Supplemented Daily Mean Discharge at Bedukan River Gauging Station (1976) (unit: $m^3/s/100km^2$)

DAY	1	2	3	4	5	6	7	8	9	10	11	12
1	8.85	6.25	1.30	1.08	1.21	0.99	1.37	1.20	2.61	0.58	4.45	4.10
2	4.62	5.96	1.22	0.99	2.55	0.97	1.18	1.62	2.24	0.50	4.06	2.73
3	3.43	3.86	1.15	0.92	3.12	1.15	1.36	3.08	2.79	0.45	5.99	2.26
4	2.67	3.12	1.23	0.99	3.88	1.02	0.83	3.52	1.92	0.42	7.40	2.01
5	2.18	2.53	1.52	1.09	2.64	1.27	0.76	1.68	1.98	0.39	4.77	2.15
6	1.87	2.17	1.94	1.44	1.88	1.46	0.72	1.47	1.39	0.16	4.48	2.44
7	1.54	3.67	1.47	1.04	1.68	1.26	2.24	1.13	1.18	0.27	6.10	2.40
8	2.17	3.40	1.21	1.97	2.26	2.09	2.59	1.00	1.02	2.20	6.53	1.61
9	2.64	3.14	3.59	1.98	2.29	1.78	2.41	0.90	0.92	1.31	8.10	1.31
10	1.82	2.99	5.46	1.23	2.52	1.39	2.88	0.79	0.81	2.06	8.83	1.32
11	1.59	3.63	3.77	0.96	4.30	1.34	3.22	0.74	0.71	1.81	8.23	1.38
12	7.75	2.32	1.96	0.86	3.30	1.69	2.42	0.84	0.78	1.20	5.75	1.42
13	7.27	3.78	1.49	1.25	2.35	1.67	2.33	0.95	0.86	1.38	5.72	1.44
14	3.93	2.72	1.26	1.31	1.92	1.40	1.68	1.06	0.63	5.38	5.98	1.33
15	2.94	2.20	1.14	1.35	1.81	1.29	2.03	1.32	0.51	7.50	5.26	1.20
16	3.09	2.01	1.17	1.95	1.97	0.99	3.85	1.54	0.49	6.02	4.80	1.20
17	4.24	1.90	1.21	1.36	1.71	0.93	1.75	1.33	0.50	4.34	4.11	1.31
18	2.73	1.79	1.25	0.96	2.41	1.05	1.66	0.98	0.54	4.34	3.64	1.42
19	4.41	1.71	1.30	0.83	1.11	1.33	2.77	2.56	0.57	5.06	3.24	4.43
20	3.19	1.63	1.34	0.76	0.94	0.88	1.44	1.95	0.61	6.91	2.79	5.60
21	2.66	1.56	1.64	0.70	1.02	0.75	1.22	1.14	0.65	6.53	2.53	7.46
22	2.44	1.48	2.38	0.71	9.52	0.77	1.18	4.43	0.99	5.23	3.00	5.03
23	2.11	1.41	1.26	0.74	15.21	1.24	1.47	6.80	4.63	6.63	3.69	3.29
24	8.52	1.69	1.17	0.76	2.58	0.84	1.33	5.24	10.51	6.52	5.50	6.38
25	21.07	1.53	1.08	0.79	1.82	0.79	1.03	2.45	2.14	5.07	6.45	6.96
26	36.89	1.84	0.99	0.82	1.46	0.74	0.91	1.83	1.22	4.46	5.29	5.06
27	19.01	1.95	0.91	0.84	1.24	0.69	1.15	1.68	0.90	3.67	4.06	4.15
28	15.46	1.82	1.01	2.47	1.10	0.71	1.27	1.63	0.74	3.05	3.13	3.89
29	10.28	1.42	1.92	3.35	1.03	1.42	1.36	1.82	0.75	3.21	3.42	3.79
30	7.19		1.62	2.11	0.96	1.66	4.18	4.06	0.64	6.04	3.72	4.08
31	5.67		1.22		1.04		1.46	2.69		5.99		3.13
TOTAL	204.23	75.48	51.18	37.61	82.83	35.56	56.05	63.43	46.23	108.68	151.02	96.28
AVERAGE	6.59	2.60	1.65	1.25	2.67	1.19	1.81	2.05	1.54	3.51	5.03	3.11
MAXIMUM	36.89	6.25	5.46	3.35	15.21	2.09	4.18	6.80	10.51	7.50	8.83	7.46
MINIMUM	1.54	1.41	0.91	0.70	0.94	0.69	0.72	0.74	0.49	0.16	2.53	1.20

ANNUAL			
TOTAL	AVERAGE	MAXIMUM	MINIMUM
1008.58	2.76	36.89	0.16

Supplemented Daily Mean Discharge at Bedukan River Gauging Station (1977)

(unit: $m^3/s/100km^2$)

DAY	1	2	3	4	5	6	7	8	9	10	11	12
1	3.21	2.48	6.50	1.15	1.00	2.72	2.59	1.83	3.02	3.70	4.18	5.34
2	4.76	2.49	5.30	1.07	0.86	2.09	2.69	1.52	2.61	9.42	5.68	4.29
3	6.05	2.15	4.74	1.01	0.87	1.69	2.56	1.39	2.29	4.80	5.02	3.90
4	3.83	2.25	4.20	0.97	0.91	1.68	2.07	1.32	2.00	4.07	4.98	3.80
5	2.85	19.41	3.78	1.04	0.96	1.67	1.75	1.43	1.70	3.88	5.38	6.10
6	2.30	28.58	4.14	1.14	1.00	2.26	1.76	1.89	1.47	5.63	5.45	7.60
7	2.01	10.48	4.32	1.28	1.04	4.10	1.95	4.51	1.35	13.85	5.37	6.54
8	2.07	11.11	5.65	1.06	1.09	3.85	3.57	4.01	1.29	8.76	6.85	5.82
9	2.22	16.64	4.30	0.97	1.18	3.36	4.67	2.84	1.24	7.97	8.01	5.38
10	2.46	7.91	4.02	0.88	2.12	2.85	5.55	2.51	1.18	6.13	7.85	4.67
11	4.92	5.91	3.24	0.90	1.29	3.27	4.36	2.49	1.13	4.91	10.85	4.13
12	7.09	5.01	2.88	1.05	1.96	3.65	4.03	1.97	1.07	5.67	8.25	3.89
13	6.90	4.25	2.61	1.97	2.57	12.25	6.16	1.74	1.02	5.52	6.74	3.53
14	27.10	6.30	2.55	3.32	2.50	8.16	6.57	1.85	0.96	4.74	6.41	3.19
15	21.07	7.33	2.73	4.19	5.72	10.01	4.74	1.65	0.91	4.18	6.28	3.03
16	11.83	6.89	2.90	2.32	4.01	9.43	3.71	1.41	0.85	4.38	6.14	2.88
17	11.10	13.49	2.76	3.03	2.47	5.90	3.15	1.21	0.75	4.89	5.17	3.53
18	7.65	40.67	3.09	2.11	1.81	10.10	3.32	1.24	0.64	4.54	4.53	4.11
19	6.54	23.48	2.60	1.29	1.60	6.66	2.78	1.34	0.53	4.24	3.89	3.64
20	5.02	47.89	2.87	1.35	1.24	5.14	2.70	1.43	0.45	4.05	3.77	4.58
21	4.16	50.69	2.46	1.41	1.63	4.57	2.82	1.59	0.42	9.36	3.67	4.35
22	3.58	22.98	2.01	1.04	1.83	4.75	3.01	3.69	0.33	5.30	3.56	3.88
23	4.48	19.73	1.87	0.91	2.73	4.38	3.17	4.71	9.20	6.06	3.52	3.35
24	6.21	16.58	1.72	3.56	2.66	4.01	2.59	7.54	5.05	4.81	3.27	3.06
25	5.23	11.15	1.58	1.99	2.41	4.18	2.86	4.72	2.97	3.74	3.19	2.86
26	5.59	8.61	1.46	2.01	5.24	3.14	2.69	3.58	2.24	3.84	4.39	2.68
27	4.28	7.25	1.36	1.68	5.02	2.61	4.56	6.80	1.79	4.00	6.70	2.51
28	3.34	6.88	1.27	1.47	4.98	2.77	6.01	9.05	1.55	4.15	8.44	2.41
29	2.82		1.19	1.45	5.45	2.88	3.94	7.10	1.84	4.66	10.05	2.35
30	2.52		1.25	1.14	4.33	2.69	2.72	4.75	4.29	4.30	9.20	2.28
31	2.47		1.41		3.79		2.24	3.42		4.13		2.21
TOTAL	185.66	408.59	92.76	48.76	76.27	136.82	107.29	96.53	56.14	169.18	176.79	121.89
AVERAGE	5.99	14.59	2.99	1.63	2.46	4.56	3.46	3.11	1.87	5.46	5.89	3.93
MAXIMUM	27.10	50.69	6.50	4.19	5.72	12.25	6.57	9.05	9.20	13.85	10.85	7.60
MINIMUM	2.01	2.15	1.19	0.88	0.86	1.67	1.75	1.21	0.33	3.20	3.19	2.21

ANNUAL			
TOTAL	AVERAGE	MAXIMUM	MINIMUM
1676.68	4.59	50.69	0.33

Supplemented Daily Mean Discharge at Bedukan River Gauging Station (1978) (unit: $m^3/s/100km^2$)

DAY	1	2	3	4	5	6	7	8	9	10	11	12
1	2.15	1.49	1.90	0.77	2.34	3.31	4.80	2.84	2.48	1.28	4.28	3.41
2	2.03	1.44	1.71	1.55	2.08	2.95	5.24	2.71	2.30	1.35	3.33	2.61
3	1.88	1.40	1.57	2.63	1.99	2.59	4.70	2.65	1.33	1.40	3.03	3.04
4	1.69	1.37	1.42	1.30	2.02	1.98	4.03	2.65	1.31	1.07	3.82	6.50
5	1.86	1.76	1.43	0.81	1.75	1.68	3.30	2.68	2.32	1.52	6.52	6.94
6	10.66	1.53	1.46	1.41	1.43	1.86	3.51	2.70	3.23	1.00	6.92	4.65
7	4.15	1.22	1.46	1.27	1.21	3.46	5.19	2.68	3.59	0.97	9.14	3.82
8	4.63	1.04	1.89	1.11	1.16	2.52	5.52	2.67	3.31	1.21	5.62	4.28
9	4.38	1.01	4.25	0.92	1.50	8.13	3.75	2.68	2.60	6.90	5.51	4.02
10	3.49	0.96	7.50	0.76	2.05	6.55	3.44	2.68	4.47	6.66	5.40	4.16
11	3.81	0.90	2.94	0.46	2.71	5.82	2.97	4.20	2.29	10.32	14.46	4.58
12	5.08	0.91	2.08	0.45	3.18	5.94	2.84	5.02	2.18	7.70	10.03	16.94
13	21.81	0.90	1.70	0.67	2.75	6.39	4.21	3.30	2.68	3.99	8.58	7.90
14	8.97	1.30	1.42	0.97	2.07	4.36	4.38	2.97	1.84	2.66	6.51	6.74
15	5.47	3.05	1.31	5.59	2.54	3.05	4.64	2.71	2.66	2.33	5.61	5.22
16	4.23	3.10	1.25	3.52	4.11	2.93	3.72	2.38	2.16	2.11	6.17	4.97
17	3.44	3.27	1.22	2.35	4.36	3.67	3.94	3.89	1.88	13.25	5.43	7.03
18	3.07	5.08	1.82	1.65	6.45	3.60	3.57	2.59	1.60	8.36	5.32	8.38
19	2.75	2.40	1.66	1.28	4.96	6.71	2.93	2.59	1.32	6.61	4.81	5.57
20	2.54	1.89	1.25	0.89	3.91	7.63	3.49	2.47	1.27	5.50	3.88	4.59
21	2.41	1.48	1.21	0.94	4.04	8.63	3.71	2.25	1.60	5.16	4.04	4.47
22	2.46	1.19	1.32	1.31	7.40	11.76	3.62	2.14	1.40	6.58	3.92	4.38
23	3.56	1.46	2.13	5.04	4.83	7.70	4.24	1.96	2.24	5.52	3.41	3.65
24	5.57	5.55	1.34	5.39	3.28	7.47	4.32	1.66	2.29	4.64	7.27	3.18
25	4.72	6.96	1.22	7.54	2.69	7.00	4.34	1.26	8.53	3.70	4.89	2.81
26	3.26	3.75	1.15	5.35	2.39	5.29	3.77	1.20	4.29	3.30	3.94	2.55
27	2.73	3.28	1.02	6.30	2.13	8.58	3.46	1.29	2.72	3.52	3.36	2.26
28	2.36	2.29	0.90	4.82	1.88	5.57	3.03	1.26	2.01	2.75	3.00	2.23
29	1.97		0.81	5.01	1.70	5.68	2.64	1.11	1.51	3.48	2.72	2.64
30	1.78		0.78	3.10	1.87	4.22	2.49	1.05	1.32	6.52	2.97	2.33
31	1.62		0.76		3.00		2.55	1.44		6.44		5.23
TOTAL	130.53	61.98	53.88	75.16	89.78	157.03	118.34	75.68	74.73	137.80	163.89	151.08
AVERAGE	4.21	2.21	1.74	2.51	2.90	5.23	3.82	2.44	2.49	4.45	5.46	4.87
MAXIMUM	21.81	6.96	7.50	7.54	7.40	11.76	5.52	5.02	8.53	13.25	14.46	16.94
MINIMUM	1.62	0.90	0.76	0.45	1.16	1.68	2.49	1.05	1.27	0.97	2.72	2.23

A N N U A L			
T O T A L	A V E R A G E	M A X I M U M	M I N I M U M
1289.88	3.53	21.81	0.45

Supplemented Daily Mean Discharge at Bedukan River Gauging Station (1979) (unit: $m^3/s/100km^2$)

DAY	1	2	3	4	5	6	7	8	9	10	11	12
1	5.46	1.24	0.33	0.96	0.56	2.26	4.05	3.29	3.45	3.41	5.40	5.63
2	5.43	1.22	0.95	1.02	1.00	4.25	5.22	2.97	3.39	2.68	4.27	5.28
3	4.81	1.22	2.28	2.28	1.72	3.99	3.32	2.51	4.93	2.80	3.56	6.29
4	3.83	1.10	1.54	1.59	1.06	3.86	2.54	2.42	2.95	4.88	4.19	6.31
5	3.69	0.99	1.36	3.17	1.51	2.62	3.44	2.51	1.96	7.23	6.71	4.50
6	3.00	0.93	2.45	1.69	1.17	2.11	2.47	2.85	1.44	10.49	7.48	3.98
7	2.56	0.88	1.65	1.23	1.06	1.48	2.61	2.66	1.39	14.36	6.42	3.79
8	2.40	0.82	3.00	1.06	5.40	1.60	2.23	1.97	1.49	20.33	10.39	3.55
9	2.13	0.74	3.76	0.94	7.23	2.72	3.75	1.68	1.57	18.45	10.01	6.02
10	1.98	0.68	1.92	0.81	4.03	4.42	2.77	1.58	3.30	12.31	6.83	9.93
11	1.86	0.94	1.46	0.84	4.58	2.62	2.39	1.51	3.89	8.69	10.13	7.94
12	1.65	1.07	2.07	0.92	4.86	2.26	4.00	1.58	3.58	9.85	13.05	8.66
13	1.41	1.23	2.36	2.10	2.25	5.31	3.83	1.54	3.25	11.14	9.93	7.36
14	1.35	2.27	3.85	2.42	1.67	9.50	4.25	1.36	4.21	7.39	6.94	5.37
15	1.32	3.38	2.11	1.73	1.31	8.40	3.63	1.24	5.33	6.11	6.00	4.47
16	1.29	1.90	10.13	1.25	1.28	4.50	7.90	1.16	3.94	5.39	5.13	3.98
17	1.25	1.33	7.13	1.04	1.12	6.70	7.15	1.09	4.15	4.57	5.25	3.81
18	1.19	1.15	3.53	0.95	1.43	5.80	4.14	1.08	13.84	3.98	6.27	3.57
19	1.14	1.02	2.83	0.89	1.82	6.12	4.43	1.33	7.04	3.70	6.14	3.23
20	1.29	0.91	2.20	0.83	1.68	7.93	5.01	2.30	8.58	6.76	5.71	3.64
21	1.06	0.82	2.41	1.16	1.48	5.43	5.53	2.92	12.43	6.65	4.94	5.81
22	1.53	0.77	1.77	1.77	1.61	4.78	4.92	2.81	7.07	6.58	3.75	7.42
23	1.81	0.75	1.54	1.13	2.09	5.69	8.03	3.79	7.03	5.11	3.99	7.68
24	1.82	0.70	1.37	1.05	1.41	3.59	7.84	2.90	6.23	4.23	5.81	6.78
25	1.71	0.72	1.24	0.96	1.10	3.10	5.40	2.06	4.91	5.29	5.20	6.35
26	1.71	0.66	1.18	1.26	1.08	3.01	4.20	1.74	5.85	4.66	4.49	6.33
27	1.44	0.54	1.10	0.88	1.37	4.32	4.29	2.46	6.37	4.37	4.51	6.11
28	1.22	0.38	1.22	0.78	1.51	3.95	5.30	2.14	4.47	3.84	6.71	6.39
29	1.13		1.74	0.71	0.97	3.92	3.94	4.22	3.50	6.06	5.24	5.94
30	1.16		1.31	0.63	1.70	3.29	3.29	4.00	3.78	11.39	5.68	4.64
31	1.76		1.06		3.03		3.24	3.10		6.19		3.97
TOTAL	66.19	30.36	72.85	38.05	64.09	129.53	135.11	70.77	145.32	228.89	190.13	174.73
AVERAGE	2.14	1.08	2.35	1.27	2.07	4.32	4.36	2.28	4.84	7.38	6.34	5.64
MAXIMUM	5.46	3.38	10.13	3.17	7.23	9.50	8.03	4.22	13.84	20.33	13.05	9.93
MINIMUM	1.13	0.38	0.33	0.63	0.56	1.48	2.23	1.08	1.39	2.68	3.56	3.23

ANNUAL			
TOTAL	AVERAGE	MAXIMUM	MINIMUM
1346.02	3.69	20.33	0.33

5. Discharge Duration at Bedukan G/S

Discharge Duration at Bedukan River Gauging Station (1970-1979) (unit: $m^3/s/100km^2$)

NO.	Q i n	NO.	Q i n	NO.	Q i n	NO.	Q i n	NO.
1	58.178	51	6.232	101	4.305	151	3.238	
2	39.672	52	6.174	102	4.290	152	3.226	
3	30.019	53	6.148	103	4.249	153	3.215	
4	24.098	54	6.080	104	4.223	154	3.200	
5	20.103	55	6.047	105	4.190	155	3.184	
6	17.951	56	5.975	106	4.152	156	3.165	
7	17.193	57	5.910	107	4.132	157	3.144	
8	13.987	58	5.874	108	4.105	158	3.123	
9	13.358	59	5.808	109	4.080	159	3.104	
10	12.476	60	5.772	110	4.061	160	3.093	
11	11.843	61	5.747	111	4.039	161	3.070	
12	11.560	62	5.694	112	4.007	162	3.056	
13	10.943	63	5.633	113	3.985	163	3.042	
14	10.714	64	5.599	114	3.958	164	3.021	
15	10.255	65	5.550	115	3.922	165	3.009	
16	10.046	66	5.508	116	3.907	166	2.990	
17	9.810	67	5.476	117	3.857	167	2.974	
18	9.584	68	5.441	118	3.836	168	2.963	
19	9.326	69	5.417	119	3.819	169	2.951	
20	9.105	70	5.381	120	3.798	170	2.925	
21	8.907	71	5.325	121	3.776	171	2.914	
22	8.744	72	5.287	122	3.754	172	2.892	
23	8.608	73	5.250	123	3.737	173	2.871	
24	8.436	74	5.201	124	3.723	174	2.847	
25	8.313	75	5.173	125	3.709	175	2.841	
26	8.237	76	5.125	126	3.695	176	2.807	
27	8.092	77	5.094	127	3.680	177	2.797	
28	7.938	78	5.054	128	3.662	178	2.782	
29	7.850	79	5.021	129	3.640	179	2.775	
30	7.746	80	4.997	130	3.610	180	2.767	
31	7.665	81	4.973	131	3.588	181	2.743	
32	7.603	82	4.939	132	3.559	182	2.729	
33	7.456	83	4.908	133	3.549	183	2.717	
34	7.388	84	4.882	134	3.530	184	2.696	
35	7.323	85	4.860	135	3.507	185	2.669	
36	7.235	86	4.829	136	3.497	186	2.659	
37	7.158	87	4.803	137	3.476	187	2.645	
38	7.114	88	4.785	138	3.464	188	2.623	
39	7.046	89	4.747	139	3.448	189	2.611	
40	6.966	90	4.725	140	3.425	190	2.594	
41	6.888	91	4.699	141	3.416	191	2.577	
42	6.836	92	4.644	142	3.399	192	2.557	
43	6.728	93	4.595	143	3.372	193	2.543	
44	6.664	94	4.548	144	3.350	194	2.531	
45	6.601	95	4.520	145	3.341	195	2.521	
46	6.560	96	4.473	146	3.330	196	2.510	
47	6.499	97	4.446	147	3.311	197	2.501	
48	6.429	98	4.403	148	3.294	198	2.488	
49	6.372	99	4.351	149	3.278	199	2.476	
50	6.299	100	4.329	150	3.248	200	2.459	
51	6.232	101	4.305	151	3.238			

Discharge Duration at Bedukan River Gauging Station (1970-1979) (unit: $m^3/s/100km^2$)

NO.	Q i n	NO.	Q i n	NO.	Q i n	NO.	Q i n	NO.
201	2.447	251	1.826	301	1.279	351	0.709	
202	2.415	252	1.814	302	1.273	352	0.688	
203	2.393	253	1.800	303	1.260	353	0.675	
204	2.380	254	1.789	304	1.246	354	0.658	
205	2.373	255	1.776	305	1.241	355	0.651	
206	2.356	256	1.768	306	1.218	356	0.627	
207	2.342	257	1.755	307	1.212	357	0.606	
208	2.332	258	1.745	308	1.192	358	0.591	
209	2.319	259	1.728	309	1.185	359	0.579	
210	2.313	260	1.719	310	1.170	360	0.552	
211	2.298	261	1.713	311	1.164	361	0.521	
212	2.286	262	1.699	312	1.155	362	0.497	
213	2.273	263	1.688	313	1.140	363	0.468	
214	2.262	264	1.681	314	1.126	364	0.406	
215	2.245	265	1.673	315	1.118	365	0.369	
216	2.232	266	1.662	316	1.107			
217	2.221	267	1.651	317	1.097			
218	2.214	268	1.639	318	1.089			
219	2.199	269	1.627	319	1.072			
220	2.196	270	1.624	320	1.060			
221	2.185	271	1.602	321	1.050			
222	2.165	272	1.596	322	1.043			
223	2.145	273	1.584	323	1.035			
224	2.131	274	1.572	324	1.022			
225	2.122	275	1.560	325	1.014			
226	2.105	276	1.547	326	1.008			
227	2.093	277	1.541	327	1.003			
228	2.090	278	1.536	328	0.987			
229	2.080	279	1.523	329	0.971			
230	2.063	280	1.504	330	0.959			
231	2.052	281	1.494	331	0.955			
232	2.036	282	1.485	332	0.942			
233	2.019	283	1.477	333	0.937			
234	2.009	284	1.462	334	0.930			
235	1.985	285	1.450	335	0.923			
236	1.974	286	1.435	336	0.900			
237	1.963	287	1.426	337	0.893			
238	1.955	288	1.414	338	0.882			
239	1.939	289	1.404	339	0.874			
240	1.927	290	1.393	340	0.869			
241	1.919	291	1.381	341	0.858			
242	1.908	292	1.374	342	0.838			
243	1.898	293	1.359	343	0.822			
244	1.881	294	1.349	344	0.800			
245	1.871	295	1.333	345	0.790			
246	1.866	296	1.322	346	0.774			
247	1.857	297	1.314	347	0.755			
248	1.842	298	1.304	348	0.745			
249	1.839	299	1.293	349	0.737			
250	1.835	300	1.283	350	0.727			
251	1.826	301	1.279	351	0.709			

