JSEG2025 in Sapporo - JSEG and AEG Collaboration Session-
日本応用地質学会 2025 札幌大会　JSEG･AEG 協働セッション

Geo-related Risks for Dams
- Investigation, Evaluation, and Remediation Measures.

地質関連リスクとダム
－調査、評価と緩和対策－

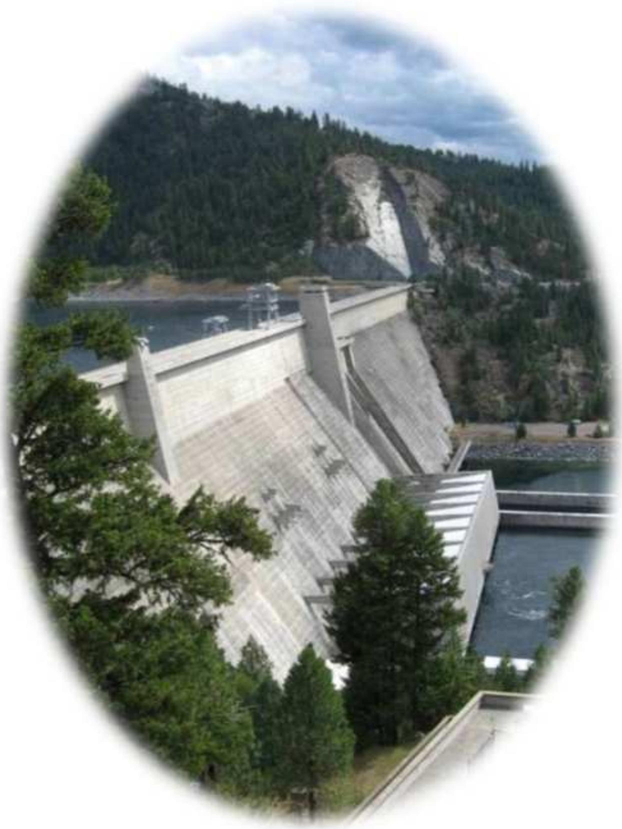
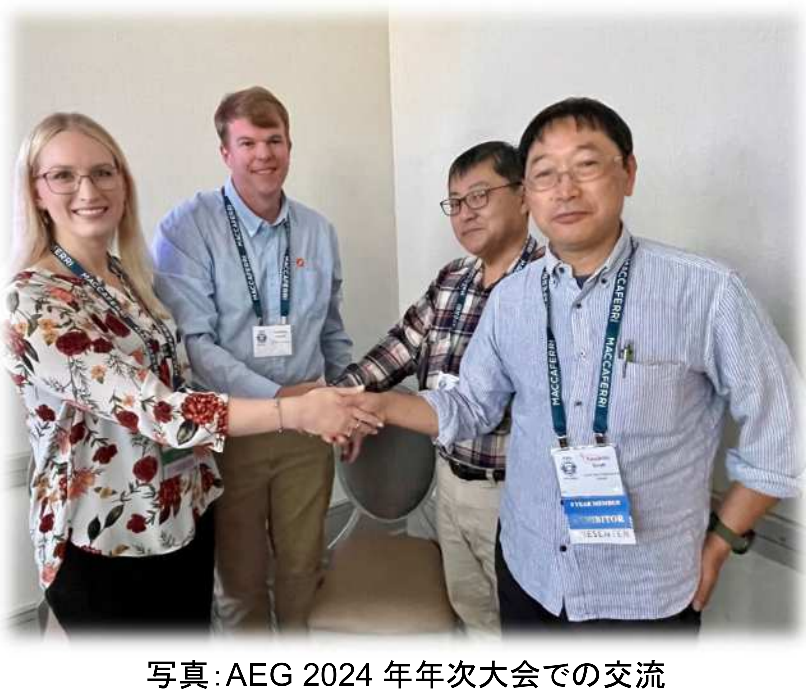


Photo: Libby Dam (Montana) and wedge slide at left abutment
写真: リビーダム（モンタナ州）と左岸アバット部のくさび滑り
（本セッションにて米国陸軍工兵隊（USACE）の Todd Loar 氏が発表予定。写真は USACE HP より）

AIMS（目的）

This session is a collaborative hybrid session co-organized by the Association of Environmental and Engineering Geologists (AEG) and the Japan Society of Engineering Geology (JSEG) and will be conducted in English. It will focus on geological risks as common challenges faced by dams in both Japan and the United States, presenting mitigation strategies and case studies. Both Japan and the U.S. are situated in the Pacific Ring of Fire, sharing common issues such as geological disaster risks (e.g., earthquakes and volcanic activity), climate change risks (e.g., hurricanes and typhoons), and infrastructure aging risks. Therefore, this collaboration is planned to continue for several years. Through this joint effort, we aim to broaden the perspectives and enhance the knowledge of participating engineers, thereby contributing to the improvement of safety standards and practices for infrastructure like dams in both countries and the international community.

このセッションは、Association of Environmental and Engineering Geologists（AEG）と日本応用地質学会（JSEG）の共催によるハイブリッド形式の協働セッションであり、英語で実施される。本セッションでは、日米のダムが抱える共通の課題として地質関連リスクに焦点を当て、その対処方法やケーススタディを紹介する。日本と米国はともに環太平洋火山帯に位置し、地震や火山などの地質災害リスク、ハリケーンや台風といった気候変動リスク、さらにはインフラの老朽化リスクなど、共通の課題を抱えている。このため、この協力関係は数年間継続される予定である。この協働を通じて、参加する技術者の視野と知見の向上を図り、両国および国際社会におけるダム等のインフラの安全基準と実務の改善に貢献する。



写真：AEG 2024 年年次大会での交流

左から AEG ダム・堤防 WG 座長の Wagner 氏、Gagnon 氏、JSEG 土木地質研究部会綿谷副部会長、佐々木顧問

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Japan Society of Dam Engineers (JSDE) 一般社団法人ダム工学会

Japan Society Engineering Geology Hokkaido Branch 北海道応用地質研究会

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Japan Civil Engineering Consultants Association (JCCA) 一般社団法人建設コンサルタンツ協会

Japan Dam Engineering Center (JDEC) 一般財団法人ダム技術センター

Planning Committee for Master of the Fields フィールドの達人企画委員会

Photo: Conowingo Dam (Maryland, USA)　写真: コノウィンゴダム（米国メリーランド州）
（AEG2024 年大会見学地。佐々木靖人撮影）

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SCEDULE（スケジュール）

From	To	Program
		Session Chair: ***Hirokazu Ueda (NEWJEC Inc.)*** **Vice Session Chair:** ***Kyohei Kamada (NEWJEC Inc.)***
11:00	11:10	**Opening Remarks（開会あいさつ）** *Hiroyuki Watatani (CTI Engineering Co., Ltd)* *Yasuhito Sasaki (Japan Dam Engineering Center)*
11:10	12:00	**Invited Lecture（招待講演）** **Variation and Design Values of Mechanical Properties of Dam Rock Foundations** *Dr. Yoshikazu Yamaguchi* *Vice President of Japan Dam Engineering Center (JDEC)* *Vice President of Japan Society of Dam Engineers (JSDE)* *Executive Director of Japan Commission on Large Dams (JCOLD))*
12:00	13:40	**General Lectures by AEG members（AEG 一般発表）**
12:00	12:20	**Federal Dam Safety Programs in the US: Evolution and Structure of Risk Assessment** *Todd Loar and Cassandra Wagner (U. S. Army Corps of Engineers)*
12:20	12:40	**An Introduction to Private Industry Risk Assessments for Dams in the United States** *Hawkins Gagnon (Schnabel Engineering）*
12:40	13:00	**Geological Factors in Dam Safety Risk Assessment (US Practice)** *Cassandra Wagner and Todd Loar (U. S. Army Corps of Engineers）*
13:00	13:20	**Complex Risk Analysis on Rock Wedge Stability at Libby Dam, Montana** *Jessica Rudd, Sharon Gelinas and Todd Loar (U. S. Army Corps of Engineers）*
13:20	13:40	**Lessons Learned: Embankment Protection ("HydroTurf") on a High Hazard Dam in Maryland** *Visty Dalal (Maryland Department of Environment）*
13:40	13:50	**Tea / Coffee Break（休憩）**
13:50	15:30	**General Lectures by JSEG members（JSEG 一般発表）**
13:50	14:10	**Geotechnical Risk Management for Dam Upgrading Projects in Japan** *Yoshinori Yajima (Public Works Research Institute）*
14:10	14:30	**Evaluation of Geo-related Risks: A Perspective on Engineering Education** *Takashi Isomura (Yachiyo Engineering. Co., Ltd.）*
14:30	14:50	**Assessment of Sheeting Joint Development in the Foundation Rock of the Asuwagawa Dam and Engineering Countermeasures During Construction** *Kyohei Kamada (NEWJEC Inc.）*
14:50	15:10	**Stability Study of a Long Slope Affected by Hydrothermal Alteration Andesite** *Kazuhisa Ashida (Nippon Koei Co., Ltd.）*
15:10	15:30	**A Case Study of Geo-related Risks Identified in Dam Construction Projects in Soft Rock Distribution Areas and Countermeasures** *Ryoichi Yamaura (CTI Engineering Co., Ltd.）*
15:30	15:55	**Discussion（総合討論）** **Moderator:** ***Hirokazu Ueda and Kyohei Kamada (NEWJEC Inc.)***
15:55	16:00	**Closing Remarks（閉会あいさつ）** *Masahiro Katayama　(Kumagai Gumi Co., Ltd.）*

■ Invited Speaker

Dr. Yoshikazu Yamaguchi (‘Yoshi’)

Ph. D. in Eng., PE. JP (Civil Eng.)
Vice President of Japan Dam Engineering Center (JDEC)
Vice President of Japan Society of Dam Engineers (JSDE)
Executive Director of Japan Commission on Large Dams (JCOLD)

He started his career as dam engineer at the Public Works Research Institute (PWRI), the Japanese Government in 1984. He made research & development on investigation, design, execution, management and upgrading of dams, and technical support to many Japanese dams with his technical experience and knowledge during about 35-year career at PWRI. He submitted many refereed papers to several eminent scientific societies and received more than 10 awards from several scientific societies. He resigned from PWRI as Vice President in 2019.

He has been working for the Japan Dam Engineering Center (JDEC) from 2019. JDEC provides high-quality dam engineering services appropriately adapted to various circumstances surrounding dams in order to act as Japan’s foremost think-tank dealing with dam engineering.

As a Vice President of the JDEC, he supervises the activities of the JDEC including (1) conducting surveys and research, (2) providing technological assistance, (3) training personnel, (4) implementing public awareness programs, and (5) conducting international affairs. Other activities include precast formwork projects and examination and certification programs for the newly developed technologies.

■ AEG Speakers

Mr. Todd Loar

Certified Engineering Geologist (CEG)
Senior Geological Engineer at the US Army Corps of Engineers (USACE), Risk Management Center (RMC)
Adjunct professor in geological engineering at the Colorado School of Mine and University of Colorado

He serves as a subject matter expert and technical advisor for the USACE national dam and levee safety program. Todd has degrees in geology and geological engineering from University of California, Santa Cruz (BA), and the Colorado School of Mines (MS), respectively, and more than 29 years of experience in both private and public sectors for a wide range of engineering projects within the US and internationally.

He worked on many different projects all over the United States and internationally. These have included site characterization, analysis, design, and construction for all different types of large civil works infrastructure. Apart from projects, he occasionally teach site characterization at both Colorado School of Mines and the University of Colorado up in Boulder.

Mr. Hawkins Gagnon (‘Hawkins’)

Professional Geologist, Licensed Geologist
Associate Geologist with Schnabel Engineering
Co-chair of AEG’s Dams and Levees Technical Working Group

a. Lead Geologist
  i. Proposed Lewis Ridge Pumped Storage Hydropower
  ii. Proposed Tazewell Hybrid Energy Center
b. Geology Subject Matter Expert for Dam Safety Risk Analyses
  i. Noxon Rapids HED
  ii. Narrows Dam - Yadkin Hydroelectric Project
  iii. New Bullards Bar Dam
  iv. Logan Martin Dam
c. Project Manager
  i. Bath County Pumped Storage Station - various tasks
  ii. Salt River Project Proposed Pumped Storage Project - design project management

One last thing…
‘I'm married and proud father of two children that are 7 and 3 years old.’

Ms. Cassandra Wagner ('Cassie')

Professional Geologist
Chief, Geosciences Branch, Dam Safety Production Center (DSPC), South Pacific Division (SPD), USACE
Co-chair of AEG's Dams and Levees Technical Working Group

She's an engineering geologist, and an geological engineer that has worked on a wide variety of dam and levee safety risk assessments, tunneling projects, and geologic support to dam safety modifications.

Her primary focus has been in dam safety, including the development of field investigation programs, risk analysis, site characterization, and design and construction activities.

