THE INTERNATIONAL ENERGY AGENCY TECHNOLOGY COLLABORATION PROGRAMME ON HYDROPOWER

IEA Hydropower

MAINTENANCE WORKS AND DECISION-MAKING FOR HYDRO FACILITIES

Main Report

Annex XV

October 2021

Contents

Acknowledgment

This report may hopefully serve as a meaningful document for hydropower business operators, E&M manufacturers, and various consulting firms in their future activity.

Taking this opportunity, we would like to express our gratitude to a number of staff members in the 25 hydropower business operators in Japan, Alex Beckitt of Hydro Tasmania, Brad Spangler of Snohomish County PUD、Joseph Summers, Jake Nink and Adegoke Okediji of U.S. Bureau of Reclamation Idaho Office, Shannon Rauch of Tacoma Power, Gray Proulx, Peter Ludewig, Philip Saglimbene, Alan Ettlinger and Christina S. Park of New York Power Authority, Steve Hope, Lucian Ciocoiu, Brent Russell, Kenyon Campbell and Brad Stykel of Fortis BC Inc.,. Jane M, Travers, Kent Keeler, Brad Snelgrove and Kyla Veldhuis of Ontario Power Generation Inc., Mr. Jako Abrie of Trustpower Limited, Jacob Roiz, Chris Hayes and Paul Smith of CEATI, and Boudewijn Neijens of Copperleaf. We also express our special thanks to Niels Nielsen, executive committee secretary, who created opportunities to interview various utilities in each of the hydropower operating nations. The activity of Annex XV would not have been so fruitful without him. I also express my appreciation for Yutaro Mizuhashi, Hiroyasu Akaike and Shingo Takagi serving on the former Operating Agent of this Annex, as well as Muneharu Toriya, Sadahiko Hiramatsu and Kazushi Fukao who provided needed instructions and assisted in the document preparation through a special committee in Japan. And finally I express special thanks for Hiroshi Murashige, JEPIC for completing this report and the annex activities.

Nirou Okamoto, Chief Operating Agent of IEA Annex-XV, March 2021

International Energy Agency (IEA)

IEA is an independent organization established in November 1974 in the framework of Organization for Economic Co-operation and Development (OECD). IEA is promoting a wide diversity of programs concerning energy cooperation among 29 countries of the 34 OECD member states (as of January 2021), such as:

- To maintain and improve a system for handling the oil supply disruption
- To promote optimized energy policies against the current world situation through cooperative relationships with non-member states, industrial circles and international organizations
- To manage a lasting information system regarding the international oil market
- To enhance the world energy demand-supply structure by developing alternative energy sources and improving energy utilization efficiency
- To support the integration of environmental policies and energy policies

The IEA Technology Collaboration Programme on Hydropower

The IEA Technology Collaboration Programme on Hydropower (IEA Hydro) is a working group of International Energy Agency member countries and others that have a common interest in advancing hydropower worldwide. Current members of the IEA Hydro TCP are Australia, Brazil, China, EU, Finland, Japan, Norway, Switzerland and the USA. Sarawak EB is a sponsor. Member governments either participate themselves, or designate an organization in their country to represent them on the Executive Committee (ExCo) and the working groups (Annexes), through which IEA Hydro's work is carried out. Some activities are collaborative ventures between the IEA and other hydropower organizations.

Vision

Through the facilitation of worldwide recognition of hydropower as a well-established and socially desirable energy technology, advance the development of new hydropower and the modernization of existing hydropower

Mission

To encourage through awareness, knowledge, and support the sustainable use of water resources for the development and management of hydropower.

To accomplish its Mission, the Executive Committee has identified the following programme- based strategy to:

- Apply an interdisciplinary approach to the research needed to encourage the public acceptance of hydropower as a feasible, socially desirable form of renewable energy.
- Increase the current wealth of knowledge on a wide array of issues currently associated with hydropower.
- Explore areas of common interest among international organizations in the continued use of hydropower as a socially desirable energy resource.
- Bring a balanced view of hydropower to the worldwide debate on its feasibility as an environmentally desirable energy resource.
- Encourage technology.

IEA Hydro is keen to promote its work programmes and to encourage increasing involvement of non-participating countries. All OECD and non-OECD countries are eligible to join. Information about membership and research activities can be found on the IEA Hydro website www.ieahydro.org

1. Introduction

In recent years, following worldwide deregulation of power markets, major utilities have focused on corporate management and putting emphasis on asset management for maintaining and improving the value of existing assets. These drivers have become the basis for decision-making while the establishment of ISO55001 has standardized asset management methods at an international level, and therefore it is deemed that more and more power utilities are introducing asset management in their organizations.

Against this background, Japan proposed to the IEA Executive Committee to investigate the implementation status of asset management in the advanced hydro countries and to prepare a decision-making manual for hydropower maintenance. Japan was appointed to serve as the Operating Agent of Annex-XV and cooperate with other member states.

Study Flow of this Annex is as shown in Fig. 1.1. The result of Asset Management Status Research is described in Chapter 3. Collection of Decision-Making Good Practice is described in Chapter 4 and 5.

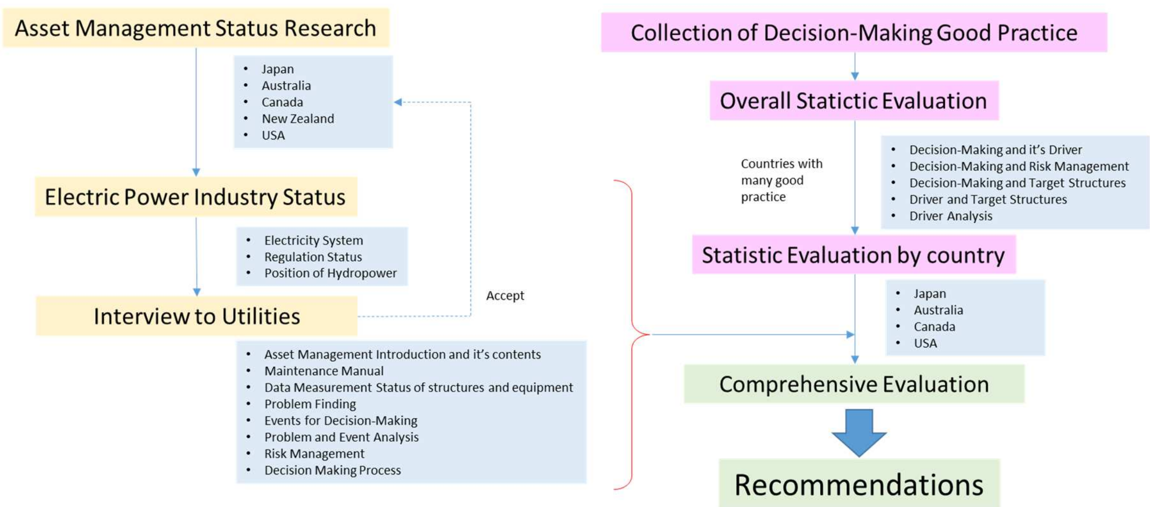


Fig. 1.1: Study Flow of Annex XV

In Chapter 4, 196 good practices, gathered from all over the world, were systematically analyzed into six decision-making categories as follows;

- Overhaul & Repair (O&R)
- Renewal & Expansion (R&E)
- Refurbishment
- Redevelopment
- Abolition
- Other

and five key drivers in the decision-making processes, which in turn revealed the characteristics of decision making in hydropower maintenance practiced in advanced hydropower representative countries, as follows;

- Aging
- External factors
- Asset optimization & review of operation
- Disaster
- Poor maintenance

Behind these decision-making drivers are the power demand situation or system unique to the hydropower in each country. This report which consolidated the above information may hopefully serve as a meaningful document for hydropower business operators, E&M manufacturers, and various consulting firms in their future activity.

2. Summary

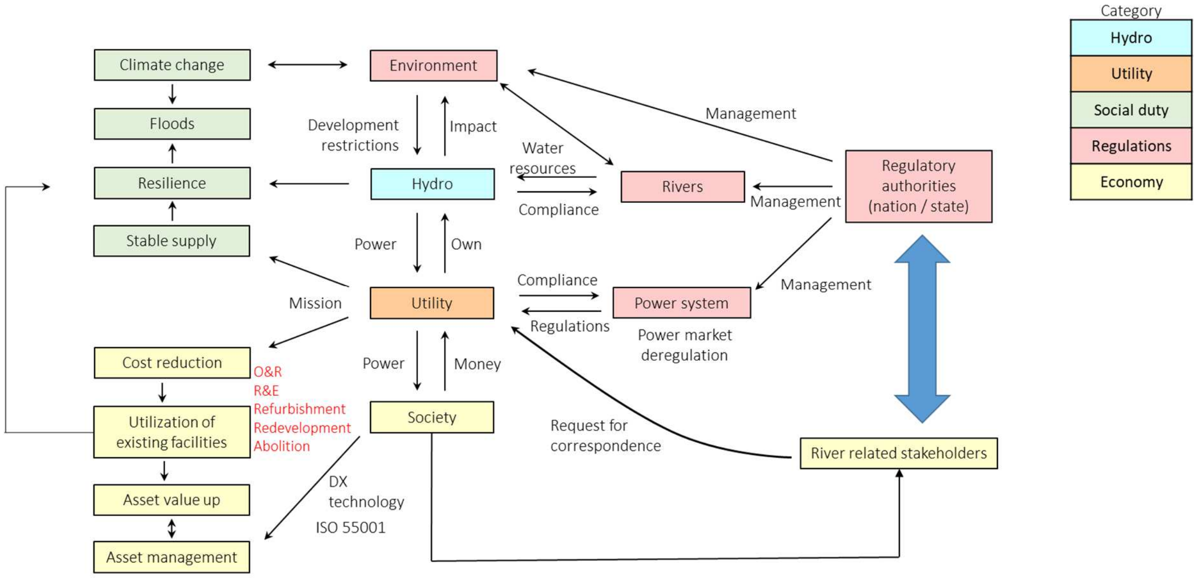


Fig. 2.1: Overall Sketch of Annex-XV

This Report provides the results of the asset management investigation on the main members of IEA Hydropower Technology Collaboration Programme on Hydropower, the collection and statistic evaluation of good practices drivers of decision making for hydropower maintenance and the decision-making process based on those good practices.

By the asset management investigation, current status of asset management and it's background are revealed.

And according to the collection and statistic evaluation of good practices drivers of decision making, the findings are as follows;

- ✓ Decision making for hydropower maintenance is mainly driven by aging and External Factors.
- ✓ Decision making prompted by aging aims at the maintenance and enhancement of the value of existing assets.
- ✓ The agenda for External Factors differ from country to country, but what is common to all is the prevention of third-party damage. Hydropower utilizes rivers, and rivers involve many people other than those engaging in hydropower generation business. Such a public nature of hydropower generation leads to the idea that it should never cause damage to the third parties.

These elements are outlined in Fig. 2.1 as a schematic that covers the scope of Annex XV.

This diagram indicates the following:

- ✓ Utilities have mission of "Stable supply of electricity" and "Cost Down". "Cost Down" is necessary to keep tariff cheap against request by public.
- ✓ To accomplish "Stable supply", hydropower stations owned by utilities should keep resilience against natural conditions by maintenance works.
- ✓ To accomplish "Cost Down", utilities should make decision to utilize existing facilities effectively

so that their value should be improved. This process is called as “Asset Management”.

- ✓ On the other hand, utilities should face various External Factors as described.
- ✓ For example, the United States carries out water resource management in a highly systematic manner, whereby considerations are given to the water resources so that they are equally utilized for a wide variety of stakeholders including local communities, flood control, agriculture, industry, fishery, transport, tourism, and recreation, in addition to hydropower generation.
- ✓ The positioning of hydropower among the various uses of water resources varies from country to country. The regulation level is determined by the river administration policy of the country, which in turn is manifested as differences in the External Factors for decision making.
- ✓ The environment is another major element closely related to hydropower. Since hydropower development causes an environmental impact, restrictions are imposed on the development. When such restrictions pose a large obstacle to hydropower development, the focus is increasingly shifted from new development to the maintenance and enhancement of the asset value of existing hydropower. (The insufficient power supply is replaced by other energy sources)
- ✓ On the other hand, in the environmental aspect, more disasters have been caused by the climate change on a global scale and thus affecting the existing facilities, which necessitates certain countries to prioritize technical correspondence in their decision making. (Japan)

3. Asset Management Status by Hydropower Utilities in IEA Member Countries

3.1 Survey Contents

To investigate current status of hydropower asset management, hearings were conducted on utilities that operate hydropower generation facilities in the U.S.A., Canada, and New Zealand. Current status of hydropower utilities interviewed by study team are shown in Table 3.1-1.

Hearings were conducted on the following topics;

- When asset management was introduced;
- Whether or not maintenance instruction manual exists;
- Data measurement status of each structure and electric and mechanical equipment;
- Identification of problems;
- Events that require decision making;
- Analysis of problems and events;
- Risk assessment;
- Method of decision making and its implementation regarding such issues as “subsequent maintenance”, “preventive maintenance”, “funding”, “spare parts and emergency response”, “operation and constraint”, policy, standards, and planning etc.

Table 3.1-1: Interviewed Hydropower Utilities Status

Name	Country	Installed Hydro Capacity	Number of Hydropower Stations	Remarks
Snohomish County PUD	The USA	70 MW	6	Local Public Utility
Reclamation Office Idaho		7,463 MW	10	US Bureau of Reclamation, exercising Jurisdiction over Pacific North and West region
Tacoma Power		637 MW	6	Local Public Utility
New York Power Authority		4,411 MW	7	State owned utility
Fortis BC Inc.	Canada	822 MW	6	Private Utility
Ontario Power Generation		7,438 MW	66	State owned utility
Tasmania Hydro	Australia	2,166 MW	27	State owned utility
Trust Power	New Zealand	431.5 MW	28	Private utility

Regarding to utilities in Japan, hearings were conducted on the following topics;

- Status of Decision Making Drivers
- Status of Asset Management Process
- Components of Asset Management

- Asset Management Process at Asset Levels
- Components and Strategy of Asset Management

Status of survey target in Japan is as shown in Table 3.1-2.

Table 3.1-2: Feature of Survey Targets in Japan

Issue	Public Utility or Local Government	Private Utility
Number of entities	19	6
Owned hydropower capacity	11 to 355 MW	2,446 to 9,871 MW
Number of owned hydropower plants	1 to 32	61 to 209
Number of owned turbine & generator	1 to 37	111 to 311
Average service years	33 to 62	44 to 77
Range of service years	52 to 93	64 to 127

3.2 Current Status of Electric Power Industry of Surveyed Countries

3.2.1 Share of Hydropower in Electricity

Shares of hydropower in installed capacity and annual generated energy are shown in Table 3.2-1. Shares of hydropower in Canada and New Zealand are between 50% and 60%, which are comparatively large among countries.

Table 3.2-1: Share of Hydropower in each country

Country	Installed Capacity（10^3kW）			Annual generated energy (10^9kWh)			Remarks
	Total	Hydro	Share	Total	Hydro	Share	
Japan[1)]	259,510		19 %	1,044		8%	2015
The USA[2)]	1,074,330	79,910	7%	4,077	261	6.4%	2016
Canada	143,442[3)]	80,846[3)]	56%	648[4)]	383[4)]	59%	2016
Australia[5)]	54,234	6,920	13%	218.6	14.5	6.6%	2016
New Zealand[6)]	9,723	5,381	55%	43	26	61%	2017

3.2.2 Electric Power Industry Status of the countries

Comparison of each country is shown in Table 3.2-2.

Table 3.2-2: Electric Power Industry Status of the countries

Country	Regulation & Administrator	Electricity Market Status	Utility
Japan[7)]	・Ministry of Economy, Trade and Industry ・Electricity Business Act ・OCCTO：Organization for Cross-regional Coordination of Transmission Operators ・Electricity and Gas Market Surveillance Commission ・Others (rights to the use of water, environment)	・Full liberalization of electricity retailing ・Separation of electrical power production from power distribution and transmission ・Japan Electric Power Exchange (JEPEX)	・Transmission and Distribution Utility (Permission) ・Power Producer (Notification) ・Retailer (Registration) ・Specified Transmission and Distribution Utility (Notification)
The USA[8)]	・the federal government, the state governments, local governments, and tribal government ・Regulation by the federal government FERC: Federal Energy Regulation Committee USBR: US Bureau of Reclamation USACE: US Army Corp of Engineers ・Regulation by the states Public Utility Commission Others (local city planning committees, disaster prevention and safety authorities, power plant location examination committees, state environmental regulators etc.)	・The present wholesale market is classified into 2 types as shown in Fig. 3.2-1 and Table 3.2-3 ・the bilateral trading based market Vertically integrated traditional utilities are generally authorized by the local government to provide power generation, transmission and distribution services in a specified geographic region. Therefore they monopolize the market of the region but they are regulated by the federal or state regulators. (“Northwest” in Fig. 3.2-1) Snohomish County PUD, Reclamation Office Idaho, and Tacoma Power are located here. ・the market of organized trades among cross-regional transmission operators Retail competition has been introduced, and expansion of competition is intended. New York Power Authority belongs to this market. (NYISO)	・Classification depending on the owners Private utilities Federally owned utilities* Local public utilities Corporative utilities *: One of Federally owned utilities are the Power Administration which exist 4 area in the USA. Interviewed utilities located in the North Pacific region are making electricity trade with the Bonneville Power Administration (BPA).
Canada[9)]	・Federal Government, State Government ・Federal Regulation Limited to transmission facilities construction and system operation over the borders between the countries and nuclear power development. National Energy Board (NEB) and Canadian Nuclear Safety Commission (CNSC) are the electricity business regulators. ・Provincial Regulation Present to the utilities both the federal government policies and goals of such policies regarding the electricity market structure, tariff and business regulation. Have important role in the present operation of electricity business, planning its future system and in deciding implementation method of such plans.	・Independent by province ・Deregulation of electricity market is executed in 8 provinces except Newfoundland and Prince Edward Island ・Separation of electrical power production from power distribution and transmission is executed by major provincial utilities ・There exist vertically integrated private utilities as well as many small scale municipal utilities and independent power producers, besides the large provincial utilities. ・Full deregulation of retail market is executed in Alberta and Ontario. (only 2 provinces at the end of 2017)	・Provincial Utility ・Private Utility ・Municipal Utility ・Industrial power generation ・Independent Power Producer (Alberta, Ontario)
Australia[10)]	・NEL (National Electricity Law) ・NER (National Electricity Rules) ・Federal level and State level Originally, Australian State Governments owned regulated	・NEM five states (New South Wales, Victoria, South Australia, Queensland and Tasmania) and the Australian Capital Territory	Regarding electricity generators, there are three classifications: ・“Scheduled generators” which are power generators

	electricity businesses, but in May 1996 the NEM (National Electricity Market) was established which lessened the regulation by the State Governments while that on the federal level was extended. This made the trend of encouraging cross-regional operation and competition between utilities in the market. ・Federal Level Regulator the AER (Australian Energy Regulator) the ACCC (Australian Competition and Consumer Commission)	・Western Australia ・Northern Territory ・Now in the Eastern region and Western Australia, power generation, transmission, distribution, and retail sectors are separated and generation and retail markets are deregulated. ・ AEMO (Australian Energy Market Operator) manages and operates NEM. AEMO is in charge of various roles, such as maintaining the demand and supply balance, publishing various market indices, calculating spot prices and ensuring settlement between market participants.	whose power is more than 30MW, ・ "Semi-scheduled generators" which are power generators whose intermittent power such as wind is more than 30MW. ・ "Non-scheduled generators" which are power generators whose power is less than 30MW.
New Zealand [11]	・Electricity Act 1992 ・Electricity Reform Act 1998	・Frame work of Electricity system ECNZ: Electricity Corporation of NZ Trans power: The transmission sector is monopolized by the state-owned enterprise NZEM : New Zealand Electricity Market NZX: the trades are settled at New Zealand Exchange (NZX).	・Players at the time of 2019 5 Utilities (such as "Contact Energy" etc.) 1 Transmission company（Trans power） 29 Distribution companies (such as "Vector", "Wellington Electricity" etc.） Retailers（Almost all of them are subsidiary of utilities.）

