The battery system for mitigate the VRE output fluctuation

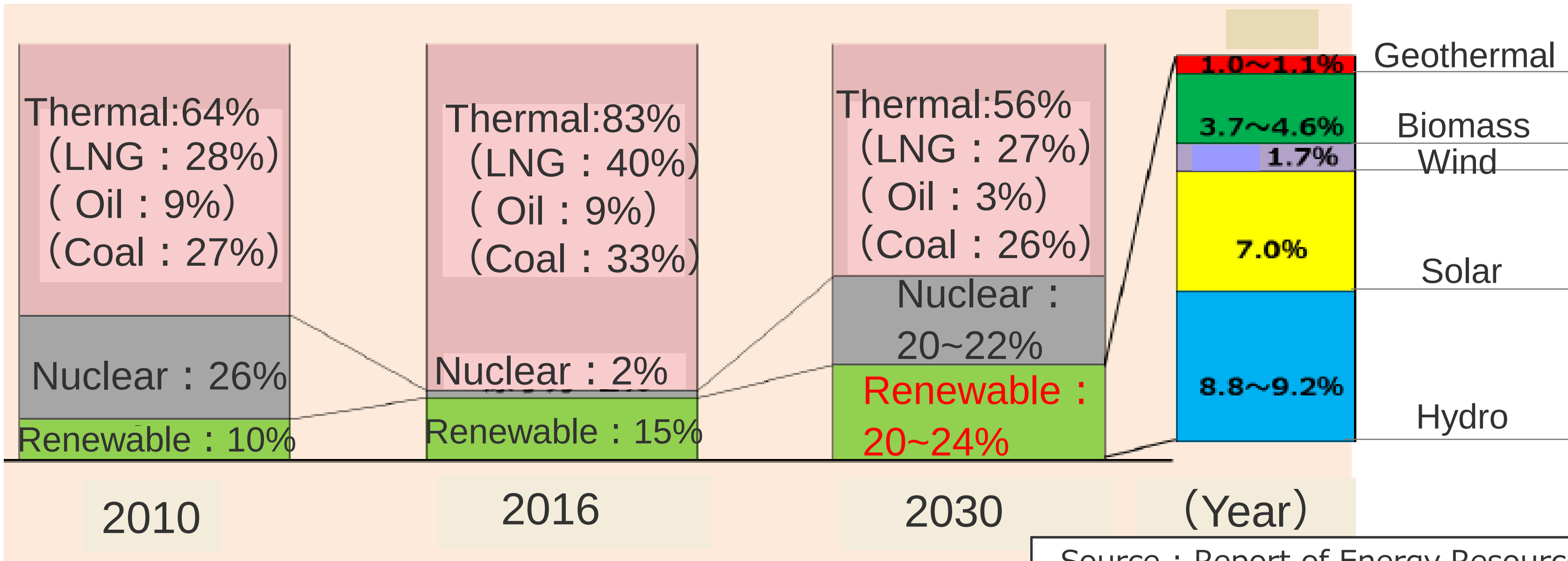
(Demonstration test with island as field of power system)

July 1, 2020

Chubu Electric Power Co., Inc.
Nippon Koei Co., Ltd.

2030 year energy plan in Japan

In Japan, we are aiming to realize an "energy mix" toward the SDGs achievement in 2030.



Source : Report of Energy Resource Agency

In order to stably use the electric power obtained from wind power generation, etc., it is necessary to establish the operation technology of the electric power system.

For that purpose, establishment of energy storage technology is important.

Object of verification test
(Demonstration of island power system in the field)

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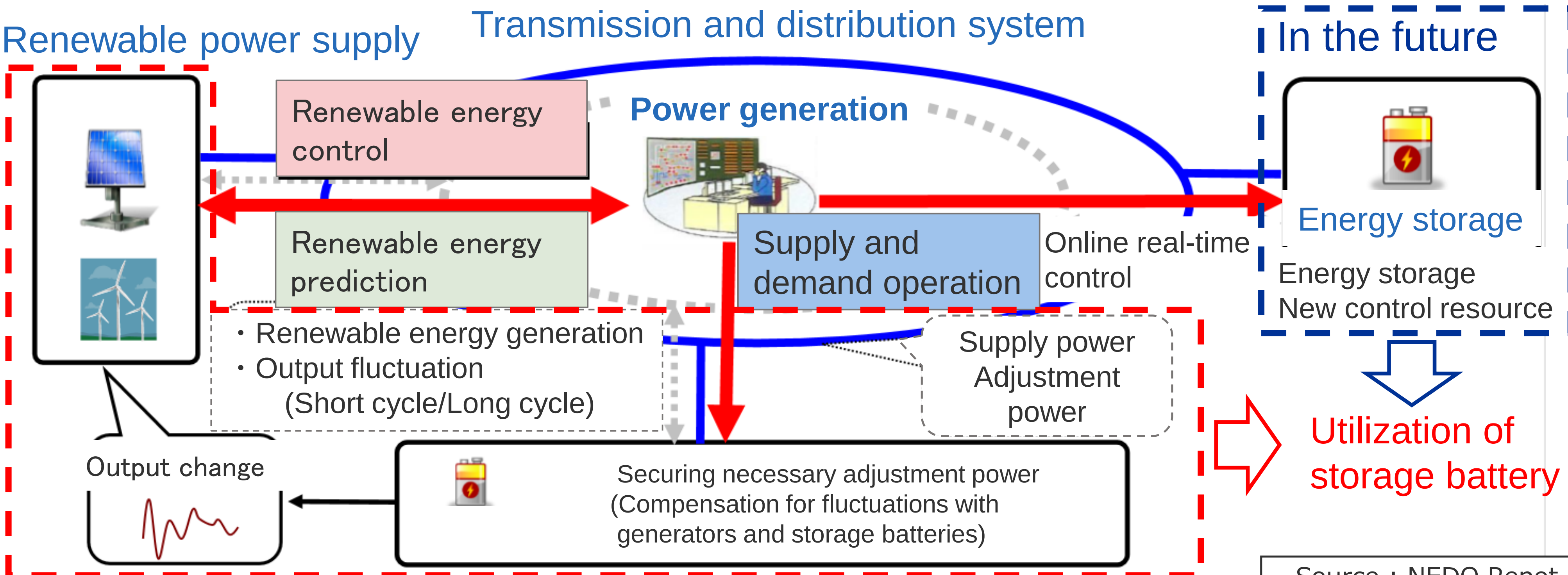
In Japan, demonstration test on a remote island simulating the energy mix of 2030

Output prediction and output control/suppression of wind power and solar power generation, coordinated operation control with existing power sources and energy storage such as storage batteries.

➡Construction of a grid system capable of maximally accepting renewable energy by utilizing energy storage.

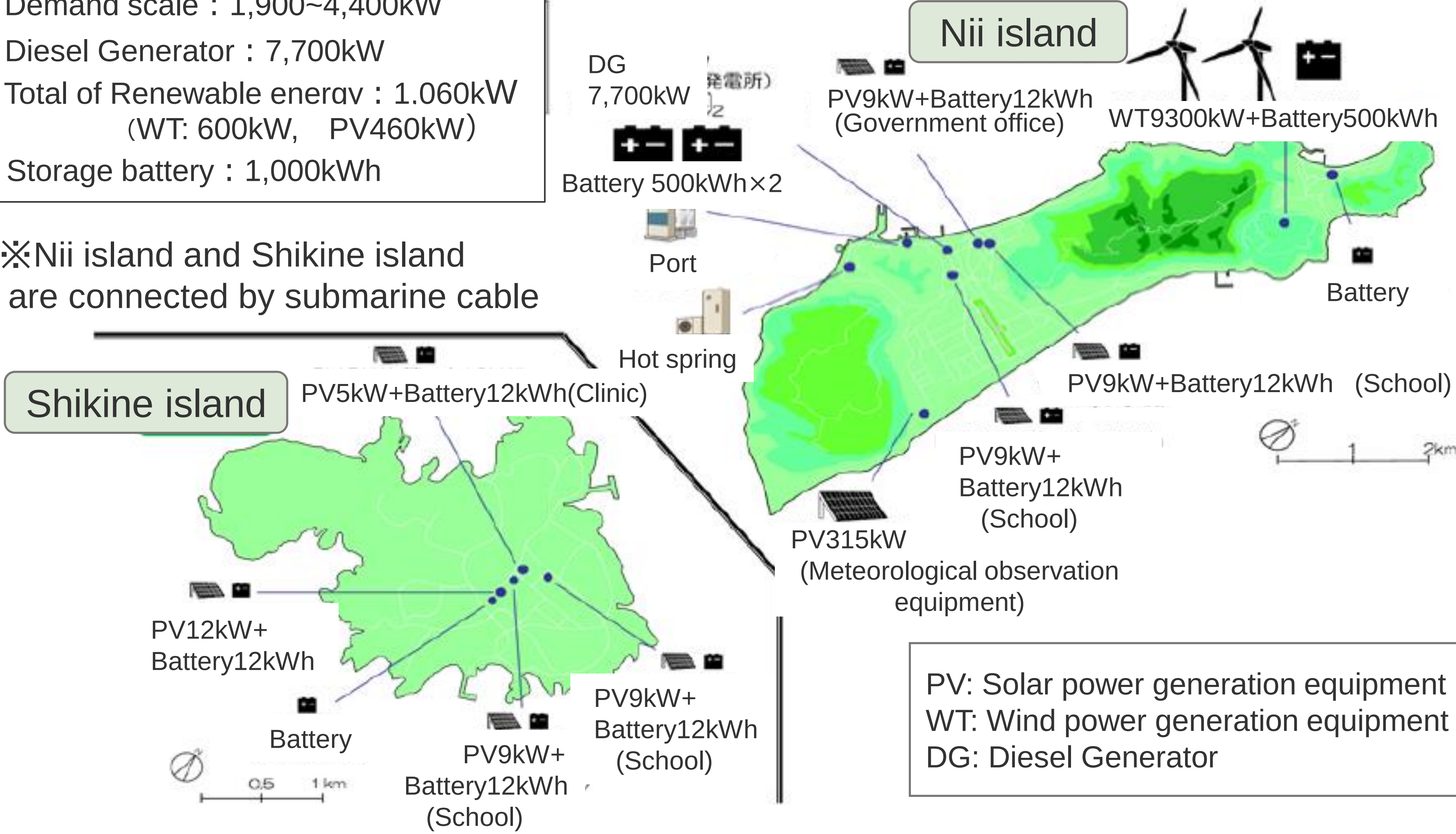


Source：NEDO Repot

Outline of verification test

Demand scale：1,900~4,400kW
Diesel Generator：7,700kW
Total of Renewable energy：1,060kW
(WT: 600kW,　PV460kW)
Storage battery：1,000kWh

※Nii island and Shikine island are connected by submarine cable



PV: Solar power generation equipment
WT: Wind power generation equipment
DG: Diesel Generator

Source：NEDO Repot

Overview of demonstration equipment

① Wind power generation equipment
(WT： 300kW×2unites, Battery: 500kWh,
PCS:500kW)

②Solar power generation equipment
(PV：318kW, PCS: 315kW)

③Storage battery equipment
(Battery: 500kWh×2
PCS: 1,000kW×2unites)

④Small PV equipment +
Storage battery equipment
(PV:5kV～12kV, Battery: 12kWh, PCS:10kW)

PCS: Power Conditioner System

③Storage battery equipment

④Small PV equipment +
Storage battery equipment

Source：NEDO Repot

Object of battery control

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We will verify the optimized control of the entire power system by effectively controlling the combination of renewable energy and storage battery equipment.

	Object	Contents of control	Device
Countermeasure of surplus power ⇩ Comparison of pumped storage and storage battery	Renewable energy output control Energy storage direct control	Renewable energy suppression control Surplus power charging by energy storage	Renewable energy generation + Storage battery equipment
	Demand shift when suppressing renewable energy	Renewable energy suppression control Storage battery charge power control	Renewable energy generation + Storage battery equipment
Mitigation of frequency fluctuations	Mitigating output fluctuations on the renewable energy side	Storage battery charge power control	WT/PV+ Storage battery equipment
	Frequency fluctuation suppression control to mitigate fluctuations in renewable energy and demand	Power consumption control	HP
Power generation plan	Imbalance compensation with power generation plan	Storage battery charge power control	WT/PV+ Storage battery equipment

HP: Heat Pump

Source：NEDO Repot

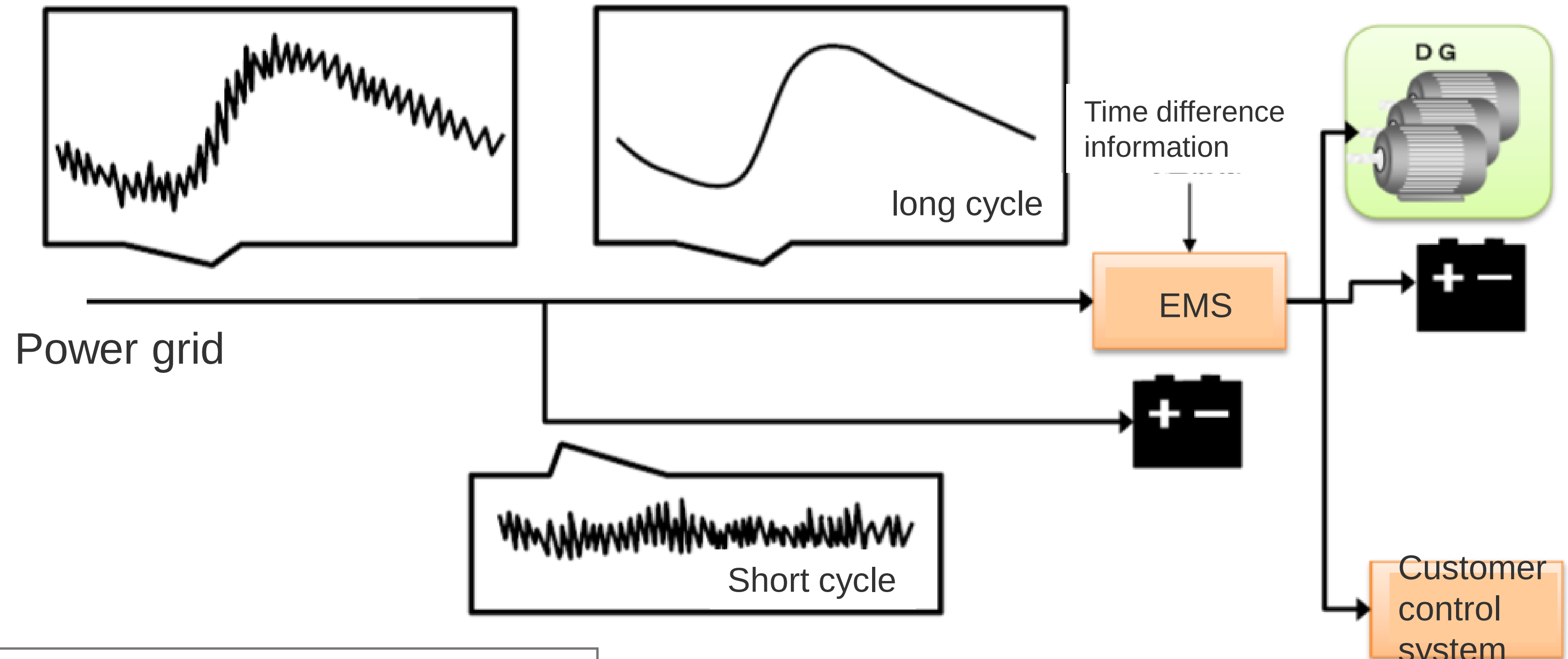
Control of short cycle/long cycle fluctuation

- Short cycle fluctuation control

  For rapid fluctuations in renewable energy such as PV and WT, the frequency adjustment mode of the storage battery itself is used.

- Long cycle fluctuation control

  For slow fluctuations in load, pumped storage power generation, storage batteries, etc. will be used to take measures against fluctuations.



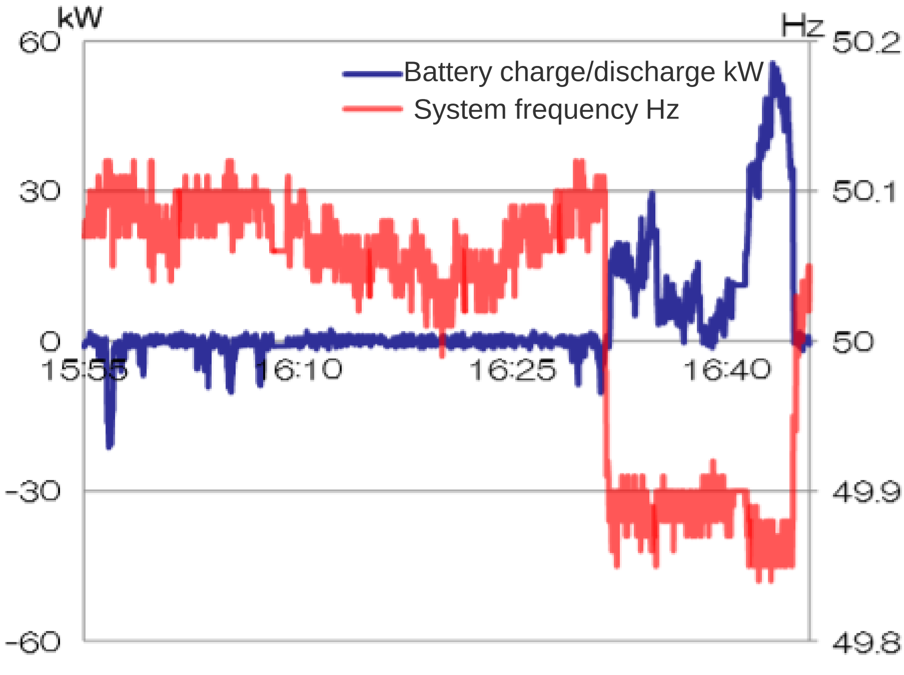
EMS: Energy Management System

Source：NEDO Repot

Storage system fluctuation suppression test results

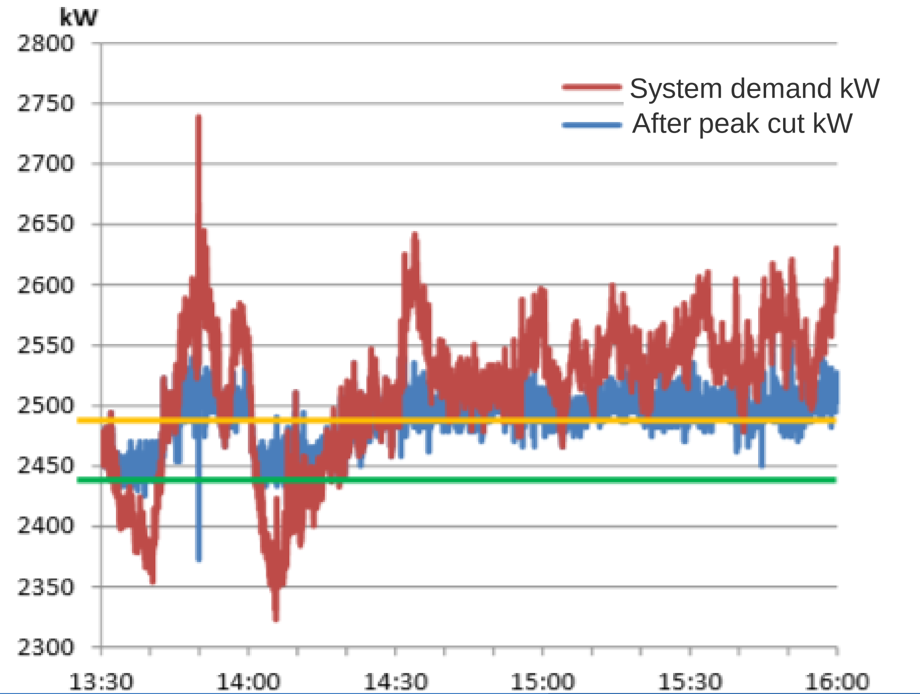
① Frequency fluctuation suppression

- It will be charged when the system frequency exceeds the upper limit of 50.1Hz.
- It will be discharged when the system frequency falls below the lower limit of 49.9Hz.



② Peak cut

- It will be discharged when the system power demand exceeds the upper limit of 2500kW.
- It will be charged when the system power demand falls below the lower limit of 2450 kW.



Source：NEDO Repot

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Studies on Stabilizing a Power System with Massive PV Penetration using VSG
(VSG: Virtual Synchronous Generator)

November 4, 2020

Chubu Electric Power Co., Inc.
Nippon Koei Co., Ltd.

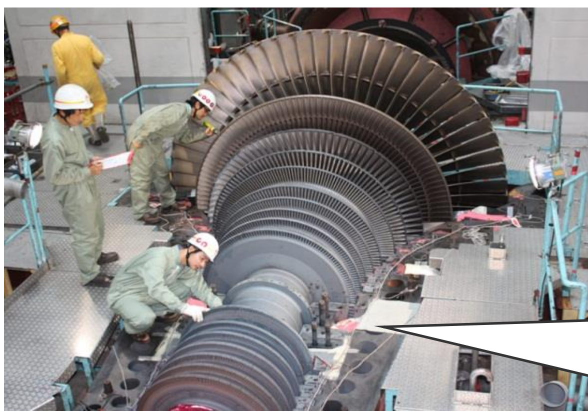
Contents

1.1 Introduction

Massive PV Penetration

Many conventional generating units are disconnected

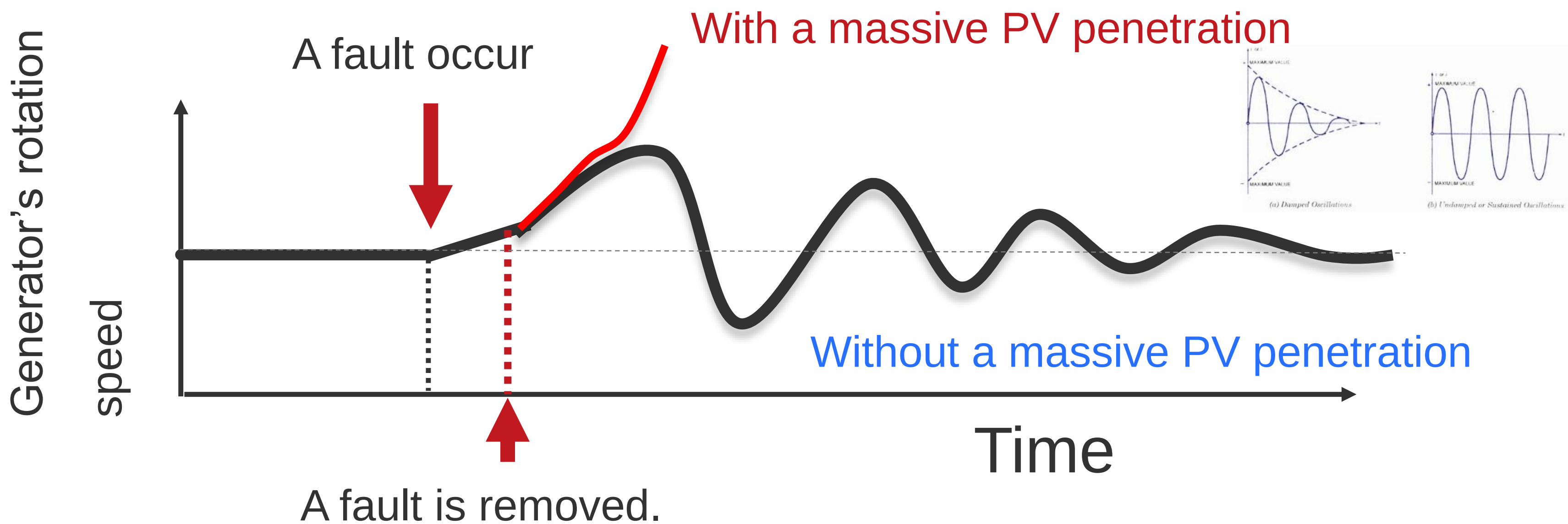
- Voltage Problem
- Frequency Problem
- Stability Problem



A conventional generator's rotor

The rotational mass of conventional generators has an ability to absorb and supply energy due to its inertia. A PV doesn't have it.

1.2 Generator stability



When many conventional generating units are disconnected and replaced by PV, synchronizing and/or damping power tend to decrease as the PV doesn't have inertia.

The synchronizing power is the power to restore a rotor to the rated rotation speed and the damping power is the power to damp the rotor's swing as a damper.

1. 3 Synchronizing Power and Damping Power

To maintain stability,

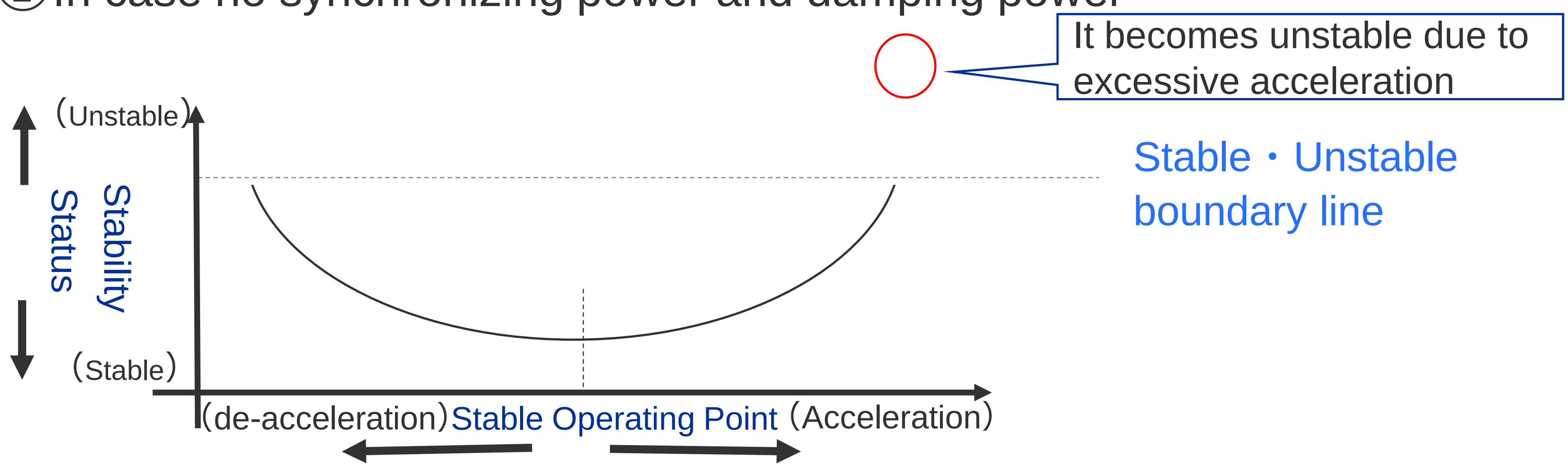
・Synchronizing Power (Ks) [ΔP/Δδ]

The power to restore original and stable position of synchronous generator against acceleration and de-acceleration in case of disturbance.

・Damping Power (Kd) [ΔP/Δω]

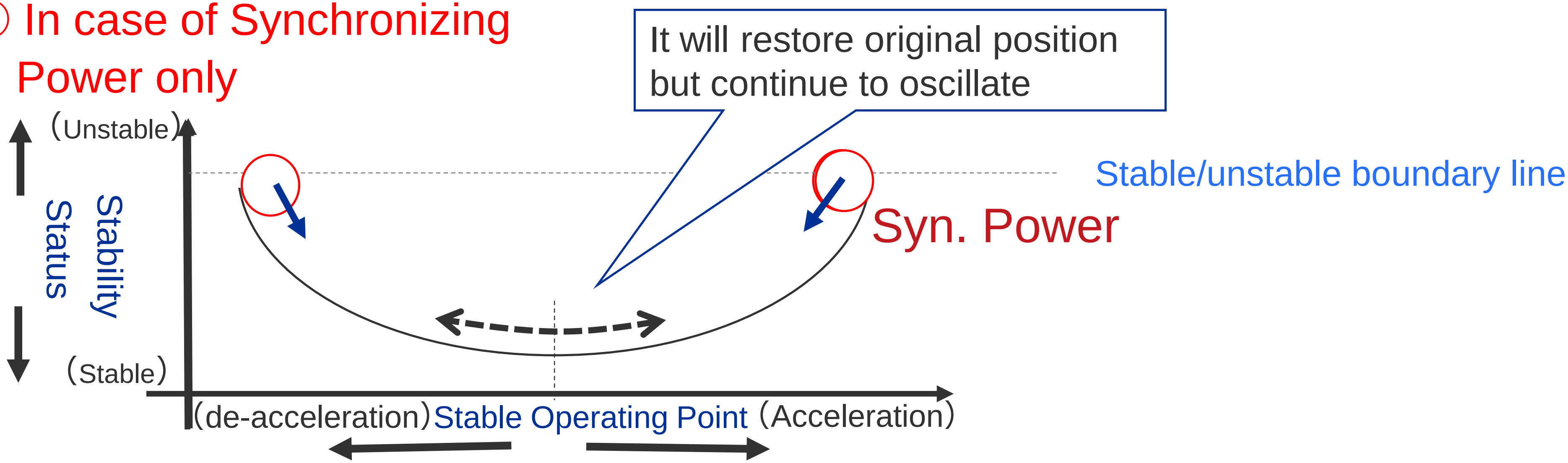
The power to damp generator oscillations in case of disturbance

①In case no synchronizing power and damping power・・・

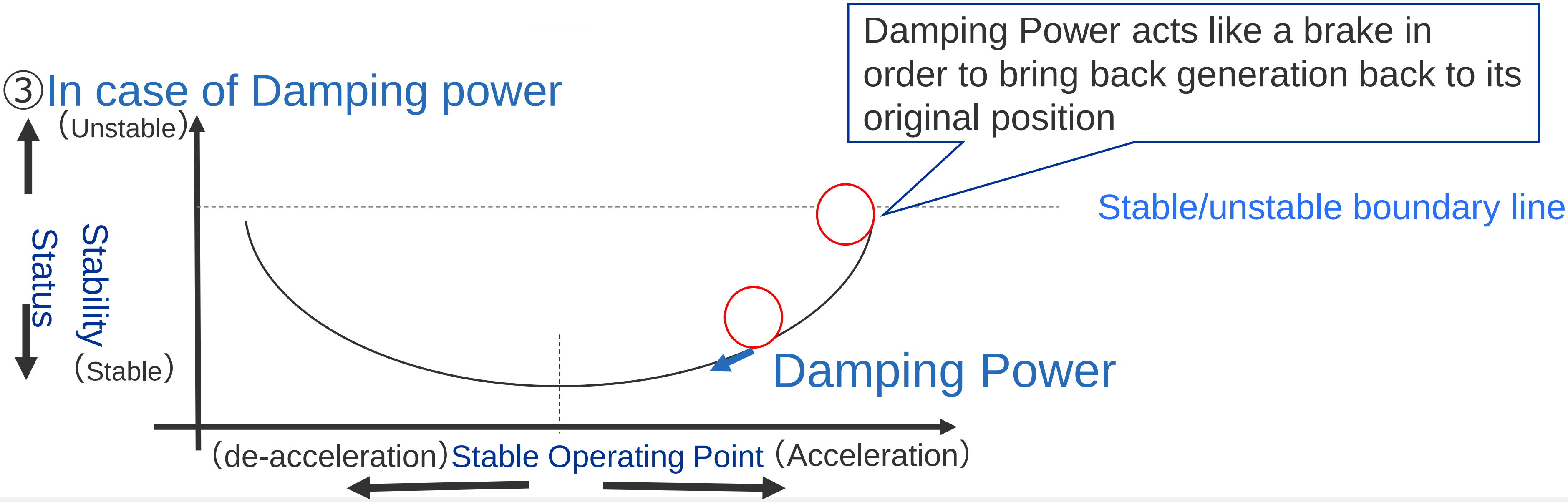


1. 4 Synchronizing Power and Damping Power

② In case of Synchronizing Power only

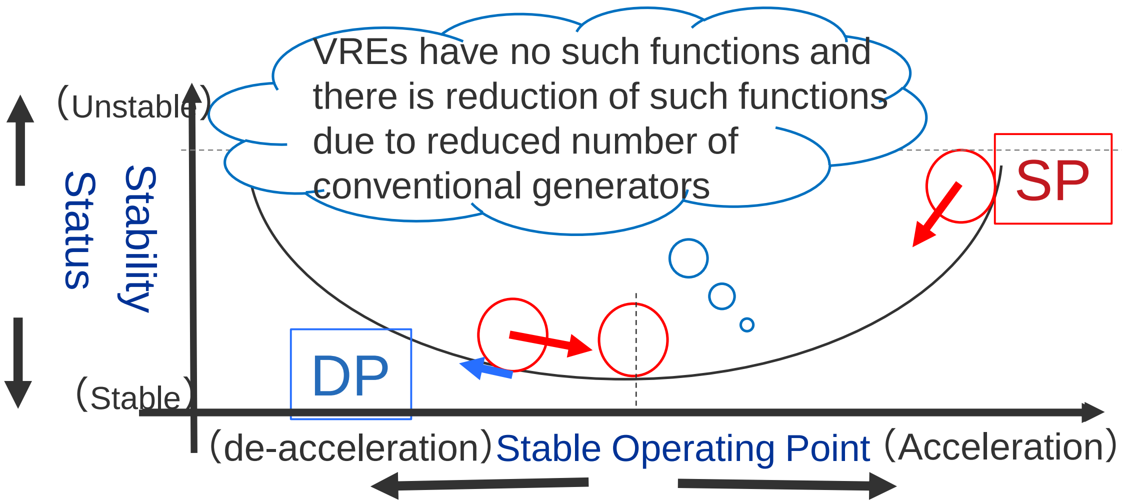


③In case of Damping power



1. 5 Virtual Synchronous Generator (VSG)

④Conventional Generators have both Synchronizing Power (SP) & Damping Power (DP)



Energy Storage & Release due to Inertia

Conventional Generator
(Rotary synchronous generator)

■ Virtual Synchronous Generator (VSG)

A device that behaves in the same way as a rotary synchronous generator in response to system disturbances such as failures. This device consists of a power supply (storage battery) and an inverter, and by appropriately controlling these, it has synchronization power and damping power.

VSG prototype model is developed/ studied using regenerative type DC supply in lieu of a storage battery as a viable solution to stabilize power system

1. 6 Virtual Synchronous Generator (VSG)

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In this study:
①The impact of different PV penetration levels on the dynamic and transient stability was evaluated.
②As a countermeasure, the prototype Virtual Synchronous Generator was developed and its effectiveness was checked experimentally using an analog simulator.

Where, Virtual Synchronous Generator (VSG)
- It consists of an inverter combined with some power sources (PV connected with battery, Battery only etc.).
- It behaves as a rotating type synchronous generator when a system disturbance occurs.

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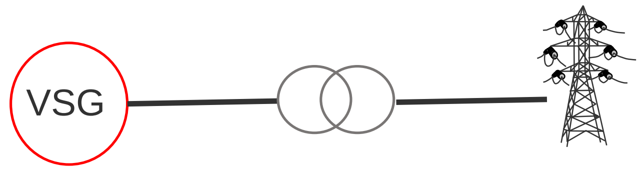
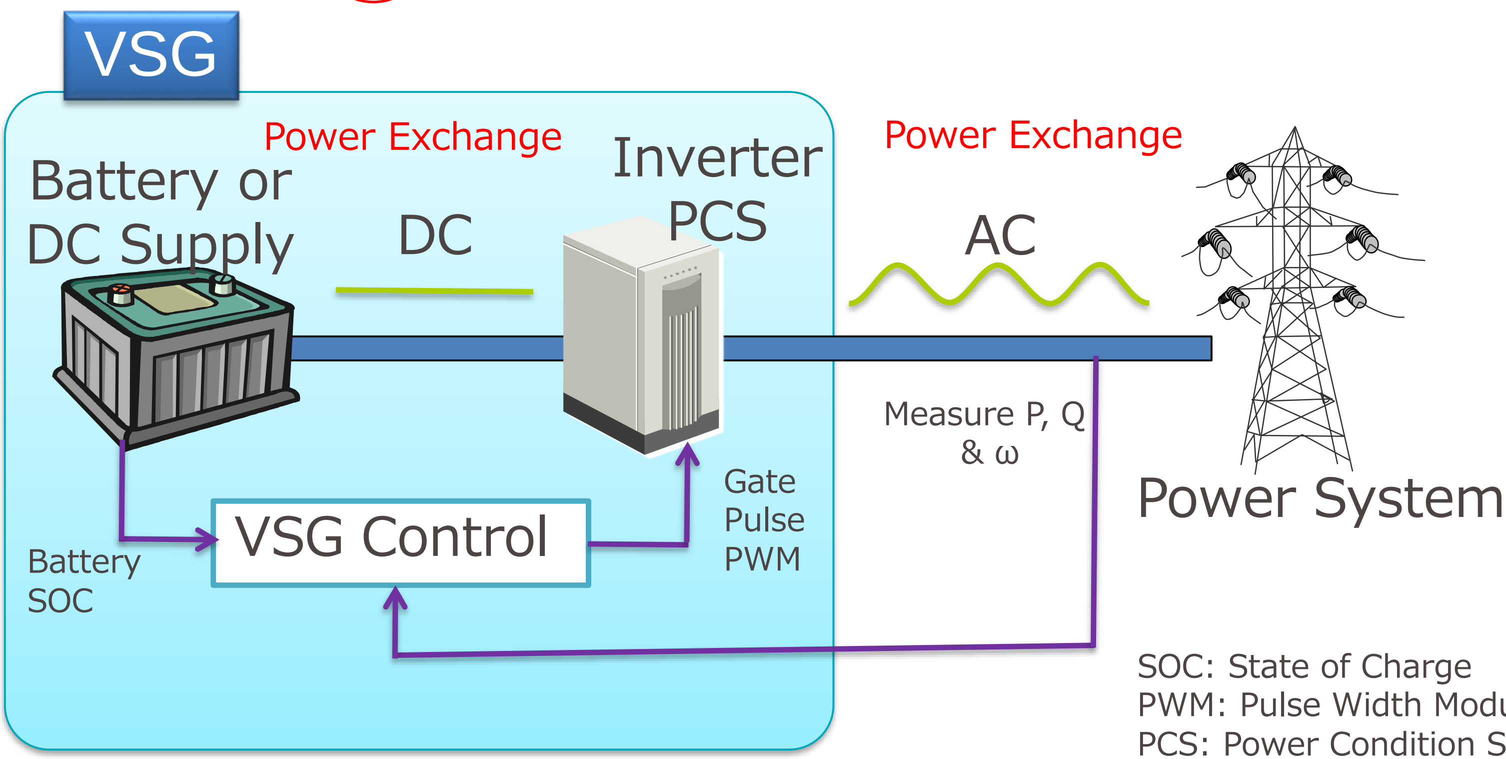
2.1 Basics of VSG

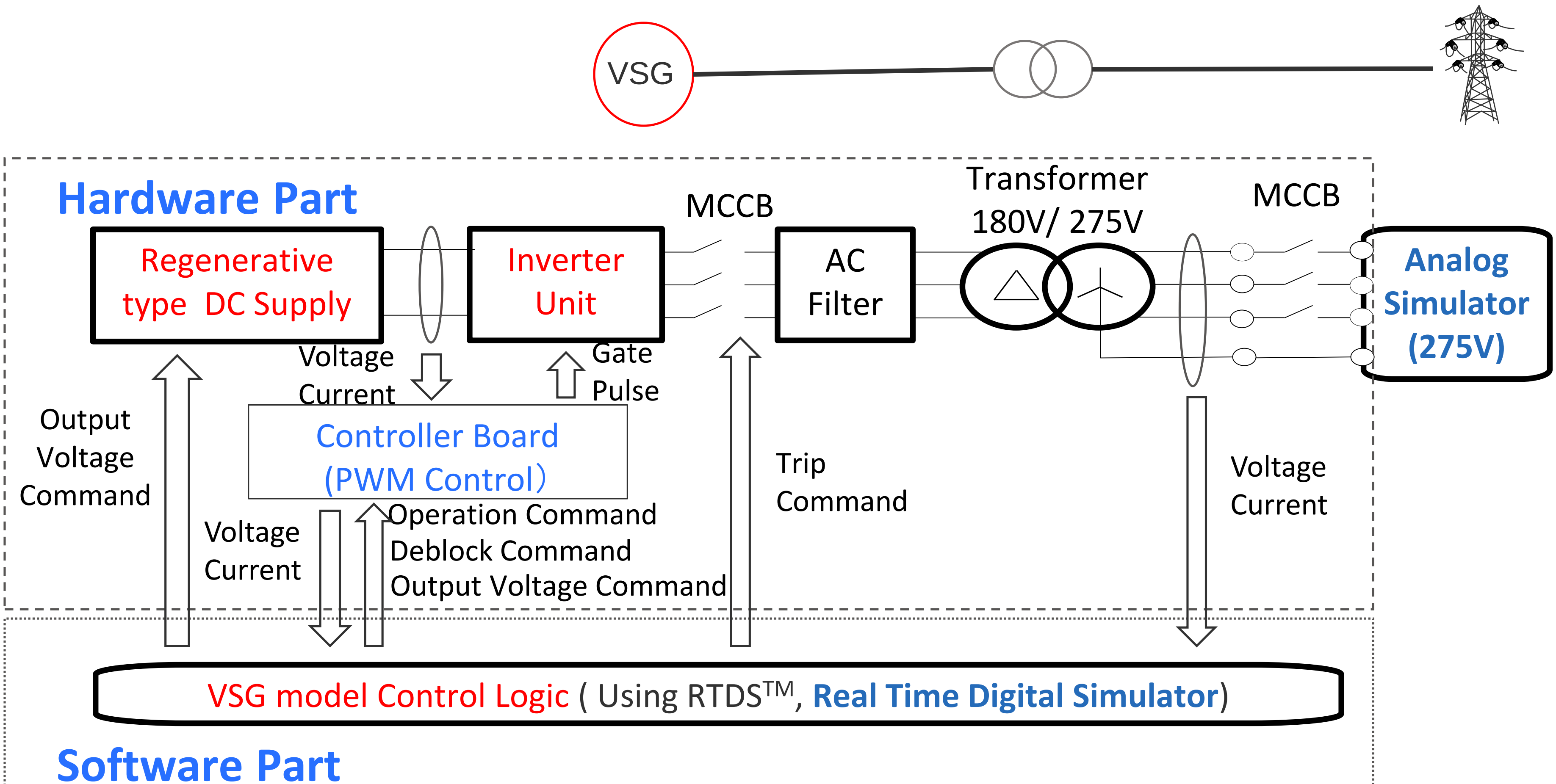




SOC: State of Charge
PWM: Pulse Width Modulation
PCS: Power Condition System

In this circuit, the power flows from DC supply to an analog simulator via an inverter unit. By using the regenerative supply, power can be absorbed and supplied.

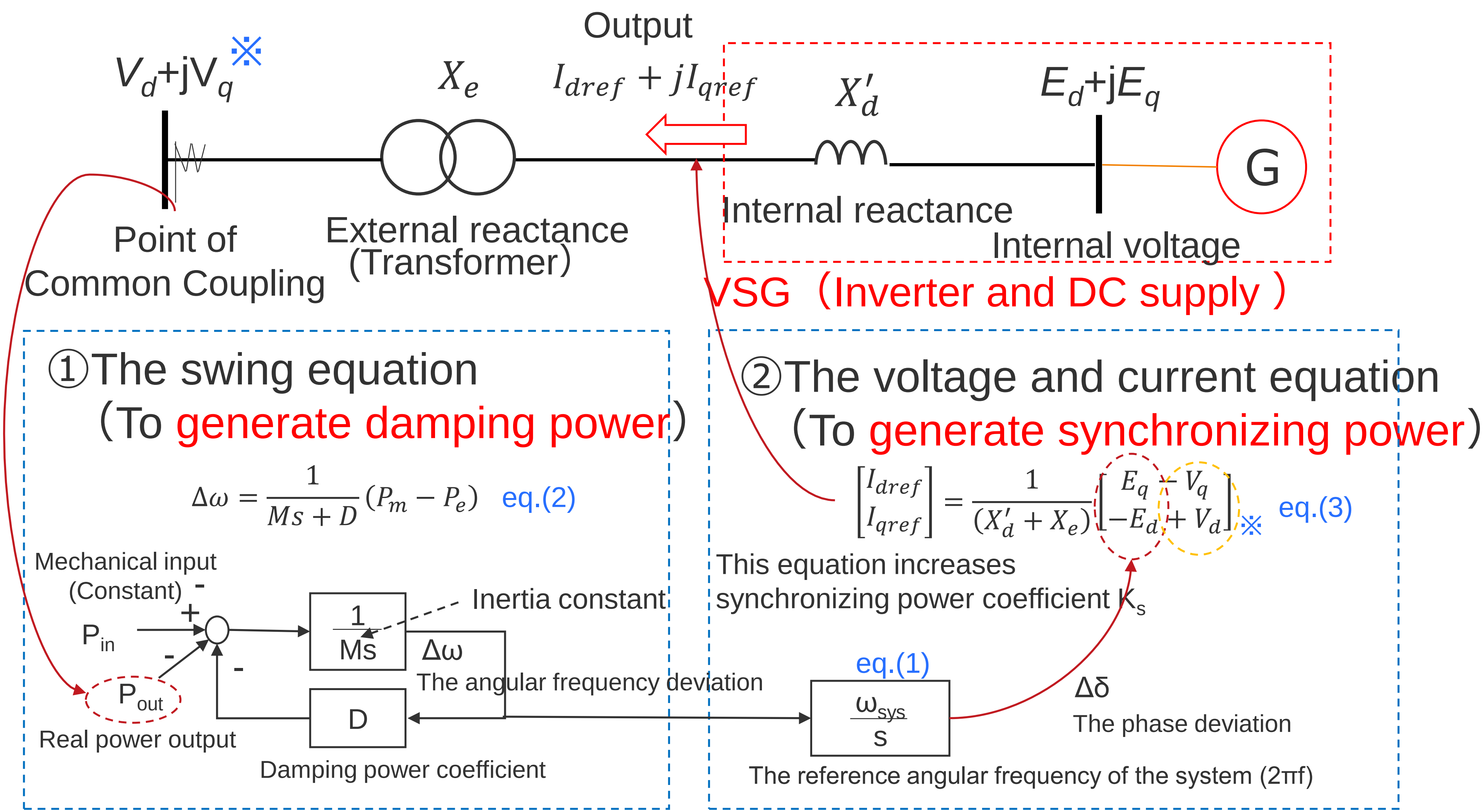
2.2 Schematic Diagram of Prototype VSG



In this circuit, the power flows from DC supply to an analog simulator via an inverter unit. By using the regenerative supply, power can be absorbed and supplied.

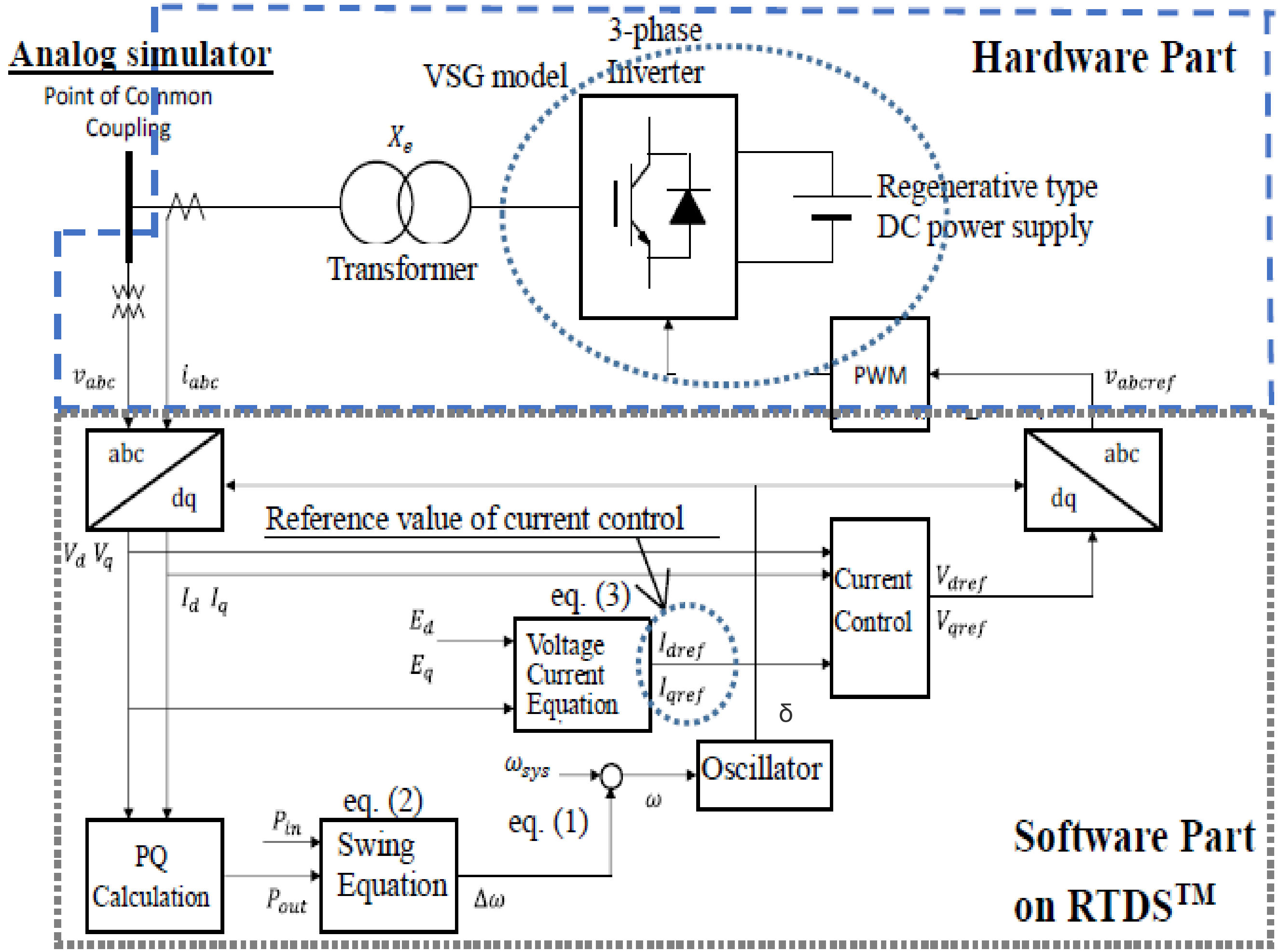
MCCB: Molded Case Circuit Breaker

2.3 Details of VSG Model

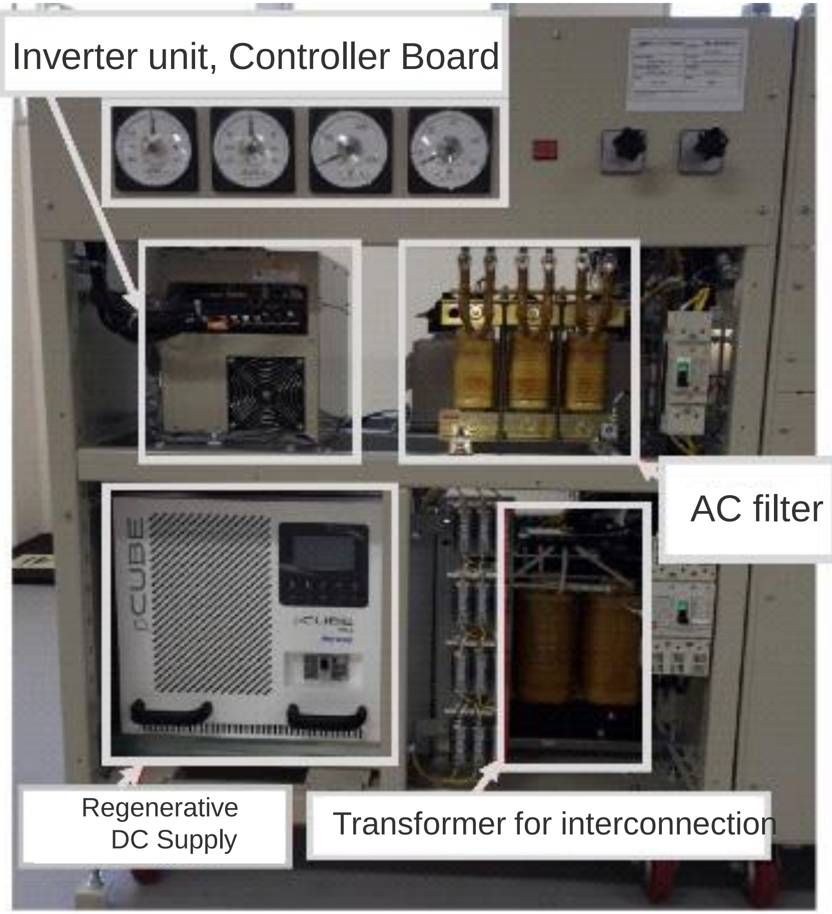


※These equations are modeled on RTDS™.

2.3 Control scheme of the VSG model



2.4 Specification of Prototype VSG

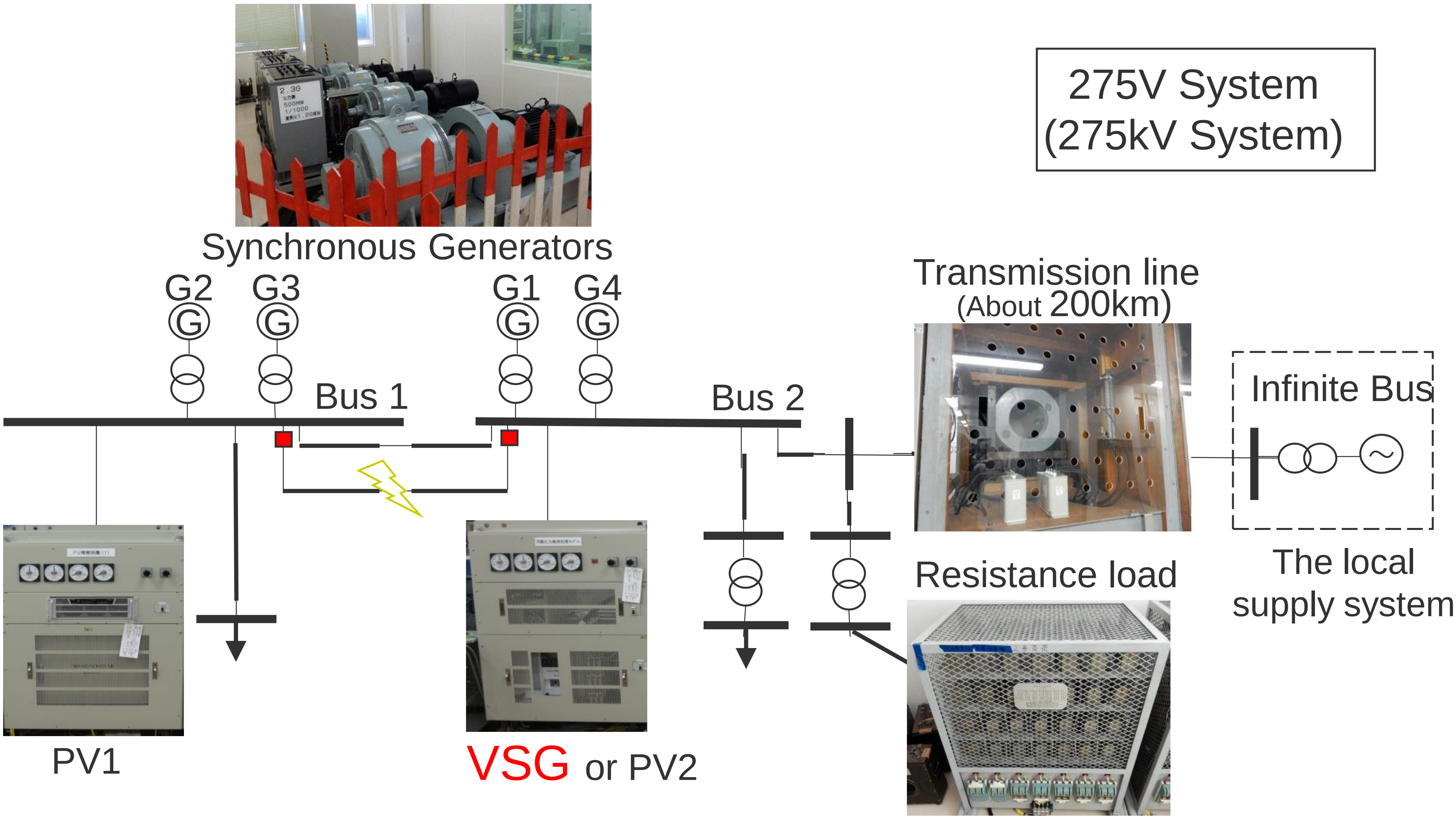


The main Specification of the Prototype VSG.

Category	Value
Rated frequency(AC)	60Hz
Rated capacity(AC)	10kVA
Rated output(AC)	10kW
Transformer Primary voltage(AC)	$275V_{rms}$
PWM Carrier frequency	10kHz

Before a prototype was manufactured, the specifications were determined using a digital model.