Dr. Visty Dalal ('Visty')

Ed. D. in 'Higher Education Leadership' in STEM education
Senior engineering geologist with the Maryland Dam Safety Program at the Maryland Department, USA
Adjunct STEM professor at Southern New Hampshire University

Dr. Dalal has served the Maryland Dam Safety Program for the past 34 years. As a state regulator, he supervises over a hundred dams, including their inspection, construction, maintenance, and repairs. He also coordinates the 'Emergency Action Plan' (EAP) tabletop and functional exercises. He is a certified 'Expert Witness' in the Maryland Administrative Court on dam-related cases. He is active in the 'Association of State Dam Safety Officials' (ASDSO) and 'Association of Environmental & Engineering Geologists' (AEG) and has published several technical papers at the conferences and in their journals. He and his AEG Dams & Levees Technical Working Group (D&L-TWG) colleagues, along with scientists from the Japan Society of Engineering Geology (JSEG), are responsible for the formation of IAEG's Dams & Levees Commission (DLC), which was unanimously approved by all the IAEG Council Members at the September 7, 2025, meeting in Namibia. The DLC Committee looks forward to collaborating with scientists on dams and levees worldwide and invites their participation by writing directly to Dr. Dalal.

■ JSEG Speakers

Mr. Yoshinori Yajima ('Yaji')

Professional Engineer JP (Applied Science)
Leader of geology team at National Research and Development Agency Public Works Research Institute (PWRI)

He joined Public Works Research Institute (PWRI) in 2004 and has since been engaged primarily in research on the evaluation of foundation rock for dams, particularly shear strength evaluation of rock joint, as well as reservoir-related landslides, road slope disaster prevention and simplified sounding tests for ground investigation.

In recent year, he has been engaged in providing technical support for dam projects across Japan, and in research on geological and geotechnical risk management related to public infrastructure projects.

Mr. Takashi Isomura ('Iso')

Professional Engineer JP (Applied Science)
Deputy General Manager with Yachiyo Engineering Co. Ltd.
Chief Secretary of Planning Committee for Master of the Fields
Vice Chair of Dam and Power Generation committee in Japan Civil Engineering Consultant Association (JCCA)

@Kasabori Dam site under construction

The picture below is his first project after joining Yachiyo; the Kasabori Dam in Niigata Pref. The dam crest rose additionally by 4 meters for a disaster recovery measure due to two past floods. As the geology lead, he was tasked with estimating the bedrock conditions in a tight schedule, which he and his coworkers then verified during construction. He's pleased to report that their estimates were largely accurate, and the project was completed successfully.

One last thing…

'I'm too busy, but I never miss a task of head coach of a little league team in Higashi-Murayama City.'

Mr. Kyohei Kamata ('Kevin')

Engineering geologist with NEWJEC Inc.
Member of JSEG's International Committee

He was born and raised in Sapporo, Hokkaido, where he lived until graduating from high school.

He graduated with a degree in Resource Science from Akita University, before joining NEWJEC.

With about five years of professional experience, he is currently engaged in foundation excavation surveys and grouting analysis for gravity dams, building on his expertise in drilling surveys and geological analysis.

Mr. Kazuhisa Ashida ('Ashiyan')

Professional Engineer JP (Applied Science)
Engineering geologist with Nippon Koei Co., Ltd. (Sapporo Branch)

In the redevelopment project of the gravity-type concrete dam (Shinkatsurazawa Dam) using the coaxial elevation method in a snowy and cold region, he was consistently involved from the initial implementation survey in 1998 to the completion in 2024. His contributions included geological structure analysis of the dam foundation, seepage control measures, and evaluation of trial impoundment.(Recipient of the Japan Society of Civil Engineers Technology Award)

- Additional Information to Highlight -

In addition to dam geological surveys, he has handled a wide range of tasks related to geology and groundwater, including groundwater analysis, slope stability assessments, and responses to naturally occurring heavy metals.

Mr. Ryoichi Yamaura ('Ryo')

Professional Engineer JP (Applied Science)
Engineering geologist with CTI Engineering Co., Ltd. (Kyusyu Office)

He has been involved in projects evaluating dam foundation bedrock and assessing reservoir landslide slopes and countermeasures. Beyond this presentation, he contributed to properly conducting reservoir landslide slope assessments for a gravity concrete dam built in a volcanic rock area, enabling the safe completion of trial impoundment.

- Additional Information to Highlight -

In the dam construction projects he has been involved in have been located in geological zones with numerous potential risks, geo-related risks as Quaternary pyroclastic flow deposits and volcanic rocks, as well as Mesozoic accretionary complexes. At dam sites bearing many geo-related risks, he thinks that the cost of the dam project hinges on the appropriate judgment of geological engineers.

10. Variation and Design Values of Mechanical Properties of Dam Rock Foundations

Yoshikazu Yamaguchi
Vice President of JDEC, Vice President of JSDE and Executive Director of JCOLD

1. Introduction

The dam foundation is generally composed of rocks with various mechanical properties and geological discontinuities. The combination of these properties of rock foundation significantly affects its mechanical properties, such as deformability and shear strength, which are very important for dam structural design. Furthermore, the effects of tectonic movements, subsequent stress release and weathering vary from one damsite to another, making their spatial distribution crucial for dam design. Therefore, assessing the mechanical properties and their spatial distribution of the rock foundation is crucial for appropriate dam structural design.

Due to the complex physical properties of dam rock foundation and the difficulty of visually assessing its overall structure, not a few past dam incidents have been attributed to their rock foundation (e.g., ICOLD [1]).

The mechanical properties of rock foundation, such as deformability and shear strength, vary depending on many factors and their combinations. However, the most important factors are the rock strength and the frequency and condition of discontinuities. Therefore, rock mass classification is an effective tool for relating the condition of the rock foundation to its mechanical properties and evaluating their spatial distribution. In addition, when rock foundation has anisotropy due to schistosity and/or bedding, attention must also be paid to the anisotropy of deformation and strength characteristics.

Currently, when designing a dam rock foundation, rock masses are classified as described above, and in-situ deformation tests and shear strength tests are conducted to match each rock type and rock class with mechanical property values (design values) such as deformability and shear characteristics. However, in-situ deformation tests and shear strength tests must be made to appropriately include discontinuities that significantly affect the mechanical properties of the rock mass. This naturally results in a large test scale, limiting the number of tests that can be conducted for each rock type and rock class. Furthermore, rock mass properties that are significantly affected by discontinuities are significantly influenced by the characteristics and distribution of discontinuities in the test area, resulting in a certain degree of variability in results even for the same rock type and rock class. Therefore, when designing a dam rock foundation, appropriate design values must be set taking into account the variability in the results of various mechanical tests of the rock mass.

2. Design of rock foundation for dams

The structural design of dams in Japan is based on the Japanese Cabinet Order on Structure of River Management Facilities, a legally binding design standard [2]. This design standard stipulates that a dam rock foundation must be designed to have the necessary watertightness and to prevent sliding or seepage failure due to anticipated loads. For this reason, when designing a dam, various tests are conducted on the foundation rock to determine its mechanical properties, such as shear strength and deformability, as well as its rock hydraulic properties, such as permeability and seepage failure resistance. Design values are then set based on the results of these tests, taking into account an appropriate safety margin. Structural calculations are also performed based on anticipated loads, and it is confirmed that the various design values of rock foundation satisfy the required structural safety factors against the generated forces due to anticipated loads.

In addition, appropriate foundation treatment is also required to ensure the necessary watertightness of the foundation rock. For rock foundation, cement grouting is commonly used as foundation treatment method, and technical guidelines for this technique have been established in Japan[3].

3. Evaluation of in-situ tests for dam rock foundation in Japan

This paper introduces design responses to variations in mechanical properties obtained from in-situ tests in the design of rock foundation for concrete gravity dams in Japan.

3.1 Plate loading test [4]

The following are points to note regarding variability in the results of plate loading tests, which are deformation tests on rock masses, and test accuracy:

- Tests should be conducted at three or more locations with the same rock mass conditions.
- The deformation characteristics of rock masses can vary greatly due to slight differences in the state of cracks

below the loading plate.

- When the deformability of the rock mass is expected to be anisotropic due to discontinuities such as joints or bedding, the loading direction must be set taking into account the design load direction and the direction of the discontinuities.
- It is important to evaluate deformability by referring to the results of various rock tests and in-situ deformation tests other than plate loading tests.

3.2 Shear strength test [4)]

The following points should be noted regarding variability in the results of in-situ shear tests to determine the shear strength of rock mass and test accuracy.

- Tests should be conducted at four or more locations on rock mass of the same rock class.
- After the specimen has been shaped, the representativeness of the test locations must be confirmed based on the results of simple tests, etc.
- Depending on the type of rock mass, evaluation based on the Mohr-Coulomb failure criterion may be difficult.
- The expected situation of rock mass of the same rock mass class may not always be met.
- Under low normal stress, shear strength may be underestimated due to local tensile failure near the shear load surface.

3.3 Borehole loading test [4)]

The following points should be noted regarding variability in the results and test accuracy of borehole loading tests, which are in-situ deformation tests for rock mass using boreholes.

- Because boreholes are used, tests can be conducted in test holes of any depth or direction.
- In order to obtain design constants for each target geological condition and rock mass class, and to obtain representative or average values, tests should be conducted at least three locations that are thought to belong to the same geology and rock class.
- Even for the same geological condition and rock mass class, deformation characteristics can increase with depth, meaning that there is confining pressure dependence, so care must be taken when setting design deformability values for rock foundation.

4. Advanced technologies for dam foundation design considering its variation

As explained in Chapter 3, in order to design dams while taking into account the variability in the mechanical properties of rock foundations, it is important not only to accurately assess the representativeness of test sites, especially in-situ tests, but also to accurately assess the distribution of various geologies, rock types, and particularly weak layers. In other words, collaboration between geologists and civil engineers is essential for the proper design of dam rock foundation, and it is expected that the rationalization and sophistication of design of dam rock foundation will be promoted.

Some research results aimed at the development of technologies for the rationalization and sophistication of dam rock foundation design are listed below. As part of a study of design methods that take into account the variability in the physical properties of rock foundation, one study used Monte Carlo simulation (MCS) to examine the variability in the deformability and permeability of dam foundation rock using a probabilistic approach. There are also studies that use percolation theory to identify weak areas in rock foundation and continuous water paths.

5. Conclusions

While the rock mass that forms the foundation for a dam is generally considered to constitute a solid foundation, its mechanical properties vary greatly and often exhibit uneven spatial distribution. Given this situation, in order to design a dam that takes into account the variability in the mechanical properties of the rock mass, it is important not only to accurately assess the representativeness of the target locations for various tests, especially in-situ tests, but also to evaluate with appropriate precision the distribution of various geologies, rock classes, and particularly weak layers. To resolve the above issues and properly design the rock mass for a dam foundation, collaboration between geologists and civil engineers is required to properly design the rock mass for a dam foundation, and it is hoped that this will lead to the rationalization and sophistication of dam rock foundation.

References

1) International Commission on Large Dams (ICOLD) (1995): Dam Failures Statistical Analysis, Bulletin 99.
2) Japan Innovation Center of Civil Engineering (JICE) (2000): Commentary for "Japanese Cabinet Order on Structure of River Management Facilities". (in Japanese)
3) Japan Innovation Center of Civil Engineering (JICE) (2003): Technical Guidelines and Commentary for Dam Rock Foundation Grouting. (in Japanese)
4) Japan Society of Civil Engineers (JSCE) (2004): Suggested Methods for In-situ Test. (in Japanese)

11. Federal Dam Safety Programs in the US: Evolution and Structure of Risk Assessment

〇Todd Loar (U.S. Army Corps of Engineers), Cassandra Wagner (U.S. Army Corps of Engineers)

1. Introduction

The U.S. Army Corps of Engineers (USACE) is an engineering branch of the United States Army with a mission to deliver vital military and civil engineering solutions securing the Nation's challenges, energizing the economy, and reducing disaster risks. This mission includes planning, design, construction, operation, monitoring, and management of flood reduction infrastructure and maintaining coastal and inland navigation systems that consists of over 710 dams and 15,000 miles of levees.

In August 2005 Hurricane Katrina caused significant damage in New Orleans, LA, and many people were directly impacted by several levee failures and the subsequent flooding. Following this devastating event, USACE recognized that aging infrastructure and increasing downstream populations require different approaches to evaluating dam and levee safety. This resulted in implementation of substantial modifications to the previous deterministic dam and levee safety program to address these inadequacies.

The current USACE dam and levee safety program includes performing comprehensive risk analysis (RA) to support risk informed decision making (RIDM). The objective is to better understand and characterize system vulnerabilities, make informed management decisions, and reduce risks posed by USACE infrastructure to downstream communities.

Over the past 19 years the Risk Management Center (RMC), in conjunction with USACE partners at Divisions, Districts, and Head Quarters have developed trainings, tools, methods, and processes to characterize the risk of each of structures and evaluate how they fit within the entire portfolio. This process helps leadership make informed decisions about priorities, modifications, communication of risks, and collaborate with other agencies, local authorities, and the public.