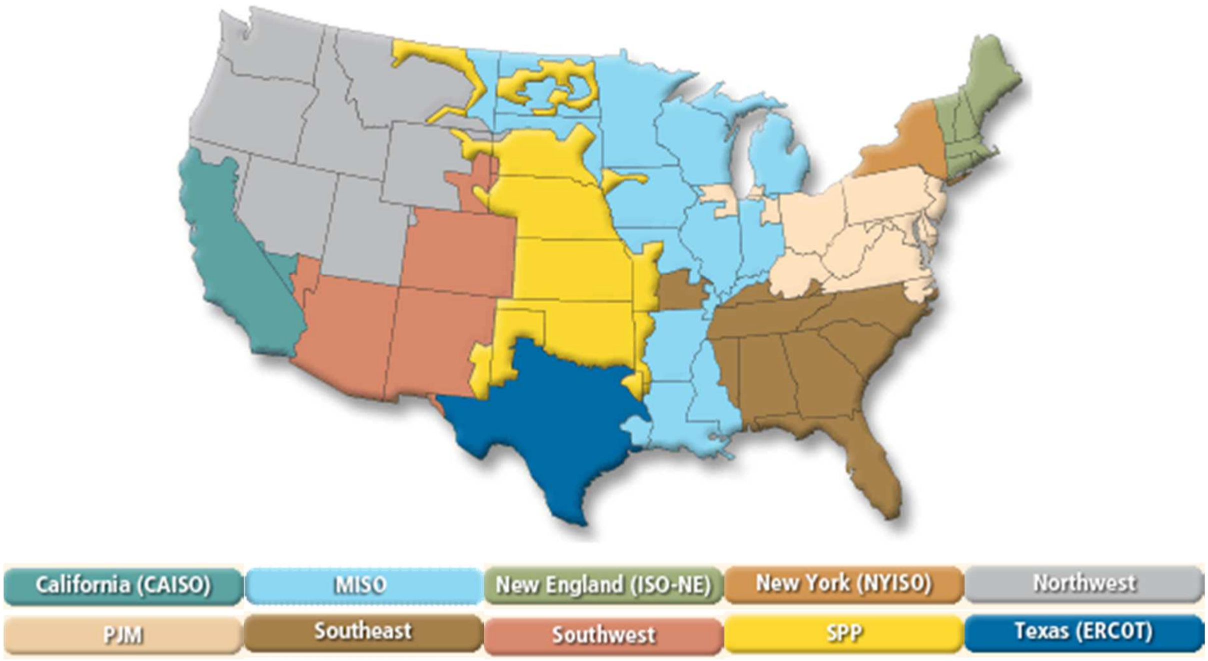


Fig. 3.2-1: Electricity Wholesales Market Distribution in USA[12)]

Table 3.2-3: Classification of USA Electricity Market[13)]

ISO/RTO	ISO-NE	NYISO	PJM	MISO	SPP	ERCOT	CAISO
Established Year	1997 (RTO approved by FERC in 2005)	1999	1997 (RTO approved by FERC in 2001)	1998 (RTO approved by FERC in 2001)	2004 (RTO approved by FERC)	1996	1998
Establishment History	Transition to ISO with the existing power pool (established in 1971)	Transition to ISO with the existing power pool established to prevent	Transition to ISO with the existing power pool (established in 1927)	Independently established by transmission line owners who agreed to ISO	Established with the power pool built by local utilities to meet regional power demand by munitions industry	ISO nominated by public utility commission in accordance with State Public Utility	Established by State Electricity Business Reorganization Law

		recurrence of 1965 blackout in northeast		establishment scheme of FERC	at the beginning of World War II	Regulation Amendment	
Concerned State (All or Partial)	CT、MA、RI、VT、NH、ME	NY	DE、DC、MD NJ、OH、PA、VA、WV、IN、IL、KY、MI NC、TN	AR、IL、IN IA、KY、LA、MI、MN、MS、MO、MT、ND、SD、TX、WI	AR、IA、KS、LA、MS、MO、NE、NM、ND、OK、SD、TX WY	TX	CA and part of NV
Past Record of Power Demand (as of July in 2018)	28,130MW (2006)	33,956MW (2013)	158,043MW (2011)	127,125MW (2011)	50,622MW (2018)	73,260MW (2018)	50,116MW (2016)
Installed Capacity	About 31,000MW	38,777MW (2017)	178,563MW (2017)	174,724MW (2017)	65,410MW (2016)	78,000MW (2017)	73,306MW (2016)
Supplying Population (million)	14,8	19,8	65	48	18	24	30
Operation Market							
Capacity Market	○	○	○	○	-	-	-
One Day before Market	○	○	○	○	○	○	○
Financial Transmission Right (FTR)	○	○	○	○	○	○	○
Real Time Market	○	○	○	○	○	○	○
Frequency Control Market	○	○	○	○	○	○	○
Price Determining Method	By Place	By Place	By Place	By Place	By Place	By Place	By Place

3.3 Summary

3.3.1 Interview (the USA, Canada, Australia, and New Zealand)

(1) Asset Management Introduction

- In the USA, asset management was introduced by New York Power Authority in 2004. The other utilities introduce asset management in the beginning of 2010's.
- In Canada, it was introduced around 2010.
- In Australia, it was introduced in 1990's.
- In New Zealand, it was introduced in the beginning of 2010's.

(2) Maintenance Manual Preparation Status

- Manuals for civil structures are prepared based on the regulation by authorities.
- Manuals for electro-mechanical equipment is diverted from OEM manual by manufactures at the beginning. But original manuals are prepared after number of owned assets are increased.
- For manual preparation, some utilities are supported by the organization which supports ISO55001 certification, CEATI.

(3) Data Measurement Status

- In the USA, data measurement for important civil structures such as dams is made based on the regulation by utilities, except New York Power Authority. On the other hand, New York Power Authority always makes measurement for electro-mechanical equipment under operation. Other utilities check the operation status of electro-mechanical equipment by check list and OM manual.

- In Canada, both utilities make measurements for civil structures. For electro-mechanical equipment Fortis BC checks operation status by the values shown on operation panels. Ontario Power Generation always makes measurement of operation status.
- In New Zealand, Trust Power makes measurement on dams. They emphasize vibration and temperature of bearing for electro-mechanical equipment.

(4) Problem Identification Status

- Problems are identified when measurement data is out of the standard value zone, or when singular events are identified under site inspection.

(5) Events that require decision making

- Events that require decision making differ by utilities in the USA. Some make decision by singular events under site inspection, some by the number of migrating fish species in the river, some comprehensively make decision based on periodical inspection and overhaul. Utility whose number of hydropower assets is large makes decision in such ways.
- In Canada, Fortis BC Inc. emphasizes events concerned with safety, and Ontario Power Generation comprehensively make decision by bench marking and etc. OPG's annual budget for operation and maintenance is flat rate, and maintenance is based on subsequent maintenance.
- Problems found under daily site inspection is emphasized in Australia.
- Decision making for local correspondence is emphasized in New Zealand.

(6) Analysis of problems and events

- Reclamation Office Idaho make long term maintenance plan by using software for deterioration diagnosis of electro-mechanical equipment and financial analysis. Hydro Tasmania also make long term maintenance plan by the daily site inspection records and financial analysis.
- Snohomish County PUD and Tacoma Power make analysis based on check list.
- New York Power Authority, Fortis BC, Ontario Power Generation, and Trust Power make analysis based on data base of each asset.

(7) Risk Management

- Many utilities evaluate assets by total life cycle cost with expressing failure risk in numerical form.（Reclamation Office Idaho、New York Power Authority、Tacoma Hydro、Fortis BC）

(8) Decision Making Process

- Reclamation Office Idaho, Fortis BC, and Hydro Tasmania decide maintenance work priority by present value of total life cycle cost.
- Tacoma Hydro and Ontario Power Generation emphasize on subsequent maintenance.
- New York Power Authority make decision on outlier of measured value occurrence.
- Trust Power emphasizes on intention of shareholders.

3.3.2 The United States

- With large hydropower capacity, Reclamation Office Idaho has a highly developed asset management program. As they do not expect many new hydropower development projects in the future, they do their best to utilize existing hydropower facilities as effective as possible, and attach great importance to "discipline and control" at site.

- As Reclamation Office Idaho is a federally owned utility, they operate hydropower plants in accordance with their own standards.
- Snohomish County PUD is at the status to start asset management because of the limited capacity of their own hydropower facilities. On the other hand, Tacoma Power Inc. seems to have prepared the asset management system. It needs to decrease cost for power generation to keep tariff low.
- Tacoma Power Inc. is supported by CEATI*, a private organization based on Canada that give advice on asset management and acquisition of ISO 55001 certification to utilities worldwide.
  ＊： CEATI is the Centre for Energy Advancement through Technological Innovation, which is an organization to provide participating utilities for a fee with solvers of technical issues, supporting industrial development through sharing practical and applicable knowledge. It is based in Montreal.
- As New York Power Authority is located at the region where market liberalization has well progressed, operation data management of their generator facilities is thorough. They seem to regard the revenue creation capability of the generators highly. Considering the fact that they have not started measurement of the structures, they do not have the same regard for them.
- As Snohomish County PUD and Tacoma Power Inc. operate hydropower plants under the license of FERC, they must absolutely comply with the regulation. Especially important issue for the license is protection of anadromous fish going up the rivers.
- In the discussion with Reclamation Office Idaho, Snohomish County PUD, and Tacoma Power Inc., there was no reference whatsoever to the dealings with local communities regarding dam reservoir management. They seem to acknowledge that the reservoir management should not be their job.

3.3.3 Canada

- Probably due to the double reasons of Ontario Power Generation being a provincial utility and electricity business having been deregulated in Ontario, OPG seems to have developed and operated the asset management program unique to the company
- As Fortis BC is a private utility, it manages its assets with perfect compliance with the provincial government regulation.

3.3.4 Australia

- Although Hydro Tasmania is state owned utility, it introduced asset management for effective use of existing assets in accordance with depletion of new hydropower projects.
- Hydro Tasmania establishes their own asset management system.

3.3.5 New Zealand

- Trust Power Inc. had a needs to introduce asset management with background as follows:
  - ✓ Although it is originally a local public utility, it has grown up as utility by buying and selling assets.

- ✓ It needs to uniformly manage miscellany assets.
- ✓ Some assets are country withdrawal, and they had been well maintained.

- ➢ As digitalization is permeating among utilities through reformation of electricity system in New Zealand, each utility has established environment which can easily promote asset management based on digital technology.
- ➢ Opportunities to buy and sell assets which are not only domestic but also overseas are increasing, this increases the needs of asset management introduction.

3.3.6 Japan

(1) Decision Making Drivers

- ➢ Many utilities consider that 'compliance to regulation' is "fundamental across the portfolio of hydropower plants and decisions must address this issue."
- ➢ Many utilities consider that 'initiatives to safety maintenance and social & environmental issues' are "fundamental across the portfolio of hydropower plants and decisions must address this issue."
- ➢ Half of targeted utilities answered that 'satisfaction of electricity market requirements' is "not considered under normal circumstances."
- ➢ Multiple utilities consider that 'asset risk management' and 'maintenance of asset values' are "highly important across the portfolio of hydropower plants and drives major decisions."
- ➢ Multiple utilities consider that 'asset value improvement' is "generally important, or highly important for a few hydropower plants," or "modest, of limited importance overall or only considered for a few hydropower plants."

(2) Total Asset Management Process

- ➢ Many utilities have partially or fully implemented asset management process
- ➢ Multiple utilities make mid- to long-term facility maintenance plan. (Example of mid- to long-term: 5-15 years; annual and profit making plan: 1 year)
- ➢ No utilities have their asset management process certified by ISO 55001.

(3) Asset Management Components

- ➢ Many utilities have issues, risks, assessment of issues and risks, prioritization, treatment, treatment implementation as their asset management components.
- ➢ Multiple utilities implement CBM (Condition Based Maintenance), RBM (Risk Based Maintenance), and TBM (Time Based Maintenance).

(4) Asset Management Process at Asset Levels

- ➢ Many utilities have inspection plans at the plant level and the equipment level.
- ➢ For technical support, technical design, construction work management, and work implementation, resources are mainly procured in-house or from affiliates, but sometimes outsourced resource are also used.

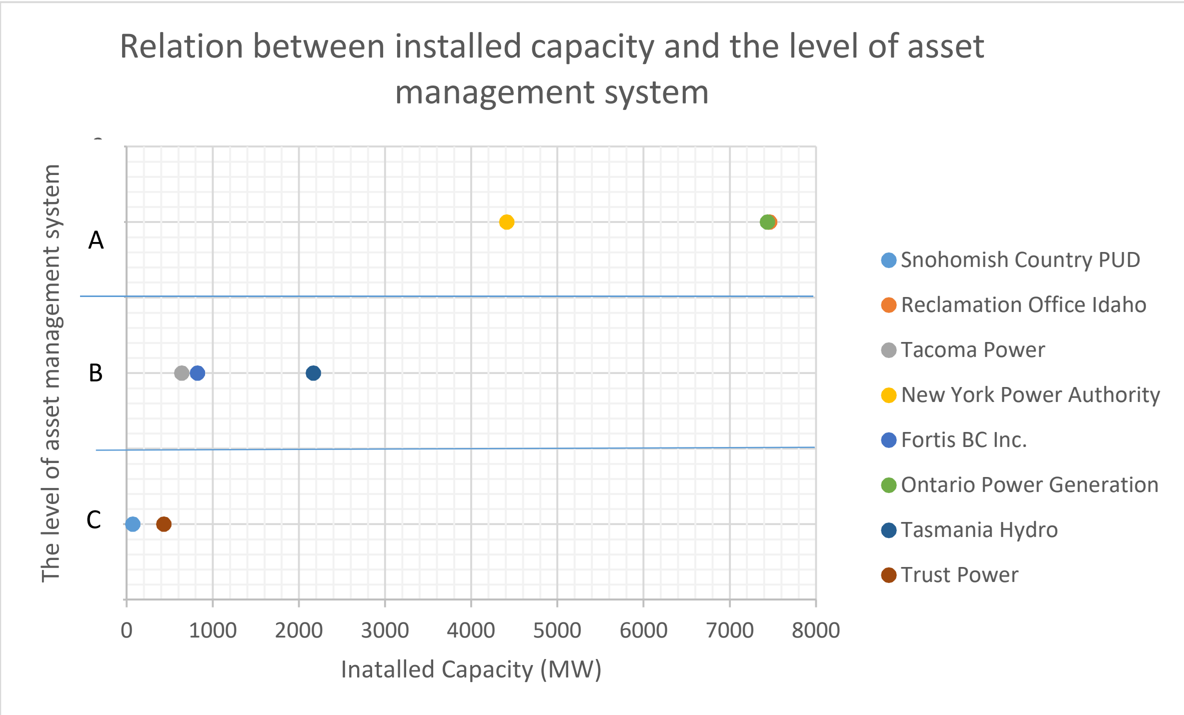
(5) Asset Management Components and Strategy

- ➢ Many utilities have their own software and systems.

- Few utilities use software or systems for risk management.

3.3.7 Overall

- According to the hearing result, installed capacity of each utility has the impact on the level of asset management system establishment as shown in Fig. 3.3-1.



The level of Asset management system A: Establish its own asset management system

B: Seeking for higher system establishment

C: Just introduced

Fig. 3.3-1: Relation between Installed Capacity and the level of asset management system

4. Statistic Evaluation of Decision-Making Good Practice Cases

4.1. Methodology

For the decision making of maintenance and upgrading of hydropower facilities, it is required to extend the service life of target plants, improve the value thereof by adopting latest technologies and upgrading the output, capacity and functions as needed, and also to maintain and, if necessary, restore their normal functions. For this reason, the owners of hydropower facilities are carrying out strategic asset management.

In such a situation, there are various drivers which affect the decision making for facility maintenance and upgrading. One of the most important purposes of this Annex is to understand how such drivers differ among the facility owners, states, and regions.

In order to collect the relevant cases with a wide-ranged viewpoint, we set out six types of decision making as indicated in Table 4.1-1: "Maintenance Works and Decision-Making for Hydro Facilities." Decision making is based on risk management, which was categorized and defined as shown in Table 4.1-2. Also, in order to systematically analyze the collected cases, the drivers for decision making and target structures are arranged as shown in Table 4.1-3. Additionally, External factors in Table 4.1-3 was categorized in view of the investigation results as indicated in Table 4.1-5. While power development policies can greatly affect the decision making, we excluded this factor from the investigation of this Annex.

