CHAPTER 4 AREA NGOMA22・DESIGNING IRRIGATION SECTOR

4-1. Irrigation designing

4-1-1. Planning of water supply

(1) Studying of Available Water Quantity

(a) Estimation of Available River Flow Rate

ⅰ) Methodology

The runoff model that can calculate the daily river flow rates through inputting the daily rainfalls shall be obtained by analyzing the relationship between the rainfall record and the river flow rate record that have been being observed since this February.

The Tank Model Method shall be applied as the analysis method considering the following conditions.

- The target is to estimate the long-term river flow rate such as the annual cumulative river flow rate.
- The river flow rate in this area is much affected by the degree of saturation in the ground brought from previous rainfalls.
- The Tank Model Method is appropriate to such analysis conditions.

ⅱ) Examination to the Observation Data

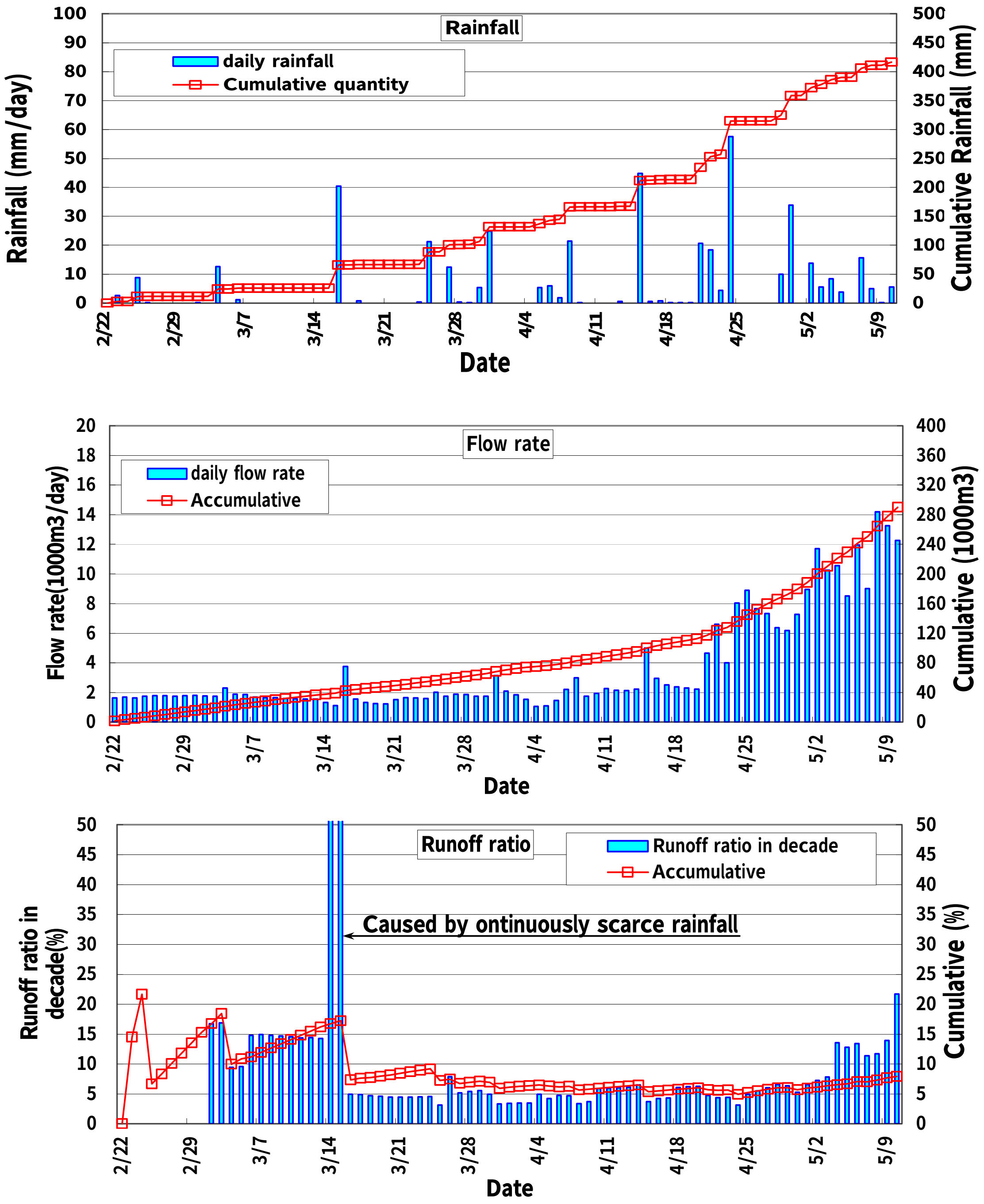
The data that have been being observed shall be summarized in daily records (decade records in runoff's case) and in cumulative records from the beginning of the observation, and shown as the following record diagrams.

- Based on these diagrams, followings would be pointed out. As for the runoff ratio that plays an important role in the runoff analysis to the long-term river flow rate, the decade runoff ratio changes from 15 % approximately in February to mid March to 5 % approximately in late March to late April, and turns to 15 % in early May.
- As for the daily river flow rates, they are almost constant to be 2,000 m^3/day approximately since the beginning of the observation, late February, till mid April; and the river flow rate does not respond to the daily rainfall less than 20 mm.
- The daily river flow rates after considerable precipitations falling in the site at the end of mid April record the values more than 6,000 m^3/day continuously.

The low runoff ratios ranging from 5% to 15% would be caused by the permeable ground surface, precipitations on the dry ground being absorbed and difficult to run off, and the high degree of evapo-traspiration. The continuous river flow rates of 2,000 m^3/day would be the reflection of the base flow.

The increase of the daily river flow rate following the precipitation after late April would be caused by the phenomenon that the runoff ratio increases due to the continuous rainfalls making the ground saturated.

＊This study was carried out based on the observation record from 22nd of February 2012 to 10th of May 2012. In the Final Report, the analysis would be reexamined based on the observation record till the end of June.



Examination to the observation record

Period 2012/2/22-2012/5/10	
Correlation factor	0.955
Accumulative flow rate	290 ×1000 m3
Accumulative rainfall	417 mm
Converted flow rate	3,666 ×1000 m3
Runoff ratio	7.9%

(rainfall(mm)×8.8km2)

Fig. 4-1-1-1 Observation records of rainfall & runoff

iii) Building of the Tank Model

a) Evapo-transpiration

The amount of decade evapo-transpiration is estimated and shown on the table below following the one of paddy rice calculated by CROPWAT-8 using the daily rainfall record in GAHORORO, 1970.

The tanks from which water depth the amount of evapo-transpiration is deducted are the upper (first) tank and the middle (second) tank; only in case of the water depth in the upper tank being not enough, the water depth less than 50 % of the shortage is deducted from the water depth in the middle tank.

Table 4-1-1-1 Evapo-transpiration in decade Unit; mm/day

January			February			March			April		
Early	Mid	Late	Early	Mid	Late	Early	Mid	Late	Early	Mid	Late
3.7	3.73	3.95	4.21	4.47	4.39	4.28	4.16	4.11	3.96	3.72	3.61
May			June			July			August		
Early	Mid	Late	Early	Mid	Late	Early	Mid	Late	Early	Mid	Late
3.61	3.61	3.61	3.61	3.61	3.61	3.61	3.61	3.61	4.44	4.44	4.76
September			October			November			December		
Early	Mid	Late	Early	Mid	Late	Early	Mid	Late	Early	Mid	Late
4.80	4.69	4.57	4.90	4.40	4.27	4.10	3.92	3.91	3.80	3.63	3.49

b) Constant of the tank model

The constants shown in the illustration above are decided through trial calculations aiming to obtain the correlation coefficient between observed values and calculated ones higher than 90 % and to get approximately same values of runoff ratio between the observed and the calculated. The following diagrams show the final result of these trial calculations with the correlation coefficient of 0.955 and the same runoff ratio of 7.9 %.

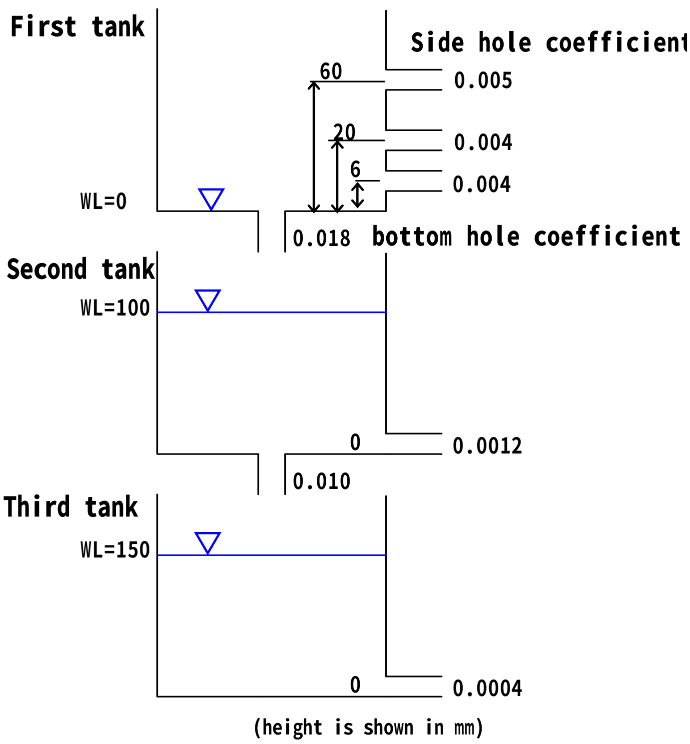
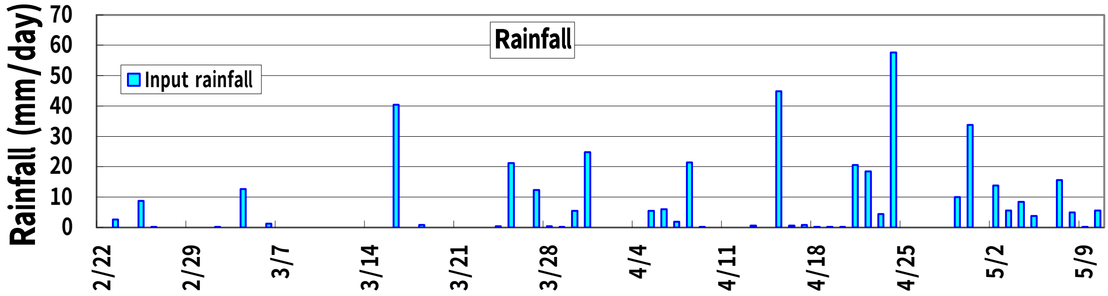
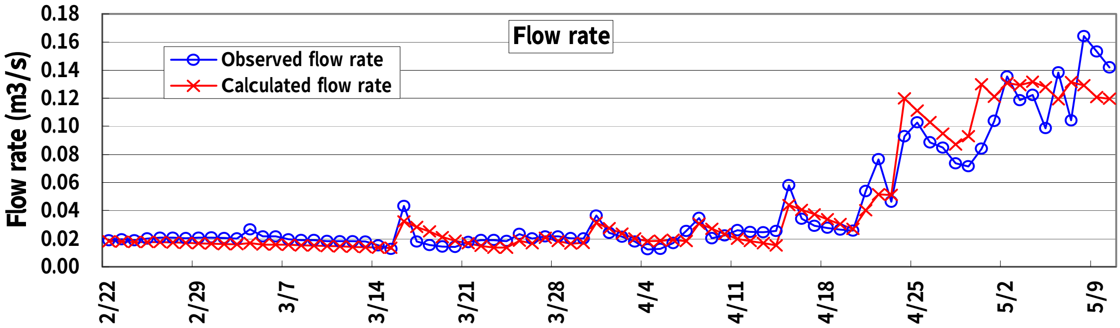


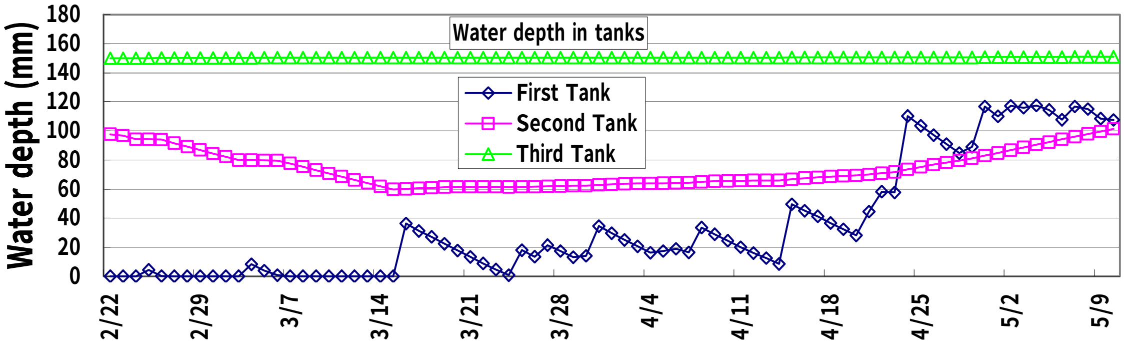
Fig. 4-1-1-2 Conceptual diagram of tank model

Calculated result By TANK MODEL

Period	2012/2/22-2012/5/10		
Correlation coeffcient	0.955	Runoff ratio(%)	
Cumulative, calculated	289 ×1000m3	Calculated	7.9%
Cumulative,observed	290 ×1000m3	Observed	7.9%
Cumulative rainfall	417		







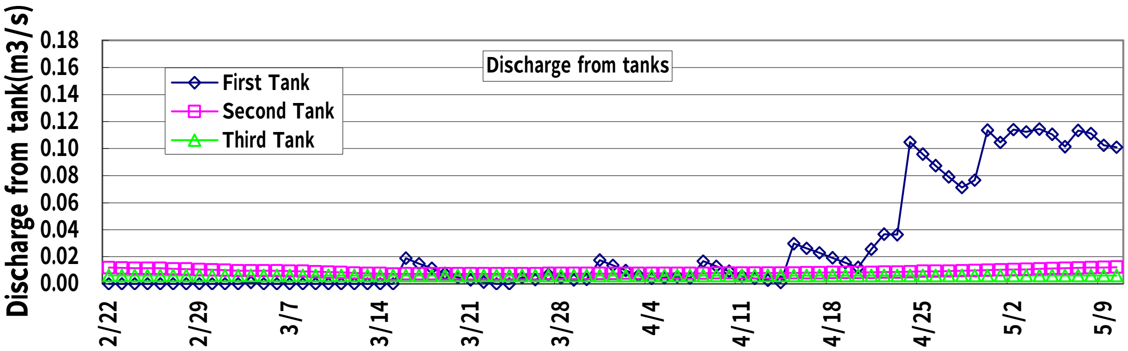


Fig. 4-1-1-3 Comparison of runoff between calculated value and observed value

iv) Estimation of the cumulative quantity of annual river flow rate

The daily rainfall record of Gahororo Weather Station is applied to the analysis based on the following view points.

- Short distance to the dam site
- Daily rainfall record of 34 years from 1960 to 1993
- KIBUNGO Weather Station is also close to the dam site and has the daily rainfall records of 63 years from 1931 to 1994; but these records lack of the recent ones from 1981 to 1989. It is appropriate to adopt Gahororo Station with recent records considering the tendency of the annual rainfall decreasing in these years.

Fig. 4-1-1-4 Location map of the dam site and GAHORORO weather station

The tank model built through the process in the previous section can produce the daily river flow rates corresponding to the each daily rainfall record of 34 years from 1960 to 1993. The following table and figures show the estimated quantity of annual river flow rate that is the accumulation of these daily values.

In addition, the calculation of each year, which starts on 1st of January, is treated to start from the initial water depth conditions of the first tank with 0 mm, of the second tank with 100 mm and of the third tank with 150 mm to avoid the expansion of error through sequential calculation covering 34 years.

Table 4-1-1-2 Results of tank model analysis

Calculation result of each year

Year	Annual flow rate (m3)	Annual rainfall(mm)	Runoff ratio	Wet year ranking	Dry year ranking	
1960	1,050	1,133	10.5	11	24	
1961	1,251	1,320	10.8	6	29	
1962	620	1,067	6.6	26	9	
1963	982	1,183	9.4	13	22	
1964	604	1,094	6.3	27	8	
1965	1,275	1,304	11.1	5	30	
1966	1,336	1,366	11.1	4	31	rainfall record modified
1967	364	856	4.8	34	1	
1968	1,691	1,349	14.2	2	33	
1969	858	1,095	8.9	18	17	
1970	709	1,134	7.1	21	14	
1971	567	984	6.6	29	6	
1972	573	1,147	5.7	28	7	
1973	543	918	6.7	30	5	
1974	638	1,002	7.2	24	11	
1975	444	1,022	4.9	33	2	
1976	802	1,145	8.0	19	16	
1977	873	1,166	8.5	16	19	
1978	1,126	1,268	10.1	8	27	
1979	1,614	1,269	14.5	3	32	
1980	626	883	8.1	25	10	including missing data
1981	860	1,124	8.7	17	18	
1982	657	637	11.7	22	13	including missing data
1983	541	822	7.5	31	4	including missing data
1984	901	1,077	9.5	15	20	
1985	1,715	1,349	14.4	1	34	
1986	1,036	1,046	11.3	12	23	including missing data
1987	913	1,161	8.9	14	21	including missing data
1988	1,114	1,306	9.7	9	26	
1989	1,077	1,270	9.6	10	25	
1990	1,155	1,283	10.2	7	28	
1991	755	1,100	7.8	20	15	
1992	455	994	5.2	32	3	
1993	647	927	7.9	23	12	
Average	877	1,105	8.8			
Min	364	637	4.8			
Max	1,715	1,366	14.5			

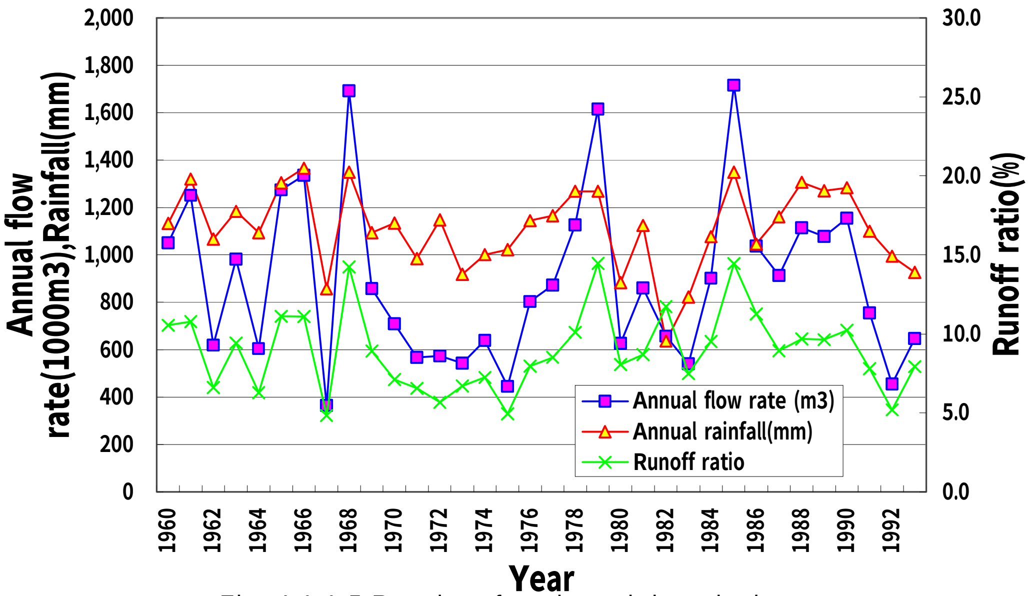


Fig. 4-1-1-5 Results of tank model analysis

Ⅴ) Base year and the available annual river flow rate

The probability occurrence is examined to the annual river flow rates obtained by the Tank Model Analysis; and the dry year with the probability occurrence of 3/10 approximately is adopted as the base year, which is as same as in Nyanza-23 of the LWH Project, and the annual river flow rate of this year is considered to be the available quantity.

Based on the calculation results shown below, the available quantity is considered to be 700,000 m^3 (697,149 m^3) that corresponds to the three (3) year probability occurrence and the year 1970 the annual value of which is 709,000 m^3 is to be the base year in the irrigation planning.

Table 4-1-1-3 Results of provable rainfall (1)

data number in 10 % range at both edges of distribution N/10	Constant of lower limit b
3	-17.7

	xl Max	xs Min	xg $\log_{10}xg = \sum \log_{10}xi$	$xl \cdot xs - xg^2$	2xg-(xl+xs)	bs $xl \cdot xs - xg^2$ /2xg-(xl+xs)	b mean bs
1	1,715.000	364.000	833.0151	-69654.10	-412.97	168.67	168.7
2	1,691.000	444.000	833.0151	56889.90	-468.97	-121.31	23.7
3	1,614.000	455.000	833.0151	40455.90	-402.97	-100.39	-17.7
4	1,275.000	543.000	833.0151	-1589.10	-151.97	10.46	-10.6
5	1,251.000	567.000	833.0151	15402.90	-151.97	-101.35	-28.8
6	1,155.000	573.000	833.0151	-32099.10	-61.97	517.98	62.3
7	1,126.000	604.000	833.0151	-13810.10	-63.97	215.88	84.3
8	1,114.000	620.000	833.0151	-3234.10	-67.97	47.58	79.7
9	1,077.000	638.000	833.0151	-6788.10	-48.97	138.62	86.2
10	1,050.000	647.000	833.0151	-14564.10	-30.97	470.27	124.6

standard deviation Sx	1/a
0.17868	0.25733

occurrence period of year T year	ξ	1/a · ξ	mean(Y) +1/a · ξ	x+b	Probability prediction to the occurrence period x
1	0.0000	0.0000	2.9105	813.8	831.499
2	0.0000	0.0000	2.9105	813.8	831.499
3	0.3045	0.0784	2.8322	679.5	697.149
4	0.4769	0.1227	2.7878	613.5	631.167
5	0.5951	0.1531	2.7574	572.0	589.670
6	0.6858	0.1765	2.7340	542.1	559.741
7	0.7547	0.1942	2.7163	520.4	538.056
8	0.8134	0.2093	2.7012	502.6	520.268
9	0.8634	0.2222	2.6883	487.9	505.596
10	0.9062	0.2332	2.6773	475.7	493.378

Table 4-1-1-3 Results of provable rainfall (2)

Ranking	YEAR	xi	Fn(%)	$\log_{10}xi$	xi+b	Y= log(xi+b)	Y^2	x^2	x^3	ξ	$period_1$	$period_2$	$ξ_1$	$ξ_2$	Repeat period (year)
1	1967	364.000	96.55	2.56110	346.321	2.53948	6.44895	132,496.000	48,228,544.0	1.4419	48	49	1.4404	1.4464	48.2
2	1975	444.000	93.10	2.64738	426.321	2.62974	6.91552	197,136.000	87,528,384.0	1.0912	16	17	1.0848	1.1065	16.3
3	1992	455.000	89.66	2.65801	437.321	2.64080	6.97383	207,025.000	94,196,375.0	1.0482	14	15	1.0361	1.0614	14.5
4	1973	543.000	86.21	2.73480	525.321	2.72042	7.40071	294,849.000	160,103,007.0	0.7387	6	7	0.6858	0.7547	6.8
5	1971	567.000	82.76	2.75358	549.321	2.73983	7.50665	321,489.000	182,284,263.0	0.6633	5	6	0.5951	0.6858	5.8
6	1972	573.000	79.31	2.75815	555.321	2.74454	7.53252	328,329.000	188,132,517.0	0.6450	5	6	0.5951	0.6858	5.6
7	1964	604.000	75.86	2.78104	586.321	2.76814	7.66257	364,816.000	220,348,864.0	0.5533	4	5	0.4769	0.5951	4.6
8	1962	620.000	72.41	2.79239	602.321	2.77983	7.72744	384,400.000	238,328,000.0	0.5079	4	5	0.4769	0.5951	4.3
9	1974	638.000	68.97	2.80482	620.321	2.79262	7.79871	407,044.000	259,694,072.0	0.4582	3	4	0.3045	0.4769	3.9
10	1993	647.000	65.52	2.81090	629.321	2.79887	7.83369	418,609.000	270,840,023.0	0.4339	3	4	0.3045	0.4769	3.8
11	1970	709.000	62.07	2.85065	691.321	2.83968	8.06378	502,681.000	356,400,829.0	0.2753	2	3	0.0000	0.3045	2.9
12	1991	755.000	58.62	2.87795	737.321	2.86766	8.22346	570,025.000	430,368,875.0	0.1666	2	3	0.0000	0.3045	2.5
13	1976	802.000	55.17	2.90417	784.321	2.89449	8.37810	643,204.000	515,849,608.0	0.0623	2	3	0.0000	0.3045	2.2
14	1969	858.000	51.72	2.93349	840.321	2.92445	8.55238	736,164.000	631,628,712.0	-0.0541	1	2	0.0000	0.0000	1.0
15	1981	860.000	48.28	2.93450	842.321	2.92548	8.55842	739,600.000	636,056,000.0	-0.0581	1	2	0.0000	0.0000	1.0
16	1977	873.000	44.83	2.94101	855.321	2.93213	8.59738	762,129.000	665,338,617.0	-0.0839	1	2	0.0000	0.0000	1.0
17	1984	901.000	41.38	2.95472	883.321	2.94612	8.67962	811,801.000	731,432,701.0	-0.1383	1	2	0.0000	0.0000	1.0
18	1963	982.000	37.93	2.99211	964.321	2.98422	8.90558	964,324.000	946,966,168.0	-0.2864	1	2	0.0000	0.0000	1.0
19	1960	1050.000	34.48	3.02119	1,032.321	3.01381	9.08308	1,102,500.000	1,157,625,000.0	-0.4014	1	2	0.0000	0.0000	1.0
20	1989	1077.000	31.03	3.03222	1,059.321	3.02503	9.15079	1,159,929.000	1,249,243,533.0	-0.4449	1	2	0.0000	0.0000	1.0
21	1988	1114.000	27.59	3.04689	1,096.321	3.03994	9.24122	1,240,996.000	1,382,469,544.0	-0.5029	1	2	0.0000	0.0000	1.0
22	1978	1126.000	24.14	3.05154	1,108.321	3.04467	9.26999	1,267,876.000	1,427,628,376.0	-0.5213	1	2	0.0000	0.0000	1.0
23	1990	1155.000	20.69	3.06258	1,137.321	3.05588	9.33842	1,334,025.000	1,540,798,875.0	-0.5648	1	2	0.0000	0.0000	1.0
24	1961	1251.000	17.24	3.09726	1,233.321	3.09108	9.55475	1,565,001.000	1,957,816,251.0	-0.7016	1	2	0.0000	0.0000	1.0
25	1965	1275.000	13.79	3.10551	1,257.321	3.09945	9.60657	1,625,625.000	2,072,671,875.0	-0.7341	1	2	0.0000	0.0000	1.0
26	1979	1614.000	10.34	3.20790	1,596.321	3.20312	10.25998	2,604,996.000	4,204,463,544.0	-1.1370	1	2	0.0000	0.0000	1.0
27	1968	1691.000	6.90	3.22814	1,673.321	3.22358	10.39146	2,859,481.000	4,835,382,371.0	-1.2165	1	2	0.0000	0.0000	1.0
28	1985	1715.000	3.45	3.23426	1,697.321	3.22976	10.43138	2,941,225.000	5,044,200,875.0	-1.2405	1	2	0.0000	0.0000	1.0

(b) Available Quantity of Ground Water

ⅰ) Estimation of the Utilization Potential of Ground Water for the Gravity Irrigation

There are three (3) valleys where streams, swampy lands and springs were observed in the field survey carried out at the end of dry season. They are the Dried Valley, the Right-bank-downstream Valley and the Confluence-downstream Valley; and the utilization potentials of these valleys are estimated as follows.

Table 4-1-1-4 Estimation of utilization potential of grand water for gravity irrigation

Valley	Obervations	Estimation
Dried Valley (CA=1.7km2)	①The artificial water way with about 1 ℓ/sec of flow rate and two streams were confirmed on the mid way to the valley exit in the field survey on 18th of March. ②It might be possible to expect about 3 ℓ/sec of available ground/stream water. (refer to the trial calculation) ③According to the analysis result of Tank Model, the base flow itself at the dam site with 8.8 km^2 of catchment area becomes less than 1 ℓ/sec from July to September in case of the dry year such as 1970, the base year for irrigation planning.	It would be able to obtain the ground water and the surface water totally about 1ℓ/sec to 5ℓ/sec. The ground water would occupy the main portion, but the total quantity of water would differ much seasonally. It would be appropriate to estimate it to be 3ℓ/sec or so, a bit smaller side value.
Right-bank-down stream Valley (CA=0.5km2)	①Small streams and swampy lands on the mid way of the valley , and springs in the inmost recesses of the valley were confirmed on 18th of March. ②About 2ℓ/sec of the ground/surface water might be expected to be available.（refer to the trial calculation) ③ Ditto	About 0.5ℓ/sec to 2ℓ/sec of the ground/surface water might be available; but the fluctuation of quantity might be large. It would be adequate to estimate it to be 1ℓ/sec.
Confluence-down stream Valley (CA=0.8km2)	①A stream with about 2ℓ/sec of flow rate on the mid way of the valley, and about 0.5ℓ/sec of a spring water in the inmost recesses of the valley were confirmed on 18th of March. ③ Ditto	About 1.0ℓ/sec to 3ℓ/sec of the ground/surface water might be available; but the fluctuation of quantity might be large. It would be adequate to estimate it to be 1ℓ/sec.

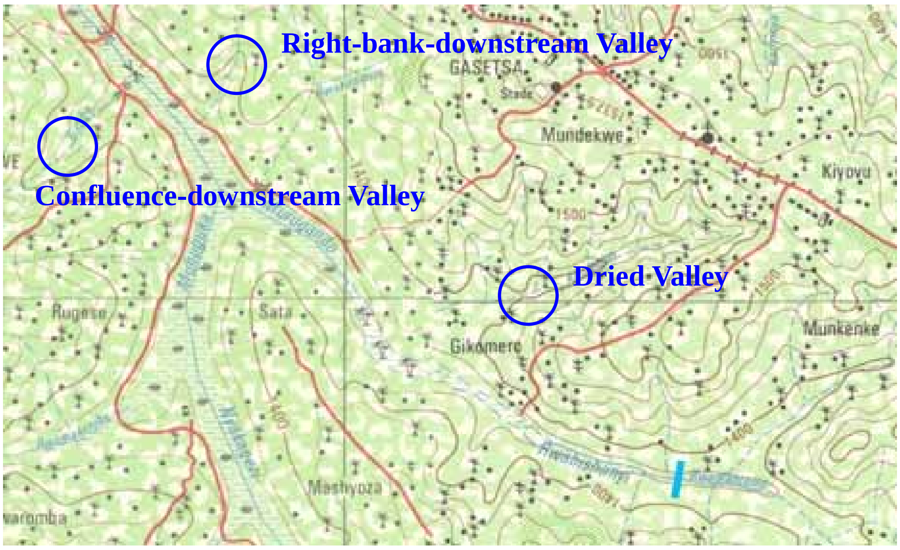


Fig. 4-1-1-6 Location map of candidate site of grand water for gravity irrigation

There is a basic recognition that the seasonal fluctuation in quantity is small when we attempt to utilize the ground water for the irrigation use by gathering it through constructing a simple/cheap structure. If this recognition is far from the reality, i.e. the quantity of ground water differs seasonally as much as the result of the tank model analysis where 20 ℓ/sec of the base flow rate in March and April changes to the one less than 10 ℓ/sec in August and September (refer to the following figure), it would be necessary to construct the structure like dams also to utilize the ground water.

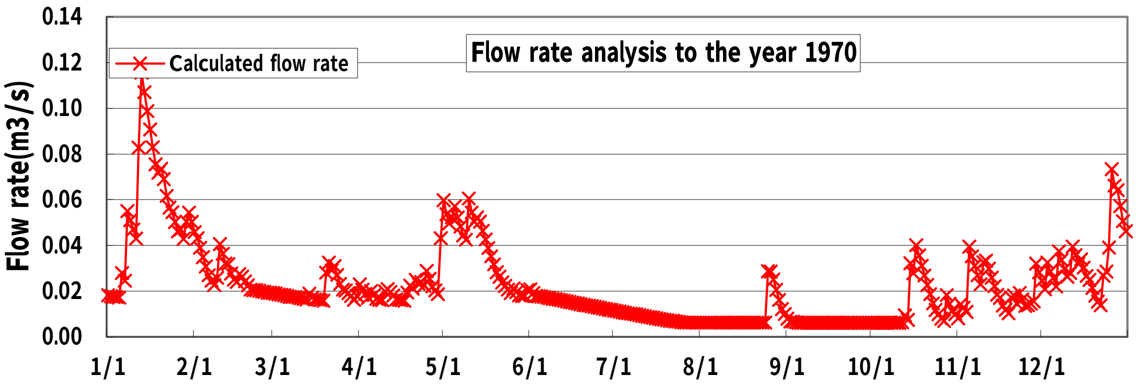


Fig. 4-1-1-7 Results of flow rate analysis

The flow rate observation at the dam site has not yet experienced the dry season of July, August and September, so that the analyzed result by the tank model is the presumption without any confirmation against the reality. In terms of the ground water, it is difficult to estimate the available quantity with a considerable reliability without any kind of continuous observation records. The estimated values shown on the table above are the temporary ones estimated moderately.

Therefore, the ground water is not counted as the water resource at this design stage but treated as the supplemental one though the ground water has the high potential for the water resource of irrigation water and has the high possibility of utilization. The way how to utilize the ground water as the resource of irrigation water would be studied based on the observation in the coming dry season of July to September and the confirmation of the facilities' efficiency of the water-gathering structure through a model/trial construction works.

＊Trial calculation to the Dried Valley

The permeability coefficient of the surface soil layer is estimated to be 6×10−3 cm/sec following the field permeability test result in the dam site; and the thickness of this layer is to be 4 m in the same way.

The quantity of the ground water flowing down in this permeable layer is calculated by the formula: Q=k・i・A.

Then

Q=6×10−3cm/sec×(0.25×400×5000+0.2×400×3000+0.04×400×700+0.1×400×2500+0.1×400×4000=6,067 cm^3/sec 6ℓ/sec

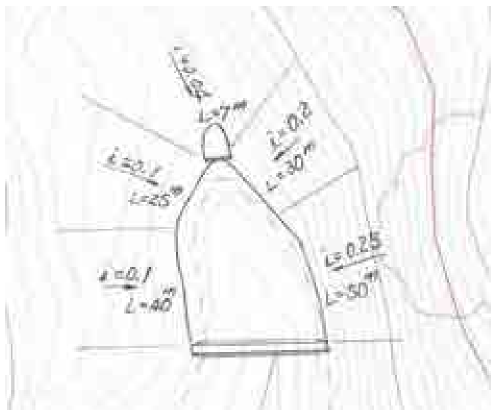


Fig. 4-1-1-8 Plan of the dried valley

When considering the gradient of the ground water surface to be one half of the ground surface's gradient, the expected water quantity would be about 3ℓ/sec.

＊Trial calculation to the Right-bank-downstream Valley

The conditions are estimated as same as above.

Q=6×10－3cm/sec×(0.33×400×7000×　2)

=11,088 cm^3/sec　11ℓ/sec

The recharge of ground water would be small due to the relatively small catchment area so that the gradient of the ground water surface would be considerably smaller than the one of the ground surface and the available quantity would be expected to be 2 ℓ/sec or so.

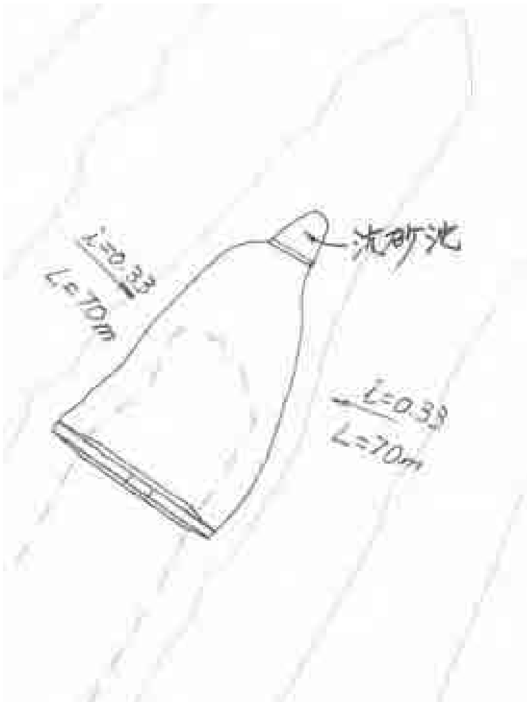


Fig. 4-1-1-9 Plan of the right bank downstream valley

iii) Utilization of Ground Water by Pumping

In the pumping test conducted on the left bank slope upstream to the dam site, the aquifer was caught at the depth of 45 m and the constant pumping of 1.25 ℓ/sec for 48 continuous hours was carried out successfully. The annual water quantity pumped up by the solar pumping system would be estimated as shown below.

1.25ℓ/sec×86,400×8.5/24×302day×0.7　8,000m^3

The estimated quantity is not so much due to the operation time and operation efficiency of the solar pump. Therefore, the utilization of the ground water by pumping is not included in the irrigation plan but is applied to the supply of domestic water as the compensation of the river water being kept away from villagers' use at the dam site in future.

(c) Total Quantity of Available Water

Available quantity of river water：700,000m^3

Ground water and surface water (Supplemental water resource)

：5ℓ/sec×86,400×365／1,000=158,000m^3

Total：700,000m^3　(+supplemental: 158,000m^3)

(2) Studying of Irrigation Water

(a) Assessment of the Irrigation Water for Paddy Fields and the River Flow Rate Decreased by Supplying the Irrigation Water to Dry Fields (Studied by Mr. Akihisa Nakano, MINAGRI Irrigation Advisor, JICA Expert)

ⅰ) Assessment of the Savable Water in the Irrigation Unit

1) Quantity of the Supplied Water and the Return Water

The unit irrigation model is set up in the downstream paddy fields, that would make it possible to assess the quantity of irrigation water needed to each irrigation unit, and would be called "ridge-through irrigation model".

For the sake of assessment, the unit irrigation model is defined to be 24 are of paddy fields, that corresponds to the real/average farming size of one household in this Ngoma-22 valley and the actual irrigation area from which the ridge area is excluded, composed of 6 lots with 400 m^2 (=20m×20m) each.

These 6 lots extend on one side of river bed in two rows toward the hill and in three rows toward the downstream; the irrigation water is supplied to three lots, Lot- A, Lot-B and Lot-C, through the earthen canal and other three lots, Lot-D, Lot-E and Lot-F, receive the irrigation water from former three lots as the ridge-through irrigation water or leakage water.