Following this framework other federal agencies, state dam safety programs, and private utilities have incorporated a modified RA and RIDM methods to meet their specific objectives.

2. Methodology and Approach

The USACE approach to RIDM and infrastructure management is rooted in established RA principles, emphasizing a proactive and systematic process implemented by a multi-disciplinary team of experienced engineers and scientists. RA follow a sequential and iterative process involving both qualitative and quantitative methods:

1) Loading: Characterize the potential external loading including flooding, earthquakes, or rapid reservoir fluctuations presented in a probabilistic framework (e.g., annual chance of exceedance, loading curves).
2) Potential Failure Modes Analysis (PFMs): Project vulnerabilities or flaws exploited under the anticipated or future loading conditions supported by historical construction and performance reviews; site investigations; and engineering judgement, experience, and analyses. For each PFM an event tree may be developed to depict the sequential conditions, processes, and physics that must occur or be present for the failure to evolve from loading to initiation, progression, and failure.
3) Probability of Loading + Failure Estimation: Probabilities of failure are estimated for each PFM accounting for the background information, site conditions, monitoring data, analysis results, and expert judgment. Uncertainty in these factors are explicitly addressed with the probability assessment to characterize the confidence in the elicited results from the risk assessment team.
4) Consequence Estimation: a dam breach inundation analysis is performed for different reservoir discharges and breach elevations to simulate the downstream flood (arrival time, depth, velocity, inundation area). The analysis also may estimate the warning times and methods, evacuation preparedness and routes, time of day/night, and potential range of life loss and economic damages incurred.
5) Risk Calculation: The total risk of the PFM or project is function of the probability of the loading (e.g., flooding or earthquake) and subsequent failure (e.g., hazards and vulnerabilities) compared to the incurred downstream consequences (e.g., life, economic, environmental losses) due to that failure. It's mathematically expressed as: Risk

= Likelihood x Consequence.

6) Continuous Improvement: RAs are not static; they are iterative and updated on a regular basis or as new information becomes available, a modification design is implemented, or if significant loading or changes occur (damages, overtopping, earthquake, piping, settlement, etc.).

Key risk assessment concepts include:

・**<u>Uncertainty</u>**: recognizing and explicitly addressing and communicating the range of uncertainty in both likelihood of failure and consequence estimates.

・**<u>Tolerable Risk Guidelines (TRGs)</u>**: assessing the characterized risk relative to acceptable safety thresholds levels of tolerability based on individual and societal values and with respect to the actions, expectations, process, and experience expected of a responsible dam owner.

The results of the RA ultimately involve plotting the individual risk driving failure modes, or the cumulative project risk, on a f-N matrix to graphically portray the risks being evaluated. An example of the f-N matrix is shown in Figure 1, highlighting the key features and aspects of the USACE risk characterization graph for reference.

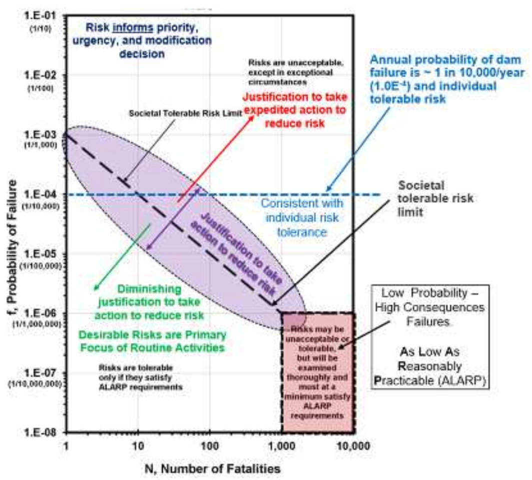

Fig. 1. Example Risk Analysis Matrix

Based on the risk characterization, supporting documentation, and communication to senior leadership decisions about prioritization, potential structural modifications or improvements (e.g., repair, raise, spillway, anchoring), or potential non-structural measures (e.g., emergency action planning, communication, improved coordination with local agencies) can be made to manage and reduce risks posed to impacted communities or infrastructure.

This program has evolved significantly over time with improved training, analysis tools and applications, loading analysis, and understanding of dam and levee deficiencies. The USACE RA program includes increasing levels (as necessary) of RA complexity and focus as the project dictates.

The process considers aspects such as design, construction, management, and operation, as well as advancements in state-of-the-art for dam and levee safety including hydrologic and consequence modeling. RIDM provides a framework for prioritization of limited resources to manage the portfolio safely and effectively under a range of loading conditions, informed by dam and levee safety principles and authorizations.

3. Conclusions

USACE-RMC's approach to RA and RIDM is essential for ensuring the safety, reliability, and sustainability of the nation's civil works infrastructure. Continuous refinement of methodologies and tools, coupled with a commitment to portfolio-level risk management, is critical for addressing the evolving challenges of the 21st century.

The RMC website (https://www.rmc.usace.army.mil/) serves as a central repository for guidance documents, training materials, software tools, and information on upcoming events. It is considered a vital resource for anyone involved in risk management within the USACE or working on USACE infrastructure.

References

1) USACE Engineering Regulation: Safety of Dams - Policy and Procedures, ER 1110-2-1156
2) Federal Guidelines for Dam Safety, Federal Emergency Management Agency, FEMA, 2004)
3) Federal Guidelines for Dam Safety Risk Management (FEMA P-1025, 2015)
4) Engineering Guidelines for the Evaluation of Hydropower Projects, Federal Energy Regulatory Commission, https://www.ferc.gov/industries-data/hydropower/dam-safety-and-inspections/eng-guidelines.
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12. An Introduction to Private Industry Risk Assessments for Dams in the United States

○Hawkins Gagnon (Schnabel Engineering)

1. Introduction

The nature and standards for dam safety and dam safety risk assessments vary widely across the United States based upon the dam's location, purpose, owner, and most importantly, the degree of risk that failure would present to the public. Federal and state agencies play a significant role in dam safety in the United States; however, this presentation will focus on the role of private consultants in dam safety in the United States. More specifically, this presentation will focus on the risk assessment process for hydropower projects, regulated by the Federal Energy Regulatory Commission (FERC).

The FERC regulates more than 1,795 dams, of which, more than two-thirds are more than 50 years old. In addition to potential issues related to the ageing of these structures, flood and seismic loadings have been updated and in some instances were not considered in the design of the structures.

The FERC inspects dams under their jurisdiction on an annual basis. In addition, inspections are performed by independent consultants every five years. This presentation will cover the workflow of periodic and comprehensive dam safety assessments including the Potential Failure Modes Analyses (PFMAs) and Semi-Quantitative Risk Analyses (SQRA) performed by independent consultant teams. This presentation will include a discussion of how risk-informed decision making, and the results of the risk assessment process, are used by dam owners and regulators to inform their decision making. Actions taken to improve dam safety after risk assessments are often driven by "risk-driving" potential failure modes and the dam's Dam Safety Risk Classification (DSRC). Since these dam owners are private entities, with finite financial resources, potential dam safety actions start with considerations for public safety (life loss) but also consider financial and environmental damages.

2. Dam Safety Overview

According to the National Inventory of Dams1, there are more than 92,000 dams in the United States and roughly 60,000 are privately owned. Privately-owned hydropower dams are regulated by the Federal Energy Regulatory Commission (FERC). These dams are required to go through the FERC Part 12D dam safety process2. New regulations were passed on December 16, 2021 and revised on March 29, 2023. These regulatory updates require a Level 2 Risk Assessment be performed once every 10 years. This change has come in response to recent dam-related incidents like the Oroville and Edenville Dam incidents. These changes also bring the FERC program more in line with federal dam safety programs.

3. FERC Part 12D Inspections

Inspections are performed in accordance with Chapters 16 through 18 of the FERC Engineering Guidelines for the Evaluation of Hydropower Projects [3]. There are two tiers of inspections:

a. Tier 1 – Periodic Inspections

b. Tier 2 – Comprehensive Assessments

Tier 1 - Periodic Inspections focus on the review and interpretation of instrumentation data and a site inspection to identify emerging potential failure modes.

Tier 2 - Comprehensive assessments require a deep dive into construction records, design calculations and assumptions, analyses of record, and other related dam safety documents to identify and account for previously unidentified issues. Document review is followed by a potential failure modes analysis (PFMA) workshop to identify relevant potential failure modes (PFMs). PFMs that have a likelihood of less than 1/1,000,000 are no longer considered. The remaining PFMs are evaluated in a Level 2 Risk Analysis (L2RA). An L2RA involves semi-quantitative estimates of the annual likelihood of failure as well as the associated life loss, should failure occur. Each PFM is then plotted in logarithmic fashion on both axes, with likelihood on the y-axis and life loss on the x-axis. The example provided in the FERC Engineering Guidelines3 is provided as Figure 1, below.

4. Risk-Informed Decision Making

Recent changes in regulations have pivoted from traditional standards-based dam safety decision making to more of a risk-informed decision-making framework. The objective is for owners to work with the FERC to identify critical issues across their dams portfolio to mitigate risk. This typically involves using the results of the L2RA to address "risk driving failure modes", those PFMs that are above, or within, an order of magnitude of tolerable risk

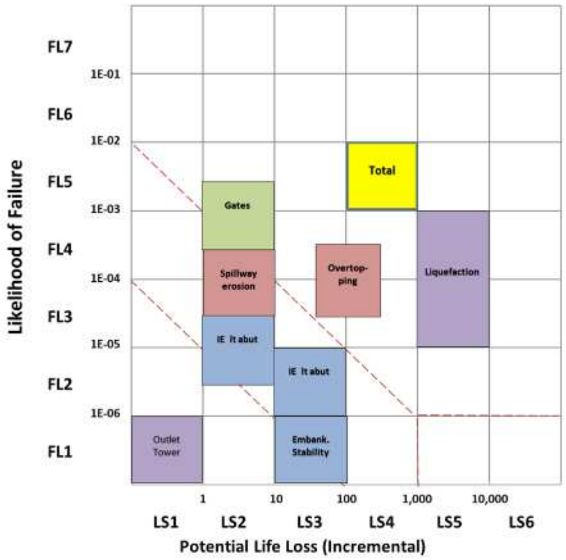

Fig. 1. Example Risk Analysis Matrix

guidelines. Additionally, each dam is assigned a Dam Safety Risk Classification Rating (DSRC)4, as shown in Figure 2, below. The rating is used to determine necessary actions. The intent of the program is for the Owner to evaluate not just individual project risk, but their portfolio risk such that limited funding is targeted towards reducing risk to the public, not meeting standards-based design criteria.

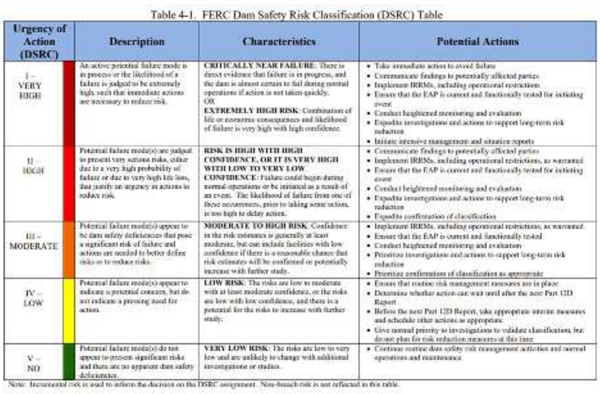

Table 4-1. FERC Dam Safety Risk Classification (DSRC) Table

Urgency of Action (DSRC)	Description	Characteristics	Potential Actions
I – VERY HIGH	An active potential failure mode is in process or the likelihood of a failure is judged to be extremely high, such that immediate actions are necessary to reduce risk.	**CRITICALLY NEAR FAILURE**: There is direct evidence that failure is in progress, and the dam is almost certain to fail during normal operations if action is not taken quickly. OR **EXTREMELY HIGH RISK**: Combination of life or economic consequences and likelihood of failure is very high with high confidence.	• Take immediate action to avoid failure • Communicate findings to potentially affected parties • Implement IRRMs, including operational restrictions • Ensure that the EAP is current and functionally tested for initiating event • Conduct heightened monitoring and evaluation • Expedite investigations and actions to support long-term risk reduction • Initiate intensive management and situation reports
II – HIGH	Potential failure mode(s) are judged to present very serious risks, either due to a very high probability of failure or due to very high life loss, that justify an urgency in actions to reduce risk.	**RISK IS HIGH WITH HIGH CONFIDENCE, OR IT IS VERY HIGH WITH LOW TO VERY LOW CONFIDENCE**: Failure could begin during normal operations or be initiated as a result of an event. The likelihood of failure from one of these occurrences, prior to taking some action, is too high to delay action.	• Communicate findings to potentially affected parties • Implement IRRMs, including operational restrictions, as warranted • Ensure that the EAP is current and functionally tested for initiating event • Conduct heightened monitoring and evaluation • Expedite investigations and actions to support long-term risk reduction • Expedite confirmation of classification
III – MODERATE	Potential failure mode(s) appear to be dam safety deficiencies that pose a significant risk of failure and actions are needed to better define risks or to reduce risks.	**MODERATE TO HIGH RISK**: Confidence in the risk estimates is generally at least moderate, but can include facilities with low confidence if there is a reasonable chance that risk estimates will be confirmed or potentially increase with further study.	• Implement IRRMs, including operational restrictions, as warranted • Ensure that the EAP is current and functionally tested • Conduct heightened monitoring and evaluation • Prioritize investigations and actions to support long-term risk reduction • Prioritize confirmation of classification as appropriate
IV – LOW	Potential failure mode(s) appear to indicate a potential concern, but do not indicate a pressing need for action.	**LOW RISK**: The risks are low to moderate with at least moderate confidence, or the risks are low with low confidence, and there is a potential for the risks to increase with further study.	• Ensure that routine risk management measures are in place • Determine whether action can wait until after the next Part 12D Report • Before the next Part 12D Report, take appropriate interim measures and schedule other actions as appropriate • Give normal priority to investigations to validate classification, but do not plan for risk reduction measures at this time
V – NO	Potential failure mode(s) do not appear to present significant risks and there are no apparent dam safety deficiencies.	**VERY LOW RISK**: The risks are low to very low and are unlikely to change with additional investigations or studies.	• Continue routine dam safety risk management activities and normal operations and maintenance

Note: Incremental risk is used to inform the decision on the DSRC assignment. Non-breach risk is not reflected in this table.

