APPENDIX-J

DESIGN AND COST ESTIMATION

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Contents

PART J-1 STRUCTURAL DESIGN

PART J-II COST ESTIMATE

List of Tables

List of Figures

List of Attachments

APPENDIX-J

DESIGN AND COST ESTIMATION

PART J-I STRUCTURAL DESIGN

CHAPTER J-1 UPPER SLAKOU RIVER IRRIGATION RECONSTRUCTION PLAN (USP)

In the plan of USP, irrigation water to be impound in Tumnup Lok Reservoir and Kpob Trobek Reservoir that are connected by diversion canal will be conveyed to Canal No.33, and diverted to six (6) secondary canals, named as Canal 3U, Canal 23, Canal 22, Canal 21, Canal 20 and Canal 3D, through off-take structures. After that the irrigation water will be delivered to each plot through tertiary canal and water course.

In this Chapter, design procedure and design results of reservoirs and irrigation canal system are presented.

J-1.1 Reservoirs

J-1.1.1 General Condition

General condition for design of both Tumnup Lok and Kpob Trobek Reservoirs is as presented in Table J-1. The seismic force is not taken into account in the design of dike and appurtenances.

J-1.1.2 Tumnup Lok Reservoir

(1) Dike

1) Embankment material and zoning

An earth fill type dam with impervious inclined core zone and semi-pervious shell zone is adopted for new embankment section. The inclined surface protection on upstream slope using impervious material is adopted for the rehabilitation of existing dike.

The materials for the impervious zone will be laterite, clayey gravel and mixed material of laterite and clayey gravel with excavated material of the existing dikes and inside the reservoir. The excavated material of the existing dikes and inside the reservoir should be used for shell zone.

2) Design value

The design values of fill material and existing dike of Tumnup Lok Reservoir are shown in the following table, which have been obtained based on the results of soil mechanical test performed on Third Field Work of Phase II of the Study.

Zone		Wet unit weight (tf/m^3)	Saturated unit weight (tf/m^3)	Submerged unit weight (tf/m^3)	Internal friction angle (°)	Cohesion (tf/m^2)
Zone I (Impervious zone)	total stress	2.00	2.25	1.25	15.0	3.0
	effective stress				25.0	3.0
Zone II (Shell zone)		1.93	2.08	1.08	25	1.5
Riprap		2.00	2.20	1.20	40	0.0
Existing dike		2.02	2.18	1.18	25	1.0

The soil properties of fill material and existing dike are shown in Table J-2 and J-3

(a) Zone I (Impervious zone)

The soil property of Zone I material is summarized as shown in following table.

	Specific gravity Gs	Natural water content (%)	Maximum dry density (tf/m^3)	Permeability (cm/sec)	Unconfined compression strength qu (kg/cm^2)
average	2.96	10.63	2.018	5.0E-6	9.6
σ_{n-1}	0.09	2.20	0.05		5.9

σ_{n-1} ; standard deviation

The fill material of dike shall be compacted to at least D_{95} (95 % density of maximum dry density obtained by the compaction test). Water content of this material during construction should be between W_{opt} (optimum water content) and W_{95wet} (water content at D_{95} wet side). The water content between W_{95wet} and W_{opt} is about 5 % depending on the compaction test. Because the natural water content ranges from 4 % dry to 2 % wet of W_{opt}, the moisture conditioning should consist of spraying the material with water. The degree of saturation of more than 75 % should be necessary.

a) Design unit weight

Design unit weight would be determined to be 95 % density of maximum dry density. Design value would be determined as shown below:

$$X_m = \Sigma X_i / n$$

$$\sigma_{n-1} = \sqrt{\frac{\Sigma(Xi - Xm)^2}{n-1}}$$

$$X_d = X_m - \sigma_{n-1}/2$$

where, X_m : mean value
X_i : measurement value
σ_{n-1} : standard deviation
n : numbers of measurement value
X_d : design value

- Specific gravity and Field water content

Gs = 2.92 Gs : specific gravity

W = 9.53 % w : natural water content

- Unit weight

γd = 0.95 x γd_{max} = 0.95 x (2.018 – 0.05/2)

= 1.89 tf/m^3

γt = $\gamma d \times$(1 + w/100) = 1.89 x (1 + 0.0953) γt : wet unit weight

= 2.07 $\rightarrow$2.00 tf/m^3

e = $(Gs \cdot \gamma_w)/\gamma d - 1$ e : void ratio

= 0.54 γ_w : unit weight of water (= 1.0)

γsat = $(Gs+e) \cdot \gamma_w/(1+e)$ γsat : saturated unit weight

= 2.25 tf/m^3

γsub = $\gamma sat - \gamma_w$ γsub : submerged unit weight

= 1.25 tf/m^3

b) Design shear strength

- Effective stress during operation of reservoir

Cohesion (c) is determined using the unconfined compression strength. Design value is rounded down to conservative side.

qu = 9.6 – 5.9/2 = 6.6 tf/m^2

c = qu/2 = 3.3 $\rightarrow$3.0 tf/m^2

Internal friction angle is assumed based on the density.

ϕ = 25.0 degree

- Total stress at immediately after reservoir construction

Cohesion c = 3.0 tf/m^2

Internal friction angle ϕ = 15.0 degree

c) Coefficient of permeability

The coefficient of permeability of impervious zone should be under 1×10^{-5} cm/sec.

(b) Zone II (Shell zone)

The soil property of Zone II material is shown in the following table:

	Specific gravity Gs	Natural water content (%)	Maximum dry density (tf/m^3)	Permeability (cm/sec)	Unconfined compression strength qu (kg/cm^2)
average	2.66	13.87	1.86	1.1E-5	5.4
σ_{n-1}	0.03	4.82	0.09		3.7

The excavated material of existing dike and inside the reservoir is classified as CL, SC and SM based on unified soil classification. The material of SC and SM will have difficulty of compaction, be weak against erosion by rainfall, and be of low trafficability during construction. When such materials are used for embankment, well-compaction having the water content within ± 3 % of optimum water content is very much necessary.

a) Design unit weight

Design unit weight would be determined to be 95 % density of maximum dry density.

- Specific gravity and Field water content

Gs = 2.65

W = 11.5 %

- Unit weight

$\gamma d = 0.95 \times \gamma d_{max} = 0.95 \times (1.86 - 0.09/2) = 1.73\ tf/m^3$

$\gamma t = \gamma d \times (1 + w/100) = 1.73 \times (1 + 0.115) = 1.93\ tf/m^3$

$e = (Gs \cdot \gamma_w)/\gamma d - 1 = 0.53$

$\gamma sat = (Gs+e) \cdot \gamma_w/(1+e) = 2.08\ tf/m^3$

$\gamma sub = \gamma sat - \gamma_w = 1.08\ tf/m^3$

b) Design shear strength

Cohesion (c) is determined using the unconfined compression strength. Design value is rounded down to conservative side.

$qu = 5.4 - 3.7/2 = 3.55\ tf/m^2$

$c = qu/2 = 1.8 \rightarrow 1.5\ tf/m^2$

Internal friction angle is assumed based on the density.

ϕ = 25.0 degree

(c) Existing dike

The material of existing dike of Tumnup Lok Reservoir is mostly classified into SC and SM. The soil property of SC and SM material is obtained as shown in the following table by the geotechnical boring and the soil mechanical test on three reservoirs.

	Specific gravity Gs	Field water content (%)	Field dry density (tf/m^3)	N Value	Conversed Internal friction angle $\phi = \sqrt{12N}+15$	Conversed Internal friction angle $\phi = \sqrt{15N}+15$
average	2.67	7.28	1.88	19.6	29.2	30.8
σ_{n-1}	0.01	3.68	0.13	16.2	6.02	6.75

a) Design unit weight

- Specific gravity and Field water content

Gs = 2.67

w = 7.28 %

- Unit weight

γd = 1.88 tf/m^3

γt = $\gamma d \times (1 + w/100) = 1.88 \times (1 + 0.073) =$ 2.02 tf/m^3

e = $(Gs \cdot \gamma_w)/\gamma d - 1 =$ 0.42

$\gamma sat = (Gs+e) \cdot \gamma_w/(1+e) = 2.18$ tf/m^3

$\gamma sub = \gamma sat - \gamma_w = 1.18$ tf/m^3

b) Design shear strength

The cohesion and internal friction angle of the existing dike are evaluated by using N-value.

Cohesion (c) is determined as follows.

N = 19.6 – 16.2/2 = 11.5

qu = N/5 = 11.5/5 = 2.3 tf/m^2

c = qu/2 = 2.3/2 =1.15 $\rightarrow$1.0 tf/m^2

Internal friction angle is calculated by using the following formula of relation with N value.

$\phi = \sqrt{12N}+15 = 29.2^o$ ----- $\phi = 29.2 - 6.0/2 = 26.2^o$

$\phi = \sqrt{15N} + 15 = 30.8^{o}$ ---- $\phi = 30.8 - 6.8/2 = 27.4^{o}$

Designed value of internal friction angle is determined as 25.0^{o}.

(d) Stability analysis

a) Method of stability analysis and safety factor

Slip circle slice method is applied to stability analysis of dike. Allowable safety factor (Fs) would be taken Fs≧1.2

$$Fs = \frac{\Sigma\{cl + N - U - Ne)\tan\phi\}}{\Sigma(T + Te)}$$

Where, Fs: Safety factor

c: Cohesion on sliding surface of each slice

ϕ: Internal friction angle of material on sliding surface of each slice.

l: Length of a sliding surface of each slide (= b/cosα)

b: Width of each slice

N: Normal loading acting on sliding surface of each slice

T: Tangential load acting on sliding surface of each slice

Te: Tangential seismic load acting on sliding surface of each slice

Ne: Normal seismic load acting on sliding surface of each slice

U: Pore pressure acting on sliding surface of each slice

b) Study cases of stability analysis

Stability analysis was conducted for the new embankment section and rehabilitation section of the existing dike. Study cases of stability analysis of each section are as follows:

New embankment section

Case 1 : HWL Under normal (full) water condition
Case 2 : IAC Immediately after completion

Rehabilitation section of existing dike

Case 3 : HWL Normal (full) water condition

c) Seepage line

Seepage line through the body of dike under normal water level condition is estimated by applying Casagrande method. Because the difference between the coefficient of permeability of Zone I and that of Zone II will be less than ten (10) times, existing dike (the body of dike) is assumed to be homogeneous. Generally, in case that the fill is compacted with the tamping roller, the horizontal permeability (k_h) is different from the vertical permeability (k_v) due to the compaction mechanism. The following relation is assumed as an average value for the tamping roller.

$k_v : k_h = 1 : (2 \sim 10)$ average value for the tamping roller $\rightarrow$ 5

$k = \sqrt{k_v \times k_h}$

Therefore, the scale of the horizontal abscissa of the calculated section shall shrink to root (1/5) times. The calculation results are shown in Table J-4 and J-5.

d) Results of stability analysis

The safety factor is resulted as follows.

New embankment section

Case 1 : Upstream; Fs = 3.255 Downstream; Fs = 2.651

Case 2 : Upstream; Fs = 3.149 Downstream; Fs = 2.679

Rehabilitation section of existing dike

Case 3 : Upstream; Fs = 2.408 Downstream; Fs = 1.800

The analysis results are shown in Figure J-1, J-2 and J-3.

(2) Spillway

1) Type and Location

Spillway type was selected in accordance with the following principal:

- to make both initial construction cost and O&M cost as low as possible in due consideration of function, safety and duration,
- to avoid operation miss for protection of reservoir function, and
- to select familiar type in and around the Study area

Usually, spillway type for the small-scale reservoir is classified into three; gate type; orifice type, and overflow type. Original spillway for the reservoirs are gate type, and the reservoir dike was damaged by improper operation of spillway gate at flood time. Gate type will need much O&M cost to keep proper function than the other types. Orifice type is not common in Cambodia, and there is no orifice type in and around the Study area. Overflow type is familiar in and around the Study area less than the other types in O&M cost, and basically operation free. The results of the preliminary evaluation of each type is as follows:

Evaluation of Spillway Type

Type	Investment Cost	O&M Cost	Operation Facility	Experience
Overflow Type	○	○	○	○
Gate Type	○	×	×	○
Orifice Type	○	○	○	×

Considering the above, it is concluded that the overflow type has advantage.

Since the overflow type is classified into several types, comparative study was conducted from viewpoint of direct construction cost between Ogee type that is typical of the overflow type and rock spillway type that has been often adopted in Cambodia. The results of the comparison is shown the following table, and the rock spillway has been selected for both the reservoirs.

Direct Construction Cost of Spillway by Type

(Unit : US$)

Type	Direct Construction Cost	
	Tumnup Lok Reservoir	Kpob Trobek Reservoir
Ogee Type	1,463,000	835,000
Rock Spillway Type	815,000	653,000

Spillway will be located on the embankment portion across the existing Slakou River. The station number of center of spillway is STA.2+100.

The spillway is composed of inlet portion, chute portion and stilling basin. These components will be constructed by using the rock material and gravel.

2) Length of overflow weir

Design flood discharge is as follows:

Flood discharge m^3/sec	Return period
420	100-year
290	20-year

Relation between overflow depth and length of overflow weir can be expressed below.

$$Q = C \cdot B \cdot H^{3/2}$$

where, Q : Discharge (m^3/sec)
C : Coefficient of overflow
B : Effective length of weir (m)
H : Total head above weir crest (including approach velocity head)

The coefficient of overflow of 1.71 is applied to this type overflow weir. The overflow depth is 1.10m and the approach velocity is not taken into account. The length of overflow weir is designed to be 215 m.

$$B = Q/(C \times H^{3/2}) = 420/(1.71 \times 1.1^{3/2}) = 212.9 \rightarrow 215 \text{ m}$$

3) Hydraulic calculation

(a) Overflow weir

Length of overflow weir L = 215 m

Discharge per unit width q = Q/L = 420/215 = 1.95 m^3/sec/m

Discharge per unit width $q = Q/L = 420/215 = 1.95\ m^3/sec/m$

At crest Critical depth $hc = (q^2/g)^{1/3} = 0.73\ m$ g ; gravity acceleration

Critical velocity $Vc = q/hc = 2.67\ m/sec$

At toe of weir Water depth (ho) is calculated by the following formula:

$$ho^3 - Eo \times ho^2 + q^2/2g = 0$$

$Eo = D + 1.5 \times hc$ D ; height of weir (2.0 m)

Water depth $ho = 0.26\ m$

Velocity $Vo = q/ho = 7.50\ m/sec$

Hydraulic jump Depth (h_1) $h_1 = ho/2 \times ((1+8Fo^2)^{1/2} - 1)$

$Fo = Vo/(g \times ho)^{1/2}$ F ; froude number

$Fo = 7.50/(g \times 0.26)^{1/2} = 4.699$

$h_1 = 1.60\ m$

Velocity $V_1 = q/ h_1 = 1.22\ m/sec$

Length (L) $L = 4.5 \sim 6.0 \times h_1 = 7.20 \sim 9.60\ m$

The weight of rock is estimated by following formula.

$$W > \alpha\ (\rho_w / (\rho_b - \rho_w))^3 \times \rho_b/g^2 \times (V/\beta)^6$$

where,
- W : weight of rock (tf)
- V : velocity of flow(m/sec)
- g : gravity acceleration ($9.8\ m/sec^2$)
- ρ_w : density of water (tf/m^3)
- ρ_b : density of rock (tf/m^3)
- α : shape factor ($= 0.83 \times 10^{-3}$)
- β : factor of effect by friction of rock (=1.4)

When rock is sphere with diameter of 0.8m; density of rock is 2.5 tf/m^3,

$$\alpha\ (\rho_w / (\rho_b - \rho_w))^3 \times \rho_b/g^2 \times (V/\beta)^6 = 0.15\ tf$$

$W = 4/3 \times \pi \times r^3 \times \rho_b = 0.67tf > 0.60tf = 0.15 \times 4$(safety factor) -----OK!

Therefore, the maximum size of rock is determined to be diameter of 0.8 m.

