Appendix E :
Feasibility Grade Design

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Appendix E Feasibility Grade Design

E1 Sediment Flushing

The regulating dam will be constructed with a sediment capacity of 123,000 m^3 on the Yangran River. Though this capacity will be filled up within less than 10 years by sediment entering from its upstream reach, which is estimated to be 19,000 m^3 or 2,300 m^3/km^2 per year.

Therefore, it is necessary to preserve long-term storage capacity aggressively by utilizing a sediment control capacity of the siltation dam and conducting sediment flushing at the regulating dam.

E1.1 Characteristics of Sediment

(1) Grain Size Distribution

A grain size distribution of incoming sediment is estimated from the results of the sediment surveys in the Kulekhani reservoir and the construction material surveys sampled in front of the Kulekhani I hydropower station.

A ratio of wash load to total sediment volume is assumed to be at 60 % from the results of the sediment surveys while a grain size distribution of coarser material follows those of the material surveys. The estimated grain size distribution has an average grain size of 20 mm with the maximum grain size of over 100 mm and is tabulated below:

Grain Size (mm)	Ratio of Sdmnt. Passing (%)	Grain Size (mm)	Ratio of Sdmnt. Passing (%)	Grain Size (mm)	Ratio of Sdmnt. Passing (%)
100	96.6	25	80.9	1.2	63.4
80	92.5	20	75.9	0.6	63.0
60	92.0	15	73.0	0.3	62.8
50	89.0	10	67.5	0.15	62.5
40	86.4	5	67.5	<0.1	60.0
30	83.9	2.5	64.8		

(2) Mode of Sediment Transport

Under the following cases, modes of sediment transport in the annual flood event, will be classified as tabulated below:

Case-1: Present riverbed
Case-2: Stabilized sediment slope in the siltation dam
Case-3: Stabilized sediment slope in the regulating dam

	Channel Slope	Channel Width (m)	Mode of Sediment Transport Range of Grain Size (mm)			
			Max. Transportable	Bed Load	Suspended Load	Wash Load
Case-1	1/15	13	417	over 31	0.3 – 31	below 0.3
Case-2	1/50	16	158	over 12	0.2 – 12	below 0.2
Case-3	1/17	13	552	over 29	0.3 – 29	below 0.3

(3) Annual Sediment Balance

An annual sediment balance in the regulating pond basin should be predicted and verified by numerical simulations and/or hydraulic model tests in further studies. Although, in this study, it is supposed as follows:

At siltation dam site (drainage area of 7.0 km^2)

Sediment Discharge: 2,300 m^3/ km^2/yr. x 7.0 km^2 = 16,100 m^3 /yr.

It is assumed that suspended and bed loads will be captured by the siltation dam and wash load will be released to its downstream reach.

The sediment control capacity of the siltation dam of 40,000 m^3, except a sediment detaining capacity of 5,000 m^3, will be fulfilled by sediment deposits of 6,400 m^3/yr. within 6 years. An annual maintenance cost for excavation and removal of these deposits will amount to 15,000 US$, applying a unit price of common excavation at 2.3 US$/ m^3.

Mode of Sdmnt. Transport	Grain Size (mm)	Ratio (%)	Sediment Vol. (m^3)	Remarks
Wash Load	Below 0.2	60	9,700	Released to Downstream
Suspended Load	0.2 – 12	10	1,600	Captured by Siltation Dam
Bed Load	Over 12	30	4,800	Captured by Siltation Dam
Total	-	100	16,100	-

At Regulating dam site (drainage area of 8.1 km^2)

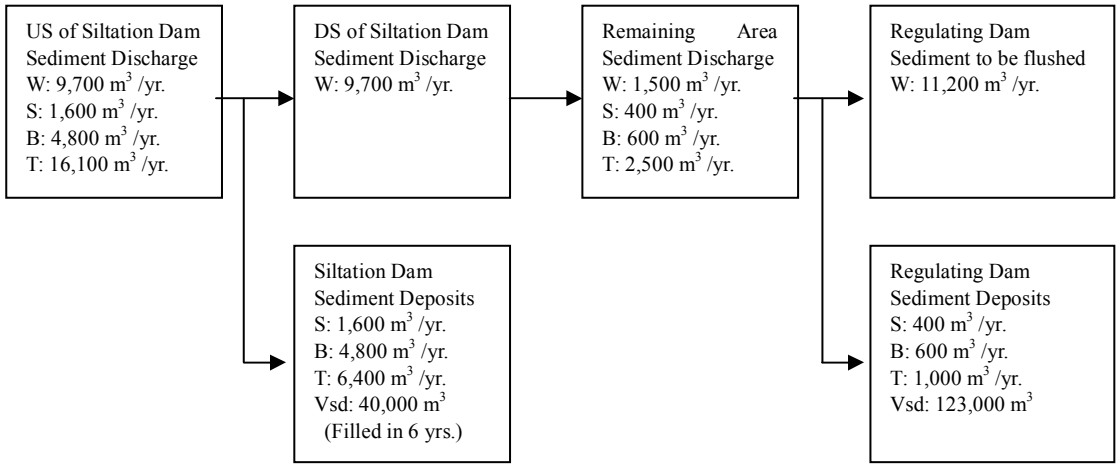
Sediment Discharge: 2,300 m^3/ km^2/yr. x (8.1-7.0) km^2 = 2,500 m^3 /yr.

