, contracts, etc.				Collaborative research	
8.2 Collaboration with overseas research organizations	•Research cooperation on the basis of agreements, contracts, etc.				Collaborative research	

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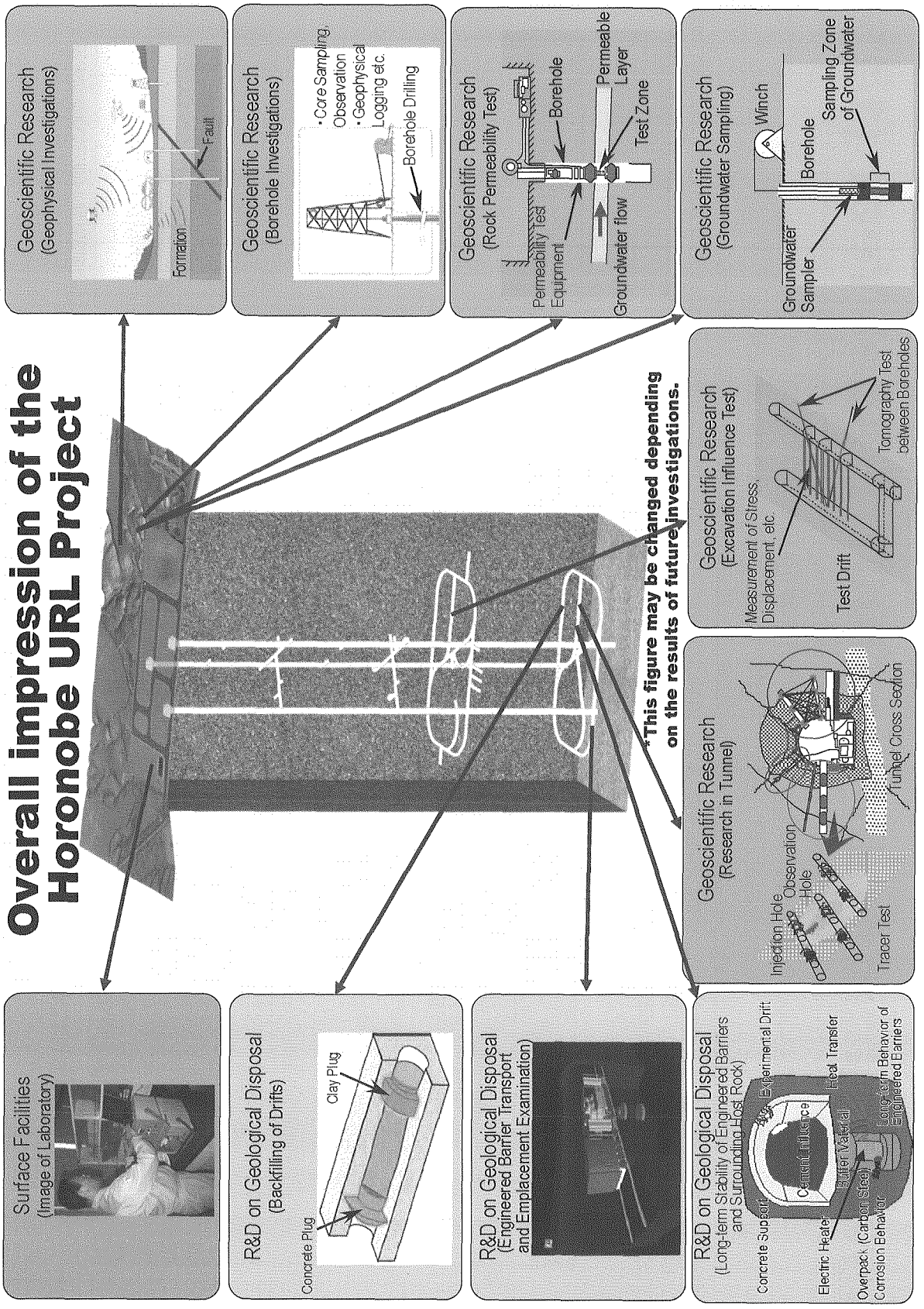
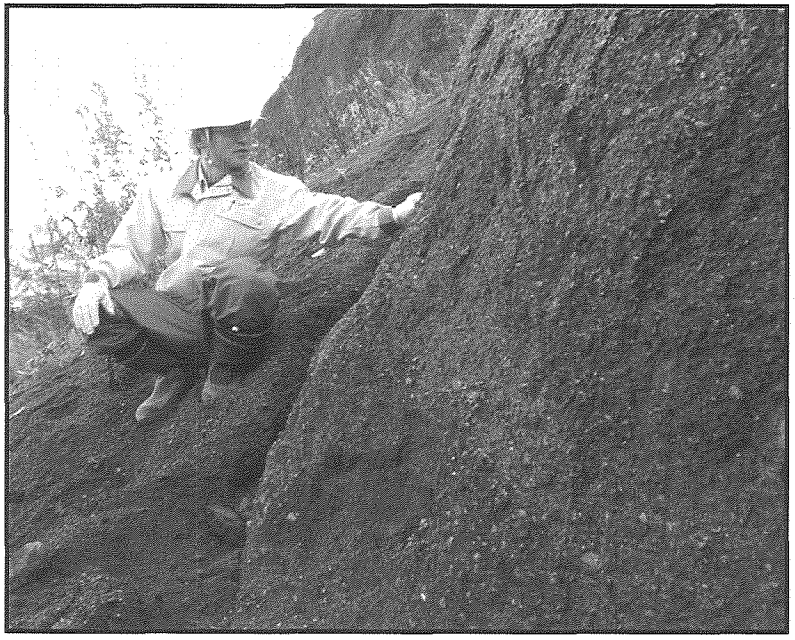

Overall impression of the Horonobe URL Project
Geoscientific Research (Geophysical Investigations)
Formation
Fault
Geoscientific Research (Borehole Investigations)
• Core Sampling, Observation
• Geophysical Logging etc.
Borehole Drilling
Geoscientific Research (Rock Permeability Test)
Borehole
Permeable Layer
Test Zone
Permeability Test Equipment
Groundwater flow
Geoscientific Research (Groundwater Sampling)
Winch
Borehole
Sampling Zone of Groundwater
Groundwater Sampler
Geoscientific Research (Excavation Influence Test)
Measurement of Stress, Displacement, etc
Test Drift
Tomography Test between Boreholes
Geoscientific Research (Research in Tunnel)
Injection Hole
Observation Hole
Tracer Test
Tunnel Cross Section
R&D on Geological Disposal (Long-term Stability of Engineered Barriers and Surrounding Host Rock)
Concrete Support
Experimental Drift
Cement influence
Heat Transfer
Buffer Material
Electric Heater
Overpack (Carbon Steel)
Corrosion Behavior
Long-term Behavior of Engineered Barriers
R&D on Geological Disposal (Engineered Barrier Transport and Emplacement Examination)
R&D on Geological Disposal (Backfilling of Drifts)
Concrete Plug
Clay Plug
Surface Facilities (Image of Laboratory)
*This figure may be changed depending on the results of future investigations.

Investigations in the 2007 Fiscal Year (1/15)

Development of techniques for investigating the geological environment (acquisition of geoscientific data: geological structure)

The following investigations are carried out at the shafts wall, on the borehole investigation in the vicinity of the ventilation shaft and at the URL area and its surroundings: geological mapping, chemical and petrological/mineralogical analyses using rock samples. Observations of gas concentrations and gas analyses in shallow boreholes of several meters to several tens of meters deep drilled during FY 2003-2005 are also carried out.