(b) Chute portion

Chute portion with width of 250 m is designed as supercritical flow channel. Calculation of non-uniform flow has been carried out from the beginning point of the chute toward downstream. Coefficient of roughness (n) is 0.035. Calculation results are shown in Table J-6(1/2).

(c) First stilling basin (EL.37.00 m)

Design flood discharge for the first stilling basin is 100-year flood discharge of

420 m^3/sec. The hydraulic calculation for stilling basin is expressed as follows:

$$L = 6\ h_2$$

$$h_2 = (h_1/2) \bullet (\sqrt{1+8F_r^2} - 1)$$

where, L : length of hydraulic jump (m)

h_2 : water depth after hydraulic jump (m)

h_1 : water depth of inflow (m)

Fr : Froude number

h_1 = 0.314 m (result of calculation on chute portion)

V_1 = 6.214 m/sec (result of calculation on chute portion)

$Fr = v/ (g \times h_1)^{1/2} = 3.541$

h_2 = 1.425 m

L = 8.6 m

(d) Second stilling basin (EL.35.50 m)

Design flood discharge for second stilling basin is 20-year flood discharge of 290 m^3/sec. Calculation of non-uniform flow of chute portion with width of 50 m has been carried out from the end point of the first stilling basin toward downstream on assumption that the critical flow will occur at the end point of the first stilling basin. The calculation results are shown in Table J-6(2/2).

$$L = 6\ h_2$$

$$h_2 = (h_1/2) \bullet (\sqrt{1+8F_r^2} - 1)$$

h_1 = 0.962 m (results of calculation on chute portion)

V_1 = 6.031 m/sec (results of calculation on chute portion)

$Fr = v/ (g \times h_1)^{1/2} = 1.964$

h_2 = 2.233 m

L = 13.4 m

2) Stability analysis

Stability of concrete structure of spillway was checked against overturning, sliding and ground reaction. The loads are the self weight of structure, earth pressure, static water pressure, uplift pressure and live load by vehicle. Coulomb's formula shall be applied to calculation of the coefficient of earth pressure. The seismic inertia force is not considered in the analysis.

(a) Design condition

The following condition was applied for stability analysis of the spillway structures.

Unit weight	Reinforced concrete	γc	= 2.40 tf/m^3
	Backfill (wet)	γt	= 1.80 tf/m^3
	Backfill (saturated)	γsat	= 2.00 tf/m^3
	Water	γw	= 1.00 tf/m^3

	Anchor rock (wet)	γt	= 2.00 tf/m^3
	Anchor rock (saturated)	γsat	= 2.20 tf/m^3
Internal friction angle	Embankment	ϕ	= 30.0^o
	Backfill	ϕ	= 25.0^o
Embanked slope of backfill		b	= 0.0^o
Live load	under normal condition	q	= 0.50 tf/m^2
	under flood condition	q	= 0.00 tf/m^2
Coefficient of friction between concrete and foundation			f = 0.47 (ϕ = 25^o)
Shearing stress of foundation		τ	= 2.00 tf/m2
Allowable bearing capacity of foundation		qa	= 20.00 tf/m2
Flood water level (FWL)		EL.42.40 m	
Normal water level (HWL)		EL.41.30 m	

(b) Safety factor

The condition for stability is as follows:

a) Overturning:

Under normal condition: $e \leq B/6$

Under flood condition: $e \leq B/3$

$e = B/2 - (\Sigma Mr - \Sigma Mt)/\Sigma V$

where,
- e : eccentric distance (m)
- B : bottom width of structure (m)
- ΣMr : total resistance moment (tf.m)
- ΣMt : total sliding moment (tf.m)
- ΣV : total vertical force (tf/m)

b) Sliding:

Under normal condition: Fs >1.5

Under flood condition: Fs >1.2

$Fs = (f \times \Sigma V + \tau \times B)/ \Sigma H$

where,
- f : coefficient of friction between concrete and foundation
- t : shearing stress of foundation
- B : bottom width of structure (m)
- ΣV : total vertical force (tf/m)
- ΣH : total horizontal force (tf/m)

c) Ground reaction:

Ground reaction shall be less than the allowable bearing capacity of foundation.

In the case of $e < B/6$

$q = \Sigma V/B \times (1 \pm 6e/B)$

In the case of $e > B/6$

(3) Intake Structure

Three intake structures will be provided on the Tumnup Lok Reservoir; one is to Kpob Trobek reservoir through Diversion Canal and the others are for tertiary blocks just downstream of Tumnup Lok Reservoir.

Main features of both types of intake structures are presented below;

Intake Structure to Diversion Canal

Discharge	3.50 m^3/s
Intake Width	3.00 m
Gate Size and Nos.	1.20×1.20 m×2 nos.
Conduit Size and Nos.	1.20×1.20 m×2 nos.
Dike Top EL.	EL. 43.30 m
Intake Sill EL.	EL. 39.00 m

Intake Structure to TL-1

Discharge	5.5 lit./s
Intake Width	0.60 m
Gate Size and Nos.	0.60×0.60 m×1 Nos.
Conduit Size and Nos.	ϕ0.60 m×1 Nos.
Dike Top EL.	EL. 43.30 m
Intake Sill EL.	EL. 40.00 m

Intake Structure to TL-2

Discharge	11.0 lit./s
Intake Width	0.60 m
Gate Size and Nos.	0.60×0.60 m×1 nos.
Conduit Size and Nos.	ϕ0.60 m×1 nos.
Dike Top EL.	EL. 43.30 m
Intake Sill EL.	EL. 40.00 m

(4) Maintenance Gate

A maintenance gate facility with two sluice gates of 1.5 m x 1.5 m is proposed on the right side of the spillway. The sluice gates would be used for reservoir maintenance, discharge of river maintenance flow, and removal of some sediment on the upstream of the spillway. The gates would be operated manually.

Main features of the maintenance gate facility are presented as follows:

Inlet Width	3.60 m
Gate Size and Nos.	1.50×1.50 m×2 nos.
Conduit Size and Nos.	1.50×1.50 m×2 nos.
Dike Top EL.	43.30 m
Intake Sill EL.	37.50 m

J-1.1.3 Kpob Trobek Resevoir

(1) Dike

1) Embankment material and zoning

The inclined surface protection on the upstream slope using the impervious material is adopted for the rehabilitation of existing dike. The embankment at the spillway is filled by impervious material and semi-pervious material.

The fill materials are the same as mentioned in Section J-1.1.2 (1).

2) Design value

The sandy soil from top of dike to a depth of about 4m would be underlain by clayey soil in accordance with the result of geotechnical boring. Since only a part of the long dike was investigated, the stability analysis was conducted for two (2) cases. One is case that the existing dike is considered as homogeneous from soil mechanical view point. The otehr is case that the existing dike is composed of two zones of sandy soil and clayey soil. The design values of existing dike were determined for each case, which are summarized in following table:

Zone		Wet unit weight (tf/m^3)	Saturated unit weight (tf/m^3)	Submerged unit weight (tf/m^3)	Internal friction angle (^{o})	Cohesion (tf/m^2)
Zone I (Impervious zone)	total stress	2.00	2.25	1.25	15.0	3.0
	effective stress				25.0	3.0
Existing dike (sandy soil + clayey soil)		2.00	2.20	1.20	25	1.0
Existing dike (sandy soil)		2.02	2.18	1.18	25	1.0
Existing dike (clayey soil)		1.90	2.08	1.08	15	2.5
Riprap		2.00	2.20	1.20	40	0.0

(a) Zone I (Impervious zone)

The design value of Zone I is the same as that of Tumnup Lok Reservoir.

(b) Existing dike (in case that the existing dike is assumed to be homogeneous.)

The soil property is as shown in the following table.

	Specific gravity Gs	Natural water content (%)	Field dry density (tf/m^3)	N Value	Conversed Internal friction angle $\phi=\sqrt{12N}+15$	$\phi=\sqrt{15N}+15$
average	2.69	8.02	1.85	17.8	29.2	30.8
σ_{n-1}	0.04	4.19	0.14	15.5	6.02	6.75

a) Design unit weight

Design unit weight would be determined based on average of field dry density.

- Specific gravity and Field water content

$Gs = 2.69$
$W = 8.02\ \%$

- Unit weight

$\gamma d = 1.85\ tf/m^3$
$\gamma t = \gamma d \times (1 + w/100) = 1.85 \times (1 + 0.08) = 2.00\ tf/m^3$
$e = (Gs \cdot \gamma_w)/\gamma d - 1 = 0.41$
$\gamma sat = (Gs+e) \cdot \gamma_w/(1+e) = 2.20\ tf/m^3$
$\gamma sub = \gamma sat - \gamma_w = 1.20\ tf/m^3$

b) Design shear strength

Cohesion (c) is determined as follows:

$N = 17.8 - 15.5/2 = 10.05$
$qu = N/5 = 10.05/5 = 2.01\ tf/m^2$
$c = qu/2 = 2.01/2 = 1.01 \rightarrow 1.0\ tf/m^2$

Internal friction angle is calculated by using the following formula of relation with N value:

$\phi = \sqrt{12N} + 15 = 29.2^o$ ----- $\phi = 29.2 - 6.0/2 = 26.2^o$
$\phi = \sqrt{15\ N} + 15 = 30.8^o$ ---- $\phi = 30.8 - 6.8/2 = 27.4^o$

Designed value of internal friction angle is determined at 25^o.

(c) Existing dike (Sandy soil)

The design value of sandy soil zone is the same as that of existing dike of Tumnup Lok Reservoir.

(d) Existing dike (Clayey soil)

The soil property is as shown in the following table.

	Specific gravity Gs	Natural water content (%)	Field dry density (tf/m^3)	N Value
average	2.75	12.01	1.70	10.3
σ_{n-1}	0.04	4.93	0.07	2.08

Design value is expressed as follows:

a) Design unit weight

- Specific gravity and field water content

$Gs = 2.75$

$W = 12.01\ \%$

- Unit weight

$\gamma d = 1.70\ tf/m^3$

$\gamma t = \gamma d \times (1 + w/100) = 1.85 \times (1 + 0.12) = 1.90\ tf/m^3$

$e = (Gs \cdot \gamma_w)/\gamma d - 1 = 0.62$

$\gamma sat = (Gs+e) \cdot \gamma_w/(1+e) = 2.08\ tf/m^3$

$\gamma sub = \gamma sat - \gamma_w = 1.08\ tf/m^3$

b) Design shear strength

Unconfined compression strength (qu) and N value are related to as follows:

$qu = N/5 \sim N$

$N = 10.0 - 2.0/2 = 9.0$

$qu = 9/5 \sim 9 = 1.8 \sim 9$

$c = qu/2 = 0.9 \sim 4.5\ tf/m^2 \rightarrow 2.5\ tf/m^2$ (average)

Internal friction angle is assumed as follows:

$\phi = 15.0$ degree

3) Stability analysis

(a) Study cases of stability analysis

Stability analysis was conducted for the rehabilitation section of the existing dike.

Case 1 : In case that the existing dike is assumed to be homogeneous under normal (full) water condition

Case 2 : In case that the existing dike is composed of two zones under normal (full) water condition

(b) Seepage line

The calculation results of seepage line are shown in Table J-7.

(c) Results of stability analysis

The safety factor obtained is as follows.

Case 1 : Upstream; Fs = 2.680 Downstream; Fs = 2.010

Case 2 : Upstream; Fs = 3.062 Downstream; Fs = 2.488

The calculation results are shown in Figure J-4 and J-5.

(2) Spillway

1) Location

The spillway will be located on a place between STA.1+442 and STA.1+638 where the top of the existing dike has been once eroded. The station number of center of spillway is STA.1+540.

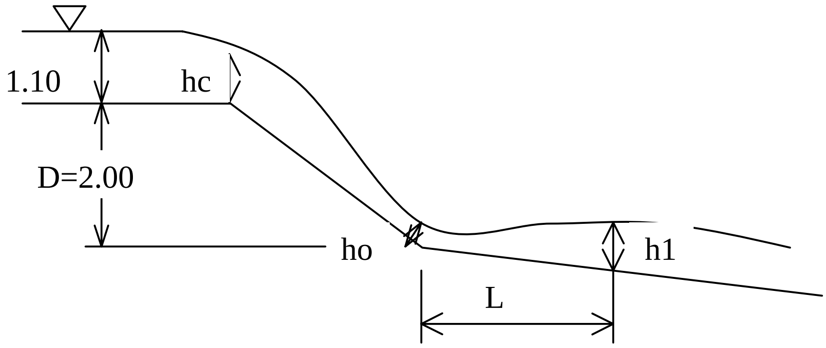
2) Length of overflow weir

Design flood discharge is as follows:

Flood discharge m^3/sec	Return period
195	100-year
135	20-year

The overflow depth for Kpob Trobek Reservoir is 0.80 m. The length of overflow weir is 160 m.

$B = Q/(C \times H^{3/2}) = 195/(1.71 \times 0.8^{3/2}) = 159.4 \rightarrow 160$ m



3) Hydraulic calculation

(a) Overflow weir

Length of overflow weir L = 160 m

Discharge per unit width $q = Q/L = 195/160 = 1.22$ $m^3/sec/m$

At crest Critical depth $hc = (q^2/g)^{1/3} = 0.53$ m

g : gravity acceleration

Critical velocity $Vc = q/hc = 2.29$ m/sec

At toe of weir, water depth (ho) is calculated by the following formula:

$ho^3 - Eo \times ho^2 + q^2/2g = 0$

$Eo = D + 1.5 \times hc$ D ; height of weir (2.0 m)

Water depth ho = 0.17 m

Velocity Vo = q/ho = 7.20 m/sec

Hydraulic jump Depth (h_1) $h_1 = ho/2 \times ((1+8Fo^2)^{1/2} - 1)$

$Fo = Vo/(g \times ho)^{1/2}$ F : Froude number

$Fo = 7.20/(g \times 0.17)^{1/2} = 5.52$

$h_1 = 1.25$ m

Velocity $V_1 = q/h_1 = 0.97$ m/sec

Length (L) $L = 4.5 \sim 6.0 \times h_1 = 5.64 \sim 7.52$ m

The maximum size of anchor rock is 0.8 m which is the same as that of the spillway of Tumnup Lok Reservoir.

(b) Chute portion

Chute portion with the width of 160 m is designed as supercritical flow channel. Calculation of non-uniform flow has been conducted from the beginning point of the chute toward downstream. Coefficient of roughness (n) is 0.035. Calculation results are shown in Table J-8.

(c) Stilling basin

Design flood discharge for stilling basin is 100-year flood discharge of 195 m^3/sec.

$$L = 6\ h_2$$

$$h_2 = (h_1/2)\cdot(\sqrt{1+8F_r^{\ 2}}\ -1)$$

where, L : length of hydraulic jump (m)
h_2 : water depth after hydraulic jump (m)
h_1 : water depth of inflow (m)
Fr : Froude number

h_1 = 0.244 m (result of calculation on chute portion)
V_1 = 5.00 m/sec (result of calculation on chute portion)
Fr = v/ (g x h_1)$^{1/2}$ = 3.234
h_2 = 1.00 m
L = 6 x 1.0 = 6.0 m

4) Stability analysis

The condition and the method of stability analysis for concrete structure are the same as those in Tumnup Lok Reservoir.

The results of stability analysis are shown in Attachment - 2.

(3) Intake Structure

Two intake structures will be provided on the Kpob Trobek Reservoir; one is to Canal 33 and the other is to Canal 24.

Main features of the intake structures are presented as follows:

Intake Structure to Canal 33

Discharge	3.22 m^3/s
Intake Width	3.00 m
Gate Size and Nos.	1.20×1.20 m×2 nos.
Conduit Size and Nos.	1.20×1.20 m×2 nos.
Dike Top EL.	39.00 m
Intake Sill EL.	33.50 m

Intake Structure to Canal 24

Discharge	0.62 m^3/s
Intake Width	2.05 m
Gate Size and Nos.	0.80×0.80 m×2 nos.