3.1 Experimental System



※V：1/1,000, I：1/100, Z： 1/10, Output：1/100,000

3.2 Experimental Conditions

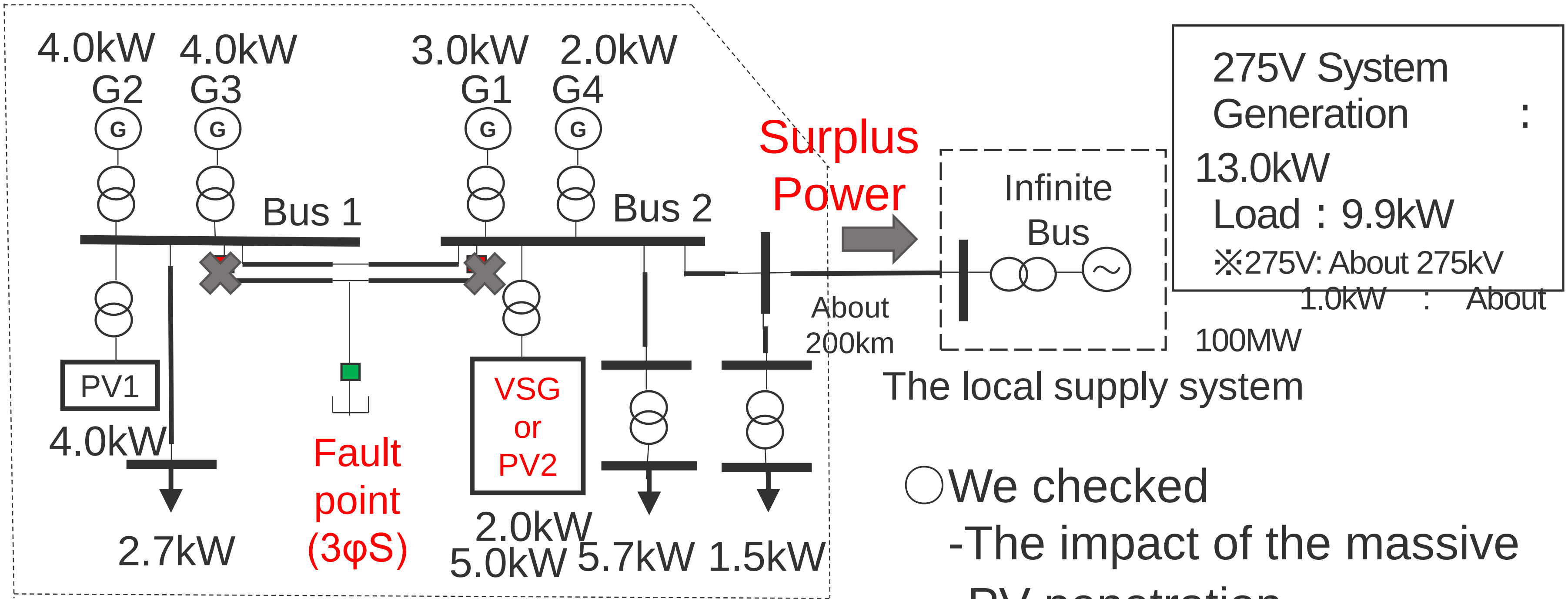


TABLE. THE OUTPUT AT EACH PV PENETRATION LEVEL.

	PV Penetration Level [%]	1G [kW]	2G [kW]	3G [kW]	4G [kW]	PV1 [kW]	VSG or PV2 [kW]
Low	0.0%	3.0	4.0	4.0	2.0	-	-
	15.4%	3.0	4.0	4.0	-	-	2.0
High	38.5%	-	4.0	4.0	-	-	5.0
	69.2%	-	4.0	-	-	4.0	5.0

○We checked
- -The impact of the massive PV penetration
- -The effectiveness of the VSG

○We performed
- -Dynamic Stability Experiment
- -Transient Stability Experiment

3.3 Evaluation Method of Dynamic Stability Results

The dynamic stability is assessed using the criterion that synchronizing power coefficients K_S>0 and damping power coefficients K_D>0. The K_S, K_D are computed as follows. ※

$$K_S = \frac{dP}{d\delta} = \frac{M(\sigma^2 + \omega^2)}{\omega_0}$$

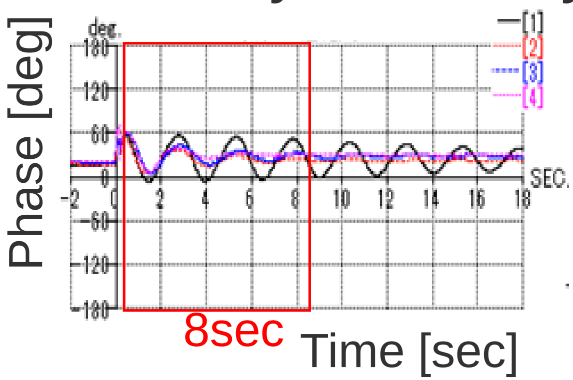
M[s]:inertia constant

ω_0[rad/s]: rated angular frequency

$$K_D = \frac{dP}{d\omega} = -2M\sigma \ (\sigma < 0)$$

※P.KUNDUR, Power System Stability and Control,1994

Where, the eigenvalue(σ *and* ω) of a analysis result is estimated by the Prony analysis.



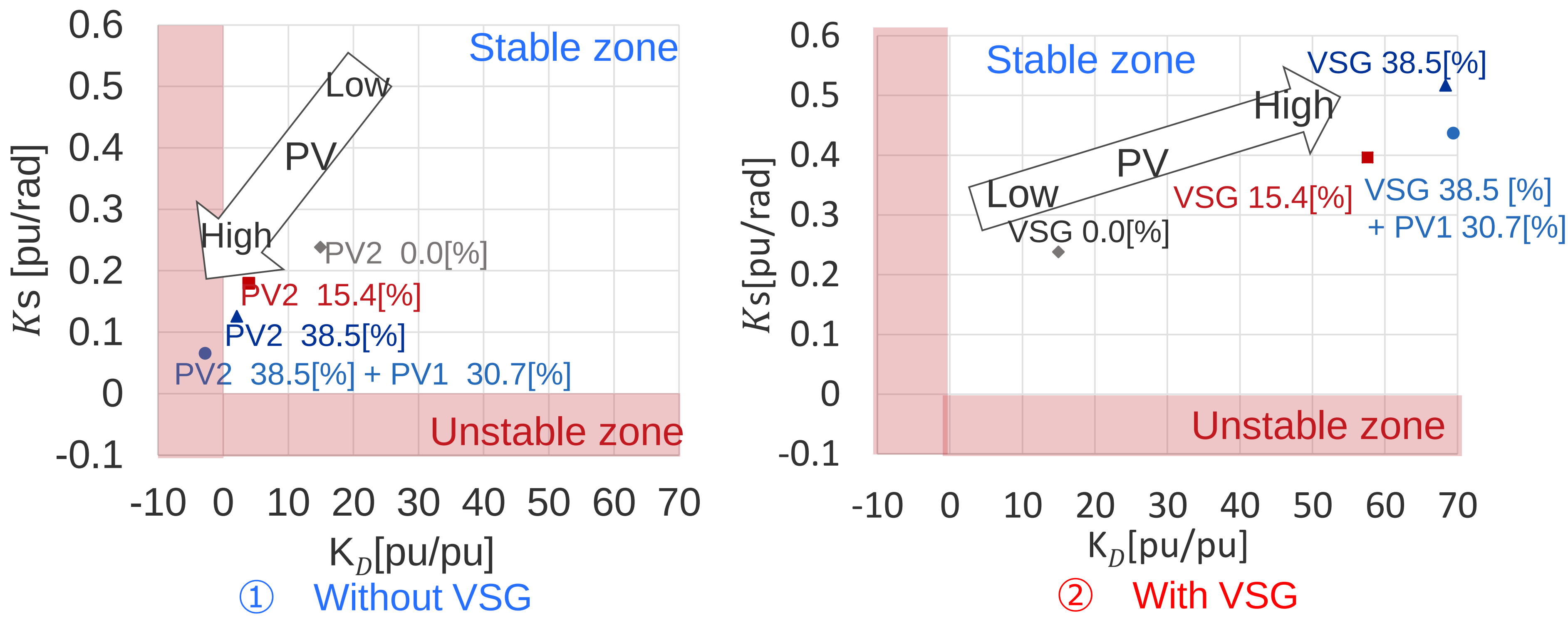
Eigen value

$$y(t) = Ae^{(\sigma + j\omega)t}$$

y(t): signal of interest, A : amplitude, t: time, σ: damping

ω: angular frequency of an oscillation mode.

3.4 Dynamic Stability Results



①With the increase of PV penetration level, the K_S and K_D decrease due to reduced number of the connecting synchronous generators.

② K_S and K_D are increased by using the VSG which has the ability to improve the dynamic stability.

3.5 Transient Stability Results

PV Penetration Level [%]	VSG Or PV2 with FRT on	Fault Duration				
		4cycle	6cycle	8cycle	10cycle	12cycle
0.0	-	○	○	○	○	×
15.4	PV2	○	○	○	○	×
	VSG	○	○	○	○	○
38.5	PV2	○	○	△	×	×
	VSG	○	○	○	○	○
69.2	PV2	×	×	×	×	×
	VSG	○	○	○	○	○

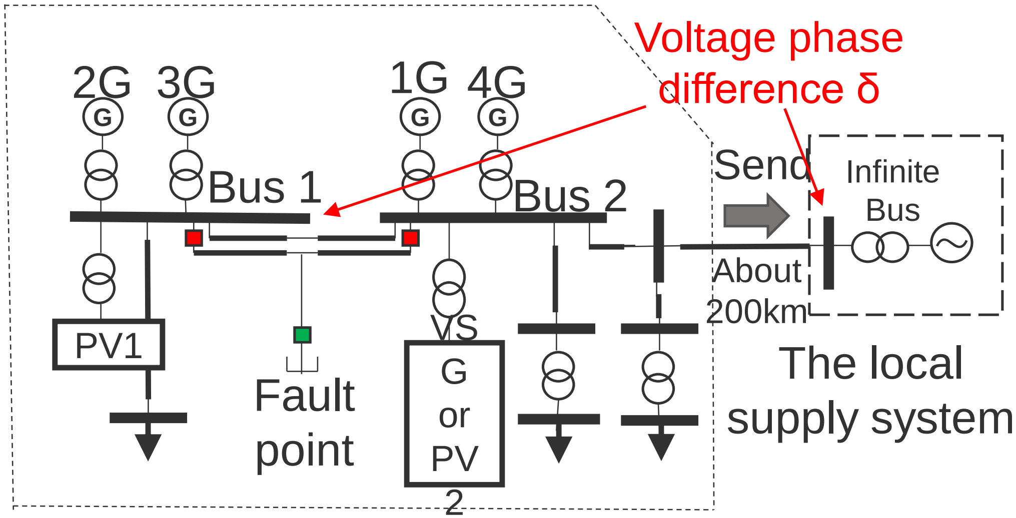
Unstable

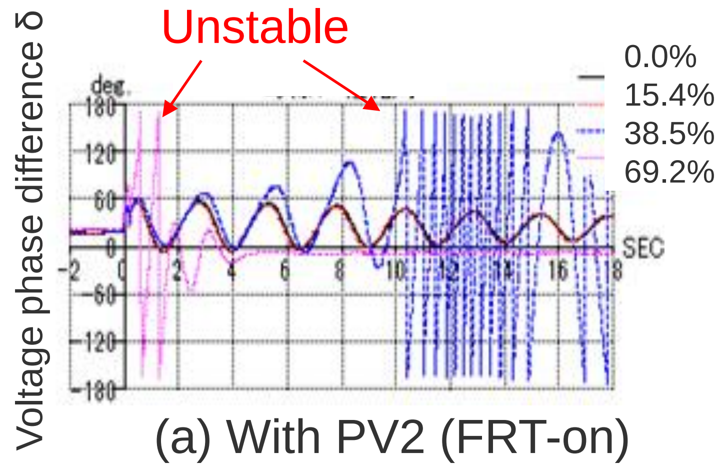
○:Stable △ : Oscillatory × : Unstable (Out-of-step)

①With the increase of the PV penetration level, the generators tend to become unstable even when a fault duration is short.

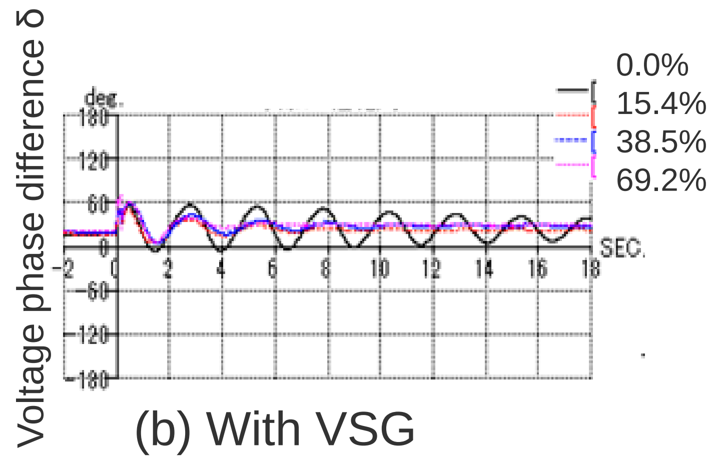
②All the cases with VSG become stable.

3.6 Evaluation Method of Transient Stability Results





(a) With PV2 (FRT-on)



(b) With VSG

※Fault Duration 10cycle

With the voltage phase difference δ between Bus 1 and Infinite Bus, a transient stability is judged as follows.

Stable : $|\delta| \leqq 90$ deg

Unstable : $|\delta| > 90$ deg

Where, measured time duration is 18 [sec]

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4. Conclusion

-The impact of different PV penetration levels on the dynamic and transient stability was assessed by performing experiments using an analog simulator and PV models.

-The prototype VSG was developed and its effectiveness was checked experimentally to improve the dynamic and transient stability.

-In future studies, it is important to optimize the VSG capacity and its placement with respect to a realistic power system with massive PV penetration.

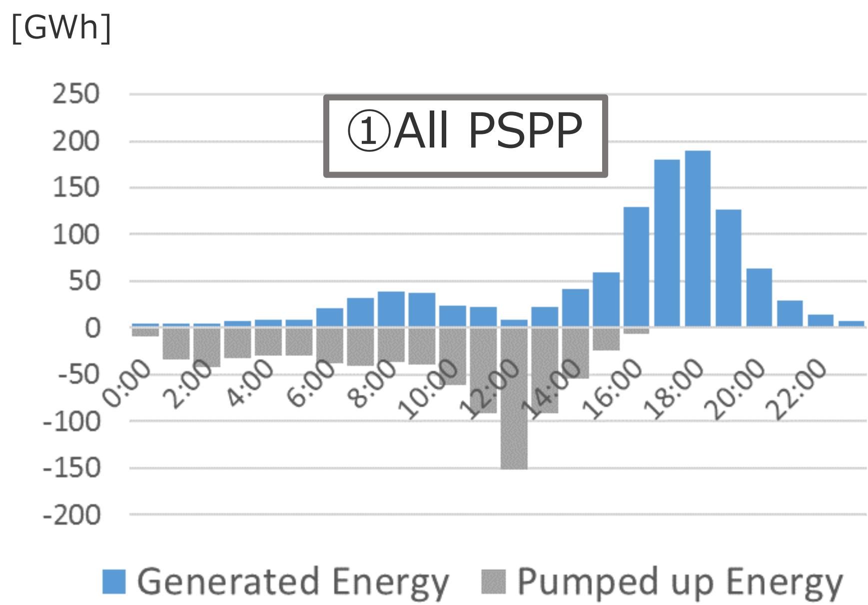
-The field testing is also important to get more insight about practicality in the real world system.

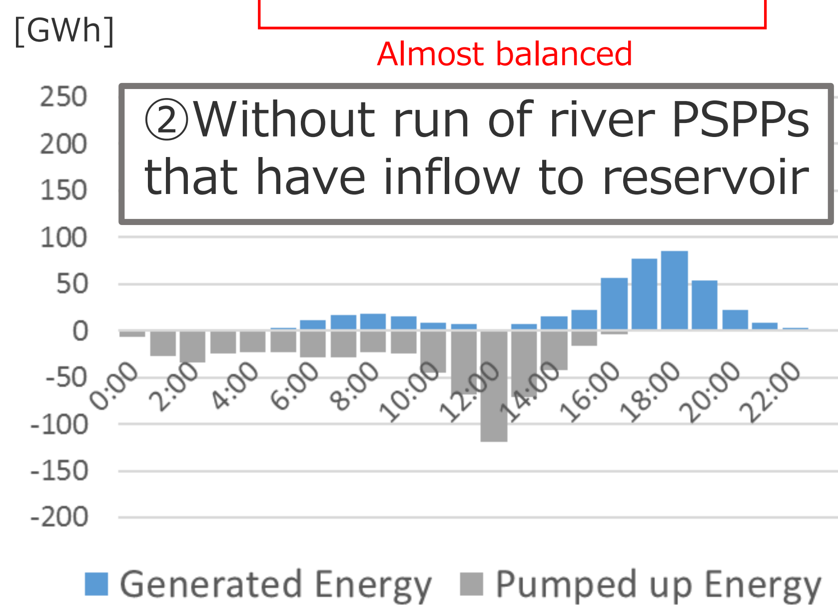
2019fy PSPP Utilization and its purposes in Chubu Area

2019fy Data

	PSPP Total Capacity in Chubu	PSPP Total Generated Energy	PSPP Total Pumped Energy
①All PSPPs	3,880MW	1090GWh	810GWh (Energy for Generation 810×70% = 567GWh)
②Without run of river PSPPs that have inflow to reservoir	2,603MW	437GWh	611GWh (Energy for Generation 611×70% = 428GWh)

Almost balanced





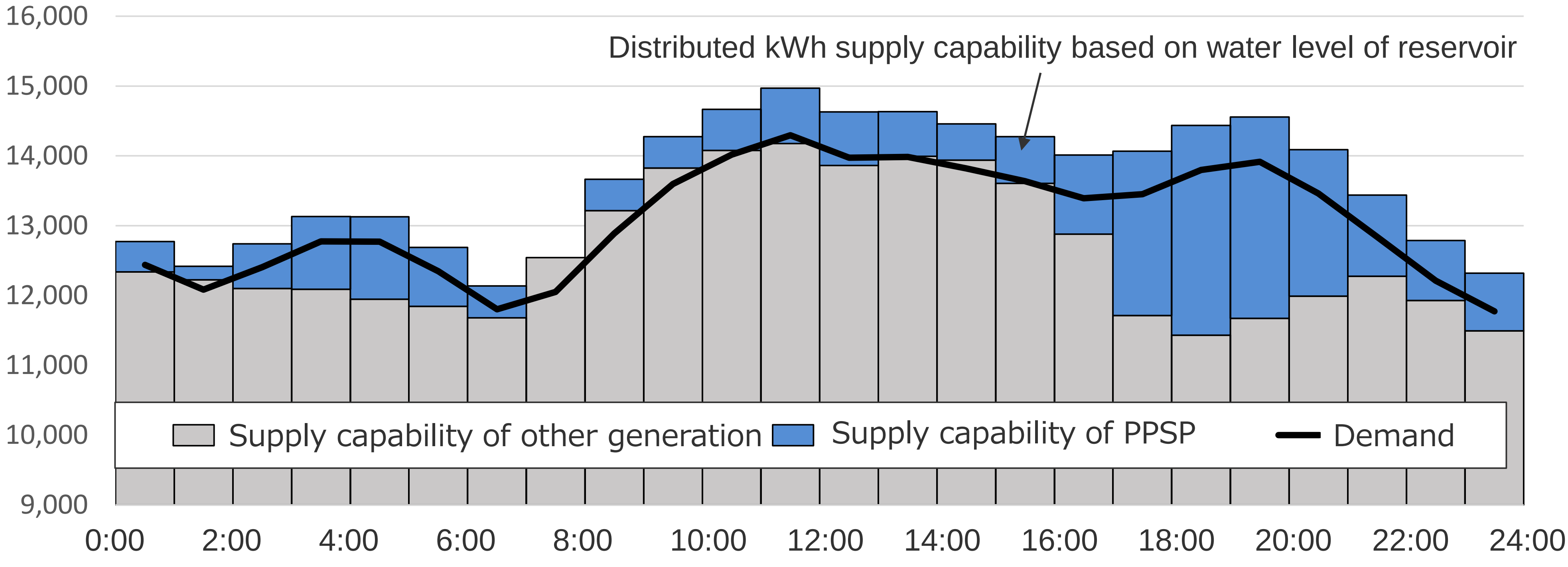
PSPP Utilization Purposes

CHUBU Electric Power

	Purpose		Note
Generation	Supply Capability		kWh distribution of Reservoir (See slide No.4)
	Upward Reserve Margin		
	→	Load Frequency Control	Time Range < 5 min (From Stop Mode)
	→	Governor Free Capability	・Time Range < 10 sec (During Running) ・Chubu Criterion = 3% × Area Demand (See slide No.5)
Pump up	Downward Reserve Margin		
	→	VRE Curtailment Reduction	Time Range > 15 min(From Stop Mode)
	→	Keep Frequency in N-1 Contingency by Shedding PSPP	・Time Range ≒ instant (During Running) ・Chubu Criterion = Keeping 59.5Hz in N-1 Contingency
Pump up ↓ Generation	Economical Operation		Marginal Cost for Pumping up Divided by 70% vs Substituted Marginal Cost by PSPP Generation after Pumping up
Other	Voltage Control		Operation of Voltage Control Mode
	Black Start		–

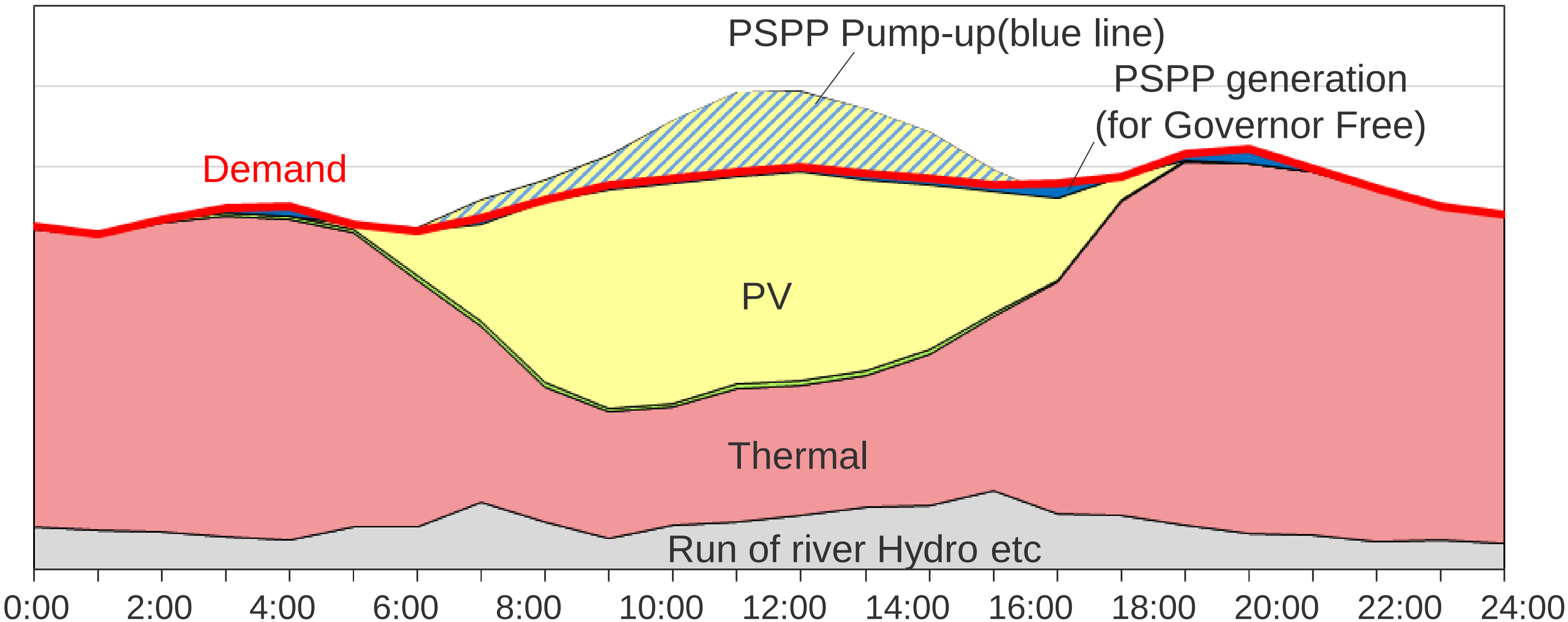
What is “kWh distribution of Reservoir and PSPP Hydro”

- There is a kWh constraint of Reservoir and PSPP Hydro, therefore they do not keep their nominal capacity all time.
- It is a common measure to evaluate their supply capability as distributing their kWh based on reservoir water level to each time to equalize reserve ratio against predicted demand in Japan.



Generation in a day of 1st week. May 2020

- We utilize PSPP pump-up function to maximize the VRE generation in day time.
- Simultaneously another PPSP unit is started up for generation to keep enough Frequency Containment Reserve(Governor Free) and keep to run at minimum output.



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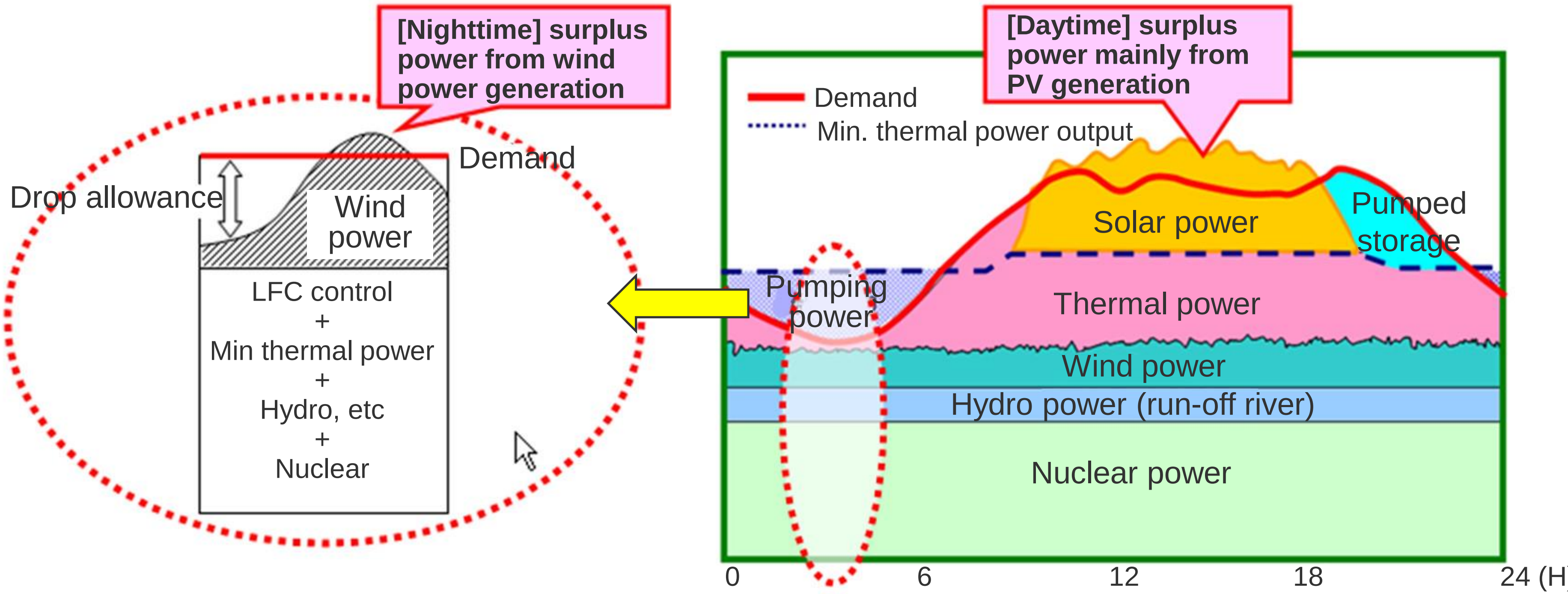
Outline of Storage battery

May 20, 2020

Chubu Electric Power Co., Inc.
Nippon Koei Co., Ltd.

Supply-demand Control

➢If Renewable Energy output increases greatly when demand is low,
supply demand balance cannot be maintained even if output of existing supply capabilities (thermal power) is controlled to the limit (power generation >>demand)



Measures

- Utilize storage energy
- Utilize inter-regional transmission lines, control Renewable Energy output
- Restriction of interconnected Renewable Energy

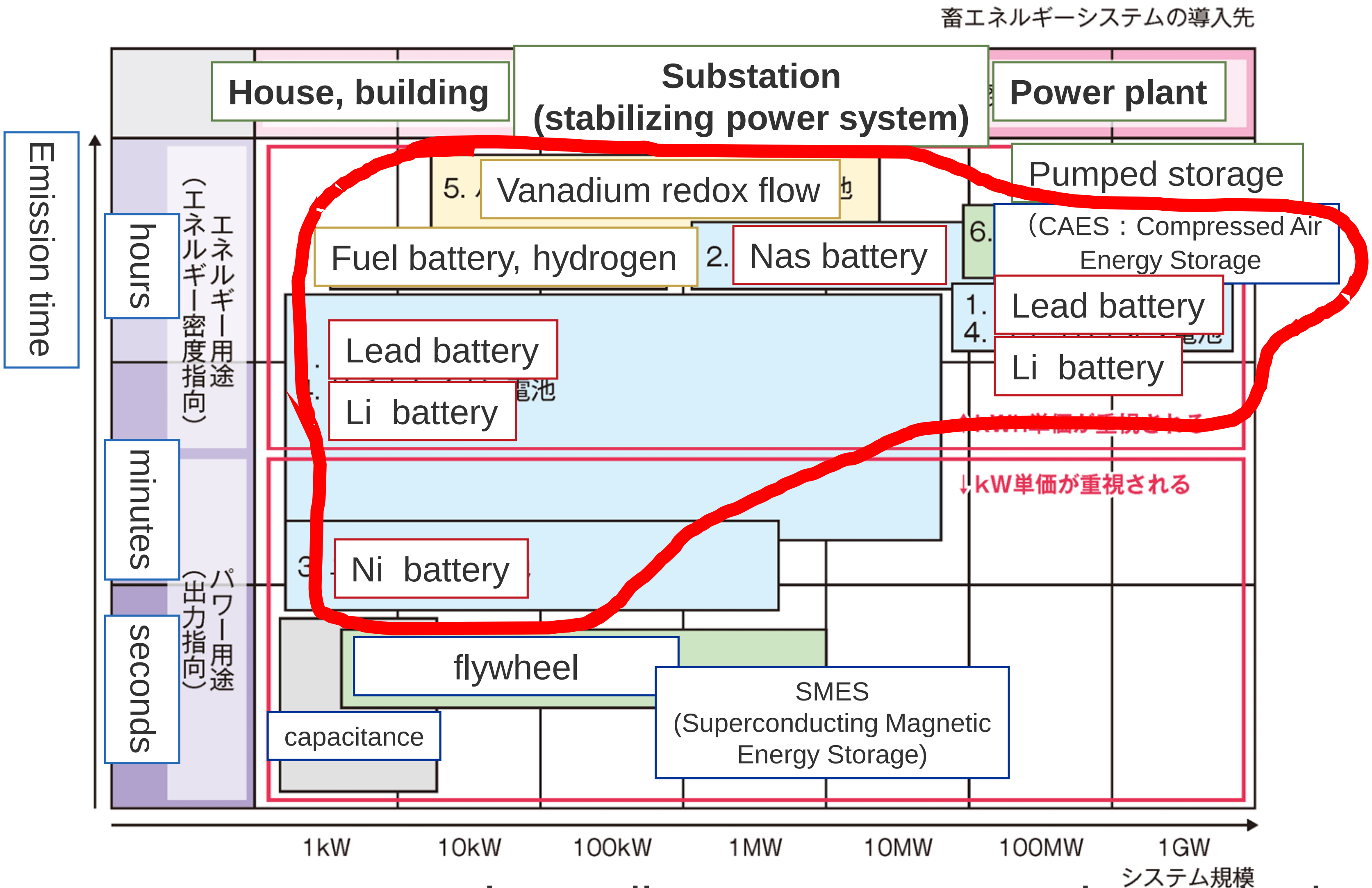
Storage Energy

- Countermeasure to absorb fluctuation of Renewable Energy output
- Technology for stabilizing power flow

Technology of Storage Energy	Shape of storage	Method	Characteristic
Storage battery	Chemical energy	Lead, Ni, NaS Li, Redox	Charge and discharge repeatedly
（CAES： Compressed Air Energy Storage	Pressure energy	compress air at night, Use it daytime to generate power	Efficiency is high, because combustion energy is not necessary.
Hydrogen storage	Chemical energy	Use for fuel battery	Fuel battery vehicle
Pumped storage	Hydro energy	Pumping water with surplus electricity, Discharge when needed	Low running cost And Long-term usage

source: NEDO(new energy and industrial technology development organization) renewable energy technology white book ver.2

Use of Storage batteries

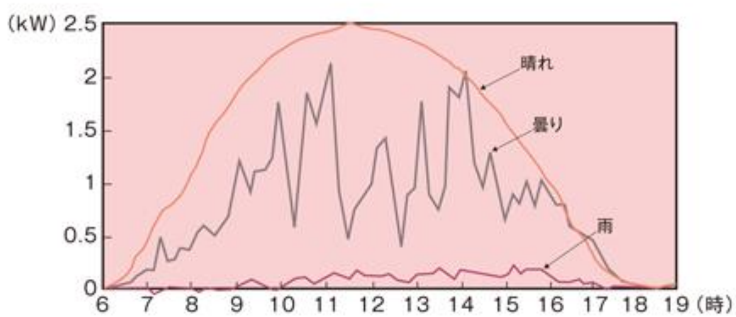


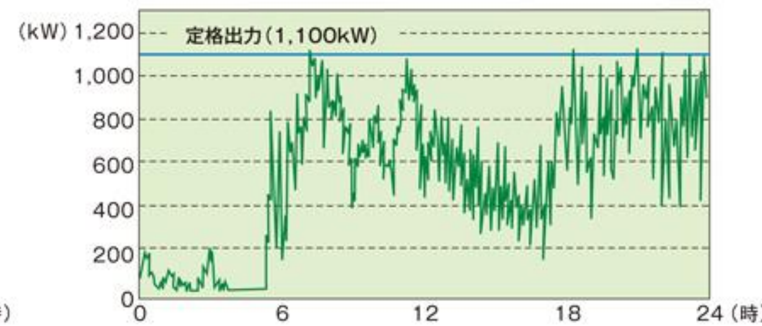
Various storage energy depending on purpose and magnitude

source: NEDO(new energy and industrial technology development organization) renewable energy technology white book ver.2

Absorbing fluctuation output (short term: frequency control)

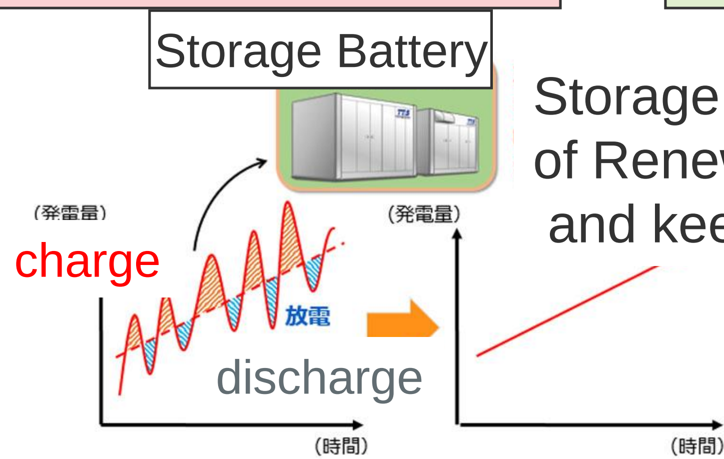
Output fluctuations of PV	Output fluctuations of wind power





PV generation output changes with <u>time of day and weather</u>

Wind power generation output changes with <u>wind forces</u>



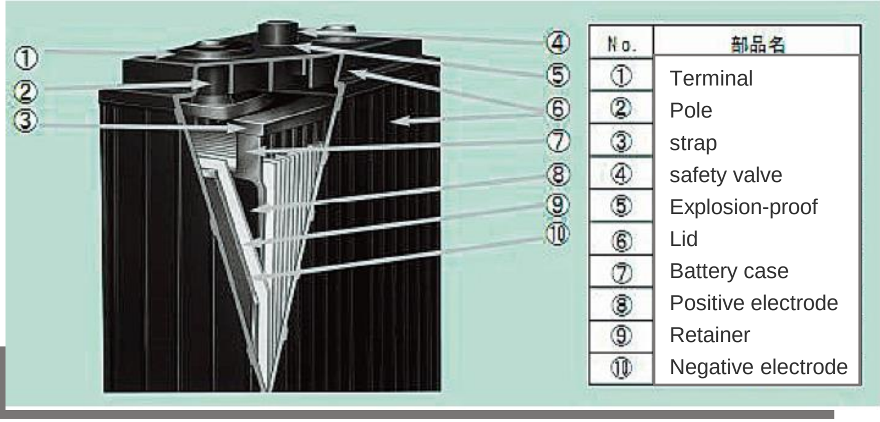
Storage Battery absorbs fluctuation of Renewable Energy output, and keep frequency stable

Storage battery type

Battery name	Energy density／Output density	Charge and discharge efficiency	Cycle longevity	Characteristics	Price
Lead storage 	○／○	○	○	Average charge is necessary	◎
NaS 	◎／△	◎	○	Heater loss	◎
Ni hydrogen 	◎／○	○	◎	Average charge is necessary	○
Li 	◎／△	◎	○	None	△
Vanadium redox flow 	○／△	○	○	Pump loss	○

 source: NEDO(new energy and industrial technology development organization) renewable energy technology white book ver.2

Lead storage Battery

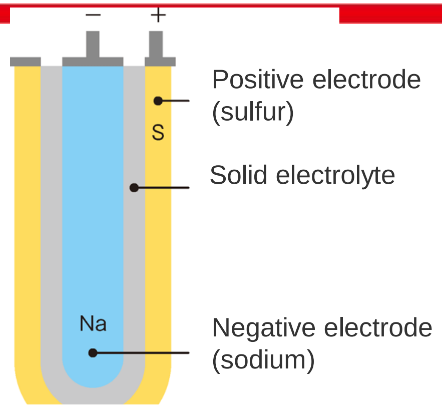


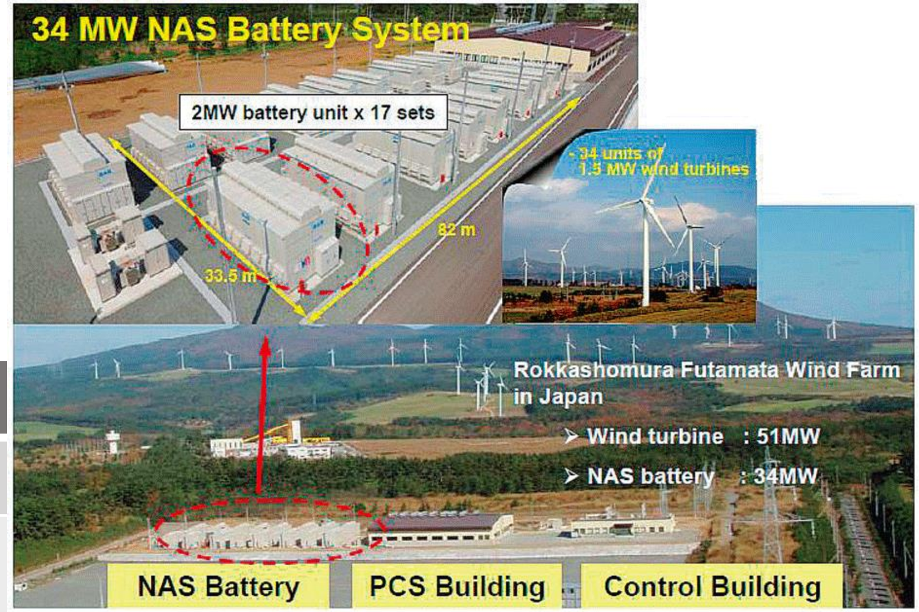
Large capacity achievement	1MWh
Charge and discharge speed	1C (1 hour from full charge to empty by rated current)
Efficiency of charge and discharge	75~87%
Longevity	4500cycle(15 years)
Energy density	Volume energy density: approx. 40~80Wh/L Weight energy density(theory):167Wh/kg Weight energy density(actual):35Wh/kg
Price	500$/kWh, 2000$/kW,
Technical level	practical

Recently longevity becomes longer.

source: NEDO(new energy and industrial technology development organization) renewable energy technology white book ver.2

NaS Battery





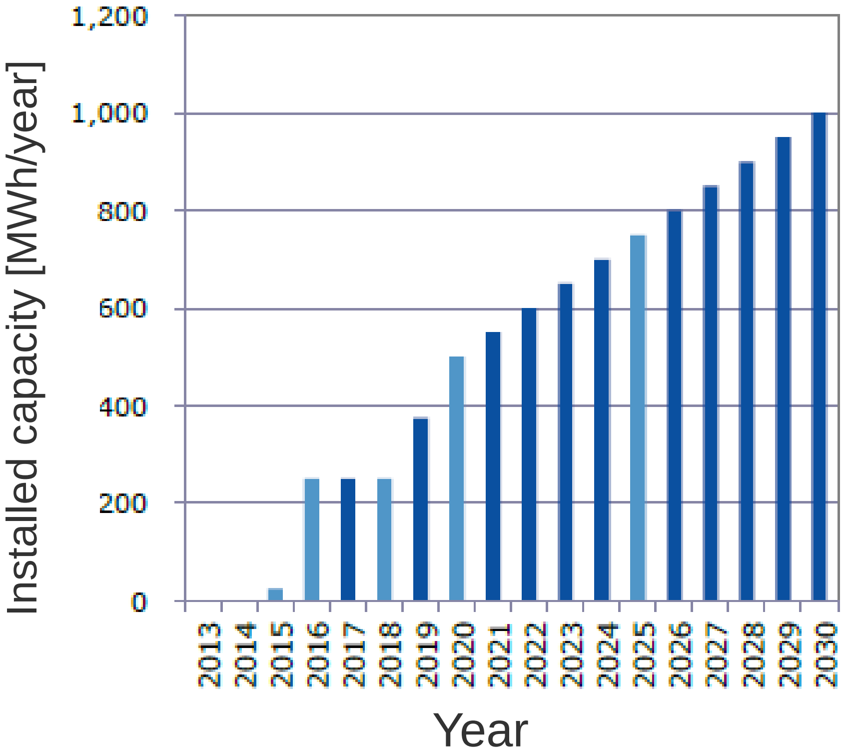
Large capacity achievement	200MWh
Charge and discharge speed	0.2~0.5C
Efficiency of charge and discharge	90%
Longevity	4500cycle(15 years)
Energy density	Volume energy density: approx. 140~170Wh/L Weight energy density(theory):780Wh/kg Weight energy density(actual):110Wh/kg
Price	400$/kWh, 2000$/kW, 300~400$/kWh in 2020
Technical level	practical

High energy density, Large capacity achievement

source: NEDO(new energy and industrial technology development organization) renewable energy technology white book ver.2

NaS Battery

Assumption of Installed capacity : 500MWh(2020) 1,000MWh(2030)
Assumption of System price: 370USD/kWh(2020) 140USD/kWh(2030)



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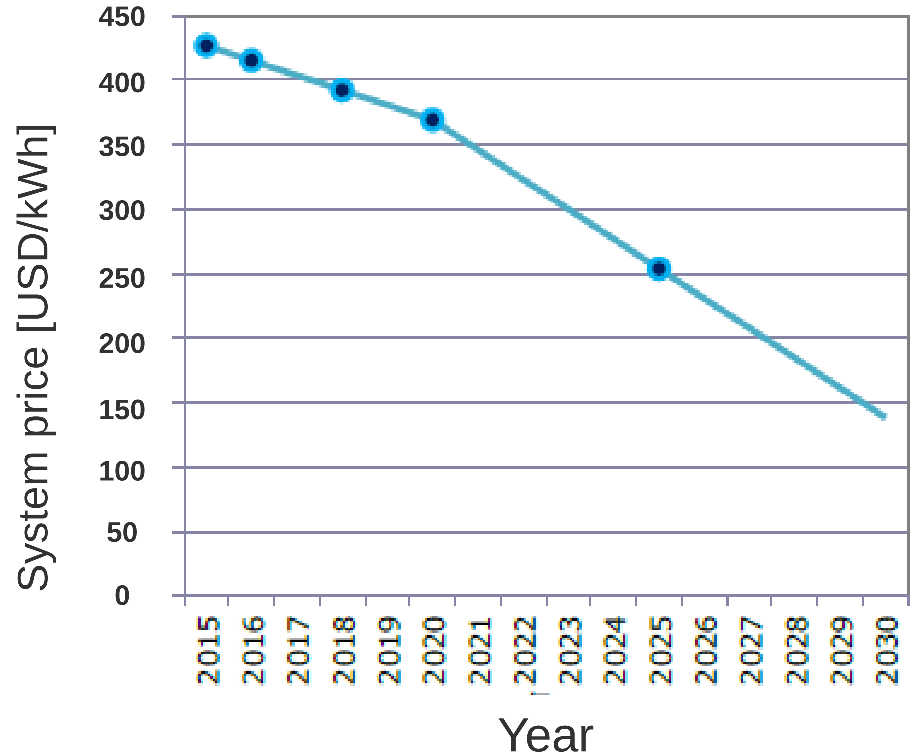
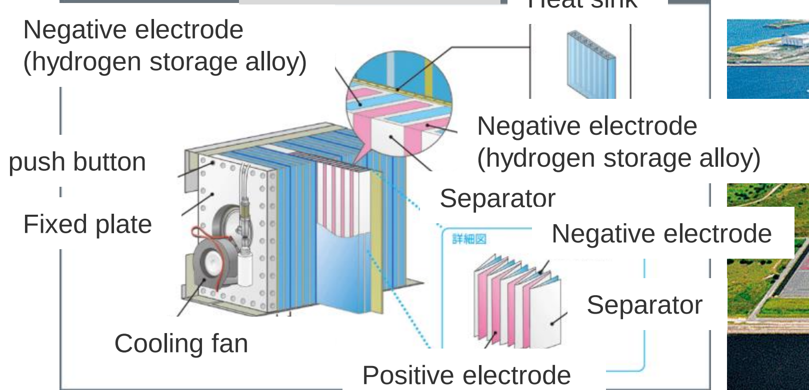


※Includes O&M costs and amortization costs.

source: 平成27年度新エネルギー当導入促進調査　再生可能エネルギー当の関連産業に関する調査（平成28年3月　みずほ情報総研株式会社）

Ni hydrogen

Gigacell structure



Ni hydorogen (100kWh)

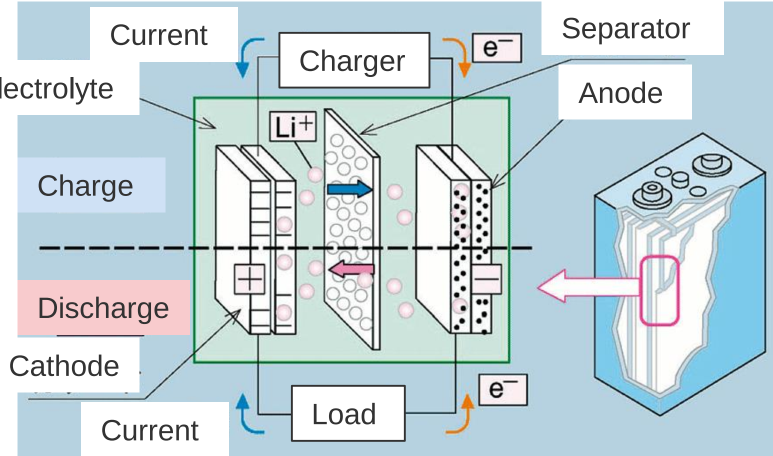
Large capacity achievement	Hundreds kWh
Charge and discharge speed	1~max 10C
Efficiency of charge and discharge	80~90%
Longevity	6000~8000 cycle(20 years)
Energy density	Volume energy density: approx. 40~100Wh/L Weight energy density(theory):275Wh/kg Weight energy density(actual):60Wh/kg
Price	3000$/kWh, 1000$/kW, 400$/kWh in 2020
Technical level	practical

Longevity is long, but temperature management is necessary, expensive.

source: NEDO(new energy and industrial technology development organization) renewable energy technology white book ver.2

Li

ESS(Energy Storage System)



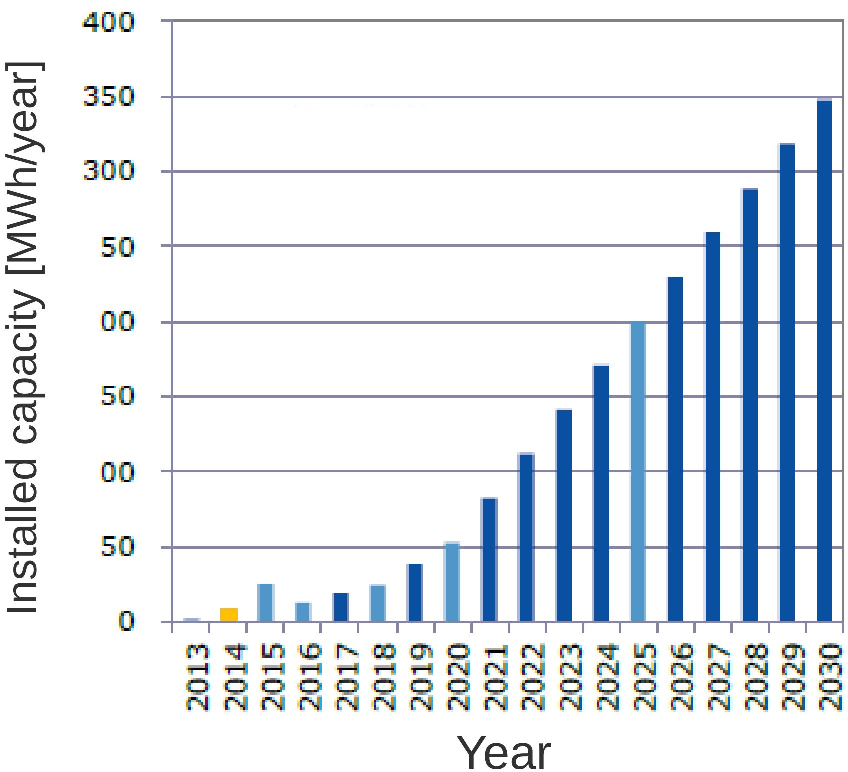
Large capacity achievement	Hundreds~thousands kWh
Charge and discharge speed	max 3C
Efficiency of charge and discharge	94~96%
Longevity	3500 cycle(10 years)
Energy density	Volume energy density: approx. 140~210Wh/L Weight energy density(theory):360Wh/kg Weight energy density(actual):120Wh/kg
Price	2000$/kWh, 1500$/kW, 500$/kWh in 2020
Technical level	practical

High energy density, Short term fluctuation control, microgrid

source: NEDO(new energy and industrial technology development organization) renewable energy technology white book ver.2

Li

Assumption of Installed capacity : 52.5MWh(2020) 347.5MWh(2030)
Assumption of System price : 1,380USD/kWh(2020) 1,040USD/kWh(2030)



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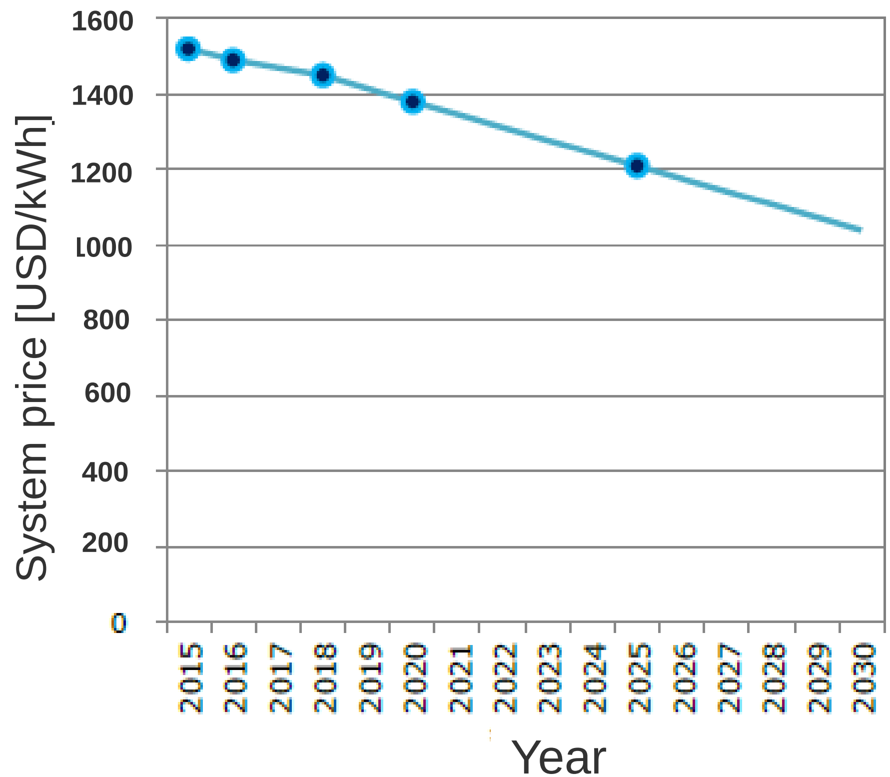
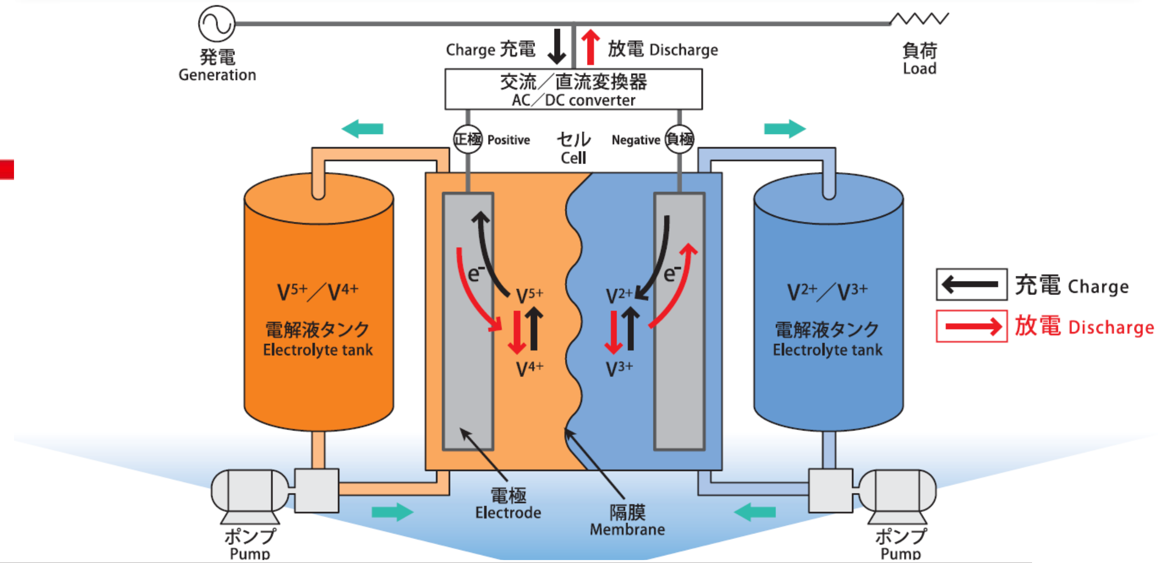


※Includes O&M costs and amortization costs.

source: 平成27年度新エネルギー当導入促進調査　再生可能エネルギー当の関連産業に関する調査（平成28年3月　みずほ情報総研株式会社）

Vanadium redox flow



Large capacity achievement	**1000 kWh**
Charge and discharge speed	max 1C
Efficiency of charge and discharge	80~90%
Longevity	20 years(electrolyte is usable permanently)
Energy density	Volume energy density: none Weight energy density(theory):103Wh/kg Weight energy density(actual):6~12Wh/kg
Price	600$/kWh, 4000$/kW
Technical level	practical

redox: reduction and oxidation

Instant response is useful for instant voltage drop. Energy density is small.

source: NEDO(new energy and industrial technology development organization) renewable energy technology white book ver.2

Vanadium redox flow

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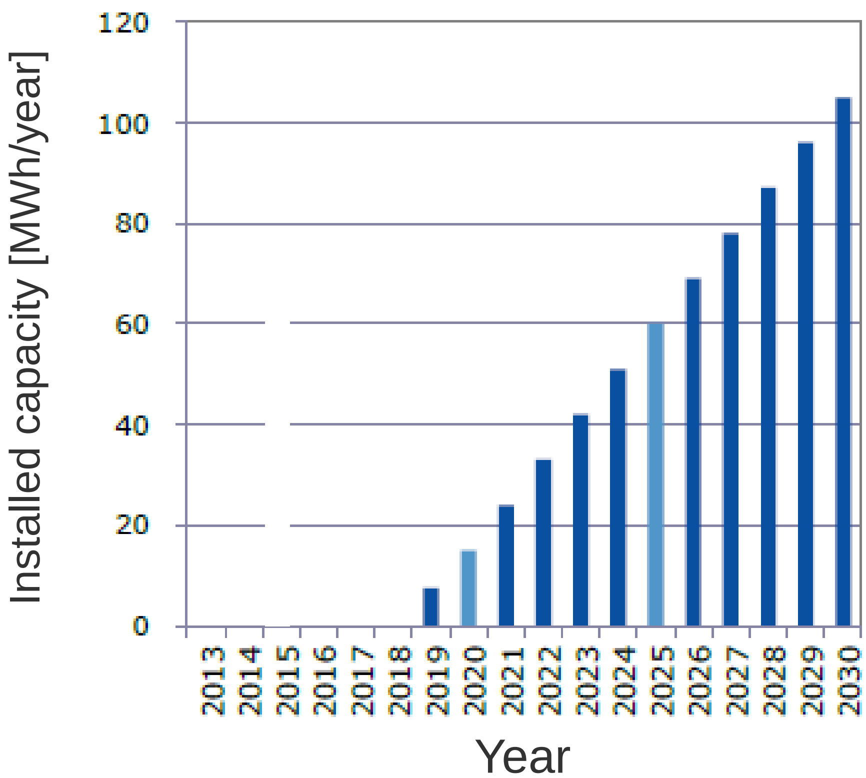
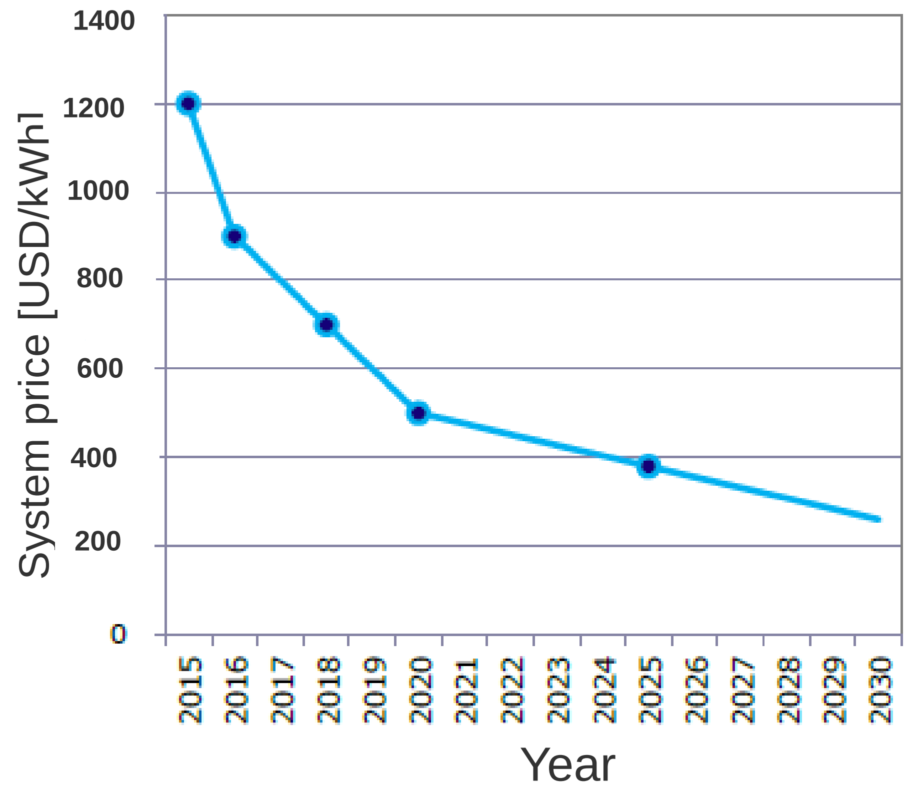
Assumption of Installed capacity : 15MWh(2020) 105MWh(2030)
Assumption of System price : 500USD/kWh(2020) 260USD/kWh(2030)

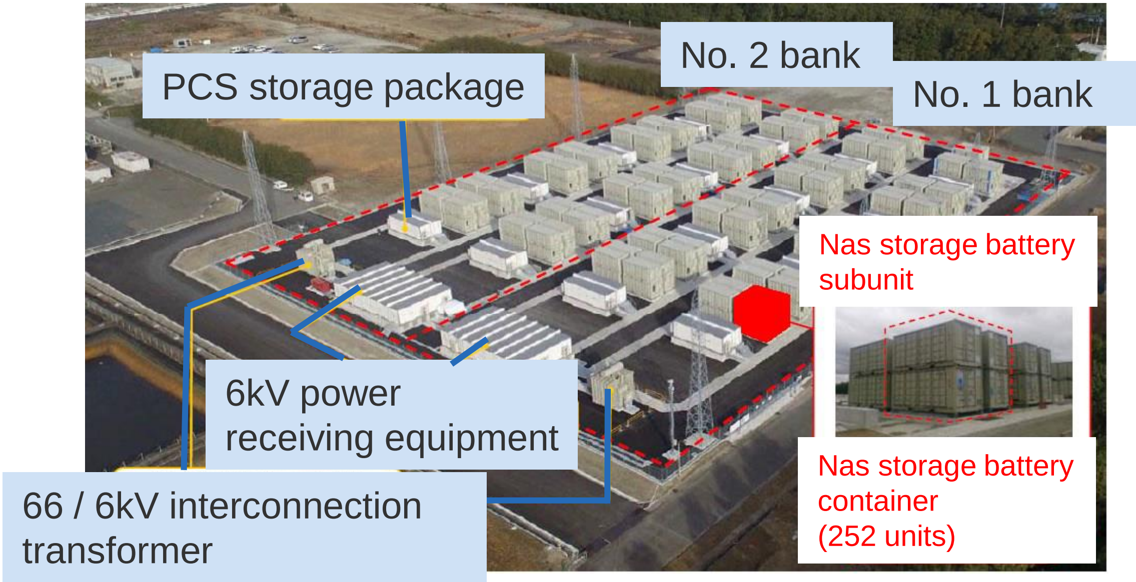




※Includes O&M costs and amortization costs.