（Unit irrigation model）

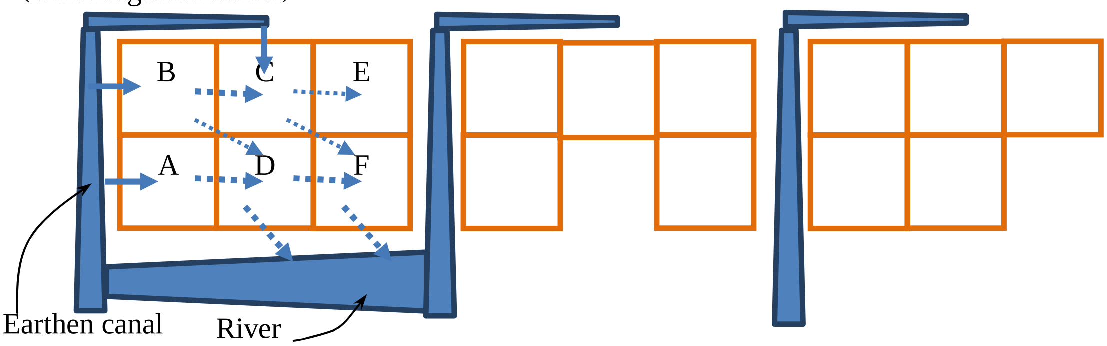


Fig. 4-1-1-10 Ridge-through irrigation model

Here, it is assumed that Lot-A, Lot-B and Lot-C supply the irrigation water to the adjacent lot each as the ridge-through water and the leakage water, that the water supply of 115 mm/day to Lot-A, Lot-B and Lot-C each would satisfy the irrigation need of these in case of the water requirement rate of paddy fields being 110 mm/day (vertical percolation: 20 mm/day, leakage through the ridge: 90 mm/day) and ETc being 5 mm/day, estimated at maximum, and that the irrigation need in Lot-D, Lot-E and Lot-F would be satisfied in case of 115 mm/day of water, which would be additional for Lot-A, Lot-B and Lot-C, being supplied from the former each lot to the latter each lot.

Note-1; The phrase "water requirement rate" does not include ET (Evapo-transpiration) in this paper for the convenience sake of expression.

Note-2; The vertical percolation is estimated to be 20 mm/day based on the field tests' result shown on the table below, considering the fluctuation and focusing on the maximum value.
The leakage quantity through ridges is estimated to be 90 mm/day based on the tests' result, considering the large fluctuation and focusing on the average value. In addition, the cause of large quantity of leakage through ridges would be the structural contents of the ridges that are composed of grasses and soils.

Table 4-1-1-5 Results of percolation survey

Test Location	Vertical Percolation mm/day	mm/day
A (Upstream)	7.9	-
B (Upstream)	18.3	51.5
C (Midstream)	**20.1**	122.0
D (Downstream)	**20.0**	83.3
E (Upstream)	-	58.0
F (Midstream)	7.2	196.0
G (Downstream)	8.0	31.0
Average	13.6	**93.7**

Note-3; When examining the ETc of the paddy rice from the view point of causes, followings are pointed out.

- Both evaporation and transpiration is affected by the wind; Rwanda is located in the equatorial calm zone so that the degree of ETc becomes low.
- Both evaporation and transpiration is affected by the temperature; the elevation of the site is about 1,400 m and the temperature condition for cultivating paddy rice is lower by about 5 ℃ at maximum than the one (about 28℃) in Japan so that the degree of ETc becomes low.
- Transpiration is affected by the growth stage of plant; transpiration becomes maximum in the rainy season during which evaporation is minimum in Rwanda, such circumstances are opposite to Japan where the short rainy season (dry season) with the high potential of evaporation and the maximum growth stage of paddy rice occur simultaneously, so that ETc of paddy rice in Rwanda would be lower the one in Japan.
- Based on the factors above, the peak ETc of paddy rice in Rwanda would be adequate to be 5 mm/day, which is lower than the one in Japan ranging from 6 mm/day to 8 mm/day.
  * According to the calculation result of ETc of paddy rice by CROPWAT8 applying the rainfalls in the base year 1970, ETc values do not fluctuate so much and the maximum is 4.8 mm/day in the second decade of September.

Based on the conditions shown above, quantity of water needed for the unit irrigation model is estimated as follows.

	Lot-A, Lot-B, Lot-C	Lot-D, Lot-E, Lot-F
Vertical percolation	20 mm (return to the river, almost completely)	20 mm (return to the river, almost completely)
ETc	5 mm	5 mm
Leakage through ridges	90 mm to the adjacent lot, 115 mm totally	90 mm (return to the river)
Ridge-through irrigation	115-90=25 mm	Total 115 mm
	Total irrigation supply; 140 mm/day	Total return flow rate; 130 mm/day

Therefore, water quantity needed to the irrigation of one lot is estimated as follows.

140 ㎜／day×400m^2＝56.0m^3／lot／day

Water quantity required for the one unit of irrigation model becomes as follows.

56.0×3＝**168.0m^3**

Water quantity taken from the river and supplied to the unit irrigation model, which corresponds to the average paddy field area of one household, is **168.0m^3／day**……………….①

Here, the ratio of return flow rate is treated to be 100 % as the result of assuming that the 90 mm of leakage through ridges of lot-D, Lot-E and Lot-F and 20 mm of the vertical percolation from each 6 lots return completely to the river. The fact that the river flow rate increases along with the river flowing down is understood to be brought from the water supply from the left side and the right side hills and the return flow rate of 100 % or so. (described latter again)

2）Saved Water Quantity by Improving the Paddy Field Condition

Here, let us suppose the condition that 90 mm/day of leakage through ridges is reduced to 10 mm/day, which corresponds to 50 % of the vertical percolation of the paddy field, through reconstruction of the ridges only made of clay and the ridge-painting work by mud.

In this case, the required quantity of water for Lot-A, Lot-B and Lot-C is estimated to be 35 mm/day and also the same for Lot-D, Lot-E and Lot-F based on the condition of the vertical percolation being 20 mm/day, leakage through ridges being 10 mm/day and ETc being 5 mm/day.

	Lot-A, Lot-B, Lot-C		Lot-D, Lot-E, Lot-F
Vertical percolation	20 mm (return to the river, almost completely)		20 mm (return to the river, almost completely)
ETc	5 mm		5 mm
Leakage through ridges	10 mm	to the adjacent lot, 35 mm totally	10 mm (return to the river)
Ridge-through irrigation	25 mm		Total 35 mm
	Total irrigation supply; 60 mm/day		Total return flow rate; 50 mm/day

Therefore, water quantity needed to the irrigation of one lot is estimated as follows.

$60\ \text{mm}/\text{day} \times 400\text{m}^2 = 24.0\text{m}^3/\text{lot}/\text{day}$

Water quantity required for the one unit of irrigation model becomes as follows.

$24.0 \times 3 = \mathbf{72.0m^3}$

Water quantity taken from the river and supplied to the unit irrigation model, which corresponds to the average paddy field area of one household, is **72.0m^3／day**.................②

Now, it becomes clear that the degree of water saving by improving the paddy field condition is estimated to be **57.1 %** (②72.0／①168.0＝42.9%), reaching more than 50 %.

3) Setting Up of the Paddy Field Distribution Model

Here, the calculation model of the paddy field area shall be set up in relation to the flowing-down distance of the river.

According to the topographical survey, in the Ngoma-22 valley the total area of the paddy fields is 35 ha and the river length from the dam site to the exit of the valley is 3.8 km.

The paddy field width (B) at the exit of the valley is calculated by the following equation based on the assumption that the river is assumed to be leaner as the actual river does not wind, the paddy fields are distributed in trapezoid, and the paddy field width at the upper end is 20 m.

$(20+B) * 3{,}800 / 2 = 35*100*100 \quad (\text{m}^2)$

The answer of this equation is B=164 m.

* The actual width of the paddy field at the exit of the valley is about 150 to 175 m in the topographical map so that the trapezoidal model of paddy field distribution with 20 m of upper hem, 164 m of lower hem and 3800 m of height is adequate for assessing roughly the relationship between the river flow rate and the irrigation water requirement of the paddy fields.

Accordingly, the net quantity of saved water to the 35 ha in the Ngoma-22 valley totally is calculated as follows.

$(168.0-72.0) / 0.24 \times 35 = 14{,}000\text{m}^3/\text{day}$ …cumulative saved water in 35ha

* Here the ratio of areal reduction caused by the river, canals and ridges is not counted.

However, the actual quantity of saved water is not 14,000 m^3 because the required irrigation water for 35 ha is not supplied all at once but the water supply from the river to the paddy fields and the return flow from the paddy fields to the river occur sequentially toward the downstream through conducting the ridge-through irrigation.

It would be said from the view point of sequence of the water supply and the return flow that the return flow quantity decreases at the same time of the decrease of water supply, which is obtained by improving the paddy field conditions, that quantity of saved water is same as the reduced quantity of return flow brought from the decrease of water supply, i.e. saved water supply to Lot-A, Lot-B and Lot-C, 80 mm/day (=**140 mm／day－60 mm／day**), equals to the decreased quantity of return flow from Lot-D, Lot-E and Lot-F, 80 mm/day (=**130 mm/day－50 mm/day**), and that an attempt of reducing the leakage quantity through ridges does not bring the increase of available water or additional water under the circular relations of the irrigation water and the river water. The consumed quantity of irrigation water is ETc only; the available quantity of irrigation water is not affected by the leakage.

4) Estimation of the Base Flow Rate during the Irrigation Season

0.070 m^3/sec of the river flow rate was observed at the exit of the Ngoma-22 valley at 10 AM on 25th of March, 2012. The time of this observation corresponds to the beginning of rainy season so that the base flow rate might be increased; but this possibility is considered to be very low as the precipitation during the previous 7 days is only 1.2 mm according to the rain gauge station installed in the Ngoma-22 catchment area.

The river flow rate at 10 AM on 25th of March, 2012 observed at the flow rate recording station is 0.0176 m^3/sec corresponding to 42 mm of over-flow depth; this flow rate is small and equal to the base flow rate in the end of February, i.e. the dry season, so that 0.070 m^3/sec is considered to be the flow rate level in the dry season.

Based on those described above, 0.0176 m^3/sec shall be used in this study as the base flow rate at the dam site during the irrigation season and 0.070 m^3/sec as the one at the exit of the valley.

Then the daily river flow rate of each becomes as follows.

At the dam site：$0.0176m^3/sec \times 3600 \times 24 = \mathbf{1{,}521m^3/day}$

At the exit of the valley：$0.070m^3/sec \times 3600 \times 24 = \mathbf{6{,}048m^3/day}$

ⅱ) Assessment of the Irrigation Water for Paddy Fields and the River Flow Rate Decreased to the Quantity Level of 1/3 by Supplying the Irrigation Water to Dry Fields

Here, the affection the paddy field irrigation would receive when 2/3 of the base flow rate is lost at the dam site through supplying irrigation water to the dry fields shall be examined, where water saving by improving the paddy field conditions shall be considered.

The actual examination is to check if the flow rate of Ngoma-22 river, that increases by the ground water coming from the hill side together with its flowing down, can satisfy the water requirement of the downstream paddy fields expanding from the dam site to the exit of the valley in case of the river flow rate at the dam site decreasing from 17.6 ℓ/sec to 5.9 ℓ/sec (=17.6／3, 185,000 m^3/year). The decrease from 17.6 ℓ/sec to 5.9 ℓ/sec means that about 510,000 m^3/year is used for the dry fields' irrigation from 700,000 m^3/year of the available annual river flow rate at the dam site.

1) Approximate Model of the River Flow Rate

The river flow rate is assumed to increase two-dimensionally to its flow-down distance as the cause of increase is the runoff of rainfall and the runoff quantity is under the influence of area.

When attempting to show the river flow rate (y) by a model equation, the equation would be the quadratic expression between y and the flow-down distance (x), and 1,521 m^3/day of the river flow rate at the dam site and 6,048 m^3/day at the exit of the valley would become the conditions to solve the equation. In addition, 0 m^3/day of the river flow rate at the divide also becomes the condition to solve. Provided that the dam site is origin, these conditions are expressed as follows.

At x＝-2000,	0 m^3／day	(-2000, 0)	… a
At x＝0,	1,521 m^3／day	(0, 1521)	… b
At x＝3800,	6,048 m^3／day	3800, 6048)	… c

Here, for the convenience sake of study, the model equation is examined on the x-y coordination system shifted by -2000 in terms of x axis; and the equation is expressed as follows.

y'＝A*x'^2 + B*x'

This equation is solved on the assumption that the excursion of the equation passes three points of a' (0, 0), b' (2000, 1521), c' (5800, 6048).

The answer is A=0.000074278, B=0.61194.

Then the model equation;

$y' = 0.00007428*x'^2 + 0.6119*x'$

Then the model equation shifted back to the original x-y coordination system;

$y = 0.00007428*\{(x+2000)^2\} + 0.6119*(x+2000)$

Then final model equation of the river flow rate;

$\boxed{\mathbf{y = 0.00007428*x^2 + 0.9090*x + 1521}}$ **…equation①**

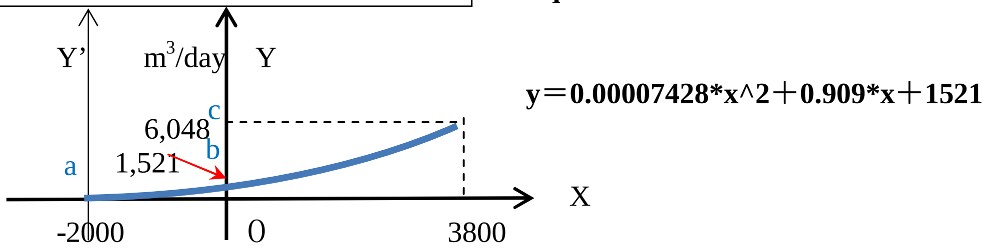


Fig .4-1-1-11 Approximate model of river flow

（Checking）

At x＝-2000m, $y = 0.00007428*(-2000^2) + 0.909*(-2000) + 1521 =$ 0.12 m^3／day

At x＝ 0m, $y = 0.00007428*(0^2) + 0.909*(0) + 1521$ ＝ 1,521 m^3／day

At x＝ 3800m, $y = 0.00007428*(3800^2) + 0.909*(3800) + 1521$ ＝ 6,047.8032 m^3／day

2) Approximate Model of the Net Consumed Water by ETc

The real consumed water in 35 ha of the paddy fields is estimated as follows. The real consumed water corresponds to ETc (evapo-transpiration of paddy rice) only due to the circular relationship between irrigation water and the river water.

Consumed water per one unit of irrigation model;

5 ㎜×400 m^2×6 lots＝12.0 m^3／0.24 ha

Next, the real irrigated area is estimated as follows by setting aside the river, canals and ridges from 35 ha of the total paddy fields.

The area of the river (Ar) is estimated as follows based on the assumption of about 1.7 m wide at the dam site and about 3 m wide at the exit of the valley.

Ar＝1/2×(1.7＋3)×3800＝8,930 m^2

The ratio of the actual planted area to the paddy field area is estimated as follows based on the assumption of the average width of ridges including the inner water ways being 50 cm and the size of one lot of paddy field being 20 m×20 m.

（20－0.5/2 - 0.5/2）^2 ／ 20^2 ＝ 0.950625 95%

Then the total area of the water surface in the paddy fields;

（350000 - 8930）* 95% ＝ 324016 32.4ha （ratio of areal reduction：32.4／35＝92.6%）

Then the total quantity of consumed water in the Ngoma-22 valley;

12.0 m^3／0.24 ha×32.4 ha ＝ **1,620 m^3 ／day …Net consumed water in 35 ha**

Next, let us try to devise a model equation of cumulative quantity of water consumed in the paddy fields from the dam site (x=0 m) to the exit of the valley (x=3800 m) as the preparation for estimating the decrease of the river flow rate by the consumed water in the paddy fields.

The paddy field distribution model has already been set up as the trapezoid one with 20 m of upper hem (at the dam site), 164 m of lower hem (at the exit of the valley), 3800 m of height and 35 ha of the total paddy field area. Following this model, the paddy field width (b) at the distance x from the dam site is expressed as follows by a linear equation passing the point (x=0, y=20) with (164-20)/3800 of inclination.

$b = (164-20) / 3800 *x + 20 = 0.037895*x + 20$

Then the area (A) of the paddy fields expanding from the dam site, the origin (x=0), to the location at x m from the dam site is expressed as follows.

A = (20+0.037895*x+20) *x / 2

= 0.01895*(x^2) + 20*x

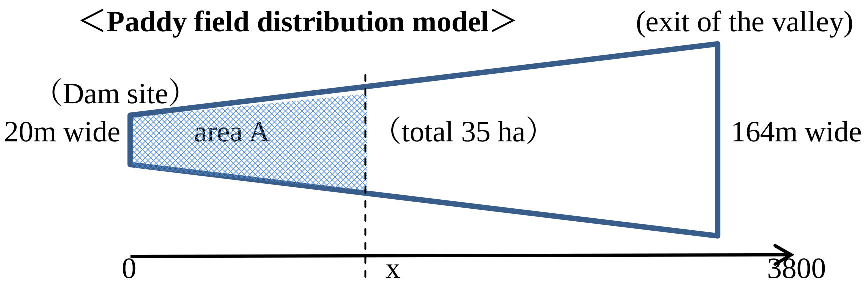


Fig. 4-1-1-12 Paddy field distribution model

(Checking)

At x=3800m, B= 0.01895*(3800^2) + 20*3800 = 349,638 35ha

Then the quantity of consumed water per 1 m^2 is derived as follows from the one per one irrigation unit.

v= 12.0m^3 / 2400 m^2 =0.005 m^3/m^2

When considering the ratio of areal reduction, 32.40ha／35.0ha＝$\boxed{\textbf{92.57\%}}$;

v'=0.005*92.57% = 0.004630 m^3/m^2

Now, the cumulative quantity (Vp) of consumed water of the paddy fields from the dam site to the location at x m is expressed as follows.

Vp = v' * A = 0.00008773*(x^2) + 0.09260*x

(Checking)

At x= 3800 (m), Vp = 0.00008773*(3800^2) +0.09260*3800 =1,618.7012 1,620 m^3 / 35 ha

$\boxed{y = 0.00008773*x^2+0.0926*x}$ **…equation②; cumulative quantity of ETc of paddy rice**

3) Water Supply Quantity to Paddy Fields every 100 m of the River Flowing Down

The real quantity of consumed water is the one by ETc only; but the water quantity actually supplied to the paddy fields must include the quantity of the vertical percolation, ridge-through irrigation water to the adjacent paddy field, and the leakage through ridges.

Here, let us examine the relation between the remaining river flow rate and the water supply quantity to paddy fields.

The water supply quantity per one unit of irrigation model has already been estimated to be 72.0 m^3 ／0.24 ha.

At first, let us estimate the area of the paddy fields and the water supply quantity to this area at the interval of 100 m as the preparation for the further study.

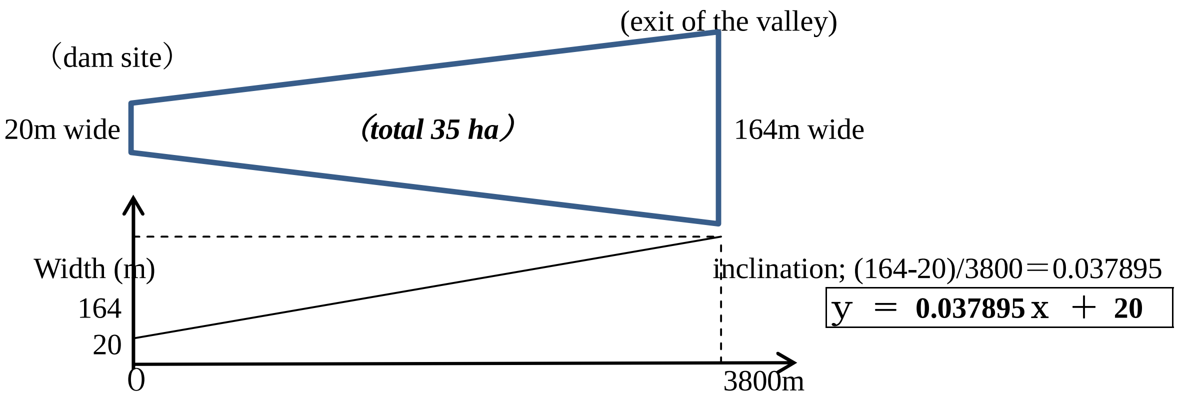


Fig. 4-1-1-13 Relation between length of river and area of paddy field

Then, the area of the paddy fields between the location at (x m) from the dam site and the location at (x+100 m) from the dam site is given by the following equation.

$$A = \{(0.037895(x)+20)+(0.037895(x+100)+20)\}\times 100/2$$
$$= (0.07579x+43.7895)\times 50$$
$$= 3.7895x+2189.5 \quad (\text{unit: } m^2\text{、condition}: 0<X<3800,\ 100m \text{ interval})$$

The water supply quantity to one unit of irrigation model becomes as follows when considering the ratio of areal reduction 92.6 %.

$$vt = 72.0\ m^3/2400\ m^2 * 92.6\% = 0.02778\ m^3/m^2$$

Then the water supply quantity per arbitrary 100 m becomes as follows.

$$y = vt * A = 0.10527x+60.824$$

$$\boxed{y = 0.1053x + 60.82} \quad (\text{unit: } m^3/\text{day、condition}: 0<X<3800,\ 100m \text{ interval})$$

…**equation③ water supply quantity every 100m**

Next, let us set up the actual interval of irrigation water supply to the paddy fields considering the existing site conditions surveyed on 22nd of May, 2012.

[Site Conditions]

- The intake mouths are seen at the interval of less than 100 m in the upstream and midstream area ranging from 0 m to 3000 m in the distance from the dam site.
- At about 2800 m from the dam site, the river delivers a left branch and turns/winds to the right.
- At about 3000 m from the dam site, the main river comes back to the valley center leaving the left and the right branches that were constructed by the Chinese aid. Regarding the main river, at its starting point there is an incomplete dam with leakage made of wooden poles and bundles of straw; and the river bed plunges down behind the dam and keeps its level in the downstream that brings the differential of about 2 m in maximum between the river bed and the paddy fields' elevation. Such circumstances force the farmers to make 4 temporary weirs to dam up the river water and lead it to the paddy fields; and it means the interval of the irrigation water supply is about 200 m from about 3000 m from the dam site to the exit of the valley.

Considering the conditions above, following two cases shall be set up for this simulation analysis.

(Case-1 ; Plan)

Interval of irrigation water supply ; 200m all through the river

(Case-2 ; Existing conditions)

Interval of irrigation water supply ; 100m from 0m to 3000m along the river

: 200m from 3000m to 3800m along the river

Then, let us examine if it is possible or not for the river flow rate to supply the irrigation water to paddy fields at each intake mouth by using the equation-1 (the river flow rate), the equation-2 (cumulative quantity of ETc of paddy rice) and the equation-3 (water supply quantity every 100m) in case of 2/3 of the river flow rate at the dam site being put aside as the irrigation water for dry fields.

Note; In the other course of study, the calculated maximum ETc in the base year 1970 was changed from 5 mm/day to 6 mm/day due to the unusual high temperature in July to September. Considering this change, the calculated value by equation-② that was devised based on ETc=5 mm shall be multiplied by 6/5 and the calculated value by equation-③ shall be multiplied by 74.4/72 due to the water quantity required for the one unit of irrigation model being changed from 72 mm/day to 74.4 mm/day.

4) Result and Examination

[Case-1; Plan]

The calculated result is shown as Table 3-3-1-1(1)

- The calculation starts from the river flow rate 506 m^3/day at the dam site, that is residual after supplying irrigation water to dry fields, and ends up at the exit of the valley with the residual flow rate 3,091 m^3/day.
- On its way, the residual flow rate exceeds largely the quantity of irrigation water supply at each intake mouth, among which the maximum is 920 m^3day. Even near the exit of the valley where the demand becomes maximum, the residual flow rate 2,977 m^3/day is more than three times of the demand 920 m^3/day (2,977/920>3) so that it seems that the shortage of irrigation water would not appear in case of the river flow rate at the dam site being reduced to 1/3 by supplying the irrigation water to dry fields.
- In terms of the influence of the utilization of ground water (5ℓ/sec×86400＝432m^3/day), the irrigation conditions of paddy fields would be scarcely affected by this utilization because the location of this utilization structure is not so close to the river and the decreased quantity of inflow caused by this utilization would be only a part of the pumped water 432m^3/day considering 7 % of the average annual runoff ratio (including the base flow) of the Ngoma-22 valley river.
- This simulation analysis examines the capability of supplying irrigation water to the paddy fields under the conditions of the river flow rate being the base flow level in the irrigation season (=dry season), the river flow rate being reduced to 1/3 due to supplying irrigation water to dry fields at the dam site, the river flow rate being not increased by the inflow of rainfall or from the reservoir, and the consumed water quantity by ETc being always 6 mm/day, maximum in the base year.
- Actually, the river flow rate would be more than the one estimated in this analysis as a longer period of the irrigation season overlaps with the rainy season and the base flow rate increases.
- 6 mm/day of ETc used in this study is the maximum value calculated under the climate conditions of the base year 1970; but this value seems to be affected by the unusual high temperature in July to September so that the actual consumed water quantity by ETc would be smaller than in the analysis.
- The calculation conditions are strict and in safety side one of which is to consider the 10 mm/day of leakage through ridges even after conducting the improvement works to ridges.
- Moreover, the reservoir is constructed at the upstream of paddy fields, so that the paddy fields would receive not only the surface and ground water from the residual catchment area but also the seepage water from the reservoir.
- **As far as the improvement works are conducted to the ridges' permeability, it is possible to supply the irrigation water needed to the whole paddy fields in the Ngoma-22 valley. Therefore, it is said that this river has an enough potential to provide the dry fields with 1,015 m^3/day of irrigation water that is put aside at the dam site.**

【Addition】

1. This simulation analysis is based on the assumption that the paddy field conditions are improved in the way of restraint of leakage through ridges, lining to the earthen canal and installing of intake structures that enable the stable supply of irrigation water.

Without these improvements, the water supply quantity might become about 3.9 times larger totally as the supply quantity shall increase by 2.3 times (=168/72) in terms of leakage through ridges and by 1.67 times (conveyance efficiency : 0.6, 1/0.6=1.67) in terms of earthen canals. Therefore, the improvement of paddy field conditions is the prerequisite of the scheme planning.

2. The simulation analysis is carried out under the condition that the river flow rate is reduced to 1/3 at the dam site by supplying the irrigation water to dry fields; but it is possible for the paddy fields to be almost fully supplied with irrigation water by the inflow from the residual catchment area along the downstream river according to the result of calculation.

To be concrete, the minimum discharge in calculation is 63 m^3/day of the water supply quantity to the first block from the dam site and the available water quantity is about 95 % (=1,521-63) of the initial quantity 1,521 m^3/day according to the relationship between the gradient of residual river flow rate and the water supply quantity at each intake mouth shown in Illustration-2.

But the aim of this simulation analysis is not to study the minimum discharge. The aim is to clarify the circumstances of water supply between the paddy field irrigation and the dry field irrigation, and to confirm the sufficiency of the river flow rate for supplying the irrigation water to the paddy fields so that the analysis is carried out on the assumption of 2/3 of the river flow rate being put aside for the dry field irrigation at the dam site.

3. In this simulation, the unit water requirement is assessed to the unit irrigation model with 6 lots of paddy fields where the irrigation water is supplied to the first 3 lots and the latter 3 lots receive the irrigation water by ridge-through irrigation from the former 3 lots based on the assumption that the actual conditions around ridge-through irrigation match with the farming management conditions of one household. Here, the number of ridge-through irrigation is assumed to be one time, which corresponds to one water supply behavior at one intake mouth.

Now if the number of ridge-through irrigation increases, accordingly the amount of water supply at one intake mouth must be increased. Such situation would probably happen especially in the downstream area where rows of paddy fields extend crosswise.

Then let us image the ridge-through model with 2 times of passing that is composed of 9 lots of paddy fields and calculate the amount of supplied irrigation water. The model is shown below and the water quantity becomes 85 mm/day that is about 1.4 times larger than 60 mm/day required for the unit irrigation model with one time of ridge-through water supply.

[Ridge-through Model with 2 times of passing composed of 9 lots]

	Lot-A, Lot-B, Lot-C	Lot-D, Lot-E, Lot-F	Lot-G, Lot-H, Lot-I
Vertical percolation	20 mm (return to the river, almost completely)	20 mm (return to the river, almost completely)	20 mm (return to the river, almost completely)
ETc	5 mm	5 mm	5 mm
Leakage through ridges	10 mm to the adjacent lot, 60 mm totally	10 mm to the adjacent lot, 35 mm totally	10 mm (return to the river)
Ridge-through irrigation	50 mm	25 mm	35 mm/day
	Total irrigation supply; 85 mm/day 85/60=1.41	Total 60 mm/day	Total quantity of return flow; 70 mm/day

But thinking of the actual quantity of irrigation water supply per area, the water requirement reduces by about 5 % as shown below due to the targeted irrigation area increasing from 6 lots to 9 lots and by 50 %; the increase of ridge-through irrigation from one time to two times save about 5 % of irrigation supply quantity.

(85 mm/9 lots)／(60 mm/6 lots)=0.944

According to the simulation result, the residual river flow rate 2,057 m^3/day is more than 2.2 times compared to the water requirement 920 m^3/day at the intake mouth 3,600 m from the dam site where the allowance of residual river flow rate to the water requirement is smallest. Circumstances of the number of ridge-through irrigation tending to increase in the downstream area would make this allowance larger.

In the facility designing, it would be necessary to consider that to increase the number of ridge-through irrigation is effective to save quantity of irrigation water supply, and to shorten the interval of supplying water, i.e. the intake mouth or the intake weir, is effective to decrease the water quantity per one water supply behavior.

[Case-2; Existing Conditions]

The aim of the simulation analysis to this case is, though data are not enough, to duplicate the existing conditions under which the irrigation water supply is tight during the irrigation period with the base flow rate in the dry season. The results are as follows.

（Analysis conditions）

- The river flow rate is not reduced at the dam site for supplying irrigation water to dry fields.
- ETc value of paddy rice is 5 mm/day considering the duplication of existing circumstances.
- The water supply quantity to one unit of irrigation model is modified considering the situation of paddy field improving works being not done from 72 mm/day, after improving works, to 168 mm/day, before improving works, and also considering the situation of the water ways being earthen canals with 50 % of the conveyance loss, so that the calculated results by the equation-③ shall be multiplied by 168/72/0.5.
- The interval of irrigation water supply to the paddy fields is as follows based on the field survey carried out on 22nd of May, 2012.
  Interval of irrigation water supply: 100m from 0m to 3000m along the river
  : 200m from 3000m to 3800m along the river

（Analysis results）

At the most downstream unit of irrigation water supply 3,600 m from the dam site, the amount of required water (3,462m^3/day) is more than 80 % of the river flow rate (4,286m^3/day).

Therefore, the simulation succeeded to duplicate generally the existing conditions that in the upstream and midstream area, supplying irrigation water is easily done, but in the downstream it is tight, and in total it tends to be in shortage.

Table 4-1-1-6 Results of simulation analysis of river flow and irrigation water supply(1)

Simulation analysis to the Ngoma-22 river flow rate and the paddy field irrigation model
(the river flow rate = base flow rate in dry season, ETc=6mm/day)

(calculation table9

Distance	River flow rate	Precedent supply to dry fields	River flow rate after precedent	Cumulative ETc in Paddy	Residual river flow rate	(Re) Intake Quantity per 100m	Interval (m)	Intake Q. per Block
	Equation①	④ 1,521*66.7%	⑤=①−④	Equation②	①−②	Eq.③/72*168/0.6	-	③×Interval
0	**1,521**	1,015	506	0	506	63	200	137
100	1,613	1,015	598	12	586	74		0
200	1,706	1,015	691	26	665	85	200	180
300	1,800	1,015	786	43	743	95		0
400	1,896	1,015	882	61	821	106	200	224
500	1,994	1,015	980	82	898	117		0
600	2,093	1,015	1,079	105	974	128	200	267
700	2,194	1,015	1,179	129	1,050	139		0
800	2,296	1,015	1,281	156	1,125	150	200	311
900	2,399	1,015	1,385	185	1,199	161		0
1000	2,504	1,015	1,490	216	1,273	172	200	354
1100	2,611	1,015	1,596	250	1,347	183		0
1200	2,719	1,015	1,704	285	1,419	193	200	398
1300	2,828	1,015	1,814	322	1,491	204		0
1400	2,939	1,015	1,925	362	1,563	215	200	441
1500	3,052	1,015	2,037	404	1,634	226		0
1600	3,166	1,015	2,151	447	1,704	237	200	485
1700	3,281	1,015	2,266	493	1,773	248		0
1800	3,398	1,015	2,383	541	1,842	259	200	528
1900	3,516	1,015	2,502	591	1,911	270		0
2000	3,636	1,015	2,622	643	1,978	280	200	572
2100	3,757	1,015	2,743	698	2,045	291		0
2200	3,880	1,015	2,866	754	2,112	302	200	615
2300	4,005	1,015	2,990	812	2,178	313		0
2400	4,130	1,015	3,116	873	2,243	324	200	659
2500	4,258	1,015	3,243	936	2,307	335		0
2600	4,387	1,015	3,372	1,001	2,371	346	200	702
2700	4,517	1,015	3,502	1,067	2,435	357		0
2800	4,649	1,015	3,634	1,136	2,498	368	200	746
2900	4,782	1,015	3,767	1,208	2,560	378		0
3000	4,917	1,015	3,902	1,281	2,621	389	200	789
3100	5,053	1,015	4,038	1,356	2,682	400		0
3200	5,190	1,015	4,176	1,434	2,742	411	200	833
3300	5,330	1,015	4,315	1,513	2,802	422		0
3400	5,470	1,015	4,456	1,595	2,861	433	200	876
3500	5,612	1,015	4,598	1,679	2,919	444		0
3600	5,756	1,015	4,742	1,764	2,977	455	200	920
3700	5,901	1,015	4,887	1,852	3,034	465		0
3800	**6,048**	1,015	5,033	1,942	***3,091***	-		

(Note) 1. The allongment of the river is estimated to be 3.8km from the dam site to the exit of the valley.
2. The analysis stands on the safe side based on the assumption of no rain, no dam, river flow rate in dry season.
3. Water supply to the paddy fields is estimated to the unit irrigation model with 6 blocks after the paddy field leakage condition being improved..
4. ETc=6mm/day is adopted considering the examination results by CROPWAT8.
5. Considering the low runoff ratio in this site, the river flow rate would be scarcely affected by the ground water develoment(10 ℓ/sec=864m3/day).

Graph-1 River flow rate after precedent intake for dey fields
and the Paddy fields water consumption

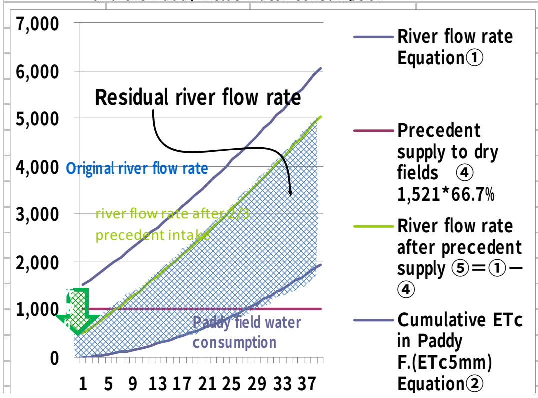


Fig. 4-1-1-14 Relationship among water quantity (1)

Graph-2 Residual river flow rate and the water supply to each irrigation bloc

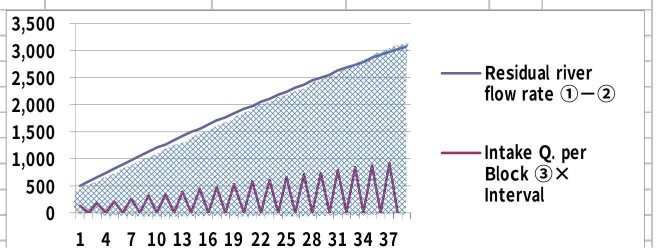


Fig. 4-1-1-15 Water supply and residual river flow rate (1)

Table 4-1-1-6 Results of simulation analysis of river flow and irrigation water supply (2)

Simulation analysis to the Ngoma-22 river flow rate and the paddy field irrigation model
(River flow rate=base flow rate in dry season, No precedent intake for dry fields,
No rehabilitation/improvement work to the existing paddy field, Analysis to existing conditions)

(calculation table9

Distance	River flow rate	Precedent supply to dry fields	River flow rate after precedent supply	Cumulative ETc in Paddy F.(ETc5mm)	Residual river flow rate	(Re) Intake Quantity per 100m	Interval (m)	Intake Q. per Block
	Equation①	④ 1,521*66.7%	⑤=①−④	Equation②	①−②	Eq.③/72*168/0.6	-	③×Interval
0	1,521			0	1,521	237	100	237
100	1,613			10	1,603	277	100	277
200	1,706			22	1,684	318	100	318
300	1,800			36	1,765	359	100	359
400	1,896			51	1,845	400	100	400
500	1,994			68	1,926	441	100	441
600	2,093			87	2,006	482	100	482
700	2,194			108	2,086	523	100	523
800	2,296			130	2,166	564	100	564
900	2,399			154	2,245	605	100	605
1000	2,504			180	2,324	646	100	646
1100	2,611			208	2,403	687	100	687
1200	2,719			237	2,481	728	100	728
1300	2,828			269	2,560	769	100	769
1400	2,939			302	2,638	810	100	810
1500	3,052			336	2,715	851	100	851
1600	3,166			373	2,793	892	100	892
1700	3,281			411	2,870	933	100	933
1800	3,398			451	2,947	974	100	974
1900	3,516			493	3,024	1,015	100	1,015
2000	3,636			536	3,100	1,056	100	1,056
2100	3,757			581	3,176	1,096	100	1,096
2200	3,880			628	3,252	1,137	100	1,137
2300	4,005			677	3,328	1,178	100	1,178
2400	4,130			728	3,403	1,219	100	1,219
2500	4,258			780	3,478	1,260	100	1,260
2600	4,387			834	3,553	1,301	100	1,301
2700	4,517			890	3,627	1,342	100	1,342
2800	4,649			947	3,701	1,383	100	1,383
2900	4,782			1,006	3,775	1,424	100	1,424
3000	4,917			1,067	3,849	1,465	200	2,971
3100	5,053			1,130	3,923	1,506		0
3200	5,190			1,195	3,996	1,547	200	3,135
3300	5,330			1,261	4,069	1,588		0
3400	5,470			1,329	4,141	1,629	200	3,299
3500	5,612			1,399	4,214	1,670		0
3600	5,756			1,470	4,286	1,711	200	3,462
3700	5,901			1,544	4,358	1,752		0
3800	6,048			1,619	4,429	-		

(Note) 1. The allongment of the river is estimated to be 3.8km from the dam site to the exit of the valley.
2. The analysis stands on the safe side based on the assumption of no rain, no dam, river flow rate in dry season.
3. Water supply to the paddy fields is estimated to be as same level as existing conditions, i.e. earthen canal with conveyance loss 60%.
4. ETc=5mm/day is adopted considering to reflect the existing conditions.
5. Considering the low runoff ratio in this site, the river flow rate would be scarcely affected by the ground water develoment(10 ℓ/sec=864m3/day).