Conduit Size and Nos.	0.80×0.80 m×2 nos.
Dike Top EL.	39.00 m
Intake Sill EL.	34.10 m

(4) Maintenance Gate

Two maintenance gate structures having a sluice gate of 1.5 m x 1.5 m each are proposed at the existing spillways. The sluice gates would be used for reservoir maintenance and discharge of river maintenance flow. The gates would be operated manually.

Inlet Width	1.50 m
Gate Size and Nos.	1.50×1.50 m×1 nos.
Conduit Size and Nos.	1.50×1.50 m×1 nos.
Dike Top EL.	39.00 m
Intake Sill EL.	33.70 m

J-1.2 Irrigation Canal System

J-1.2.1 Hydraulic Calculation

(1) Flow Formula

The following criteria was applied for the design of irrigation facilities:

Manning Formula expressed below was adopted for the uniform flow calculation.

$$Q = A \times V$$

$$V = 1/n \times R^{2/3} \times I^{1/2}$$

where,
- Q : Design discharge (m^3/sec)
- A : Flow area (m^2)
- V : Mean velocity (m/sec)
- n : Roughness coefficient
- R : Hydraulic radius
- I : Hydraulic gradient

(2) Roughness Coefficient

Roughness coefficients are determined considering i) canal construction material (lining type), ii) the foundation condition and iii) proper maintenance. The adopted roughness coefficients are as follow:

Lining Type	Applied Roughness Coefficient
Unlined Canal	0.035
Earth Lining (laterite pavement)	0.025
Soil Cement Lining	0.015
Concrete Block Lining	0.015
Concrete Structure	0.015

(3) Permissible Velocity

The maximum permissible velocity in irrigation canals is determined so as not to cause erosion, while the minimum permissible velocity is determined so as not to induce the growth of aquatic plant and moss, and not to cause sedimentation in the canal.

Lining Type	Minimum	Maximum
Unlined Canal	0.40	0.60
Earth Lining (laterite pavement)	0.40	1.00
Soil Cement Lining	0.40	1.50
Concrete Block Lining	0.40	1.50
Concrete Structure	0.40	1.50

J-1.2.2 Diversion Canal

(1) Canal Route

Diversion canal route was determined by use of topographic map with a scale of 1:50,000 and results of canal route survey, which were conducted during Phase I and II of the Study. In the canal route, the existing canals were utilized as much as possible, to minimize lengths of new canals, and to avoid the influence of backwater from O Saray reservoir. The canal route and the locations of related canal structures of the diversion canal are shown in Figure J-6.

(2) Canal Cross Section and Lining

For the selection of suitable lining type for the diversion canal, four (4) types of the canal lining, i.e. unlined canal, earth lining (laterite), soil cement lining and concrete block lining, were compared in terms of direct construction costs. For the comparison, the following assumptions were set up mainly from hydraulic condition such as allowable velocity of erosion and sedimentation and stability of the canal cross section:

<u>Unlined Canal</u>

Design Discharge:	3.50 m^3/sec	Canal Bed Elevation of E.P.:	35.48 m
Design Velocity:	0.43 m/sec	Canal Bed Width:	2.20 m
Canal Bed Slope:	1/3,000	Water Depth:	1.55 m
Roughness Coefficient:	0.035	Canal Depth:	1.80 m
Canal Bed Elevation of B.P.:	38.86 m	Canal Side Slope:	1/2.0

Remarks: Design water level at the end point of the diversion canal (EL.37.03 m) will be below the high water level of Kpob Trobek reservoir (El.37.30 m). To avoid adverse flow from Kpob Trobek Reservoir to the diversion canal, water gate should be installed at the end of the canal.

Earth Lining

Design Discharge:	3.50 m^3/sec	Canal Bed Elevation of E.P.:	36.46 m
Design Velocity:	0.52 m/sec	Canal Bed Width:	2.00 m
Canal Bed Slope:	1/4,400	Water Depth:	1.39 m
Roughness Coefficient:	0.025	Canal Depth:	1.70 m
Canal Bed Elevation of B.P.:	38.86 m	Canal Side Slope:	1/2.0

Remarks: Lining material will be laterite, and the thickness of the lining should be 50 cm.

Soil Cement Lining

Design Discharge:	3.50 m^3/sec	Canal Bed Elevation of E.P.:	37.44 m
Design Velocity:	0.62 m/sec	Canal Bed Width:	1.80 m
Canal Bed Slope	1/8,000	Water Depth:	1.30 m
Roughness Coefficient:	0.015	Canal Depth:	1.60 m
Canal Bed Elevation of B.P.:	38.86 m	Canal Side Slope:	1/2.0

Remarks: Soil cement is assumed to contain 7 % of cement in dry condition and 93 % of sandy soil mixed beside the canal. The thickness of the soil cement is 7 cm. To protect canal lining, weep hole, drainpipe, filter and construction joint should be provided.

Concrete Block Lining

Design Discharge:	3.50 m^3/sec	Canal Bed Elevation of E.P.:	37.44 m
Design Velocity:	0.62 m/sec	Canal Bed Width:	1.80 m
Canal Bed Slope	1/8,000	Water Depth:	1.30 m
Roughness Coefficient:	0.015	Canal Depth:	1.60 m
Canal Bed Elevation of B.P.:	38.86 m	Canal Side Slope:	1/2.0

Remarks: Concrete block is assumed to be made at the stockyard. To protect canal lining, weep hole, drainpipe and filter should be provided.

The results of the direct construction cost comparison based on the above assumption are shown the following table, and the earth lining was selected for diversion canal.

(Unit : US$)

Direct Construction Cost	Unlined	Earth Lining	Soil Cement	Concrete Block
Canal	1,748,900	1,770,500	2,168,500	2,255,600
Canal Related Structures	145,900	99,600	95,400	95,400
Total	1,894,800	1,870,300	2,263.900	2,351,000

(3) Canal Related Structures

1) Krouch Siphon

Diversion canal will cross Krouch stream, water source of O Saray Reservoir, at STA. 5+830. A siphon was selected as crossing structure of the stream, because aqueduct has more disadvantageous than siphon as follows:

- It is difficult to keep big clearance from bottom slab of the aqueduct to flood water level of the stream due to the topographic condition,
- aqueduct is more difficult to construct than siphon and construction period will be long, and
- An aqueduct is generally more costly than siphon.

Main features of the Krouch siphon are shown as follows:

Total length:	75.0 m
Size of barrel:	1.30 x 1.30 m x 2nos.
Design water level at inlet transition:	EL. 38.87 m
Design water level at outlet transition:	EL. 38.69 m
Water Velocity at canal:	0.52 m/s
Water Velocity at barrel:	0.71 m/s
Head loss:	0.18 m
Canal design discharge:	3.50 m^3/sec
Design flood discharge of Krouch stream:	90 m^3/sec

2) Road Crossing

Diversion canal will cross two major roads and one footpath at STA. 4+200, STA. 7+025, and STA. 2+800, respectively. For these road crossings, a box culvert is proposed. The box culvert is of double barrels having size of 1.5 x 2.0 m with slab thickness of 0.3 m and length of 6m for major road and 3.0 m for footpath. Before and after the culvert, five meter-length of wet stone masonry (0.2 m thick) will be provided to protect the canal cross section from erosion.

3) Cross Drain

Drainage water from southwestern part of Krouch stream catchment area flows into the Diversion Canal at STA. 4+220 at present. If the existing condition will remain, the canal will be damaged by rapid change of discharge of drainage water. To avoid such situation, a cross drain and another watercourse should be constructed.

Box culvert, size of which is 1.5 x 2.0 m x 2nos, with slab thickness of 0.3 m and length of 10 m, is adopted as the cross drain. The section of existing diversion canal route from STA. 4+220 to the existing O Saray Reservoir will be utilized as drainage canal to convey the drainage water.

J-1.2.3 Main and Secondary Canal

(1) Canal Layout and Cross Section

1) Canal Layout

Irrigation canal layout and irrigation diagram are shown in Drawings No.4 and No.5, respectively. In the system, no tertiary block is irrigated directly from main canal. Canal length, command area and design discharge at beginning point of each canal are summarized in the following table:

Irrigation Canal	Canal Length	Command Area	Design Discharge at B.P.
Main Canal			
Canal 33		2,924.0 ha	3.21 m^3/sec
Secondary Canal			
Canal 24	5,715 m	561.0 ha	0.62 m^3/sec
Canal 3U	1,410 m	137.4 ha	0.15 m^3/sec
Canal 23	9,245 m	773.6 ha	0.85 m^3/sec
Canal 22	8,040 m	608.8 ha	0.67 m^3/sec
Canal 21	6,930 m	489.8 ha	0.54 m^3/sec
Canal 20*	6,690 m	619.0 ha	0.68 m^3/sec
Canal 3D	6,675 m	295.4 ha	0.32 m^3/sec
Total (Secondary Canal)	44,705 m	3,485.0 ha	3.83 m^3/sec

2) Cross Section

Most of the main and secondary canals are proposed to be unlined canal, but for some sections, earth lining or soil cement lining will be adopted so as to keep the minimum permissible velocity. Lengths of lining type are summarized in the following table:

Irrigation Canal	Unlined	Earth Lining	Soil Cement	Total
Main Canal				
Canal 33	7,301 m	0 m	0 m	7,301 m
Secondary Canal				
Canal 24	5,715 m	0 m	0 m	5,715 m
Canal 3U	1,410 m	0 m	0 m	1,410 m
Canal 23	7,595 m	1,200 m	450 m	9,245 m
Canal 22	5,705 m	0 m	2,335 m	8,040 m
Canal 21	3,745 m	2,075 m	1,110 m	6,930 m
Canal 20	5,180 m	1,510 m	0 m	6,690 m
Canal 3D	5,070 m	1,605 m	0 m	6,675 m
Total (Secondary Canal)	34,420 m	6,390 m	3,895 m	44,705 m

Typical cross section and dimension of canals are shown in each canal profile of Drawing (Main Canal: Drawings No.30–32, Secondary Canal : Drawings No.33–40).

(2) Canal Related Structure

1) Diversion Structure

Diversion structure is classified as shown in the following table by design discharge of the section:

	Gate Size	Total Length of Structure
Main Canal		
Q≧2.00 m^3/sec	1.50 x 1.50m x 2nos.	28.10 m
Secondary Canal		
Q<0.25 m^3/sec	0.60 x 0.60m x 1no.	16.60~21.60 m
0.25≦Q<0.40m^3/sec	0.80 x 0.80m x 1no.	19.10~24.10 m
0.40≦Q<0.50m^3/sec	0.60 x 0.60m x 2nos.	21.85~26.85 m
0.50≦Q<0.90m^3/sec	0.80 x 0.80m x 2nos.	22.60~29.60 m

Detailed dimension of the diversion structure is presented in Drawing No. 45.

2) Off-take

Off-takes are provided to divert irrigation water to secondary or tertiary canals from the parent canal. Pipe flow type of off-take is proposed so as to cross an O&M road or canal dike. The pipe length varies depending on the parent canal dimension, and diameter of pipe also varies; ϕ =1,000 mm, 800 mm, 600 mm, and 400 mm, depending on the discharge.

Four types of off-take structure are proposed as shown in Drawing No. 47.

3) Drop Structure

To keep maximum permissible velocity in canal and to keep earth work volume smaller, twelve drop structures in total will be provided for main and secondary canals.

Vertical drop with stilling basin type was selected as drop structure. There are two types of the drop structure in the plan; one is constructed accompanied with diversion structure and the other is constructed without diversion structure. The number of each type by canal is shown in the following table:

Irrigation Canal	Accompanied with Diversion	Drop Alone Without Diversion	Total
Main Canal			
Canal 33	3 nos.	1 no.	4 nos.
Secondary Canal			
Canal 24	0	0	0
Canal 3U	0	0	0
Canal 23	2 nos.	1 no.	3 nos.
Canal 22	1 no.	0	1 no.
Canal 21	2 nos.	1 no.	3 nos.
Canal 20	1 no.	0	1 no.
Canal 3D	0	0	0
Total	9 nos.	3 nos.	12 nos.

4) Road Crossing Structure

Box culvert was adopted for road crossing structure of main canal and pipe culvert was adopted for secondary canal. Road crossing structure is classified into five types by discharge as shown in the following table:

	Culvert Size	Numbers of Crossing Structure		
		Road Crossing L = 6.00m	Foot Crossing L = 3.00m	Total
Main Canal				
$Q \geqq 2.00\ m^3/sec$	1.50 x 2.00m x 2nos.	7 nos.	0	7 nos.
Secondary Canal				
$Q < 0.20\ m^3/sec$	ф600 x 1 no.	8 nos.	11 nos.	19 nos.
$0.20 \leqq Q < 0.40 m^3/sec$	ф600 x 2 nos.	5 nos.	15 nos.	20 nos.
$0.40 \leqq Q < 0.50 m^3/sec$	ф800 x 1 no.	0	5 nos.	5 nos.
$0.50 \leqq Q < 1.00 m^3/sec$	ф800 x 2 nos.	2 nos.	11 nos.	13 nos.
Total		22 nos.	42 nos.	64 nos.

5) Cross Drain

In the irrigation area, there exist several drainage canals flowing from south to north and finally into the Slakou river. The drainage canals and secondary canals cross at almost right angles. To convey the drainage water safely, cross drain was proposed to be constructed at crossing points. A typical figure and dimension of the structure is shown in Drawing No. 50.

J-1.2.4 Tertiary Block

Irrigation water conveyed by secondary canal is diverted into tertiary canal through off-take and delivered to each plot by water course. Typical layout of the tertiary block is presented in Drawings No.41 and 42. Main facilities of the tertiary block are tertiary canal, water course and off-take structure.

Typical dimension of tertiary canal is as follows:

Tertiary Canal (Model)

Command Area	33.3 ha
Design Discharge	73.3 l/s
Canal Bed Width	0.5 m
Canal Depth	0.6 m
Canal Side Slope (Inside and Outside)	1:1.0
Width of Dike Top	0.5 m

CHAPTER J-2 SMALL RESERVOIR REHABILITATION PLAN (SRP)

J-2.1 General

Ang 160 and Kim Sei Small Reservoirs were selected as priority projects of SRP. These reservoirs were designed based on topographic map with a scale of 1:10,000 which was prepared by the Study Team and the results of supplemental topographic survey and field investigation.

General conditions for design and main features of both reservoirs are presented in TableJ-9.

J-2.2 Design Concept

The SRP was designed in accordance with the following basic concept:

- Existing irrigation canal system should be utilized as much as possible, and minor improvement works of canal and related structures should be carried out by beneficiaries.
- Rehabilitation level of the reservoirs is to recover the original function of the structure and not to add new concept.
- Structures should be simple so as to make O&M works as easy as possible, because entire system will be operated by FWUC.

J-2.3 Ang 160 Reservoir

(1) Structural Layout

In the original design, a spillway is wrongly located at southern edge of the eastern dike. Water source is originated from Noreai Mountains and water flows into a small stream. But it does not flow into the reservoir. Therefore, this stream is able to provide water to the reservoir but the spillway does not rightly function due to wrong location during flood. As a result, reservoir dike was flushed away by flood at STA. 0+385 (width of which is about 15m). At present, water flowing into the reservoir flows out from the point and runs in the original route of the stream, while small watercourse is running in the center of irrigation area which finally joins the stream.

Considering such condition, the spillway is proposed to be shifted to STA. 0+271 at the upstream of the watercourse and the excess water will be able to flow into the watercourse and finally joints the stream.

At present, one intake structure of the reservoir exists near the crossing point of eastern dike and northern dike. If the spillway is constructed at STA.0+271, irrigation area needs to be divided into two by the watercourse. For easier irrigation management, one additional intake structure is proposed to be constructed at STA.0+140.

General plan of the reservoir is presented in Drawing No. 51.

(2) Dike

Dike rehabilitation will include i) reconstruction of two sections (from STA. 0+037 to STA. 0+047 and from STA. 0+377 to STA. 0+396) that were flushed away by flood, and ii) shaping of present rough sections of eastern dike.