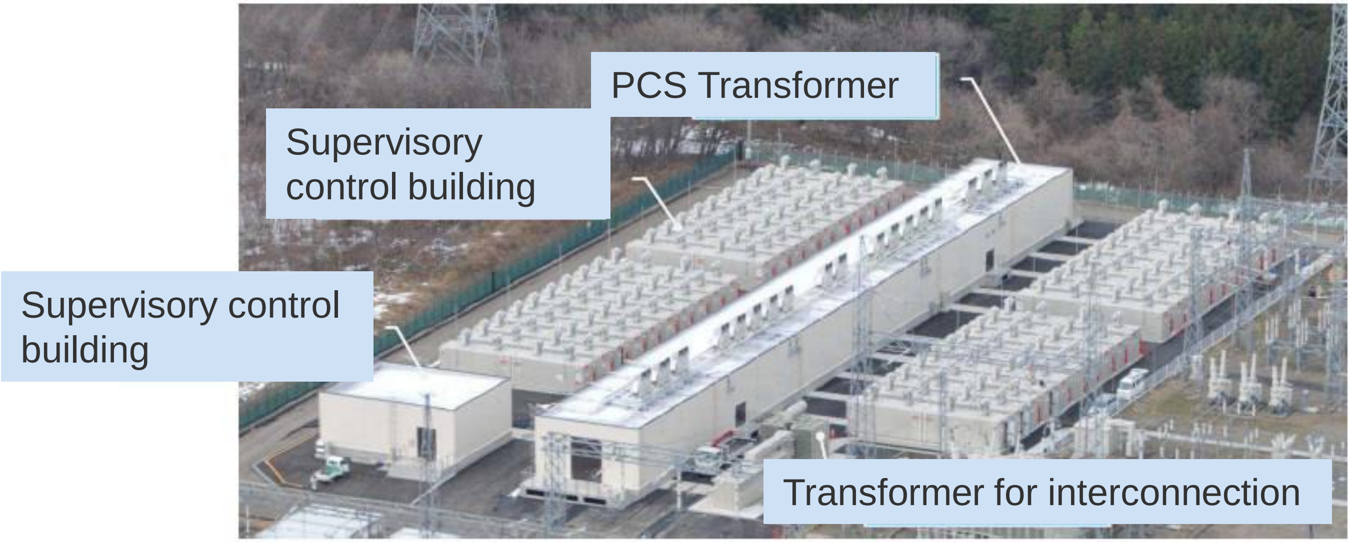
source: 平成27年度新エネルギー当導入促進調査　再生可能エネルギー当の関連産業に関する調査（平成28年3月　みずほ情報総研株式会社）

Practical examples of using storage batteries in Japan ①
（Buzen Storage Battery Substation（Kyushu Electric Power Company））



Installation area	14,000m^2
Demonstration period	2015-2016
Storage battery type	Nas battery
Output capacity	Output:50,000kW Capacity:300,000kWh
Purpose	Measures against frequency fluctuations

Practical examples of using storage batteries in Japan ②
（Nishi Sendai Substation（Touhoku Electric Power Company））



Installation area	6,000m^2 (100m×60m)
Demonstration period	2013-2017
Storage battery type	Li battery
Output capacity	Output:20,000kW Capacity:20,000kWh
Purpose	Measures against frequency fluctuations

Capital and Operation costs（NAS)

Object	Costs	Other
NAS 1200kW/ 7200kWh （6hours) （Container NAS Battery： 3600kWh＋ PCS：600kW × 2 parts)	【Capital Cost】 2,880,000USD（2.88MUSD) （2,400USD／kW, 400USD/kWh)	（※) If you plan to replace only the deteriorated parts, you can reduce the inspection cost. The cost will change depending on the installation conditions and specifications. The cost of power loss due to charging and discharging is not included in the operation cost.
	【Operating Cost】 Total cost : 81,000 USD／year １．Contract with a call center in the event of an abnormality : 6,000 USD / year （90,000 USD / 15 years) • Check operation data (only when an abnormality occurs) • Accepting inquiries in the event of an abnormality, etc. ２．Periodic inspection of NAS battery: 35,000 USD / year (525,000 USD / 15 years) • Inspection every two years • Replace all items recommended by the manufacturer （※) ３．Regular inspection of PCS: 40,000 USD / year (600,000 USD / 15 years) • Inspection and replacement of all parts recommended by the manufacturer （※)	

Capital and Operation costs （Lithium ion)

Object	Costs	Others
Li 5MW 30MWh（6hours）	【Capital Cost】 25,000,000USD （25MUSD） (5,000USD/kW, 833USD/kWh) 【Operating Cost】 750,000USD/year Annual operating cost is about 3% of capital cost (Inspection, replacement of parts, etc.)	The cost will change depending on the installation conditions and specifications. The cost of power loss due to charging and discharging is not included in the operation cost.

Capital and Operation costs （Redox Flow)

Object	Costs	Others
Redox Output：5MW Capacity：30MWh (6hours)	【Capital Cost】 19,500,000USD (19.5MUSD) (3,900USD/kW, 650USD/kWh)	The cost will change depending on the installation conditions and specifications.
	【Operating Cost】 195,000 USD / year Annual operating cost is about 1% of capital cost	The cost of power loss due to charging and discharging is not included in the operation cost.

Cost varies depending on capacity.

The recommended maintenance items and schedule are as follows.

*recommended

			Interval* (Year)	Year																				
				Install	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Annual Inspection			1		o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	
Parts Replacement																								
Flow Battery	1	Fuse	10											o										
Flow Battery	2	Heat Exchanger Fan	5						o					o					o					
Flow Battery	3	Electrolyte Pump	5						o					o					o					
Flow Battery	4	Pump Inverter	10											o										
Flow Battery	5	(N_2 Gen.) Compressor**	1		o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	
Flow Battery	6	(N_2 Gen.) Cylinder**	2			o		o		o		o		o		o		o		o		o		
Flow Battery	7	(N_2 Gen.) Electric Valve**	4					o				o				o				o				
Flow Battery	8	(BMS) Touch Panel	10											o										
Flow Battery	9	(BMS) CPU Board	10											o										
Flow Battery	10	(BMS) Power supply unit	5						o					o					o					
PCS	11	Cooling fan	5						o					o					o					
PCS	12	Circuit breaker	10											o										
PCS	13	Touch Panel	10											o										
PCS	14	Relay	10											o										
PCS	15	Electrolytic capacitor	10											o										
PCS	16	Fuse	10											o										
PCS	17	Power supply unit	10											o										

PSPP Capacity Consideration in Sri Lanka and Japan

Installed PSPP Capacity as Balancing Resources

(MW)

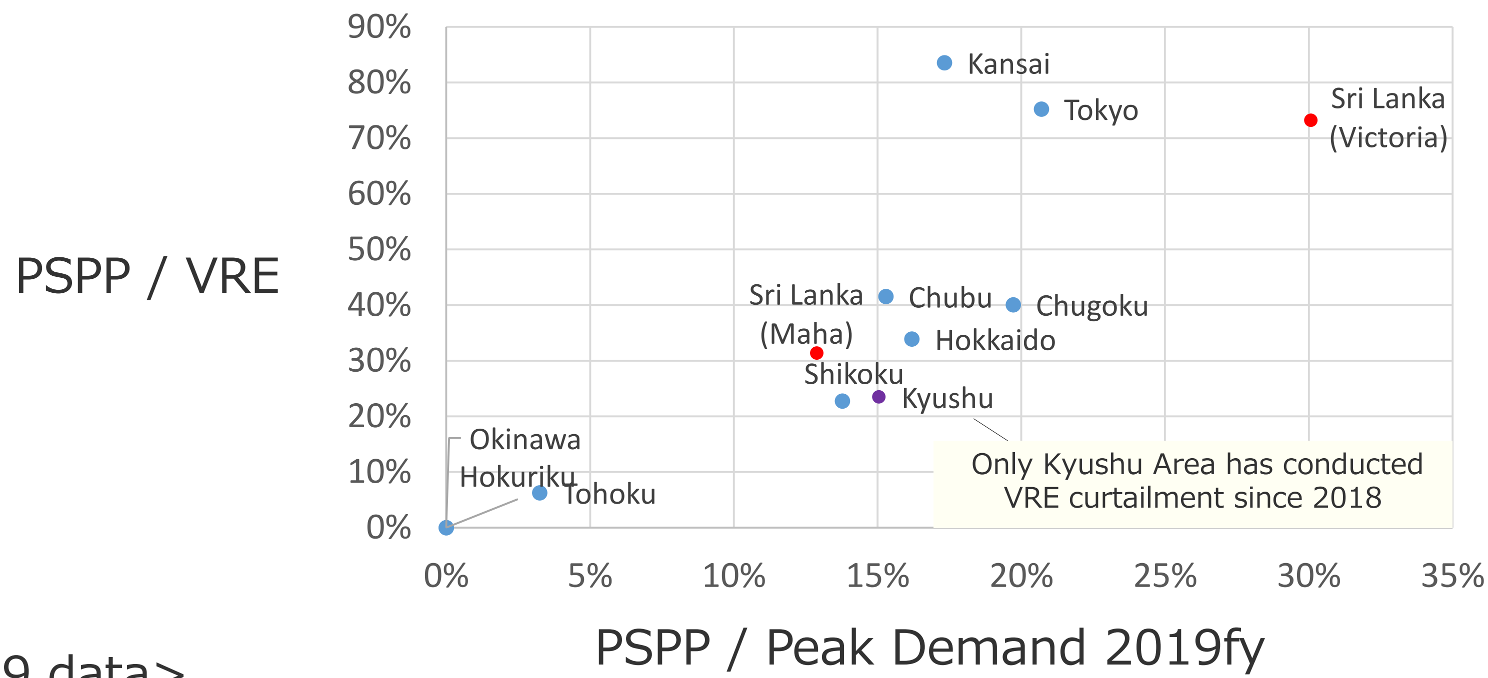
Control Area	(A) PSPP Capacity	(B) Peak Demand 2019fy	(C) Installed PV Capacity	(D) Installed WF Capacity	A/B	A/C+D
Hokkaido	800	4,940	1,880	480	16%	34%
Tohoku	460	14,170	5,760	1,580	3%	6%
Tokyo	11,400	55,090	14,720	430	21%	75%
Chubu	3,880*	25,370	8,970	370	15%	42%
Hokuriku	0	5,030	1,030	160	0%	0%
Kansai	4,880	28,160	5,720	120	17%	84%
Chugoku	2,120	10,750	4,930	360	20%	40%
Shikoku	690	5,010	2,750	280	14%	23%
Kyushu	2,350	15,620	9,440	580	15%	23%
Okinawa	0	1,480	350	14	0%	0%

*The capacity includes PSPPs owned by other companies

Mar 2020 data

Source : OCCTO, METI

Graph(2029 Condition of Sri Lanka)



<2029 data>

(MW)

Control Area	(A) PSPP Capacity	(B) Annual Demand	(C) Installed PV Capacity	(D) Installed WF Capacity	A/B	A/C+D
Sri Lanka (Victoria)	1,400	4,655	1,110	803	30%	73%
Sri Lanka (Maha)	600	4,655	1,110	803	13%	31%

Source:LTGEP2020-2039(Mar 2020)

Graph(2039 Condition of Sri Lanka)

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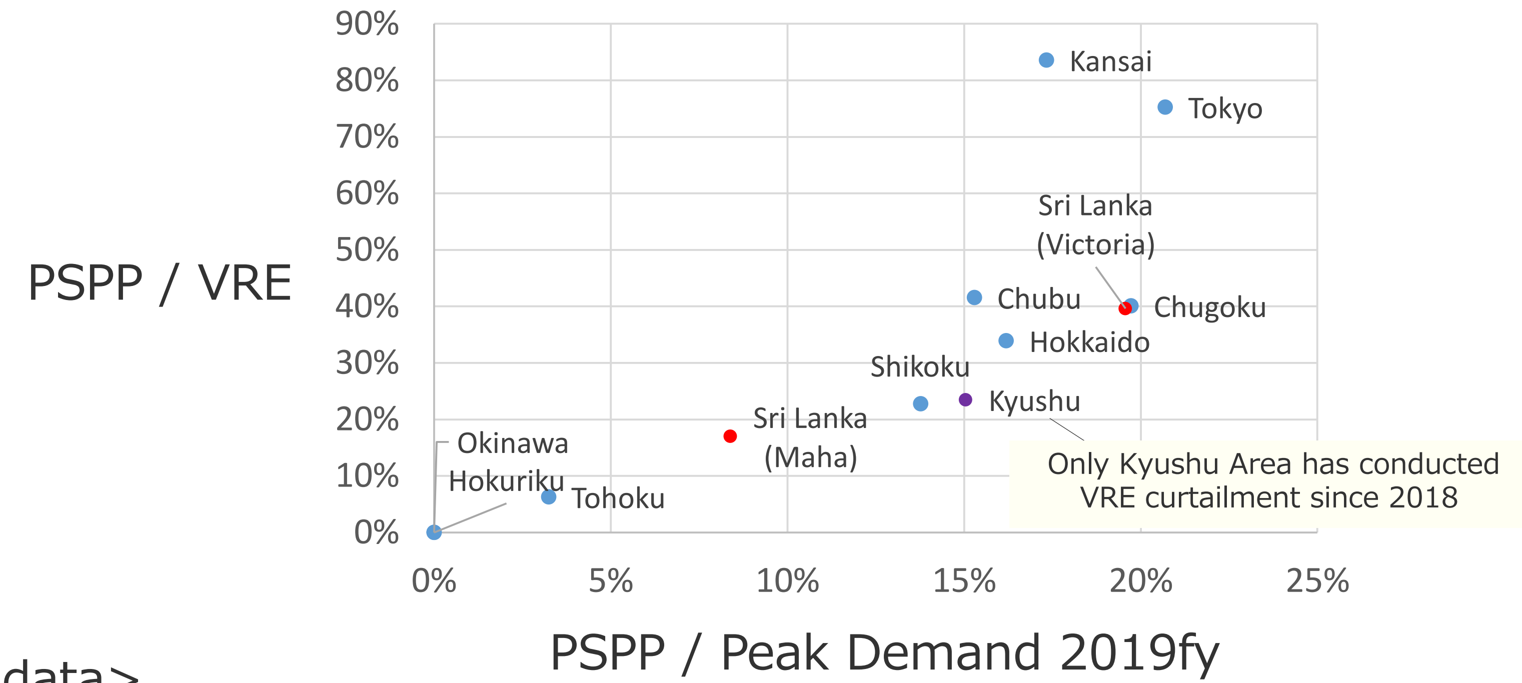


<2039 data>

(MW)

Control Area	(A) PSPP Capacity	(B) Annual Demand	(C) Installed PV Capacity	(D) Installed WF Capacity	A/B	A/C+D
Sri Lanka (Victoria)	1,400	7,155	2,210	1,323	20%	40%
Sri Lanka (Maha)	600	7,155	2,210	1,323	8%	17%

Source:LTGEP2020-2039(Mar 2020)

Suggestion (Simulations of appropriate PSPP capacity)

Is it worthy for you to conduct simulations to calculate appropriate PSPP capacity?

<**Objective function**>

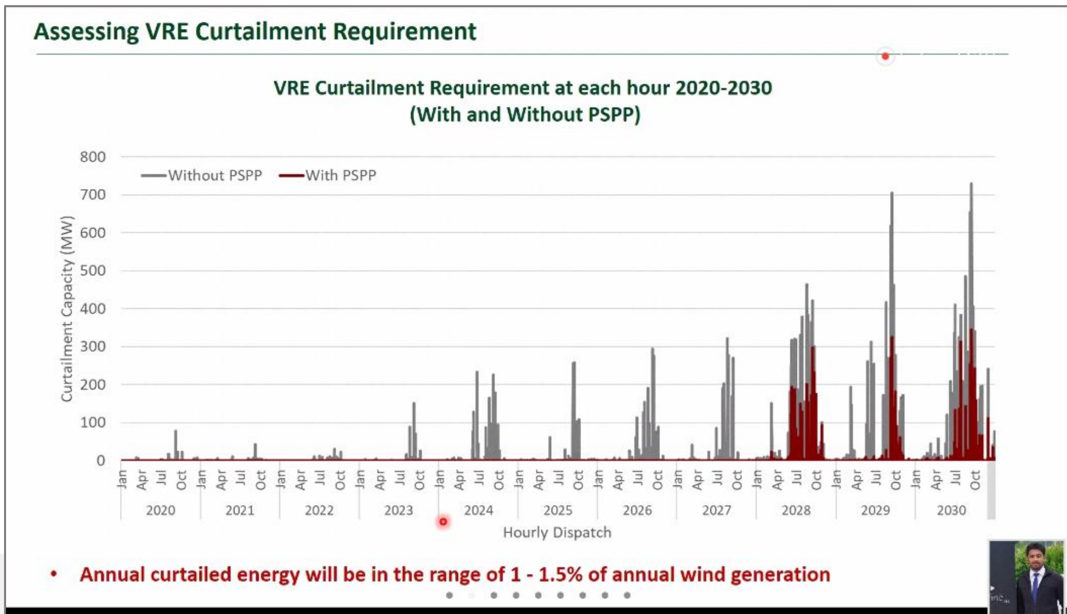
Total Merit = (CO_2 emission price[USD/MWh] + thermal marginal cost[USD/MWh]) × thermal generation reduction*[MWh]

*VRE curtailment reduction × 70% (PSPP efficiency)

<**What will C/P do?**>

To conduct the following simulation on several patterns of installed PSPP capacity and output simulation result as VRE curtailment reduction by cumulative MWh until 2030.

If you agree with this suggestion, we would like to output the simulation result prior to the next site survey planned in October.



Source : CEB

<Question>

Could you tell me the premises on which your simulations are based?

1. Thermal output in VRE Curtailment (Stop or minimum running output) →minimum running output
2. How to consider PSPP reservoirs constraint (with SDDP possible?) →Yes

Simulation Premises and Output Image1

〇When the simulations with various scenario are until 2030, they are for battery installation considering PSPP installation will be after 2030.
Therefore, installed capacity is reduced from the original one, and it includes 50MW battery CEB planned to install in 2025.

〇**The time of battery installation is 2025**, considering CEB's 50 MW battery installation plan?

Installed Battery Capacity [MW]	Thermal Generation Reduction [cumulative MWh until 2030]	CO_2 Emission Reduction Merit [USD]	Thermal Generation Reduction Merit [USD]	Total Merit [USD]
50				
50+100				
50+200				
50+300				
50+400				
50+500				

Simulation Premises and Output Image2

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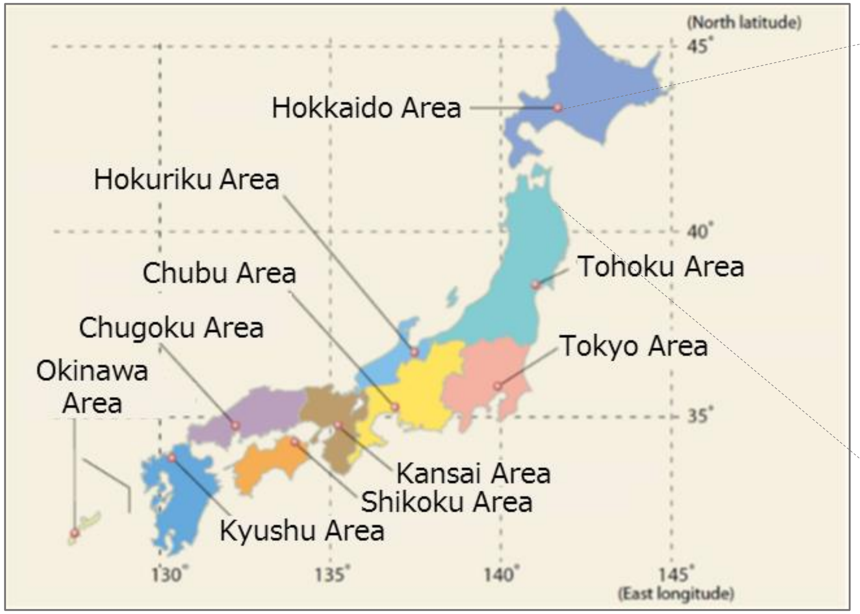
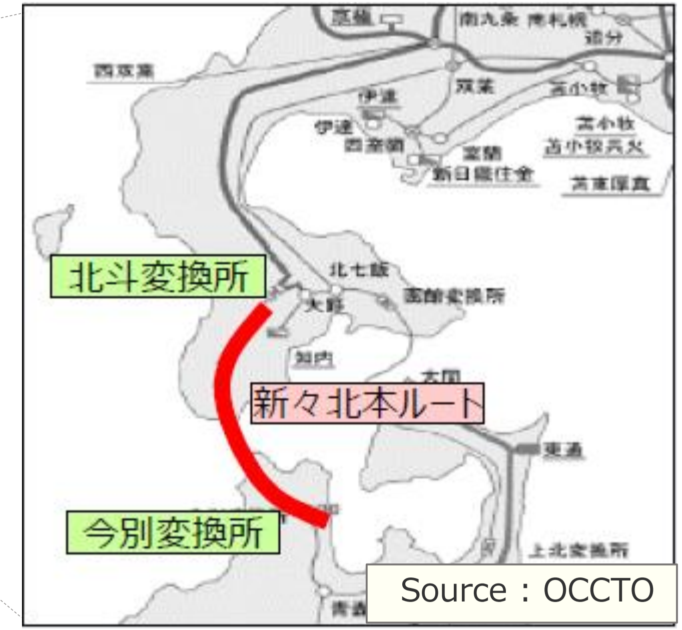
- ○If it is possible to conduct **a simulation with only base case scenario** from 2031 until 2039, it is for PSPP & battery installation.
- ○**The installation time is 2030 considering PSPP construction period**?
- ○Installed capacity includes 50MW + 100MW battery CEB planned to install in 2025 and 2030.
- ○Installed capacity is up to 150MW+1400MW considering constructions of both maha3 and Victoria in 2030 are not realistic.

Installed battery & PSPP Capacity [MW]	Thermal Generation Reduction [cumulative MWh until 2039]	CO_2 Emission Reduction Merit [USD]	Thermal Generation Reduction Merit [USD]	Total Merit [USD]
150+200				
150+400				
150+600				
150+800				
150+1000				
150+1200				
150+1400				

Cost Benefit Evaluation of Reinforcement of Hokkaido-Honshu HVDC link





Source：OCCTO

燃種 (燃料費, CO2コスト単価(円/kWh))
石油（23.9, 3.9）
ＬＮＧ （11.0～15.5, 2.0～2.8）
石炭※（5.9, 4.5）
太陽光，風力（0, 0）

Source：OCCTO

Fuel type (Marginal cost, CO2 emission price) [USD / MWh] @ JPY/USD = 106
Oil (225, 37)
LNG (104 - 146, 19 - 26)
Coal (56, 42)
VRE (0, 0)

Examination of storage battery introduction amount

December 16, 2021

Chubu Electric Power Co., Inc.
Nippon Koei Co., Ltd.

CHUBU Electric Power
NIPPON KOEI

Examination of storage battery introduction amount

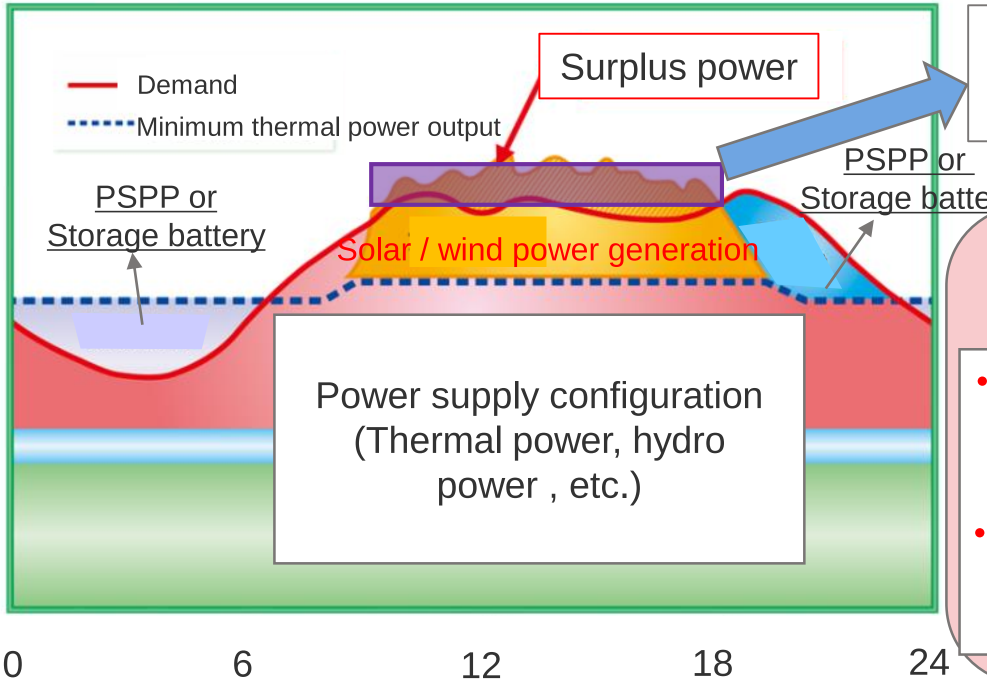
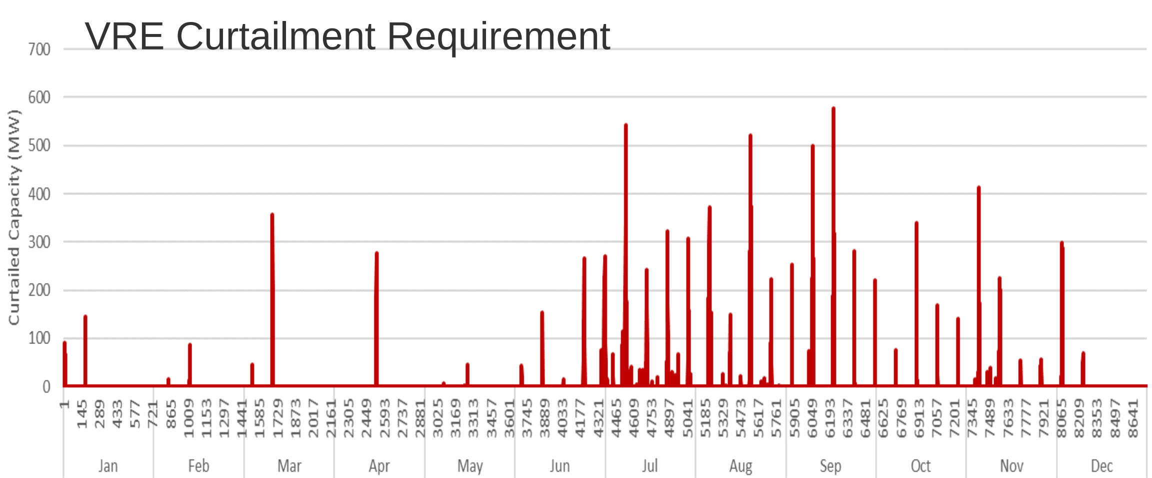


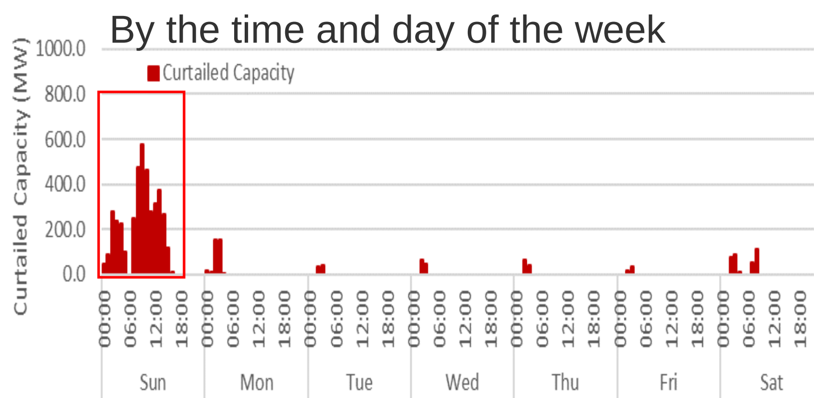
Image of surplus power generation

Calculate surplus power and consider the amount of storage batteries to be introduced.

Theme: It is necessary to introduce a battery with an appropriate capacity in consideration of economic efficiency and future potential.

- A large-capacity storage battery is required to determine the amount of storage battery to be introduced in consideration of Sunday, which is an excessive evaluation.
- It is necessary to determine the amount of storage batteries to be installed in consideration of the development of PSPP in the future..





Previous presentation material from CEB

How to proceed with the examination of the amount of storage batteries introduced

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Calculate the amount of storage battery installed from the surplus power.

In case of proceeding with Proposal ①

Based on the Curtailment Requirement calculated by CEB, consider the amount of storage batteries introduced in consideration of PSPP.

Merit

Compared to proposal②, the amount of work is small and evaluation does't take time.

Demerit

It cannot be evaluated from various aspects such as suppression of thermal power generation because it is not judged by the power source composition,

In case of proceeding with Proposal ②

Consider the amount of storage batteries to be installed by comprehensively judging the power source composition and power demand.

Merit

Surplus power can be judged comprehensively based on the nature of each power source.

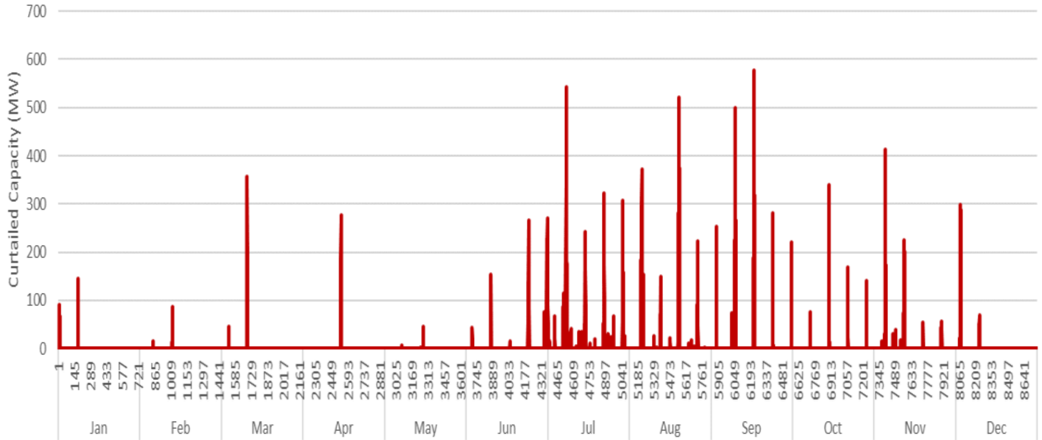
Demerit

The amount of work is larger than that of proposal①, and it takes time and effort.

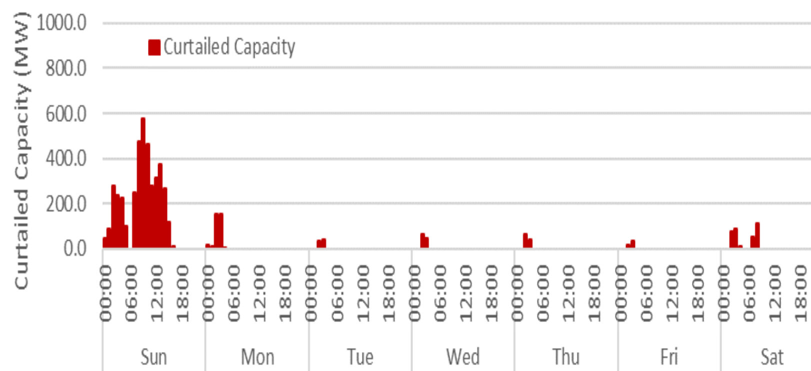
We would like to proceed with proposal①. What is your opinion from CEB?

In case of proceeding with Proposal ①

VRE Curtailment Requirement



By the time and day of the week



6 .

Previous presentation material from CEB

- Please tell us the calculation conditions of the data provided above.
- Please tell us the forecast VRE Curtailment Requirement data for 2030 and 2040.

Requests from JICA expert team②

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In case of proceeding with Proposal ②

We would like to receive the following information (data).

① Data for the maximum and minimum power demand curves for a day.

② Power generation configuration and the amount of power generated by each power generation in case①.

③ Suppressible power generation (MW) such as thermal power generation etc. according to solar / wind power generation.

④ The amount of solar and wind power targets introduced by 2025 and 2030. (equipment capacity: MW)

Considering of storage battery introduction amount

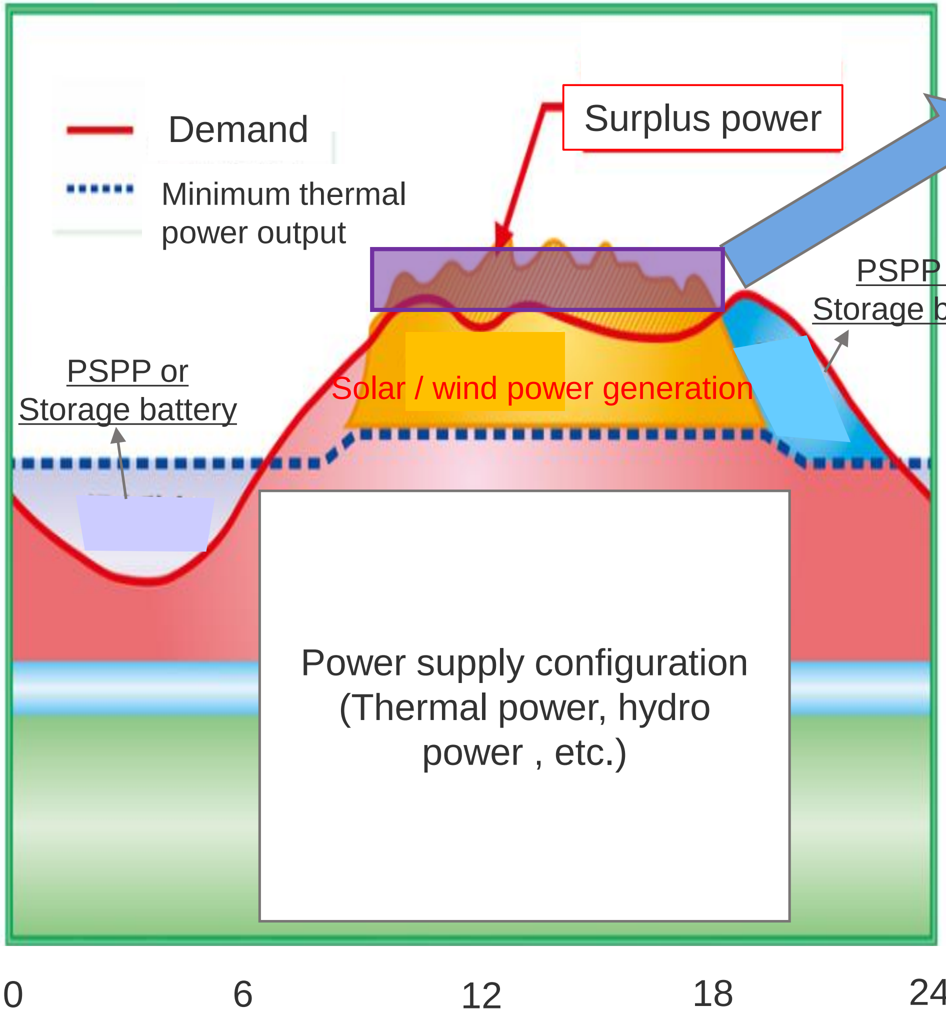

Image of surplus power generation

With the target of achieving 70% renewable energy in 2030, calculate surplus power and consider the amount of storage batteries to be introduced.

① The surplus power and renewable energy introduction amount were calculated by SDDP simulations under the condition of the battery introduction amount of some patterns. (Including utilization of PSPP)

② Utilizing the results of SDDP simulations, we calculated the effect of reducing thermal fuel and CO2, and considered the amount of storage batteries to be introduced.

① SDDP simulation calculation result

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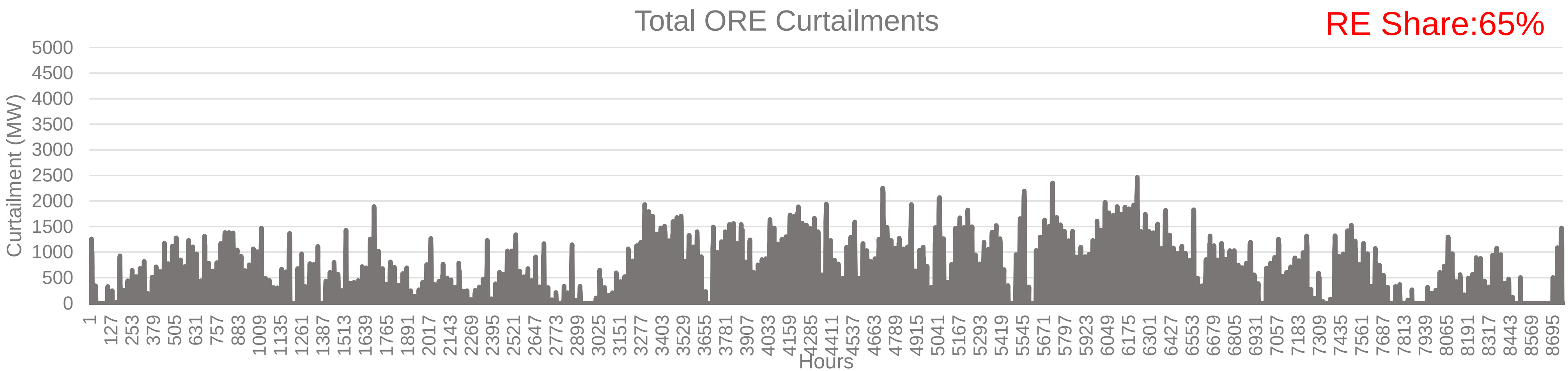
When not installing a storage battery



	Total Thermal	LVPS 1	LVPS 2	LVPS 3	New CCY 1	New CCY 2	KCCP 1	KCCP 2	West Coast	Uthuru Janani	Kelanitissa New GTs	Containerized Emergency Power Plant	Firm Thermal Power
Annual Fuel Cost (USD million)	581.03	86.72	105.20	74.82	81.27	86.18	13.39	6.66	92.33	2.07	0.45	0.88	31.06
Annual CO2 Emissions (Tons)	9150146	2369400	2874400	2044300	480260	509230	79106	39367	545590	15645	2649	7170	183029

Contents of discussion with CEB Aiming to introduce 70% of renewable energy in 2030, consider the optimum introduction amount based on the storage battery introduction cost, etc.

- SDDP simulation with a storage battery capacity of 5 patterns (500MW*4h, 1,000MW*4h, 1,500MW*4h, 2,000MW*4h, 2,500MW*4h)
- Calculate the renewable energy ratio (%), surplus electricity, thermal fuel cost, and CO2 emissions.

①　SDDP simulation calculation result

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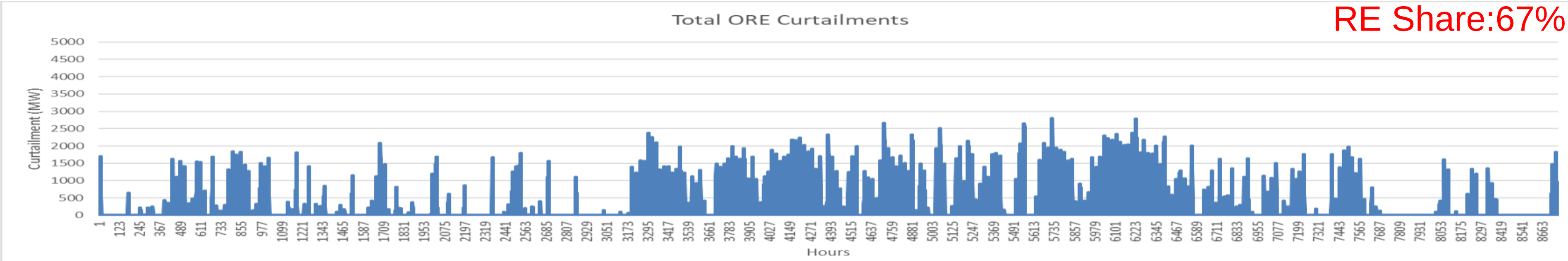
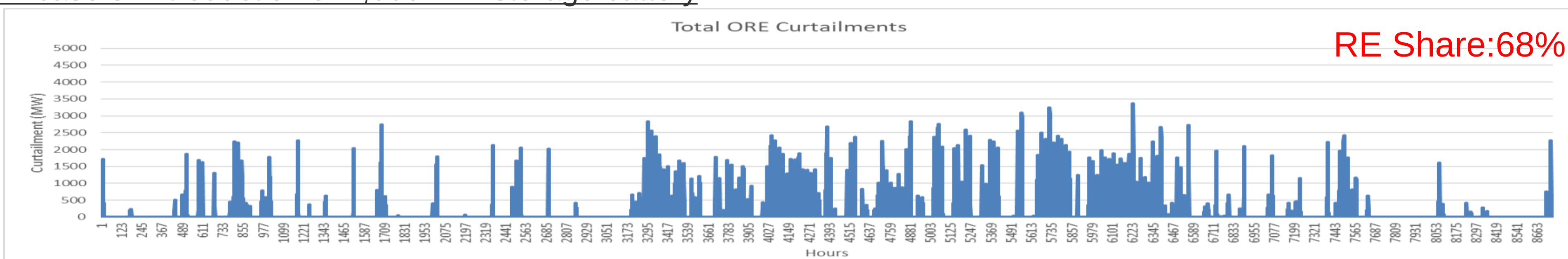
①In case of introduction of 500 MW storage battery



	Total Thermal	LVPS 1	LVPS 2	LVPS 3	New CCY 1	New CCY 2	KCCP 1	KCCP 2	West Coast	Uthuru Janani	Kelanitissa New GTs	Containerized Emergency Power Plant	Firm Thermal Power
Annual Fuel Cost (USD million)	546	83	106	75	77	81	15	7	90	2	0	1	9
Annual CO2 Emissions (Tons)	8,881,666	2,255,000	2,906,000	2,050,700	452,750	477,830	86,607	43,146	534,380	14,632	310	5,407	54,903

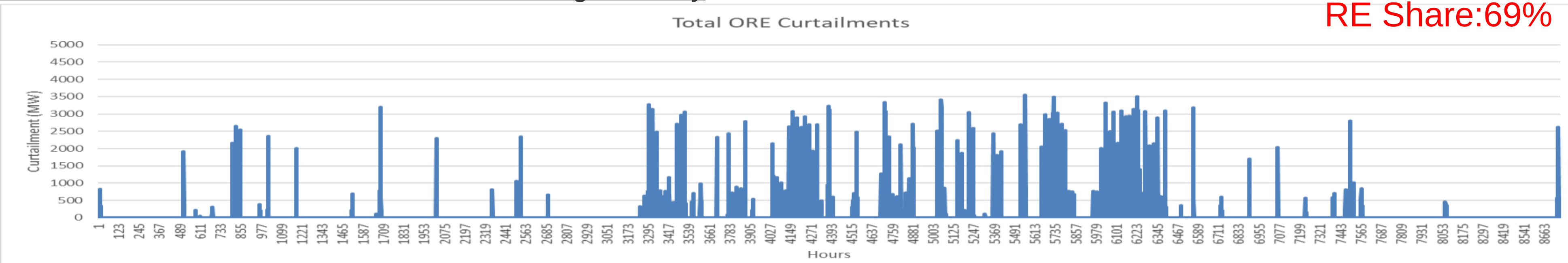
②In case of introduction of 1,000 MW storage battery



	Total Thermal	LVPS 1	LVPS 2	LVPS 3	New CCY 1	New CCY 2	KCCP 1	KCCP 2	West Coast	Uthuru Janani	Kelanitissa New GTs	Containerized Emergency Power Plant	Firm Thermal Power
Annual Fuel Cost (USD million)	522.22	77.11	106.32	74.87	80.82	74.83	13.02	5.59	86.43	1.29	0.00	0.11	1.82
Annual CO2 Emissions (Tons)	8619086	2106700	2904800	2045700	477570	442200	76933	33055	510720	9730	0	896	10782

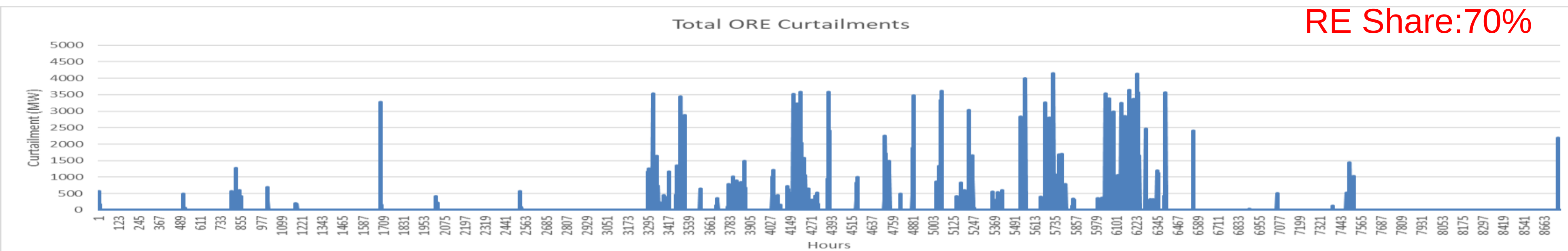
① SDDP simulation calculation result

③In case of introduction of 1,500 MW storage battery



	Total Thermal	LVPS 1	LVPS 2	LVPS 3	New CCY 1	New CCY 2	KCCP 1	KCCP 2	West Coast	Uthuru Janani	Kelanitissa New GTs	Containerized Emergency Power Plant	Firm Thermal Power
Annual Fuel Cost (USD million)	507.53	72.22	106.26	75.20	67.68	70.08	10.60	7.35	93.08	1.77	0.02	0.24	3.02
Annual CO2 Emissions (Tons)	8434750	1973100	2903400	2054800	399930	414090	62661	43438	550010	13382	114	1991	17834

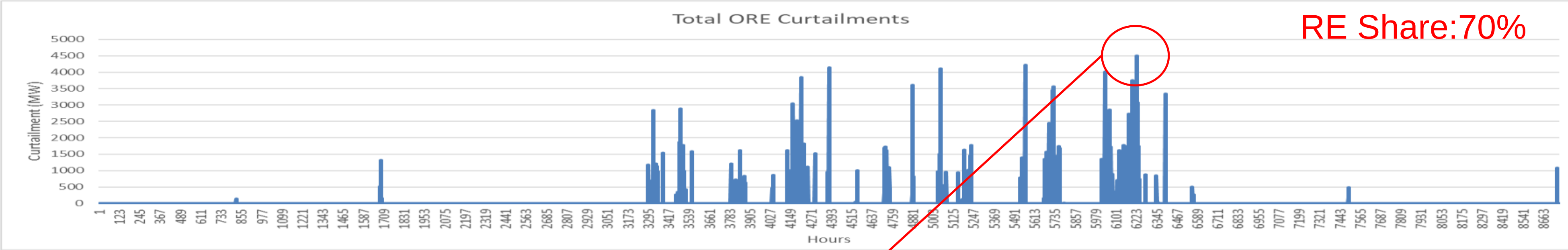
④In case of introduction of 2,000 MW storage battery



	Total Thermal	LVPS 1	LVPS 2	LVPS 3	New CCY 1	New CCY 2	KCCP 1	KCCP 2	West Coast	Uthuru Janani	Kelanitissa New GTs	Containerized Emergency Power Plant	Firm Thermal Power
Annual Fuel Cost (USD million)	499.63	68.98	106.50	75.19	74.37	67.49	10.91	5.51	86.66	1.22	0.00	0.02	2.77
Annual CO2 Emissions (Tons)	8322133	1884600	2909900	2054500	439480	398820	64493	32588	512070	9180	0	157	16345

①　SDDP simulation calculation result

⑤In case of introduction of 2,500 MW storage battery



	Total Thermal	LVPS 1	LVPS 2	LVPS 3	New CCY 1	New CCY 2	KCCP 1	KCCP 2	West Coast	Uthuru Janani	Kelanitissa New GTs	Containerized Emergency Power Plant	Firm Thermal Power
Annual Fuel Cost (USD million)	497.33	68.97	106.05	75.11	65.20	77.11	11.12	2.20	88.09	1.26	0.00	0.10	2.13
Annual CO2 Emissions (Tons)	8297217	1884500	2897600	2052100	385290	455660	65719	12995	520500	9488	0	802	12564

1568	200	200	500		600	200	1523	4040		
4760	247	-353	-383	14296	1859	1388	4380	6669		205
Total Hydro	PSPP (Gen)	PSPP (Pump)	Battery Storage	Total ORE	Mini Hydro	Biomass	Wind	Solar		Total ORE Curtailments
212.589	0	-198	-282.06	1613.8	330	160	1123.8	0		0
212.589	65.964	-198	-144.52	1695.5	330	160	1205.5	0		0
264.04	44.229	-198	1211.4	394.86	130.56	6.0398	250.81	7.4504		1320.174
212.589	24.858	-198	-1047.7	2522.32	330	160	1216.3	816.02		0
212.589	154.17	-198	-1595.9	3310.8	330	160	1230.3	1590.5		0
310.964	184.36	-198	-2091.3	4044.8	330	160	1170.7	2384.1		0
317.789	151.25	-198	-2154.9	4226.8	330	160	1248.4	2488.4		0
317.961	197.96	-198	2159	0	0	0	0	0		4495.1
386.229	197.96	-198	-2463	4581.7	330	160	1181.4	2910.3		0
319.684	137.22	-198	1318.1	731.269	82.055	52.464	197.99	398.76		3075.79
289.269	197.96	-198	-1792.1	3897.8	330	160	1195.9	2211.9		0
291.873	193.39	-198	-1483.3	3585.4	330	160	1239.5	1855.9		0

The ORE curtailment includes battery discharge.

ORE curtailment capacity max affects the PCS installation burden of power generators.

② Optimal amount of storage batteries to be introduced

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【Batteries introduction amount examination conditions and priorities】

① 70% introduction of renewable energy in 2030
② Storage battery introduction cost (storage battery, Inverter)
③ Reduction of fuel cost for thermal power generation
④ Reduction of CO_2 emissions
⑤ PCS installation burden cost on the power generation side

Mn USD	Mn USD
Inverter price / MW	Battery price / MWh
0.3	1.04

Mn USD
CO2 price / Ton
0.000005

Mn USD
PCS price / kW
0.0003

			Replacement cycle: 15 years					Replacement cycle: 10 years	
%	MW	Hours	Mn USD	Mn USD	Tons	Mn USD	MW	Mn USD	Mn USD
RE percentage	Battery Capacity	Battery Duration	Battery Installation Cost(Yearly)	Thermal Fuel Cost	CO2 Emission	CO2 Emission Cost	RE Curtailment capacity max	PCS Installation Cost	Total Cost(Annual)
70	2500	4	743.3333333	497	8,297,217	41	4,495	135	1,417
70	2000	4	594.6666667	500	8,322,133	42	4,152	125	1,260
69	1500	4	446	508	8,434,750	42	3,545	106	1,102
68	1000	4	297.3333333	522	8,619,086	43	3,363	101	964
67	500	4	148.6666667	546	8,881,666	44	2,802	84	823

※ Battery price is assumed to be 2030 (lithium battery)
Storage battery: 1,040 USD / kWh Converter: 300 USD / kW Replacement cycle: 15 years

If 70% is the first priority in 2030, 2,000 MW storage battery will be introduced.

② Optimal amount of storage batteries to be introduced

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【Cost-effectiveness of introducing storage batteries】

			Replacement cycle: 15 years					Replacement cycle: 10 years	
%	MW	Hours	Mn USD	Mn USD	Tons	Mn USD	MW	Mn USD	Mn USD
RE percentage	Battery Capacity	Battery Duration	Battery Installation Cost(Yearly)	Thermal Fuel Cost	CO2 Emission	CO2 Emission Cost	RE Curtailment capacity max	PCS Installation Cost	Total Cost(Annual)
70	2500	4	743.3333333	497	8,297,217	41	4,495	135	1,417
70	2000	4	594.6666667	500	8,322,133	42	4,152	125	1,260
69	1500	4	446	508	8,434,750	42	3,545	106	1,102
68	1000	4	297.3333333	522	8,619,086	43	3,363	101	964
67	500	4	148.6666667	546	8,881,666	44	2,802	84	823

According to the SDDP simulation results, the renewable energy introduction rate increases by only about 1% for the introduction of 500 MW storage battery.

Consideration is needed to achieve the 70% renewable energy introduction target in 2030, such as cost effectiveness and further curbing of thermal power generation.

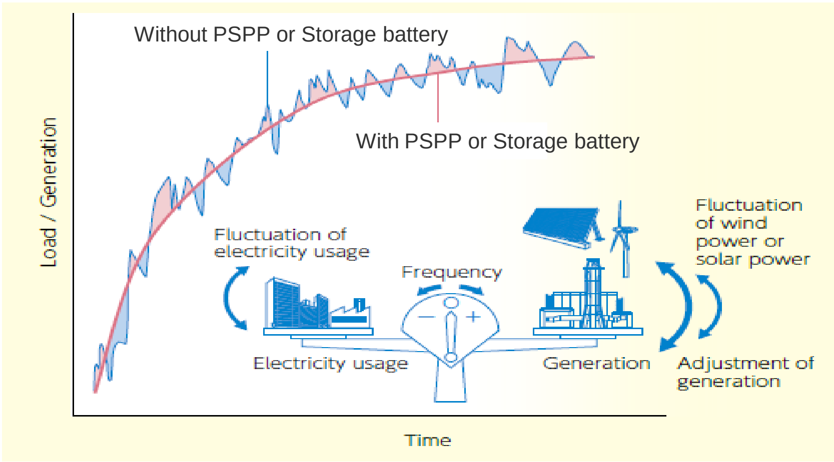
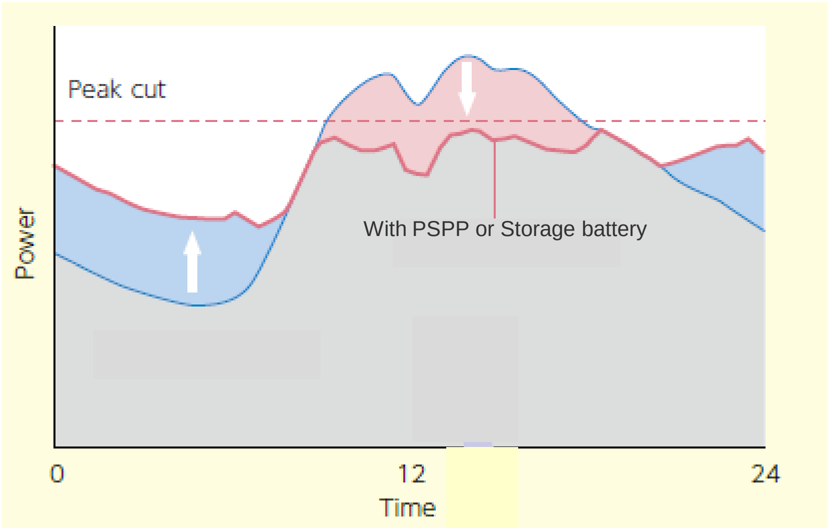
1st Technical Seminar

（Comparison of the cost merit between PSPP and storage battery）

15th December, 2020

Chubu Electric Power Co., Inc.
Nippon Koei Co., Ltd.