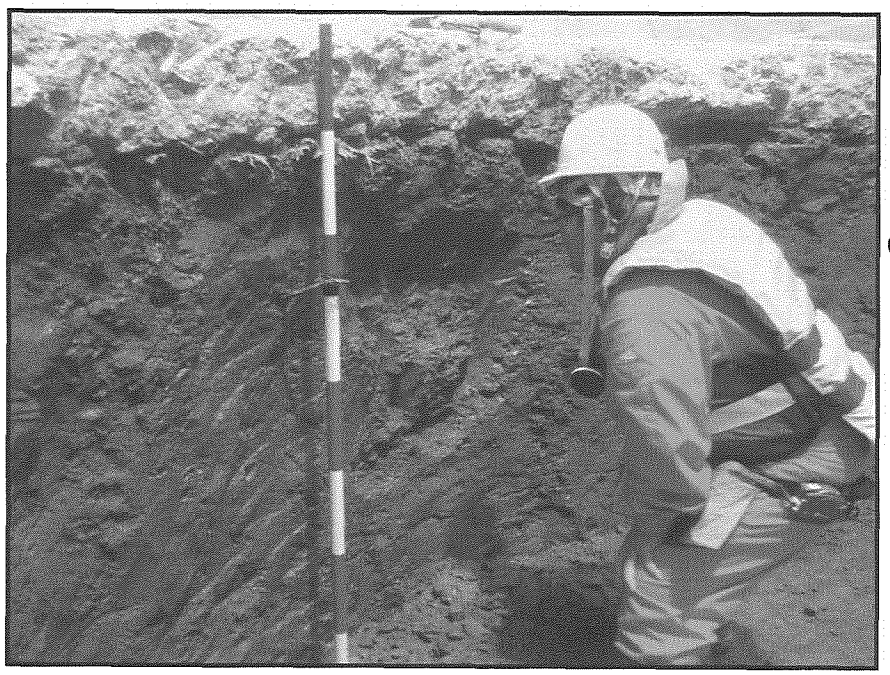


Outcrop observation

Observation of gas concentration

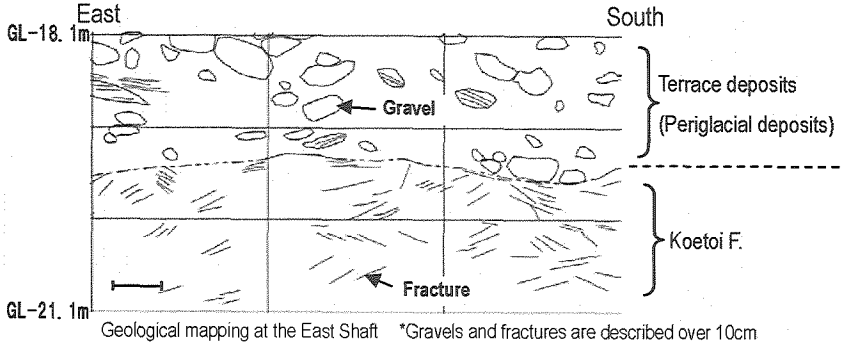
Investigations in the 2007 Fiscal Year (2/15)

Development of techniques for investigating the geological environment (acquisition of geoscientific data: geological structure)

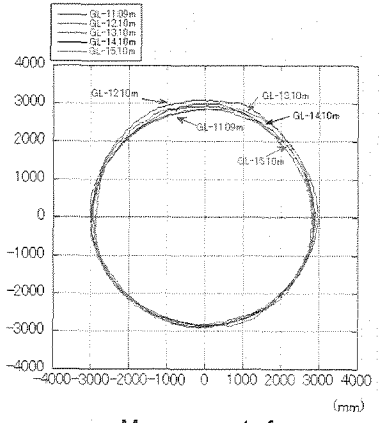


Shaft wall observation

(At the East Shaft: G.L.-10.0m ~ -11.5m)



Geological mapping at the East Shaft *Gravels and fractures are described over 10cm



Measurement of

Record of shaft wall before applying tunnel lining

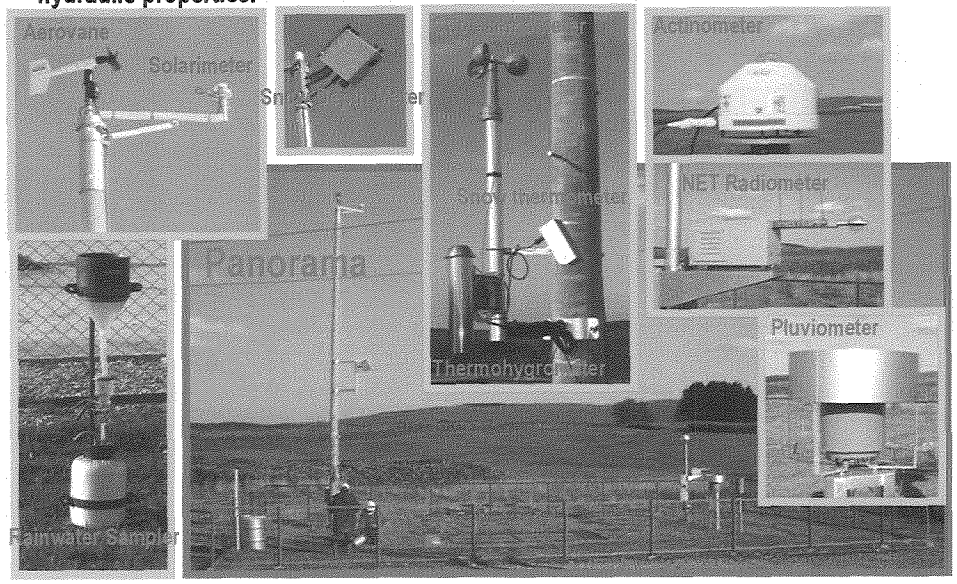
Investigations in the 2007 Fiscal Year (3/15)

Development of techniques for investigating the geological environment (acquisition of geoscientific data: hydrogeology)

Data collections will be continued by using the meteorological observation system (precipitation, temperature, humidity, wind velocity, wind direction and evapotranspiration rate) and the river flux observation system.

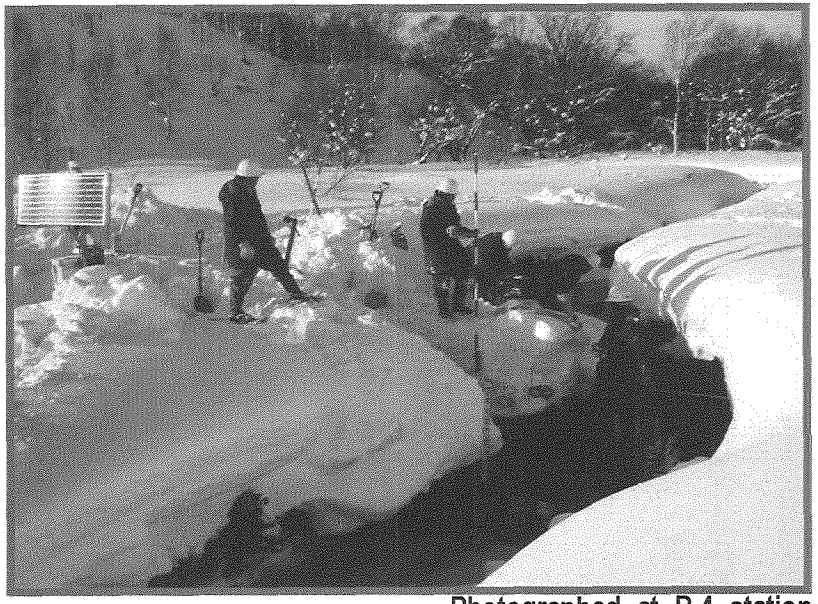
Groundwater level and soil moisture observation will also be continued by using existing boreholes. Based on data from these observations and the results of water chemistry for river water and precipitation, groundwater flow in the shallower part of the underground environment can be roughly understood and the recharge rate from ground surface to deep underground can be estimated. Groundwater pressures are continuously monitored and any influences due to the construction of the underground facilities are confirmed.

In the underground facilities, information on hydrogeological structures including the properties of water-conducting features and the inflow rate from the surrounding rock, are acquired in parallel with the shaft and drift excavation. Also on the Pre-boring investigations, information on hydraulic conductivity and hydrogeological structures are also acquired. In addition, laboratory experiments using rock samples obtained in the shafts are also conducted to investigate hydraulic properties.



Photographed at Hokushin Weather station

Meteorological apparatus



Photographed at P-4 station

River flux observation

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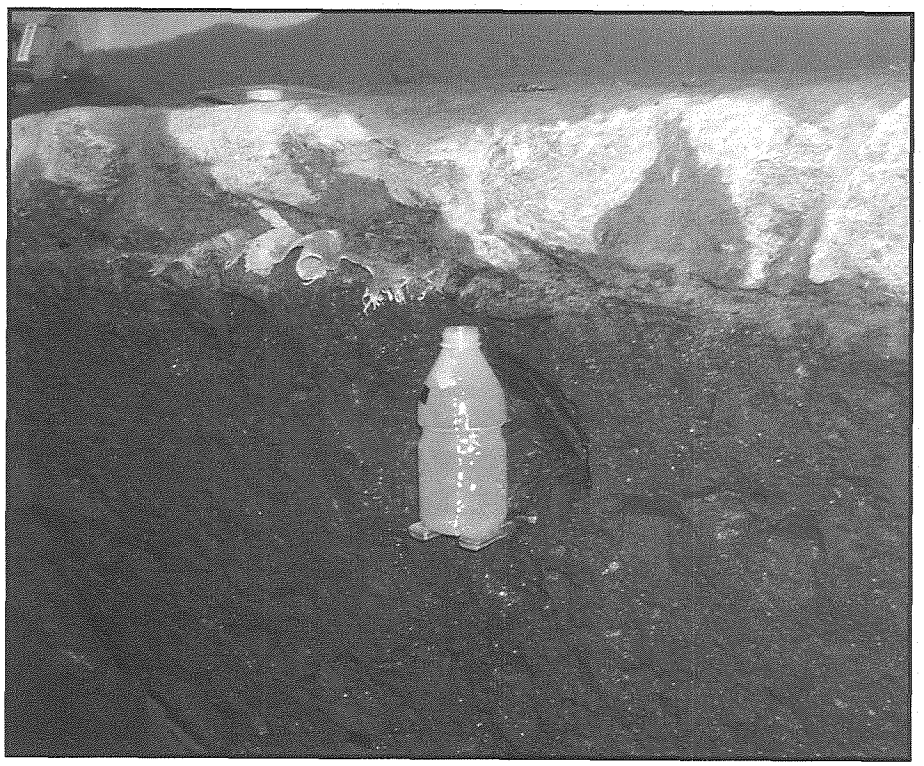
Investigations in the 2007 Fiscal Year (4/15)

Development of techniques to investigate the geological environment (acquisition of geoscientific data: Groundwater chemistry)

Water is being sampled by squeezing drillcores and by collection from the muck of excavation, from the Pre-boring investigation and from the shaft wall, and chemically analyzed. The water sampling and analysis from the existing boreholes such as HDB-1 - 11, and from shallow boreholes, are also conducted. Sampling and chemical analyses of river water and precipitation are also conducted.