As material for dike rehabilitation, excavated soil material, which is available at reservoir area will be utilized. The material consists of CL, SC and SM in accordance with unified soil classification. Sufficient shear strength is expected through satisfactory compaction.

Cross section of the dike is basically the same as that of existing one, except lateraite pavement (0.3m thick) on dike top. The typical cross section of the dike is presented in the Drawing No. 52.

(3) Spillway

Design flood discharge of the spillway was estimated at 6.0m^3/sec with 20 year return period estimated from maximum daily rainfall data of Kompong Spueu Station.

The spillway was a rock spillway type. The overflow depth was determined at 0.60 m. The following formula is applied for calculation of crest length.

$$B = Q/(C \times H^{3/2}) = 6.0/(1.71 \times 0.6^{3/2}) = 7.53\text{m} \rightarrow 7.60\text{m}$$

where, Q : Discharge (m^3/sec)
C : Coefficient of overflow
B : Effective length of weir (m)
H : Total head above weir crest (including approach velocity head)

(4) Intake Structure

Intake structure is provided to take irrigation water from the reservoir to irrigation canal. Design discharge of the structure is 29.5 l/sec for Block A and 30.35 l/sec for Block B. Type of intake structure is a pipe flow with slide gate, and the discharge volume will be controlled by the gate (0.6 x 0.6m). The pipe length and diameter are L=10.0m and ϕ=400mm, respectively.

Design and detailed dimension of intake structure is presented in Drawing No. 54.

J-2.4 Kim Sei Reservoir

(1) Structural Layout

Planed structural layout of Kim Sei Small Reservoir is the same as the original layout. General plan of the reservoir is presented in Drawing No. 55.

(2) Dike

Dike rehabilitation will include i) reconstruction of the section From STA. 0+956 to STA. 0+962 that was flushed away by flood, ii) raising the dike top which is lower than design dike top elevation (EL. 13.80m), and iii) shaping of the present rough sections.

As material for dike rehabilitation, excavated soil material, which is available at reservoir area will be utilized. The material consists of CL, SC and SM according to unified soil classification. Sufficient shear strength will be expected through satisfactory compaction.

Cross section of the dike is basically the same as that of existing one, except laterite pavement (0.3m thick) on dike top. The typical cross section of the dike is presented in Drawing No. 57.

(3) Spillway

Design flood discharge of the spillway was estimated at 12.6m^3/sec with 20 year return period estimated from maximum daily rainfall data of Kompong Spueu Station.

Type of the spill way was a rock spillway type. The overflow depth was determined at 0.60 m. The following formula is applied for calculation of crest length.

$$B = Q/(C \times H^{3/2}) = 11.4/(1.71 \times 0.6^{3/2}) = 14.30\text{m}$$

where, Q : Discharge (m^3/sec)
C : Coefficient of overflow
B : Effective length of weir (m)
H : Total head above weir crest (including approach velocity head)

(4) Intake Structure

Type of the intake structure is a pipe flow with slide gate (0.6 x 0.4m) type. The pipe length and diameter are L=10.0m and ϕ=200mm, respectively. Design discharge of structures is 11.6 l/sec for Block A, 10.1 l/sec for Block B, 22.8 l/sec for Block C and 20.2 l/sec for Block D.

The design and detailed dimension are presented in Drawing No. 59.

PART J-II COST ESTIMATE

CHAPTER J-3 BASIC CONDTIONS AND ASSUMPTIONS FOR COST ESTIMATE

The project cost of three main plans and one support program, namely, Upper Slakou River Irrigation Reconstruction Plan (USP), Small Reservoir Rehabilitation Plan (SRP), Small Pond Development Plan (PDP), and Rural Road Improvement Program (RIP) was estimated on the basis of the following conditions and assumptions:

1) Project cost was estimated for the best alternative of USP, Kim Sei and Ang 160 Reservoirs for SRP, 30 small ponds in Trapeang Snao Village for PDP, and 3 rural roads (total 23.62 km) for RIP.
2) Cost estimate refers to the prices as of October 2001.
3) Unit prices of labor, construction materials, engineering works, etc., were collected from MOWRAM and MRD.
4) Construction is undertaken on contract basis, and bidding of contractor is done based on the work volume and technical requirements.
5) Project cost comprises i) preparatory work, ii) direct construction cost, iii) O&M equipment, iv) institutional development, v) relocation and land expropriation cost, vi) administration cost, vii) consulting service and viii) contingencies.
6) Contingencies comprises physical contingency and price escalation. The physical contingency is 10% of the Project cost.
7) Price escalation is evaluated based upon 2.5% per annum for foreign currency portion and 3.0% per annum for local currency portion.
8) Construction equipment is used on a rental basis for the O&M works.
9) The institutional development cost includes the cost for training, extension, and other supporting services identified in the supporting programs.
10) Conversion rate is assumed at US$ 1.0 = Riel 4,022.20 = ¥ 120.53 (as of October 5, 2001).

Labor wage, rental charge of equipment and unit price of construction materials which are used for cost estimate of the Project is as shown in Table J-10,11 and 12.

CHAPTER J-4 COST ESTIMATE

J-4.1 Upper Slakou River Irrigation Reconstruction Plan (USP)

J-4.1.1 Project Cost

The total amount of the Project cost of the Plan is Riel 76,624.6 million as shown in Table J-13 and summarized below, and the detailed explanation is shown in following sections.

Project Cost of USP

(Unit : million Riel)

Work Item	F/C	L/C	Total
1) Preparatory Work	2,484.9	846.3	3,331.2
2) Direct Construction Cost	30,633.5	14,238.0	44,871.5
3) O&M Equipment	156.7	10.3	167.0
4) Institutional Development	666.9	1,760.8	2,427.7
5) Relocation and Land Compensation Cost	3.3	197.0	200.3
6) Administration Cost	155.7	824.3	980.0
7) Consulting Service	11,921.7	623.5	12,545.2
8) Contingencies	8,358.0	3,743.7	12,101.7
Total	54,380.7	22,243.9	76,624.6

(1) Preparatory Work

Preparatory work comprises: i) Rehabilitation of three access roads (total 30.0km) and related structures, ii) Coffer dams and temporary diversion channel for reservoirs and iii) Construction site development. The total amount of the preparatory work cost was estimated as Riel 3,331.2 million.

(2) Direct Construction Cost

Direct construction cost consists of i) Tumnup Lok Reservoir, ii) Diversion canal(9.4km), iii) Kpob Trobek Reservoir, iv) Main canal(7.3km), v) Secondary canals(44.7km), vi) Tertiary development (3,500ha), vii) Building works (3nos.). Among these items, tertiary development and building works are estimated based on local competitive bidding (LCB), while the other items are on international competitive bidding (ICB). The total amount of the direct construction cost is estimated as Riel 44,871.5 million.

(3) O&M Equipment

O&M equipment cost comprises communication equipment, transportation equipment, office equipment and furniture for Project office, FWUS and marketing assistance unit. The total amount of the O&M equipment cost is Riel 167.0 million. Brake down of the cost is presented in the table below.

Break Down of O&M Equipment Cost

(Unit : thousand Riel)

Required Equipment	Unit	Cost
I. Project Office		
1) Walky-talky	3 Units	6,000
2) Pick-up	1 Unit	80,000
3) Mortar Bike	8 Units	38,400
4) Computer and Printer	2 Units	5,600
5) Copy Machine	1 Unit	8,000
6) Generator	1 Unit	10,000
7) Furniture	1 Set	7,200
Sub-total		155,200
II. APEX Committee Office		
1) Scale	6 Unit	2,160
2) Furniture	1 Set	6,720
Sub-total		8,880
III. Marketing Assistance Unit		
1) Scale (Big)	2 Units	720
2) Scale (Small)	2 Units	160
3) Generator (10kw)	1 Unit	2,000
Sub-total		2,880
Total		**166,960**

(4) Institutional Development

Institutional development cost consists of i) cost for local experts, ii) rental charge and O&M cost of vehicle, iii) cost for teaching material and iv) audio and visual equipment. The total amount of the cost is Riel 2,427.7 million.

Break Down of Institutional Development Cost

(Unit : thousand Riel)

Required Equipment	Unit	Cost
1) Local Consultant	200 M/M	1,608,880
2) Vehicle Rents	48 nos./M	386,131
3) Fuel for Vehicle	L.S.	34,752
4) Training Material	for 48 nos./M	144,799
5) Training Equipment	1 Set	213,177
6) Lunch and Snak for Training Participants	L.S.	40,000
Total		**2,427,739**

(5) Relocation and Land Compensation Cost

Land compensation cost for 23ha and house relocation cost for 67 houses are included in the cost. The total amount of the cost is estimated as Riel 200.3 million.

(6) Administration Cost

Administration cost comprises i) salary for staff, ii) fuel and parts for transportation equipment, iii) environment monitoring cost and iv) cost for extension work. The total amount of the cost is estimated as Riel 980.0 million. The break down and the disbursement of the cost is presented in the Table J-14.

(7) Consulting Service

Design and construction supervision and institutional development and capacity building consist of the consulting service. The cost comprises i) remuneration for consultant, ii) rental charge and O&M cost of vehicle, iii) cost for sublet contract (survey, geological and soil mechanical investigation, etc.,) and iv) equipment and materials for the service. The total amount of consultant service is estimated as Riel 12,545.2 million. The brake down of the cost is presented in the table below.

Break Down of Consulting Service

(Unit : thousand Riel)

Description	Unit	Cost
I. Design and Construction Supervision		
1) Foreign Consultant	37 M/M	3,126,000
2) Air Fare	8 Trips	28,200
3) Local Consultant	50 M/M	402,220
4) Sub-let Contract	L.S.	500,000
5) Car Rents	30 nos./M	241,332
6) Fuel for Car	for 40 nos./M	21,720
7) Office Equipment	L.S.	402,220
8) Miscellaneous	L.S.	98,413
Sub-total		4,820,105
II. Institutional Development and Capacity Building		
1) Foreign Consultant	86 M/M	7,264,100
2) Air Fare	10 Trips	40,222
3) Car Rents	48 nos./M	386,131
4) Fuel for Car	for 48 nos./M	34,652
Sub-total		7,725,105
Total		**12,545,210**

(8) Contingencies

Contingencies comprise physical contingency and price escalation. The total amount of contingencies are estimated at Riel 12,101.7 million, and the details are presented in Table IV6.3.2 of Main Report.

J-4.1.2 Annual Disbursement Schedule

The annual disbursement schedule is worked out as shown in Table IV-6.3.2 of Main Report, based on the project implementation program described in Sub-Section IV-6.2 and Figure IV-6.2.1 of Main Report.

J-4.1.3 Replacement Cost

Economic life time of some project facilities and equipment is shorter than those of project life of 50 years. Therefore, they will require replacement during the proposed 50 years of the project life. The following table shows durable life time and replacement cost of the materials and equipment to be replaced. The disbursement of the cost is presented in Table L-23 of Appendix-L.

Replacement Cost of USP

(Unit : million Riel)

Description	Economic Life Time	Replacement Cost
Office / Facilities	30 years	411.2
Gates	25 years	1,726.0
Steel Plate	10 years	45.4
Transportation Equipment & Generator	10 years	290.3
Administrative Equipment	8 years	39.5
Marketing Equipment	8 years	3.1
Wooden Stoplog	5 years	11.7

J-4.1.4 Annual O&M Cost

The annual O&M cost of the project facilities includes the salaries of the staff for the Project office, staff of FWUCs, staff of marketing unit, material and labor cost for annual maintenance, the cost of operation, repair and maintenance of transportation equipment, and large scale maintenance by contract basis every five years. The total amount of the cost is Riel 193.0 million. Break down of the Annual O&M cost is presented the table below.

Annual O&M Cost of USP

(Unit : thousand Riel)

		Description	Unit	Cost
I.		**Appex Commitee**		
	1)	Personnel Expenses	102 M/M	10,260
	2)	Office Expenses	L.S.	1,760
	3)	Fuel for Equipment	L.S.	10,416
	4)	Spare Parts	L.S.	1,992
	5)	Maintenance Cost of Reservoirs and Main Canals	L.S.	14,000
		Sub-total		38,428
II.		**FWUCs (6 Units)**		
	1)	Personnel Expenses	1,095 M/M	88,920
	2)	Office Expenses	L.S.	10,560
	3)	Fuel for Equipment	L.S.	11,088
	4)	Spare Parts	L.S.	576
	5)	Maintenance Cost of Secondary and On-farm Canals	L.S.	14,000
		Sub-total		125,144
III.		**Marketing Unit**		
	1)	Personnel Expenses	108 M/M	9,360
	2)	Office Expenses	L.S.	1,440
	3)	Fuel for Equipment	L.S.	16,480
	4)	Spare Parts	L.S.	1,200
	5)	Entrance Charge	L.S.	920
		Sub-total		29,400
		Total		192,972

J-4.2 Small Reservoir Rehabilitation Plan (SRP)

J-4.2.1 Project Cost

The total amount of Project cost of the Plan is Riel 474,367,000 as shown in the following table, and the detailed explanation is shown in the following sections.

Description	Ang 160 SRP			Kim Sei SRP			Total
	F/C	L/C	Sub-total	F/C	L/C	Sub-total	
1) Preparatory Work	43,613	12,698	56,311	1,560	451	2,011	58,322
2) Direct Construction Cost	78,606	38,629	117,235	128,775	60,522	189,297	306,532
3) Institutional Development	754	3,680	4,434	599	2,923	3,522	7,956
4) Administration Cost	672	2,385	3,057	672	2,385	3,057	6,114
5) Engineering Services	3,524	13,833	17,357	3,885	15,244	19,129	36,486
Sub-total	127,169	71,225	198,394	135,491	81,525	217,016	415,410
6) Contingencies	15,919	9,393	25,312	20,426	13,219	33,645	58,957
Total	143,088	80,618	223,706	155,917	94,744	250,661	474,367

(1) Preparatory Work

Preparatory work comprises : Rehabilitation of access roads (2.8km for Ang 160 and 0.1km for Kim Sei), related structures and construction site development. The total amount of the preparatory work cost is estimated as Riel 58,322,000.

(2) Direct Construction Cost

Direct construction cost for Ang 160 consists of i) rehabilitation of dike (510m), ii) construction of spillway design (1no.) and iii) construction of intake structure, while that for Kim Sei consists of i) rehabilitation of dike (1,600 m), ii) reconstruction of spillway (1no.) and iii) reconstruction of intake structures (4 nos.). The direct construction cost are estimated as Riel 223,706,000 for Ang 160 SRP and 250,661,000 for Kim Sei SRP. Therefore the total amount of the direct construction cost becomes Riel 474,367,000.

(3) Institutional Development

Institutional development cost consists of i) training cost of FOs (Farmer Organizers), ii) cost for establishment of demonstration plot, and iii) cost for extension work. Institutional development cost is estimated at Riel 4,434,000 for Ang 160 SRP and Riel 3,522,000 for Kim Sei SRP. The total amount comes to Riel 7,956,000.

(4) Administration Cost

Administration cost consists of i) salary for staff of DOWRAM Take office, ii) transportation cost and iii) cost for office supply. The cost is estimated at Riel 3,057,000 for each reservoir, and the total amount comes to Riel 6,114,000.

(5) Engineering Service

Cost for engineering service is estimated at Riel 17,357,000 for Ang 160 SRP and Riel 19,129,000 for Kim Sei SRP, respectively. The total amount comes to Riel 36,486,000. The cost is estimated at ten percent of the its direct construction cost.

(6) Contingencies

The total amount of contingencies is estimated at Riel 58,957,000. The details are presented in Table IV6.3.4 of Main Report.

J-4.2.2 Annual Disbursement Schedule

The annual disbursement schedule is worked out as shown in Table IV-6.3.4 of Main Report, based on the project implementation program described in Sub-Section IV-6.2 and Figure IV-6.2.2 of Main Report.

J-4.2.3 Replacement Cost

For the SRP, the materials and equipment that is to be replaced is intake gates only. Economic life time and replacement cost of each small reservoir is as shown in the following table, and the disbursement of the cost is presented in Table L-23 of Appendix-L.