Fig. 2. FERC Dam Safety Risk Classification Table[4)]

5. Lessons Learned

The new regulations are still new, and the industry is still adapting. Only a small percentage of the FERC portfolio have undergone comprehensive assessments. Lessons learned so far include:

a. There are limited human resources who understand the risk assessment process. This has restricted widespread adoption and regulation. A steep learning curve is necessary for success, especially as the number of dams that need to be inspected increases exponentially.

b. Old habits die hard. It's difficult to move engineers and regulators away from the mindset of standards-based analyses. Part of that challenge is to strip away the conservatism that is built into our analyses in order to come up with realistic probabilities of failure.

c. The status of available dm safety records is a key factor in the success of risk analyses. Most projects are more than 50 years old. As such, many construction records, and institutional knowledge held by their operators and constructors are gone. Oftentimes useful records are disorganized and orand difficult to find, making the assessment more time-consuming and expensive. On the positive side, the process has required Owners to organize and compile key dam safety files, which should help engineers in the future.

References

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13. Geological Factors in Dam Safety Risk Assessment (US Practice)

○Cassandra Wagner (U.S. Army Corps of Engineers), Todd Loar (U.S. Army Corps of Engineers)

1. Introduction

Dam safety risk assessment is fundamentally linked to understanding the geological conditions at each project site. This manuscript outlines a holistic approach to integrating geological expertise throughout the dam safety lifecycle, emphasizing the critical role geologists play in identifying vulnerabilities and communicating their contribution to potential failure modes. A robust understanding of the geological context is not simply a component of dam safety; it is foundational to effective risk management.

The approach discussed herein begins with a comprehensive desktop (i.e., office) study, establishing a baseline understanding of the regional geological processes, hazards, tectonic settings, climate history, stratigraphy, geologic structure, and resulting geomorphology. This "start big, then narrow" approach allows for the development of a preliminary site model – a working hypothesis guiding targeted investigations, mirroring the foundational principles established by Terzaghi. Effective communication through spatial data compilation and the creation of clear, integrated geologic figures is paramount during this initial phase.

2. Holistic Evaluation and Uncertainty Management

No single piece of evidence provides a complete picture of site conditions. A holistic evaluation of all available data is essential, demanding an interdisciplinary approach and active collaboration. During this phase, the practitioner must focus on answering critical questions related to the developing site model, and actively seek input from the entire team to characterize uncertainties. For example, identifying the potential for internal erosion may necessitate specialized investigations to assess foundation conditions that directly pertain to the mechanisms of internal erosion in the context of potential failure mode analysis. The investigations may need to span multiple perspectives – such as drilling and sample, specialized lab testing, hydrogeology, tracer testing, geophysical studies, and instrumentation analysis – to cohesively develop an understanding of the site.

In Fookes[1)], the authors discuss uncertainty in geological knowledge for dam sites, stemming from both natural variability and knowledge uncertainty – arising from limitations in available data and evolving engineering standards and best practices. Fig. 1 below, modified from Fookes[1)], provides a hypothetical example illustrating various levels of geologic understanding as investigations progress. Critically, the quality of a risk assessment – even in cases where extensive ground investigations are not pursued – is heavily influenced by the thoroughness of the initial desk study and site visit.

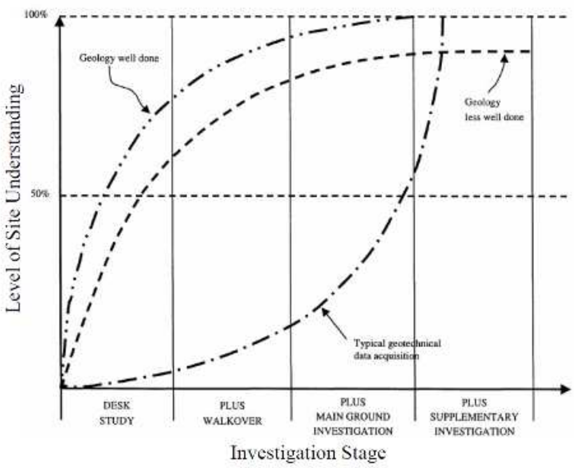

Fig. 1. Fookes (1997), provides a hypothetical example illustrating various levels of geologic understanding as investigations progress[1)].

3. Hazard Identification and Potential Failure Mode Analysis

Identifying potential geologic hazards – such as landslides, mineral dissolution, and erosion potential – requires thorough site characterization. Understanding historical foundation failure modes through case histories is vital for hypothesizing "reasonably possible" conditions, and is discussed more below.

Earthen embankments present unique challenges related to seepage, stability, liquefaction, and internal erosion, necessitating detailed characterization of material properties, foundation, and water conditions. In the U.S. Practice, detailed information for evaluating earthen dams is available in the guidance document, "Best Practices in Dam and Levee Safety Risk Analysis," which was jointly developed by two Federal Agencies – the U.S. Army Corps of Engineers, and the Bureau of Reclamation.2

Concrete dams, despite their robust construction, experience a significant proportion of failures –

approximately 70% – originating in the abutment or foundation. This highlights the geologist's critical role in assessing abutment/foundation stability through discontinuity and rock mass mapping, and developing a three-dimensional understanding of the subsurface, foundation configuration, and appropriate rock support designs.

Geologists also contribute to loading analyses, including probabilistic seismic hazard assessments and paleoflood hydrology, providing essential data for evaluating potential external forces. However, risk assessment isn't about designing for worst-case scenarios. It's about identifying and planning for the most probable conditions, while acknowledging and communicating unfavorable and conceivable deviations.

4. Learning from Past Performance – The Value of Case Histories

A cornerstone of effective dam safety risk assessment is learning from past failures and performance issues. Understanding how and why failures have occurred in similar geological settings is essential for hypothesizing "reasonably possible" conditions. Case histories provide invaluable insights into the complex interplay of geological factors, engineering design, and operational practices that can contribute to dam failure.

By thoroughly reviewing documented failures – such as the St. Francis Dam failure, the Teton Dam failure, and more recent incidents – engineers can identify recurring patterns and potential warning signs. These observations should inform the development of site-specific site models, ensuring that the assessment process considers conditions grounded in real-world experience, rather than relying solely on theoretical assumptions.

Specifically, analyzing past performance allows for a more realistic assessment of uncertainty. For example, observations from dams experiencing internal erosion can inform the selection of appropriate seepage criteria and the design of effective drainage systems. Similarly, case histories of slope failures can help refine slope stability analyses and identify critical monitoring parameters. Applying lessons learned from past failures fosters a culture of continuous improvement and enhances our ability to anticipate and mitigate potential risks.

5. Risk Reduction and Effective Communication

When identified uncertainties are deemed unacceptable, targeted exploration programs can be implemented to reduce risk, refine understanding, and inform potential construction modifications. Ultimately, effective communication – consolidating data, clearly portraying uncertainties, and delivering accessible products – is key to informing risk teams, reviewers, and decision-makers. Building a robust site record through high-quality documentation minimizes redundant studies and fosters a culture of learning from past failures, developing the expertise essential for effective dam safety management. This can be thought of as a continual cycle, as exemplified in Fig. 2 below.

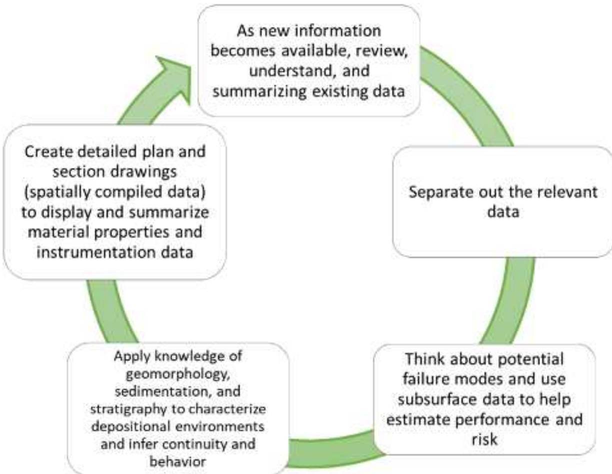

Fig. 2. Process of refining the site model, and building the site record through high-quality documentation minimizes redundant studies.

References

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14. Complex Risk Analysis of Rockslide Stability at Libby Dam, Montana

〇Todd Loar (U.S. Army Corps of Engineers)

1. Introduction

Libby Dam is located in northwestern Montana on the Kootenai River, approximately 17 miles upstream of Libby, MT and 220 miles upstream of its confluence with the Columbia River. The dam is a 432-ft (131.5 m) high, 2,887-ft (880 m) long concrete gravity structure constructed between 1967-1973. The dam was authorized primarily for flood control, but also provides hydropower, recreation, and environmental benefits. The main components of the project include an integrated spillway, stilling basin with gated outlet works, a powerhouse, and administrative buildings and visitors center at the right abutment (Fig. 1.).

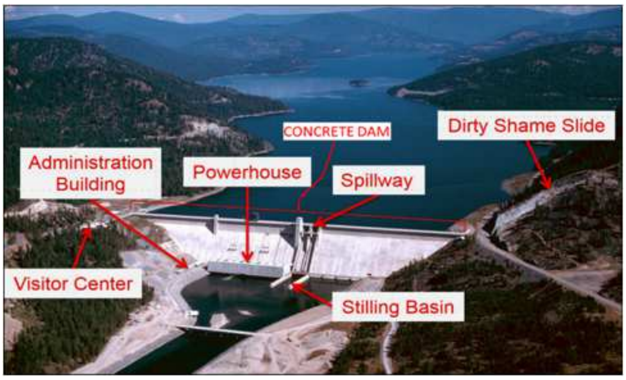

Fig. 1. Project Features

2. Dam Safety Risk Assessment

USACE initiated a semi-quantitative risk assessment (SQRA) in 2018 and then advanced to a quantitative risk assessment (QRA) in 2020 to further evaluate the primary risk drivers of concern: 1) overtopping; 2) concentrated leak erosion through fill on the right abutment; 3) deep-seated rockslide on the left abutment leading to instability of monoliths; and 4) large rockslide upstream in reservoir causing seiche wave overtopping.

Numerous large rockslides have previously occurred along the left reservoir slope including the "dirty shame" rockslide above the left abutment triggered by construction activities in 1971. Therefore, most of the risk analysis effort was focused on evaluating a potential deep-seated rockslide located on the left abutment that would project under the dam foundation. The concern was that a large rock wedge, formed by adversely oriented bedding layers, joints, and fault surfaces could initiate movement during extreme loading events (i.e., high pore pressures and/or regional earthquake). This displacement could undermine, distress, and/or deform the left abutment monoliths resulting in rapid and catastrophic release of the reservoir (Fig. 2.).

Fig. 2. Failure Mode Diagram

3. Reducing Uncertainty

To analyze the potential presence and stability of the slope under the anticipated loading conditions USACE implemented a detailed geological and rock mechanics characterization study to define the conditions that control the rock wedge stability. This investigation involved implementing a robust field mapping, drilling, sampling, testing, data evaluation, kinematic and stability analysis to inform risk estimates and reduce uncertainties associated with the geologic and subsurface conditions controlling stability of the rock wedge structure.

Fig. 3. Rock Wedge Mapping on Road Cut

4. Rock Wedge Stability Analysis

The team evaluated multiple scenarios for the deep-seated rockslide stability analysis. These included varying the depth and geometry of the wedge discontinuities and the passive wedge, or "kick-out" at the toe; shear strengths of the failure surfaces; impact of reservoir loading, pore pressures, seismic loading; and the structural stability of the monoliths.

A critical aspect of the wedge analysis was the potential for a passive wedge, or "kick-out," at the toe of the rock mass. Because the ground slope is slightly shallower than the rock wedge intersection, failure would require rupture at the toe – either along a discontinuity or through the rock mass itself. Kinematic stereographic analysis, utilizing in-hole televiewer data, indicated that deformation would likely engage the competent rock mass rather than a major planar discontinuity, thus enhancing wedge stability.