Table 4.1-1: Maintenance Works and Decision-Making for Hydro Facilities

Decision making matters	Descriptions
Overhaul & Repair (O&R)	Repair as an urgent measure of main plant structures / facilities or peripheral electric facilities
Renewal & Expansion (R&E)	Planned renewal and expansion of main plant structures / facilities or peripheral electric facilities (for power generation)
Refurbishment	Refurbishment required by surrounding social / natural environments of main plant structures / facilities or peripheral electric facilities (except for power generation)
Redevelopment	Development of plant with major construction work due to development of other projects or disasters
Abolition	Abolition of plant
Other	Change in operation / management methods, construction work of other than main plant structures / facilities or peripheral electric facilities

- Main plant structures: dam, intake, headrace, tank, penstock, powerhouse building, machine unit foundation, tailrace, outlet
- Main plant facilities: electric facilities (turbine, generation, etc.), mechanical facilities (indoor crane, gate, screen, piping, etc.)
- Peripheral facilities: facilities not directly related to power generation

Table 4.1-2: Risk Management

Risk management	Descriptions
Avoidance	Not engaging in actions related to risks, or withdrawing from risky situations
Reduction	Reducing probability or impact scale of risks, or both of them
Transfer	Insurance policies, etc.
Tolerance	Positive tolerance (reserve funds, provision funds, savings, etc.), negative tolerance (not taking any measures upon recognition, disapproval, etc.)

Table 4.1-3: Drivers for Decision Making

Drivers	Descriptions
Aging	Corresponds to what is being affected by aging of power generation facitlities
External factors	Corresondes to Public works, third party damage prevention, turbid water countermeasure, design standard changes, compliance
Asset optimization & review of operation	Corresponds to gateless modification of spillPassage, installation of dust remover in intake, Upgrading pump turbine generator in pumped storage plant from fixed to variable speed type, expansion of powerhouse building in connection with the foregoing, etc
Disaster	Corresponds to damage by earthquake or flood
Poor maintenance	Corresponds to insufficient maintenance, management

Table 4.1-4: Target Structures of Decision Making

Names	Descriptions
Dam	Dam body. Includes weir
Spillway	Concrete structure including gate and other metal components
Reservoir	
Water Passage	Intake, headrace, tank, penstock, tailrance, spillway and their peripheral facilities
Powerhouse building	Structures above assembled units level in power plant
Turbine generator	Turbine generator and its peripheral equipment. Plant foundation concrete work is for renewal is included herein.
Peripheral electric facilities	Electric facilities other than turbine generator and its peripheral equipment
Other	Facilities other than the above

Table 4.1-5: Descriptions of External factors

Social drivers	Descriptions
Public works	Infrastructure improvement projects in the vicinity of power plants undertaken by the government. In this report, mainly dam redevelopment projects.
Environmental correspondence	Decision making for environmental conservation.
Fishery protection	Decision making for protecting fishes, etc. inhabiting rivers.
Third party damage prevention	Decision making for preventing damage to third parties in the vicinity of plant facilities
Demand & supply correspondence	Decision making required for corresponding to power demand and supply
Turbid water countermeasure	Decision making for taking countermeasures against turbid water in reservoirs caused by inflow mud and sand due to rainfalls
Design standard changes	Decision making in connection with changes in design standards
Compliance	Decision making required for compliance with laws and regulations
Civil unrest	Instability in domestic politics

4.2 Good Practice Collection

4.2.1 How to collect Good Practice

Good practice collection was conducted using a survey questionnaire in connection with the investigation for asset management discussed in Chapter 3. In addition, we also found the possible cases for this Annex from the cases collected for Annex-XI which are closely related to the maintenance of hydropower plants and other cases featured in academic journals and conferences for hydropower engineering.

4.2.2 Model format of Good Practice reports

The basic concept for the model format is based on the process of decision making presented in the discussions with the participant states upon preparation of Statement of Objective for Annex-XV.

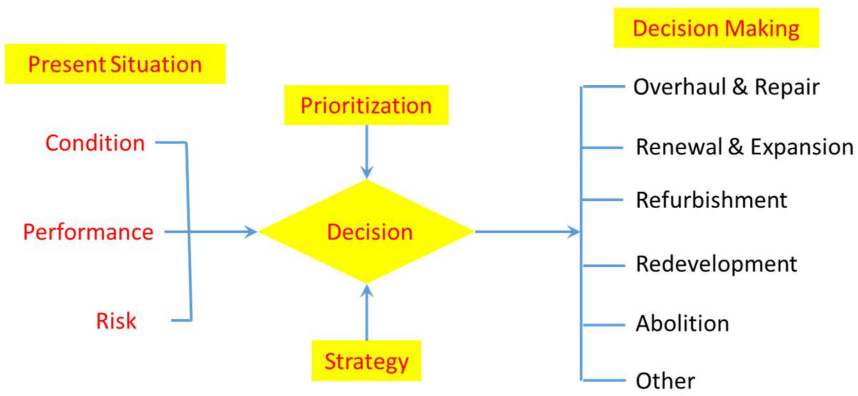


Fig. 4.2.2-1: Image of Decision Making Process

It is not appropriate to rigidly formulate the introductory descriptions of possible good practices as their features are diverse, but it is still desired from the standpoint of readers to unify the format to the extent possible for easily understanding those cases and comparing them with other cases.

For this reason, based on Fig. 4.2.2-1, we decided to unify the survey format as much as possible for collecting the information in a systematic and accurate manner as mentioned below:

- Plant Information (name, specifications, commissioning year and month, owner, and etc.)
- Type of decision making (choices from Table 4.1-2)
- Time of decision-making
- Target structure(s) (choices from Table 4.1-4)
- Driver (choices from Table 4.1-3)
- Phenomena caused by driver
- Type of Risk Management (choices from Table 4.1-2)
    - Risks for plant operation
    - Specific risk management
- (1) Current Status (Before decision making)

- 1) General Status
- 2) Operation Status
- 3) Risk
  - ✓ Potential risk in case of no decision making
  - ✓ Potential risk when implementing decision making

➢ (2) Priorities

➢ (3) Strategy

- Against potential risk in case of no decision making
- Against potential risk when implementing decision making

➢ (4) How decision-making was implemented and technologies adopted?

➢ Reference documents / sources

Regarding to the relation between above items and Fig. 4.2.2-1 is as shown in Fig. 4.2.2-2.

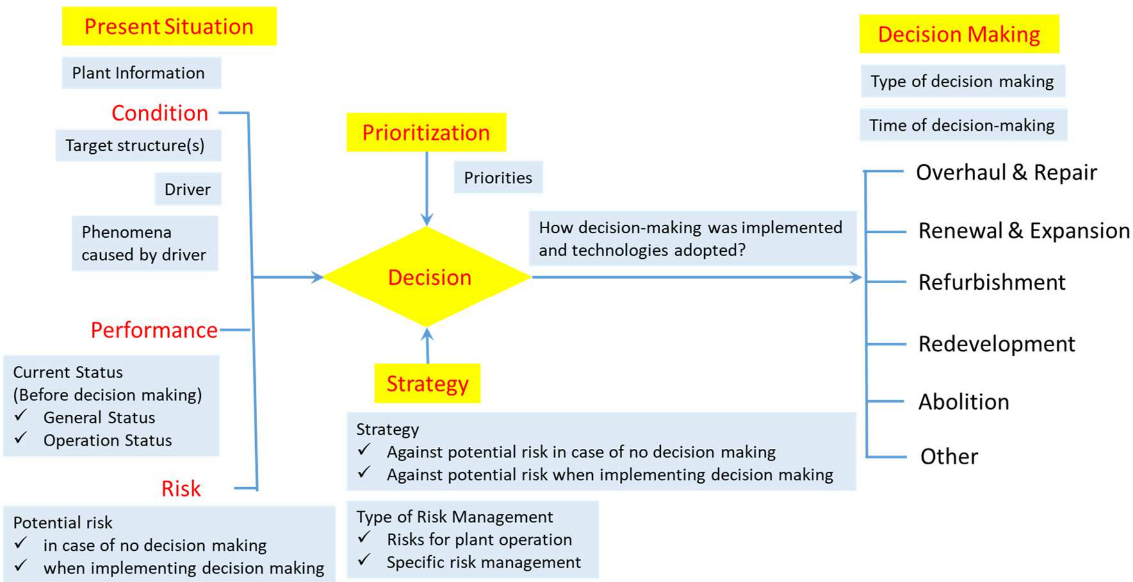


Fig. 4.2.2-2: Position of the table items in the process of Decision-Making

4.2.3 Quality assurance of case reports

In order to ensure the quality and reliability of the case reports, we arranged hydropower experts to perform peer review on the reports, conducted hearings from the report writers, and endeavor to refer to the documents and data publicized by third party institutions, etc. and thereby confirmed the material information to be incorporated in the reports.

4.3 Results of Case Collection

4.3.1 Status of Collection

We were able to collect 140 cases from Japan and 56 cases from 20 other countries. Of those 11 cases each were collected from Australia, Canada, and the United States. They are listed at the end of this volume as “Good Practice List in Japan” and “Good Practice List in oversea countries.

The case collection results from countries other than Japan are shown in Table 4.3.1-1.

Each case is generalized in the table with manners as described in 4.2.2. Appendix-1 is a portfolio of 140 good practices from Japan. And Appendix-2 is a portfolio of 56 good practices from 20 other countries (oversea).

Table 4.3.1-1: Breakdown of Decision-Making Cases in Countries Other Than Japan

(56 cases in 20 countries)

Countries	Decision making						Total
	O&R	R&E	Refurbishment	Redevelopment	Abolition	Other	
Argentina & Uruguay		1					1
Australia	1	2	4		1	3	11
Brazil & Paraguay		1					1
Brazil	1						1
Bulgaria			1				1
Canada	1	5	4	1			11
China		1					1
Finland		1					1
France		1					1
India	1		1				2
Liberia				1			1
New Zealand		1		1			2
Nigeria		1					1
Norway		5					5
Portugal		1					1
Russia	1						1
Slovenia		1					1
Spain			1				1
Uganda		1					1
United States	1	3	2	1		4	11
Total	6	25	13	4	1	7	56

4.3.2 Overall of collected decision-making good practice

(1) Decision Making and Drivers

Table 4.3.2-1 shows the compositional ratios of decision-making cases in each driver categorized according to the decision-making types presented in Table 4.1-1 and the drivers for decision making in Table 4.1-3. Also, the compositional ratios of decision-making cases in each driver are shown in Table 4.3.2-2. Reviewing the results, the following finding was obtained.

- ➢ The decisions were made mainly for refurbishment, renewal & expansion, overhaul & repair.
- ➢ The main drivers for decision making were aging, external factors and disaster.
- ➢ The main drivers for refurbishment were aging and external factors.
- ➢ The main driver for renewal & expansion was aging.
- ➢ The drivers for overhaul & repair were aging and disaster.
- ➢ The drivers for redevelopment were aging and external factors.
- ➢ The main cases of decision making by driver were as follows:
  - ✓ Renewal & expansion and refurbishment driven by aging
  - ✓ Refurbishment driven by external factors

Table 4.3.2-1: Compositional Ratios of Decisions Made and Their Drivers

Decisions made	Drivers					Totals
	Aging	Disaster	External factors	Asset optimization & Review of operation	Poor maintenance	
O&R	9.1%	8.1%	0.0%	0.0%	0.5%	17.8%
R&E	19.3%	0.5%	0.5%	1.5%	0.5%	22.3%
Refurbishment	17.8%	8.1%	14.7%	2.0%	0.5%	43.1%
Redevelopment	5.6%	0.5%	5.6%	0.0%	0.0%	11.7%
Abolition	1.0%	0.0%	0.5%	0.0%	0.0%	1.5%
Other	0.0%	0.0%	3.6%	0.0%	0.0%	3.6%
Totals	52.8%	17.3%	24.9%	3.6%	1.5%	100.0%

Of the above, compositional ratios of the details of decisions made driven by external factors is shown in Table 4.3.2-2. The characteristics of decisions made driven by external factors are as follows:

- The main decisions made driven by external factors were refurbishment, redevelopment, and "other."
- Of external factors, the main drivers are public works, third party damage prevention, turbid water countermeasure, and compliance.
- However, public works and turbid water countermeasure are unique to Japan, and it has to be kept in mind that they account for high ratios because the number of cases in Japan is large.
- The main drivers for refurbishment were third party damage prevention and turbid water countermeasure.
- The main drivers for redevelopment were public works.
- The drivers for "Other" were diverse including compliance, environmental correspondence, fishery protection and demand & supply correspondence.

Table 4.3.2-2: Compositional Ratios of Decisions Made Driven by External factors

External factors	Decisions made						Totals
	O&R	R&E	Refurbishment	Redevelopment	Abolition	Other	
Public works	0.0%	0.0%	6.1%	18.4%	0.0%	0.0%	24.5%
Environmental Correspondence	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%	2.0%
Fishery protection	0.0%	0.0%	2.0%	0.0%	0.0%	2.0%	4.1%
Third party damage prevention	0.0%	0.0%	20.4%	0.0%	2.0%	0.0%	22.4%
Demand & supply correspondence	0.0%	2.0%	0.0%	2.0%	0.0%	2.0%	6.1%
Turbid water countermeasure	0.0%	0.0%	16.3%	0.0%	0.0%	0.0%	16.3%
Design standard changes	0.0%	0.0%	6.1%	0.0%	0.0%	0.0%	6.1%
Compliance	0.0%	0.0%	8.2%	0.0%	0.0%	8.2%	16.3%
Civil unrest	0.0%	0.0%	0.0%	2.0%	0.0%	0.0%	2.0%
Totals	0.0%	2.0%	59.2%	22.4%	2.0%	14.3%	100.0%

(2) Risk Management in Decision Making

The compositional ratios of the details of risk management and the compositional ratios are as shown in Table 4.3.2-3. Reviewing the results, the following finding was obtained.

- Most of the risk management was implemented for avoidance and reduction.
- The main decisions made for risk avoidance were refurbishment, renewal & expansion, and redevelopment.
- The main decisions made for risk reduction were refurbishment and overhaul & repair.

Table 4.3.2-3: Details of Risk Management in Decision Making and Compositional Ratios

Decisions made	Risk management				Totals
	Avoidance	Reduction	Transfer	Tolerance	
O&R	3.6%	13.3%	1.0%	0.0%	17.9%
R&E	19.9%	1.5%	0.0%	0.0%	8.7%
Refurbishment	26.5%	16.8%	0.5%	0.0%	37.2%
Redevelopment	11.2%	0.5%	0.0%	0.0%	9.7%
Abolition	0.5%	0.0%	0.0%	1.0%	1.0%
Other	2.6%	1.0%	0.0%	0.0%	0.0%
Totals	**64.3%**	**33.2%**	**1.5%**	**1.0%**	**100.0%**

(3) Decision Making and Target Structures

The compositional ratios of the details of decisions made and the target structures are shown in Tables 4.3.2-4. Reviewing the results, the following finding was obtained.

- The main decisions made were refurbishment, renewal & expansion, overhaul & repair, and redevelopment.
- The targets of refurbishment were water passage, spillway and dam in many case.
- The main target of renewal & expansion was turbine generator.
- The targets of overhaul & repair were water passage, spillway and dam in many cases.
- The targets for redevelopment were water passage, turbine generator, powerhouse building, or all facilities.

Table 4.3.2-4: Details and Compositional Ratios of Decisions Made and Target Structures

Target structures	Decisions made						Totals
	O&R	R&E	Refurbishment	Redevelopment	Abolition	Other	
a. Dam	3.1%	0.0%	9.7%	0.0%	0.0%	0.0%	12.8%
b. Spillway	3.6%	0.0%	12.2%	0.0%	0.0%	0.0%	15.8%
c. Reservoir	1.0%	0.0%	4.1%	0.0%	0.0%	1.0%	6.1%
d. Water Passage	6.6%	0.0%	15.8%	0.0%	0.0%	1.0%	23.5%
e. T/G	0.5%	14.3%	0.0%	0.5%	0.0%	0.0%	15.3%
f. Electric facilities	0.0%	2.0%	0.5%	0.0%	0.0%	0.0%	2.6%
g. Dam & Water Passage	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	1.5%
h. Water Passage & T/G	0.0%	0.5%	0.0%	3.1%	0.0%	0.0%	3.6%
i. T/G & powerhouse building	0.5%	3.6%	1.0%	0.5%	0.0%	0.0%	5.6%
j. Water Passage & T/G & powerhouse building	0.5%	1.0%	0.0%	4.1%	0.0%	0.0%	5.6%
k. All facilities	0.5%	0.5%	0.0%	3.6%	1.5%	0.0%	6.1%
l. Other	0.0%	0.0%	0.0%	0.0%	0.0%	1.5%	1.5%
Totals	**17.9%**	**21.9%**	**43.4%**	**11.7%**	**1.5%**	**3.6%**	**100.0%**

4.4 Evaluation of Drivers by Decision Made and Key Point

4.4.1 Details of Decisions Made by Driver

The details of decisions made by driver, their compositional ratios, and, of those, the details of decisions made by driver of “External Factors” and their compositional ratios are as shown in Tables 4.3.2-1 and -2.

With regard to the decision making by driver, the following finding was obtained from the standpoint of driver analysis:

- The main drivers for decision making were aging, External factors, and disaster.
- The main decisions made driven by aging were renewal & expansion and refurbishment.

- The main decision made driven by External factors was refurbishment, but other decisions such as redevelopment and "other" were made, as well.
- The main decisions made driven by disaster were overhaul & repair and refurbishment.

Additionally, with regard to the details of decision making driven by External factors, the following finding was obtained from the standpoint of driver analysis:

- Of External factors, the main drivers were public works, third party damage prevention, turbid water countermeasure, and compliance.
  - ✓ However, public works and turbid water countermeasure are unique to Japan, and it has to be kept in mind that they account for high ratios because the number of cases in Japan is large.
- The main decision made driven by public works was redevelopment.
- The main decision made driven by third-party damage prevention was refurbishment.
- The main decision made driven by turbid water countermeasure was refurbishment.
- The main decisions made driven by compliance were refurbishment and "other."

4.4.2 Risk Management against Drivers

Compositional ratios of the details of risk management taken by driver are as shown in Tables 4.4.2-1. Reviewing the results, the following finding was obtained:

- The risk management was mainly implemented for avoidance and reduction.
- The decision-making drivers for risk avoidance were aging and External factors.
- The decision-making drivers for risk reduction were aging, External factors, and disaster.