Purpose of power storage technology

Purpose	Explanatory diagram	Utilization contents
Measures for frequency fluctuation		**Imbalance between demand and supply could cause frequency fluctuation. Utilizing storage technology can achieve minimization of frequency fluctuation by utilizing their high-speed response.**
Measures for surplus electricity		**It stores surplus electricity such as solar power generation and utilizes the stored electricity when needed.**

Types of power storage technology

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Technology of Storage Energy	Shape of storage	Method
Storage battery	Chemical energy	NAS, Li (Lithium-ion battery) Vanadium redox flow
CAES (Compressed Air Energy Storage)	Pressure energy	compress air at night, using it daytime to generate power
Hydrogen storage	Chemical energy	Use for fuel battery
PSPP (Pumped storage power plants)	Hydro energy	Pumping water with surplus electricity, discharge when needed

Comparison (Storage battery ↔ PSPP)

We would like to propose the best method for Sri Lanka.

source: NEDO(new energy and industrial technology development organization) renewable energy technology white book ver.2

Examination of Pros and cons of PSPP and Battery, Determining the Direction

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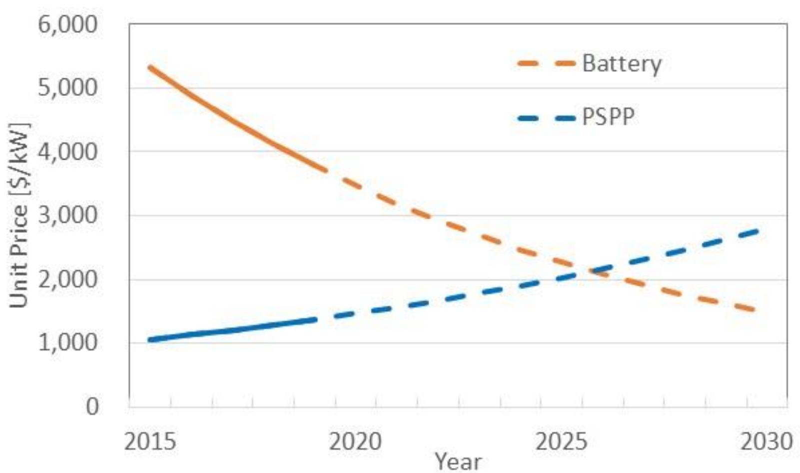
There are some options as balancing power.

- Careful consideration of advantages and disadvantages for prospective options rather than PSPP is very important
- After thorough discussions with the C/P and JICA, final conclusions would be made regarding what should be the best balancing power source and reported at the 1st Technical Seminar.

Item	Merit	Demerit
PSPP	➢ Large scale development ➢ Low running cost ➢ Long-term usage	➢ Long development term (5 years for construction, 5 years and over for land negotiation) ➢ Require the resettlement ➢ Staged development is impossible. ➢ Initial investment is large and financing (loan) is difficult. ➢ Development sites is limited ➢ Operation is restricted by river law ➢ Loss is bigger than storage battery: about 30%
Battery	➢ Short development term Total within 2 years(6 months for design, 1 year for construction) ➢ Staged develop is possible ➢ Low loss (5-15%) ➢ Significant price decline (Expected to fall by 40% in the next 5 years) (Figure 3-4) ➢ Charge and discharge can be switched without stopping	➢ Unit price of storage batteries is still high, but the rate of decline is large. ➢ The standard life of the storage battery is about 10 years.



✓ Battery innovation is remarkable, price drop is remarkable as well

✓ Reversal of construction costs would be real within 10 years

Comparison of PSPP and Storage battery①

CHUBU

		PSPP (Assuming Maha3 (※1))		Storage Battery (NAS) Current		Storage Battery (NAS) Around 2030 year	
①	Condition	Output:600MW Generation / Discharge Time: 6hours Storage capacity: 3,600MWh					
	Construction (MUSD)	720		1,080		378	
	Construction Cost (US cents／kWh)	20		32		11	
	Construction Cost／Replacement cycle (US cents ／kWh／year) PSPP：40year Storage Battery：20year	0.5	○	1.6	△	0.6	○
②	Condition	Days of operation: 250day Times of operation: 1,500h／year					
	(A)Power generation cost for equipment (US cents／kWh) (Annual expense ratio: **%)	4.8 (6%)		12.0 (10%)		4.0 (10%)	
	(B)Power generation cost for PSPP operation or Storage battery operation (US cents／kWh)	10.0		10.0			
	(C)Power generation efficiency (loss) (US cents／kWh)	3.0 (PSPP efficiency: 70%)		1.0 (Storage Battery efficiency: 90%)			
	Power generation Cost (US cents／kWh): (A)+(B)+(C)	17.8	○	23.0	△	15.0	○

Source: Potential Capacity and Cost of Pumped-Storage Power in Japan　Proposal Paper for Policy Making and Governmental Action　toward Low Carbon Societies (January 2020 Japan Science and Technology Agency)

Comparison of PSPP and storage battery②

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		PSPP		NAS Battery		Li Battery		Redox flow	
③	Construction period（Year）	8～10	△	1～2					○
④	Replacement cycle（Year）	40（※2）	○	15	△	10~20	△	20	△
⑤	Advantages	・Suitable for surplus electricity countermeasures. ・Large scale development ・Long-term usage		・Suitable for frequency fluctuation countermeasures. ・Staged develop is possible ・Low loss (10-30%) ・Significant price decline ・The construction period is short.					
	Disadvantages	・Development sites is limited. ・Staged development is impossible. ・Loss is bigger than storage battery: about 30%		・The replacement cycle of the storage battery (10~20 year) is shorter than PSPP.					

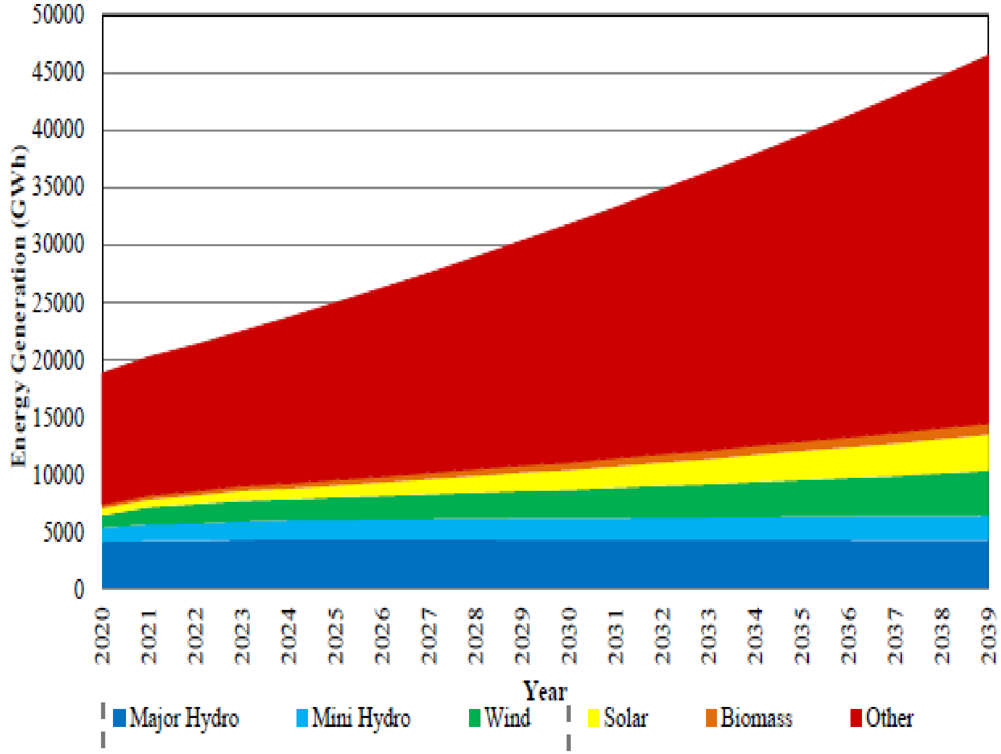
[Notices]

（※１） The comparison target of the storage battery was the PSPP of Maha3. Because Victoria Lake's investigation has many uncertainties.

（※２） The replacement cycle of PSPP (40year) is described from the Maha3 report.
（Average 40year : Civil works 50year, Hydro-mechanical and electro-mechanical equipment 35year）

source: Potential Capacity and Cost of Pumped-Storage Power in Japan Proposal Paper for Policy Making and Governmental Action toward Low Carbon Societies （January 2020 Japan Science and Technology Agency）

Suggestion from JICA Expert Team



ure 8.7 –Renewable Contribution over next 20 years based on energy resource

source: LONG TERM GENERATION EXPANSION PLAN (2020-2039) (March 2020 SriLanka)

PSPP Measures for surplus electricity	Survey, Finance, Detailed design, Procurement → Constriction	Operation
Storage Battery Measures for frequency fluctuation	Survey, Finance, Detailed design, Procurement → Constriction → Operation	Operation → Replacement

- PSPP takes a lot of time to complete.
- Renewable energy will gradually increase.

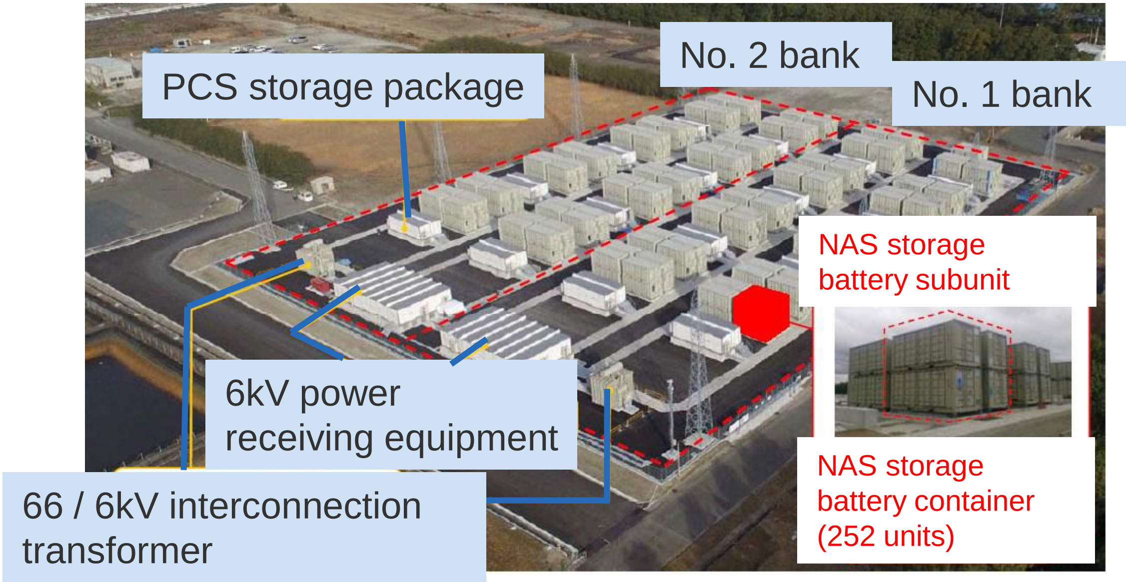
(Recent years)
When gradually introducing renewable energy, it is necessary to take measures against frequency fluctuations.
(Storage battery will be used as a measure against frequency fluctuations.)

(10 years later)
When a large amount introducing renewable energy , it is necessary to take measures against surplus electricity.
(PSPP will be used as a measure against surplus electricity.)

We would like to take measures against renewable energy by best mixing PSPP and storage battery.

Thank you for attention

Practical examples of using NAS battery in Japan
（Buzen Storage Battery Substation（Kyushu Electric Power Company））



Installation area	14,000m^2
Demonstration period	2015-2016
Storage battery type	NAS battery
Output capacity	Output:50MW Capacity:300MWh
Purpose	Measures against frequency fluctuations

NAS Battery

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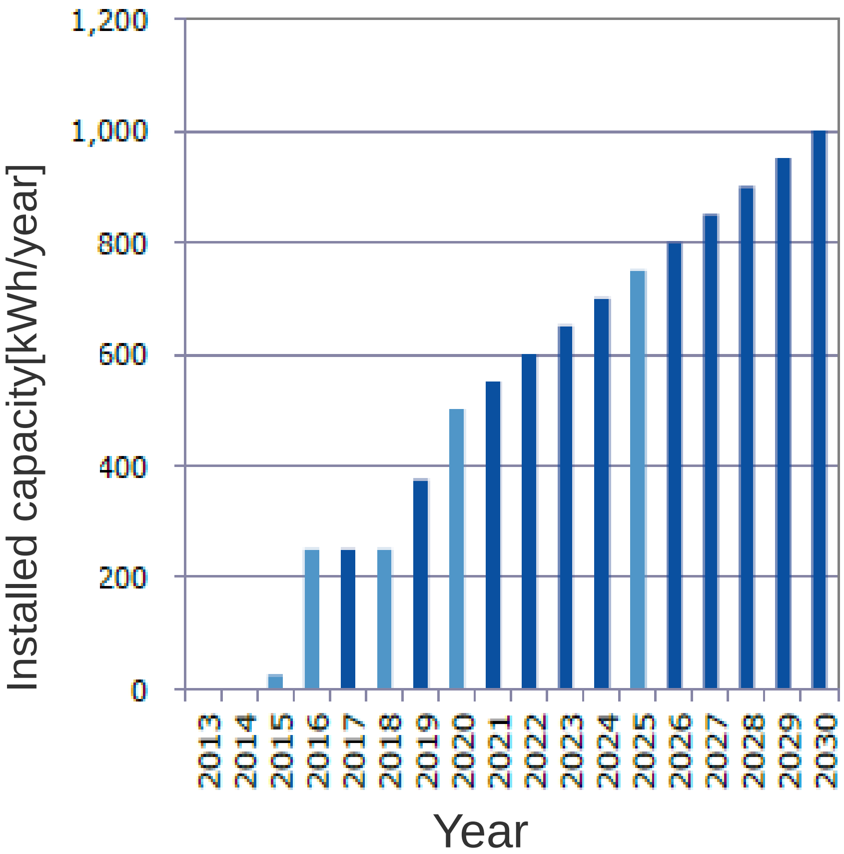
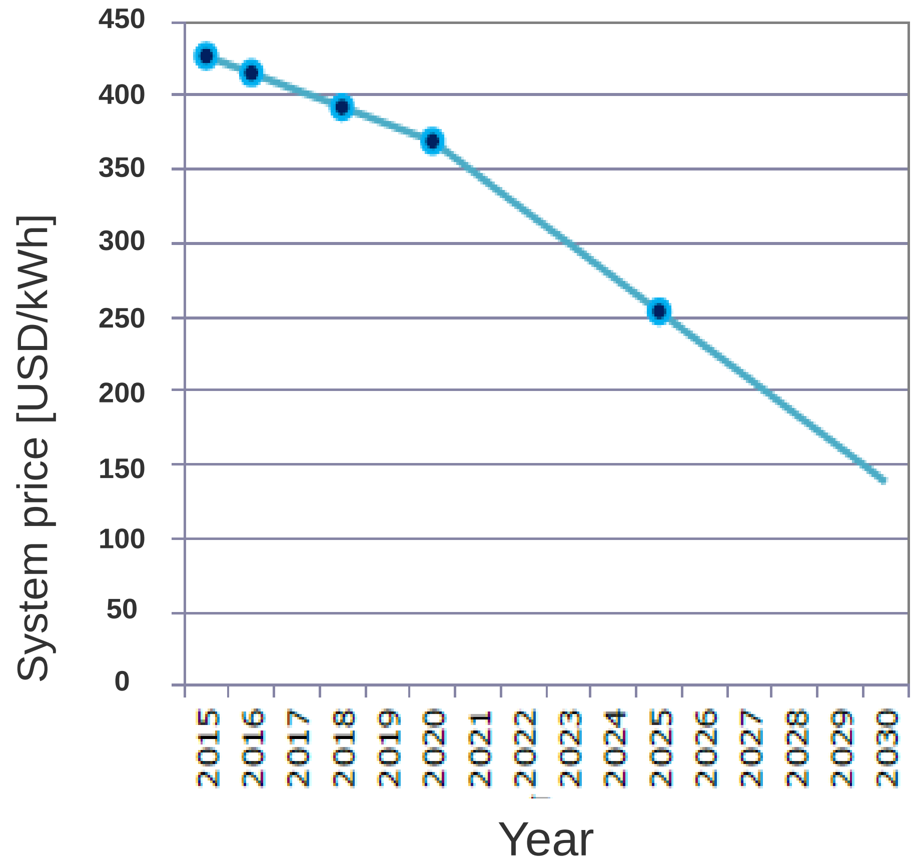
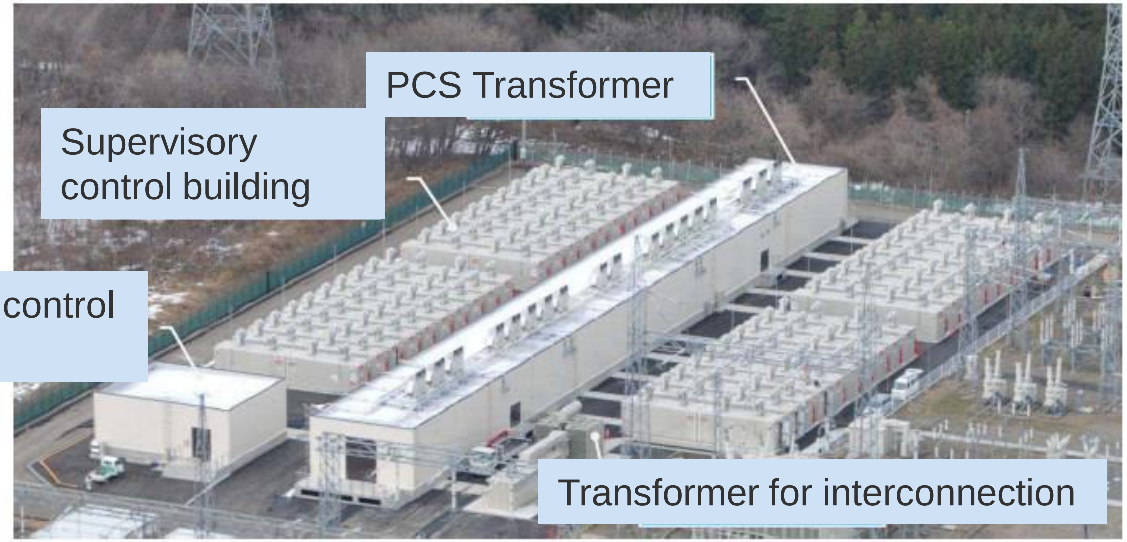




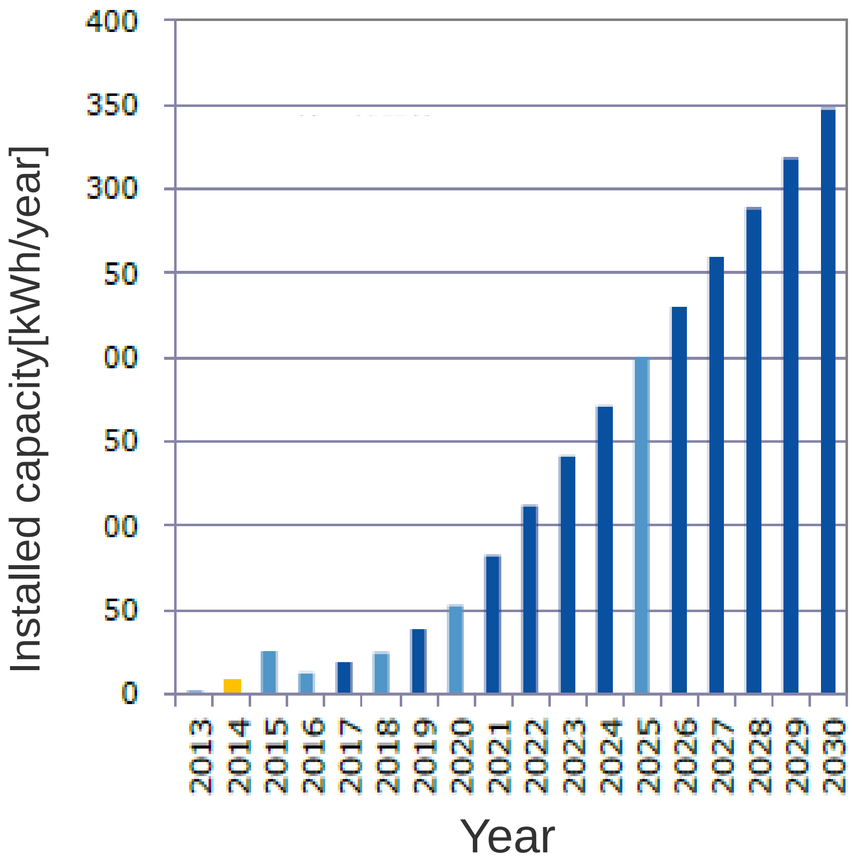
※Includes O&M costs and amortization costs.

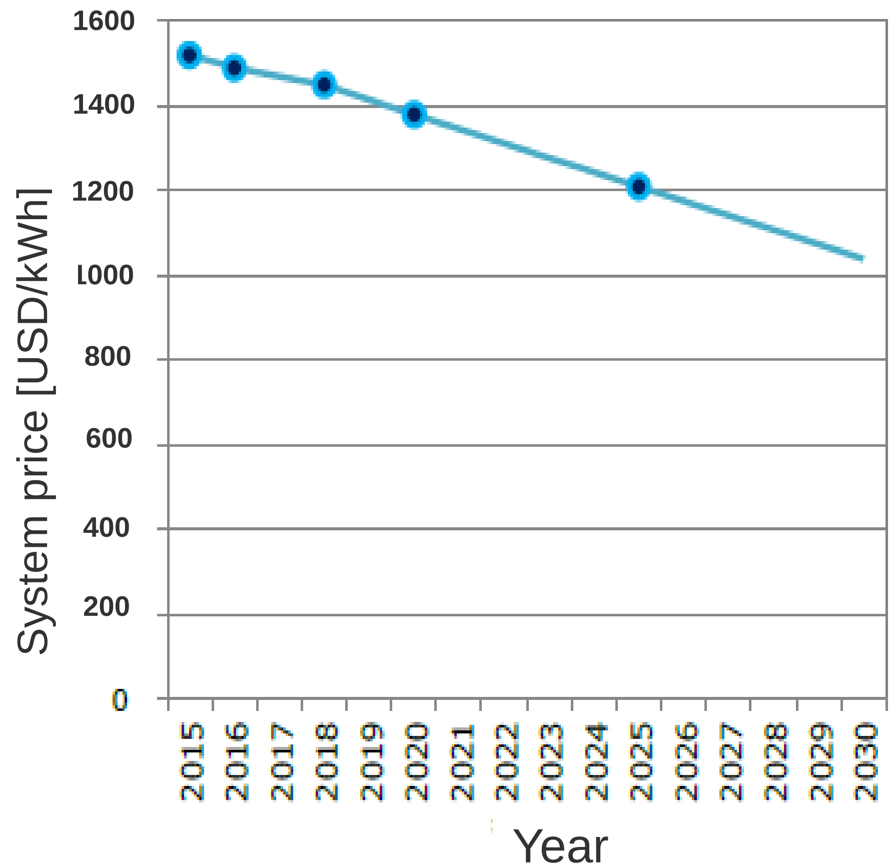
source: 平成27年度新エネルギー当導入促進調査　再生可能エネルギー当の関連産業に関する調査（平成28年3月　みずほ情報総研株式会社）

Practical examples of using Li battery in Japan
（Nishi Sendai Substation（Touhoku Electric Power Company））



Installation area	6,000m^2 (100m×60m)
Demonstration period	2013-2017
Storage battery type	Li battery
Output capacity	Output:20MW Capacity:20MWh
Purpose	Measures against frequency fluctuations





※Includes O&M costs and amortization costs.

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Practical examples of using Vanadium redox flow battery in Japan （Minamihayakita Substation（Hokkaido Electric Power Company））

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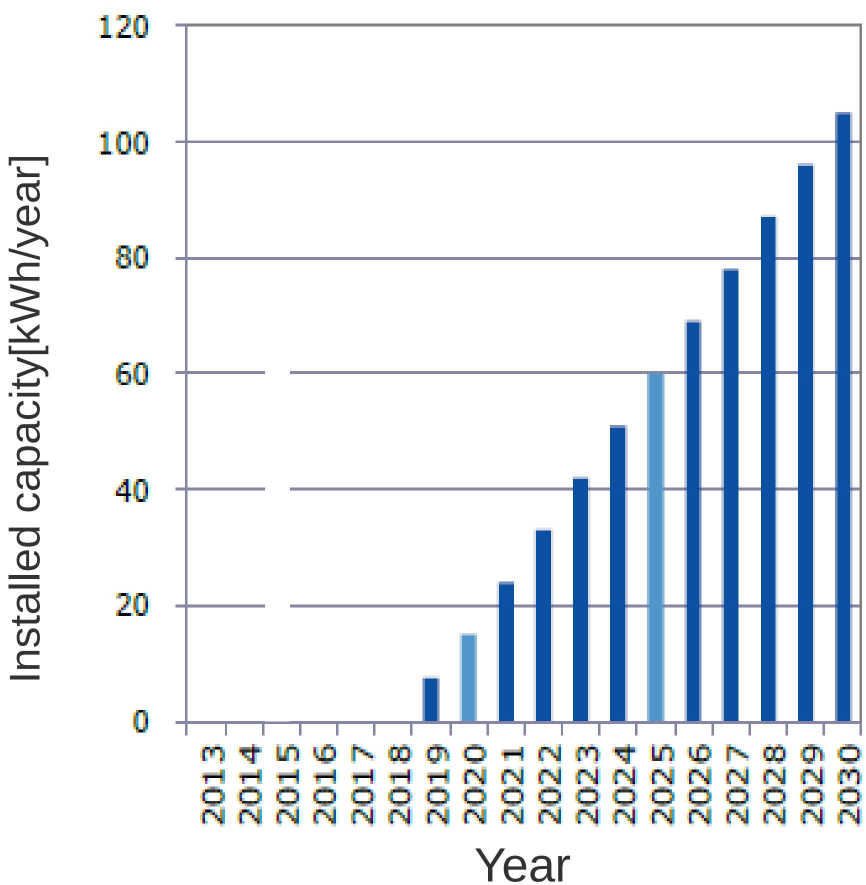
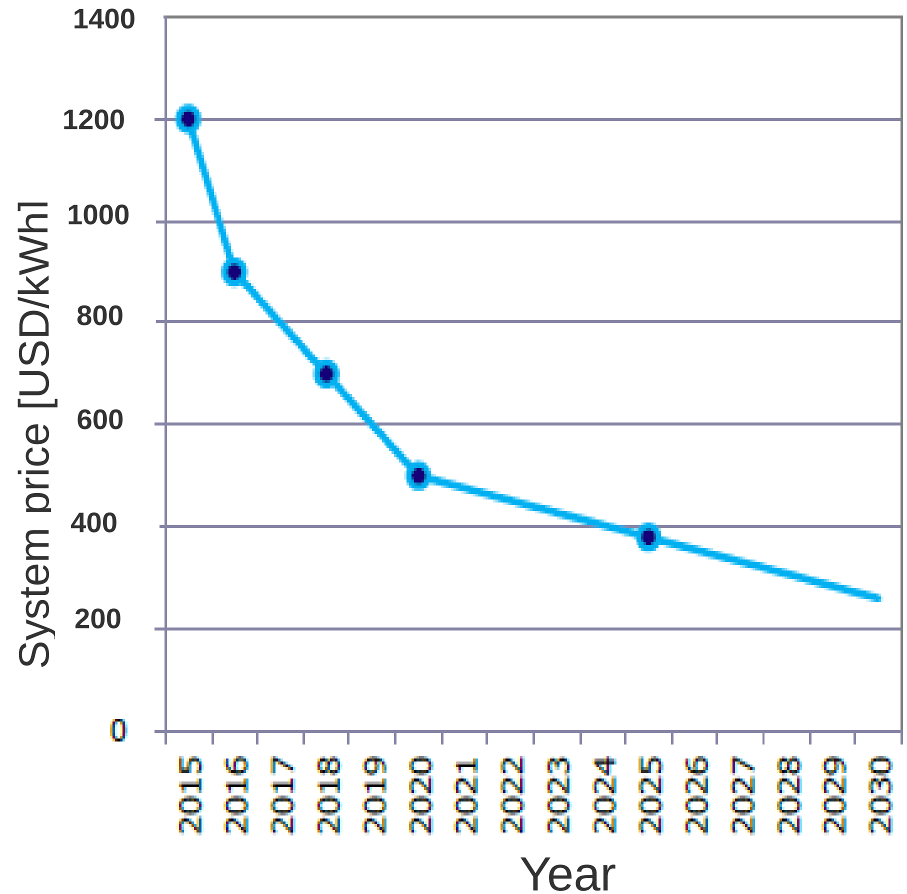
Exterior view of storage battery building

Electrolyte tank

Installation area	5,000m^2
Demonstration period	2013-2019
Storage battery type	Vanadium redox flow battery
Output capacity	Output:15MW Capacity:60MWh
Purpose	Measures against frequency fluctuations

Vanadium redox flow





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Democratic Socialist Republic of Sri Lanka

The Project for Capacity Development on the Power Sector Master Plan Implementation Program

Capacity of Battery Storage introduction

Sep 2022

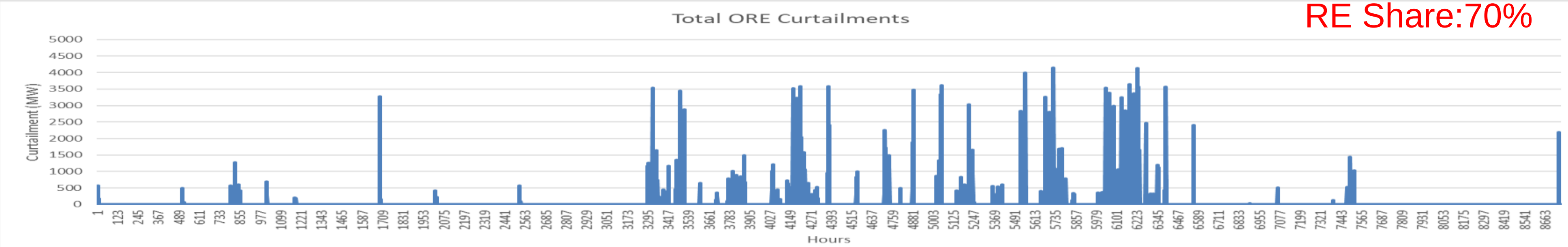
Chubu Electric Power Co., Inc.
Nippon Koei Co., Ltd.

Topics

- SDDP Calculation results(Review of the last meeting)
- Main ideas for improvement of the RE ratio
  - The effect of improving the renewable energy ratio from a supply side
  - Calculation method of the SNSP permission level
- Optimal capacity of storage battery introduction

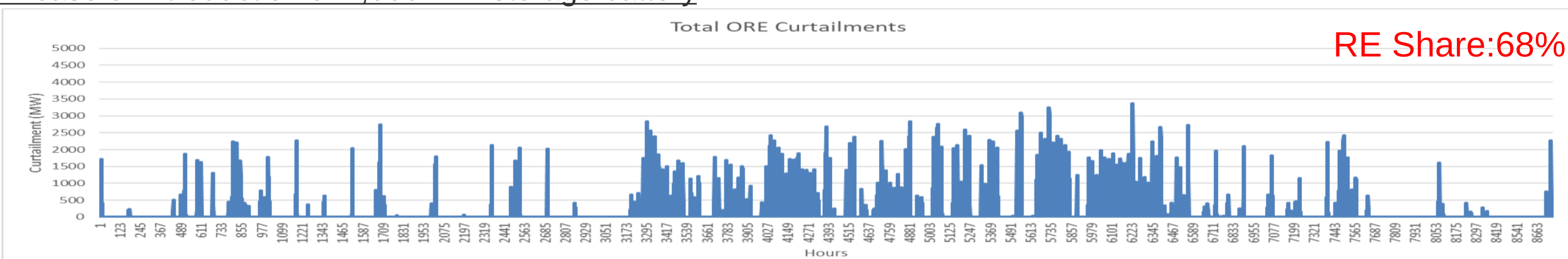
SDDP simulation calculation result

①In case of introduction of 2,000 MW storage battery



	Total Thermal	LVPS 1	LVPS 2	LVPS 3	New CCY 1	New CCY 2	KCCP 1	KCCP 2	West Coast	Uthuru Janani	Kelanitissa New GTs	Containerized Emergency Power Plant	Firm Thermal Power
Annual Fuel Cost (USD million)	499.63	68.98	106.50	75.19	74.37	67.49	10.91	5.51	86.66	1.22	0.00	0.02	2.77
Annual CO2 Emissions (Tons)	8322133	1884600	2909900	2054500	439480	398820	64493	32588	512070	9180	0	157	16345

②In case of introduction of 1,000 MW storage battery



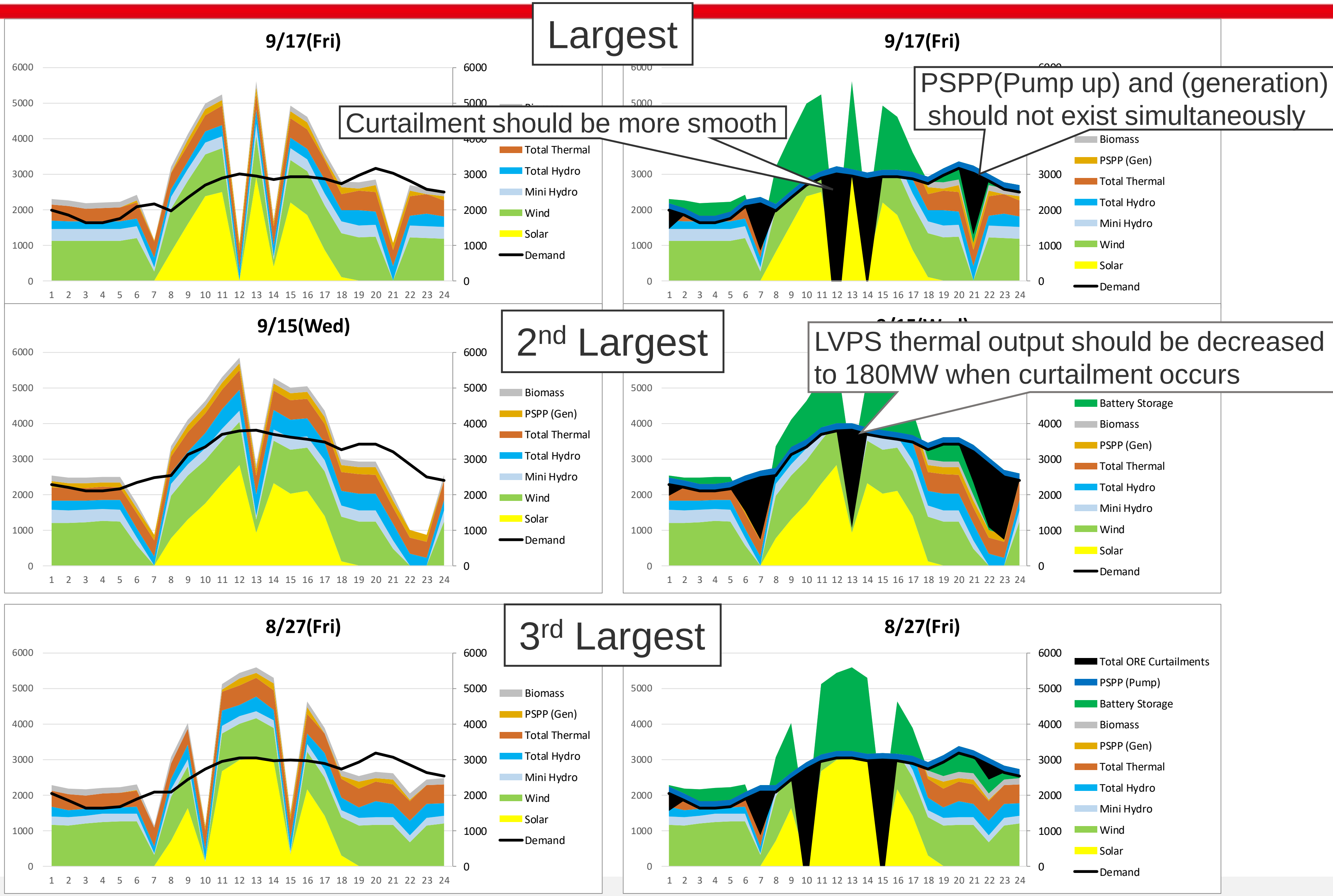
	Total Thermal	LVPS 1	LVPS 2	LVPS 3	New CCY 1	New CCY 2	KCCP 1	KCCP 2	West Coast	Uthuru Janani	Kelanitissa New GTs	Containerized Emergency Power Plant	Firm Thermal Power
Annual Fuel Cost (USD million)	522.22	77.11	106.32	74.87	80.82	74.83	13.02	5.59	86.43	1.29	0.00	0.11	1.82
Annual CO2 Emissions (Tons)	8619086	2106700	2904800	2045700	477570	442200	76933	33055	510720	9730	0	896	10782

Optimization Methodology of supply-demand control

- Supply side
  - Thermal power
    - **Lower to the minimum output**
    - Daily start and stop during daytime
  - PSPP, Battery
    - Charge during surplus power(SMP: cheap), discharge during peak time(SMP: expensive)
    - SOC
  - VRE
    - Reduce curtailment
- Demand side
  - Demand side management
    - Electricity tariff (Time of Use)
    - Market incentive
  - Create new demand such as hydrogen
- Transmission side
  - Interconnect with India

SMP: system marginal price

Supply demand curve sorted by curtailment amount



Improved RE ratio by lowering thermal power output during curtailment (Battery capacity : 1000MW)

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- Pick up the time when the thermal power is not the lowest even though there is a curtailment

Minimum Loading Level (MW)						180	180	180	140	140	100	110	108	0	45	5	550										
Installed Capacity (MW)						270	270	270	350	350	161	163	270	27	130	50	1100	1568	200	200	1000		600	200	1523	4040	
Total Generation (GWh)				27315	9098	1668	2322	1953	957	881	140	61	1084	14	0	1	16	4762	319	-456	-245	13837	1837	1373	4315	6312	664
Month	Day	Hour		Demand	Total Thermal	LVPS 1	LVPS 2	LVPS 3	New CCY 1	New CCY 2	KCCP 1	KCCP 2	West Coast	Uthuru Janani	Kelanitissa New GTs	Containerized Emergency	Firm Thermal Power	Total Hydro	PSPP (Gen)	PSPP (Pump)	Battery Storage	Total ORE	Mini Hydro	Biomass	Wind	Solar	Total ORE Curtailments
1	1	13	Sun	2624.7	810	270	270	270	0	0	0	0	0	0	0	0	0	108.651	0	-198	-437.09	2341.136	66.936	100	148.3	2025.9	821

- the time when the thermal power is not the lowest even though there is a curtailment = 1,048h /8760h

- Improvement generation amount = when total ORE curtailment >0

  $\sum_{i=1}^{3}(LVPS\ i\ - 180\ )$ = 179.1GWh

- Improved RE ratio = 179.1 / annual ORE generation = 179.1 / 14502 = 1.24%

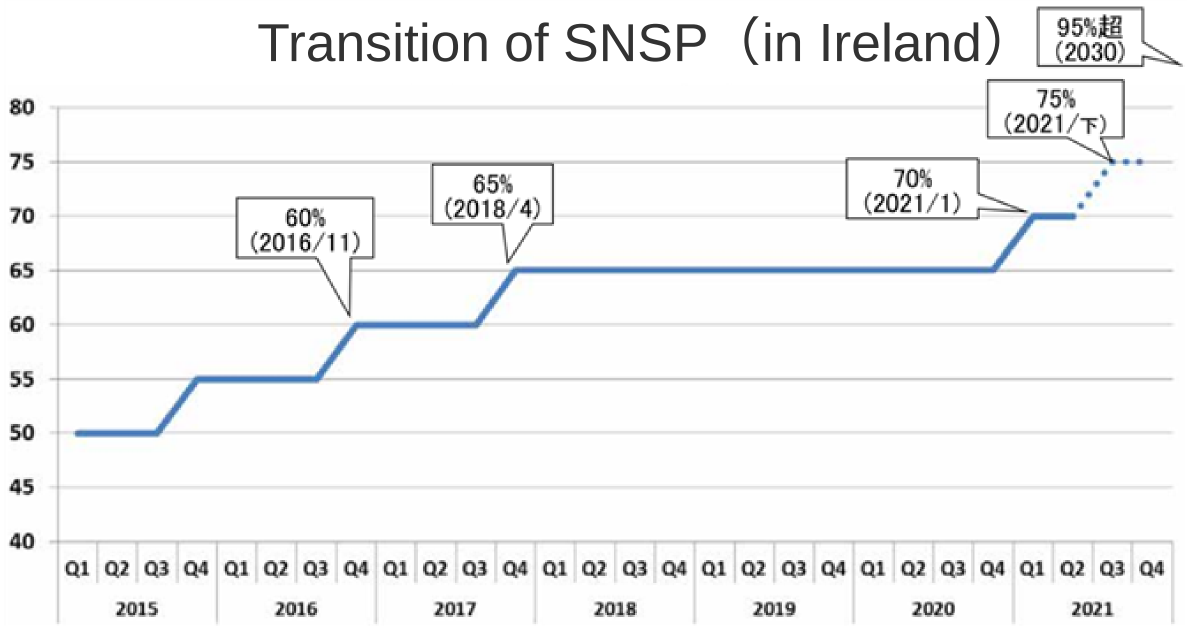
> If we decrease the thermal power output to the lowest level , we can improve RE ratio.
>
> But you mentioned you have to continue outputting the thermal power generation of the fixed quantity to hold SNSP level down to 65% or less.

Outline of SNSP(the System Non-Synchronous Penetration)

$$\text{SNSP(\%)} = \frac{\text{Non-Synchronus Power Output} + \text{Import(Direct current cooperation line)}}{\text{Demand} + \text{Export(Direct current cooperation line)}}$$

In Sri Lanka, SNSP level must be controlled by 65% or less.
In Ireland, SNSP level has already reached 75%.

Transition of SNSP（in Ireland）



（注）SNSP：The System Non-Synchronous Penetration
（出所）Shaping our electricity future Technical report（AirGrid、SONI 2021/2） に加筆

At first , if SNSP exceeded 50%, it was expected that the simultaneous dropout of the renewable-energy power occurred.

They raised SNSP in these 5 years from 50% to 75% by carrying out measures for the renewable-energy introduction.
In addition, they plan to raise SNSP to 95% in 2030

Main countermeasures of grid

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RE introduction rate: High → Low

Issues	Countermeasures	Status
Decrease of short circuit capacity	・Review of the protection cooperation	No introduction (For Off grid)
Inertial force dropout in the grid	・Establishment of the estimation technique of inertial power quantity in real time ・Development of PCS with the frequency maintenance function	Under introduction examination in Ireland,UK,Texas etc..)
Fluctuation of short frequency	・Battery storage ・Governor free operation ・Load Frequency Control etc..	Ancillary service market has been formed in some countries.(including Japan)
Fluctuation of long frequency	・Output control of PV ・Forecast of RE output	
Lack of transmission capacity	・Connect & Manage ・Conductor temperature management by dynamic rating	
Voltage flicker	・Prevention of independent driving function	
The voltage movement of the distribution line	・Development of the smart inverter	No introduction

This project's target (Fluctuation of short frequency; Fluctuation of long frequency)

Main improvement measures of SNSP(in case of Ireland)

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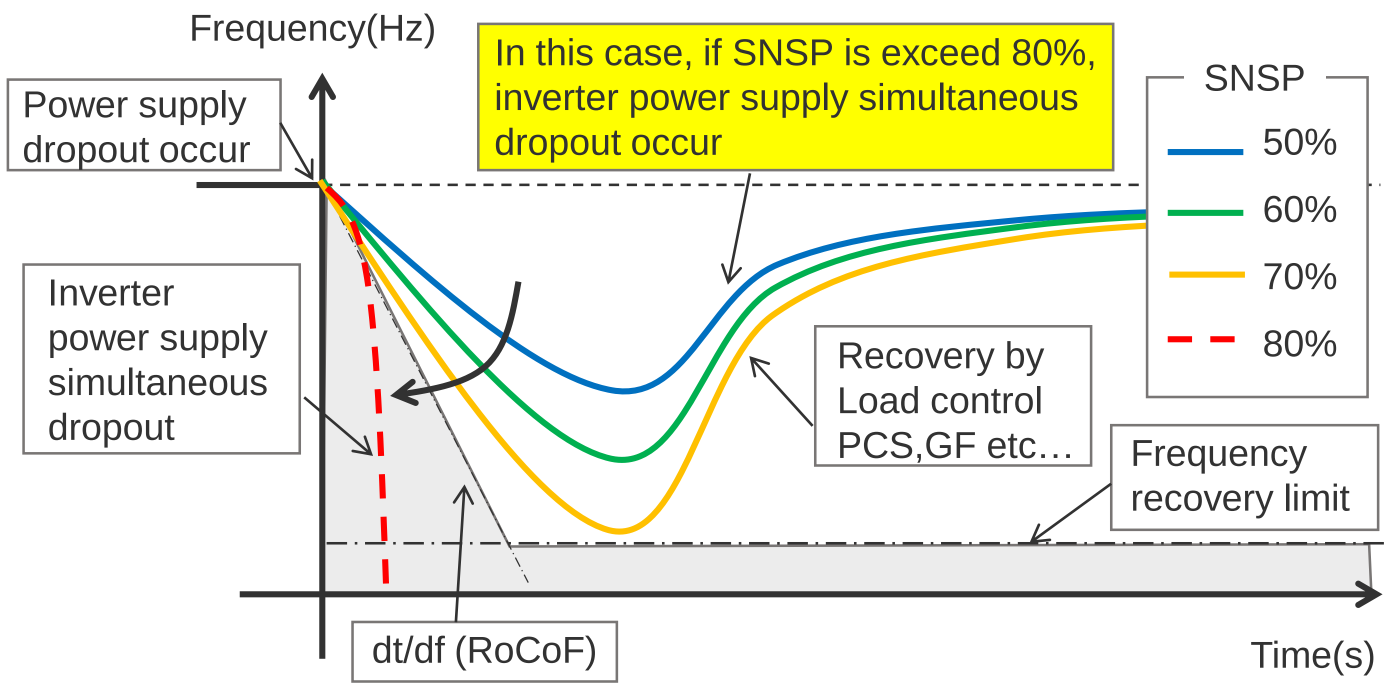
Subject	Concrete contents
Decrease of synchronous power output	The 2018 third-quarter：23,000MWs The 2019 fourth-quarter：20,000MWs The 2020 first-quarter：17,500MWs
Reconsideration of RoCoF(Rate of Change of Frequency)	The 2018 third-quarter：0.5HZ/s The 2019 fourth-quarter：1.0HZ/s
Adoption of various kind of the ancillary service	In addition to 11 existing services, they introduce 3 following services The 2018 third-quarter：FFR（Fast Frequency Response） The 2019 third-quarter：DRR（Dynamic Reactive Response）and FPFAPR（Fast Post-Fault Active Power Recovery）
Modification of Grid Code	Consideration of modification of the following Grid Code About wind power, Voltage control at steady state and dynamic control of the active power and reactive power

These are similar with our activities in this project.
we can raise an future SNSP permission level.

Calculation method of the SNSP permission level

【Simulation image of SNSP】



【Requirements for analysis】

・Quantity of synchronization power supply dropout
(Main thermal power plant output, 〇〇% of demand …etc.)

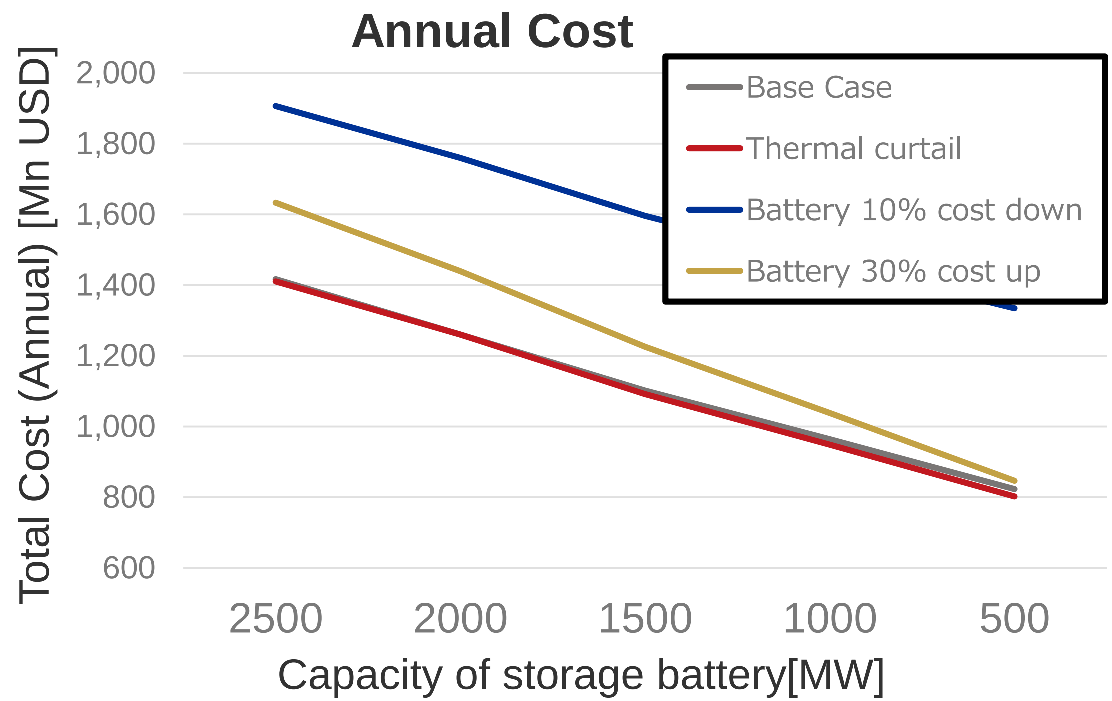
・RoCoF（Defined by Grid Code, It can be improved by introduction of PCS)

・Frequency recovery limit （47.0-52.0Hz）

Optimal capacity of storage battery introduction

【Cost-effectiveness of introducing storage batteries】

Terms	%	MW	Mn USD
	RE Ratio	Battery Capacity	Total Cost (Annual)
Base Case	69.8%	2500	1417
	68.1%	1000	964
	66.7%	500	823
Thermal Curtail	70.0%	2500	1410
	69.3%	1000	949
	68.7%	500	802



In case of 1000MW storage battery , by curtailing thermal output, the RE ratio improve from 68.1% to 69.3%, and we can reduce annual cost 15 Million USD.

We could considerably get rid of the differences of RE ratio between 1000MW and 2000MW, so we would like to conduct future consideration based on 1000MW introduction.

Democratic Socialist Republic of Sri Lanka

The Project for Capacity Development on the Power Sector Master Plan Implementation Program

Cost Evaluation

Nov 2022

Chubu Electric Power Co., Inc.
Nippon Koei Co., Ltd.

Battery Cost

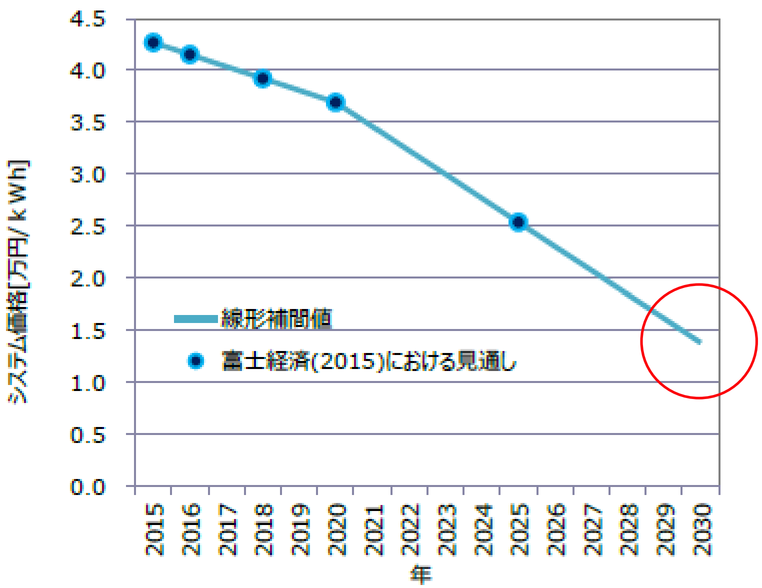
NaS：15,000¥/kWh ×4 = 400USD/kW

NaS battery is mainly made by Japanese manufacturers(NGK), so I referred to Japanese materials.

Li：200USD/kWh ×4 = 800USD/kW

Li battery is mainly made by international companies, so I referrerd to NREL(National Renewable Energy Laboratory)

【 NaS 】



【出典：富士経済、エネルギー・大型二次電池・材料の将来展望2015 動力・電力貯蔵・家電分野編 P.127 】

【 Li 】

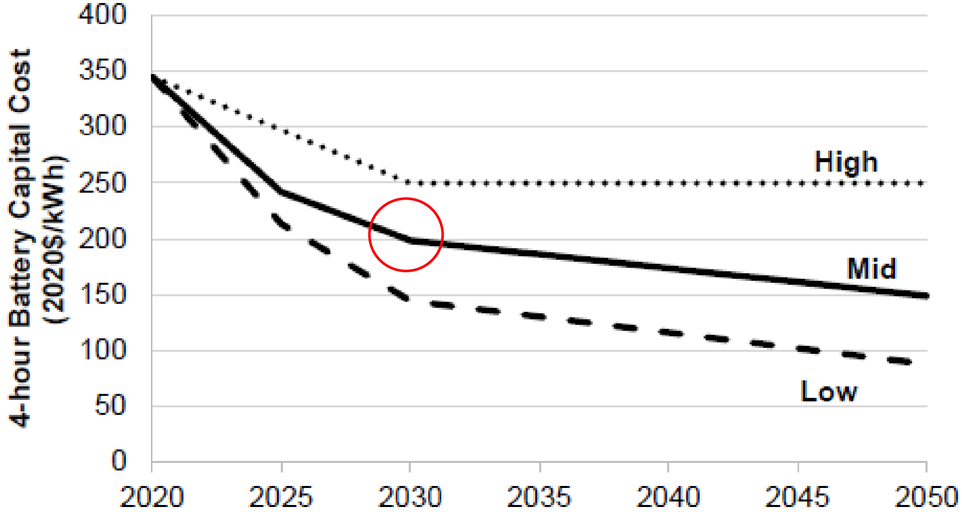


Figure ES-2. Battery cost projections for 4-hour lithium ion systems.