Appendix 4 DEVELOPMENT PLAN DATA

Appendix 4

DEVELOPMENT PLAN DATA

CONTENTS

1. Data of Site Selection Study in Chapter 5

SMALL HYDRO PROJECTS AT UPPER LIWAGU RIVER

Naradaw A

1.	Inst. Capacity	kW	1,340
2.	Firm Peak Power	kW	1,060
3.	Energy	GWh	10.3
4.	Construction Cost	1,000 M$	11,410
5.	Cost per kW	M$/kW	8,515
6.	Cost per kWh	M$/kWh	1.11
7.	Plant Factor	%	88
8.	Development Plan		Tot. Li Me
	(1) Catchment Area	km^2	60.3 31.9 28.4
	(2) 365 days, 100% flow	m^3/s	0.51 0.37 0.14
	(3) 347 days, 95% flow	m^3/s	0.78 0.55 0.23
	(4) 256 days, 70% flow	m^3/s	1.33 0.84 0.49
	(5) 183 days, 50% flow	m^3/s	2.05 1.22 0.83
	(6) Des. Flow	m^3/s	1.33 0.84 0.49
	(7) Intake WL	m (ft)	L 994 (3,260) M 986 (3,230)
	(8) T'race WL	m (ft)	848 (2,780)
	(9) Gross head	m (ft)	146
	(10) Head loss	m	20.4
	(11) Net Head	m	126
	(12) Firm Power	kW	710
	(13) 100% Power	kW	460

				Cost
9.	Layout			
	(1) Intake		Concrete type	483
	(2) L.P. Pipe	L (m) D (m) L (m) D (m)	Mesilau 1,137 0.6 Liwagu 2,220 0.7	2,404
	(3) L.P. Tunnel	H x B (m) L (m)		
	(4) Head Pond	(m^3)	5,750	424
	(5) Penstock	L (m) x D (m)	547 x 0.8	1,138
	(6) Power Station	Structural Steel Superstructure		247
	(7) Access Roads Improve	km km	4.1 1.2	564
	(8) Turb./Generator	Type RPM V	Turgo Impulse/3φ Synchronous Gen. x 2 units 350 3,300	4,370
	(9) Transformer	KVA High (V) Low (V)	1,580 x 1 unit 3φ OA 11,000 3,300	
	(10) Trans. Lines	Type Size KV L (km)	Steel Post HAL 0.166 sq.in 11 1.0	43
10.	Construction Cost			
	Establishment	1,000 M$		300
	Civil	1,000 M$		5,303
	Mech/Electr.	1,000 M$		4,370
	Contingencies	1,000 M$		840
	Engineering	1,000 M$		597
	Total	1,000 M$		11,410

SMALL HYDRO PROJECTS AT UPPER LIWAGU RIVER

Naradaw B

1.	Inst. Capacity	kW	850
2.	Firm Peak Power	kW	750
3.	Energy	GWh	6.6
4.	Construction Cost	1,000 M$	8,656
5.	Cost per kW	M$/kW	10,184
6.	Cost per kWh	M$/kWh	1.31
7.	Development Plan		
	(1) Catchment Area	km^2	31.9
	(2) 365, days 100% flow	m^3/s	0.37
	(3) 347, days 95% flow	m^3/s	0.55
	(4) 256, days 70% flow	m^3/s	0.84
	(5) 183, days 50% flow	m^3/s	1.22
	(6) Des. Flow	m^3/s	0.84
	(7) Intake WL	m (ft)	L 994 (3,260)
	(8) T'race WL	m (ft)	848 (2,780)
	(9) Gross head	m	146
	(10) Head loss	m	20.4
	(11) Net Head	m	126
	(12) Firm Power	kW	500
	(13) 100% Power	kW	373

				Cost
9.	Layout			
	(1) Intake		Concrete type	250
	(2) L.P. Pipe	L (m) D (m)	2,220 0.7	287
	(3) Tunnel	H x B (m) L (m)	-- --	1,665
	(4) Head Pond	(m^3)	3,600	335
	(5) Surge Tank	D (m)	--	--
	(6) Penstock	D (m) L (m)	0.6 547	908
	(7) Power Station		Structural steel Superstructure	188
	(8) Access Roads Improv.	km km	P.S 0.8 km, Pipe 2.2 km 1.2 km	432
	(9) Turb./Generator	Type RPM V	Turgo Impulse/3φ Synchronous Gen x 2 units 500 3,300	
	(10) Transformer	kVA High (V) Low (V)	1,000 x 1 unit 3φ, OA 11,000 3,300	3,481
	(11) Trans. Lines	Type Size kV L (km)	Steel Post HAL 0.166 sq.in 11.0 1.0	43
10.	Construction Cost			
	Establishment			250
	Civil			3,858
	Mech/Electr.			3,481
	Contingencies			616
	Engineering			451
	Total			8,656

SMALL HYDRO PROJECTS AT UPPER LIWAGU RIVER

Naradaw C

1.	Inst. Capacity	kW	490
2.	Firm Peak Power	kW	310
3.	Energy	GWh	3.7
4.	Construction Cost	1,000 M$	6,090
5.	Cost per kW	M$/kW	12,429
6.	Cost per kWh	M$/kWh	1.65
7.	Development Plan		
	(1) Catchment Area	km^2	28.4
	(2) 365, days 100% flow	m^3/s	0.14
	(3) 347, days 95% flow	m^3/s	0.23
	(4) 256, days 70% flow	m^3/s	0.49
	(5) 183, days 50% flow	m^3/s	0.83
	(6) Des. Flow	m^3/s	0.49
	(7) Intake WL	m (ft)	986 (3,230)
	(8) T'race WL	m (ft)	848 (2,780)
	(9) Gross head	m	138
	(10) Head loss	m	13
	(11) Net Head	m	125
	(12) Firm Power	kW	210
	(13) 100% Power	kW	126

				Cost
9.	Layout			
	(1) Intake		Concrete type	203
	(2) L.P. Pipe	L (m) D (m)	1,137 0.6	739
	(3) Tunnel	H x B (m) L (m)	-- --	--
	(4) Head Pond	(m^3)	2,120	257
	(5) Surge Tank	D (m)	--	--
	(6) Penstock	D (m) L (m)	0.5 547	782
	(7) Power Station	Structural Steel Superstructure		135
	(8) Access Roads Improv.	km km	2.0 1.2	304
	(9) Turb./Generator	Type RPM V	Turgo Impulse/3ϕ Synchronous Gen x 2 units 500 rpm 3,300	2,648
	(10) Transformer	kVA High (V) Low (V)	580 x 1 unit 3ϕ, OA 11,000 3,300	
	(11) Trans. Lines	Type Size kV L (km)	Steel Post HAL 0.166 sq.in 11.0 1.0	43
10.	Construction Cost			
	Establishment			250
	Civil			2,463
	Mech/Electr.			2,648
	Contingencies			407
	Engineering			322
	Total			6,090

SMALL HYDRO PROJECTS AT UPPER LIWAGU RIVER

Naradaw D

1.	Inst. Capacity	kW	1,540
2.	Firm Peak Power	kW	1,100
3.	Energy	GWh	11.9
4.	Construction Cost	1,000 M$	11,410
5.	Cost per kW	M$/kW	7,409
6.	Cost per kWh	M$/kWh	0.96
7.	Development Plan		Tot. Li Me
	(1) Catchment Area	km^2	59.2 31.1 28.1
	(2) 365, days 100% flow	m^3/s	0.40 0.26 0.14
	(3) 347, days 95% flow	m^3/s	0.62 0.40 0.22
	(4) 256, days 70% flow	m^3/s	1.17 0.69 0.48
	(5) 183, days 50% flow	m^3/s	1.88 1.06 0.82
	(6) Des. Flow	m^3/s	1.17 0.69 0.48
	(7) Intake WL	m (ft)	Li 1,037 (3,400) Me 1,032 (3,380)
	(8) T'race WL	m (ft)	848 (2,780)
	(9) Gross head	m	189
	(10) Head loss	m	24
	(11) Net Head	m	165
	(12) Firm Power	kW	740
	(13) 100% Power	kW	480

				Cost
9.	Layout			
	(1) Intake		Concrete type	461
	(2) L.P. Pipe	L (m) D (m)	Liwagu 2,640 0.7 Mesilau 600 0.6	2,370
	(3) Tunnel	H x B (m) L (m)		
	(4) Head Pond	(m^3)	5,100	399
	(5) Surge Tank	D (m)	--	
	(6) Penstock	D (m) L (m)	0.7 624	1,167
	(7) Power Station	Structual steel superstructure		291
	(8) Access Roads Improv.	km km	4.1 1.2	564
	(9) Turb./Generator	Type RPM V	Turgo Impulse/3φ Synchronous Gen x 2 units 1,000 3,500	4,380
	(10) Transformer	kVA High (V) Low (V)	1,820 x 1 unit 3φ, OA 11,000 3,300	
	(11) Trans. Lines	Type Size kV L (km)	Steel Post HAL 0.166 sq.in 11 1.0	43
10.	Construction Cost			
	Establishment			300
	Civil			5,295
	Mech/Electr.			4,380
	Contingencies			839
	Engineering			596
	Total			11,410

SMALL HYDRO PROJECTS AT UPPER LIWAGU RIVER

Naradaw E

1.	Inst. Capacity	kW	1,070
2.	Firm Peak Power	kW	840
3.	Energy	GWh	8.3
4.	Construction Cost	1,000 M$	10,620
5.	Cost per kW	M$/kW	9,925
6.	Cost per kWh	M$/kWh	1.28
7.	Development Plan		Tot. Li Me
	(1) Catchment Area	km^2	60.3 31.9 28.4
	(2) 365, days 100% flow	m^3/s	0.51 0.37 0.14
	(3) 347, days 95% flow	m^3/s	0.78 0.55 0.23
	(4) 256, days 70% flow	m^3/s	1.33 0.84 0.49
	(5) 183, days 50% flow	m^3/s	2.05 1.22 0.83
	(6) Des. Flow	m^3/s	1.33 0.84 0.49
	(7) Intake WL	m (ft)	Li 994 (3,260) Me 986 (3,230)
	(8) T'race WL	m (ft)	874 (2,870)
	(9) Gross head	m	120
	(10) Head loss	m	20
	(11) Net Head	m	100
	(12) Firm Power	kW	560
	(13) 100% Power	kW	370

				Cost
9.	Layout			
	(1) Intake		Concrete type	483
	(2) L.P. Pipe	L (m) D (m)	Liwagu 2,370 0.7 Mesilau 987 0.6	2,419
	(3) Tunnel	H x B (m) L (m)		
	(4) Head Pond	(m^3)	5,750	424
	(5) Surge Tank	D (m)	--	
	(6) Penstock	D (m) L (m)	0.8 317	660
	(7) Power Station		Structual steel superstructure	201
	(8) Access Roads Improv.	km km	4.6 1.2	624
	(9) Turb./Generator	Type RPM V	Turgo Impulse/3φ Synchronous Gen x 2 units 750 3,300	4,138
	(10) Transformer	kVA High (V) Low (V)	1,265 x 1 unit 3φ, OA 11,000 3,300	
	(11) Trans. Lines	Type Size kV L (km)	Steel Post HAL 0.166 sq.in 11 1	43
10.	Construction Cost			
	Establishment			300
	Civil			4,854
	Mech/Electr.			4,138
	Contingencies			773
	Engineering			555
	Total			10,620

SMALL HYDRO PROJECTS AT UPPER LIWAGU RIVER

Gantong A

1.	Inst. Capacity	kW	1,600
2.	Firm Peak Power	kW	1,260
3.	Energy	GWh	12.3
4.	Construction Cost	1,000 M$	16,580
5.	Cost per kW	M$/kW	10,363
6.	Cost per kWh	M$/kWh	1.35
7.	Plant Factor	%	88
8.	Development Plan		
	(1) Catchment Area	km^2	65.5
	(2) 365 days, 100% flow	m^3/s	0.55
	(3) 347 days, 95% flow	m^3/s	0.85
	(4) 256 days, 70% flow	m^3/s	1.45
	(5) 183 days, 50% flow	m^3/s	2.23
	(6) Des. Flow	m^3/s	1.45
	(7) Intake WL	m (ft)	830 (2,730)
	(8) T'race WL	m (ft)	671 (2,200)
	(9) Gross head	m (ft)	159
	(10) Head loss	m	22
	(11) Net Head	m	137
	(12) Firm Power	kW	840
	(13) 100% Power	kW	540

				Cost
9.	Layout			
	(1) Intake		Concrete type	450
	(2) L.P. Pipe	L (m) D (m)	1,500 1.0	1,620
	(3) L.P. Tunnel	H x B (m) L (m)	1.8 x 1.5 1,000	5,000
	(4) Head Pond	(m^3)	6,264	442
	(5) Penstock	D (m) L (m)	0.8 520	1,082
	(6) Power Station	Structural Steel Superstructure		282
	(7) Access Roads Improve	km km	1.6 3.5	402
	(8) Turb./Generator	Type RPM V	Turgo Impulse/3φ Synchronous Gen. x 2 units 750 3,300	4,676
	(9) Transformer	KVA High (V) Low (V)	1,880 x 1 unit 3φ OA 11,000 3,300	
	(10) Trans. Lines	Type Size KV L (km)	Steel Post HAL 0.166 sq.in 11.0 1.0	22
10.	Construction Cost			
	Establishment	1,000 M$		300
	Civil	1,000 M$		9,300
	Mech/Electr.	1,000 M$		4,676
	Contingencies	1,000 M$		1,440
	Engineering	1,000 M$		864
	Total	1,000 M$		16,580

SMALL HYDRO PROJECTS AT UPPER LIWAGU RIVER

Gantong B

1.	Inst. Capacity	kW	2,140
2.	Firm Peak Power	kW	1,700
3.	Energy	GWh	16.5
4.	Construction Cost	1,000 M$	21,290
5.	Cost per kW	M$/kW	9,949
6.	Cost per kWh	M$/kWh	1.29
7.	Plant Factor	%	88
8.	Development Plan		
	(1) Catchment Area	km^2	65.5
	(2) 365 days, 100% flow	m^3/s	0.55
	(3) 347 days, 95% flow	m^3/s	0.85
	(4) 256 days, 70% flow	m^3/s	1.45
	(5) 183 days, 50% flow	m^3/s	2.23
	(6) Des. Flow	m^3/s	1.45
	(7) Intake WL	m (ft)	830 (2,730)
	(8) T'race WL	m (ft)	610 (2,000)
	(9) Gross head	m	220
	(10) Head loss	m	36
	(11) Net Head	m	184
	(12) Firm Power	kW	1,130
	(13) 100% Power	kW	730

				Cost
9.	Layout			
	(1) Intake		Concrete type	450
	(2) L.P. Pipe	L (m) D (m)	2,070 1.0	2,236
	(3) Tunnel	H x B (m) L (m)	 1,000	5,000
	(4) Head Pond	(m^3)	6,264	442
	(5) Surge Tank	D (m)	--	0
	(6) Penstock	D (m) L (m)	1.0 1,910	367
	(7) Power Station	Structural Steel Superstructure		
	(8) Access Roads Improv.	km km	3.8 4.0	690
	(9) Turb./Generator	Type RPM V	Turgo Impulse/3ϕ Synchronous Gen x 2 units 1,000 3,300	5,024
	(10) Transformer	kVA High (V) Low (V)	2,520 x 1 unit 3ϕ, OA 11,000 3,300	
	(11) Trans. Lines	Type Size kV L (km)	Steel Post HAL 0.166 sq.in 11,000 1.0	39
10.	Construction Cost			
	Establishment			300
	Civil			12,877
	Mech/Electr.			5,024
	Contingencies			1,977
	Engineering			1,112
	Total			21,290

SMALL HYDRO PROJECTS AT UPPER LIWAGU RIVER

Gantong C

1.	Inst. Capacity	kW	2,340
2.	Firm Peak Power	kW	1,850
3.	Energy	GWh	18.1
4.	Construction Cost	1,000 M$	25,300
5.	Cost per kW	M$/kW	10,812
6.	Cost per kWh	M$/kWh	1.40
7.	Plant Factor	%	88
8.	Development Plan		Tol. Li Mo.
	(1) Catchment Area	km^2	78.5 65.5 13.0
	(2) 365 days, 100% flow	m^3/s	0.66 0.55 0.11
	(3) 347 days, 95% flow	m^3/s	1.02 0.85 0.17
	(4) 256 days, 70% flow	m^3/s	1.74 1.45 0.29
	(5) 183 days, 50% flow	m^3/s	2.67 2.23 0.44
	(6) Des. Flow	m^3/s	1.74 1.45 0.29
	(7) Intake WL	m (ft)	830 (2,730)
	(8) T'race WL	m (ft)	610 (2,000)
	(9) Gross head	m	220
	(10) Head loss	m	52
	(11) Net Head	m	168
	(12) Firm Power	kW	1,230
	(13) 100% Power	kW	800

				Cost
9.	Layout			
	(1) Intake		Concrete type	650
	(2) L.P. Pipe	L (m) D (m)	5,160 1.0 - 1.1	5,765
	(3) Tunnel	H x B (m) L (m)	1.5 x 1.2 1,000	5,000
	(4) Head Pond	(m^3)	7,517	485
	(5) Surge Tank	D (m)	--	0
	(6) Penstock	D (m) L (m)	1.0 1.150	2,737
	(7) Power Station	Structural Steel Superstructure		376
	(8) Access Roads Improv.	km km	5.3 3.5	841
	(9) Turb./Generator	Type RPM V	Turgo Impulse/3φ Synchronous Gen x 2 units 1,000 3,300	5,375
	(10) Transformer	kVA High (V) Low (V)	2,760 x 1 unit 3φ, OA 11,000 3,300	
	(11) Trans. Lines	Type Size kV L (km)	Steel Post HAL 0.166 sq.in 11.0 0.5	22
10.	Construction Cost			
	Establishment			300
	Civil			15,876
	Mech/Electr.			5,375
	Contingencies			2,426
	Engineering			1,323
	Total			25,300

SMALL HYDRO PROJECTS AT UPPER LIWAGU RIVER

Gantong D

1.	Inst. Capacity	kW	1,610
2.	Firm Peak Power	kW	1,280
3.	Energy	GWh	12.4
4.	Construction Cost	1,000 M$	13,510
5.	Cost per kW	M$/kW	8,391
6.	Cost per kWh	M$/kWh	1.09
7.	Plant Factor	%	88
8.	Development Plan		
	(1) Catchment Area	km^2	63.5
	(2) 365 days, 100% flow	m^3/s	0.53
	(3) 347 days, 95% flow	m^3/s	0.82
	(4) 256 days, 70% flow	m^3/s	1.40
	(5) 183 days, 50% flow	m^3/s	2.16
	(6) Des. Flow	m^3/s	1.40
	(7) Intake WL	m (ft)	842 (2,760)
	(8) T'race WL	m (ft)	671 (2,200)
	(9) Gross head	m	171
	(10) Head loss	m	27
	(11) Net Head	m	144
	(12) Firm Power	kW	1,280
	(13) 100% Power	kW	550

				Cost
9.	Layout			
	(1) Intake		Concrete type	450
	(2) L.P. Pipe	L (m) D (m)	1,920 1.0	2,074
	(3) Tunnel	H x B (m) L (m)	-- --	0
	(4) Head Pond	(m^3)	6,050	435
	(5) Surge Tank	D (m)	--	0
	(6) Penstock	D (m) L (m)	1.0 2,010	3,280
	(7) Power Station		Structual Steel Superstructure	271
	(8) Access Roads Improv.	km km	2.3 1.0	336
	(9) Turb./Generator	Type RPM V	Turgo Impulse/3φ Synchronous Gen. x 2 units 750 3,300	4,560
	(10) Transformer	kVA High (V) Low (V)	1,900 x 1 unit 3φ, OA 11,000 3,300	
	(11) Trans. Lines	Type Size kV L (km)	Steel Post HAL 0.166 sq.in 11.0 0.5	22
10.	Construction Cost			
	Establishment			300
	Civil			6,868
	Mech/Electr.			4,560
	Contingencies			1,075
	Engineering			707
	Total			13,510

SMALL HYDRO PROJECTS AT UPPER LIWAGU RIVER

Gantong E

1.	Inst. Capacity	kW	1,700
2.	Firm Peak Power	kW	1,320
3.	Energy	GWh	11.2
4.	Construction Cost	1,000 M$	14,340
5.	Cost per kW	M$/kW	8,435
6.	Cost per kWh	M$/kWh	1.28
7.	Plant Factor	%	75
8.	Development Plan		
	(1) Catchment Area	km^2	63.5
	(2) 365 days, 100% flow	m^3/s	0
	(3) 347 days, 95% flow	m^3/s	0.29
	(4) 256 days, 70% flow	m^3/s	1.40
	(5) 183 days, 50% flow	m^3/s	2.16
	(6) Des. Flow	m^3/s	1.40
	(7) Intake WL	m (ft)	842 (2,760)
	(8) T'race WL	m (ft)	671 (2,200)
	(9) Gross head	m	171
	(10) Head loss	m	22
	(11) Net Head	m	149
	(12) Firm Power	kW	350
	(13) 100% Power	kW	0

				Cost
9.	Layout			
	(1) Intake		Concrete type	443
	(2) L.P. Pipe	L (m) D (m)	2,040 1.0	2,203
	(3) Tunnel	H x B (m) L (m)	1.5 x 1.2 500	2,500
	(4) Head Pond	(m^3)	6,050	435
	(5) Surge Tank	D (m)	--	0
	(6) Penstock	D (m) L (m)	0.8 475	988
	(7) Power Station		Structual Steel Superstructure	300
	(8) Access Roads Improv.	km km	3.2 2	509
	(9) Turb./Generator	Type RPM V	Turgo Impulse/3φ Synchronous Gen x 2 units 1,000 3,300	4,720
	(10) Transformer	kVA High (V) Low (V)	2,000 x 1 unit 3φ, OA 11,000 3,300	
	(11) Trans. Lines	Type Size kV L (km)	Steel Post HAL 0.166 sq.in 11.0 1.0	34
10.	Construction Cost			
	Establishment			300
	Civil			7,412
	Mech/Electr.			4,720
	Contingencies			1,157
	Engineering			751
	Total			14,340

SMALL HYDRO PROJECTS AT UPPER LIWAGU RIVER

Pakai

1.	Inst. Capacity	kW	2,700
2.	Firm Peak Power	kW	850
3.	Energy	GWh	17.7
4.	Construction Cost	1,000 M$	22,270
5.	Cost per kW	M$/kW	8,248
6.	Cost per kWh	M$/kWh	1.26
7.	Plant Factor	%	75
8.	Development Plan		
	(1) Catchment Area	km^2	88.9
	(2) 365 days, 100% flow	m^3/s	0
	(3) 347 days, 95% flow	m^3/s	0.41
	(4) 256 days, 70% flow	m^3/s	1.96
	(5) 183 days, 50% flow	m^3/s	3.02
	(6) Des. Flow	m^3/s	1.96
	(7) Intake WL	m (ft)	625 (2,050)
	(8) T'race WL	m (ft)	415 (1,360)
	(9) Gross head	m (ft)	210
	(10) Head loss	m	37
	(11) Net Head	m	173
	(12) Firm Power	kW	570
	(13) 100% Power	kW	0

				Cost
9.	Layout			
	(1) Intake		Concrete type	549
	(2) L.P. Pipe	L (m) D (m)	3,360 1.0	8,965
	(3) L.P. Tunnel	H x B (m) L (m)	1.8 x 1.5 1,000	0
	(4) Head Pond	(m^3)	8,467	514
	(5) Penstock	D (m) L (m)	0.9 724	1,651
	(6) Power Station	Structural Steel Superstructure		414
	(7) Access Roads Improve	km km	4.4 2.0	631
	(8) Turb./Generator	Type RPM V	Turgo Impulse/3φ Synchronous Gen. x 2 units 1,000 3,300	5,731
	(9) Transformer	KVA High (V) Low (V)	3,180 x 1 unit 3φ OA 11,000 3,300	
	(10) Trans. Lines	Type Size KV L (km)	Steel Post HAL 0.166 sq.in 11.0 7.0	301
10.	Construction Cost			
	Establishment	1,000 M$		350
	Civil	1,000 M$		13,025
	Mech/Electr.	1,000 M$		5,731
	Contingencies	1,000 M$		2,006
	Engineering	1,000 M$		1,158
	Total	1,000 M$		22,270