Mode of Sdmnt. Transport	Grain Size (mm)	Ratio (%)	Sediment Vol. (m^3)	Remarks
Wash Load	Below 0.2	-	9,700	Flushed
Wash Load	Below 0.3	60	1,500	Flushed
Suspended Load	0.3 – 29	15	400	Deposited in Reg. Pond
Bed	Over 29	25	600	Deposited in Reg. Pond
Total	-	100	2,500	-

When it is assumed that suspended and bed loads will accumulate in the regulating pond and wash load will be removed by sediment flushing, a volume of sediment to be flushed from the dam is as follows:

Sediment to be flushed (Wash Load) 11,200 m^3 /yr

In the regulating pond, the annual sediment deposits of 1,000 m^3 will be accumulated to 100,000 m^3 for 100 years.



Annual Sediment Balance in the Regulating Pond Basin
(W: Wash Load, S: Suspended Load, B: Bed Load, T: Total Sediment Discharge, Vsd: Sediment Capacity)

E1.2 Sediment Flushing

(1) Methodology

Hydraulic flushing involves reservoir drawdown by opening a low-level outlet to temporarily establish riverine flow along the impounded reach, eroding a channel through the deposits and flushing the eroded sediment through the outlet.

(2) Precognition

An average rainfall duration, which had been recorded for 3 years at Tistung as over 40 mm uninterrupted precipitation, is estimated to be 8 hours. In accordance with the Kraven's and Rziha's formulas, floods will reach the regulating dam within 0.5 hours from its uppermost reach. On the other hand, it takes 3 to 4 hours to empty the regulating pond by opening a low-level outlet. Consequently, a sediment flushing will be enabled continuously for about 4 hours during one flood event. Therefore, it is essential for effective flushing to control a series of operations automatically after predicting the occurrence of the flood event, in advance, by rainfall monitoring systems installed in the uppermost reach.

(3) Reservoir Drawdown

If the design discharge for the sediment flushing is supposed at 25 m^3/s, which is equivalent to the peak discharge of the annual average flood in the Yangran River basin, discharge capacity of a sluice channel is considered as follows:

- To maximize effectiveness, flushing should be performed under free flow conditions through the sluice channel without producing backwater.
- Considering the rainfall duration of 8 hours, the sluice channel should be designed to empty the regulating pond within a relatively short period prior to flushing operations, which utilizes temporarily established riverrine flow by opening the low-level outlet during the flood event.

The sluice channel, with 3.0 m in width, 2.0 m in height and 1/15 in slope, will be capable to release the peak discharge during the annual flood event under free flow conditions and enable to empty the regulating pond within 3 hours.

(4) Flushing

Flushing efficiency

A flushing efficiency is defined as the ratio of deposit volume eroded to water volume used during flushing over any specified time interval. This water volume contributing directly to the flushing consists of total inflow during reservoir drawdown and during free flow.

Reported values for the flushing efficiency vary widely and are heavily influenced by flushing duration and by the amount of sediment inflow during the preceding impounding period. According to a result of literature studies, it is reported that the flushing efficiency of 0.01 to 0.06 was achieved at several sites under conditions of reservoir emptying. Achievable flushing efficiencies should be verified by numerical simulations and/or hydraulic model test with sufficient data, such as flood hydrographs, grain size distributions, shape of sediment deposits and so on. The flushing efficiency of 0.01 is assumed in this study.

(5) Number of Sediment Flushing

Based on available data, the average number of sediment flushing per year is roughly estimated under the following conditions:

Sediment deposits to be flushed per year	: V_s = 11,200 m^3
Average rainfall duration	: t = 8 hours
Flushing efficiency	: F_e = 0.01
Water volume required for flushing	: V = 1,120,000 m^3 (= V_s / F_e)

Flood volumes are estimated by the rational formula and an equation for effective rainfall intensity based on the daily basin rainfall of the Kulekhani reservoir and the average rainfall duration of 8 hours.