【出典： *National Renewable Energy Laboratory* 「Cost Projections for Utility-Scale Battery Storage: 2021 Update 」】

Optimal capacity of storage battery introduction

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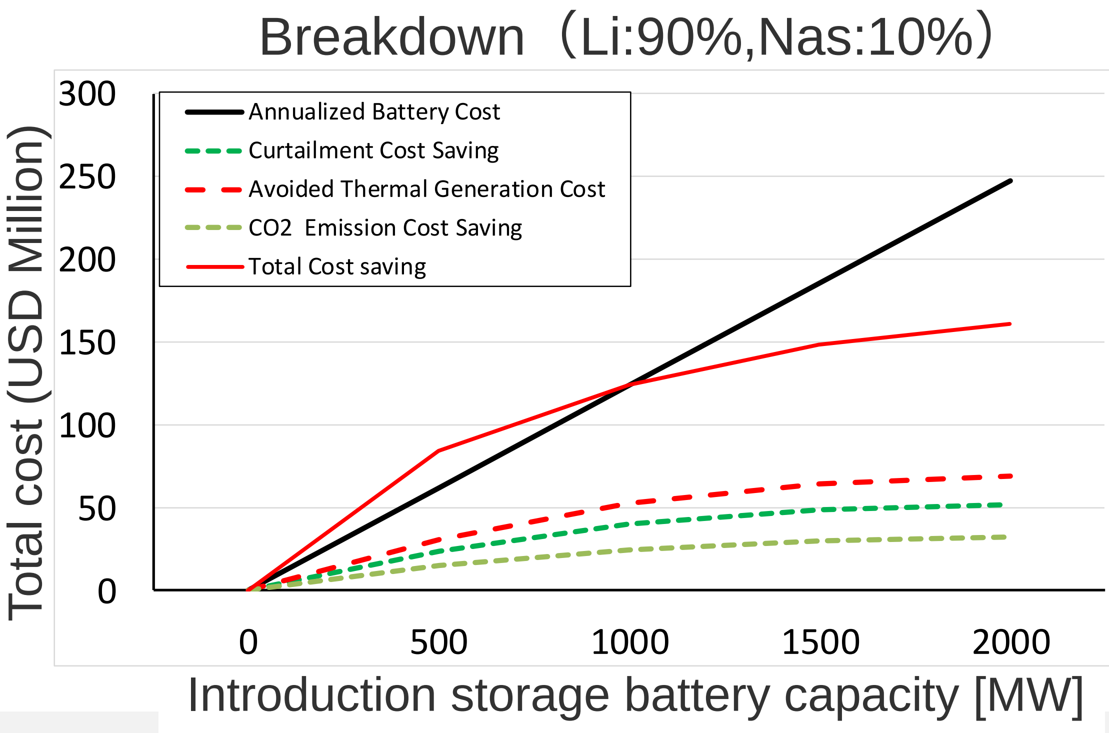
1. Present continuous operation range is 49.5 – 50.5Hz in CEB Grid Code.
2. Assuming that system coefficient K is equal to 5%(Hz/MW) approximately, it would be frequently to violate 49.5Hz in 2030 under 70% RE situation.
   Offpeak : 2,000MW × 5% (Hz/MW)× (0.5Hz/1Hz) = ***50MW*** fluctuation leads to frequency violation (50MW out of ～1,000MW wind output)

   Peak : 3,500MW × 5% (Hz/MW)× (0.5Hz/1Hz) = ***87.5MW*** fluctuation leads to frequency violation (87.5MW out of ～1,000MW wind output & ～2,000MW solar output)



Li battery capacity

200MW (50% SOC)

Capacity	Annualized Battery Cost	Total Cost Saving
(MW)	(USD million)	
0	0	0
500	62	69
1,000	124	117
1,500	186	143
2,000	247	153

CHUBU Electric Power

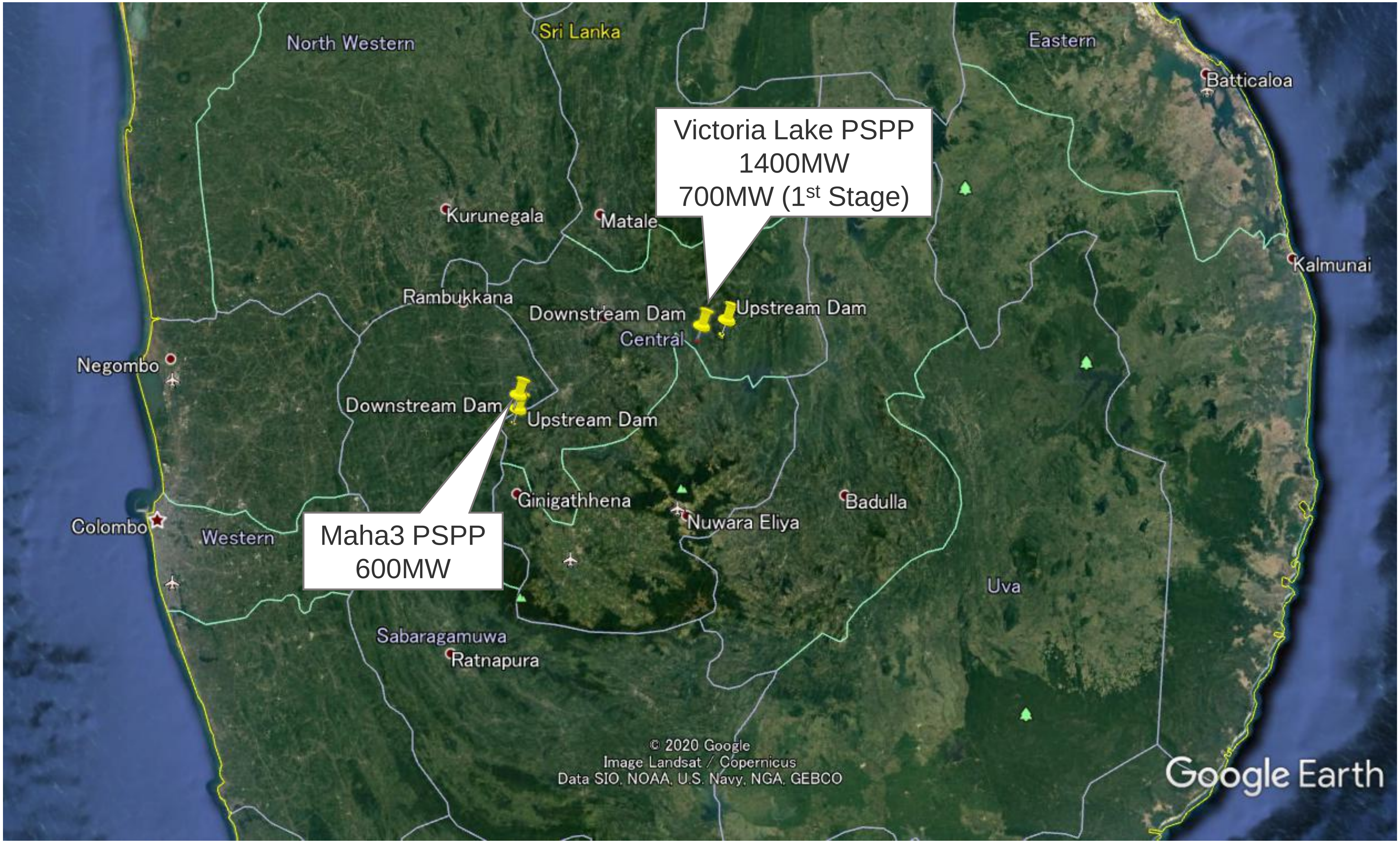
NIPPON KOEI

1st Technical Seminar
（Issues of PSPP）

15th December, 2020

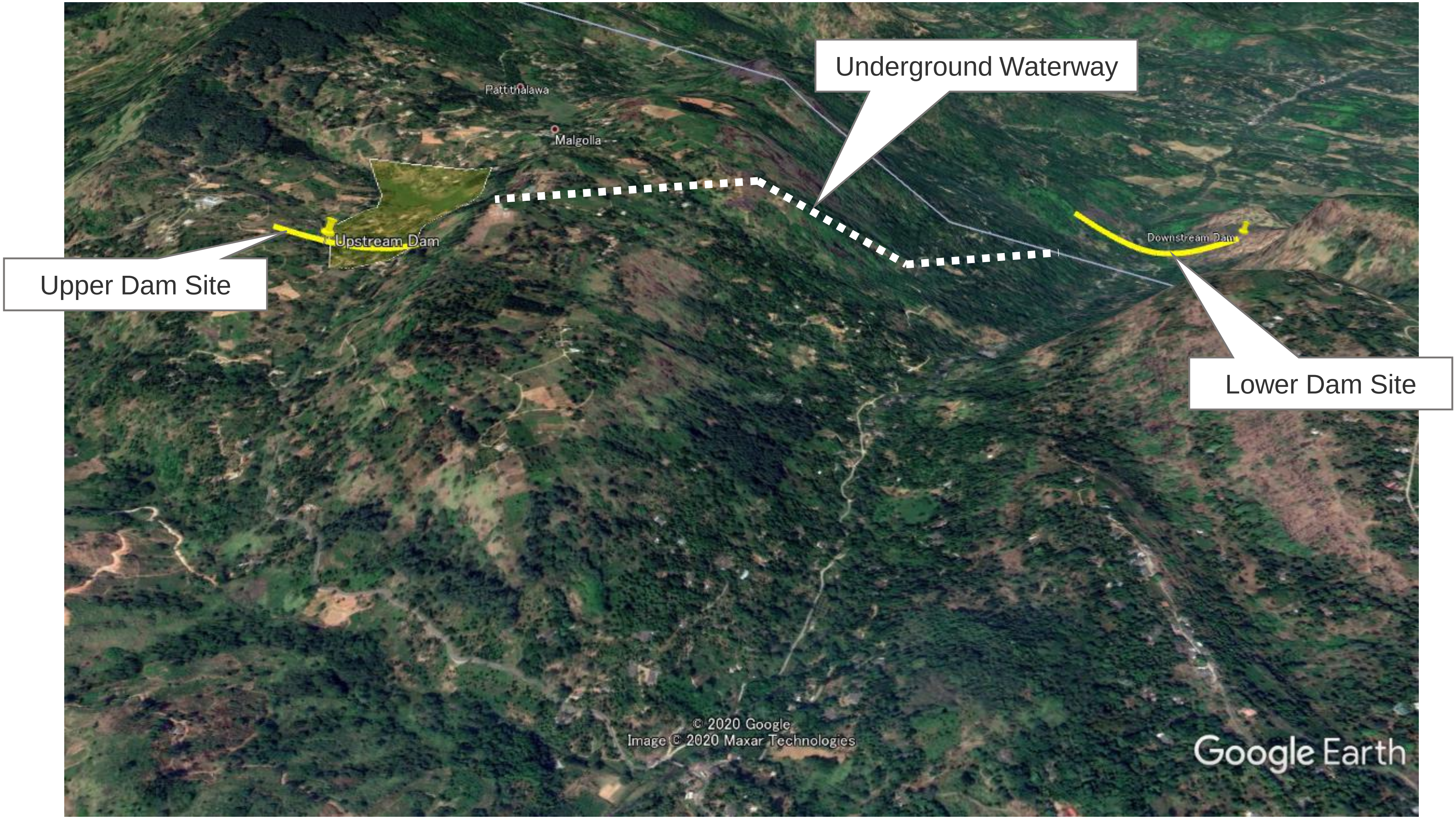
Chubu Electric Power Co., Inc.
Nippon Koei Co., Ltd.

Maha3 and Victoria Lake PSPP: Locations



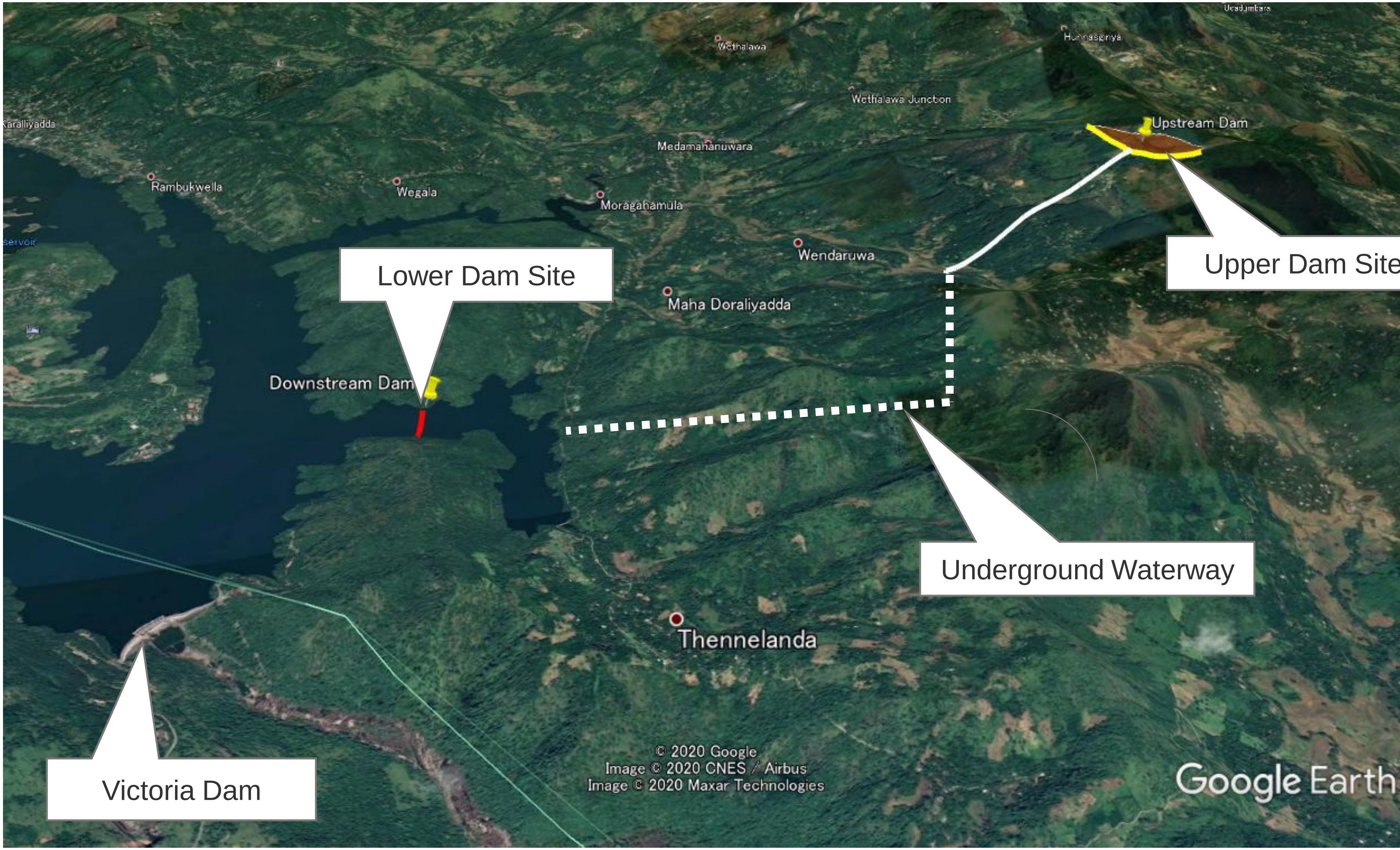
Source: Google Earth

Maha3 PSPP: General Layout Image



Source: Google Earth

Victoria Lake PSPP: General Layout Image



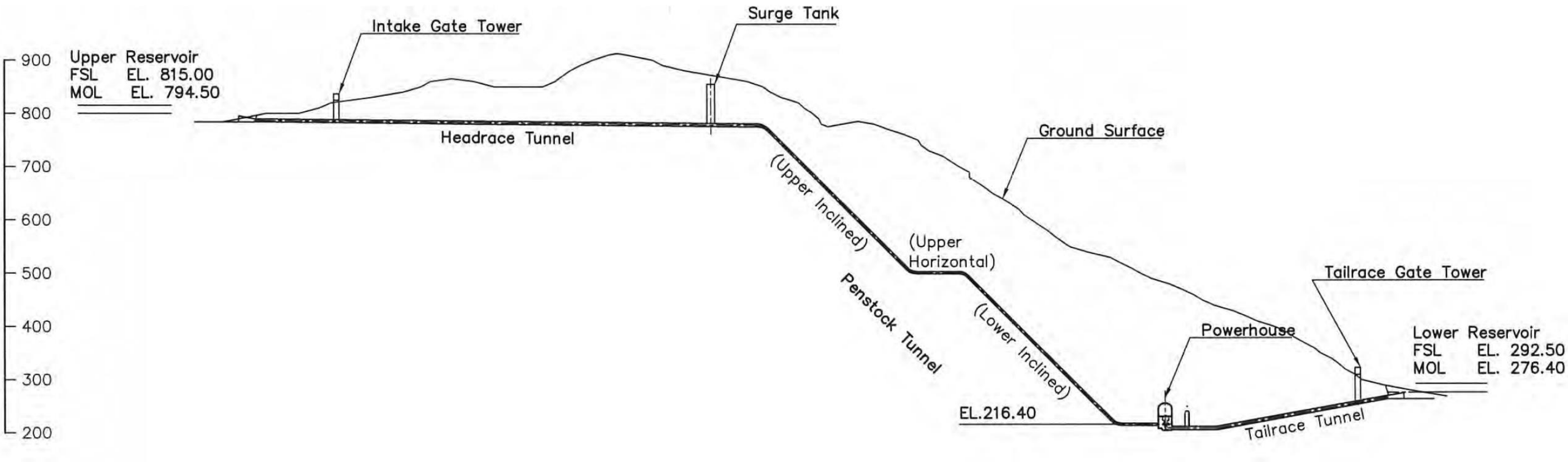
Source: Google Earth

Key Features of Reservoirs

	Maha 3 PSPP		Victoria Lake PSPP	
	Upper Reservoir	Lower Reservoir	Upper Reservoir	Lower Reservoir
HWL	EL. 815 m	EL. 292.5 m	EL. 1160 m	EL. 438 m
LWL	EL. 794.4 m	EL. 276.4 m	EL. 1125 m	EL. 407 m
Drawdown	20.5 m	16.1 m	35 m	31 m
Gross Capacity	3.71 mil. m^3	6.22 mil. m^3	5.5 mil. m^3	10.0 mil. m^3
Available Capacity	3.15 mil. m^3	3.20 mil. m^3	5.1 mil. m^3	5.1 mil. m^3
Reservoir Area	0.22 km^2	0.24 km^2	0.17 km^2	0.3 km^2
Dam Height	59 m	74 m	40 m	42 m

Source: JICA Reports

Maha3 PSPP: Longitudinal Profile of Waterway



Source: Development Planning on Optimal Power Generation for Peak Demand in Sri Lanka, 2015, JICA

Issues of Geology on Maha 3 Site

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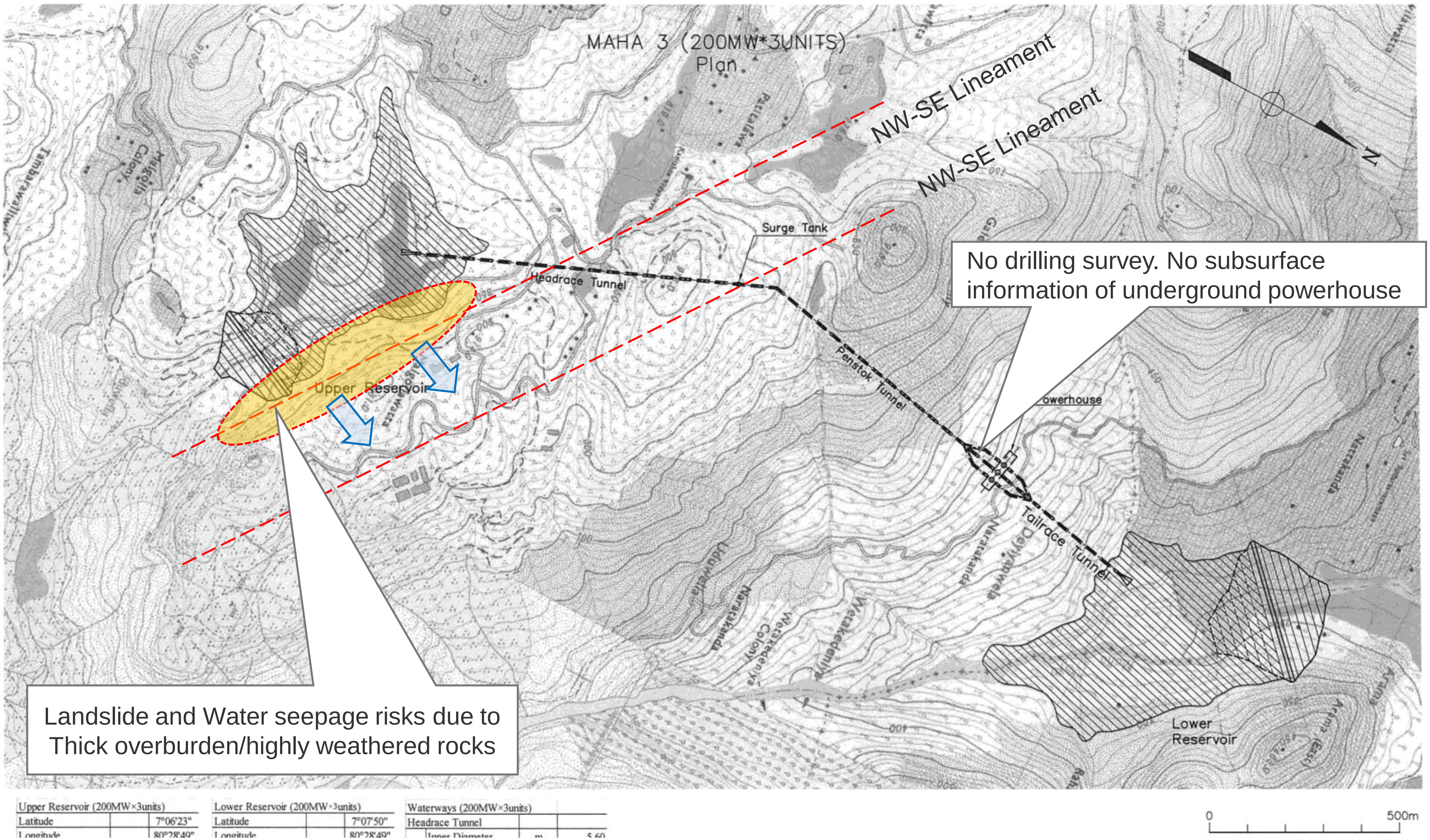
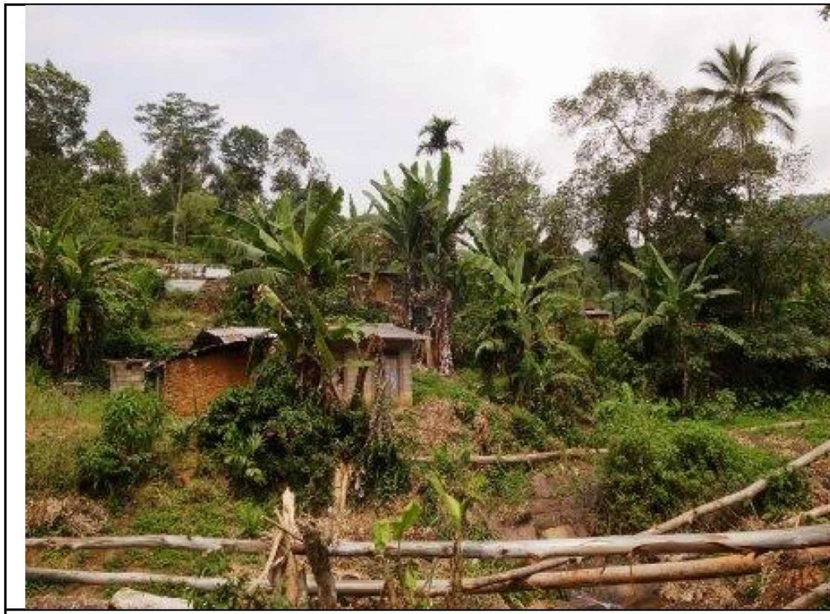
Structures	Check points	Major considerable issues
Upper storage dam	• Safety of dam foundation • Water tightness	• Thick talus deposits/highly weathered rocks on left bank • Impermeable layer seems to be deep on left bank (more than 50 m in depth)
Reservoir	• Landslide risks • Water seepage risks	• No information, but daily fluctuation of water level might thick weather zone on the left bank might trigger landslides especially on left bank covered with thick overburden. • No information, but seepage risks on left bank are anticipated.
Water way	• Landslide risks of portals • Rock condition along water ways	• No information • Geological structures nearly parallel to the waterway route. • NE-SW lineaments (possible faults) were identified.
Underground powerhouse	• Rock condition	• Biotite gneiss according to existing geological map. • No critical issues according to the Report (2015)
Lower storage dam and reservoir	• Same as upper storage dam and reservoir (Safety of dam foundation, Water tightness, Landslide risks and Water seepage risks)	• No critical issues according to the Report (2015)

Maha3: Layout of the Structures and Geological Issues

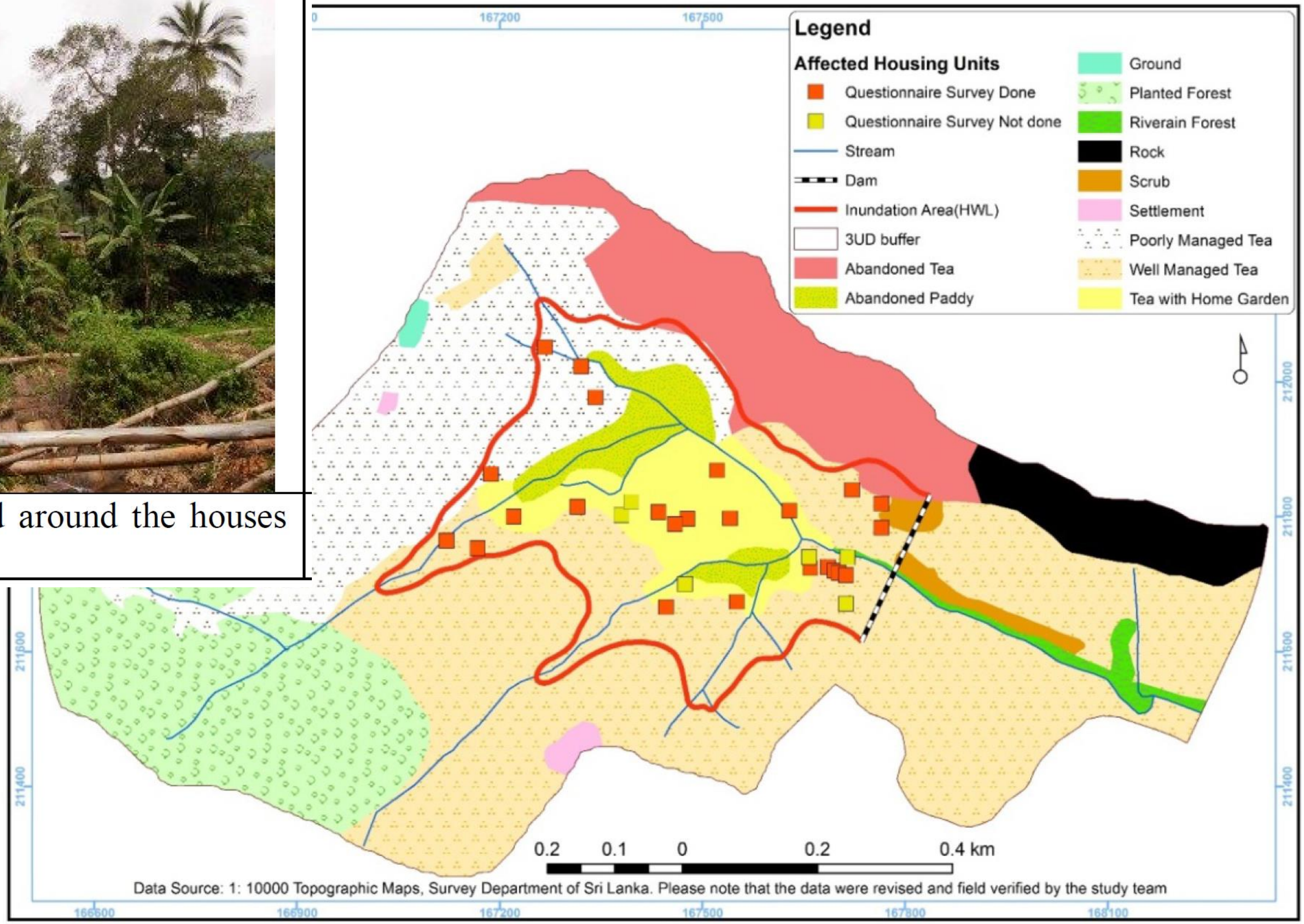


Source: Development Planning on Optimal Power Generation for Peak Demand in Sri Lanka, 2015, JICA, JICA Study Team added the geological information.

Maha3: Land Use and Location of Houses in Upper Reservoir

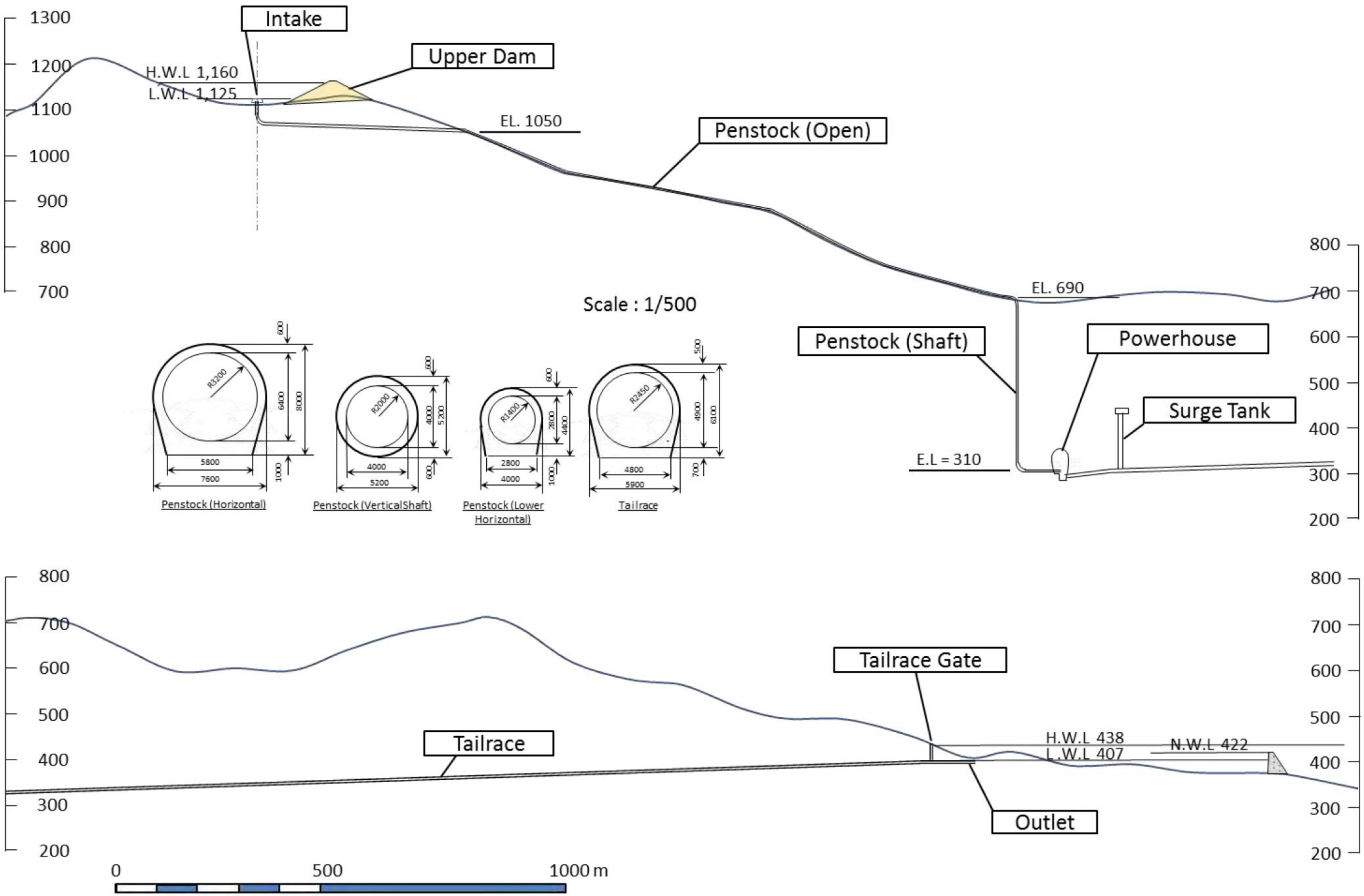


Home gardens are developed around the houses with some tea plantation.



Source: Development Planning on Optimal Power Generation for Peak Demand in Sri Lanka, 2015, JICA

Victoria Lake PSPP: Longitudinal Profile of Waterway

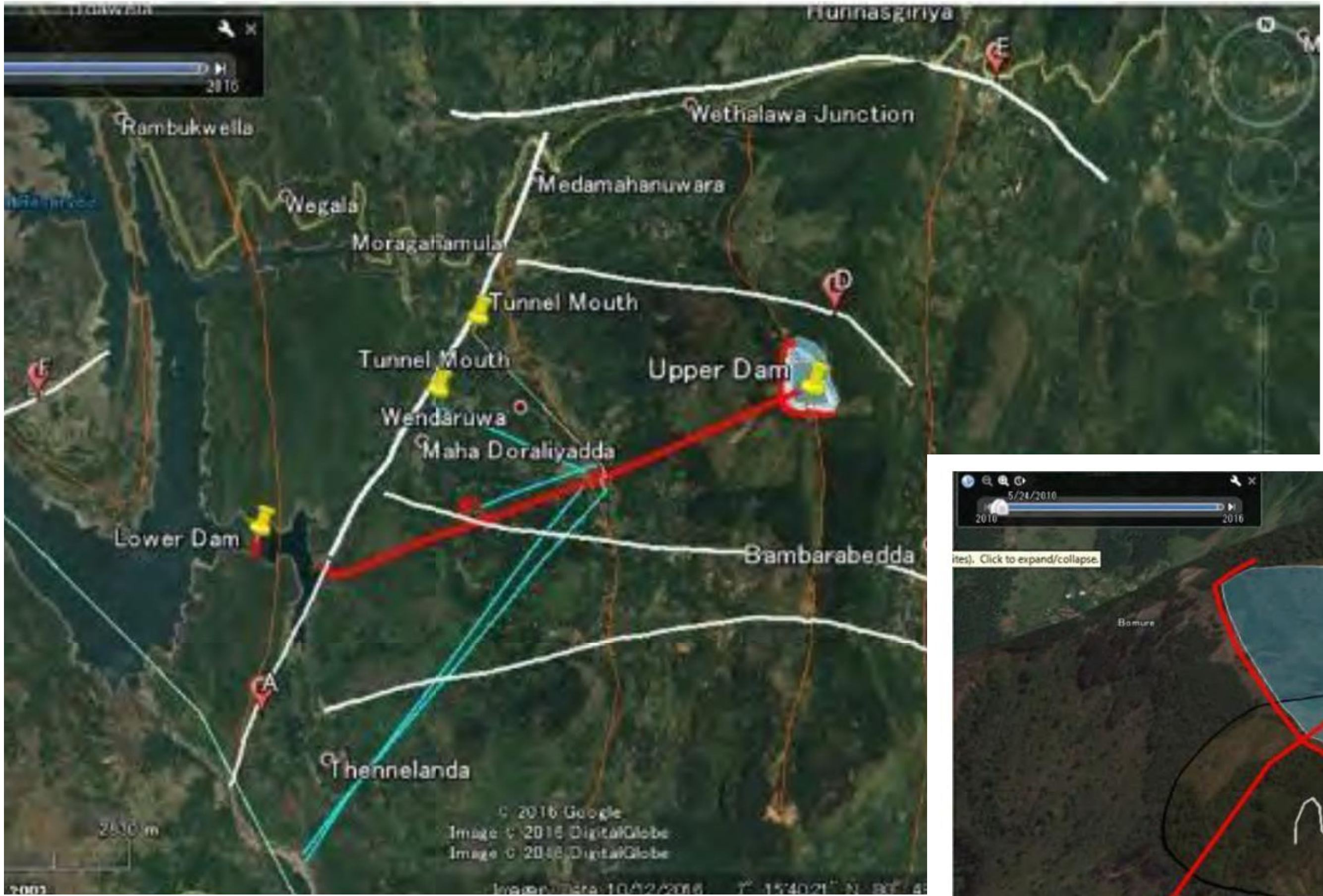


Source: *Project on Electricity Sector Master Plan Study in Democratic Socialist Republic of Sri Lanka, 2018, JICA*

Issues of Geology on Victoria Lake Site

Structures	Check points	Major considerable issues
Upper storage dam	• Safety of dam foundation • Water tightness	• Possibility of landslide risks • No information
Reservoir	• Landslide risks • Water seepage risks	• Ditto • No information
Water way	• Landslide risks of portals • Rock condition along water ways	• No information • One lineament (possibly fracture zone) crossing the tunnel.
Underground powerhouse	• Rock condition	• No information
Lower storage dam and reservoir	• Safety of dam foundation, Water tightness, Landslide risks and Water seepage risks	• No information

Victoria Lake PSPP: Geological Lineament and Landslide

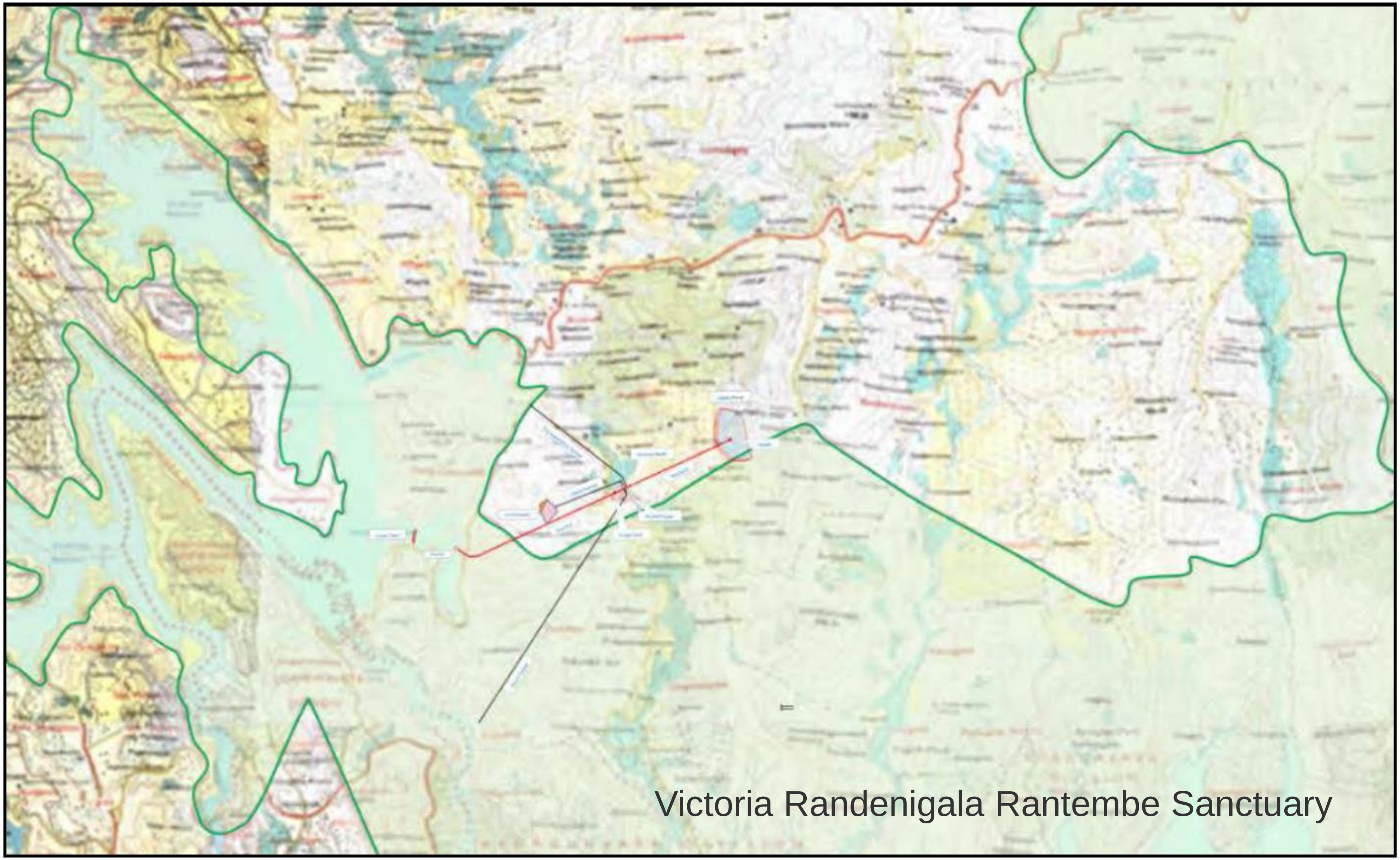


Lineaments (white line)

Upper reservoir and Possible landslide (black line)

Source: Project on Electricity Sector Master Plan Study in Democratic Socialist Republic of Sri Lanka, 2018, JICA

Victoria Lake PSPP: Protection Area



Source: Project on Electricity Sector Master Plan Study in Democratic Socialist Republic of Sri Lanka, 2018, JICA

Record of Francis Type Reversible Pump Turbine

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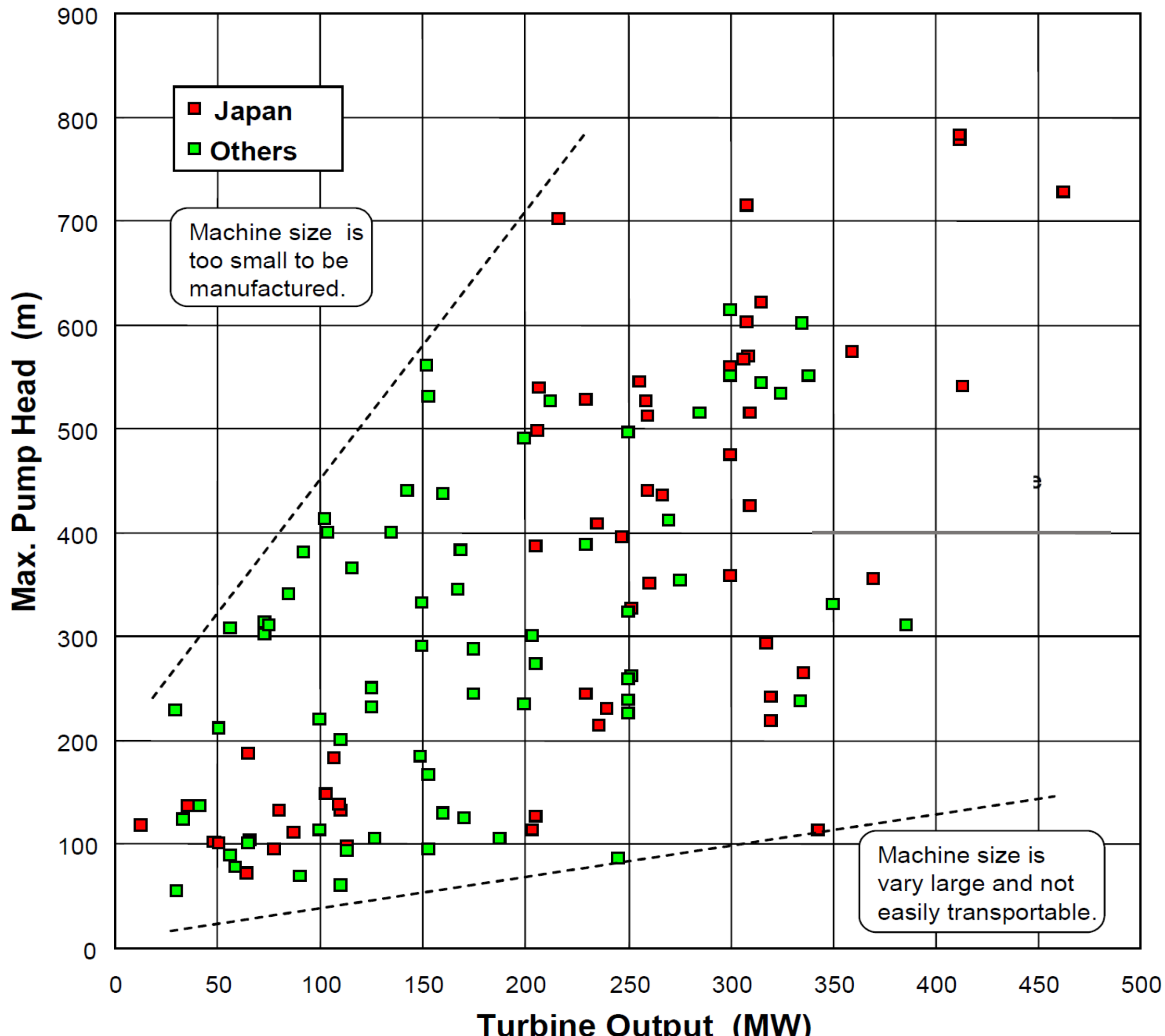
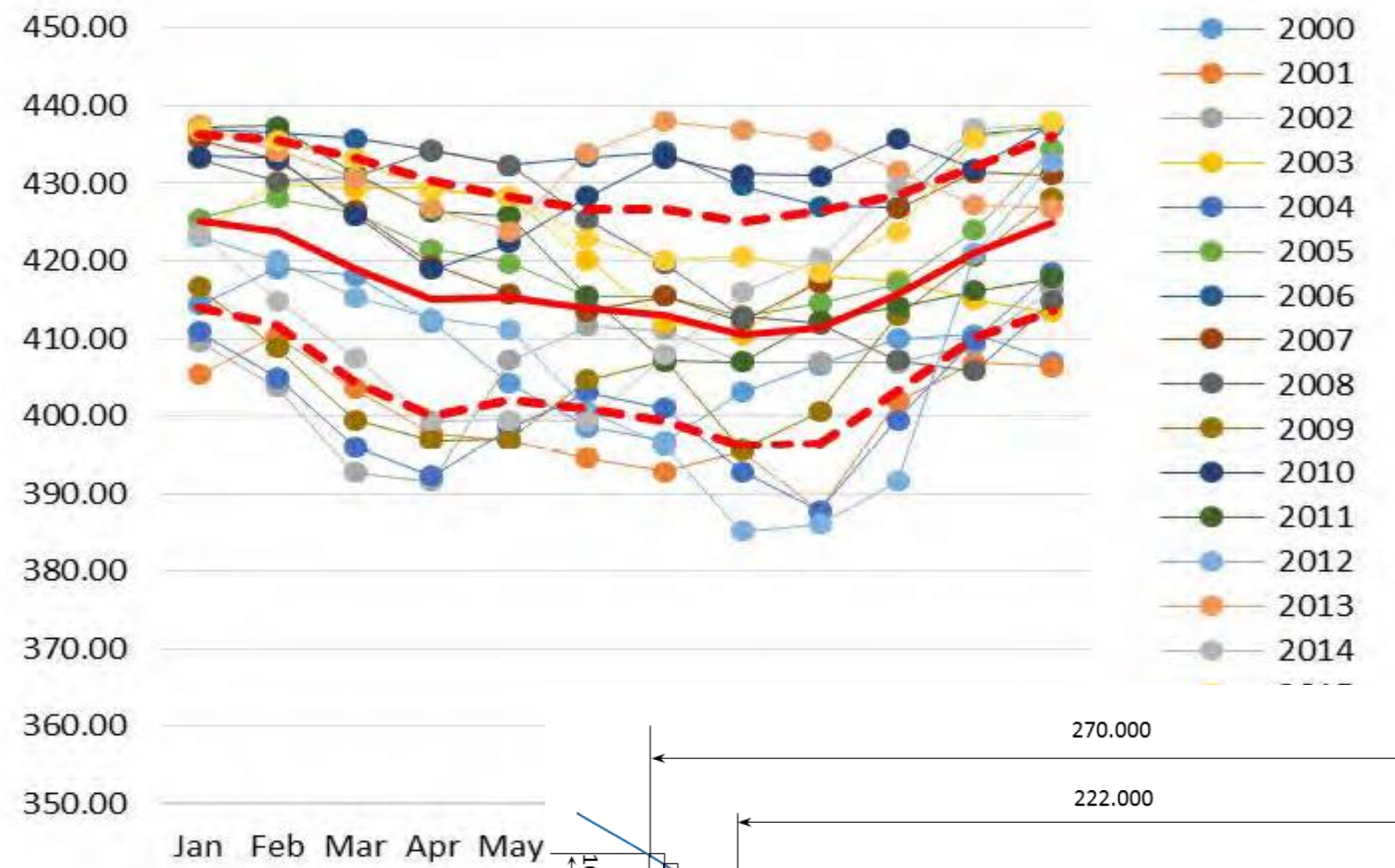
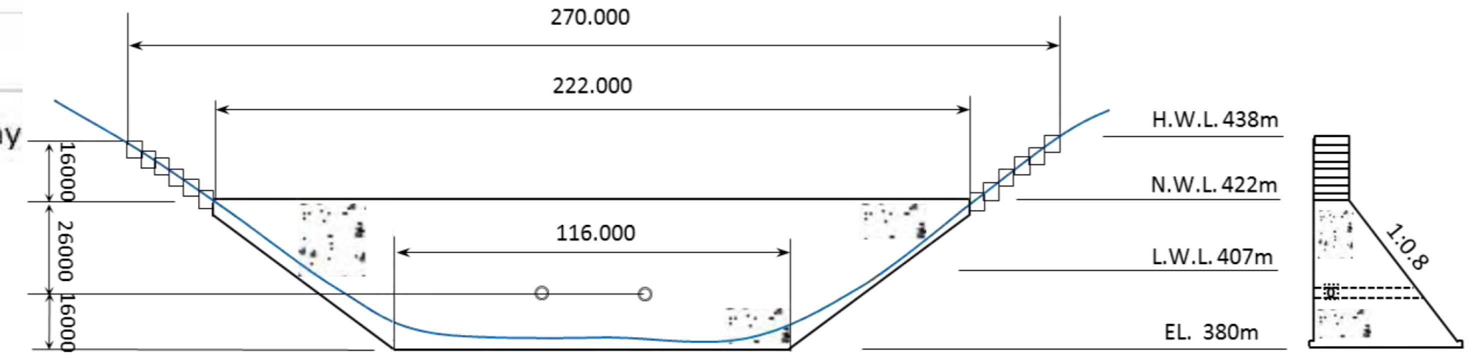


Source: Development Planning on Optimal Power Generation for Peak Demand in Sri Lanka, 2015, JICA

Victoria Lake PSPP: Lower Dam





Source: Project on Electricity Sector Master Plan Study in Democratic Socialist Republic of Sri Lanka, 2018, JICA

Issues of Maha3 and Victoria Lake PSPPs

	Maha3 PSPP	Victoria Lake PSPP
Source of Info.	• Development Planning on Optimal Power Generation for Peak Demand in Sri Lanka, 2015, JICA	• Project on Electricity Sector Master Plan Study in Democratic Socialist Republic of Sri Lanka, 2018, JICA
Geology	• Site investigation: in 2015 • **Upper dam: thick deposit on the left bank of the talus** • Lower dam: no critical issue • Waterway: layers nearly parallel to the water route	• Site reconnaissance: in 2018 • **Upper dam: possibility of existence of landslide** • Lower dam: unclear • Waterway: lineament
Environment	• Environmental study: in 2015 • Natural: out of the protection area • **Social: resettlement of 28 households within the inundated area**.	• Site reconnaissance: in 2018 • **Natural: lower dam within the protection area.** • Social: direct impacts on the village may not be substantial.
Technical Aspect		• **Pumping head: more than 700m** • **Lower dam: construction in the Victoria Lake**

Project Cost of PSPP

CHUBU Electric Power
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	Installed Capacity	Project Cost Base Year 2014	USD per kW	Source
Maha3 PSPP	600MW	USD 638 mil.	USD 1,060/kW	2015, JICA
Victoria Lake PSPP	700MW (1st Stage)	USD 590 mil.	USD 840/kW	2018, JICA

- Investigation is more advanced in Maha 3 PSPP compared to Victoria Lake PSPP, especially for geological information.
- For Victoria Lake PSPP, there are critical aspects on which further examination is needed in the next stage, such as upper reservoir geology, lower dam construction in Victoria Lake and construction in forest sanctuary.
- Therefore, at this stage it is adequate to consider the Maha3 PSPP's cost as the benchmark of PSPP cost for comparison with the battery option.
- The said Maha3 PSPP's cost is escalated with annual price escalation at 2% to obtain 2020 price; thus **USD 1,200/kW** is considered as the benchmark of PSPP cost for comparison with battery.

Victoria Lake PSPP: Geological Investigation

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#	Issue	Approach
1	Basic Sequence, Tasks and Schedule	CEB to confirm.
2	Permission for investigation in Sanctuary Area	JICA's policy is still being confirmed.
3	Counterpart in CEB	CEB to formulate.
4	Existing topographic maps (Grid No. 5521, scale 1:10,000 issued by Survey Department of Srilanka)	CEB to assist JICA Expert to obtain.
5	Subcontractor	JICA Expert to determine with bidding/quotation in accordance with JICA guideline.

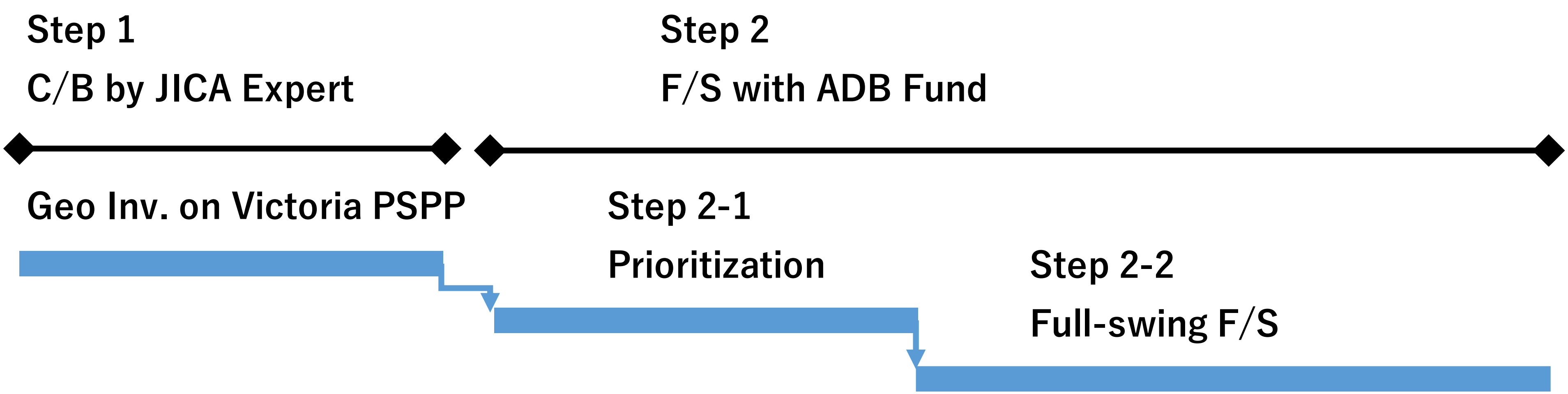
Progress to Date

Geo. Investigation Item	Maha 3	Victoria Lake
Topographic survey	Done	N/A
Geological mapping	Done (dam sites)	N/A
Geophysical prospecting	N/A	N/A
Core drilling	Done (dam sites)	N/A
Laboratory test	Done (dam sites)	N/A
Exploratory adit	N/A	N/A

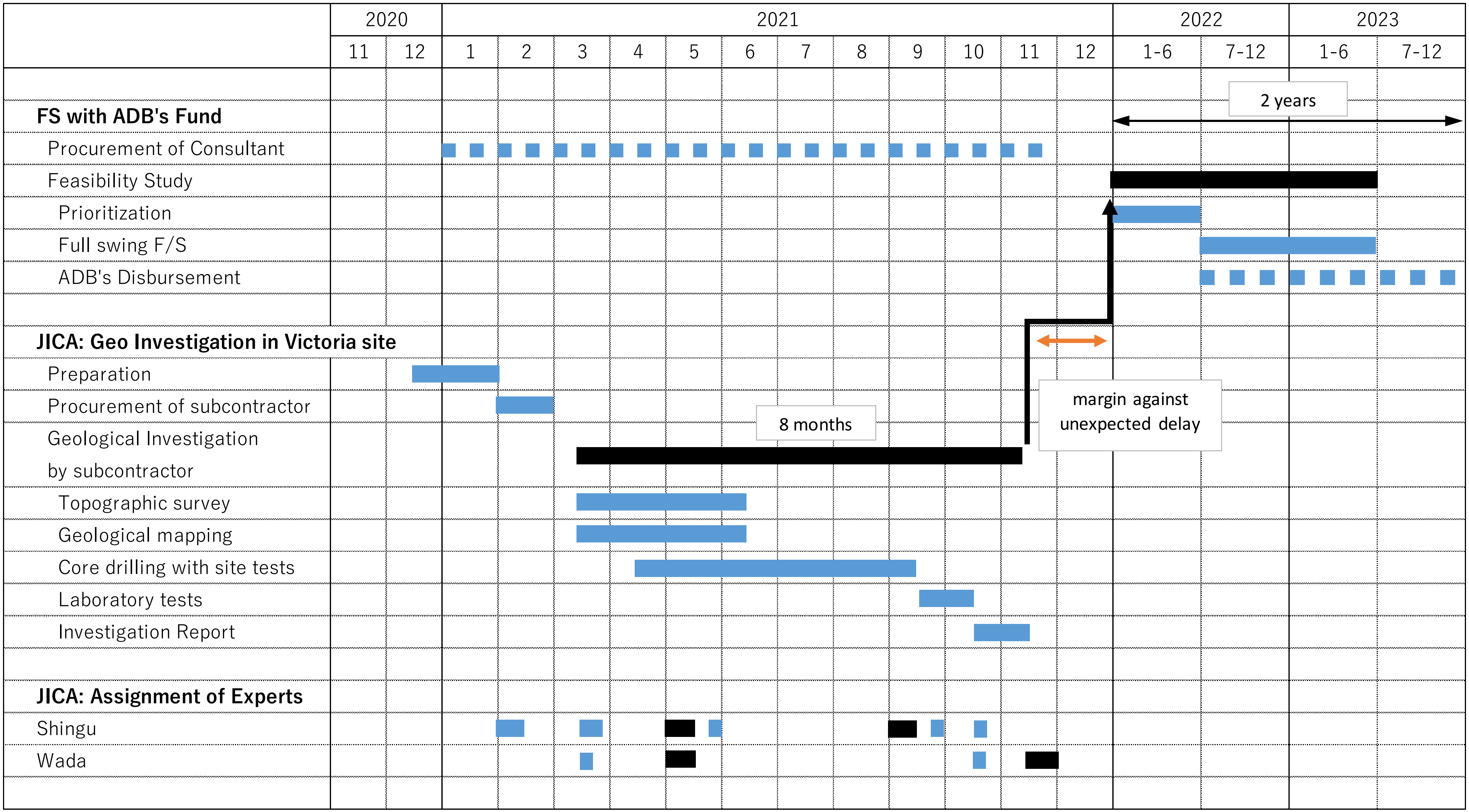
Step 1: Tasks

Step	Tasks	Remarks
Step 1 Capacity Building (C/B) by JICA Expert		
Geological investigation on Victoria Lake PSPP	- Geological investigation by subcontractor ◆ Topographic survey ◆ Geological mapping ◆ Core drilling with site tests (SPT and permeability test) at upper & lower dam sites ◆ Laboratory tests ◆ Preparation of geological investigation report - Activities by JICA Expert ◆ Preparation of technical specifications ◆ Procurement of subcontractor ◆ Supervision of subcontractor's activities ◆ Check of subcontractor's geological investigation report ◆ Recommendation for further geological investigation for Victoria Lake PSPP	- Same items & levels of geo. inv. as done for Maha3 in 2015 - Output of the activities is; ◆ Geological investigation Report for Victoria Lake PSPP prepared by the subcontractor and checked by JICA Expert - The followings are **Not** included in the Scope 1: ◆ Geophysical prospecting (seismic prospecting and electrical resistivity prospecting) ◆ Core drillings for underground powerhouse and underground tunnels ◆ Underwater core drilling for lower dam at Victoria Lake ◆ Review of Maha3's geology ◆ Environmental survey ◆ Layout study ◆ Comparison & prioritization among Maha3 and Victoria - Activities at Lower Dam and Lower Reservoir area are subject to permission by CEB & JICA, as they are within the protected area. If not permitted, investigations at these area shall be omitted from the scope of Step 1.