SMALL HYDRO PROJECTS AT UPPER LIWAGU RIVER

Kauluan

1.	Inst. Capacity	kW	1,150
2.	Firm Peak Power	kW	620
3.	Energy	GWh	8.8
4.	Construction Cost	1,000 M$	10,980
5.	Cost per kW	M$/kW	9,548
6.	Cost per kWh	M$/kWh	1.25
7.	Plant Factor	%	87
8.	Development Plan		
	(1) Catchment Area	km^2	22.2
	(2) 365, days 100% flow	m^3/s	0.09
	(3) 347, days 95% flow	m^3/s	0.14
	(4) 256, days 70% flow	m^3/s	0.35
	(5) 183, days 50% flow	m^3/s	0.61
	(6) Des. Flow	m^3/s	0.35
	(7) Intake WL	m (ft)	1.418 (4,650)
	(8) T'race WL	m (ft)	976 (3,200)
	(9) Gross head	m	442
	(10) Head loss	m	30
	(11) Net Head	m	412
	(12) Firm Power	kW	410
	(13) 100% Power	kW	270

				Cost
9.	Layout			
	(1) Intake		Concrete type	156
	(2) L.P. Pipe	L (m) D (m)	1,740 0.5	940
	(3) Tunnel	H x B (m) L (m)		0
	(4) Head Pond	(m^3)	1,512	217
	(5) Surge Tank	D (m)	--	--
	(6) Penstock	D (m) L (m)	0.4 2,630	3,630
	(7) Power Station	Structural steel Superstructure		321
	(8) Access Roads Improv.	km km	5.4 2.0	828
	(9) Turb./Generator	Type RPM V	Pelton/3ϕ Synchronous Gen x 2 units 1,500 3,300	3,014
	(10) Transformer	kVA High (V) Low (V)	1,350 11,000 3,300	
	(11) Trans. Lines	Type Size kV L (km)	Steel Post HAL 0.166 sq.in 11 0.8	34
10.	Construction Cost			
	Establishment			300
	Civil			6,126
	Mech/Electr.			3,014
	Contingencies			964
	Engineering			576
	Total			10,980

SMALL HYDRO PROJECTS AT UPPER LIWAGU RIVER

Lamas 2

1.	Inst. Capacity	kW	8,400
2.	Firm Peak Power	kW	4,450
3.	Energy	GWh	65.0
4.	Construction Cost	1,000 M$	37,790
5.	Cost per kW	M$/kW	4,500
6.	Cost per kWh	M$/kWh	0.58
7.	Plant Factor	%	88
8.	Development Plan		
	(1) Catchment Area	km^2	72.9
	(2) 365, days 100% flow	m^3/s	0.61
	(3) 347, days 95% flow	m^3/s	0.95
	(4) 256, days 70% flow	m^3/s	1.61
	(5) 183, days 50% flow	m^3/s	2.48
	(6) Des. Flow	m^3/s	1.61
	(7) Intake WL	m (ft)	1,220 (4,000)
	(8) T'race WL	m (ft)	534 (1,750)
	(9) Gross head	m	686
	(10) Head loss	m	34
	(11) Net Head	m	652
	(12) Firm Power	kW	4,450
	(13) 100% Power	kW	2,870

				Cost
9.	Layout			
	(1) Intake		Concrete type	475
	(2) L.P. Pipe	L (m) D (m)	3,360 1.0	3,629
	(3) Tunnel	H x B (m) L (m)	-- --	
	(4) Head Pond	(m^3)	--	0
	(5) Surge Tank	(m^3)	580	135
	(6) Penstock	D (m) L (m)	0.8 1,370	4,672
	(7) Power Station	Structural Steel Superstructure		1,217
	(8) Access Roads Improv.	km km	84 5	10,303
	(9) Turb./Generator	Type RPM V	Pelton/3ϕ Synchronous Gen x 2 units 1,500 3,300	7,255
	(10) Transformer	kVA High (V) Low (V)	9,880 x 1 unit 3ϕ, OA 66,000 3,300	
	(11) Trans. Lines	Type Size kV L (km)	Steel Tower HAL 0.1045 sq.in 66 32.5	3,900
10.	Construction Cost			
	Establishment			500
	Civil			24,331
	Mech/Electr.			7,255
	Contingencies			3,730
	Engineering			1,974
	Total			37,790

SMALL HYDRO PROJECTS AT UPPER LIWAGU RIVER

Lamas 3

1.	Inst. Capacity	kW	3,180
2.	Firm Peak Power	kW	3,180
3.	Energy	GWh	27.7
4.	Construction Cost	1,000 M$	29,080
5.	Cost per kW	M$/kW	9,145
6.	Cost per kWh	M$/kWh	1.05
7.	Plant Factor	%	99
8.	Development Plan		
	(1) Catchment Area	km^2	72.9
	(2) 365, days 100% flow	m^3/s	0.61
	(3) 347, days 95% flow	m^3/s	0.95
	(4) 256, days 70% flow	m^3/s	1.61
	(5) 183, days 50% flow	m^3/s	2.48
	(6) Des. Flow	m^3/s	0.61
	(7) Intake WL	m (ft)	1,220 (4,000)
	(8) T'race WL	m (ft)	534 (1,750)
	(9) Gross head	m	686
	(10) Head loss	m	34
	(11) Net Head	m	652
	(12) Firm Power	kW	3,180
	(13) 100% Power	kW	2,860

				Cost
9.	Layout			
	(1) Intake		Concrete type	236
	(2) L.P. Pipe	L (m) D (m)	3,360 0.65	2,352
	(3) Tunnel	H x B (m) L (m)	-- --	
	(4) Head Pond	(m^3)		--
	(5) Surge Tank	D (m)		74
	(6) Penstock	D (m) L (m)	0.60 1,370	2,042
	(7) Power Station	Structual steel superstructure		680
	(8) Access Roads Improv.	km km	84 5	10,303
	(9) Turb./Generator	Type RPM V	Pelton/3φ Synchronous Gen x 2 units 1,500 3,300	4,464
	(10) Transformer	kVA High (V) Low (V)	3,750 x 1 unit 66,000 3,300	
	(11) Trans. Lines	Type Size kV L (km)	Steel Post HAL 0.1045 sq.in 66 32.5	3,900
10.	Construction Cost			
	Establishment			500
	Civil			19,587
	Mech/Electr.			4,464
	Contingencies			3,013
	Engineering			1,516
	Total			29,080

2. Selection of Optimum Plan in Chapter 9

(1) Saleable Energy of Alternative Plans

(2) Cash Flow of Benefit Cost Ratio of Alternative Plans

(3) Construction Cost of Alternative Plans

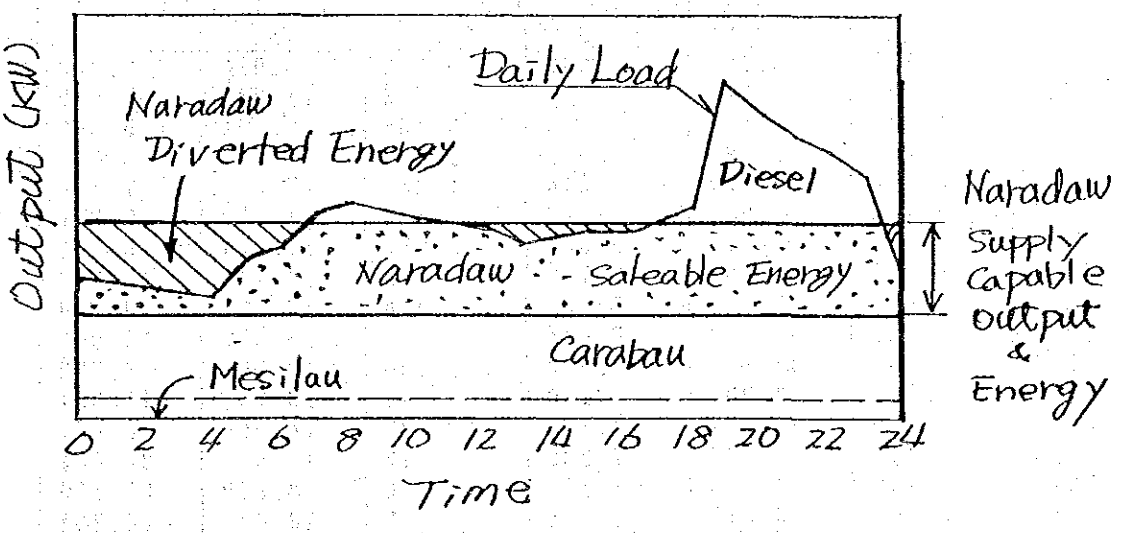
These Data relate to **Table 9-2** in Final Report.

2. Selection of Optimum Plan

(1) Saleable Energy of Alternative Plans

Saleable Energy of Mesilau & Carabau

Year	Demand		Energy Supplied (MWh)				Diesel (MWh)
	Max. Demand (kW)	Annual Energy (MWh)	Mesilau Saleable 299 kW		Carabau Saleable 2,000 kW		
			Used	Disch	Used	Disch	
1992	1,690	7,719	1,925	0	4,796	4,690	998
1993	1,920	8,921	1,925	0	5,589	3,896	1,407
1994	2,200	10,208	1,925	0	6,345	3,140	1,938
1995	2,520	11,583	1,925	0	7,036	2,449	2,622
1996	2,740	12,943	1,925	0	7,614	1,871	3,404
1997	3,020	14,267	1,925	0	8,115	1,371	4,227
1998	3,320	15,715	1,925	0	8,579	906	5,211
1999	3,640	17,201	1,925	0	8,891	594	6,385
2000	3,930	18,958	1,925	0	9,103	383	7,930
2001	4,220	20,320	1,925	0	9,213	272	9,182
2002	4,530	21,843	1,925	0	9,311	174	10,607
2003	4,880	23,494	1,925	0	9,390	95	12,179
2004	5,230	25,204	1,925	0	9,448	37	13,831
2005	5,620	27,064	1,925	0	9,485	0	15,654
2006	5,960	28,715	1,925	0	9,485	0	17,305
2007	6,310	30,467	1,925	0	9,485	0	19,057
	Total	294,622	30,805	0	131,887	19,878	



Minimum water requirement at the river between two intakes and the powerhouse is assumed to be 0.10 m³/s in total

Saleable Energy Naradaw 1,220 KW

He = 115 m

Year	Demand		Energy Supplied (MWh)			
	Max. Demand (kW)	Annual Energy (MWh)	Mesilau 299 kW		Carabau 2,000 kW	
			Used	Disch	Used	Disch
2000	3,930	18,958	1,925	0	9,103	383
2001	4,220	20,320	1,925	0	9,213	272
2002	4,530	21,843	1,925	0	9,311	174
2003	4,880	23,494	1,925	0	9,390	95
2004	5,230	25,204	1,925	0	9,448	37
2005	5,620	27,064	1,925	0	9,485	0
2006	5,960	28,715	1,925	0	9,485	0
2007	6,310	30,467	1,925	0	9,485	0
2008	6,690	32,325	1,925	0	9,485	0
2009	7,100	34,297	1,925	0	9,485	0
2010	7,590	36,585	1,925	0	9,485	0
2011	7,860	37,902	1,925	0	9,485	0
2012	8,150	39,267	1,925	0	9,485	0
2013	8,440	40,680	1,925	0	9,485	0
2014	8,740	42,145	1,925	0	9,485	0
2015	9,050	43,617	1,925	0	9,485	0
	Total	502,883	30,805	0	150,804	961

Year	Demand		Energy Supplied (MWh)			
	Max. Demand (kW)	Annual Energy (MWh)	Naradawl saleable 1,220 kW		Hydro Total	Diesel
			Used	Disch	Used	
2000	3,930	18,958	3,982	3,236	15,010	3,948
2001	4,220	20,320	4,507	2,712	15,645	4,675
2002	4,530	21,843	5,054	2,165	16,291	5,552
2003	4,880	23,494	5,582	1,637	16,897	6,597
2004	5,230	25,204	6,014	1,205	17,388	7,816
2005	5,620	27,064	6,322	896	17,733	9,331
2006	5,960	28,715	6,533	685	17,944	10,771
2007	6,310	30,467	6,710	509	18,120	12,347
2008	6,690	32,325	6,860	358	18,271	14,054
2009	7,100	34,297	6,984	234	18,395	15,902
2010	7,590	36,585	7,092	126	18,503	18,082
2011	7,860	37,902	7,140	78	18,551	19,351
2012	8,150	39,267	7,180	39	18,590	20,677
2013	8,440	40,680	7,206	13	18,616	22,064
2014	8,740	42,145	7,218	0	18,629	23,516
2015	9,050	43,617	7,218	0	18,629	24,988
	Total	502,883	101,603	13,893	283,212	219,671

64,962

166,565

Average for 25 yrs (2000 ~2024) 6,663

Average for 16 yrs (2000 ~2015) 6,350

Saleable Energy Naradaw 1,200 kW

He = 170 m

Year	Demand		Energy Supplied (MWh)			
	Max. Demand (kW)	Annual Energy (MWh)	Mesilau 299 kW		Carabau 2,000 kW	
			Used	Disch	Used	Disch
2000	3,930	18,958	1,925	0	9,103	383
2001	4,220	20,320	1,925	0	9,213	272
2002	4,530	21,843	1,925	0	9,311	174
2003	4,880	23,494	1,925	0	9,390	95
2004	5,230	25,204	1,925	0	9,448	37
2005	5,620	27,064	1,925	0	9,485	0
2006	5,960	28,715	1,925	0	9,485	0
2007	6,310	30,467	1,925	0	9,485	0
2008	6,690	32,325	1,925	0	9,485	0
2009	7,100	34,297	1,925	0	9,485	0
2010	7,590	36,585	1,925	0	9,485	0
2011	7,860	37,902	1,925	0	9,485	0
2012	8,150	39,267	1,925	0	9,485	0
2013	8,440	40,680	1,925	0	9,485	0
2014	8,740	42,145	1,925	0	9,485	0
2015	9,050	43,617	1,925	0	9,485	0
	Total	502,883	30,805	0	150,804	961

Year	Demand		Energy Supplied (MWh)			
	Max. Demand (kW)	Annual Energy (MWh)	Naradaw3 Saleable 1,200 kW		Hydro Total	Diesel
			Used	Disch	Used	
2000	3,930	18,958	4,498	3,253	15,525	3,433
2001	4,220	20,320	5,039	2,712	16,177	4,143
2002	4,530	21,843	5,597	2,154	16,834	5,009
2003	4,880	23,494	6,136	1,615	17,451	6,043
2004	5,230	25,204	6,567	1,184	17,941	7,263
2005	5,620	27,064	6,875	875	18,286	8,778
2006	5,960	28,715	7,087	664	18,498	10,217
2007	6,310	30,467	7,260	491	18,671	11,796
2008	6,690	32,325	7,408	342	18,819	13,506
2009	7,100	34,297	7,530	221	18,940	15,357
2010	7,590	36,585	7,634	117	19,045	17,540
2011	7,860	37,902	7,680	71	19,090	18,812
2012	8,150	39,267	7,716	34	19,127	20,140
2013	8,440	40,680	7,742	9	19,153	21,527
2014	8,740	42,145	7,751	0	19,161	22,984
2015	9,050	43,617	7,751	0	19,161	24,456
	Total	502,883	110,270	13,742	291,880	211,003

69,759

180,029

Average for 25 yrs (2000 ~2024) 7,201

Average for 16 yrs (2000 ~2015) 6,892

Saleable Energy Naradaw 1,600KW

He = 170 m

Year	Demand		Energy Supplied (MWh)			
	Max. Demand (kW)	Annual Energy (MWh)	Mesilau 299 kW		Carabau 2,000 kW	
			Used	Disch	Used	Disch
2000	3,930	18,958	1,925	0	9,103	383
2001	4,220	20,320	1,925	0	9,213	272
2002	4,530	21,843	1,925	0	9,311	174
2003	4,880	23,494	1,925	0	9,390	95
2004	5,230	25,204	1,925	0	9,448	37
2005	5,620	27,064	1,925	0	9,485	0
2006	5,960	28,715	1,925	0	9,485	0
2007	6,310	30,467	1,925	0	9,485	0
2008	6,690	32,325	1,925	0	9,485	0
2009	7,100	34,297	1,925	0	9,485	0
2010	7,590	36,585	1,925	0	9,485	0
2011	7,860	37,902	1,925	0	9,485	0
2012	8,150	39,267	1,925	0	9,485	0
2013	8,440	40,680	1,925	0	9,485	0
2014	8,740	42,145	1,925	0	9,485	0
2015	9,050	43,617	1,925	0	9,485	0
	Total	502,883	30,805	0	150,804	961

Year	Demand		Energy Supplied (MWh)			
	Max. Demand (kW)	Annual Energy (MWh)	Naradaw2 saleable 1,600 kW		Hydro Total	Diesel
			Used	Disch	Used	
2000	3,930	18,958	4,806	4,885	15,834	3,124
2001	4,220	20,320	5,446	4,245	16,585	3,735
2002	4,530	21,843	6,117	3,573	17,354	4,489
2003	4,880	23,494	6,802	2,888	18,118	5,376
2004	5,230	25,204	7,437	2,254	18,811	6,393
2005	5,620	27,064	8,044	1,646	19,455	7,609
2006	5,960	28,715	8,437	1,253	19,848	8,867
2007	6,310	30,467	8,733	957	20,144	10,323
2008	6,690	32,325	8,968	723	20,378	11,947
2009	7,100	34,297	9,157	533	20,568	13,729
2010	7,590	36,585	9,337	354	20,747	15,838
2011	7,860	37,902	9,420	271	20,830	17,072
2012	8,150	39,267	9,491	199	20,902	18,365
2013	8,440	40,680	9,555	136	20,966	19,714
2014	8,740	42,145	9,608	83	21,018	21,127
2015	9,050	43,617	9,649	41	21,060	22,557
	Total	502,883	131,009	24,041	312,618	190,265

87,210

218,219

Average for 25yrs (2000~2024) 8,729

Average for 16yrs (2000~2015) 8,189

Saleable Energy Naradaw 2,000KW

He = 170 m

Year	Demand		Energy Supplied (MWh)			
	Max. Demand (kW)	Annual Energy (MWh)	Mesilau 299 kW		Carabau 2,000 kW	
			Used	Disch	Used	Disch
2000	3,930	18,958	1,925	0	9,103	383
2001	4,220	20,320	1,925	0	9,213	272
2002	4,530	21,843	1,925	0	9,311	174
2003	4,880	23,494	1,925	0	9,390	95
2004	5,230	25,204	1,925	0	9,448	37
2005	5,620	27,064	1,925	0	9,485	0
2006	5,960	28,715	1,925	0	9,485	0
2007	6,310	30,467	1,925	0	9,485	0
2008	6,690	32,325	1,925	0	9,485	0
2009	7,100	34,297	1,925	0	9,485	0
2010	7,590	36,585	1,925	0	9,485	0
2011	7,860	37,902	1,925	0	9,485	0
2012	8,150	39,267	1,925	0	9,485	0
2013	8,440	40,680	1,925	0	9,485	0
2014	8,740	42,145	1,925	0	9,485	0
2015	9,050	43,617	1,925	0	9,485	0
	Total	502,883	30,805	0	150,804	961

Year	Demand		Energy Supplied (MWh)			
	Max. Demand (kW)	Annual Energy (MWh)	Naradaw4 Saleable 2,000 kW		Hydro Total	Diesel
			Used	Disch	Used	
2000	3,930	18,958	4,932	6,409	15,959	2,999
2001	4,220	20,320	5,622	5,719	16,761	3,559
2002	4,530	21,843	6,344	4,997	17,581	4,262
2003	4,880	23,494	7,080	4,261	18,395	5,099
2004	5,230	25,204	7,815	3,526	19,188	6,016
2005	5,620	27,064	8,565	2,776	19,975	7,089
2006	5,960	28,715	9,180	2,161	20,590	8,125
2007	6,310	30,467	9,707	1,634	21,117	9,350
2008	6,690	32,325	10,093	1,248	21,504	10,821
2009	7,100	34,297	10,380	961	21,791	12,506
2010	7,590	36,585	10,639	702	22,049	14,536
2011	7,860	37,902	10,753	588	22,164	15,738
2012	8,150	39,267	10,866	475	22,276	16,991
2013	8,440	40,680	10,965	376	22,376	18,304
2014	8,740	42,145	11,058	283	22,469	19,676
2015	9,050	43,617	11,133	208	22,544	21,073
	Total	502,883	145,131	36,325	326,741	176,142

102,069

247,200

Average for 25 yrs (2000 ~2024) 9,888

Average for 16 yrs (2000 ~2015) 9,071

Saleable Energy Naradaw 2400KW

He = 170 m

Year	Demand		Energy Supplied (MWh)			
	Max. Demand (kW)	Annual Energy (MWh)	Mesilau 299 kW		Carabau 2,000 kW	
			Used	Disch	Used	Disch
2000	3,930	18,958	1,925	0	9,103	383
2001	4,220	20,320	1,925	0	9,213	272
2002	4,530	21,843	1,925	0	9,311	174
2003	4,880	23,494	1,925	0	9,390	95
2004	5,230	25,204	1,925	0	9,448	37
2005	5,620	27,064	1,925	0	9,485	0
2006	5,960	28,715	1,925	0	9,485	0
2007	6,310	30,467	1,925	0	9,485	0
2008	6,690	32,325	1,925	0	9,485	0
2009	7,100	34,297	1,925	0	9,485	0
2010	7,590	36,585	1,925	0	9,485	0
2011	7,860	37,902	1,925	0	9,485	0
2012	8,150	39,267	1,925	0	9,485	0
2013	8,440	40,680	1,925	0	9,485	0
2014	8,740	42,145	1,925	0	9,485	0
2015	9,050	43,617	1,925	0	9,485	0
	Total	502,883	30,805	0	150,804	961

Year	Demand		Energy Supplied (MWh)			
	Max. Demand (kW)	Annual Energy (MWh)	Naradaw5 Saleable 2,400 kW		Hydro Total	Diesel
			Used	Disch	Used	
2000	3,930	18,958	4,972	7,780	16,000	2,958
2001	4,220	20,320	5,700	7,052	16,839	3,481
2002	4,530	21,843	6,469	6,284	17,705	4,138
2003	4,880	23,494	7,248	5,504	18,563	4,931
2004	5,230	25,204	8,000	4,752	19,373	5,831
2005	5,620	27,064	8,788	3,965	20,198	6,866
2006	5,960	28,715	9,476	3,276	20,887	7,828
2007	6,310	30,467	10,139	2,613	21,550	8,917
2008	6,690	32,325	10,766	1,986	22,177	10,148
2009	7,100	34,297	11,245	1,507	22,655	11,642
2010	7,590	36,585	11,622	1,130	23,032	13,553
2011	7,860	37,902	11,782	970	23,193	14,709
2012	8,150	39,267	11,934	818	23,345	15,922
2013	8,440	40,680	12,061	691	23,472	17,208
2014	8,740	42,145	12,180	572	23,591	18,554
2015	9,050	43,617	12,290	462	23,701	19,916
	Total	502,883	154,671	49,362	336,281	166,602