Replacement Cost of SRP

(Unit : Thousand Riel)

Description	Economic Life Time	Replacement Cost
Gates for Ang 160 Reservoir	25 years	8,120
Gates for Kim Sei Reservoir	25 years	272

J-4.2.4 Annual O&M Cost

The annual O&M cost of the project facilities includes the salaries of FO (Farmer Organizers), equipment and materials for annual maintenance. The estimated cost is Riel 2,630,000 per year for Ang 160, and Riel 2,430,000 per year for Kim Sei.

J-4.3 Small Pond Development Plan (PDP)

J-4.3.1 Project Cost

The total amount of the Project cost of the Plan is Riel 180,549,000 as shown in Table IV-6.3.5 of Main Report.

J-4.3.2 Annual Disbursement Schedule

The annual disbursement schedule is worked out as shown in Table IV-6.3.6, based on the project implementation program described in Section IV-6.2.2 and Fig. IV-6.2.2.

J-4.3.3 Annual O&M Cost

The annual O&M cost of the project facilities is labor cost for pond maintenance only. The cost is estimated at Riel 1,600,000 per year.

J-4.4 Rural Road Improvement Program (RIP)

J-4.4.1 Project Cost

The total amount of the Project cost of the Plan is Riel 4,175,162,000 as shown in Table IV-6.3.7.

J-4.4.2 Annual Disbursement Schedule

The annual disbursement schedule is worked out as shown in Table IV-6.3.8, based on the project implementation program described in Section IV-6.2.3 and Fig. IV-6.2.3.

J-4.4.3 Annual O&M Cost

The annual O&M cost of the project facilities is annual maintenance work on the contract basis only. The estimated cost is Riel 14,000,000 per year.

Tables

Table J-1 General Condition and Main Features of USP Reservoirs

Description	Tumnup Lok Reservoir	Kpob Trobek Reservoir
Hydrological Data		
River	Slakou River	Don Phe Stream
Catchment Area	$332km^2$	$137km^2$
River Gradient : At Reservoir	1/460	1/540
River Bed Level	EL.36.26m	EL.33.25m
Unit Sedimentation Rate	$0.1mm/km^2/year$	$0.1mm/km^2/year$
Mean Annual Rainfall	1,200mm	1,200mm
Mean Annual Runoff	$2.57m^3/sec$	$1.06m^3/sec$
Reservoir		
Surface Area at FSL	209ha	293ha
Gross Storage Capacity	1.66MCM	2.77MCM
Effective Storage Capacity	1.00MCM	2.63MCM
Dead Storage (20 years)	0.66MCM	0.13MCM
Flood Water Level	EL.42.40m	EL.38.10m
High Water Level	EL.41.30m	EL.37.30m
Low Water Level	EL.40.40m	EL.34.20m
Spillway		
Type	Rock Spillway Type	Rock Spillway Type
Location (Center)	STA.2+100	STA.1+540
Crest Length	215m	160m
Crest Level	EL.41.30 m	EL.38.30m
Design Flood Discharge (100years)	$420m^3/sec$	$195m^3/sec$
Design Flood Discharge (20years)	$290m^3/sec$	$135m^3/sec$
Overflow Depth	1.10m	0.80m
Dike		
Type of Embankment	Zone Earth Fill Type	Zone Earth Fill Type
EL. of Dike Top	EL.43.30m	EL.40.0m
Length of Dike	2,468m	3,287 m
Width of Dike Top	5.0m	5.0m
Slope : Upstream	1:2.5	1:2.5
: Downstream	1:2.0	1:2.0
Embankment Volume	$24,500\ m^3$	$13,800\ m^3$
Intake Structure		
Type	Sluice Gate	Sluice Gate
Size	To Diversion Canal : 1.20x1.20mx2nos. To Tertiary Canal : 0.60x0.60m, 2nos.	To Main Canal 33 : 1.20x1.20mx2nos. To Canal 24 : 0.80x0.80mx2nos.
Other Works		
Maintenance Gate	1.50x1.50mx2nos.	1.50x1.50m, 2nos.

Table J-2　Summary of Soil Property of Embankment Material

Zone I

Pit No.	Location	Sample No.	Depth (m)	Soil classifi-cation	Specific Gravity	Natural moisture content	Compaction Test				Permeability test	Initial Specimen Condition				Unconfined compression test	Initial Specimen Condition						
							Max. dry density	Wopt	Void ratio	Sr	Permea-bility	Dry density	Water content	Void ratio	Sr	qu	Dry density	Water content	Void ratio				
					Gs	(%)	(g/cm^3)	(%)	e	(%)	(cm/sec)	(g/cm^3)	(%)	e	(%)	(KPa)	(g/cm^3)	(%)	e	D_{95}	W_{d95}	Nmc-Wopt	Nmc-W_{d95}
P9	Borrow Pit B-2	S 17M	1.0 ~ 1.2	GC	3.02	7.92	2.050	11.80	0.47	75.8	4.4E-04	1.96	11.8	0.54	66.0	58.1	2.05	11.14	0.47	1.948	15.3	-3.88	-7.38
		S 18L	1.8 ~ 2.0	GC	3.02	11.67	1.928	14.60	0.57	77.4	9.9E-06	1.86	14.6	0.62	71.1	78.0	1.96	13.91	0.54	1.832	18.7	-2.93	-7.03
P10	Borrow Pit B-2	S 19M	1.0 ~ 1.2	GC	2.87	10.85	1.992	13.50	0.44	88.1	3.5E-07	1.89	13.5	0.52	74.5	37.0	1.95	13.20	0.47	1.892	16.5	-2.65	-5.65
		S 20L	1.8 ~ 2.0	GC	3.00	14.21	2.035	13.00	0.47	83.0	9.8E-07	1.93	13.0	0.55	70.9	133.6	1.99	12.29	0.51	1.933	15.9	1.21	-1.69
	Combined	S 22C		GC	3.02	9.05	2.060	12.50	0.47	80.3		1.92	12.5	0.57	66.2	71.3	2.00	11.85	0.51	1.957	15.0	-3.45	-5.95
	Combined	S 24C		SC	2.82	10.05	2.040	11.10	0.38	82.4	1.6E-06	1.94	11.1	0.45	69.6	197.1	1.99	10.98	0.42	1.938	14.2	-1.05	-4.15
				Average	2.96	10.625	2.018	12.75	0.47	81.2	5.0.E-06	1.90	12.8	0.50	69.7	95.9	2.00	12.20	0.50	1.917	15.9	-2.1	-5.3
				Standard deviation	0.09	2.20	0.05	1.24	0.06	4.40		0.04	1.24	0.06	3.2	59.1	0.04	1.15	0.04	0.047	1.57	1.90	2.11

Zone II

																				D_{95}	W_{d95}	Nmc-Wopt	Nmc-W_{d95}
P1	Tumnop Lok	S 1	0.2 ~ 0.5	SC	2.63	12.91	1.936	9.80	0.36	71.6	2.9E-06	1.84	13.3	0.43	81.3	60.2	1.87	12.19	0.41	1.839	13.3	3.11	-0.39
		S 2	1.8 ~ 2.0	CL	2.59	21.96	1.762	14.50	0.47	79.9	9.5E-05	1.67	18.0	0.55	84.8	130.0	1.71	16.78	0.51	1.674	18.1	7.46	3.86
P2	O Saray	S 3	0.2 ~ 0.5	SC	2.68	7.50	1.910	8.60	0.40	57.6	2.4E-06	1.81	13.8	0.48	77.1	23.3	1.87	10.62	0.43	1.815	13.9	-1.10	-6.40
		S 4	1.8 ~ 2.0	SC	2.67	7.87	1.965	9.50	0.36	70.5	6.9E-06	1.86	13.2	0.44	80.1	34.8	1.92	8.99	0.39	1.867	13.3	-1.63	-5.43
P3	Kpob Trobek	S 5	0.2 ~ 0.5	SM	2.65	14.51	1.776	12.10	0.49	65.4	2.1E-05	1.69	16.8	0.57	78.1	27.1	1.70	11.78	0.56	1.687	16.5	2.41	-1.99
		S 6	1.8 ~ 2.0	S-M	2.65	15.91	1.698	14.00	0.56	66.3	3.6E-05	1.61	19.9	0.65	81.1	19.2	1.63	13.47	0.63	1.613	19.9	1.91	-3.99
P4	Main Canal No.1	S 7	0.2 ~ 0.5	SM	2.66	17.95	1.834	11.30	0.45	66.8		1.78	14.3	0.49	77.6	30.7	1.83	10.85	0.45	1.742	15.7	6.65	2.25
		S 8	1.8 ~ 2.0	CL	2.72	14.48	1.988	10.50	0.37	77.2		1.89	13.5	0.44	83.5	96.0	1.91	13.36	0.42	1.889	13.5	3.98	0.98
P6	Main Canal No.3	S 11	0.2 ~ 0.5	SM	2.67	17.39	1.876	10.35	0.42	65.8	2.6E-05	1.81	13.4	0.48	74.3	40.0	1.94	10.04	0.38	1.782	14.8	7.04	2.59
		S 12	1.8 ~ 2.0	SC	2.66	8.19	1.832	10.70	0.45	63.2	2.6E-06	1.78	13.7	0.49	74.4	76.6	1.96	10.55	0.36	1.740	15.5	-2.51	-7.31
				Average	2.66	13.87	1.86	11.14	0.43	68.4	1.1E-05	1.77	14.99	0.50	79.2	53.79	1.83	11.86	0.45	1.700	15.45	2.73	-1.58
				Standard deviation	0.03	4.82	0.09	1.90	0.06	6.59		0.09	2.38	0.07	3.56	36.63	0.11	2.24	0.09	0.092	2.21	3.65	4.03

(Source ; Soil mechanical test on Phase-II Third Field Works)

Table J-3 Soil Property of Existing Dike (1/2)

Location	Sample No.	Depth (m)	Specific Gravity Gs	Soil classification	Unified soil classification	Field dry density (g/cm^3)	Moisture content (%)	Void ratio e	Max.dry density (g/cm^3)	D-value	N Value	Converted Internal friction angle ϕ $\sqrt{12N}+15$	$\sqrt{15N}+15$
Tumnop Lok Reservoir	F1	0.5	2.68	Clayey sand	SC	1.854	11.41	0.45	1.936	95.8	-	-	-
	BH-1	1.0		Clayey sand	SC	1.903	14.23	0.41	1.936	98.3	12	27.0	28.4
Tumnop Lok Reservoir	F2	0.5	2.65	Silty sand	SC (NP)	1.587	7.50	0.67	1.936	82.0	-	-	-
	BH-2	1.0		Silty sand	SC (NP)	1.802	6.18	0.47	1.936	93.1	2	19.9	20.5
		2.0		Silty sand	SC (NP)	1.821	3.42	0.46	1.936	94.1	10	26.0	27.2
		3.0		Silty sand	SC (NP)	1.974	4.75	0.34	1.936	102.0	24	32.0	34.0
O Saray Reservoir	F3	0.5	2.67	Silty sand	SC (NP)	1.722	9.39	0.55	1.910	90.2	-	-	-
	BH-3	1.0		Silty sand	SC (NP)	1.727	11.21	0.55	1.910	90.4	6	23.5	24.5
		2.0		Silty sand	SC (NP)	2.005	10.14	0.33	1.965	102.0	3	21.0	21.7
		3.0		Silty sand	SC (NP)	1.968	9.71	0.36	1.965	100.2	15	28.4	30.0
		4.0		Silty sand	SC (NP)	1.832	13.54	0.46	1.965	93.2	7	24.2	25.2
		5.0	2.68	Sand with clay	S-C (NP)	2.087	7.14	0.28	1.965	106.2	8	24.8	26.0
		6.0		Sand with clay	S-C (NP)	1.805	14.78	0.48	1.965	91.9	25	32.3	34.4
O Saray Reservoir	F4	0.5	2.67	Silty sand	SC (NP)	1.672	2.38	0.60	1.910	87.5	-	-	-
	BH-4	1.0		Silty sand	SC (NP)	1.767	3.79	0.51	1.910	92.5	15	28.4	30.0
		2.0		Silty sand	SC (NP)	1.814	5.68	0.47	1.910	95.0	10	26.0	27.2
		3.0		Silty sand	SC (NP)	1.988	9.56	0.34	1.965	101.2	16	28.9	30.5
Kpob Trobek Reservoir	F5	0.5	2.66	Clayey sand	SC	1.912	4.41	0.39	1.936	98.8	-	-	-
	BH-5	1.0		Clayey sand	SC	2.032	7.20	0.31	1.936	105.0	50/23cm	39.5	42.4
		2.0		Clayey sand	SC	1.893	2.43	0.41	1.936	97.8	49	39.2	42.1
		3.0	2.71	Sandy clay	CL	1.733	17.84	0.56	1.762	98.4	1	-	-
		4.0		Sandy clay	CL	1.768	9.87	0.53	1.762	100.3	8	-	-
		5.0	2.69	Clayey sand	SC	1.991	2.87	0.35	1.936	102.8	9	25.4	26.6
Kpob Trobek Reservoir	F6	0.5	2.79	Sandy clay	CL	1.601	6.32	0.74	1.762	90.9	-	-	-
	BH-6-1	1.0	2.68	Clayey sand	SC	2.055	5.36	0.30	1.965	104.6	50/26cm	39.5	42.4
		2.0		Clayey sand	SC	1.936	7.85	0.38	1.965	98.5	31	34.3	36.6
		3.0		Clayey sand	SC	1.940	9.00	0.38	1.965	98.7	11	26.5	27.8
		4.0	-	Sandy clay	CL	1.662	9.55	-	-	-	11	-	-
		5.0		Sandy clay	CL	1.711	16.49	-	-	-	12	-	-
Kpob Trobek Reservoir	BH-6-2	1.0	2.68	Silty sand	SM (NP)	1.932	2.88	0.39	1.776	108.8	50/22cm	39.5	42.4
		2.0		Silty sand	SM (NP)	2.104	4.03	0.27	1.776	118.5	20	30.5	32.3
		3.0		Silty sand	SM (NP)	1.667	5.82	0.61	1.776	93.9	8	24.8	26.0
		Average	2.687			1.852	8.02	0.45	1.907	97.8	17.8	29.2	30.8
		Standard deviation	0.04			0.14	4.19	0.12	0.07	7.11	15.53	6.02	6.75

Table J-3 Soil Property of Existing Dike (2/2)