Table 4.4.2-1: Compositional Ratios of Details of Risk Management against Drivers

Drivers	Risk management				Totals
	Avoidance	Reduction	Transfer	Tolerance	
Aging	38.3%	14.8%	0.0%	0.5%	53.6%
Disaster	7.7%	8.2%	1.5%	0.0%	17.3%
External factors	14.8%	9.2%	0.0%	0.5%	24.5%
Asset optimization & review of operation	2.6%	1.0%	0.0%	0.0%	3.6%
Poor maintenance	1.0%	0.0%	0.0%	0.0%	1.0%
Totals	64.3%	33.2%	1.5%	1.0%	100.0%

Along with the above, below are the risks of each target structure sorted out by driver and the countermeasures against them as outlined in Tables 4.4.2-2 to -6.

Table 4.4.2-2: Risks at Dams by Driver and Countermeasures

Drivers	Detail items	Phenomena	Possible risks	Countermeasures
Aging	Weir	Flowing out Higher repair cost	Damage to downstream Difficult management	Rubber roof weir, SR weir
	Scour gate	Malfunction	Sedimentation increase	Renewal
	Front apron	Wear / corrosion by mud and sand flow	Destruction	Installing anti-wear steel plate Self-filling concrete casting
	Facing membrane	Degradation, damage	Increased leakage, less power generation	Cutting and re-pavement
	Drain hole	Clogging	Dam body instability due to increased uplift	Re-boring
		Declining anchor strength	Fall	Renewing anchor
Disaster	Dam control room	Flowing out	Gate operation not possible	Gateless modification (removal of spillPassage)
External factors	Fishery protection	Fishes not able to go upstream due to dam	Reduced catch, species endangered	Installing catching boxes, lifting equipment
	Compliance	Non-compliance with regulations	License not renewed	Fishery transport system
Poor management	Measuring instruments	Overflow / collapse of dam due to malfunction of level meter	Damage to downstream	Enforcing stricter control of measuring instruments

Table 4.4.2-3: Risks at Spillway by Driver and Countermeasures

Drivers	Detail items	Phenomena	Possible risks	Countermeasures
Aging	Body	Staff not accessible Work inefficiency	Damage to downstream	Gateless modification
	Gate	Aging	Malfunctioning during floods, damage to downstream	Renewal, repair, removal (gateless modification)
Disaster	Connecting bridge	Needs for improvement earthquake resistance	Collapse	High damping bumper
External factors	Gate	Instructions from regulatory authorities	Damage to downstream, license revoked	Renewal

Table 4.4.2-4: Risks at Reservoir by Driver and Countermeasures

Drivers	Detail items	Phenomena	Possible risks	Countermeasures
Aging	Lining	Degradation, damage	Leakage	Lining renewal
External factors	Turbid water	Generation of turbid water	Complaints from local communities	Surface intake facility, pure water bypassing way, turbid water prevention screen
	Fishery protection	Level changes impacting rare species	Endangering rare species	Review of water level control
	Third party damage prevention	Reduction of water pressure against spillway gate	Damage to downstream by destroyed gate	Review of water level control

Table 4.4.2-5: Risks at Water Passage by Driver and Countermeasures

Drivers	Detail items	Phenomena	Possible risks	Countermeasures
Aging	Intake screen	Damage by vibration	Inflow of objects	Renewal
	Headrace	Degradation, damage	Reduced power generation due to leakage	Repair, lining conduit
	Penstock	Thinning	Reduced power generation due to leakage	Coating of carbon fiber
	Scour Passage	Wear / scouring	Damage, destruction	Installing anti-wear steel plate
Disaster	Intake	Buried by flood mud	Unable to generate power	Refurbishment by Tyrolian type or culvert type
	Outlet			Transfer
External factors	Spillway	Discharge	Third party damage	Energy dissipater
	Head tank	Lake regeneration needs after abolition	Criticism from society	Landscape improvement, restoration of functions
	Intake screen	Reduction of fishes going upstream	License not renewed	Installing special screen
	Sluice	Increased level changes due to peak operation	Collapse of dike	Review of generation operation
Asset optimization & review of operation	Intake	Inflow of debris, removal by human staff	Inflow of objects, inefficiency of work	Automatic dust remover

Table 4.4.2-6: Risks at Plant, Turbine Generator, Peripheral Electric Facilities by Driver and Countermeasures

Structures	Drivers	Detail items	Phenomena	Possible risks	Countermeasures
Plant	Aging			Aging of each facility	Overhaul & repair, refurbishment, redevelopment
			Effective utilization after abolition	Turning to ruins	Museum
	External factors	Peak response		Loss of profit	Renewal, runner replacement
Turbine generator	Aging		Leak, wear, cracks	Destruction, unable to generate power	Overhaul & repair, renewal & expansion , redevelopment
	Asset optimization & review of operation		Needs for operation efficiency		Centralization of monitor control / protection
	Poor maintenance		Spare parts not available due to production end	Unable to generate power	Renewal
			Damage by vibration	Unable to generate power	Overhaul & repair
Peripheral electric facilities	Aging				Digital renewal
		Transformer	Oil leak	Environmental degradation	Renewal
		Governor	Oil leak	Flow into rivers	Air pressure type
Other	External factors	Compliance	Fishery protection	License not renewed	Installing hatchery, setting periods of no power generation

4.4.3 Drivers and Decision-Making Target Structures

Compositional ratios of the details of decision-making drivers and their target structures are as shown in Tables 4.4.3-1.

Reviewing the results, the following finding was obtained.

- The decision-making drivers are aging, External factors and disaster.
- The main targets of decision making driven by aging were turbine generator, water passage, dam and spillway.
- The main targets of decision making driven by External factors were water passage, reservoir and all facilities.
- The main targets of decision making driven by disaster were water passage, dam and spillway.

Table 4.4.3-1: Compositional Ratios of Details of Decision-Making Factors and Target Structures

Target structures	Decision making drivers					Totals
	Aging	Disaster	External factors	Asset optimization & Review of operation	Poor maintenance	
a. Dam	8.1%	3.0%	1.0%	0.0%	0.5%	12.7%
b. Spillway	8.1%	3.6%	2.5%	1.5%	0.0%	15.7%
c. Reservoir	1.0%	0.0%	5.1%	0.0%	0.0%	6.1%
d. Water Passage	8.6%	7.1%	7.1%	0.5%	0.0%	23.4%
e. T/G	14.2%	0.0%	0.5%	0.5%	0.5%	15.7%
f. Electric facilities	2.0%	0.0%	0.0%	0.5%	0.0%	2.5%
g. Dam & Water Passage	0.0%	1.5%	0.0%	0.0%	0.0%	1.5%
h. Water Passage & T/G	2.0%	0.0%	1.5%	0.0%	0.0%	3.6%
i. T/G & powerhouse building	2.5%	0.5%	1.5%	0.5%	0.5%	5.6%
j. Water Passage & T/G & powerhouse building	4.1%	1.0%	0.5%	0.0%	0.0%	5.6%
k. All facilities	2.0%	0.5%	3.6%	0.0%	0.0%	6.1%
l. Other	0.0%	0.0%	1.5%	0.0%	0.0%	1.5%
Totals	52.8%	17.3%	24.9%	3.6%	1.5%	100.0%

4.5 Decision-Making Status in Hydropower Advanced Countries

4.5.1 Comparisons of Collected Good Practice Cases

Among countries in Table 4.3.1-1, Australia, Canada and the USA are chosen as examples of Hydropower Advanced Countries with Japan. In this section, Decision-Making Status between these countries are compared.

(1) Decision Making and Drivers

Table 4.5.1-1 to -4 show the details of decisions made by driver and the compositional ratios of the cases of Japan, Australia, Canada, and the United States. Colored cells are used for characteristic findings of each of the countries.

Table 4.5.1-1: Compositional Ratios of Details of Decision Making and Drivers (Japan)

Decisions made	Drivers					Totals
	Aging	Disaster	External factors	Asset optimization & Review of operation	Poor maintenance	
O&R	10.7%	10.0%	0.0%	0.0%		20.7%
R&E	10.7%	0.7%	0.0%	0.7%		12.1%
Refurbishment	21.4%	10.7%	17.1%	2.9%		52.1%
Redevelopment	6.4%	0.7%	6.4%	0.0%		13.6%
Abolition	0.7%	0.0%	0.7%	0.0%		1.4%
Other						
Totals	**50.0%**	**22.1%**	**24.3%**	**3.6%**		**100.0%**

Table 4.5.1-2: Compositional Ratios of Details of Decision Making and Drivers (Australia)

Decisions made	Drivers					Totals
	Aging	Disaster	External factors	Asset optimization & Review of operation	Poor maintenance	
O&R	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
R&E	27.3%	0.0%	0.0%	0.0%	0.0%	27.3%
Refurbishment	27.3%	0.0%	9.1%	0.0%	0.0%	36.4%
Redevelopment	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Abolition	9.1%	0.0%	0.0%	0.0%	0.0%	9.1%
Other	0.0%	0.0%	27.3%	0.0%	0.0%	27.3%
Totals	63.6%	0.0%	36.4%	0.0%	0.0%	100.0%

Table 4.5.1-3: Compositional Ratios of Details of Decision Making and Drivers (Canada)

Decisions made	Drivers					Totals
	Aging	Disaster	External factors	Asset optimization & Review of operation	Poor maintenance	
O&R	9.1%	0.0%	0.0%	0.0%	0.0%	9.1%
R&E	45.5%	0.0%	0.0%	0.0%	0.0%	45.5%
Refurbishment	9.1%	0.0%	27.3%	0.0%	0.0%	36.4%
Redevelopment	0.0%	0.0%	9.1%	0.0%	0.0%	9.1%
Abolition	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Other	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Totals	63.6%	0.0%	36.4%	0.0%	0.0%	100.0%

Table 4.5.1-4: Compositional Ratios of Details of Decision Making and Drivers (the United States)

Decisions made	Drivers					Totals
	Aging	Disaster	External factors	Asset optimization & Review of operation	Poor maintenance	
O&R	0.0%	9.1%	0.0%	0.0%	0.0%	9.1%
R&E	27.3%	0.0%	0.0%	0.0%	0.0%	27.3%
Refurbishment	0.0%	0.0%	9.1%	0.0%	9.1%	18.2%
Redevelopment	9.1%	0.0%	0.0%	0.0%	0.0%	9.1%
Abolition	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Other	0.0%	0.0%	36.4%	0.0%	0.0%	36.4%
Totals	36.4%	9.1%	45.5%	0.0%	9.1%	100.0%

(2) Decision Making Driven by External Factors

Tables 4.5.1-5 to -8 show the details of decisions made driven by external factors and the compositional ratios of the cases of Japan, Australia, Canada, and the United States. Colored cells are used for characteristic findings of each of the countries

Table 4.5.1-5: Compositional Ratios of Decisions Driven by External factors (Japan)

External factors	Decisions made						Totals
	O&R	R&E	Refurbishment	Redevelopment	Abolition	Other	
Public works	0.0%	0.0%	8.8%	26.5%	0.0%	0.0%	35.3%
Environmental correspondence	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Fishery protection	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Third party damage prevention	0.0%	0.0%	26.5%	0.0%	2.9%	0.0%	29.4%
Demand & supply correspondence	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Turbid water countermeasure	0.0%	0.0%	23.5%	0.0%	0.0%	0.0%	23.5%
Design standard changes	0.0%	0.0%	8.8%	0.0%	0.0%	0.0%	8.8%
Compliance	0.0%	0.0%	2.9%	0.0%	0.0%	0.0%	2.9%
Civil unrest	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Totals	**0.0%**	**0.0%**	**70.6%**	**26.5%**	**2.9%**	**0.0%**	**100.0%**

Table 4.5.1-6: Compositional Ratios of Decisions Driven by External factors (Australia)

External factors	Decisions made						Totals
	O&R	R&E	Refurbishment	Redevelopment	Abolition	Other	
Public works	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Environmental correspondence	0.0%	0.0%	0.0%	0.0%	0.0%	25.0%	25.0%
Fishery protection	0.0%	0.0%	25.0%	0.0%	0.0%	25.0%	50.0%
Third party damage prevention	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Demand & supply correspondence	0.0%	0.0%	0.0%	0.0%	0.0%	25.0%	25.0%
Turbid water countermeasure	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Design standard changes	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Compliance	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Civil unrest	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Totals	0.0%	0.0%	25.0%	0.0%	0.0%	75.0%	100.0%

Table 4.5.1-7: Compositional Ratios of Decisions Driven by External factors (Canada)

External factors	Decisions made						Totals
	O&R	R&E	Refurbishment	Redevelopment	Abolition	Other	
Public works	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Environmental correspondence	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Fishery protection	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Third party damage prevention	0.0%	0.0%	25.0%	0.0%	0.0%	0.0%	25.0%
Demand & supply correspondence	0.0%	0.0%	0.0%	25.0%	0.0%	0.0%	25.0%
Turbid water countermeasure	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Design standard changes	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Compliance	0.0%	0.0%	50.0%	0.0%	0.0%	0.0%	50.0%
Civil unrest	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Totals	0.0%	0.0%	75.0%	25.0%	0.0%	0.0%	100.0%

Table 4.5.1-8: Compositional Ratios of Decisions Driven by External factors (the United States)

External factors	Decisions made						Totals
	O&R	R&E	Refurbishment	Redevelopment	Abolition	Other	
Public works	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Environmental correspondence	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Fishery protection	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Third party damage prevention	0.0%	0.0%	0.0%	0.0%	0.0%	20.0%	20.0%
Demand & supply correspondence	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Turbid water countermeasure	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Design standard changes	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Compliance	0.0%	0.0%	20.0%	0.0%	0.0%	60.0%	80.0%
Civil unrest	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Totals	0.0%	0.0%	20.0%	0.0%	0.0%	80.0%	100.0%

(3) Decision Making and Targets

Table 4.5.1-9 to -12 show compositional ratios of the details the target structures of decision making of the cases of Japan, Australia, Canada, and the United States.

Table 4.5.1-9: Decision Making and Targets (Japan)

Target structures	Decisions made						Totals
	O&R	R&E	Refurbishment	Redevelopment	Abolition	Other	
a. Dam	3.6%	0.0%	10.0%	0.0%	0.0%	0.0%	13.6%
b. Spillway	4.3%	0.0%	15.0%	0.0%	0.0%	0.0%	19.3%
c. Reservoir	0.7%	0.0%	5.7%	0.0%	0.0%	0.0%	6.4%
d. Water Passage	9.3%	0.0%	19.3%	0.0%	0.0%	0.0%	28.6%
e. T/G	0.0%	4.3%	0.0%	0.7%	0.0%	0.0%	5.0%
f. Electric facilities	0.0%	0.0%	0.7%	0.0%	0.0%	0.0%	0.7%
g. Dam & Water Passage	2.1%	0.0%	0.0%	0.0%	0.0%	0.0%	2.1%
h. Water Passage & T/G	0.0%	0.7%	0.0%	3.6%	0.0%	0.0%	4.3%
i. T/G & powerhouse building	0.0%	5.0%	1.4%	0.7%	0.0%	0.0%	7.1%
j. Water Passage & T/G & powerhouse building	0.0%	1.4%	0.0%	5.7%	0.0%	0.0%	7.1%
k. All facilities	0.7%	0.7%	0.0%	2.9%	1.4%	0.0%	5.7%
l. Other	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Totals	**20.7%**	**12.1%**	**52.1%**	**13.6%**	**1.4%**	**0.0%**	**100.0%**

Table 4.5.1-10: Decision Making and Targets (Australia)

Target structures	Decisions made						Totals
	O&R	R&E	Refurbishment	Redevelopment	Abolition	Other	
a. Dam	0.0%	0.0%	18.2%	0.0%	0.0%	0.0%	18.2%
b. Spillway	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
c. Reservoir	0.0%	0.0%	0.0%	0.0%	0.0%	9.1%	9.1%
d. Water Passage	0.0%	0.0%	18.2%	0.0%	0.0%	18.2%	36.4%
e. T/G	0.0%	18.2%	0.0%	0.0%	0.0%	0.0%	18.2%
f. Electric facilities	0.0%	9.1%	0.0%	0.0%	0.0%	0.0%	9.1%
g. Dam & Water Passage	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
h. Water Passage & T/G	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
i. T/G & powerhouse building	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
j. Water Passage & T/G & powerhouse building	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
k. All facilities	0.0%	0.0%	0.0%	0.0%	9.1%	0.0%	9.1%
l. Other	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Totals	**0.0%**	**27.3%**	**36.4%**	**0.0%**	**9.1%**	**27.3%**	**100.0%**

Table 4.5.1-11: Decision Making and Targets (Canada)

Target structures	Decisions made						Totals
	O&R	R&E	Refurbishment	Redevelopment	Abolition	Other	
a. Dam	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
b. Spillway	0.0%	0.0%	18.2%	0.0%	0.0%	0.0%	18.2%
c. Reservoir	9.1%	0.0%	0.0%	0.0%	0.0%	0.0%	9.1%
d. Water Passage	0.0%	0.0%	18.2%	0.0%	0.0%	0.0%	18.2%
e. T/G	0.0%	36.4%	0.0%	0.0%	0.0%	0.0%	36.4%
f. Electric facilities	0.0%	9.1%	0.0%	0.0%	0.0%	0.0%	9.1%
g. Dam & Water Passage	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
h. Water Passage & T/G	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
i. T/G & powerhouse building	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
j. Water Passage & T/G & powerhouse building	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
k. All facilities	0.0%	0.0%	0.0%	9.1%	0.0%	0.0%	9.1%
l. Other	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Totals	**9.1%**	**45.5%**	**36.4%**	**9.1%**	**0.0%**	**0.0%**	**100.0%**

Table 4.5.1-12: Decision Making and Targets (the United States)

Target structures	Decisions made						Totals
	O&R	R&E	Refurbishment	Redevelopment	Abolition	Other	
a. Dam	0.0%	0.0%	18.2%	0.0%	0.0%	0.0%	18.2%
b. Spillway	9.1%	0.0%	0.0%	0.0%	0.0%	0.0%	9.1%
c. Reservoir	0.0%	0.0%	0.0%	0.0%	0.0%	9.1%	9.1%
d. Water Passage	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
e. T/G	0.0%	27.3%	0.0%	0.0%	0.0%	0.0%	27.3%
f. Electric facilities	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
g. Dam & Water Passage	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
h. Water Passage & T/G	0.0%	0.0%	0.0%	9.1%	0.0%	0.0%	9.1%
i. T/G & powerhouse building	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
j. Water Passage & T/G & powerhouse building	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
k. All facilities	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
l. Other	0.0%	0.0%	0.0%	0.0%	0.0%	27.3%	27.3%
Totals	**9.1%**	**27.3%**	**18.2%**	**9.1%**	**0.0%**	**36.4%**	**100.0%**

(4) Decision Making Drivers and Targets

Table 4.5.1-13 to -16 show the details of the target structures by decision making driver and the compositional ratios of the cases of Japan, Australia, Canada, and the United States.

