TABLE 11 WATERWAY MAJOR DIMENSION (1/2) (ROR. TYPE)

(Unit: m)

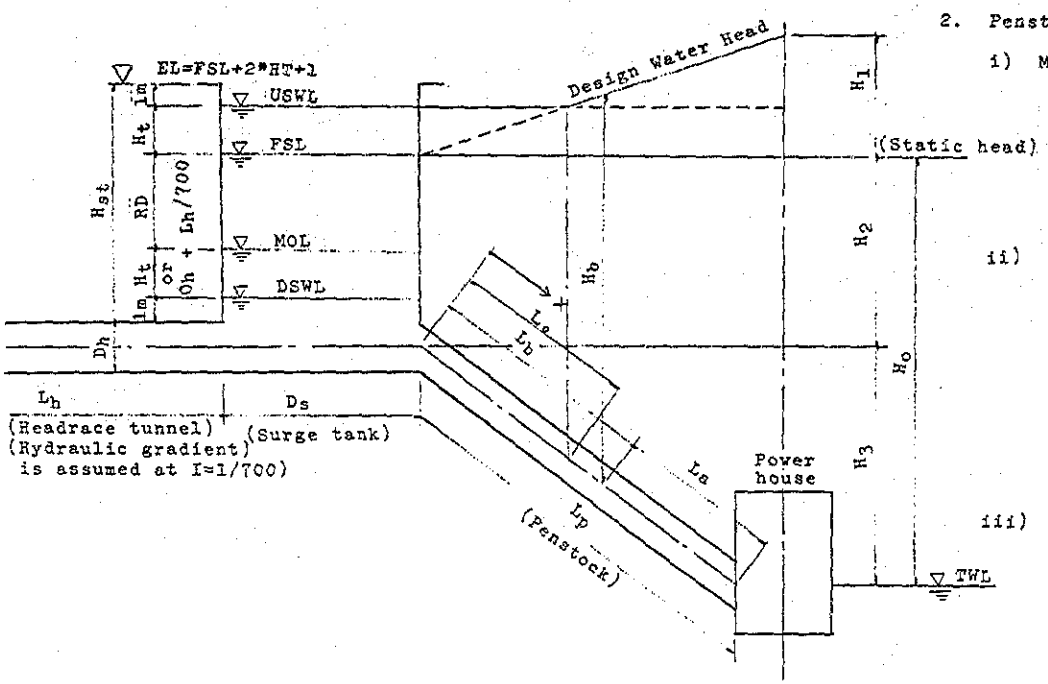
Scheme Name	Headrace		Penstock		Water Transfer Tunnel (Length x Dia.)	Tailrace Width
	Length	Diameter	Length	Diameter		
Naguilian	9010	3.0	1190	1.9		46.2
Luya	6750	4.4	230	3.3		50.3
Bakum	4670	2.6	1000	1.5		57.8
Amburayan	9330	4.1	220	2.9	3800 x 2.7	50.3
Abra	6150	2.2	340	1.5		18.2
Apayao	8610	2.9	230	2.1		32.2
Chico-1R	2300	4.8	90	4.0		22.4
Chico-1R(+Sadanga)	2300	4.8	90	4.0		22.4
Chico-2R	5220	4.2	150	3.2		22.1
Chico-3R	3770	3.7	160	2.9		21.0
Chico-4R	7180	2.8	160	2.0		19.3
Saltan	7230	2.3	450	1.5	1670 x 2	18.5
Pasil	9800	2.3	610	1.4	600 x 2,700 x 2, 600 x 2,600 x 2	19.0
Tanudan	8080	2.8	530	1.8		19.9
Ibulao	7890	2.4	450	1.5	1100 x 2	30.7
Casecnan	5470	3.0	130	2.3		31.7
Upper Casecnan	6720	2.9	150	2.1		31.7
Agno-2	5980	2.4	240	1.7	1900 x 2	41.5
Agno-3	5540	2.4	510	1.4	1060 x 2,200 x2 300 x 2	40.1

TABLE 11 WATERWAY MAJOR DIMENSION (2/2) (RES. TYPE)

(Unit: m)

Scheme Name	Headrace		Penstock		Surge Tank			Tailrace Width
	Length	Tunnel No. * Dia.	Length	Line No. * Dia.	Height	Top Elevation	Tank No. * Dia.	
Supo	537	1x7.4	108	1x6.3	58.3	328.1	1x29.6	31.1
Eteb	576	1x7.1	135	1x6.2	55.9	379.2	1x28.5	30.1
Supo (+Eteb)	1480	1x7.1	110	1x6.3	34.4	274.6	1x28.4	30.0
Sisiritan	750	4x7.3	168	4x6.4	53.1	109.2	4x29.2	86.7
Bulu	540	2x7.9	194	2x6.7	73.9	226.7	2x31.8	73.0
Nababarayan	470	2x7.1	251	2x5.9	68.5	247.6	2x28.4	68.7
Dibagat	788	2x6.4	244	2x5.0	96.0	349.4	2x25.5	65.9
Agbulu	-	-	216	3x3.9	-	-	-	47.9
Sisiritan (+Agb.+Bulu)	528	2x8.3	133	2x8.0	34.4	77.2	2x33.4	46.2
Sisiritan (+Agbulu)	750	2x9.2	168	2x8.4	56.9	110.0	2x36.9	84.4
Bulu (+Agbulu)	540	2x8.6	125	2x7.7	53.4	184.3	2x34.5	79.1
Basao	650	1x6.7	378	1x5.4	24.0	674.1	1x26.8	29.4
Sadanga	1120	1x7.1	281	1x5.5	90.9	900.4	1x28.4	45.9
Sadanga (Alternative)	1640	1x7.1	570	1x5.4	102.7	902.1	1x28.6	62.5
Bantay	-		385	1x6.6	-	-	-	28.3
Maliano	650	1x7.4	235	1x6.1	76.8	300.8	1x29.5	31.2
Tabu	550	1x7.1	245	1x6.1	30.0	412.0	1x28.6	30.4
Kanan	872	1x7.1	334	1x5.6	81.9	303.5	1x28.3	46.1
Up. Agos 2	-	-	184	2x3.9	-	-	-	28.8
Kanan (+Up. Agos 2)	-	-	300	1x7.1	-	-	-	31.2
Wawa	-	-	144	2x3.1	-	-	-	24.4
Bosigon	585	1x6.3	60	1x5.8	38.2	87.5	1x25.3	27.2

TABLE 12 CALCULATION SHEET FOR SURGE TANK AND PENSTOCK DIMENSION



1. Surge tank

Diameter : $D_s = 4 * D_h$ (m)

where, D_h : Headrace tunnel diameter (m)
Ref. to Design Criteria

Height : $H_{st} = RD + 2 * H_t + 2$ (m) or
$RD + H_t + D_h + L_h/700 + 1$ (m)
(To adopt the bigger height of them)

where, RD : Reservoir draw-down depth (m)
= FSL - MOL

H_t : Surging depth
$= 0.72 * Q_p^{1/3} ((L_h/700)^{1/2} + (L_h/700)^{1/3})$

2. Penstock steel pipe

i) Minimum thickness of pipe

$$T_{min} = \frac{D_p + 800}{400} \geq 6 \text{ mm}$$

where, D_p : Steel pipe diameter (mm)
Ref. to Design Criteria.

ii) Steel pipe stress by inner pressure

$$\sigma = \frac{P * D_p}{2 * (T - \varepsilon)\eta} \leq \sigma a = 1{,}200 \text{ kg/cm}^2 \text{ (SM41 property in JIS)}$$

where, P : Design head pressure (kg/cm²)=0.1*H
H : Design water head (m)
Dp: Steel pipe diameter (cm)
T : Steel pipe thickness (cm)
ε : Tolerance for rust or friction loss=0.15 cm
η : Stress decrease ratio due to connecting effect = 0.9

iii) Design water head

$$H_1 = \left(\frac{N}{2} + \frac{1}{2}\sqrt{N^2+4N}\right) * H_o \quad \text{(Allievi's equation)}$$

where, H_1: Head increase by water hammer

$$N = \left(\frac{L_p * V_o}{9.8 * T * H_o}\right)^2$$

V_o: Velocity (m/sec)=Q_p/sectional area
T : Guide vane closing time

10 MW ≦	2 sec.
10-50 MW	3 sec.
50 MW ≧	4 sec.

If $X \leq L_o = H_t * L_p/H_1$,
$H(X) = H_t + H_2 + H_3 * X/L_p$
If $X > L_o = H_t * L_p/H_1$
$H(X) = H_1 * X/L_p + H_2 + H_3 * X/L_p$
where, H (X) : Design water head (m)

iv) Water head to be resisted by minimum thickness

$H_b = 2 * (T_{min} - \varepsilon) * \eta * \sigma_{sa}/D_p$

If $H_2 + H_t > H_b$, then $L_b = 0$

If $H_2 + H_t \leq H_b$, then $L_b = \frac{H_b - H_t - H_2}{H_3} * L_p$ or $L_b = \frac{H_b - H_2 - H_t}{H_1 + H_3 - H_t} L_p$

If $H_o + H_1 < H_b$, then $L_a = 0$, $L_b = L_p$

v) Steel pipe thickness for downstream

$H_a = (H_b + H_o + H_1)/2$

$T = H_a * D_p/(2 * \sigma_{sa} * \eta) + \varepsilon$

$L_a = L_p - L_b$

TABLE 13 CALCULATION SHEET FOR PENSTOCK DIAMETER

Economical penstock diameter equation:

$$D = \left\{ \frac{5 * 78.4\ Tg * C_1 * f^2 \eta * \phi * Sa}{A * C_2 * \gamma * g * \pi^3 * p * (1+k_2)} \right\}^{1/7} * Q_p^{3/7}$$

where,

- D : Economical penstock diameter (m)
- Tg : Annual operational hour = 365 days * 12 hrs/day = 4,380 hrs. (Assuming 12 hrs peak operation)
- C_1 : Energy cost at power plant = 1.2 ₱/KWh = 0.0591 $/KWh
- f : Manning's roughness = 0.014
- η : Power plant efficiency = 0.84
- ϕ : Stress decrease ratio due to connecting effect = 0.9
- A : Ratio of operation and maintenance cost, construction cost interest and so on, to construction cost = 0.1
- Sa : Allowable stress of steel = 1,200 kg/cm² (SM41 property in JIS)
- C_2 : Steel penstock construction unit cost = 4,000 $/ton
- γ : Unit weigth of steel = 7.8 t/m³
- g : Gravity acceleration = 9.8 m/sec²
- k_2 : Weight increase ratio due to accessories such as stiffner, flanges, rivets and so on = 0.2

The above variables are applied to the equation,

$$D = \left\{ \frac{5 * 78.4 * 4,380 * 0.0591 * 0.014 * 0.84 * 0.9 * 1,200}{0.1 * 4,000 * 7.8 * 9.8 * 3.1416^3 * p * (1+0.2)} \right\}^{1/7} * Q_p^{3/7}$$

$$= 1.018\ Q_p^{0.429} / p^{0.143}$$

where,

- p : Design water pressure (kg/cm²), assuming that total static head (m) (FSL - TWL) multiplied by 1.3
- Q_p : Peak discharge (m³/sec)

TABLE 14 WATERWAY COST COMPARISON (1/4)
(Run-of -river type scheme, draw down=0 m)

C_1 = Waterway cost with surge tank
C_2 = Waterway cost without surge tank
C_d = C_1 - C_2

(Unit: $*10^6$\$)

			L=100m	L=150	L=200	L=250	L=300	L=350	L=400
H=50m	Q=5 m³/s	C_1	0.118	0.168	0.218	0.270	0.322	0.375	0.427
		C_2	0.212	0.247	0.282	0.317	0.350	0.384	0.417
		C_d	-0.094	-0.080	-0.064	-0.047	-0.028	-0.009	0.011
	Q=10	C_1	0.221	0.313	0.408	0.505	0.602	0.700	0.798
		C_2	0.348	0.401	0.451	0.500	0.551	0.601	0.651
		C_d	-0.127	-0.088	-0.043	0.004	0.051	0.099	0.147
	Q=15	C_1	0.307	0.434	0.566	0.700	0.836	0.971	1.107
		C_2	0.468	0.534	0.598	0.660	0.721	0.783	0.845
		C_d	-0.160	-0.100	-0.031	0.041	0.115	0.188	0.262
	Q=20	C_1	0.384	0.544	0.709	0.876	1.046	1.215	1.386
		C_2	0.580	0.658	0.733	0.806	0.878	0.949	1.022
		C_d	-0.195	-0.115	-0.025	0.070	0.168	0.267	0.364
H=100m	Q=5	C_1	0.174	0.222	0.275	0.331	0.389	0.448	0.507
		C_2	0.259	0.302	0.337	0.372	0.409	0.440	0.474
		C_d	-0.084	-0.080	-0.062	-0.041	-0.017	0.008	0.034
	Q=10	C_1	0.303	0.386	0.478	0.576	0.677	0.779	0.882
		C_2	0.425	0.494	0.547	0.597	0.647	0.697	0.747
		C_d	-0.123	-0.109	-0.069	-0.021	0.030	0.082	0.135
	Q=15	C_1	0.408	0.520	0.645	0.777	0.912	1.050	1.190
		C_2	0.569	0.660	0.726	0.790	0.852	0.913	0.975
		C_d	-0.161	-0.140	-0.081	0.013	0.060	0.137	0.214
	Q=20	C_1	0.502	0.640	0.794	0.956	1.122	1.292	1.463
		C_2	0.704	0.814	0.893	0.968	1.041	1.113	1.184
		C_d	-0.202	-0.175	-0.100	-0.013	0.081	0.179	0.280
H=150m	Q=5	C_1	0.240	0.282	0.332	0.387	0.446	0.506	0.568
		C_2	0.360	0.360	0.404	0.439	0.474	0.508	0.542
		C_d	-0.121	-0.078	-0.072	-0.051	-0.028	-0.002	0.026
	Q=10	C_1	0.413	0.486	0.572	0.667	0.768	0.872	0.978
		C_2	0.596	0.596	0.665	0.717	0.768	0.817	0.868
		C_d	-0.183	-0.110	-0.093	-0.050	0.000	0.055	0.110
	Q=15	C_1	0.555	0.654	0.770	0.898	1.033	1.173	1.316
		C_2	0.798	0.798	0.889	0.956	1.019	1.081	1.142
		C_d	-0.243	-0.145	-0.119	-0.057	0.014	0.092	0.174
	Q=20	C_1	0.683	0.804	0.947	1.104	1.271	1.442	1.681
		C_2	0.985	0.985	1.096	1.175	1.249	1.322	1.394
		C_d	-0.302	-0.182	-0.149	-0.070	0.021	0.120	0.224

TABLE 14 WATERWAY COST COMPARISON (2/4)

			L=100m	L=150	L=200	L=250	L=300	L=350	L=400
H=200m	Q=5	C_1	0.317	0.354	0.401	0.454	0.511	0.571	0.634
		C_2	0.475	0.475	0.475	0.518	0.553	0.588	0.622
		C_d	-0.158	-0.120	-0.074	-0.065	-0.042	-0.017	0.011
	Q=10	C_1	0.547	0.611	0.691	0.783	0.881	0.985	1.093
		C_2	0.791	0.791	0.791	0.860	0.912	0.963	1.012
		C_d	-0.244	-0.180	-0.099	-0.077	-0.031	0.023	0.081
	Q=15	C_1	0.738	0.825	0.933	1.056	1.190	1.330	1.476
		C_2	1.064	1.064	1.064	1.154	1.221	1.284	1.346
		C_d	-0.326	-0.239	-0.130	-0.098	-0.031	0.046	0.129
	Q=20	C_1	0.909	1.017	1.150	1.302	1.466	1.639	1.819
		C_2	1.314	1.314	1.314	1.424	1.503	1.578	1.651
		C_d	-0.404	-0.297	-0.163	-0.122	-0.037	0.062	0.168

TABLE 14 WATERWAY COST COMPARISON (3/4)
(Reservoir type scheme, Drawdown depth=20 m)

C_1 = Waterway cost with surge tank
C_2 = Waterway cost without surge tank
C_d = C_1 - C_2

(Unit: $x10^6$\$)

			L=200m	L=300	L=400	L=500	L=600	L=700	L=800
H=70m	Q=50m³/s	C_1	1.365	2.040	2.731	3.429	4.129	4.832	5.535
		C_2	2.619	2.901	3.175	3.452	3.732	4.008	4.280
		C_d	-1.254	-0.861	-0.444	-0.023	0.397	0.824	1.255
	Q=100	C_1	2.531	3.783	5.064	6.358	7.657	8.960	10.264
		C_2	4.314	4.754	5.178	5.593	6.024	6.455	6.879
		C_d	-1.783	-0.971	-0.113	0.765	1.634	2.505	3.385
	Q=200	C_1	4.625	6.911	9.253	11.616	13.990	16.369	18.753
		C_2	7.280	7.998	8.685	9.354	10.015	10.721	11.414
		C_d	-2.656	-1.087	0.568	2.262	3.975	5.648	7.339
	Q=300	C_1	6.550	9.788	13.104	16.451	19.813	23.183	26.559
		C_2	9.979	10.941	11.858	12.747	13.620	14.541	15.470
		C_d	-3.429	-1.153	1.247	3.703	6.193	8.642	11.089
H=120	Q=50	C_1	1.693	2.384	3.118	3.871	4.634	5.403	6.175
		C_2	2.984	3.273	3.550	3.821	4.104	4.381	4.655
		C_d	-1.291	-0.889	-0.432	0.050	0.531	1.021	1.519
	Q=100	C_1	2.747	3.869	5.061	6.283	7.522	8.769	10.022
		C_2	4.972	5.426	5.856	6.275	6.694	7.129	7.557
		C_d	-2.224	-1.557	-0.795	0.008	0.828	1.640	2.466
	Q=200	C_1	4.855	6.836	8.943	11.103	13.291	15.496	17.710
		C_2	8.454	9.200	9.899	10.576	11.239	11.925	12.624
		C_d	-3.599	-2.363	-0.956	0.527	2.053	3.571	5.086
	Q=300	C_1	6.773	9.537	12.476	15.490	18.542	21.617	24.706
		C_2	11.627	12.631	13.566	14.468	15.348	16.232	17.170
		C_d	-4.855	-3.094	-1.091	1.022	3.194	5.385	7.536
H=170	Q=50	C_1	2.028	2.683	3.410	4.171	4.951	5.742	6.540
		C_2	3.442	3.744	4.026	4.300	4.577	4.857	5.133
		C_d	-1.413	-1.061	-0.616	-0.128	0.374	0.885	1.407
	Q=100	C_1	3.345	4.426	5.625	6.880	8.167	9.471	10.787
		C_2	5.801	6.282	6.721	7.145	7.560	7.991	8.422
		C_d	-2.456	-1.856	-1.096	-0.265	0.606	1.480	2.364
	Q=200	C_1	5.870	7.766	9.870	12.073	14.330	16.619	18.928
		C_2	9.942	10.739	11.457	12.143	12.812	13.474	14.180
		C_d	-4.072	-2.973	-1.586	-0.070	1.518	3.145	4.748
	Q=300	C_1	8.165	10.803	13.729	16.793	19.933	23.116	26.327
		C_2	13.721	14.801	15.764	16.680	17.569	18.442	19.363
		C_d	-5.556	-3.999	-2.035	0.114	2.363	4.674	6.965