Water sampling from shaft wall

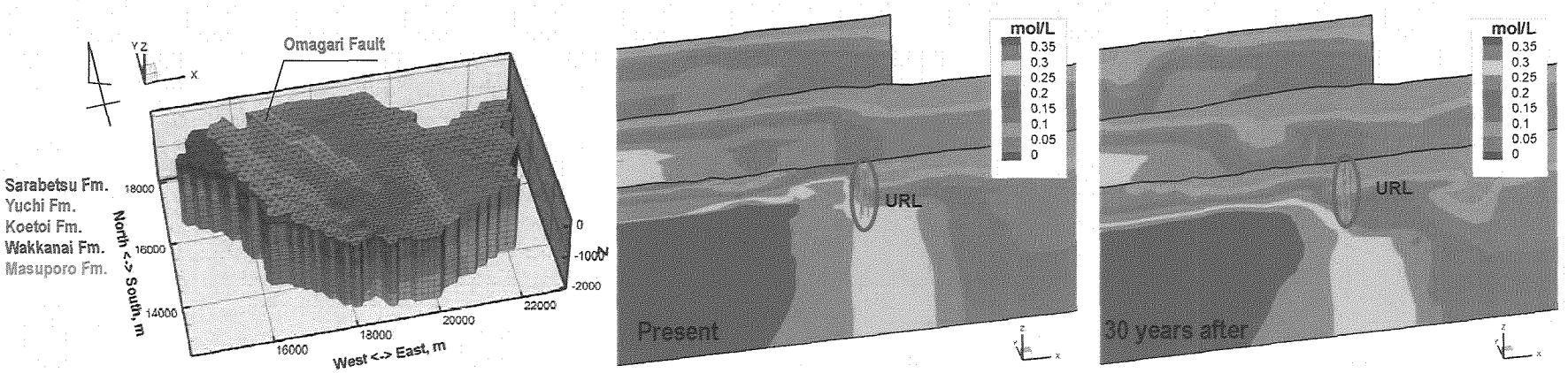
Investigations in the 2007 Fiscal Year (5/15)

Evaluation of methodologies on investigations/analyses, and modeling the geological environment

The applicability of models of the geological environment developed in Phase 1 is confirmed and they are improved based on data on the geological environment acquired during construction of the underground facilities and the Pre-boring investigations. This allows methodologies of investigation, analysis and modeling to be systematized and models of the geological environment covering an area of several meters to several tens meters square around the underground facilities to be newly developed.

The data of the geological environment acquired by the 2006 fiscal year are also registered to the database.

In addition, as a part of organizing information such as know-how and knowledge based on actual experience into usage format for research and evaluation on in-situ geological environment, grounds of the technical descriptions in plans and reports through the Horonobe URL Project are extracted and ordered.



Changes of the groundwater chemistry after shafts excavation
(density of chloride ion)

Hydrochemistry model

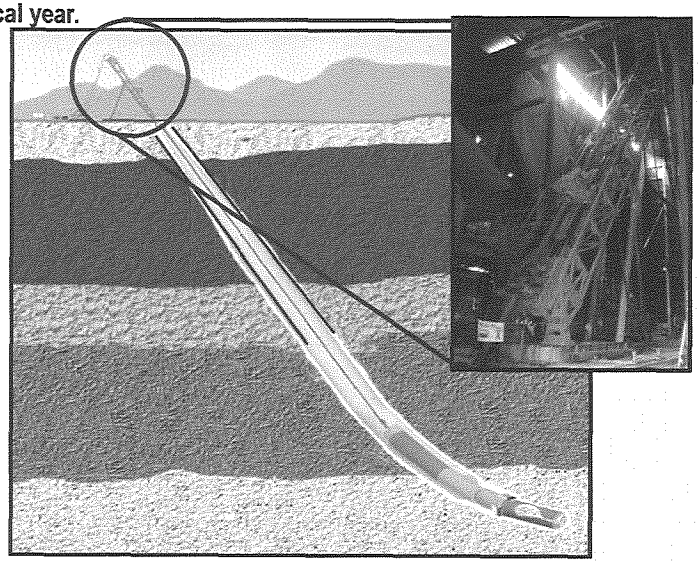
Investigations in the 2007 Fiscal Year (6/15)

Development of investigation techniques and equipment

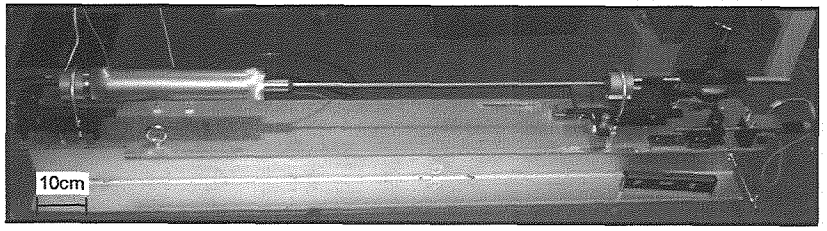
Compiling know-how and knowledge database on the Phase 1 investigations is conducted. As part of the continuing development of surface-based investigation techniques, the applicability of drilling methods capable of controlling the angle and direction of boreholes (controlled drilling) is confirmed. The controlled drilling towards the Omagari Fault is ongoing from the 2006 fiscal year in the Kami-Horonobe area. And also in the area, for confirming the applicability of the groundwater pressure monitoring system, ca. 100-meter-length borehole is drilled and the monitoring system is installed in the borehole.

As for the investigation in the underground facility, development of the investigation techniques and equipment required for data acquisition concerning the geological environment is ongoing. Concerning hydrogeology, equipment for measuring the hydraulic conductivity in a borehole drilled from the drift wall into the surrounding rock is confirmed for its applicability. The in-situ equipments capable of monitoring the pH, redox potential (Eh), etc. of groundwater are also confirmed their applicability. In rock mechanics, optical displacement meters for stable measurement of the displacement of the sedimentary rock on the long term during shaft and drift excavation are being developed since the 2006 fiscal year. In addition, on investigation of groundwater flow, water property and mass transport focused on the boundary of saline water and freshwater, one of the most important issues for the Horonobe URL Project, collaborative study with other research organization is started.

For the sake of monitoring changes in the geological environment of the URL area during construction of the underground facilities, changes in specific resistivity distribution related with geochemistry are examined by electrical prospecting at measurement points allocated along the lines started on the HDB-6 borehole since the 2006 fiscal year.



Concept of controlled drilling



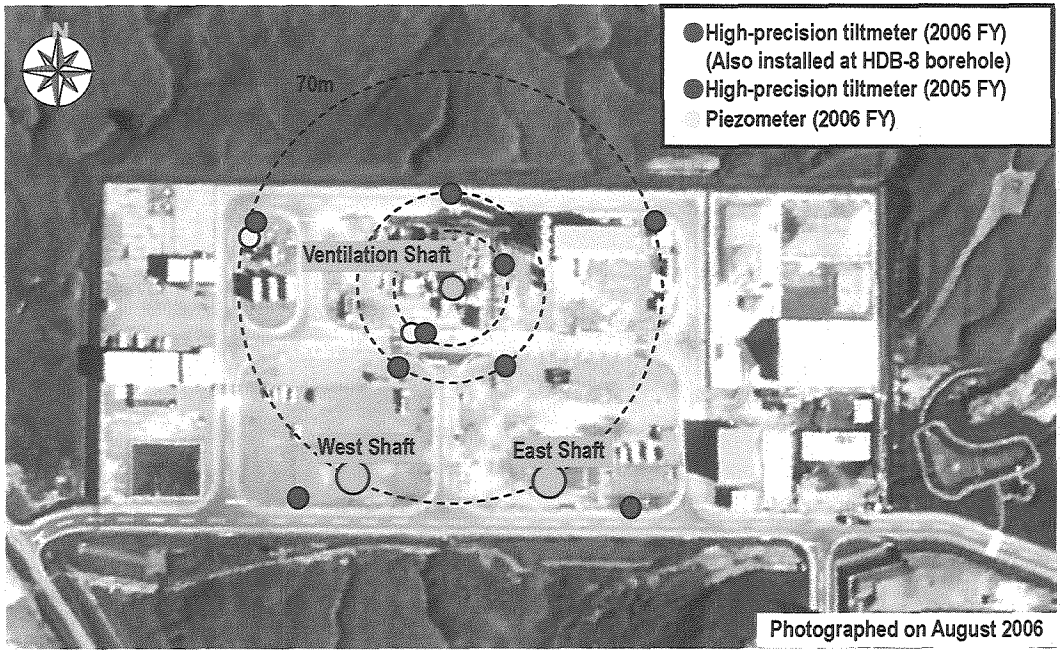
Optical fiber type extensometer

Investigations in the 2007 Fiscal Year (7/15)