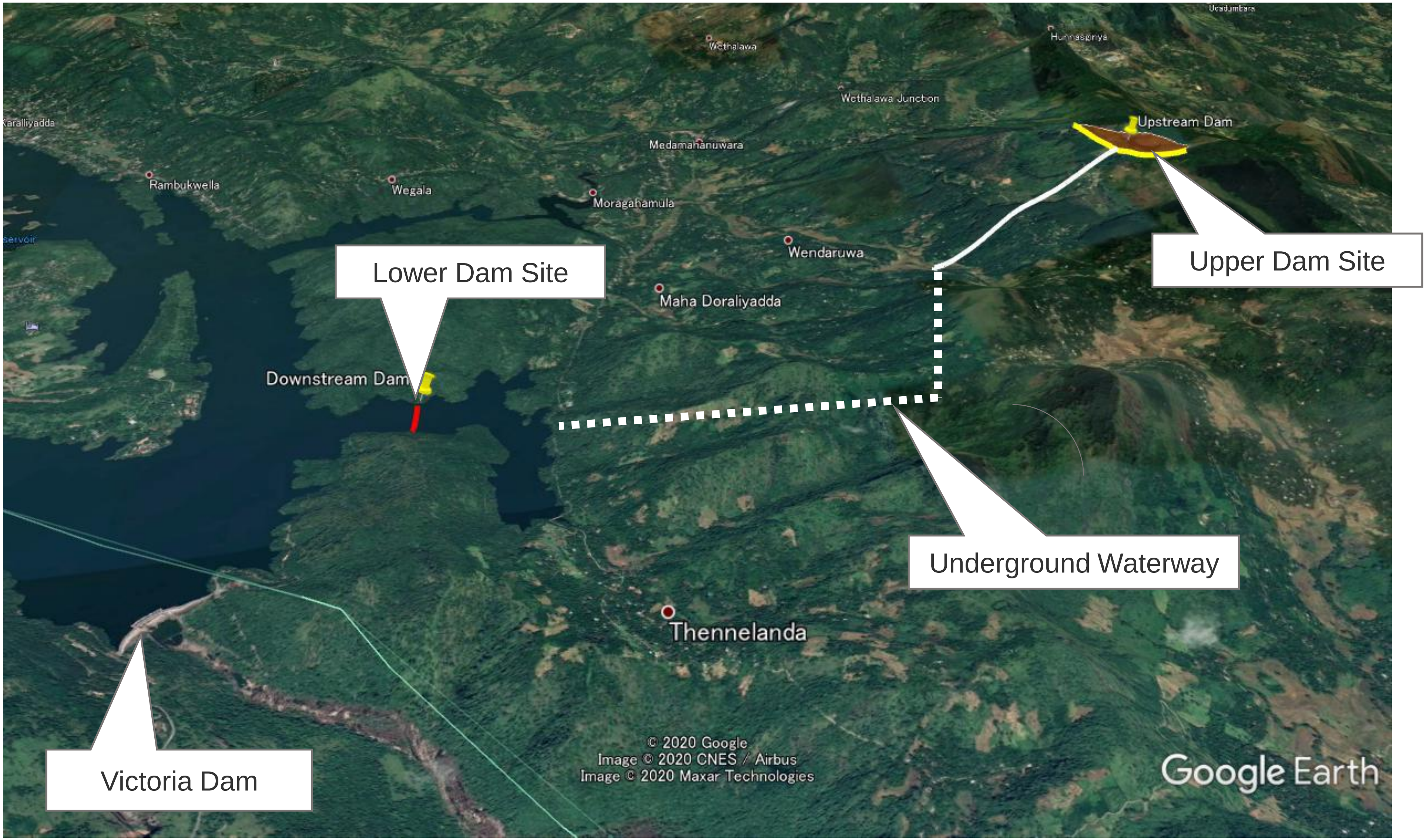
Basic Sequence



Schedule

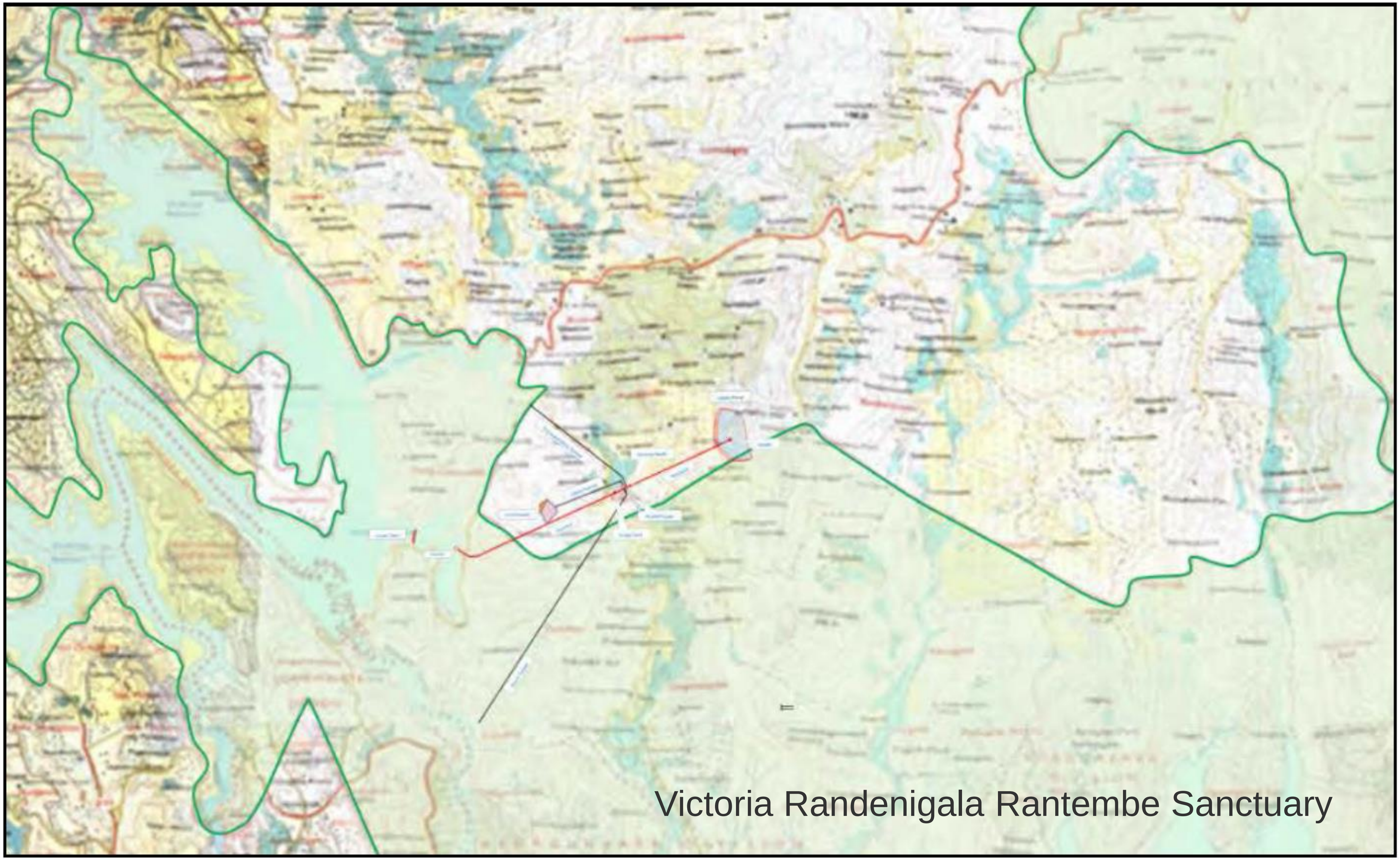

2020
2021
2022
2023
11
12
1
2
3
4
5
6
7
8
9
10
11
12
1-6
7-12
1-6
7-12
2 years
FS with ADB's Fund
Procurement of Consultant
Feasibility Study
Prioritization
Full swing F/S
ADB's Disbursement
JICA: Geo Investigation in Victoria site
Preparation
Procurement of subcontractor
Geological Investigation
by subcontractor
8 months
margin against
unexpected delay
Topographic survey
Geological mapping
Core drilling with site tests
Laboratory tests
Investigation Report
JICA: Assignment of Experts
Shingu
Wada

Victoria Lake PSPP: General Layout Image



Source: Google Earth

Victoria Lake PSPP: Protection Area



Source: Project on Electricity Sector Master Plan Study in Democratic Socialist Republic of Sri Lanka, 2018, JICA

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Democratic Socialist Republic of Sri Lanka

The Project for Capacity Development on the Power Sector Master Plan Implementation Program

2nd Technical Seminar

Evaluation on Geological Investigation Result at Victoria PSPP site

December 22nd, 2021

Chubu Electric Power Co., Inc.
Nippon Koei Co., Ltd.

Basic Sequence of Overall Schedule

CHUBU Electric Power
NIPPON KOEI

Step 1 (2021)
C/B by JICA Expert

Geo Inv. on Victoria PSPP

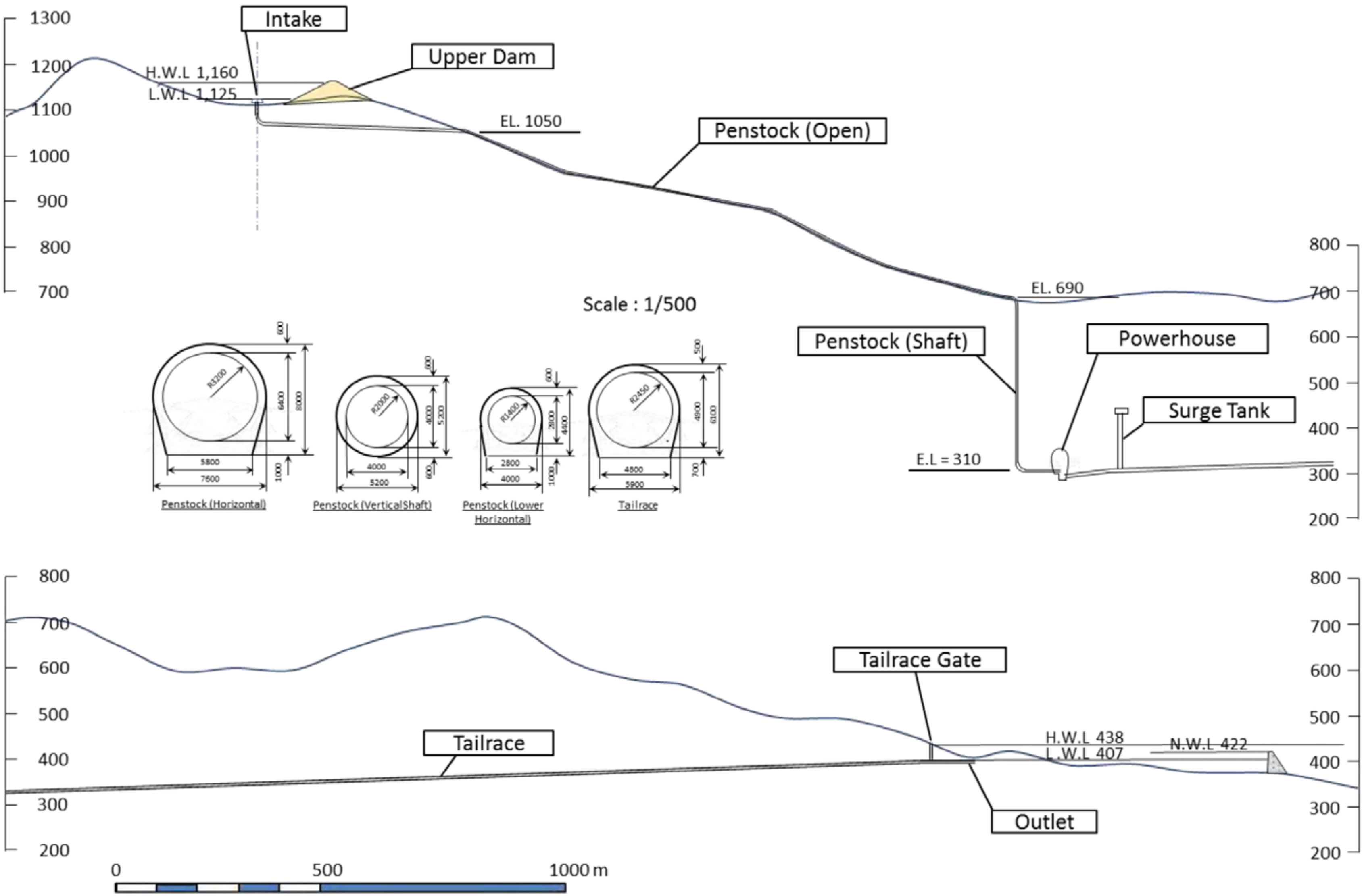
Current Stage

Step 2 (2022-2023)
F/S with ADB Fund

Step 2-1
Prioritization

Step 2-2
Full-swing F/S

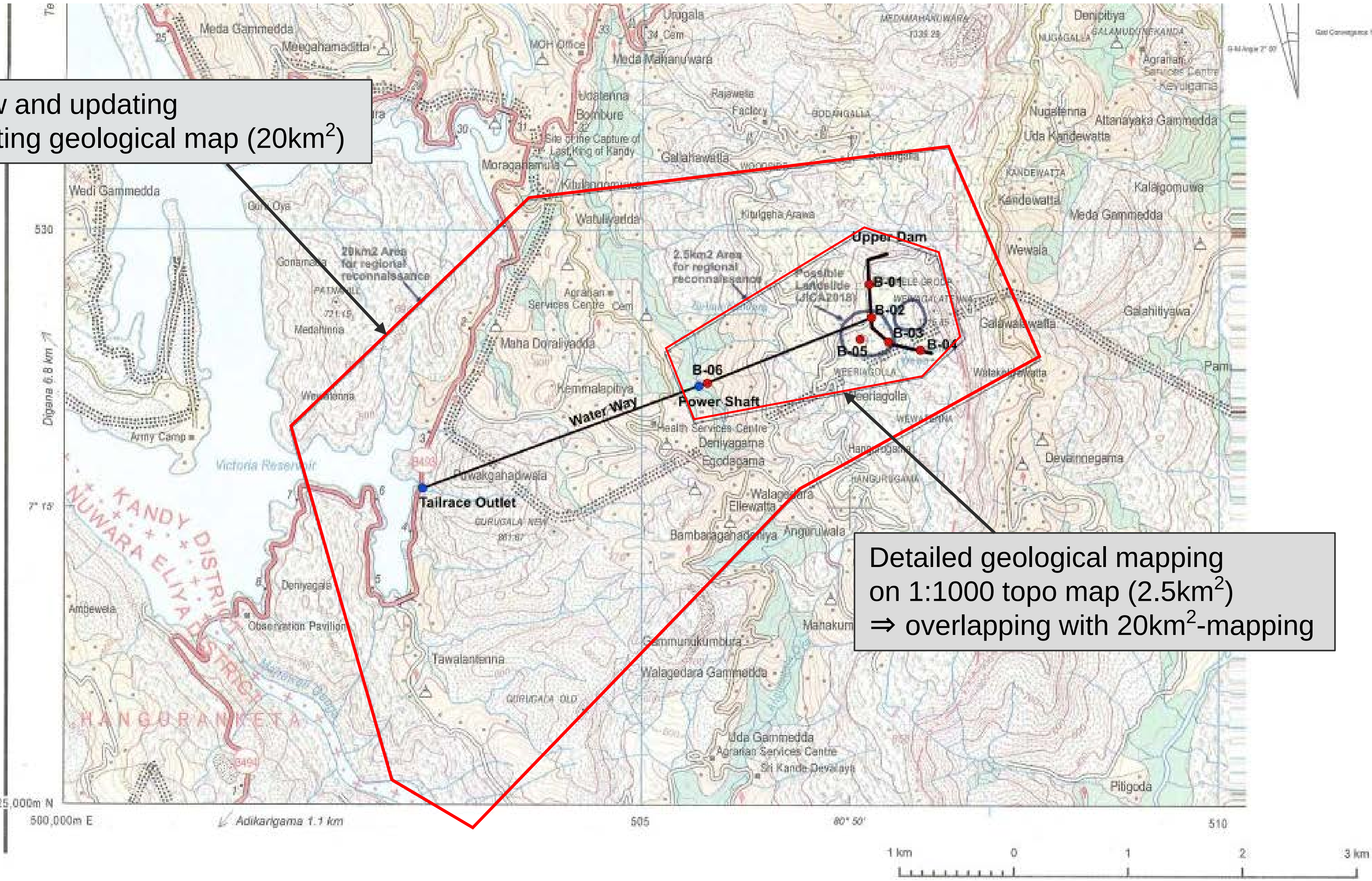
Victoria Lake PSPP: Longitudinal Profile of Waterway



Source: *Project on Electricity Sector Master Plan Study in Democratic Socialist Republic of Sri Lanka, 2018, JICA*

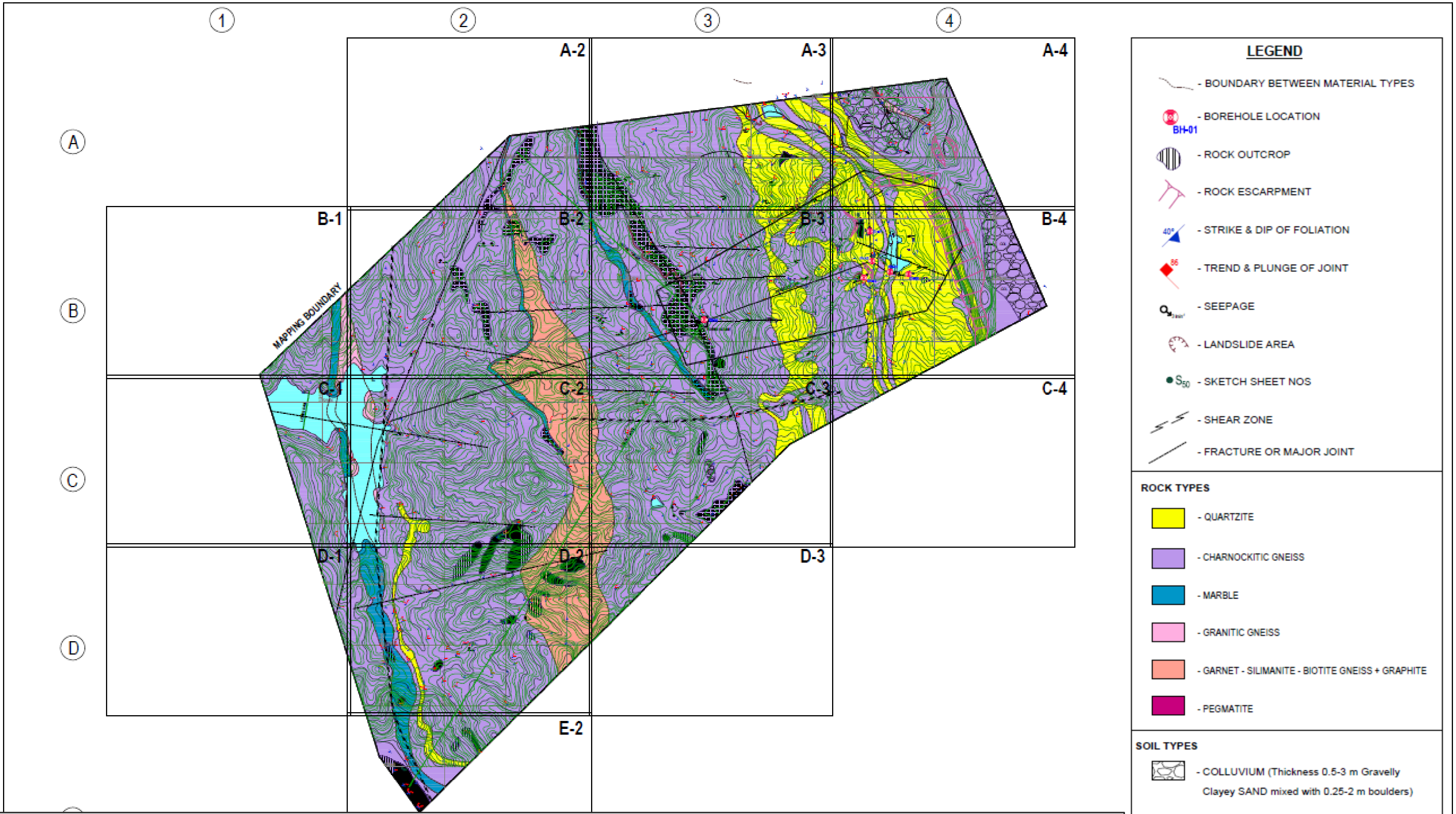
Geological Investigation: Plan of Mapping

Review and updating of existing geological map ($20km^2$)



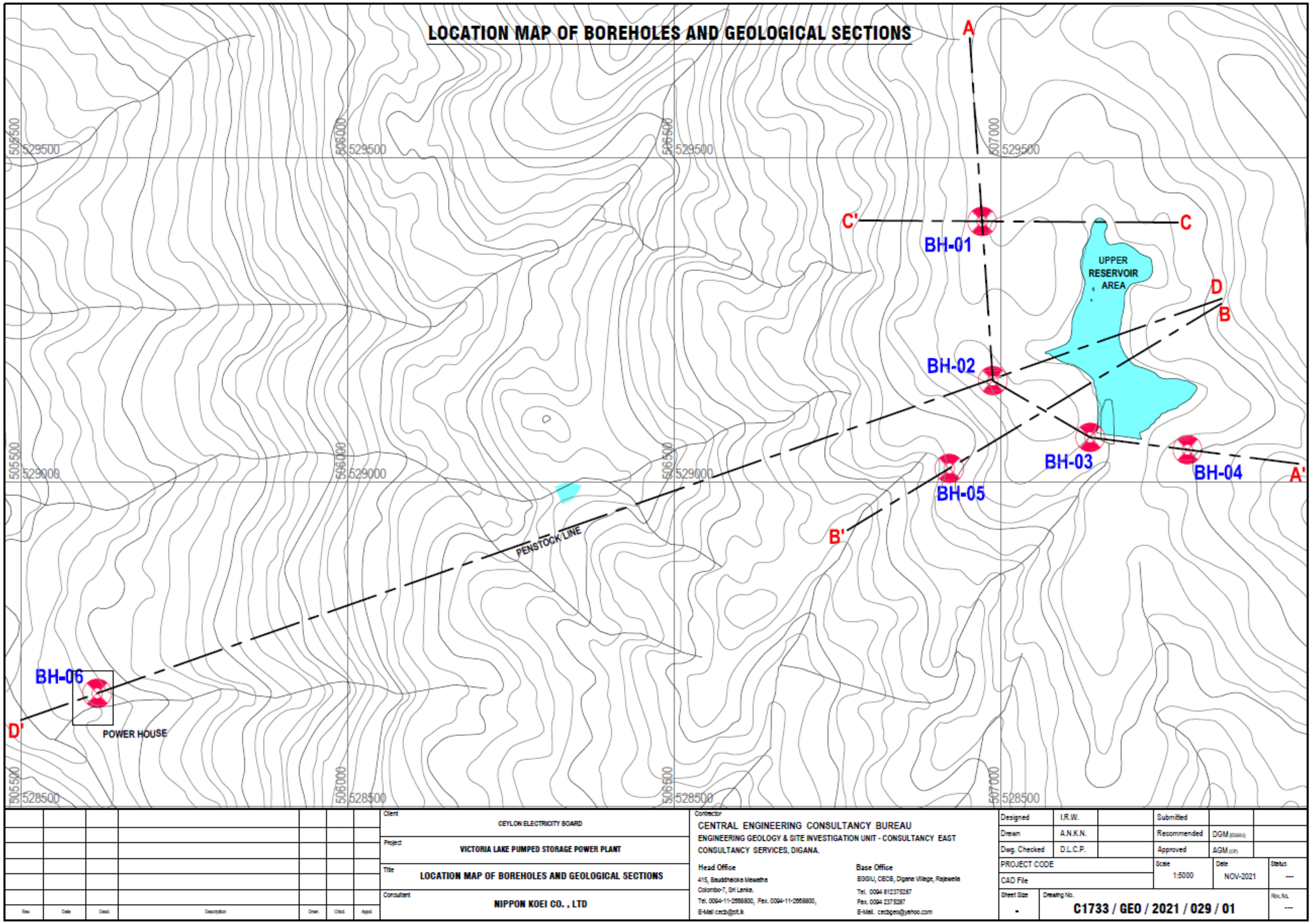
Detailed geological mapping on 1:1000 topo map ($2.5km^2$)
⇒ overlapping with $20km^2$-mapping

Geological Mapping

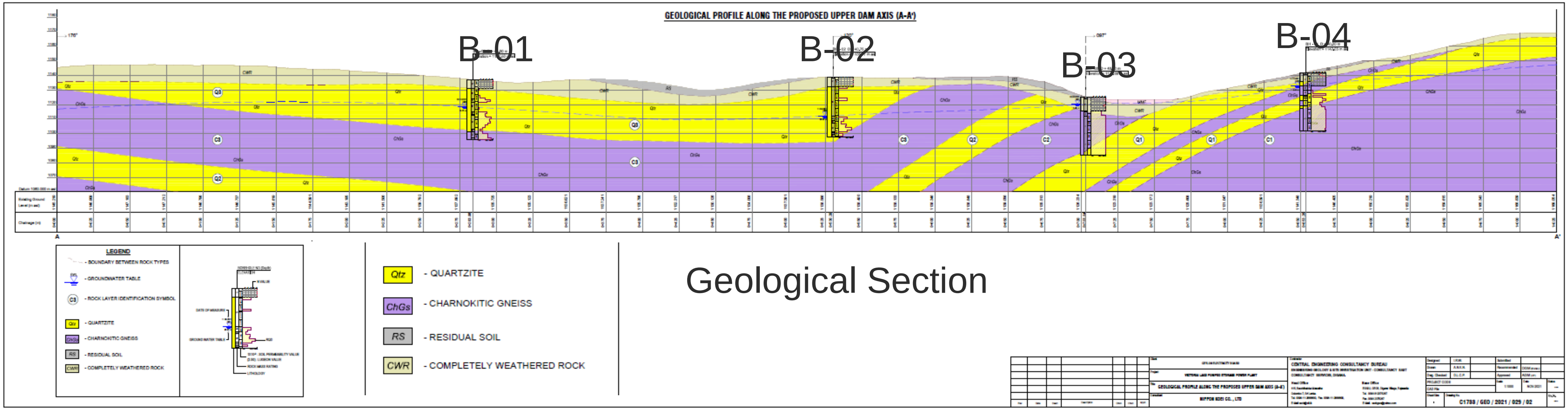


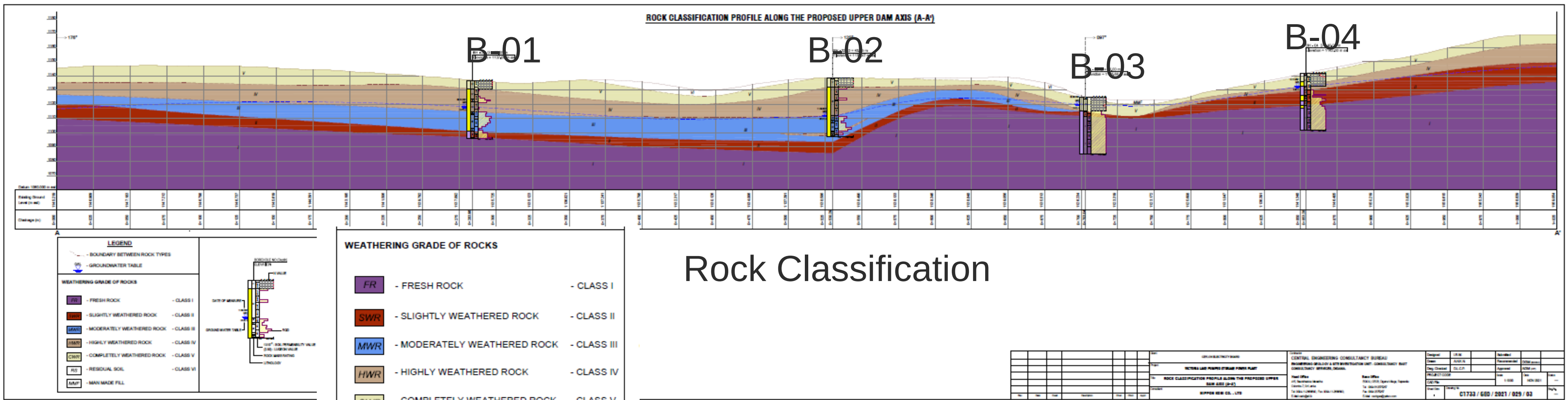
Note: Geology between lower part of the penstock and outlet of the waterway including underground powerhouse site is not only Charnokitic gneiss but possibly composed of various type of gneisses due to its mineral compositions. The Charnockitic gneiss associated with powerhouse shows more acidic features. Geology and rock condition especially for underground powerhouse site need to be confirmed by core drilling survey in next stage.

Geological Investigation: Plan of Core Boring



Geological Sections A-A





WEATHERING GRADE OF ROCKS

FR	- FRESH ROCK	- CLASS I
SWR	- SLIGHTLY WEATHERED ROCK	- CLASS II
MWR	- MODERATELY WEATHERED ROCK	- CLASS III
HWR	- HIGHLY WEATHERED ROCK	- CLASS IV
CWR	- COMPLETELY WEATHERED ROCK	- CLASS V
RS	- RESIDUAL SOIL	- CLASS VI
MMF	- MAN MADE FILL	

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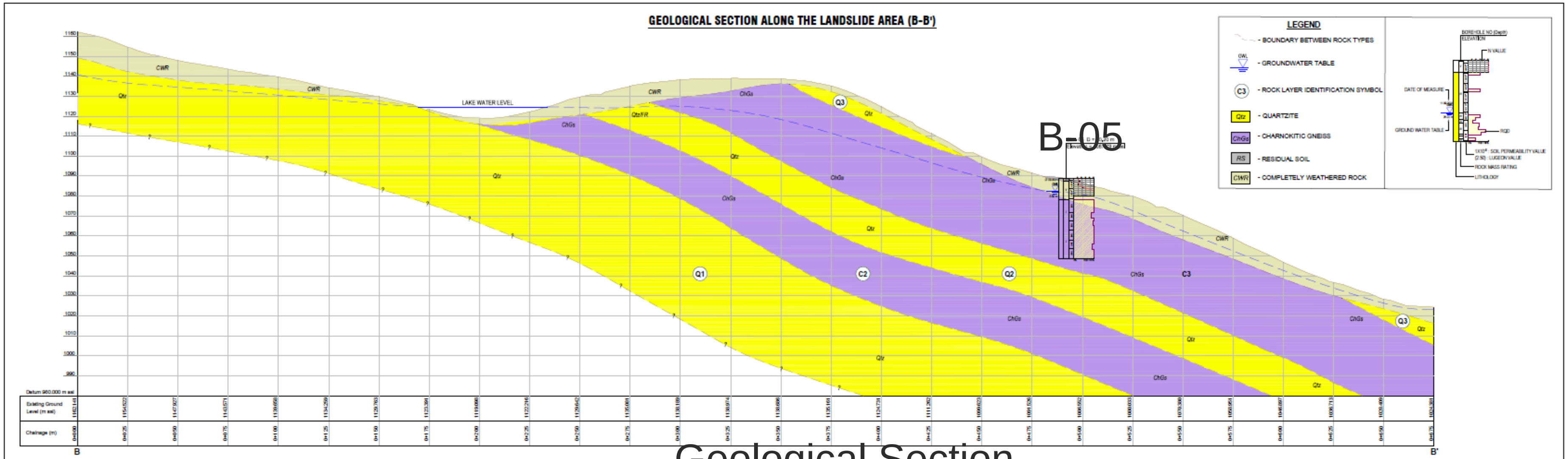
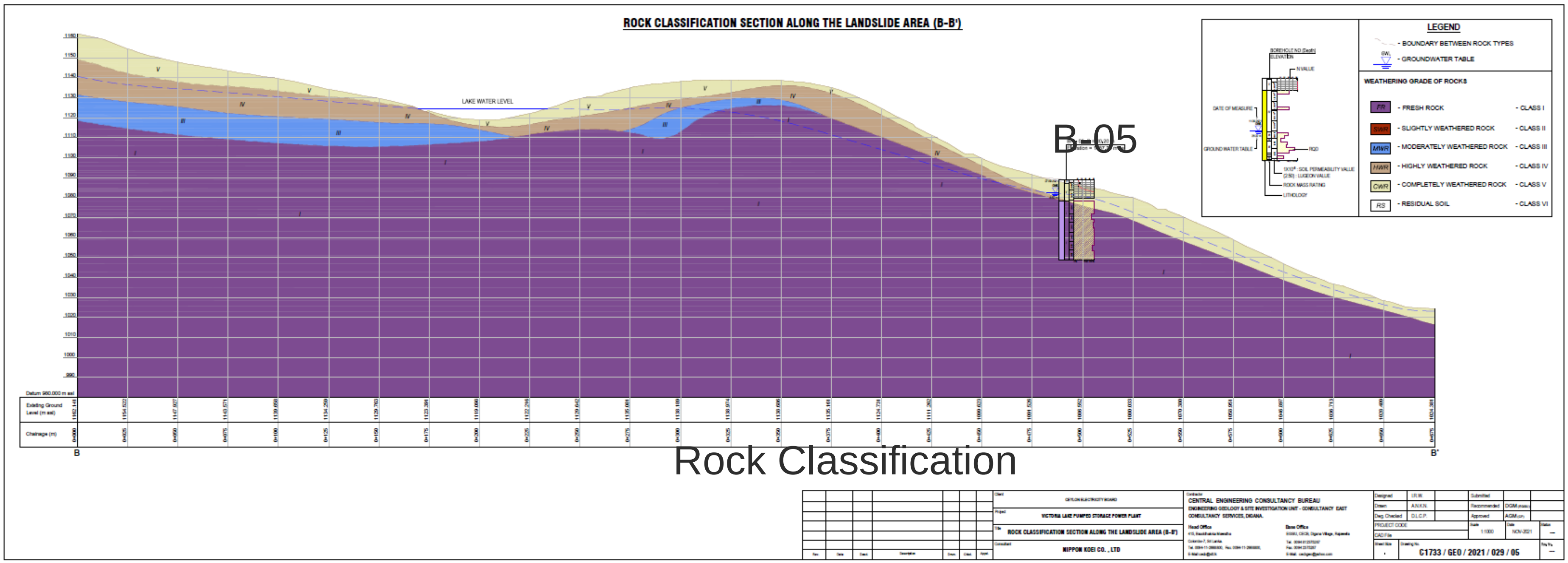
Geological Sections B-B



Geological Section



Rock Classification

Geological Sections C-C

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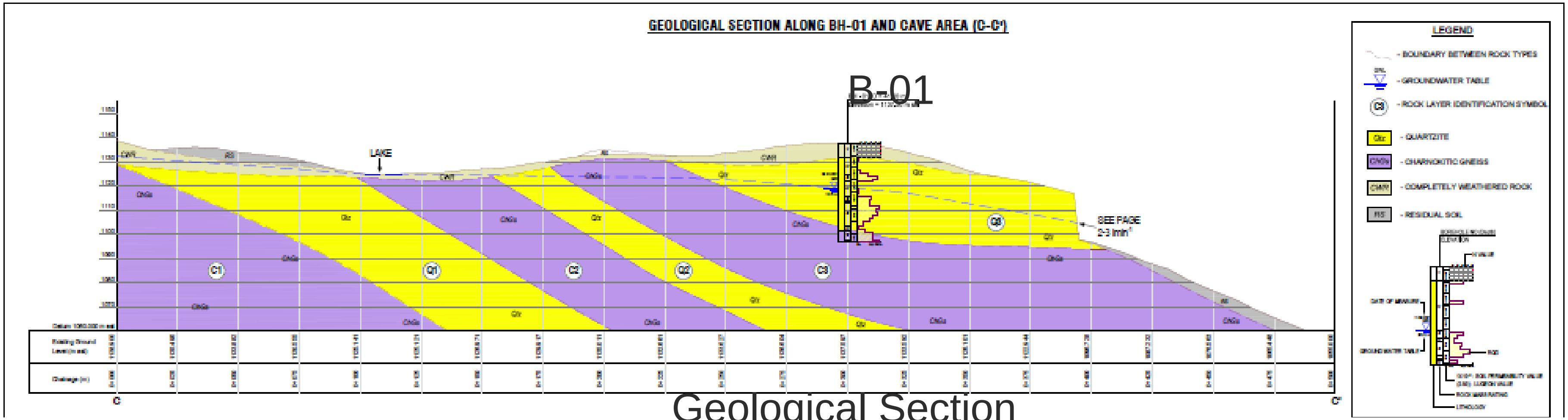
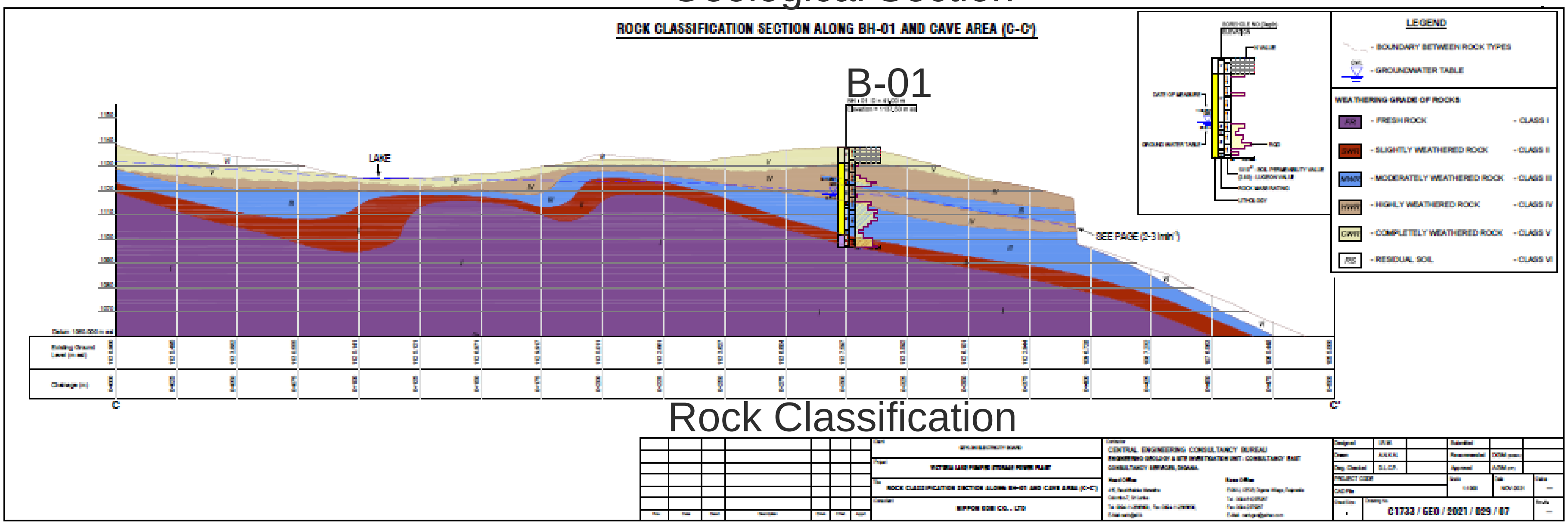


Geological Section



Rock Classification

Geological Sections D-D

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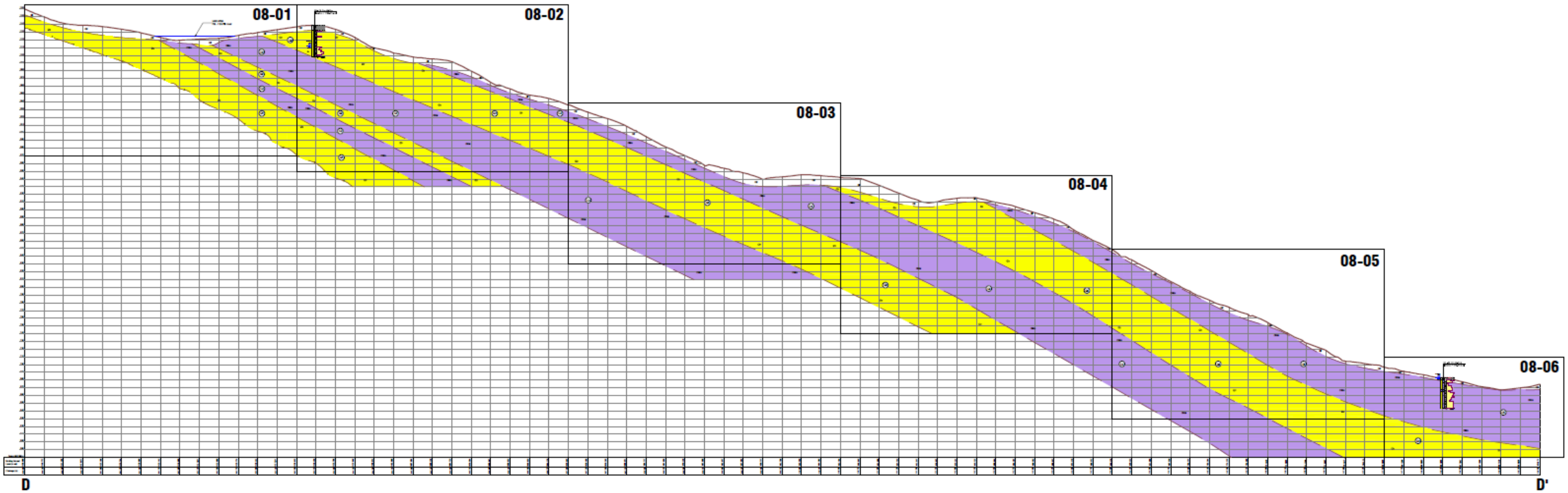
B-02



Geological Section

Evaluation of Investigation Result (1/3)

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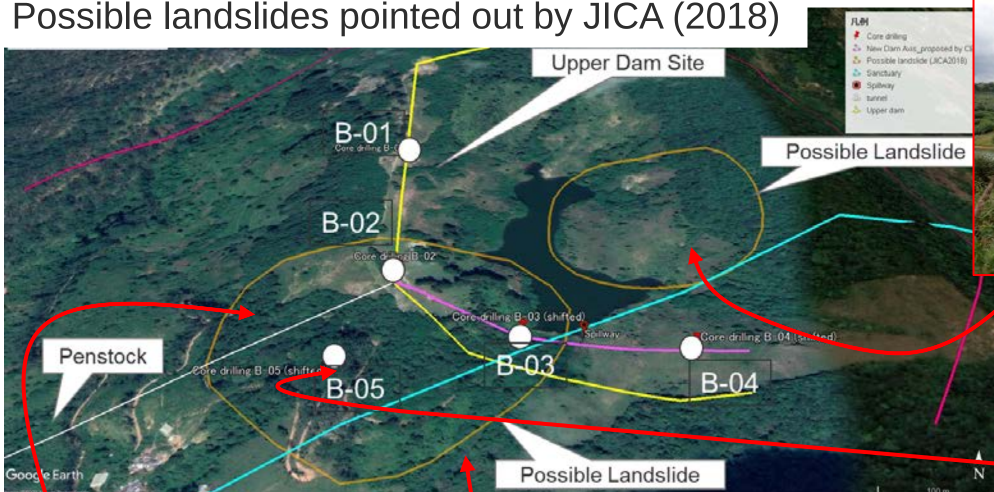
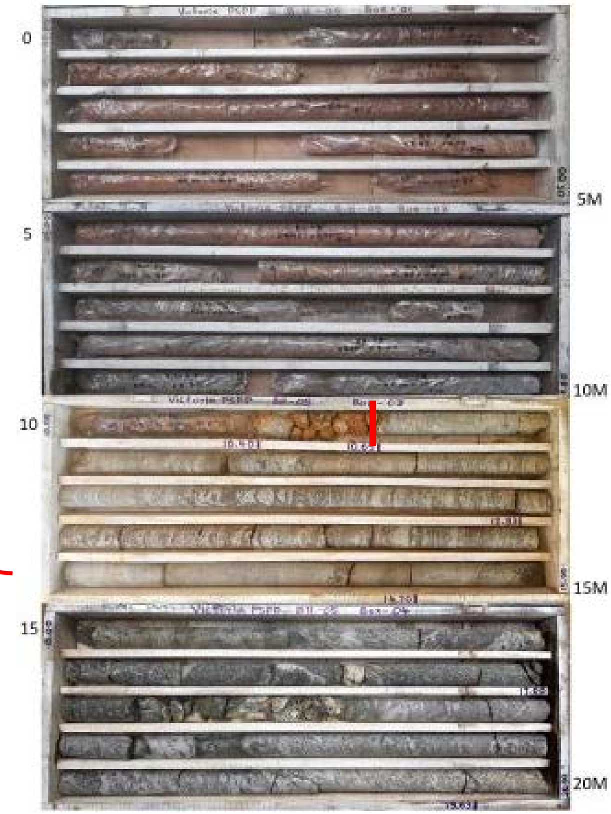
For upper area of Victoria PSPP site, fatal geological risks seem not exist, based on investigation results in this stage (2021)

- Possibility of landslide risks seem low around upper dam site and penstock areas → need final confirmation in F/S 1st stage

Possible landslides pointed out by JICA (2018)



Many fresh outcrops exists inside slope, without any disturbing direction of rock foliation



Encountering hard rock at shallow depth (10.60m) in drill No.BH-05

Large outcrop of fresh rock inside possible landslide block

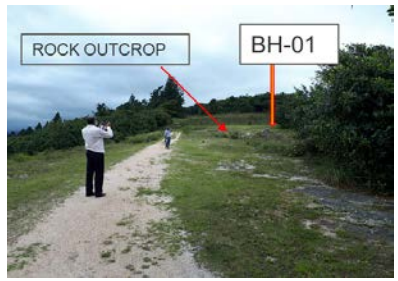
No identical phenomena of landslide around slope

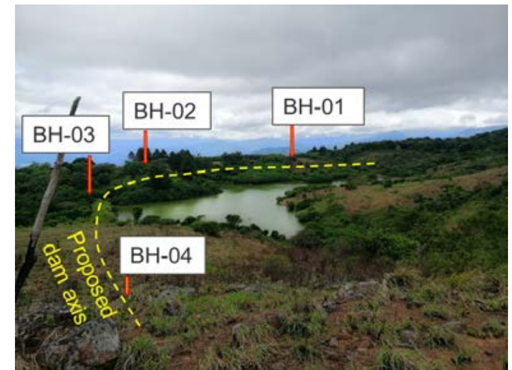
Evaluation of Investigation Result (2/3)

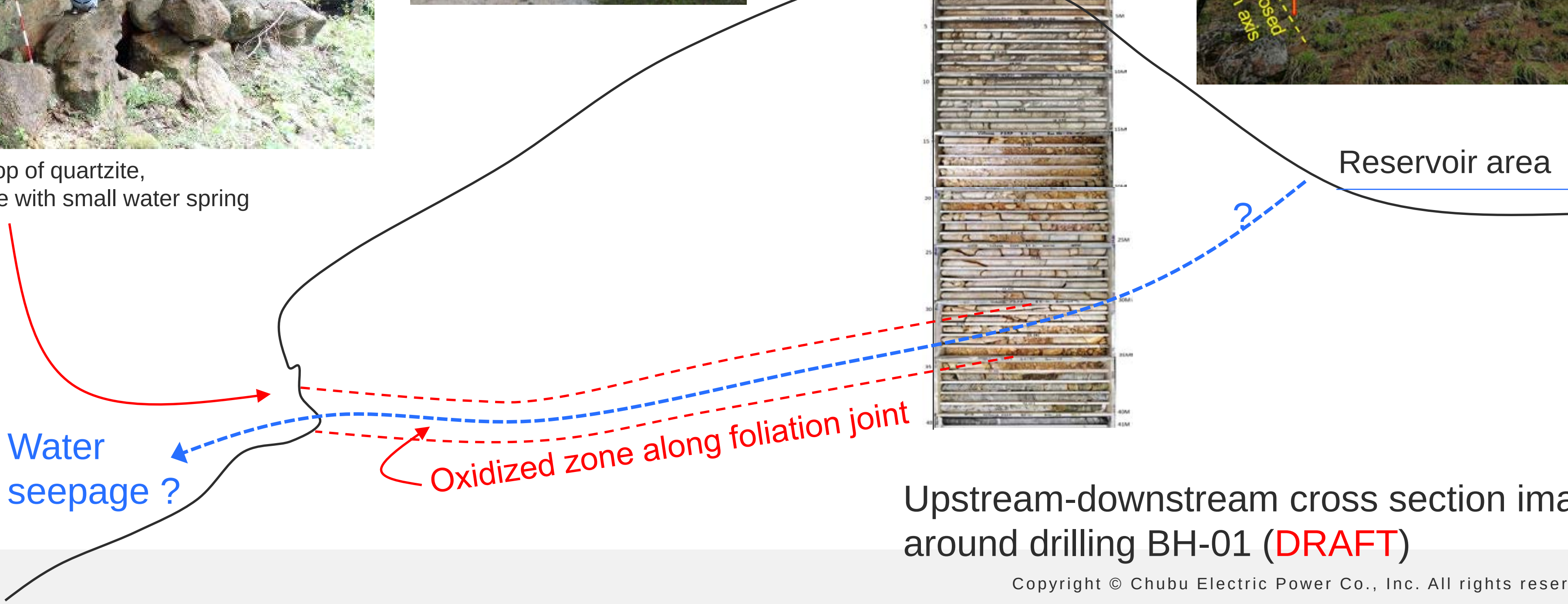
However, some considerable issues are identified for upper area of Victoria PSPP site

- Basically, water permeability seems low around upper dam site and reservoir area, but possible minor seepage should be considered at right bank → need evaluation in F/S stage

Large outcrop of quartzite, forming cave with small water spring





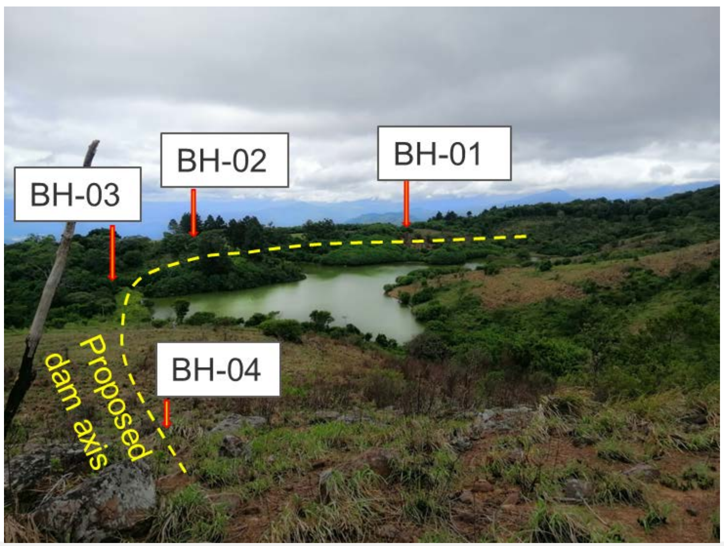


Upstream-downstream cross section image around drilling BH-01 (DRAFT)

Evaluation of Investigation Result (3/3)

- Quartzite around right bank of upper dam foundation seems fragile in core sample, while seems hard in outcrop. → caused by drilling operation inside tight-joint rich zone ? →difficult to estimate geotechnical parameters → recommending adit observation with in-situ tests, such as rock shear test and loading test in F/S stage

Fragile core sample (BH-02: 15-20m)



Hard outcrop of quartzite around right bank of upper dam site

EXAMPLE: adit in other project

Conclusion (1/2)

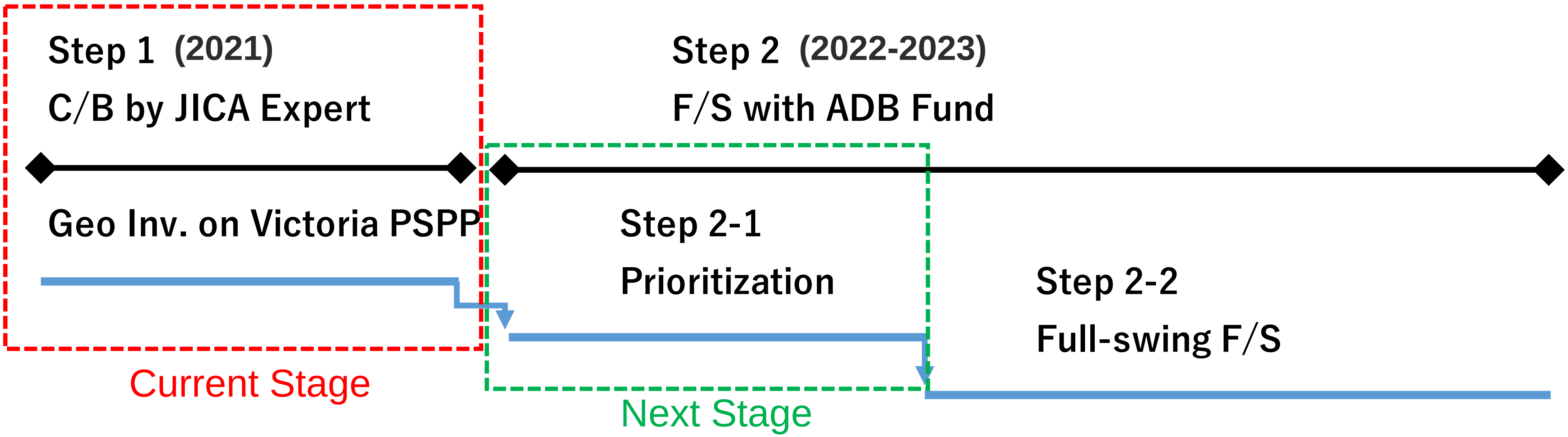
Structures	Check points	Major conceivable issues	
		Focused by JICA (2018)	Based on this investigation (2021)
Upper storage dam	1. Safety of dam foundation 2. Water tightness	1. Possibility of landslide risks 2. No information	1. Possibility of landslide risks seem low. 2. Basically tight, but possible minor seepage at right bank. 3 Quartzite at right bank seems. moderately weak, need to check strength of quartzite. 4 Original dam axis should be slightly shifted to upstream side in consideration of creep length and stability of foundation rock.
Reservoir	1. Landslide risks 2. Water seepage risks	1. Possibility of landslide risks 2. No information	1. No landslide risks. 2. Seepage risks seem low, but need check narrow ridges condition surrounding reservoir.
Upper water way	1. Landslide risks of portals 2. Rock condition along water ways	1. No information 2. No information	1. Possibility of landslide risks seem low. 2. No identified risks along penstock. 3 Quartzite around intake seems moderately weak, need to check strength of quartzite. 4 Possibility of minor water inflow.

Conclusion (2/2)

Structures	Check points	Major conceivable issues	
		Focused by JICA (2018)	Based on this investigation (2021)
Underground Powerhouse	1. Rock condition	1. No information	1. No information, but - possibly marble layer is not so thick, based on the regional geological mapping - weak and permeable sheared zone and anisotropic biotite gneiss described in published geological map
Lower water way	1. Landslide risks of portals 2. Rock condition along water ways	1. No information 2. Two lineaments (possibly fracture zone) crossing the tunnel.	1. No information 2. Two lineaments (possibly fracture zone) crossing the tunnel.
Lower storage dam and reservoir	Safety of dam foundation, water tightness, landslide and water seepage risks	No information	No information, but following issues are described in published geological map - permeable marble - weak and permeable shared zone - anisotropic biotite gneiss

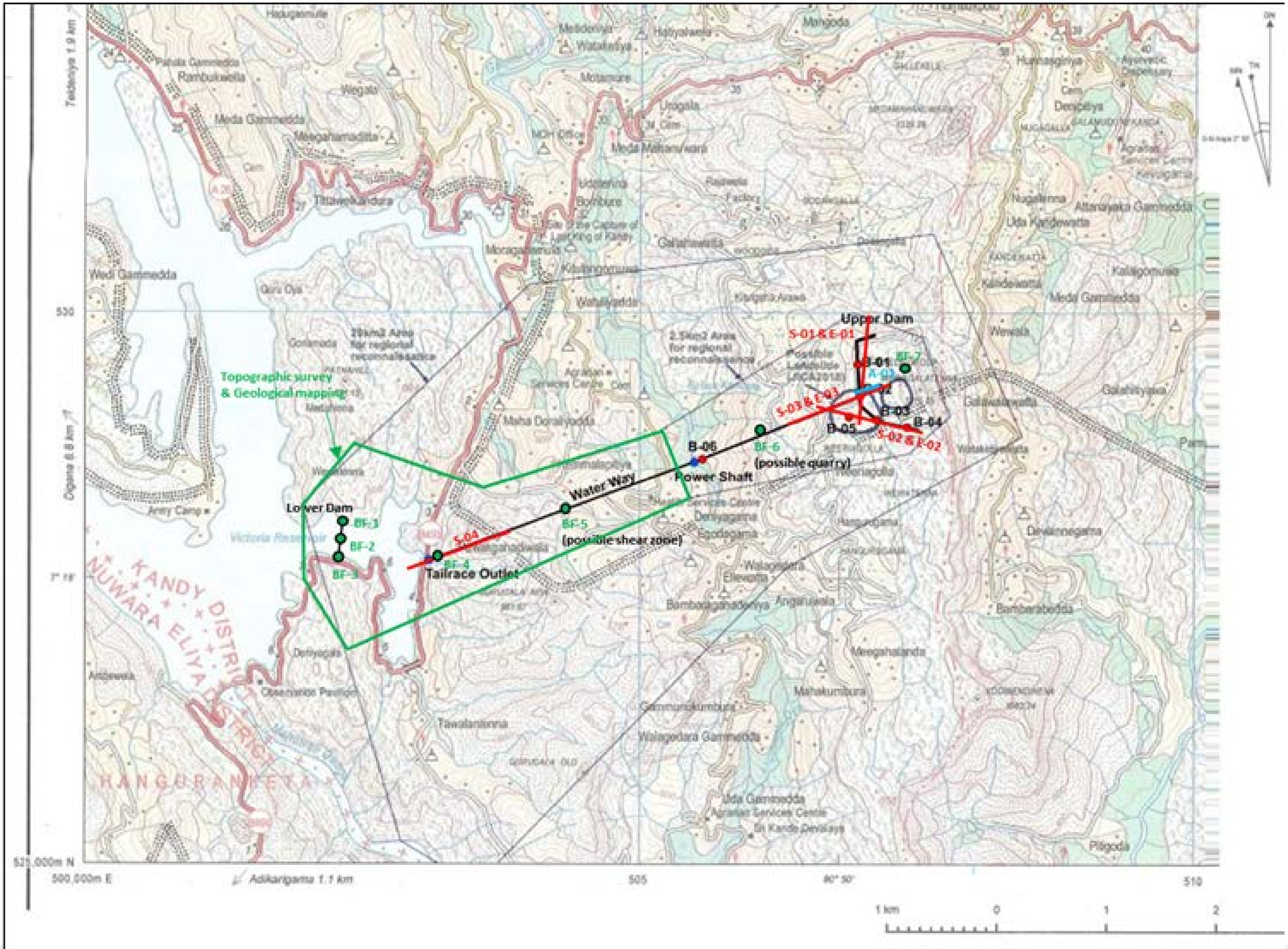
No geotechnical investigation were conducted in this stage (2021)

Basic Sequence of Overall Schedule



Recommendation in Next F/S 1st Stage

Proposed layout of geological investigation for Victoria Lake site in Next F/S 1st stage



Completed drilling location (2021):

- Drilling (B-01 to 06)
- Topographic survey & Geological mapping

Proposed layout of investigation for F/S 1st stage:

- Drilling (BF-)
- Seismic prospecting (S-)
- Electrical resistivity prospecting (E-)
- Test Adit (A-)
- Topographic survey & Geological mapping

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PSPP On-site Training in WG2 (Geology & Geological Investigations)

October 28, 2020

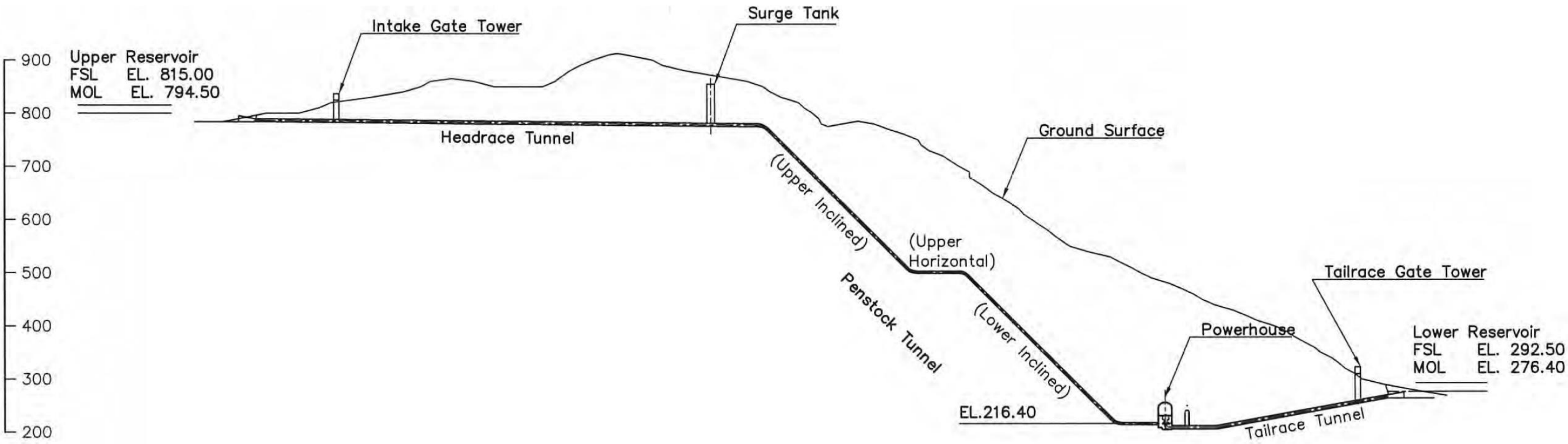
Chubu Electric Power Co., Inc.
Nippon Koei Co., Ltd.