TABLE 14 WATERWAY COST COMPARISON (4/4)

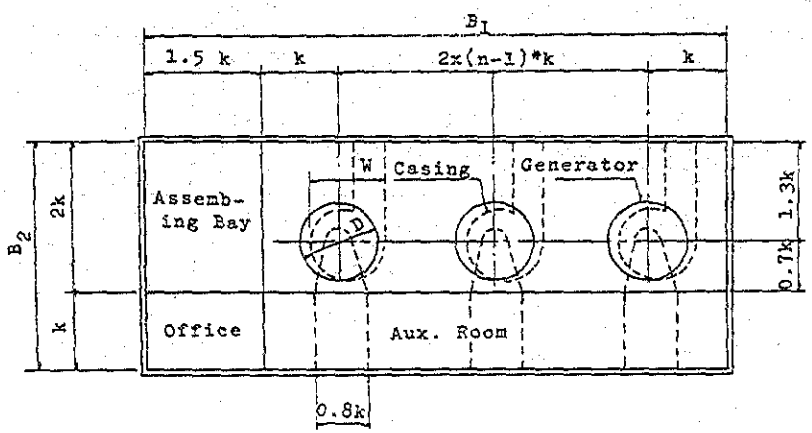
(Reservoir type scheme, Drawdown depth=50 m)

C_1 = Waterway cost with surge tank
C_2 = Waterway cost without surge tank
C_d = C_1 - C_2

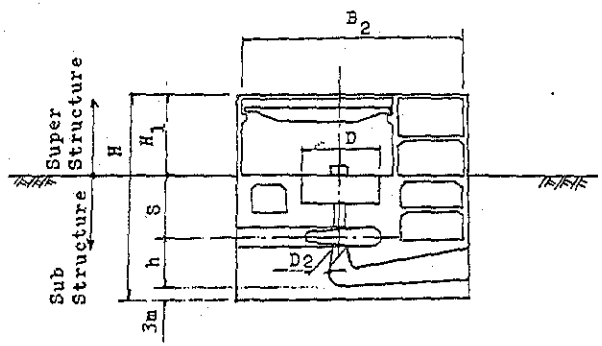
(Unit: x 10^6\$)

			L=200m	L=300	L=400	L=500	L=600	L=700	L=800
H=70m	Q=50m³/s	C_1	2.038	3.196	4.394	5.606	6.825	8.048	9.273
		C_2	4.134	4.413	4.685	4.966	5.244	5.519	5.790
		C_d	-2.097	-1.217	-0.291	0.640	1.581	2.529	3.482
	Q=100	C_1	4.008	6.286	8.642	11.027	13.424	15.829	18.239
		C_2	6.577	7.011	7.431	7.845	8.282	8.711	9.134
		C_d	-2.569	-0.725	1.211	3.181	5.142	7.118	9.105
	Q=200	C_1	7.625	11.959	16.442	20.978	25.540	30.115	34.698
		C_2	10.697	11.403	12.083	12.748	13.425	14.126	14.816
		C_d	-3.072	0.556	4.359	8.230	12.115	15.988	19.882
	Q=300	C_1	11.001	17.254	23.722	30.267	36.848	43.449	50.062
		C_2	14.344	15.289	16.196	17.080	17.948	18.891	19.815
		C_d	-3.343	1.965	7.526	13.187	18.900	24.558	30.247
H=120	Q=50	C_1	1.881	2.716	3.624	4.561	5.513	6.474	7.439
		C_2	4.547	4.831	5.106	5.381	5.662	5.938	6.211
		C_d	-2.665	-2.115	-1.482	-0.819	-0.149	0.535	1.228
	Q=100	C_1	3.070	4.432	5.913	7.443	8.997	10.564	12.139
		C_2	7.319	7.764	8.190	8.607	9.033	9.466	9.891
		C_d	-4.250	-3.332	-2.277	-1.164	-0.036	1.098	2.247
	Q=200	C_1	5.490	7.925	10.574	13.309	16.087	18.889	21.706
		C_2	12.022	12.749	13.440	14.112	14.771	15.472	16.167
		C_d	-6.532	-4.824	-2.866	-0.803	1.316	3.417	5.538
	Q=300	C_1	7.704	11.122	14.840	18.679	22.578	26.511	30.464
		C_2	16.204	17.181	18.104	18.998	19.873	20.700	21.713
		C_d	-8.500	-6.058	-3.264	-0.319	2.705	5.731	8.751
H=170	Q=50	C_1	2.150	2.867	3.690	4.562	5.460	6.372	7.294
		C_2	5.037	5.331	5.609	5.881	6.162	6.441	6.715
		C_d	-2.887	-2.463	-1.919	-1.319	-0.702	-0.068	0.579
	Q=100	C_1	3.565	4.754	6.119	7.565	9.053	10.565	12.093
		C_2	8.207	8.669	9.103	9.524	9.937	10.374	10.803
		C_d	-4.642	-3.915	-2.984	-1.959	-0.885	0.191	1.290
	Q=200	C_1	6.294	8.393	10.803	13.355	15.982	18.653	21.350
		C_2	13.613	14.375	15.081	15.761	16.426	17.103	17.805
		C_d	-7.319	-5.981	-4.278	-2.406	-0.444	1.550	3.546
	Q=300	C_1	8.783	11.712	15.074	18.636	22.302	26.029	29.793
		C_2	18.445	19.473	20.418	21.325	22.209	23.077	24.019
		C_d	-9.662	-7.761	-5.344	-2.689	0.094	2.952	5.774

TABLE 15 CALCULATION SHEET FOR POWER HOUSE DIMENSION



Power House Plan



Power House Section

1. Power House Length and Width

$B_1 = 1.5 * k + 2 * n * k$

$B_2 = 3 * k$

$k = D = 8 * H_d^{-0.08} * P_e^{0.13}$ (High head power plant)

or

$(W + 7)/2 : W = 14 * (P_e/H_d)^{0.5}$ (Lower head power plant)

(k is to be bigger dimension of the above)

where,

B_1 : Power house length (m)

B_2 : Power house width (m)

n : Generator nos.

D : Generator dia. (m)

W : Turbine casing width (m)

P_e : Installed power capacity (MW)

H_d : Design head

2. Power House Height

$H_1 = P_e^{0.21} + 5$

$S = 0.8367 * P_e^{0.1767} + 0.287 * P_e^{0.2796}$

$h = 2.7 * D_2$

$D_2 = D_1 * (0.04478 * N_s^{0.6091})$

$D_1 = 84.6 * k_u * H_d^{0.5}/N$

$k_u = 0.834 - 10.66/N_s$

$N_s = 2419/H_d^{0.489}$

where,

H_1 : Super-structure height (m)

S : Height from casing center to floor (m)

h : Height from casing center to draft tube bottom (m)

P_e : Installed power capacity (KW)

D_2 : Runner outlet diameter. (m)

D_1 : Runner inlet diameter (m)

k_u : Runner circumference speed coefficient

N_s : Specific speed (m-kw)

N : Revolution speed = 400 RPM

TABLE 16 ROUGH ESTIMATION OF POWER HOUSE DIMENSION (1/2) (ROR. TYPE)

River	Scheme	Pmax (MW)	Unit* Unit Cap. (MW)	Head (m)	W (m)	D (m)	Ns (m-KW)	D_1 (m)	D_2 (m)	h (m)	S (m)	H_1 (m)	B_1 (m)	B_2 (m)	H (m)	Remarks
Naguilian	Naguilian	37.2	4x9.3	301.1	2.4	6.8	148	2.8	2.6	7.1	7.9	11.8	64.3	20.3	29.8	
Amburayan	Luya	39.6	4x9.9	119.4	4.0	7.4	233	1.8	2.3	6.1	8.0	11.9	69.8	22.1	29.0	
	Bakum	33.9	4x8.5	407.0	2.0	6.5	128	3.2	2.8	7.4	7.7	11.7	62.1	19.6	29.9	
	Amburayan	10.7	4x15.3	214.2	3.7	7.4	175	2.4	2.5	6.7	8.8	12.6	70.5	22.3	31.1	
Abra	Abra	10.7	2x5.3	189.2	2.3	6.5	186	2.3	2.4	6.6	6.9	11.1	35.9	19.6	27.6	
Apayao	Apayao	15.7	3x5.2	135.8	2.7	6.7	219	1.9	2.3	6.2	6.9	11.0	50.2	20.1	27.2	
Chico	Chico-1R	26.6	2x13.3	63.4	6.4	8.0	318	1.3	2.0	5.4	8.6	12.3	44.1	24.1	29.4	Combined with Sadanga.
	Chico-1R	26.4	2x13.2	62.9	6.4	8.0	319	1.3	2.0	5.4	8.5	12.3	44.2	24.1	29.4	
	Chico-2R	33.4	2x16.7	109.1	5.5	7.9	244	1.7	2.2	6.0	9.0	12.7	43.6	23.8	30.7	
	Chico-3R	17.8	2x8.9	81.5	4.6	7.5	281	1.5	2.1	5.7	7.8	11.8	41.1	22.4	28.3	
	Chico-4R	11.8	2x5.9	112.5	3.2	6.9	240	1.8	2.2	6.0	7.1	11.2	38.0	20.7	27.4	
Saltan	Saltan	12.1	2x6.1	201.7	2.4	6.6	181	2.3	2.5	6.7	7.2	11.2	36.4	19.9	28.1	
Pasil	Pasil	20.0	2x10.0	329.1	2.4	6.8	142	2.9	2.7	7.2	8.0	11.9	37.3	20.4	30.2	
Tanudan	Tanudan	24.5	2x12.3	249.9	3.1	7.1	163	2.6	2.6	6.9	8.4	12.2	39.2	21.4	30.5	
Ibulao	Ibulao	16.3	3x5.4	254.1	2.0	6.4	161	2.6	2.6	6.9	6.9	11.1	48.0	19.2	28.0	
Casecnan	Casecnan	11.2	3x3.7	89.8	2.8	6.6	268	1.6	2.1	5.8	6.4	10.6	49.6	19.9	25.8	
	Up. Casecnan	12.2	3x4.1	112.7	2.7	6.6	240	1.8	2.2	6.0	6.6	10.7	49.4	19.8	26.4	
Agno	Agno-2	10.5	4x2.6	148.5	1.9	6.1	209	2.0	2.3	6.3	5.9	10.2	57.7	18.2	25.5	
	Agno-3	9.3	4x2.3	183.0	1.6	5.9	189	2.2	2.4	6.6	5.8	10.1	55.8	17.6	25.4	

TABLE 16 ROUGH ESTIMATION OF POWER HOUSE DIMENSION (2/2) (RES. TYPE)

	Scheme	Abbriv.	Pmax (MW)	Unit* Unit Cap. (MW)	Head (m)	W (m)	D (m-KW)	Ns (m)	D_1 (m)	D_2 (m)	h (m)	S (m)	H_1 (m)	B_1 (m)	B_2 (m)	H (m)	Remarks
Abra	Supo	SPo	142.2	2x71.1	99.5	11.8	9.6	255	1.7	2.2	5.9	12.5	15.4	53.0	28.9	36.9	
	Eteb	ETo	107.0	2x53.5	82.5	11.3	9.4	280	1.5	2.1	5.7	11.8	14.8	51.9	28.3	35.3	
	Supo	ETo+SP_1	99.8	2x49.9	78.1	11.2	9.4	287	1.5	2.1	5.7	11.6	14.7	51.6	28.2	34.9	
Abulog	Siriritan	SSo	417.6	4x104.4	75.9	16.4	10.4	291	1.5	2.1	5.6	13.7	16.3	111.2	35.1	38.7	
	Bulu	BLo	408.1	4x102.0	118.2	13.0	10.0	234	1.8	2.3	6.1	13.6	16.3	95.0	30.0	39.0	
	Nababa-rayan	NAo	304.2	4x76.1	118.6	11.2	9.6	234	1.8	2.3	6.1	12.7	15.6	91.1	28.8	37.4	
	Dibagat	DIo	301.7	4x75.4	156.4	9.7	9.4	204	2.1	2.4	6.4	12.7	15.6	89.0	28.1	37.7	
	Agbulu	AGo	215.9	3x72.0	135.3	10.2	9.4	219	1.9	2.3	6.2	12.6	15.5	70.6	28.2	37.3	
	Sisiritan	AGo+BL_1 + SS_1	199.2	2x99.6	50.7	19.6	10.6	355	1.2	1.9	5.2	13.6	16.2	73.2	40.0	38.0	
	Sisiritan	AGo+SSo	389.4	4x97.4	75.9	15.9	10.3	291	1.5	2.1	5.6	13.5	16.2	108.6	34.3	38.3	
	Bulu	AGo+BL_1	356.5	4x89.1	82.8	14.5	10.1	279	1.5	2.1	5.7	13.2	16.0	102.2	32.3	37.9	
Chico	Basao	SD_1+BS_1	163.2	2x81.6	148.5	10.4	9.5	211	2.0	2.3	6.3	13.0	15.8	52.3	28.5	38.0	
	Sadanga	SDo	238.4	3x79.5	186.1	9.2	9.3	188	2.2	2.4	6.6	12.9	15.7	69.8	27.9	38.1	
	Sadanga	SD_1	301.8	4x75.5	232.0	8.0	9.1	169	2.5	2.5	6.8	12.7	15.6	86.2	27.2	38.1	
Paret	Bantay	BTo	39.8	2x19.9	34.9	10.6	8.9	426	1.0	1.8	4.9	9.4	13.0	48.9	26.6	30.3	
Ilagan	Maliano	MLo	175.4	2x87.7	123.9	11.8	9.7	229	1.8	2.3	6.1	13.2	15.9	53.5	29.2	38.2	
Agno	Tabu	BGo+B_1	134.4	2x67.2	103.1	11.3	9.5	251	1.7	2.2	5.9	12.4	15.3	52.5	28.6	36.7	
Agos	Kanan	KNo	213.5	3x71.2	168.5	9.1	9.2	197	2.1	2.4	6.5	12.5	15.4	69.3	27.6	37.5	
	Up. Agos 2	UA2o	135.2	2x67.6	131.0	10.1	9.4	223	1.9	2.3	6.2	12.4	15.3	51.5	28.1	36.9	
	Kanan	UA2o+KN_1	77.2	2x38.6	51.5	12.1	9.4	352	1.2	1.9	5.2	10.9	14.2	52.6	28.7	33.3	
Mari-kina	Wawa	WAo	60.3	2x30.2	109.9	7.3	8.6	243	1.8	2.2	6.0	10.3	13.7	47.1	25.7	33.1	
Labo	Bosigon	BSo	44.4	2x22.2	47.3	9.6	8.8	357	1.2	1.9	5.2	9.6	13.2	48.4	26.4	31.0	

TABLE 17 CALCULATION SHEET FOR WORK QUANTITY (1/10)

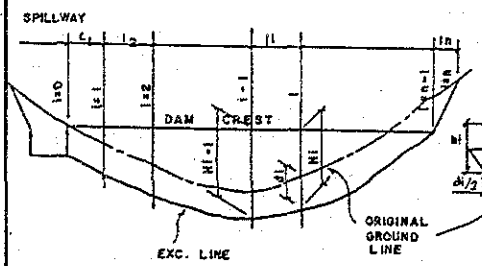
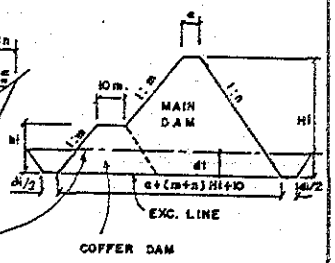
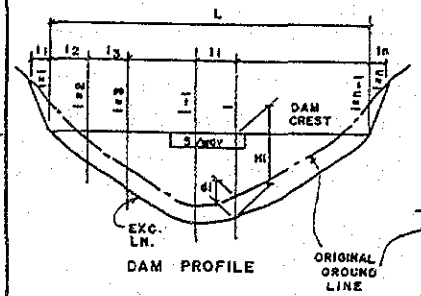
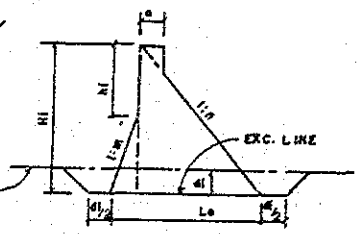
	QUANTITY FORMULA	SYMBOLS	SKETCH & REMARKS
I. STORAGE DAM	(1) Dam volume (i) Fill dam (Rockfill & earth-fill) $V_{df} = \Sigma(A_{i-1}+A_i)*l_i/2$ $A_i = [a+(m+n)*H_i/2]*H_i+10*h_i$	V_{df}: Embankment volume, (m^3) i : Cross section no., i=1 to n, $n \leq 15$ A_i : Cross sectional area at section i, (m^2) l_i : Interval between cross section i=1 and i, (m) H_i : Dam height at cross section i, (m) m : Upstream embankment slope n : Downstream embankment slope a : Crest width, (m) h_i : Coffer dam height at cross section i, (m)	 DAM PROFILE  DAM CROSS SECTION
	(ii) Concrete gravity dam $V_{dc} = \Sigma(A_{i-1}+A_i)*l_i/2+(a^2*L)/(n*2)$ $A_i = [(H_i-h_i)^2*m+H_i^2*n]/2$, if $H_i > h_i$ $A_i = H_i^2*n/2$, if $H_i \leq h_i$	V_{dc}: Concrete volume, (m^3) i : Cross section no., i=1 to n, $n \leq 15$ A_i : Cross sectional area at section i, (m^2) l_i : Interval between cross sections i=1 and i, (m) H_i : Dam height at cross section i h_i : Height from the top of fillet to dam crest, (m) m : Upstream fillet slope n : Downstream slope a : Crest width (m) L : Dam crest length (m)	 DAM PROFILE  DAM CROSS SECTION
	(2) Dam excavation volume (i) Fill dam $V_{ef} = \Sigma(A_{i-1}+A_i)*l_i/2$ $A_i = [a+(m+n)*H_i+10+d_i]*d_i$	V_{ef}: Excavation volume, (m^3) d_i : Excavation depth at cross section i, (m) Other symbols are same as those for dam volume calculation.	(Ref. to above fig.)
	(ii) Concrete gravity dam $V_{ec} = \Sigma(A_{i-1}+A_i)*l_i/2$ $A_i = (L_o+d_i)*d_i$ $L_o = m*(H_i-h_i)+n*H_i+d_i$, if $H_i > h_i$ $L_o = n*H_i+d_i$, if $a/n < H_i \leq h_i$ $L_o = a+d_i$, if $H_i \leq a/n$	V_{ec}: Excavation volume, (m^3) d_i : Excavation depth at cross section i, (m) L_o : Excavation width at bottom Other symbols are same as those for dam volume calculation.	