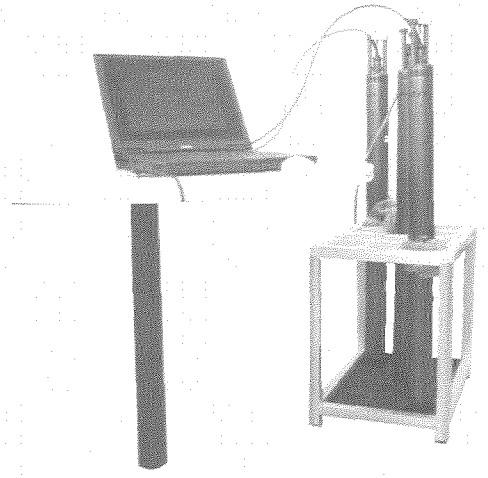
Development of techniques for long-term monitoring of geological environment (Development of monitoring techniques in borehole)

Observations of groundwater pressure/geochemistry are ongoing using long-term monitoring systems for the sake of performance confirmation and a technique for monitoring influences originating from various investigation activities and from construction of the underground facilities are being developed. Methods for processing and analysis of the monitoring data are ongoingly developed to provide an accurate understanding of the changes in groundwater pressures.

In order to observe the microscopic rock deformation at subsurface caused by excavation, monitoring using high-precision tiltmeters and pore pressure meters installed in 2005 and 2006 is ongoing. An analysis method using these acquired data is developed.



Layout of high-precision tiltmeters

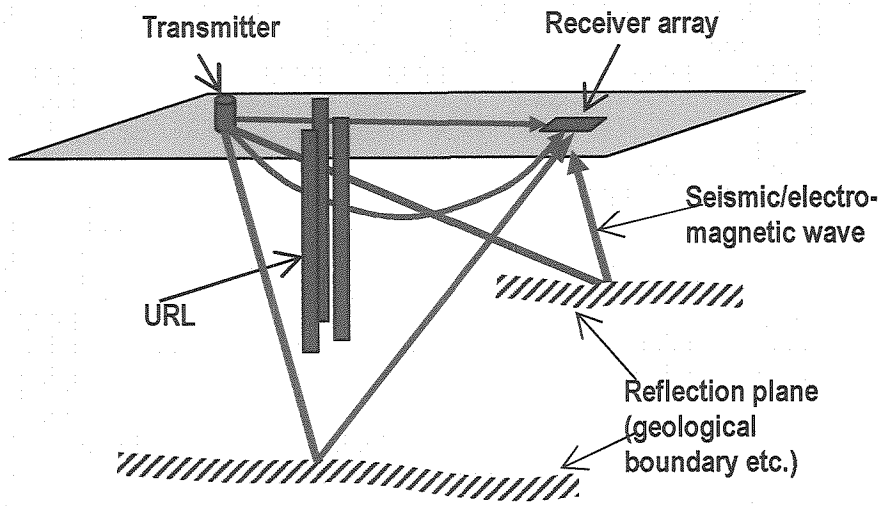


High-precision tiltmeters installed around the shaft

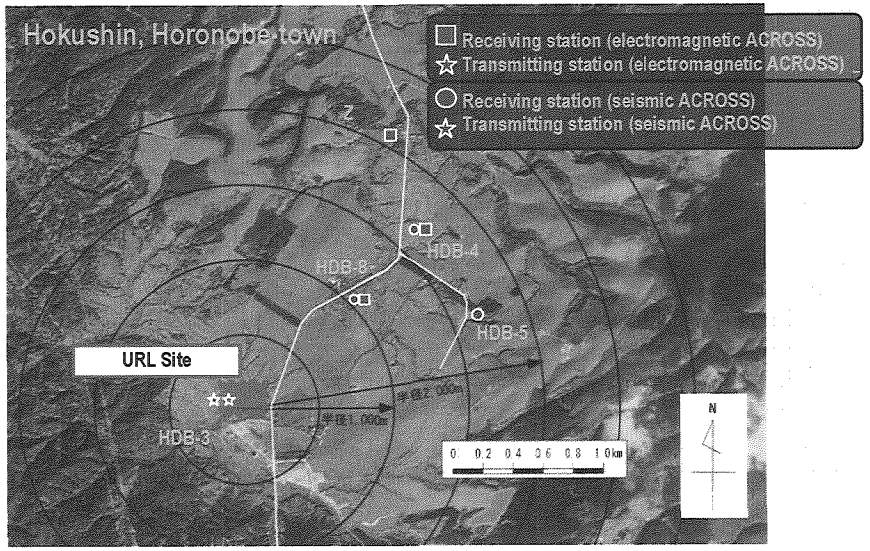
Investigations in the 2007 Fiscal Year (8/15)

Development of techniques for long-term monitoring of geological environment (Development of a remotely operated monitoring system)

Long-term monitoring at existing measurement points is continued. Processing and analysis of the acquired data are tried out. How the change in the geological environment caused by construction of the underground facility appears to an analytical result is examined.



Concept of a remotely operated monitoring system (seismic ACROSS)



Stations of remotely operated monitoring system

JAEA-Research 2008-070

Investigations in the 2007 Fiscal Year (9/15)

Studies on the long-term stability of the geological environment

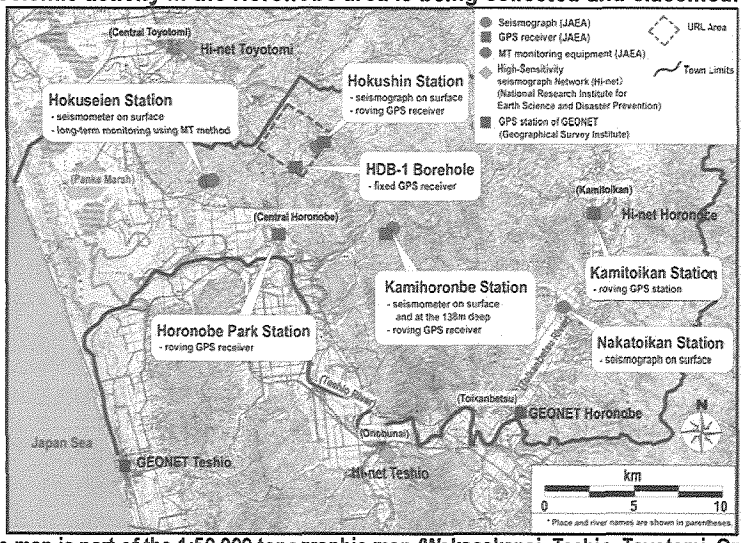
- Studies on long-term changes in the geological environment

  Investigations on topography, deformation of geological formations and fault activity and analyses of microfossils and petrology/mineralogy using rock samples obtained from outcrops and from underground facility are being conducted. Information on crustal movements and climate changes in and around Horonobe are collected and classified. The crustal movements and climate changes from the Neogene to the Quaternary in and around Horonobe are synthetically examined by combining the results of microfossil analyses, the analyzed result of geological formation and geological information acquired so far. Based on these information, information on influences of natural phenomena on the geological environment are classified.

  In addition, GPS measurements at existing points are continuing and the extent of the crustal movements is being analyzed by newly equipping GPS measurement points around the URL area for the purpose of examination on fault/fold activities distributing in and around the URL area. The data on deep geological specific resistivity obtained by the electromagnetic measurements are summarized on the relevance of seismogenic process.

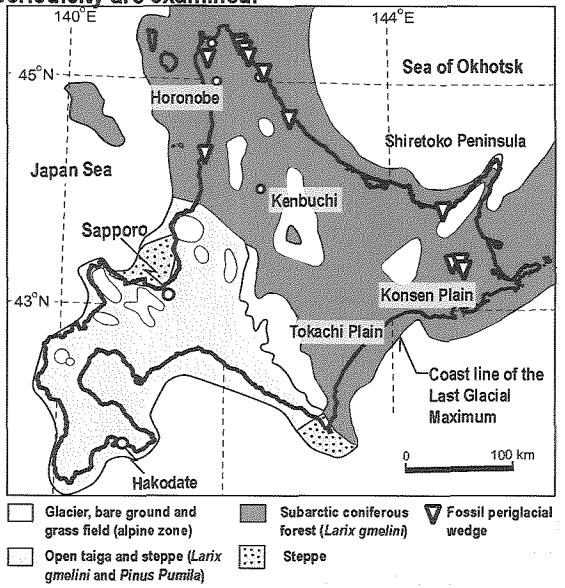
- Seismological studies

  Observations were made of earthquakes in the Horonobe area and its surroundings using seismographs installed at ground surface and at the bottom of a 138 m-deep borehole. Based on these data, hypocenter distribution and geological structure in the deep underground are studied. In addition, information on past seismic activity in the Horonobe area is being collected and classified. Then seismogenetic area and periodicity are examined.