The rockslide stability scenarios were analyzed using both 2-D and 3-D methods under the various loading, geometric, and strength conditions. The potential resisting or buttressing effects of the concrete dam were not included in the wedge stability assessment. Additionally, the monoliths were assessed for sliding, overturning, and bearing capacity thresholds due to a rockslide failure to inform the risk characterization.

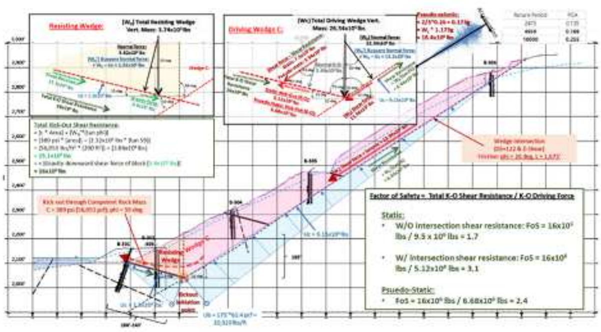

Fig. 4. 2-D Stability Diagram

5. Risk Characterization

The potential slope failure PFM was characterized by developing multiple joint-loading conditions and multi-branch nodal event tree. The detailed site characterization and stability analysis efforts informed the assessment team at each PFM node and significantly reduced uncertainties in the risk characterization of the failure mode. Major findings identified include the following:

· Likely existence and continuity of the discontinuities forming rock wedge geometry.

· Unlikely existence of adverse discontinuities at the rock wedge toe in the kickout. This directly relates to initiation of a wedge failure, resulting in higher factors of safety for stability of the rock wedge rupturing through the rock mass.

· Pore pressures alone are not likely to initiate failure due to the depth of the wedge toe kickout.

6. Conclusions

The geological characterization effort provided invaluable details regarding the rock wedge geometry, strength, and mechanics helped the team better understand the risk and reduce uncertainty for this failure mode. The results were considered highly beneficial and provided USACE decision makers with a better understanding of the risk of a large abutment rockslide at Libby Dam.

This presentation summarizes the team's approach to reducing nodal uncertainties in the potential failure mode event tree and key factors evaluated for estimating risk of deep-seated rockslide on the left abutment.

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15. Lessons learned: Embankment Protection (HydroTurf®) on a High Hazard Dam in Maryland, USA

○Visty P. Dalal (Maryland Dam Safety Program, USA)

1. Introduction

The Gerwig Lane Dam in Howard County, Maryland, is located adjacent to Route 32 highway, in Howard County, Maryland, USA. The Howard County Stormwater Management Program (HCSMP) owns the property and was seeking to rehabilitate the dam and the pond to provide water quality and quantity benefits to the local community and to the state of Maryland. HCSMP contacted the Maryland Dam Safety Program for guidance on retrofitting the dam to increase its storage capacity. Several collaborative technical discussions between HCSMP, their engineers, and the Maryland Dam Safety Program led to the conclusion that the dam could not be raised due to its proximity to Rt. 32 highway. The dam breach analysis conducted for the dam classed it as a 'High Hazard' dam with significant flow of water going over it at half and full-probable maximum floods.

2. Project Description

The Gerwig Lane Dam Project was permitted by the Maryland Dam Safety Program for modifications to an existing water quality facility, replacing the principal spillway, and stabilizing the outfall and downstream channels.

Several erosional and piping problems were observed at the existing structure with the Corrugated Metal Pipe (CMP) riser and barrel severally deteriorated and falling apart. To extend the life of the principal spillway, stop-gap measures like wrapping the barrel with geotextile fabric and dumping riprap on top to prevent water from flooding the dam (Pic. 1). The riser structure was rusted from top to bottom and leaning on one-side (Pic. 2).

3. Dam Breach Analysis and Hazard Classification

Gerwig Lane Pond is a SWM pond in Use IV-P waters of the state in the Patuxent River Watershed. The breach analysis included Sunny Day/100-year/Brim Full/Half PMF, and PMF events and their impacts downstream were calculated.

Breach parameters were calculated using '*Simple Dam Break*' worksheet and discharges determined using HEC-1 model. HEC-RAS 2D model was used to provide max depths and velocities for each event overtopping roadways.

Breach of Gerwig Lane Dam will impact on 4 roadway crossings: Exit Ramp from MD 32 W.B. to Broken Land Parkway, MD 32 W.B., MD 32 E.B., and on ramp from Broken Land Parkway to MD 32 W.B. This will impact structures and traveling public.

As per the USBR Hazard Charts (1988) for '*Flood Dangers For Cars*', and 'Population-at-Risk' (PAR=33) – the Gerwig Lane Dam was classed as 'High Hazard' Dam.

4. Overtopping Protection on the Dam

Brim-up, ½ PMF, and PMF storm events cause overtopping on all four roadway crossings downstream. However, the PMF storm event also causes overtopping on Gerwig Lane Dam. Several options for protecting the dam were discussed by the owner, EIC, Maryland Dam Safety, and other professionals on the project. HydroTurf ® protection was chosen for this dam, based on research and communication with the manufacturer, Watershed Geosynthetics ® of Alpharetta, GA.

The HydroTurf ® system consists of the following components: Geomembrane – this is installed directly on top of the dam; Engineered Synthetic Turf – is laid out on top of the geomembrane; and HydroBinder ® - is a cementitious infill brushed into the turf and hydrated.

5. Lessons Learned

Pros:

First installation of HydroTurf components on Maryland dams – will learn from this experience. Relatively easy application of the artificial overtopping protection on earthen dams. Relatively less expensive than traditional overtopping protection methods/materials. Relatively easy maintenance and replacement of damaged layers with trained staff (picture 3).

Cons:

Requires conducive weather conditions – warmer conditions favored for multiple reasons. Subsurface problems in dam are not easily detected during inspections – may need geophysical, non-intrusive, periodic tests, however, HydroTurf is flexible and will deform with changes in the subgrade. Gerwig Lane Dam is a test case in

Maryland. It will be annually inspected and changes in the surface noted for future applications of HydroTurf on other dams in the state.

Pic. 1. Deteriorated barrel of the principal spillway being covered by riprap.

Pic. 2. Highly corroded riser leaning on one side.

Pic. 3. Gerwig Lane Dam in 2024

16. Geotechnical Risk Management for Dam Upgrading Projects in Japan

〇Yoshinori Yajima（Public Works Research Institute）

1. Introduction

Dam is designed to retain an enormous volume of water with dam body supported by the foundation rock mass. Because of this, if the dam breaks, it will cause catastrophic loss of life and property in downstream areas, making the evaluation of the foundation rock mass critically important. Japan lies at the boundary of four interacting tectonic plates, where geological structures are complex and strongly influenced by faults, weathering, and alteration. As a result, the rock mass is characterized by high heterogeneity. To construct a dam in such regions, it is most efficient to identify risks without omissions, recognize the uncertainty in geotechnical evaluations at each stage, carry out supplementary investigations at the necessary times, and implement the project while managing risk.

This paper introduces the geotechnical risk management practices commonly implemented in dam projects overseen by Ministry of Land, Infrastructure, Transport and Tourism (MLIT) in Japan in order to facilitate efficient project execution. It also discusses uncertainty in geotechnical evaluations and risk responses in upgrading projects of existing dam.

2. Framework for geotechnical risk management for dam projects in Japan

Fig.1 shows the geotechnical risk management framework for dam projects overseen by MLIT. From the planning stage of a project, geotechnical engineers participate, engaging in repeated discussions with civil design engineers while conducting the necessary geotechnical investigations to reduce the uncertainty at each stage. At annual or otherwise regular intervals, it has commissioned "integrated geotechnical analysis work" that compiles the geotechnical investigations conducted to date, the results of monitoring, analysis, and evaluation, and the plans and issues for future investigations. This process enables the sharing and handover of geotechnical-related risks. In addition to close discussions among geotechnical engineers, civil design engineers, and the project operator at each project stage, continuous technical support is provided by in-house engineers with specialized expertise from institutes such as PWRI and NILIM to help resolve issues. Furthermore, when moving to subsequent stages—such as project initiation, selection of dam site and dam type,

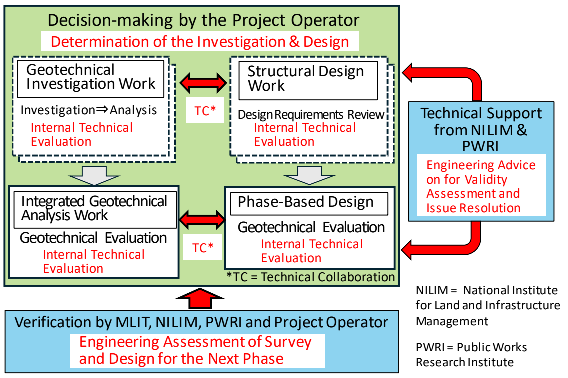

Fig.1 Geotechnical Risk Management Framework for Dam Projects in Japan [1)]

and commencement of construction— MLIT conducts a confirmation of the technical review results together with the project operator, relevant administrative officials, and the in-house experts, and the project budget is allocated through this confirmation process.

The required depth of analysis at each stage vanes with the level of expected risks. For example, the absence of active faults and landslides that could affect the construction of the dam must be reliably ascertained by the time the dam site is selected. By contrast, for dam body materials, if sufficient availability can be expected, the details can be confirmed before the final design is fixed. Similarly, in evaluating the foundation rock mass, it is standard practice at the early stage of a project to conduct preliminary investigations to verify that there are no critical issues for the planned construction of dam and then, in accordance with the project stage, to improve the maturity of investigations by conducting those necessary. Equally important is the continuous implementation of geotechnical risk management: based on the latest standards and guidelines, investigation results, design conditions, and so forth, it is necessary to review evaluations and responses and examine whether any new risks have emerged. As a guide to the studies required at each stage, MLIT has prepared a unified checklist, which is used across individual dam projects.

3. Geotechnical risk management practices in dam upgrading projects

In Japan, the construction of new dams has declined in recent years. However, in response to climate change and other challenges, upgrading of existing dam has been being implemented, now accounting for nearly half of all ongoing dam projects.

The Geological Risk Management framework for dam upgrading projects follows the same framework as that for new constructions. The fundamental approach is to reduce uncertainty at each stage of the project. If sufficient geotechnical data from the original construction of the existing dam are available, the uncertainty in geotechnical evaluations during the upgrading project can be significantly reduced. However, for older dam—often the target of upgrading—such records are frequently missing.

In these cases, new geotechnical investigations must be conducted to verify the adequacy previous rock mass evaluation. In evaluating the foundation rock mass for dam upgrading, geotechnical investigations are often limited due to the presence of existing dam and resolver. Moreover, for areas where no excavation is conducted, the uncertainty in geotechnical conditions remains high even during the construction stage. Therefore, in order to evaluate geotechnical information beneath dam body during the investigation stage, vertical boreholes are drilled around dam crest, gallery, and dam toe—as well as inclined boreholes and historical construction photographs are also utilized to gather as much geotechnical data as possible for evaluation. Recently, geophysical exploration techniques have also been employed to identify subsurface geological structures and weak zones beneath dam body.

A notable example is New Katsurazawa dam where a large-scale raising was implemented. Although geotechnical data from no sketches of excavation surface were available, numerous construction photographs remained. By identifying the photographed areas and interpreting features such as joint spacing and weathering conditions, indirect data were combined with direct borehole information to evaluate the geotechnical conditions beneath dam body. Given the high uncertainty of photo-based assessments, the evaluation included a confidence rating—high for direct borehole data, low for unclear photos—and applied a one-rank lower rock mass classification in low-confidence areas to mitigate the risk.

In cases where upgrading involves raising dam height or adding spillway to dam body, changes in self-weight and highest water level alter the required shear strength of the foundation rock mass. In dam projects overseen by MLIT, the PWRI rock mass classification is used (Table-1). This method subdivides rock types based on three factors: (1) rock fragment hardness, (2) joint spacing, and (3) joint condition. Each combination defines a rock class, and corresponding design shear strength values are assigned. The most reliable method for determining rock shear strength is conducting in-situ rock shear tests via investigation tunnels. However, such tests are often impractical in dam upgrading due to site constraints. Therefore, shear strength values are typically estimated using test results from other dam sites with similar geological and rock mass characteristics. “Similarity” here refers to matching detailed classification criteria and combinations within the PWRI rock mass classification. Since these criteria are site-specific, the classifications of the upgrading dam may not align perfectly with those of similar dam. Thus, it is crucial to confirm that the upgrading dam’s classification is equal to or better than the similar dam and to consider the uncertainty by evaluating multiple similar dams. Rock fragment hardness has the strongest correlation with rock mass shear strength among the three classification factors. Traditionally, the hardness has been assessed qualitatively via hammering, and uniaxial compression tests have been limited in number, making hardness comparisons difficult to other dams. Recently, in Japan, the Leeb hardness test, a non-destructive method, has begun using to quantitatively evaluate rock fragment hardness. This advancement is expected to facilitate the selection of similar dam and improve shear strength evaluation.