TABLE 17 CALCULATION SHEET FOR WORK QUANTITY (2/10)

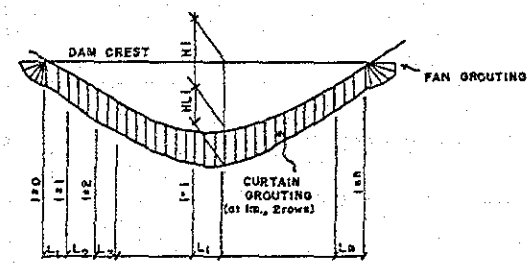
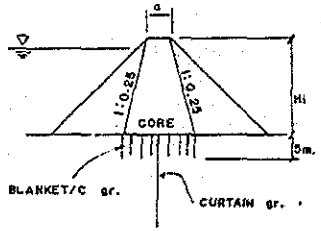
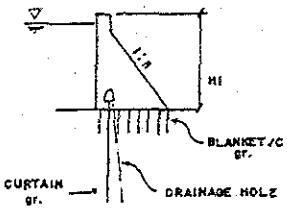
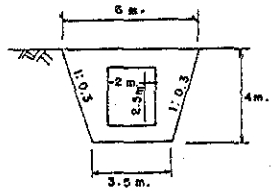
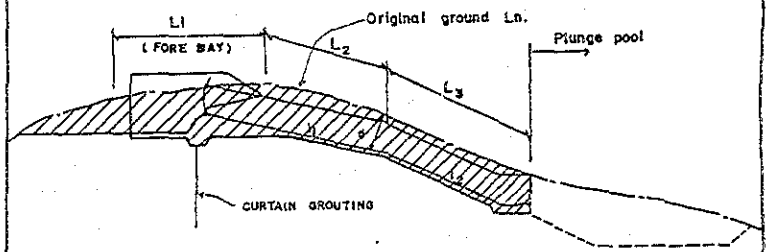
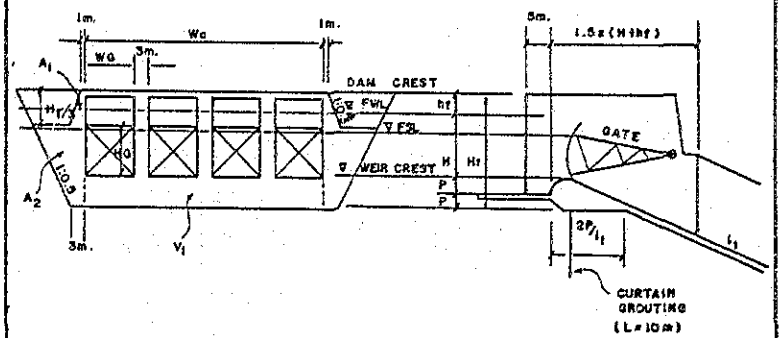
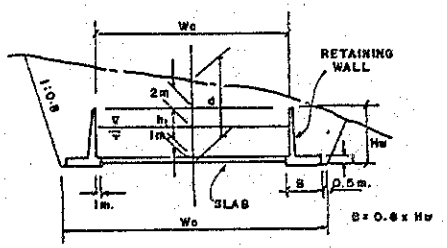
	QUANTITY FORMULA	SYMBOLS	SKETCH & REMARKS
1. STORAGE DAM	3) Grouting (i) Curtain grouting (@ 2m, 2 rows) $CG = \sum[(HL_{i-1}+HL_i)*l_i/2] + l_m*N$ $HL_i = 0.4*H_i + l_g \geq 15m$, if $H_i \geq 15m$ (conc. dam) $HL_i = 0.4*H_i \geq 10m$, if $H_i < 15m$, (conc. dam) $HL_i = 0.4*H_i \geq 10m$, (Fill dam)	CG : Total curtain grouting length (m) i : Cross section no., i=1 to n HL_i : Hole length at section i, (m) l_g : Drilling in dam body, assumed at 5m length l_m : Fan grouting length = 10m N : Fan grouting nos. = 20 H_i : Dam height at section i, (m) l_i : Intervals between sections (m)	
	(ii) Blanket/consolidation grouting - For filldam (@ 4m, d=5m) $BG = \sum((a+0.5*H_i)*l_i/16*5)$ - For concrete dam (@4m, d=10m) $BG = \sum(n*H_i*l_i/16*10)$	BG : Blanket/consolidation grouting length (m) Other symbols are same as those for curtain grouting. n : Dam downstream slope Other symbols are same as those for curtain grouting.	 FILL DAM  CONCRETE DAM
	(4) Drainage holes (Concrete dam) (@ 10m) $DH = \sum(HL_{i-1}+HL_i)*l_i/20$	DH : Drainage holes length (m). Other symbols are same as those for curtain grouting.	
	(5) Inspection gallery (Fill dam) $V_c = 14*L$ $W_s = 0.1*V_c$ $V_e = 19*L$	V_c : Concrete volume (m^3) W_s : Re-bar weight (ton) V_e : Trench exc. volume (m^3) L : Gallery length (m)	 EXC. AREA = 19 m.2 CONC. AREA = 14 m2
2. SPILLWAY	(1) Excavation volume $V_{es} = d*(W_o+d*0.8)*L_o$ $W_o = W_c+2*B-1$	V_{es} : Excavation volume excepting plunge pool(m^3) L_o : Spillway length = $L_1+L_2+L_3$ (L_1 is to be representative length for forebay excavation volume). (m) d : Average excavation depth (m) W_o : Excavation width (Ref. to 2(2)(ii)), (m) B : Footing width of retaining wall (Ref. to 2.(2)(ii)), (m) W_c : Waterway width (m)	

TABLE 17 CALCULATION SHEET FOR WORK QUANTITY (3/10)

	QUANTITY FORMULA	SYMBOLS	SKETCH & REMARKS
2. SPILLWAY	(2) Concrete volume & re-bar weight (i) Overflow weir concrete $V_{ow} = V_1+V_2+V_3$ $V_1 = 2*P*P*W_c/i_1$ $V_2 = (A_1+A_2)*(10+3*(H+h_f))$ $A_1 = (1+0.05H_t)*H_t/3$ $A_2 = (2+H_t/9)*H_t$ $V_3 = 4.5*(H+P+h_f)*(H+h_f)*(N_g-1)$ If, $N_g = 0$ (Non-gated) then $V_3' = 30*(H+h_f)*INT(W_c/30)$ If $W_c \leq 30$, $V_3 = 0$	V_{ow} : Concrete volume for overflow weir structure (m^3) V_1 : Weir concrete volume, (m^3) V_2 : Abutment concrete volume (m^3) V_3 : Pier concrete volume (m^3) H : Flood water overflow depth (m) P : Height of weir (assumed at H/5) (m) h_f : Free board (1.5m) W_c : Weir width (m) N_g : Gate numbers V_3' : Bridge pier concrete volume in case of non-gated weir. Pier dimension = 3m*10m. Max. bridge span = 30m. H_t : Total height = h_f+H+2*P (m) i_1 : Chuteway slope	
	(ii) Chuteway concrete $V_{cw} = V_s+V_w$ $V_s = (W_c-2)*(L_2+L_3)$ $V_w = \Sigma (6*H_w-20)*L_i$ $H_w = h_1+3$	V_{cw} : Chuteway concrete volume (m^3) W_c : Chuteway width (m) V_w : Retaining wall volume (m^3) H_w : Retaining wall height (m) (Min.=4m) h_1 : Design flood uniform flow depth V_s : Chuteway slab volume (m^3) L_i : Chuteway length (m)	 RETAINING WALL VOLUME V = 3xHw - 10 (m^3/m)
	(iii) Re-bar weigth $W_r = W_{ow}+W_s+W_w$ $W_{ow} = V_{ow}*0.04$ $W_s = V_s*0.015$ $W_w = \Sigma (12*H_w+20)*V_w*0.001$	W_r : Re-bar weight (ton) W_{ow} : Re-bar weight for overflow weir (ton) W_s : Re-bar weight for chuteway slab (ton) W_w : Re-bar weight for chuteway wall (ton)	W = 6xHw+10 (kg./m^3) ∠1: RE-BAR WEIGHT per UNIT LENGTH WALL ∠2: RE-BAR WEIGHT per UNIT CONCRETE VOLUME (Ref. to 2.(2)(i))
	(3) Gates $WG = (7.4-1.4*HG+0.12*HG^2)*WG*NG$	WG : Weight of gates (ton) HG : Gate height (m) WG : Gate width (m) NG : Gate numbers (nos.)	

Hw (m)	Re-bar∠1 (kg/m)	Re-bar∠2 (kg/m^3)
5	190	42
10	977	59
15	3,528	103

TABLE 17 CALCULATION SHEET FOR WORK QUANTITY (4/10)

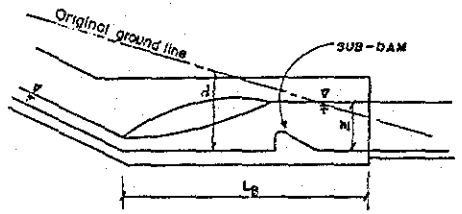
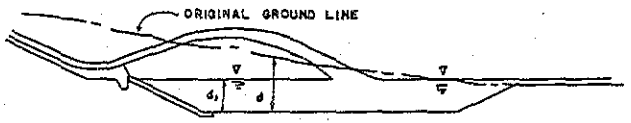
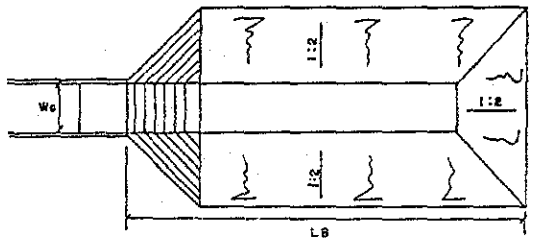
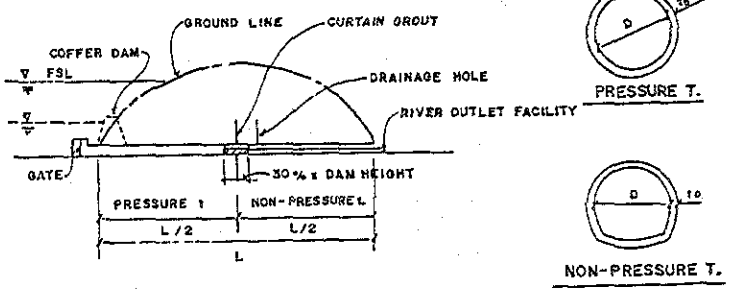
	QUANTITY FORMULA	SYMBOLS	SKETCH & REMARKS
2. SPILLWAY	(4) Curtain grouting (@ 2m, 2 rows, 10m depth) $CG = 10*(W_c+10)$ (5) Energy dissipator (i) Sub-dam type (Mainly for conc. dam) $VCB = [2.0*W_c+(0.15*h_2+2.5)*(h_2+3.0)]*LB$ $WS = VCB*0.06$ $VE = d*W_c*LB$ (ii) Ski-jump type (Mainly for fill dam) $VE = (W_c+2*d)*L_B*d$ $VC = \sqrt{5}*W_c*d_1*2$ $WS = 0.03*VC$ $L_B = 125*Q^{0.03}$ $d_1 = 0.1*L_B$	CG : Curtain grouting length (m) W_c : Spillway width (m) VCB : Stilling basin conc. vol. (m^3) W_c : Chuteway width (m) LB : Length of stilling basin (m) h_2 : Flow depth after hydraulic jump (m) WS : Re-bar weight VE : Excavation volume (m^3) d : Average excavation depth (m) VE : Excavation volume VC : Concrete volume WS : Re-bar weight d : Average exc. depth L_B : Plunge pool length W_c : Chuteway width	(Ref. to 2.(2)(i))   
3. RIVER DIVERSION	(1) Diversion tunnel $VET = (0.8*(D+2*t_o)^2*L/2)*N$ (Pressure t.) $(0.84*(D+2*t_o)^2*L/2)*N$ (Non-pressure t.) $VCT = VET-(0.8*D^2*L/2)*N$ (Pressure t.) $VET-(0.84*D^2*L/2)*N$ (Non-pressure t.) $t_o = 0.75-0.5/\sqrt{D/2}$ (Pressure t.) $0.6-0.4/\sqrt{D/2}$ (Non-pressure t.) $RST = 0.06*VCT$ (Pressure t.) $0.005*VCT$ (Non-pressure t.)	VET : Tunnel excavation volume (m^3) VCT : Tunnel lining concrete volume (m^3) RST : Re-bar weight (ton) L : Tunnel length (m) N : Tunnel nos. t_o Lining thickness (m) D : Tunnel diameter (m)	

TABLE 17 CALCULATION SHEET FOR WORK QUANTITY (5/10)

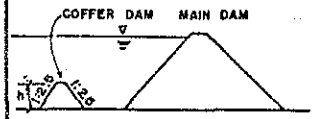
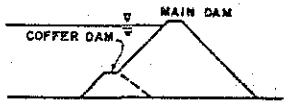
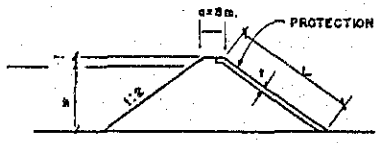
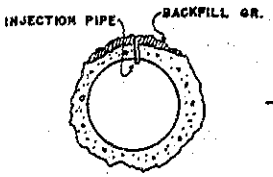
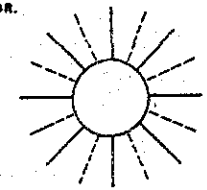
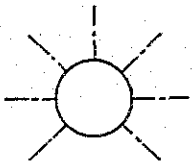
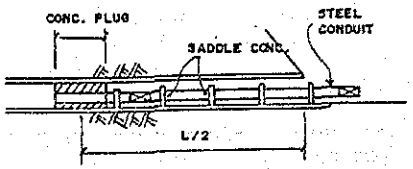
	QUANTITY FORMULA	SYMBOLS	SKETCH & REMARKS
3. RIVER DIVERSION	(2) Coffer dam (i) Independent coffer dam from fill type main dam VCF = (2.5*h+10)*h*LCF*$\frac{2}{3}$	VCF : Cofferdam volume (m^3) h : Cofferdam height (m) LCF : Cofferdam crest length (m)	 INDEPENDENT C. DAM CREST WIDTH at a=10m. $A = \frac{10 \times 2 \times 2.5h + 10}{2} h$ =(2.5h+10)h  INTEGRATED C. DAM COFFER DAM VOLUME IS TO BE COMPUTED AS PART OF MAIN DAM (REF. TO I(1)(i))
	(ii) For concrete dam VCF = (2*h+8)*h*LCF*$\frac{2}{3}$ VPB = $\frac{2}{3}$ *LCF*L VPC = $\frac{2}{3}$ *LCF*L*0.5	VCF : Cofferdam volume (m^3) VPB : Crib slope protection (m^3) VPC : Concrete slope protection (m^3) L : Slope length Other symbols are same as above	 A=((8+4xh+8)/2)xh =(2h+8)h $L = \sqrt{h^2 + 4h^2} + a/2$ $= \sqrt{5}h + 4$ t = 2m (1m. FOR CRIB 0.5m. FOR CONCRETE)
	(3) Grouting (i) Backfill grout Cost will be computed by applying Unit cost per tunnel unit length (Ref. to)		 BACKFILL GROUT WILL BE MADE THROUGH WHOLE TUNNEL LENGTH. BACKFILL GROUT
	(ii) Curtain grout LCG = 16*H*N	LCG : Curtain grout length (m) H : Dam height (m) N : Tunnel nos.	 AT 45°±4 ROWS = 32 NOS. L = DAM HEIGHT x 50% CURTAIN GROUT
	(iii) Drainage hole LDH = 3.5*H*N	LDH : Drainage hole length (m)	 7 NOS. L= DAM HEIGHT x 50% DRAINAGE HOLE
	(4) River outlet facility WCP = 12.33*(D*t+t^2)*n*$\frac{L}{2}$	WCP : Conduit pipe weight (ton) t : Pipe thickness = (D+0.8)/400 (m) (t_{min} = 0.006m) D : Conduit pipe dia. = 0.5*Tunnel dia. (m) L : Tunnel length (m) n : Conduit pipe nos.	 CONDUIT PIPE NOS. $F = \frac{0.0122 \times L}{D^{4/3}}$ $V = \sqrt{\frac{gH}{1.2+F}}$ (H: DAM HEIGHT) $N = \frac{\text{RES. VOLUME}}{A \times V \times 604800 \text{ (1 WEEK)}}$ (Nmax = TUNNEL NOS.)