Location	Sample No.	Depth (m)	Specific Gravity Gs	Soil classification	Unified soil classification	Field dry density (g/cm^3)	Moisture content (%)	Void ratio e	Max.dry density (g/cm^3)	D-value	N Value	Converted Internal friction angle φ $\sqrt{12N}+15$	$\sqrt{15N}+15$
Tumnop Lok Reservoir	F1	0.5	2.68	Clayey sand	SC	1.854	11.41	0.45	1.936	95.8	-	-	-
	BH-1	1.0		Clayey sand	SC	1.903	14.23	0.41	1.936	98.3	12	27.0	28.4
Tumnop Lok Reservoir	F2	0.5	2.65	Silty sand	SC (NP)	1.587	7.50	0.67	1.936	82.0	-	-	-
	BH-2	1.0		Silty sand	SC (NP)	1.802	6.18	0.47	1.936	93.1	2	19.9	20.5
		2.0		Silty sand	SC (NP)	1.821	3.42	0.46	1.936	94.1	10	26.0	27.2
		3.0		Silty sand	SC (NP)	1.974	4.75	0.34	1.936	102.0	24	32.0	34.0
O Saray Reservoir	F3	0.5	2.67	Silty sand	SC (NP)	1.722	9.39	0.55	1.910	90.2	-	-	-
	BH-3	1.0		Silty sand	SC (NP)	1.727	11.21	0.55	1.910	90.4	6	23.5	24.5
		2.0		Silty sand	SC (NP)	2.005	10.14	0.33	1.965	102.0	3	21.0	21.7
		3.0		Silty sand	SC (NP)	1.968	9.71	0.36	1.965	100.2	15	28.4	30.0
		4.0		Silty sand	SC (NP)	1.832	13.54	0.46	1.965	93.2	7	24.2	25.2
		5.0	2.68	Sand with clay	S-C (NP)	2.087	7.14	0.28	1.965	106.2	8	24.8	26.0
		6.0		Sand with clay	S-C (NP)	1.805	14.78	0.48	1.965	91.9	25	32.3	34.4
O Saray Reservoir	F4	0.5	2.67	Silty sand	SC (NP)	1.672	2.38	0.60	1.910	87.5	-	-	-
	BH-4	1.0		Silty sand	SC (NP)	1.767	3.79	0.51	1.910	92.5	15	28.4	30.0
		2.0		Silty sand	SC (NP)	1.814	5.68	0.47	1.910	95.0	10	26.0	27.2
		3.0		Silty sand	SC (NP)	1.988	9.56	0.34	1.965	101.2	16	28.9	30.5
Kpob Trobek Reservoir	F5	0.5	2.66	Clayey sand	SC	1.912	4.41	0.39	1.936	98.8	-	-	-
	BH-5	1.0		Clayey sand	SC	2.032	7.20	0.31	1.936	105.0	50/23cm	39.5	42.4
		2.0		Clayey sand	SC	1.893	2.43	0.41	1.936	97.8	49	39.2	42.1
		5.0	2.69	Clayey sand	SC	1.991	2.87	0.35	1.936	102.8	9	25.4	26.6
	BH-6-1	1.0	2.68	Clayey sand	SC	2.055	5.36	0.30	1.965	104.6	50/26cm	39.5	42.4
		2.0		Clayey sand	SC	1.936	7.85	0.38	1.965	98.5	31	34.3	36.6
		3.0		Clayey sand	SC	1.940	9.00	0.38	1.965	98.7	11	26.5	27.8
Kpob Trobek Reservoir	BH-6-2	1.0	2.68	Silty sand	SM (NP)	1.932	2.88	0.39	1.776	108.8	50/22cm	39.5	42.4
		2.0		Silty sand	SM (NP)	2.104	4.03	0.27	1.776	118.5	20	30.5	32.3
		3.0		Silty sand	SM (NP)	1.667	5.82	0.61	1.776	93.9	8	24.8	26.0
		Average	2.67			1.881	7.28	0.43	1.923	97.9	19.6	29.2	30.8
		Standard deviation	0.01			0.13	3.68	0.11	0.06	7.37	16.18	6.02	6.75

Location	Sample No.	Depth (m)	Specific Gravity Gs	Soil classification	Unified soil classification	Field dry density (g/cm^3)	Moisture content (%)	Void ratio e	Max.dry density (g/cm^3)	D-value	N Value	Converted Internal friction angle φ $\sqrt{12N}+15$	$\sqrt{15N}+15$
	BH-5	3.0	2.71	Sandy clay	CL	1.733	17.84	0.56	1.762	98.4	1	-	-
		4.0		Sandy clay	CL	1.768	9.87	0.53	1.762	100.3	8	-	-
Kpob Trobek Reservoir	F6	0.5	2.79	Sandy clay	CL	1.601	6.32	0.74	1.762	90.9	-	-	-
	BH6-1	4.0	2.75	Sandy clay	CL	1.662	9.55	0.65	1.762	94.3	11	-	-
		5.0		Sandy clay	CL	1.711	16.49	0.61	1.762	97.1	12	-	-
		Average	2.75			1.695	12.01	0.62	1.762	96.2	10.3		
		Standard deviation	0.04			0.07	4.93	0.08	0.00	3.68	2.08		

Table J-4 Tumnup Lok Reservoir ; Seepage Line through Embankment Section

Casagrande's Method — Normal Water Level (El.41.30)

Typical Cross Section	Elevation at the crest	EL.	43.00
	Elevation at the bottom	EL.	38.50
	Width of the crest of core zone (m)		5.00
	Height of the core zone (m)		4.50
	Gradient of the upstream slope	1:	2.50
	Gradient of the downstream slope	1:	2.00
	Width of core zone at bottom (upstream side from dam axis) (m)		13.75
	Width of core zone at bottom (downstream side from dam axis) (m)		11.50
	Water Level (m)	EL.	41.30
	Depth of Water h(m)		2.80
Analyzing cross section	Width of the crest of core zone (m)		2.236
equivalent coefficient =	Width of core zone at bottom (upstream side from dam axis) Bu (m)		6.149
0.447	Width of core zone at bottom (downstream side from dam axis) Bd (m)		5.143
	Width of core zone at bottom B=Bu+Bd		11.292
	Angle of upstream slope αu (°)		41.81
	Angle of downstream slope αd (°)		48.19
	L1 (m)		3.13
	0.3L1(m)		0.94
	L2 = B - L1 (m)		8.16
	d = L2 + 0.3L1 (m)		9.10
	$yo=\sqrt{h^2+d^2}-d$		0.42
	c=⊿a/(a + ⊿a)		0.33
	a +⊿a = yo / (1 - cos α)		1.26
	⊿a		0.42
	a		0.85
Original Section	Elevation at the exudation point (m)	EL.	39.13
	Distance from the exudation point to dam axis (m)		10.24
	Eelevation at dam axis (m)	EL.	40.62

$y=\sqrt{2\cdot yo\cdot X+yo^2}$

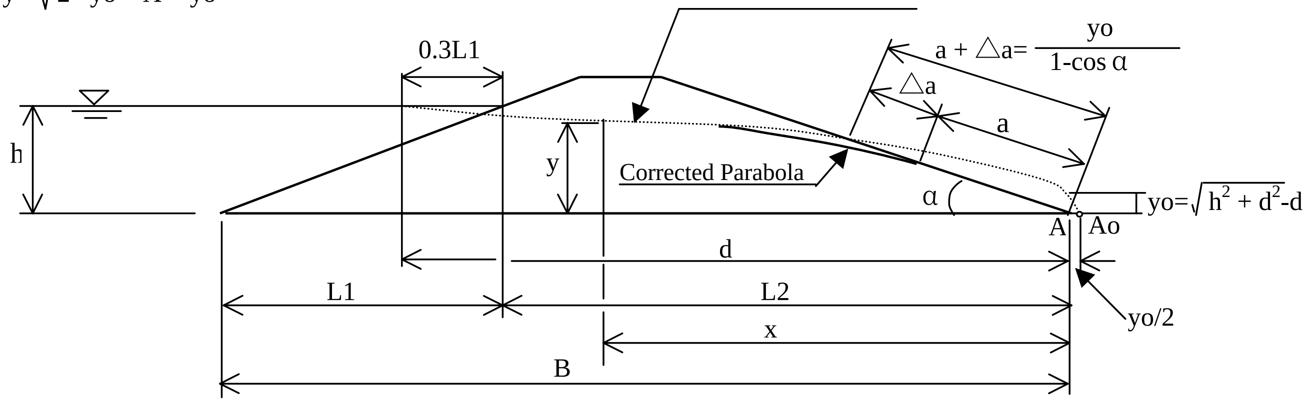


Table J-5 Tumnup Lok Reservoir ; Seepage Line through Existing Dike

Casagrande's Method	Normal Water Level (WL.41.30)		
Typical Cross Section	Elevation at the crest	EL.	43.00
	Elevation at the bottom	EL.	37.00
	Width of the crest of core zone (m)		10.75
	Height of the core zone (m)		6.00
	Gradient of the upstream slope	1:	2.50
	Gradient of the downstream slope	1:	2.00
	Width of core zone at bottom (upstream side from dam axis) (m)		20.38
	Width of core zone at bottom (downstream side from dam axis) (m)		17.38
	Water Level (m)	EL.	41.30
	Depth of Water h(m)		4.30
Analyzing cross section	Width of the crest of core zone (m)		4.808
equivalent coefficient =	Width of core zone at bottom (upstream side from dam axis) Bu (m)		9.112
0.447	Width of core zone at bottom (downstream side from dam axis) Bd (m)		7.770
	Width of core zone at bottom B=Bu+Bd		16.882
	Angle of upstream slope αu (°)		41.81
	Angle of downstream slope αd (°)		48.19
	L1 (m)		4.81
	0.3L1(m)		1.44
	L2 = B - L1 (m)		12.07
	d = L2 + 0.3L1 (m)		13.52
	$yo=\sqrt{h^2+d^2}-d$		0.67
	c=⊿a/(a + ⊿a)		0.33
	a +⊿a = yo / (1 - cos α)		2.00
	⊿a		0.66
	a		1.34
Original Section	Elevation at the exudation point (m)	EL.	38.00
	Distance from the exudation point to dam axis (m)		15.37
	the seepage surface elevation at dam axis (m)	EL.	40.29

$$y=\sqrt{2\cdot yo\cdot X+yo^2}$$

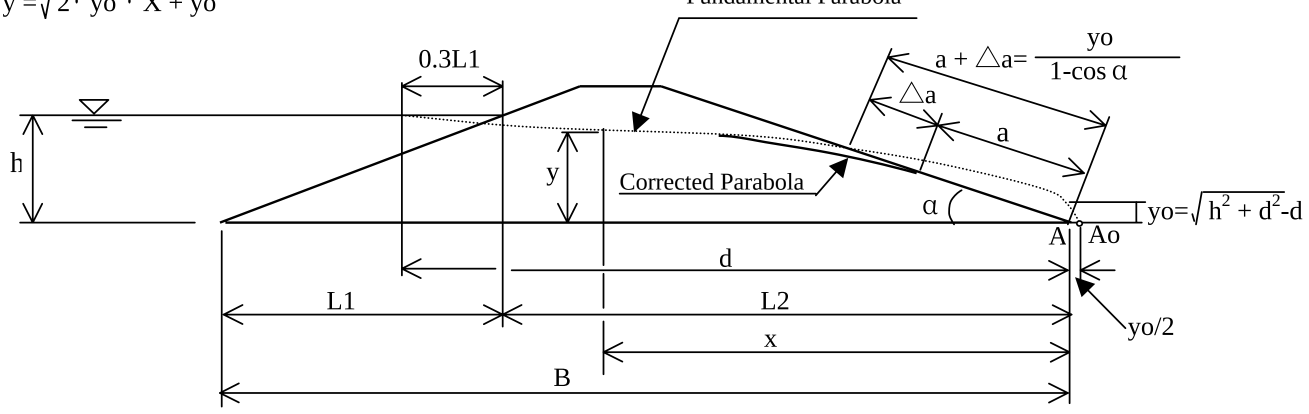


Table J-6 Tumnup Lok Reservoir ; Hydraulic Calculation of Chute Portion (1/2)

Discharge	420.000 (m^3/s)	Roughness	0.035	Slope	=	1／	4.233
B.P. EL	41.300 (m)	Width	215.000 (m)		(	13.292 °	)
E.P. EL	37.000	B.P. depth	0.730 (m)				

Increased	Distance		Depth		Area	Velocity	Velocity	Wetted	H.M.D		Co. of friction		Friction		Bottom	EL. of	EL. of	Error	Froude
distance	H-distance	S-distance	Vertical	Right-A.			Head	Perimeter					headloss	$h*\cos^2\theta$		energy	energy	⑯－⑮	number
(m)	(m)	(m)	h(m)	h'(m)	$A(m^2)$	v(m/s)	$v^2/2g$(m)	P(m)	R(m)	$R^{(4/3)}$	S_f	S_f'	(m)	(m)	(EL. m)	(m)	(m)	(m)	
①	②	②'	③	③'	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬	⑭	⑮	⑯	⑰	⑱
0.000	0.000	0.000	0.730	0.730	156.950	2.676	0.365	216.460	0.725	0.651	0.01347				41.300	42.395			1.000
1.600	1.600	1.644	0.457	0.445	95.623	4.392	0.984	215.890	0.443	0.338	0.06999	0.04173	0.069	0.421	40.922	42.328	42.327	-0.001	2.104
3.200	1.600	1.644	0.403	0.392	84.323	4.981	1.266	215.784	0.391	0.286	0.10638	0.08818	0.145	0.371	40.544	42.181	42.183	0.001	2.541
4.800	1.600	1.644	0.374	0.364	78.256	5.367	1.470	215.728	0.363	0.259	0.13639	0.12138	0.200	0.345	40.166	41.980	41.982	0.001	2.842
6.400	1.600	1.644	0.356	0.346	74.489	5.638	1.622	215.693	0.345	0.242	0.16074	0.14856	0.244	0.328	39.788	41.738	41.736	-0.002	3.060
8.000	1.600	1.644	0.345	0.336	72.188	5.818	1.727	215.672	0.335	0.232	0.17843	0.16958	0.279	0.318	39.410	41.455	41.459	0.004	3.207
9.600	1.600	1.644	0.337	0.328	70.514	5.956	1.810	215.656	0.327	0.225	0.19293	0.18568	0.305	0.311	39.032	41.153	41.150	-0.003	3.322
11.200	1.600	1.644	0.332	0.323	69.469	6.046	1.865	215.646	0.322	0.221	0.20277	0.19785	0.325	0.306	38.654	40.825	40.828	0.002	3.398
12.800	1.600	1.644	0.328	0.319	68.630	6.120	1.911	215.638	0.318	0.217	0.21113	0.20695	0.340	0.302	38.276	40.489	40.485	-0.004	3.460
14.400	1.600	1.644	0.326	0.317	68.213	6.157	1.934	215.635	0.316	0.216	0.21546	0.21330	0.351	0.300	37.898	40.133	40.139	0.006	3.492
16.000	1.600	1.644	0.324	0.315	67.794	6.195	1.958	215.631	0.314	0.214	0.21993	0.21769	0.358	0.299	37.520	39.777	39.775	-0.002	3.524
17.600	1.600	1.644	0.323	0.314	67.585	6.214	1.970	215.629	0.313	0.213	0.22220	0.22106	0.363	0.298	37.142	39.410	39.414	0.003	3.541
18.200	0.600	0.617	0.323	0.314	67.585	6.214	1.970	215.629	0.313	0.213	0.22220	0.22220	0.137	0.298	37.000	39.269	39.273	0.005	3.541

Table J-6 Tumnup Lok Reservoir ; Hydraulic Calculation of Chute Portion (2/2)

Discharge	290.000 (m^3/s)	Roughness	0.035	Slope	=	1／	6.000
B.P. EL	36.167 (m)	Width	50.000 (m)			(	9.462 °)
E.P. EL	35.500	B.P. depth	1.508 (m)				

Increased	Distance		Depth		Area	Velocity	Velocity	Wetted	H.M.D		Co. of friction		Friction		Bottom	EL. of	EL. of	Error	Froude
distance	H-distance	S-distance	Vertical	Right-A.			Head	Perimeter					headloss	$h*cos^2\theta$		energy	energy	⑯－⑮	number
(m)	(m)	(m)	h(m)	h'(m)	$A(m^2)$	v(m/s)	$v^2/2g$(m)	P(m)	R(m)	$R^{(4/3)}$	S_f	S_f'	(m)	(m)	(EL. m)	(m)	(m)	(m)	
①	②	②'	③	③'	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬	⑭	⑮	⑯	⑰	⑱
0.000	0.000	0.000	1.508	1.508	75.400	3.846	0.755	53.016	1.422	1.599	0.01133				36.167	38.429			1.000
0.500	0.500	0.507	1.240	1.223	61.157	4.742	1.147	52.446	1.166	1.227	0.02244	0.01689	0.009	1.190	36.083	38.421	38.421	0.000	1.370
1.000	0.500	0.507	1.173	1.157	57.852	5.013	1.282	52.314	1.106	1.144	0.02692	0.02468	0.013	1.126	36.000	38.408	38.408	0.000	1.489
1.500	0.500	0.507	1.123	1.108	55.386	5.236	1.399	52.215	1.061	1.082	0.03105	0.02898	0.015	1.078	35.917	38.393	38.393	-0.000	1.589
2.000	0.500	0.507	1.083	1.068	53.413	5.429	1.504	52.137	1.024	1.033	0.03496	0.03301	0.017	1.039	35.833	38.377	38.377	-0.000	1.678
2.500	0.500	0.507	1.050	1.036	51.786	5.600	1.600	52.071	0.995	0.993	0.03870	0.03683	0.019	1.008	35.750	38.358	38.358	0.000	1.758
3.000	0.500	0.507	1.022	1.008	50.405	5.753	1.689	52.016	0.969	0.959	0.04229	0.04049	0.021	0.981	35.667	38.336	38.337	0.001	1.830
3.500	0.500	0.507	0.997	0.983	49.172	5.898	1.775	51.967	0.946	0.929	0.04587	0.04408	0.022	0.957	35.583	38.315	38.314	-0.001	1.900
4.000	0.500	0.507	0.975	0.962	48.087	6.031	1.856	51.923	0.926	0.903	0.04936	0.04761	0.024	0.936	35.500	38.291	38.291	-0.001	1.964