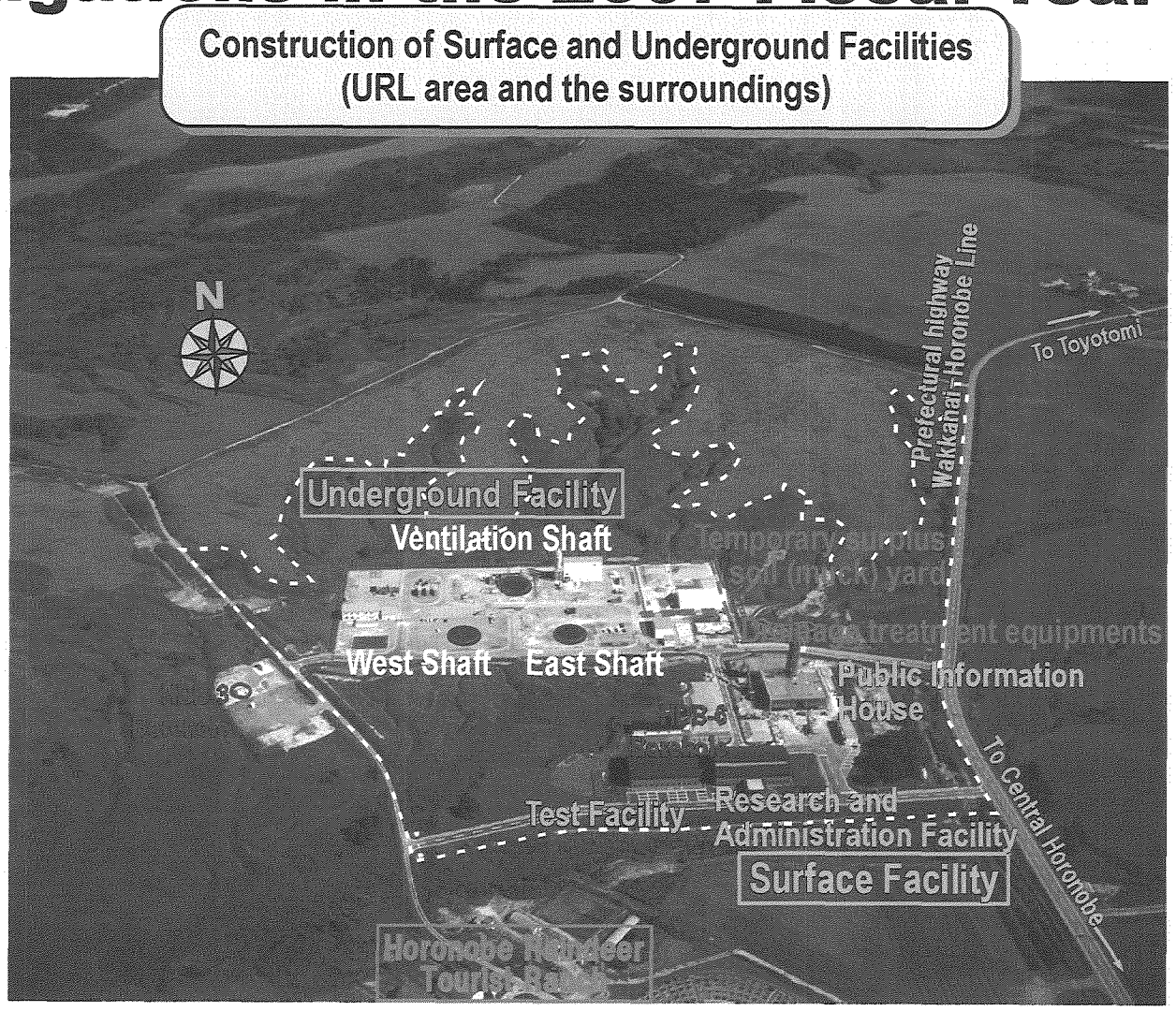
Base map is part of the 1:50,000 topographic map (Wakasakanai, Teshio, Toyotomi, Onobunai, Kami-sarufutsu, Pinneshiri) Published by the Geographical Survey Institute.

Observation stations in Horonobe

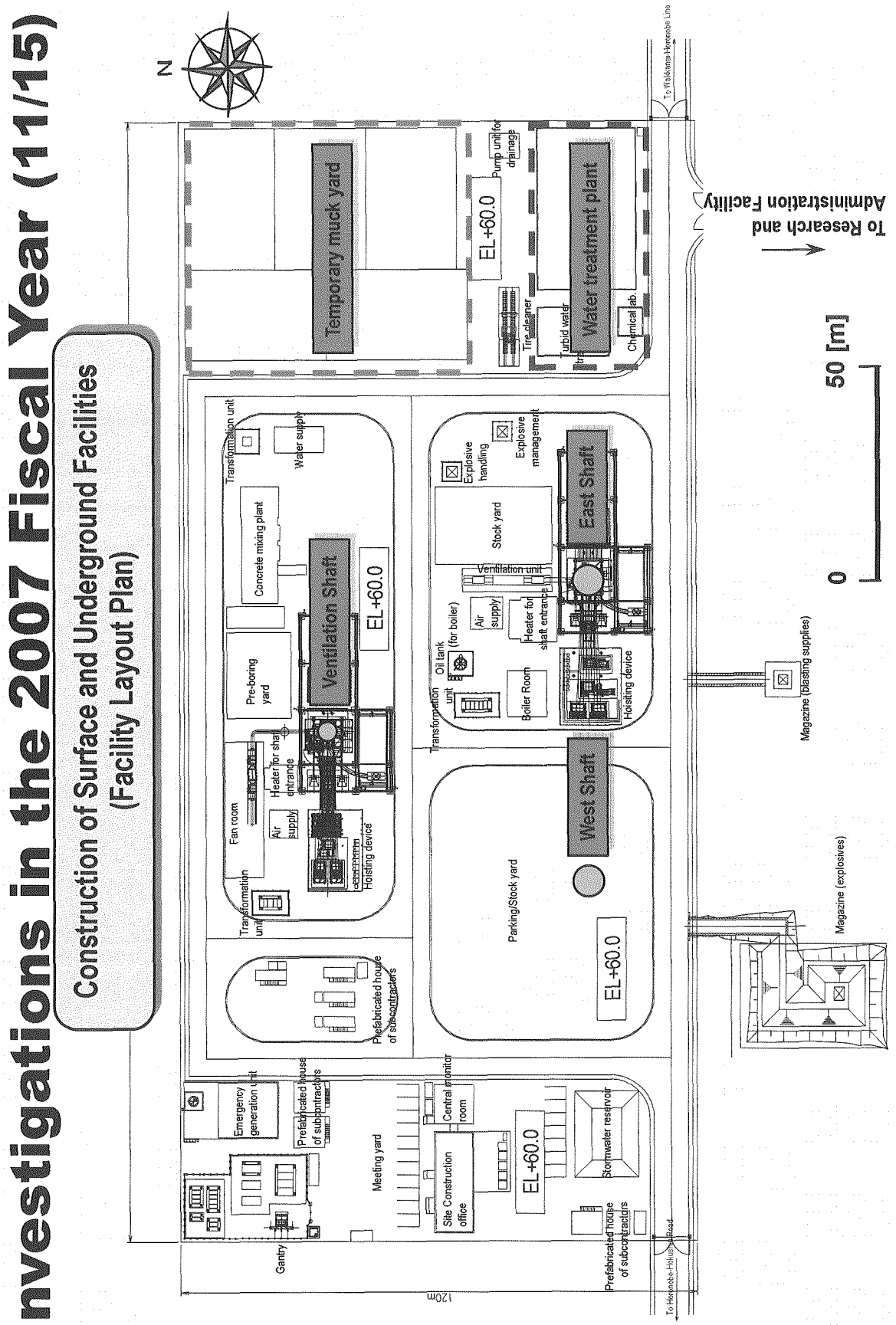


Vegetation of the Last Glacial Maximum

Investigations in the 2007 Fiscal Year (10/15)