TABLE 17 CALCULATION SHEET FOR WORK QUANTITY (6/10)

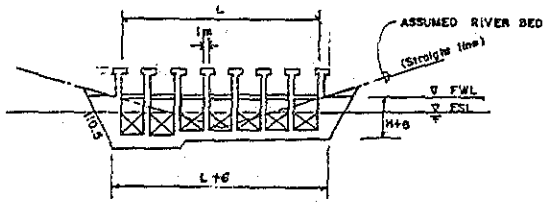
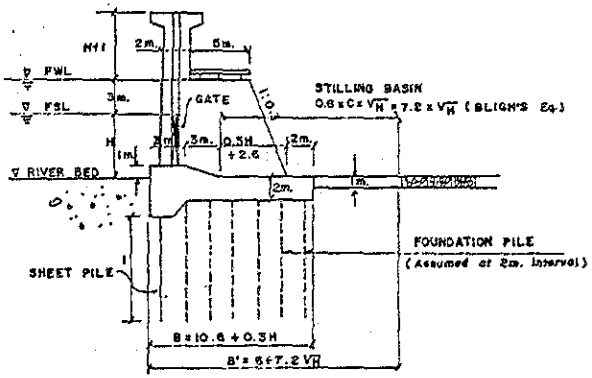
	QUANTITY FORMULA	SYMBOLS	SKETCH & REMARKS
3. RIVER DIVERSION	(5) Tunnel plug & gates $VP = 0.24*D^2*H*N$ $WG = (-0.47+0.13*D^2-7.3*10^{-4}*D^4)*H*N$	VP : Plug concrete volume (m^3) WG : Gate weight (ton) D : Diversion tunnel diameter (m) H : Dam height N : Tunnel nos.	(REF. TO 3(1))
4. RIVER INTAKE WEIR	(1) Non-gated weir $VED = 0.285*(HDD*LDD)^{1.57}$ $VCD = 1.15*HDD^2*LDD$ $RSD = 0.01*VCD$	VED : Excavation volume (m^3) VCD : Concrete volume (m^3) RSD : Re-bar weight (ton) HDD : Height of dam above excavation line (m) LDD : Crest length	
	(2) Gated weir $VEW = (L+8)^2(H+4)(L-H-4)/4(H-L+4)^2 +(L+6)*B'$ or $VEW = Aex*B'$ $VCW = C_1+C_2+C_3+C_4$ $C_1 = (2*B+4.5)*L$ $C_2 = (0.5*H^2+12*H+54)*B'$ $C_3 = [(H+3)(B+4)*0.5+2*(H+1)]*N$ $C_4 = (B'-B)*L$ $B = 10.6+0.3H$ $B' = 6+7.2\sqrt{H}$ $RSW = VCW*0.05$ $WGW = (1.9-0.12*GH+0.07*GH^2)*GW*N$ $GH = H-1$ $SPA = 1*L=(2.5H-1.2\sqrt{H}-1)*L$ $FPL = (L+6)*B*(2.5H-1.2\sqrt{H})/4$	VEW : Excavation volume (m^3) VCW : Total concrete volume (m^3) C_1 : Sluiceway weir volume (m^3) C_2 : Abutment volume (m^3) C_3 : Pier volume (m^3) C_4 : Stilling basin, slab volume (m^3) L : Weir length (m) B : Weir width (m) B' : Weir width + stilling basin (m) H : Water depth at FSL (m) N : Gate nos. GH : Gate height (m) GW : Gate width (m) RSW : Re-bar weight (ton) WGW : Gate weight (ton) SPA : Sheet pile area (m^2) (Applicable only for floating weir) FPL : Foundation pile length (m) (Applicable only for floating weir) l : Sheet pile length A_{ex} : Excavation area measured in drwg. (m^2)	  LENGTH OF SHEET PILE (LANE'S Eq.) CREEP RATIO ASSUMED at 5. (COARSE SAND) $l = (C*H - 1/3\ B')/2$ $= 2.5H-1.2\sqrt{H}-1$
	(3) River coffering River coffering cost is assumed at 20% of the above work.		

TABLE 17 CALCULATION SHEET FOR WORK QUANTITY (7/10)

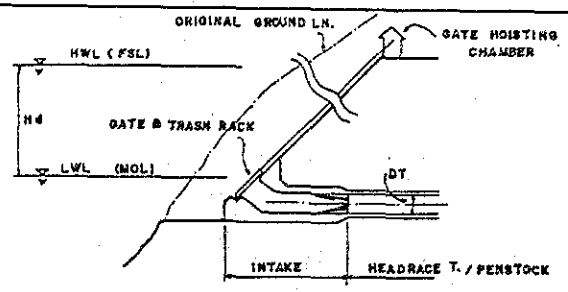
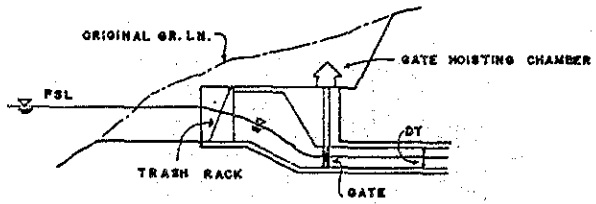
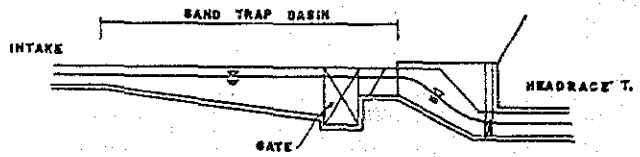
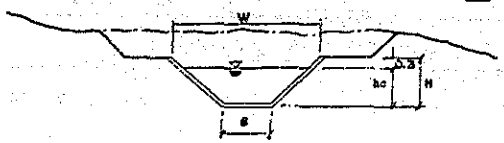
	QUANTITY FORMULA	SYMBOLS	SKETCH & REMARKS
5. INTAKE STRUCTURE	(1) Pressure type intake $VEI_p = 250*\left[(H_d+DT)*Q_p\right]^{0.5}*N^{1/3}$ $VCI_p = 90*\left[(H_d+DT)*Q_p\right]^{0.5}*N^{1/3}$ $RSI_p = 0.04*VCI_p$ $WGI_p = 0.9*(H_d+DT)^{1/9}*Q_p$ $WSI_p = 0.5*(H_d+DT)^{1/9}*Q_p$ (Where inlet structure is constructed in concrete dam, WGI_p and WSI_p are counted.)	VEI_p : Excavation volume (m^3) VCI_p : Concrete volume (m^3) RSI_p : Re-bar weight (ton) WGI_p : Gate weight (ton) WSI_p : Trashrack weight (ton) H_d : Reservoir drawdown depth DT : Tunnel diameter Q_p : Max. plant discharge (m^3/s) N : Intake nos.	
	(2) Non-pressure type intake $VEI_n = 200*(DT*Q_p/2)^{0.83}$ $VCI_n = 70*(DT*Q_p/2)^{0.86}$ $RSI_n = 0.04*VCI_n$ $WGI_n = 3.4*(DT*Q_p/2)^{1/2}$ $WGS_n = 1.3*(DT*Q_p/2)^{1/2}$	VEI_n : Excavation volume (m^3) VCI_n : Concrete volume (m^3) RSI_n : Re-bar weight (ton) WGI_n : Gate weight (ton) WGS_n : Trash rack (ton) DT : Tunnel diameter (Equivalent diameter in case of open channel) (m) Q_p : Max. plant discharge (m^3/s)	
	(3) Sand trap basin $VEB = 1{,}200*Q_p^{3/4}$ $VCB = 380*Q_p^{3/4}$ $RSB = 0.05*VCB$ $WGB = 2.0*(DT*Q_p/2)^{0.5}$ $WSB = 0.27*Q_p$	VEB : Excavation volume (m^3) VCB : Concrete volume (m^3) RSB : Re-bar weight (ton) WGB : Gate weight (ton) WSB : Trash rack weight (ton)	
6. HEADRACE	(1) Pressure/Non-pressure tunnel Same as diversion tunnel (Ref. to 3.(1))		TUNNEL DIAMETER : D (MANNINGS FORMULA) PRESSURE TUNNEL (CIRCULAR SEC.) $\frac{D}{2} = \left(\frac{n \cdot Q \cdot 2^{2/3}}{\pi \sqrt{I}}\right)^{3/8}$ $D = 1.07 \times q^{.375}$ [n = 0.014 (MANNING'S Roughness) I = 1/700 (Hydraulic gradient)] NON-PRESSURE TUNNEL (HORSE SHOE SEC.) $\frac{D}{2} = \left(\frac{nq}{2.2462\sqrt{I}}\right)^{3/8}$ $D = 1.09 \times q^{.375}$ [n = .014 I = 1/1000 (Tunnel slope)]
	(2) Open channel Excavation quantity shall be computed on a basis of cross section drawings. VCC = 0.25*(B+2.83*H)*LT RSC = 0.03*VCC	VCC : Concrete volume (m^3) RSC : Re-bar weight (ton) B : Channel width H : Channel height	

TABLE 17 CALCULATION SHEET FOR WORK QUANTITY (8/10)

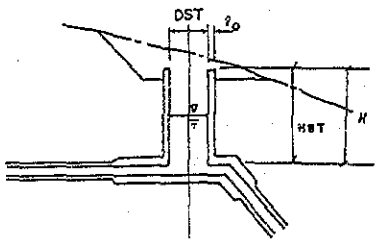
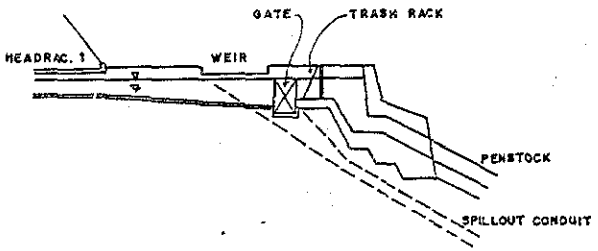
	QUALITY FORMULA	SYMBOLS	SKETCH & REMARKS
6. HEADRACE	(3) Grouting for tunnel (i) Backfill grout Cost will be computed by applying unit cost per tunnel unit length. (Ref. to).		Backfill grout will be made through whole tunnel length. (Ref. to 3.(3) (i))
	(ii) Curtain grout LCG = 32*H*N	LCG : Curtain grout length (m) H : (FSL-MOL)*0.5 (m) N : Tunnel nos.	(Ref. to 3. (3) (iii))
7. SURGE TANK / HEAD TANK	(1) Surge tank VES = $0.86*(DST+2*t_o)^2*H*N$ VCS = $3.44*(DST*to+to^2)*HST*N$ RSS = 0.06*VCS	VES : Excavation volume (m^3) VCS : Concrete volume (m^3) RSS : Re-bar weight (ton) DST : Diameter of surge tank=4*headrace tunnel dia. (m) HST : Height of surge tank (Ref. to Design Criteria) (m) t_o : Lining thickness = $1.2-0.8/\sqrt{DST}$ N : Surge tank nos. H : Shaft excavation depth (m)	
	(2) Head tank (i) Headtank VEH = $1,200*Q_p^{0.61}$ VCH = 0.3*VEH RSH = 0.03*VCH WGH = $0.5*Q_p$ WSH = $0.2*Q_p$	VEH : Excavation volume (m^3) VCH : Concrete volume (m^3) RSH : Re-bar weight (ton) WGH : Gate weight (ton) WSH : Trashrack weight (ton) Q_p : Max. plant discharge (m^3/s)	
	(ii) Spillout conduit VED = $12*DCD^{1.5}*LD$ VCD = $3.6*DCD^{0.96}*LD$ RSD = 0.03*VCD WCD = 12.3*DCD*t*LD DCD = $(Q_p/5.05)^{1/2}$ t = (DCD+0.8)/400	VED : Excavation volume (m^3) VCD : Concrete volume (m^3) RSD : Re-bar weight (ton) WCD : Weight of conduit (ton) DCD : Diameter of conduit (m) t : Conduit thickness (m) LD : Conduit length (m)	

TABLE 17 CALCULATION SHEET FOR WORK QUANTITY (9/10)

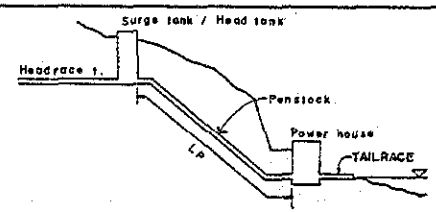
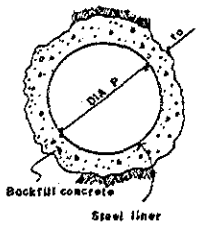
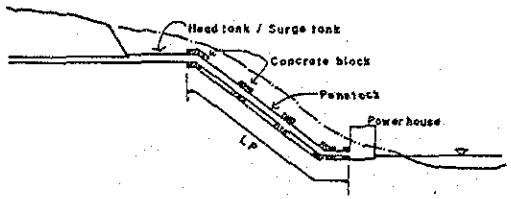
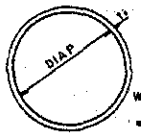
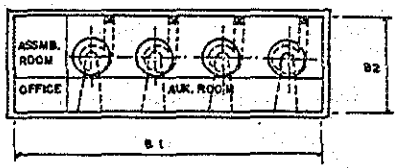
	QUANTITY FORMULA	SYMBOLS	SKETCH & REMARKS
8. PENSTOCK	(1) Tunnel shaft $VEP = 0.8*(DIAP+t_o)^2*LP*N_p$ $VCP = VEP-0.8*DIAP^2*LP*N_p$ $RSP = 0.012*VCP$	VEP : Pressure shaft excavation volume (m^3) VCP : Backfill concrete volume (m^3) RSP : Re-bar weight (ton) LP : Penstock length (m) N : Penstock nos.	 
	(2) Open-air penstock $VEA = 10.50*DIAP^{1.85}*LP*N_p$ $VCA = 3.40*DIAP^{1.16}*LP*N_p$ $RSA = 0.015*VCA$	VEA : Open excavation volume (m^3) VCA : Concrete volume (m^3) RSA : Re-bar weight (ton)	
	(3) Steel pipe $WP = 12.3*DIAP*t_i*LP_i*N_p$	WP : Steel pipe weight (ton) t_i : Steel pipe thickness (m) N_p : Steel pipe nos.	$DIA\ P = 1.171 \times Qp^{3/7} / p^{1/7}$ Qp = Max. plant discharge (m^3/s) (Ref. to Design Criteria) (t = Ref. to Design Criteria)  $W = \frac{\pi}{4} \times \delta \times ((DIA\ P+t)^2 - DIA\ P^2)$ $= 12.3 \times DIA\ P \times t$
9. POWER HOUSE	(1) Superstructure $VB_1 = 23*(P/\sqrt{H_e})^{0.7}$ $VB_2 = VB_1*RB$ $RB = 6.3*VB_1^{-0.78}$ Or volume measured in drwg.	VB_1 : Main building volume (m^3) VB_2 : Appurtenant building volume (m^3) RB : Ratio of VB_2 to VB_1 P : Installed capacity (kW) He : Effective head (m)	Building height $H = KVA^{0.2}+5$ (m) 
	(2) Substructure $VEB = 540*Q_p^{1/2}*H_e^{1/3}$ $VCB = 200*Q_p^{1/2}*H_e^{1/3}$ $RSB = VCB*0.06$	VEB : Excavation volume (m^3) VCB : Concrete volume (m^3) RSB : Re-bar weight (ton) Q_p : Max. plant discharge (m^3/s) N : No. of units H_e : Effective head (m)	

TABLE 17 CALCULATION SHEET FOR WORK QUANTITY (10/10)

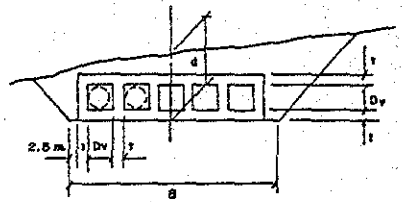
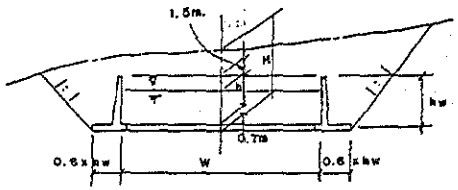
	QUANTITY FORMULA	SYMBOLS	SKETCH & REMARKS
10. TAILRACE	(1) Waterway (i) Pressure/Non-pressure tunnel type To adopt the same criteria as headrace pressure tunnel. (Ref. to 6.(1))		
	(ii) Cut-and-cover conduit pipe $VEV = \left[(D_v+t)*N+t+5+d\right]*d*LV$ $VCV = \left[\left[(D_v+t)*N+t\right]*(D+2t)-D_v^2*N\right]*LV$ $RSV = 0.06*VCV$	VEV : Excavation volume (m^3) VCV : Concrete volume (m^3) RSV : Re-bar weight (ton) D_v : Diameter (width) of conduit (m) t : Wall thickness = $D_v^{0.9}/7.5$ (m) L_v : Tailrace length (m) N : Conduit nos. d : Excavation depth (m)	
	(iii) Open channel $VEY = (W+H+1.2h_w)*LY$ $VCY = C_1+C_2$ $C_1 = 2.0*h_w*LY$, if $h_w < 4m$ $(6*h_w-20)*LY$, if $h_w \geq 5m$ $C_2 = 0.7*W*LY$ $RSY = 0.05*VCY$ $h = Q_p/w/0.5$ $h_w = h+1.5$	VEY : Excavation volume (m^3) VCY : Concrete volume (m^3) RSY : Re-bar weight (ton) h_w : Wall height (m) W : Channel width = Generator interval* Generator nos. (m) h : Water depth (m) LY : Channel length (m) Q_p : Max. plant discharge (m^3/s) H : Excavation depth (m)	
	(2) Outlet (Applied for tunnel type) $VEZ = 100*(DIAR*Q_p/2)^{0.83}$ $VCZ = 40*(DIAR*Q_p/2)^{0.86}$ $RSZ = 0.04*VCZ$	VEZ : Excavation volume (m^3) VCZ : Concrete volume (m^3) RSZ : Re-bar weight (ton) DIAR : Tailrace diameter (m) Q_p : Max. plant discharge (m^3/s)	
11. OTHERS	(1) Water transfer facilities Work quantities of the structures such as sub-dam, connecting tunnel, intake, water transfer tunnel, etc. are to be computed by using applicable formula stated above.		
	(2) After bay To apply the same formula as those for gated intake weir (Ref. to 4(2).		