Graph-1 Precedent water supply, water consumption and residual water quantity

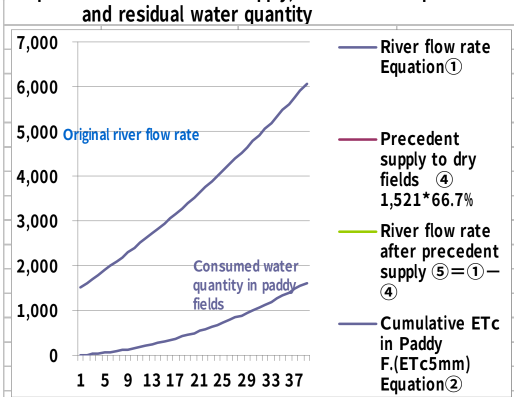


Fig. 4-1-1-14 Relationship among water quantity (2)

Graph-2 Residual river flow rate and the water supply to each irrigation block

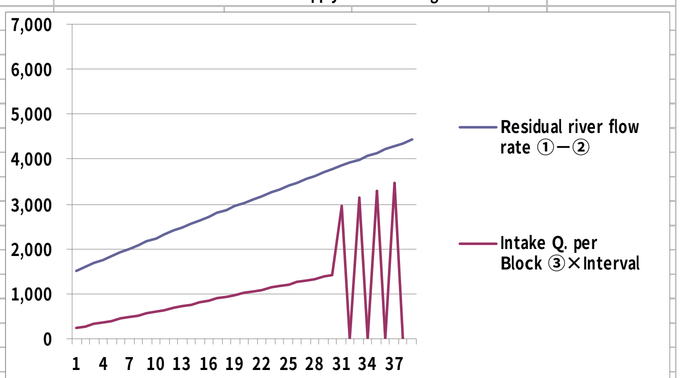


Fig. 4-1-1-15 Water supply and residual river flow rate (2)

(b) Supplemental Water Supply to the Downstream Paddy Fields and Water Supply Quantity to the Dry Field Irrigation

[General]

35 ha of paddy fields expand on the downstream river bed about 4 km long from the dam site to the confluence with the main river. It is usual for the river flow to be cut by the dam construction and for the downstream paddy fields to depend on the dam/reservoir regarding the irrigation water. But in case of these paddy fields, the downstream river flow has its own catchment area summed up to be about 9 km^2 extending from the dam site to the confluence point. Accordingly, after the river flowing down for a proper distance the irrigation water shall be supplied sufficiently as surface water and ground water from the both hill sides. (Actually, more than 10 springs can be seen at the foot of the hill slopes from the dam site to the exit of the valley; and these spring waters are used as the villagers' domestic water and led to the paddy fields as the irrigation water.)

[Total View]

According to the Tank Model Analysis, the runoff ratio between the estimated annual river flow rate at the dam site and the annual precipitation in 1970, the base year, is 7.1 %. The expected water supply from the hill side at the given point on the downstream river is calculated by applying this precipitation and runoff ratio to the catchment area ranging from the dam site to the given point.

The water requirement for irrigation shall be estimated based on the paddy field area from the dam site to the given point and the irrigation water requirement (ETc, refer to Table 3-3-1-2) calculated by CROPWAT-8.

The balance sheet becomes as follows. In case of counting the whole precipitation including floods that are counted in the runoff ratio 7.1 % together with the base flow, the downstream paddy fields are self-sufficient and independent from the water supply through the reservoir.

Table 4-1-1-7 Supplemental water supply to downstream paddy fields and water supply quantity to dry field irrigation

Item / Location	1 km from the dam site	2 km from the dam site	3 km from the dam site	Confluence Point
Catchment area (km2)	1.7	3.7	7.4	9.2
Annual precipitation (mm)	1,134	1,134	1,134	1,134
Runoff ratio (%)	7.1	7.1	7.1	7.1
Expected in-flow (m3)	136873.8	297901.8	595803.6	740728.8
Paddy field area (ha)	3.6	10.3	19.6	35.0
ETc* (mm)	1097	1097	1097	1097
Irrigation water supply (m3)	39492.0	112991.0	215012.0	383950.0

(*refer to Table 4-1-1-8)

[Precise View]

Though paddy fields are able to store rainfalls to a some extent, they can not keep water of whole rainfalls actually. According to the runoff analysis by the Tank Model, the base flow rate in March is 0.02 m^3/sec and is 0.007 m^3/sec from August to October; it is necessary to confirm the circumstances in the downstream paddy fields during such period with very small base flow.

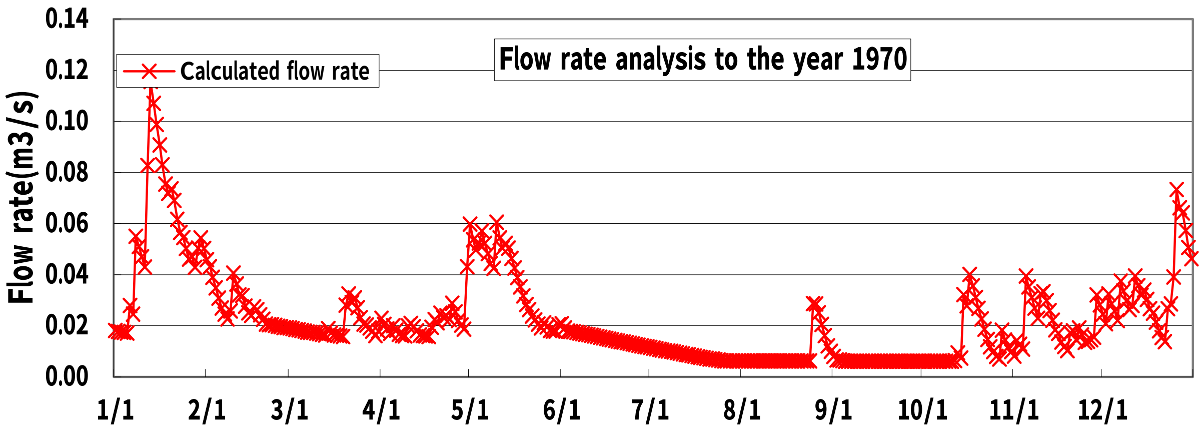


Fig. 4-1-1-18 Results of flow rate analysis

In addition, the paddy fields lying in just downstream area to the dam site do not have the catchment area from which surface/ground water flows in so that the irrigation water must be supplied all through a year.

Based on the recognition above, the cumulative calculations at every 50 m interval ranging from the dam site to the exit of the valley are carried out monthly to confirm the circumstances between supply and demand in irrigation water, i.e. the relationship among the irrigation water requirement, the in-flow rate from the catchment area, and the water supply to the immediate paddy fields in the downstream of the reservoir. The calculations are done under the following assumptions.

- The intake mouths are set up at 100 m interval near the starting point and the end point, and at 200 m interval through the other portion.
- The calculation interval is 50 m composed of two lots of paddy fields between which the ridge-through irrigation and horizontal leakage is considered. The in-flow of surface/ground water is estimated to this section where the specific discharge from the runoff analysis on the base year 1970 by Tank Model is applied.
  The required water supply to the paddy fields is composed of the ETc, the vertical percolation 13.6 mm and the horizontal leakage 5 mm. The ETc (mm/day)/irrigation water requirement is calculated monthly to the following total values per month.

Table.4-1-1-8 Irrigation Water Requirement per Month

Month	1	2	3	4	5	6	7	8	9	10	11	12
Etc (mm/month)	134.0	225.3	57.4	9.0	34.0	86.0	10.3	166.4	293.0	66.2	9.5	5.9

- Except for ETc, the vertical percolation and the horizontal leakage are circularly used by 100 %. (return-flow rate; 100%, refer to the comments below.) Regarding the ratio of seepage composed of percolation and leakage, the seepage out ratio to the river is 1/3 and the seepage out ratio to the adjacent paddy field is 2/3.
- At the intake mouth, the whole seepage out quantity to the river is caught and taken as the return flow. In case of this whole quantity being smaller than the irrigation water requirement at that intake point, the insufficient amount of water is discharged from the reservoir.

＊Return-flow rate of the vertical percolation water in the downstream paddy fields

In this Ngoma-22 valley, more than 10 springs seep out at the foot of the right and the left hills from the dam site to the exit of the valley. These springs are brought by the shallow ground water, which flows into the river, appearing on the ground surface.

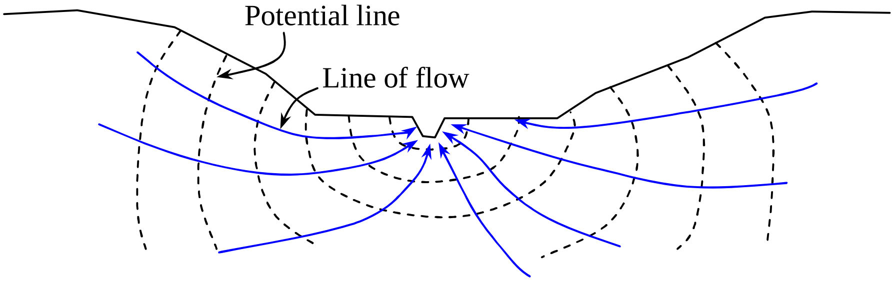


Fig. 4-1-1-19 Potential head

The water surface in the paddy field has the higher seepage potential than the paddy field surface so that the vertical percolation occurs; but this percolated water meets with and ride on the ground water flowing into the river. Therefore, the return-flow rate of the percolation water is considered to be 100 %.

The calculation results are shown on (Table 4-1-1-10(1)~Table 4-1-1-10(2)) and summarized as follows.

Table 4-1-1-9 Summary of supplemental water supply to downstream paddy field

Mon.	Circumstances in the downstream paddy fields	Water supply needed (m^3)	Cumulative sum (m^3)
1	0m～400m range must be covered by supplying water.	1,453	1,453
2	0m～400m range and mid portions must be covered by supplying water.	17,438	18,891
3	0m～400m range must be covered by supplying water.	2,647	21,538
4	0m～400m range must be covered by supplying water.	1,974	23,512
5	0m～400m range must be covered by supplying water.	1,452	24,964
6	0m～400m range and one section in downstream must be covered by supplying water.	3,695	28,659
7	0m～400m range must be covered by supplying water.	2,774	31,433
8	Almost all range must be covered by supplying water.	40,122	71,555
9	Almost all range must be covered by supplying water.	90,350	161,905
10	0m～400m range must be covered by supplying water.	2,990	164,895
11	0m～400m range must be covered by supplying water.	1,995	166,890
12	0m～400m range must be covered by supplying water.	1,409	168,299

Based on the summarization above, 170,000 m^3 of water supply shall be planned as the total water supply to the downstream paddy fields that is composed of the water supply to the immediate paddy fields in the downstream of the reservoir and the supplementary water supply in the dry season, February, June, August and September.

Then the available quantity of irrigation water to the dry fields is 530,000 m^3 (=700,000m^3 -170,000m^3).

Table 4-1-1-10(1) Calculation of Water Quantity for Supplemental Supply to the Paddy Field (January)

Jan. Water Re= 22.92 mm/day

		①		②	③	④	⑤	⑥	⑦=⑤×⑥	⑧=②+⑦×31	⑨	⑩=①×⑨×10000/1000	⑪=⑧-⑩	⑫=⑪×0.67	⑬=⑪×0.33
NO.	Distance (m)	Paddy Area (ha)	Cumulative Area (ha)	W.S./initial, return (m3/mon)	Intake quantity (m3/mon.)	Supplemental supply (m3/mon)	Specific discharge (m3/km2)	catchment area (km2)	Flow-in volume (m3/day)	Irrigation water (m3/mon)	ETc (mm/mon)	Water loss (m3/mon)	Residual water (m3/mon.	Horizontal leakage (m3/mon.)	Return to the river (m3/mon.)
1	50.0	0.18	0.18	1279.1			543.9	0.085	46.2315	2712.3	134.0	241.2	2471.1	1655.61	815.45
2	100.0	0.18	0.36	2558.2	815.4	87.1	543.9	0.085	46.2315	4078.4	134.0	241.2	3837.2	2570.95	1266.29
3	150.0	0.18	0.54	2571.0		0.0	543.9	0.085	46.2315	4004.1	134.0	241.2	3762.9	2521.16	1241.77
4	200.0	0.18	0.72	5116.3	2508.1	87.1	543.9	0.085	46.2315	6549.5	134.0	241.2	6308.3	4226.56	2081.74
5	250.0	0.18	0.9	4226.6		0.0	543.9	0.085	46.2315	5659.7	134.0	241.2	5418.5	3630.42	1788.12
6	300.0	0.18	1.08	3630.4		0.0	543.9	0.085	46.2315	5063.6	134.0	241.2	4822.4	3231.00	1591.39
7	350.0	0.18	1.26	3231.0		0.0	543.9	0.085	46.2315	4664.2	134.0	241.2	4423.0	2963.40	1459.58
8	400.0	0.18	1.44	9884.2	6920.8	0.0	543.9	0.085	46.2315	11317.4	134.0	241.2	11076.2	7421.06	3655.15
9	450.0	0.18	1.62	7421.1		0.0	543.9	0.085	46.2315	8854.2	134.0	241.2	8613.0	5770.73	2842.30
10	500.0	0.18	1.8	5770.7		0.0	543.9	0.085	46.2315	7203.9	134.0	241.2	6962.7	4665.01	2297.69
11	550.0	0.18	1.98	4665.0		0.0	543.9	0.085	46.2315	6098.2	134.0	241.2	5857.0	3924.18	1932.81
12	600.0	0.18	2.16	14652.1	10727.9	0.0	543.9	0.085	46.2315	16085.3	134.0	241.2	15844.1	10615.55	5228.56
13	650.0	0.18	2.34	10615.6		0.0	543.9	0.085	46.2315	12048.7	134.0	241.2	11807.5	7911.04	3896.48
14	700.0	0.18	2.52	7911.0		0.0	543.9	0.085	46.2315	9344.2	134.0	241.2	9103.0	6099.02	3004.00
15	750.0	0.18	2.7	6099.0		0.0	543.9	0.085	46.2315	7532.2	134.0	241.2	7291.0	4884.97	2406.03
16	800.0	0.18	2.88	19420.0	14535.1	0.0	543.9	0.085	46.2315	20853.2	134.0	241.2	20612.0	13810.05	6801.96
17	850.0	0.18	3.06	13810.0		0.0	543.9	0.085	46.2315	15243.2	134.0	241.2	15002.0	10051.36	4950.67
18	900.0	0.18	3.24	10051.4		0.0	543.9	0.085	46.2315	11484.5	134.0	241.2	11243.3	7533.03	3710.30
19	950.0	0.18	3.42	7533.0		0.0	543.9	0.085	46.2315	8966.2	134.0	241.2	8725.0	5845.76	2879.25
20	1000.0	0.18	3.6	24187.9	18342.2	0.0	543.9	0.085	46.2315	25621.1	134.0	241.2	25379.9	17004.55	8375.37
21	1050.0	0.335	3.935	17004.5		0.0	543.9	0.1	54.39	18690.6	134.0	448.9	18241.7	12221.96	6019.77
22	1100.0	0.335	4.27	12222.0		0.0	543.9	0.1	54.39	13908.1	134.0	448.9	13459.2	9017.63	4441.52
23	1150.0	0.335	4.605	9017.6		0.0	543.9	0.1	54.39	10703.7	134.0	448.9	10254.8	6870.73	3384.09
24	1200.0	0.335	4.94	29091.5	22220.8	0.0	543.9	0.1	54.39	30777.6	134.0	448.9	30328.7	20320.22	10008.46
25	1250.0	0.335	5.275	20320.2		0.0	543.9	0.1	54.39	22006.3	134.0	448.9	21557.4	14443.46	7113.94
26	1300.0	0.335	5.61	14443.5		0.0	543.9	0.1	54.39	16129.6	134.0	448.9	15680.7	10506.04	5174.62
27	1350.0	0.335	5.945	10506.0		0.0	543.9	0.1	54.39	12192.1	134.0	448.9	11743.2	7867.96	3875.26
28	1400.0	0.335	6.28	34040.3	26172.3	0.0	543.9	0.1	54.39	35726.3	134.0	448.9	35277.4	23635.89	11641.56
29	1450.0	0.335	6.615	23635.9		0.0	543.9	0.1	54.39	25322.0	134.0	448.9	24873.1	16664.96	8208.11
30	1500.0	0.335	6.95	16665.0		0.0	543.9	0.1	54.39	18351.1	134.0	448.9	17902.2	11994.44	5907.71
31	1550.0	0.335	7.285	11994.4		0.0	543.9	0.1	54.39	13680.5	134.0	448.9	13231.6	8865.19	4366.44
32	1600.0	0.335	7.62	38989.0	30123.8	0.0	543.9	0.1	54.39	40675.1	134.0	448.9	40226.2	26951.55	13274.65
33	1650.0	0.335	7.955	26951.6		0.0	543.9	0.1	54.39	28637.6	134.0	448.9	28188.7	18886.46	9302.29
34	1700.0	0.335	8.29	18886.5		0.0	543.9	0.1	54.39	20572.5	134.0	448.9	20123.6	13482.84	6640.80
35	1750.0	0.335	8.625	13482.8		0.0	543.9	0.1	54.39	15168.9	134.0	448.9	14720.0	9862.42	4857.61
36	1800.0	0.335	8.96	43937.8	34075.3	0.0	543.9	0.1	54.39	45623.9	134.0	448.9	45175.0	30267.22	14907.74
37	1850.0	0.335	9.295	30267.2		0.0	543.9	0.1	54.39	31953.3	134.0	448.9	31504.4	21107.96	10396.46
38	1900.0	0.335	9.63	21108.0		0.0	543.9	0.1	54.39	22794.0	134.0	448.9	22345.1	14971.25	7373.90
39	1950.0	0.335	9.965	14971.2		0.0	543.9	0.1	54.39	16657.3	134.0	448.9	16208.4	10859.65	5348.78
40	2000.0	0.335	10.3	48886.5	38026.9	0.0	543.9	0.1	54.39	50572.6	134.0	448.9	50123.7	33582.89	16540.83
41	2050.0	0.465	10.765	33582.9		0.0	543.9	0.185	100.6215	36702.2	134.0	623.1	36079.1	24172.97	11906.09
42	2100.0	0.465	11.23	24173.0		0.0	543.9	0.185	100.6215	27292.2	134.0	623.1	26669.1	17868.32	8800.81
43	2150.0	0.465	11.695	17868.3		0.0	543.9	0.185	100.6215	20987.6	134.0	623.1	20364.5	13644.21	6720.28
44	2200.0	0.465	12.16	57612.2	43968.0	0.0	543.9	0.185	100.6215	60731.5	134.0	623.1	60108.4	40272.62	19835.77
45	2250.0	0.465	12.625	40272.6		0.0	543.9	0.185	100.6215	43391.9	134.0	623.1	42768.8	28655.09	14113.70
46	2300.0	0.465	13.09	28655.1		0.0	543.9	0.185	100.6215	31774.4	134.0	623.1	31151.3	20871.34	10279.91
47	2350.0	0.465	13.555	20871.3		0.0	543.9	0.185	100.6215	23990.6	134.0	623.1	23367.5	15656.23	7711.28
48	2400.0	0.465	14.02	67596.9	51940.7	0.0	543.9	0.185	100.6215	70716.2	134.0	623.1	70093.1	46962.35	23130.71
49	2450.0	0.465	14.485	46962.3		0.0	543.9	0.185	100.6215	50081.6	134.0	623.1	49458.5	33137.20	16321.31
50	2500.0	0.465	14.95	33137.2		0.0	543.9	0.185	100.6215	36256.5	134.0	623.1	35633.4	23874.36	11759.01
51	2550.0	0.465	15.415	23874.4		0.0	543.9	0.185	100.6215	26993.6	134.0	623.1	26370.5	17668.25	8702.27
52	2600.0	0.465	15.88	77581.6	59913.3	0.0	543.9	0.185	100.6215	80700.8	134.0	623.1	80077.7	53652.07	26425.65
53	2650.0	0.465	16.345	53652.1		0.0	543.9	0.185	100.6215	56771.3	134.0	623.1	56148.2	37619.32	18528.92
54	2700.0	0.465	16.81	37619.3		0.0	543.9	0.185	100.6215	40738.6	134.0	623.1	40115.5	26877.38	13238.11
55	2750.0	0.465	17.275	26877.4		0.0	543.9	0.185	100.6215	29996.6	134.0	623.1	29373.5	19680.27	9693.27
56	2800.0	0.465	17.74	87566.2	67885.9	0.0	543.9	0.185	100.6215	90685.5	134.0	623.1	90062.4	60341.80	29720.59
57	2850.0	0.465	18.205	60341.8		0.0	543.9	0.185	100.6215	63461.1	134.0	623.1	62838.0	42101.44	20736.53
58	2900.0	0.465	18.67	42101.4		0.0	543.9	0.185	100.6215	45220.7	134.0	623.1	44597.6	29880.39	14717.21
59	2950.0	0.465	19.135	29880.4		0.0	543.9	0.185	100.6215	32999.7	134.0	623.1	32376.6	21692.30	10684.26
60	3000.0	0.465	19.6	97550.9	75858.6	0.0	543.9	0.185	100.6215	100670.2	134.0	623.1	100047.1	67031.52	33015.53
61	3050.0	0.77	20.37	67031.5		0.0	543.9	0.09	48.951	68549.0	134.0	1031.8	67517.2	45236.53	22280.68
62	3100.0	0.77	21.14	45236.5		0.0	543.9	0.09	48.951	46754.0	134.0	1031.8	45722.2	30633.88	15088.33
63	3150.0	0.77	21.91	30633.9		0.0	543.9	0.09	48.951	32151.4	134.0	1031.8	31119.6	20850.11	10269.45
64	3200.0	0.77	22.68	101504.1	80654.0	0.0	543.9	0.09	48.951	103021.6	134.0	1031.8	101989.8	68333.15	33656.63
65	3250.0	0.77	23.45	68333.1		0.0	543.9	0.09	48.951	69850.6	134.0	1031.8	68818.8	46108.62	22710.21
66	3300.0	0.77	24.22	46108.6		0.0	543.9	0.09	48.951	47626.1	134.0	1031.8	46594.3	31218.18	15376.12
67	3350.0	0.77	24.99	31218.2		0.0	543.9	0.09	48.951	32735.7	134.0	1031.8	31703.9	21241.59	10462.27
68	3400.0	0.77	25.76	103446.8	82205.2	0.0	543.9	0.09	48.951	104964.3	134.0	1031.8	103932.5	69634.77	34297.72
69	3450.0	0.77	26.53	69634.8		0.0	543.9	0.09	48.951	71152.3	134.0	1031.8	70120.5	46980.70	23139.75
70	3500.0	0.77	27.3	46980.7		0.0	543.9	0.09	48.951	48498.2	134.0	1031.8	47466.4	31802.48	15663.91
71	3550.0	0.77	28.07	31802.5		0.0	543.9	0.09	48.951	33320.0	134.0	1031.8	32288.2	21633.07	10655.09
72	3600.0	0.77	28.84	105389.5	83756.5	0.0	543.9	0.09	48.951	106907.0	134.0	1031.8	105875.2	70936.40	34938.82
73	3650.0	0.77	29.61	70936.4		0.0	543.9	0.09	48.951	72453.9	134.0	1031.8	71422.1	47852.79	23569.29
74	3700.0	0.77	30.38	106360.9	58508.1	0.0	543.9	0.09	48.951	107878.4	134.0	1031.8	106846.6	71587.21	35259.37
75	3750.0	0.77	31.15	71587.2		0.0	543.9	0.09	48.951	73104.7	134.0	1031.8	72072.9	48288.84	23784.05
76	3800.0	0.77	31.92	107332.3	59043.4	0.0	543.9	0.09	48.951	108849.7	134.0	1031.8	107817.9	72238.02	35579.92
77	3850.0	0.77	32.69	72238.0		0.0	543.9	0.09	48.951	73755.5	134.0	1031.8	72723.7	48724.88	23998.82
78	3900.0	0.77	33.46	108303.6	59578.7	0.0	543.9	0.09	48.951	109821.1	134.0	1031.8	108789.3	72888.84	35900.47
79	3950.0	0.77	34.23	72888.8		0.0	543.9	0.09	48.951	74406.3	134.0	1031.8	73374.5	49160.93	24213.59
80	4000.0	0.77	35	109275.0	60114.1	0.0	543.9	0.09	48.951	110792.5	134.0	1031.8	109760.7	73539.65	36221.02
				1279.1		174.2									

Total water supply = 1453.3

Water re.＝Virtical percolation 13.6mm+Horizontal leakage 5mm+⑨ (ETc mm/mon.) ／days in month (ETc: calculated by CROPWAT-8)

②;=upper one column in ⑫ row (2/3×Horizontal leakage), at the intake point, larger one between the former value and supply target area×(ETc+Virtical 13.6mm+ Horizontal 5n

③;intake quantity of the total return flow in ⑬row after the previous intake point

④;resupply quantity in case of the total return flow being less than irrigation water requirement at the relevant intake point

⑤;=total flow rate at the dam site per month (estimated by the Tank Model Analysis) devided by catchment area 8.8km2 and devided by the days' number of the relevant month

Table 4-1-1-10(2) Calculation of Water Quantity for Supplemental Supply to the Paddy Field (February)

Feb. Water Re= 26.65 mm/day

NO.	Distance (m)	① Paddy Area (ha)	Cumulative Area (ha)	② W.S./initial, return (m3/mon)	③ Intake quantity (m3/mon.)	④ Supplemental supply (m3/mon)	⑤ Specific discharge (m3/km2)	⑥ catchment area (km2)	⑦=⑤×⑥ Flow-in volume (m3/day)	⑧=②+⑦×28 Irrigation water (m3/mon)	⑨ ETc (mm/mon)	⑩=①×⑨×10000/1000 Water loss (m3/mon)	⑪=⑧-⑩ Residual water (m3/mon.	⑫=⑪×0.67 Horizontal leakage (m3/mon.)	⑬=⑪×0.33 Return to the river (m3/mon.)
1	50.0	0.18	0.18	1486.9			270.7	0.085	23.0095	2131.1	225.3	405.5	1725.6	1156.15	569.45
2	100.0	0.18	0.36	2973.7	569.4	1248.1	270.7	0.085	23.0095	4866.2	225.3	405.5	4460.6	2988.61	1472.00
3	150.0	0.18	0.54	2988.6		0.0	270.7	0.085	23.0095	3632.9	225.3	405.5	3227.3	2162.32	1065.02
4	200.0	0.18	0.72	5755.6	2537.0	1056.3	270.7	0.085	23.0095	6399.9	225.3	405.5	5994.4	4016.22	1978.14
5	250.0	0.18	0.9	4016.2		0.0	270.7	0.085	23.0095	4660.5	225.3	405.5	4254.9	2850.81	1404.13
6	300.0	0.18	1.08	2850.8		0.0	270.7	0.085	23.0095	3495.1	225.3	405.5	3089.5	2069.99	1019.55
7	350.0	0.18	1.26	2070.0		0.0	270.7	0.085	23.0095	2714.3	225.3	405.5	2308.7	1546.84	761.88
8	400.0	0.18	1.44	6710.5	5163.7	0.0	270.7	0.085	23.0095	7354.8	225.3	405.5	6949.3	4656.00	2293.26
9	450.0	0.18	1.62	4656.0		0.0	270.7	0.085	23.0095	5300.3	225.3	405.5	4894.7	3279.47	1615.26
10	500.0	0.18	1.8	3279.5		0.0	270.7	0.085	23.0095	3923.7	225.3	405.5	3518.2	2357.19	1161.00
11	550.0	0.18	1.98	2357.2		0.0	270.7	0.085	23.0095	3001.5	225.3	405.5	2595.9	1739.26	856.65
12	600.0	0.18	2.16	7665.4	5926.2	0.0	270.7	0.085	23.0095	8309.7	225.3	405.5	7904.2	5295.79	2608.37
13	650.0	0.18	2.34	5295.8		0.0	270.7	0.085	23.0095	5940.1	225.3	405.5	5534.5	3708.12	1826.39
14	700.0	0.18	2.52	3708.1		0.0	270.7	0.085	23.0095	4352.4	225.3	405.5	3946.9	2644.39	1302.46
15	750.0	0.18	2.7	2644.4		0.0	270.7	0.085	23.0095	3288.7	225.3	405.5	2883.1	1931.69	951.43
16	800.0	0.18	2.88	8620.3	6688.7	0.0	270.7	0.085	23.0095	9264.6	225.3	405.5	8859.1	5935.57	2923.49
17	850.0	0.18	3.06	5935.6		0.0	270.7	0.085	23.0095	6579.8	225.3	405.5	6174.3	4136.78	2037.52
18	900.0	0.18	3.24	4136.8		0.0	270.7	0.085	23.0095	4781.0	225.3	405.5	4375.5	2931.59	1443.92
19	950.0	0.18	3.42	2931.6		0.0	270.7	0.085	23.0095	3575.9	225.3	405.5	3170.3	2124.11	1046.20
20	1000.0	0.18	3.6	9575.2	7451.1	0.0	270.7	0.085	23.0095	10219.5	225.3	405.5	9814.0	6575.36	3238.61
21	1050.0	0.335	3.935	6575.4		0.0	270.7	0.1	27.07	7333.3	225.3	754.8	6578.6	4407.64	2170.93
22	1100.0	0.335	4.27	4407.6		0.0	270.7	0.1	27.07	5165.6	225.3	754.8	4410.8	2955.27	1455.58
23	1150.0	0.335	4.605	2955.3		0.0	270.7	0.1	27.07	3713.2	225.3	754.8	2958.5	1982.18	976.30
24	1200.0	0.335	4.94	9997.7	7841.4	174.2	270.7	0.1	27.07	10755.7	225.3	754.8	10000.9	6700.63	3300.31
25	1250.0	0.335	5.275	6700.6		0.0	270.7	0.1	27.07	7458.6	225.3	754.8	6703.8	4491.57	2212.27
26	1300.0	0.335	5.61	4491.6		0.0	270.7	0.1	27.07	5249.5	225.3	754.8	4494.8	3011.50	1483.28
27	1350.0	0.335	5.945	3011.5		0.0	270.7	0.1	27.07	3769.5	225.3	754.8	3014.7	2019.85	994.85
28	1400.0	0.335	6.28	10010.6	7990.7	0.0	270.7	0.1	27.07	10768.5	225.3	754.8	10013.8	6709.22	3304.54
29	1450.0	0.335	6.615	6709.2		0.0	270.7	0.1	27.07	7467.2	225.3	754.8	6712.4	4497.33	2215.10
30	1500.0	0.335	6.95	4497.3		0.0	270.7	0.1	27.07	5255.3	225.3	754.8	4500.5	3015.36	1485.18
31	1550.0	0.335	7.285	3015.4		0.0	270.7	0.1	27.07	3773.3	225.3	754.8	3018.6	2022.44	996.13
32	1600.0	0.335	7.62	10023.4	8000.9	0.0	270.7	0.1	27.07	10781.3	225.3	754.8	10026.6	6717.81	3308.77
33	1650.0	0.335	7.955	6717.8		0.0	270.7	0.1	27.07	7475.8	225.3	754.8	6721.0	4503.08	2217.94
34	1700.0	0.335	8.29	4503.1		0.0	270.7	0.1	27.07	5261.0	225.3	754.8	4506.3	3019.21	1487.07
35	1750.0	0.335	8.625	3019.2		0.0	270.7	0.1	27.07	3777.2	225.3	754.8	3022.4	2025.02	997.40
36	1800.0	0.335	8.96	10036.2	8011.2	0.0	270.7	0.1	27.07	10794.2	225.3	754.8	10039.4	6726.40	3313.00
37	1850.0	0.335	9.295	6726.4		0.0	270.7	0.1	27.07	7484.4	225.3	754.8	6729.6	4508.84	2220.77
38	1900.0	0.335	9.63	4508.8		0.0	270.7	0.1	27.07	5266.8	225.3	754.8	4512.0	3023.07	1488.97
39	1950.0	0.335	9.965	3023.1		0.0	270.7	0.1	27.07	3781.0	225.3	754.8	3026.3	2027.60	998.67
40	2000.0	0.335	10.3	12907.5	8021.4	2858.5	270.7	0.1	27.07	13665.5	225.3	754.8	12910.7	8650.19	4260.54
41	2050.0	0.465	10.765	8650.2		0.0	270.7	0.185	50.0795	10052.4	225.3	1047.6	9004.8	6033.20	2971.58
42	2100.0	0.465	11.23	6033.2		0.0	270.7	0.185	50.0795	7435.4	225.3	1047.6	6387.8	4279.81	2107.97
43	2150.0	0.465	11.695	4279.8		0.0	270.7	0.185	50.0795	5682.0	225.3	1047.6	4634.4	3105.04	1529.35
44	2200.0	0.465	12.16	13974.5	10869.4	0.0	270.7	0.185	50.0795	15376.7	225.3	1047.6	14329.1	9600.47	4728.59
45	2250.0	0.465	12.625	9600.5		0.0	270.7	0.185	50.0795	11002.7	225.3	1047.6	9955.1	6669.88	3285.17
46	2300.0	0.465	13.09	6669.9		0.0	270.7	0.185	50.0795	8072.1	225.3	1047.6	7024.5	4706.39	2318.07
47	2350.0	0.465	13.555	4706.4		0.0	270.7	0.185	50.0795	6108.6	225.3	1047.6	5061.0	3390.85	1670.12
48	2400.0	0.465	14.02	15392.8	12002.0	0.0	270.7	0.185	50.0795	16795.0	225.3	1047.6	15747.4	10550.75	5196.64
49	2450.0	0.465	14.485	10550.7		0.0	270.7	0.185	50.0795	11953.0	225.3	1047.6	10905.3	7306.57	3598.76
50	2500.0	0.465	14.95	7306.6		0.0	270.7	0.185	50.0795	8708.8	225.3	1047.6	7661.2	5132.97	2528.18
51	2550.0	0.465	15.415	5133.0		0.0	270.7	0.185	50.0795	6535.2	225.3	1047.6	5487.6	3676.66	1810.89
52	2600.0	0.465	15.88	16811.1	13134.5	0.0	270.7	0.185	50.0795	18213.4	225.3	1047.6	17165.7	11501.02	5664.68
53	2650.0	0.465	16.345	11501.0		0.0	270.7	0.185	50.0795	12903.2	225.3	1047.6	11855.6	7943.26	3912.35
54	2700.0	0.465	16.81	7943.3		0.0	270.7	0.185	50.0795	9345.5	225.3	1047.6	8297.8	5559.55	2738.29
55	2750.0	0.465	17.275	5559.6		0.0	270.7	0.185	50.0795	6961.8	225.3	1047.6	5914.1	3962.47	1951.66
56	2800.0	0.465	17.74	18229.5	14267.0	0.0	270.7	0.185	50.0795	19631.7	225.3	1047.6	18584.0	12451.30	6132.73
57	2850.0	0.465	18.205	12451.3		0.0	270.7	0.185	50.0795	13853.5	225.3	1047.6	12805.9	8579.94	4225.94
58	2900.0	0.465	18.67	8579.9		0.0	270.7	0.185	50.0795	9982.2	225.3	1047.6	8934.5	5986.13	2948.39
59	2950.0	0.465	19.135	5986.1		0.0	270.7	0.185	50.0795	7388.4	225.3	1047.6	6340.7	4248.28	2092.43
60	3000.0	0.465	19.6	20704.3	15399.5	1056.5	270.7	0.185	50.0795	22106.5	225.3	1047.6	21058.9	14109.43	6949.42
61	3050.0	0.77	20.37	14109.4		0.0	270.7	0.09	24.363	14791.6	225.3	1734.8	13056.8	8748.05	4308.74
62	3100.0	0.77	21.14	8748.0		0.0	270.7	0.09	24.363	9430.2	225.3	1734.8	7695.4	5155.92	2539.48
63	3150.0	0.77	21.91	5155.9		0.0	270.7	0.09	24.363	5838.1	225.3	1734.8	4103.3	2749.19	1354.08
64	3200.0	0.77	22.68	22979.9	15151.7	5079.0	270.7	0.09	24.363	23662.0	225.3	1734.8	21927.2	14691.25	7235.99
65	3250.0	0.77	23.45	14691.2		0.0	270.7	0.09	24.363	15373.4	225.3	1734.8	13638.6	9137.86	4500.74
66	3300.0	0.77	24.22	9137.9		0.0	270.7	0.09	24.363	9820.0	225.3	1734.8	8085.2	5417.10	2668.12
67	3350.0	0.77	24.99	5417.1		0.0	270.7	0.09	24.363	6099.3	225.3	1734.8	4364.4	2924.18	1440.27
68	3400.0	0.77	25.76	22979.9	15845.1	4210.6	270.7	0.09	24.363	23662.0	225.3	1734.8	21927.2	14691.25	7235.99
69	3450.0	0.77	26.53	14691.2		0.0	270.7	0.09	24.363	15373.4	225.3	1734.8	13638.6	9137.86	4500.74
70	3500.0	0.77	27.3	9137.9		0.0	270.7	0.09	24.363	9820.0	225.3	1734.8	8085.2	5417.10	2668.12
71	3550.0	0.77	28.07	5417.1		0.0	270.7	0.09	24.363	6099.3	225.3	1734.8	4364.4	2924.18	1440.27
72	3600.0	0.77	28.84	18769.3	15845.1	0.0	270.7	0.09	24.363	19451.5	225.3	1734.8	17716.7	11870.16	5846.49
73	3650.0	0.77	29.61	11870.2		0.0	270.7	0.09	24.363	12552.3	225.3	1734.8	10817.5	7247.73	3569.78
74	3700.0	0.77	30.38	16664.0	9416.3	0.0	270.7	0.09	24.363	17346.2	225.3	1734.8	15611.4	10459.61	5151.75
75	3750.0	0.77	31.15	10459.6		0.0	270.7	0.09	24.363	11141.8	225.3	1734.8	9407.0	6302.67	3104.30
76	3800.0	0.77	31.92	14558.7	8256.0	0.0	270.7	0.09	24.363	15240.9	225.3	1734.8	13506.1	9049.06	4457.00
77	3850.0	0.77	32.69	9049.1		0.0	270.7	0.09	24.363	9731.2	225.3	1734.8	7996.4	5357.60	2638.82
78	3900.0	0.77	33.46	12721.0	7095.8	267.6	270.7	0.09	24.363	13403.2	225.3	1734.8	11668.4	7817.80	3850.56
79	3950.0	0.77	34.23	7817.8		0.0	270.7	0.09	24.363	8500.0	225.3	1734.8	6765.2	4532.65	2232.50
80	4000.0	0.77	35	10615.7	6083.1	0.0	270.7	0.09	24.363	11297.9	225.3	1734.8	9563.1	6407.25	3155.81
				1486.9		15950.7									
					Total water supply =	17437.6									

Water re.=Virtical percolation 13.6mm+Horizontal leakage 5mm+⑨ (ETc mm/mon.) ／days in month (ETc: calculated by CROPWAT-8)

②;=upper one column in ⑫ row (2/3×Horizontal leakage), at the intake point, larger one between the former value and supply target area×(ETc+Virtical 13.6mm+ Horizontal 5n

③;intake quantity of the total return flow in ⑬row after the previous intake point

④;resupply quantity in case of the total return flow being less than irrigation water requirement at the relevant intake point

⑤;=total flow rate at the dam site per month (estimated by the Tank Model Analysis) devided by catchment area 8.8km2 and devided by the days' number of the relevant month

Table 4-1-1-10(3)Calculation of Water Quantity for Supplemental Supply to the Paddy Field (March)