Photographed on Oct. 20, 2007


Investigations in the 2007 Fiscal Year (11/15)
Construction of Surface and Underground Facilities
(Facility Layout Plan)
N
To Research and Administration Facility
0
50 [m]
Temporary muck yard
EL+60.0
Pump unit for drainage
Water treatment plant
Tire cleaner
Turbid water
Chemical lab.
To Wakkanai-Horonobe Line
Transformation unit
Water supply
Concrete mixing plant
Ventilation Shaft
EL+60.0
Pre-boring yard
Fan room
Air supply
Heater for shaft entrance
Hoisting device
Transformation unit
Prefabricated house of subcontractors
Explosive handling
Explosive management
Stock yard
East Shaft
Ventilation unit
Air supply
Heater for shaft entrance
Oil tank (for boiler)
Transformation unit
Boiler Room
Hoisting device
Parking/Stock yard
West Shaft
EL+60.0
Magazine (blasting supplies)
Magazine (explosives)
Emergency generation unit
Prefabricated house of subcontractors
Central monitor room
Meeting yard
Site Construction office
EL+60.0
Stormwater reservoir
Gantry
Prefabricated house of subcontractors
120m
To Hosinoabe-Horonobe Road

Investigations in the 2007 Fiscal Year (12/15)

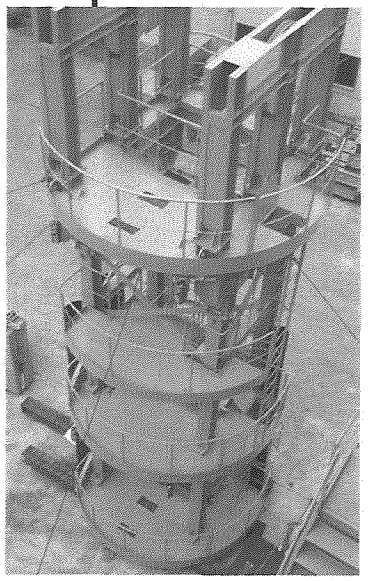
Construction of Underground Facilities

Excavation method

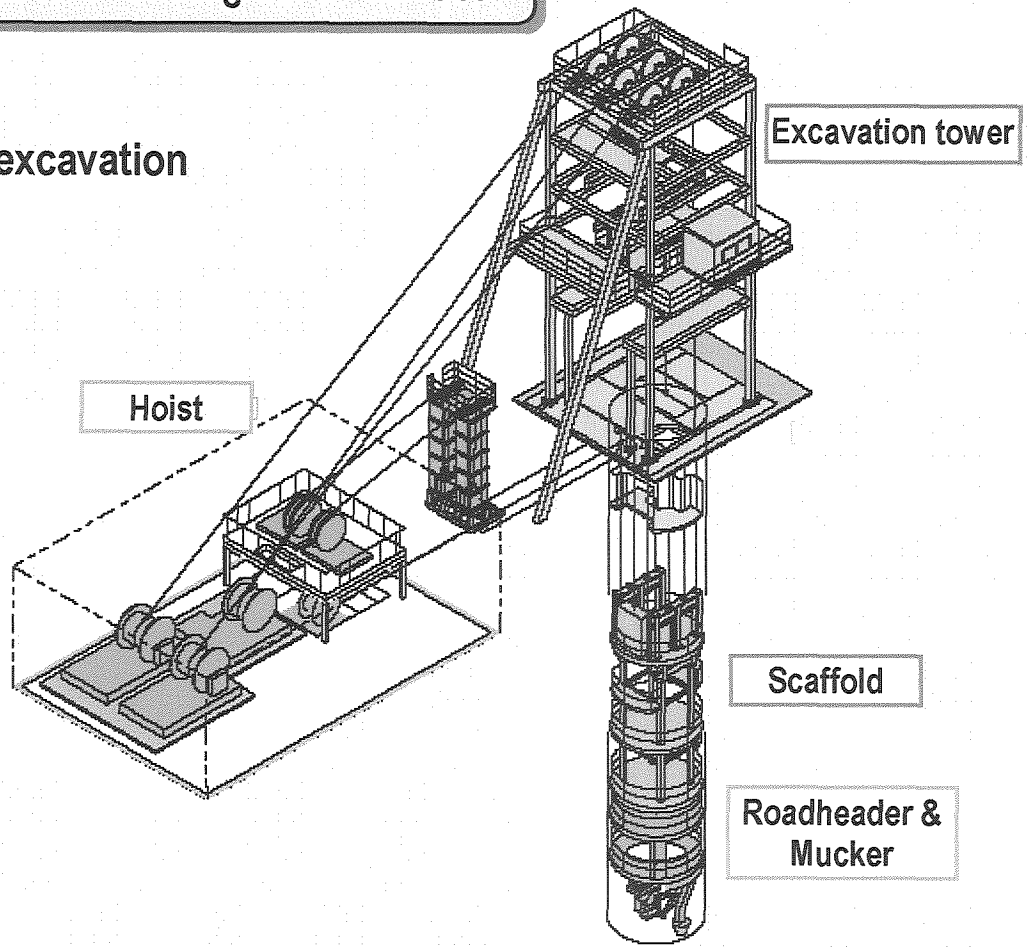
Ventilation/West Shaft: Mechanical excavation
East Shaft: Blasting excavation

Supporting method

Short step



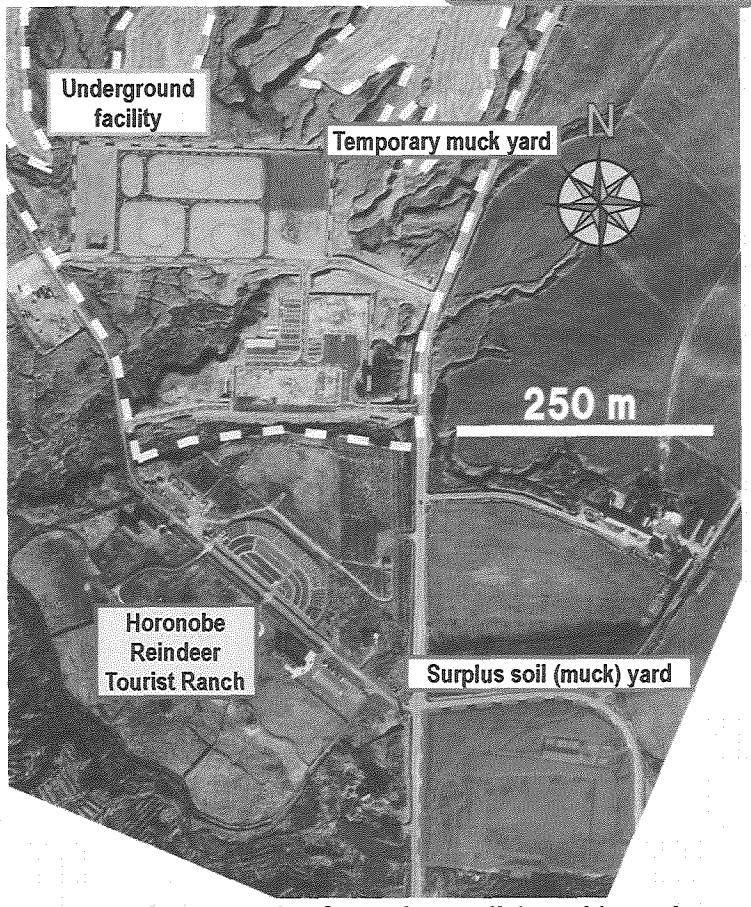
Scaffold



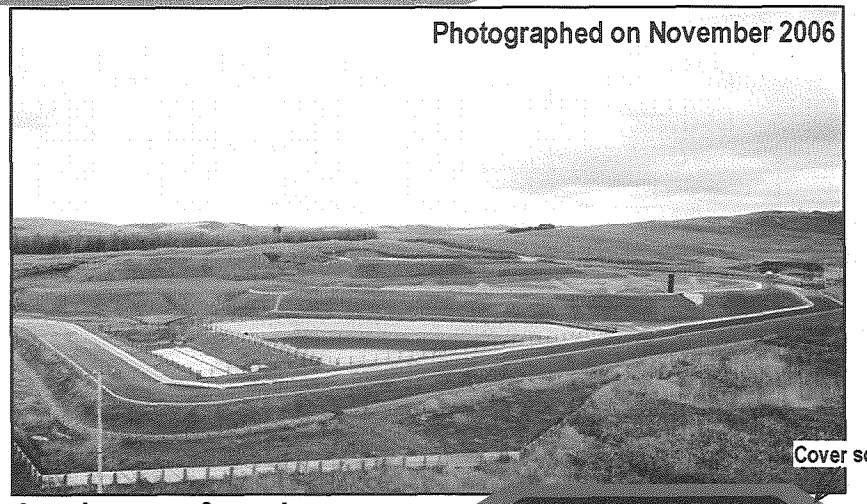
Schematic illustration of excavation tower

Investigations in the 2007 Fiscal Year (13/15)

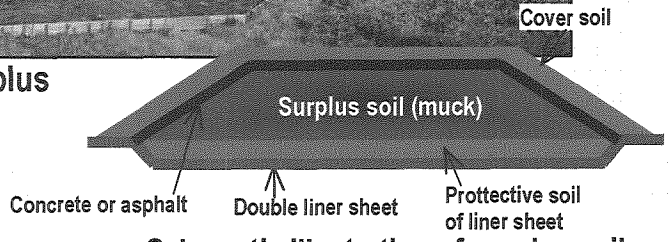
Construction of Surface and Underground Facilities (Surplus Soil (Muck) Yard)