TABLE 18. CONSTRUCTION UNIT PRICES (1/5)

Unit----------US $
Time estimated price----Late 1985
Exchange rate----------1 US $ = 18.6 Peso

WORK ITEM	UNIT OF QTY	UNIT PRICE
1. GENERAL		
Re-bar installment	ton	1100.0
Gate installment	ton	7500.0
Trashrack installment	ton	3600.0
2. STORAGE DAM		
Dam embankment		
Rockfill dam	m^3	12.0
Earthfill dam	m^3	8.0
Excavation		
Filldam foundation	m^3	6.0
Trench exavation	m^3	12.0
Concrete dam foundation	m^3	8.0
Concrete		
Inspection gallery	m^3	100.0
Concrete dam	m^3	$200V^{-0.09}<110$ if $V<10^4$ m^3; $110V^{-0.03}$ if $V>10^4$ m^3; V:Volume
Curtain grouting	m	75.0
Blanket/Consoli. grouting	m	75.0
Dranage hole	m	75.0
Miscellaneous	%	5.0
2. SPILLWAY		
Exavation		
Forebay and chuteway	m^3	6.0
Energy dissipator	m^3	8.0
Concrete		
Forebay and chuteway	m^3	90.0
Energy dissipator	m^3	100.0
Grouting	m	75.0
Miscellaneous	%	5.0

TABLE 18. CONSTRUCTION UNIT PRICES (2/5)

WORK ITEM	UNIT OF QTY	UNIT PRICE
3. RIVER DIVERSION WORKS		
Tunnel Excavation	m^3	$80D^{-0.15}$ D:Diameter
Cofferdam embankment	m^3	3.0
Tunnel lining concrete	m^3	$125D^{-0.18}$ D:Diameter
Slope protection	m^3	90.0
Plug concrete	m^3	90.0
Fill grouting	m^3	17D+28 D:Diameter
Curtain grouting	m	75.0
Drainage hole	m	75.0
Conduit steel pipe	ton	3000.0
Miscellaneous	%	5.0
4. RIVER INTAKE WEIR		
Foundation excavation	m^3	6.0
Intake weir concrete	m^3	80.0
Sheet pile walling	m^2	300.0
Foundation piling	m	200.0
Miscellaneous	%	5.0
Diversion works	%	20.0
5. INTAKE STRUCTURE		
Foundation excavation	m^3	6.0
Concrete work	m^3	100.0
Miscellaneous	%	5.0
6. HEADRACE WATERWAY		
Tunnel Excavation	m^3	$80D^{-0.15}$ D:Diameter
Open channel excavation	m^3	6.0
Tunnel lining concrete	m^3	$125D^{-0.18}$ D:Diameter
Channel lining concrete	m^3	90.0
Fill grouting	m	17D+28 D:Diameter

TABLE 18. CONSTRUCTION UNIT PRICES (3/5)

WORK ITEM	UNIT OF QTY	UNIT PRICE
Curtain grouting	m	75.0
Miscellaneous	%	5.0
7. SURGE/HEAD TANK		
Tunnel shaft excavation	m^3	70.0
Open excavation for head tank	m^3	6.0
Tunnel shaft lining concrete	m^3	90.0
Open concrete for head tank	m^3	90.0
Steel conduit pipe	ton	3000.0
Miscellaneous	%	5.0
8. PENSTOCK		
Pressure shaft excavation	m^3	$210D^{-0.82}$ D;Diameter
Open excavation	m^3	6.0
Backfill concrete	m^3	75.0
Conc. for open air penstock	m^3	90.0
Steel liner	ton	4000.0
Miscellaneous	%	5.0
9. POWER HOUSE		
Building super structure	m^3	180.0
Excavation	m^3	12.0
Concrete	m^3	$365V^{-0.083}$ V:Volume
Miscellaneous	%	5.0
Switch yard civil work	%	30.0 (Of switch yard equip. cost)
10. TAILRACE		
Tunnel excavation	m^3	$80D^{-0.15}$ D:Diameter
Open excavation	m^3	6.0
Tunnel concrete lining	m^3	$125D^{-0.18}$ D:Diameter
Open concrete	m^3	160.0
Fill grouting	m	17D+28 D:Diameter
Surge tank excavation	m^3	80.0

TABLE 18. CONSTRUCTION UNIT PRICES (4/5)

WORK ITEM	UNIT OF QTY	UNIT PRICE
Surge tank concrete	m^3	180.0
Miscellaneous	%	5.0
11. TAILRACE OUTLET		
Excavation	m^3	6.0
Concrete	m^3	160.0
Miscellaneous	%	5.0
12. WATER TRANSFER FACILITIES		
Inclined shaft excavation	m^3	$210D^{-0.82}$ D:Diameter
Shaft lining concrete	m^3	$300D^{-0.5}$ D:Diameter
Fill grouting	m	400.0
Consolidation grouting	m	800.0
Miscellaneous	%	5.0
13. MISCELLANEOUS CIVIL WORK	%	5.0
	(Total civil work cost except access road)	
14. POWER EQUIPMENT		$6500.0(P/He)^{0.9}$ P:Installed capacity (kw) He:Design head (m)
15. ACCESS ROAD		
Flat land	km	220000.0
Swampy land	km	220000.0
Rolling terrain	km	200000.0
Hilly land	km	250000.0
Improv. of existing road	km	90000.0
Bridge	m	5000.0
16. TRNSMISSION LINE		
69 kv single	km	23000.0
115 kv single	km	34000.0
230 kv double	km	111000.0
500 kv double	km	678000.0

TABLE 18. CONSTRUCTION UNIT PRICES (5/5)

WORK ITEM	UNIT OF QTY	UNIT PRICE
17. SWITCH YARD AND SUBSTATION		
69 kv	line	270000.0
115 kv	line	310000.0
230 kv	line	480000.0
500 kv	line	1860000.0
18. LAND PROCUREMENT AND RESETTLEMENT		
Caltivated land	ha	700.0
Swamp	ha	500.0
Bushes and shrubs	ha	150.0
Forest	ha	50.0

TABLE 19 COST ADJUSTMENT MULTIPLIER

Description	Application	Multiplier
1. Multiplier for site remoteness from port	Total cost	
- Distance less than 100 km		1.0
- Distance from 100 to 200 km		1.005
- Distance more than 200 km		1.01
2. Mutiplier for grouting quantity	Grouting q'ty	
- Geological class A (Very good)		0.7
- Geological class B (Good)		1.0
- Geological class C (Acceptable)		2.3
3. Multiplier for dam material cost	Unit price	
- Near material source (>5 km)		0.9
- Modelately near material source (>10 km)		1.0
- Far material source (<10 km)		1.15
4. Multiplier for tunnel excavation	Unit price	
- Geological class A (Very good)		0.8
- Geological class B (Good)		1.0
- Geological class C (Acceptable)		1.15
5. Multiplier for tunnel lining	Unit price	
- Geological class A (Very good)		0.9
- Geological class B (Good)		1.0
- Geological class C (Acceptable)		1.05
6. Multiplier for consolidation grouting	Unit price	
- Geological class A (Very good)		0.25
- Geological class B (Good)		0.5
- Geological class C (Acceptable)		1.0
7. Multiolier for headrace channel or open air penstock excavation	Excav. q'ty	
- Flat & uniform topography		1.0
- Undulating topography		1.5-2.0

TABLE 20 CONSTRUCTION COST SUMMARY SHEET (ROR TYPE) (1/2)

(Unit: 10^6 US$)

SCHEME NAME	SCHEME ID. NO.	POWER DEVELOPMENT CONSTRUCTION COST													OTHER COSTS (ACCESS ROAD) (TRANSMISSION LINE) (LAND ACQUISITION)	TOTAL CONSTRUCTION COST
		RIVER INTAKE WEIR	INTAKE	HEADRACE	HEAD TANK	PENSTOCK	POWER HOUSE	TAILRACE	WATER TRANSFER FACILITY	MISCELLANEOUS CIVIL WORK	POWER EQUIPMENT	ENGINEERING & ADMINISTRATION	CONTINGENCY	SUB-TOTAL		
NAGUILIAN	1-003-00-02-0-2	2.22	0.32	10.71	1.20	4.49	4.47	0.87	0.00	1.21	8.05	4.19	5.66	43.38	5.15	48.53
LUYA	1-010-00-01-1-2	4.67	0.85	14.06	1.25	1.10	5.43	0.78	0.00	1.41	10.91	5.06	6.83	52.35	7.99	60.34
BAKUM	1-010-00-02-0-2	4.57	0.22	4.38	1.01	2.68	4.07	0.31	0.00	0.86	6.37	3.06	4.13	31.67	3.71	35.38
ABMURAYAN	1-010-01-04-0-2	4.86	0.73	19.89	0.89	1.01	5.88	0.34	4.25	1.89	12.47	6.52	8.81	67.53	7.91	75.44
ABRA	1-022-00-10-0-2	2.07	0.16	4.57	0.47	0.51	2.37	0.12	0.00	0.51	3.26	1.76	2.37	18.16	3.33	21.49
APAYAO	2-066-01-08-0-2	2.30	0.30	9.78	0.64	0.52	3.25	0.32	0.00	0.86	4.42	2.80	3.78	28.97	10.40	39.37
CHICO-1R	2-008-03-04-0-2	6.99	1.07	5.47	1.14	0.48	4.29	0.22	0.00	0.98	10.10	3.84	5.19	39.77	0.96	40.73
CHICO-1R (+SADANGA)	2-008-03-04-1-2	5.71	1.07	5.48	1.14	0.48	4.20	0.22	0.00	0.92	10.07	3.66	4.94	37.88	0.96	38.84
CHICO-2R	2-008-03-06-0-2	3.13	0.78	11.58	0.94	0.65	4.28	0.18	0.00	1.08	9.77	4.05	5.46	41.90	1.44	43.34
CHICO-3R	2-008-03-07-0-2	3.85	0.56	6.19	0.90	0.54	3.44	0.21	0.00	0.78	6.25	2.84	3.84	29.41	0.54	29.95
CHICO-4R	2-008-03-09-0-2	7.05	0.27	7.70	0.54	0.33	2.68	0.18	0.00	0.94	3.73	2.93	3.95	30.31	0.38	30.69
SALTAN	2-008-05-15-0-2	2.70	0.17	5.57	0.52	0.73	2.46	0.13	1.08	0.67	3.57	2.20	2.97	22.75	2.44	25.19
PASIL	2-008-06-22-0-2	2.56	0.17	7.61	0.63	1.12	2.80	0.25	1.81	0.85	4.44	2.78	3.75	28.77	1.18	29.95
TANUDAN	2-008-06-23-0-2	2.79	0.26	8.34	0.62	1.28	3.19	0.27	0.00	0.84	5.03	2.83	3.82	29.28	4.68	33.96
IBULAO	2-008-20-46-0-2	1.78	0.18	6.33	0.60	0.78	2.98	0.18	0.74	0.68	4.15	2.30	3.10	23.78	5.49	29.27
CASECNAN	2-008-29-58-0-2	2.18	0.33	6.52	0.56	0.30	3.04	0.26	0.00	0.66	3.98	2.23	3.01	23.06	5.06	28.12
UP. CASECNAN	2-008-29-59-0-2	2.92	0.28	7.34	0.49	0.31	3.03	0.26	0.00	0.73	3.84	2.40	3.24	24.85	6.72	31.57
AGNO-2	3-077-00-06-0-2	2.11	0.19	5.09	0.49	0.40	2.95	0.31	1.30	0.64	3.60	2.14	2.88	22.10	2.35	24.45
AGNO-3	3-077-00-07-0-2	3.08	0.14	3.86	0.43	0.80	2.71	0.22	1.10	0.62	2.92	1.99	2.68	20.56	1.30	21.86

TABLE 20 CONSTRUCTION COST SUMMARY SHEET (RES TYPE) (2/2)

(Unit: 10^6 US$)

SCHEME NAME	SCHEME ID. NO.	POWER DEVELOPMENT CONSTRUCTION COST														OTHER COST (ACCESS ROAD) (TRANSMISSION LINE) (LAND ACQUISITION)	TOTAL CONSTRUCTION COST
		DAM	SPILLWAY	DIVERSION	INTAKE	HEADRACE	SURGE TANK	PENSTOCK	POWER HOUSE	TAILRACE	MISCELLANEOUS CIVIL WORK	POWER EQUIPMENT	ENGINEERING & ADMINISTRATION	CONTINGENCY	SUB-TOTAL		
SUPO	1-22-0-5-0-1	77.58	19.85	32.38	3.80	3.05	2.83	1.53	8.23	0.80	7.50	36.74	24.19	32.77	251.24	6.76	258.00
SUPO (+ETEB)	1-22-0-5-4-1	20.79	16.33	24.01	2.73	7.87	1.75	1.32	7.36	1.17	5.28	29.80	17.59	23.74	182.03	6.65	188.68
ETEB	1-22-0-6-0-1	72.60	23.16	15.14	3.48	3.11	3.21	1.77	7.50	1.68	6.58	31.09	21.17	28.57	219.06	6.71	225.77
SISIRITAN	2-6-0-1-0-1	218.35	32.05	20.86	13.14	16.68	11.77	9.31	25.92	3.94	17.60	109.85	39.02	77.77	596.27	14.26	610.53
SISIRITAN (+AGBULU)	2-6-0-1-1-1	218.35	32.05	20.86	12.06	14.08	10.19	8.24	22.57	3.79	17.11	103.09	38.28	75.10	575.77	14.27	590.04
SISIRITAN (+AG. + BULU)	2-6-0-1-2-1	93.71	29.47	19.17	8.41	8.56	6.97	4.94	15.29	4.01	9.53	67.92	28.68	44.50	341.15	7.83	348.98
BULU	2-6-0-3-0-1	220.33	30.22	37.55	9.13	6.83	9.44	5.58	17.87	3.78	17.04	87.94	37.54	72.49	555.75	21.51	577.26
BULU (+AGBULU)	2-6-0-3-1-1	106.65	32.49	35.38	10.36	9.23	10.80	5.25	19.95	2.00	11.60	91.53	32.29	55.13	422.64	21.27	443.91
NABABARAYAN	2-6-1-4-0-1	209.89	27.32	36.61	7.03	5.07	8.19	5.90	14.14	1.91	15.80	67.33	35.41	65.19	499.78	24.45	524.23
DIBAGAT	2-6-1-5-0-1	249.83	20.35	43.75	6.16	7.29	9.25	4.92	13.08	1.00	17.78	59.00	36.94	70.40	539.74	23.96	563.70
AGBULU	2-6-1-6-0-1	198.17	20.94	10.74	3.21	0.00	0.00	2.86	10.15	1.81	12.39	46.76	30.82	50.68	388.53	14.48	403.01
BASAO (+SADANGA)	2-8-3-3-1-1	353.41	29.99	20.10	2.28	3.19	1.20	4.93	8.10	0.52	21.19	34.93	39.03	77.83	596.68	4.20	600.88
SADANGA	2-8-3-5-0-1	319.77	30.10	15.19	3.92	5.13	5.36	3.69	10.22	0.72	19.70	44.13	38.08	74.40	570.41	9.31	579.72
SADANGA (+CHICO-1R)	2-8-3-5-1-1	319.77	30.10	15.19	4.09	7.56	5.47	10.90	11.62	0.59	20.26	49.34	38.82	77.06	590.78	9.31	600.09
BANTAY	2-8-7-24-0-1	28.46	23.77	0.51	2.82	0.00	0.00	4.91	5.70	2.56	3.44	20.38	11.57	15.62	119.74	13.61	133.35
MALIANO	2-8-14-34-0-1	250.42	28.58	17.00	4.09	3.69	5.20	3.00	8.67	2.31	16.15	40.29	34.47	62.08	475.96	22.06	498.02
TABU (+BINGA)	3-77-0-4-1-1	86.49	42.87	43.69	2.87	2.96	2.26	3.29	7.96	0.59	9.65	34.95	26.91	39.67	304.16	8.61	312.77
KANAN	4-7-0-1-0-1	430.85	23.75	32.68	3.79	4.65	4.81	4.45	9.87	1.42	25.81	41.81	43.31	94.08	721.28	8.32	729.60
KANAN (+UP. AGOS 2)	4-7-0-1-1-1	20.48	38.82	10.55	2.95	0.00	0.00	3.24	7.29	1.67	4.25	28.85	14.76	19.93	152.78	7.79	160.57
UPPER AGOS 2	4-7-0-5-0-1	136.94	16.92	7.58	2.03	0.00	0.00	1.56	7.59	1.43	8.70	31.15	25.45	35.90	275.24	9.93	285.17
WAWA	4-115-1-1-0-1	83.18	13.46	4.56	1.11	0.00	0.00	0.65	5.45	1.04	5.47	16.44	16.42	22.17	169.95	5.25	175.20
BOSIGON	5-14-1-1-0-1	31.04	24.71	5.27	2.39	2.66	1.79	0.58	5.66	0.74	3.74	19.68	12.28	16.58	127.12	5.04	132.16

FIGURES

FIG. 1 RIVER DIVERSION ECONOMICAL COMPARISON (1/4)