Table-1 Example of the PWRI Rock Mass Classification

Detailed Classification Criteria	Examples of Detailed Classification Criteria	
	Category	Condition
Rock Fragment Hardness	A	Metallic sound on hammering , Resistant to repeated hammer blows
	B	Breaks under heavy hammering
	C	Crushed by light hammering
Joint Spacing	Ⅰ	30cm＜
	Ⅱ	15cm～30cm
	Ⅲ	5～15cm
	Ⅳ	>5cm
Joint Condition	a	Fresh and Closed joint
	b	Weathering is limited to joints, Rock fragments remain fresh
	c	Weathered joint fragments, Clay-filled joints

Rock fragment hardness		A			B			C		
Joint spacing		a	b	c	a	b	c	a	b	c
Joint condition	Ⅰ	B	CH		CH	CH				
	Ⅱ	CH	CH	CM	CH	CM	CM		CL	CL
	Ⅲ	CH	CH	CM	CM	CM	CL		CL	CL
	Ⅳ		CM	CM		CL	CL		CL	D

4. Conclusion

This paper has introduced geotechnical risk management for dam projects in Japan, with particular emphasis on the challenges, countermeasures, and practical examples in dam upgrading projects. We also intend to analyze initiatives in other countries and incorporate them into geotechnical risk management practices in Japan.

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17. Evaluation of Geo-related Risks: A Perspective on Engineering Education

○Takashi Isomura（Yachiyo Engineering. Co., Ltd.）
Planning Committee for Master of the Fields (*Tatsujin* Group)

1. Introduction

In Japan, a shift in flood control plans for rivers to "plans that consider factors such as increased rainfall due to climate change". As one of the solutions, redevelopment or regeneration projects for existing dams are increasing. These methods differ from new dam construction projects in that the bedrock cannot be directly confirmed, and the procedures for evaluating the bedrock may vary from those currently in use. Therefore, the experience gained from involvement in new dam construction has become a critical factor in the analysis. On the other hand, there are few engineers with experience in new dam construction, and those who do have experience are aging, which poses a challenge for the succession of technical knowledge. This issue is not limited to the field of dam engineering but extends to the entire field of applied geological engineering in general. Therefore, to address the geological problems related to civil engineering structures, including dam projects, effectively in the future, we will introduce initiatives that focus on continuous education for engineers.

The initiative introduced here is led by the "Planning Committee for Master of the Fields (*Tatsujin* Group)", a private voluntary organization distinct from academic societies, with a history spanning over 40 years. The term “*Tatsujin*” refers to an expert among practical civil engineering geologists. This committee aims to improve the overall industry level by transcending company boundaries and involving geological engineers from construction consultancies. It focuses on the enlightenment and transmission of applied geological technology, and the enhancement of geological survey and analysis skills among young engineers, facilitated through mutual exchange and collaboration among researchers and engineers in applied geology.

The content of this paper builds upon Nishiyanagi (2020)[1], with the addition of new data. The author, Nishiyanagi, is my predecessor as the chair of the *Tatsujin* Group.

2. Technical education activities on engineering geology

To achieve the aforementioned objectives, the *Tatsujin* Group conducts the following educational activities in cooperation with the Dam Geology Subcommittee of the Dam and Hydropower Generation Committee（DHGC）, under the Japan Civil Engineering Consultants Association（JCCA）.

(1) Monthly workshops and study groups
(2) Annual symposium（in August）by the DHGC/JCCA
(3) Annual technical visit to a dam construction site by the DHGC/JCCA
(4) The practical courses in engineering geology
(5) Activities of the Wakate Group
(6) Publish educational books

2.1 Workshops and study groups

The Workshops and study groups from the perspective of contributing to the technical enhancement of the entire related industry, is now an open meeting where anyone can participate upon registration. The sessions are held on a monthly basis from April to December each year, excluding the busy periods of January to March and August. The objective of this workshop is not for participants to present polished research findings as one would at an academic conference. Rather, its primary purpose is to provide a forum where attendees can introduce topics based on the real-world challenges, questions, and ideas they encounter in their professional duties. The workshop encourages participants to exchange opinions and engage in deep discussions from their individual perspectives, transcending organizational affiliations, with the ultimate aim of broadening their technical horizons. The July and December sessions feature invited lectures by experts on recent advances in the field.

2.2 Annual symposium

The annual symposium on engineering geology was inaugurated in 1980, hosted by the Japan Innovation Center of Civil Engineering, and continued from the following year as an independent activity. Since 1995, the JCCA has been the organizer, ensuring the event's continuous operation. This year marks the 45th session. To date, the cumulative number of participants has exceeded 6,000. In recent years, it has grown into a major event, attracting over 200 attendees annually through a hybrid format combining in-person and online participation.

The annual symposium focuses on themes relevant to current societal trends and topics in civil engineering geology, particularly concerning dams. The program is structured with a morning session featuring invited lectures by academic experts, followed by an afternoon session dedicated to technical reports and status updates from active dam construction sites.

2.3 Technical visit to a dam construction site

The field trips involve selecting and visiting a dam site that is under active construction for the year. Participants are given the opportunity to observe features such as the foundation bedrock, which become inaccessible after the dam's completion. At these active construction sites, concrete details -including the internal structure, embedded pipes, construction facilities, and work methodologies- can also be observed firsthand. This provides a valuable opportunity for the examination of future redevelopment and regeneration projects, which are increasing in number. To date, nearly 60 dam construction sites have been visited throughout Japan.

2.4 The practical courses in engineering geology

Co-hosted annually with the Japan Society of Engineering Geology, this program is designed for about 20 early- to mid-career engineers. It aims to transfer technology and enhance practical, field-oriented skills through a combination of lectures and hands-on field training. Each year, the course is held on a theme selected in rotation from four main fields of engineering geology: groundwater, civil engineering geology (rock mass classification), landslides, and topography.

2.5 Activities of the Wakate Group

The Wakate Group formed by early-career engineers from various companies who met at the workshops. Their activities include holding opinion exchanges on designated themes and organizing short training sessions led by veteran engineers. Through these engagements, the group aims to strengthen peer networks while honing technical skills and enhancing abilities in logical thinking and analysis. Founded in 2019, the group resumed full activities last year after a pandemic-related slowdown. Last year, for instance, the members themselves planned and conducted a geological excursion to Izu Oshima island -a site known for the full evacuation of its residents during the 1986 volcanic eruption. The event included outcrop observations and a tour of Sabo facilities, along with a lecture by Mr. Chiba, who experienced the 1986 eruption, and an interactive session with local geo-guides.

2.6 Publish educational books

In recent years, enhancing experiential knowledge has become increasingly difficult as the volume of site investigations, budgets for analysis, and opportunities for fieldwork have all diminished. In response, our committee discussed strategies for transferring the tacit knowledge of veteran engineers to the next generation. During these discussions, it was pointed out that know-how for geological surveys and analyses acquired through long-term field experience typically exists only as tacit knowledge inherent to individual engineers, with almost no codified textbooks on the subject. Therefore, as a method of knowledge transfer, we launched an initiative to transform this tacit knowledge into explicit and collective intelligence by documenting it and publishing it in book form. To date, four volumes have been published, which generously and clearly detail the wisdom and "secret techniques" accumulated from past experiences.

3. Rationale for Technical Education Activities

"The evaluation of geo-related risks," the theme of this special session, is a complex task demanding considerable experience, especially in large-scale projects like dams where the role of engineering geology is vital. This discipline becomes beneficial to society only when it translates geological history, constructed from specialized knowledge, into practical engineering information. This is achieved by linking geological findings to the physical properties and strength values required in civil engineering, and effectively bridging this information to designers and contractors. Engineering geology is an empirical discipline; its knowledge typically becomes tacit, accumulated by individual engineers through a repetitive process of on-site observation, fact-based analysis, and verification. It requires a foundational understanding of the design and construction of diverse civil structures and, most importantly, hands-on field experience. Meanwhile, new dam construction has markedly decreased in Japan, reducing the very on-site opportunities necessary for gaining such experience. Furthermore, at the university level, where foundational geology has traditionally been taught, there is a growing emphasis on interdisciplinary education. This has led to a trend where specialized geological education is often postponed until the graduate level. Moreover, research funding for geology as a basic science is continually shrinking, which has also led to a decline in opportunities for field-based training and laboratory experiments at universities. Given these circumstances, we believe the technical education activities conducted by our committee are highly significant. They provide a crucial venue for the continuous learning required to foster competent geological engineers who can meet societal demands. Furthermore, it is of critical importance that engineers continue passing down technical knowledge and skills in field of civil engineering geology through their own volunteerism.

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18. Assessment of Sheeting Joint Development in the Foundation Rock of the Asuwagawa Dam and Engineering Countermeasures during Construction

〇Kyohei Kamada, Tomoyuki Hitotsuyanagi（NEWJEC Inc.）

1. Introduction

In dam construction, the stability of the foundation bedrock is an extremely important factor that determines the overall safety of the structure. Particularly when the foundation is composed of intrusive rocks such as granite, the presence of sheeting joints becomes a significant issue. Sheeting joints are fractures that develop almost parallel to the ground surface and are formed due to the removal of overburden pressure (caused by the erosion of materials that once covered the rock mass). Although the bedrock may appear stable at first glance, sliding along the sheeting joint surfaces or water leakage through these joint surfaces may occur. Therefore, detailed investigation and evaluation are essential.

This presentation introduces findings on the distribution and characteristics of sheeting joints that develop in granite, based on pre-construction surveys and additional investigations conducted during construction, using the foundation bedrock of the Asuwagawa Dam, which is currently under construction in Fukui Prefecture, as a case study. Furthermore, the presentation will also report on the measures implemented at the site based on these survey results.

2. Scope of Investigation

The foundation bedrock of the Asuwagawa Dam mainly consists of Jurassic to Triassic granite from the Mesozoic era (Funatsu Granite, Gr), with andesite dikes intruding into it (Figure 1). During the investigation and design stages, various surveys and investigations were conducted, including outcrop surveys, borehole drilling surveys (a total of 112 boreholes), Adit surveys(a total of 10 tunnels), elastic wave exploration, and airborne electromagnetic surveys.

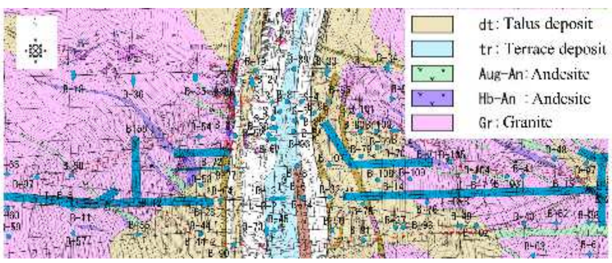

Figure-1 Geological Plan of the Dam Site

3. Results of Investigation

3.1. Design stage

Based on the results of the outcrop surveys, the adit surveys, and the drilling surveys (including borehole analysis and Lugeon tests), the distribution of sheeting joints was identified near the dam's toe area in the riverbed section.

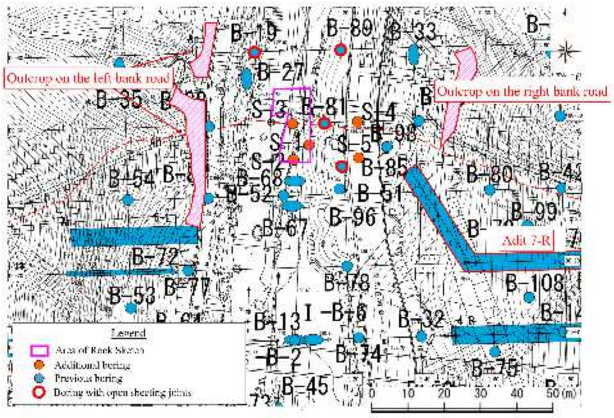

Figure-2 Survey location map

In the outcrop survey, sheeting joints were confirmed at the outcrops along the forest roads on the left and right banks, as shown in Figure 2. The sheeting joints were intersected by other joints, andesite (intrusive rock), and crushed veins, resulting in poor continuity, with a maximum length of 4.5 meters (Figure 3).

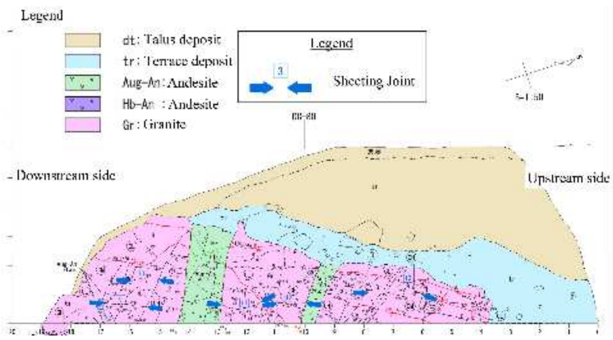

Figure-3 The outcrop sketch of the downstream section of the left-bank road

In the adit surveys, sheeting joints were identified in the 7-R tunnel on the right bank, as shown in Figure 2. The sheeting joints were intersected by faults, andesite (intrusive rock), and other joints, resulting in poor continuity. The most continuous sheeting joint was an open joint containing inflow clay and had a length of approximately 13 meters. However, in a borehole located about 20 meters away, no similar open sheeting joints were observed.