Table J-7 Kpob Trobek Reservoir ; Seepage Line through Existing Dike

Normal Water Level (WL.37.30)

Typical Cross Section	Elevation at the crest	EL.	38.70
	Elevation at the bottom	EL.	33.80
	Width of the crest of core zone (m)		10.75
	Height of the core zone (m)		4.90
	Gradient of the upstream slope	1:	2.50
	Gradient of the downstream slope	1:	2.00
	Width of core zone at bottom (upstream side from dam axis) (m)		17.63
	Width of core zone at bottom (downstream side from dam axis) (m)		15.18
	Water Level (m)	EL.	37.30
	Depth of Water h(m)		3.50
Analyzing cross section	Width of the crest of core zone (m)		4.808
equivalent coefficient =	Width of core zone at bottom (upstream side from dam axis) Bu (m)		7.882
0.447	Width of core zone at bottom (downstream side from dam axis) Bd (m)		6.786
	Width of core zone at bottom B=Bu+Bd		14.668
	Angle of upstream slope αu (°)		41.81
	Angle of downstream slope αd (°)		48.19
	L1 (m)		3.91
	0.3L1(m)		1.17
	L2 = B - L1 (m)		10.76
	d = L2 + 0.3L1 (m)		11.93
	$yo=\sqrt{h^2 + d^2}-d$		0.50
	c=⊿a/(a + ⊿a)		0.33
	a +⊿a = yo / (1 - cos α)		1.51
	⊿a		0.50
	a		1.01
Original Section	Elevation at the exudation point (m)	EL.	34.55
	Distance from the exudation point to dam axis (m)		13.67
	the seepage surface elevation at dam axis (m)	EL.	36.46

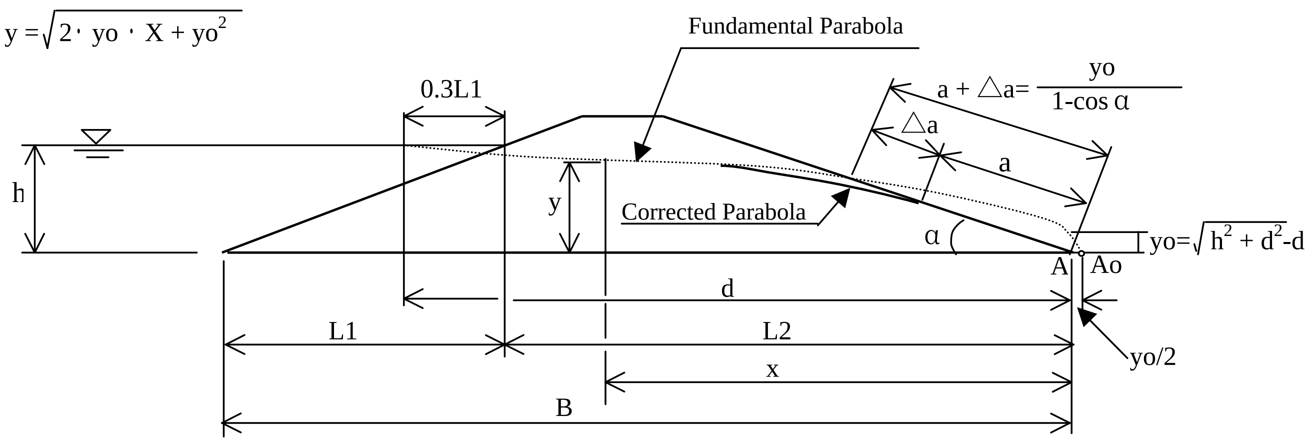


Table J-8 Kpob Trobek Reservoir ; Hydraulic Calculation of Chute Portior

Discharge	195.000 (m^3/s)	Roughness	0.035	Slope	=	1／	4.849
B.P. EL	37.300 (m)	Width	160.000 (m)			(	11.653 °)
E.P. EL	32.000	B.P. depth	0.533 (m)				

Increased distance (m) ①	Distance H-distance (m) ②	Distance S-distance (m) ②'	Depth Vertical h(m) ③	Depth Right-A. h'(m) ③'	Area $A(m^2)$ ④	Velocity v(m/s) ⑤	Velocity Head $v^2/2g$(m) ⑥	Wetted Perimeter P(m) ⑦	H.M.D R(m) ⑧	$R^{(4/3)}$ ⑨	Co. of friction S_f ⑩	Co. of friction S_f' ⑪	Friction headloss (m) ⑫	$h*\cos^2\theta$ (m) ⑬	Bottom (EL. m) ⑭	EL. of energy (m) ⑮	EL. of energy (m) ⑯	Error ⑯−⑮ (m) ⑰	Froude number ⑱
0.000	0.000	0.000	0.533	0.533	85.280	2.287	0.267	161.066	0.529	0.428	0.01495				37.300	38.100			1.000
2.200	2.200	2.246	0.307	0.301	48.186	4.047	0.836	160.602	0.300	0.201	0.09988	0.05742	0.129	0.289	36.846	37.971	37.971	0.000	2.356
4.400	2.200	2.246	0.275	0.269	43.093	4.525	1.045	160.539	0.268	0.173	0.14486	0.12237	0.275	0.258	36.393	37.696	37.696	0.000	2.785
6.600	2.200	2.246	0.261	0.256	40.966	4.760	1.156	160.512	0.255	0.162	0.17144	0.15815	0.355	0.246	35.939	37.340	37.340	-0.000	3.005
8.800	2.200	2.246	0.255	0.250	39.958	4.880	1.215	160.499	0.249	0.157	0.18627	0.17886	0.402	0.240	35.485	36.940	36.939	-0.001	3.119
11.000	2.200	2.246	0.252	0.247	39.490	4.938	1.244	160.494	0.246	0.154	0.19373	0.19000	0.427	0.237	35.031	36.512	36.513	0.001	3.175
13.200	2.200	2.246	0.250	0.245	39.246	4.969	1.260	160.491	0.245	0.153	0.19776	0.19575	0.440	0.235	34.578	36.073	36.073	-0.000	3.205
15.400	2.200	2.246	0.250	0.245	39.125	4.984	1.267	160.489	0.244	0.152	0.19981	0.19879	0.447	0.235	34.124	35.626	35.626	0.000	3.220
17.600	2.200	2.246	0.249	0.244	39.062	4.992	1.271	160.488	0.243	0.152	0.20088	0.20035	0.450	0.234	33.670	35.176	35.176	-0.000	3.227
19.800	2.200	2.246	0.249	0.244	39.032	4.996	1.273	160.488	0.243	0.152	0.20140	0.20114	0.452	0.234	33.217	34.724	34.724	0.000	3.231
22.000	2.200	2.246	0.249	0.244	39.014	4.998	1.275	160.488	0.243	0.152	0.20170	0.20155	0.453	0.234	32.763	34.271	34.271	-0.000	3.233
24.200	2.200	2.246	0.249	0.244	39.006	4.999	1.275	160.488	0.243	0.152	0.20184	0.20177	0.453	0.234	32.309	33.818	33.818	-0.000	3.234
25.700	1.500	1.532	0.249	0.244	39.005	4.999	1.275	160.488	0.243	0.152	0.20187	0.20185	0.309	0.234	32.000	33.509	33.509	0.000	3.234

Table J-9 General Condition and Main Features of Reservoirs for SRP

Description	Ang 160 SRP	Kim Sei SRP
Hydrological Data		
Catchment Area	2.0km^2	5.2km^2
Unit Sedimentation Rate	0.1mm/km^2/year	0.1mm/km^2/year
Mean Annual Rainfall	1,200mm	1,200mm
Annual Runoff (80% Depend.)	0.24 MCM	0.53 MCM
Annual Runoff (50% Depend.)	0.49 MCM	1.06 MCM
Reservoir		
Surface Area at HWL	4.3 ha	8.8 ha
Gross Storage Capacity	36,300 m^3	27,500 m^3
Effective Storage Capacity	29,300 m^3	19,700 m^3
Dead Storage (20 years)	7,000 m^3	7,800 m^3
Flood Water Level	EL.45.90m	EL.13.20m
High Water Level	EL.45.30m	EL.12.60m
Low Water Level	EL.44.00m	EL.12.00m
Spillway		
Type	Rock Spillway Type	Rock Spillway Type
Location (Center)	STA.0+271	STA.0+669
Crest Length	7.60m	14.30m
Crest Level	EL.45.30m	EL.12.60m
Design Flood Discharge (100years)	7.8m^3/sec	14.8m^3/sec
Design Flood Discharge (20years)	6.0m^3/sec	11.4m^3/sec
Overflow Depth	0.60m	0.60m
Dike		
Type of Embankment		
Dike Top Elevation	EL.46.50m	EL.13.80m
EL. of Dike Top	EL.43.30m	EL.40.0m
Length of Dike	520m	1,600 m
Width of Dike Top	3.0m	3.0–4.0m
Slope : Upstream	1:2.0	1:2.0
: Downstream	1:1.5	1:1.5-2.0
Intake Structure		
Type	Sluice Gate	Sluice Gate
Size	0.6x0.6mx2nos.	0.6x0.4mx4nos.

Table J-10 Labor Wage

(Unit : Riel)

Description	Unit	Wage	Remarks
Common Labor	Man / day	13,000	8hour /day
Skilled Labor	Man / day	49,000	- ditto -
Foreman	Man / day	81,000	- ditto -
Operator, Heavy Equipment	Man / day	53,000	- ditto -
Assistant Operator, Heavy Equipment	Man / day	41,000	- ditto -
Operator, Light Equipment	Man / day	41,000	- ditto -
Assistant Operator, Light Equipment	Man / day	41,000	- ditto -
Driver, Dump Track	Man / day	53,000	- ditto -
Driver, Others	Man / day	43,000	- ditto -
Mechanic, Repair	Man / day	61,000	- ditto -
Assistant Mechanic, Repair	Man / day	49,000	- ditto -
Electrician	Man / day	61,000	- ditto -
Carpenter	Man / day	63,000	- ditto -
Mason	Man / day	53,000	- ditto -
Plasterer	Man / day	49,000	- ditto -
Concrete Worker	Man / day	33,000	- ditto -
Steel Worker	Man / day	43,000	- ditto -

Table J-11 Rental Charge of Construction Equipment

(Unit : Riel)

Description	Unit	Charge
Bulldozer (3ton)	no. / day	1,006,000
Bulldozer (7ton)	no. / day	1,207,000
Bulldozer (11ton)	no. / day	1,408,000
Bulldozer (15ton)	no. / day	1,609,000
Rake Dozer (11ton)	no. / day	1,609,000
Back Hoe (0.4m^3)	no. / day	805,000
Back Hoe (0.7m^3)	no. / day	1,006,000
Tractor Shovel (Wheel Type, 1.7m^3)	no. / day	1,006,000
Dump Track (6ton)	no. / day	403,000
Dump Track (11ton)	no. / day	523,000
Crawler Crane (35 ton)	no. / day	1,288,000
Truck (4ton)	no. / day	322,000
Truck (11ton)	no. / day	483,000
Truck Crane (4.8 ton)	no. / day	805,000
Vibration Hammer (40kw)	no. / day	805,000
Concrete Breaker (20kg)	no. / day	121,000
Motor Grader (3.1m)	no. / day	1,006,000
Vibration Roller (6.0 ton)	no. / day	805,000
Vibration Roller (2.5 ton)	no. / day	403,000
Concrete Plant (30m^3/h)	no. / day	1,448,000
Concrete Plant (0.05m^3)	no. / day	81,000
Truck Mixer (4.5m^3)	no. / day	604,000
Water Tank Truck (10kl)	no. / day	483,000
Air Compressor (10.5m^3)	no. / day	282,000
Submersible Pump (100mm)	set / day	121,000
Submersible Pump (200mm)	set / day	181,000
Generator Set (200 kvA)	set / day	403,000
Generator Set (10 kvA)	set / day	81,000
Concrete Mixer (0.2m^3)	no. / day	81,000
Well Drilling Equipment (30m)	no. / day	523,000

Table J-12 Unit Price of Construction Material

(Unit : Riel)

Description	Unit	Unit Price
Cement	ton	387,000
Cement Admixture	kg	13,000
Aggregate	m^3	68,000
Crushed Stone (50-100mm)	m^3	57,000
Sand	m^3	21,000
Gravel	m^3	41,000
Round Bar	ton	2,213,000
Deformed Bar	ton	2,414,000
L-Shape Steel	ton	2,213,000
Steel Plate (t=3.2 - 4.5mm)	ton	2,213,000
Band Wire (#16)	kg	3,000
Barbed Wire (#14)	kg	3,000
Steel Slide Gate (1.5 x 1.5m)	no.	10,901,000
Steel Slide Gate (1.2 x 1.2m)	no.	10,056,000
Steel Slide Gate (1.0 x 1.0m)	no.	8,326,000
Steel Slide Gate (0.8 x 0.8m)	no.	6,034,000
Steel Slide Gate (0.6 x 0.6m)	no.	4,023,000
Steel Slide Gate (0.6 x 0.4m)	no.	3,218,000
Steel Pile (t=6mm)	ton	4,827,000
Timber , Plank	m^3	1,006,000
Timber , Square	m^3	1,086,000
Plywood (t=6mm)	m^2	15,000
Concrete Pipe (φ=1,000mm)	m	222,000
Concrete Pipe (φ=800mm)	m	181,000
Concrete Pipe (φ=600mm)	m	141,000
Concrete Pipe (φ=400mm)	m	121,000
Concrete Pipe (φ=200mm)	m	81,000
PVC Pipe (φ=75mm)	m	21,000
PVC Pipe (φ=50mm)	m	13,000
PVC Water Stop (w=150mm)	m	61,000
PVC Water Stop (w=300mm)	m	101,000
Gasoline	l	3,000
Diesel	l	3,000
Gabion (0.5 x 1.2 x 2.0m)	no.	194,000
Sand Bug (0.6 x 0.9m)	no.	2,000
Plastic Sheet (t=0.4mm)	m^2	3,000
Jute Bag (for concrete curing)	m^2	3,000
Electric Cable (600V, CV)	m	7,000
Fluorescent Lamp (30W)	no.	4,000
Switch Box (30A)	no.	89,000
Sodding	m^2	21,000

Table J-13 Project Cost for Upper Slakou River Irrigation Reconstruction Plan (1/2)

(Unit : Million Riel)