Mar. Water Re= 20.45 mm/day

		①		②	③	④	⑤	⑥	⑦=⑤×⑥	⑧=②+⑦×31	⑨	⑩=①×⑨×10000/1000	⑪=⑧-⑩	⑫=⑪×0.67	⑬=⑪×0.33
NO.	Distance (m)	Paddy Area (ha)	Cumulative Area (ha)	W.S./initial, return (m3/mon)	Intake quantity (m3/mon.)	Supplemental supply (m3/mon)	Specific discharge (m3/km2)	catchment area (km2)	Flow-in volume (m3/day)	Irrigation water (m3/mon)	ETc (mm/mon)	Water loss (m3/mon)	Residual water (m3/mon.)	Horizontal leakage (m3/mon.)	Return to the river (m3/mon.)
1	50.0	0.18	0.18	1141.2			186.5	0.085	15.8525	1632.6	57.4	103.3	1529.3	1024.64	504.67
2	100.0	0.18	0.36	2282.4	504.7	753.1	186.5	0.085	15.8525	3526.9	57.4	103.3	3423.6	2293.81	1129.79
3	150.0	0.18	0.54	2293.8		0.0	186.5	0.085	15.8525	2785.2	57.4	103.3	2681.9	1796.89	885.03
4	200.0	0.18	0.72	4564.8	2014.8	753.1	186.5	0.085	15.8525	5056.2	57.4	103.3	4952.9	3318.45	1634.46
5	250.0	0.18	0.9	3318.4		0.0	186.5	0.085	15.8525	3809.9	57.4	103.3	3706.6	2483.39	1223.16
6	300.0	0.18	1.08	2483.4		0.0	186.5	0.085	15.8525	2974.8	57.4	103.3	2871.5	1923.90	947.59
7	350.0	0.18	1.26	1923.9		0.0	186.5	0.085	15.8525	2415.3	57.4	103.3	2312.0	1549.05	762.96
8	400.0	0.18	1.44	6117.2	4568.2	0.0	186.5	0.085	15.8525	6608.7	57.4	103.3	6505.3	4358.58	2146.76
9	450.0	0.18	1.62	4358.6		0.0	186.5	0.085	15.8525	4850.0	57.4	103.3	4746.7	3180.28	1566.41
10	500.0	0.18	1.8	3180.3		0.0	186.5	0.085	15.8525	3671.7	57.4	103.3	3568.4	2390.82	1177.57
11	550.0	0.18	1.98	2390.8		0.0	186.5	0.085	15.8525	2882.2	57.4	103.3	2778.9	1861.88	917.05
12	600.0	0.18	2.16	7669.7	5807.8	0.0	186.5	0.085	15.8525	8161.1	57.4	103.3	8057.8	5398.70	2659.06
13	650.0	0.18	2.34	5398.7		0.0	186.5	0.085	15.8525	5890.1	57.4	103.3	5786.8	3877.16	1909.65
14	700.0	0.18	2.52	3877.2		0.0	186.5	0.085	15.8525	4368.6	57.4	103.3	4265.3	2857.73	1407.54
15	750.0	0.18	2.7	2857.7		0.0	186.5	0.085	15.8525	3349.2	57.4	103.3	3245.8	2174.71	1071.13
16	800.0	0.18	2.88	9222.1	7047.4	0.0	186.5	0.085	15.8525	9713.5	57.4	103.3	9610.2	6438.83	3171.37
17	850.0	0.18	3.06	6438.8		0.0	186.5	0.085	15.8525	6930.3	57.4	103.3	6826.9	4574.05	2252.89
18	900.0	0.18	3.24	4574.0		0.0	186.5	0.085	15.8525	5065.5	57.4	103.3	4962.2	3324.65	1637.51
19	950.0	0.18	3.42	3324.6		0.0	186.5	0.085	15.8525	3816.1	57.4	103.3	3712.8	2487.54	1225.21
20	1000.0	0.18	3.6	10774.5	8287.0	0.0	186.5	0.085	15.8525	11265.9	57.4	103.3	11162.6	7478.96	3683.67
21	1050.0	0.335	3.935	7479.0		0.0	186.5	0.1	18.65	8057.1	57.4	192.3	7864.8	5269.43	2595.39
22	1100.0	0.335	4.27	5269.4		0.0	186.5	0.1	18.65	5847.6	57.4	192.3	5655.3	3789.04	1866.25
23	1150.0	0.335	4.605	3789.0		0.0	186.5	0.1	18.65	4367.2	57.4	192.3	4174.9	2797.19	1377.72
24	1200.0	0.335	4.94	12320.2	9523.0	0.0	186.5	0.1	18.65	12898.4	57.4	192.3	12706.1	8513.07	4193.00
25	1250.0	0.335	5.275	8513.1		0.0	186.5	0.1	18.65	9091.2	57.4	192.3	8898.9	5962.28	2936.65
26	1300.0	0.335	5.61	5962.3		0.0	186.5	0.1	18.65	6540.4	57.4	192.3	6348.1	4253.25	2094.89
27	1350.0	0.335	5.945	4253.3		0.0	186.5	0.1	18.65	4831.4	57.4	192.3	4639.1	3108.21	1530.91
28	1400.0	0.335	6.28	13863.6	10755.4	0.0	186.5	0.1	18.65	14441.8	57.4	192.3	14249.5	9547.17	4702.34
29	1450.0	0.335	6.615	9547.2		0.0	186.5	0.1	18.65	10125.3	57.4	192.3	9933.0	6655.13	3277.90
30	1500.0	0.335	6.95	6655.1		0.0	186.5	0.1	18.65	7233.3	57.4	192.3	7041.0	4717.46	2323.53
31	1550.0	0.335	7.285	4717.5		0.0	186.5	0.1	18.65	5295.6	57.4	192.3	5103.3	3419.23	1684.10
32	1600.0	0.335	7.62	15407.1	11987.9	0.0	186.5	0.1	18.65	15985.2	57.4	192.3	15792.9	10581.27	5211.67
33	1650.0	0.335	7.955	10581.3		0.0	186.5	0.1	18.65	11159.4	57.4	192.3	10967.1	7347.98	3619.15
34	1700.0	0.335	8.29	7348.0		0.0	186.5	0.1	18.65	7926.1	57.4	192.3	7733.8	5181.67	2552.17
35	1750.0	0.335	8.625	5181.7		0.0	186.5	0.1	18.65	5759.8	57.4	192.3	5567.5	3730.25	1837.29
36	1800.0	0.335	8.96	16950.5	13220.3	0.0	186.5	0.1	18.65	17528.7	57.4	192.3	17336.4	11615.38	5721.01
37	1850.0	0.335	9.295	11615.4		0.0	186.5	0.1	18.65	12193.5	57.4	192.3	12001.2	8040.83	3960.41
38	1900.0	0.335	9.63	8040.8		0.0	186.5	0.1	18.65	8619.0	57.4	192.3	8426.7	5645.88	2780.81
39	1950.0	0.335	9.965	5645.9		0.0	186.5	0.1	18.65	6224.0	57.4	192.3	6031.7	4041.27	1990.48
40	2000.0	0.335	10.3	18494.0	14452.7	0.0	186.5	0.1	18.65	19072.1	57.4	192.3	18879.8	12649.48	6230.34
41	2050.0	0.465	10.765	12649.5		0.0	186.5	0.185	34.5025	13719.1	57.4	266.9	13452.2	9012.94	4439.21
42	2100.0	0.465	11.23	9012.9		0.0	186.5	0.185	34.5025	10082.5	57.4	266.9	9815.6	6576.46	3239.15
43	2150.0	0.465	11.695	6576.5		0.0	186.5	0.185	34.5025	7646.0	57.4	266.9	7379.1	4944.01	2435.11
44	2200.0	0.465	12.16	21287.8	16343.8	0.0	186.5	0.185	34.5025	22357.4	57.4	266.9	22090.5	14800.63	7289.86
45	2250.0	0.465	12.625	14800.6		0.0	186.5	0.185	34.5025	15870.2	57.4	266.9	15603.3	10454.21	5149.09
46	2300.0	0.465	13.09	10454.2		0.0	186.5	0.185	34.5025	11523.8	57.4	266.9	11256.9	7542.11	3714.77
47	2350.0	0.465	13.555	7542.1		0.0	186.5	0.185	34.5025	8611.7	57.4	266.9	8344.8	5591.00	2753.78
48	2400.0	0.465	14.02	24498.5	18907.5	0.0	186.5	0.185	34.5025	25568.1	57.4	266.9	25301.2	16951.78	8349.39
49	2450.0	0.465	14.485	16951.8		0.0	186.5	0.185	34.5025	18021.4	57.4	266.9	17754.4	11895.48	5858.97
50	2500.0	0.465	14.95	11895.5		0.0	186.5	0.185	34.5025	12965.1	57.4	266.9	12698.1	8507.76	4190.39
51	2550.0	0.465	15.415	8507.8		0.0	186.5	0.185	34.5025	9577.3	57.4	266.9	9310.4	6237.99	3072.44
52	2600.0	0.465	15.88	27709.2	21471.2	0.0	186.5	0.185	34.5025	28778.7	57.4	266.9	28511.8	19102.93	9408.91
53	2650.0	0.465	16.345	19102.9		0.0	186.5	0.185	34.5025	20172.5	57.4	266.9	19905.6	13336.75	6568.85
54	2700.0	0.465	16.81	13336.8		0.0	186.5	0.185	34.5025	14406.3	57.4	266.9	14139.4	9473.41	4666.01
55	2750.0	0.465	17.275	9473.4		0.0	186.5	0.185	34.5025	10543.0	57.4	266.9	10276.1	6884.97	3391.11
56	2800.0	0.465	17.74	30919.8	24034.9	0.0	186.5	0.185	34.5025	31989.4	57.4	266.9	31722.5	21254.08	10468.43
57	2850.0	0.465	18.205	21254.1		0.0	186.5	0.185	34.5025	22323.7	57.4	266.9	22056.7	14778.02	7278.73
58	2900.0	0.465	18.67	14778.0		0.0	186.5	0.185	34.5025	15847.6	57.4	266.9	15580.7	10439.06	5141.63
59	2950.0	0.465	19.135	10439.1		0.0	186.5	0.185	34.5025	11508.6	57.4	266.9	11241.7	7531.96	3709.77
60	3000.0	0.465	19.6	34130.5	26598.6	0.0	186.5	0.185	34.5025	35200.1	57.4	266.9	34933.2	23405.23	11527.95
61	3050.0	0.77	20.37	23405.2		0.0	186.5	0.09	16.785	23925.6	57.4	442.0	23483.6	15734.00	7749.58
62	3100.0	0.77	21.14	15734.0		0.0	186.5	0.09	16.785	16254.3	57.4	442.0	15812.4	10594.28	5218.08
63	3150.0	0.77	21.91	10594.3		0.0	186.5	0.09	16.785	11114.6	57.4	442.0	10672.6	7150.66	3521.97
64	3200.0	0.77	22.68	35168.2	28017.6	0.0	186.5	0.09	16.785	35688.6	57.4	442.0	35246.6	23615.22	11631.38
65	3250.0	0.77	23.45	23615.2		0.0	186.5	0.09	16.785	24135.6	57.4	442.0	23693.6	15874.70	7818.88
66	3300.0	0.77	24.22	15874.7		0.0	186.5	0.09	16.785	16395.0	57.4	442.0	15953.1	10688.54	5264.51
67	3350.0	0.77	24.99	10688.5		0.0	186.5	0.09	16.785	11208.9	57.4	442.0	10766.9	7213.82	3553.08
68	3400.0	0.77	25.76	35481.7	28267.8	0.0	186.5	0.09	16.785	36002.0	57.4	442.0	35560.0	23825.21	11734.81
69	3450.0	0.77	26.53	23825.2		0.0	186.5	0.09	16.785	24345.5	57.4	442.0	23903.6	16015.39	7888.18
70	3500.0	0.77	27.3	16015.4		0.0	186.5	0.09	16.785	16535.7	57.4	442.0	16093.7	10782.81	5310.94
71	3550.0	0.77	28.07	10782.8		0.0	186.5	0.09	16.785	11303.1	57.4	442.0	10861.2	7276.98	3584.18
72	3600.0	0.77	28.84	35795.1	28518.1	0.0	186.5	0.09	16.785	36315.4	57.4	442.0	35873.4	24035.20	11838.23
73	3650.0	0.77	29.61	24035.2		0.0	186.5	0.09	16.785	24555.5	57.4	442.0	24113.6	16156.08	7957.47
74	3700.0	0.77	30.38	35951.8	19795.7	0.0	186.5	0.09	16.785	36472.1	57.4	442.0	36030.1	24140.20	11889.95
75	3750.0	0.77	31.15	24140.2		0.0	186.5	0.09	16.785	24660.5	57.4	442.0	24218.6	16226.43	7992.12
76	3800.0	0.77	31.92	36108.5	19882.1	0.0	186.5	0.09	16.785	36628.8	57.4	442.0	36186.9	24245.19	11941.66
77	3850.0	0.77	32.69	24245.2		0.0	186.5	0.09	16.785	24765.5	57.4	442.0	24323.5	16296.78	8026.77
78	3900.0	0.77	33.46	36265.2	19968.4	0.0	186.5	0.09	16.785	36785.5	57.4	442.0	36343.6	24350.19	11993.38
79	3950.0	0.77	34.23	24350.2		0.0	186.5	0.09	16.785	24870.5	57.4	442.0	24428.5	16367.13	8061.42
80	4000.0	0.77	35	36421.9	20054.8	0.0	186.5	0.09	16.785	36942.3	57.4	442.0	36500.3	24455.19	12045.09
				1141.2		1506.2									

Total water supply = 2647.4

Water re.＝Virtical percolation 13.6mm+Horizontal leakage 5mm+⑨ (ETc mm/mon.) ／days in month (ETc: calculated by CROPWAT-8)

②;=upper one column in ⑫ row (2/3×Horizontal leakage), at the intake point, larger one between the former value and supply target area×(ETc+Virtical 13.6mm+ Horizontal 5n

③;intake quantity of the total return flow in ⑬row after the previous intake point

④;resupply quantity in case of the total return flow being less than irrigation water requirement at the relevant intake point

⑤;=total flow rate at the dam site per month (estimated by the Tank Model Analysis) devided by catchment area 8.8km2 and devided by the days' number of the relevant month

Table 4-1-1-10(4) Calculation of Water Quantity for Supplemental Supply to the Paddy Field (April)

Apr. Water Re= 18.90 mm/day

		①		②	③	④	⑤	⑥	⑦=⑤×⑥	⑧=②+⑦×30	⑨	⑩=①×⑨×10000/1000	⑪=⑧-⑩	⑫=⑪×0.67	⑬=⑪×0.33
NO.	Distance (m)	Paddy Area (ha)	Cumulative Area (ha)	W.S./initial, return (m3/mon)	Intake quantity (m3/mon.)	Supplemental supply (m3/mon)	Specific discharge (m3/km2)	catchment area (km2)	Flow-in volume (m3/day)	Irrigation water (m3/mon)	ETc (mm/mon)	Water loss (m3/mon)	Residual water (m3/mon.	Horizontal leakage (m3/mon.)	Return to the river (m3/mon.)
1	50.0	0.18	0.18	1054.6			206.2	0.085	17.527	1598.0	9.0	16.2	1581.8	1059.78	521.98
2	100.0	0.18	0.36	2109.2	522.0	527.5	206.2	0.085	17.527	3180.1	9.0	16.2	3163.9	2119.79	1044.07
3	150.0	0.18	0.54	2119.8		0.0	206.2	0.085	17.527	2663.1	9.0	16.2	2646.9	1773.44	873.48
4	200.0	0.18	0.72	4082.4	1917.6	391.4	206.2	0.085	17.527	4625.7	9.0	16.2	4609.5	3088.39	1521.15
5	250.0	0.18	0.9	3088.4		0.0	206.2	0.085	17.527	3631.7	9.0	16.2	3615.5	2422.40	1193.12
6	300.0	0.18	1.08	2422.4		0.0	206.2	0.085	17.527	2965.7	9.0	16.2	2949.5	1976.19	973.35
7	350.0	0.18	1.26	1976.2		0.0	206.2	0.085	17.527	2519.5	9.0	16.2	2503.3	1677.23	826.10
8	400.0	0.18	1.44	6190.9	4513.7	0.0	206.2	0.085	17.527	6734.3	9.0	16.2	6718.1	4501.12	2216.97
9	450.0	0.18	1.62	4501.1		0.0	206.2	0.085	17.527	5044.5	9.0	16.2	5028.3	3368.93	1659.32
10	500.0	0.18	1.8	3368.9		0.0	206.2	0.085	17.527	3912.3	9.0	16.2	3896.1	2610.36	1285.70
11	550.0	0.18	1.98	2610.4		0.0	206.2	0.085	17.527	3153.7	9.0	16.2	3137.5	2102.13	1035.38
12	600.0	0.18	2.16	8299.5	6197.4	0.0	206.2	0.085	17.527	8842.8	9.0	16.2	8826.6	5913.84	2912.79
13	650.0	0.18	2.34	5913.8		0.0	206.2	0.085	17.527	6457.2	9.0	16.2	6441.0	4315.46	2125.52
14	700.0	0.18	2.52	4315.5		0.0	206.2	0.085	17.527	4858.8	9.0	16.2	4842.6	3244.54	1598.06
15	750.0	0.18	2.7	3244.5		0.0	206.2	0.085	17.527	3787.9	9.0	16.2	3771.7	2527.02	1244.65
16	800.0	0.18	2.88	10408.0	7881.0	0.0	206.2	0.085	17.527	10951.4	9.0	16.2	10935.2	7326.57	3608.61
17	850.0	0.18	3.06	7326.6		0.0	206.2	0.085	17.527	7869.9	9.0	16.2	7853.7	5261.98	2591.72
18	900.0	0.18	3.24	5262.0		0.0	206.2	0.085	17.527	5805.3	9.0	16.2	5789.1	3878.71	1910.41
19	950.0	0.18	3.42	3878.7		0.0	206.2	0.085	17.527	4422.0	9.0	16.2	4405.8	2951.92	1453.93
20	1000.0	0.18	3.6	12516.6	9564.7	0.0	206.2	0.085	17.527	13059.9	9.0	16.2	13043.7	8739.30	4304.43
21	1050.0	0.335	3.935	8739.3		0.0	206.2	0.1	20.62	9378.5	9.0	30.2	9348.4	6263.41	3084.96
22	1100.0	0.335	4.27	6263.4		0.0	206.2	0.1	20.62	6902.6	9.0	30.2	6872.5	4604.56	2267.92
23	1150.0	0.335	4.605	4604.6		0.0	206.2	0.1	20.62	5243.8	9.0	30.2	5213.6	3493.13	1720.50
24	1200.0	0.335	4.94	14870.9	11377.8	0.0	206.2	0.1	20.62	15510.2	9.0	30.2	15480.0	10371.61	5108.40
25	1250.0	0.335	5.275	10371.6		0.0	206.2	0.1	20.62	11010.8	9.0	30.2	10980.7	7357.05	3623.62
26	1300.0	0.335	5.61	7357.1		0.0	206.2	0.1	20.62	7996.3	9.0	30.2	7966.1	5337.30	2628.82
27	1350.0	0.335	5.945	5337.3		0.0	206.2	0.1	20.62	5976.5	9.0	30.2	5946.4	3984.07	1962.30
28	1400.0	0.335	6.28	17307.2	13323.1	0.0	206.2	0.1	20.62	17946.4	9.0	30.2	17916.3	12003.91	5912.38
29	1450.0	0.335	6.615	12003.9		0.0	206.2	0.1	20.62	12643.1	9.0	30.2	12613.0	8450.70	4162.28
30	1500.0	0.335	6.95	8450.7		0.0	206.2	0.1	20.62	9089.9	9.0	30.2	9059.8	6070.05	2989.72
31	1550.0	0.335	7.285	6070.0		0.0	206.2	0.1	20.62	6709.3	9.0	30.2	6679.1	4475.01	2204.11
32	1600.0	0.335	7.62	19743.5	15268.5	0.0	206.2	0.1	20.62	20382.7	9.0	30.2	20352.6	13636.22	6716.35
33	1650.0	0.335	7.955	13636.2		0.0	206.2	0.1	20.62	14275.4	9.0	30.2	14245.3	9544.35	4700.95
34	1700.0	0.335	8.29	9544.3		0.0	206.2	0.1	20.62	10183.6	9.0	30.2	10153.4	6802.79	3350.63
35	1750.0	0.335	8.625	6802.8		0.0	206.2	0.1	20.62	7442.0	9.0	30.2	7411.9	4965.94	2445.91
36	1800.0	0.335	8.96	22179.8	17213.8	0.0	206.2	0.1	20.62	22819.0	9.0	30.2	22788.8	15268.53	7520.32
37	1850.0	0.335	9.295	15268.5		0.0	206.2	0.1	20.62	15907.7	9.0	30.2	15877.6	10637.99	5239.61
38	1900.0	0.335	9.63	10638.0		0.0	206.2	0.1	20.62	11277.2	9.0	30.2	11247.1	7535.53	3711.53
39	1950.0	0.335	9.965	7535.5		0.0	206.2	0.1	20.62	8174.8	9.0	30.2	8144.6	5456.88	2687.72
40	2000.0	0.335	10.3	24616.1	19159.2	0.0	206.2	0.1	20.62	25255.3	9.0	30.2	25225.1	16900.84	8324.29
41	2050.0	0.465	10.765	16900.8		0.0	206.2	0.185	38.147	18083.4	9.0	41.9	18041.5	12087.83	5953.71
42	2100.0	0.465	11.23	12087.8		0.0	206.2	0.185	38.147	13270.4	9.0	41.9	13228.5	8863.12	4365.42
43	2150.0	0.465	11.695	8863.1		0.0	206.2	0.185	38.147	10045.7	9.0	41.9	10003.8	6702.57	3301.26
44	2200.0	0.465	12.16	28647.3	21944.7	0.0	206.2	0.185	38.147	29829.8	9.0	41.9	29788.0	19957.93	9830.03
45	2250.0	0.465	12.625	19957.9		0.0	206.2	0.185	38.147	21140.5	9.0	41.9	21098.6	14136.09	6962.55
46	2300.0	0.465	13.09	14136.1		0.0	206.2	0.185	38.147	15318.6	9.0	41.9	15276.8	10235.45	5041.34
47	2350.0	0.465	13.555	10235.5		0.0	206.2	0.185	38.147	11418.0	9.0	41.9	11376.2	7622.03	3754.13
48	2400.0	0.465	14.02	33210.1	25588.1	0.0	206.2	0.185	38.147	34392.6	9.0	41.9	34350.8	23015.03	11335.76
49	2450.0	0.465	14.485	23015.0		0.0	206.2	0.185	38.147	24197.6	9.0	41.9	24155.7	16184.34	7971.39
50	2500.0	0.465	14.95	16184.3		0.0	206.2	0.185	38.147	17366.9	9.0	41.9	17325.0	11607.78	5717.27
51	2550.0	0.465	15.415	11607.8		0.0	206.2	0.185	38.147	12790.3	9.0	41.9	12748.5	8541.49	4207.00
52	2600.0	0.465	15.88	37772.9	29231.4	0.0	206.2	0.185	38.147	38955.5	9.0	41.9	38913.6	26072.12	12841.49
53	2650.0	0.465	16.345	26072.1		0.0	206.2	0.185	38.147	27254.7	9.0	41.9	27212.8	18232.59	8980.23
54	2700.0	0.465	16.81	18232.6		0.0	206.2	0.185	38.147	19415.2	9.0	41.9	19373.3	12980.11	6393.19
55	2750.0	0.465	17.275	12980.1		0.0	206.2	0.185	38.147	14162.7	9.0	41.9	14120.8	9460.95	4659.87
56	2800.0	0.465	17.74	42335.7	32874.8	0.0	206.2	0.185	38.147	43518.3	9.0	41.9	43476.4	29129.22	14347.23
57	2850.0	0.465	18.205	29129.2		0.0	206.2	0.185	38.147	30311.8	9.0	41.9	30269.9	20280.85	9989.07
58	2900.0	0.465	18.67	20280.8		0.0	206.2	0.185	38.147	21463.4	9.0	41.9	21421.6	14352.44	7069.11
59	2950.0	0.465	19.135	14352.4		0.0	206.2	0.185	38.147	15535.0	9.0	41.9	15493.1	10380.41	5112.74
60	3000.0	0.465	19.6	46898.6	36518.2	0.0	206.2	0.185	38.147	48081.1	9.0	41.9	48039.3	32186.31	15852.96
61	3050.0	0.77	20.37	32186.3		0.0	206.2	0.09	18.558	32761.6	9.0	69.3	32692.3	21903.85	10788.46
62	3100.0	0.77	21.14	21903.8		0.0	206.2	0.09	18.558	22479.1	9.0	69.3	22409.8	15014.60	7395.25
63	3150.0	0.77	21.91	15014.6		0.0	206.2	0.09	18.558	15589.9	9.0	69.3	15520.6	10398.80	5121.80
64	3200.0	0.77	22.68	49557.3	39158.5	0.0	206.2	0.09	18.558	50132.6	9.0	69.3	50063.3	33542.38	16520.88
65	3250.0	0.77	23.45	33542.4		0.0	206.2	0.09	18.558	34117.7	9.0	69.3	34048.4	22812.42	11235.97
66	3300.0	0.77	24.22	22812.4		0.0	206.2	0.09	18.558	23387.7	9.0	69.3	23318.4	15623.34	7695.08
67	3350.0	0.77	24.99	15623.3		0.0	206.2	0.09	18.558	16198.6	9.0	69.3	16129.3	10806.65	5322.68
68	3400.0	0.77	25.76	51581.3	40774.6	0.0	206.2	0.09	18.558	52156.6	9.0	69.3	52087.3	34898.46	17188.79
69	3450.0	0.77	26.53	34898.5		0.0	206.2	0.09	18.558	35473.8	9.0	69.3	35404.5	23720.99	11683.47
70	3500.0	0.77	27.3	23721.0		0.0	206.2	0.09	18.558	24296.3	9.0	69.3	24227.0	16232.08	7994.90
71	3550.0	0.77	28.07	16232.1		0.0	206.2	0.09	18.558	16807.4	9.0	69.3	16738.1	11214.51	5523.57
72	3600.0	0.77	28.84	53605.2	42390.7	0.0	206.2	0.09	18.558	54180.5	9.0	69.3	54111.2	36254.53	17856.71
73	3650.0	0.77	29.61	36254.5		0.0	206.2	0.09	18.558	36829.8	9.0	69.3	36760.5	24629.56	12130.98
74	3700.0	0.77	30.38	54617.2	29987.7	0.0	206.2	0.09	18.558	55192.5	9.0	69.3	55123.2	36932.57	18190.67
75	3750.0	0.77	31.15	36932.6		0.0	206.2	0.09	18.558	37507.9	9.0	69.3	37438.6	25083.84	12354.73
76	3800.0	0.77	31.92	55629.2	30545.4	0.0	206.2	0.09	18.558	56204.5	9.0	69.3	56135.2	37610.61	18524.63
77	3850.0	0.77	32.69	37610.6		0.0	206.2	0.09	18.558	38185.9	9.0	69.3	38116.6	25538.13	12578.48
78	3900.0	0.77	33.46	56641.2	31103.1	0.0	206.2	0.09	18.558	57216.5	9.0	69.3	57147.2	38288.65	18858.59
79	3950.0	0.77	34.23	38288.6		0.0	206.2	0.09	18.558	38863.9	9.0	69.3	38794.6	25992.41	12802.23
80	4000.0	0.77	35	57653.2	31660.8	0.0	206.2	0.09	18.558	58228.5	9.0	69.3	58159.2	38966.68	19192.55
				1054.6		918.9									

Total water supply = 1973.5

Water re.＝Virtical percolation 13.6mm+Horizontal leakage 5mm+⑨ (ETc mm/mon.) ／days in month (ETc: calculated by CROPWAT-8)

②;=upper one column in ⑫ row (2/3×Horizontal leakage), at the intake point, larger one between the former value and supply target area×(ETc+Virtical 13.6mm+ Horizontal 5n

③;intake quantity of the total return flow in ⑬row after the previous intake point

④;resupply quantity in case of the total return flow being less than irrigation water requirement at the relevant intake point

⑤;=total flow rate at the dam site per month (estimated by the Tank Model Analysis) devided by catchment area 8.8km2 and devided by the days' number of the relevant month

Table 4-1-1-10(5) Calculation of Water Quantity for Supplemental Supply to the Paddy Field (May)

May Water Re= 19.70 mm/day

		①		②	③	④	⑤	⑥	⑦=⑤×⑥	⑧=②+⑦×31	⑨	⑩=①×⑨×10000/1000	⑪=⑧-⑩	⑫=⑪×0.67	⑬=⑪×0.33
NO.	Distance (m)	Paddy Area (ha)	Cumulative Area (ha)	W.S./initial, return (m3/mon)	Intake quantity (m3/mon.)	Supplemental supply (m3/mon)	Specific discharge (m3/km2)	catchment area (km2)	Flow-in volume (m3/day)	Irrigation water (m3/mon)	ETc (mm/mon)	Water loss (m3/mon)	Residual water (m3/mon.	Horizontal leakage (m3/mon.)	Return to the river (m3/mon.)
1	50.0	0.18	0.18	1099.1			373.4	0.085	31.739	2083.0	34.0	61.2	2021.8	1354.60	667.19
2	100.0	0.18	0.36	2198.2	667.2	176.4	373.4	0.085	31.739	3358.4	34.0	61.2	3297.2	2209.15	1088.09
3	150.0	0.18	0.54	2209.2		0.0	373.4	0.085	31.739	3193.1	34.0	61.2	3131.9	2098.35	1033.51
4	200.0	0.18	0.72	4396.3	2121.6	176.4	373.4	0.085	31.739	5380.2	34.0	61.2	5319.0	3563.75	1755.28
5	250.0	0.18	0.9	3563.7		0.0	373.4	0.085	31.739	4547.7	34.0	61.2	4486.5	3005.93	1480.53
6	300.0	0.18	1.08	3005.9		0.0	373.4	0.085	31.739	3989.8	34.0	61.2	3928.6	2632.19	1296.45
7	350.0	0.18	1.26	2632.2		0.0	373.4	0.085	31.739	3616.1	34.0	61.2	3554.9	2381.78	1173.12
8	400.0	0.18	1.44	8087.2	5705.4	0.0	373.4	0.085	31.739	9071.1	34.0	61.2	9009.9	6036.61	2973.26
9	450.0	0.18	1.62	6036.6		0.0	373.4	0.085	31.739	7020.5	34.0	61.2	6959.3	4662.74	2296.58
10	500.0	0.18	1.8	4662.7		0.0	373.4	0.085	31.739	5646.7	34.0	61.2	5585.5	3742.25	1843.20
11	550.0	0.18	1.98	3742.3		0.0	373.4	0.085	31.739	4726.2	34.0	61.2	4665.0	3125.52	1539.44
12	600.0	0.18	2.16	11778.0	8652.5	0.0	373.4	0.085	31.739	12761.9	34.0	61.2	12700.7	8509.47	4191.23
13	650.0	0.18	2.34	8509.5		0.0	373.4	0.085	31.739	9493.4	34.0	61.2	9432.2	6319.56	3112.62
14	700.0	0.18	2.52	6319.6		0.0	373.4	0.085	31.739	7303.5	34.0	61.2	7242.3	4852.32	2389.95
15	750.0	0.18	2.7	4852.3		0.0	373.4	0.085	31.739	5836.2	34.0	61.2	5775.0	3869.27	1905.76
16	800.0	0.18	2.88	15468.8	11599.6	0.0	373.4	0.085	31.739	16452.7	34.0	61.2	16391.5	10982.33	5409.21
17	850.0	0.18	3.06	10982.3		0.0	373.4	0.085	31.739	11966.2	34.0	61.2	11905.0	7976.38	3928.66
18	900.0	0.18	3.24	7976.4		0.0	373.4	0.085	31.739	8960.3	34.0	61.2	8899.1	5962.39	2936.70
19	950.0	0.18	3.42	5962.4		0.0	373.4	0.085	31.739	6946.3	34.0	61.2	6885.1	4613.01	2272.08
20	1000.0	0.18	3.6	19159.7	14546.6	0.0	373.4	0.085	31.739	20143.6	34.0	61.2	20082.4	13455.19	6627.18
21	1050.0	0.335	3.935	13455.2		0.0	373.4	0.1	37.34	14612.7	34.0	113.9	14498.8	9714.22	4784.61
22	1100.0	0.335	4.27	9714.2		0.0	373.4	0.1	37.34	10871.8	34.0	113.9	10757.9	7207.76	3550.09
23	1150.0	0.335	4.605	7207.8		0.0	373.4	0.1	37.34	8365.3	34.0	113.9	8251.4	5528.44	2722.96
24	1200.0	0.335	4.94	23213.3	17684.9	0.0	373.4	0.1	37.34	24370.8	34.0	113.9	24256.9	16252.15	8004.79
25	1250.0	0.335	5.275	16252.1		0.0	373.4	0.1	37.34	17409.7	34.0	113.9	17295.8	11588.18	5707.61
26	1300.0	0.335	5.61	11588.2		0.0	373.4	0.1	37.34	12745.7	34.0	113.9	12631.8	8463.32	4168.50
27	1350.0	0.335	5.945	8463.3		0.0	373.4	0.1	37.34	9620.9	34.0	113.9	9507.0	6369.66	3137.30
28	1400.0	0.335	6.28	27387.9	21018.2	0.0	373.4	0.1	37.34	28545.4	34.0	113.9	28431.5	19049.10	9382.39
29	1450.0	0.335	6.615	19049.1		0.0	373.4	0.1	37.34	20206.6	34.0	113.9	20092.7	13462.14	6630.60
30	1500.0	0.335	6.95	13462.1		0.0	373.4	0.1	37.34	14619.7	34.0	113.9	14505.8	9718.87	4786.91
31	1550.0	0.335	7.285	9718.9		0.0	373.4	0.1	37.34	10876.4	34.0	113.9	10762.5	7210.88	3551.63
32	1600.0	0.335	7.62	31562.4	24351.5	0.0	373.4	0.1	37.34	32720.0	34.0	113.9	32606.1	21846.06	10760.00
33	1650.0	0.335	7.955	21846.1		0.0	373.4	0.1	37.34	23003.6	34.0	113.9	22889.7	15336.10	7553.60
34	1700.0	0.335	8.29	15336.1		0.0	373.4	0.1	37.34	16493.6	34.0	113.9	16379.7	10974.42	5405.31
35	1750.0	0.335	8.625	10974.4		0.0	373.4	0.1	37.34	12132.0	34.0	113.9	12018.1	8052.10	3965.96
36	1800.0	0.335	8.96	35737.0	27684.9	0.0	373.4	0.1	37.34	36894.5	34.0	113.9	36780.6	24643.01	12137.60
37	1850.0	0.335	9.295	24643.0		0.0	373.4	0.1	37.34	25800.6	34.0	113.9	25686.7	17210.06	8476.59
38	1900.0	0.335	9.63	17210.1		0.0	373.4	0.1	37.34	18367.6	34.0	113.9	18253.7	12229.98	6023.72
39	1950.0	0.335	9.965	12230.0		0.0	373.4	0.1	37.34	13387.5	34.0	113.9	13273.6	8893.32	4380.29
40	2000.0	0.335	10.3	39911.5	31018.2	0.0	373.4	0.1	37.34	41069.1	34.0	113.9	40955.2	27439.97	13515.21
41	2050.0	0.465	10.765	27440.0		0.0	373.4	0.185	69.079	29581.4	34.0	158.1	29423.3	19713.62	9709.69
42	2100.0	0.465	11.23	19713.6		0.0	373.4	0.185	69.079	21855.1	34.0	158.1	21697.0	14536.97	7160.00
43	2150.0	0.465	11.695	14537.0		0.0	373.4	0.185	69.079	16678.4	34.0	158.1	16520.3	11068.61	5451.71
44	2200.0	0.465	12.16	46905.2	35836.6	0.0	373.4	0.185	69.079	49046.7	34.0	158.1	48888.6	32755.34	16133.23
45	2250.0	0.465	12.625	32755.3		0.0	373.4	0.185	69.079	34896.8	34.0	158.1	34738.7	23274.92	11463.77
46	2300.0	0.465	13.09	23274.9		0.0	373.4	0.185	69.079	25416.4	34.0	158.1	25258.3	16923.04	8335.23
47	2350.0	0.465	13.555	16923.0		0.0	373.4	0.185	69.079	19064.5	34.0	158.1	18906.4	12667.28	6239.11
48	2400.0	0.465	14.02	54838.6	42171.3	0.0	373.4	0.185	69.079	56980.1	34.0	158.1	56822.0	38070.72	18751.25
49	2450.0	0.465	14.485	38070.7		0.0	373.4	0.185	69.079	40212.2	34.0	158.1	40054.1	26836.22	13217.84
50	2500.0	0.465	14.95	26836.2		0.0	373.4	0.185	69.079	28977.7	34.0	158.1	28819.6	19309.11	9510.46
51	2550.0	0.465	15.415	19309.1		0.0	373.4	0.185	69.079	21450.6	34.0	158.1	21292.5	14265.95	7026.51
52	2600.0	0.465	15.88	62772.0	48506.1	0.0	373.4	0.185	69.079	64913.5	34.0	158.1	64755.4	43386.09	21369.27
53	2650.0	0.465	16.345	43386.1		0.0	373.4	0.185	69.079	45527.5	34.0	158.1	45369.4	30397.53	14971.92
54	2700.0	0.465	16.81	30397.5		0.0	373.4	0.185	69.079	32539.0	34.0	158.1	32380.9	21695.19	10685.69
55	2750.0	0.465	17.275	21695.2		0.0	373.4	0.185	69.079	23836.6	34.0	158.1	23678.5	15864.62	7813.92
56	2800.0	0.465	17.74	70705.4	54840.8	0.0	373.4	0.185	69.079	72846.9	34.0	158.1	72688.8	48701.47	23987.29
57	2850.0	0.465	18.205	48701.5		0.0	373.4	0.185	69.079	50842.9	34.0	158.1	50684.8	33958.83	16725.99
58	2900.0	0.465	18.67	33958.8		0.0	373.4	0.185	69.079	36100.3	34.0	158.1	35942.2	24081.26	11860.92
59	2950.0	0.465	19.135	24081.3		0.0	373.4	0.185	69.079	26222.7	34.0	158.1	26064.6	17463.29	8601.32
60	3000.0	0.465	19.6	78638.8	61175.5	0.0	373.4	0.185	69.079	80780.3	34.0	158.1	80622.2	54016.84	26605.31
61	3050.0	0.77	20.37	54016.8		0.0	373.4	0.09	33.606	55058.6	34.0	261.8	54796.8	36713.88	18082.95
62	3100.0	0.77	21.14	36713.9		0.0	373.4	0.09	33.606	37755.7	34.0	261.8	37493.9	25120.89	12372.97
63	3150.0	0.77	21.91	25120.9		0.0	373.4	0.09	33.606	26162.7	34.0	261.8	25900.9	17353.58	8547.29
64	3200.0	0.77	22.68	82962.1	65608.5	0.0	373.4	0.09	33.606	84003.9	34.0	261.8	83742.1	56107.20	27634.89
65	3250.0	0.77	23.45	56107.2		0.0	373.4	0.09	33.606	57149.0	34.0	261.8	56887.2	38114.42	18772.77
66	3300.0	0.77	24.22	38114.4		0.0	373.4	0.09	33.606	39156.2	34.0	261.8	38894.4	26059.25	12835.15
67	3350.0	0.77	24.99	26059.3		0.0	373.4	0.09	33.606	27101.0	34.0	261.8	26839.2	17982.29	8856.95
68	3400.0	0.77	25.76	86082.1	68099.8	0.0	373.4	0.09	33.606	87123.8	34.0	261.8	86862.0	58197.57	28664.47
69	3450.0	0.77	26.53	58197.6		0.0	373.4	0.09	33.606	59239.4	34.0	261.8	58977.6	39514.96	19462.59
70	3500.0	0.77	27.3	39515.0		0.0	373.4	0.09	33.606	40556.7	34.0	261.8	40294.9	26997.61	13297.33
71	3550.0	0.77	28.07	26997.6		0.0	373.4	0.09	33.606	28039.4	34.0	261.8	27777.6	18610.99	9166.61
72	3600.0	0.77	28.84	89202.0	70591.0	0.0	373.4	0.09	33.606	90243.8	34.0	261.8	89982.0	60287.93	29694.06
73	3650.0	0.77	29.61	60287.9		0.0	373.4	0.09	33.606	61329.7	34.0	261.8	61067.9	40915.50	20152.41
74	3700.0	0.77	30.38	90762.0	49846.5	0.0	373.4	0.09	33.606	91803.8	34.0	261.8	91542.0	61333.11	30208.85
75	3750.0	0.77	31.15	61333.1		0.0	373.4	0.09	33.606	62374.9	34.0	261.8	62113.1	41615.78	20497.32
76	3800.0	0.77	31.92	92321.9	50706.2	0.0	373.4	0.09	33.606	93363.7	34.0	261.8	93101.9	62378.29	30723.64
77	3850.0	0.77	32.69	62378.3		0.0	373.4	0.09	33.606	63420.1	34.0	261.8	63158.3	42316.05	20842.23
78	3900.0	0.77	33.46	93881.9	51565.9	0.0	373.4	0.09	33.606	94923.7	34.0	261.8	94661.9	63423.47	31238.43
79	3950.0	0.77	34.23	63423.5		0.0	373.4	0.09	33.606	64465.3	34.0	261.8	64203.5	43016.32	21187.14
80	4000.0	0.77	35	95441.9	52425.6	0.0	373.4	0.09	33.606	96483.7	34.0	261.8	96221.9	64468.65	31753.22
				1099.1		352.7									