The daily rainfall records, which are ranked as the 1st to 5th largest of each year, are averaged for a period 1972 to 2000 and the flood volume during each storm is estimated as tabulated below:

		1st	2nd	3rd	4th	5th
Average Basin Rainfall	mm	107	78	64	57	52
Estimated Flood Volume	10^3 m^3	694	461	370	316	284
Accumulated Flood Volume	10^3 m^3	694	1,155	1,525	1,841	2,125

On the basis of these conditions, it is supposed that the sediment flushing requires to be conducted 2 times per year as shown in the above table.

Considering water volume for emptying the pond, the discharge requirement that needs to be deducted from the annual inflow into the regulating pond is estimated as follows:

Annual inflow to the regulating pond (Daily mean discharge of 5.28 m^3/s)	: 166,510,000 m^3
Water volume required for flushing	: 1,120,000 m^3
Water volume for emptying the pond (F.S.L. to S.D.L.)	: 529,000 m^3 /flushing
Average number of sediment flushing	: 2 times /year
Deduction from the annual inflow	: 2,178,000 m^3

This deduction corresponds to approximately 1 % of the annual inflow into the regulating pond.

Appendix F :

Construction Plan and Cost Estimate

Appendix F : Construction Plan and Cost Estimate

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Appendix F Construction Plan and Cost Estimate

F1 Monthly Progress of the Tunnel Excavation Works

The monthly progress of the tunnel excavation works for connection tunnel, adit tunnel, headrace tunnel, tailrace tunnel, pilot shaft and enlargement shaft, have been computed by reference to the authorized guidelines which are available in Japan. The results are summarized below and detailed in Table F.T.1 to F.T.6 respectively.

Tunnel	Monthly Progress (m/month)
Connection tunnel	134
Adit tunnel	128
Headrace tunnel	117
Tailrace tunnel	105
Pilot shaft	70
Enlargement shaft	65

As shown in the table, each of the above monthly progress is an average of each monthly progress calculated based on the rock grade, the distribution of which has been set in the geological and geotechnical condition of the sites.

TABLES

Appendix F

Table F.T.1 Cycle Time Analysis for Connection Tunnel Excavation Work

	Description	B (CH)	CI (CM)	CII (CL)	D	Average
1. Basic Condition						
	Length	1,685	1,495	220	75	3,475
A1	Excavation area (m2)	12.0	12.0	12.0	12.0	12.0
B	Advance per cycle (m)	2.0	1.5	1.5	1.0	1.7
C	Drilling time per m2 (min/m2)	3.1	2.5	2.5	1.4	2.8
	Circle length of excavation area(m)	12.2	12.2	12.2	12.2	12.2
M	Spray area per cycle (m2)	18.4	13.8	13.8	9.2	15.9
N	Shotcret thickness (m)	0.05	0.05	0.05	0.10	0.05
P	Nos. of rock bolt per cycle (nos.)	0.0	7.7	7.7	9.2	4.0
2. Cycle time (min)						
	Drilling & blasting					
	Preparation	15	15	15	15	15
T1	Drilling T1=A1*C	37	30	30	16	33
	Charging, blasting, ventilation etc.	50	50	50	50	50
	Sub-total	102	95	95	81	98
	Mucking					
	Preparation	10	10	10	10	10
T2	Mucking T2=60*Q0/Qs	65	49	49	32	56
	Clearing	10	10	10	10	10
	Measurement	10	10	10	10	10
	Sub-total	95	79	79	62	86
	Shotcrete					
	Preparation	15	15	15	15	15
T3	Spraying T3=M*N*f*60/4	35	29	32	33	32
	Clearing	15	15	15	15	15
	Sub-total	65	59	62	63	62
	Rock bolt					
	Preparation	0	10	10	10	5
T4	Rock bolt setting T4=P*6	0	45	45	55	23
	Clearing	0	15	15	15	8
	Sub-total	0	70	70	80	36
T5	Wire net setting	0	0	0	10	0
	Steel support					
	Preparation	0	0	0	15	0
T6	Steel support setting	0	0	0	25	1
	Sub-total	0	0	0	40	1
	Others (Change muck car, rail extention, etc.)	70	70	70	70	70
Q	Total	332	373	376	406	354
	Workable days (days/month)	25	25	25	25	25.0
	Working hours (hrs/day)	18	18	18	18	18.0
3. Monthly progress						
	Nos. of round per day	3.25	2.90	2.87	2.66	3.06
	Daily progress (m)	6.51	4.34	4.31	2.66	5.35
	Monthly progress (m)	162.65	108.58	107.71	66.50	133.83