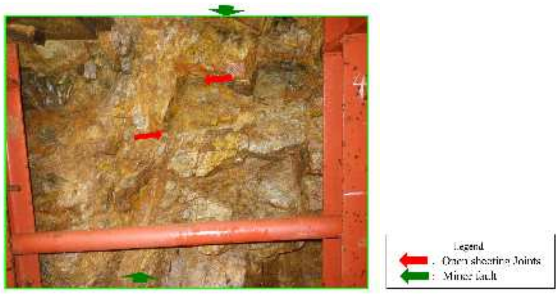

Figure-4 Sheeting joints on the downstream wall of Adit 7-R

In the drilling surveys (including borehole observation and Lugeon tests), the distribution of both open and tight sheeting joints was identified in boreholes B-19, B-81, B-85, and B-89, as shown in Figure 2. Based on borehole video observations and Lugeon test results, zones within a depth of approximately 20 meters or less showed Lugeon values exceeding 100Lu, indicating areas where pressurization was not observed. In these zones, the presence of open sheeting joints was confirmed.

Based on these investigation results, it was determined that the area shown in Figure 5 likely contains continuous open sheeting joints that could pose issues for dam construction. Therefore, during the design phase, excavation and removal of this area were planned as part of the construction strategy

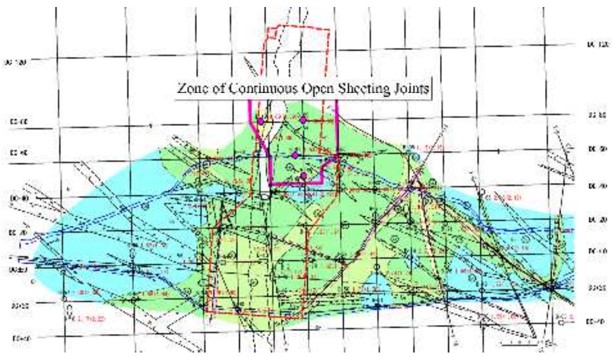

Figure-5 Distribution of Sheeting Joints

3.2. Pre-foundation excavation stage

To reassess the continuity of the sheeting joints distributed near the dam toe area in the riverbed section, which was assumed during the design phase, detailed additional investigations (drilling surveys and excavation surface surveys) were conducted prior to foundation excavation.

The additional investigations were carried out at the locations indicated in Figure 2. In the Lugeon tests and borehole video observations and analyses, open sheeting joints were confirmed; however, zones showing Lugeon values exceeding 100 Lu, where pressurization could not be observed, were only found in the section from GL.-1.0m to GL.-5.0m in borehole S-2, and no such zones were identified elsewhere.

In the excavation surface survey conducted near the dam toe area in the riverbed section, 19 sheeting joints were confirmed. These sheeting joints were intersected by faults, cataclasite veins, clay seams, and other joints, and even the most continuous ones extended only up to a maximum length of approximately 3.8 meters.

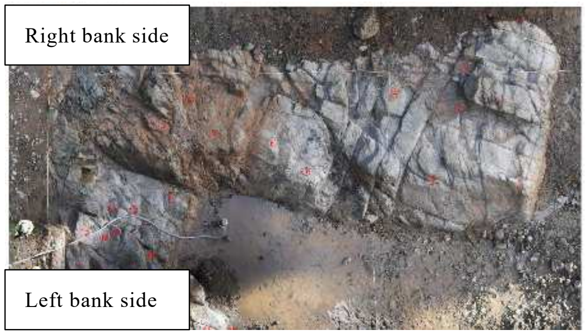

Figure-6 Orthophoto of the Excavation Face of the Riverbed Section

Based on the results of the additional investigations, it was determined that no continuous open sheeting joints that would pose issues for dam construction are distributed near the dam toe area in the riverbed section.

4. On-site measures

Although the additional investigations conducted prior to foundation excavation confirmed that the open sheeting joints lacked continuity, their distribution extended to the dam toe area in the riverbed. Therefore, consolidation grouting was planned to fill the openings. Since CL-class bedrock was distributed in the sections sandwiched by faults and their surrounding areas, these sections were also included as targets for consolidation grouting to reinforce weak zones.

5. Conclusion

Investigations conducted during the design phase identified the presence of open sheeting joints distributed within the granite that constitutes the foundation bedrock. However, additional investigations carried out prior to foundation excavation confirmed that these joints lacked continuity. Nevertheless, despite their lack of continuity, the open sheeting joints were found to be distributed near the dam toe area in the riverbed. Therefore, consolidation grouting was implemented to reinforce weak zones.

19. Stability Study of a Long Slope Affected by Hydrothermal Alteration

○Kazuhisa Ashida (Nippon Koei Co., Ltd.)

1. Overview of Komagome Dam

Komagome Dam is a multipurpose dam currently under construction on the Komagome River, part of the Tsutsumigawa River system flowing through Aomori City, Aomori Prefecture. The dam is a gravity-type concrete structure with a height of 84.5 m, a crest length of 290.1 m, and a total storage capacity of 7.8 million cubic m. On the right bank abutment slope, a constructed abutment structure has been planned to address deteriorated zones caused by hydrothermal alteration. Above this structure, a large-scale slope with a height difference of 100 m is planned (Fig.1.).

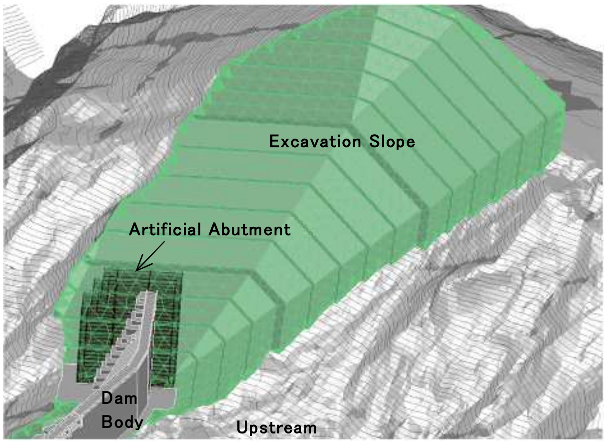

Fig. 1. The Excavated Right Bank Slope

2. Overview of the Right Bank Excavation Slope

The dam foundation bedrock consists of hard andesitic rocks of the Kanegasawa F. However, in the right bank abutment area, zones of deterioration caused by hydrothermal alteration are present, which are unsuitable as a foundation for a gravitytype concrete dam. The deteriorated zone is to be addressed by constructing a man-made abutment. This engineered abutment will be a sloped structure with a height of 45 meters, a width of 20 meters, and a length of 44 meters. While the foundation of the abutment rests on the hard andesitic rocks of the Kanegasawa F, a large excavation slope is required behind and above the abutment due to the presence of hydrothermally altered and deteriorated bedrock. The excavation slopes are designed with gradients of approximately 1:1 to 1:1.2, closely matching the natural slope before excavation. Three slope faces are constructed to surround the engineered abutment, and a large-scale slope with a height of 100 meters is planned at the rear of the abutment.

Several hydrothermally altered zones, each consisting of clay-like material several meters wide, are distributed within these strata. At the base of the H-wt layer, a horizontally intercalated clay-altered zone approximately 5 meters thick has formed along the unconformity surface due to ancient weathering and hydrothermal alteration.

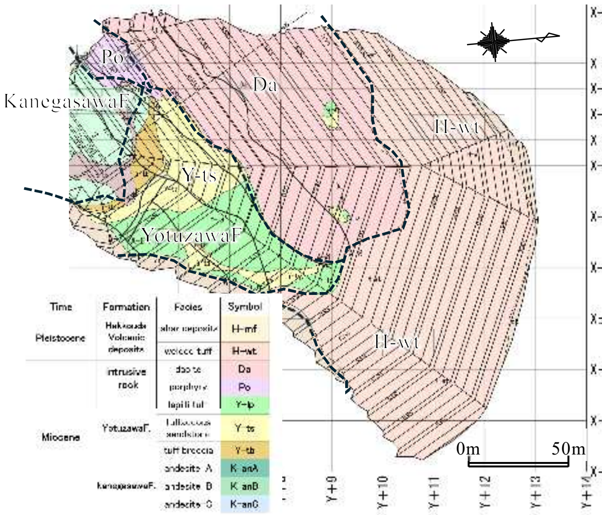

Fig. 2. Geological Profile of Excavation Face

3. Examination of Geological Factors Affecting Slope Stability

Geological factors contributing to the instability of the excavation slope were examined, including:

- the primary consolidation strength of the rock,
- dip slope structures,
- hydrothermal alteration,
- loosening near the surface,
- groundwater seepage,
- wedge-shaped rock masses.

Loosening near the surface has developed around the outer edges of the slope in contact with the ground surface. In particular, at the upstream top of the H-wt layer, a fault-like topography has formed along the break-in-slope at the boundary with the flat surface, where a large open fracture has been identified. Groundwater seepage was identified in areas where the groundwater level, dammed by low permeability alteration zones, emerges around the periphery of these zones. Additionally, at the unconformity surface of the H-wt layer, perched water is considered to form during rainfall and snowmelt periods, resulting in temporary seepage. Wedge-shaped rock masses were extracted as unstable bodies formed by the combination of opposing discontinuities. In particular, within the Y-ts distribution area, large unstable rock blocks are expected to form due to the combination of bedding planes in dip slope structures and steeply dipping alteration zones trending toward the mountain.

Based on the overlap of these instability factors, the excavation slope was divided into ten zones, and slope stability was classified into five grades from A to E for each zone (Fig. 3.; Table 1.).

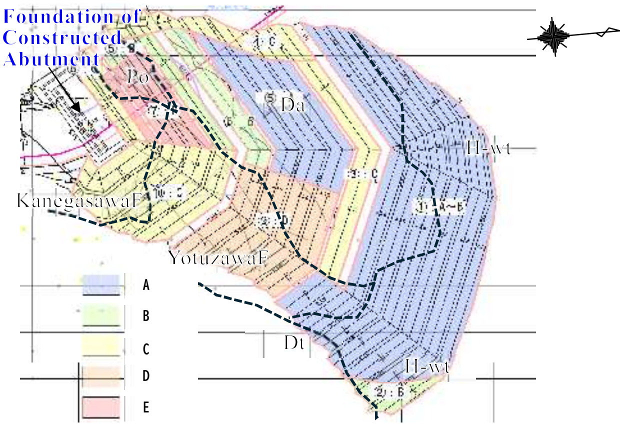

Fig. 3. Excavation Slope Stability Classification Map

Table 1. Stability Classification of Excavated Slope

	Characteristics
A	The slope is stable, with no destabilizing factors present.
B	Although one destabilizing factor has been identified, the risk of collapse is considered low. Deterioration prevention measures are in place.
C	Several destabilizing elements are present, and triggering conditions such as groundwater emergence due to rainfall may lead to slope failure. Countermeasures such as stabilization works are required.
D	Multiple destabilizing factors are acting in combination, increasing the potential for large-scale failure. Stability analysis is required to determine the necessary resisting force, and countermeasures must be implemented.
E	The entire alteration zone is highly susceptible to toppling failure, and stabilization measures are essential.

Zones classified as Stability Grades A and B show minimal signs of instability and generally do not require countermeasures. On the other hand, Grades C to E indicate areas where some form of stabilization work is necessary to ensure post-excavation slope stability. In particular, areas classified as Grade E are considered to have a high potential for large-scale toppling failures due to the parallel distribution of steeply dipping alteration zones along the slope, which dam up the groundwater level.

As a result of the stability analysis for areas with a stability grade of C or lower, it was confirmed that Zones ③, ⑦, and ⑨ did not meet the required safety factor, and countermeasures were deemed necessary to ensure slope stability. The excavation face in Zone No. ⑦ forms a wedge-shaped rock mass due to the combination of bedding planes aligned with the dip slope and steeply inclined altered zones. A composite sliding surface was defined, and FEM analysis was conducted, resulting in the highest required resisting force of 2,058 kN/m.

4. Countermeasures

Slope countermeasures were planned to include: (1) support works to satisfy the required resisting force obtained from the stability analysis, (2) protective works to prevent surface deterioration of the slope, and (3) drainage measures to address seepage from the slope. In Zone ③, to meet the required resisting force of 29 kN/m, rock bolts (D19, L = 5 m) were arranged at 2-meter intervals. In Zone ⑨, to meet the required resisting force of 160 kN/m, rock bolts (D25, L = 8.5 m) were planned at 2-meter intervals. For Zone ⑦, where the highest required resisting force of 2,058 kN/m was calculated, a system of 10 rows of ground anchors (Td = 801.3 kN/anchor) was planned. Drainage measures were designed to eliminate groundwater dammed within altered zones. These included long drainage boreholes drilled from outside the slope area and additional drainage holes targeting locations on the excavated slope where seepage is expected.