Total water supply = 1451.8

Water re.＝Virtical percolation 13.6mm+Horizontal leakage 5mm+⑨ (ETc mm/mon.) ／days in month (ETc: calculated by CROPWAT-8)

②;=upper one column in ⑫ row (2/3×Horizontal leakage), at the intake point, larger one between the former value and supply target area×(ETc+Virtical 13.6mm+ Horizontal 5n

③;intake quantity of the total return flow in ⑬row after the previous intake point

④;resupply quantity in case of the total return flow being less than irrigation water requirement at the relevant intake point

⑤;=total flow rate at the dam site per month (estimated by the Tank Model Analysis) devided by catchment area 8.8km2 and devided by the days' number of the relevant month

Table 4-1-1-10(6) Calculation of Water Quantity for Supplemental Supply to the Paddy Field (June)

June Water Re= 21.47 mm/day

		①		②	③	④	⑤	⑥	⑦=⑤×⑥	⑧=②+⑦×30	⑨	⑩=①×⑨×10000/1000	⑪=⑧-⑩	⑫=⑪×0.67	⑬=⑪×0.33
NO.	Distance (m)	Paddy Area (ha)	Cumulative Area (ha)	W.S./initial, return (m3/mon)	Intake quantity (m3/mon.)	Supplemental supply (m3/mon)	Specific discharge (m3/km2)	catchment area (km2)	Flow-in volume (m3/day)	Irrigation water (m3/mon)	ETc (mm/mon)	Water loss (m3/mon)	Residual water (m3/mon.	Horizontal leakage (m3/mon.)	Return to the river (m3/mon.)
1	50.0	0.18	0.18	1197.8			147.3	0.085	12.5205	1586.0	86.0	154.8	1431.2	958.89	472.29
2	100.0	0.18	0.36	2395.7	472.3	964.5	147.3	0.085	12.5205	3748.3	86.0	154.8	3593.5	2407.66	1185.86
3	150.0	0.18	0.54	2407.7		0.0	147.3	0.085	12.5205	2795.8	86.0	154.8	2641.0	1769.47	871.53
4	200.0	0.18	0.72	4636.8	2057.4	809.9	147.3	0.085	12.5205	5024.9	86.0	154.8	4870.1	3262.99	1607.14
5	250.0	0.18	0.9	3263.0		0.0	147.3	0.085	12.5205	3651.1	86.0	154.8	3496.3	2342.54	1153.79
6	300.0	0.18	1.08	2342.5		0.0	147.3	0.085	12.5205	2730.7	86.0	154.8	2575.9	1725.84	850.04
7	350.0	0.18	1.26	1725.8		0.0	147.3	0.085	12.5205	2114.0	86.0	154.8	1959.2	1312.64	646.53
8	400.0	0.18	1.44	5570.1	4257.5	0.0	147.3	0.085	12.5205	5958.3	86.0	154.8	5803.5	3888.33	1915.15
9	450.0	0.18	1.62	3888.3		0.0	147.3	0.085	12.5205	4276.5	86.0	154.8	4121.7	2761.52	1360.15
10	500.0	0.18	1.8	2761.5		0.0	147.3	0.085	12.5205	3149.7	86.0	154.8	2994.9	2006.55	988.30
11	550.0	0.18	1.98	2006.6		0.0	147.3	0.085	12.5205	2394.7	86.0	154.8	2239.9	1500.72	739.16
12	600.0	0.18	2.16	6503.5	5002.8	0.0	147.3	0.085	12.5205	6891.6	86.0	154.8	6736.8	4513.67	2223.15
13	650.0	0.18	2.34	4513.7		0.0	147.3	0.085	12.5205	4901.8	86.0	154.8	4747.0	3180.49	1566.51
14	700.0	0.18	2.52	3180.5		0.0	147.3	0.085	12.5205	3568.6	86.0	154.8	3413.8	2287.27	1126.56
15	750.0	0.18	2.7	2287.3		0.0	147.3	0.085	12.5205	2675.4	86.0	154.8	2520.6	1688.80	831.80
16	800.0	0.18	2.88	7436.8	5748.0	0.0	147.3	0.085	12.5205	7825.0	86.0	154.8	7670.2	5139.01	2531.15
17	850.0	0.18	3.06	5139.0		0.0	147.3	0.085	12.5205	5527.1	86.0	154.8	5372.3	3599.47	1772.87
18	900.0	0.18	3.24	3599.5		0.0	147.3	0.085	12.5205	3987.6	86.0	154.8	3832.8	2567.98	1264.83
19	950.0	0.18	3.42	2568.0		0.0	147.3	0.085	12.5205	2956.1	86.0	154.8	2801.3	1876.88	924.43
20	1000.0	0.18	3.6	8370.2	6493.3	0.0	147.3	0.085	12.5205	8758.3	86.0	154.8	8603.5	5764.35	2839.16
21	1050.0	0.335	3.935	5764.3		0.0	147.3	0.1	14.73	6221.0	86.0	288.1	5932.9	3975.03	1957.85
22	1100.0	0.335	4.27	3975.0		0.0	147.3	0.1	14.73	4431.7	86.0	288.1	4143.6	2776.18	1367.37
23	1150.0	0.335	4.605	2776.2		0.0	147.3	0.1	14.73	3232.8	86.0	288.1	2944.7	1972.96	971.76
24	1200.0	0.335	4.94	9109.1	7136.1	0.0	147.3	0.1	14.73	9565.7	86.0	288.1	9277.6	6216.01	3061.62
25	1250.0	0.335	5.275	6216.0		0.0	147.3	0.1	14.73	6672.6	86.0	288.1	6384.5	4277.64	2106.90
26	1300.0	0.335	5.61	4277.6		0.0	147.3	0.1	14.73	4734.3	86.0	288.1	4446.2	2978.93	1467.24
27	1350.0	0.335	5.945	2978.9		0.0	147.3	0.1	14.73	3435.6	86.0	288.1	3147.5	2108.80	1038.66
28	1400.0	0.335	6.28	9783.2	7674.4	0.0	147.3	0.1	14.73	10239.8	86.0	288.1	9951.7	6667.67	3284.08
29	1450.0	0.335	6.615	6667.7		0.0	147.3	0.1	14.73	7124.3	86.0	288.1	6836.2	4580.25	2255.95
30	1500.0	0.335	6.95	4580.3		0.0	147.3	0.1	14.73	5036.9	86.0	288.1	4748.8	3181.68	1567.10
31	1550.0	0.335	7.285	3181.7		0.0	147.3	0.1	14.73	3638.3	86.0	288.1	3350.2	2244.64	1105.57
32	1600.0	0.335	7.62	10457.3	8212.7	0.0	147.3	0.1	14.73	10914.0	86.0	288.1	10625.9	7119.33	3506.53
33	1650.0	0.335	7.955	7119.3		0.0	147.3	0.1	14.73	7576.0	86.0	288.1	7287.9	4882.87	2404.99
34	1700.0	0.335	8.29	4882.9		0.0	147.3	0.1	14.73	5339.5	86.0	288.1	5051.4	3384.43	1666.96
35	1750.0	0.335	8.625	3384.4		0.0	147.3	0.1	14.73	3841.1	86.0	288.1	3553.0	2380.49	1172.48
36	1800.0	0.335	8.96	11131.5	8751.0	0.0	147.3	0.1	14.73	11588.1	86.0	288.1	11300.0	7570.99	3728.99
37	1850.0	0.335	9.295	7571.0		0.0	147.3	0.1	14.73	8027.6	86.0	288.1	7739.5	5185.48	2554.04
38	1900.0	0.335	9.63	5185.5		0.0	147.3	0.1	14.73	5642.1	86.0	288.1	5354.0	3587.19	1766.82
39	1950.0	0.335	9.965	3587.2		0.0	147.3	0.1	14.73	4043.8	86.0	288.1	3755.7	2516.33	1239.39
40	2000.0	0.335	10.3	11805.6	9289.2	0.0	147.3	0.1	14.73	12262.2	86.0	288.1	11974.1	8022.65	3951.45
41	2050.0	0.465	10.765	8022.6		0.0	147.3	0.185	27.2505	8867.4	86.0	399.9	8467.5	5673.23	2794.28
42	2100.0	0.465	11.23	5673.2		0.0	147.3	0.185	27.2505	6518.0	86.0	399.9	6118.1	4099.13	2018.97
43	2150.0	0.465	11.695	4099.1		0.0	147.3	0.185	27.2505	4943.9	86.0	399.9	4544.0	3044.48	1499.52
44	2200.0	0.465	12.16	13308.7	10264.2	0.0	147.3	0.185	27.2505	14153.5	86.0	399.9	13753.6	9214.89	4538.68
45	2250.0	0.465	12.625	9214.9		0.0	147.3	0.185	27.2505	10059.7	86.0	399.9	9659.8	6472.04	3187.72
46	2300.0	0.465	13.09	6472.0		0.0	147.3	0.185	27.2505	7316.8	86.0	399.9	6916.9	4634.32	2282.58
47	2350.0	0.465	13.555	4634.3		0.0	147.3	0.185	27.2505	5479.1	86.0	399.9	5079.2	3403.06	1676.13
48	2400.0	0.465	14.02	15088.2	11685.1	0.0	147.3	0.185	27.2505	15932.9	86.0	399.9	15533.0	10407.13	5125.90
49	2450.0	0.465	14.485	10407.1		0.0	147.3	0.185	27.2505	11251.9	86.0	399.9	10852.0	7270.84	3581.16
50	2500.0	0.465	14.95	7270.8		0.0	147.3	0.185	27.2505	8115.6	86.0	399.9	7715.7	5169.52	2546.18
51	2550.0	0.465	15.415	5169.5		0.0	147.3	0.185	27.2505	6014.3	86.0	399.9	5614.4	3761.64	1852.75
52	2600.0	0.465	15.88	16867.6	13106.0	0.0	147.3	0.185	27.2505	17712.4	86.0	399.9	17312.5	11599.37	5713.12
53	2650.0	0.465	16.345	11599.4		0.0	147.3	0.185	27.2505	12444.1	86.0	399.9	12044.2	8069.64	3974.60
54	2700.0	0.465	16.81	8069.6		0.0	147.3	0.185	27.2505	8914.4	86.0	399.9	8514.5	5704.72	2809.79
55	2750.0	0.465	17.275	5704.7		0.0	147.3	0.185	27.2505	6549.5	86.0	399.9	6149.6	4120.22	2029.36
56	2800.0	0.465	17.74	18647.1	14526.9	0.0	147.3	0.185	27.2505	19491.9	86.0	399.9	19092.0	12791.61	6300.34
57	2850.0	0.465	18.205	12791.6		0.0	147.3	0.185	27.2505	13636.4	86.0	399.9	13236.5	8868.44	4368.04
58	2900.0	0.465	18.67	8868.4		0.0	147.3	0.185	27.2505	9713.2	86.0	399.9	9313.3	6239.91	3073.39
59	2950.0	0.465	19.135	6239.9		0.0	147.3	0.185	27.2505	7084.7	86.0	399.9	6684.8	4478.80	2205.98
60	3000.0	0.465	19.6	20426.5	15947.7	0.0	147.3	0.185	27.2505	21271.3	86.0	399.9	20871.4	13983.85	6887.57
61	3050.0	0.77	20.37	13983.8		0.0	147.3	0.09	13.257	14394.8	86.0	662.2	13732.6	9200.85	4531.76
62	3100.0	0.77	21.14	9200.9		0.0	147.3	0.09	13.257	9611.8	86.0	662.2	8949.6	5996.24	2953.37
63	3150.0	0.77	21.91	5996.2		0.0	147.3	0.09	13.257	6407.2	86.0	662.2	5745.0	3849.16	1895.85
64	3200.0	0.77	22.68	20117.7	16268.6	0.0	147.3	0.09	13.257	20528.7	86.0	662.2	19866.5	13310.54	6555.94
65	3250.0	0.77	23.45	13310.5		0.0	147.3	0.09	13.257	13721.5	86.0	662.2	13059.3	8749.74	4309.57
66	3300.0	0.77	24.22	8749.7		0.0	147.3	0.09	13.257	9160.7	86.0	662.2	8498.5	5694.00	2804.51
67	3350.0	0.77	24.99	5694.0		0.0	147.3	0.09	13.257	6105.0	86.0	662.2	5442.8	3646.65	1796.11
68	3400.0	0.77	25.76	19835.2	15466.1	722.4	147.3	0.09	13.257	20246.2	86.0	662.2	19584.0	13121.26	6462.71
69	3450.0	0.77	26.53	13121.3		0.0	147.3	0.09	13.257	13532.2	86.0	662.2	12870.0	8622.92	4247.11
70	3500.0	0.77	27.3	8622.9		0.0	147.3	0.09	13.257	9033.9	86.0	662.2	8371.7	5609.03	2762.66
71	3550.0	0.77	28.07	5609.0		0.0	147.3	0.09	13.257	6020.0	86.0	662.2	5357.8	3589.72	1768.07
72	3600.0	0.77	28.84	18830.3	15240.5	0.0	147.3	0.09	13.257	19241.2	86.0	662.2	18579.0	12447.95	6131.08
73	3650.0	0.77	29.61	12448.0		0.0	147.3	0.09	13.257	12858.9	86.0	662.2	12196.7	8171.80	4024.92
74	3700.0	0.77	30.38	18327.8	10156.0	0.0	147.3	0.09	13.257	18738.8	86.0	662.2	18076.6	12111.30	5965.27
75	3750.0	0.77	31.15	12111.3		0.0	147.3	0.09	13.257	12522.3	86.0	662.2	11860.1	7946.25	3913.82
76	3800.0	0.77	31.92	17825.3	9879.1	0.0	147.3	0.09	13.257	18236.3	86.0	662.2	17574.1	11774.65	5799.45
77	3850.0	0.77	32.69	11774.6		0.0	147.3	0.09	13.257	12185.6	86.0	662.2	11523.4	7720.69	3802.73
78	3900.0	0.77	33.46	17322.9	9602.2	0.0	147.3	0.09	13.257	17733.8	86.0	662.2	17071.6	11438.00	5633.64
79	3950.0	0.77	34.23	11438.0		0.0	147.3	0.09	13.257	11849.0	86.0	662.2	11186.8	7495.13	3691.63
80	4000.0	0.77	35	16820.4	9325.3	0.0	147.3	0.09	13.257	17231.4	86.0	662.2	16569.2	11101.34	5467.83
				1197.8		2496.9									

Total water supply = 3694.7

Water re.＝Virtical percolation 13.6mm+Horizontal leakage 5mm+⑨ (ETc mm/mon.) ／days in month (ETc: calculated by CROPWAT-8)

②;=upper one column in ⑫ row (2/3×Horizontal leakage), at the intake point, larger one between the former value and supply target area×(ETc+Virtical 13.6mm+ Horizontal 5n

③;intake quantity of the total return flow in ⑬row after the previous intake point

④;resupply quantity in case of the total return flow being less than irrigation water requirement at the relevant intake point

⑤;=total flow rate at the dam site per month (estimated by the Tank Model Analysis) devided by catchment area 8.8km2 and devided by the days' number of the relevant month

Table 4-1-1-10(7) Calculation of Water Quantity for Supplemental Supply to the Paddy Field (July)

July Water Re= 18.93 mm/day

		①		②	③	④	⑤	⑥	⑦=⑤×⑥	⑧=②+⑦×31	⑨	⑩=①×⑨×10000/1000	⑪=⑧-⑩	⑫=⑪×0.67	⑬=⑪×0.33
NO.	Distance (m)	Paddy Area (ha)	Cumulative Area (ha)	W.S./initial, return (m3/mon)	Intake quantity (m3/mon.)	Supplemental supply (m3/mon)	Specific discharge (m3/km2)	catchment area (km2)	Flow-in volume (m3/day)	Irrigation water (m3/mon)	ETc (mm/mon)	Water loss (m3/mon)	Residual water (m3/mon.	Horizontal leakage (m3/mon.)	Return to the river (m3/mon.)
1	50.0	0.18	0.18	1056.4			82.0	0.085	6.97	1272.5	10.3	18.5	1254.0	840.15	413.80
2	100.0	0.18	0.36	2112.8	413.8	858.9	82.0	0.085	6.97	3187.8	10.3	18.5	3169.3	2123.40	1045.86
3	150.0	0.18	0.54	2123.4		0.0	82.0	0.085	6.97	2339.5	10.3	18.5	2320.9	1555.03	765.91
4	200.0	0.18	0.72	4225.7	1811.8	858.9	82.0	0.085	6.97	4441.8	10.3	18.5	4423.2	2963.55	1459.66
5	250.0	0.18	0.9	2963.6		0.0	82.0	0.085	6.97	3179.6	10.3	18.5	3161.1	2117.92	1043.16
6	300.0	0.18	1.08	2117.9		0.0	82.0	0.085	6.97	2334.0	10.3	18.5	2315.5	1551.35	764.10
7	350.0	0.18	1.26	1551.4		0.0	82.0	0.085	6.97	1767.4	10.3	18.5	1748.9	1171.75	577.13
8	400.0	0.18	1.44	5015.8	3844.0	0.0	82.0	0.085	6.97	5231.9	10.3	18.5	5213.3	3492.93	1720.40
9	450.0	0.18	1.62	3492.9		0.0	82.0	0.085	6.97	3709.0	10.3	18.5	3690.5	2472.61	1217.85
10	500.0	0.18	1.8	2472.6		0.0	82.0	0.085	6.97	2688.7	10.3	18.5	2670.1	1788.99	881.15
11	550.0	0.18	1.98	1789.0		0.0	82.0	0.085	6.97	2005.1	10.3	18.5	1986.5	1330.97	655.55
12	600.0	0.18	2.16	5805.9	4474.9	0.0	82.0	0.085	6.97	6022.0	10.3	18.5	6003.5	4022.31	1981.14
13	650.0	0.18	2.34	4022.3		0.0	82.0	0.085	6.97	4238.4	10.3	18.5	4219.8	2827.29	1392.55
14	700.0	0.18	2.52	2827.3		0.0	82.0	0.085	6.97	3043.4	10.3	18.5	3024.8	2026.63	998.19
15	750.0	0.18	2.7	2026.6		0.0	82.0	0.085	6.97	2242.7	10.3	18.5	2224.2	1490.19	733.97
16	800.0	0.18	2.88	6596.0	5105.9	0.0	82.0	0.085	6.97	6812.1	10.3	18.5	6793.6	4551.69	2241.88
17	850.0	0.18	3.06	4551.7		0.0	82.0	0.085	6.97	4767.8	10.3	18.5	4749.2	3181.98	1567.24
18	900.0	0.18	3.24	3182.0		0.0	82.0	0.085	6.97	3398.0	10.3	18.5	3379.5	2264.27	1115.24
19	950.0	0.18	3.42	2264.3		0.0	82.0	0.085	6.97	2480.3	10.3	18.5	2461.8	1649.41	812.39
20	1000.0	0.18	3.6	7386.2	5736.8	0.0	82.0	0.085	6.97	7602.2	10.3	18.5	7583.7	5081.07	2502.62
21	1050.0	0.335	3.935	5081.1		0.0	82.0	0.1	8.2	5335.3	10.3	34.5	5300.8	3551.51	1749.25
22	1100.0	0.335	4.27	3551.5		0.0	82.0	0.1	8.2	3805.7	10.3	34.5	3771.2	2526.71	1244.50
23	1150.0	0.335	4.605	2526.7		0.0	82.0	0.1	8.2	2780.9	10.3	34.5	2746.4	1840.09	906.31
24	1200.0	0.335	4.94	8242.8	6402.7	0.0	82.0	0.1	8.2	8497.0	10.3	34.5	8462.5	5669.85	2792.62
25	1250.0	0.335	5.275	5669.9		0.0	82.0	0.1	8.2	5924.1	10.3	34.5	5889.5	3946.00	1943.55
26	1300.0	0.335	5.61	3946.0		0.0	82.0	0.1	8.2	4200.2	10.3	34.5	4165.7	2791.01	1374.68
27	1350.0	0.335	5.945	2791.0		0.0	82.0	0.1	8.2	3045.2	10.3	34.5	3010.7	2017.18	993.53
28	1400.0	0.335	6.28	9121.6	7104.4	0.0	82.0	0.1	8.2	9375.8	10.3	34.5	9341.3	6258.64	3082.61
29	1450.0	0.335	6.615	6258.6		0.0	82.0	0.1	8.2	6512.8	10.3	34.5	6478.3	4340.48	2137.85
30	1500.0	0.335	6.95	4340.5		0.0	82.0	0.1	8.2	4594.7	10.3	34.5	4560.2	3055.32	1504.86
31	1550.0	0.335	7.285	3055.3		0.0	82.0	0.1	8.2	3309.5	10.3	34.5	3275.0	2194.26	1080.75
32	1600.0	0.335	7.62	10000.3	7806.1	0.0	82.0	0.1	8.2	10254.5	10.3	34.5	10220.0	6847.42	3372.61
33	1650.0	0.335	7.955	6847.4		0.0	82.0	0.1	8.2	7101.6	10.3	34.5	7067.1	4734.97	2332.15
34	1700.0	0.335	8.29	4735.0		0.0	82.0	0.1	8.2	4989.2	10.3	34.5	4954.7	3319.62	1635.04
35	1750.0	0.335	8.625	3319.6		0.0	82.0	0.1	8.2	3573.8	10.3	34.5	3539.3	2371.34	1167.98
36	1800.0	0.335	8.96	10879.1	8507.8	0.0	82.0	0.1	8.2	11133.3	10.3	34.5	11098.8	7436.20	3662.61
37	1850.0	0.335	9.295	7436.2		0.0	82.0	0.1	8.2	7690.4	10.3	34.5	7655.9	5129.45	2526.45
38	1900.0	0.335	9.63	5129.5		0.0	82.0	0.1	8.2	5383.7	10.3	34.5	5349.1	3583.93	1765.22
39	1950.0	0.335	9.965	3583.9		0.0	82.0	0.1	8.2	3838.1	10.3	34.5	3803.6	2548.43	1255.20
40	2000.0	0.335	10.3	11757.9	9209.5	0.0	82.0	0.1	8.2	12012.1	10.3	34.5	11977.6	8024.99	3952.60
41	2050.0	0.465	10.765	8025.0		0.0	82.0	0.185	15.17	8495.3	10.3	47.9	8447.4	5659.73	2787.63
42	2100.0	0.465	11.23	5659.7		0.0	82.0	0.185	15.17	6130.0	10.3	47.9	6082.1	4075.01	2007.10
43	2150.0	0.465	11.695	4075.0		0.0	82.0	0.185	15.17	4545.3	10.3	47.9	4497.4	3013.25	1484.14
44	2200.0	0.465	12.16	13244.7	10231.5	0.0	82.0	0.185	15.17	13715.0	10.3	47.9	13667.1	9156.95	4510.14
45	2250.0	0.465	12.625	9157.0		0.0	82.0	0.185	15.17	9627.2	10.3	47.9	9579.3	6418.15	3161.18
46	2300.0	0.465	13.09	6418.1		0.0	82.0	0.185	15.17	6888.4	10.3	47.9	6840.5	4583.15	2257.37
47	2350.0	0.465	13.555	4583.2		0.0	82.0	0.185	15.17	5053.4	10.3	47.9	5005.5	3353.70	1651.82
48	2400.0	0.465	14.02	14934.2	11580.5	0.0	82.0	0.185	15.17	15404.5	10.3	47.9	15356.6	10288.92	5067.67
49	2450.0	0.465	14.485	10288.9		0.0	82.0	0.185	15.17	10759.2	10.3	47.9	10711.3	7176.56	3534.73
50	2500.0	0.465	14.95	7176.6		0.0	82.0	0.185	15.17	7646.8	10.3	47.9	7598.9	5091.29	2507.65
51	2550.0	0.465	15.415	5091.3		0.0	82.0	0.185	15.17	5561.6	10.3	47.9	5513.7	3694.16	1819.51
52	2600.0	0.465	15.88	16623.7	12929.6	0.0	82.0	0.185	15.17	17094.0	10.3	47.9	17046.1	11420.88	5625.21
53	2650.0	0.465	16.345	11420.9		0.0	82.0	0.185	15.17	11891.2	10.3	47.9	11843.3	7934.98	3908.27
54	2700.0	0.465	16.81	7935.0		0.0	82.0	0.185	15.17	8405.3	10.3	47.9	8357.4	5599.43	2757.93
55	2750.0	0.465	17.275	5599.4		0.0	82.0	0.185	15.17	6069.7	10.3	47.9	6021.8	4034.61	1987.20
56	2800.0	0.465	17.74	18313.2	14278.6	0.0	82.0	0.185	15.17	18783.5	10.3	47.9	18735.6	12552.85	6182.74
57	2850.0	0.465	18.205	12552.8		0.0	82.0	0.185	15.17	13023.1	10.3	47.9	12975.2	8693.40	4281.82
58	2900.0	0.465	18.67	8693.4		0.0	82.0	0.185	15.17	9163.7	10.3	47.9	9115.8	6107.57	3008.20
59	2950.0	0.465	19.135	6107.6		0.0	82.0	0.185	15.17	6577.8	10.3	47.9	6529.9	4375.06	2154.88
60	3000.0	0.465	19.6	20002.7	15627.7	0.0	82.0	0.185	15.17	20473.0	10.3	47.9	20425.1	13684.81	6740.28
61	3050.0	0.77	20.37	13684.8		0.0	82.0	0.09	7.38	13913.6	10.3	79.3	13834.3	9268.97	4565.31
62	3100.0	0.77	21.14	9269.0		0.0	82.0	0.09	7.38	9497.7	10.3	79.3	9418.4	6310.35	3108.08
63	3150.0	0.77	21.91	6310.4		0.0	82.0	0.09	7.38	6539.1	10.3	79.3	6459.8	4328.08	2131.74
64	3200.0	0.77	22.68	20873.5	16545.4	0.0	82.0	0.09	7.38	21102.3	10.3	79.3	21023.0	14085.39	6937.58
65	3250.0	0.77	23.45	14085.4		0.0	82.0	0.09	7.38	14314.2	10.3	79.3	14234.9	9537.36	4697.50
66	3300.0	0.77	24.22	9537.4		0.0	82.0	0.09	7.38	9766.1	10.3	79.3	9686.8	6490.17	3196.65
67	3350.0	0.77	24.99	6490.2		0.0	82.0	0.09	7.38	6719.0	10.3	79.3	6639.6	4448.56	2191.08
68	3400.0	0.77	25.76	21471.4	17022.8	0.0	82.0	0.09	7.38	21700.2	10.3	79.3	21620.9	14485.97	7134.88
69	3450.0	0.77	26.53	14486.0		0.0	82.0	0.09	7.38	14714.7	10.3	79.3	14635.4	9805.74	4829.70
70	3500.0	0.77	27.3	9805.7		0.0	82.0	0.09	7.38	10034.5	10.3	79.3	9955.2	6669.99	3285.22
71	3550.0	0.77	28.07	6670.0		0.0	82.0	0.09	7.38	6898.8	10.3	79.3	6819.5	4569.04	2250.42
72	3600.0	0.77	28.84	22069.3	17500.2	0.0	82.0	0.09	7.38	22298.0	10.3	79.3	22218.7	14886.55	7332.18
73	3650.0	0.77	29.61	14886.5		0.0	82.0	0.09	7.38	15115.3	10.3	79.3	15036.0	10074.13	4961.89
74	3700.0	0.77	30.38	22368.2	12294.1	0.0	82.0	0.09	7.38	22597.0	10.3	79.3	22517.7	15086.84	7430.83
75	3750.0	0.77	31.15	15086.8		0.0	82.0	0.09	7.38	15315.6	10.3	79.3	15236.3	10208.33	5027.98
76	3800.0	0.77	31.92	22667.1	12458.8	0.0	82.0	0.09	7.38	22895.9	10.3	79.3	22816.6	15287.13	7529.48
77	3850.0	0.77	32.69	15287.1		0.0	82.0	0.09	7.38	15515.9	10.3	79.3	15436.6	10342.52	5094.08
78	3900.0	0.77	33.46	22966.1	12623.6	0.0	82.0	0.09	7.38	23194.9	10.3	79.3	23115.6	15487.42	7628.13
79	3950.0	0.77	34.23	15487.4		0.0	82.0	0.09	7.38	15716.2	10.3	79.3	15636.9	10476.72	5160.17
80	4000.0	0.77	35	23265.0	12788.3	0.0	82.0	0.09	7.38	23493.8	10.3	79.3	23414.5	15687.71	7726.78
				1056.4		1717.8									

Total water supply = 2774.2

Water re.＝Virtical percolation 13.6mm+Horizontal leakage 5mm+⑨ (ETc mm/mon.) ／days in month (ETc: calculated by CROPWAT-8)
②;=upper one column in ⑫ row (2/3×Horizontal leakage), at the intake point, larger one between the former value and supply target area×(ETc+Virtical 13.6mm+ Horizontal 5n
③;intake quantity of the total return flow in ⑬row after the previous intake point
④;resupply quantity in case of the total return flow being less than irrigation water requirement at the relevant intake point
⑤;=total flow rate at the dam site per month (estimated by the Tank Model Analysis) devided by catchment area 8.8km2 and devided by the days' number of the relevant month

Table 4-1-1-10(8) Calculation of Water Quantity for Supplemental Supply to the Paddy Field (August)

Aug. Water Re= 23.97 mm/day

NO.	Distance (m)	① Paddy Area (ha)	Cumulative Area (ha)	② W.S./initial, return (m3/mon)	③ Intake quantity (m3/mon.)	④ Supplemental supply (m3/mon)	⑤ Specific discharge (m3/km2)	⑥ catchment area (km2)	⑦=⑤×⑥ Flow-in volume (m3/day)	⑧=②+⑦×31 Irrigation water (m3/mon)	⑨ ETc (mm/mon)	⑩=①×⑨×10000/1000 Water loss (m3/mon)	⑪=⑧-⑩ Residual water (m3/mon.)	⑫=⑪×0.67 Horizontal leakage (m3/mon.)	⑬=⑪×0.33 Return to the river (m3/mon.)
1	50.0	0.18	0.18	1337.4			92.2	0.085	7.837	1580.3	166.4	299.5	1280.8	858.15	422.67
2	100.0	0.18	0.36	2674.8	422.7	1394.0	92.2	0.085	7.837	4311.7	166.4	299.5	4012.2	2688.17	1324.03
3	150.0	0.18	0.54	2688.2		0.0	92.2	0.085	7.837	2931.1	166.4	299.5	2631.6	1763.17	868.43
4	200.0	0.18	0.72	5349.6	2192.5	1394.0	92.2	0.085	7.837	5592.5	166.4	299.5	5293.0	3546.33	1746.70
5	250.0	0.18	0.9	3546.3		0.0	92.2	0.085	7.837	3789.3	166.4	299.5	3489.8	2338.14	1151.62
6	300.0	0.18	1.08	2338.1		0.0	92.2	0.085	7.837	2581.1	166.4	299.5	2281.6	1528.65	752.92
7	350.0	0.18	1.26	1528.6		0.0	92.2	0.085	7.837	1771.6	166.4	299.5	1472.1	986.29	485.78
8	400.0	0.18	1.44	5349.6	4137.0	226.3	92.2	0.085	7.837	5592.5	166.4	299.5	5293.0	3546.33	1746.70
9	450.0	0.18	1.62	3546.3		0.0	92.2	0.085	7.837	3789.3	166.4	299.5	3489.8	2338.14	1151.62
10	500.0	0.18	1.8	2338.1		0.0	92.2	0.085	7.837	2581.1	166.4	299.5	2281.6	1528.65	752.92
11	550.0	0.18	1.98	1528.6		0.0	92.2	0.085	7.837	1771.6	166.4	299.5	1472.1	986.29	485.78
12	600.0	0.18	2.16	5349.6	4137.0	226.3	92.2	0.085	7.837	5592.5	166.4	299.5	5293.0	3546.33	1746.70
13	650.0	0.18	2.34	3546.3		0.0	92.2	0.085	7.837	3789.3	166.4	299.5	3489.8	2338.14	1151.62
14	700.0	0.18	2.52	2338.1		0.0	92.2	0.085	7.837	2581.1	166.4	299.5	2281.6	1528.65	752.92
15	750.0	0.18	2.7	1528.6		0.0	92.2	0.085	7.837	1771.6	166.4	299.5	1472.1	986.29	485.78
16	800.0	0.18	2.88	5349.6	4137.0	226.3	92.2	0.085	7.837	5592.5	166.4	299.5	5293.0	3546.33	1746.70
17	850.0	0.18	3.06	3546.3		0.0	92.2	0.085	7.837	3789.3	166.4	299.5	3489.8	2338.14	1151.62
18	900.0	0.18	3.24	2338.1		0.0	92.2	0.085	7.837	2581.1	166.4	299.5	2281.6	1528.65	752.92
19	950.0	0.18	3.42	1528.6		0.0	92.2	0.085	7.837	1771.6	166.4	299.5	1472.1	986.29	485.78
20	1000.0	0.18	3.6	8804.6	4137.0	3681.2	92.2	0.085	7.837	9047.5	166.4	299.5	8748.0	5861.14	2886.83
21	1050.0	0.335	3.935	5861.1		0.0	92.2	0.1	9.22	6147.0	166.4	557.4	5589.5	3744.98	1844.54
22	1100.0	0.335	4.27	3745.0		0.0	92.2	0.1	9.22	4030.8	166.4	557.4	3473.4	2327.15	1146.21
23	1150.0	0.335	4.605	2327.2		0.0	92.2	0.1	9.22	2613.0	166.4	557.4	2055.5	1377.21	678.33
24	1200.0	0.335	4.94	9956.2	6555.9	2023.1	92.2	0.1	9.22	10242.0	166.4	557.4	9684.6	6488.67	3195.91
25	1250.0	0.335	5.275	6488.7		0.0	92.2	0.1	9.22	6774.5	166.4	557.4	6217.0	4165.42	2051.63
26	1300.0	0.335	5.61	4165.4		0.0	92.2	0.1	9.22	4451.2	166.4	557.4	3893.8	2608.85	1284.95
27	1350.0	0.335	5.945	2608.8		0.0	92.2	0.1	9.22	2894.7	166.4	557.4	2337.2	1565.94	771.29
28	1400.0	0.335	6.28	9956.2	7303.8	1086.5	92.2	0.1	9.22	10242.0	166.4	557.4	9684.6	6488.67	3195.91
29	1450.0	0.335	6.615	6488.7		0.0	92.2	0.1	9.22	6774.5	166.4	557.4	6217.0	4165.42	2051.63
30	1500.0	0.335	6.95	4165.4		0.0	92.2	0.1	9.22	4451.2	166.4	557.4	3893.8	2608.85	1284.95
31	1550.0	0.335	7.285	2608.8		0.0	92.2	0.1	9.22	2894.7	166.4	557.4	2337.2	1565.94	771.29
32	1600.0	0.335	7.62	9956.2	7303.8	1086.5	92.2	0.1	9.22	10242.0	166.4	557.4	9684.6	6488.67	3195.91
33	1650.0	0.335	7.955	6488.7		0.0	92.2	0.1	9.22	6774.5	166.4	557.4	6217.0	4165.42	2051.63
34	1700.0	0.335	8.29	4165.4		0.0	92.2	0.1	9.22	4451.2	166.4	557.4	3893.8	2608.85	1284.95
35	1750.0	0.335	8.625	2608.8		0.0	92.2	0.1	9.22	2894.7	166.4	557.4	2337.2	1565.94	771.29
36	1800.0	0.335	8.96	9956.2	7303.8	1086.5	92.2	0.1	9.22	10242.0	166.4	557.4	9684.6	6488.67	3195.91
37	1850.0	0.335	9.295	6488.7		0.0	92.2	0.1	9.22	6774.5	166.4	557.4	6217.0	4165.42	2051.63
38	1900.0	0.335	9.63	4165.4		0.0	92.2	0.1	9.22	4451.2	166.4	557.4	3893.8	2608.85	1284.95
39	1950.0	0.335	9.965	2608.8		0.0	92.2	0.1	9.22	2894.7	166.4	557.4	2337.2	1565.94	771.29
40	2000.0	0.335	10.3	12853.9	7303.8	3984.2	92.2	0.1	9.22	13139.7	166.4	557.4	12582.3	8430.13	4152.15
41	2050.0	0.465	10.765	8430.1		0.0	92.2	0.185	17.057	8958.9	166.4	773.8	8185.1	5484.04	2701.09
42	2100.0	0.465	11.23	5484.0		0.0	92.2	0.185	17.057	6012.8	166.4	773.8	5239.0	3510.16	1728.89
43	2150.0	0.465	11.695	3510.2		0.0	92.2	0.185	17.057	4038.9	166.4	773.8	3265.2	2187.66	1077.51
44	2200.0	0.465	12.16	13819.8	9659.6	1972.5	92.2	0.185	17.057	14348.6	166.4	773.8	13574.8	9095.12	4479.69
45	2250.0	0.465	12.625	9095.1		0.0	92.2	0.185	17.057	9623.9	166.4	773.8	8850.1	5929.59	2920.54
46	2300.0	0.465	13.09	5929.6		0.0	92.2	0.185	17.057	6458.4	166.4	773.8	5684.6	3808.68	1875.92
47	2350.0	0.465	13.555	3808.7		0.0	92.2	0.185	17.057	4337.4	166.4	773.8	3563.7	2387.67	1176.02
48	2400.0	0.465	14.02	13819.8	10452.2	980.0	92.2	0.185	17.057	14348.6	166.4	773.8	13574.8	9095.12	4479.69
49	2450.0	0.465	14.485	9095.1		0.0	92.2	0.185	17.057	9623.9	166.4	773.8	8850.1	5929.59	2920.54
50	2500.0	0.465	14.95	5929.6		0.0	92.2	0.185	17.057	6458.4	166.4	773.8	5684.6	3808.68	1875.92
51	2550.0	0.465	15.415	3808.7		0.0	92.2	0.185	17.057	4337.4	166.4	773.8	3563.7	2387.67	1176.02
52	2600.0	0.465	15.88	13819.8	10452.2	980.0	92.2	0.185	17.057	14348.6	166.4	773.8	13574.8	9095.12	4479.69
53	2650.0	0.465	16.345	9095.1		0.0	92.2	0.185	17.057	9623.9	166.4	773.8	8850.1	5929.59	2920.54
54	2700.0	0.465	16.81	5929.6		0.0	92.2	0.185	17.057	6458.4	166.4	773.8	5684.6	3808.68	1875.92
55	2750.0	0.465	17.275	3808.7		0.0	92.2	0.185	17.057	4337.4	166.4	773.8	3563.7	2387.67	1176.02
56	2800.0	0.465	17.74	13819.8	10452.2	980.0	92.2	0.185	17.057	14348.6	166.4	773.8	13574.8	9095.12	4479.69
57	2850.0	0.465	18.205	9095.1		0.0	92.2	0.185	17.057	9623.9	166.4	773.8	8850.1	5929.59	2920.54
58	2900.0	0.465	18.67	5929.6		0.0	92.2	0.185	17.057	6458.4	166.4	773.8	5684.6	3808.68	1875.92
59	2950.0	0.465	19.135	3808.7		0.0	92.2	0.185	17.057	4337.4	166.4	773.8	3563.7	2387.67	1176.02
60	3000.0	0.465	19.6	20618.3	10452.2	7778.4	92.2	0.185	17.057	21147.0	166.4	773.8	20373.3	13650.08	6723.17
61	3050.0	0.77	20.37	13650.1		0.0	92.2	0.09	8.298	13907.3	166.4	1281.3	12626.0	8459.45	4166.59
62	3100.0	0.77	21.14	8459.4		0.0	92.2	0.09	8.298	8716.7	166.4	1281.3	7435.4	4981.72	2453.68
63	3150.0	0.77	21.91	4981.7		0.0	92.2	0.09	8.298	5239.0	166.4	1281.3	3957.7	2651.65	1306.03
64	3200.0	0.77	22.68	22884.4	14649.5	5583.3	92.2	0.09	8.298	23141.6	166.4	1281.3	21860.4	14646.44	7213.92
65	3250.0	0.77	23.45	14646.4		0.0	92.2	0.09	8.298	14903.7	166.4	1281.3	13622.4	9127.01	4495.39
66	3300.0	0.77	24.22	9127.0		0.0	92.2	0.09	8.298	9384.2	166.4	1281.3	8103.0	5428.99	2673.98
67	3350.0	0.77	24.99	5429.0		0.0	92.2	0.09	8.298	5686.2	166.4	1281.3	4404.9	2951.31	1453.63
68	3400.0	0.77	25.76	22884.4	15836.9	4096.2	92.2	0.09	8.298	23141.6	166.4	1281.3	21860.4	14646.44	7213.92
69	3450.0	0.77	26.53	14646.4		0.0	92.2	0.09	8.298	14903.7	166.4	1281.3	13622.4	9127.01	4495.39
70	3500.0	0.77	27.3	9127.0		0.0	92.2	0.09	8.298	9384.2	166.4	1281.3	8103.0	5428.99	2673.98
71	3550.0	0.77	28.07	5429.0		0.0	92.2	0.09	8.298	5686.2	166.4	1281.3	4404.9	2951.31	1453.63
72	3600.0	0.77	28.84	18788.2	15836.9	0.0	92.2	0.09	8.298	19045.5	166.4	1281.3	17764.2	11902.01	5862.18
73	3650.0	0.77	29.61	11902.0		0.0	92.2	0.09	8.298	12159.2	166.4	1281.3	10878.0	7288.24	3589.73
74	3700.0	0.77	30.38	16740.1	9451.9	0.0	92.2	0.09	8.298	16997.4	166.4	1281.3	15716.1	10529.79	5186.31
75	3750.0	0.77	31.15	10529.8		0.0	92.2	0.09	8.298	10787.0	166.4	1281.3	9505.7	6368.85	3136.90
76	3800.0	0.77	31.92	14692.1	8323.2	0.0	92.2	0.09	8.298	14949.3	166.4	1281.3	13668.0	9157.57	4510.45
77	3850.0	0.77	32.69	9157.6		0.0	92.2	0.09	8.298	9414.8	166.4	1281.3	8133.5	5449.47	2684.07
78	3900.0	0.77	33.46	12644.0	7194.5	0.0	92.2	0.09	8.298	12901.2	166.4	1281.3	11619.9	7785.36	3834.58
79	3950.0	0.77	34.23	7785.4		0.0	92.2	0.09	8.298	8042.6	166.4	1281.3	6761.3	4530.08	2231.23
80	4000.0	0.77	35	10595.9	6065.8	0.0	92.2	0.09	8.298	10853.1	166.4	1281.3	9571.9	6413.14	3158.71
				1337.4		38785.0									