114,768

269,439

Average for 25 yrs (2000 ~2024) 10,778

Average for 16 yrs (2000 ~2015) 9,667

2. Selection of Optimum Plan

(2) Cash Flow of Benefit and Cost of Alternative Plans

Input Data : Naradaw P= 1,220 kW

Year of Start (n=0) 1997

(Thousand M$)

	n	Year	Naradaw Invest.	Diesel Invest.	Diesel kWh	Year
Const.	0	1997	1,060	0		1997
Const.	1	1998	6,360	349		1998
Const.	2	1999	3,180	349		1999
Opera.	3	2000	159	35	3,982	2000
Opera.	4	2001			4,507	2001
Opera.	5	2002			5,054	2002
Opera.	6	2003			5,582	2003
Opera.	7	2004			6,014	2004
Opera.	8	2005			6,322	2005
Opera.	9	2006			6,533	2006
Opera.	10	2007			6,710	2007
Opera.	11	2008			6,860	2008
Opera.	12	2009			6,984	2009
Opera.	13	2010			7,092	2010
Opera.	14	2011			7,140	2011
Opera.	15	2012			7,180	2012
Re-Const	16	2013		349 + 35	7,206	2013
Re-Const	17	2014		349 + 35	7,218	2014
Opera.	18	2015			7,218	2015
Opera.	19	2016			7,218	2016
Opera.	20	2017			7,218	2017
Opera.	21	2018			7,218	2018
Opera.	22	2019			7,218	2019
Opera.	23	2020			7,218	2020
Opera.	24	2021			7,218	2021
Opera.	25	2022			7,218	2022
Opera.	26	2023			7,218	2023
Opera.	27	2024	159	35	7,218	2024
			(2)	(3)		

(Narada) * 1,000 M$

(1) Const. cost 20,600 * → (2)

(2) O & M Cost 159 * = (1) X 0.015 = 159 → (2)

(3) Energy ~~generated~~ supply capable 7.2 * X 10^6 kWh

(4) Firm power 400 kW

(Diesel)

(5) Inst. capacity 500 kW = (4) X 1.25 = 400 X 1.25 = 500

(6) Const. cost 698 * = (5) X 1,395 M$/kW → (3)

(7) O & M cost 35 * = (6) X 0.05 → (3)

(8) Fuel cost 1,260 * = (3) X 0.97 X 0.18 M$/kWh (0.175) → (4)

Benefit Cost Ratio Calculation : Naradaw P= 1,220 kW

(Thousand M$)

Year	n	1/1.1 n	Cost Stream		Benefit Stream			
			Naradaw		Alternative (Diesel)			
			Invest.	C Value	Invest.	Fuel	Total	B Value
1997	0	1.000	1,060	1,060	0	0	0	0
1998	1	0.909	6,360	5,782	349	0	349	317
1999	2	0.826	3,180	2,628	349	0	349	288
2000	3	0.751	159	119	35	697	732	550
2001	4	0.683	159	109	35	789	824	563
2002	5	0.621	159	99	35	884	919	571
2003	6	0.564	159	90	35	977	1,012	571
2004	7	0.513	159	82	35	1,052	1,087	558
2005	8	0.467	159	74	35	1,106	1,141	532
2006	9	0.424	159	67	35	1,143	1,178	500
2007	10	0.386	159	61	35	1,174	1,209	466
2008	11	0.350	159	56	35	1,201	1,236	433
2009	12	0.319	159	51	35	1,222	1,257	401
2010	13	0.290	159	46	35	1,241	1,276	370
2011	14	0.263	159	42	35	1,250	1,285	338
2012	15	0.239	159	38	35	1,257	1,292	309
2013	16	0.218	159	35	384	1,261	1,645	358
2014	17	0.198	159	31	384	1,263	1,647	326
2015	18	0.180	159	29	35	1,263	1,298	233
2016	19	0.164	159	26	35	1,263	1,298	212
2017	20	0.149	159	24	35	1,263	1,298	193
2018	21	0.135	159	21	35	1,263	1,298	175
2019	22	0.123	159	20	35	1,263	1,298	159
2020	23	0.112	159	18	35	1,263	1,298	145
2021	24	0.102	159	16	35	1,263	1,298	132
2022	25	0.092	159	15	35	1,263	1,298	120
2023	26	0.084	159	13	35	1,263	1,298	109
2024	27	0.076	159	12	35	1,263	1,298	99
		Total		10,663				9,029

B/C	0.85
B-C	-1,633

Input Data : Naradaw P= 1,200 kW

Year of Start (n=0) 1997

(Thousand M$)

	n	Year	Naradaw	Diesel		Year
			Invest.	Invest.	kWh	
Const.	0	1997	1,020	0		1997
Const.	1	1998	6,120	488		1998
Const.	2	1999	3,060	488		1999
Opera.	3	2000	153	49	4,498	2000
Opera.	4	2001			5,039	2001
Opera.	5	2002			5,597	2002
Opera.	6	2003			6,136	2003
Opera.	7	2004			6,567	2004
Opera.	8	2005			6,875	2005
Opera.	9	2006			7,087	2006
Opera.	10	2007			7,260	2007
Opera.	11	2008			7,408	2008
Opera.	12	2009			7,530	2009
Opera.	13	2010			7,634	2010
Opera.	14	2011			7,680	2011
Opera.	15	2012			7,716	2012
Re-Const	16	2013		488+49	7,742	2013
Re-Const	17	2014		488+49	7,751	2014
Opera.	18	2015			7,751	2015
Opera.	19	2016			7,751	2016
Opera.	20	2017			7,751	2017
Opera.	21	2018			7,751	2018
Opera.	22	2019			7,751	2019
Opera.	23	2020			7,751	2020
Opera.	24	2021			7,751	2021
Opera.	25	2022			7,751	2022
Opera.	26	2023			7,751	2023
Opera.	27	2024	153	49	7,751	2024
			(2)	(3)		

(Narada) * 1,000 M$

(1) Const. cost 10,200 * → (2)

(2) O & M Cost 153 * = (1) X 0.015 → (2)

(3) Energy ~~generated~~ supply capable 7.8 * X 10^6 kWh

(4) Firm power 560 kW

(Diesel)

(5) Inst. capacity 700 kW = (4) X 1.25 = 560 X 1.25 = 700

(6) Const. cost 976 * = (5) X 1,395 M$/kW → (3)

(7) O & M cost 49 * = (6) X 0.05 → (3)

(8) Fuel cost 1,365 * = (3) X 0.97 X 0.18 M$/kWh → (4)
0.175

Benefit Cost Ratio Calculation : Naradaw P= 1,200 kW

(Thousand M$)

Year	n	1/1.1 n	Cost Stream		Benefit Stream			
			Naradaw		Alternative (Diesel)			
			Invest.	C Value	Invest.	Fuel	Total	B Value
1997	0	1.000	1,020	1,020	0	0	0	0
1998	1	0.909	6,120	5,564	488	0	488	444
1999	2	0.826	3,060	2,529	488	0	488	403
2000	3	0.751	153	115	49	787	836	628
2001	4	0.683	153	105	49	882	931	636
2002	5	0.621	153	95	49	979	1,028	639
2003	6	0.564	153	86	49	1,074	1,123	634
2004	7	0.513	153	79	49	1,149	1,198	615
2005	8	0.467	153	71	49	1,203	1,252	584
2006	9	0.424	153	65	49	1,240	1,289	547
2007	10	0.386	153	59	49	1,271	1,320	509
2008	11	0.350	153	54	49	1,296	1,345	472
2009	12	0.319	153	49	49	1,318	1,367	435
2010	13	0.290	153	44	49	1,336	1,385	401
2011	14	0.263	153	40	49	1,344	1,393	367
2012	15	0.239	153	37	49	1,350	1,399	335
2013	16	0.218	153	33	537	1,355	1,892	412
2014	17	0.198	153	30	537	1,356	1,893	375
2015	18	0.180	153	28	49	1,356	1,405	253
2016	19	0.164	153	25	49	1,356	1,405	230
2017	20	0.149	153	23	49	1,356	1,405	209
2018	21	0.135	153	21	49	1,356	1,405	190
2019	22	0.123	153	19	49	1,356	1,405	173
2020	23	0.112	153	17	49	1,356	1,405	157
2021	24	0.102	153	16	49	1,356	1,405	143
2022	25	0.092	153	14	49	1,356	1,405	130
2023	26	0.084	153	13	49	1,356	1,405	118
2024	27	0.076	153	12	49	1,356	1,405	107
		Total		10,260				10,143

B/C	0.99
B-C	-118

Cash Flow of Benefit and Cost

Input Data : Naradaw P= 1,600 kW

Year of Start (n=0) 1997

(Thousand M$)

	n	Year	Naradaw Invest.	Diesel Invest.	Diesel kWh	Year
Const.	0	1997	1,150	0		1997
Const.	1	1998	6,900	488		1998
Const.	2	1999	3,450	488		1999
Opera.	3	2000	173	49	4,806	2000
Opera.	4	2001			5,446	2001
Opera.	5	2002			6,117	2002
Opera.	6	2003			6,802	2003
Opera.	7	2004			7,437	2004
Opera.	8	2005			8,044	2005
Opera.	9	2006			8,437	2006
Opera.	10	2007			8,733	2007
Opera.	11	2008			8,968	2008
Opera.	12	2009			9,157	2009
Opera.	13	2010			9,337	2010
Opera.	14	2011			9,420	2011
Opera.	15	2012		49	9,491	2012
Re-Const	16	2013		488+ 49	9,555	2013
Re-Const	17	2014		488+ 49	9,608	2014
Opera.	18	2015		49	9,649	2015
Opera.	19	2016			9,690	2016
Opera.	20	2017			9,690	2017
Opera.	21	2018			9,690	2018
Opera.	22	2019			9,690	2019
Opera.	23	2020			9,690	2020
Opera.	24	2021			9,690	2021
Opera.	25	2022			9,690	2022
Opera.	26	2023			9,690	2023
Opera.	27	2024	173	49	9,690	2024
			(2)	(3)		

(Narada) * 1,000 M$

(1) Const. cost 11,500 * → (2)

(2) O & M Cost 173 * = (1) X 0.015 → (2)

(3) Energy ~~generated~~ supply capable 9.7 * X 10^6 kWh

(4) Firm power 560 kW

(Diesel)

(5) Inst. capacity 700 kW = (4) X 1.25 = 560 X 1.25 = 700

(6) Const. cost 976 * = (5) X 1,395 M$/kW → (3)

(7) O & M cost 49 * = (6) X 0.05 → (3)

(8) Fuel cost 1,698 * = (3) X 0.97 X 0.18 M$/kWh 0.175 → (4)

Benefit Cost Ratio Calculation : Naradaw P= 1,600 kW

(Thousand M$)

Year	n	1/1.1 n	Cost Stream		Benefit Stream			
			Naradaw		Alternative (Diesel)			
			Invest.	C Value	Invest.	Fuel	Total	B Value
1997	0	1.000	1,150	1,150	0	0	0	0
1998	1	0.909	6,900	6,273	488	0	488	444
1999	2	0.826	3,450	2,851	488	0	488	403
2000	3	0.751	173	130	49	841	890	669
2001	4	0.683	173	118	49	953	1,002	684
2002	5	0.621	173	107	49	1,070	1,119	695
2003	6	0.564	173	98	49	1,190	1,239	700
2004	7	0.513	173	89	49	1,301	1,350	693
2005	8	0.467	173	81	49	1,408	1,457	680
2006	9	0.424	173	73	49	1,476	1,525	647
2007	10	0.386	173	67	49	1,528	1,577	608
2008	11	0.350	173	61	49	1,569	1,618	567
2009	12	0.319	173	55	49	1,602	1,651	526
2010	13	0.290	173	50	49	1,634	1,683	487
2011	14	0.263	173	46	49	1,649	1,698	447
2012	15	0.239	173	41	49	1,661	1,710	409
2013	16	0.218	173	38	537	1,672	2,209	481
2014	17	0.198	173	34	537	1,681	2,218	439
2015	18	0.180	173	31	49	1,689	1,738	313
2016	19	0.164	173	28	49	1,696	1,745	285
2017	20	0.149	173	26	49	1,696	1,745	259
2018	21	0.135	173	23	49	1,696	1,745	236
2019	22	0.123	173	21	49	1,696	1,745	214
2020	23	0.112	173	19	49	1,696	1,745	195
2021	24	0.102	173	18	49	1,696	1,745	177
2022	25	0.092	173	16	49	1,696	1,745	161
2023	26	0.084	173	15	49	1,696	1,745	146
2024	27	0.076	173	13	49	1,696	1,745	133
		Total		11,572				11,699

B/C	1.01
B-C	127

Input Data : Naradaw P= 2,000 kW

Year of Start (n=0) 1997

(Thousand M$)

	n	Year	Naradaw	Diesel		Year
			Invest.	Invest.	kWh	
Const.	0	1997	1,310	0		1997
Const.	1	1998	7,860	488		1998
Const.	2	1999	3,930	488		1999
Opera.	3	2000	197	49	4,932	2000
Opera.	4	2001			5,622	2001
Opera.	5	2002			6,344	2002
Opera.	6	2003			7,080	2003
Opera.	7	2004			7,815	2004
Opera.	8	2005			8,565	2005
Opera.	9	2006			9,180	2006
Opera.	10	2007			9,707	2007
Opera.	11	2008			10,093	2008
Opera.	12	2009			10,380	2009
Opera.	13	2010			10,639	2010
Opera.	14	2011			10,753	2011
Opera.	15	2012			10,866	2012
Re-Const	16	2013		488+49	10,965	2013
Re-Const	17	2014		488+49	11,058	2014
Opera.	18	2015			11,133	2015
Opera.	19	2016			11,341	2016
Opera.	20	2017			11,341	2017
Opera.	21	2018			11,341	2018
Opera.	22	2019			11,341	2019
Opera.	23	2020			11,341	2020
Opera.	24	2021			11,341	2021
Opera.	25	2022			11,341	2022
Opera.	26	2023			11,341	2023
Opera.	27	2024	197	49	11,341	2024
			(2)	(3)		

(Narada) * 1,000 M$

(1) Const. cost 13,100 * → (2)

(2) O & M Cost 197 * = (1) X 0.015 → (2)

(3) Energy ~~generated~~ supply capable 11.3 * X 10^6 kWh

(4) Firm power 560 kW

(Diesel)

(5) Inst. capacity 700 kW = (4) X 1.25 = 560 x1.25 = 700

(6) Const. cost 976 * = (5) X 1,395 M$/kW → (3)

(7) O & M cost 49 * = (6) X 0.05 → (3)

(8) Fuel cost 1,978 * = (3) X 0.97 X 0.18 M$/kWh (0.175) → (4)

Benefit Cost Ratio Calculation : Naradaw P= 2,000 kW

(Thousand M$)

Year	n	1/1.1^n	Cost Stream Naradaw Invest.	C Value	Benefit Stream Alternative (Diesel) Invest.	Fuel	Total	B Value
1997	0	1.000	1,310	1,310	0	0	0	0
1998	1	0.909	7,860	7,145	488	0	488	444
1999	2	0.826	3,930	3,248	488	0	488	403
2000	3	0.751	197	148	49	863	912	685
2001	4	0.683	197	135	49	984	1,033	705
2002	5	0.621	197	122	49	1,110	1,159	720
2003	6	0.564	197	111	49	1,239	1,288	727
2004	7	0.513	197	101	49	1,368	1,417	727
2005	8	0.467	197	92	49	1,499	1,548	722
2006	9	0.424	197	84	49	1,607	1,656	702
2007	10	0.386	197	76	49	1,699	1,748	674
2008	11	0.350	197	69	49	1,766	1,815	636
2009	12	0.319	197	63	49	1,817	1,866	594
2010	13	0.290	197	57	49	1,862	1,911	553
2011	14	0.263	197	52	49	1,882	1,931	508
2012	15	0.239	197	47	49	1,902	1,951	467
2013	16	0.218	197	43	537	1,919	2,456	534
2014	17	0.198	197	39	537	1,935	2,472	489
2015	18	0.180	197	35	49	1,948	1,997	359
2016	19	0.164	197	32	49	1,985	2,034	333
2017	20	0.149	197	29	49	1,985	2,034	302
2018	21	0.135	197	27	49	1,985	2,034	275
2019	22	0.123	197	24	49	1,985	2,034	250
2020	23	0.112	197	22	49	1,985	2,034	227
2021	24	0.102	197	20	49	1,985	2,034	206
2022	25	0.092	197	18	49	1,985	2,034	188
2023	26	0.084	197	17	49	1,985	2,034	171
2024	27	0.076	197	15	49	1,985	2,034	155
		Total		13,181				12,758

B/C	0.97
B-C	-423

Input Data : Naradaw P= 2,400 kW

Year of Start (n=0) 1997

(Thousand M$)

	n	Year	Naradaw	Diesel		Year
			Invest.	Invest.	kWh	
Const.	0	1997	1,430	0		1997
Const.	1	1998	8,580	488		1998
Const.	2	1999	4,290	488		1999
Opera.	3	2000	215	49	4,792	2000
Opera.	4	2001			5,700	2001
Opera.	5	2002			6,469	2002
Opera.	6	2003			7,248	2003
Opera.	7	2004			8,000	2004
Opera.	8	2005			8,788	2005
Opera.	9	2006			9,476	2006
Opera.	10	2007			10,139	2007
Opera.	11	2008			10,766	2008
Opera.	12	2009			11,245	2009
Opera.	13	2010			11,622	2010
Opera.	14	2011			11,782	2011
Opera.	15	2012			11,934	2012
Re-Const	16	2013		488+49	12,061	2013
Re-Const	17	2014		488+49	12,180	2014
Opera.	18	2015			12,290	2015
Opera.	19	2016			12,752	2016
Opera.	20	2017			12,752	2017
Opera.	21	2018			12,752	2018
Opera.	22	2019			12,752	2019
Opera.	23	2020			12,752	2020
Opera.	24	2021			12,752	2021
Opera.	25	2022			12,752	2022
Opera.	26	2023			12,752	2023
Opera.	27	2024	215	49	12,752	2024
			(2)	(3)		

(Narada) * 1,000 M$

(1) Const. cost 14,300 * (2)

(2) O & M Cost 215 * = (1) X 0.015 (2)

(3) Energy ~~generated~~ supply capabe 12.8 * X 10^6 kWh

(4) Firm power 560 kW

(Diesel)

(5) Inst. capacity 700 kW = (4) X 1.25 = 560 x 1.25 = 700

(6) Const. cost 976 * = (5) X 1,395 M$/kW (3)

(7) O & M cost 49 * = (6) X 0.05 (3)

(8) Fuel cost 2,240 * = (3) X 0.97 X 0.18 M$/kWh 0.175 (4)

Benefit Cost Ratio Calculation : Naradaw P= 2,400 kW

(Thousand M$)

Year	n	1/1.1^n	Cost Stream Naradaw		Benefit Stream Alternative (Diesel)			
			Invest.	C Value	Invest.	Fuel	Total	B Value
1997	0	1.000	1,430	1,430	0	0	0	0
1998	1	0.909	8,580	7,800	488	0	488	444
1999	2	0.826	4,290	3,545	488	0	488	403
2000	3	0.751	215	162	49	839	888	667
2001	4	0.683	215	147	49	998	1,047	715
2002	5	0.621	215	133	49	1,132	1,181	733
2003	6	0.564	215	121	49	1,268	1,317	744
2004	7	0.513	215	110	49	1,400	1,449	744
2005	8	0.467	215	100	49	1,538	1,587	740
2006	9	0.424	215	91	49	1,658	1,707	724
2007	10	0.386	215	83	49	1,774	1,823	703
2008	11	0.350	215	75	49	1,884	1,933	678
2009	12	0.319	215	69	49	1,968	2,017	643
2010	13	0.290	215	62	49	2,034	2,083	603
2011	14	0.263	215	57	49	2,062	2,111	556
2012	15	0.239	215	51	49	2,088	2,137	512
2013	16	0.218	215	47	537	2,111	2,648	576
2014	17	0.198	215	43	537	2,132	2,669	528
2015	18	0.180	215	39	49	2,151	2,200	396
2016	19	0.164	215	35	49	2,232	2,281	373
2017	20	0.149	215	32	49	2,232	2,281	339
2018	21	0.135	215	29	49	2,232	2,281	308
2019	22	0.123	215	26	49	2,232	2,281	280
2020	23	0.112	215	24	49	2,232	2,281	255
2021	24	0.102	215	22	49	2,232	2,281	232
2022	25	0.092	215	20	49	2,232	2,281	210
2023	26	0.084	215	18	49	2,232	2,281	191
2024	27	0.076	215	16	49	2,232	2,281	174
		Total		14,388				13,470

B/C	0.94
B-C	-919

Re

2. Selection of Optimum Plan

(3) Construction Cost of Alternative Plans

Naradaw 1,220 kW
He = 115 m

OPTIMIZATION AT NARADAW

01. Plan

Installed Capacity	1,220 KW	Net head	115 m
Maximum discharge	1.33 m3/s		
Construction Cost	10,600,000 M$		

02. Layout

(1) Intake M.R.	Concrete type			
L.R.	Concrete type			
		(weir ~ pond)		(Pond ~ surge tank)
(2) L.P. Conduit M.R.	L(m)	320 (1.1 × 290 m)		640 (1.1 × 585)
	D(m)	0.6 ($0.8\sqrt{0.49}$)		0.7 ($0.8\sqrt{0.78}$)
(3) Conduit L.R.	L(m)	2,440	= 1.1 × 2,220 m	
	D(m)	0.7	$= 0.8\sqrt{Q} = 0.8\sqrt{0.84} = 0.73$	
(4) Head Pond	(m3)	2,000	$= \frac{400-250}{8 \times 115m} \times 2.5^h \times 3{,}600^s \times 1.4$	
(5) Surge Tank	D (m)			
(6) Penstock	D (m)	0.8	$= 0.65\sqrt{Q} = 0.65\sqrt{1.33} = 0.75$	
	L (m)	495	$= \sqrt{\ell^2+h^2} = \sqrt{480^2+(992.5-852)^2}$	
(7) Power Station				
(8) Access Roads	km	3.2		
Improv.	km	2.2		
(9) Turb./Generator	Type	Tango Impulse/3φ Synchronous Generator x 2 units		
	RPM			
	V			
(10) Transformer	KVA	1,800 x 1 unit, 3φ, 0 A		
	High (V)	11,000		
	Low (V)	3,300		
(11) Trans. Lines	Type	Steel post		
	Size	HAL 0.166 sq. in.		
	KV	11		
	L (km)	1.0		

Note: D = Diameter, L = Length, V = Voltage
M.R. = Mesilau River L.R. = Liwagu River

(12) Spill way	L(m)	495	= Penstock
	D(m)	0.7	

1

Naradaw 1,220 KW
He=115 m

Summary of Coasts (Unit 1,000 M$)

(1)	Establishment	400	= P<1,000 KW 350,000 $, P≧1,000 KW 400,000 $
(2)	Div Weir/Intake	490	M.R = $374 \times \sqrt{D_1 \times Q_1} = 374 \times \sqrt{0.6 \times 0.99} = 203$ L.R = $374 \times \sqrt{D_2 \times Q_2} = 374 \times \sqrt{0.7 \times 0.84} = 287$
(3)	L. P. Condult	2,518	M.R = L ~~640~~ 320 m @ ~~750~~ 650 (~~D 0.7 m~~ D 0.6) L.R = L 2,440 m @ 750 (D 0.7 m)
(4)	Head Pond	500	= V 2,000 m³ @ 250 $/m³
(5)	Surge Tank	90	
(6)	Penstock	658	= L 495 m @ 1,330 Pen (D 0.8 m)
(7)	Spillway	371	= L 495 m @ 750 L.P (D 0.7 m)
(8)	Power Station	227	= $770 (P\sqrt{He})^{0.6} = 770 \times (1,220 \times \sqrt{115})^{0.6}$
(9)	Access Roads	516	Power St. 0.8 km @ 120,000 $/km = 96 Pipe 2.4 km @ 120,000 = 288 Const ~~1.0~~ 1.2 km @ 60,000 = 132
(10)	Turb./Generator Transformer/etc	2,942	= $107 \cdot (\frac{P}{\sqrt{He}})^{0.7} = 107 \cdot (\frac{1,220}{\sqrt{115}})^{0.7}$
(11)	Trans. Lines	43	= L 1 km @ 43,000 $/km
(12)	Sub Total	8,755	