Table F.T.2 Cycle Time Analysis for Adit Tunnel Excavation Work

	Description	B (CH)	CI (CM)	CII (CL)	D	Average
1. Basic Condition						
	Length	1,685	1,495	220	75	3,475
A1	Excavation area (m2)	30.0	30.0	30.0	30.0	30.0
B	Advance per cycle (m)	2.0	1.5	1.2	1.0	1.7
	Circle length of excavation area(m)	18.8	18.8	18.8	18.8	18.8
M	Spray area per cycle (m2)	28.3	21.2	17.0	14.1	24.2
N	Shotcret thickness (m)	0.05	0.10	0.10	0.15	0.08
P	Nos. of rock bolt per cycle (nos.)	9.4	9.4	9.4	11.8	9.5
2. Operation time (min)						
T1	Wheel jumbo, 2 boom	157	162	143	192	159
T2	Heavy breaker, 800kg	20	20	20	20	20
T3	Muck loader, S-dump, 2.3m3	100	79	67	53	88
T4	Dump truck, 10ton	238	178	142	129	204
T5	Backhoe, 0.28m3	40	32	27	21	35
T6	Mortar sprayer	35	40	38	40	37
T7	Agitator truck	43	48	46	48	45
T8	Dust collector	367	357	323	380	360
T9	Mortar injection	48	63	63	91	56
T10	Truck, 2ton	10	10	10	10	10
T11	Truck, 4ton with crane 2.9ton	20	20	20	35	20
T12	Spray plant	30	30	30	30	30
3. Cycle time (min)						
Q	Maximum operation item (Dust collector)	367	357	323	380	360
	Workable days (days/month)	25	25	25	25	25.0
	Working hours (hrs/day)	18	18	18	18	18.0
3. Monthly progress						
	Nos. of round per day	2.94	3.03	3.34	2.84	3.00
	Daily progress (m)	5.89	4.54	4.01	2.84	5.12
	Monthly progress (m)	147.14	113.45	100.31	71.05	128.04

Table F.T.3 Cycle Time Analysis for Headrace Tunnel Excavation Work

	Description	B (CH)	CI (CM)	CII (CL)	D	Average
1. Basic Condition						
	Length	54	315	20	0	389
A1	Excavation area (m2)	27.0	27.0	27.0	27.0	27.0
B	Advance per cycle (m)	2.0	1.5	1.2	1.0	1.6
	Circle length of excavation area(m)	16.0	16.0	16.0	16.0	16.0
M	Spray area per cycle (m2)	24.0	18.0	14.4	12.0	18.7
N	Shotcret thickness (m)	0.05	0.10	0.10	0.15	0.09
P	Nos. of rock bolt per cycle (nos.)	8.0	8.0	8.0	10.0	8.0
2. Operation time (min)						
T1	Wheel jumbo, 2 boom	157	162	143	192	160
T2	Heavy breaker, 800kg	20	20	20	20	20
T3	Muck loader, S-dump, 2.3m3	100	79	67	53	81
T4	Dump truck, 10ton	238	178	142	129	184
T5	Backhoe, 0.28m3	40	32	27	21	33
T6	Mortar sprayer	35	40	38	40	39
T7	Agitator truck	43	48	46	48	47
T8	Dust collector	367	357	323	380	357
T9	Mortar injection	48	63	63	91	61
T10	Truck, 2ton	10	10	10	10	10
T11	Truck, 4ton with crane 2.9ton	20	20	20	35	20
T12	Spray plant	30	30	30	30	30
3. Cycle time (min)						
Q	Maximum operation item (Dust collector)	367	357	323	380	357
	Workable days (days/month)	25	25	25	25	25.0
	Working hours (hrs/day)	18	18	18	18	18.0
3. Monthly progress						
	Nos. of round per day	2.94	3.03	3.34	2.84	3.03
	Daily progress (m)	5.89	4.54	4.01	2.84	4.70
	Monthly progress (m)	147.14	113.45	100.31	71.05	117.45