Table 4.5.1-13: Compositional Ratios of Decision-Making Drivers and Targets (Japan)

Target structures	Decision making drivers					Totals
	Aging	Disaster	External factors	Asset optimization & Review of operation	Poor maintenance	
a. Dam	9.3%	4.3%	0.0%	0.0%	0.0%	13.6%
b. Spillway	11.4%	3.6%	2.1%	2.1%	0.0%	19.3%
c. Reservoir	0.7%	0.0%	5.7%	0.0%	0.0%	6.4%
d. Water Passage	10.0%	10.0%	7.9%	0.7%	0.0%	28.6%
e. T/G	5.0%	0.0%	0.0%	0.0%	0.0%	5.0%
f. Electric facilities	0.7%	0.0%	0.0%	0.0%	0.0%	0.7%
g. Dam & Water Passage	0.0%	2.1%	0.0%	0.0%	0.0%	2.1%
h. Water Passage & T/G	2.1%	0.0%	2.1%	0.0%	0.0%	4.3%
i. T/G & powerhouse building	3.6%	0.7%	2.1%	0.7%	0.0%	7.1%
j. Water Passage & T/G & powerhouse building	5.7%	0.7%	0.7%	0.0%	0.0%	7.1%
k. All facilities	1.4%	0.7%	3.6%	0.0%	0.0%	5.7%
l. Other	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Totals	50.0%	22.1%	24.3%	3.6%	0.0%	100.0%

Table 4.5.1-14: Compositional Ratios of Decision-Making Drivers and Targets (Australia)

Target structures	Decision making drivers					Totals
	Aging	Disaster	External factors	Asset optimization & Review of operation	Poor maintenance	
a. Dam	9.1%	0.0%	9.1%	0.0%	0.0%	18.2%
b. Spillway	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
c. Reservoir	0.0%	0.0%	9.1%	0.0%	0.0%	9.1%
d. Water Passage	18.2%	0.0%	18.2%	0.0%	0.0%	36.4%
e. T/G	18.2%	0.0%	0.0%	0.0%	0.0%	18.2%
f. Electric facilities	9.1%	0.0%	0.0%	0.0%	0.0%	9.1%
g. Dam & Water Passage	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
h. Water Passage & T/G	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
i. T/G & powerhouse building	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
j. Water Passage & T/G & powerhouse building	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
k. All facilities	9.1%	0.0%	0.0%	0.0%	0.0%	9.1%
l. Other	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Totals	63.6%	0.0%	36.4%	0.0%	0.0%	100.0%

Table 4.5.1-15: Compositional Ratios of Decision-Making Drivers and Targets (Canada)

Target structures	Decision making drivers					Totals
	Aging	Disaster	External factors	Asset optimization & Review of operation	Poor maintenance	
a. Dam	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
b. Spillway	0.0%	0.0%	18.2%	0.0%	0.0%	18.2%
c. Reservoir	9.1%	0.0%	0.0%	0.0%	0.0%	9.1%
d. Water Passage	9.1%	0.0%	9.1%	0.0%	0.0%	18.2%
e. T/G	36.4%	0.0%	0.0%	0.0%	0.0%	36.4%
f. Electric facilities	9.1%	0.0%	0.0%	0.0%	0.0%	9.1%
g. Dam & Water Passage	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
h. Water Passage & T/G	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
i. T/G & powerhouse building	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
j. Water Passage & T/G & powerhouse building	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
k. All facilities	0.0%	0.0%	9.1%	0.0%	0.0%	9.1%
l. Other	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Totals	**63.6%**	**0.0%**	**36.4%**	**0.0%**	**0.0%**	**100.0%**

Table 4.5.1-16 Compositional Ratios of Decision-Making Drivers and Targets (the United States)

Target structures	Decision making drivers					Totals
	Aging	Disaster	External factors	Asset optimization & Review of operation	Poor maintenance	
a. Dam	0.0%	0.0%	9.1%	0.0%	9.1%	18.2%
b. Spillway	0.0%	9.1%	0.0%	0.0%	0.0%	9.1%
c. Reservoir	0.0%	0.0%	9.1%	0.0%	0.0%	9.1%
d. Water Passage	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
e. T/G	27.3%	0.0%	0.0%	0.0%	0.0%	27.3%
f. Electric facilities	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
g. Dam & Water Passage	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
h. Water Passage & T/G	9.1%	0.0%	0.0%	0.0%	0.0%	9.1%
i. T/G & powerhouse building	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
j. Water Passage & T/G & powerhouse building	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
k. All facilities	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
l. Other	0.0%	0.0%	27.3%	0.0%	0.0%	27.3%
Totals	**36.4%**	**9.1%**	**45.5%**	**0.0%**	**9.1%**	**100.0%**

4.5.2 Overall Assessment

In this Chapter, for Japan, Australia, Canada, and the United States from which a number of good practice cases of decision making were gathered, the good practices and their drivers in each country were sorted out, analyzed, and compared with one another.

The general assessment of each country based on the power business environment surrounding hydropower and the analysis of drivers for the collected decision-making cases is as follows:

(1) Japan

- The decision making driven by overhaul & repair and refurbishment due to frequent cases of flood disaster has been manifested. The target has been water passage in many cases. The frequent occurrences of flood disaster are supposedly related to the impact of climate change on a global scale.
- The public works undertaken by the river control bureaus are often dam redevelopment projects. The decision-making cases driven by redevelopment of power plants along with the said public works are unique to Japan.
- The generation of turbid water in the reservoirs due to floods, etc. is related to the geographical, geological, and meteorological conditions of Japan, and decisions have been made in correspondence to that. Such decisions have been made out of consideration to the local communities.

(2) Australia

- The drivers for decision making were of External factors, such as fishery protection, environmental correspondence, and demand & supply correspondence.
- All cases driven by fishery protection and environmental correspondence are associated with the environment, and therefore it is deemed the social demands are high for the hydropower regarding environmental considerations.
- The decisions for demand & supply correspondence are measures for performing peak demand operation during the time periods wherein the electricity price is higher, and this type of decision making was related to power market deregulation.
- In addition to general types of decision making for refurbishing plant related facilities, some decisions were made for the software aspect not requiring direct cost such as reviewing of operations of existing reservoirs or plants.

(3) Canada

- Decisions driven by External factors were out of consideration for third parties (local communities) in many cases.
- Aging driven decisions have been made such as renewal & expansion of turbine generators or overhaul & repair and refurbishment of dam, spillway, and water passage, as needed, designed to maintain and enhance the asset values of existing power plants.
- Decision making cases were quite orthodox in many cases.

(4) The United States

- Hydropower is under the river water management system and positioned as one of the diverse utilizations of water resources, so it is being treated equally to other water usages also because of the national trait of the United States, which therefore seems to require coordination with the involved stakeholders.
- The license acquisition (renewal) of hydropower is the top priority for hydro operators, so they need to meet the criteria of FERC which regulate the above water resource management including the

securement of fishery going upstream in the rivers. Therefore, the target of decision-making falls in the category of those other than the plant related facilities ("other").

- As new hydropower development cannot be expected, the enhancement of the existing values is necessary. Therefore, the emphasis is put on asset management.
- The decision making gives priority to compliance and optimization of existing assets.

(5) Overall Assessment

- The decision making for maintenance works has been driven mainly by aging and external factors.
- The targets of decision making driven by aging were primarily turbine generator, and dam, spillway and water passage, and such decisions were intended to maintain and enhance the value of existing assets.
- Although the details of External factors vary from country to country, what is common to all is the prevention of damage to third parties. Hydropower utilizes rivers, and rivers involve many stakeholders other than the hydropower generation sector. It seems that the public nature of hydropower prompts the idea that it should never cause damage to third parties.
- The policy for water resource utilization of the country (water resource management) largely influences the decision making of hydropower plant owners which use the water flowing in the rivers to generate power. This factor is responsible for the differences in the social drivers for decision

5. Decision-Making Process Flowcharts

For the collected good practice cases introduced in "4. Overview and Analysis of Decision-Making Cases," we sorted out the involved issues, decisions made and their purposes, and specific measures taken for each target structure and each driver, and thus we summarized those cases in decision-making process flowcharts.

Below, a decision-making process flowchart is provided for each of the cases in Japan and other countries. The number given at the end of each of the decisions made indicates the Index Number of Appendix-1 for the flowchart numbers starting with 5.1, which are also shown in "List of Good Practice (Japan)" at the end of this volume, as well as the Index Number of Appendix-2 for those starting with 5.2, which are also shown in "List of Good Practice (Other countries)". For the details of each case, please see the Appendix documents and reference documents indicated herein.

Legends of each figure is as follows;

- Box with Pink color: Driver of Decision-Making
- Box with Yellow color: Targeted Structure
- Box with Blue color: Phenomena regarded as "Problem" at the site
- Box with Green color: Problem to be solved
- Box with Orange color: Overview of Decision-Making
- Box with Blue outline with numbers: For "5.1", index number in Appendix-1 is shown to identify Decision-Making Good Practice. And for "5.2", index number in Appendix-2 is shown.

5.1 Japan

5.1.1. Dam

(1) Aging

Decisions made due to the aging of dam were refurbishment and overhaul & repair. The decision-making process flowchart of refurbishment is shown in Fig. 5.1.1-1.

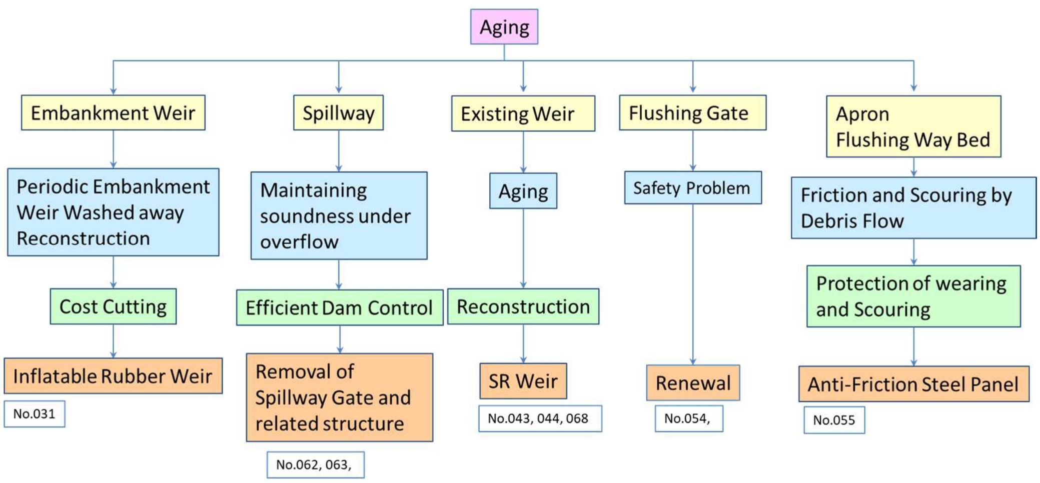


Fig. 5.1.1-1: Decision-Making Process Flowchart for "Refurbishment" for Aging of Dams

The decision-making process flowchart of overhaul & repair is shown in Fig. 5.1.1-2.

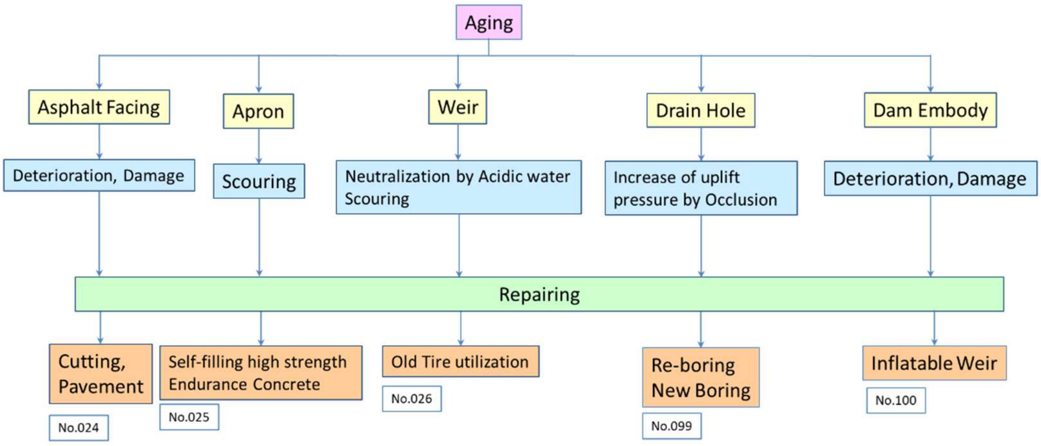


Fig. 5.1.1-2: Decision-Making Process Flowchart for “Overhaul & Repair” for Aging of Dams

(2) Disaster (Flood)

Decision made driven by disaster (flood) for dams was refurbishment only. The decision-making process flowchart for this case is shown in Fig. 5.1.1-3.

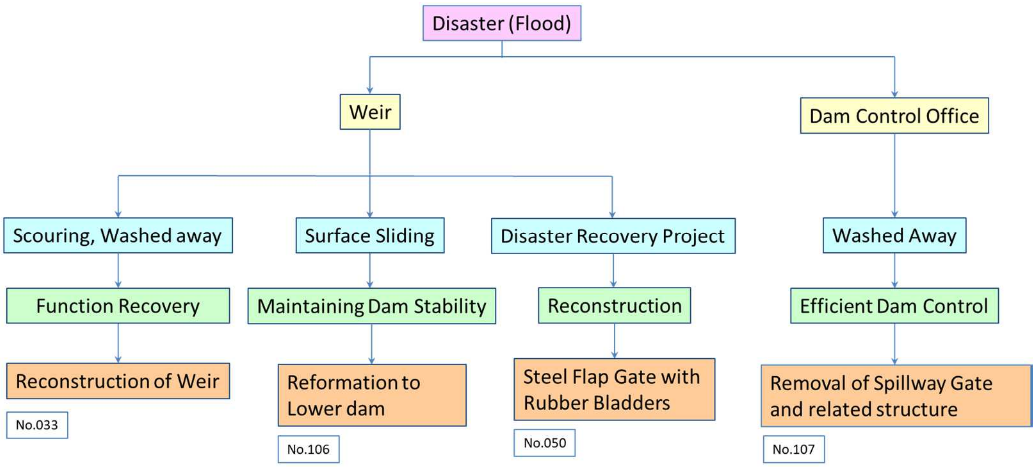


Fig. 5.1.1-3: Decision-Making Process Flowchart of “Refurbishment” for Aging of Dams

(3) Disaster (Earthquake)

Decisions made driven by disaster (earthquake) for dams were refurbishment and overhaul & repair.

The decision-making process flowchart for these cases is shown Fig. 5.1.1-4.

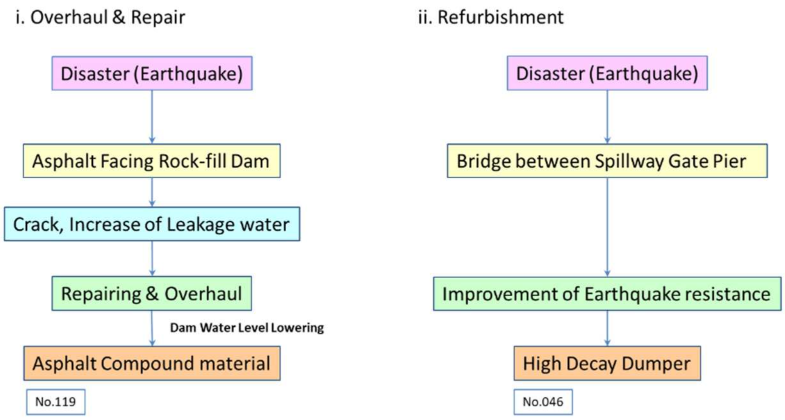


Fig. 5.1.1-4: Decision-Making Process Flowchart of “Overhaul & Repair” and “Refurbishment” of Dams

5.1.2 Spillway

(1) Aging

Decisions made driven by aging of spillway are refurbishment and overhaul & repair.

The decision-making process flowchart of refurbishment is shown in Figure 5.1.2-1.

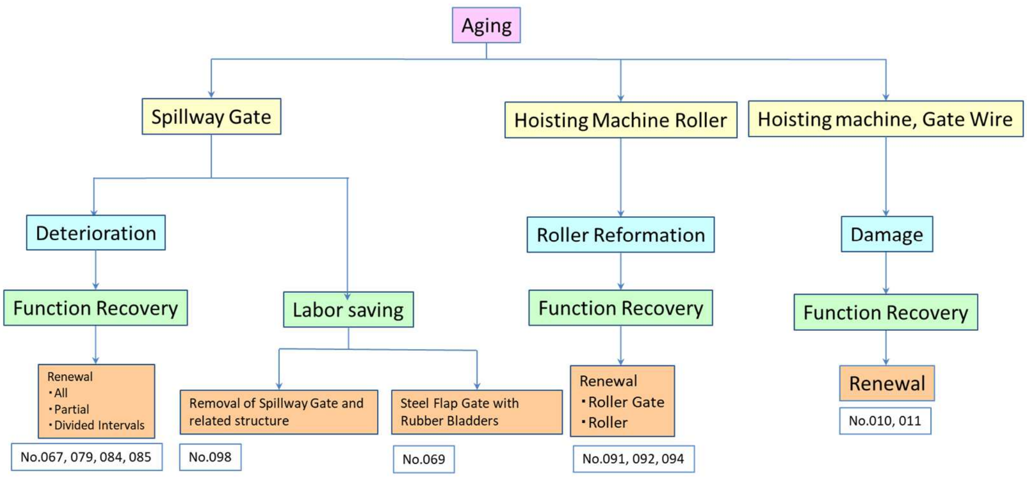


Fig. 5.1.2-1: Decision-Making Process Flowchart of “Refurbishment” for Aging of Spillways

The decision-making process flowchart of overhaul & repair is shown in Fig. 5.1.2-2.