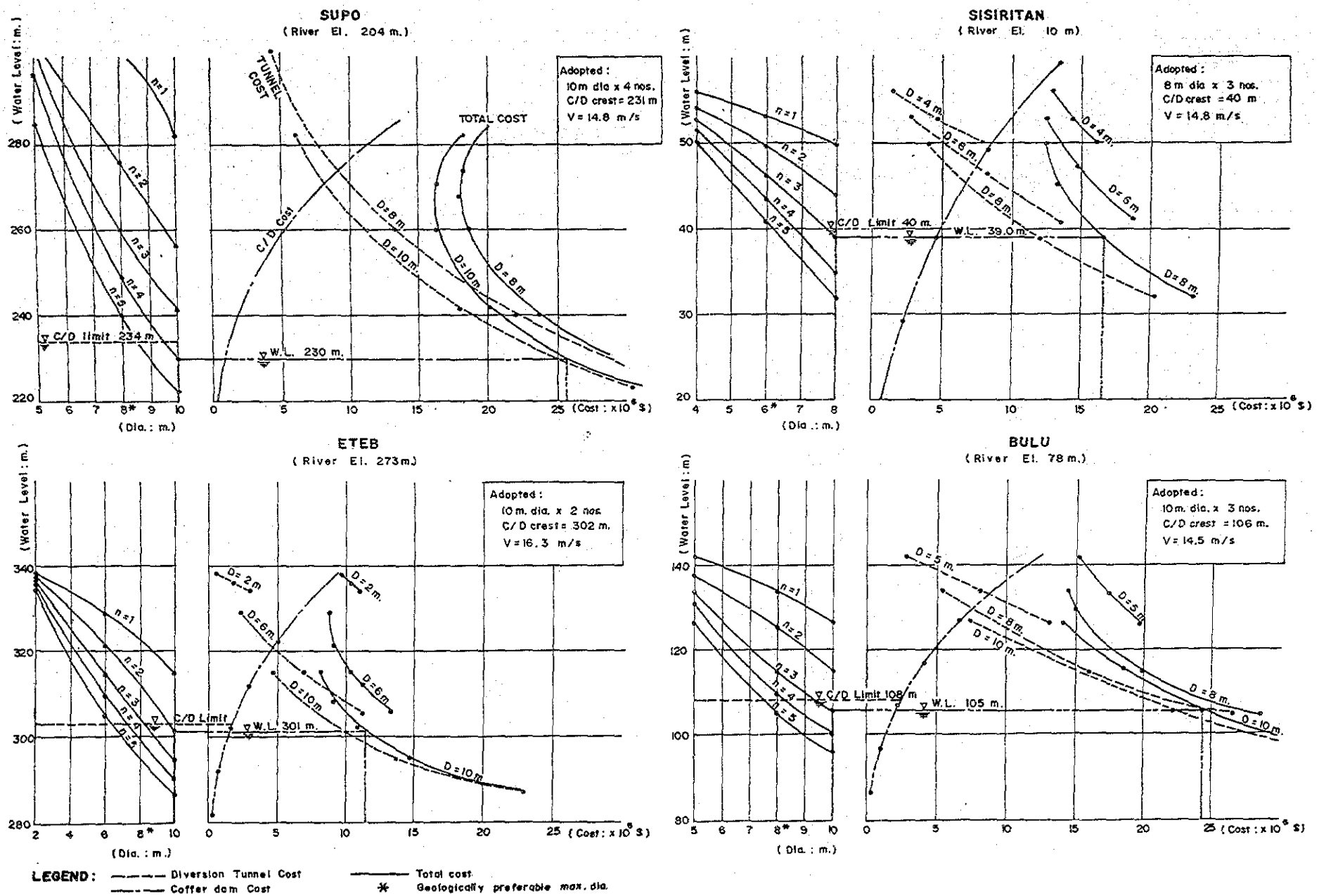


FIG. 1 RIVER DIVERSION ECONOMICAL COMPARISON (2/4)

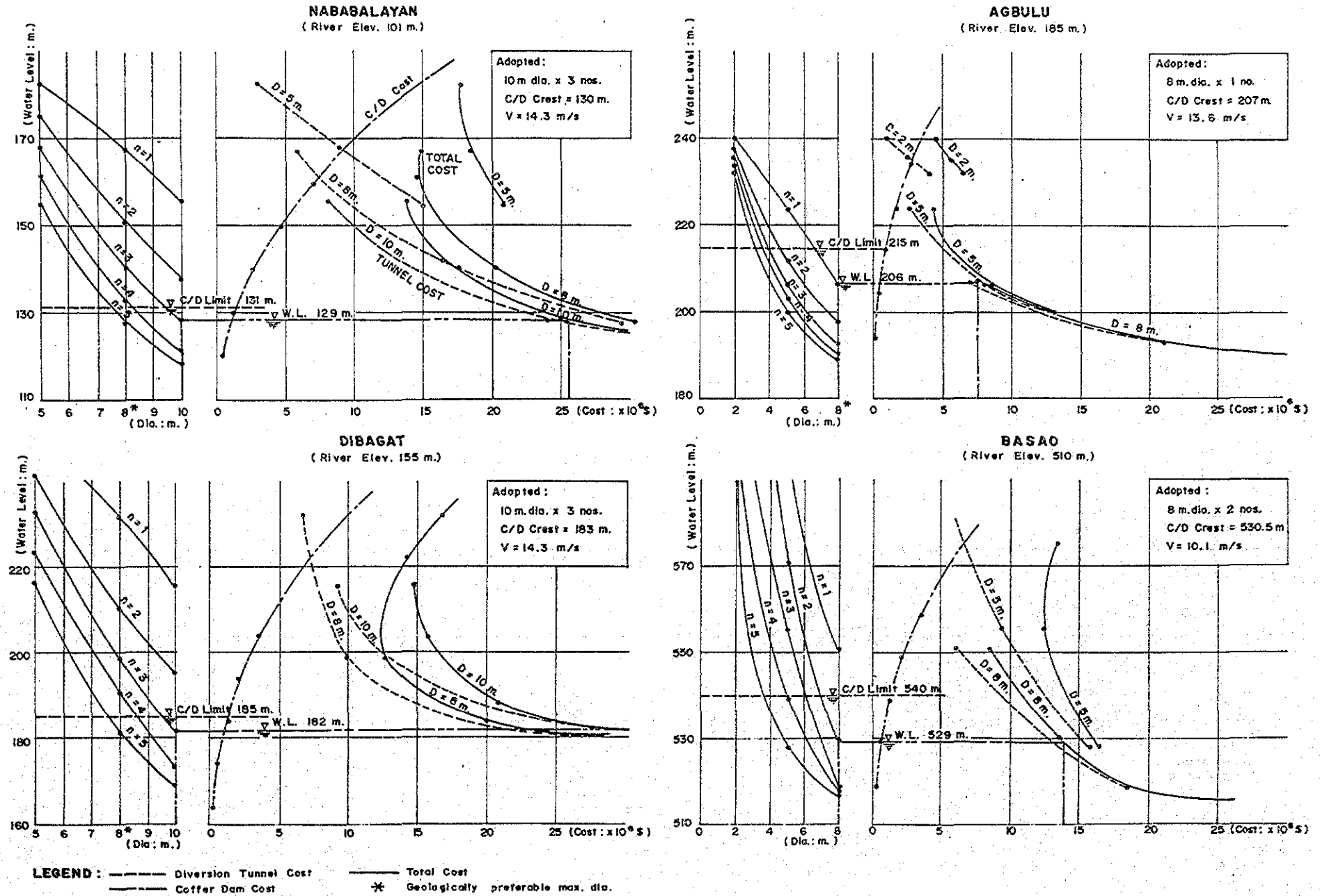


FIG. 1 RIVER DIVERSION ECONOMICAL COMPARISON (3/4)

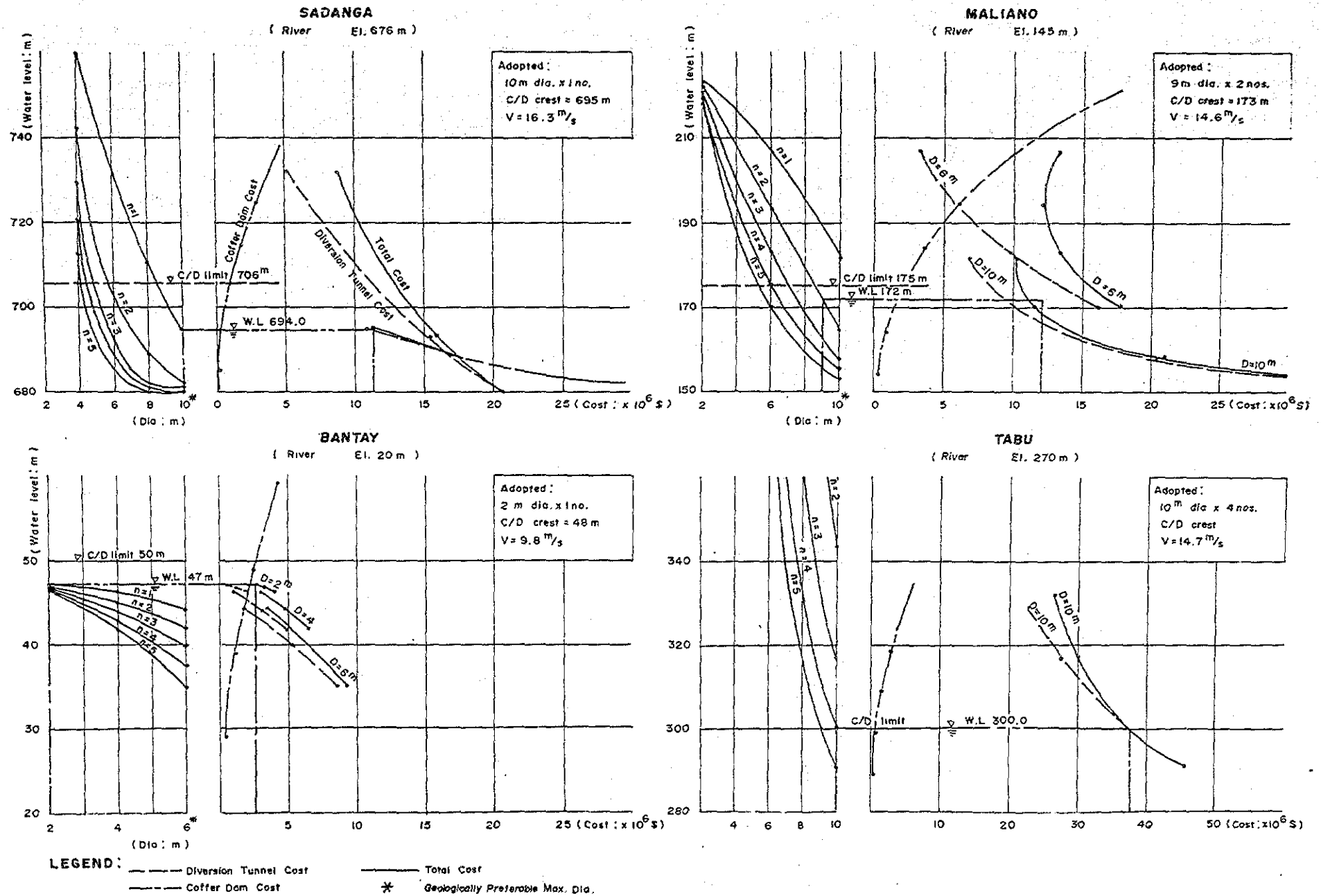


FIG. 1 RIVER DIVERSION ECONOMICAL COMPARISON (4/4)

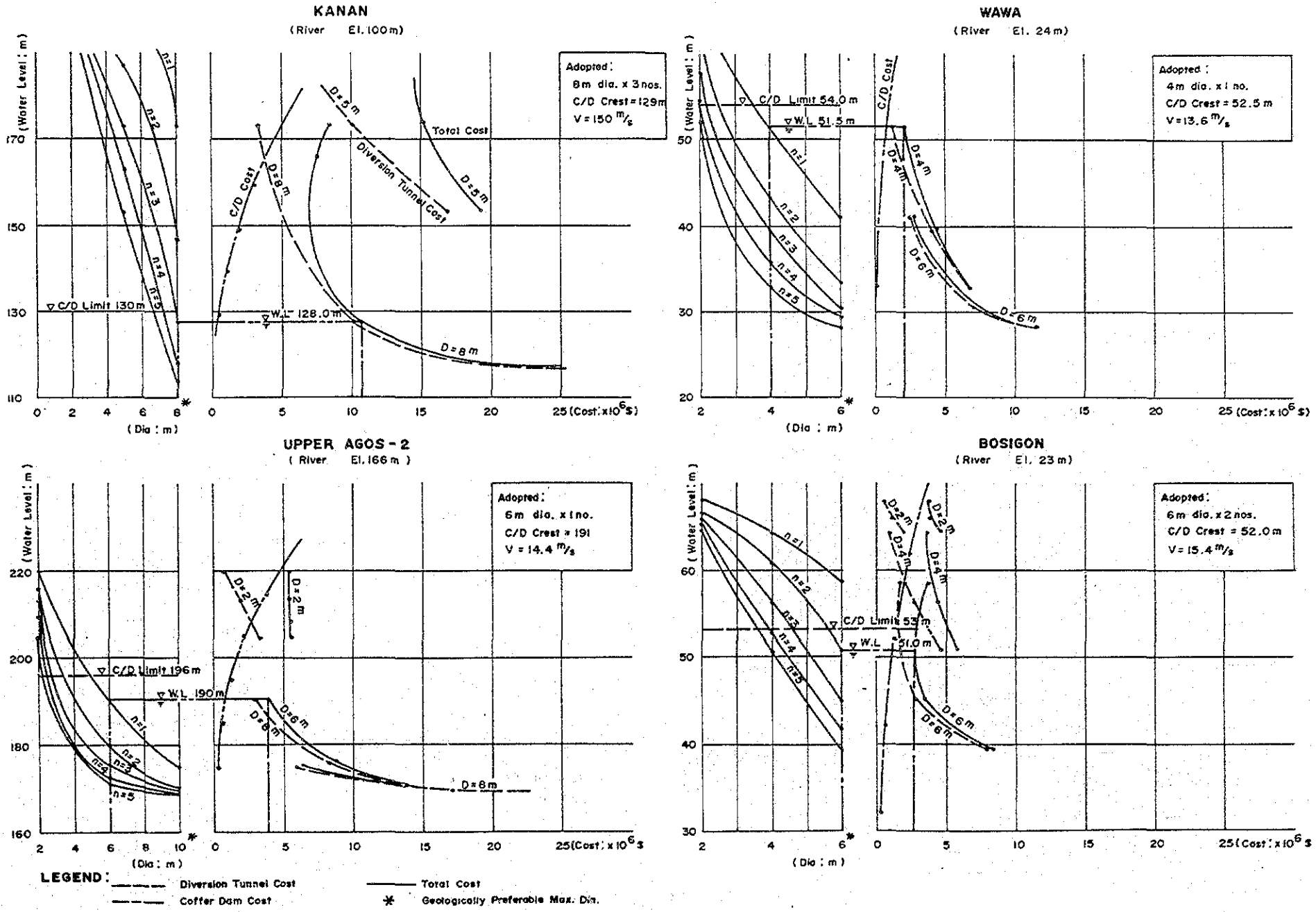


FIG. 2 SPILLWAY ECONOMICAL COMPARISON (1/5)

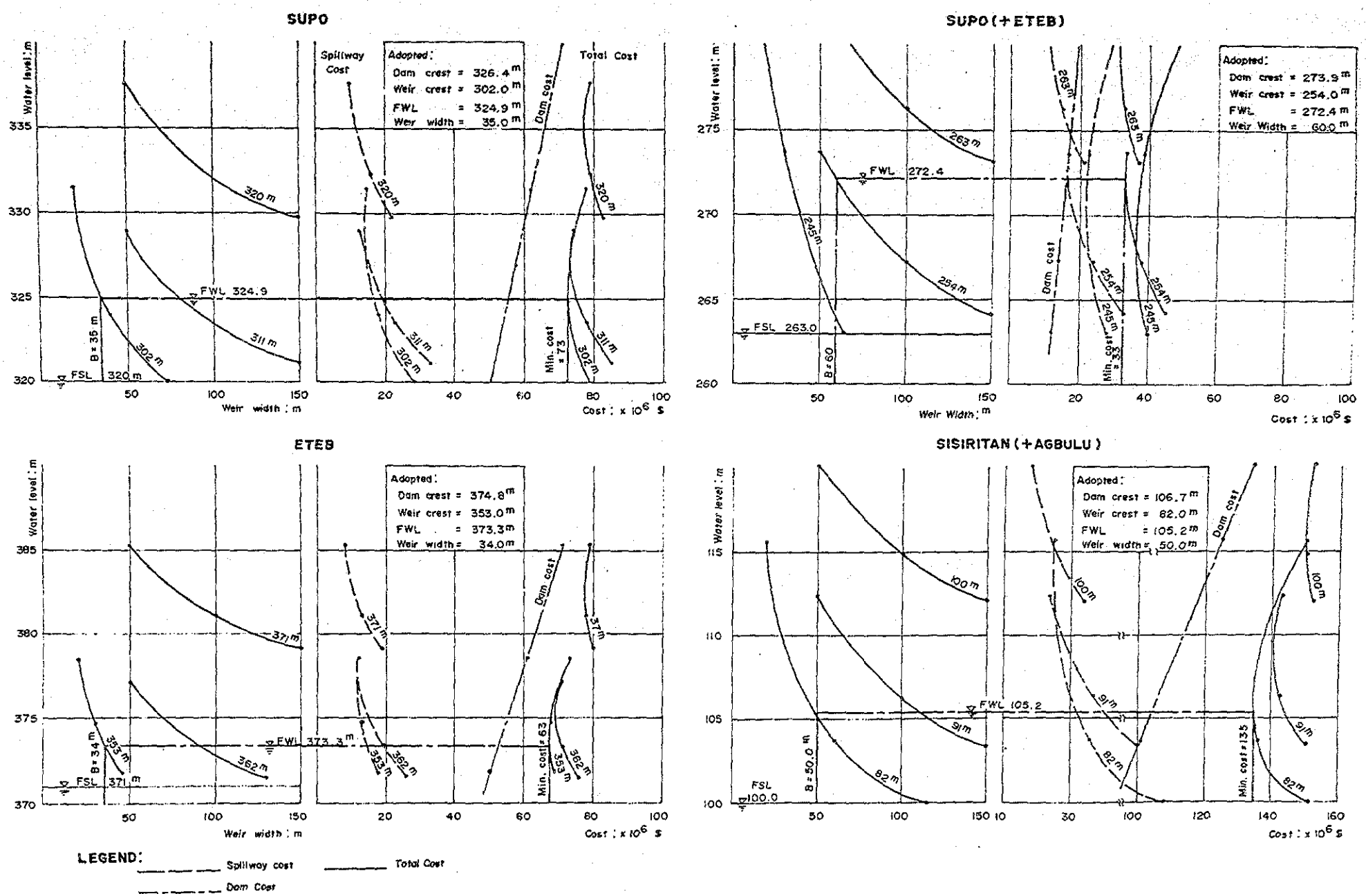


FIG. 2 SPILLWAY ECONOMICAL COMPARISON (2/5)