Aerial photograph of surplus soil (muck) yard



Landscape of surplus soil (muck) yard



Schematic illustration of surplus soil (muck) yard

Basic Plan

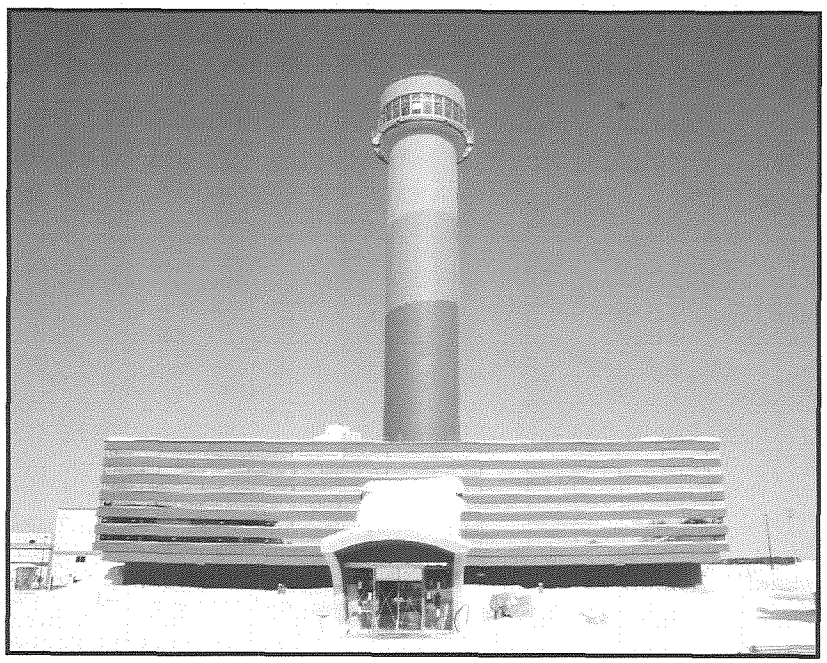
Environmental management is carried out in accordance with the "Soil Contamination Countermeasures Law", the "Water Pollution Control Law" and other applicable regulations.

Specification

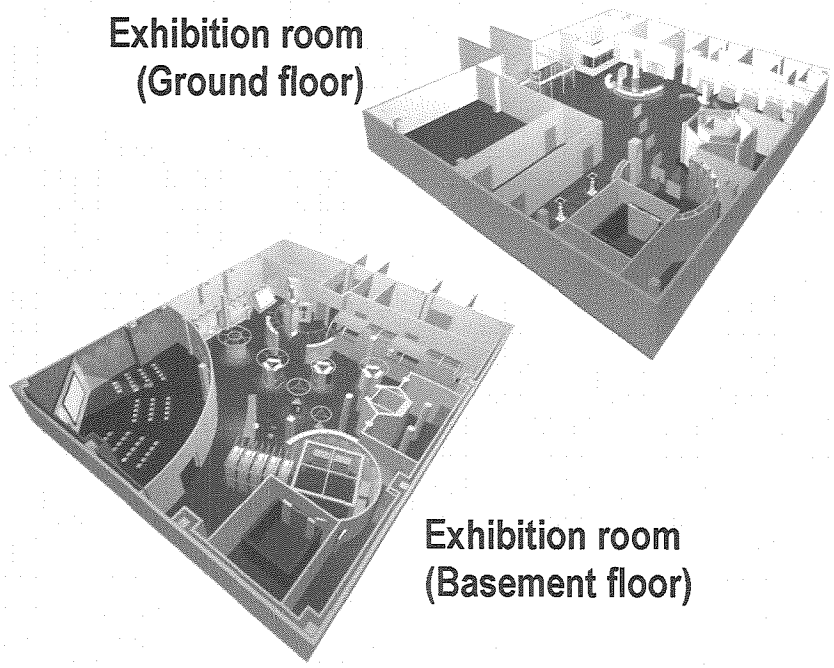
- Construction area: approx. 23,000m^2
- Capacity: approx. 100,000m^3
- Impervious containment type pursuant to the Soil Contamination Countermeasures Law

Investigations in the 2007 Fiscal Year (14/15)

Construction of Surface Facilities



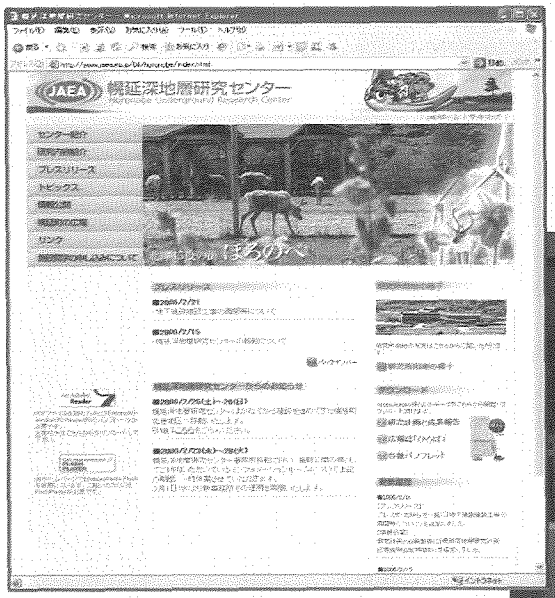
Public Information House
(photographed on Feb. 26, 2007)



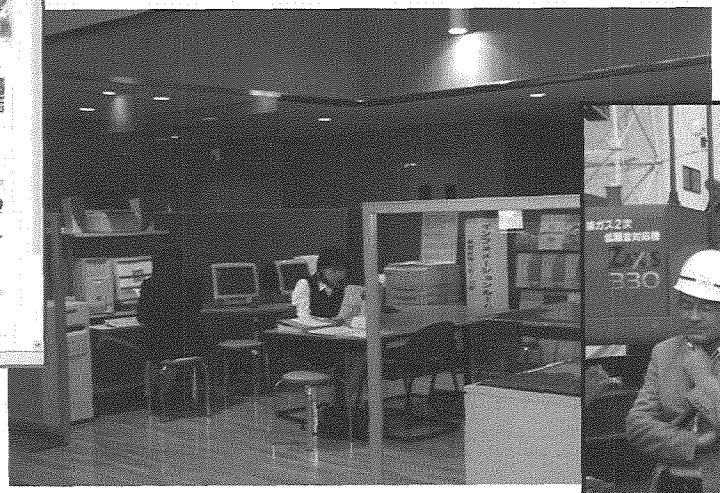
Interior design of Public Information House

Investigations in the 2007 Fiscal Year (15/15)

Open Research



Website of JAEA Horonobe
(http://ww.jaea.go.jp/04/horonobe)



Information Room
(Research and Administration Facility)

Information exchange with foreign researchers
The 16th NEA Clay Club Conference
September 6-9, 2005

国際単位系（SI）

表１．SI 基本単位

基本量	SI 基本単位	
	名称	記号
長さ	メートル	m
質量	キログラム	kg
時間	秒	s
電流	アンペア	A
熱力学温度	ケルビン	K
物質量	モル	mol
光度	カンデラ	cd

表２．基本単位を用いて表されるSI組立単位の例

組立量	SI 基本単位	
	名称	記号
面積	平方メートル	m^2
体積	立法メートル	m^3
速さ，速度	メートル毎秒	m/s
加速度	メートル毎秒毎秒	m/s^2
波数	毎メートル	m^{-1}
密度（質量密度）	キログラム毎立法メートル	kg/m^3
質量体積（比体積）	立法メートル毎キログラム	m^3/kg
電流密度	アンペア毎平方メートル	A/m^2
磁界の強さ	アンペア毎メートル	A/m
（物質量の）濃度	モル毎立方メートル	mol/m^3
輝度	カンデラ毎平方メートル	cd/m^2
屈折率	（数の）1	1

表５．SI 接頭語

乗数	接頭語	記号	乗数	接頭語	記号
10^{24}	ヨタ	Y	10^{-1}	デシ	d
10^{21}	ゼタ	Z	10^{-2}	センチ	c
10^{18}	エクサ	E	10^{-3}	ミリ	m
10^{15}	ペタ	P	10^{-6}	マイクロ	μ
10^{12}	テラ	T	10^{-9}	ナノ	n
10^{9}	ギガ	G	10^{-12}	ピコ	p
10^{6}	メガ	M	10^{-15}	フェムト	f
10^{3}	キロ	k	10^{-18}	アト	a
10^{2}	ヘクト	h	10^{-21}	ゼプト	z
10^{1}	デカ	da	10^{-24}	ヨクト	y