Total water supply = 40122.4

Water re.=Virtical percolation 13.6mm+Horizontal leakage 5mm+⑨ (ETc mm/mon.) ／days in month (ETc: calculated by CROPWAT-8)

②;=upper one column in ⑫ row (2/3×Horizontal leakage), at the intake point, larger one between the former value and supply target area×(ETc+Virtical 13.6mm+ Horizontal 5n

③;intake quantity of the total return flow in ⑬row after the previous intake point

④;resupply quantity in case of the total return flow being less than irrigation water requirement at the relevant intake point

⑤;=total flow rate at the dam site per month (estimated by the Tank Model Analysis) devided by catchment area 8.8km2 and devided by the days' number of the relevant month

Table 4-1-1-10(9) Calculation of Water Quantity for Supplemental Supply to the Paddy Field (September)

Sep. Water Re= 28.37 mm/day

NO.	Distance (m)	① Paddy Area (ha)	Cumulative Area (ha)	② W.S./initial, return (m3/mon)	③ Intake quantity (m3/mon.)	④ Supplemental supply (m3/mon)	⑤ Specific discharge (m3/km2)	⑥ catchment area (km2)	⑦=⑤×⑥ Flow-in volume (m3/day)	⑧=②+⑦×30 Irrigation water (m3/mon)	⑨ ETc (mm/mon)	⑩=①×⑨×10000/1000 Water loss (m3/mon)	⑪=⑧-⑩ Residual water (m3/mon.	⑫=⑪×0.67 Horizontal leakage (m3/mon.)	⑬=⑪×0.33 Return to the river (m3/mon.)
1	50.0	0.18	0.144	1582.9			61.5	0.085	5.2275	1744.9	293.0	527.4	1217.5	815.73	401.78
2	100.0	0.18	0.324	3165.7	401.8	1948.2	61.5	0.085	5.2275	5276.0	293.0	527.4	4748.6	3181.55	1567.03
3	150.0	0.18	0.504	3181.5		0.0	61.5	0.085	5.2275	3343.6	293.0	527.4	2816.2	1886.85	929.35
4	200.0	0.18	0.684	6127.2	2496.4	1744.0	61.5	0.085	5.2275	6289.3	293.0	527.4	5761.9	3860.44	1901.41
5	250.0	0.18	0.864	3860.4		0.0	61.5	0.085	5.2275	4022.5	293.0	527.4	3495.1	2341.71	1153.38
6	300.0	0.18	1.044	2341.7		0.0	61.5	0.085	5.2275	2503.8	293.0	527.4	1976.4	1324.16	652.20
7	350.0	0.18	1.224	1324.2		0.0	61.5	0.085	5.2275	1486.2	293.0	527.4	958.8	642.41	316.41
8	400.0	0.18	1.404	6127.2	4023.4	1461.4	61.5	0.085	5.2275	6289.3	293.0	527.4	5761.9	3860.44	1901.41
9	450.0	0.18	1.584	3860.4		0.0	61.5	0.085	5.2275	4022.5	293.0	527.4	3495.1	2341.71	1153.38
10	500.0	0.18	1.764	2341.7		0.0	61.5	0.085	5.2275	2503.8	293.0	527.4	1976.4	1324.16	652.20
11	550.0	0.18	1.944	1324.2		0.0	61.5	0.085	5.2275	1486.2	293.0	527.4	958.8	642.41	316.41
12	600.0	0.18	2.124	6127.2	4023.4	1461.4	61.5	0.085	5.2275	6289.3	293.0	527.4	5761.9	3860.44	1901.41
13	650.0	0.18	2.304	3860.4		0.0	61.5	0.085	5.2275	4022.5	293.0	527.4	3495.1	2341.71	1153.38
14	700.0	0.18	2.484	2341.7		0.0	61.5	0.085	5.2275	2503.8	293.0	527.4	1976.4	1324.16	652.20
15	750.0	0.18	2.664	1324.2		0.0	61.5	0.085	5.2275	1486.2	293.0	527.4	958.8	642.41	316.41
16	800.0	0.18	2.844	6127.2	4023.4	1461.4	61.5	0.085	5.2275	6289.3	293.0	527.4	5761.9	3860.44	1901.41
17	850.0	0.18	3.024	3860.4		0.0	61.5	0.085	5.2275	4022.5	293.0	527.4	3495.1	2341.71	1153.38
18	900.0	0.18	3.204	2341.7		0.0	61.5	0.085	5.2275	2503.8	293.0	527.4	1976.4	1324.16	652.20
19	950.0	0.18	3.384	1324.2		0.0	61.5	0.085	5.2275	1486.2	293.0	527.4	958.8	642.41	316.41
20	1000.0	0.18	3.564	10084.4	4023.4	5418.5	61.5	0.085	5.2275	10246.4	293.0	527.4	9719.0	6511.73	3207.27
21	1050.0	0.335	3.899	6511.7		0.0	61.5	0.1	6.15	6702.4	293.0	981.6	5720.8	3832.96	1887.87
22	1100.0	0.335	4.234	3833.0		0.0	61.5	0.1	6.15	4023.6	293.0	981.6	3042.1	2038.18	1003.88
23	1150.0	0.335	4.569	2038.2		0.0	61.5	0.1	6.15	2228.8	293.0	981.6	1247.3	835.68	411.60
24	1200.0	0.335	4.904	11403.4	6510.6	4057.1	61.5	0.1	6.15	11594.1	293.0	981.6	10612.5	7110.38	3502.13
25	1250.0	0.335	5.239	7110.4		0.0	61.5	0.1	6.15	7301.0	293.0	981.6	6319.5	4234.05	2085.43
26	1300.0	0.335	5.574	4234.0		0.0	61.5	0.1	6.15	4424.7	293.0	981.6	3443.1	2306.91	1136.24
27	1350.0	0.335	5.909	2306.9		0.0	61.5	0.1	6.15	2497.6	293.0	981.6	1516.0	1015.73	500.28
28	1400.0	0.335	6.244	11403.4	7224.1	3163.6	61.5	0.1	6.15	11594.1	293.0	981.6	10612.5	7110.38	3502.13
29	1450.0	0.335	6.579	7110.4		0.0	61.5	0.1	6.15	7301.0	293.0	981.6	6319.5	4234.05	2085.43
30	1500.0	0.335	6.914	4234.0		0.0	61.5	0.1	6.15	4424.7	293.0	981.6	3443.1	2306.91	1136.24
31	1550.0	0.335	7.249	2306.9		0.0	61.5	0.1	6.15	2497.6	293.0	981.6	1516.0	1015.73	500.28
32	1600.0	0.335	7.584	11403.4	7224.1	3163.6	61.5	0.1	6.15	11594.1	293.0	981.6	10612.5	7110.38	3502.13
33	1650.0	0.335	7.919	7110.4		0.0	61.5	0.1	6.15	7301.0	293.0	981.6	6319.5	4234.05	2085.43
34	1700.0	0.335	8.254	4234.0		0.0	61.5	0.1	6.15	4424.7	293.0	981.6	3443.1	2306.91	1136.24
35	1750.0	0.335	8.589	2306.9		0.0	61.5	0.1	6.15	2497.6	293.0	981.6	1516.0	1015.73	500.28
36	1800.0	0.335	8.924	11403.4	7224.1	3163.6	61.5	0.1	6.15	11594.1	293.0	981.6	10612.5	7110.38	3502.13
37	1850.0	0.335	9.259	7110.4		0.0	61.5	0.1	6.15	7301.0	293.0	981.6	6319.5	4234.05	2085.43
38	1900.0	0.335	9.594	4234.0		0.0	61.5	0.1	6.15	4424.7	293.0	981.6	3443.1	2306.91	1136.24
39	1950.0	0.335	9.929	2306.9		0.0	61.5	0.1	6.15	2497.6	293.0	981.6	1516.0	1015.73	500.28
40	2000.0	0.335	10.264	8239.8	7224.1	0.0	61.5	0.1	6.15	8430.5	293.0	981.6	7448.9	4990.76	2458.14
41	2050.0	0.465	10.729	4990.8		0.0	61.5	0.185	11.3775	5343.5	293.0	1362.5	3981.0	2667.28	1313.74
42	2100.0	0.465	11.194	2667.3		0.0	61.5	0.185	11.3775	3020.0	293.0	1362.5	1657.5	1110.55	546.99
43	2150.0	0.465	11.659	1110.5		0.0	61.5	0.185	11.3775	1463.2	293.0	1362.5	100.8	67.54	33.26
44	2200.0	0.465	12.124	15828.6	4352.1	11408.9	61.5	0.185	11.3775	16181.3	293.0	1362.5	14818.9	9928.63	4890.22
45	2250.0	0.465	12.589	9928.6		0.0	61.5	0.185	11.3775	10281.3	293.0	1362.5	8918.9	5975.65	2943.23
46	2300.0	0.465	13.054	5975.7		0.0	61.5	0.185	11.3775	6328.4	293.0	1362.5	4965.9	3327.16	1638.75
47	2350.0	0.465	13.519	3327.2		0.0	61.5	0.185	11.3775	3679.9	293.0	1362.5	2317.4	1552.66	764.74
48	2400.0	0.465	13.984	15828.6	10236.9	4039.0	61.5	0.185	11.3775	16181.3	293.0	1362.5	14818.9	9928.63	4890.22
49	2450.0	0.465	14.449	9928.6		0.0	61.5	0.185	11.3775	10281.3	293.0	1362.5	8918.9	5975.65	2943.23
50	2500.0	0.465	14.914	5975.7		0.0	61.5	0.185	11.3775	6328.4	293.0	1362.5	4965.9	3327.16	1638.75
51	2550.0	0.465	15.379	3327.2		0.0	61.5	0.185	11.3775	3679.9	293.0	1362.5	2317.4	1552.66	764.74
52	2600.0	0.465	15.844	15828.6	10236.9	4039.0	61.5	0.185	11.3775	16181.3	293.0	1362.5	14818.9	9928.63	4890.22
53	2650.0	0.465	16.309	9928.6		0.0	61.5	0.185	11.3775	10281.3	293.0	1362.5	8918.9	5975.65	2943.23
54	2700.0	0.465	16.774	5975.7		0.0	61.5	0.185	11.3775	6328.4	293.0	1362.5	4965.9	3327.16	1638.75
55	2750.0	0.465	17.239	3327.2		0.0	61.5	0.185	11.3775	3679.9	293.0	1362.5	2317.4	1552.66	764.74
56	2800.0	0.465	17.704	15828.6	10236.9	4039.0	61.5	0.185	11.3775	16181.3	293.0	1362.5	14818.9	9928.63	4890.22
57	2850.0	0.465	18.169	9928.6		0.0	61.5	0.185	11.3775	10281.3	293.0	1362.5	8918.9	5975.65	2943.23
58	2900.0	0.465	18.634	5975.7		0.0	61.5	0.185	11.3775	6328.4	293.0	1362.5	4965.9	3327.16	1638.75
59	2950.0	0.465	19.099	3327.2		0.0	61.5	0.185	11.3775	3679.9	293.0	1362.5	2317.4	1552.66	764.74
60	3000.0	0.465	19.564	23615.3	10236.9	11825.6	61.5	0.185	11.3775	23968.0	293.0	1362.5	22605.5	15145.69	7459.82
61	3050.0	0.77	20.334	15145.7		0.0	61.5	0.09	5.535	15317.3	293.0	2256.1	13061.2	8750.99	4310.19
62	3100.0	0.77	21.104	8751.0		0.0	61.5	0.09	5.535	8922.6	293.0	2256.1	6666.5	4466.53	2199.94
63	3150.0	0.77	21.874	4466.5		0.0	61.5	0.09	5.535	4638.1	293.0	2256.1	2382.0	1595.95	786.07
64	3200.0	0.77	22.644	26210.8	14756.0	9858.8	61.5	0.09	5.535	26382.4	293.0	2256.1	24126.3	16164.61	7961.67
65	3250.0	0.77	23.414	16164.6		0.0	61.5	0.09	5.535	16336.2	293.0	2256.1	14080.1	9433.66	4646.43
66	3300.0	0.77	24.184	9433.7		0.0	61.5	0.09	5.535	9605.2	293.0	2256.1	7349.1	4923.93	2425.22
67	3350.0	0.77	24.954	4923.9		0.0	61.5	0.09	5.535	5095.5	293.0	2256.1	2839.4	1902.41	937.01
68	3400.0	0.77	25.724	26210.8	15970.3	8338.1	61.5	0.09	5.535	26382.4	293.0	2256.1	24126.3	16164.61	7961.67
69	3450.0	0.77	26.494	16164.6		0.0	61.5	0.09	5.535	16336.2	293.0	2256.1	14080.1	9433.66	4646.43
70	3500.0	0.77	27.264	9433.7		0.0	61.5	0.09	5.535	9605.2	293.0	2256.1	7349.1	4923.93	2425.22
71	3550.0	0.77	28.034	4923.9		0.0	61.5	0.09	5.535	5095.5	293.0	2256.1	2839.4	1902.41	937.01
72	3600.0	0.77	28.804	17872.7	15970.3	0.0	61.5	0.09	5.535	18044.3	293.0	2256.1	15788.2	10578.11	5210.11
73	3650.0	0.77	29.574	10578.1		0.0	61.5	0.09	5.535	10749.7	293.0	2256.1	8493.6	5690.71	2802.89
74	3700.0	0.77	30.344	13703.7	8013.0	0.0	61.5	0.09	5.535	13875.3	293.0	2256.1	11619.2	7784.86	3834.33
75	3750.0	0.77	31.114	7784.9		0.0	61.5	0.09	5.535	7956.4	293.0	2256.1	5700.3	3819.23	1881.11
76	3800.0	0.77	31.884	13542.2	5715.4	4007.6	61.5	0.09	5.535	13713.8	293.0	2256.1	11457.7	7676.68	3781.05
77	3850.0	0.77	32.654	7676.7		0.0	61.5	0.09	5.535	7848.3	293.0	2256.1	5592.2	3746.75	1845.41
78	3900.0	0.77	33.424	13542.2	5626.5	4169.0	61.5	0.09	5.535	13713.8	293.0	2256.1	11457.7	7676.68	3781.05
79	3950.0	0.77	34.194	7676.7		0.0	61.5	0.09	5.535	7848.3	293.0	2256.1	5592.2	3746.75	1845.41
80	4000.0	0.77	34.964	9373.2	5626.5	0.0	61.5	0.09	5.535	9544.8	293.0	2256.1	7288.7	4883.43	2405.27
				1582.9		88767.8									

Total water supply = 90350.7

Water re.＝Virtical percolation 13.6mm+Horizontal leakage 5mm+⑨ (ETc mm/mon.) ／days in month (ETc: calculated by CROPWAT-8)

②;=upper one column in ⑫ row (2/3×Horizontal leakage), at the intake point, larger one between the former value and supply target area×(ETc+Virtical 13.6mm+ Horizontal 5n

③;intake quantity of the total return flow in ⑬row after the previous intake point

④;resupply quantity in case of the total return flow being less than irrigation water requirement at the relevant intake point

⑤;=total flow rate at the dam site per month (estimated by the Tank Model Analysis) devided by catchment area 8.8km2 and devided by the days' number of the relevant month

Table 4-1-1-10(10) Calculation of Water Quantity for Supplemental Supply to the Paddy Field (October)

Oct. Water Re= 20.74 mm/day

NO.	Distance (m)	① Paddy Area (ha)	Cumulative Area (ha)	② W.S./initial, return (m3/mon)	③ Intake quantity (m3/mon.)	④ Supplemental supply (m3/mon)	⑤ Specific discharge (m3/km2)	⑥ catchment area (km2)	⑦=⑤×⑥ Flow-in volume (m3/day)	⑧=②+⑦×31 Irrigation water (m3/mon)	⑨ ETc (mm/mon)	⑩=①×⑨×10000/1000 Water loss (m3/mon)	⑪=⑧-⑩ Residual water (m3/mon.)	⑫=⑪×0.67 Horizontal leakage (m3/mon.)	⑬=⑪×0.33 Return to the river (m3/mon.)
1	50.0	0.18	0.18	1157.0			136.5	0.085	11.6025	1516.7	66.2	119.2	1397.6	936.36	461.19
2	100.0	0.18	0.36	2314.1	461.2	916.5	136.5	0.085	11.6025	3590.3	66.2	119.2	3471.1	2325.65	1145.47
3	150.0	0.18	0.54	2325.7		0.0	136.5	0.085	11.6025	2685.3	66.2	119.2	2566.2	1719.33	846.84
4	200.0	0.18	0.72	4628.2	1992.3	916.5	136.5	0.085	11.6025	4987.8	66.2	119.2	4868.7	3262.01	1606.66
5	250.0	0.18	0.9	3262.0		0.0	136.5	0.085	11.6025	3621.7	66.2	119.2	3502.5	2346.70	1155.84
6	300.0	0.18	1.08	2346.7		0.0	136.5	0.085	11.6025	2706.4	66.2	119.2	2587.2	1733.43	853.78
7	350.0	0.18	1.26	1733.4		0.0	136.5	0.085	11.6025	2093.1	66.2	119.2	1974.0	1322.55	651.40
8	400.0	0.18	1.44	5590.2	4267.7	0.0	136.5	0.085	11.6025	5949.9	66.2	119.2	5830.7	3906.60	1924.15
9	450.0	0.18	1.62	3906.6		0.0	136.5	0.085	11.6025	4266.3	66.2	119.2	4147.1	2778.57	1368.55
10	500.0	0.18	1.8	2778.6		0.0	136.5	0.085	11.6025	3138.2	66.2	119.2	3019.1	2022.79	996.30
11	550.0	0.18	1.98	2022.8		0.0	136.5	0.085	11.6025	2382.5	66.2	119.2	2263.3	1516.41	746.89
12	600.0	0.18	2.16	6552.3	5035.9	0.0	136.5	0.085	11.6025	6912.0	66.2	119.2	6792.8	4551.19	2241.63
13	650.0	0.18	2.34	4551.2		0.0	136.5	0.085	11.6025	4910.9	66.2	119.2	4791.7	3210.44	1581.26
14	700.0	0.18	2.52	3210.4		0.0	136.5	0.085	11.6025	3570.1	66.2	119.2	3451.0	2312.14	1138.82
15	750.0	0.18	2.7	2312.1		0.0	136.5	0.085	11.6025	2671.8	66.2	119.2	2552.7	1710.28	842.38
16	800.0	0.18	2.88	7514.4	5804.1	0.0	136.5	0.085	11.6025	7874.0	66.2	119.2	7754.9	5195.77	2559.11
17	850.0	0.18	3.06	5195.8		0.0	136.5	0.085	11.6025	5555.5	66.2	119.2	5436.3	3642.32	1793.98
18	900.0	0.18	3.24	3642.3		0.0	136.5	0.085	11.6025	4002.0	66.2	119.2	3882.8	2601.50	1281.33
19	950.0	0.18	3.42	2601.5		0.0	136.5	0.085	11.6025	2961.2	66.2	119.2	2842.0	1904.15	937.87
20	1000.0	0.18	3.6	8476.4	6572.3	0.0	136.5	0.085	11.6025	8836.1	66.2	119.2	8717.0	5840.36	2876.60
21	1050.0	0.335	3.935	5840.4		0.0	136.5	0.1	13.65	6263.5	66.2	221.8	6041.7	4047.97	1993.77
22	1100.0	0.335	4.27	4048.0		0.0	136.5	0.1	13.65	4471.1	66.2	221.8	4249.3	2847.06	1402.28
23	1150.0	0.335	4.605	2847.1		0.0	136.5	0.1	13.65	3270.2	66.2	221.8	3048.4	2042.46	1005.99
24	1200.0	0.335	4.94	9321.1	7278.6	0.0	136.5	0.1	13.65	9744.2	66.2	221.8	9522.5	6380.06	3142.42
25	1250.0	0.335	5.275	6380.1		0.0	136.5	0.1	13.65	6803.2	66.2	221.8	6581.4	4409.56	2171.88
26	1300.0	0.335	5.61	4409.6		0.0	136.5	0.1	13.65	4832.7	66.2	221.8	4610.9	3089.33	1521.61
27	1350.0	0.335	5.945	3089.3		0.0	136.5	0.1	13.65	3512.5	66.2	221.8	3290.7	2204.78	1085.94
28	1400.0	0.335	6.28	10126.6	7921.8	0.0	136.5	0.1	13.65	10549.8	66.2	221.8	10328.0	6919.76	3408.24
29	1450.0	0.335	6.615	6919.8		0.0	136.5	0.1	13.65	7342.9	66.2	221.8	7121.1	4771.16	2349.98
30	1500.0	0.335	6.95	4771.2		0.0	136.5	0.1	13.65	5194.3	66.2	221.8	4972.5	3331.60	1640.94
31	1550.0	0.335	7.285	3331.6		0.0	136.5	0.1	13.65	3754.8	66.2	221.8	3533.0	2367.10	1165.88
32	1600.0	0.335	7.62	10932.1	8565.0	0.0	136.5	0.1	13.65	11355.3	66.2	221.8	11133.5	7459.46	3674.06
33	1650.0	0.335	7.955	7459.5		0.0	136.5	0.1	13.65	7882.6	66.2	221.8	7660.8	5132.76	2528.08
34	1700.0	0.335	8.29	5132.8		0.0	136.5	0.1	13.65	5555.9	66.2	221.8	5334.1	3573.87	1760.27
35	1750.0	0.335	8.625	3573.9		0.0	136.5	0.1	13.65	3997.0	66.2	221.8	3775.3	2529.42	1245.83
36	1800.0	0.335	8.96	11737.7	9208.2	0.0	136.5	0.1	13.65	12160.8	66.2	221.8	11939.0	7999.16	3939.88
37	1850.0	0.335	9.295	7999.2		0.0	136.5	0.1	13.65	8422.3	66.2	221.8	8200.5	5494.36	2706.18
38	1900.0	0.335	9.63	5494.4		0.0	136.5	0.1	13.65	5917.5	66.2	221.8	5695.7	3816.14	1879.59
39	1950.0	0.335	9.965	3816.1		0.0	136.5	0.1	13.65	4239.3	66.2	221.8	4017.5	2691.74	1325.78
40	2000.0	0.335	10.3	12543.2	9851.4	0.0	136.5	0.1	13.65	12966.3	66.2	221.8	12744.6	8538.85	4205.70
41	2050.0	0.465	10.765	8538.9		0.0	136.5	0.185	25.2525	9321.7	66.2	307.8	9013.9	6039.28	2974.57
42	2100.0	0.465	11.23	6039.3		0.0	136.5	0.185	25.2525	6822.1	66.2	307.8	6514.3	4364.57	2149.71
43	2150.0	0.465	11.695	4364.6		0.0	136.5	0.185	25.2525	5147.4	66.2	307.8	4839.6	3242.51	1597.06
44	2200.0	0.465	12.16	14169.6	10927.0	0.0	136.5	0.185	25.2525	14952.4	66.2	307.8	14644.5	9811.85	4832.70
45	2250.0	0.465	12.625	9811.8		0.0	136.5	0.185	25.2525	10594.7	66.2	307.8	10286.8	6892.19	3394.66
46	2300.0	0.465	13.09	6892.2		0.0	136.5	0.185	25.2525	7675.0	66.2	307.8	7367.2	4936.01	2431.17
47	2350.0	0.465	13.555	4936.0		0.0	136.5	0.185	25.2525	5718.8	66.2	307.8	5411.0	3625.38	1785.63
48	2400.0	0.465	14.02	16069.5	12444.2	0.0	136.5	0.185	25.2525	16852.4	66.2	307.8	16544.5	11084.84	5459.70
49	2450.0	0.465	14.485	11084.8		0.0	136.5	0.185	25.2525	11867.7	66.2	307.8	11559.8	7745.09	3814.75
50	2500.0	0.465	14.95	7745.1		0.0	136.5	0.185	25.2525	8527.9	66.2	307.8	8220.1	5507.46	2712.63
51	2550.0	0.465	15.415	5507.5		0.0	136.5	0.185	25.2525	6290.3	66.2	307.8	5982.5	4008.25	1974.21
52	2600.0	0.465	15.88	17969.5	13961.3	0.0	136.5	0.185	25.2525	18752.4	66.2	307.8	18444.5	12357.83	6086.69
53	2650.0	0.465	16.345	12357.8		0.0	136.5	0.185	25.2525	13140.7	66.2	307.8	12832.8	8598.00	4234.83
54	2700.0	0.465	16.81	8598.0		0.0	136.5	0.185	25.2525	9380.8	66.2	307.8	9073.0	6078.91	2994.09
55	2750.0	0.465	17.275	6078.9		0.0	136.5	0.185	25.2525	6861.7	66.2	307.8	6553.9	4391.12	2162.79
56	2800.0	0.465	17.74	19869.5	15478.4	0.0	136.5	0.185	25.2525	20652.3	66.2	307.8	20344.5	13630.83	6713.69
57	2850.0	0.465	18.205	13630.8		0.0	136.5	0.185	25.2525	14413.7	66.2	307.8	14105.8	9450.90	4654.92
58	2900.0	0.465	18.67	9450.9		0.0	136.5	0.185	25.2525	10233.7	66.2	307.8	9925.9	6650.35	3275.55
59	2950.0	0.465	19.135	6650.4		0.0	136.5	0.185	25.2525	7433.2	66.2	307.8	7125.4	4773.98	2351.37
60	3000.0	0.465	19.6	21769.5	16995.5	0.0	136.5	0.185	25.2525	22552.3	66.2	307.8	22244.5	14903.82	7340.69
61	3050.0	0.77	20.37	14903.8		0.0	136.5	0.09	12.285	15284.7	66.2	509.7	14774.9	9899.19	4875.72
62	3100.0	0.77	21.14	9899.2		0.0	136.5	0.09	12.285	10280.0	66.2	509.7	9770.3	6546.09	3224.20
63	3150.0	0.77	21.91	6546.1		0.0	136.5	0.09	12.285	6926.9	66.2	509.7	6417.2	4299.52	2117.67
64	3200.0	0.77	22.68	21857.8	17558.3	0.0	136.5	0.09	12.285	22238.6	66.2	509.7	21728.9	14558.35	7170.53
65	3250.0	0.77	23.45	14558.4		0.0	136.5	0.09	12.285	14939.2	66.2	509.7	14429.4	9667.73	4761.72
66	3300.0	0.77	24.22	9667.7		0.0	136.5	0.09	12.285	10048.6	66.2	509.7	9538.8	6391.01	3147.81
67	3350.0	0.77	24.99	6391.0		0.0	136.5	0.09	12.285	6771.8	66.2	509.7	6262.1	4195.61	2066.50
68	3400.0	0.77	25.76	21342.2	17146.6	0.0	136.5	0.09	12.285	21723.0	66.2	509.7	21213.3	14212.89	7000.38
69	3450.0	0.77	26.53	14212.9		0.0	136.5	0.09	12.285	14593.7	66.2	509.7	14084.0	9436.27	4647.71
70	3500.0	0.77	27.3	9436.3		0.0	136.5	0.09	12.285	9817.1	66.2	509.7	9307.4	6235.93	3071.43
71	3550.0	0.77	28.07	6235.9		0.0	136.5	0.09	12.285	6616.8	66.2	509.7	6107.0	4091.71	2015.32
72	3600.0	0.77	28.84	20826.6	16734.8	0.0	136.5	0.09	12.285	21207.4	66.2	509.7	20697.6	13867.42	6830.22
73	3650.0	0.77	29.61	13867.4		0.0	136.5	0.09	12.285	14248.3	66.2	509.7	13738.5	9204.81	4533.71
74	3700.0	0.77	30.38	20568.7	11363.9	0.0	136.5	0.09	12.285	20949.6	66.2	509.7	20439.8	13694.69	6745.15
75	3750.0	0.77	31.15	13694.7		0.0	136.5	0.09	12.285	14075.5	66.2	509.7	13565.8	9089.08	4476.71
76	3800.0	0.77	31.92	20310.9	11221.9	0.0	136.5	0.09	12.285	20691.8	66.2	509.7	20182.0	13521.96	6660.07
77	3850.0	0.77	32.69	13522.0		0.0	136.5	0.09	12.285	13902.8	66.2	509.7	13393.1	8973.35	4419.71
78	3900.0	0.77	33.46	20053.1	11079.8	0.0	136.5	0.09	12.285	20434.0	66.2	509.7	19924.2	13349.23	6574.99
79	3950.0	0.77	34.23	13349.2		0.0	136.5	0.09	12.285	13730.1	66.2	509.7	13220.3	8857.61	4362.71
80	4000.0	0.77	35	19795.3	10937.7	0.0	136.5	0.09	12.285	20176.1	66.2	509.7	19666.4	13176.49	6489.91
				1157.0		1833.0									
				Total water supply =		2990.1									

Water re.=Virtical percolation 13.6mm+Horizontal leakage 5mm+⑨ (ETc mm/mon.) ／days in month (ETc: calculated by CROPWAT-8)

②;=upper one column in ⑫ row (2/3×Horizontal leakage), at the intake point, larger one between the former value and supply target area×(ETc+Virtical 13.6mm+ Horizontal 5n

③;intake quantity of the total return flow in ⑬row after the previous intake point

④;resupply quantity in case of the total return flow being less than irrigation water requirement at the relevant intake point

⑤;=total flow rate at the dam site per month (estimated by the Tank Model Analysis) devided by catchment area 8.8km2 and devided by the days' number of the relevant month

Table 4-1-1-10(11) Calculation of Water Quantity for Supplemental Supply to the Paddy Field (November)