Establishment	400	
Civil	5,413	
Mech/Electr.	2,942	
Contingencies	1,313	= 0.15 × (~~Esta+Civil~~ (12)) = 0.15 × (8,755)
Engineering	554	= 5.5% × (above cost) = 0.055 × 10,068
Total	10,622	≒ 10,600 × 10³ M$

1 M$ = 0.38 US$ = 54 ¥

Naradaw 1,200kW
H_e= 170m

OPTIMIZATION AT NARADAW

1. Plan
   - Installed Capacity P= 1,200 KW — Net head = 169 m → 170 m
   - Maximum discharge Q= 0.89 m3/s
   - Construction Cost 10,200,000 M$

2. Layout

(1) Intake M.R.	Concrete type		
L.R.	Concrete type		
(2) L.P. Conduit M.R.	L(m)	1,000	$= 1.1 \ell = 1.1 \times 910$
	D_1(m)	0.6	$= 0.8\sqrt{Q_1} = 0.8 \times \sqrt{0.40} = 0.506$
(3) L.P. Conduit L.R.	L(m)	2,890	$= 1.1 \ell = 1.1 \times 2{,}630$
	D_2(m)	0.6	$= 0.8\sqrt{Q_2} = 0.8 \times \sqrt{0.49} = 0.56$
(4) Head Pond	(m3)	2,000	
(5) Surge Tank	D (m)	–	
(6) Penstock	D (m)	0.7	$= 0.65\sqrt{Q} = 0.65 \times \sqrt{0.89} = 0.613$
	L (m)	805	$= \sqrt{\ell^2 + h^2} = \sqrt{785^2 + (1{,}030 - 852)^2}$
(7) Power Station		Structual steel supperstructure	
(8) Access Roads	km	4.69	
Improv.	km	1.2	
(9) Turb./Generator	Type	Targo Impulse/3φ Synchronous Generator x 2 units	
	RPM		
	V		
(10) Transformer	KVA	x 1 unit, 3φ, 0 A	
	High (V)	11,000	
	Low (V)	3,300	
(11) Trans. Lines	Type	Steel post	
	Size	HAL 0.166 sq. in.	
	KV	11	
	L (km)	1.0	

Note: D = Diameter, L = Length, V = Voltage
M.R. = Mesilau River L.R. = Liwagu River

(12) Spillway	L (m)	210	$= 1.1 \ell = 1.1 \times \sqrt{180^2 + (1030 - 980)^2}$
	D (m)	0.7	$= 0.65\sqrt{Q} = 0.65 \times \sqrt{0.89} = 0.613$

1

Re

Naradaw 1,200 KW
He = 170 m

Summary of Coasts (Unit 1,000 M$)

(1)	Establishment	400	= P < 1,000 KW ~~250~~ 350,000 $, P ≥ 1,000 KW ~~300~~ 388,000 $
(2)	Div Weir/Intake	386	M.R = $374 \times \sqrt{D_1 \times Q_1} = 374 \times \sqrt{0.6 \times 0.40} = 183$ L.R = $374 \times \sqrt{D_2 \times Q_2} = 374 \times \sqrt{0.6 \times 0.49} = 203$
(3)	L. P. Condult	2,529	M.R = L 2,000 m @ 650 (D_1 0.6 m) L.R = L 2,890 m @ 650 (D_2 0.6 m)
(4)	Head Pond	500	= V 2,000 m³ @ 250 $/m³
(5)	Surge Tank	–	
(6)	Penstock	982	= L 805 m @ 1220 Pen (D 0.7 m)
(7)	Spillway	158	= L 210 m @ 750 L.P (D 0.7 m)
(8)	Power Station	253	= $770 (P\sqrt{He})^{0.6} = 770 \times (1,200 \times \sqrt{169})^{0.6}$
(9)	Access Roads	635	Power St. 0.8 km @ 120,000 $/km = 96 Pipe 3.89 km @ 120,000 = 467 Const 1.2 km @ 60,000 = 72
(10)	Turb./Generator Transformer/etc	2,541	= $107 \left(\frac{P}{\sqrt{He}}\right)^{0.7} = 107 \left(\frac{1,200}{\sqrt{169}}\right)^{0.7}$
(11)	Trans. Lines	43	= L 1 km @ 43,000 $/km
(12)	Sub Total	8,427	

		8486
Establishment	400	
Civil	5,486	
Mech/Electr.	2,541	
Contingencies	1,264	= 0.15 × (~~Esta+Civil~~ 12) = 0.15 × (8,427)
Engineering	533	= 5.5% × (above cost) = 0.055 × 9,691
Total	10,224	= 10,200 × 10³ M.$

1 M$ = 0.38 US$ = 54 ¥

Naradaw 1,600 KW
He = 170 m

OPTIMIZATION AT NARADAW

1. Plan
   - Installed Capacity 1,600 KW Net head 169 m → 170 m
   - Maximum discharge 1.18 m3/s → 1.2 m3/s
   - Construction Cost 11,500,000 M$

2. Layout

(1) Intake M.R.	Concrete type	Water level	1,036 m	
L.R.	Concrete type	Water level	1,048 m	
(2) L.P. Conduit M.R.	L(m)	1,000	$= 1.1\ell = 1.1 \times 910$	
	D(m)	0.6	$= 0.8\sqrt{Q} = 0.8 \times \sqrt{0.48} = 0.55$	
(3) Conduit L.R.	L(m)	2,890	$= 1.1\ell = 1.1 \times 2{,}630$	
	D(m)	0.7	$= 0.8\sqrt{Q} = 0.8 \times \sqrt{0.70} = 0.669$	
(4) Head Pond	(m3)	2,000		
(5) Surge Tank	D (m)	—		
(6) Penstock	D (m)	0.8	$= 0.65\sqrt{Q} = 0.65 \times \sqrt{1.18} = 0.706$	
	L (m)	805	$= \sqrt{\ell^2 + h^2} = 785^2 + \sqrt{(1{,}030 - 852)^2}$	
(7) Power Station		Structual steel supperstructure		
(8) Access Roads	km	4.69		
Improv.	km	1.2		
(9) Turb./Generator	Type	Targo Impulse/3φ Synchronous Generator x 2 units		
	RPM			
	V			
(10) Transformer	KVA	x 1 unit, 3φ, 0 A		
	High (V)	11,000		
	Low (V)	3,300		
(11) Trans. Lines	Type	Steel post		
	Size	HAL 0.166 sq. in.		
	KV	11		
	L (km)	1.0		
(12) Spillway	L (m)	210	$= 1.1\ell = 1.1 \times \sqrt{180^2 + (1030 - 980)^2}$	
	D (m)	0.7	$= 0.65\sqrt{Q} = 0.65 \times \sqrt{1.18} = 0.706$	

Note: D = Diameter, L = Length, V = Voltage
M.R. = Mesilau River, L.R. = Liwagu River

Re

Naradaw 1,600kW
He ≒ 170m

Summary of Coasts (Unit 1,000 M$)

(1)	Establishment	400	= P<1,000kW 250,000$, P≧1,000kW 300,000$ +100,000
(2)	Div Weir/Intake	463	M.R = $374 \times \sqrt{D \times Q} = 374 \times \sqrt{0.6 \times 0.48} = 201$ L.R = $374 \times \sqrt{D \times Q} = 374 \times \sqrt{0.7 \times 0.70} = 262$
(3)	L. P. Condult	2,818	M.R = L 1,000 m @ 650 (D0.6m) L.R = L 2,890 m @ 750 (D0.7m)
(4)	Head Pond	500	= V 2,000 m3 @ 250 $/m3
(5)	Surge Tank	–	
(6)	Penstock	1,071	= L 805 m @ 1,330 Pen (D0.8m)
(7)	Spillway	158	= L 210 m @ 750 L.P (D0.7m)
(8)	Power Station	300	= $770 (P\sqrt{He})^{0.6} = 770 \times (1,600 \times \sqrt{169})^{0.6}$
(9)	Access Roads	635	Power St. 0.8 km @ 120,000 $/km = 96 Pipe 3.89 km @ 120,000 = 467 Const 1.2 km @ 60,000 = 72
(10)	Turb./Generator Transformer/etc	3,108	= $107 \left(\frac{P}{\sqrt{He}}\right)^{0.7} = 107 \left(\frac{1,600}{\sqrt{169}}\right)^{0.7}$
(11)	Trans. Lines	43	= L 1 km @ 43,000 $/km
(12)	Sub Total	9,496	

Establishment	400	
Civil	5,988	
Mech/Electr.	3,108	
Contingencies	1,424	= 0.15 × (~~Esta+Civil~~ (12)) = 0.15 × (9,496)
Engineering	601	= 5.5% × (above cost) = 0.055 × 10,920
Total	11,521	≒ 11,500 × 10^3 M$

1 M$ = 0.38 US$ = 54 ¥

Naradaw 2,000 KW
He = 170 m

OPTIMIZATION AT NARADAW

1. Plan
   Installed Capacity P= 2,000 KW   Net head He= 169 → 170 m
   Maximum discharge Q= 1.48 m3/s
   Construction Cost , 00,000 M$

2. Layout

(1) Intake	M.R.	Concrete type		
	L.R.	Concrete type		
(2) L.P. Conduit	M.R.	L(m)	1,000	$= 1.1\ell = 1.1\times 910$
		D_1(m)	0.7	$= 0.8\sqrt{Q_1} = 0.8\times\sqrt{0.57} = 0.604$
(3) Conduit	L.R.	L(m)	2,890	$= 1.1\ell = 1.1\times 2{,}630$
		D_2(m)	0.8	$= 0.8\sqrt{Q_2} = 0.8\times\sqrt{0.91} = 0.763$
(4) Head Pond		(m3)	2,000	
(5) Surge Tank		D (m)	–	
(6) Penstock		D (m)	0.9	$= 0.65\sqrt{Q} = 0.65\times\sqrt{1.48} = 0.791$
		L (m)	805	$= \sqrt{\ell^2+h^2} = 785^2 + (1{,}030-852)^2$
(7) Power Station			Structual steel supperstructure	
(8) Access Roads		km	4.69	
Improv.		km	1.2	
(9) Turb./Generator		Type	Targo Impulse/3φ Synchronous Generator x 2 units	
		RPM		
		V		
(10) Transformer		KVA	x 1 unit, 3φ, 0 A	
		High (V)	11,000	
		Low (V)	3,300	
(11) Trans. Lines		Type	Steel post	
		Size	HAL 0.166 sq. in.	
		KV	11	
		L (km)	1.0	

Note: D = Diameter   L = Length,   V = Voltage
M.R. = Mesilau River   L.R. = Liwagu River

(12) Spillway	L (m)	210	$= 1.1\ell = 1.1\times\sqrt{180^2+(1030-980)^2}$
	D (m)	0.8	$= 0.65\sqrt{Q} = 0.65\times\sqrt{1.48} = 0.791$

1

Re

Naradaw 2,000 KW
He = 170 m

Summary of Coasts (Unit 1,000 M$)

(1)	Establishment	500	= P<1,000 KW ~~250~~ 350,000 $, P ≥ 1,000 KW ~~500~~ 400,000 $ (P ≥ 2,000: 500)
(2)	Div Weir/Intake	555	M.R = $374 \times \sqrt{D_1 \times Q_1} = 374 \times \sqrt{0.7 \times 0.57} = 236$ L.R = $374 \times \sqrt{D_2 \times Q_2} = 374 \times \sqrt{0.8 \times 0.91} = 319$
(3)	L. P. Condult	3,235	M.R = L 1,000 m @ 750 (D_1 0.7 m) L.R = L 2,890 m @ 860 (D_2 0.8 m)
(4)	Head Pond	500	= V 2,000 m³ @ 250 $/m³
(5)	Surge Tank		
(6)	Penstock	1,143	= L 805 m @ 1,420 Pen (D 0.9 m)
(7)	Spillway	181	= L 210 m @ 860 L.P (D 0.8 m)
(8)	Power Station	343	= $770 (P\sqrt{He})^{0.6} = 770 \times (2,000 \times \sqrt{169})^{0.6}$
(9)	Access Roads	635	Power St. 0.8 km @ 120,000 $/km = 96 Pipe 3.89 km @ 120,000 = 467 Const 1.2 km @ 60,000 = 72
(10)	Turb./Generator Transformer/etc	3,634	= $107 \left(\frac{P}{\sqrt{He}}\right)^{0.7} = 107 \left(\frac{2,000}{\sqrt{169}}\right)^{0.7}$
(11)	Trans. Lines	43	= L 1 km @ 43,000 $/km
(12)	Sub Total	10,769	

Establishment	500	
Civil	6,635	
Mech/Electr.	3,634	
Contingencies	1,615	= 0.15 × (~~Esta+Civil~~ 12) = 0.15 × (10,769)
Engineering	681	= 5.5% × (above cost) = 0.055 × 12,384
Total	13,065	= 13,100 × 10³ M$

1 M$ = 0.38 US$ = 54 ¥

Naradaw 2,400 KW
He = 170 m

OPTIMIZATION AT NARADAW

1. Plan
   Installed Capacity P = 2,400 KW   Net head He = 169 m → 170 m
   Maximum discharge Q = 1.78 m3/s
   Construction Cost , 00,000 M$

2. Layout

(1) Intake	M.R.	Concrete type		
	L.R.	Concrete type		
(2) L.P. Conduit	M.R.	L(m)	1,000	$= 1.1\ell = 1.1 \times 910$
		D_1(m)	0.7	$= 0.8\sqrt{Q} = 0.8\times\sqrt{0.65} = 0.64$
(3) Conduit	L.R.	L(m)	2,890	$= 1.1\ell = 1.1 \times 2{,}630$
		D_2(m)	0.9	$= 0.8\sqrt{Q} = 0.8\times\sqrt{1.13} = 0.85$
(4) Head Pond		(m3)	2,000	
(5) Surge Tank		D (m)	–	
(6) Penstock		D (m)	1.0	$= 0.65\sqrt{Q} = 0.65\times\sqrt{1.78} = 0.867$
		L (m)	805	$= \sqrt{\ell^2+h^2} = 785^2 + (1{,}030-852)^2$
(7) Power Station			Structual steel supperstructure	
(8) Access Roads		km	4.69	
Improv.		km	1.2	
(9) Turb./Generator		Type	Targo Impulse/3φ Synchronous Generator x 2 units	
		RPM		
		V		
(10) Transformer		KVA	x 1 unit, 3φ, 0 A	
		High (V)	11,000	
		Low (V)	3,300	
(11) Trans. Lines		Type	Steel post	
		Size	HAL 0.166 sq. in.	
		KV	11	
		L (km)	1.0	

Note: D = Diameter   L = Length,   V = Voltage
M.R. = Mesilau River   L.R. = Liwagu River

(12) Spillway	L (m)	210	$= 1.1\ell = 1.1\times\sqrt{180^2+(1030-980)^2}$
	D (m)	0.9	$= 0.65\sqrt{Q} = 0.65\times\sqrt{1.78} = 0.867$

Re

Naradaw 2,400 KW

Summary of Coasts (Unit 1,000 M$)

(1)	Establishment	500	= P<1,000 KW 250,000 (350 $), P≥1,000 KW 300,000 (400 $); P≥2,000 KW 500
(2)	Div Weir/Intake	629	$H.R = 374 \times \sqrt{D_1 \times Q_1} = 374 \times \sqrt{0.7 \times 0.65} = 252$ $L.R = 374 \times \sqrt{D_2 \times Q_2} = 374 \times \sqrt{0.9 \times 1.13} = 377$
(3)	L. P. Condult	3,553	H.R = L 2,000 m @ 750 (D_1 0.7m) L.R = L 2,890 m @ 970 (D_2 0.9m)
(4)	Head Pond	500	= V 2,000 m³ @ 250 $/m³
(5)	Surge Tank	–	
(6)	Penstock	1,224	= L 805 m @ 1,520 Pen (D 1.0 m)
(7)	Spillway	204	= L 210 m @ 970 L.P (D 0.9 m)
(8)	Power Station	383	$= 770\,(P\sqrt{He})^{0.6} = 770 \times (2{,}400 \times \sqrt{169})^{0.6}$
(9)	Access Roads	635	Power St. 0.8 km @ 120,000 $/km = 96 Pipe 3.89 km @ 120,000 = 467 Const 1.2 km @ 60,000 = 72
(10)	Turb./Generator Transformer/etc	4,128	$= 107\left(\frac{P}{\sqrt{He}}\right)^{0.7} = 107\left(\frac{2{,}400}{\sqrt{169}}\right)^{0.7}$
(11)	Trans. Lines	43	= L 1 km @ 43,000 $/km
(12)	Sub Total	11,799	

Establishment	500	
Civil	7,171	
Mech/Electr.	4,128	
Contingencies	1,770	= 0.15 × (~~Esta+Civil~~ 12) = 0.15 × (11,799)
Engineering	746	= 5.5% × (above cost) = 0.055 × 13,569
Total	14,315	= 14,300 × 10³ M$

1 M$ = 0.38 US$ = 54 ¥

3. Calculation Data for Commissioning Year in Chapter 9

3 Calculation Data for Comissioning Year

Related to the Following Benefit Cost Ratio

Benefit Cost Ratio of Naradaw Scheme

(In Case of Carabaw Two Units)

Commissioning Year	Saleable Energy (GWh)	Construction Cost (1,000 M$)	Benefit/Cost
2000	7.4	11,500	1.01
2001	7.8	11,500	1.05
2003	8.6	11,500	1.12

Note (1) Saleable energy is an average for 10 years from each commissioning year.

(2) Minimum river maintenance water is assumed to be 0.1 m^3/s in total.

(3) Construction cost of M$11,500,000 is simply estimated for the purpose of the optimization only.

Benefit Cost Ratio of Naradaw Scheme

(In Case of Carabau One Unit)

Commissioning Year	Saleable Energy (GWh)	Construction Cost (1,000 M$)	Benefit/Cost
1996	7.1	11,500	0.98
1997	7.7	11,500	1.03
2000	8.9	11,500	1.15

Note; same as the note mentioned above.

Calculation Criterion

* 1,000 M$

(1) Const. cost	11,500	*	
(2) O & M Cost	173	*	= (1) X 0.015
(3) Supply capable, Energy	9.7	*	X 10^6 kWh
(4) Firm power	560	kW	

(Diesel)

(5) Inst. capacity	700	kW	= (4) X 1.25 = 560 X 1.25 = 700
(6) Const. cost	976	*	= (5) X 1,395 M$/kW
(7) O & M cost	49	*	= (6) X 0.05
(8) Fuel cost	1,698	*	= (3) X 0.97 X 0.18 M$/kWh (0.175)

Input Data : Naradaw P= 1,600 kW

Year of Start (n=0) 2000

(Thousand M$)

	n	Year	Naradaw Invest.	Diesel Invest.	Diesel kWh	Year
Const.	0	2000	1,150	0		2000
Const.	1	2001	6,900	488		2001
Const.	2	2002	3,450	488		2002
Opera.	3	2003	173	49	6,802	2003
Opera.	4	2004			7,437	2004
Opera.	5	2005			8,044	2005
Opera.	6	2006			8,437	2006
Opera.	7	2007			8,733	2007
Opera.	8	2008			8,968	2008
Opera.	9	2009			9,157	2009
Opera.	10	2010			9,337	2010
Opera.	11	2011			9,420	2011
Opera.	12	2012			9,491	2012
Opera.	13	2013			9,555	2013
Opera.	14	2014			9,608	2014
Opera.	15	2015		49	9,649	2015
Re-Const	16	2016		488+49	9,691	2016
Re-Const	17	2017		488+49	9,691	2017
Opera.	18	2018		49	9,691	2018
Opera.	19	2019			9,691	2019
Opera.	20	2020			9,691	2020
Opera.	21	2021			9,691	2021
Opera.	22	2022			9,691	2022
Opera.	23	2023			9,691	2023
Opera.	24	2024			9,691	2024
Opera.	25	2025			9,691	2025
Opera.	26	2026			9,691	2026
Opera.	27	2027	173	49	9,691	2027

Benefit Cost Ratio Calculation : Naradaw P= 1,600 kW

In case of Carabau 2×1000kW

(Thousand M$)

Year	n	1/1.1^n	Cost Stream Naradaw Invest.	Cost Stream Naradaw C Value	Benefit Stream Alternative (Diesel) Invest.	Fuel	Total	B Value
2000	0	1.000	1,150	1,150	0	0	0	0
2001	1	0.909	6,900	6,273	488	0	488	444
2002	2	0.826	3,450	2,851	488	0	488	403
2003	3	0.751	173	130	49	1,190	1,239	931
2004	4	0.683	173	118	49	1,301	1,350	922
2005	5	0.621	173	107	49	1,408	1,457	904
2006	6	0.564	173	98	49	1,476	1,525	861
2007	7	0.513	173	89	49	1,528	1,577	809
2008	8	0.467	173	81	49	1,569	1,618	755
2009	9	0.424	173	73	49	1,602	1,651	700
2010	10	0.386	173	67	49	1,634	1,683	649
2011	11	0.350	173	61	49	1,649	1,698	595
2012	12	0.319	173	55	49	1,661	1,710	545
2013	13	0.290	173	50	49	1,672	1,721	499
2014	14	0.263	173	46	49	1,581	1,730	456
2015	15	0.239	173	41	49	1,689	1,738	416
2016	16	0.218	173	38	537	1,696	2,233	486
2017	17	0.198	173	34	537	1,696	2,233	442
2018	18	0.180	173	31	49	1,696	1,745	314
2019	19	0.164	173	28	49	1,696	1,745	285
2020	20	0.149	173	26	49	1,696	1,745	259
2021	21	0.135	173	23	49	1,696	1,745	236
2022	22	0.123	173	21	49	1,696	1,745	214
2023	23	0.112	173	19	49	1,696	1,745	195
2024	24	0.102	173	18	49	1,696	1,745	177
2025	25	0.092	173	16	49	1,696	1,745	161
2026	26	0.084	173	15	49	1,696	1,745	146
2027	27	0.076	173	13	49	1,696	1,745	133
		Total		11,572				12,939

B/C	1.12
B-C	1,367

Input Data : Naradaw P= 1.600 kW

Year of Start (n=0) 1998

(Thousand M$)

	n	Year	Naradaw Invest.	Diesel Invest.	Diesel kWh	Year
Const.	0	1998	1.150	0		1998
Const.	1	1999	6.900	488		1999
Const.	2	2000	3.450	488		2000
Opera.	3	2001	173	49	5.446	2001
Opera.	4	2002			6.117	2002
Opera.	5	2003			6.802	2003
Opera.	6	2004			7.437	2004
Opera.	7	2005			8.044	2005
Opera.	8	2006			8.437	2006
Opera.	9	2007			8.733	2007
Opera.	10	2008			8.968	2008
Opera.	11	2009			9.157	2009
Opera.	12	2010			9.337	2010
Opera.	13	2011			9.420	2011
Opera.	14	2012			9.491	2012
Opera.	15	2013		49	9.555	2013
Re-Const	16	2014		488+49	9.608	2014
Re-Const	17	2015		488+49	9.649	2015
Opera.	18	2016		49	9.691	2016
Opera.	19	2017			9.691	2017
Opera.	20	2018			9.691	2018
Opera.	21	2019			9.691	2019
Opera.	22	2020			9.691	2020
Opera.	23	2021			9.691	2021
Opera.	24	2022			9.691	2022
Opera.	25	2023			9.691	2023
Opera.	26	2024			9.691	2024
Opera.	27	2025	173	49	9.691	2025

Benefit Cost Ratio Calculation : Naradaw P= 1.600 kW

In case of Carabau 2× 1000 kW

(Thousand M$)