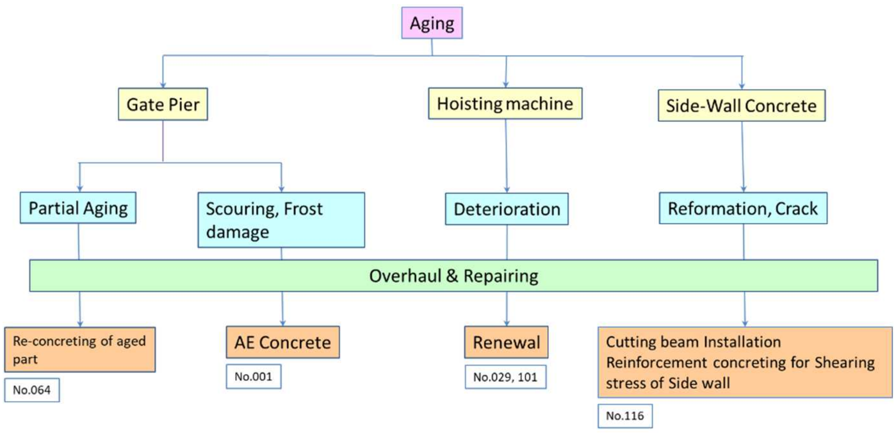


Fig. 5.1.2-2: Decision-Making Process Flowchart of “Overhaul & Repair” for Aging of Spillways

(2) Disaster

Decision made driven by disaster for spillways was refurbishment only, and the decision-making process flowchart for this case is shown in Fig. 5.1.2-3.

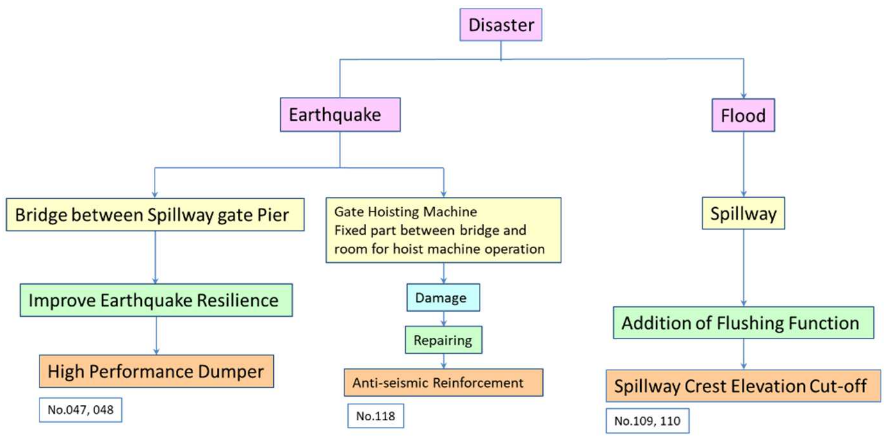


Fig. 5.1.2-3: Decision-Making Process Flowchart of “Refurbishment” Spillways against Disaster

(3) External factors

Decision made driven by external factors for spillway was refurbishment only, and the decision-making process flowchart for this case is shown in Fig. 5.1.2-4.

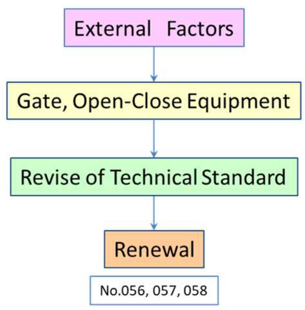


Fig. 5.1.2-4: Decision-Making Process Flowchart of “Refurbishment” of Spillways for External factors

(4) Asset Optimization & Review of Operation

Decision made driven by asset optimization & review of operation of spillway was refurbishment only, and the decision-making process flowchart for this case is shown in Fig. 5.1.2-5.

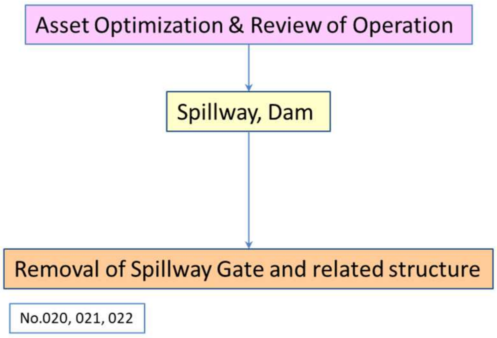


Fig. 5.1.2-5: Decision-Making Process Flowchart of “Refurbishment” of Spillways For Asset Optimization & Review of Operation

5.1.3 Reservoir

Decision made driven by external factors for reservoir was “refurbishment” only. The decision-making process flowchart for this case is shown in Fig. 5.1.3-1.

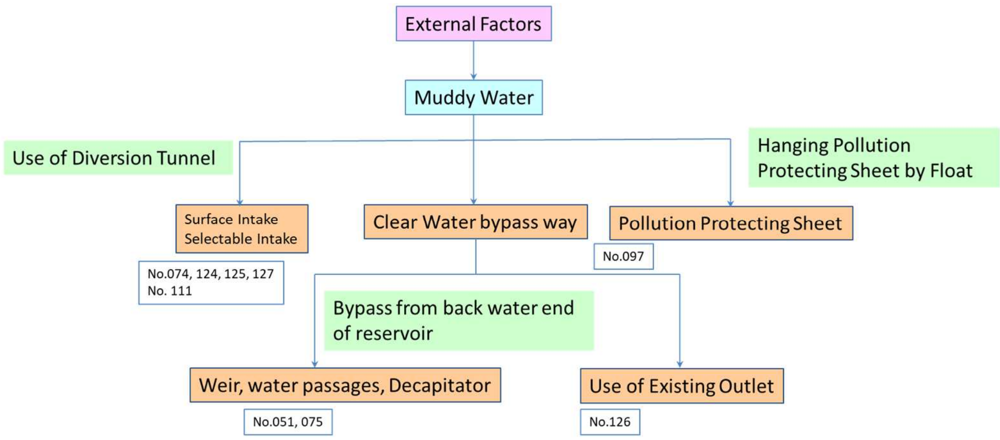


Fig. 5.1.3-1: Decision-Making Process Flowchart of “Refurbishment” of Reservoir for External factors

5.1.4 Water Passage

(1) Aging

Decisions made driven by aging of water passages were refurbishment and overhaul & repair.

The decision-making process flowchart of refurbishment is shown in Fig. 5.1.4-1.

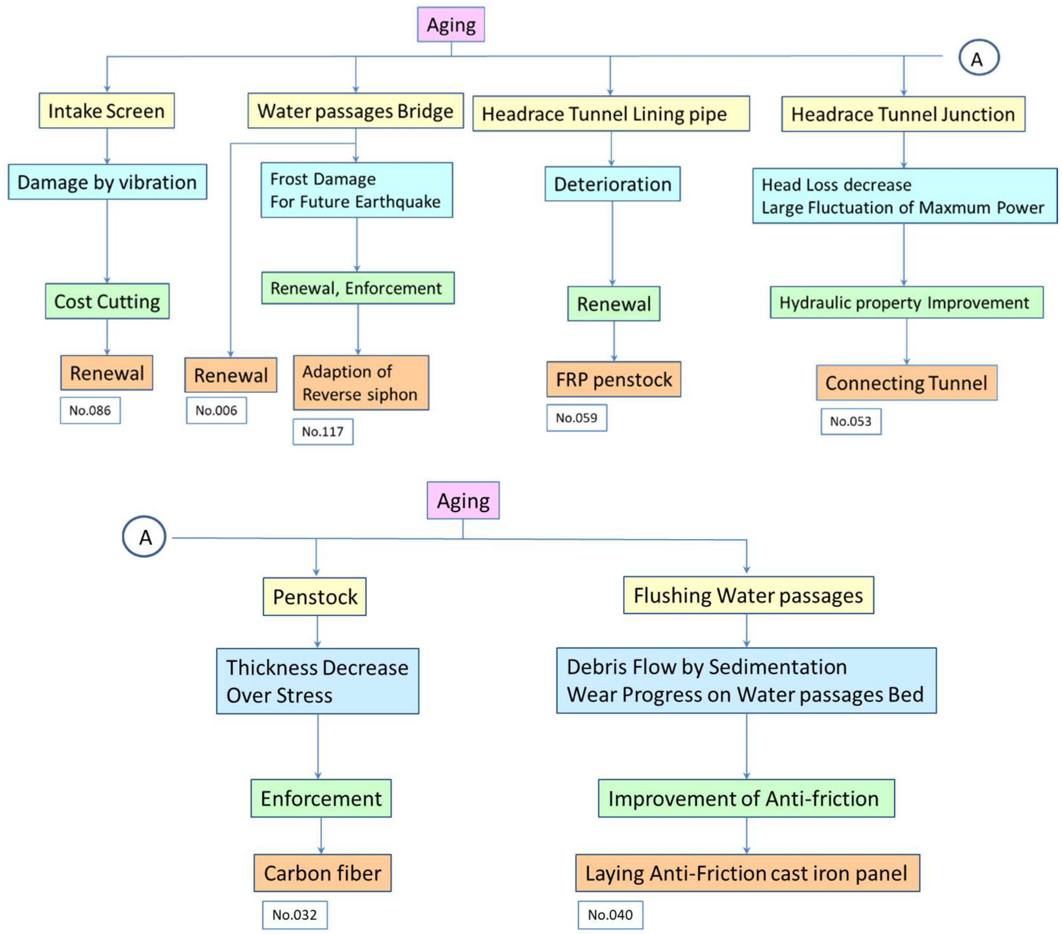


Fig. 5.1.4-1: Decision-Making Process Flowchart of “Refurbishment” for Aging of Water Passages

The decision-making process flowchart of overhaul & repair is shown in Fig. 5.1.4-2.

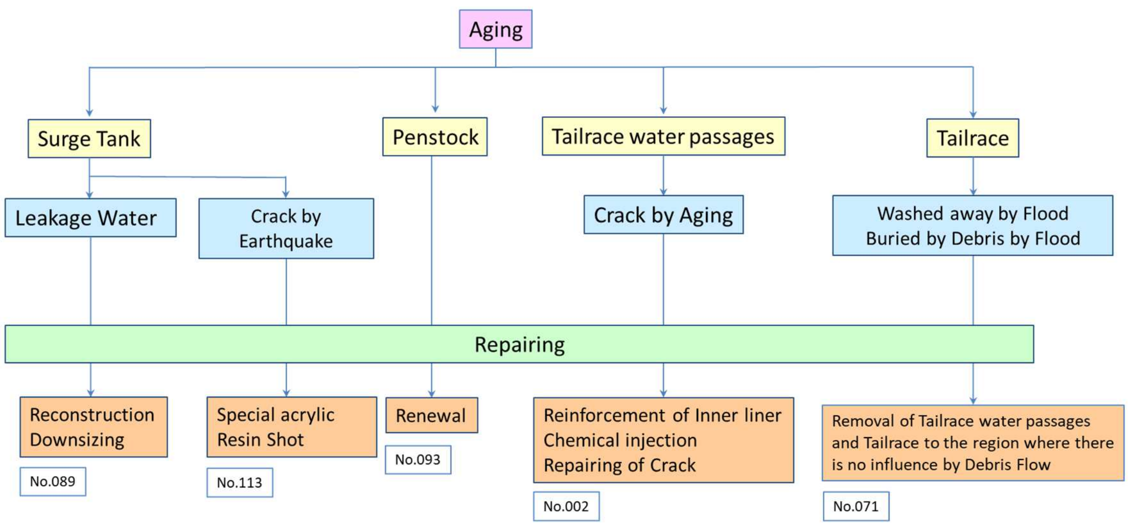


Fig. 5.1.4-2: Decision-Making Process Flowchart of “Overhaul & Repair” for Aging of Water Passages

(2) Disaster

Decisions made driven by disaster at water passages were refurbishment and overhaul & repair.

The decision-making process flowchart of "refurbishment" is shown in Fig. 5.1.4-3.

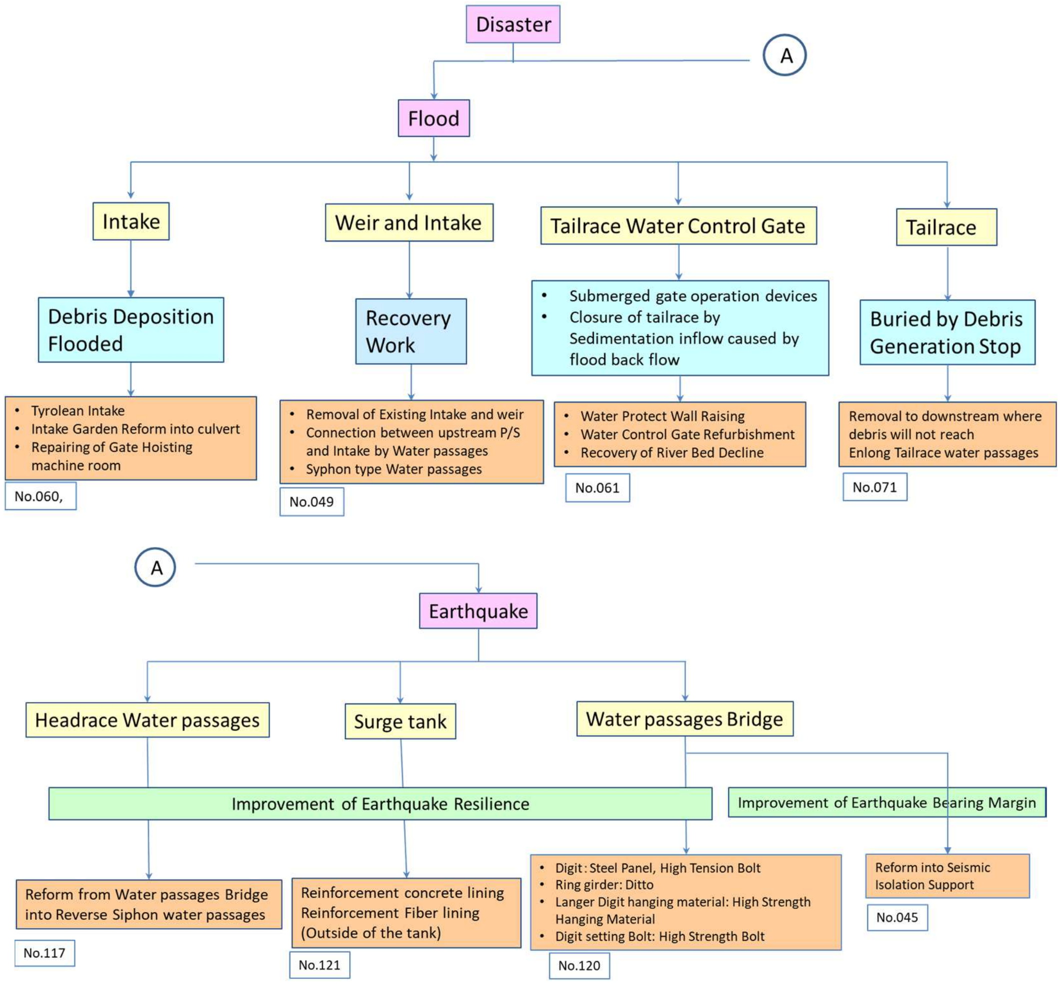


Fig. 5.1.4-3: Decision-Making Process Flowchart of "Refurbishment" for Disaster at Water Passages

The decision-making process flowchart of overhaul & repair is shown in Fig. 5.1.4-4.

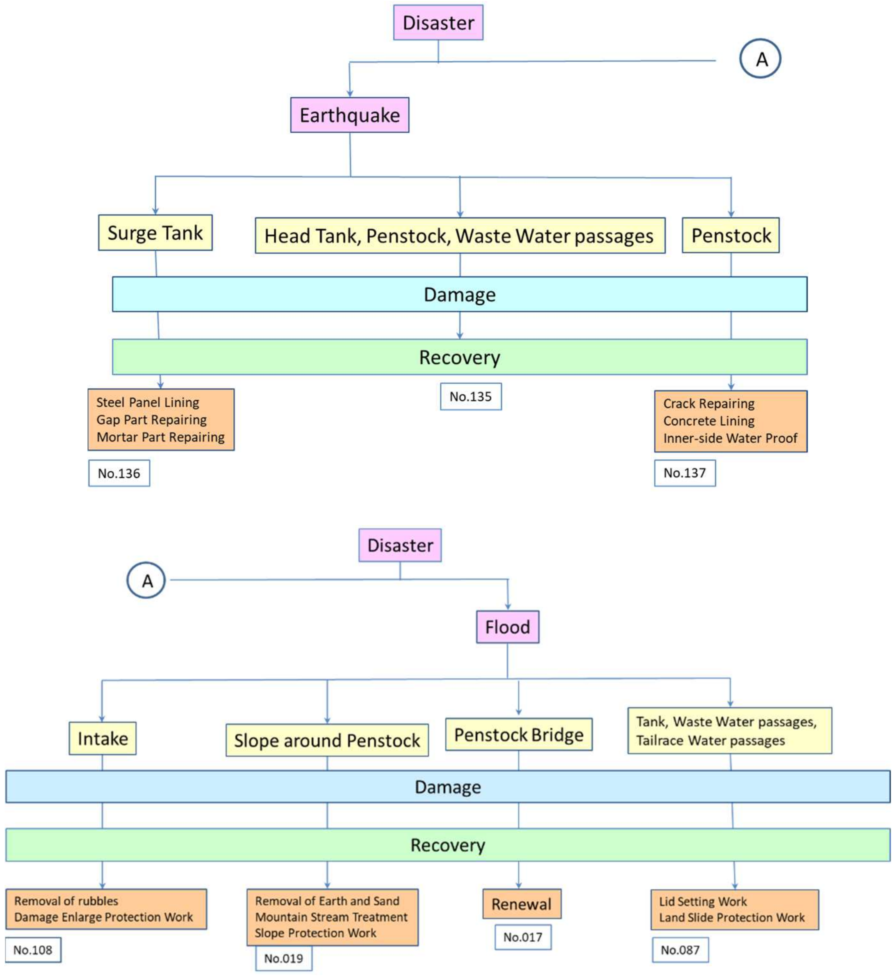


Fig. 5.1.4-4: Decision-Making Process Flowchart of “Overhaul & Repair” for Disaster at Water Passages

(3) External factors

Decision made driven by external factors for water passages was refurbishment only, and the decision-making process flowchart for this case is shown in Fig. 5.1.4-5.