Nov. Water Re= 18.92 mm/day

NO.	Distance (m)	① Paddy Area (ha)	Cumulative Area (ha)	② W.S./initial, return (m3/mon)	③ Intake quantity (m3/mon.)	④ Supplemental supply (m3/mon)	⑤ Specific discharge (m3/km2)	⑥ catchment area (km2)	⑦=⑤×⑥ Flow-in volume (m3/day)	⑧=②+⑦×30 Irrigation water (m3/mon)	⑨ ETc (mm/mon)	⑩=①×⑨×10000/1000 Water loss (m3/mon)	⑪=⑧-⑩ Residual water (m3/mon.)	⑫=⑪×0.67 Horizontal leakage (m3/mon.)	⑬=⑪×0.33 Return to the river (m3/mon.)
1	50.0	0.18	0.18	1055.6			202.9	0.085	17.2465	1590.2	9.5	17.1	1573.1	1053.97	519.12
2	100.0	0.18	0.36	2111.1	519.1	538.0	202.9	0.085	17.2465	3183.8	9.5	17.1	3166.7	2121.66	1044.99
3	150.0	0.18	0.54	2121.7		0.0	202.9	0.085	17.2465	2656.3	9.5	17.1	2639.2	1768.26	870.94
4	200.0	0.18	0.72	4086.0	1915.9	401.8	202.9	0.085	17.2465	4620.6	9.5	17.1	4603.5	3084.37	1519.17
5	250.0	0.18	0.9	3084.4		0.0	202.9	0.085	17.2465	3619.0	9.5	17.1	3601.9	2413.28	1188.63
6	300.0	0.18	1.08	2413.3		0.0	202.9	0.085	17.2465	2947.9	9.5	17.1	2930.8	1963.65	967.17
7	350.0	0.18	1.26	1963.7		0.0	202.9	0.085	17.2465	2498.3	9.5	17.1	2481.2	1662.40	818.79
8	400.0	0.18	1.44	6156.2	4493.8	0.0	202.9	0.085	17.2465	6690.8	9.5	17.1	6673.7	4471.38	2202.32
9	450.0	0.18	1.62	4471.4		0.0	202.9	0.085	17.2465	5006.0	9.5	17.1	4988.9	3342.58	1646.35
10	500.0	0.18	1.8	3342.6		0.0	202.9	0.085	17.2465	3877.2	9.5	17.1	3860.1	2586.28	1273.84
11	550.0	0.18	1.98	2586.3		0.0	202.9	0.085	17.2465	3120.9	9.5	17.1	3103.8	2079.56	1024.26
12	600.0	0.18	2.16	8226.3	6146.8	0.0	202.9	0.085	17.2465	8761.0	9.5	17.1	8743.9	5858.40	2885.48
13	650.0	0.18	2.34	5858.4		0.0	202.9	0.085	17.2465	6393.0	9.5	17.1	6375.9	4271.88	2104.06
14	700.0	0.18	2.52	4271.9		0.0	202.9	0.085	17.2465	4806.5	9.5	17.1	4789.4	3208.91	1580.51
15	750.0	0.18	2.7	3208.9		0.0	202.9	0.085	17.2465	3743.6	9.5	17.1	3726.5	2496.72	1229.73
16	800.0	0.18	2.88	10296.5	7799.8	0.0	202.9	0.085	17.2465	10831.1	9.5	17.1	10814.0	7245.41	3568.63
17	850.0	0.18	3.06	7245.4		0.0	202.9	0.085	17.2465	7780.0	9.5	17.1	7762.9	5201.18	2561.77
18	900.0	0.18	3.24	5201.2		0.0	202.9	0.085	17.2465	5735.8	9.5	17.1	5718.7	3831.54	1887.18
19	950.0	0.18	3.42	3831.5		0.0	202.9	0.085	17.2465	4366.2	9.5	17.1	4349.1	2913.88	1435.20
20	1000.0	0.18	3.6	12366.7	9452.8	0.0	202.9	0.085	17.2465	12901.3	9.5	17.1	12884.2	8632.42	4251.79
21	1050.0	0.335	3.935	8632.4		0.0	202.9	0.1	20.29	9261.4	9.5	31.8	9229.6	6183.82	3045.76
22	1100.0	0.335	4.27	6183.8		0.0	202.9	0.1	20.29	6812.8	9.5	31.8	6781.0	4543.26	2237.73
23	1150.0	0.335	4.605	4543.3		0.0	202.9	0.1	20.29	5172.3	9.5	31.8	5140.4	3444.08	1696.34
24	1200.0	0.335	4.94	14675.7	11231.6	0.0	202.9	0.1	20.29	15304.7	9.5	31.8	15272.9	10232.82	5040.05
25	1250.0	0.335	5.275	10232.8		0.0	202.9	0.1	20.29	10861.8	9.5	31.8	10830.0	7256.09	3573.90
26	1300.0	0.335	5.61	7256.1		0.0	202.9	0.1	20.29	7885.1	9.5	31.8	7853.3	5261.68	2591.57
27	1350.0	0.335	5.945	5261.7		0.0	202.9	0.1	20.29	5890.7	9.5	31.8	5858.8	3925.43	1933.42
28	1400.0	0.335	6.28	17064.4	13138.9	0.0	202.9	0.1	20.29	17693.4	9.5	31.8	17661.5	11833.22	5828.30
29	1450.0	0.335	6.615	11833.2		0.0	202.9	0.1	20.29	12462.2	9.5	31.8	12430.4	8328.36	4102.03
30	1500.0	0.335	6.95	8328.4		0.0	202.9	0.1	20.29	8957.3	9.5	31.8	8925.5	5980.10	2945.42
31	1550.0	0.335	7.285	5980.1		0.0	202.9	0.1	20.29	6609.1	9.5	31.8	6577.3	4406.77	2170.50
32	1600.0	0.335	7.62	19453.0	15046.3	0.0	202.9	0.1	20.29	20082.0	9.5	31.8	20050.2	13433.62	6616.56
33	1650.0	0.335	7.955	13433.6		0.0	202.9	0.1	20.29	14062.6	9.5	31.8	14030.8	9400.63	4630.16
34	1700.0	0.335	8.29	9400.6		0.0	202.9	0.1	20.29	10029.6	9.5	31.8	9997.8	6698.52	3299.27
35	1750.0	0.335	8.625	6698.5		0.0	202.9	0.1	20.29	7327.5	9.5	31.8	7295.7	4888.11	2407.58
36	1800.0	0.335	8.96	21841.7	16953.6	0.0	202.9	0.1	20.29	22470.7	9.5	31.8	22438.8	15034.03	7404.82
37	1850.0	0.335	9.295	15034.0		0.0	202.9	0.1	20.29	15663.0	9.5	31.8	15631.2	10472.90	5158.29
38	1900.0	0.335	9.63	10472.9		0.0	202.9	0.1	20.29	11101.9	9.5	31.8	11070.1	7416.94	3653.12
39	1950.0	0.335	9.965	7416.9		0.0	202.9	0.1	20.29	8045.9	9.5	31.8	8014.1	5369.45	2644.66
40	2000.0	0.335	10.3	24230.3	18860.9	0.0	202.9	0.1	20.29	24859.3	9.5	31.8	24827.5	16634.43	8193.08
41	2050.0	0.465	10.765	16634.4		0.0	202.9	0.185	37.5365	17798.1	9.5	44.2	17753.9	11895.10	5858.78
42	2100.0	0.465	11.23	11895.1		0.0	202.9	0.185	37.5365	13058.7	9.5	44.2	13014.6	8719.75	4294.80
43	2150.0	0.465	11.695	8719.8		0.0	202.9	0.185	37.5365	9883.4	9.5	44.2	9839.2	6592.27	3246.94
44	2200.0	0.465	12.16	28185.9	21593.6	0.0	202.9	0.185	37.5365	29349.5	9.5	44.2	29305.3	19634.57	9670.76
45	2250.0	0.465	12.625	19634.6		0.0	202.9	0.185	37.5365	20798.2	9.5	44.2	20754.0	13905.20	6848.83
46	2300.0	0.465	13.09	13905.2		0.0	202.9	0.185	37.5365	15068.8	9.5	44.2	15024.7	10066.52	4958.14
47	2350.0	0.465	13.555	10066.5		0.0	202.9	0.185	37.5365	11230.2	9.5	44.2	11186.0	7494.60	3691.37
48	2400.0	0.465	14.02	32663.7	25169.1	0.0	202.9	0.185	37.5365	33827.3	9.5	44.2	33783.2	22634.72	11148.44
49	2450.0	0.465	14.485	22634.7		0.0	202.9	0.185	37.5365	23798.3	9.5	44.2	23754.2	15915.30	7838.88
50	2500.0	0.465	14.95	15915.3		0.0	202.9	0.185	37.5365	17078.9	9.5	44.2	17034.8	11413.28	5621.47
51	2550.0	0.465	15.415	11413.3		0.0	202.9	0.185	37.5365	12576.9	9.5	44.2	12532.7	8396.94	4135.80
52	2600.0	0.465	15.88	37141.5	28744.6	0.0	202.9	0.185	37.5365	38305.2	9.5	44.2	38261.0	25634.86	12626.12
53	2650.0	0.465	16.345	25634.9		0.0	202.9	0.185	37.5365	26798.5	9.5	44.2	26754.3	17925.39	8828.92
54	2700.0	0.465	16.81	17925.4		0.0	202.9	0.185	37.5365	19089.0	9.5	44.2	19044.8	12760.05	6284.80
55	2750.0	0.465	17.275	12760.0		0.0	202.9	0.185	37.5365	13923.7	9.5	44.2	13879.5	9299.27	4580.24
56	2800.0	0.465	17.74	41619.4	32320.1	0.0	202.9	0.185	37.5365	42783.0	9.5	44.2	42738.8	28635.00	14103.81
57	2850.0	0.465	18.205	28635.0		0.0	202.9	0.185	37.5365	29798.6	9.5	44.2	29754.5	19935.49	9818.97
58	2900.0	0.465	18.67	19935.5		0.0	202.9	0.185	37.5365	21099.1	9.5	44.2	21054.9	14106.81	6948.13
59	2950.0	0.465	19.135	14106.8		0.0	202.9	0.185	37.5365	15270.4	9.5	44.2	15226.3	10201.60	5024.67
60	3000.0	0.465	19.6	46097.2	35895.6	0.0	202.9	0.185	37.5365	47260.8	9.5	44.2	47216.6	31635.15	15581.49
61	3050.0	0.77	20.37	31635.1		0.0	202.9	0.09	18.261	32201.2	9.5	73.2	32128.1	21525.82	10602.27
62	3100.0	0.77	21.14	21525.8		0.0	202.9	0.09	18.261	22091.9	9.5	73.2	22018.8	14752.57	7266.19
63	3150.0	0.77	21.91	14752.6		0.0	202.9	0.09	18.261	15318.7	9.5	73.2	15245.5	10214.49	5031.02
64	3200.0	0.77	22.68	48695.5	38481.0	0.0	202.9	0.09	18.261	49261.5	9.5	73.2	49188.4	32956.23	16232.17
65	3250.0	0.77	23.45	32956.2		0.0	202.9	0.09	18.261	33522.3	9.5	73.2	33449.2	22410.94	11038.23
66	3300.0	0.77	24.22	22410.9		0.0	202.9	0.09	18.261	22977.0	9.5	73.2	22903.9	15345.60	7558.28
67	3350.0	0.77	24.99	15345.6		0.0	202.9	0.09	18.261	15911.7	9.5	73.2	15838.5	10611.82	5226.72
68	3400.0	0.77	25.76	50667.2	40055.4	0.0	202.9	0.09	18.261	51233.3	9.5	73.2	51160.2	34277.31	16882.85
69	3450.0	0.77	26.53	34277.3		0.0	202.9	0.09	18.261	34843.4	9.5	73.2	34770.3	23296.07	11474.18
70	3500.0	0.77	27.3	23296.1		0.0	202.9	0.09	18.261	23862.2	9.5	73.2	23789.0	15938.64	7850.37
71	3550.0	0.77	28.07	15938.6		0.0	202.9	0.09	18.261	16504.7	9.5	73.2	16431.6	11009.16	5422.42
72	3600.0	0.77	28.84	52639.0	41629.8	0.0	202.9	0.09	18.261	53205.1	9.5	73.2	53131.9	35598.39	17533.54
73	3650.0	0.77	29.61	35598.4		0.0	202.9	0.09	18.261	36164.5	9.5	73.2	36091.3	24181.19	11910.14
74	3700.0	0.77	30.38	53624.9	29443.7	0.0	202.9	0.09	18.261	54191.0	9.5	73.2	54117.8	36258.93	17858.88
75	3750.0	0.77	31.15	36258.9		0.0	202.9	0.09	18.261	36825.0	9.5	73.2	36751.9	24623.76	12128.12
76	3800.0	0.77	31.92	54610.8	29987.0	0.0	202.9	0.09	18.261	55176.8	9.5	73.2	55103.7	36919.47	18184.22
77	3850.0	0.77	32.69	36919.5		0.0	202.9	0.09	18.261	37485.6	9.5	73.2	37412.4	25066.32	12346.10
78	3900.0	0.77	33.46	55596.6	30530.3	0.0	202.9	0.09	18.261	56162.7	9.5	73.2	56089.6	37580.01	18509.56
79	3950.0	0.77	34.23	37580.0		0.0	202.9	0.09	18.261	38146.1	9.5	73.2	38073.0	25508.88	12564.08
80	4000.0	0.77	35	56582.5	31073.6	0.0	202.9	0.09	18.261	57148.6	9.5	73.2	57075.5	38240.56	18834.90
				1055.6		939.8									
				Total water supply =		1995.4									

Water re.=Virtical percolation 13.6mm+Horizontal leakage 5mm+⑨ (ETc mm/mon.) ／days in month (ETc: calculated by CROPWAT-8)

②;=upper one column in ⑫ row (2/3×Horizontal leakage), at the intake point, larger one between the former value and supply target area×(ETc+Virtical 13.6mm+ Horizontal 5n

③; intake quantity of the total return flow in ⑬row after the previous intake point

④; resupply quantity in case of the total return flow being less than irrigation water requirement at the relevant intake point

⑤;=total flow rate at the dam site per month (estimated by the Tank Model Analysis) devided by catchment area 8.8km2 and devided by the days' number of the relevant month

Table 4-1-1-10(12) Calculation of Water Quantity for Supplemental Supply to the Paddy Field (December)

Dec. Water Re= 18.79 mm/day

NO.	Distance (m)	① Paddy Area (ha)	Cumulative Area (ha)	② W.S./initial, return (m3/mon)	③ Intake quantity (m3/mon.)	④ Supplemental supply (m3/mon)	⑤ Specific discharge (m3/km2)	⑥ catchment area (km2)	⑦=⑤×⑥ Flow-in volume (m3/day)	⑧=②+⑦×31 Irrigation water (m3/mon)	⑨ ETc (mm/mon)	⑩=①×⑨×10000/1000 Water loss (m3/mon)	⑪=⑧-⑩ Residual water (m3/mon.	⑫=⑪×0.67 Horizontal leakage (m3/mon.)	⑬=⑪×0.33 Return to the river (m3/mon.)
1	50.0	0.18	0.144	1048.5			333.5	0.085	28.3475	1927.3	5.9	10.6	1916.7	1284.16	632.50
2	100.0	0.18	0.324	2097.0	632.5	180.3	333.5	0.085	28.3475	3156.1	5.9	10.6	3145.5	2107.49	1038.02
3	150.0	0.18	0.504	2107.5		0.0	333.5	0.085	28.3475	2986.3	5.9	10.6	2975.6	1993.68	981.96
4	200.0	0.18	0.684	4194.0	2020.0	180.3	333.5	0.085	28.3475	5072.8	5.9	10.6	5062.2	3391.64	1670.51
5	250.0	0.18	0.864	3391.6		0.0	333.5	0.085	28.3475	4270.4	5.9	10.6	4259.8	2854.06	1405.73
6	300.0	0.18	1.044	2854.1		0.0	333.5	0.085	28.3475	3732.8	5.9	10.6	3722.2	2493.88	1228.33
7	350.0	0.18	1.224	2493.9		0.0	333.5	0.085	28.3475	3372.7	5.9	10.6	3362.0	2252.56	1109.47
8	400.0	0.18	1.404	7666.6	5414.0	0.0	333.5	0.085	28.3475	8545.4	5.9	10.6	8534.8	5718.29	2816.47
9	450.0	0.18	1.584	5718.3		0.0	333.5	0.085	28.3475	6597.1	5.9	10.6	6586.4	4412.92	2173.53
10	500.0	0.18	1.764	4412.9		0.0	333.5	0.085	28.3475	5291.7	5.9	10.6	5281.1	3538.32	1742.75
11	550.0	0.18	1.944	3538.3		0.0	333.5	0.085	28.3475	4417.1	5.9	10.6	4406.5	2952.33	1454.13
12	600.0	0.18	2.124	11139.2	8186.9	0.0	333.5	0.085	28.3475	12018.0	5.9	10.6	12007.4	8044.94	3962.43
13	650.0	0.18	2.304	8044.9		0.0	333.5	0.085	28.3475	8923.7	5.9	10.6	8913.1	5971.77	2941.32
14	700.0	0.18	2.484	5971.8		0.0	333.5	0.085	28.3475	6850.5	5.9	10.6	6839.9	4582.75	2257.17
15	750.0	0.18	2.664	4582.7		0.0	333.5	0.085	28.3475	5461.5	5.9	10.6	5450.9	3652.10	1798.80
16	800.0	0.18	2.844	14611.8	10959.7	0.0	333.5	0.085	28.3475	15490.6	5.9	10.6	15480.0	10371.59	5108.39
17	850.0	0.18	3.024	10371.6		0.0	333.5	0.085	28.3475	11250.4	5.9	10.6	11239.7	7530.63	3709.11
18	900.0	0.18	3.204	7530.6		0.0	333.5	0.085	28.3475	8409.4	5.9	10.6	8398.8	5627.18	2771.60
19	950.0	0.18	3.384	5627.2		0.0	333.5	0.085	28.3475	6506.0	5.9	10.6	6495.3	4351.87	2143.46
20	1000.0	0.18	3.564	18084.4	13732.6	0.0	333.5	0.085	28.3475	18963.2	5.9	10.6	18952.6	12698.24	6254.36
21	1050.0	0.335	3.899	12698.2		0.0	333.5	0.1	33.35	13732.1	5.9	19.8	13712.3	9187.26	4525.07
22	1100.0	0.335	4.234	9187.3		0.0	333.5	0.1	33.35	10221.1	5.9	19.8	10201.3	6834.90	3366.44
23	1150.0	0.335	4.569	6834.9		0.0	333.5	0.1	33.35	7868.7	5.9	19.8	7849.0	5258.82	2590.16
24	1200.0	0.335	4.904	21994.8	16736.0	0.0	333.5	0.1	33.35	23028.7	5.9	19.8	23008.9	15415.98	7592.95
25	1250.0	0.335	5.239	15416.0		0.0	333.5	0.1	33.35	16449.8	5.9	19.8	16430.1	11008.15	5421.92
26	1300.0	0.335	5.574	11008.1		0.0	333.5	0.1	33.35	12042.0	5.9	19.8	12022.2	8054.90	3967.34
27	1350.0	0.335	5.909	8054.9		0.0	333.5	0.1	33.35	9088.7	5.9	19.8	9069.0	6076.22	2992.76
28	1400.0	0.335	6.244	26051.2	19975.0	0.0	333.5	0.1	33.35	27085.0	5.9	19.8	27065.3	18133.73	8931.54
29	1450.0	0.335	6.579	18133.7		0.0	333.5	0.1	33.35	19167.6	5.9	19.8	19147.8	12829.04	6318.78
30	1500.0	0.335	6.914	12829.0		0.0	333.5	0.1	33.35	13862.9	5.9	19.8	13843.1	9274.89	4568.23
31	1550.0	0.335	7.249	9274.9		0.0	333.5	0.1	33.35	10308.7	5.9	19.8	10289.0	6893.61	3395.36
32	1600.0	0.335	7.584	30107.5	23213.9	0.0	333.5	0.1	33.35	31141.4	5.9	19.8	31121.6	20851.48	10270.13
33	1650.0	0.335	7.919	20851.5		0.0	333.5	0.1	33.35	21885.3	5.9	19.8	21865.6	14649.93	7215.64
34	1700.0	0.335	8.254	14649.9		0.0	333.5	0.1	33.35	15683.8	5.9	19.8	15664.0	10494.89	5169.12
35	1750.0	0.335	8.589	10494.9		0.0	333.5	0.1	33.35	11528.7	5.9	19.8	11509.0	7711.01	3797.96
36	1800.0	0.335	8.924	34163.9	26452.9	0.0	333.5	0.1	33.35	35197.7	5.9	19.8	35178.0	23569.23	11608.72
37	1850.0	0.335	9.259	23569.2		0.0	333.5	0.1	33.35	24603.1	5.9	19.8	24583.3	16470.82	8112.49
38	1900.0	0.335	9.594	16470.8		0.0	333.5	0.1	33.35	17504.7	5.9	19.8	17484.9	11714.89	5770.02
39	1950.0	0.335	9.929	11714.9		0.0	333.5	0.1	33.35	12748.7	5.9	19.8	12729.0	8528.41	4200.56
40	2000.0	0.335	10.264	38220.2	29691.8	0.0	333.5	0.1	33.35	39254.1	5.9	19.8	39234.3	26286.98	12947.32
41	2050.0	0.465	10.729	26287.0		0.0	333.5	0.185	61.6975	28199.6	5.9	27.4	28172.2	18875.35	9296.81
42	2100.0	0.465	11.194	18875.3		0.0	333.5	0.185	61.6975	20788.0	5.9	27.4	20760.5	13909.56	6850.98
43	2150.0	0.465	11.659	13909.6		0.0	333.5	0.185	61.6975	15822.2	5.9	27.4	15794.7	10582.48	5212.27
44	2200.0	0.465	12.124	44889.9	34307.4	0.0	333.5	0.185	61.6975	46802.5	5.9	27.4	46775.0	31339.28	15435.76
45	2250.0	0.465	12.589	31339.3		0.0	333.5	0.185	61.6975	33251.9	5.9	27.4	33224.5	22260.39	10964.07
46	2300.0	0.465	13.054	22260.4		0.0	333.5	0.185	61.6975	24173.0	5.9	27.4	24145.6	16177.54	7968.04
47	2350.0	0.465	13.519	16177.5		0.0	333.5	0.185	61.6975	18090.2	5.9	27.4	18062.7	12102.03	5960.70
48	2400.0	0.465	13.984	52430.6	40328.6	0.0	333.5	0.185	61.6975	54343.2	5.9	27.4	54315.8	36391.58	17924.21
49	2450.0	0.465	14.449	36391.6		0.0	333.5	0.185	61.6975	38304.2	5.9	27.4	38276.8	25645.43	12631.33
50	2500.0	0.465	14.914	25645.4		0.0	333.5	0.185	61.6975	27558.1	5.9	27.4	27530.6	18445.52	9085.11
51	2550.0	0.465	15.379	18445.5		0.0	333.5	0.185	61.6975	20358.1	5.9	27.4	20330.7	13621.57	6709.13
52	2600.0	0.465	15.844	59971.4	46349.8	0.0	333.5	0.185	61.6975	61884.0	5.9	27.4	61856.5	41443.88	20412.66
53	2650.0	0.465	16.309	41443.9		0.0	333.5	0.185	61.6975	43356.5	5.9	27.4	43329.1	29030.48	14298.59
54	2700.0	0.465	16.774	29030.5		0.0	333.5	0.185	61.6975	30943.1	5.9	27.4	30915.7	20713.50	10202.17
55	2750.0	0.465	17.239	20713.5		0.0	333.5	0.185	61.6975	22626.1	5.9	27.4	22598.7	15141.12	7457.57
56	2800.0	0.465	17.704	67512.1	52371.0	0.0	333.5	0.185	61.6975	69424.7	5.9	27.4	69397.3	46496.19	22901.11
57	2850.0	0.465	18.169	46496.2		0.0	333.5	0.185	61.6975	48408.8	5.9	27.4	48381.4	32415.52	15965.85
58	2900.0	0.465	18.634	32415.5		0.0	333.5	0.185	61.6975	34328.1	5.9	27.4	34300.7	22981.47	11319.23
59	2950.0	0.465	19.099	22981.5		0.0	333.5	0.185	61.6975	24894.1	5.9	27.4	24866.7	16660.66	8206.00
60	3000.0	0.465	19.564	75052.9	58392.2	0.0	333.5	0.185	61.6975	76965.5	5.9	27.4	76938.0	51548.49	25389.55
61	3050.0	0.77	20.334	51548.5		0.0	333.5	0.09	30.015	52479.0	5.9	45.4	52433.5	35130.46	17303.06
62	3100.0	0.77	21.104	35130.5		0.0	333.5	0.09	30.015	36060.9	5.9	45.4	36015.5	24130.38	11885.11
63	3150.0	0.77	21.874	24130.4		0.0	333.5	0.09	30.015	25060.8	5.9	45.4	25015.4	16760.33	8255.09
64	3200.0	0.77	22.644	79593.1	62832.8	0.0	333.5	0.09	30.015	80523.6	5.9	45.4	80478.2	53920.38	26557.80
65	3250.0	0.77	23.414	53920.4		0.0	333.5	0.09	30.015	54850.8	5.9	45.4	54805.4	36719.63	18085.79
66	3300.0	0.77	24.184	36719.6		0.0	333.5	0.09	30.015	37650.1	5.9	45.4	37604.7	25195.13	12409.54
67	3350.0	0.77	24.954	25195.1		0.0	333.5	0.09	30.015	26125.6	5.9	45.4	26080.2	17473.71	8606.45
68	3400.0	0.77	25.724	83133.3	65659.6	0.0	333.5	0.09	30.015	84063.8	5.9	45.4	84018.3	56292.28	27726.05
69	3450.0	0.77	26.494	56292.3		0.0	333.5	0.09	30.015	57222.7	5.9	45.4	57177.3	38308.80	18868.51
70	3500.0	0.77	27.264	38308.8		0.0	333.5	0.09	30.015	39239.3	5.9	45.4	39193.8	26259.87	12933.97
71	3550.0	0.77	28.034	26259.9		0.0	333.5	0.09	30.015	27190.3	5.9	45.4	27144.9	18187.09	8957.82
72	3600.0	0.77	28.804	86673.4	68486.3	0.0	333.5	0.09	30.015	87603.9	5.9	45.4	87558.5	58664.17	28894.29
73	3650.0	0.77	29.574	58664.2		0.0	333.5	0.09	30.015	59594.6	5.9	45.4	59549.2	39897.97	19651.24
74	3700.0	0.77	30.344	88443.5	48545.5	0.0	333.5	0.09	30.015	89374.0	5.9	45.4	89328.5	59850.12	29478.42
75	3750.0	0.77	31.114	59850.1		0.0	333.5	0.09	30.015	60780.6	5.9	45.4	60735.2	40692.55	20042.60
76	3800.0	0.77	31.884	90213.6	49521.0	0.0	333.5	0.09	30.015	91144.0	5.9	45.4	91098.6	61036.06	30062.54
77	3850.0	0.77	32.654	61036.1		0.0	333.5	0.09	30.015	61966.5	5.9	45.4	61921.1	41487.14	20433.96
78	3900.0	0.77	33.424	91983.6	50496.5	0.0	333.5	0.09	30.015	92914.1	5.9	45.4	92868.7	62222.01	30646.66
79	3950.0	0.77	34.194	62222.0		0.0	333.5	0.09	30.015	63152.5	5.9	45.4	63107.0	42281.72	20825.33
80	4000.0	0.77	34.964	93753.7	51472.0	0.0	333.5	0.09	30.015	94684.2	5.9	45.4	94638.7	63407.96	31230.79
				1048.5		360.7									

Total water supply = 1409.2

Water re.=Virtical percolation 13.6mm+Horizontal leakage 5mm+⑨ (ETc mm/mon.) ／days in month (ETc: calculated by CROPWAT-8)

②;=upper one column in ⑫ row (2/3×Horizontal leakage), at the intake point, larger one between the former value and supply target area×(ETc+Virtical 13.6mm+ Horizontal 5n

③;intake quantity of the total return flow in ⑬row after the previous intake point

④;resupply quantity in case of the total return flow being less than irrigation water requirement at the relevant intake point

⑤;=total flow rate at the dam site per month (estimated by the Tank Model Analysis) devided by catchment area 8.8km2 and devided by the days' number of the relevant month

(3) Irrigation Planning

(a) Irrigation Water Requirement

Irrigation water requirement is calculated based on cropping pattern & acreage, which are studied in "*4-2. Farming Management Plan*", and meteorological data as follows:

i) Conditions of Study

1) Cropping Pattern

Cropping pattern & acreage, which is recommended to be introduced to command area of Ngoma 22, are shown in will be introduced to Ngoma-22 area and it acreage is shown in the following figure and table:

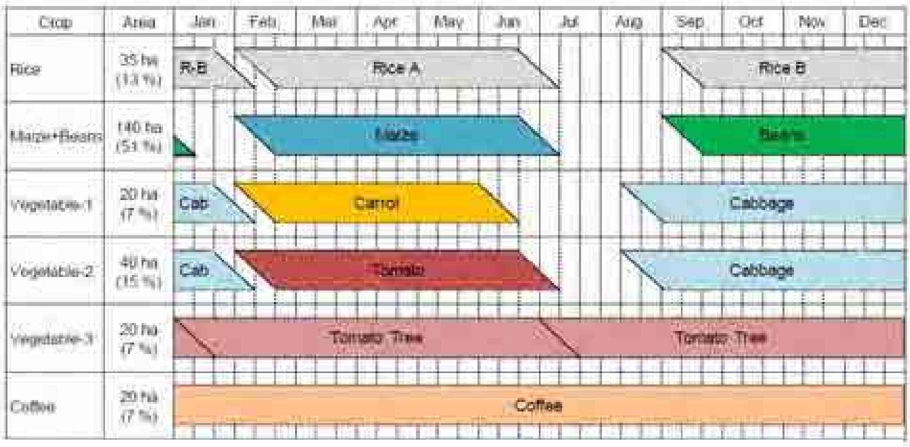


Fig. 4-1-1-20 Cropping Pattern & Acreage of Ngoma-22 (Planed)

Table 4-1-1-11 Cropping Pattern & Acreage of Ngoma-22 (Planed)

Crop		Cropping Acreage	Remarks
Rice Paddy		35 ha (13 %)	
Upland Cropping	Maize + Beans	140 ha (51 %)	
	Vegetable-1	20 ha (7 %)	Carrot + Cabbage
	Vegetable-2	40 ha (15 %)	Tomato + Cabbage
	Vegetable-3	20 ha (7 %)	Tomato Tree
	Coffee	20 ha (7 %)	
	Sub-total	240 ha (87 %)	
Total		275 ha (100 %)	

2) Meteorological Data

In this study, rainfall and temperature observed at Gahororo station, the nearest weather station by command area of Ngoma 22, are adopted for calculation of irrigation water requirement. And other meteorological data, such as relative humidity, wind velocity and sunshine hours observed at Kigali national airport station are adopted since these data are not observed at Gahororo station.

Table 4-1-1-12 Meteorological Data

	Rainfall (mm)	Min.Temp. (℃)	Max.Temp (℃)	Humidity (%)	Wind (km/day)	Sunshine (hrs.)	Radiation ($MJ/m^2/day$)	RET (mm/day)
Jan.	188.2	10.0	25.3	77	324	6.1	18.6	4.01
Feb.	70.7	9.8	26.4	77	297	6.2	19.2	4.20
Mar.	91.8	10.3	26.6	77	257	4.9	17.2	3.93
Apr.	152.6	10.0	25.4	84	188	5.2	17.0	3.38
May	104.9	10.3	24.3	82	206	5.6	16.5	3.21
Jun.	4.5	11.1	25.6	84	197	5.4	15.6	3.09
Jul.	5.7	10.9	26.3	77	222	4.7	14.9	3.39
Aug.	53.5	9.9	26.8	64	292	7.7	20.2	4.79
Sep.	20.7	10.6	28.4	72	307	6.0	18.6	4.62
Oct.	118.4	9.5	27.5	74	336	6.7	19.9	4.68
Nov.	161.7	10.0	26.0	83	24	4.7	16.4	3.51
Dec.	161.6	10.4	23.8	85	226	5.4	17.3	3.26
Total/Ave.	1,134.3	10.2	26.0	78	258	5.7	17.6	3.84

Notes
*1) Rainfall: Gahororo Station (Rurenge Sector, Ngoma District), 1970.01-12
*2) Minimum Temperature: Gahororo Station, 1970.01-12
*3) Maximum Temperature: Gahororo Station, 1970.01, 1974.02-04, 1970.05-12
*4) Humidity, Wind, and Sunshine: Kigali Station, 1974.01-12
*5)Radiation and RET (Reference Evapotranspiration) is calculated by CROPWAT8.0 based on other data.

ⅱ) Study of Irrigation Water Requirement

1) Unit Irrigation Water Requirement (UIWR)

Unit irrigation water requirement (UIWR) is the quantity of water necessary for crop growth, and expressed in millimeters (mm). It is calculated by CROPWAT8.0, which is a decision support tool developed by the Land Water Development Division of FAO (Food and Agriculture Organization), based on meteorology, soil and crop data.

The results of computation of unit irrigation water requirement (UIWR) are shown in (Table 4-1-1-15) and (Table 4-1-1-16).

2) Net Irrigation Water Requirement (NIWR)

Net irrigation water requirement (NIWR) is the quantity of water for crop growth taking into account cropping acreage, and expressed in cubic-meters (m^3). It is calculated based on UIWR and cropping acreage as follows:

NIWR (m^3) = UIWR (mm) / 1,000 (mm/m) * cropping acreage (ha) * 10,000 (m^2/ha)

The results of computation of net irrigation water requirement (NIWR) are shown in (Table 4-1-1-17).

3) Gross Irrigation Water Requirement (GIWR)

Gross irrigation water requirement (GIWR) is the quantity of water to be applied in reality taking into account water losses, and expressed in cubic-meters (m^3). It is calculated based on NIWR, irrigation efficiency (E) and wetting area coefficient (Kw) and as follows:

GIWR (m^3) = NIWR (m^3) / E (%) * Kw (%)

Irrigation Efficiency (E)

In order to express which percentage of irrigation water is used efficiently and which percentage of is lost, the term irrigation efficiency (E) is used. Irrigation efficiency is subdivided in to conveyance efficiency (Ec) and field application efficiency (Ea) as follows:

E = Ec * Ea

Conveyance efficiency (Ec) presents the efficiency of water transport in canals. It mainly depends on the length of the canals, the soil type or permeability of the canal banks and the condition of canals as shown in the following table:

Table 4-1-1-13 Conveyance Efficiency (Ec)

Description			Conveyance Efficiency (Ec)			
Canal Type			Earthen Canals			**Lined Canals**
Soil Type			Sand	Loam	Clay	-
Canal Length	Long	(> 2,000m)	60 %	70 %	80 %	**95 %**
	Medium	(200- 2,000m)	70 %	75 %	85 %	**95 %**
	Short	(< 200m)	80 %	85 %	90 %	**95 %**

(Irrigation Scheduling, Training Manual No.4, Irrigation Water Management, FAO 1989)

Field application efficiency (Ea) presents the efficiency of water application in the field. It mainly depends on the irrigation method and the level of farmer discipline as shown in the following table:

Table 4-1-1-14 Field Application Efficiency (Ea)

Irrigation Methods	Field Application Efficiency (Ea)
Surface Irrigation (Border, Furrow, Basin)	60 %
Sprinkler Irrigation	75 %
Drip Irrigation	**90 %**

(Irrigation Scheduling, Training Manual No.4, Irrigation Water Management, FAO 1989)

In this study, 95 % is applied as conveyance efficiency (Ec) since stone masonry and pipeline is adopted for main & lateral canal and secondary canal respectively. In addition, 90 % is applied as field application efficiency since hose irrigation method is adopted as on-firm irrigation system.

Therefore, irrigation efficiency is estimated as follows:

E = Ec * Ea = 95 % * 90 % = 85 %

Wetting Area Coefficient

The shape of wet area in a field is different and it depends on the irrigation method and the arrangement of emitters of irrigation system and so on. The ratio of wet area to whole area is expressed by wetting area coefficient (Kw).

According to ”Manual on Design Standard of Efficient Irrigation System and On-farm Irrigation Management” provided by JICA study team for “Project on Development of Efficient Irrigation Techniques and Extension in Syria (DEITEX)” conducted in Syria for three (3) years since March 2005, wetting area coefficient (Kw) is defined as follows:

- Surface and Sprinkler Irrigation
  : Surface and sprinkler irrigation method create whle wet area, and Kw of those is 100 %.
- GR Irrigation (Drip Tube Irrigation)
  : GR irrigation method forms the partial wet zones with a certain width along the drip tubes, and Kw of it varies from 70 to 100 %.
- Micro Irrigation (Micro Emitter, Micro Sprinkler)

: Micro irrigation method forms the isolated wet area around crop plants, and Kw of it varies from 40 to 70 % in accordance with spacing of the crop plants, specification of the emitters and soil type as well.

Since hose irrigation method is adopted as on-firm irrigation system in this study, wetting area coefficient (Kw) for micro irrigation method is applied since hose irrigation method is adopted. Therefore, in this study, comparative study is conducted in four (4) cases, such as Kw = 40, 50, 60 and 70 %.

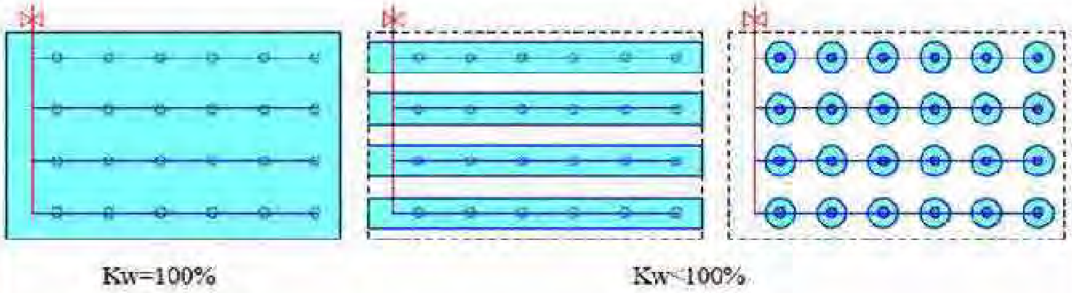


Table 4.5 Wetting area coefficient Kw

Irrigation method	Kw (%)	Remarks
Surface irrigation	100	
Sprinkler irrigation	100	
GR irrigation	70-100	GR : Drip tube
Micro irrigation	40–70	Micro emitter, Micro sprinkler

The results of computation of gross irrigation water requirement (GIWR) are shown in (Table 4-1-1-1~4-1-1-21).

Table 4-1-1-15 Unit Irrigation Water Requirement (per Crop)

Unit Irrigation Water Requirement (per Crop)

(Units: mm/dec)

Month	Decade	Days	Rice Paddy: Rice A 1st.Plant	Rice A 2nd.Plant	Rice A 3rd.Plant	Rice A Average	Rice Paddy: Rice B 1st.Plant	Rice B 2nd.Plant	Rice B 3rd.Plant	Rice B Average	Upland Cropping: Maize 1st.Plant	Maize 2nd.Plant	Maize 3rd.Plant	Maize Average
Jan.	1st.	10	0.0			0.0	0.0	0.0	1.3	0.4				0.0
	2nd.	10	101.6	0.0		33.9	0.0	0.0	0.0	0.0				0.0
	3rd.	11	182.7	106.8	0.0	96.5		0.0	9.5	3.2				0.0
Feb.	1st.	10	19.6	208.2	120.0	115.9			3.0	1.0	0.0			0.0
	2nd.	10	29.3	29.3	218.0	92.2				0.0	0.0	0.0		0.0
	3rd.	8	16.2	16.2	16.2	16.2				0.0	0.0	0.0	0.0	0.0
Mar.	1st.	10	21.0	20.5	20.5	20.7				0.0	0.0	0.0	0.0	0.0
	2nd.	10	20.0	18.6	18.1	18.9				0.0	3.6	0.0	0.0	1.2
	3rd.	11	19.2	17.8	16.3	17.8				0.0	10.6	1.0	0.0	3.9
Apr.	1st.	10	7.0	5.9	4.6	5.8				0.0	6.2	0.0	0.0	2.1
	2nd.	10	0.0	0.0	0.0	0.0				0.0	0.0	0.0	0.0	0.0
	3rd.	10	3.3	3.3	3.0	3.2				0.0	3.5	3.4	2.2	3.0
May	1st.	10	6.0	6.0	6.0	6.0				0.0	6.2	6.2	6.1	6.2
	2nd.	10	7.6	7.6	7.5	7.6				0.0	7.8	7.7	7.7	7.7
	3rd.	11	19.3	21.0	21.0	20.4				0.0	16.1	21.2	21.1	19.5
Jun.	1st.	10	29.1	32.2	33.9	31.7				0.0	19.9	29.1	34.1	27.7
	2nd.	10	29.8	32.9	36.0	32.9				0.0	14.9	23.9	32.9	23.9
	3rd.	10		30.5	33.8	21.4				0.0		15.1	24.4	13.2
Jul.	1st.	10			30.8	10.3				0.0			15.0	5.0
	2nd.	10				0.0				0.0				0.0
	3rd.	11				0.0				0.0				0.0
Aug.	1st.	10				0.0	0.0			0.0				0.0
	2nd.	10				0.0	129.7	0.0		43.2				0.0
	3rd.	11				0.0	231.2	138.3	0.0	123.2				0.0
Sep.	1st.	10				0.0	44.9	234.4	145.2	141.5				0.0
	2nd.	10				0.0	49.1	49.1	238.5	112.2				0.0
	3rd.	10				0.0	39.3	39.3	39.3	39.3				0.0
Oct.	1st.	10				0.0	27.9	26.8	26.8	27.2				0.0
	2nd.	10				0.0	21.2	19.2	18.2	19.5				0.0
	3rd.	11				0.0	21.4	19.4	17.6	19.5				0.0
Nov.	1st.	10				0.0	9.3	8.0	6.6	8.0				0.0
	2nd.	10				0.0	1.2	0.9	0.0	0.7				0.0
	3rd.	10				0.0	0.9	0.7	0.8	0.8				0.0
Dec.	1st.	10				0.0	0.9	0.8	0.9	0.9				0.0
	2nd.	10				0.0	0.0	0.0	0.0	0.0				0.0
	3rd.	11				0.0	3.4	5.7	5.9	5.0				0.0
Annual IWR (mm/yr.)			*511.7*	*556.8*	*585.7*	***551.4***	*580.4*	*542.6*	*513.6*	***545.5***	*88.8*	*107.6*	*143.5*	***113.3***
Max. IWR (mm/dec.)						***115.9***				***141.5***				***27.7***

Month	Decade	Days	Upland Cropping: Beans 1st.Plant	Beans 2nd.Plant	Beans 3rd.Plant	Beans Average	Carrot 1st.Plant	Carrot 2nd.Plant	Carrot 3rd.Plant	Carrot Average	Cabbage 1st.Plant	Cabbage 2nd.Plant	Cabbage 3rd.Plant	Cabbage Average
Jan.	1st.	10			0.0	0.0				0.0	0.0	0.0	0.0	0.0
	2nd.	10				0.0				0.0	0.0	0.0	0.0	0.0
	3rd.	11				0.0				0.0	8.2	7.6	9.8	8.5
Feb.	1st.	10				0.0	3.1			1.0		4.2	16.9	7.0
	2nd.	10				0.0	12.5	12.5		8.3			4.2	1.4
	3rd.	8				0.0	4.9	3.0	3.0	3.6				0.0
Mar.	1st.	10				0.0	11.1	6.2	4.4	7.2				0.0
	2nd.	10				0.0	13.8	8.9	4.1	8.9				0.0
	3rd.	11				0.0	14.5	11.4	6.3	10.7				0.0
Apr.	1st.	10				0.0	1.8	1.6	0.0	1.1				0.0
	2nd.	10				0.0	0.0	0.0	0.0	0.0				0.0
	3rd.	10				0.0	0.0	0.0	0.0	0.0				0.0
May	1st.	10				0.0	1.0	0.9	0.9	0.9				0.0
	2nd.	10				0.0	1.9	2.6	2.5	2.3				0.0
	3rd.	11				0.0	12.9	14.7	15.5	14.4				0.0
Jun.	1st.	10				0.0		26.6	28.2	18.3				0.0
	2nd.	10				0.0			30.5	10.2				0.0
	3rd.	10				0.0				0.0				0.0
Jul.	1st.	10				0.0				0.0				0.0
	2nd.	10				0.0				0.0				0.0
	3rd.	11				0.0				0.0				0.0
Aug.	1st.	10				0.0				0.0				0.0
	2nd.	10				0.0				0.0	14.5			4.8
	3rd.	11				0.0				0.0	21.6	21.6	3.4	15.5
Sep.	1st.	10	12.1			4.0				0.0	26.2	26.2	26.2	26.2
	2nd.	10	16.8	16.8		11.2				0.0	30.7	30.6	30.6	30.6
	3rd.	10	13.5	6.8	6.8	9.0				0.0	22.6	20.7	20.7	21.3
Oct.	1st.	10	13.2	0.5	0.0	4.6				0.0	12.8	9.9	8.0	10.2
	2nd.	10	17.0	4.0	0.0	7.0				0.0	7.0	4.1	1.1	4.1
	3rd.	11	21.0	15.3	2.8	13.0				0.0	8.5	5.5	2.6	5.5
Nov.	1st.	10	7.8	7.3	3.6	6.2				0.0	0.3	0.0	0.0	0.1
	2nd.	10	0.0	0.0	0.0	0.0				0.0	0.0	0.0	0.0	0.0
	3rd.	10	0.0	0.0	0.0	0.0				0.0	0.0	0.0	0.0	0.0
Dec.	1st.	10	0.0	0.0	0.0	0.0				0.0	0.0	0.0	0.0	0.0
	2nd.	10	0.0	0.0	0.0	0.0				0.0	0.0	0.0	0.0	0.0
	3rd.	11		0.0	0.0	0.0				0.0	0.0	0.0	0.3	0.1
Annual IWR (mm/yr.)			*101.4*	*50.7*	*13.2*	***55.1***	*77.5*	*88.4*	*95.4*	***87.1***	*152.4*	*130.4*	*123.8*	***135.5***
Max. IWR (mm/dec.)						***13.0***				***18.3***				***30.6***

Month	Decade	Days	Upland Cropping: Tomato 1st.Plant	Tomato 2nd.Plant	Tomato 3rd.Plant	Tomato Average	Tomato Tree 1st.Plant	Tomato Tree 2nd.Plant	Tomato Tree 3rd.Plant	Tomato Tree Average	Coffee 1st.Plant	Coffee 2nd.Plant	Coffee 3rd.Plant	Coffee Average
Jan.	1st.	10				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2nd.	10				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	3rd.	11				0.0	0.0	0.0	0.0	0.0	1.6	1.6	1.6	1.6
Feb.	1st.	10	0.0			0.0	6.8	2.0	0.0	2.9	11.4	11.4	11.4	11.4
	2nd.	10	8.3	8.3		5.5	21.1	16.3	11.4	16.3	20.9	20.9	20.9	20.9
	3rd.	8	0.0	0.0	0.0	0.0	13.2	9.4	5.6	9.4	9.6	9.6	9.6	9.6
Mar.	1st.	10	2.5	0.4	0.4	1.1	21.0	16.3	11.6	16.3	12.5	12.5	12.5	12.5
	2nd.	10	6.0	0.5	0.0	2.2	21.1	18.5	13.9	17.8	10.2	10.2	10.2	10.2
	3rd.	11	9.2	3.4	0.0	4.2	18.9	18.8	16.3	18.0	7.5	7.5	7.5	7.5
Apr.	1st.	10	2.5	0.0	0.0	0.8	5.5	5.4	5.3	5.4	0.0	0.0	0.0	0.0
	2nd.	10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	3rd.	10	1.5	1.5	0.0	1.0	1.7	1.6	1.5	1.6	0.0	0.0	0.0	0.0
May	1st.	10	4.3	4.3	4.2	4.3	4.5	4.4	4.3	4.4	0.0	0.0	0.0	0.0
	2nd.	10	5.9	5.8	5.8	5.8	6.1	6.0	5.9	6.0	0.0	0.0	0.0	0.0
	3rd.	11	16.0	19.1	19.1	18.1	19.4	19.3	19.1	19.3	11.7	11.0	10.2	11.0
Jun.	1st.	10	23.6	29.2	32.3	28.4	32.4	32.4	32.3	32.4	26.4	25.7	25.0	25.7
	2nd.	10	11.6	27.5	33.0	24.0	31.7	36.1	36.1	34.6	30.9	30.3	29.6	30.3
	3rd.	10		11.9	28.1	13.3	22.9	32.4	36.9	30.7	32.3	31.7	31.0	31.7
Jul.	1st.	10			11.9	4.0	18.8	23.1	32.6	24.8	32.7	32.5	31.9	32.4
	2nd.	10				0.0	19.8	19.8	24.2	21.3	34.0	34.0	33.8	33.9
	3rd.	11				0.0	22.8	19.8	19.8	20.8	37.7	37.8	37.9	37.8
Aug.	1st.	10				0.0	21.4	16.0	12.6	16.7	31.5	31.6	31.7	31.6
	2nd.	10				0.0	25.4	19.4	13.5	19.4	30.8	30.8	30.9	30.8
	3rd.	11				0.0	40.1	33.5	27.1	33.6	39.1	39.2	39.3	39.2
Sep.	1st.	10				0.0	48.4	42.7	36.9	42.7	41.7	41.7	41.8	41.7
	2nd.	10				0.0	54.1	52.3	46.7	51.0	46.0	46.0	46.1	46.0
	3rd.	10				0.0	44.3	44.1	42.3	43.6	36.1	36.1	36.2	36.1
Oct.	1st.	10				0.0	32.0	31.7	31.5	31.7	23.6	23.6	23.8	23.7
	2nd.	10				0.0	23.4	23.1	22.9	23.1	14.9	14.9	15.1	15.0
	3rd.	11				0.0	21.7	21.4	21.2	21.4	13.2	13.2	13.4	13.3
Nov.	1st.	10				0.0	8.3	8.1	7.9	8.1	1.5	1.6	1.7	1.6
	2nd.	10				0.0	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.0
	3rd.	10				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dec.	1st.	10				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2nd.	10				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	3rd.	11				0.0	0.0	0.0	3.7	1.2	0.0	0.0	0.0	0.0
Annual IWR (mm/yr.)			*91.4*	*111.9*	*134.8*	***112.7***	*226.3*	*242.0*	*257.0*	***574.7***	*557.8*	*555.4*	*553.1*	***555.4***
Max. IWR (mm/dec.)						***28.4***	*380.7*	*331.9*	*286.1*	***51.0***				***46.0***

Notes

*1) Irrigation Water Requirement : Calculated by CROPWAT8 based on cropping pattern for Ngoma22.