Year	n	1/1.1^n	Cost Stream Naradaw Invest.	Cost Stream Naradaw C Value	Benefit Stream Alternative (Diesel) Invest.	Fuel	Total	B Value
1998	0	1.000	1.150	1.150	0	0	0	0
1999	1	0.909	6.900	6.273	488	0	488	444
2000	2	0.826	3.450	2.851	488	0	488	403
2001	3	0.751	173	130	49	953	1.002	753
2002	4	0.683	173	118	49	1.070	1.119	765
2003	5	0.621	173	107	49	1.190	1.239	770
2004	6	0.564	173	98	49	1.301	1.350	762
2005	7	0.513	173	89	49	1.408	1.457	748
2006	8	0.467	173	81	49	1.476	1.525	712
2007	9	0.424	173	73	49	1.528	1.577	669
2008	10	0.386	173	67	49	1.569	1.618	624
2009	11	0.350	173	61	49	1.602	1.651	579
2010	12	0.319	173	55	49	1.634	1.683	536
2011	13	0.290	173	50	49	1.649	1.698	492
2012	14	0.263	173	46	49	1.661	1.710	450
2013	15	0.239	173	41	49	1.672	1.721	412
2014	16	0.218	173	38	537	1.681	2.218	483
2015	17	0.198	173	34	537	1.689	2.226	440
2016	18	0.180	173	31	49	1.696	1.745	314
2017	19	0.164	173	28	49	1.696	1.745	285
2018	20	0.149	173	26	49	1.696	1.745	259
2019	21	0.135	173	23	49	1.696	1.745	236
2020	22	0.123	173	21	49	1.696	1.745	214
2021	23	0.112	173	19	49	1.696	1.745	195
2022	24	0.102	173	18	49	1.696	1.745	177
2023	25	0.092	173	16	49	1.696	1.745	161
2024	26	0.084	173	15	49	1.696	1.745	146
2025	27	0.076	173	13	49	1.696	1.745	133
		Total		11.572				12.162

B/C	1.05
B-C	590

Input Data : Naradaw P= 1.600 kW

Year of Start (n=0) 1997

(Thousand M$)

	n	Year	Naradaw Invest.	Diesel Invest.	Diesel kWh	Year
Const.	0	1997	1.150	0		1997
Const.	1	1998	6.900	488		1998
Const.	2	1999	3.450	488		1999
Opera.	3	2000	173	49	4.806	2000
Opera.	4	2001			5.446	2001
Opera.	5	2002			6.117	2002
Opera.	6	2003			6.802	2003
Opera.	7	2004			7.437	2004
Opera.	8	2005			8.044	2005
Opera.	9	2006			8.437	2006
Opera.	10	2007			8.733	2007
Opera.	11	2008			8.968	2008
Opera.	12	2009			9.157	2009
Opera.	13	2010			9.337	2010
Opera.	14	2011			9.420	2011
Opera.	15	2012		49	9.491	2012
Re-Const	16	2013		488+49	9.555	2013
Re-Const	17	2014		488+49	9.608	2014
Opera.	18	2015		49	9.649	2015
Opera.	19	2016			9.691	2016
Opera.	20	2017			9.691	2017
Opera.	21	2018			9.691	2018
Opera.	22	2019			9.691	2019
Opera.	23	2020			9.691	2020
Opera.	24	2021			9.691	2021
Opera.	25	2022			9.691	2022
Opera.	26	2023			9.691	2023
Opera.	27	2024	173	49	9.691	2024

Benefit Cost Ratio Calculation : Naradaw P= 1.600 kW

In Case of Carabau 2X1000 KW

(Thousand M$)

Year	n	1/1.1 n	Cost Stream Naradaw Invest.	Cost Stream Naradaw C Value	Benefit Stream Alternative (Diesel) Invest.	Fuel	Total	B Value
1997	0	1.000	1.150	1.150	0	0	0	0
1998	1	0.909	6.900	6.273	488	0	488	444
1999	2	0.826	3.450	2.851	488	0	488	403
2000	3	0.751	173	130	49	841	890	669
2001	4	0.683	173	118	49	953	1.002	684
2002	5	0.621	173	107	49	1.070	1.119	695
2003	6	0.564	173	98	49	1.190	1.239	700
2004	7	0.513	173	89	49	1.301	1.350	693
2005	8	0.467	173	81	49	1.408	1.457	680
2006	9	0.424	173	73	49	1.476	1.525	647
2007	10	0.386	173	67	49	1.528	1.577	608
2008	11	0.350	173	61	49	1.569	1.618	567
2009	12	0.319	173	55	49	1.602	1.651	526
2010	13	0.290	173	50	49	1.634	1.683	487
2011	14	0.263	173	46	49	1.649	1.698	447
2012	15	0.239	173	41	49	1.661	1.710	409
2013	16	0.218	173	38	537	1.672	2.209	481
2014	17	0.198	173	34	537	1.681	2.218	439
2015	18	0.180	173	31	49	1.689	1.738	313
2016	19	0.164	173	28	49	1.696	1.745	285
2017	20	0.149	173	26	49	1.696	1.745	259
2018	21	0.135	173	23	49	1.696	1.745	236
2019	22	0.123	173	21	49	1.696	1.745	214
2020	23	0.112	173	19	49	1.696	1.745	195
2021	24	0.102	173	18	49	1.696	1.745	177
2022	25	0.092	173	16	49	1.696	1.745	161
2023	26	0.084	173	15	49	1.696	1.745	146
2024	27	0.076	173	13	49	1.696	1.745	133
		Total		11.572				11.699

B/C 1.01

B-C 128

Input Data : Naradaw P= 1,600 kW

Year of Start (n=0) 1993

(Thousand M$)

	n	Year	Naradaw Invest.	Diesel Invest.	Diesel kWh	Year
Const.	0	1993	1,150	0		1993
Const.	1	1994	6,900	488		1994
Const.	2	1995	3,450	488		1995
Opera.	3	1996	173	49	3,785	1996
Opera.	4	1997			4,628	1997
Opera.	5	1998			5,507	1998
Opera.	6	1999			6,390	1999
Opera.	7	2000			7,351	2000
Opera.	8	2001			7,999	2001
Opera.	9	2002			8,471	2002
Opera.	10	2003			8,796	2003
Opera.	11	2004			9,044	2004
Opera.	12	2005			9,256	2005
Opera.	13	2006			9,407	2006
Opera.	14	2007			9,532	2007
Opera.	15	2008		49	9,531	2008
Re-Const	16	2009		488+49	9,691	2009
Re-Const	17	2010		488+49	9,691	2010
Opera.	18	2011		49	9,691	2011
Opera.	19	2012			9,691	2012
Opera.	20	2013			9,691	2013
Opera.	21	2014			9,691	2014
Opera.	22	2015			9,691	2015
Opera.	23	2016			9,691	2016
Opera.	24	2017			9,691	2017
Opera.	25	2018			9,691	2018
Opera.	26	2019			9,691	2019
Opera.	27	2020	173	49	9,691	2020

Benefit Cost Ratio Calculation : Naradaw P= 1,600 kW

In case of Carabau 1 × 1000 kW

(Thousand M$)

Year	n	1/1.1^n	Cost Stream Naradaw Invest.	Cost Stream Naradaw C Value	Benefit Stream Alternative (Diesel) Invest.	Fuel	Total	B Value
1993	0	1.000	1,150	1,150	0	0	0	0
1994	1	0.909	6,900	6,273	488	0	488	444
1995	2	0.826	3,450	2,851	488	0	488	403
1996	3	0.751	173	130	49	662	711	534
1997	4	0.683	173	118	49	810	859	587
1998	5	0.621	173	107	49	964	1,013	629
1999	6	0.564	173	98	49	1,118	1,167	659
2000	7	0.513	173	89	49	1,286	1,335	685
2001	8	0.467	173	81	49	1,400	1,449	676
2002	9	0.424	173	73	49	1,482	1,531	649
2003	10	0.386	173	67	49	1,539	1,588	612
2004	11	0.350	173	61	49	1,583	1,632	572
2005	12	0.319	173	55	49	1,620	1,669	532
2006	13	0.290	173	50	49	1,646	1,695	491
2007	14	0.263	173	46	49	1,668	1,717	452
2008	15	0.239	173	41	49	1,685	1,734	415
2009	16	0.218	173	38	537	1,696	2,233	486
2010	17	0.198	173	34	537	1,696	2,233	442
2011	18	0.180	173	31	49	1,696	1,745	314
2012	19	0.164	173	28	49	1,696	1,745	285
2013	20	0.149	173	26	49	1,696	1,745	259
2014	21	0.135	173	23	49	1,696	1,745	236
2015	22	0.123	173	21	49	1,696	1,745	214
2016	23	0.112	173	19	49	1,696	1,745	195
2017	24	0.102	173	18	49	1,696	1,745	177
2018	25	0.092	173	16	49	1,696	1,745	161
2019	26	0.084	173	15	49	1,696	1,745	146
2020	27	0.076	173	13	49	1,696	1,745	133
		Total		11,572				11,390

B/C	0.98
B-C	-182

Input Data : Naradaw P= 1.600 kW

Year of Start (n=0) 1994

(Thousand M$)

	n	Year	Naradaw Invest.	Diesel Invest.	Diesel kWh	Year
Const.	0	1994	1.150	0		1994
Const.	1	1995	6.900	488		1995
Const.	2	1996	3.450	488		1996
Opera.	3	1997	173	49	4.628	1997
Opera.	4	1998			5.507	1998
Opera.	5	1999			6.390	1999
Opera.	6	2000			7.351	2000
Opera.	7	2001			7.999	2001
Opera.	8	2002			8.471	2002
Opera.	9	2003			8.796	2003
Opera.	10	2004			9.044	2004
Opera.	11	2005			9.256	2005
Opera.	12	2006			9.407	2006
Opera.	13	2007			9.532	2007
Opera.	14	2008			9.631	2008
Opera.	15	2009		49	9.691	2009
Re-Const	16	2010		488+49	9.691	2010
Re-Const	17	2011		488+49	9.691	2011
Opera.	18	2012		49	9.691	2012
Opera.	19	2013			9.691	2013
Opera.	20	2014			9.691	2014
Opera.	21	2015			9.691	2015
Opera.	22	2016			9.691	2016
Opera.	23	2017			9.691	2017
Opera.	24	2018			9.691	2018
Opera.	25	2019			9.691	2019
Opera.	26	2020			9.691	2020
Opera.	27	2021	173	49	9.691	2021

Benefit Cost Ratio Calculation : Naradaw P= 1.600 kW

In case of Carabau 1 × 1000 kW

(Thousand M$)

Year	n	1/1.1^n	Cost Stream Naradaw Invest.	Cost Stream Naradaw C Value	Benefit Stream Alternative (Diesel) Invest.	Fuel	Total	B Value
1994	0	1.000	1.150	1.150	0	0	0	0
1995	1	0.909	6.900	6.273	488	0	488	444
1996	2	0.826	3.450	2.851	488	0	488	403
1997	3	0.751	173	130	49	810	859	645
1998	4	0.683	173	118	49	964	1.013	692
1999	5	0.621	173	107	49	1.118	1.167	725
2000	6	0.564	173	98	49	1.286	1.335	754
2001	7	0.513	173	89	49	1.400	1.449	743
2002	8	0.467	173	81	49	1.482	1.531	714
2003	9	0.424	173	73	49	1.539	1.588	674
2004	10	0.386	173	67	49	1.583	1.632	629
2005	11	0.350	173	61	49	1.620	1.669	585
2006	12	0.319	173	55	49	1.646	1.695	540
2007	13	0.290	173	50	49	1.668	1.717	497
2008	14	0.263	173	46	49	1.685	1.734	457
2009	15	0.239	173	41	49	1.696	1.745	418
2010	16	0.218	173	38	537	1.696	2.233	486
2011	17	0.198	173	34	537	1.696	2.233	442
2012	18	0.180	173	31	49	1.696	1.745	314
2013	19	0.164	173	28	49	1.696	1.745	285
2014	20	0.149	173	26	49	1.696	1.745	259
2015	21	0.135	173	23	49	1.696	1.745	236
2016	22	0.123	173	21	49	1.696	1.745	214
2017	23	0.112	173	19	49	1.696	1.745	195
2018	24	0.102	173	18	49	1.696	1.745	177
2019	25	0.092	173	16	49	1.696	1.745	161
2020	26	0.084	173	15	49	1.696	1.745	146
2021	27	0.076	173	13	49	1.696	1.745	133
		Total		11.572				11.969

B/C	1.03
B-C	397

Input Data : Naradaw P= 1.600 kW

Year of Start (n=0) 1997

(Thousand M$)

	n	Year	Naradaw Invest.	Diesel Invest.	Diesel kWh	Year
Const.	0	1997	1.150	0		1997
Const.	1	1998	6.900	488		1998
Const.	2	1999	3.450	488		1999
Opera.	3	2000	173	49	7.351	2000
Opera.	4	2001			7.999	2001
Opera.	5	2002			8.471	2002
Opera.	6	2003			8.796	2003
Opera.	7	2004			9.044	2004
Opera.	8	2005			9.256	2005
Opera.	9	2006			9.407	2006
Opera.	10	2007			9.532	2007
Opera.	11	2008			9.631	2008
Opera.	12	2009			9.691	2009
Opera.	13	2010			9.691	2010
Opera.	14	2011			9.691	2011
Opera.	15	2012		49	9.691	2012
Re-Const	16	2013		488+49	9.691	2013
Re-Const	17	2014		488+49	9.691	2014
Opera.	18	2015		49	9.691	2015
Opera.	19	2016			9.691	2016
Opera.	20	2017			9.691	2017
Opera.	21	2018			9.691	2018
Opera.	22	2019			9.691	2019
Opera.	23	2020			9.691	2020
Opera.	24	2021			9.691	2021
Opera.	25	2022			9.691	2022
Opera.	26	2023			9.691	2023
Opera.	27	2024	173	49	9.691	2024

Benefit Cost Ratio Calculation : Naradaw P= 1.600 kW

In case of Carabau 1 x 1000 kW

(Thousand M$)

Year	n	1/1.1^n	Cost Stream Naradaw Invest.	Cost Stream Naradaw C Value	Benefit Stream Alternative (Diesel) Invest.	Fuel	Total	B Value
1997	0	1.000	1.150	1.150	0	0	0	0
1998	1	0.909	6.900	6.273	488	0	488	444
1999	2	0.826	3.450	2.851	488	0	488	403
2000	3	0.751	173	130	49	1.286	1.335	1.003
2001	4	0.683	173	118	49	1.400	1.449	990
2002	5	0.621	173	107	49	1.482	1.531	951
2003	6	0.564	173	98	49	1.539	1.588	897
2004	7	0.513	173	89	49	1.583	1.632	837
2005	8	0.467	173	81	49	1.620	1.669	779
2006	9	0.424	173	73	49	1.646	1.695	719
2007	10	0.386	173	67	49	1.668	1.717	662
2008	11	0.350	173	61	49	1.685	1.734	608
2009	12	0.319	173	55	49	1.696	1.745	556
2010	13	0.290	173	50	49	1.696	1.745	505
2011	14	0.263	173	46	49	1.696	1.745	459
2012	15	0.239	173	41	49	1.696	1.745	418
2013	16	0.218	173	38	537	1.696	2.233	486
2014	17	0.198	173	34	537	1.696	2.233	442
2015	18	0.180	173	31	49	1.696	1.745	314
2016	19	0.164	173	28	49	1.696	1.745	285
2017	20	0.149	173	26	49	1.696	1.745	259
2018	21	0.135	173	23	49	1.696	1.745	236
2019	22	0.123	173	21	49	1.696	1.745	214
2020	23	0.112	173	19	49	1.696	1.745	195
2021	24	0.102	173	18	49	1.696	1.745	177
2022	25	0.092	173	16	49	1.696	1.745	161
2023	26	0.084	173	15	49	1.696	1.745	146
2024	27	0.076	173	13	49	1.696	1.745	133
		Total		11.572				13.280

B/C	1.15
B-C	1.708

Appendix 5 PERMISSIBLE TRANSMISSION CAPACITY FOR 11 KV EXISTING INTERCONNECTION LINE RANAU-KUNDASANG GRID

Appendix 5

PERMISSIBLE TRANSMISSION CAPACITY FOR 11 KV EXISTING INTERCONNECTION LINE RANAU-KUNDASANG GRID

CONTENTS

Page

Permissible Transmission Capacity
for 11 kV Existing Interconnection Line Ranau-Kundasang Grid

It is to consider a three-phase overhead line 6 miles long, from proposed mini hydro P.P (Naradaw P.P) to Ranau, supplying energy at 11,000 volts with a frequency of 50 Hz.

The conductors consist of No. 0000 B&S., stranded Aluminum, spaced in a horizontal plane with a separation of 2.0 ft. between the center wire and each of the outer wires.

It is desired to calculated the maximum load in kilowatts with the power factor 0.8 which can be transmitted by this line and given that the inherent regulation (or percentage voltage drop) must not exceed 10 percent when the temperature of the wire at circumstances in 90°F.

The calculation was made based on the following conditions:

Voltage between lines at receiving end,

E = 11,000 volts

Frequency, f = 50 Hz

Power factor of load, $\cos \phi = 0.8$

Length of line, L = 6 miles

Diameter of No. 0000 stranded conductor

$2r$ = 0.522 in

Area of cross-section of wire = 0.1662 sq. in

Resistance, ohms per mile, at 20°C (68°F) = 0.430 Ω

The resistance per mile at 90°C

$R_{90} = R_{20}$ (1 + at) .... (1)

Where R_{90} = resistance at 90°C

t = temperature rise above initial temperature (20°C)

R_{20} = resistance at the initial temperature (20°C)

$$R_{90} = 0.430 \frac{(390+167)}{(390+68)} = 0.523 \; ohm$$

The increase of resistance due to skin effect need not be taken into account because the product area x frequency is 0.1662 x 50 = 8 (approximately), it is seen that the skin-effect multiplier is so small as to be negligible.

The spacing between wires, in inches are:

a = 24, b = 24, c = 48, and the equivalent spacing is

$$d = \sqrt[3]{24 \times 24 \times 48} = 30.2 \; in.$$

Using this value in formula (1), or for d in formula (2),

$$(IX) = 0.0046 \, fI \log_e \frac{\sqrt[3]{abc}}{r} + 0.000506 \, fI \; .... \; (1)$$

Reactive voltage drop (IX) per mile of single conductor

$$= 0.00466 \, fI \log (1.285 \frac{d}{r}) \; .... \; (2)$$

$\frac{d}{r} = \frac{30.2}{0.261} = 116$ which may be used in the formula (3)

x = 0.00466 x f x log (1.285 x 116) .... (3)

The result is reactance per mile of single conductor, X = 0.506 ohm

The required regulation of percentage voltage drop is

$$100 \times \frac{V - E}{E} \quad \ldots\ldots\ (4)$$

Where V stands for the voltage between conductors at the sending end of the line. The value (V - E) is equal to $\sqrt{3}$ (Vn - En) where Vn and En are star voltages (conductor to neutral) at the sending and receiving ends, respectively.

If the simplified formula (5) is used,

$$Vn = En + IR \cos \theta + IX \sin \theta \quad \ldots\ldots\ (5)$$

giving the voltage drop per conductor, the loss of voltage as measured between conductor is

$$(V - E) = \sqrt{3}\ IL\ (R \cos \theta + X \sin \theta)$$

Accordingly, the following formula (6) and (7) are obtained based on

$$I = \frac{W}{\sqrt{3}\ E \cos \theta}$$

$$(V - E) = \frac{WL\ (R \cos \theta + X \sin \theta)}{E \cos \theta}\ volts \quad \ldots\ldots\ (6) \quad (approximately)$$

$$(V - E) + \frac{WL\ (R + X \tan \theta)}{E}\ volts \quad \ldots\ldots\ (7) \quad (approximately)$$

On the other hand, the percentage voltage drop is as shown below.

$$\frac{100\ (V - E)}{E} = \frac{100\ WL\ (R + X \tan \theta)}{E^2} \quad \ldots\ldots\ (8)$$

Values for tan θ corresponding to any given power factor (cos θ) may be obtained from trigonometric tables, or following formula

$$\tan \theta = \frac{\sqrt{1 - \cos \theta}}{\cos \theta}$$

Applying formula (8) to the solution this particular problem,

$$W = \frac{\textit{percent voltage drop} \times E^2}{100L\ (R + X \tan \theta)} \quad \ldots\ldots\ldots \quad (9)$$

$$= \frac{10 \times (11{,}000)^2}{100 \times 6\ (0.523 + 0.506 \times 0.75)}$$

$$\approx \underline{\underline{2{,}200\ \text{kW}}}$$

The required answer is that the permissible maximum load at the receiving end is 2,200 kW. A load in excess of this would cause the inherent regulation to be greater than 10 percent.

Appendix 6 PRELIMINARY DESIGN

Appendix 6

PRELIMINARY DESIGN

CONTENTS

6.1 Stability Analysis of Dam

The dam bodies must be checked by making stability computation so that following requirements at any horizontal section and contact face between dambody and bedrock are satisfied against external forces and weight of the dam.

(1) No tensile stress must be produced along the upstream face (The action line of resultant force must pass through the middle third of bottom).

(2) No sliding must be ensured against shear friction force.

(3) Compressive stress at the bottom must not exceed it's allowable limit of the ground. (No settlement)

Above requirements are satisfied with following formula. Typical section of Liwagu dam is studied.