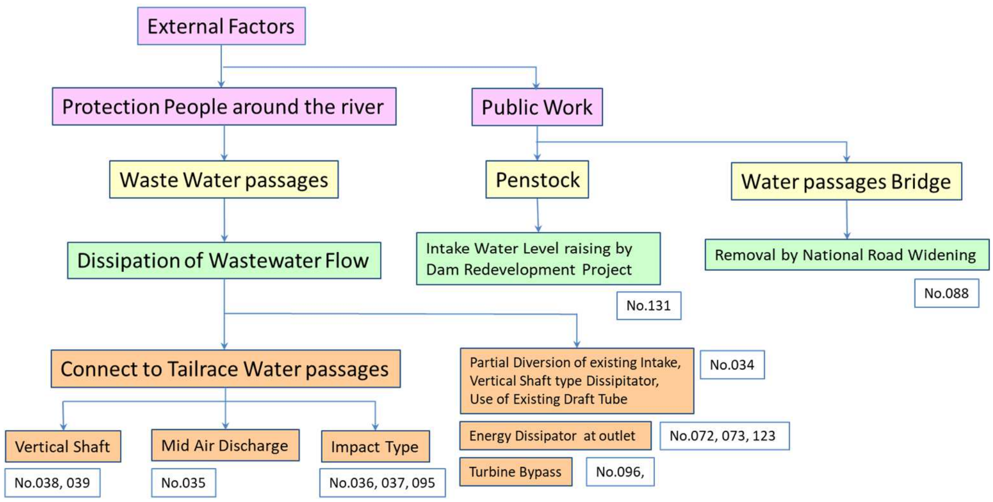


Fig. 5.1.4-5 Decision-Making Process Flowchart of “Refurbishment” of Water Passages for External factors

(4) Asset Optimization & Review of Operation

Decision made driven by asset optimization & review of operation of water passages was refurbishment only, and the decision-making process flowchart for this case is shown in Fig. 5.1.4-6.

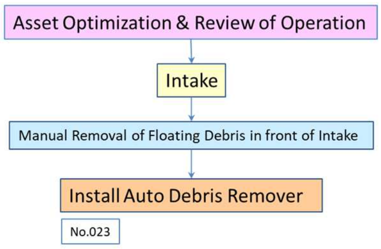


Fig. 5.1.4-6: Decision-Making Process Flowchart of “Refurbishment” of Water Passages for Asset Optimization & Review of Operation

5.1.5 Dam + Water Passage

Decision made for “dam + water passage” was driven only by disaster, and the decision was “overhaul & repair” only. The decision-making process flowchart for this case is shown in Fig. 5.1.5-1.

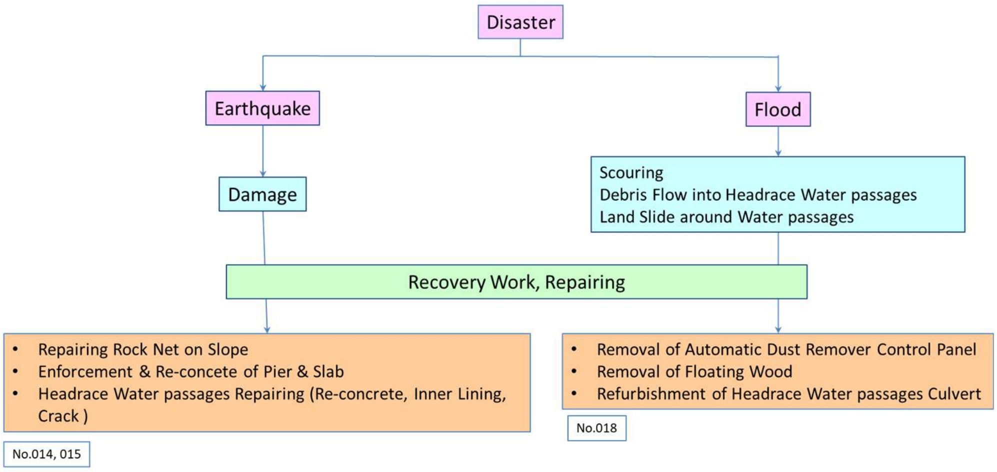


Fig. 5.1.5-1: Decision-Making Process Flowchart of “Overhaul & Repair” for Disaster at “Dam + Water Passage”

5.1.6 Power Plant

(1) Aging

The decision-making process flowchart for aging of power plant, etc. is shown in Fig. 5.1.6-1.

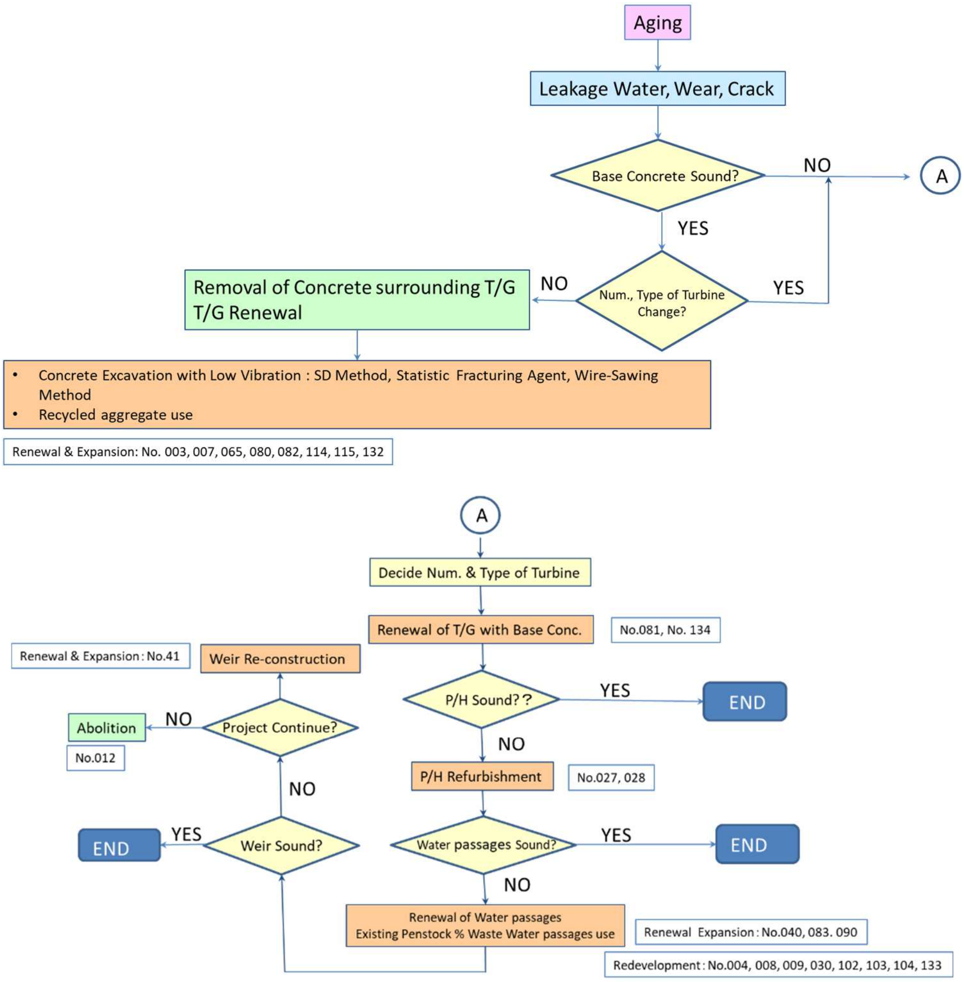


Fig. 5.1.6-1: Decision-Making Process Flowchart for Aging of Power Plant

(2) Disaster

Decision made driven by disaster at water passages was "overhaul & repair." The decision-making process flowchart for overhaul & repair is shown in Fig. 5.1.6-2.

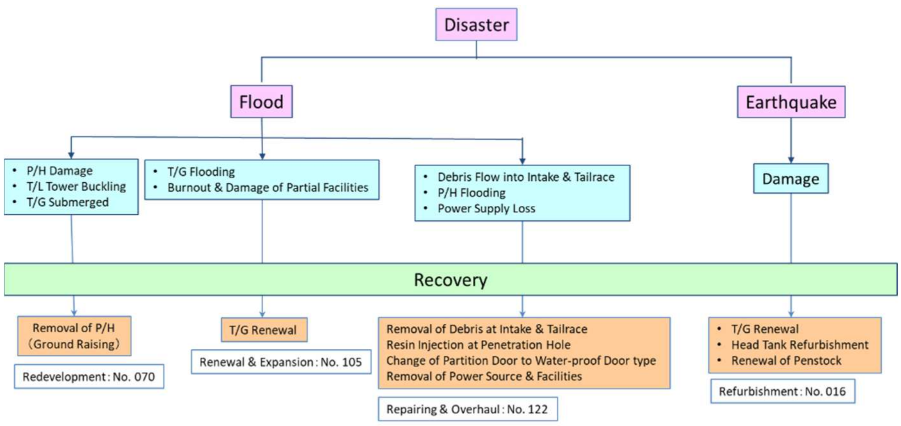


Fig. 5.1.6-2: Decision-Making Process Flowchart of "Overhaul & Repair" for Disaster at Power Plant

(3) External factors

The decision-making process flowchart for external factors regarding power plant, etc. is shown in Fig. 5.1.6-3.

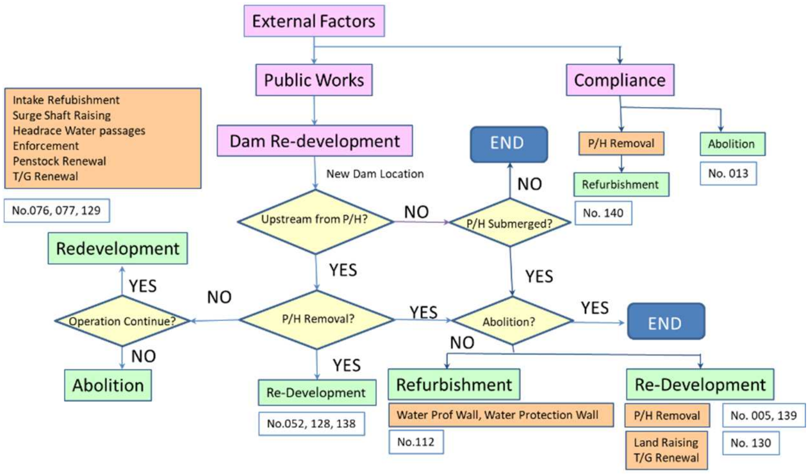


Fig. 5.1.6-3: Decision-Making Process Flowchart of External factors regarding Power Plant

(4) Asset Optimization & Review of Operation

Decision made driven by asset optimization & review of operation of water passages was renewal & expansion only, and the decision-making process flowchart for this case is shown in Fig. 5.1.6-4

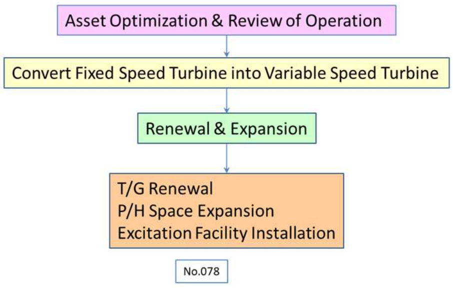


Fig. 5.1.6-4: Decision-Making Process Flowchart of Asset Optimization & Review of Operation for Power Plant

5.1.7 Peripheral electric facilities

(1) Aging

The decision-making process flowchart for aging of peripheral electric facilities is shown in Fig. 5.1.7-1.

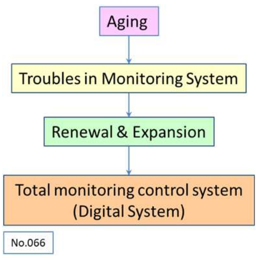


Fig. 5.1.7-1: Decision-Making Process Flowchart of Aging for Peripheral electric facilities

5.2 Other Countries

5.2.1 Dam

(1) Aging

The decision-making process flowchart for aging of dams is shown in Fig. 5.2.1-1.

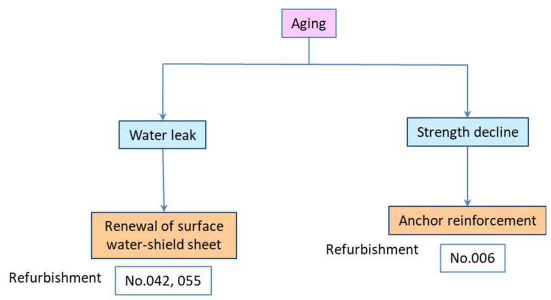


Fig. 5.2.1-1: Decision-Making Process Flowchart for Aging

(2) Poor Maintenance

The decision-making process flowchart for poor maintenance of dams is shown in Fig. 5.2.1-2.

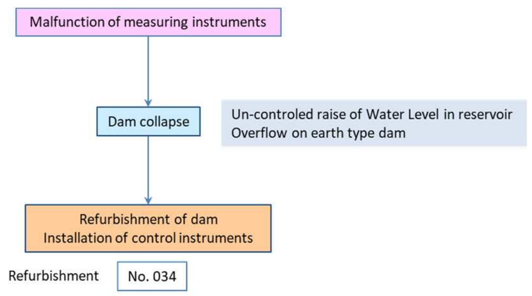


Fig. 5.2.1-2: Decision-Making Process Flowchart for Poor Maintenance

(3) External factors

The decision-making process flowchart for external factors regarding dams is shown in Fig. 5.2.1-3.

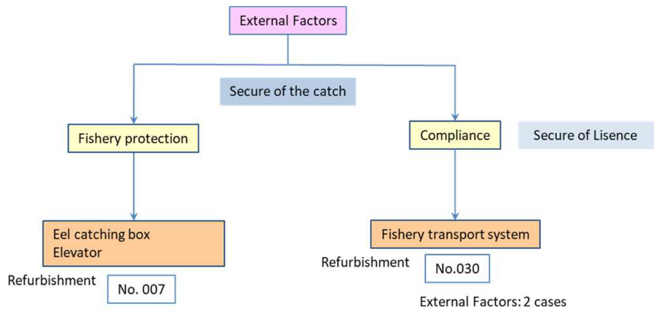


Fig. 5.2.1-3: Decision-Making Process Flowchart for External factors

5.2.2 Spillway

(1) Disaster

The decision-making process flowchart for disaster at spillway is shown in Fig. 5.2.2-1.

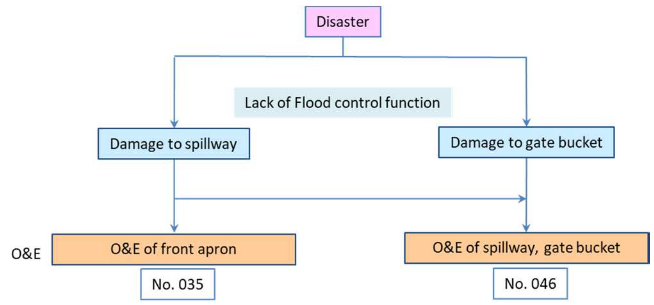


Fig. 5.2.2-1: Decision-Making Process Flowchart for Disaster

(2) External factors

The decision-making process flowchart for external factors regarding spillway is shown in Fig. 5.2.2-2.

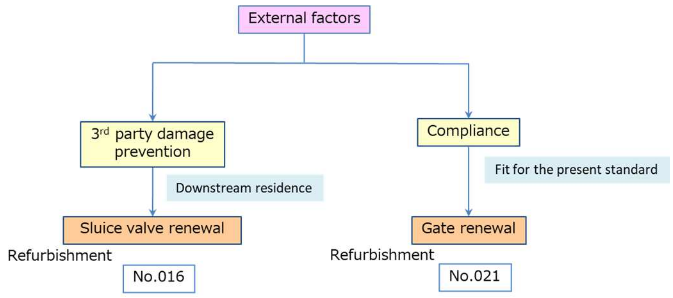


Fig. 5.2.2-2: Decision-Making Process Flowchart for External factors

5.2.3 Reservoir

(1) Aging

The decision-making process flowchart for aging of reservoirs is shown in Fig. 5.2.3-1.

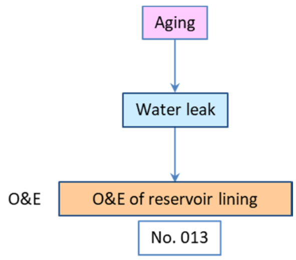


Fig. 5.2.3-1: Decision-Making Process Flowchart for Aging

(2) External factors

The decision-making process flowchart for aging of reservoirs is shown in Fig. 5.2.3-2.

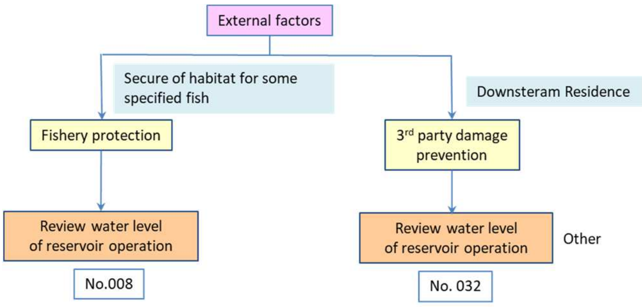


Fig. 5.2.3-2: Decision-Making Process Flowchart for External factors

5.2.4 Water Passage

(1) Aging

The decision-making process flowchart for aging of water passages is shown in Fig. 5.2.4-1.

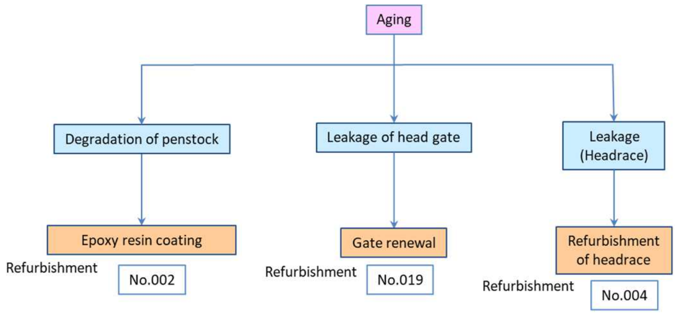


Fig. 5.2.4-1: Decision-Making Process Flowchart for Aging

(2) External factors

The decision-making process flowchart for external factors regarding water passages is shown in Fig. 5.2.4-2.