表３．固有の名称とその独自の記号で表されるSI組立単位

組立量	SI 組立単位			
	名称	記号	他のSI単位による表し方	SI基本単位による表し方
平面角	ラジアン(a)	rad		$m \cdot m^{-1}=1$(b)
立体角	ステラジアン(a)	sr(c)		$m^2 \cdot m^{-2}=1$(b)
周波数	ヘルツ	Hz		s^{-1}
力	ニュートン	N		$m \cdot kg \cdot s^{-2}$
圧力，応力	パスカル	Pa	N/m^2	$m^{-1} \cdot kg \cdot s^{-2}$
エネルギー，仕事，熱量	ジュール	J	N・m	$m^2 \cdot kg \cdot s^{-2}$
工率，放射束	ワット	W	J/s	$m^2 \cdot kg \cdot s^{-3}$
電荷，電気量	クーロン	C		s・A
電位差（電圧），起電力	ボルト	V	W/A	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-1}$
静電容量	ファラド	F	C/V	$m^{-2} \cdot kg^{-1} \cdot s^4 \cdot A^2$
電気抵抗	オーム	Ω	V/A	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-2}$
コンダクタンス	ジーメンス	S	A/V	$m^{-2} \cdot kg^{-1} \cdot s^3 \cdot A^2$
磁束	ウエーバ	Wb	V・s	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-1}$
磁束密度	テスラ	T	Wb/m^2	$kg \cdot s^{-2} \cdot A^{-1}$
インダクタンス	ヘンリー	H	Wb/A	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-2}$
セルシウス温度	セルシウス度(d)	℃		K
光束	ルーメン	lm	cd・sr(c)	$m^2 \cdot m^{-2} \cdot cd=cd$
照度	ルクス	lx	lm/m^2	$m^2 \cdot m^{-4} \cdot cd=m^{-2} \cdot cd$
（放射性核種の）放射能	ベクレル	Bq		s^{-1}
吸収線量，質量エネルギー分与，カーマ	グレイ	Gy	J/kg	$m^2 \cdot s^{-2}$
線量当量，周辺線量当量，方向性線量当量，個人線量当量，組織線量当	シーベルト	Sv	J/kg	$m^2 \cdot s^{-2}$

(a)ラジアン及びステラジアンの使用は、同じ次元であっても異なった性質をもった量を区別するときの組立単位の表し方として利点がある。組立単位を形作るときのいくつかの用例は表４に示されている。
(b)実際には、使用する時には記号rad及びsrが用いられるが、習慣として組立単位としての記号“１”は明示されない。
(c)測光学では、ステラジアンの名称と記号srを単位の表し方の中にそのまま維持している。
(d)この単位は、例としてミリセルシウス度m℃のようにSI接頭語を伴って用いても良い。

表４．単位の中に固有の名称とその独自の記号を含むSI組立単位の例

組立量	SI 組立単位		
	名称	記号	SI 基本単位による表し方
粘度	パスカル秒	Pa・s	$m^{-1} \cdot kg \cdot s^{-1}$
力のモーメント	ニュートンメートル	N・m	$m^2 \cdot kg \cdot s^{-2}$
表面張力	ニュートン毎メートル	N/m	$kg \cdot s^{-2}$
角速度	ラジアン毎秒	rad/s	$m \cdot m^{-1} \cdot s^{-1}=s^{-1}$
角加速度	ラジアン毎平方秒	rad/s^2	$m \cdot m^{-1} \cdot s^{-2}=s^{-2}$
熱流密度，放射照度	ワット毎平方メートル	W/m^2	$kg \cdot s^{-3}$
熱容量，エントロピー	ジュール毎ケルビン	J/K	$m^2 \cdot kg \cdot s^{-2} \cdot K^{-1}$
質量熱容量（比熱容量），質量エントロピー	ジュール毎キログラム毎ケルビン	J/(kg・K)	$m^2 \cdot s^{-2} \cdot K^{-1}$
質量エネルギー（比エネルギー）	ジュール毎キログラム	J/kg	$m^2 \cdot s^{-2} \cdot K^{-1}$
熱伝導率	ワット毎メートル毎ケルビン	W/(m・K)	$m \cdot kg \cdot s^{-3} \cdot K^{-1}$
体積エネルギー	ジュール毎立方メートル	J/m^3	$m^{-1} \cdot kg \cdot s^{-2}$
電界の強さ	ボルト毎メートル	V/m	$m \cdot kg \cdot s^{-3} \cdot A^{-1}$
体積電荷	クーロン毎立方メートル	C/m^3	$m^{-3} \cdot s \cdot A$
電気変位	クーロン毎平方メートル	C/m^2	$m^{-2} \cdot s \cdot A$
誘電率	ファラド毎メートル	F/m	$m^{-3} \cdot kg^{-1} \cdot s^4 \cdot A^2$
透磁率	ヘンリー毎メートル	H/m	$m \cdot kg \cdot s^{-2} \cdot A^{-2}$
モルエネルギー	ジュール毎モル	J/mol	$m^2 \cdot kg \cdot s^{-2} \cdot mol^{-1}$
モルエントロピー，モル熱容量	ジュール毎モル毎ケルビン	J/(mol・K)	$m^2 \cdot kg \cdot s^{-2} \cdot K^{-1} \cdot mol^{-1}$
照射線量（X線及びγ線）	クーロン毎キログラム	C/kg	$kg^{-1} \cdot s \cdot A$
吸収線量率	グレイ毎秒	Gy/s	$m^2 \cdot s^{-3}$
放射強度	ワット毎ステラジアン	W/sr	$m^4 \cdot m^{-2} \cdot kg \cdot s^{-3}=m^2 \cdot kg \cdot s^{-3}$
放射輝度	ワット毎平方メートル毎ステラジアン	$W/(m^2 \cdot sr)$	$m^2 \cdot m^{-2} \cdot kg \cdot s^{-3}=kg \cdot s^{-3}$

表６．国際単位系と併用されるが国際単位系に属さない単位

名称	記号	SI 単位による値
分	min	1 min=60s
時	h	1h =60 min=3600 s
日	d	1 d=24 h=86400 s
度	°	1° =(π/180) rad
分	’	1’ =(1/60)° =(π/10800) rad
秒	”	1” =(1/60)’ =(π/648000) rad
リットル	l、L	$1l=1\ dm^3=10^{-3}m^3$
トン	t	$1t=10^3$ kg
ネーパ	Np	1Np=1
ベル	B	1B=(1/2)ln10(Np)

表７．国際単位系と併用されこれに属さない単位でSI単位で表される数値が実験的に得られるもの

名称	記号	SI 単位であらわされる数値
電子ボルト	eV	$1eV=1.60217733(49) \times 10^{-19}J$
統一原子質量単位	u	$1u=1.6605402(10) \times 10^{-27}kg$
天文単位	ua	$1ua=1.49597870691(30) \times 10^{11}m$

表８．国際単位系に属さないが国際単位系と併用されるその他の単位

名称	記号	SI 単位であらわされる数値
海里		1海里=1852m
ノット		1ノット=1海里毎時=(1852/3600)m/s
アール	a	$1a=1\ dam^2=10^2m^2$
ヘクタール	ha	$1ha=1\ hm^2=10^4m^2$
バール	bar	$1\ bar=0.1MPa=100kPa=1000hPa=10^5Pa$
オングストローム	Å	$1\ Å=0.1nm=10^{-10}m$
バーン	b	$1\ b=100fm^2=10^{-28}m^2$

表９．固有の名称を含むCGS組立単位

名称	記号	SI 単位であらわされる数値
エルグ	erg	$1\ erg=10^{-7}$ J
ダイン	dyn	$1\ dyn=10^{-5}N$
ポアズ	P	$1\ P=1\ dyn \cdot s/cm^2=0.1Pa \cdot s$
ストークス	St	$1\ St=1cm^2/s=10^{-4}m^2/s$
ガウス	G	1 G ^10^-4T
エルステッド	Oe	1 Oe ^(1000/4π)A/m
マクスウェル	Mx	1 Mx ^10^-8Wb
スチルブ	sb	$1\ sb=1cd/cm^2=10^4cd/m^2$
ホト	ph	$1\ ph=10^4lx$
ガル	Gal	$1\ Gal=1cm/s^2=10^{-2}m/s^2$

表10．国際単位に属さないその他の単位の例

名称	記号	SI 単位であらわされる数値
キュリー	Ci	$1\ Ci=3.7 \times 10^{10}Bq$
レントゲン	R	$1\ R=2.58 \times 10^{-4}C/kg$
ラド	rad	$1\ rad=1cGy=10^{-2}Gy$
レム	rem	$1\ rem=1\ cSv=10^{-2}Sv$
X線単位		$1X\ unit=1.002 \times 10^{-4}nm$
ガンマ	γ	$1\gamma=1\ nT=10^{-9}T$
ジャンスキー	Jy	$1\ Jy=10^{-26}W \cdot m^{-2} \cdot Hz^{-1}$
フェルミ		$1\ fermi=1\ fm=10^{-15}m$
メートル系カラット		$1\ metric\ carat=200\ mg=2 \times 10^{-4}kg$
トル	Torr	$1\ Torr=(101\ 325/760)\ Pa$
標準大気圧	atm	$1\ atm=101\ 325\ Pa$
カロリー	cal	
ミクロン	μ	$1\ \mu=1\mu m=10^{-6}m$

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