- No tensile

$$C = \left|\frac{\Sigma M}{\Sigma V} - \frac{B}{2}\right| = \left|\frac{78.57}{23.38} - \frac{7.0}{2}\right| = 0.14 \leq \frac{B}{6} = \frac{7.0}{6} = 1.17 \qquad \therefore \text{OK}$$

- No sliding

when no earthquake

$$\frac{f \cdot \Sigma V}{\Sigma H} = \frac{0.75 \times 23.38}{12.75} = \frac{17.54}{12.75} = 1.37 \geq 1.2 \qquad \therefore \text{OK}$$

when earthquake

$$\frac{f \cdot \Sigma V}{\Sigma H} = \frac{0.75 \times 23.38}{16.69} = \frac{17.54}{16.69} = 1.05 \geq 1.0 \qquad \therefore \text{OK}$$

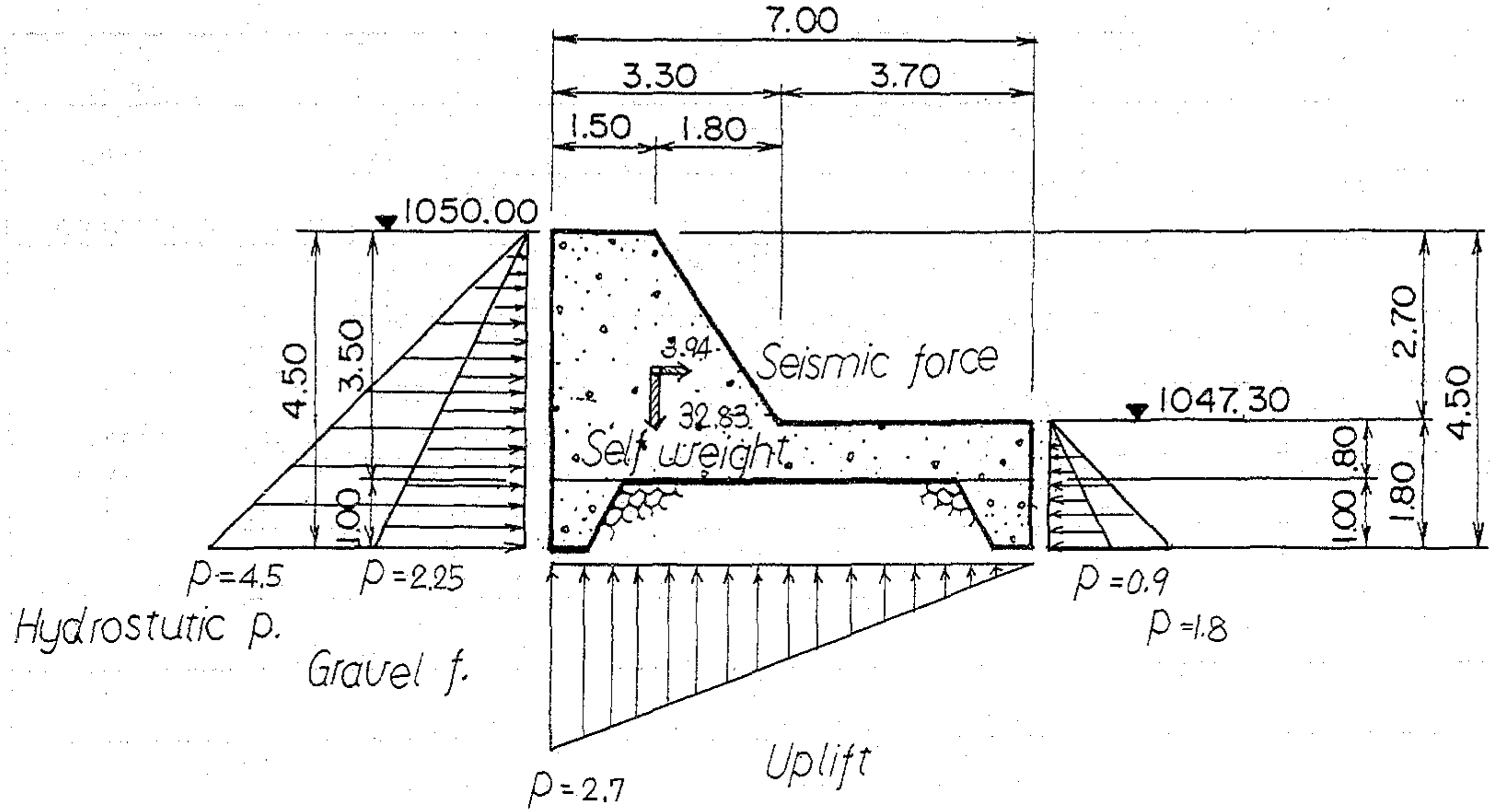
- No settlement

$$\frac{\Sigma V}{B}\left(1 + \frac{6e}{B}\right) = \frac{23.38}{7.0}\left(1 + \frac{6 \times 0.14}{7.0}\right) = 3.74 \leq 9a = 50\ ton/m^2 \qquad \therefore \text{OK}$$

Calculation Sheet

Item	External Force (ton)	Arm Length (m)	Moment (t.m)
Self Weight	13.68 m^2 x 2.4= 32.83	2.153	70.68
Seismic Force	32.83 x 0.12 = 3.94	2.183	8.60
Hydrostatic Pressure	$\frac{1}{2}$x4.5x4.5 = 10.12	$\frac{1}{3}$x4.5 = 1.5	15.18
	$-\frac{1}{2}$x2.25x4.5 = -1.62	$\frac{1}{3}$x1.8 = 0.6	-0.97
Gravel Force	$\frac{1}{2}$x2.25x4.5 = 5.06	1.5	7.59
	$-\frac{1}{2}$x0.9x1.8 = -0.81	0.6	-0.49
Uplift	$P_1=\frac{1}{3}$x2.7+1.8= 2.7 m P_2=0 m $-\frac{1}{2}$x2.7x7.0 = -9.45	$\frac{1}{3}$x7.0 = 2.33	-22.02
Σ Vertical Force	32.83-9.45 = 23.38	$\chi=\frac{78.57}{23.38}$ = 3.36	78.57
Σ Horizontal Force with Earthquake	3.94+10.12-1.62+5.06-0.81 = 16.69	--	--
Σ Horizontal F. without Earthquake	16.69-3.94 = 12.75	--	--

SECTION



7.00
3.30
3.70
1.50
1.80
1050.00
4.50
3.50
1.00
3.94
32.83
Seismic force
Self weight
1047.30
2.70
4.50
.80
1.00
1.80
P=4.5
P=2.25
Hydrostutic p.
Gravel f.
P=2.7
Uplift
P=0.9
P=1.8

6-2 Optimum Diameter of Pipeline

Optimum Diameter of Pipeline at Liwagu Site

	ITEM	D1 0.5	D2 0.55	D3 0.6	D4 0.65	D5 0.7	D6 0.75
Annual Benifit Loss B	Head Loss ΔH (m)	0.03438	0.02068	0.013	0.00849	0.00571	0.00396
	Output for Head Loss ΔP (kw)	0.2005	0.1206	0.0758	0.0495	0.0333	0.0231
	Energy for Head Loss ΔE (kwh)	1170.6	704.1	442.6	289.1	194.4	134.8
	Benifit for Firm Peak Power: B kw(MS)	47.52	28.58	17.96	11.73	7.89	5.47
	Benifit for Energy B kwh(MS)	200.17	120.4	75.68	49.44	33.24	23.05
	Total Benifit B (MS)	247.69	148.98	93.64	61.17	41.13	28.52
Equalized Annual Cost C	Construction Cost C con(MS)	370	420	460	580	710	860
	Annual Cost C (MS)	42.55	48.3	52.9	66.7	81.65	98.9
Total B + C	B + C (MS)	290.24	197.28	146.54	127.87	122.78	127.42

Q(m3) = 0.7

n = 0.013

ΔH (m) = 10.298*n^2*Q^2/D^(16/3)

ΔP (kw) = 9.8*η*Q*h

ΔE (kwh) = E*(Q/Qmax)*(Hloss/He) = 9.7*10^6*(Q/1.18)*(ΔH/169)

B kw(MS) = ΔP * Unit kw benifit = 240MS/kw*ΔP

B kwh(MS) = ΔE * Unit kwh benifit = 0.18MS/kwh*ΔE

C (MS) = Annual cost factor * Ccon = 0.115*Ccon

Optimum Diameter of Pipeline at Mesilau Site

	ITEM	D1 0.5	D2 0.55	D3 0.6	D4 0.65	D5 0.7	D6 0.75
Annual Benifit Loss B	Head Loss ΔH (m)	0.01617	0.00972	0.00611	0.00399	0.00269	0.00186
	Output for Head Loss ΔP (kw)	0.0647	0.0389	0.0244	0.016	0.0108	0.0074
	Energy for Head Loss ΔE (kwh)	377.5	226.9	142.7	93.2	62.8	43.4
	Benifit for Firm Peak Power: B kw(MS)	15.33	9.22	5.78	3.79	2.56	1.75
	Benifit for Energy B kwh(MS)	64.55	38.8	24.4	15.94	10.74	7.42
	Total Benifit B (MS)	79.88	48.02	30.18	19.73	13.3	9.17
Equalized Annual Cost C	Construction Cost C con(MS)	370	420	460	580	710	860
	Annual Cost C (MS)	42.55	48.3	52.9	66.7	81.65	98.9
Total B + C	B + C (MS)	122.43	96.32	83.08	86.43	94.95	108.07

Q(m3) = 0.48

n = 0.013

ΔH (m) = 10.298*n^2*Q^2/D^(16/3)

ΔP (kw) = 9.8*η*Q*h

ΔE (kwh) = E*(Q/Qmax)*(Hloss/He) = 9.7*10^6*(Q/1.18)*(ΔH/169)

B kw(MS) = ΔP * Unit kw benifit = 240MS/kw*ΔP

B kwh(MS) = ΔE * Unit kwh benifit = 0.18MS/kwh*ΔE

C (MS) = Annual cost factor * Ccon = 0.115*Ccon

Calculation of Benefit in terms of Firm Peak Power and Energy (1/1)

No.	Item	Unit	Calculation	
(1)	Firm peak power of Naradaw	MW	560 kW	
(2)	Dependable capacity of Naradaw	MW	(1) × $(1-H_1)\times(1-H_2)\times(1-H_3)$ = 560(1-0.01)×(1-0.06)(1-0.10) = 560×0.8375 = 469 kW	
(3)	Dependable capacity of Alternative thermal	MW	Same as the value given in (2)	
(4)	Rated capacity of Alternative thermal	MW	(3) ÷ $\{(1-T_1)\times(1-T_2)\times(1-T_3)\}$ = 469÷(1-0.04)×(1-0.13)×(1-0.20) = 469 ÷ 0.6682 ≒ 700 kW	
(5)	Annual energy production of Naradaw	10^6 kWh	9.7 × 10^6 kWh	
(6)	Available Energy of Naradaw	10^6 kWh	(5) × $(1-H_1)$ = 9.7 × (1-0.01) = 9.6 × 10^6 kWh	
(7)	Available Energy of Alternative thermal	10^6 kWh	Same as the value given in (6)	
(8)	Annual energy production of Alternative thermal	10^6 kWh	(7) ÷ $(1-T_1)$ = 9.6 × 10^6÷(1-0.04) = 10.0 × 10^6 kWh	
	Loss Rates of Hydro and Thermal		Hydro Power	Thermal Power
	Station Service Rate	%	H_1 = 1%	T_1 = 4%
	Outage Rate	%	H_2 = 6%	T_2 = 13%
	Capacity Derated Rate	%	H_3 = 10%	T_3 = 20%

Calculation of Benefit in terms of Firm Peak Power and Energy (1/2)

(9)	Fuel Consumption per kWh		0.354 ℓ/kWh	
(10)	Fuel Cost per Liter		0.50 M$/ℓ	
(11)	Construction Cost per kW	$/kW	1,395 M$/kW	
(12)	Construction Cost	$10^6$$	1,395 × 700 = 976 × 10^3 M$	
(13)	Service Life	year	n = 15 years	
(14)	Annual Interest Rate	%	i = 10%	
(15)	Capital Recovery Factor		$\{i(1+i)^n\} \div \{(1+i)^n-1\}$ $= \{0.1(1+0.1)^{1.5}\} \div \{(1+0.1)^{15}-1\}$ = 0.13	
(16)	Rate of O&M Cost to Construction Cost	%	5%	
			Fixed Cost	Variable cost
(17)	Interest & Depreciation		(12)×(15) =127×10^3M$	--
(18)	O&M Cost		(12)×(16)×0.8 =39×10^3M$	(12)×(16)×0.2 =10×10^3M$
(19)	Fuel Cost		--	(8)×(9)×(10) = 1.698×10^3M$
(20)	Total of Fixed Cost		(17)+(18) =166×10^3M$	--
(21)	Total of variable Cost		--	(18)+(19) =1.708×10^3M$
(22)	Benefit Corresponding to Firm Peak Power	$/kW	(20)÷(4) =237≒240M$/kWh	--
(23)	Benefit Corresponding to Energy	$/kW	--	(21)÷(8) =0.171≒0.18M$/kWh

6-3 Water Hammer Calculation

Gross head	195
Discharge	0.7
Liwagu	

WATER HAMMER

1. PRESSURE WAVE VELOCITY

$$a = 1/(w/g*(1/K+D/E/t))^{0.5}$$

Where,

- a : Pressure wave velocity (m/sec)
- w : Unit weight of water (1.0 tonf/m3)
- g : Accelation of gravity (9.8 m/sec2)
- K : Bulk modulus of compressibility of water (2.07 x 10^5 tonf/m2)
- E : Young's modulus of elasticity for pipe material (for steel pipe = 2.1 x 10^7 tonf/m2)
- D : Diameter of pipe (m)
- t : Pipe wall thickness (m)

	D (m)	t (m)	a (m/sec)	Length (m)
Liwagu pipeline	0.7	0.006	971.4	2680.0
Penstock	0.8	0.006	936.2	456.3
- do -	0.8	0.007	976.7	120.4
- do -	0.8	0.008	1010.7	90.3
- do -	0.8	0.009	1039.8	98.1
- do -	0.5	0.006	1055.3	15.0
				3460.1

a = L/(L1/a1+L2/a2 ···· Ln/an)
= 969.877 m/sec

2. Water Hammer caused by the rapid closing of valve (in the case T < 2*L/a = 7.14 sec)

$$H-Ho = - a/g*(V-Vo)$$

Where,
- Ho : Water head in constant flowing situation (m)
- Vo : Flow velocity in constant flowing situation (m)
- H : Water head at a given time after the valve is operated (m)
- V : Flow velocity at a given time after the valve is operated (m)

When valve is fully closed and V = 0, H-Ho =a*Vo/g is maximum additional head caused by water hammering.

In case of
Discharge in the pipeline : 0.70 m3/sec,
Mean velocity in the pipeline : 1.724 m/sec

Maximum additional head by water hammer is

$H - Ho = 170.619$ m

3. Simplified method of calculations for water hammer caused by slowly closing a valve (in the case T > 2*L/a = 7.16 sec)

This formula is based on the assumption that from the time the first reflective returns to the valve until it is fully closed, the pressure remains unchanged and that the effective opening area of the valve is changed rectilinearly.

H/Ho = 1+n/2*(n+-(n^2+4)^0.5)

In this formula, + causes rise of the pressure at the time of closing the valve, whereas, - causes drop at the time of opening.

n = L*Vo/(T*g*Ho)

Where, T : Time of valve closing (sec)
L : Length of pipeline : 3460.1 (m)
Ho : 195 (m)
Vo : 1.724 (m/sec)

Time (sec)	n	H (m) (closing)	H (m) (opening)
10	0.31215	266.11	142.89
12	0.26013	252.75	150.45
15	0.20810	240.02	158.42
18	0.17342	231.88	163.99
22	0.14189	224.70	169.23
26	0.12006	219.86	172.95
30	0.10405	216.37	175.74
35	0.08919	213.18	178.37
40	0.07804	210.82	180.36
50	0.06243	207.56	183.20
60	0.05203	205.41	185.12
80	0.03902	202.76	187.54
100	0.03122	201.18	189.01
120	0.02601	200.14	189.99
150	0.02081	199.10	190.98
200	0.01561	198.07	191.98

	CASE - II	
WATER HAMMER	Gross head	184
	Discharge	1.2
1. PRESSURE WAVE VELOCITY	Mesilau	

$a = 1/(w/g*(1/K+D/E/t))^{0.5}$

Where,

a : Pressure wave velocity (m/sec)
w : Unit weight of water (1.0 tonf/m3)
g : Accelation of gravity (9.8 m/sec2)
K : Bulk modulus of compressibility of water (2.07 x 10^5 tonf/m2)
E : Young's modulus of elasticity for pipe material (for steel pipe = 2.1 x 10^7 tonf/m2)

D : Diameter of pipe (m)
t : Pipe wall thickness (m)

	D (m)	t (m)	a (m/sec)	Length (m)
Mesilau pipeline	0.6	0.006	1010.7	990.0
Penstock	0.8	0.006	936.2	456.3
- do -	0.8	0.007	976.7	120.4
- do -	0.8	0.008	1010.7	90.3
- do -	0.8	0.009	1039.8	98.1
- do -	0.5	0.006	1055.3	15.0
				1770.1

a = L/(L1/a1+L2/a2 ···· Ln/an)
= 989.978 m/sec

2. Water Hammer caused by the rapid closing of valve
(in the case T < 2*L/a = 3.58 sec)

H-Ho = - a/g*(V-Vo)

Where, Ho : Water head in constant flowing situation (m)
Vo : Flow velocity in constant flowing situation (m)
H : Water head at a given time after the valve is operated (m)
V : Flow velocity at a given time after the valve is operated (m)

When valve is fully closed and V = 0, H-Ho =a*Vo/g is maximum additional head caused by water hammering.

In case of
Discharge in the pipeline : 1.20 m3/sec,
Mean velocity in the pipeline : 2.046 m/sec

Maximum additional head by water hammer is

H - Ho = 206.683 m

3. Simplified method of calculations for water hammer caused by slowly closing a valve
(in the case T > 2*L/a = 3.58 sec)

This formula is based on the assumption that from the time the first reflective returns to the valve until it is fully closed, the pressure remains unchanged and that the effective opening area of the valve is changed rectilinearly.

H/Ho = 1+n/2*(n+-(n^2+4)^0.5)

In this formula, + causes rise of the pressure at the time of closing the valve, whereas, - causes drop at the time of opening.

n = L*Vo/(T*g*Ho)

Where, T : Time of valve closing (sec)
L : Length of pipeline : 1770.1 (m)
Ho : 184 (m)
Vo : 2.047 (m/sec)

Time (sec)	n	H (m) (closing)	H (m) (opening)
10	0.20093	224.87	150.56
12	0.16744	217.50	155.66
15	0.13395	210.35	160.95
18	0.11163	205.72	164.58
22	0.09133	201.59	167.95
26	0.07728	198.78	170.32
30	0.06698	196.74	172.08
35	0.05741	194.87	173.74
40	0.05023	193.48	174.99
50	0.04019	191.54	176.75
60	0.03349	190.27	177.94
80	0.02512	188.68	179.44
100	0.02009	187.73	180.34
120	0.01674	187.11	180.94
150	0.01340	186.48	181.55
200	0.01005	185.86	182.16

6-4 Wall Thickness of Penstock

WALL THICKNESS (from Liwagu Intake)

No.	L (m)	TL (m)	EL (m)	H (m)	P (kg/cm2)	Ph (kg/cm2)	Pd (kg/cm2)	t (cm)	at (cm)	w (kg/m)	W (kg)	Wt (kg)
Liwagu headpond	0	0	1043.0	5.0	0.5	0.0	0.5	0.0299	0.6	103.58	0	0
	2680.0	2680.0	1025.0	23.0	2.3	2.3	4.6	0.1510	0.6	103.58	277,594	277,594
Penstock	0	2680.0	1025.0	23.0	2.3	2.3	4.6	0.1704	0.6	118.38	0	0
1	15.0	2695.0	1024.0	24.0	2.4	2.3	4.7	0.1743	0.6	118.38	1,780	1,780
2	42.0	2737.0	1024.0	24.0	2.4	2.3	4.7	0.1755	0.6	118.38	4,972	6,752
3	34.0	2771.0	1016.0	32.0	3.2	2.3	5.5	0.2037	0.6	118.38	4,020	10,771
4	11.0	2782.0	1015.0	33.0	3.3	2.4	5.7	0.2074	0.6	118.38	1,308	12,079
5	19.0	2801.0	1015.0	33.0	3.3	2.4	5.7	0.2079	0.6	118.38	2,249	14,328
6	26.0	2827.0	1015.0	33.0	3.3	2.4	5.7	0.2087	0.6	118.38	3,078	17,406
7	64.3	2891.3	1009.0	39.0	3.9	2.4	6.3	0.2310	0.6	118.38	7,610	25,015
8	41.2	2932.5	989.0	59.0	5.9	2.5	8.4	0.3002	0.6	118.38	4,875	29,891
9	21.0	2953.5	980.0	68.0	6.8	2.5	9.3	0.3315	0.6	118.38	2,489	32,379
10	24.7	2978.2	971.0	77.0	7.7	2.5	10.2	0.3628	0.6	118.38	2,924	35,303
11	12.4	2990.6	968.0	80.0	8.0	2.5	10.5	0.3734	0.6	118.38	1,464	36,768
12	11.2	3001.8	963.0	85.0	8.5	2.5	11.0	0.3907	0.6	118.38	1,324	38,091
13	13.0	3014.8	963.0	85.0	8.5	2.5	11.0	0.3911	0.6	118.38	1,539	39,630
14	40.5	3055.3	952.0	96.0	9.6	2.6	12.2	0.4297	0.6	118.38	4,797	44,427
15	23.4	3078.7	944.0	104.0	10.4	2.6	13.0	0.4576	0.6	118.38	2,771	47,198
16	57.6	3136.3	927.0	121.0	12.1	2.7	14.8	0.5172	0.6	118.38	6,815	54,013
	0.0	3136.3	927.0	121.0	12.1	2.7	14.8	0.5172	0.7	138.10	0	54,013
17	42.4	3178.6	913.0	135.0	13.5	2.7	16.2	0.5661	0.7	138.10	5,853	59,866
18	20.4	3199.0	909.0	139.0	13.9	2.7	16.6	0.5803	0.7	138.10	2,817	62,682
19	30.7	3229.7	899.0	149.0	14.9	2.7	17.6	0.6152	0.7	138.10	4,236	66,919
20	26.9	3256.6	889.0	159.0	15.9	2.8	18.7	0.6500	0.7	138.10	3,718	70,637
	0.0	3256.6	889.0	159.0	15.9	2.8	18.7	0.6500	0.8	157.83	0	70,637
21	59.1	3315.7	861.0	187.0	18.7	2.8	21.5	0.7470	0.8	157.83	9,321	79,958
22	31.2	3346.9	857.4	190.6	19.1	2.8	21.9	0.7602	0.8	157.83	4,926	84,884
	0.0	3346.9	857.4	190.6	19.1	2.8	21.9	0.7602	0.9	177.56	0	84,884
23	4.0	3350.9	857.4	190.6	19.1	2.8	21.9	0.7603	0.9	177.56	714	85,598
24	32.1	3383.0	855.0	193.0	19.3	2.9	22.2	0.7694	0.9	177.56	5,693	91,291
25	33.0	3416.0	854.0	194.0	19.4	2.9	22.3	0.7737	0.9	177.56	5,862	97,153
26	16.0	3432.0	853.0	195.0	19.5	2.9	22.4	0.7776	0.9	177.56	2,847	99,999
27	13.0	3445.0	853.0	195.0	19.5	2.9	22.4	0.7780	0.9	177.56	2,308	102,308
28	0.0	3445.0	853.0	195.0	19.5	2.9	22.4	0.4919	0.6	73.98	0	102,308
29	15.0	3460.0	853.0	195.0	19.5	2.9	22.4	0.4921	0.6	73.98	2,219	104,527

Notes :
TL : Length of pipeline
EL : Elevation of center of pipe
H : Static head
P : Static pressure
Ph : Water hammer pressure
Pd : Design pressure
t : Calculated thickness
at : Adopted thickness
W : Weight of pipe

WEIGHT OF PIPELINES AND PENSTOCK

Pipeline	t (mm)	Length (m)	Weight (ton)
Liwagu Pipeline D = 700	6	2680.0	277.6
Mesilau Pipeline	6	990.0	87.9
Connecting pipe D = 600	6	90.0	8.0
Penstock			
D = 800	6	456.3	54.0
	7	120.4	16.6
	8	90.3	14.2
	9	98.1	17.4
D = 500	6	30.0	2.2
Penstock		795.0	104.5

Appendix 7 CONSTRUCTION COSTS

Appendix 7

CONSTRUCTION COSTS

CONTENTS

Summary of Construction Cost

Description	Amount (M$)
1. Civil Engineering Works	6,099,000
1.1 Preliminaries	200,000
1.2 Liwagu Intake Facilities	509,000
1.3 Mesilau Intake Facilities	647,000
1.4 Liwagu Pipeline	2,284,000
1.5 Mesilau Pipeline	543,000
1.6 Penstock	813,000
1.7 Powerhouse	175,000
1.8 Access Road	928,000
2. Electrical and Mechanical Works	3,150,000
3. Transmission Line	140,000
4. Project Land Cost and Compensations	250,000
5. Engineering and Management (10% of above total)	965,000
6. Contingencies	896,000
10% of Civil Engineerings Works	610,000
5% of Electrical and Mechanical Works	158,000
5% of Transmission Lines	7,000
10% of Project Land Cost and Compensations	25,000
10% of Engineering, Management and Commissioning	96,000
Grand Total	11,500,000

Construction Cost No.1

1.2 Liwagu Intake Facilities

1.2.1 Intake Dam and Desilting Basin

Description	Unit	Q'ty	Unit Price (M$)	Amount (M$)
Site clearance & Setting out	L.S	1	7,000	7,000
Temporary river diversion works	L.S	1	75,000	75,000
Excavation in soft material	m^3	100	7	700
Excavation in river gravel	m^3	800	10	8,000
Excavation in rock	m^3	40	60	2,400
Mass concrete (1;3;6)	m^3	410	220	90,200
Structurel concrete (1;2;4)	m^3	240	300	72,000
Reinforcement	t	14	1,850	25,900
Embankment	m^3	70	10	700
Gabion (1.5×1.0×0.5m)	Set	60	80	4,800
Scouring gate (0.7×0.9m)	Set	2	8,000	16,000
Miscellaneous (5%)	L.S.	1		15,300
Total				318,000

Construction Cost No. 2

1.2.2 Headpond

Description	Unit	Q'ty	Unit Price (M$)	Amount (M$)
Site clearance & Setting out	L.S	1	5,000	5,000
Excavation in soft material	m^3	100	7	700
Excavation in river gravel	m^3	250	10	2,500
Excavation in rock	m^3	50	60	3,000
Embankment	m^3	960	10	9,600
Facing concrete (1;2;4)	m^3	180	300	54,000
Structure concrete (1;2;4)	m^3	200	300	60,000
Reinforcement	t	12	1,850	22,200
PVC Waterstop	m	200	20	4,000
Gravel	m^3	135	46	6,210
Scouring gate (0.7×0.9m)	Set	1	8,000	8,000
Stop gate (0.7×0.7m)	Set	1	7,000	7,000
Miscellaneous (5%)	L.S			8,790
Total				191,000