Work Item	Financial Cost F/C	Financial Cost L/C	Financial Cost Total	Cost of US$*	Per ha Cost (UD$/ha)
I. Preparatory Works					
1) Access Road and Rerated Structure	1,356.9	351.2	1,708.1	424,000	122
2) Coffer Dam for Spillway Construction	490.0	119.4	609.4	152,000	43
3) Temporary Diversion Canal	179.4	28.8	208.2	52,000	15
4) Construction Site Development	458.6	346.9	805.5	200,000	57
Total (Preparatory Work)	2,484.9	846.3	3,331.2	828,000	237
II. Direct Construction Cost					
1) Tumnup Lok Reservoir					
- Dike Rehabiulitation	2,253.3	920.8	3,174.1	789,000	225
- Spillway	2,220.6	1,059.6	3,280.2	814,000	233
- Intake Gate to Diversion Canal	95.1	58.1	153.2	38,000	11
- Intake Gate to Tertiary Block (2nos.)	79.7	43.2	122.9	31,000	9
- Maintenance Gate	107.9	68.8	176.7	44,000	13
- Miscellanies	244.2	65.7	309.9	77,000	22
Sub-total	5,000.8	2,216.2	7,217.0	1,793,000	513
2) Diversion Canal					
- Canal Rehabilitation	5,004.2	1,789.8	6,794.0	1,689,000	482
- Canal Related Structure	366.1	320.4	686.5	171,000	49
- Miscellanies	31.1	10.4	41.5	10,000	3
Sub-total	5,401.4	2,120.6	7,522.0	1,870,000	534
3) Kpob Trobek Reservoir					
- Dike Rehabiulitation	2,755.8	1,095.8	3,851.6	958,000	273
- Spillway	1,754.2	873.2	2,627.4	653,000	187
- Intake Gate to Canal 33	94.5	63.0	157.5	39,000	11
- Intake Gate to Canal 24	45.9	30.6	76.5	19,000	5
- Maintenance Gate	138.0	83.4	221.4	55,000	16
- Miscellanies	187.9	50.6	238.5	59,000	17
Sub-total	4,976.3	2,196.6	7,172.9	1,783,000	509
4) Main Canal					
- Canal Rehabiulitation	1,666.7	593.5	2,260.2	562,000	161
- Diversion Structure	395.1	320.5	715.6	178,000	51
- Drop	22.4	16.2	38.6	10,000	3
- Bridge	10.4	12.3	22.7	6,000	2
- Box Culvert	59.5	46.7	106.2	26,000	7
- Miscellanies	48.9	13.1	62.0	15,000	4
Sub-total	2,203.0	1,002.3	3,205.3	797,000	228
5) Secondary Canal					
- Canal Rehabiulitation	9,174.7	4,091.9	13,266.6	3,299,000	943
- Diversion Structure and Drop	1,476.1	1,286.7	2,762.8	687,000	196
- Bridge (Pipe Culvert)	225.1	170.9	396.0	98,000	28
- Cross Drain	255.8	194.6	450.4	112,000	32
- Miscellanies	169.1	45.5	214.6	53,000	15
Sub-total	11,300.8	5,789.6	17,090.4	4,249,000	1,214
6) Tertiary Development					
- Canal Construction	1,290.2	597.7	1,887.9	470,000	134
- Diversion Structure	161.8	89.4	251.2	62,000	18
Sub-total	1,452.0	687.1	2,139.1	532,000	152
7) Building Works					
- Project Office	167.9	126.7	294.6	73,000	21
- APEX Committee Office	90.1	68.0	158.1	39,000	11
- Assembling and Shipping Fasility	41.2	30.9	72.1	18,000	5
Sub-total	299.2	225.6	524.8	130,000	37
Total (Direct Construction Cost)	30,633.5	14,238.0	44,871.5	11,154,000.0	3,187

Table J-13 Project Cost for Upper Slakou River Irrigation Reconstruction Plan (2/2)

(Unit : Million Riel)

Work Item	Financial Cost F/C	Financial Cost L/C	Financial Cost Total	Cost of US$*	Per ha Cost (UD$/ha)
III. O&M Equipment					
1) Project Office	151.6	3.6	155.2	39,000	11
2) FWUCs	2.2	6.7	8.9	2,000	1
3) Marketing	2.9	0.0	2.9	1,000	0
Total (O&M Equipment)	156.7	10.3	167.0	42,000	12
IV. Institutional Development	666.9	1,760.8	2,427.7	604,000	173
V. Relocation and Land Compensation Cost					
1) Land Compensation	0.0	92.5	92.5	23,000	7
2) House Relocation	3.3	104.5	107.8	27,000	8
Total (Relocation and Land Compensation Cost)	3.3	197.0	200.3	50,000	15
VI. Administration Cost	155.7	824.3	980.0	244,000	70
VII. Consulting Services					
1) Design & Construction Supervision	4,256.2	563.9	4,820.1	1,198,000	342
2) Institutional Development & Capacity Building	7,665.5	59.6	7,725.1	1,921,000	549
Sub-total	11,921.7	623.5	12,545.2	3,119,000	891
Total (I ～VII)	46,022.7	18,500.2	64,522.9	16,041,000	4,583
VIII. Contingencies					
1) Physical Contingency （10% of Σ(I ～ VII)）	4,602.3	1,850.0	6,452.3	1,604,000	458
2) Price Escalation**	3,755.7	1,893.7	5,649.4	1,405,000	401
Sub-total	8,358.0	3,743.7	12,101.7	3,009,000	859
IX. Grand Total	54,380.7	22,243.9	76,624.6	19,050,000.0	5,443

Note * : Exchange rate ; Riel 4,022.20/US$

** : Price escalation rate; 2.5% per annum for foreign currency portion and 3.0% per annum for local currency portion.

Table J-14 Administration Cost for USP

	Salary for Staff	Article of Consumption	Environmental Monitoring	Extension Activity	Total	Remarks
	(1)	(2)	(3)	(4)		
2002	139,200	34,384	0	0	173,584	Design and Construction Stage
2003	139,200	34,384	0	0	173,584	
2004	139,200	34,384	15,059	0	188,643	
2005	139,200	34,384	15,059	18,612	207,255	
2006	37,440	0	7,530	39,504	84,474	O&M Stage
2007	37,440	0	7,530	8,784	53,754	
2008	37,440	0	7,530	8,784	53,754	
2009	37,440	0	7,530	0	44,970	
	706,560	137,536	60,238	75,684	980,018	

(1) Salary for Staff

≪Design and Construction Stage per Year≫

Manager	12 M/M	12,480,000
Staff	144M/M	126,720,000
Total		139,200,000

≪O&M Stage≫

Senior Engineer	36M/M	37,440,000

(2) Article of Consumption at Design and Construction Stage

Fuel for Pick-up	8,960,000
Fuel for Motor Bike	24,640,000
Parts for Equipment	104,000
Office Supply	480,000
Miscellaneous	200,000
Total	34,384,000

(3) Environmental Monitoring

7,530,000 per Time

Construction Stage (2004 - 2005)	2 times per year
O&M Stage (2006 - 2009)	1 time per year

(4) Extension Activity

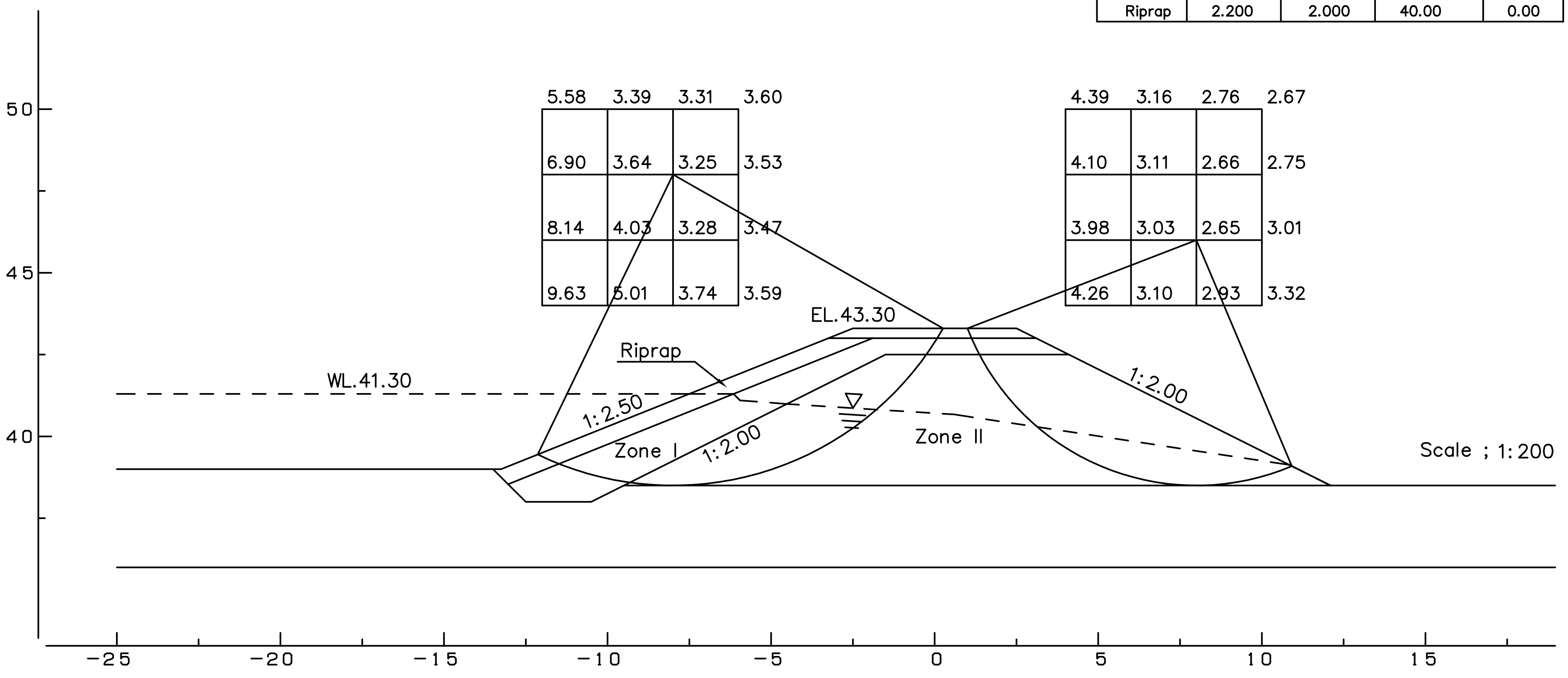
Details are presented in Table IV-5.2.3 of Main Report.

Figures

Embankment section ; Under Normal Water Condition (HWL.41.30)

			Upstream	Downstream
	Fs min=		3.255	2.651
Center of circle	x	=	−8.00 (m)	8.00 (m)
	y	=	48.00 (m)	46.00 (m)
Radius	R	=	9.50 (m)	7.50 (m)
Resistingoment	Mr	=	403.73 (tf.m)	247.52 (tf.m)
Sliding moment	Mo	=	124.03 (tf.m)	93.36 (tf.m)

Zone	Saturated unit weight (tf/m^3)	Wet unit weight (tf/m^3)	Internal friction angle (°)	Cohesion (tf/m^2)
Foundation	2.000	1.800	25.00	2.00
Zone I	2.250	2.000	25.00	3.00
Zone II	2.080	1.930	25.00	1.50
Riprap	2.200	2.000	40.00	0.00



The Study on The Rehabilitation and Reconstruction of Agricultural Production System in The Slakou River Basin, The Kingdom of Cambodia

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Figure J-1
Tumnup Lok Reservoir;
Result of Stability Analysis Case 1

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Figure J-2

Tumnup Lok Reservoir; Result of Stability Analysis Case 2

Embankment section ; Immediately after completion

			Upstream	Downstream
	Fs min=		3.149	2.679
Center of circle	x	=	−10.00 (m)	10.00 (m)
	y	=	50.00 (m)	50.00 (m)
Radius	R	=	11.50 (m)	11.50 (m)
Resistingoment	Mr	=	510.93 (tf.m)	407.26 (tf.m)
Sliding moment	Mo	=	162.23 (tf.m)	152.00 (tf.m)

Zone	Saturated unit weight (tf/m^3)	Wet unit weight (tf/m^3)	Internal friction angle (°)	Cohesion (tf/m^2)
Foundation	2.000	1.800	25.00	2.00
Zone I	2.250	2.000	15.00	3.00
Zone II	2.080	1.930	25.00	1.50
Riprap	2.200	2.000	40.00	0.00

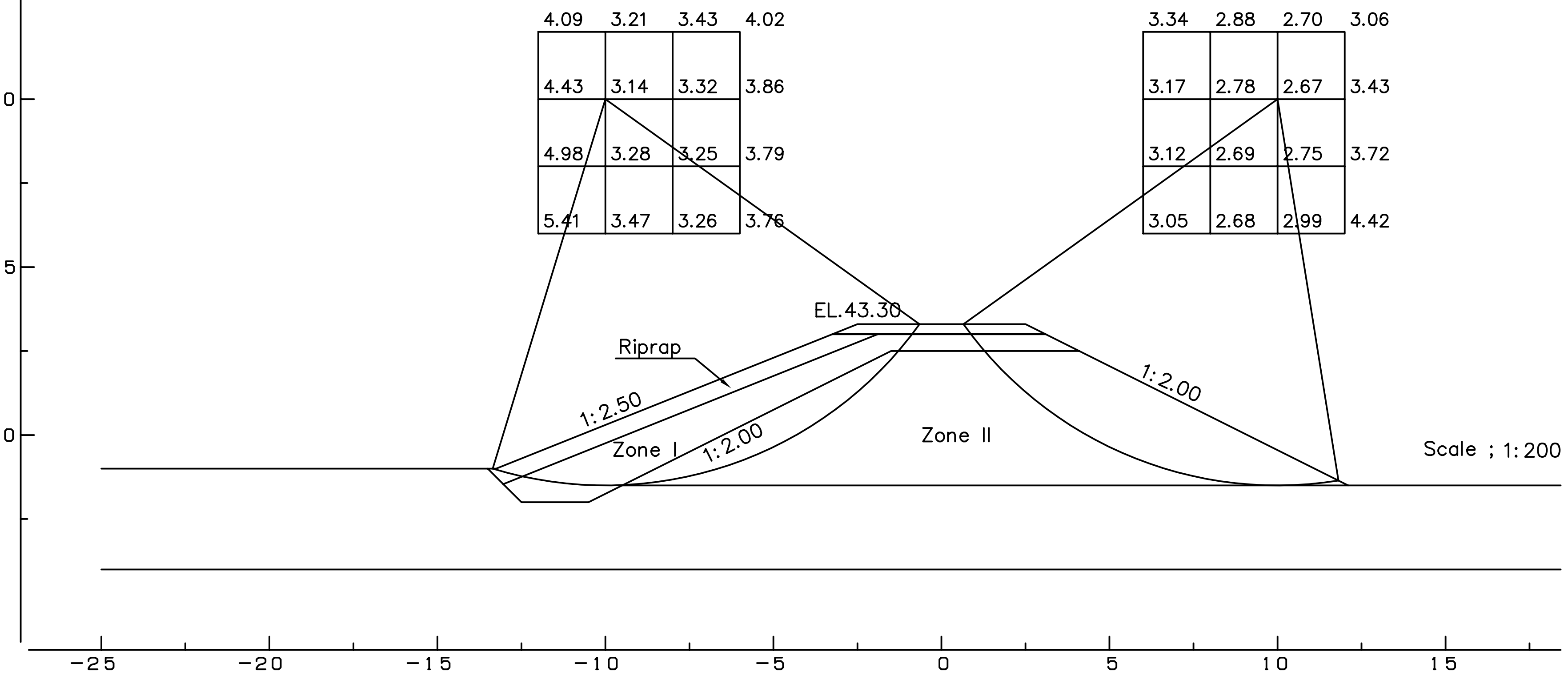

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Figure J-3

Tumnup Lok Reservoir,
Result of Stability Analysis Case 3

Existing dike section ; Under normal water condition (HWL.41.30)

			Upstream		Downstream	
	Fs min=		2.408		1.800	
Center of circle	x	=	−12.00	(m)	14.00	(m)
	y	=	50.00	(m)	48.00	(m)
Radius	R	=	13.00	(m)	11.00	(m)
Resistingoment	Mr	=	675.47	(tf.m)	395.79	(tf.m)
Sliding moment	Mo	=	280.48	(tf.m)	219.94	(tf.m)

Zone	Saturated unit weight (tf/m^3)	Wet unit weight (tf/m^3)	Internal friction angle (°)	Cohesion (tf/m^2)
Foundation	2.000	1.800	25.00	2.00
Zone I	2.250	2.000	25.00	3.00
Existing dike	2.180	2.020	25.00	1.00