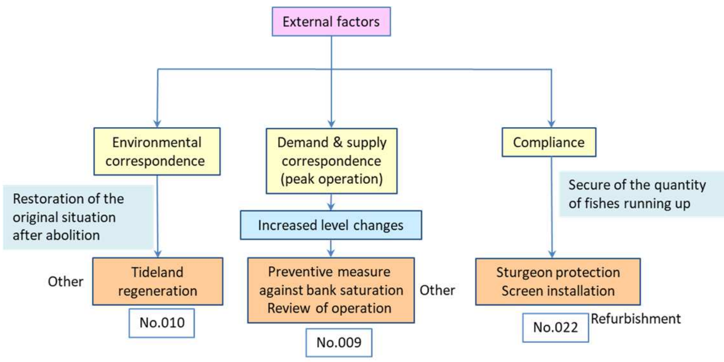


Fig. 5.2.4-2: Decision-Making Process Flowchart for External factors

5.2.5 Turbine Generator

(1) Aging

The decision-making process flowchart for aging of turbine generator is shown in Fig. 5.2.5-1.

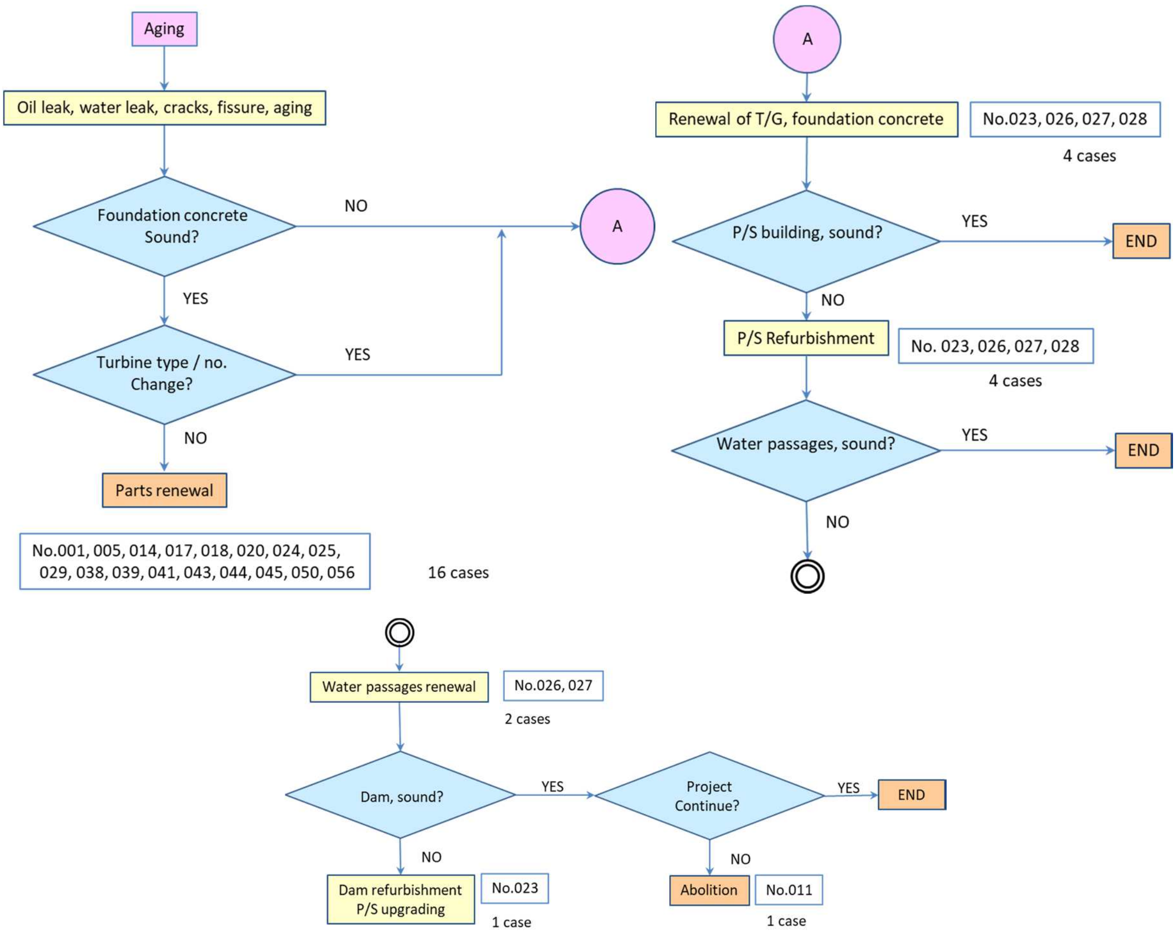


Fig. 5.2.5-1: Decision-Making Process Flowchart for Aging

(2) Poor Maintenance

The decision-making process flowchart for poor maintenance of turbine generator is shown in Fig. 5.2.5-2.

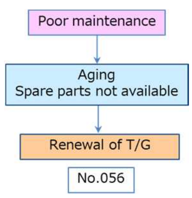


Fig. 5.2.5-2: Decision-Making Process Flowchart for Poor Maintenance

(3) External factors

The decision-making process flowchart for external factors regarding turbine generator is shown in Fig. 5.2.5-3.

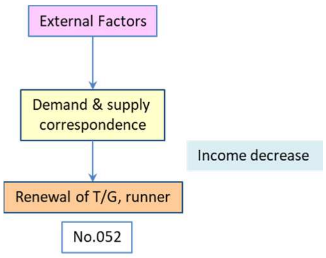


Fig. 5.2.5-3: Decision-Making Process Flowchart for External factors

(4) Asset Optimization & Review of Operation

The decision-making process flowchart for asset optimization & review of operation of turbine generator is shown in Fig. 5.2.5-4.

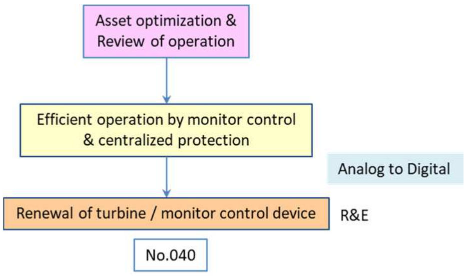


Fig. 5.2.5-4: Decision-Making Process Flowchart for Asset Optimization & Review of Operation

5.2.6 Peripheral Electric Facilities

(1) Aging

The decision-making process flowchart for aging of peripheral electric facilities is shown in Fig. 5.2.6-1.

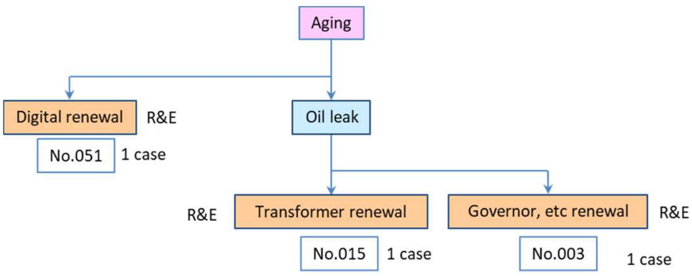


Fig. 5.2.6-1: Decision-Making Process Flowchart for Aging

(2) Asset Optimization & Review of Operation

The decision-making process flowchart for asset optimization & review of operation peripheral electric facilities is shown in Fig. 5.2.6-2.

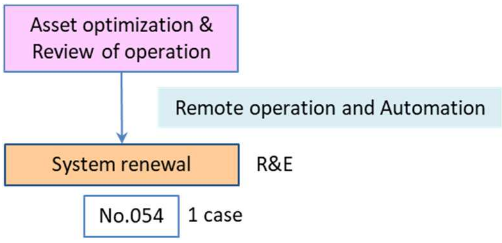


Fig. 5.2.6-2: Decision-Making Process Flowchart for Asset Optimization & Review of Operation

5.2.7 Water Passage + Turbine Generator

(1) Aging

The decision-making process flowchart for aging of water passage + turbine generator is shown in Fig. 5.2.7-1.

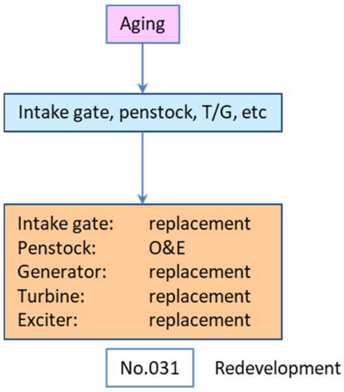


Fig. 5.2.7-1: Decision-Making Process Flowchart for Aging

5.2.8 Turbine Generator + Powerhouse Building

(1) Poor Maintenance

The decision-making process flowchart for poor maintenance of turbine generator + powerhouse building is shown in Fig. 5.2.8-1.

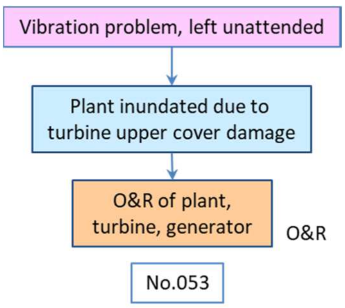


Fig. 5.2.8-1: Decision-Making Process Flowchart for Poor Maintenance

5.2.9 Water Passage + Turbine Generator + Powerhouse Building

(1) Disaster

The decision-making process flowchart for disaster at water passage + turbine generator + powerhouse building is shown in Fig. 5.2.9-1.

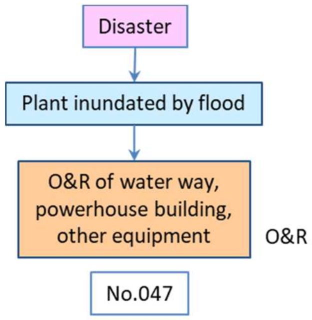


Fig. 5.2.9-1: Decision-Making Process Flowchart for Disaster

5.2.10 All Facilities

(1) Aging

The decision-making process flowchart for aging of all facilities is shown in Fig. 5.2.10-1.

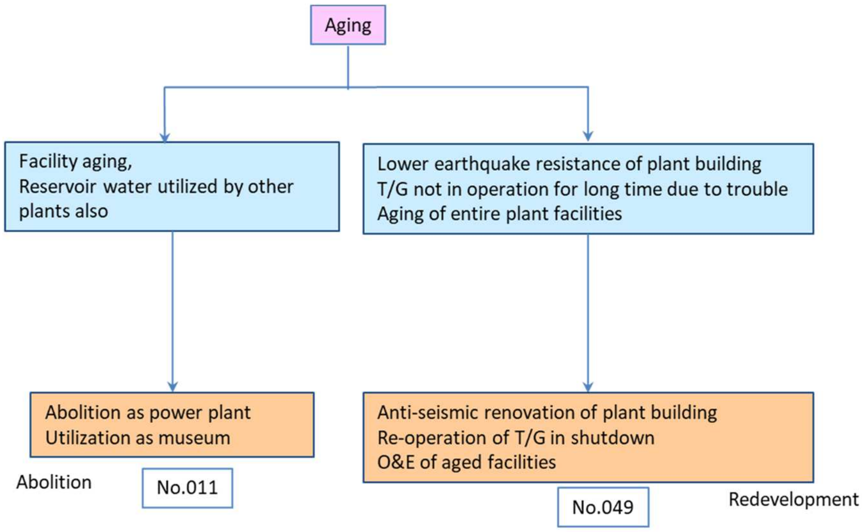


Fig. 5.2.10-1: Decision-Making Process Flowchart for Aging

(2) External factors

The decision-making process flowchart for external factors regarding all facilities is shown in Fig. 5.2.10-2.

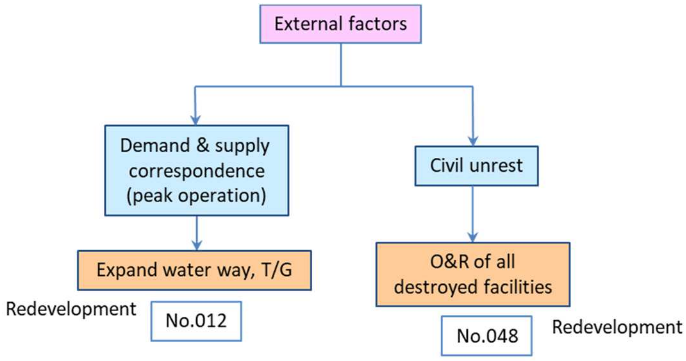


Fig. 5.2.10-2: Decision-Making Process Flowchart for External factors

5.2.11 Other

(1) External factors

The decision-making process flowchart for external factors regarding “other” is shown in Fig. 5.2.11-1.

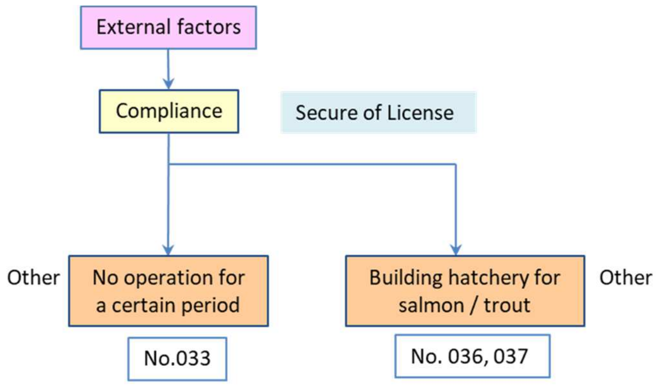


Fig. 5.2.11-1: Decision-Making Process Flowchart for External factors

6. Recommendations

Based on the information gathered in the course of this Annex on "Maintenance Works and Decision Making for Hydro Facilities" we present the following recommendations.

(1) Optimization of Maintenance Works and Decision Making

In the advanced hydropower counties, the Utilities owning hydropower plants are required to optimize their business management due to reduced opportunities for new hydropower development, power market deregulations, and requests from customers in the regulated market to keep the tariff at low levels. Prior to this, some hydropower plants were not necessarily maintained in an efficient manner after their commissioning (Hydro Tasmania, Trust Power) but under the changing circumstances mentioned above, efficient facility maintenance is now required to maintain and enhance the asset value of existing hydropower plants. At the same time, in facility-based industries other than the power industry, asset management has been increasingly introduced as an optimal maintenance management method for their infrastructure, and more and more Utilities are implementing asset management for their facilities with a view to the maintenance and enhancement of the asset value of their existing hydropower plants. (Reclamation Office Idaho, Tacoma Power, Fortis BC, Ontario Power Generation, Hydro Tasmania) Asset management has already been standardized as ISO55001, but only one Utility was certified ISO55001 in the United States in the asset management investigation we conducted (at the time of hearing), while other Utilities made ISO55001 certification as their goal for asset management. (Tacoma Power, New York Power Authority) This seems to indicate that the introduction of asset management certification has just begun in the hydropower sector, and by extension, the power industry.

Each Utility is required to strengthen their business foundation for the above-mentioned deregulations, power market liberalization, keeping the competitively reasonable prices against other energy sources, and so on, and thus it is indispensable to balance the technical and financial issues. Against this background, with regard to the establishment of optimized methods for maintenance and decision making, some Utilities try to use their own know-how (Reclamation Office Idaho, Hydro Tasmania, Ontario Power Generation), while other Utilities refer to the standardized methods outline in ISO55001 certification. (Tacoma Power, New York Power Authority, Fortis BC)

(2) Information Sharing

Due to certain internal circumstances, it is not always possible for the Utilities to disclose the information about their maintenance works and decision making for their hydropower plants. Even in such a situation, with the introduction of ISO55001 in mind, some Utilities across national borders provided their facility operation data and developed software by some organization. This software offers relevant information for maintenance and decision making for electric facilities (adopted by Reclamation Office Idaho, Tacoma Power). And it developed other software which works in conjunction with the previously mentioned software to perform financial analysis to calculate economic indices. These include the present value of total lifecycle cost (adopted by Reclamation Office Idaho, Tacoma Power, New York Power Authority). Other Utilities are provided templates of these software programs or maintenance manuals upon request (Fortis BC, New York Power Authority), or supported for the establishment of asset management know-how (eventually ISO55001 certification) by the organization.

The sharing of information on power plant maintenance among the Utilities is not progressing as desired due to certain internal circumstances of each Utility, but the Annex activities in this Report have observed a trend in information sharing whereby some of them are actively promoting it. In the advanced hydropower countries where opportunities for new hydropower development in their country are decreasing, many Utilities have sought to expand their business, come to own a number of hydropower assets in other counties, engaged in operation and maintenance these facilities, while the ISO55001-based standardization of asset management has been promoted. In such a situation, information sharing on such facility maintenance will be more and more important.

(3) Introduction of Latest Technologies

One Utility mentioned the information digitalization of their system as a driver for introducing asset management (Trust Power). Another Utility installed a system in not only hydropower but all power generating assets they own to check real-time the power generating status, bearing temperatures, vibrations, operation condition, etc. (Trust Power, New York Power Authority, Ontario Power Generation). Such advancements are a gift from DX (Digital transformation) and other technologies, and the introduction of these latest technologies will contribute to the optimization of asset maintenance and speedy decision making. One important factor for optimizing facility maintenance and decision making will be to keep tracing the trend of latest technologies in the future.

(4) Future Issues

The above proposals may be implemented inside the Utilities, while the correspondence to multiple stakeholders involved in the rivers is an important driver for decision making regarding hydropower facility maintenance. In the course of this Annex, we observed a number of cases wherein decisions were made driven by the correspondence to those multiple stakeholders, while the targets of such stakeholders to which the Utilities need to correspond were different from country to country.

Along with the introduction of asset management, the decision making implemented inside each Utility is more and more based on the assessment using numerical indices (Reclamation Office Idaho), but in the assessment, the cost for corresponding to the multiple stakeholders, as well as the numerical assessment of the benefits arising from that will be a vital issue.

In some countries, disaster is a driver for decision making for facility maintenance in a number of cases. Currently, such cases are not so many in continental counties, but the advancing climate change on a global scale is expected to increase the probabilities of disaster damage to the existing power plants in such counties also. Therefore, improvement in resilience and technical correspondence to it will be another important issue as part of the asset enhancement of the existing power plants.

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