Construction Cost No.3

1.3 Mesilau Intake Facilities

1.3.1 Intake Dam and Desilting Basin

Description	Unit	Q'ty	Unit Price (M$)	Amount (M$)
Site clearance & Setting out	L.S	1	7,000	7,000
Temporary river diversion work	L.S	1	75,000	75,000
Excavation in soft material	m^3	180	7	1,260
Excavation in river gravel	m^3	180	10	1,800
Excavation in rock	m^3	90	60	5,400
Embankment	m^3	600	10	6,000
Mass concrete (1;3;6)	m^3	440	220	96,800
Structure concrete (1;2;4)	m^3	300	300	90,000
Reinforcement	t	11	1,850	20,350
Gabion (1.5×1.0×0.5m)	Set	60	80	4,800
Scouring gate (0.6×0.7m)	Set	1	6,000	6,000
Scouring gate (1.4×1.2m)	Set	1	12,000	12,000
Stop gate (0.9×0.9m)	Set	1	10,000	10,000
Miscellaneous (5%)	L.S	1		16,590
Total				353,000

Construction Cost No.4

1.3.2 Headpond

Description	Unit	Q'ty	Unit Price (M$)	Amount (M$)
Site clearance & Setting out	L.S	1	5,000	5,000
Excavation in soft material	m^3	3,000	7	21,000
Excavation in rock	m^3	500	60	30,000
Embankment	m^3	1,200	10	12,000
Facing concrete (1;2;4)	m^3	200	300	60,000
Structure concrete (1;2;4)	m^3	100	300	30,000
Reinforcement	t	7	1,850	12,950
PVC Waterstop	m	250	20	5,000
Gravel	m^3	150	46	6,900
Masonry	m^3	25	50	1,250
Supply & inst. of connecting pipe (D=600mm)	m	90	450	40,500
Supply & inst. of scouring pipe (D=700mm)	m	36	700	25,200
Scouring valve (D=700mm)	Set	1	30,000	30,000
Stop valve (D=600mm)	Set	1	22,000	22,000
Miscellaneous (5%)	L.S	1		14,200
Total				294,000

Construction Cost No.5

1.4 Liwagu Pipeline

Description	Unit	Q'ty	Unit Price (M$)	Amount (M$)
Site clearance & Setting out	L.S	1	38,000	38,000
Excavation in soft material	m^3	940	7	6,580
Excavation in rock	m^3	0	60	0
Supply & inst. of steel pipe (D=700mm, t=6mm)	m	2,680	700	1,876,000
Saddle concrete (1;2;4)	m^3	300	300	90,000
Anchor block & pier concrete (1;2;4)	m^3	130	220	28,600
Reinforcement	t	14	1,850	25,900
Steel bridge for pipeline :l=30m	Set	1	35,000	35,000
Steel bridge for pipeline :l=20m	Set	2	20,000	40,000
Gravell	m^3	120	46	5,520
Stope valve (D=700mm)	Set	1	30,000	30,000
Miscellaneous (5%)	L.S	1		108,400
Total				2,284,000

Construction Cost No.6

1.5 Mesilau Pipeline

Description	Unit	Q'ty	Unit Price (M$)	Amount (M$)
Site clearance & Setting out	L.S	1	20,000	20,000
Excavation in soft material	m^3	160	7	1,120
Excavation in rock	m^3	0	60	0
Supply & inst. of steel pipe (D=600mm, t=6mm)	m	990	450	445,500
Saddle concrete (1;2;4)	m^3	60	300	18,000
Anchor block concrete (1;2;4)	m^3	20	220	4,400
Reinforcement	t	3	1,850	5,550
Gravell	m^3	9	46	414
Stop valve (D=600mm)	Set	1	22,000	22,000
Miscellaneous (5%)	L.S	1		26,016
Total				543,000

Construction Cost No.7

1.6 Penstock

Description	Unit	Q'ty	Unit Price (M$)	Amount (M$)
Site clearance & Setting out	L.S.	1	44,000	44,000
Excavation in soft material	m^3	2,900	7	20,300
Rock excavation	m^3	720	60	43,200
Sand foundation for penstock	m^3	620	40	24,800
Backfill for penstock	m^3	1,600	10	16,000
Supply & inst. of steel pipe (D=700&600mm, t=6mm)	m	473	1,150	543,950
Supply & inst. of steel pipe (D=700&600mm, t=7mm)	m	120	1,270	152,400
Supply & inst. of steel pipe (D=700&600mm, t=8mm)	m	90	1,350	121,500
Supply & inst. of steel pipe (D=700&600mm, t=9mm)	m	85	1,400	119,000
Supply & inst. of steel pipe (D=500mm, t=6mm)	m	32	380	12,160
Anchor block concrete (1;2;4)	m^3	140	220	30,800
Reinforcement	ton	3	1,850	5,550
Slope protection (Seeding)	m^2	3,200	2	6,400
Concrete pile (D=300mm, l=1.5m)	p.c	50	45	2,250
Miscellaneous (5%)	L.S	1		54,940
Total				1,151,000

Construction Cost No. 8

1.7 Powerhouse

Description	Unit	Q'ty	Unit Price (M$)	Amount (M$)
Site clearance & Setting out	L.S	1	7,000	7,000
Excavation in soft material	m^3	2,700	7	18,900
Excavation in rock	m^3	300	60	18,000
Embankment	m^3	0	5	0
Base concrete (1;2;4)	m^3	0	220	0
Structure concrete (1;2;4)	m^3	130	300	39,000
Reinforcement	t	4	1,850	7,400
Slope protection (Seeding)	m^2	340	2	680
Gravel	m^3	170	46	7,820
Precast concrete gutter (30×30m)	m	50	22	1,100
Superstructure	L.S	1	50,000	50,000
Hoist with girder	L.S	1	16,800	16,800
Miscellaneous (5%)	L.S.	1		8,300
Total				175,000

Construction Cost No.9

1.8 Access Road

Description	Unit	Q'ty	Unit Price (M$)	Amount (M$)
Type A	m	2,980	206	613,880
Type B	m	2,480	109	270,320
Miscellaneous	L.S.	1		43,800
Total				928,000

Type A	Site clearance	m	1	5	5
	Slope protection (Seeding)	m	6	2	12
	Excavation	m^3	18	4	70
	Gravel	m^3	1	46	28
	Precast concrete gutter (30×30cm)	m	1	22	22
	Concrete wall	m^3	0	300	60
	Hume concrete pipe	m	0	230	9
	Total				206
Type B	Site clearance	m	1	5	5
	Slope protection (Seeding)	m	2	2	4
	Excavation	m^3	9	4	35
	Gravel	m^3	1	46	28
	Concrete wall	m^3	0	300	30
	Hume concrete pipe	m	0	230	7
	Total				109

Construction Cost No.10

2. Electrical and Mechanical Works

Description	Unit	Q'ty	Unit Price	Amount
Turbine and Generator	L.S.	1		2,012,000
Transformer	L.S.	1		214,000
Telecommunication	L.S.	1		198,000
Transportation	L.S.	1		242,000
Installation (including miscellaneous materials)	L.S.	1		484,000
Total				3,150,000

Appendix 8 ENVIRONMENTAL IMPACT STUDY

Appendix 8

ENVIRONMENTAL IMPACT STUDY

CONTENTS

Lembaga Letrik Sabah
Kota Kinabalu

SMALL SCALE HYDROELECTRIC POWER DEVELOPMENT PROJECT AT UPPER LIWAGU RIVER BASIN IN SABAH

ENVIRONMENTAL IMPACT ASSESSMENT

Final Report

May 1992

Biro Penyelidikan dan Perundingan
Universiti Kebangsaan Malaysia

EXECUTIVE SUMMARY

BACKGROUND

Sabah Electricity Board (SEB) proposes to install a small hydro-electric power generation facilities in the vicinity of Kg. Naradaw, Kundasang, Sabah to cater for the growing power demand of the population and development activities along the Kundasang - Ranau grid.

The proposed Naradaw scheme is a run of river type, comprising two intake weirs: one will be on Sg. Liwagu proper and the second on Sg. Mesilau. Water extracted from these two intake weirs will be piped to a head pond before being surged down to a power house located near the confluence of the two rivers. The Naradaw site has a total catchment area of 59.2 km^2, enabling a design maximum discharge of 1.18 m^3/s. With a net head of 169 m, the installed capacity of the hydroplant is estimated at 1.6 MW.

The aim of the present study is to investigate and describe the existing status of the physicochemical, biological and human components of the environment within and in the vicinity of the project area, and thereon predict the potential impacts of the activities related to the proposed hydroelectric installation as well as suggesting appropriate mitigation and abatement measures for incorporation into the project plan.

EXISTING ENVIRONMENT

CLIMATE: The areas along the upper reaches of the Liwagu River are influenced by the southwest monsoon with rainy seasons between May - October, and dry seasons between February - April. Kundasang has one of the lowest recorded average annual rainfalls in Sabah i.e. 2,313 mm presumably due to the rainshadow effect. On the average about 1001 mm per year of rainfalll is available for runoff and infiltration into the ground. There is little seasonal variation of temperature in Kundasang; the hottest month, May, has a monthly mean daily maximum of 25.7°, the coolest being January, at 22.5°.

TOPOGRAPHY: Slopes in the Study Area are generally steep. The Naradaw site has a mountainland of elevations from 840 to 1,040 m, through which the Liwagu River and the Mesilau River meander from west-northwest to east-southeast. The gradient of the Liwagu river is approximately 1/19, while that of the Mesilau River is approximately 1/15. Slopes generally inclined 20 to 45 degrees, and parts of the slopes show old or new signs of landslides.

GEOLOGY: The project area is underlain by sedimentary rocks of Crocker Formation consisting of sandstone with minor shale/mudstone and siltstone alternations. Unconformably overlying the Crocker is the Pinosuk Gravel and recent riverine alluvium. The Crocker Formation has been extensively faulted with no prefered orientation of fault lines.

Weathered to freshly fractured sandstone boulders of the Crocker Formation are found at the intake site of the Liwagu River. At the Mesilau intake, strongly brecciated sandstone of the Crocker Formation were found at the depth of about 6 metres below the river bed.

The main soil associations found in the Study Area are those of Pinosuk, Trusmadi and Crocker Associations. The soil is suitable for the cultivation of vegetables, but because of the steepness of the terrain, there is a strong erosion risk.

From seismological data, recorded earthquakes west of Ranau have had magnitude ranging from 4 - 5.9 on the Richter scale, and are of shallow depth (less than 70 km). The most recent earthquake in this part of Sabah measuring 5 on the Ritcher Scale accurred on 27 May 1991, followed by series of aftershocks during the following weeks.

DRAINAGE: The project area lies within the catchment area of the Sg. Liwagu, which flows generally eastwards, eventually emerging in Labuk Bay on the Sulu Sea. Its source is in the Kinabalu Park, and it is this river which provides water for consumption in the Ranau District. The main tributaries upstream of the project area is Sg. Mesilau East and West and Sg. Silau Silau. The catchment areas for the Mesilau rivers upstream of the proposed intake point is estimated to be about 28 km^2 and that for Sg. Liwagu proper is 31 km^2.

LAND USE: Agricultural sector represents the main production base for the economy of the project area. The swidden agriculture appears to have given way to a more settled farming method. Their effort is being facilitated by Government agencies such as the Koperasi Pembangunan Desa (KPD) which provides water supply and sprinkler system. Most holdings appear to range from 0.6 - 0.8 ha. in size. The total area of cultivated land in Kundasang in 1984 was estimated about 750 ha. The crops most commonly grown on the holdings are mixed, non-tree crop horticulture some of which are indigenous to temperate climates. In addition to growing vegetables, many local residents keep some form of livestock.

WATER USE: The water use in the upstream area of the project site are in three main areas viz. Bundu Tuhan, Kundasang, and Pinosuk Plateau. The estimated water demand for various uses (domestic, agriculture, commercial other municipal uses) in the three areas for 1990 is estimated at nearly 22) (equivalent to 1.16 cumecs).

WATER QUALITY: Field observation indicates that the Liwagu Mesilau rivers are being directly affected by the agricultural, urbanisation, m and recreational activities in the Upper Liwagu basin although the DOE ds show that the water quality at Ranau still belongs to Class I water. Water y exaimination within the project area shows relatively high loading of dis- l solids, organics and phosphates although the dissolved oxygen level in cases are near saturation point. Available data indicate that none of the ion organochlorine pesticides occur at detectable concentration in water al- gh low quantities of these pesticides have been detected in sediment samples.

VEGETATION: The vegetation of this area is essentially that wer montane rain forest which is characterised by two floristic zones, namely upper dipterocarp forest (roughly at 750 - 900 m altitude) and oak-laurel : (900 - 1800 m). Although the original hillslope vegetation has mostly been ed and replaced with commercial vegetable plot, there are still a few remnant ry species along the Liwagu and Mesilau river valleys; these include *rocarpus* sp., *Aglaia* sp., *Shorea* sp., *Eleocarpus* sp. *and Diospyros* sp. Areas have been severely affected by shifting cultivation (slash and burnt) are ver dominated by the secondary species which include *Melochia umbellata, auclea gigantea, Brookea dasyntha, Trema* sp. and others. The above ground ass at the proposed powerhouse site was found to be only about 16 tonne/ No unique floral species of special conservation or scientific interests have found here.

WILDLIFE: Fauna representing the original community was l within the remnants of the riverine reserves. The presence of *Amolops headi* and *Ansonia longidigita* in the Mesilau river implies the existence originally larger amphibian community typical of hill forest. Nevertheless, substantial er of *Bufo juxtasper* in the Mesilau river indicates a trend towards the ification of the amphibian community caused by deforestation. Modification e Mesilau-Liwagu valleys is also evidenced by the high relative abundance of in colonising bird species (bulbuls, prinias, munias) typical of the distrubed ats of the lowlands. Few mammals were caught or sighted, again species il of disturbed lowland/hill forest. No rare or endangered species were re- ed.

AQUATIC LIFE: Of the 11 species of fish caught at the pro- l Mesilau intake point, eight belongs to Gastromyzontidae. At the Liwagu e, 15 species of fish have been sampled, 12 were found to belong to the y Gastromyzontidae, two species from Anguillidae and only one species from nidae. Of the 12 species caught from the Liwagu-Mesilau confluence, 10 from the family Gastromyzontidae and 2 species from the family Anguilli- Thus, at the range of altitude where the hydro scheme is to be located, the dominant fish family found in the streams were Gastromyzontidae.

HUMAN ENVIRONMENT: The proposed project will acquire about 10 ha. of land for laying the pipe, power house and the pond. Most of these lands are private lands. About five houses have to be relocated as they are located very close to the pipeline and the power house. All households in the study area belong to the lower income group of less than $400 per month.

The survey reveals that about 76 percent of respondents agreed the project to be built in the proposed site, 16 percent disagreed and the rest had no opinion. Those who disagreed feel that the area is not suitable for the hydroelectric project in view of constant water shortages.

POTENTIAL IMPACTS

INVESTIGATION STAGE: The potential impacts of the site surveying, engineering and geophysical investigations are expected to be of low magnitude. Nevertheless, the entry of the investigation team should be made known to the kampung head.

CONSTRUCTION AND DEVELOPMENT STAGE: Earth work and excessive use of the existing Kauluan gravel road can cause among others, (i) damage to the road, (ii) soil erosion and slope failure, (iii) increase in suspended sediment in stream waters, (iv) increase of airborne particulates during dry periods, (v) noise from the machineries deployed, and (vi) inherent risks to human safety both of onsite workers and the surrounding neighbourhood. The construction of intake weirs can result in immediate siltation of downstream water if the flow is not properly diverted. Indiscriminate disposal of wastes into the surrounding water bodies can seriously affect the aquatic ecosystem and downstream water use. Appropriate mitigation measures must therefore be taken during the civil works.

OPERATION AND MAINTENANCE: Major environmental issues that can be associated with the operation and maintenance of the proposed small scale upper Liwagu HEP project are (i) the power generation activities, particularly with regard to water extraction, and (ii) waste disposal.

Water quantity for the Liwagu and Mesilau rivers upstream of the intake points, and also the Liwagu river downstream of the power house will not be affected, as what comes into the HEP plant system will go out.

However, for the stretch between the intake points and the power house, there will be some reduction in flow. The reduction in river water quantity between the intake points and the powerhouse may lead to a number of adverse implications, the most critical being possible loss of habitat for aquatic life. Another potential negative impact will be creation of sites for mosquito breeding as low flows will lead to formation of small water pools in the rocky bed.

The ponding of water is not expected to affect the downstream water quality as the retention time in the pond is only about 2 hours.

Solid wastes, particularly the silt/sludge from the headpond and used lubrication oil from the power plant maintenance must be properly managed to avoid pollution of downstream water.

RECOMMENDATIONS

Based on the information gathered of the existing environment and the proposed development and operational plans, major recommendations with regard to environmental preservations are as follows:

1) In view of the pressing demand for water resource by the various users within the upper Liwagu catchment area, an accurate water auditing must be worked out to verify the feasibility of the proposed HEP project and avoid adverse environmental implications associated with water quantity.

2) During low flows, priority must be given to allocating sufficient quantity of flow for river maintenance purposes (for the intake - powerhouse stretch); the minimum flow recommended is 0.05 cumecs for Sg. Mesilau and 0.10 cumecs for Sg. Liwagu.

3) Affected villagers must be appropriately compensated for losses due to displacement or acquisition of land, prior to commencement of construction work.

4) As the area is still tectonically active, structures must be firmly anchored to the bedrocks; all installations must incorporate adequate safety features to minimise impact in case of foundation failure.

5) All engineering works must incorporate strict erosion control measures to minimise siltation problem of surface waters during the construction stage.

Table 1.0 summarises the potential impacts and recommended mitigation and abatement measures for the proposed upper Liwagu HEP project.

TABLE 1.0. SUMMARY OF POTENTIAL IMPACTS AND MITIGATING MEASURES OF THE PROPOSED UPPER LIWAGU SMALL-SCALE HYDROPOWER PROJECT

ITEM	PROJECT ACTIVITIES AND SOURCES OF POLLUTANTS	POTENTIAL IMPACTS	NATURE S (short-term) L (long-term) P (permanent)	PROPOSED MITIGATION MEASURES	RESIDUAL IMPACTS
A. INVESTIGATION STAGE					
Site surveying and engineering/geotechnical investigation.		Minimal in terms of traffic related impacts (airborne dust,road safety, noise)	S		
		May cause anxiety among population.	S	First inform the village head.	
		Minimal impacts on biological components.		Ensure minimal cutting of rentices/ riparian vegetation.	
Note: No new access road required.					
B. CONSTRUCTION AND DEVELOPMENT					
1.	**Access road** *Note: Existing roads are unsurfaced and on hillslopes.*	Reduction in surface water quality.	S	Make use of existing roads rather than cutting new roads.	
			S	Road surface to be improved (gravelled and compacted to appropriate specification).	
				Proper drainage should be provided for newly built stretch.	
		Reduction in air quality.	S	Water to be lightly sprayed on access roads when dust is excessive.	
		Increase in noise.	S	Working hours limited to daytime only.	
		Degradation of roads due to overloading.	S	Close supervision by Site Engineer	
				Roads to be immediately resurfaced if damaged during usage.	
		Some loss in agriculture land	P	Affected land owners to be compensated for new road stretch that cut across vegetable farms.	

TABLE 1.0. SUMMARY OF POTENTIAL IMPACTS AND MITIGATING MEASURES OF THE PROPOSED UPPER LIWAGU SMALL-SCALE HYDROPOWER PROJECT - cont'd

ITEM	PROJECT ACTIVITIES AND SOURCES OF POLLUTANTS	POTENTIAL IMPACTS	NATURE S (short-term) L (long-term) P (permanent)	PROPOSED MITIGATION MEASURES	RESIDUAL IMPACTS
2	**Site clearing**	Increased suspended solids in surface water due to surface erosion.	S	Attempt should be made at synchronising site clearing with dry periods.	
	Note: o *The area is generally devoid of primary vegetation (replaced with vegetable farms).* o *There are no endangered and rare plant and wildlife species in the area.*			Minimal cutting of riparian vegetation; replanting cleared strips.	
				Provision of temporary drain and silt trap around headpond and powerhouse areas.	
				Exposed steep slopes to be protected with plastic sheeting.	
				Use excess earth for road grading and bunds.	
		Increase in noise level.	S	Working hours near settlement areas to be limited to daytime.	
		Increase in suspended particulates in the air.	S	Water to be sprinkled during dry periods.	
				Plant debris must not be burnt on-site but properly stacked along the riparian or hill slopes to act as silt screen.	
		Displacement of houses (*Note: Land acquisition not extensive*)	P	Affected population should be adequately compensated.	Displacement of about five households.
				Resettlement of affected household to be completed first prior to site clearing.	
3	**Earthworks**	Increase in suspended particulates in air prior to stabilisation.	S	Spray water when dust is excessive.	
		Increase in suspended solids due to erosion by runoff.	S	Construct temporary drains which lead to a silt trap or settling pond.	

TABLE 1.0. SUMMARY OF POTENTIAL IMPACTS AND MITIGATING MEASURES OF THE PROPOSED UPPER LWAGU SMALL-SCALE HYDROPOWER PROJECT - cont'd

ITEM	PROJECT ACTIVITIES AND SOURCES OF POLLUTANTS	POTENTIAL IMPACTS	NATURE S (short-term) L (long-term) P (permanent)	PROPOSED MITIGATION MEASURES	RESIDUAL IMPACTS
				Earthwork is best confined to periods of expected low precipitation.	
				Excess earth to be stockpiled on levelled ground and compacted, or used for road grading or bunding.	
				Earthwork should be phased so as not to allow too much area being exposed to erosion at any one time. Exposed areas to be revegetated/turfed immediately upon completion of earthwork.	
		Siltation of streams during construction of intake weirs.	S	Proper diversion of stream flow.	
		Slope failure.	S	Minimal cutting of slope. Slope to be cut or cleared of vegetation only when the site is ready to be worked on. Work first from higher ground.	
		Increase in noise due to earthwork machinery.	S	Working time near settlement areas to be limited to day time only.	
		Reduction of aesthetics.		Good landscaping work, particularly around headpond and powerhouse.	
4	**Transportation**	Increase in suspended particulates in air.	S	Lorry loads must be covered to avoid spillage.	
				Sprinkling of road and tracks when dust is excessive.	
		Decrease in tranquility.	S	Transportation movement to be restricted to daytime.	

TABLE 1.0. SUMMARY OF POTENTIAL IMPACTS AND MITIGATING MEASURES OF THE PROPOSED UPPER LIWAGU SMALL-SCALE HYDROPOWER PROJECT - cont'd

ITEM	PROJECT ACTIVITIES AND SOURCES OF POLLUTANTS	POTENTIAL IMPACTS	NATURE S (short-term) L (long-term) P (permanent)	PROPOSED MITIGATION MEASURES	RESIDUAL IMPACTS
		Safety hazards.	S	Safety regulation and normal construction supervision to be enforced.	
				Minimise number of trips by proper planning.	
5	**Material and equipment**	Increase in noise.	S	Working hours in Kg. Naradaw is limited to daytime only.	
		Safety hazard in storage area	S	Machines, pipes etc. to be stored away from the public right of way and guarded.	
		Risk of accident at construction site.	S	Safety regulation and normal construction supervision to be enforced.	
6	**Waste disposal**	Deterioration of water quality.	S	Proper management of wastes (e.g. use of covered containers/pit)	
				Excess earth to be reused or properly stocked. Other construction wastes to be disposed off at approved waste dump site.	
				No open burning on-site.	
				No full scale maintenance work on machineries/ vehicles be allowed in the project area.	
		Water contamination by sewage.	S	Provision of temporary septic tank to worker quarters.	
7	**Base camp**	Indiscriminate dumping of wastes lead to ground and water pollutions - potential health hazard.	S	Proper management of wastes (see Waste Disposal).	
8	**Labour force**	Employment opportunities (+ve impact)	S	(Job priority given to locals).	