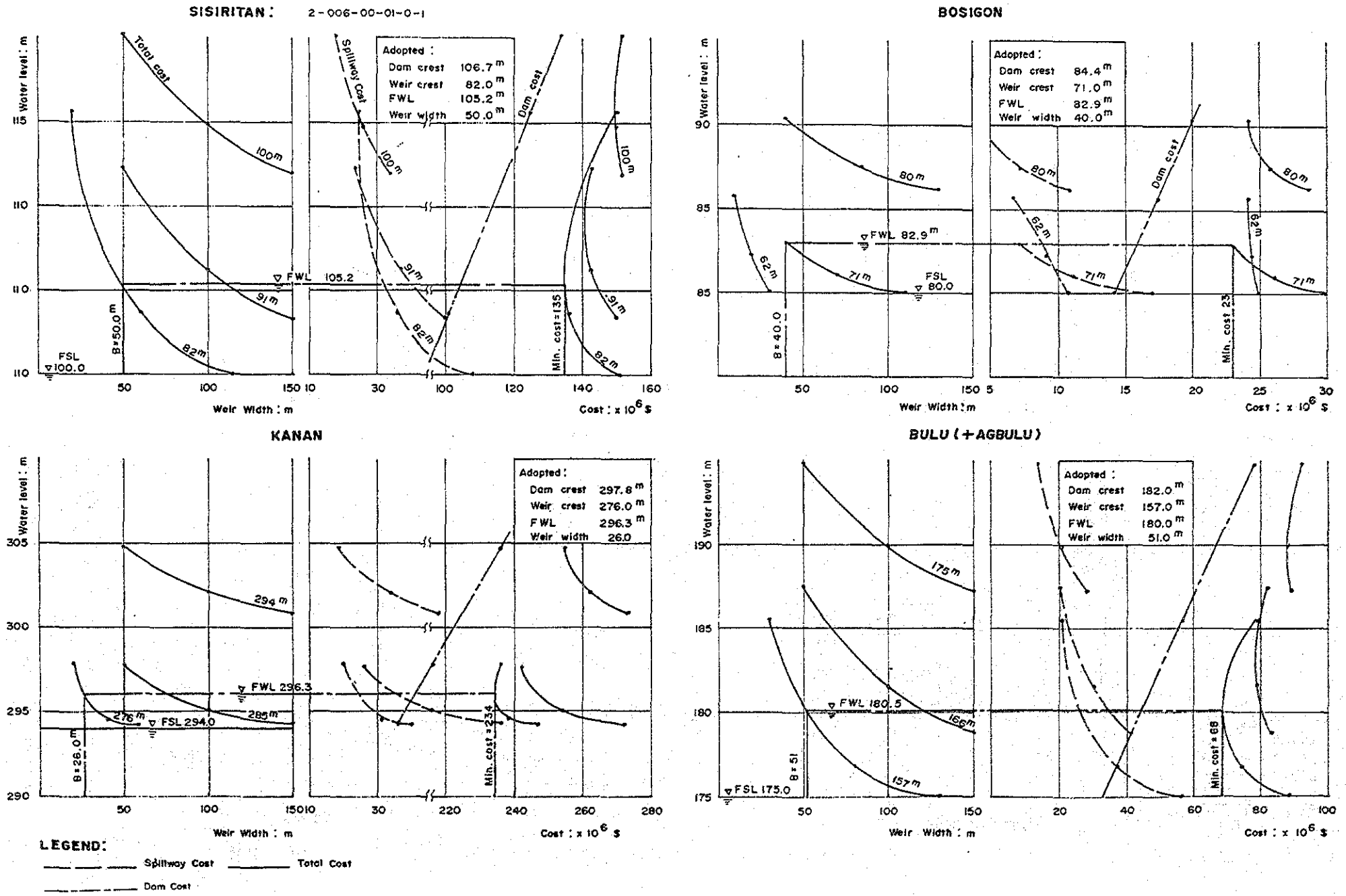


FIG. 2 SPILLWAY ECONOMICAL COMPARISON (3/5)

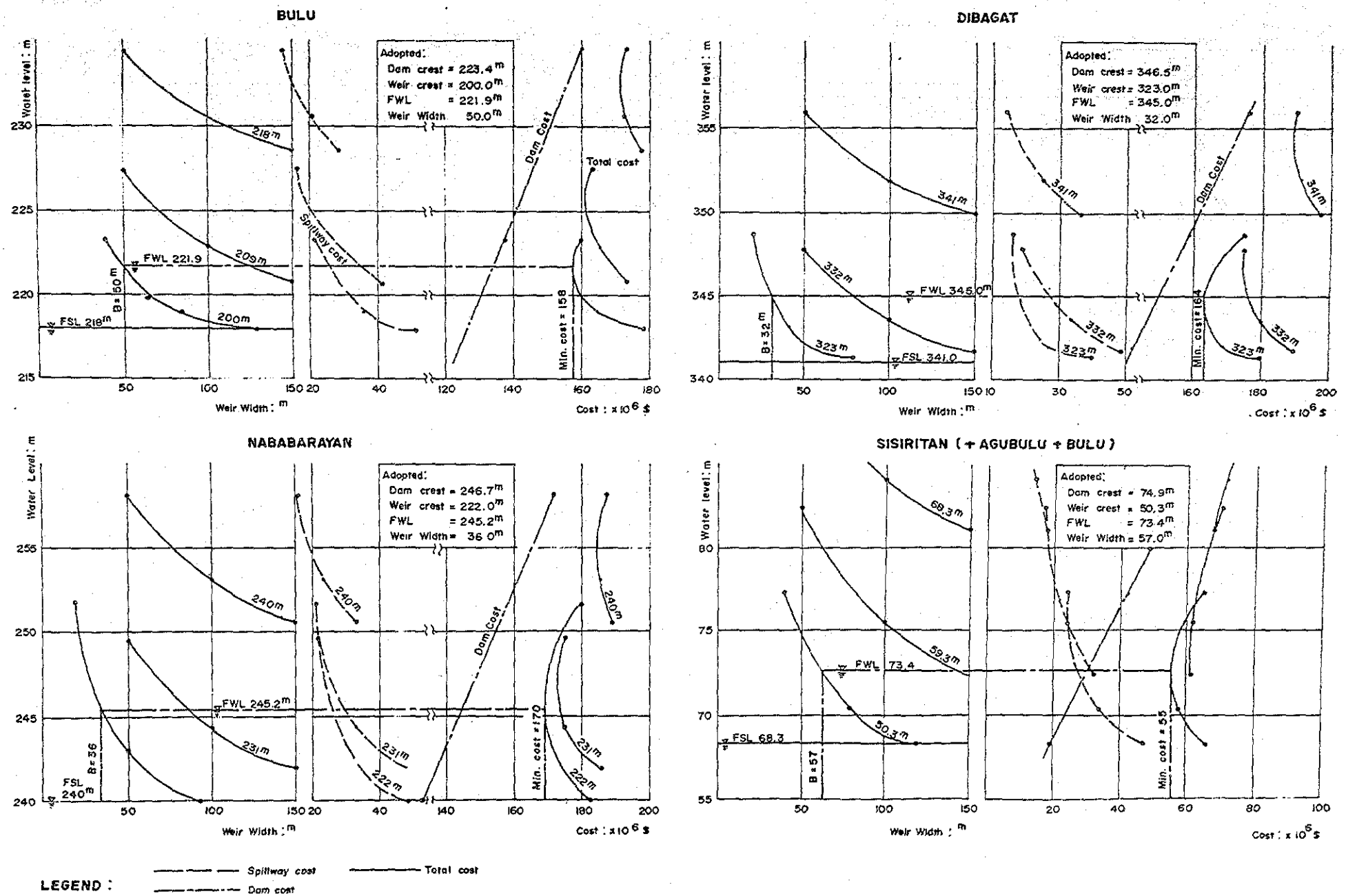


FIG. 2 SPILLWAY ECONOMICAL COMPARISON (4/5)

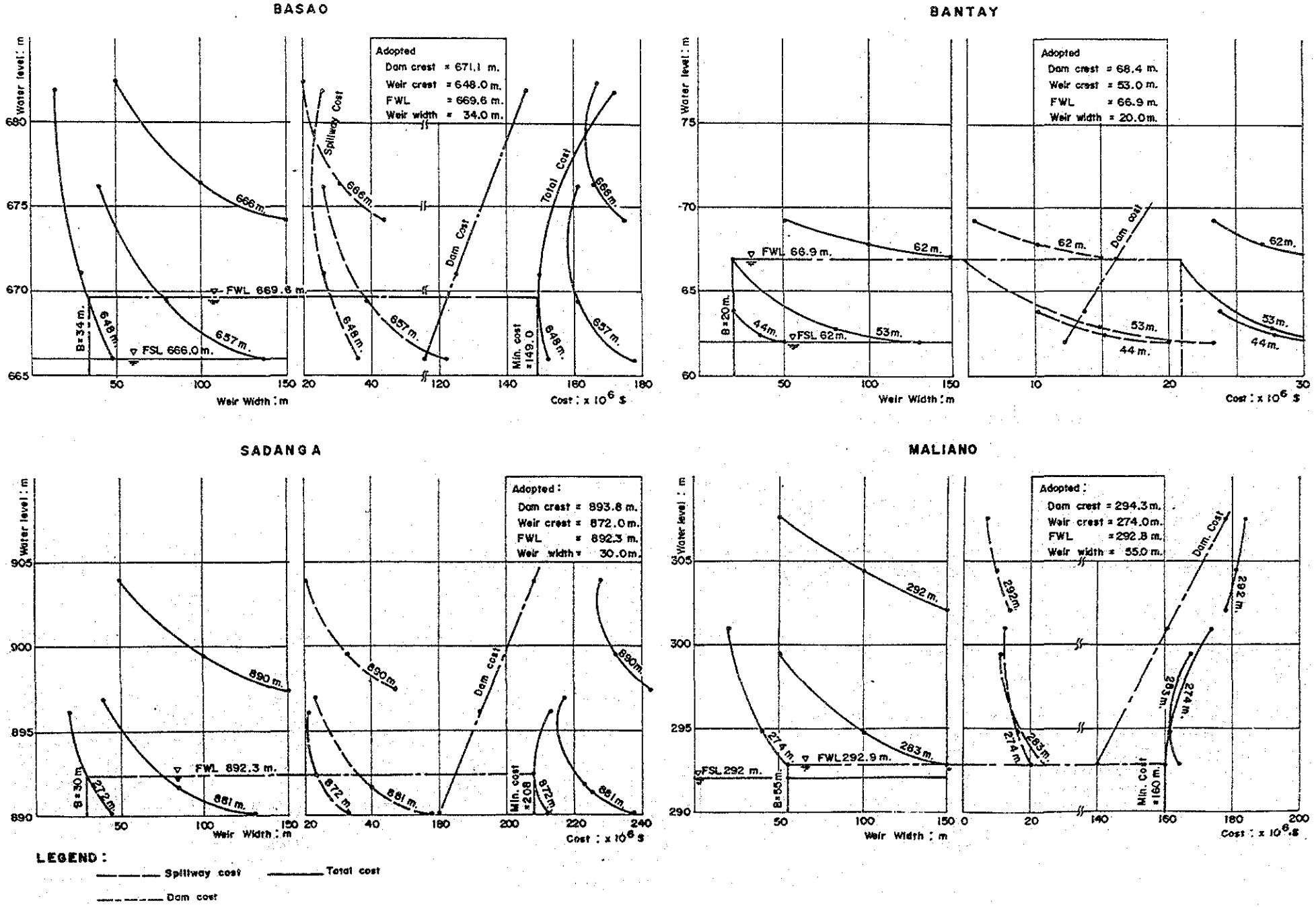
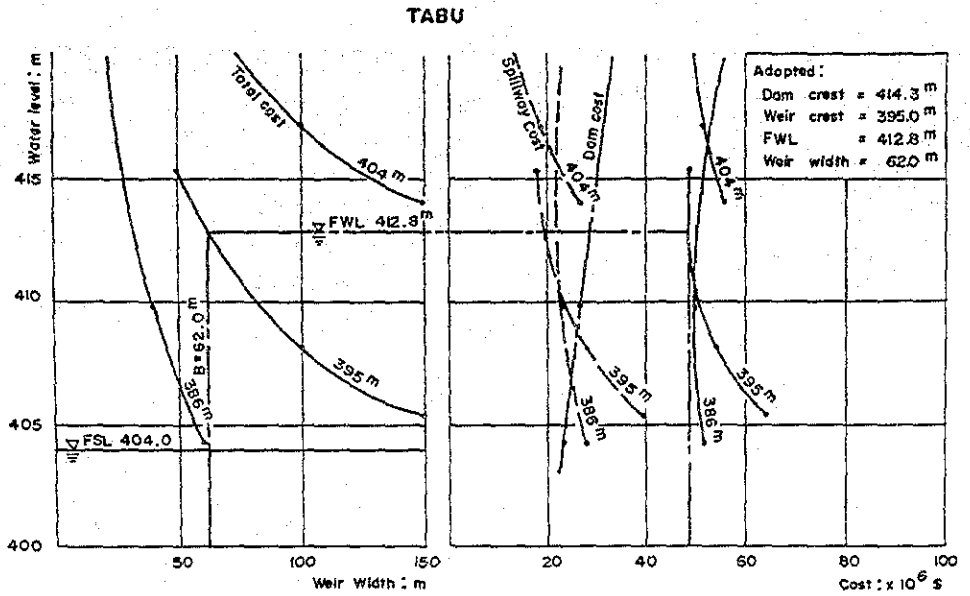
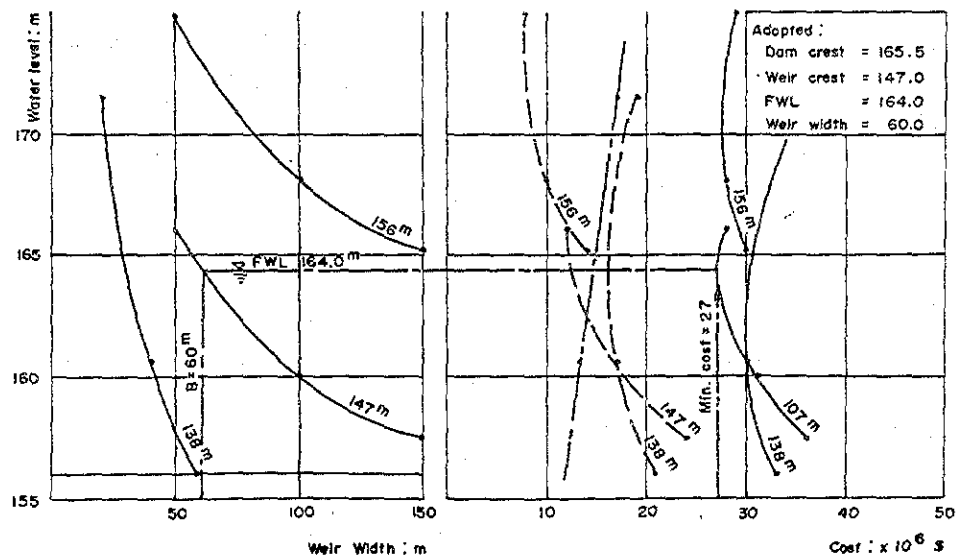


FIG. 2 SPILLWAY ECONOMICAL COMPARISON (5/5)



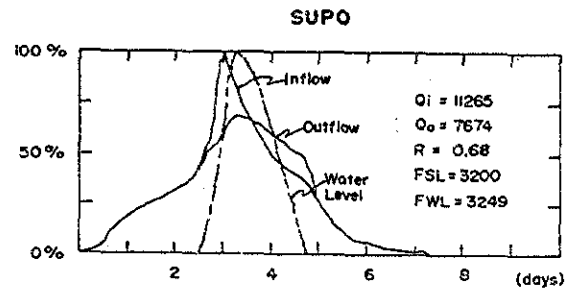


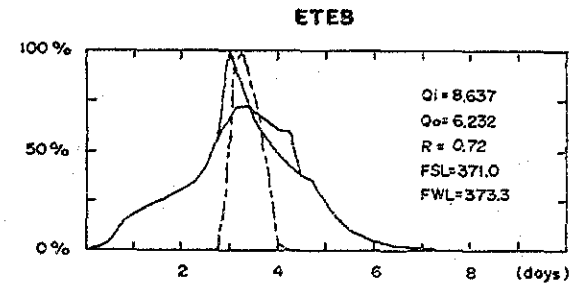
LEGEND :

Spillway cost — Total cost

Dam cost

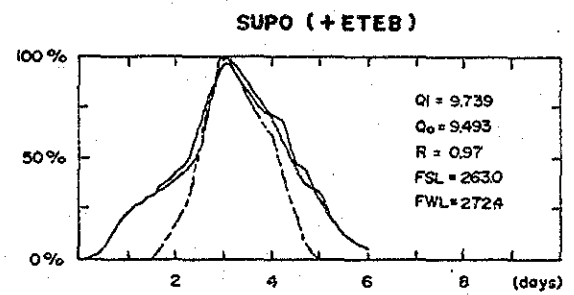
FIG. 3 SPILLWAY FLOOD ROUTING RESULT (1/3)

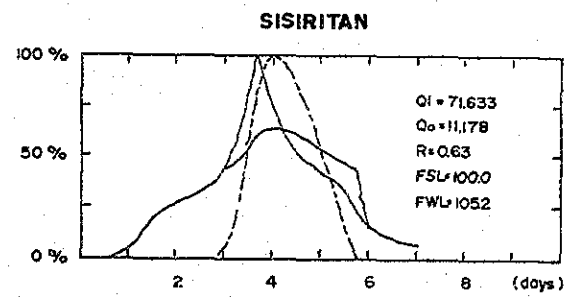


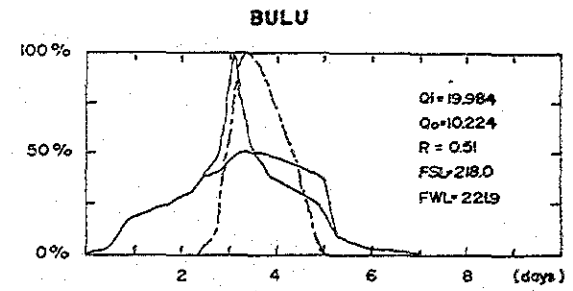


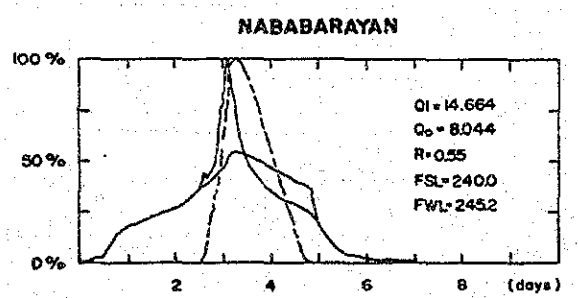
LEGEND:

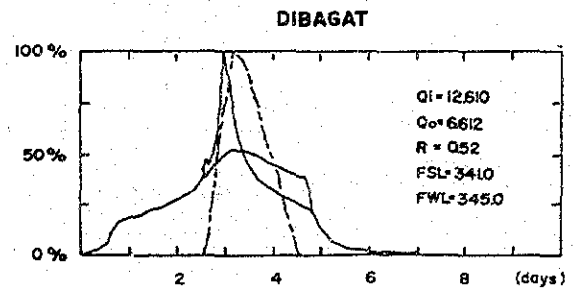
- Qi = Maximum Inflow (m^3/s)
- Qo = Maximum Outflow (m^3/s)
- R = Peak Cut Ratio = Qo/Qi
- FSL = Full Supply Level (m)
- FWL = Maximum Flood Water Level (m)
- ——— Inflow / Outflow Curve
- — — — Water Level Curve











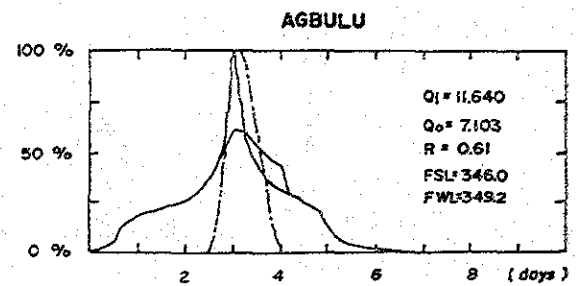
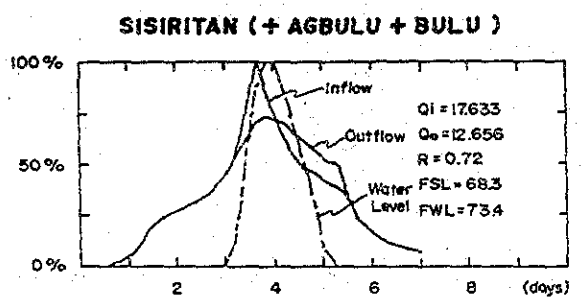
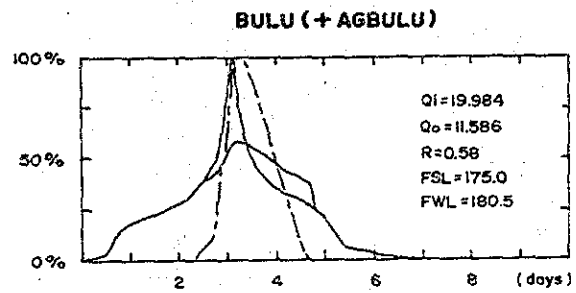


FIG. 3 SPILLWAY FLOOD ROUTING RESULT (2/3)





LEGEND:

Qi = Maximum Inflow (m^3/s)

Qo = Maximum Outflow (m^3/s)

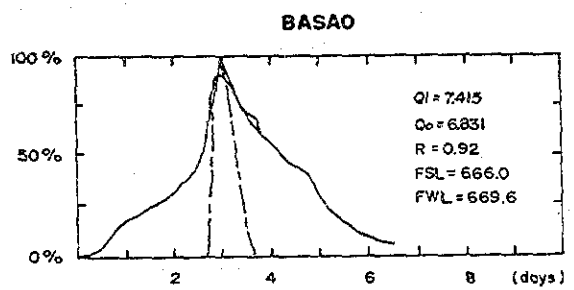
R = Peak Cut Ratio = Qo/Qi

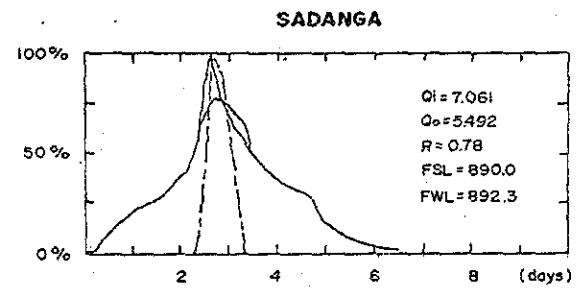
FSL = Full Supply Level (m)

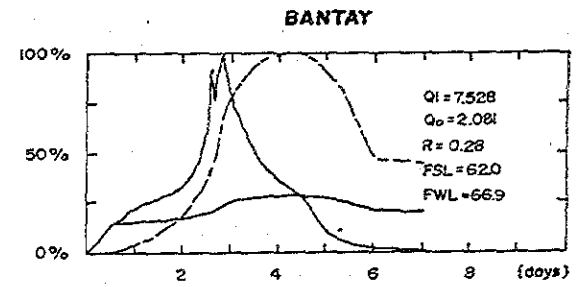
FWL = Maximum Flood Water Level (m)

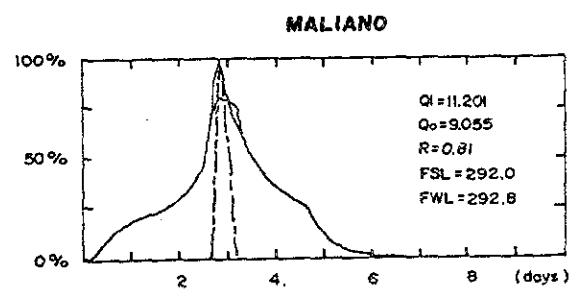
——— Inflow/Outflow Curve

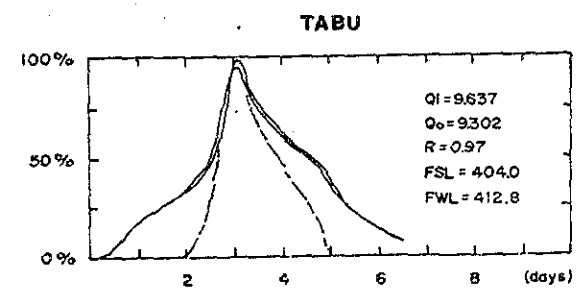
— — — Water Level Curve











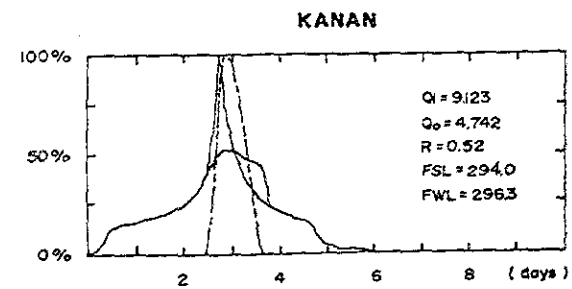
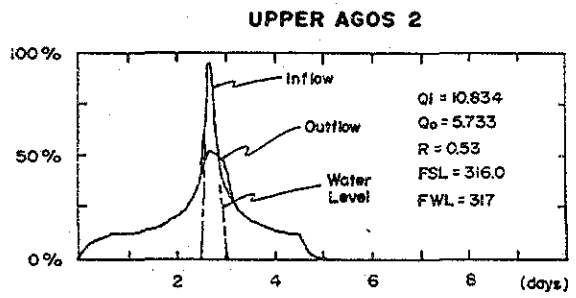
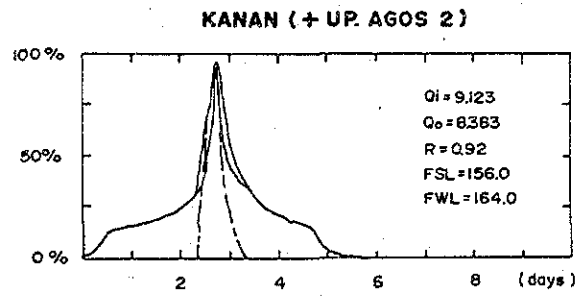


FIG. 3 SPILLWAY FLOOD ROUTING RESULT (3/3)





LEGEND:

QI = Maximum Inflow (m^3/s)

Qo = Maximum Outflow (m^3/s)

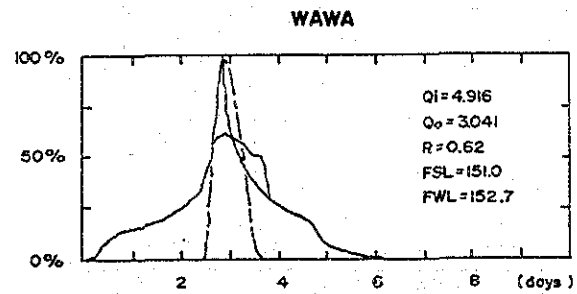
R = Peak Cut Ratio = Qo/QI

FSL = Full Supply Level (m)

FWL = Maximum Flood Water Level (m)

——— Inflow/Outflow Curve

— — — Water Level Curve



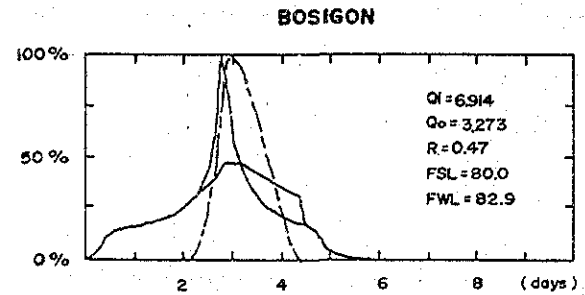
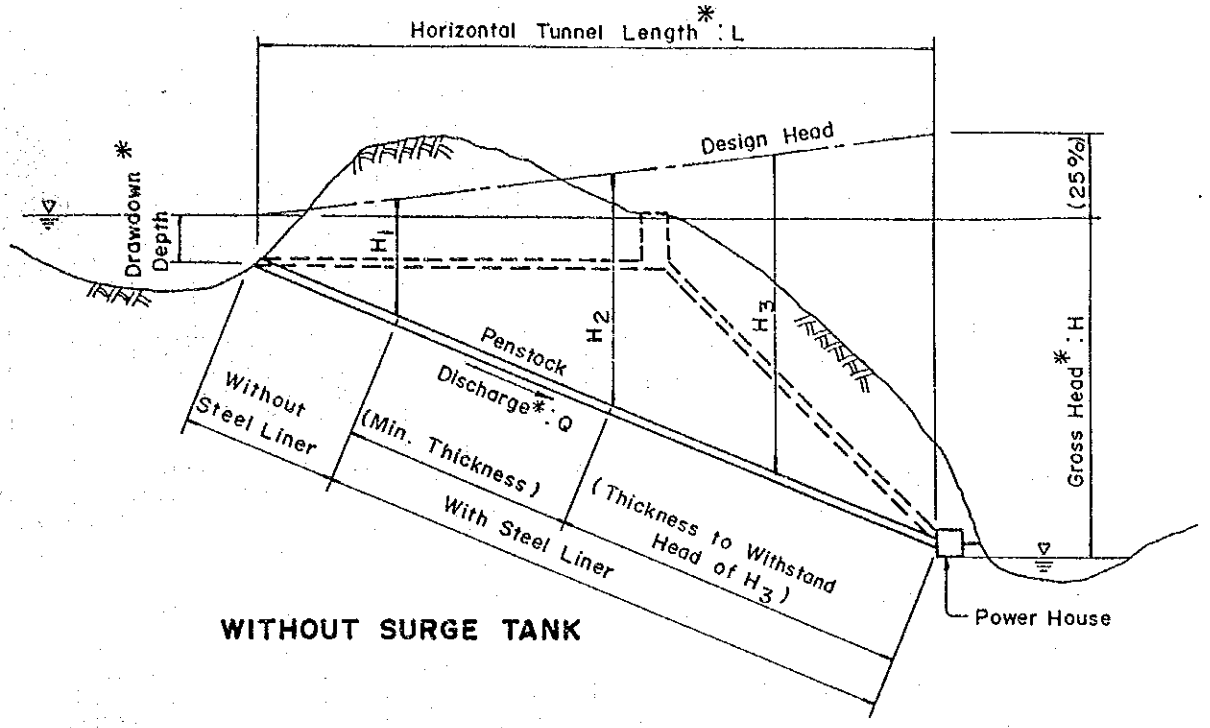
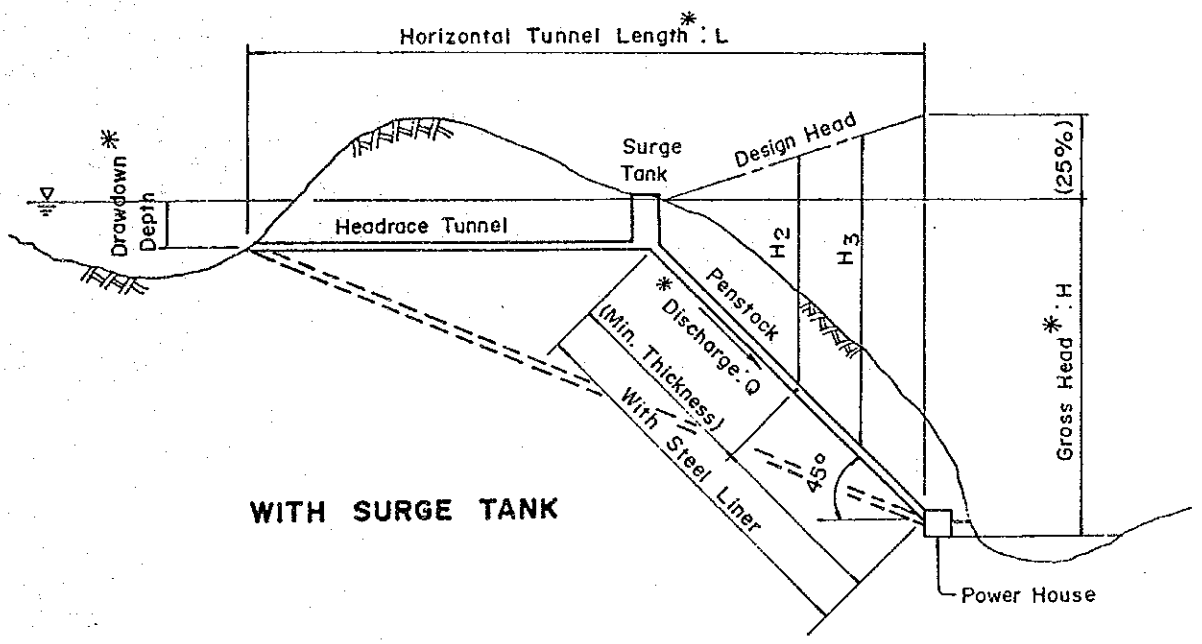


FIG. 4 ASSUMED WATERWAY PROFILE FOR ECONOMICAL COMPARISON

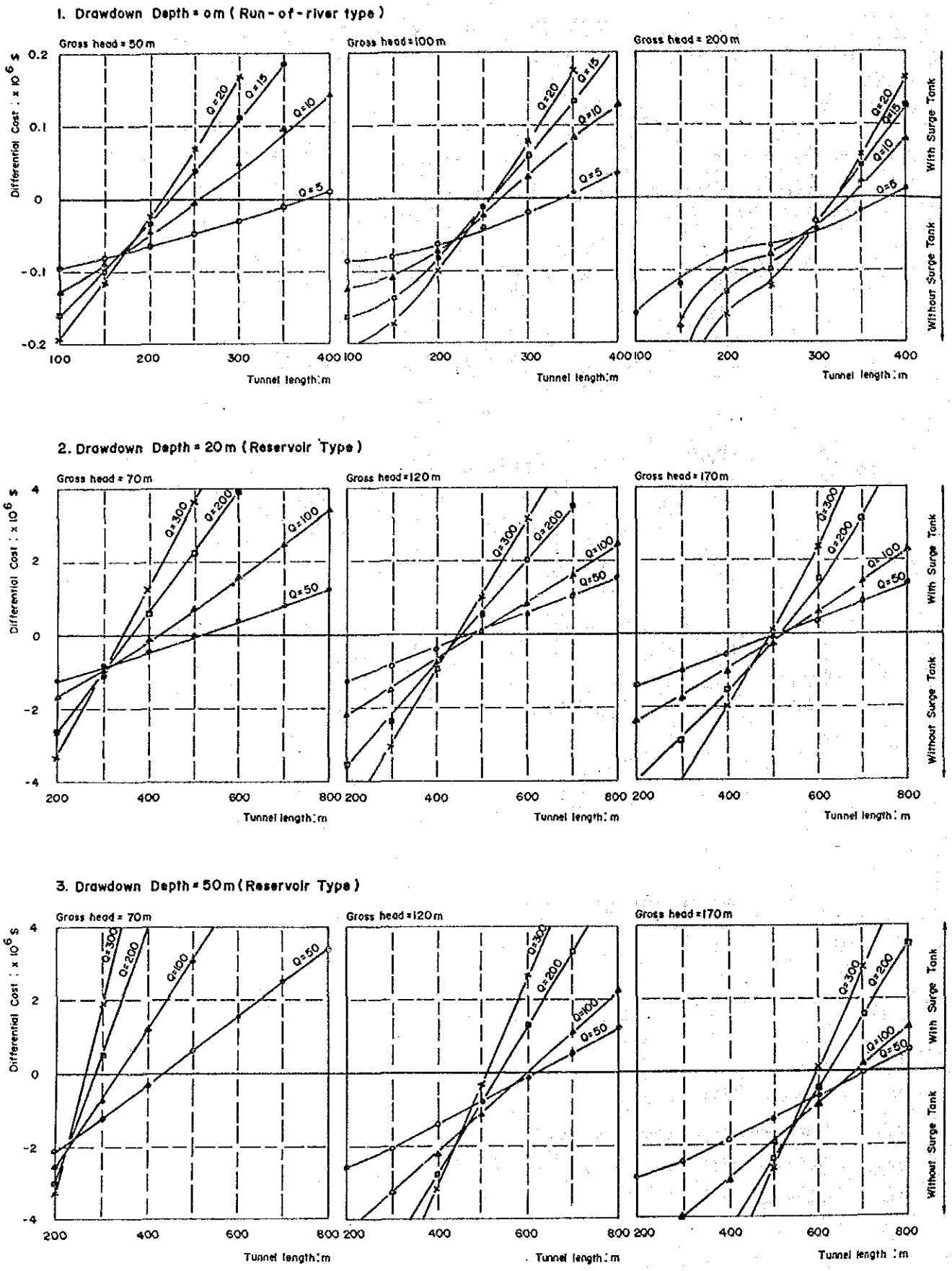




NOTES:

- * : Variables for cost comparison
- H_1 : Water head to be withstanded by concrete lining
- H_2 : Water head to be withstanded by min. thickness of steel liner
- H_3 : Design head for lower part of penstock

FIG. 5 WATERWAY ECONOMICAL COMPARISON



NOTE: Differential Cost = (Const. cost without S. tank) − (Const. cost with S. tank)

FIG. 6 TURBINE TYPE SELECTION DIAGRAM