Table F.T.4 Cycle Time Analysis for Tailrace Tunnel Excavation Work

	Description	B (CH)	CI (CM)	CII (CL)	D	Average
1. Basic Condition						
	Length	79	1,245	520	305	2,149
A1	Excavation area (m2)	30.0	30.0	30.0	30.0	30.0
B	Advance per cycle (m)	2.0	1.5	1.2	1.0	1.4
	Circle length of excavation area(m)	18.8	18.8	18.8	18.8	18.8
M	Spray area per cycle (m2)	28.3	21.2	17.0	14.1	19.4
N	Shotcret thickness (m)	0.05	0.10	0.10	0.15	0.11
P	Nos. of rock bolt per cycle (nos.)	9.4	9.4	9.4	11.8	9.8
2. Operation time (min)						
T1	Wheel jumbo, 2 boom	157	162	143	192	161
T2	Heavy breaker, 800kg	20	20	20	20	20
T3	Muck loader, S-dump, 2.3m3	100	79	67	53	73
T4	Dump truck, 10ton	238	178	142	129	165
T5	Backhoe, 0.28m3	40	32	27	21	30
T6	Mortar sprayer	35	40	38	40	39
T7	Agitator truck	43	48	46	48	47
T8	Dust collector	367	357	323	380	352
T9	Mortar injection	48	63	63	91	66
T10	Truck, 2ton	10	10	10	10	10
T11	Truck, 4ton with crane 2.9ton	20	20	20	35	22
T12	Spray plant	30	30	30	30	30
3. Cycle time (min)						
Q	Maximum operation item (Dust collector)	367	357	323	380	352
	Workable days (days/month)	25	25	25	25	25.0
	Working hours (hrs/day)	18	18	18	18	18.0
3. Monthly progress						
	Nos. of round per day	2.94	3.03	3.34	2.84	3.07
	Daily progress (m)	5.89	4.54	4.01	2.84	4.22
	Monthly progress (m)	147.14	113.45	100.31	71.05	105.49

Table F.T.5 Cycle Time Analysis for Pilot Shaft Excavation Work

Description	Pilot shaft
1. Basic Condition	
Excavation area (m2)	4.4
Nos. of hole (holes/m2)	6.0
Total holes	26
Nos. of drill	2.0
Advance per round (m)	1.00
Drilling depth (m)	1.05
Drilling speed (m/min)	0.20
Swell factor	1.7
Muck volume (loose)	7.5
Mack loading equipment	
Type	Side dump shovel
Bucket capacity	1.9
Work efficiency	0.6
Cycle time (sec)	45
Hourly production (m3/hr,l	42.9
Muck hauling equipment	
Type	11t DT
Capacity (m3/hr)	6.8
Required trip	2
Rock bolt length (m)	
Nos. of rock bolt per circle	
Rock bolt intervals (m)	
Shotcreet	
Circle length (m)	
Thickness (m)	
Adjustment factor	
Spray capacity (m3/hr)	
Workable days (days/month)	25.0
Working hours (hrs/day)	18.0
2. Cycle time (min)	
Drilling & blasting	272
Preparation	60
Drilling	82
Charging	40
Jumbo withdrawal	10
Blasting & ventilation	20
Others	60
Mucking	60
Preparation	
Mucking	
Rial extention	60
Others	
Supporting work	24
Preparation	
Scaling	
Wire net	
Rock bolt	
Shotcreet	
Steel support	24
Others	
Measurement	30
Total	386
3. Monthly progress	
Nos. of round per day	2.79
Daily progress (m)	2.79
Monthly progress (m)	69.75

Table F.T.6 Cycle Time Analysis for Enlargement Shaft Excavation Work

Description	Enlargement
1. Basic Condition	
Excavation area (m2)	15.6
Nos. of hole (holes/m2)	2.5
Total holes	40
Nos. of drill	3
Advance per round (m)	1.2
Drilling depth (m)	1.25
Drilling speed (m/min)	0.2
Swell factor	1.7
Muck volume (loose)	31.8
Mack loading equipment	
Type	Side dump loader
Bucket capacity	1.9
Work efficiency	0.6
Cycle time (sec)	45
Hourly production (m3/hr,b)	42.9
Muck hauling equipment	
Type	11t DT
Capacity (m3/hr)	6.8
Required trip	5
Rock bolt length (m)	3
Nos. of rock bolt per circle	12
Rock bolt intervals (m)	3
Shotcreet	
Circle length (m)	18
Thickness (m)	0.075
Adjustment factor	1.8
Spray capacity (m3/hr)	4.0
Workable days (days/month)	25
Working hours (hrs/day)	18
2. Cycle time (min)	
Drilling & blasting	191
Preparation	30
Drilling	97
Charging	14
Jumbo withdrawal	10
Blasting & ventilation	20
Others	20
Mucking	140
Preparation	30
Mucking	90
Rial extention	0
Others	20
Supporting work	135
Preparation	30
Scaling	10
Wire net	0
Rock bolt	38
Shotcreet	37
Steel support	0
Others	20
Measurement	30
Total	496
3. Monthly progress	
Nos. of round per day	2.17
Daily progress (m)	2.60
Monthly progress (m)	65.10