5. Conclusions

Due to the numerous technical challenges associated with the excavation slope on the right bank of the Komagome Dam, a committee-based approach has been adopted for ongoing discussions.

This committee includes the Dam Engineering Center, the Komagome Dam Main Body JV, the Aomori Prefecture Komagome Dam Construction Division, and Nippon Koei. As construction progresses, new insights gained from observations of the excavation face are used to verify the validity of the original plans and make necessary adjustments accordingly.We would like to express our sincere gratitude to the Dam Engineering Center for their invaluable support throughout the study.

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20. A Case Study of Geo-related Risks Identified in Dam Construction Projects in Soft Rock Distribution Areas and Countermeasures

○Ryoichi Yamaura ,Hiroyuki Watatani(CTI Engineering Co., Ltd.,) ,
Mitsuhiro Maruta ,Tadayoshi Sakamoto (Kagoshima Pref. Civil Engeeneering Dept.,)

1. Introduction

This study presents a case study of Geo-related risks associated at the time of dam design and construction in areas with Quaternary volcanic soft rock and sedimentary soft rock distributions, using the Nishinotani Dam as an example. The Nishinotani Dam is a gravity concrete dam constructed on the Shinkawa River in Kagoshima Prefecture. Due to the presence of low-strength Quaternary volcanic soft rock and sedimentary soft rock in the foundation bedrock, geological distribution, rock properties, and geological history were considered, and geotechnical evaluations were conducted at the time of design and construction as follows.

2. Overview of the dam site

The Nishinotani Dam, which is the case study in this paper, is a gravity concrete dam (Dry Dam) with a height of 21.5m and a crest length of 135.8m [1]. The mechanical and physical characteristics of the foundation rock layers, namely the Shiroyama Formation (Sut, Sla, Smt, Sus, Smb) and shirasu (Itb), are shown in Table 1.

Table 1 List of dynamic and physical characteristics for each rock classification.

Rock Classification	Geological Classification (abbreviation)	Needle penetration gradient*1 (N/mm)	Uniaxial compressive strength (N/mm^2)	bulk density (kN/m^3)	In-situ test: Converted elastic modulus (N/mm^2)	In-situ test: Shear strength*2 (N/mm^2)	In-situ test: N-value
[CM]	Kwd	—	—	17.84 -20.97 (n=27)	—	—	—
[CLH]	Sut	1.5～	—	—	465.5 -534.1 (n=3)	—	50< (n=14)
[CLH]	Sla	—	—	15.58 -19.70 (n=2)	514.5 -641.9 (n=5)	—	50< (n=27)
[CLH]	Smt	1.5～	0.818 -1.052 (n=20)	17.25 -18.62 (n=164)	396.9 -465.5 (n=8)	0.177 -0.271 (n=7)	38～50< (n=30)
[CLH]	Sus	1.5～	0.291 -0.607 (n=19)	18.13 -20.09 (n=58)	426.3 -494.9 (n=5)	0.172 (n=2)	48～50< (n=32)
[CLH]	Smb	1.5～	0.237 -0.457 (n=14)	14.99 -15.97	396.9 -426.3 (n=21)	0.156 (n=4)	35～50< (n=74)
[CLL]	Ttf	1.0～	—	15.09 -15.68	—	—	43～50< (n=10)
[CLL]	Itb	1.0～	—	13.82 -15.78	323.4 -362.6 (n=4)	0.078 (n=2)	37-50< (n=128)
[D]	Itb	～1.0	—	16.66 -17.05	186.2 (n=1)	—	6-12 (n=33)

*1:Needle penetration gradients are shown in ranges based on test values at the excavation surface
*2:angle of internal friction:Smt ϕ =26.2～44.9° 、Sus ϕ =40.2° 、Smb ϕ =33.6° 、Itb ϕ =28.1°

Considering their strength and permeability, the dam foundation rock layers and artificial rock layer base foundations were designed to target CLH-class rock layers of the Shiroyama Formation, while the rock layers behind the artificial rock layers were designed to target CLL-class shirasu rock layers.

3. Issues with volcanic soft rock

The volcanic soft rock distributed at the dam site corresponds to the aforementioned shirasu. Examples of geological risk responses during design and construction for shirasu are as follows.

3.1 Countermeasures for Risks During Design

Since the shear strength of shirasu was approximately 0.08 N/mm², it was determined to be unsuitable as the foundation for a gravity concrete dam during the design phase. Since the distribution surface of shirasu did not rise above an elevation of 50 m, the excavation area for the left and right abutments was reduced by using artificial rock (constructed abutments).

3.2 Risk Occurrence and Response During Construction

1) Risk occurrence in the initial stage of construction

During observation of the excavation surface in the early stages of construction, the following geological risks were identified in areas with low survey density.

① Shirasu, which is unsuitable as an artificial rock foundation, was found to be distributed in the relevant area.

②It was confirmed that a 'the base of shirasu' containing numerous heterogeneous rock fragments is distributed in part of the shirasu distributed on the back of the artificial rock layer.

③It became clear that secondary shirasu was distributed on part of the back of the artificial rock.

In response to these issues, for ①and ③, based on observations of the excavation surface, we assumed the distribution of each and decided to remove the foundation rock. For (2), we confirmed that the excavation surface was equivalent to Shirasu (composed solely of essential rock fragments) and determined that it was suitable as the foundation rock behind the artificial rock.

2) Responding to increased risks during peak construction phase

Based on the findings confirmed during the initial stages of construction, we examined the predicted expansion of risks and responses to them as shown in Table 2 in preparation for the peak season.

Table 2 Geological risks that arose during design and construction and the results of responses (shirasu)

	Risksthat emerg-ed during the initial stages of construction	Predicted increase in risk during peak Construction	Responding to anticipated risks
shirasu、secondary shirasu	Remains on the excavation surface of low-strength rock	Complex distribution along old terrain	Understanding the relationship between shirasu distribution and excavation surfaces
The base of shirasu	Distribution of complex lithofacies	Uncertainty of rock mass evaluation based only on visual inspection	Utilization of simplified penetratio n tests for rock mass evaluation

Among these, regarding the distribution of shirasu, i t is necessary to examine not only its relationship wit h the bedrock but also seepage into other watersheds. Therefore, we conducted outcrop surveys, spring surve ys, and boring surveys to understand the three-dimensi onal distribution from upstream and downstream of the reservoir to other watersheds.(figure-1)

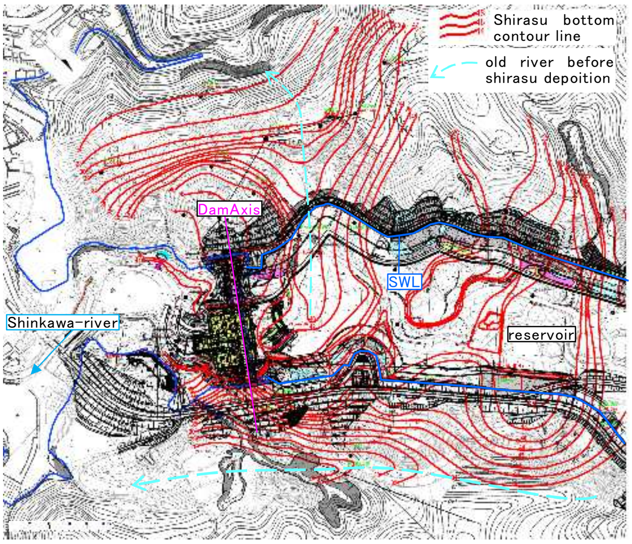

figure-1 Contour map of the bottom surface of the shirasu dam site and reservoir

4. Issues with sedimentary soft rock

The sedimentary soft rock distributed at the dam site is the Shiroyama Formation, which is a Quaternary sedimentary rock. The following are examples of geological risk responses to shirasu during design and construction.

4.1 Response to risks during design

The Shiroyama Formation was a low-strength rock mass with a shear strength of approximately 0.15 N/mm2, but it was used as the foundation for a gravity concrete dam in consideration of the scale of the dam body.

4.2 Risk Occurrence and Response During Construction

1) Risk occurrence in the initial stage of construction

The following geological risks were identified during observation of the excavation surface in the initial stage of construction.

①Loosening of the surface layer due to heavy machinery excavation[2] was confirmed.

② Variations in strength were confirmed in each rock formation.

In response to these issues, we conducted outcrop surveys, excavation surface surveys, and simple penetration tests (including shear tests) in the surrounding area to establish quantitative evaluation criteria[3] for the bedrock and propose construction methods that minimize loosening.

2) Response to increased risks during peak construction season

Based on the events confirmed during the initial stage of construction, we examined the predicted increase in risks during the peak season and our response to them, as shown in Table 3.

Table 3 Geological risks that arose during design and construction and the results of responses (Shiroyama-F.)

	Risksthat emerg-ed during the initial stages of construction	Predicted increase in risk during peak Construction	Responding to anticipated risks
Shiroyama -F.	Loosening of the surface layer after excavation. Differences in rock properties for each lithofacies.	Uncertainty of rock mass evaluation based only on visual inspection	Utilization of simplified penetratio n tests for rock mass evaluation

5. Summary and Future Prospects

In this case, many risks were identified during construction, but there were also cases where measures could have been taken during the design phase. Going forward, we believe that by referencing these methods from the design phase onwards at dam sites where soft rock is distributed, it will be possible to reduce the probability of risks occurring during construction.

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（参考：TWG of Dams and Levees(AEG) と土木地質研究部会(JSEG)の協働合意内容）

2024.9.11

AEG と JSEG とのダム地質分野における技術交流

1. 背景

米国と日本は以下の共通の問題を有している。

(1)地質学的には、両国は環太平洋火山帯に属しており、その地質環境により、火山噴火、地震、土砂災害、洪水等の自然災害に関する様々なリスクを有する。さらに、これらのリスクの一部は、気候変動によって悪化している。

(2)既存のインフラの老朽化に伴い、両国とも既存のインフラの維持管理、修復、改修への関与が強まっている。これらの老朽化した構造物を安全に維持するためには、上記のような自然災害に対する計画・準備を含む、将来に備えるための先進的な技術を用いたリスク・アセットマネジメントの実施・改善が重要である。

2. 趣旨

この交流の目的は、日米の地質技術者間の交流を促進し、共通の技術問題について協力することにより、両国および国際社会におけるダムの安全基準と実施の改善に貢献することである。

3. 事務局

交流事務局は、AEG のダムと堤防に関する TWG、及び JSEG の土木地質研究部会ならびに国際委員会とする。

4. 参加者

参加者は、両学会の会員、またはそれぞれの事務局が承認した団体または個人とする。

5. 交流の範囲

技術交流の範囲及びそのために必要な事項は、両事務局の協議により決定する。

交流の暫定的な内容は以下のとおりである。

(1)両年次大会への出席

(2)両学会の活動紹介(WG 活動の紹介等)

(3)先端技術、事例紹介、教訓・トピックスの紹介

(4)共通の技術課題に関する協働

(5)地質技術者教育、フィールドトリップ、交流会等

6. 交流期間

交流期間は 2024 年 10 月から 2028 年 9 月までとし、この期間に事務局で延長について協議する。

11th, Sep., 2024

Technical Exchange between AEG and JSEG in the Field of Engineering Geology for Dams

1. Background

The United States and Japan share the following common problems:

(1) Geologically, both countries belong to the Pacific Ring of Fire, and have various risks regarding natural disasters such as volcanic eruptions, earthquakes, landslides, and floods due to their geologic setting. Furthermore, some of these risks are being exacerbated by the climate change.

(2) Due to the age of existing infrastructure, both countries are increasingly engaged in the maintenance, rehabilitation, and renovation of existing infrastructure. To safely maintain these aging structures, it is important to implement and improve risk/asset management using advanced technologies in order to prepare for the future which includes planning and preparing for the natural disasters mentioned above.

2. Purpose

The purpose of this Exchange is to contribute to improved dam safety standards and practices in both countries, and the international community, by facilitating interaction amongst engineering geologists from the United States and Japan and collaborating on common technical issues.

3. Secretariat

The Exchange Secretariat will serve the Dams and Levees TWG of AEG, the Research Group on Engineering Geology in Civil Engineering, and the International Committee of JSEG.

4. Participant

The participants should be members of both societies and organizations or individuals approved by their respective secretariats.

5. Scopes of exchange

The scopes of technical exchange, as well as the matters necessary for this, should be determined by consultation between the two secretariats.

Tentative contents of the exchange are as follows.

(1) Participation in both annual meetings
(2) Introduction of the activities of both societies (introduction of WG activities, etc.)
(3) Introduction of advanced technologies, case studies, lessons learned and topics
(4) Collaboration on common technical issues
(5) Education for engineering geologists, field trips, exchange events, etc.

6. Period of exchange

The exchange period will be from October 2024 to September 2028, in the period the secretariats will discuss its extension.