Agenda of Today's Program

Time		Contents
9:30-12:00		✓2nd Meeting of WG2- PSPP(Pumped Storage Power Plant) On-site Training (Remotely, On the Desk)
	9:30-9:40	Address by Dr. Suresh Chand Verma, WG2 Team Leader, JICA Expert Team
	9:40-10:10	1. Issues of geology on Maha 3 and Victoria Lake PSPP development by Mr. WADA Masaki, JICA Expert Team 1-1 Upper and Lower Storage Dams 1-2 Upper and Lower Reservoirs 1-3 Waterways 1-4 Underground Powerhouse 1-5 Questions & Answers
	10:10-10:40	2. Recommended scope and schedule of geological investigation at F/S level for Maha 3 and Victoria Lake PSPP that will be performed by CEB in the future by Mr. SHINGU Hirohisa, JICA Expert Team 2-1 Contents of Geological Investigation 2-2 Bill of Quantity 2-3 Schedule 2-4 Questions & Answers
	10:40-10:55	Break
	10:55-11:25	3. General guidance on each item of geological investigations for PSPP by CEB in the future by Mr. SHINGU Hirohisa, JICA Expert Team 3-1 Geophysical Surveys 3-2 Core Drilling 3-3 Field and Laboratory Tests 3-4 Questions & Answers
	11:25-11:50	4. Discussion
	11:50-12:00	Address by Mr. D. S. R. Alahakoon, WG2 Leader of Management, CEB

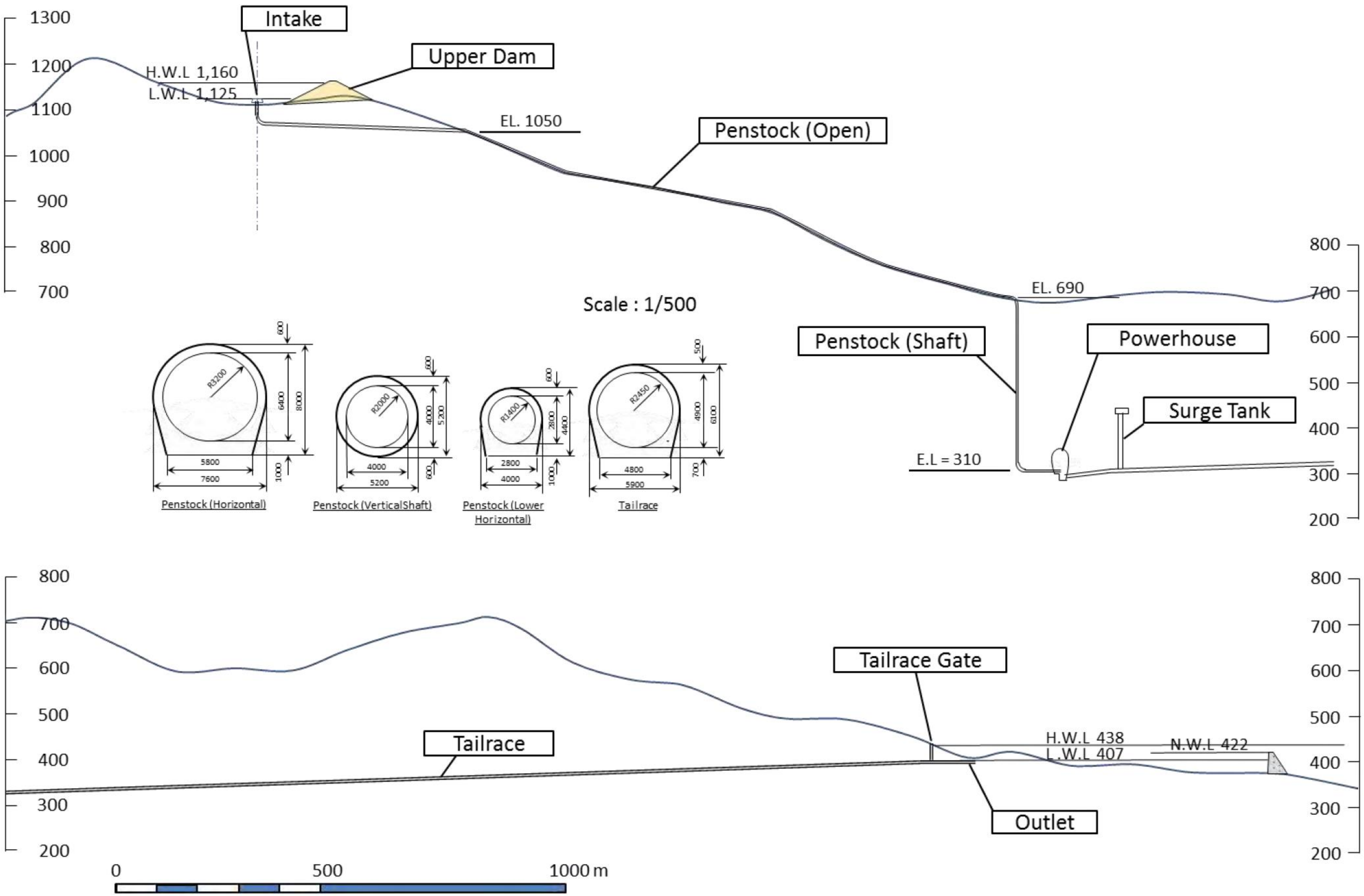
1.
Issues of Geology on Maha3 and Victoria Lake PSPP Development

Maha3 PSPP: Longitudinal Profile of Waterway



Source: Development Planning on Optimal Power Generation for Peak Demand in Sri Lanka, 2015, JICA

Victoria Lake PSPP: Longitudinal Profile of Waterway



Source: Project on Electricity Sector Master Plan Study in Democratic Socialist Republic of Sri Lanka, 2018, JICA

Issues of Maha3 and Victoria Lake PSPPs

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	Maha3 PSPP	Victoria Lake PSPP
Source of Info.	• Development Planning on Optimal Power Generation for Peak Demand in Sri Lanka, 2015, JICA	• Project on Electricity Sector Master Plan Study in Democratic Socialist Republic of Sri Lanka, 2018, JICA
Geology	• Site investigation: in 2015 • **Upper dam: thick deposit on the left bank of the talus** • Lower dam: no critical issue • Waterway: layers nearly parallel to the water route	• Site reconnaissance: in 2018 • **Upper dam: possibility of existence of landslide** • Lower dam: unclear • Waterway: lineament
Environment	• Environmental study: in 2015 • Natural: out of the protection area • **Social: resettlement of 28 households within the inundated area**.	• Site reconnaissance: in 2018 • **Natural: lower dam within the protection area.** • Social: direct impacts on the village may not be substantial.
Technical Aspect		• **Pumping head: more than 700m** • **Lower dam: construction in the Victoria Lake**

1. Issues of Geology on Maha 3 Site

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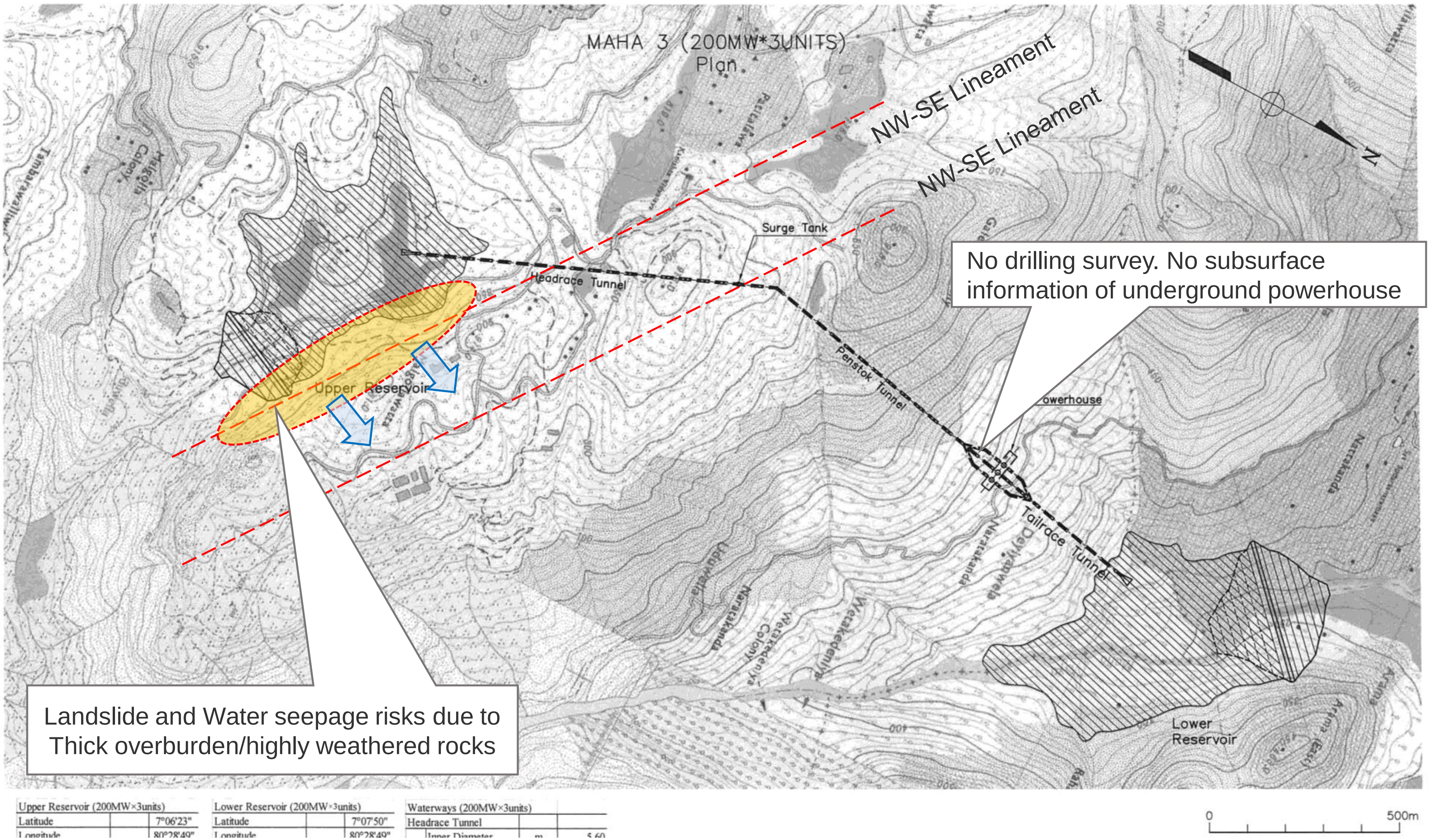
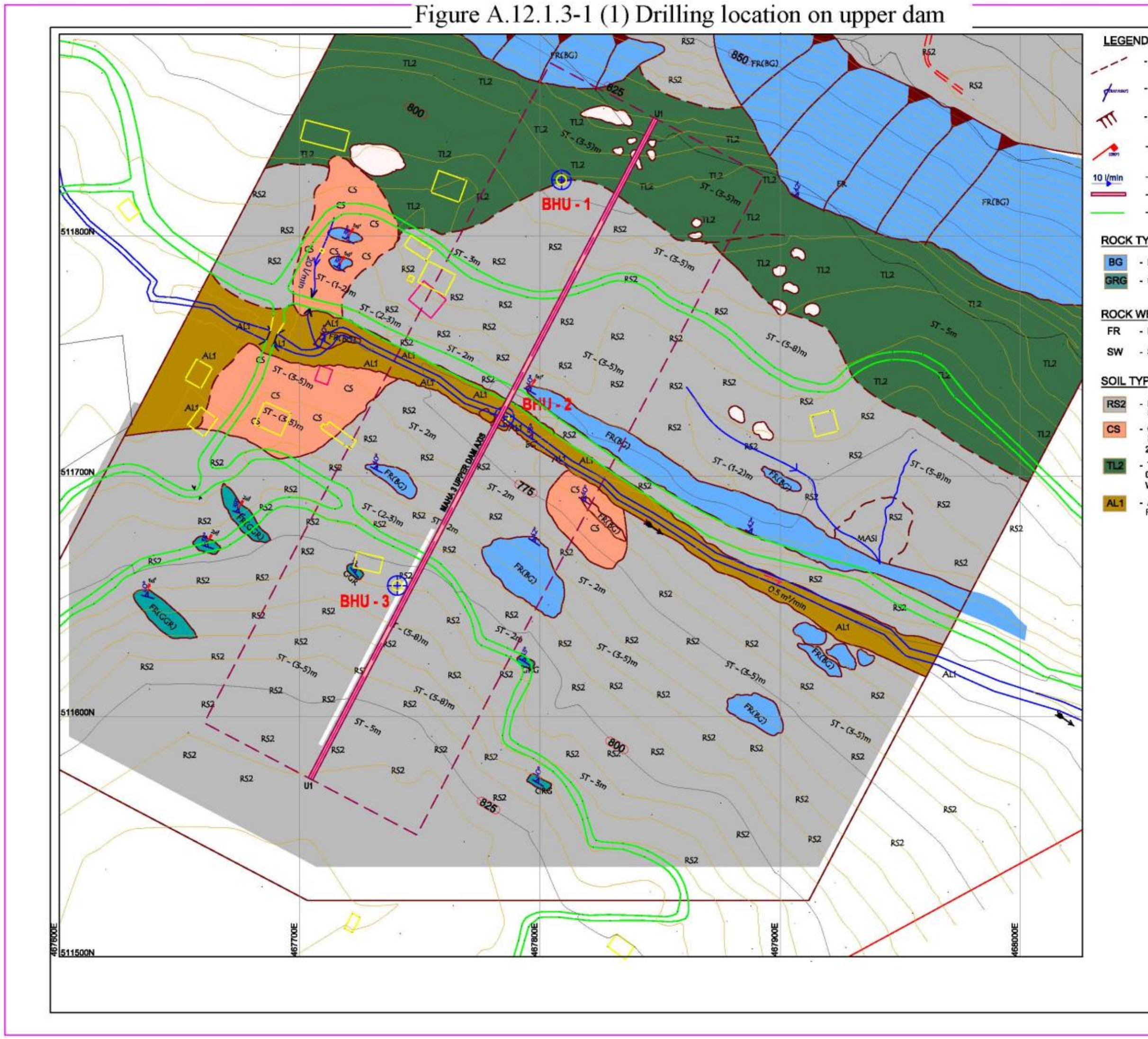
Structures	Check points	Major considerable issues
Upper storage dam	• Safety of dam foundation • Water tightness	• Thick talus deposits/highly weathered rocks on left bank • Impermeable layer seems to be deep on left bank (more than 50 m in depth)
Reservoir	• Landslide risks • Water seepage risks	• No information, but daily fluctuation of water level might thick weather zone on the left bank might trigger landslides especially on left bank covered with thick overburden. • No information, but seepage risks on left bank are anticipated.
Water way	• Landslide risks of portals • Rock condition along water ways	• No information • Geological structures nearly parallel to the waterway route. • NE-SW lineaments (possible faults) were identified.
Underground powerhouse	• Rock condition	• Biotite gneiss according to existing geological map. • No critical issues according to the Report (2015)
Lower storage dam and reservoir	• Same as upper storage dam and reservoir (Safety of dam foundation, Water tightness, Landslide risks and Water seepage risks)	• No critical issues according to the Report (2015)

Maha3: Layout of the Structures and Geological Issues



Source: Development Planning on Optimal Power Generation for Peak Demand in Sri Lanka, 2015, JICA, JICA Study Team added the geological information.

Maha3: Geological Map of Upper dam



BORE HOLE LOCATION

	EASTING	NORTHING	ELEVATION
BHU - 1	467806.96	511823.35	798.96
BHU - 2	467785.14	511724.75	765.92
BHU - 3	467740.64	511654.55	804.18

Rev	Date	Dead	Description	Drwn	Chk'd	App'd

DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA
JICA STUDY TEAM

Project: TOPOGRAPHY SURVEY AND GEOLOGICAL INVESTIGATION SURVEY FOR DEVELOPMENT PLANING ON OPTIMAL POWER GENERATION FOR PEAK DEMAND IN SRI LANKA

Title: GEOLOGY MAP ALONG MAHA 3 UPPER DAM AXIS

cecb CENTRAL ENGINEERING CONSULTANCY BUREAU
DESIGN OFFICE - EPC DIVISION , DIGANA

Designed	J.A.S.K.J.	Recommended : PM	
Drawn	A.N.K.N.		
Checked	D.L.C.P.	Approved : AGM	
Submitted	E.G.U.	Scale 1 : 1000	Date OCT - 2014 / Status -
CAD File	D - / DRAWINGS		
Sheet Size A2	Drawing No. MAH / JICA / EPCD / GSB - 003		Rev. No. -

Source: Development Planning on Optimal Power Generation for Peak Demand in Sri Lanka, 2015, JICA

Maha3: Geological Section of Upper Dam (Original)

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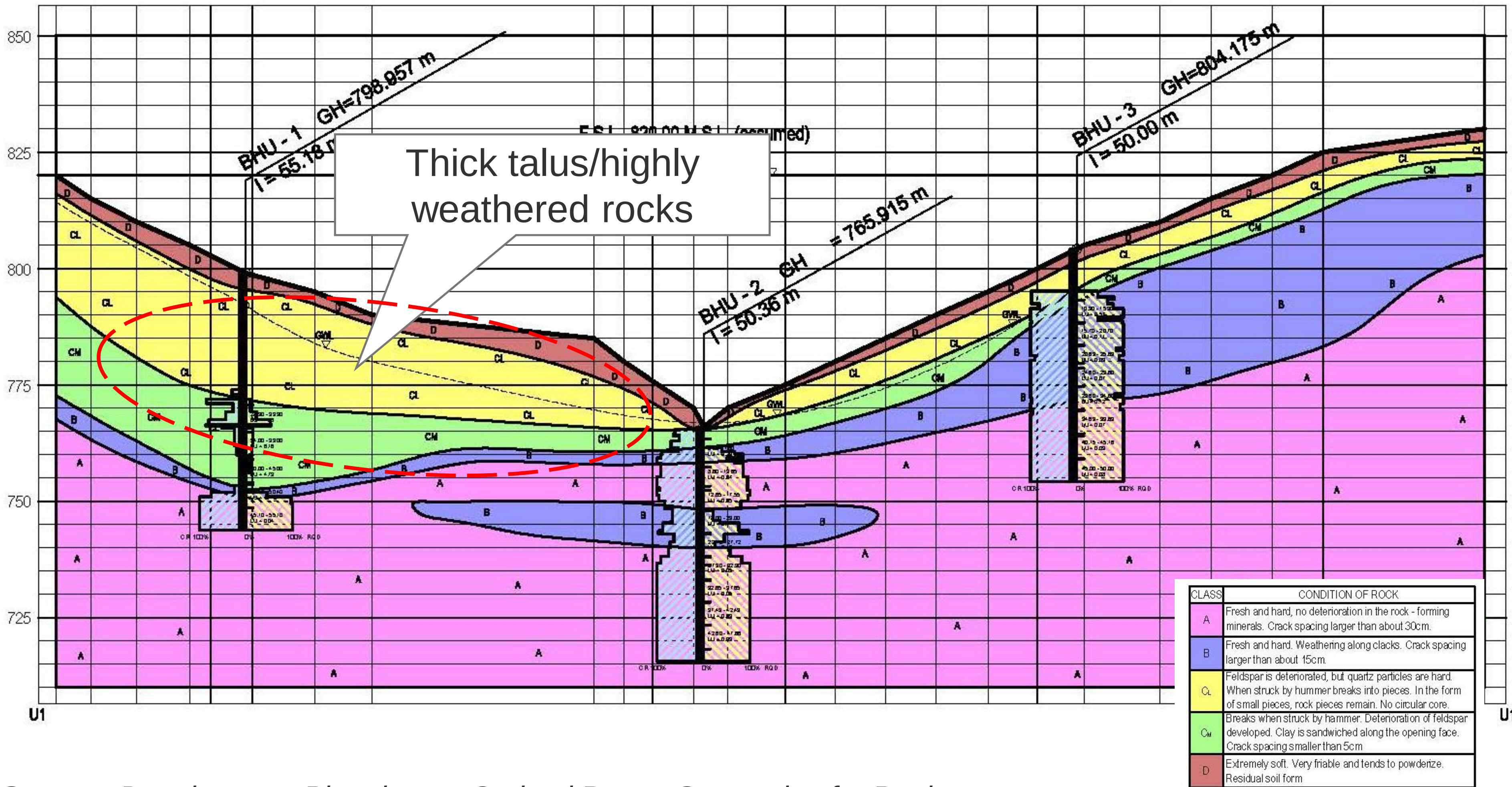
U1 - U1 Dam Axis

Geological Section Based on tentative Rock Mass Classification by CECB



Source: Development Planning on Optimal Power Generation for Peak Demand in Sri Lanka, 2015, JICA

Maha3: Geological Section of Upper Dam (Reviewed)

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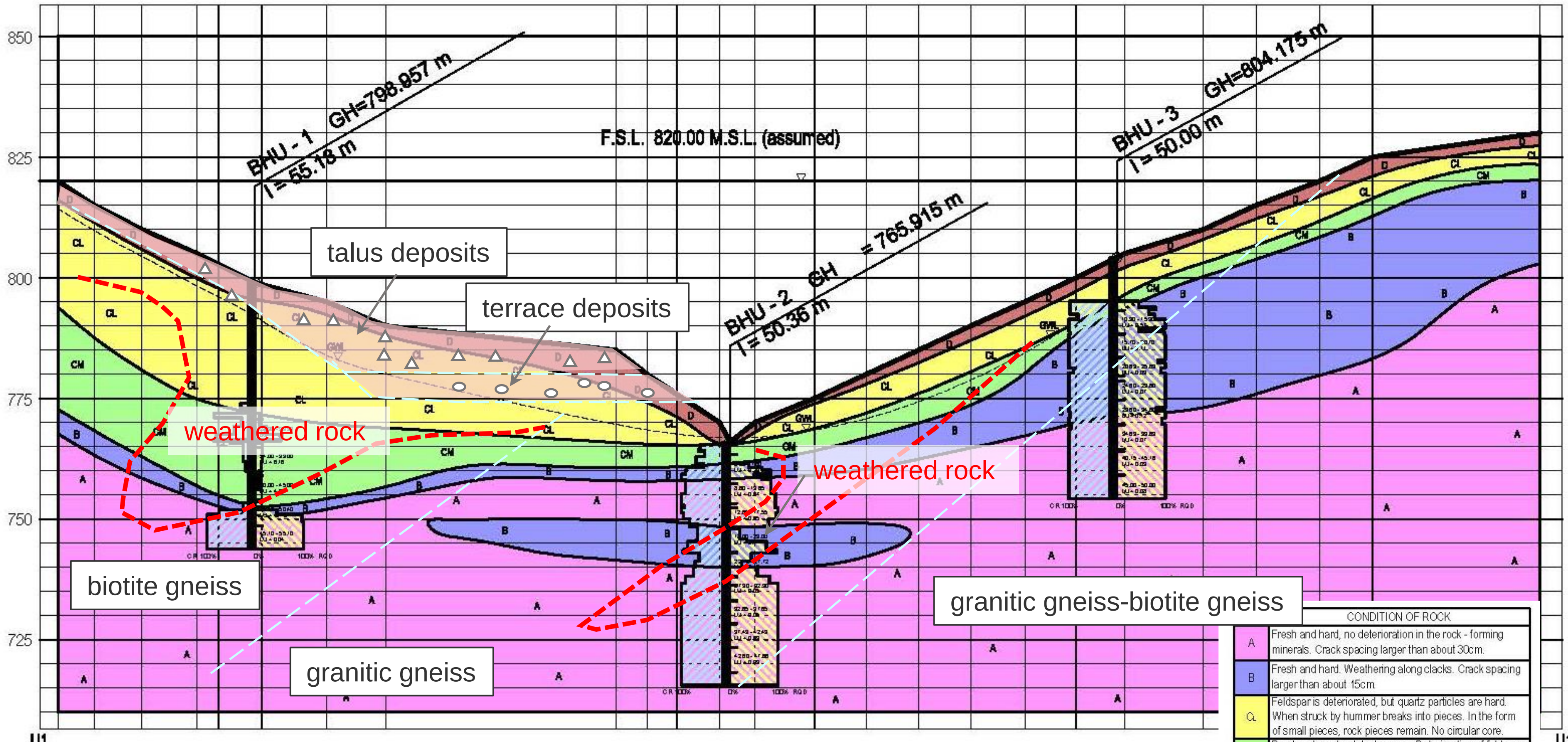
Another possibility of geological section along dam axis



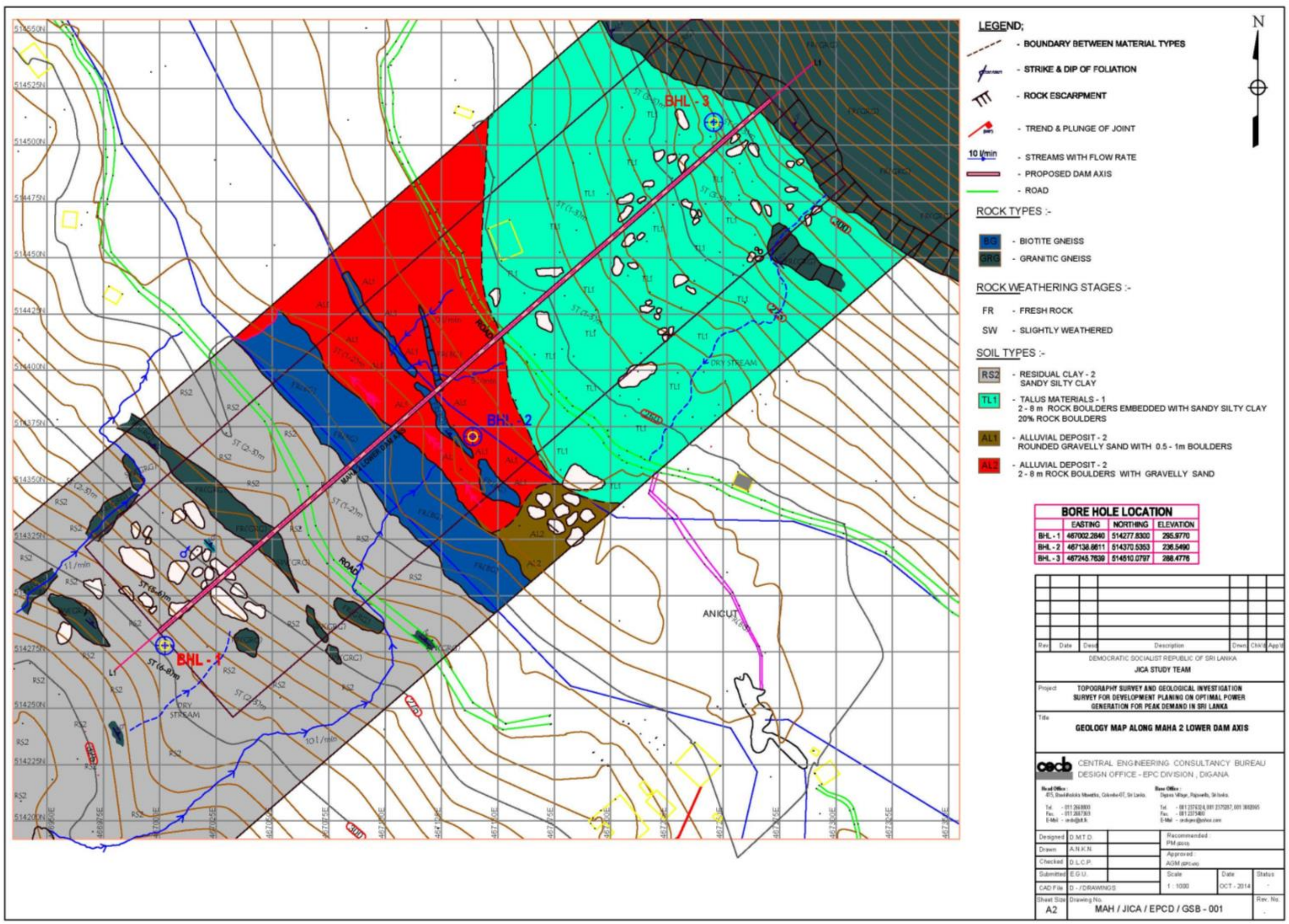
CONDITION OF ROCK	
A	Fresh and hard, no deterioration in the rock - forming minerals. Crack spacing larger than about 30cm.
B	Fresh and hard. Weathering along clacks. Crack spacing larger than about 15cm.
CL	Feldspar is deteriorated, but quartz particles are hard. When struck by hummer breaks into pieces. In the form of small pieces, rock pieces remain. No circular core.
CM	Breaks when struck by hammer. Deterioration of feldspar developed. Clay is sandwiched along the opening face. Crack spacing smaller than 5cm
D	Extremely soft. Very friable and tends to powderize. Residual soil form

Source: Development Planning on Optimal Power Generation for Peak Demand in Sri Lanka, 2015, JICA, JICA Study Team reviewed.

Maha3: Geological Map of Lower Dam

Figure A.12.1.3-1 (2) Drilling location on lower dam

Appendix A.12.1



Source: Development Planning on Optimal Power Generation for Peak Demand in Sri Lanka, 2015, JICA

Maha3: Geological Section of Lower Dam (Original)

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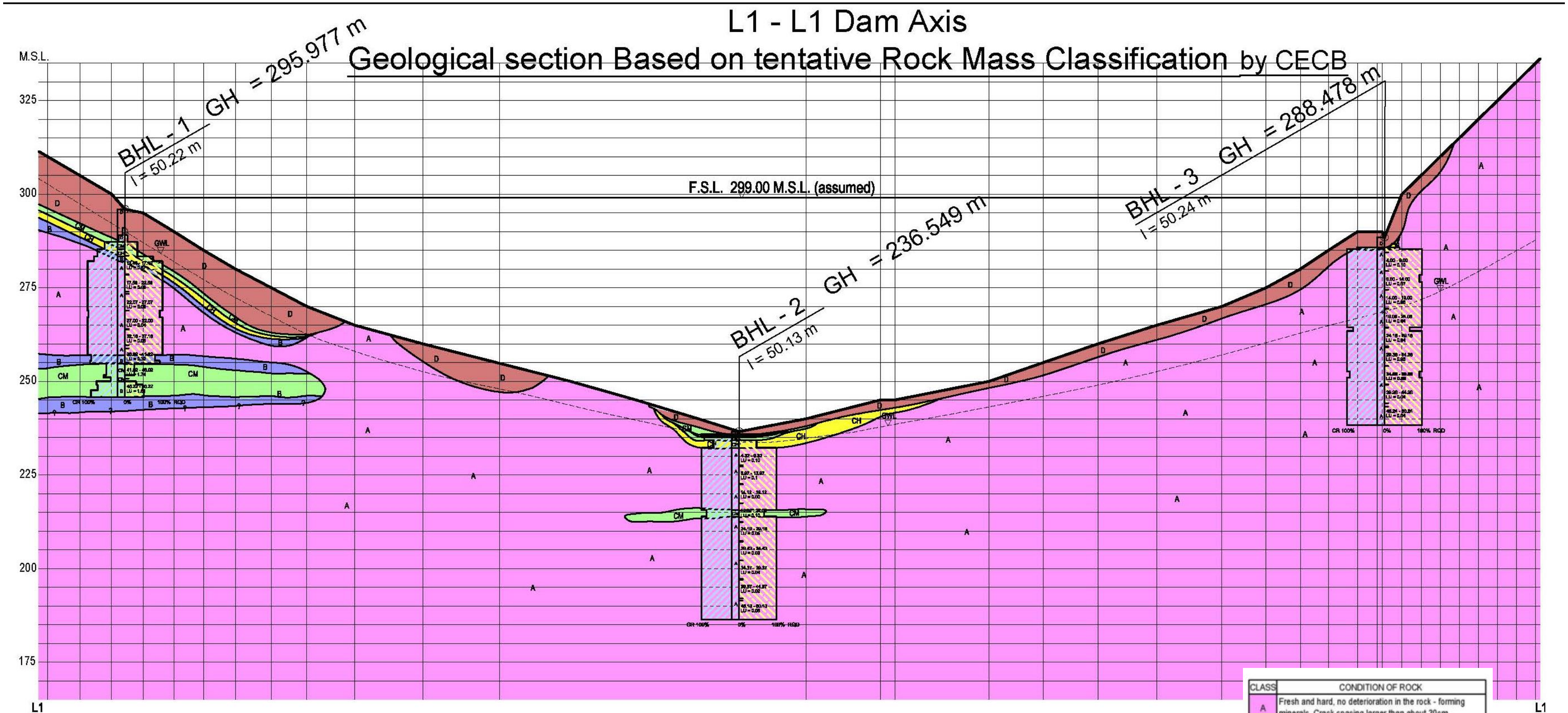
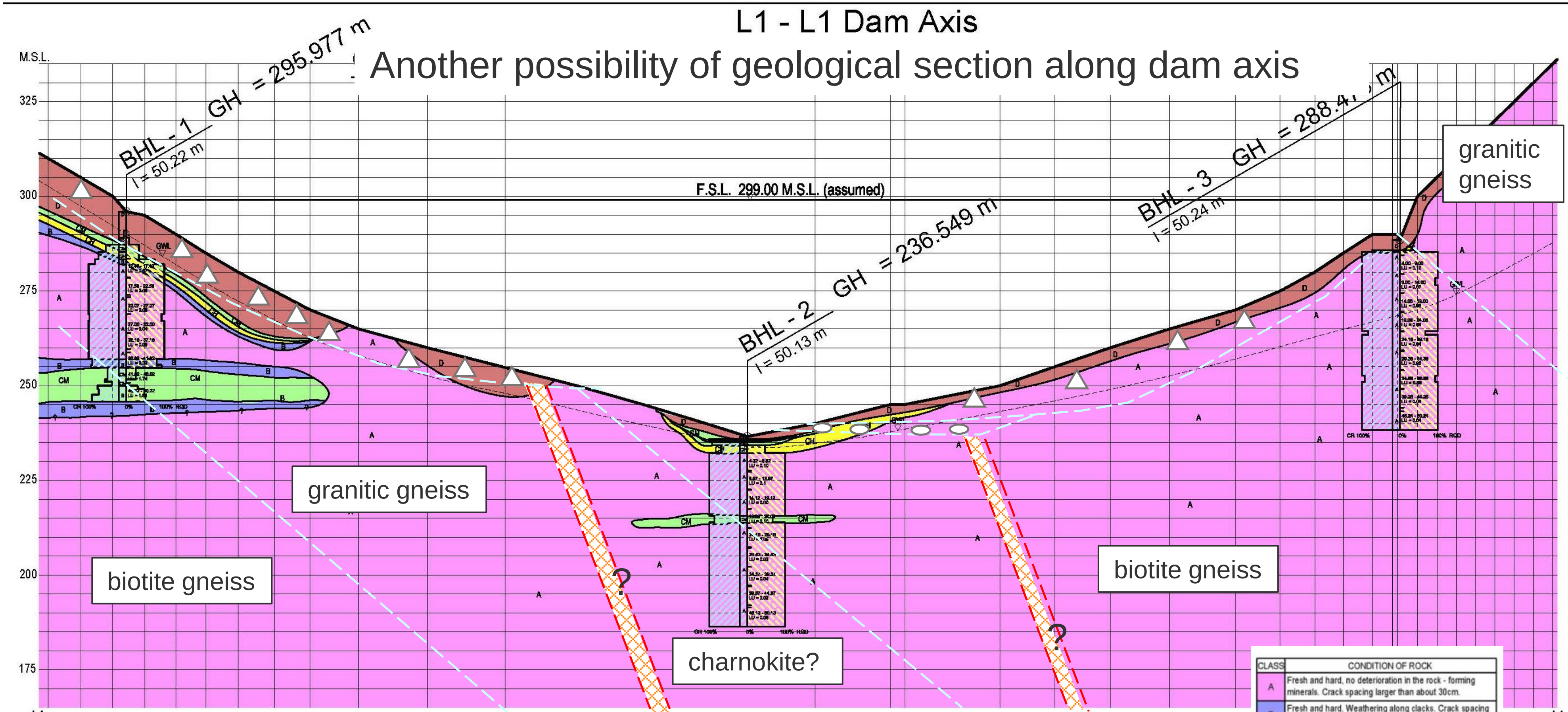


CLASS	CONDITION OF ROCK
A	Fresh and hard, no deterioration in the rock - forming minerals. Crack spacing larger than about 30cm.
B	Fresh and hard. Weathering along clacks. Crack spacing larger than about 15cm.
CH	Relatively hard. Biotite and feldspar are somewhat deteriorated. Crack spacing larger than about 5cm.
CM	Breaks when struck by hammer. Deterioration of feldspar developed. Clay is sandwiched along the opening face. Crack spacing smaller than 5cm
D	Extremely soft. Very friable and tends to powderize. Residual soil form

Source: Development Planning on Optimal Power Generation for Peak Demand in Sri Lanka, 2015, JICA

Maha3: Geological Section of Lower Dam (Reviewed)



CLASS	CONDITION OF ROCK
A	Fresh and hard, no deterioration in the rock - forming minerals. Crack spacing larger than about 30cm.
B	Fresh and hard. Weathering along clacks. Crack spacing larger than about 15cm.
C_H	Relatively hard. Biotite and feldspar are somewhat deteriorated. Crack spacing larger than about 5cm.
C_M	Breaks when struck by hammer. Deterioration of feldspar developed. Clay is sandwiched along the opening face. Crack spacing smaller than 5cm
D	Extremely soft. Very friable and tends to powderize. Residual soil form

It is noted that
- Charnokite sometimes occurs in association with limestone.
- There might be some fracture zones hiding beneath talus deposits.

Source: Development Planning on Optimal Power Generation for Peak Demand in Sri Lanka, 2015, JICA
JICA Study Team Reviewed.

Maha3: Summary of Laboratory tests

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Appendix A.12.1

Table A.12.1.5-2 Detailed results of laboratory tests

Borehole	total test depth section	rock type	Rock class (by CECB tentative classification)	dry density. Saturated density, water content for rock mass.			oven dry density, surface saturated density, absorption for coarse aggregate				UCS	tensile strength	soundness	alkali reactivity test (chemical method)	abrasion (Los Angels)
				rock core			coarse aggregate from core				rock core	rock core	coarse aggregate from core	coarse aggregate from core	coarse aggregate from core
ASTM No.				D2216	D2216	D2216	C127	C127	C127	C127	D7012	D3967	C88	C289	C131
				moisture %	dry density kg/m^3	saturated density kg/m^3	apparent specific gravity	dry density kg/m^3	saturated density kg/m^3	absorption %	MPa	MPa	loss %	reduction of alkalinity mmol/l	abrasion value % (100, 500 rev)
BHL01	8.7-10.7m	Biotite Gneiss	CM	0.1	2,844.16	2,853.70					40.58	1.61			
	10.7-12.6m	Biotite Gneiss	CH				2.73	2,620	2,660	1.4					
	15.75-22.58m	Biotite Gneiss	A	0.0	2,698.34	2,703.80	2.74	2,670	2,700	0.8	22.07	5.61	1	149.2	15, 53
	36.51-41.32m	Biotite Gneiss	A	0.0	2,731.22	2,739.15									
BHL02	2.35-3.05m	Biotite Gneiss	CH								23.00	4.71			
	4.32-8.5m	Biotite Gneiss	A	0.0	2,746.45	2,750.03	2.76	2,680	2,710	1.0	30.43	8.35			
	36.57-40.9m	Biotite Gneiss	A	0.0	2,686.41	2,690.61	2.78	2,710	2,730	0.8	25.89	7.08	1	185.7	13, 50
BHL03	5.12-9.90m	Biotite Gneiss	A	0.1	2,860.93	2,864.11	2.76	2,710	2,730	0.6	49.40	4.20			
	14.42-19.0m	Biotite Gneiss	A										2	52.1	27, 74
	20.0-28.14m	Biotite Gneiss	A	0.1	2,788.79	2,793.00	2.8	2,750	2,770	0.6	28.84	4.67			
BHU03	10.8-11.72m	Granitic Gneiss	B	0.1	2,628.64	2,634.83	2.65	2,570	2,600	1.0					
	11.72-12.77m	Granitic Gneiss	B								49.66	5.69			
	24.63-29.32m	Granitic Gneiss	A	0.1	2,706.79	2,711.64	2.69	2,630	2,650	0.7	67.14	7.28	2	50.1	13, 49
	38.01-42.63m	Biotite Gneiss	A	0.1	2,621.33	2,625.19	2.67	2,630	2,640	0.6	29.01	7.95			
BHU02	5.0-6.4m	Biotite Gneiss	B	0.1	2,722.04	2,726.41					26.80	6.30			
	10.7-15.9m	Granitic Gneiss	A	0.1	2,612.72	2,620.38	2.66	2,610	2,620	0.7	100.43	5.04			
	32.2-41.3m	Granitic Gneiss	A	0.1	2,607.02	2,611.49	2.66	2,600	2,620	0.8	68.96	7.41	1	53.3	11, 45
BHU01	27.800-37.500	Biotite Gneiss	CM	1.1	2,687.20	2,694.82	2.65	2,520	2,570	1.7	77.60	10.64			
	49.500-50.510	Biotite Gneiss	A	0.1	2,770.97	2,772.58	2.77	2,730	2,740	0.4	86.57	7.23			
	51.205-55.190	Biotite Gneiss	A	0.2	2,772.04	2,774.16	2.77	2,720	2,740	0.5	39.16	14.30			
Total No. of samples to be used				**16**	**16**	**16**	**13**	**13**	**13**	**13**	**15**	**15**	**4**	**4**	**4**

(Note: red letter samples were judged inappropriate thus ommitted)

Physical properties seems to be suitable for concrete aggregates/rock materials. However, JICA report (2015) mentioned some of these tests were not conducted properly.

⇨ These rock parameters needs to be confirmed by proper laboratory tests in FS stage.

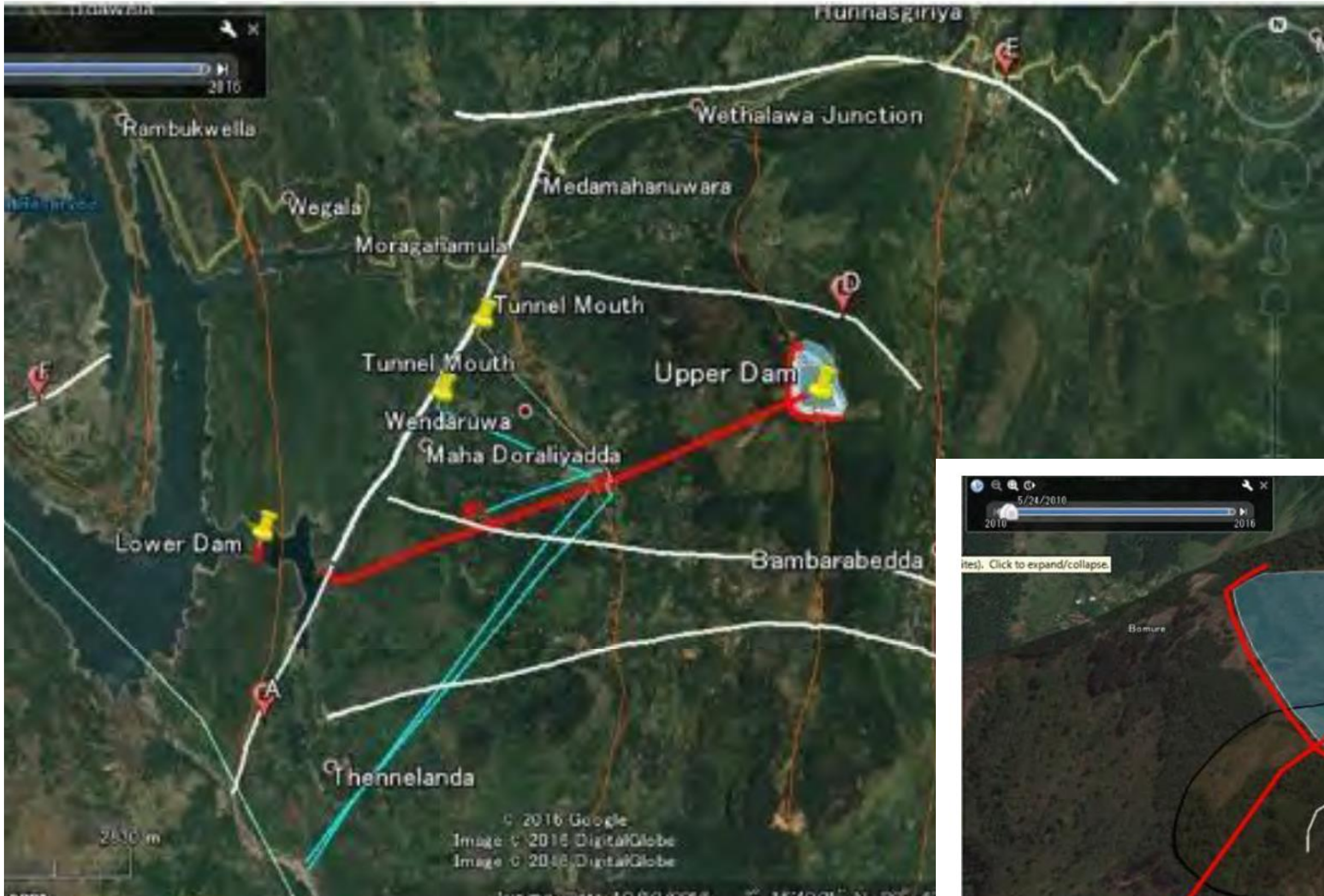
Source: Development Planning on Optimal Power Generation for Peak Demand in Sri Lanka, 2015, JICA

2. Issues of Geology on Victoria Lake Site

According to the JICA Study 2018 report,
- There are No detailed geological investigations in Victoria site.
- The project area is covered by metamorphic rocks.
- Four lineaments were identified by satellite image interpretation by use of google images

Structures	Check points	Major considerable issues
Upper storage dam	• Safety of dam foundation • Water tightness	• Possibility of landslide risks • No information
Reservoir	• Landslide risks • Water seepage risks	• Ditto • No information
Water way	• Landslide risks of portals • Rock condition along water ways	• No information • One lineament (possibly fracture zone) crossing the tunnel.
Underground powerhouse	• Rock condition	• No information
Lower storage dam and reservoir	• Safety of dam foundation, Water tightness, Landslide risks and Water seepage risks	• No information

Victoria Lake PSPP: Geological Lineament and Landslide

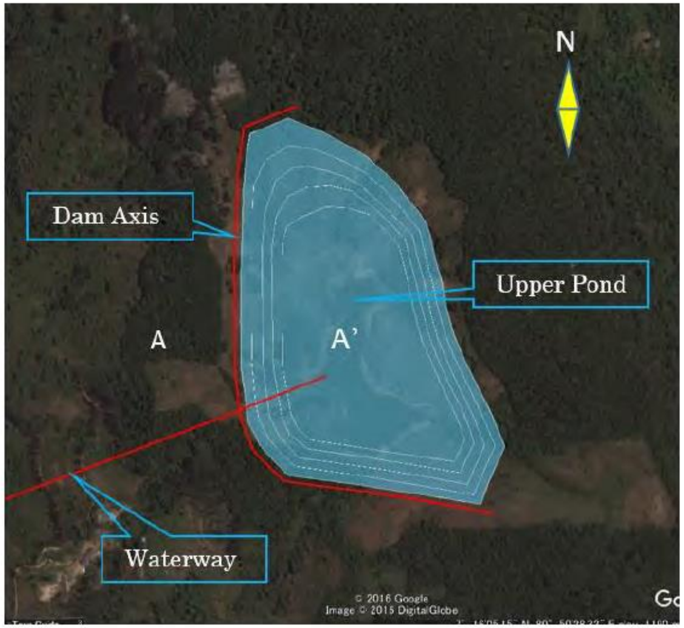


Lineaments (white line)

Upper reservoir and Possible landslide (black line)

Source: Project on Electricity Sector Master Plan Study in Democratic Socialist Republic of Sri Lanka, 2018, JICA

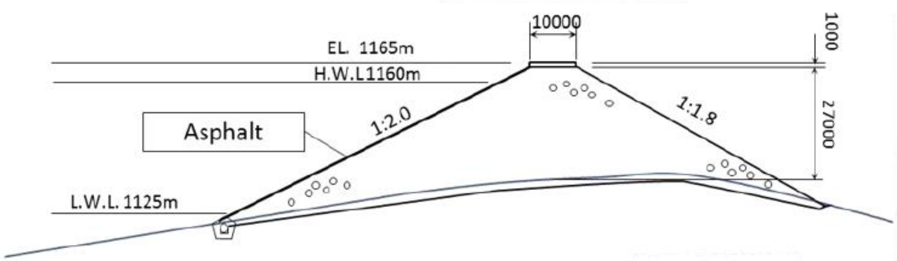
Victoria Lake PSPP: Upper Dam



Comment:

- Foundation condition needs to be further assessed. It may be required to provide sealing to cover the bottom of the reservoir also.
- Stability Dam failure, if occurred, may result in serious damage of the exposed penstock.

A - A' Section



Source: Project on Electricity Sector Master Plan Study in Democratic Socialist Republic of Sri Lanka, 2018, JICA

2.
Recommended Scope and Schedule of Geological Investigation at F/S level for Maha 3 and Victoria Lake PSPP that will be performed by CEB in the future

Guideline and Manual by JICA

CHUBU Electric Power
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Guideline and Manual for Hydropower Development Vol. 1

Conventional Hydropower and Pumped Storage Hydropower

March 2011

Japan International Cooperation Agency

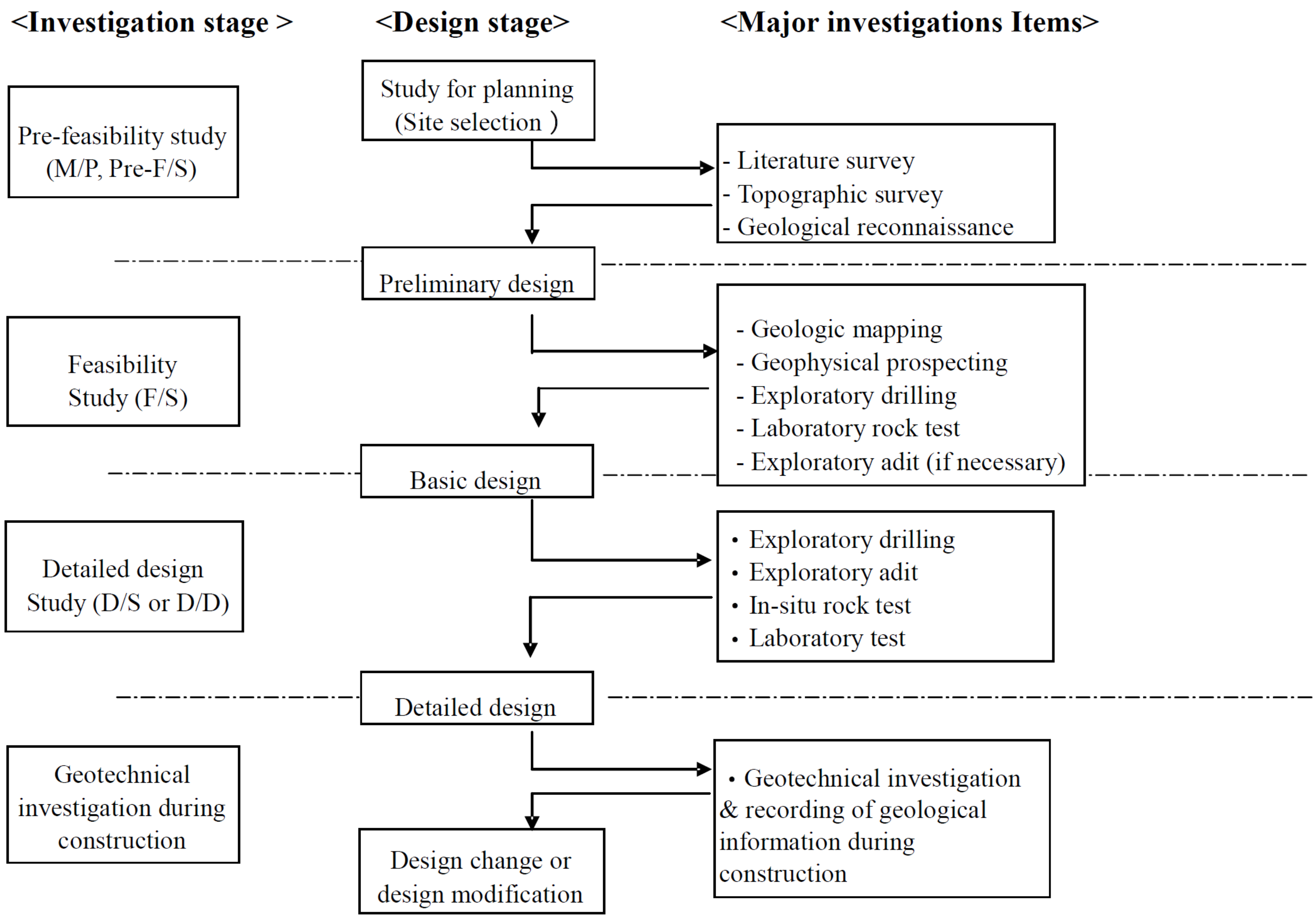
Electric Power Development Co., Ltd.

JP Design Co., Ltd.

IDD
JR
11-019

- Introduction of Guideline and Manual by JICA
  - JICA has a guideline and manual for Hydropower development.
  - The document can be downloaded by the following URL: https://openjicareport.jica.go.jp/pdf/12024881_01.pdf
  - Based on this document, status and necessary geological investigation of Maha 3 and Victoria Lake by F/S level is proposed.

Geological Investigations in Each Stage



Source: Development Planning on Optimal Power Generation for Peak Demand in Sri Lanka, 2015, JICA

Progress to Date

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■ ***Maha3 is in F/S Stage, while Victoria Lake is in Pre-F/S Stage.***

Investigation Stage	Major Investigation Items	Maha 3	Victoria Lake
Pre-feasibility study (M/P, Pre-F/S)	**Literature survey**	**Done**	**Done**
	Topographic survey	**Scale =1:5000, 1.14 km2** **Scale =1:1000, 1.0 km2**	**N/A**
	Geological reconnaissance	**Done**	**Done**
Feasibility Study (F/S)	**Geological mapping**	**Available at upper dam and lower dam site only**	**N/A**
	Geophysical prospecting	**N/A**	**N/A**
	Exploratory drilling	**Upper dam site: 3 drill holes** **Lower dam site: 3 drill holes**	**N/A**
	Laboratory rock test	**Done**	**N/A**
	Exploratory adit (if necessary)	**N/A**	**N/A**
Detailed design Study (D/S or D/D)	Exploratory drilling	N/A	N/A
	Exploratory adit	N/A	N/A
	In-situ rock test	N/A	N/A
	Laboratory test	N/A	N/A
Geotechnical investigation during construction	Geotechnical investigation & recording of geological information during construction	N/A	N/A

Stage-wise Implementation of F/S

CHUBU Electric Power
NIPPON KOEI

F/S: 1st Stage

- 1st stage geological investigation
- Layout study
- Determine to proceed or not

F/S: 2nd Stage

Full-Swing Level

- 2nd stage geological investigation
- Basic design
- Project feasibility

Scope of Geological Investigation for **Maha 3** to be conducted in **1st Stage of F/S**

CHUBU Electric Power
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Major Investigation Items	Status	Scope of Geological Investigation in 1st Stage of F/S
Literature survey	Done	-
Topographic survey	Scale =1:5000, 1.14 km2 Scale =1:1000, 1.0 km2	-
Geological reconnaissance	Done	-
Geological mapping	Available at upper dam and lower dam site only	Geological mapping of all the area is needed
Geophysical prospecting	N/A	Seismic and electric survey is required at the following; ➢ Upper Dam: Thick overburden on left bank (Seepage risk) ➢ Waterway and Underground powerhouse: No geological information is available.
Exploratory drilling	Upper dam site: 3 drill holes Lower dam site: 3 drill holes	Exploratory drilling with on-site test is required at the following; ➢ Upper Dam: Thick overburden on left bank (Seepage risk)
Laboratory rock test	Done	To be additionally done

Assumed Quantities of Geological Investigation for **Maha 3** to be conducted in **1st Stage of F/S**

CHUBU Electric Power
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Item			Requirement		
			Specification	Q'ty	Unit
Investigation					
Geological Mapping					
	G-01	Surface geological survey	1/10.000	10	km2
Seismic Prospecting					
	S-01	Upper dam	1 profile & 2 axes	1.2	km
	S-02	Waterway	center line	3.0	km
Electrical Resistivity Prospecting					
	E-01	Upper dam	1 profile & 2 axes	1.2	km
	E-02	Upper dam, ridge over left bank	1 section	0.5	km
	E-03	Waterway	center line	3.0	km
Core Drilling					
	B-01	Upper dam, left bank, upstream	vertical, soil	20	m
			vertical, rock	40	m
	B-02	Upper dam, left bank, downstream	vertical, soil	20	m
			vertical, rock	40	m
In-situ Test					
	T-01	Standard penetration test	core drilling	40	nos.
	T-02	Permeability test	core drilling	16	nos.
Laboratory Tests for Rock Cores					
	L-01	Water absorption and bulk specific gravity	rock core	10	test
	L-02	Unconfined compression of rock core specimen	rock core	10	test
	L-03	Tensile strength	rock core	10	test
	L-04	Ultrasonic test of core sample	rock core	20	test
	L-05	Los Angels Abrasion	rock core	5	test
	L-06	Soundness	rock core	5	test
	L-07	Alkali reactivity	rock core	5	test

Assumed Schedule of Geological Investigation for **Maha 3** to be conducted in **1st Stage of F/S**

Investigation Item	Unit	Qty	Month						
			1	2	3	4	5	6	7
Geological mapping	km2	10	■	■					
Seismic prospecting	km	4.2		■	■				
Electrical resistivity prospecting	km	4.7		■	■				
Core drilling (2 boreholes)	m	120				■	■		
Standard penetration test (SPT)	nos	40				■	■		
Permeability test	nos	16				■	■		
Laboratory tests (7 Types)	test	20						■	
Preparation of Investigation report	L.S.	1							■

Scope of Geological Investigation for **Victoria** to be conducted in **1st Stage of F/S**

CHUBU Electric Power
NIPPON KOEI

Major Investigation Items	Status	Scope of Geological Investigation in 1st stage of F/S
Literature survey	**Done**	**-**
Topographic survey	**N/A**	**Topographic mapping of all the area is needed**
Geological reconnaissance	**Done**	**-**
Geologic mapping	**N/A**	**Geological mapping of all the area is needed**
Geophysical prospecting	**N/A**	**Seismic and electric survey is required at the following;** ➢ **Upper Dam and Lower Dam: Safety of dam foundation, landslide and seepage risks** ➢ **Waterway and Underground powerhouse: No geological information**
Exploratory drilling	**N/A**	**Exploratory drilling with on-site test is required at the following;** ➢ **Upper Dam: Safety of dam foundation, landslide and seepage risks** ➢ **Lower Dam: Safety of dam foundation, landslide and seepage risks**
Laboratory rock test	**N/A**	**To be done**

Assumed Quantities of Geological Investigation for **Victoria** to be conducted in **1st Stage of F/S**

CHUBU Electric Power
NIPPON KOEI

Item	Specification	Q'ty	Unit
	Requirement		
Investigation			
Topographic Mapping			
T-01 Detailed mapping	1/1,000	2.5	km2
Geological Mapping			
G-01 Surface geological survey	1/10.000	20	km2
Seismic Prospecting			
S-01 Upper dam	1 axis & 2 profiles	1.2	km
S-02 Waterway	center line	6.0	km
Electrical Resistivity Prospecting			
E-01 Upper dam	1 profile & 2 axes	1.2	km
E-02 Waterway	center line	6.0	km
Core Drilling			
B-01 Upper dam, #1	vertical, soil	15	m
	vertical, rock	25	m
B-02 Upper dam, #2	vertical, soil	15	m
	vertical, rock	25	m
B-03 Upper dam/Intake, #3	vertical, soil	15	m
	vertical, rock	25	m
B-04 Upper dam/Penstock, #4	vertical, soil	15	m
	vertical, rock	25	m
B-05 Lower dam, #1	vertical, soil	20	m
	vertical, rock	40	m
B-06 Lower dam, #2	vertical, soil	20	m
	vertical, rock	40	m
In-situ Test			
T-01 Standard penetration test	bore-hole	100	nos.
T-02 Permeability test	bore-hole	36	nos.
Laboratory Tests for Rock Cores			
L-01 Water absorption and bulk specific gravity	rock core	30	test
L-02 Unconfined compression of rock core specimen	rock core	30	test
L-03 Tensile strength	rock core	30	test
L-04 Ultrasonic test of core sample	rock core	20	test
L-05 Los Angels Abrasion	rock core	5	test
L-06 Soundness	rock core	5	test
L-07 Alkali reactivity	rock core	5	test

Assumed Schedule of Geological Investigation for **Victoria** to be conducted in 1st **Stage of F/S**

Investigation Item	Unit	Qty	Month									
			1	2	3	4	5	6	7	8	9	10
Topographic mapping	km2	2.5	■	■	■							
Geological mapping	km2	20	■	■	■							
Seismic prospecting	km	7.2		■	■	■	■					
Electrical resistivity prospecting	km	7.2		■	■	■	■					
Core drilling (6 boreholes)	m	280				■	■	■	■	■		
Standard penetration test (SPT)	nos	100				■	■	■	■	■		
Permeability test	nos	36				■	■	■	■	■		
Laboratory tests (7 Types)	test	30									■	
Preparation of Investigation report	L.S.	1										■

Geological Investigation for Maha3 and Victoria to be conducted in **2nd Stage of F/S**

Scope, quantities and schedule of geological investigation for Maha3 and Victoria to be conducted in 2nd stage of F/S will depend on the output of the geological investigation and layout study in 1st stage of F/S.

The following scope will be at least required.

Major Investigation Items	Status	Scope of Geological Investigation 2nd stage of F/S
Exploratory drilling	**Partly done in 1st Stage**	**Exploratory drilling with on-site test will be required at the following;** **For both Maha3 and Victoria** ➢ **1 drilling for underground powerhouse** ➢ **2 drillings for underground tunnel** **For Victoria only** ➢ **1 underwater drilling for lower dam**
Laboratory rock test	**Partly done in 1st Stage**	**To be done**

Check List for Geological Investigations at F/S Stage

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Investigation Items	Contents
Literature survey	➢ Following literatures are obtained? - Geological map (scale 1/500,000 or more) - Aerial Photos - Seismic data - Other geological info (mines, springs, etc.) ➢ Seismic factor is analyzed (in case of seismic-prone area)?
Geological reconnaissance Geologic mapping	➢ The investigation area is covering entire planning area with sufficient marginal area of 300m or more? ➢ Geological conditions are clarified? - Stratigraphy and formation - Rock type and distribution - Age ➢ Faults are available at the planning area? - Dip and Strike - Active or non-active - Associating with share zone with spring or fault breccia ➢ Any negative geological structure is identified? (e.g. dip slope) ➢ Characteristics of recent river deposit at dam site are clarified? - Grain size and packing - Permeability ➢ Weathering of rock is clarified at dam site? - Talus deposit - Weathering at outcrops ➢ Is there any open cracks or joints available at dam foundation? ➢ Any geohazard-prone area is clarified as landslide, collapse, rockfall, etc? ➢ Any special rock are available at the area as limestone?

Investigation Items	Contents
Geological reconnaissance (Landslide survey)	➢ Interpretation of topography by topo-map and/or aerial photo is conducted? - Occurrence of Landslide and collapse with evaluation of their activity in entire planning area ➢ Site reconnaissance of landslide/geohazard survey is conducted?
Geophysical prospecting	➢ The contents of geological investigation is sufficient? - Geophysical prospecting at dam axis and underground powerhouse
Exploratory drilling	➢ The contents of geological investigation is sufficient? - 3 to 5 exploration drillings at dam foundation

3.
General Guidance on Each Item of Geological Investigations for PSPP by CEB in the future

Contents

3-1 Geophysical Surveys

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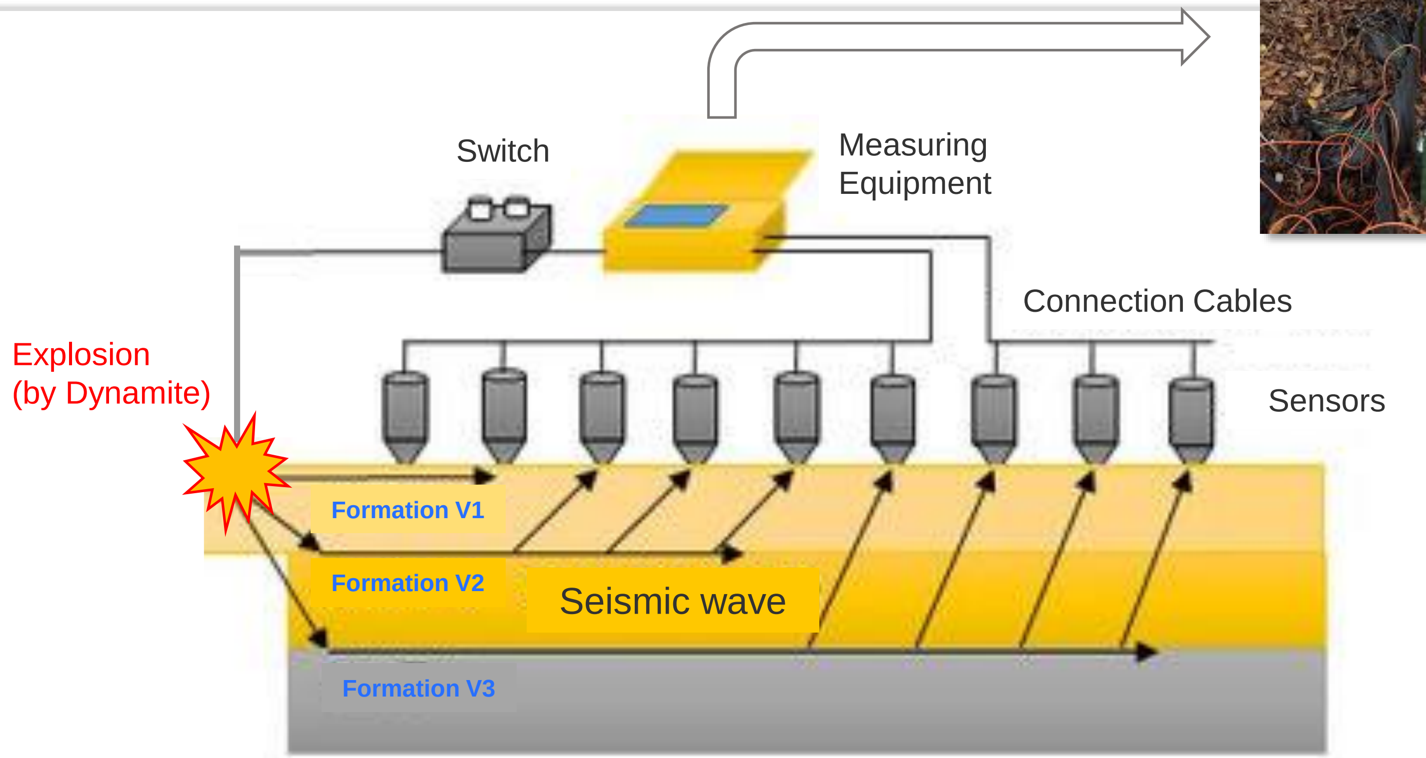
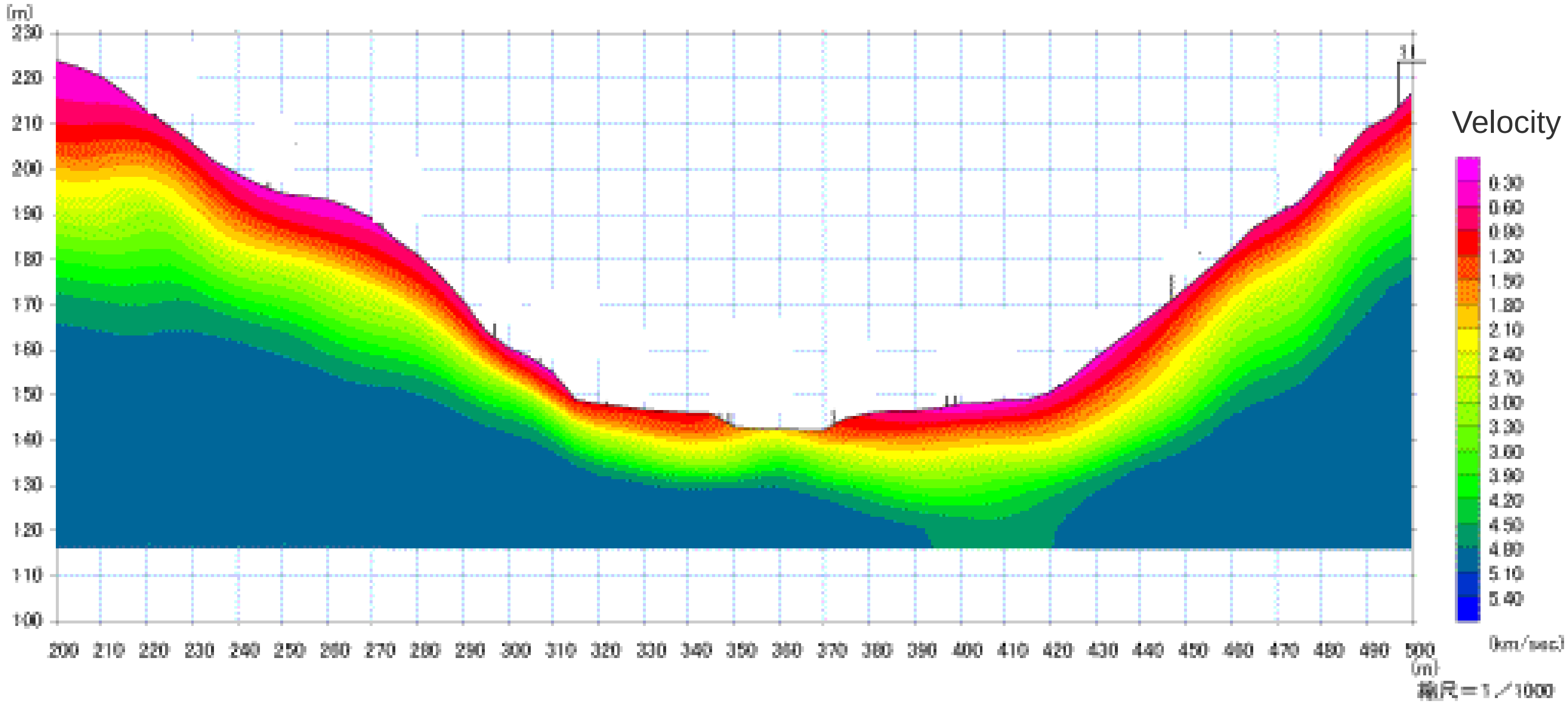
- Seismic Prospecting (video available)



Source of pictures and photos: www.chikatansa.co.jp/

3-1 Geophysical Surveys

- Result of seismic prospecting shows seismic velocity of ground
- Talus deposit, loosen part of foundation can be found



http://www.ne.jp/asahi/refra/tansa/5.html

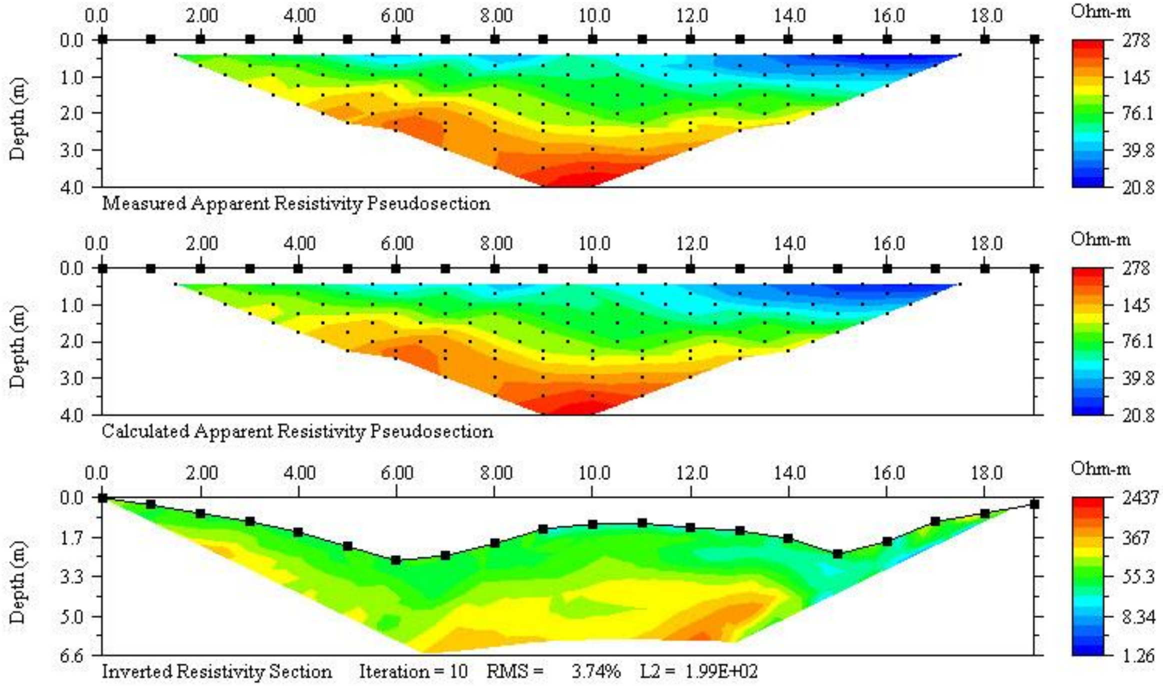
Output (Geophysical Section)

3-1 Geophysical Surveys

● Electrical Sounding (Resistivity Survey)

- ➢ Ground resistivity is measured through electrodes
- ➢ Resistivity structure may contribute the interpretation of geological structure.

Survey Equipment

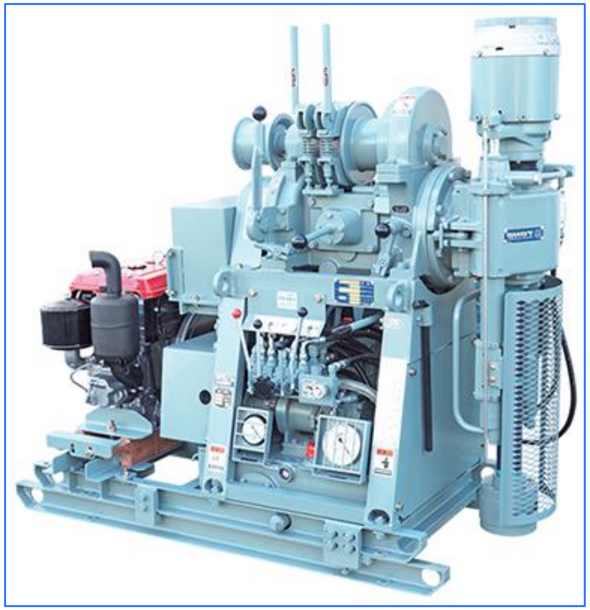


Output by inversion analysis

Source: https://archive.epa.gov/esd/archive-geophysics/web/html/resistivity_methods.html

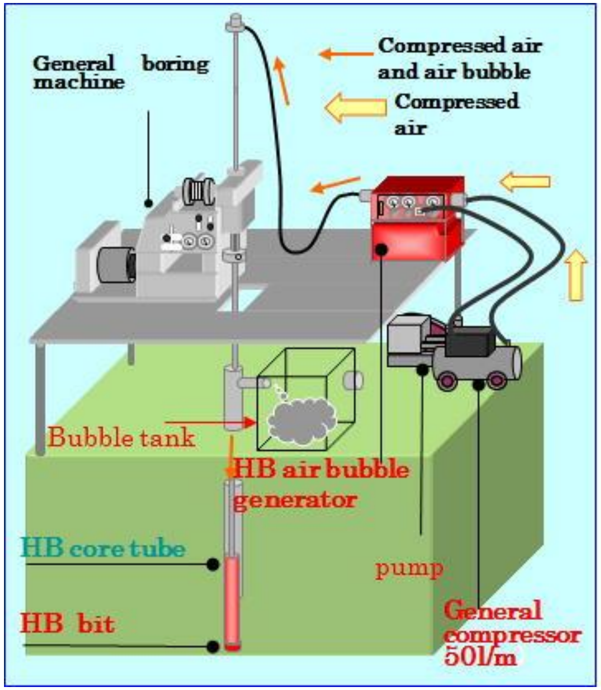
3-2 Core Drilling and Sampling

(video available)



Source: https://www.tohochikakoki.co.jp/

Core drilling machine



Source: http://hitec-homedoctor.co.jp/

System and Equipment

3-2 Core Drilling and Sampling

Source: http://www.soilsystem.jp/business/business1

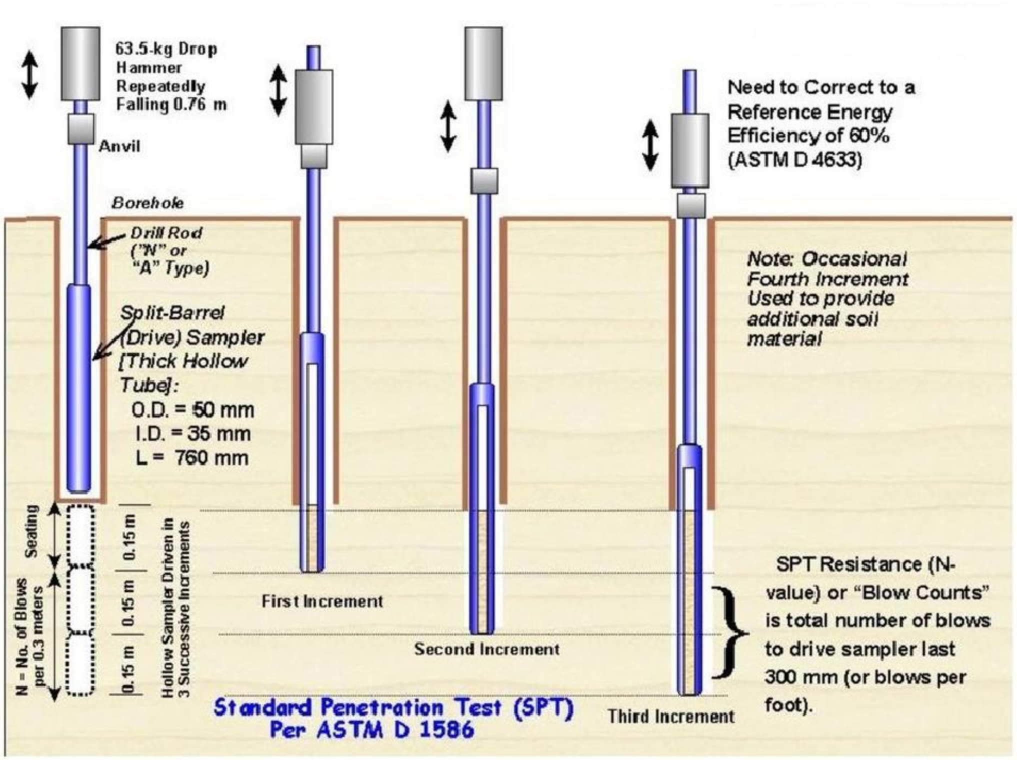
Core Drilling at site

Source: http://hitec-homedoctor.co.jp/

Drilled Core

3-3 Field and Laboratory Tests

● Standard Penetration Tests (SPT)



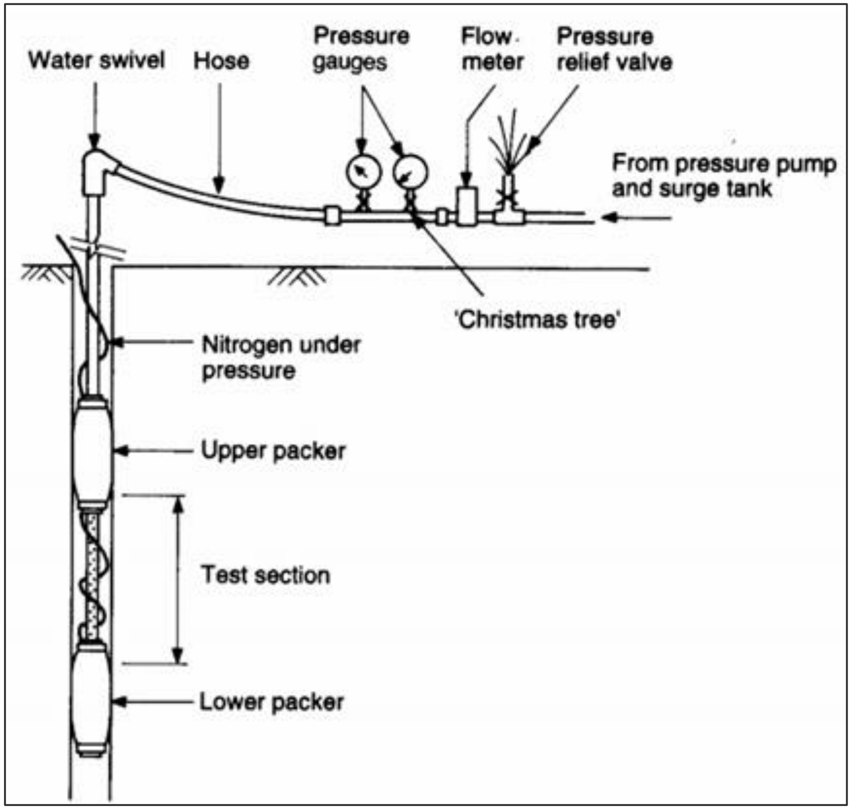
https://geologyengineering.com/2019/08/standard-penetration-test/

Test Procedure

https://www.pwri.go.jp/team/geosearch/tech_01_02.html

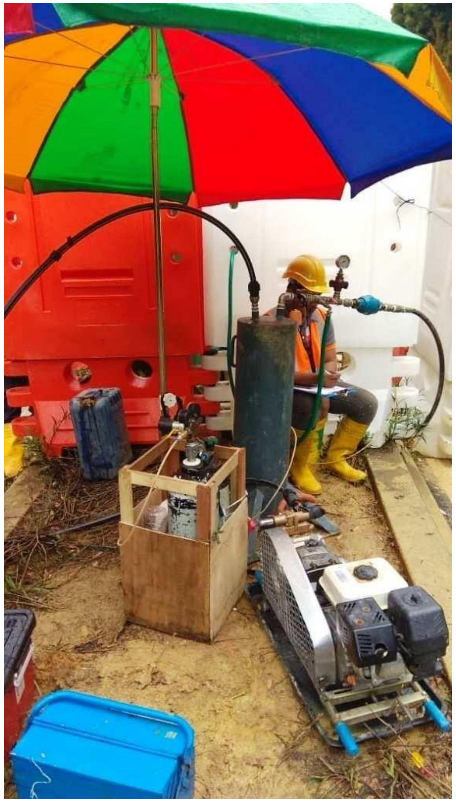
Testing

● Permeability test "Lugeon test"



http://www.geotesting.info/geotest/Lugeon_test.html

Test Equipment



https://geolab-ikram.com/soil-investigation/

Test at Drilled Borehole

Management of Geological Investigations

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- Management of geological investigations
  - Quality control
  - Cost control
  - Schedule control
  - Safety control

- Selection of qualified geotechnical company is most important.
- Monitoring work progress
- Periodical inspection at site

Thank you

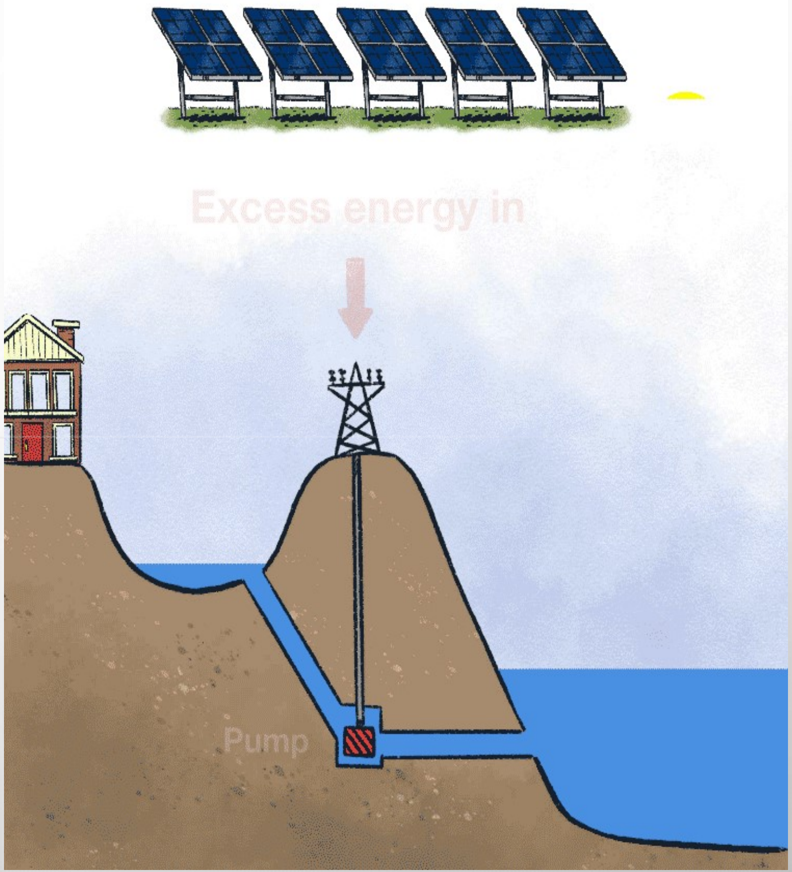
Democratic Socialist Republic of Sri Lanka
The Project for Capacity Development on the Power Sector Master Plan Implementation Program
(2nd Technical Seminar)

How to Proceed the Development of the Pumped Storage Power Plant

Transmission and Generation Planning Branch
Transmission Division
Ceylon Electricity Board
Sri Lanka

December 22, 2021

Pumped Storage Hydropower Plant

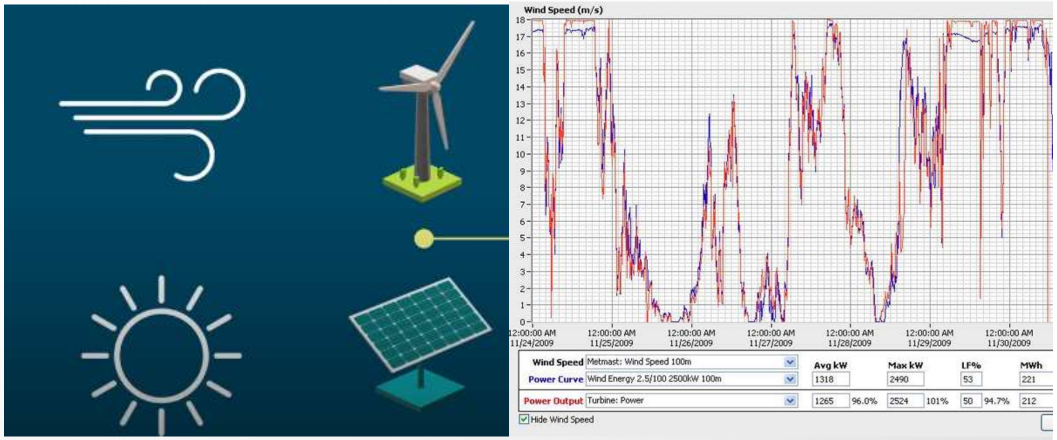


Firm Power Sources

Controllable

Non-Firm Power Sources

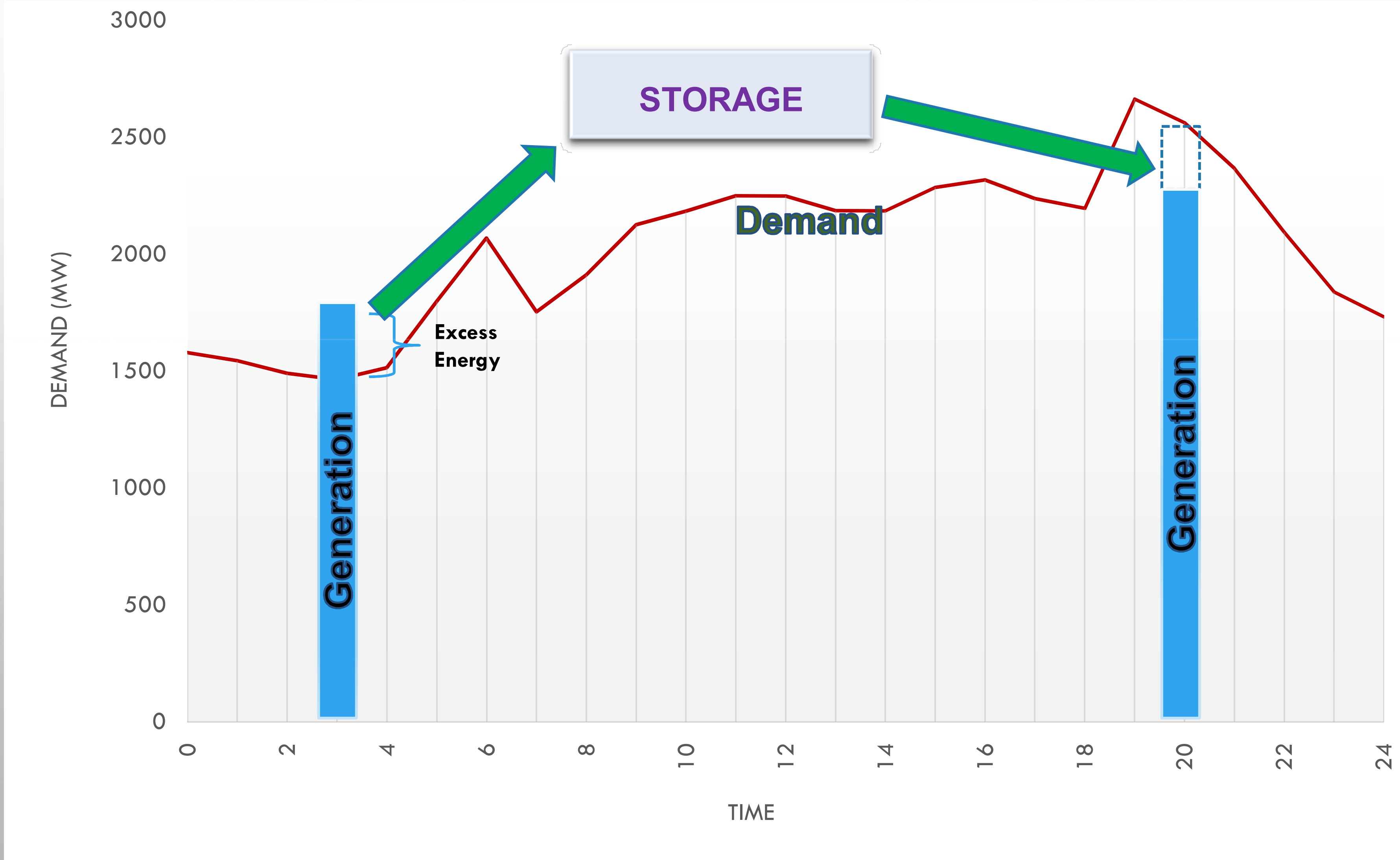
Short time Variations



Storage

Firm Power

Energy Balancing

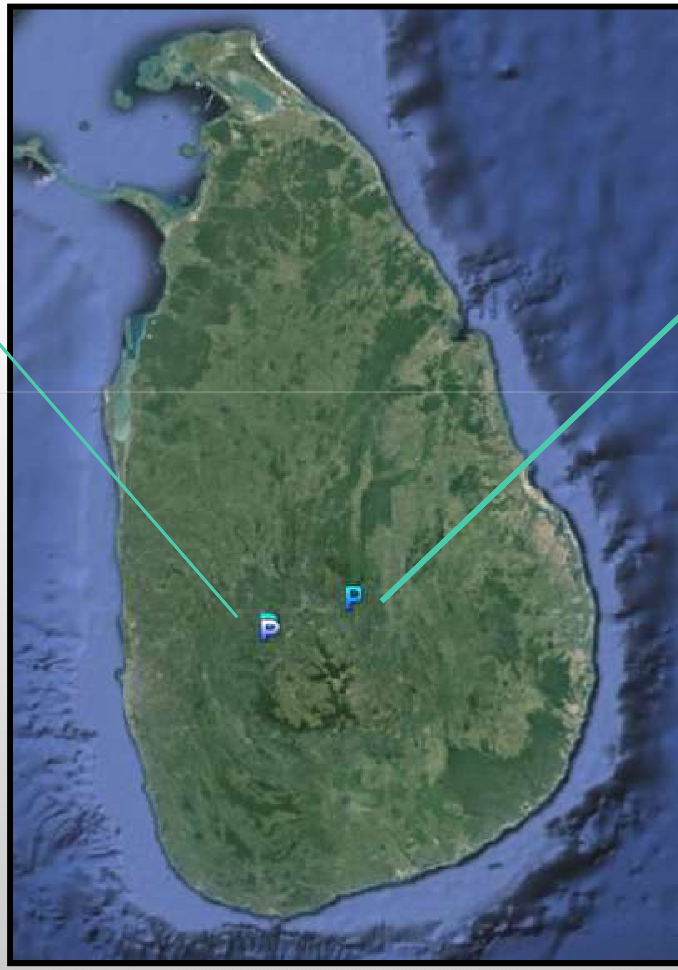


Advantages of Pumped Storage Hydropower Plants

- ENERGY BALANCING (PEAK POWER SUPPORT)
- FIRMING OUTPUT OF INTERMITTENT RESOURCES
- STABILITY AND INERTIA (MECHANICAL)
- ANCILLARY GRID SERVICES
  - FREQUENCY CONTROL
  - SPINNING RESERVE (INCREMENTAL AND DECREMENTAL)

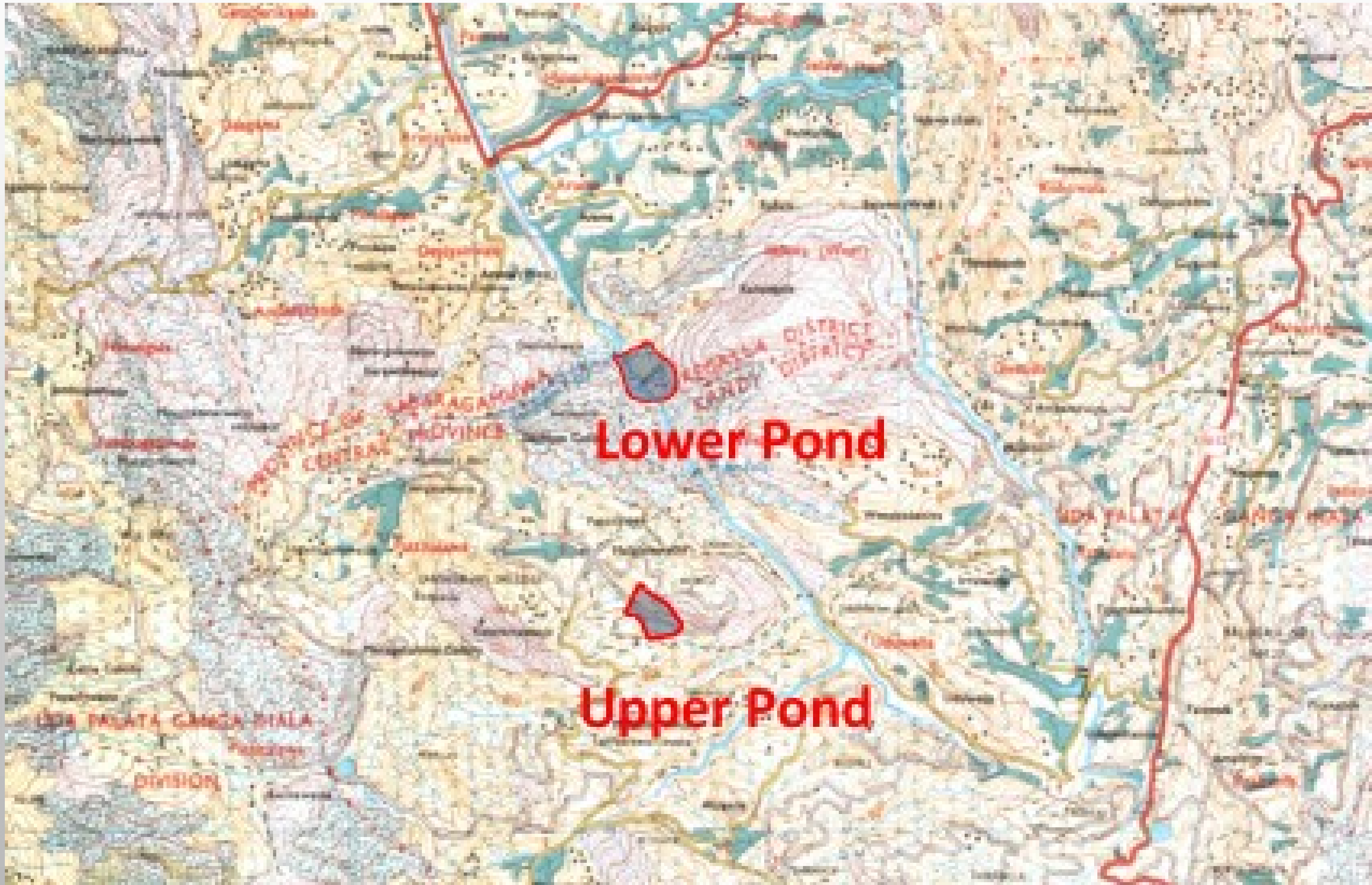
MOST PROMISING SITES

Maha3 Site (Aranayake)	
Capacity (MW)	600
Rated Head (m)	486
Upper Pond (MCM)	3.94
Lower Pond (MCM)	6.33
Peak Time (H)	6.00
Capital Cost (US$/kW)	1063



Wewathenna-Victoria Site	
Capacity (MW)	1400
Rated Head (m)	686
Upper Pond (MCM)	5.5
Lower Pond (MCM)	10
Peak Time(H)	6.00
Capital Cost (US$/kW)	689

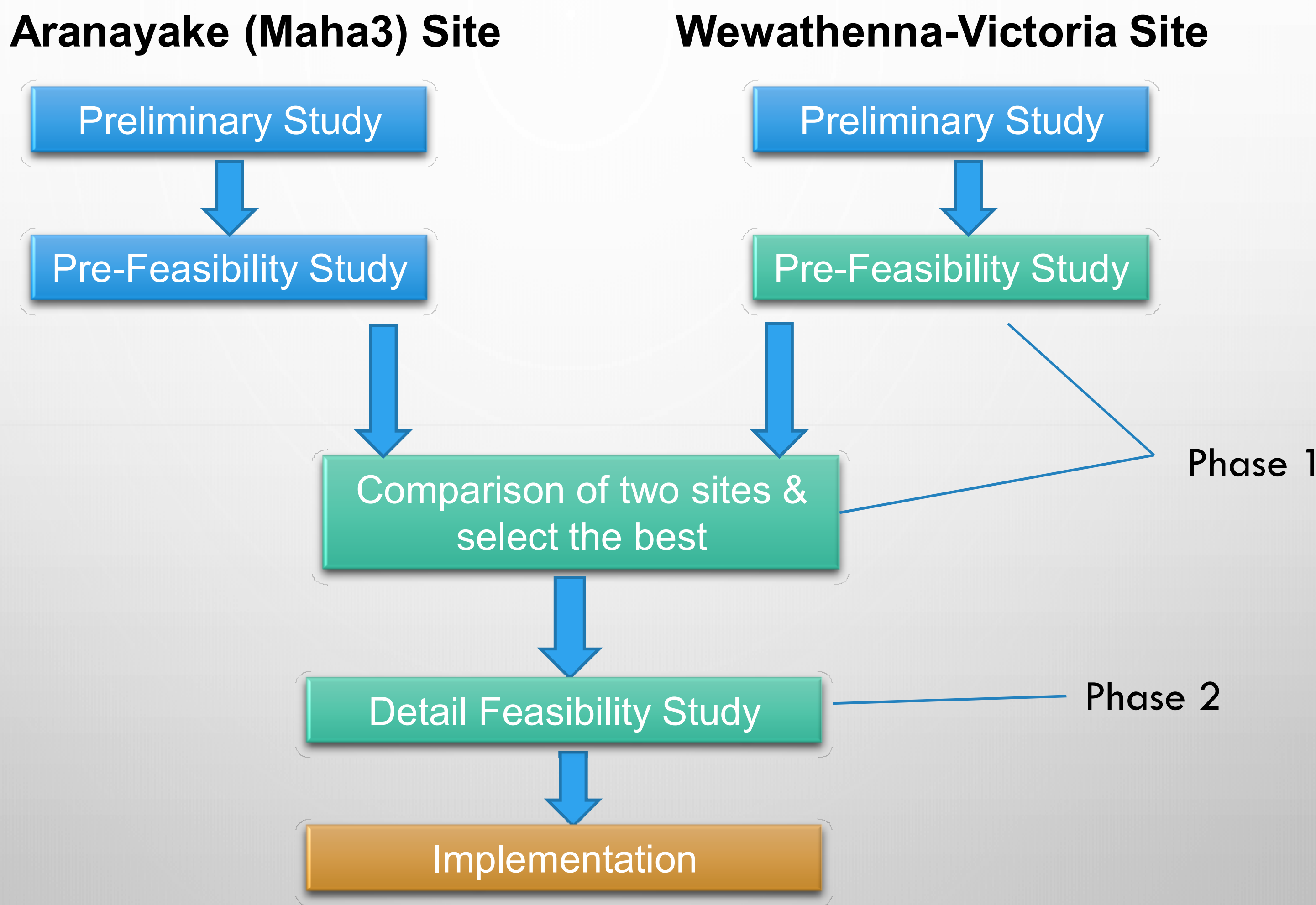
PROPOSED LOCATIONS OF ARANAYAKA (MAHA 3) SITE



PROPOSED LOCATIONS OF WEWATHENNA-VICTORIA SITE

Proposed Plot Plan of Wewathenna-Victoria

WAY FORWARD



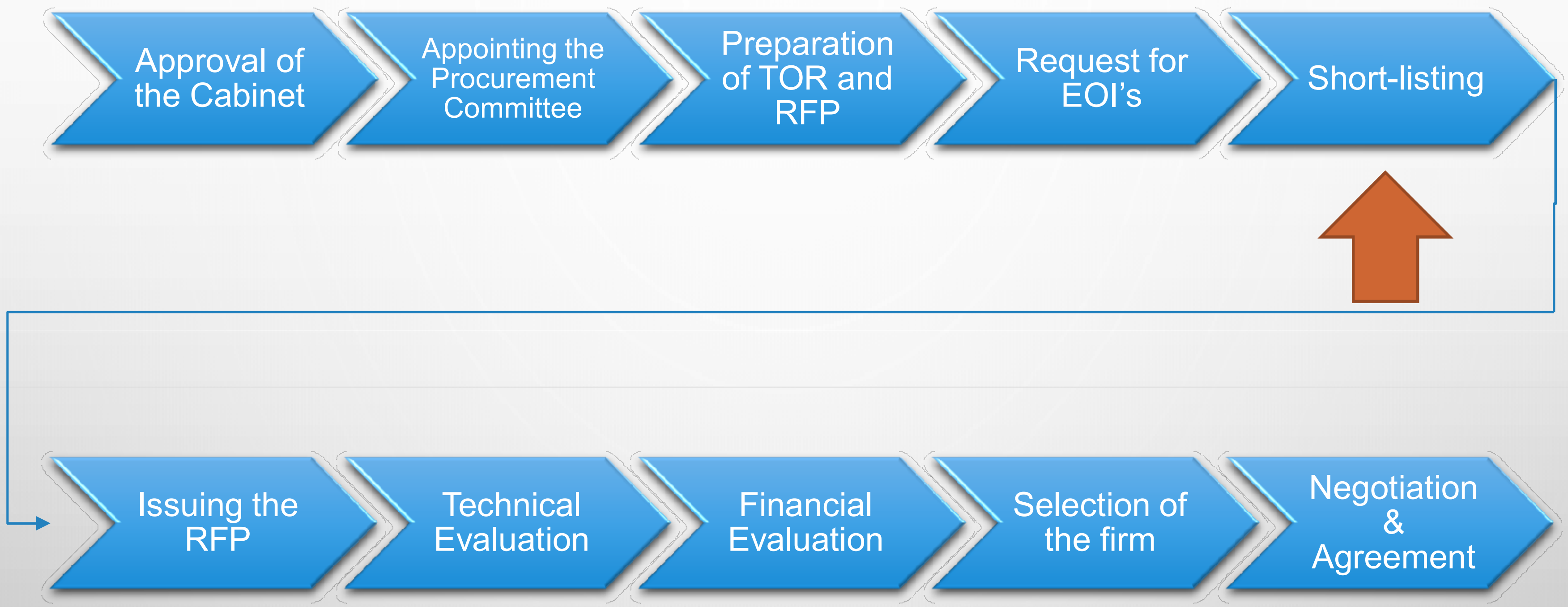
Aranayake (Maha3) Site
Wewathenna-Victoria Site
Preliminary Study
Pre-Feasibility Study
Preliminary Study
Pre-Feasibility Study
Comparison of two sites & select the best
Phase 1
Detail Feasibility Study
Phase 2
Implementation

LIST OF PROPOSED EXPERTS FOR THE STUDIES

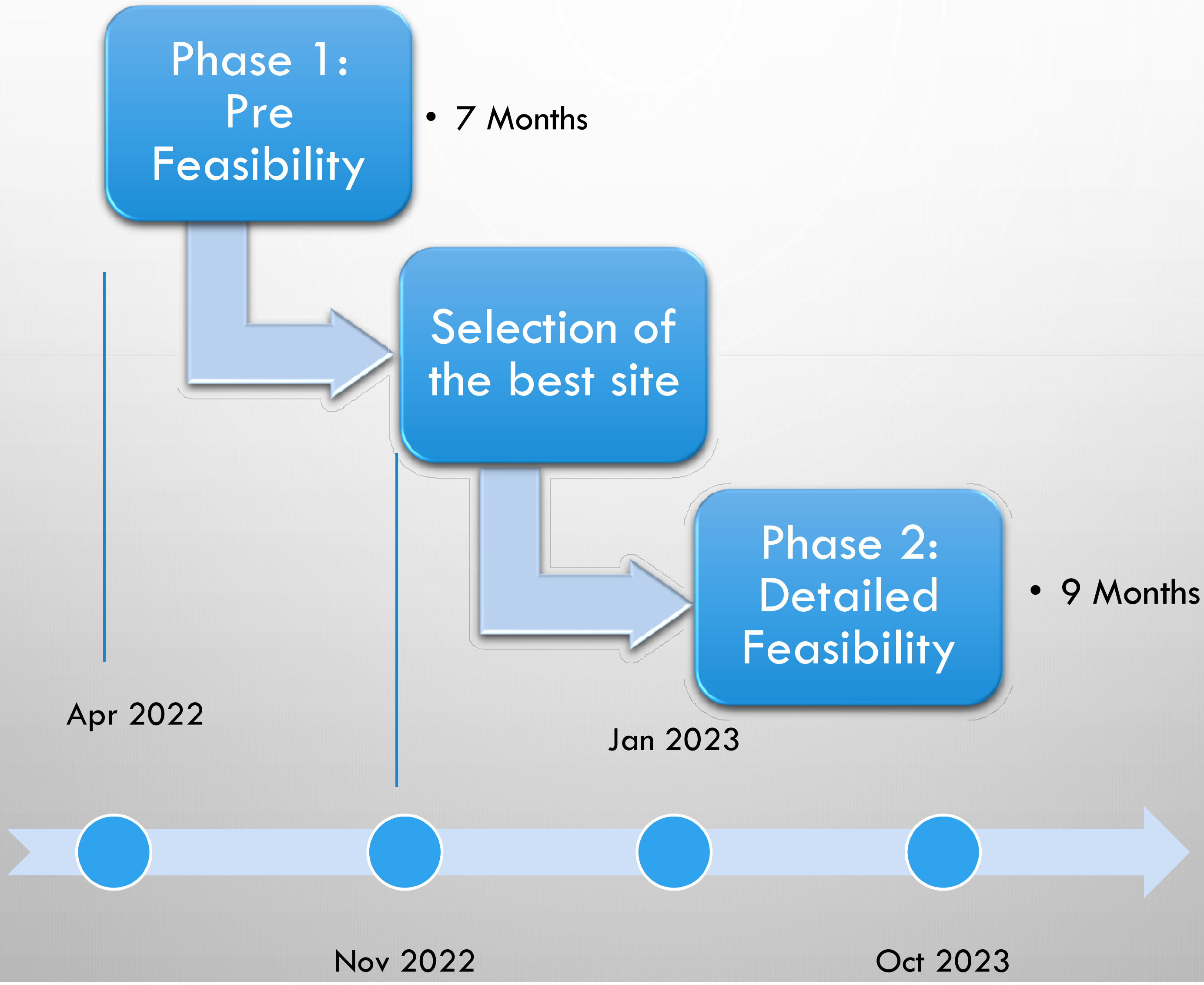
Project Manager/ Team Leader
Expert Geologist
Specialist Civil Engineering
Environmental Expert
Civil Eng. (Tunnelling & Underground works)
Civil Eng. (other structures and roads)
Civil Eng. (cost & quantities)
Civil Eng. (construction planning)
Hydro-Mechanical Engineer
Electro-Mechanical Engineer
Hydrologist
Economist
Geotechnical Engineer
Ecologist
Sociologist

Pumped Storage Specialist
Specialist Hydro-Mechanical
Specialist Electro-Mechanical
Specialist Power Systems

PRESENT PROGRESS (CONSULTANCY PROCUREMENT)



STUDY SCHEDULE



Study Scope

- TECHNICAL FEASIBILITY
  - TOPOGRAPHICAL SURVEY
  - GEOLOGICAL, GEOTECHNICAL AND MATERIAL STUDIES
  - HYDROLOGICAL STUDIES
  - POWER SYSTEM STUDIES
- ENVIRONMENTAL FEASIBILITY
  - PHYSICAL, BIOLOGICAL & SOCIAL ENVIRONMENT
- ECONOMIC/FINANCIAL FEASIBILITY
- FEASIBILITY LEVEL DESIGN
- IMPLEMENTATION PLANNING AND CONSTRUCTION SCHEDULE

Implementation Phases

- ENVIRONMENT & OTHER APPROVALS
- PROJECT FINANCING
- TENDERING
- DETAIL DESIGN
- CONSTRUCTION
  - CIVIL CONSTRUCTIONS (UPPER/LOWER RESERVOIRS, TUNNELS/PENSTOCKS, POWER HOUSE, ETC.)
  - MECHANICAL/ ELECTRICAL EQUIPMENT (PUMP-TURBINE, MOTOR-GENERATOR, AUXILIARY SYSTEMS, ETC)
  - TRANSMISSION INTERCONNECTION (TR. LINE AND SWITCH YARD)
- TESTING & COMMISSIONING

CONTRIBUTION OF JICA ON PSHP STUDIES

Sri Lanka
Ceylon Electricity Board

Development Planning on Optimal Power Generation for Peak Demand in Sri Lanka

Final Report

February 2015

Japan International Cooperation Agency
Electric Power Development Co., Ltd.

IL
JR
15-021

Ministry of Power and Renewable Energy (MPRE)
Ceylon Electricity Board (CEB)

Project on Electricity Sector Master Plan Study in Democratic Socialist Republic of Sri Lanka

Final Report

March, 2018

Japan International Cooperation Agency (JICA)

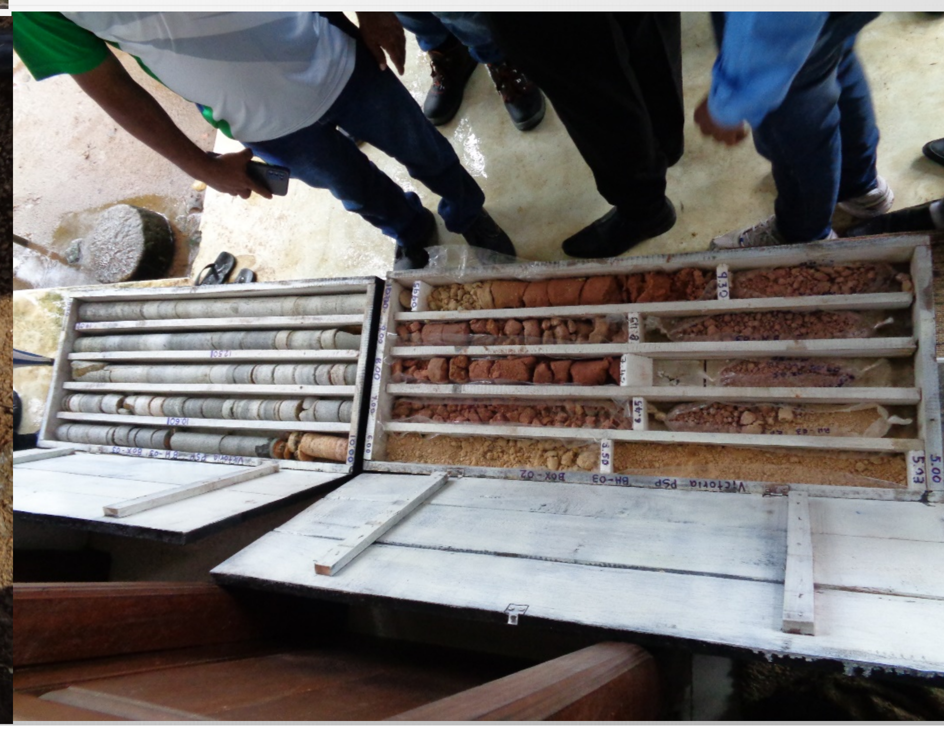
Tokyo Electric Power Company Holdings, Inc. (TEPCO HD)
TEPCO Power Grid, Incorporated (TEPCO PG)
Tokyo Electric Power Services Co., Ltd. (TEPSCO)

THE PROJECT FOR CAPACITY DEVELOPMENT ON THE POWER SECTOR MASTER PLAN IMPLEMENTATION PROGRAM

TRAINING ON GEOLOGICAL INVESTIGATIONS

Session	Date
Online session	2020-10-28
Online session	2021-07-08
Site training	2021-10-26
Online session	2021-10-28

TRAINING ON GEOLOGICAL INVESTIGATIONS




THANK YOU