Table 4-1-1-16 Unit Irrigation Water Requirement (per Cropping Pattern)

Unit Irrigation Water Requirement (per Cropping Pattern)

(Units: mm/dec)

Month	Decade	Days	Rice Paddy			Upland Cropping											
						Maize + Beans			Vegetable 1			Vegetable 2			Vegetable 3		
			Rice A (Average)	Rice B (Average)	**Total**	Maize (Average)	Beans (Average)	Sub-total	Carrot (Average)	Cabbage (Average)	Sub-total	Tomato (Average)	Cabbage (Average)	Sub-total	Tomato Tree (Average)	Coffee (Average)	**Total**
Jan.	1st.	10	0.0	0.4	**0.4**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
	2nd.	10	33.9	0.0	**33.9**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
	3rd.	11	96.5	3.2	**99.7**	0.0	0.0	0.0	0.0	8.5	8.5	0.0	8.5	8.5	0.0	1.6	**18.7**
Feb.	1st.	10	115.9	1.0	**116.9**	0.0	0.0	0.0	1.0	7.0	8.1	0.0	7.0	7.0	2.9	11.4	**29.4**
	2nd.	10	92.2	0.0	**92.2**	0.0	0.0	0.0	8.3	1.4	9.7	5.5	1.4	6.9	16.3	20.9	**53.8**
	3rd.	8	16.2	0.0	**16.2**	0.0	0.0	0.0	3.6	0.0	3.6	0.0	0.0	0.0	9.4	9.6	**22.6**
Mar.	1st.	10	20.7	0.0	**20.7**	0.0	0.0	0.0	7.2	0.0	7.2	1.1	0.0	1.1	16.3	12.5	**37.1**
	2nd.	10	18.9	0.0	**18.9**	1.2	0.0	1.2	8.9	0.0	8.9	2.2	0.0	2.2	17.8	10.2	**40.3**
	3rd.	11	17.8	0.0	**17.8**	3.9	0.0	3.9	10.7	0.0	10.7	4.2	0.0	4.2	18.0	7.5	**44.3**
Apr.	1st.	10	5.8	0.0	**5.8**	2.1	0.0	2.1	1.1	0.0	1.1	0.8	0.0	0.8	5.4	0.0	**9.4**
	2nd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
	3rd.	10	3.2	0.0	**3.2**	3.0	0.0	3.0	0.0	0.0	0.0	1.0	0.0	1.0	1.6	0.0	**5.6**
May	1st.	10	6.0	0.0	**6.0**	6.2	0.0	6.2	0.9	0.0	0.9	4.3	0.0	4.3	4.4	0.0	**15.8**
	2nd.	10	7.6	0.0	**7.6**	7.7	0.0	7.7	2.3	0.0	2.3	5.8	0.0	5.8	6.0	0.0	**21.9**
	3rd.	11	20.4	0.0	**20.4**	19.5	0.0	19.5	14.4	0.0	14.4	18.1	0.0	18.1	19.3	11.0	**82.1**
Jun.	1st.	10	31.7	0.0	**31.7**	27.7	0.0	27.7	18.3	0.0	18.3	28.4	0.0	28.4	32.4	25.7	**132.4**
	2nd.	10	32.9	0.0	**32.9**	23.9	0.0	23.9	10.2	0.0	10.2	24.0	0.0	24.0	34.6	30.3	**123.0**
	3rd.	10	21.4	0.0	**21.4**	13.2	0.0	13.2	0.0	0.0	0.0	13.3	0.0	13.3	30.7	31.7	**88.9**
Jul.	1st.	10	10.3	0.0	**10.3**	5.0	0.0	5.0	0.0	0.0	0.0	4.0	0.0	4.0	24.8	32.4	**66.2**
	2nd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.3	33.9	**55.2**
	3rd.	11	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.8	37.8	**58.6**
Aug.	1st.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.7	31.6	**48.3**
	2nd.	10	0.0	43.2	**43.2**	0.0	0.0	0.0	0.0	4.8	4.8	0.0	4.8	4.8	19.4	30.8	**59.9**
	3rd.	11	0.0	123.2	**123.2**	0.0	0.0	0.0	0.0	15.5	15.5	0.0	15.5	15.5	33.6	39.2	**103.8**
Sep.	1st.	10	0.0	141.5	**141.5**	0.0	4.0	4.0	0.0	26.2	26.2	0.0	26.2	26.2	42.7	41.7	**140.8**
	2nd.	10	0.0	112.2	**112.2**	0.0	11.2	11.2	0.0	30.6	30.6	0.0	30.6	30.6	51.0	46.0	**169.5**
	3rd.	10	0.0	39.3	**39.3**	0.0	9.0	9.0	0.0	21.3	21.3	0.0	21.3	21.3	43.6	36.1	**131.4**
Oct.	1st.	10	0.0	27.2	**27.2**	0.0	4.6	4.6	0.0	10.2	10.2	0.0	10.2	10.2	31.7	23.7	**80.4**
	2nd.	10	0.0	19.5	**19.5**	0.0	7.0	7.0	0.0	4.1	4.1	0.0	4.1	4.1	23.1	15.0	**53.2**
	3rd.	11	0.0	19.5	**19.5**	0.0	13.0	13.0	0.0	5.5	5.5	0.0	5.5	5.5	21.4	13.3	**58.8**
Nov.	1st.	10	0.0	8.0	**8.0**	0.0	6.2	6.2	0.0	0.1	0.1	0.0	0.1	0.1	8.1	1.6	**16.1**
	2nd.	10	0.0	0.7	**0.7**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	**0.1**
	3rd.	10	0.0	0.8	**0.8**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Dec.	1st.	10	0.0	0.9	**0.9**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
	2nd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
	3rd.	11	0.0	5.0	**5.0**	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.1	1.2	0.0	**1.4**
Annual IWR (mm/yr.)			*551.4*	*545.5*	***1,096.9***	*113.3*	*55.1*	*168.4*	*87.1*	*135.5*	*222.6*	*112.7*	*135.5*	*248.2*	*574.7*	*555.4*	***1,769.4***
Max. IWR (mm/dec.)			*115.9*	*141.5*	***141.5***	*27.7*	*13.0*	*27.7*	*18.3*	*30.6*	*30.6*	*28.4*	*30.6*	*30.6*	*51.0*	*46.0*	***169.5***

Table 4-1-1-17 Net Irrigation Water Requirement (per Cropping Pattern)

Net Irrigation Water Requirement (per Cropping Pattern)

(Unit: m^3/dec)

			Rice Paddy			Upland Cropping												Grand Total
						Maize + Beans			Vegetable 1			Vegetable 2			Vegetable 3	Coffee	Total	
Month	Decade	Days	Rice A	Rice B	Total	Maize	Beans	Sub-total	Carrot	Cabbage	Sub-total	Tomato	Cabbage	Sub-total	Tomato Tree			
			35.0 ha (13 %)			140.0 ha (51 %)			20.0 ha (7 %)			40.0 ha (15 %)			20.0 ha (7 %)	20.0 ha (7 %)	**240.0 ha (87 %)**	275.0 ha (100 %)
Jan.	1st.	10	0.0	151.7	**151.7**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	151.7
	2nd.	10	11,853.3	0.0	**11,853.3**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	11,853.3
	3rd.	11	33,775.0	1,108.3	**34,883.3**	0.0	0.0	0.0	0.0	1,706.7	1,706.7	0.0	3,413.3	3,413.3	0.0	320.0	**5,440.0**	40,323.3
Feb.	1st.	10	40,576.7	350.0	**40,926.7**	0.0	0.0	0.0	206.7	1,406.7	1,613.3	0.0	2,813.3	2,813.3	586.7	2,280.0	**7,293.3**	48,220.0
	2nd.	10	32,270.0	0.0	**32,270.0**	0.0	0.0	0.0	1,666.7	280.0	1,946.7	2,213.3	560.0	2,773.3	3,253.3	4,180.0	**12,153.3**	44,423.3
	3rd.	8	5,670.0	0.0	**5,670.0**	0.0	0.0	0.0	726.7	0.0	726.7	0.0	0.0	0.0	1,880.0	1,920.0	**4,526.7**	10,196.7
Mar.	1st.	10	7,233.3	0.0	**7,233.3**	0.0	0.0	0.0	1,446.7	0.0	1,446.7	440.0	0.0	440.0	3,260.0	2,500.0	**7,646.7**	14,880.0
	2nd.	10	6,615.0	0.0	**6,615.0**	1,680.0	0.0	1,680.0	1,786.7	0.0	1,786.7	866.7	0.0	866.7	3,566.7	2,040.0	**9,940.0**	16,555.0
	3rd.	11	6,218.3	0.0	**6,218.3**	5,413.3	0.0	5,413.3	2,146.7	0.0	2,146.7	1,680.0	0.0	1,680.0	3,600.0	1,500.0	**14,340.0**	20,558.3
Apr.	1st.	10	2,041.7	0.0	**2,041.7**	2,893.3	0.0	2,893.3	226.7	0.0	226.7	333.3	0.0	333.3	1,080.0	0.0	**4,533.3**	6,575.0
	2nd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0
	3rd.	10	1,120.0	0.0	**1,120.0**	4,246.7	0.0	4,246.7	0.0	0.0	0.0	400.0	0.0	400.0	320.0	0.0	**4,966.7**	6,086.7
May	1st.	10	2,100.0	0.0	**2,100.0**	8,633.3	0.0	8,633.3	186.7	0.0	186.7	1,706.7	0.0	1,706.7	880.0	0.0	**11,406.7**	13,506.7
	2nd.	10	2,648.3	0.0	**2,648.3**	10,826.7	0.0	10,826.7	466.7	0.0	466.7	2,333.3	0.0	2,333.3	1,200.0	0.0	**14,826.7**	17,475.0
	3rd.	11	7,151.7	0.0	**7,151.7**	27,253.3	0.0	27,253.3	2,873.3	0.0	2,873.3	7,226.7	0.0	7,226.7	3,853.3	2,193.3	**43,400.0**	50,551.7
Jun.	1st.	10	11,106.7	0.0	**11,106.7**	38,780.0	0.0	38,780.0	3,653.3	0.0	3,653.3	11,346.7	0.0	11,346.7	6,473.3	5,140.0	**65,393.3**	76,500.0
	2nd.	10	11,515.0	0.0	**11,515.0**	33,460.0	0.0	33,460.0	2,033.3	0.0	2,033.3	9,613.3	0.0	9,613.3	6,926.7	6,053.3	**58,086.7**	69,601.7
	3rd.	10	7,501.7	0.0	**7,501.7**	18,433.3	0.0	18,433.3	0.0	0.0	0.0	5,333.3	0.0	5,333.3	6,146.7	6,333.3	**36,246.7**	43,748.3
Jul.	1st.	10	3,593.3	0.0	**3,593.3**	7,000.0	0.0	7,000.0	0.0	0.0	0.0	1,586.7	0.0	1,586.7	4,966.7	6,473.3	**20,026.7**	23,620.0
	2nd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4,253.3	6,786.7	**11,040.0**	11,040.0
	3rd.	11	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4,160.0	7,560.0	**11,720.0**	11,720.0
Aug.	1st.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3,333.3	6,320.0	**9,653.3**	9,653.3
	2nd.	10	0.0	15,131.7	**15,131.7**	0.0	0.0	0.0	0.0	966.7	966.7	0.0	1,933.3	1,933.3	3,886.7	6,166.7	**12,953.3**	28,085.0
	3rd.	11	0.0	43,108.3	**43,108.3**	0.0	0.0	0.0	0.0	3,106.7	3,106.7	0.0	6,213.3	6,213.3	6,713.3	7,840.0	**23,873.3**	66,981.7
Sep.	1st.	10	0.0	49,525.0	**49,525.0**	0.0	5,646.7	5,646.7	0.0	5,240.0	5,240.0	0.0	10,480.0	10,480.0	8,533.3	8,346.7	**38,246.7**	87,771.7
	2nd.	10	0.0	39,281.7	**39,281.7**	0.0	15,680.0	15,680.0	0.0	6,126.7	6,126.7	0.0	12,253.3	12,253.3	10,206.7	9,206.7	**53,473.3**	92,755.0
	3rd.	10	0.0	13,755.0	**13,755.0**	0.0	12,646.7	12,646.7	0.0	4,266.7	4,266.7	0.0	8,533.3	8,533.3	8,713.3	7,226.7	**41,386.7**	55,141.7
Oct.	1st.	10	0.0	9,508.3	**9,508.3**	0.0	6,393.3	6,393.3	0.0	2,046.7	2,046.7	0.0	4,093.3	4,093.3	6,346.7	4,733.3	**23,613.3**	33,121.7
	2nd.	10	0.0	6,836.7	**6,836.7**	0.0	9,800.0	9,800.0	0.0	813.3	813.3	0.0	1,626.7	1,626.7	4,626.7	2,993.3	**19,860.0**	26,696.7
	3rd.	11	0.0	6,813.3	**6,813.3**	0.0	18,246.7	18,246.7	0.0	1,106.7	1,106.7	0.0	2,213.3	2,213.3	4,286.7	2,653.3	**28,506.7**	35,320.0
Nov.	1st.	10	0.0	2,788.3	**2,788.3**	0.0	8,726.7	8,726.7	0.0	20.0	20.0	0.0	40.0	40.0	1,620.0	320.0	**10,726.7**	13,515.0
	2nd.	10	0.0	245.0	**245.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.3	0.0	**13.3**	258.3
	3rd.	10	0.0	280.0	**280.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	280.0
Dec.	1st.	10	0.0	303.3	**303.3**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	303.3
	2nd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0
	3rd.	11	0.0	1,750.0	**1,750.0**	0.0	0.0	0.0	0.0	20.0	20.0	0.0	40.0	40.0	246.7	0.0	**306.7**	2,056.7
Annual IWR (m^3/yr.)			*192,990.0*	*190,936.7*	***383,926.7***	*158,620.0*	*77,140.0*	*235,760.0*	*17,420.0*	*27,106.7*	*44,526.7*	*45,080.0*	*54,213.3*	*99,293.3*	*114,933.3*	*111,086.7*	***605,600.0***	*989,526.7*
Max IWR (m^3/dec.)			*40,576.7*	*49,525.0*	***49,525.0***	*38,780.0*	*18,246.7*	*38,780.0*	*3,653.3*	*6,126.7*	*6,126.7*	*11,346.7*	*12,253.3*	*12,253.3*	*10,206.7*	*9,206.7*	***65,393.3***	*92,755.0*

Notes

*1) Net Irrigation Water Requirement (m^3/dec) = Unit Irrigation Water Requirement (mm/dec) / 1,000 (mm/m) * Cropping Acreage (has) * 10,000 (m^2/ha)

Legend of Table

Crop Combination		
Crop	Crop	Total
Crop Acreage (ha) (Crop Acreage (%))		

Table4-1-1-18 Gross Irrigation Water Requirement (per Cropping Pattern)

Case-1 : Wet Area Coefficient = 40%

Gross Irrigation Water Requirement (per Cropping Pattern)

(Unit: m³/dec)

Month	Decade	Days	Rice Paddy			Upland Cropping												Grand Total
						Maize + Beans			Vegetable 1			Vegetable 2			Vegetable 3	Coffee	Total	
			Rice A	Rice B	Total	Maize	Beans	Sub-total	Carrot	Cabbage	Sub-total	Tomato	Cabbage	Sub-total	Tomato Tree			
			35.0 ha (13 %)			140.0 ha (51 %)			20.0 ha (7 %)			40.0 ha (15 %)			20.0 ha (7 %)	20.0 ha (7 %)	**240.0 ha (87 %)**	275.0 ha (100 %)
Jan.	1st.	10	0.0	151.7	**151.7**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	151.7
	2nd.	10	11,853.3	0.0	**11,853.3**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	11,853.3
	3rd.	11	33,775.0	1,108.3	**34,883.3**	0.0	0.0	0.0	0.0	803.1	803.1	0.0	1,606.3	1,606.3	0.0	150.6	**2,560.0**	37,443.3
Feb.	1st.	10	40,576.7	350.0	**40,926.7**	0.0	0.0	0.0	97.3	662.0	759.2	0.0	1,323.9	1,323.9	276.1	1,072.9	**3,432.2**	44,358.8
	2nd.	10	32,270.0	0.0	**32,270.0**	0.0	0.0	0.0	784.3	131.8	916.1	1,041.6	263.5	1,305.1	1,531.0	1,967.1	**5,719.2**	37,989.2
	3rd.	8	5,670.0	0.0	**5,670.0**	0.0	0.0	0.0	342.0	0.0	342.0	0.0	0.0	0.0	884.7	903.5	**2,130.2**	7,800.2
Mar.	1st.	10	7,233.3	0.0	**7,233.3**	0.0	0.0	0.0	680.8	0.0	680.8	207.1	0.0	207.1	1,534.1	1,176.5	**3,598.4**	10,831.8
	2nd.	10	6,615.0	0.0	**6,615.0**	790.6	0.0	790.6	840.8	0.0	840.8	407.8	0.0	407.8	1,678.4	960.0	**4,677.6**	11,292.6
	3rd.	11	6,218.3	0.0	**6,218.3**	2,547.5	0.0	2,547.5	1,010.2	0.0	1,010.2	790.6	0.0	790.6	1,694.1	705.9	**6,748.2**	12,966.6
Apr.	1st.	10	2,041.7	0.0	**2,041.7**	1,361.6	0.0	1,361.6	106.7	0.0	106.7	156.9	0.0	156.9	508.2	0.0	**2,133.3**	4,175.0
	2nd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0
	3rd.	10	1,120.0	0.0	**1,120.0**	1,998.4	0.0	1,998.4	0.0	0.0	0.0	188.2	0.0	188.2	150.6	0.0	**2,337.3**	3,457.3
May	1st.	10	2,100.0	0.0	**2,100.0**	4,062.7	0.0	4,062.7	87.8	0.0	87.8	803.1	0.0	803.1	414.1	0.0	**5,367.8**	7,467.8
	2nd.	10	2,648.3	0.0	**2,648.3**	5,094.9	0.0	5,094.9	219.6	0.0	219.6	1,098.0	0.0	1,098.0	564.7	0.0	**6,977.3**	9,625.6
	3rd.	11	7,151.7	0.0	**7,151.7**	12,825.1	0.0	12,825.1	1,352.2	0.0	1,352.2	3,400.8	0.0	3,400.8	1,813.3	1,032.2	**20,423.5**	27,575.2
Jun.	1st.	10	11,106.7	0.0	**11,106.7**	18,249.4	0.0	18,249.4	1,719.2	0.0	1,719.2	5,339.6	0.0	5,339.6	3,046.3	2,418.8	**30,773.3**	41,880.0
	2nd.	10	11,515.0	0.0	**11,515.0**	15,745.9	0.0	15,745.9	956.9	0.0	956.9	4,523.9	0.0	4,523.9	3,259.6	2,848.6	**27,334.9**	38,849.9
	3rd.	10	7,501.7	0.0	**7,501.7**	8,674.5	0.0	8,674.5	0.0	0.0	0.0	2,509.8	0.0	2,509.8	2,892.5	2,980.4	**17,057.3**	24,558.9
Jul.	1st.	10	3,593.3	0.0	**3,593.3**	3,294.1	0.0	3,294.1	0.0	0.0	0.0	746.7	0.0	746.7	2,337.3	3,046.3	**9,424.3**	13,017.6
	2nd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2,001.6	3,193.7	**5,195.3**	5,195.3
	3rd.	11	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,957.6	3,557.6	**5,515.3**	5,515.3
Aug.	1st.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,568.6	2,974.1	**4,542.7**	4,542.7
	2nd.	10	0.0	15,131.7	**15,131.7**	0.0	0.0	0.0	0.0	454.9	454.9	0.0	909.8	909.8	1,829.0	2,902.0	**6,095.7**	21,227.4
	3rd.	11	0.0	43,108.3	**43,108.3**	0.0	0.0	0.0	0.0	1,462.0	1,462.0	0.0	2,923.9	2,923.9	3,159.2	3,689.4	**11,234.5**	54,342.8
Sep.	1st.	10	0.0	49,525.0	**49,525.0**	0.0	2,657.3	2,657.3	0.0	2,465.9	2,465.9	0.0	4,931.8	4,931.8	4,015.7	3,927.8	**17,998.4**	67,523.4
	2nd.	10	0.0	39,281.7	**39,281.7**	0.0	7,378.8	7,378.8	0.0	2,883.1	2,883.1	0.0	5,766.3	5,766.3	4,803.1	4,332.5	**25,163.9**	64,445.6
	3rd.	10	0.0	13,755.0	**13,755.0**	0.0	5,951.4	5,951.4	0.0	2,007.8	2,007.8	0.0	4,015.7	4,015.7	4,100.4	3,400.8	**19,476.1**	33,231.1
Oct.	1st.	10	0.0	9,508.3	**9,508.3**	0.0	3,008.6	3,008.6	0.0	963.1	963.1	0.0	1,926.3	1,926.3	2,986.7	2,227.5	**11,112.2**	20,620.5
	2nd.	10	0.0	6,836.7	**6,836.7**	0.0	4,611.8	4,611.8	0.0	382.7	382.7	0.0	765.5	765.5	2,177.3	1,408.6	**9,345.9**	16,182.5
	3rd.	11	0.0	6,813.3	**6,813.3**	0.0	8,586.7	8,586.7	0.0	520.8	520.8	0.0	1,041.6	1,041.6	2,017.3	1,248.6	**13,414.9**	20,228.2
Nov.	1st.	10	0.0	2,788.3	**2,788.3**	0.0	4,106.7	4,106.7	0.0	9.4	9.4	0.0	18.8	18.8	762.4	150.6	**5,047.8**	7,836.2
	2nd.	10	0.0	245.0	**245.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.3	0.0	**6.3**	251.3
	3rd.	10	0.0	280.0	**280.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	280.0
Dec.	1st.	10	0.0	303.3	**303.3**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	303.3
	2nd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0
	3rd.	11	0.0	1,750.0	**1,750.0**	0.0	0.0	0.0	0.0	9.4	9.4	0.0	18.8	18.8	116.1	0.0	**144.3**	1,894.3
Annual IWR (m^3/yr.)			*192,990.0*	*190,936.7*	***383,926.7***	*74,644.7*	*36,301.2*	*110,945.9*	*8,197.6*	*12,756.1*	*20,953.7*	*21,214.1*	*25,512.2*	*46,726.3*	*54,086.3*	*52,276.1*	***284,988.2***	*668,914.9*
Max IWR (m^3/dec.)			*40,576.7*	*49,525.0*	***49,525.0***	*18,249.4*	*8,586.7*	*18,249.4*	*1,719.2*	*2,883.1*	*2,883.1*	*5,339.6*	*5,766.3*	*5,766.3*	*4,803.1*	*4,332.5*	***30,773.3***	*67,523.4*

Notes

*1) Gross Irrigation Water Requirement (m^3/dec) = Net Irrigation Water Requirement (m^3/dec) / Irrigation Efficiency (%) * Wet Area Coefficient (%)

*2) Irrigation Efficiency : Rice 100 %

: Upland Cropping 85 % (= 95% (Conveyance Efficiency, "Lined Canal" FAO) * 90% (Field Application Efficiency, "Drip Irrigation" FAO)

*3) Wet Area Coefficient : Rice 100 % (= "Surface Irrigation", JICA)

: Upland Cropping **40 %** (= "Micro Irrigation", JICA)

Legend of Table

Crop Combination		
Crop	Crop	Total
Crop Acreage (ha)		
(Crop Acreage (%))		

Table 4-1-1-19 Gross Irrigation Water Requirement (per Cropping Pattern)

Case-2 : Wet Area Coefficient = 50%

Gross Irrigation Water Requirement (per Cropping Pattern)

(Unit: m^3/dec)

Month	Decade	Days	Rice Paddy			Upland Cropping												Grand Total
						Maize + Beans			Vegetable 1			Vegetable 2			Vegetable 3	Coffee	Total	
			Rice A	Rice B	Total	Maize	Beans	Sub-total	Carrot	Cabbage	Sub-total	Tomato	Cabbage	Sub-total	Tomato Tree			
			35.0 ha (13 %)			140.0 ha (51 %)			20.0 ha (7 %)			40.0 ha (15 %)			20.0 ha (7 %)	20.0 ha (7 %)	**240.0 ha (87 %)**	275.0 ha (100 %)
Jan.	1st.	10	0.0	151.7	**151.7**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	151.7
	2nd.	10	11,853.3	0.0	**11,853.3**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	11,853.3
	3rd.	11	33,775.0	1,108.3	**34,883.3**	0.0	0.0	0.0	0.0	1,003.9	1,003.9	0.0	2,007.8	2,007.8	0.0	188.2	**3,200.0**	38,083.3
Feb.	1st.	10	40,576.7	350.0	**40,926.7**	0.0	0.0	0.0	121.6	827.5	949.0	0.0	1,654.9	1,654.9	345.1	1,341.2	**4,290.2**	45,216.9
	2nd.	10	32,270.0	0.0	**32,270.0**	0.0	0.0	0.0	980.4	164.7	1,145.1	1,302.0	329.4	1,631.4	1,913.7	2,458.8	**7,149.0**	39,419.0
	3rd.	8	5,670.0	0.0	**5,670.0**	0.0	0.0	0.0	427.5	0.0	427.5	0.0	0.0	0.0	1,105.9	1,129.4	**2,662.7**	8,332.7
Mar.	1st.	10	7,233.3	0.0	**7,233.3**	0.0	0.0	0.0	851.0	0.0	851.0	258.8	0.0	258.8	1,917.6	1,470.6	**4,498.0**	11,731.4
	2nd.	10	6,615.0	0.0	**6,615.0**	988.2	0.0	988.2	1,051.0	0.0	1,051.0	509.8	0.0	509.8	2,098.0	1,200.0	**5,847.1**	12,462.1
	3rd.	11	6,218.3	0.0	**6,218.3**	3,184.3	0.0	3,184.3	1,262.7	0.0	1,262.7	988.2	0.0	988.2	2,117.6	882.4	**8,435.3**	14,653.6
Apr.	1st.	10	2,041.7	0.0	**2,041.7**	1,702.0	0.0	1,702.0	133.3	0.0	133.3	196.1	0.0	196.1	635.3	0.0	**2,666.7**	4,708.3
	2nd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0
	3rd.	10	1,120.0	0.0	**1,120.0**	2,498.0	0.0	2,498.0	0.0	0.0	0.0	235.3	0.0	235.3	188.2	0.0	**2,921.6**	4,041.6
May	1st.	10	2,100.0	0.0	**2,100.0**	5,078.4	0.0	5,078.4	109.8	0.0	109.8	1,003.9	0.0	1,003.9	517.6	0.0	**6,709.8**	8,809.8
	2nd.	10	2,648.3	0.0	**2,648.3**	6,368.6	0.0	6,368.6	274.5	0.0	274.5	1,372.5	0.0	1,372.5	705.9	0.0	**8,721.6**	11,369.9
	3rd.	11	7,151.7	0.0	**7,151.7**	16,031.4	0.0	16,031.4	1,690.2	0.0	1,690.2	4,251.0	0.0	4,251.0	2,266.7	1,290.2	**25,529.4**	32,681.1
Jun.	1st.	10	11,106.7	0.0	**11,106.7**	22,811.8	0.0	22,811.8	2,149.0	0.0	2,149.0	6,674.5	0.0	6,674.5	3,807.8	3,023.5	**38,466.7**	49,573.3
	2nd.	10	11,515.0	0.0	**11,515.0**	19,682.4	0.0	19,682.4	1,196.1	0.0	1,196.1	5,654.9	0.0	5,654.9	4,074.5	3,560.8	**34,168.6**	45,683.6
	3rd.	10	7,501.7	0.0	**7,501.7**	10,843.1	0.0	10,843.1	0.0	0.0	0.0	3,137.3	0.0	3,137.3	3,615.7	3,725.5	**21,321.6**	28,823.2
Jul.	1st.	10	3,593.3	0.0	**3,593.3**	4,117.6	0.0	4,117.6	0.0	0.0	0.0	933.3	0.0	933.3	2,921.6	3,807.8	**11,780.4**	15,373.7
	2nd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2,502.0	3,992.2	**6,494.1**	6,494.1
	3rd.	11	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2,447.1	4,447.1	**6,894.1**	6,894.1
Aug.	1st.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,960.8	3,717.6	**5,678.4**	5,678.4
	2nd.	10	0.0	15,131.7	**15,131.7**	0.0	0.0	0.0	0.0	568.6	568.6	0.0	1,137.3	1,137.3	2,286.3	3,627.5	**7,619.6**	22,751.3
	3rd.	11	0.0	43,108.3	**43,108.3**	0.0	0.0	0.0	0.0	1,827.5	1,827.5	0.0	3,654.9	3,654.9	3,949.0	4,611.8	**14,043.1**	57,151.5
Sep.	1st.	10	0.0	49,525.0	**49,525.0**	0.0	3,321.6	3,321.6	0.0	3,082.4	3,082.4	0.0	6,164.7	6,164.7	5,019.6	4,909.8	**22,498.0**	72,023.0
	2nd.	10	0.0	39,281.7	**39,281.7**	0.0	9,223.5	9,223.5	0.0	3,603.9	3,603.9	0.0	7,207.8	7,207.8	6,003.9	5,415.7	**31,454.9**	70,736.6
	3rd.	10	0.0	13,755.0	**13,755.0**	0.0	7,439.2	7,439.2	0.0	2,509.8	2,509.8	0.0	5,019.6	5,019.6	5,125.5	4,251.0	**24,345.1**	38,100.1
Oct.	1st.	10	0.0	9,508.3	**9,508.3**	0.0	3,760.8	3,760.8	0.0	1,203.9	1,203.9	0.0	2,407.8	2,407.8	3,733.3	2,784.3	**13,890.2**	23,398.5
	2nd.	10	0.0	6,836.7	**6,836.7**	0.0	5,764.7	5,764.7	0.0	478.4	478.4	0.0	956.9	956.9	2,721.6	1,760.8	**11,682.4**	18,519.0
	3rd.	11	0.0	6,813.3	**6,813.3**	0.0	10,733.3	10,733.3	0.0	651.0	651.0	0.0	1,302.0	1,302.0	2,521.6	1,560.8	**16,768.6**	23,582.0
Nov.	1st.	10	0.0	2,788.3	**2,788.3**	0.0	5,133.3	5,133.3	0.0	11.8	11.8	0.0	23.5	23.5	952.9	188.2	**6,309.8**	9,098.1
	2nd.	10	0.0	245.0	**245.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.8	0.0	**7.8**	252.8
	3rd.	10	0.0	280.0	**280.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	280.0
Dec.	1st.	10	0.0	303.3	**303.3**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	303.3
	2nd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0
	3rd.	11	0.0	1,750.0	**1,750.0**	0.0	0.0	0.0	0.0	11.8	11.8	0.0	23.5	23.5	145.1	0.0	**180.4**	1,930.4
Annual IWR (m^3/yr.)			*192,990.0*	*190,936.7*	***383,926.7***	*93,305.9*	*45,376.5*	*138,682.4*	*10,247.1*	*15,945.1*	*26,192.2*	*26,517.6*	*31,890.2*	*58,407.8*	*67,607.8*	*65,345.1*	***356,235.3***	*740,162.0*
Max IWR (m^3/dec.)			*40,576.7*	*49,525.0*	***49,525.0***	*22,811.8*	*10,733.3*	*22,811.8*	*2,149.0*	*3,603.9*	*3,603.9*	*6,674.5*	*7,207.8*	*7,207.8*	*6,003.9*	*5,415.7*	***38,466.7***	*72,023.0*

Notes

*1) Gross Irrigation Water Requirement (m^3/dec) = Net Irrigation Water Requirement (m^3/dec) / Irrigation Efficiency (%) * Wet Area Coefficient (%)

*2) Irrigation Efficiency : Rice 100 %

: Upland Cropping 85 % (= 95% (Conveyance Efficiency, "Lined Canal" FAO) * 90% (Field Application Efficiency, "Drip Irrigation" FAO)

*3) Wet Area Coefficient : Rice 100 % (= "Surface Irrigation", JICA)

: Upland Cropping **50 %** (= "Micro Irrigation", JICA)

Legend of Table

Crop Combination		
Crop	Crop	Total
Crop Acreage (ha)		
(Crop Acreage (%))		

Table 4-1-1-20 Gross Irrigation Water Requirement (per Cropping Pattern)

Case-3 : Wet Area Coefficient = 60%

Gross Irrigation Water Requirement (per Cropping Pattern)

(Unit: m^3/dec)

Month	Decade	Days	Rice Paddy: Rice A	Rice Paddy: Rice B	Rice Paddy: Total	Upland Cropping: Maize + Beans: Maize	Maize + Beans: Beans	Maize + Beans: Sub-total	Vegetable 1: Carrot	Vegetable 1: Cabbage	Vegetable 1: Sub-total	Vegetable 2: Tomato	Vegetable 2: Cabbage	Vegetable 2: Sub-total	Vegetable 3: Tomato Tree	Coffee	Upland Total	Grand Total
			35.0 ha (13 %)			140.0 ha (51 %)			20.0 ha (7 %)			40.0 ha (15 %)			20.0 ha (7 %)	20.0 ha (7 %)	**240.0 ha (87 %)**	275.0 ha (100 %)
Jan.	1st.	10	0.0	151.7	**151.7**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	151.7
	2nd.	10	11,853.3	0.0	**11,853.3**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	11,853.3
	3rd.	11	33,775.0	1,108.3	**34,883.3**	0.0	0.0	0.0	0.0	1,204.7	1,204.7	0.0	2,409.4	2,409.4	0.0	225.9	**3,840.0**	38,723.3
Feb.	1st.	10	40,576.7	350.0	**40,926.7**	0.0	0.0	0.0	145.9	992.9	1,138.8	0.0	1,985.9	1,985.9	414.1	1,609.4	**5,148.2**	46,074.9
	2nd.	10	32,270.0	0.0	**32,270.0**	0.0	0.0	0.0	1,176.5	197.6	1,374.1	1,562.4	395.3	1,957.6	2,296.5	2,950.6	**8,578.8**	40,848.8
	3rd.	8	5,670.0	0.0	**5,670.0**	0.0	0.0	0.0	512.9	0.0	512.9	0.0	0.0	0.0	1,327.1	1,355.3	**3,195.3**	8,865.3
Mar.	1st.	10	7,233.3	0.0	**7,233.3**	0.0	0.0	0.0	1,021.2	0.0	1,021.2	310.6	0.0	310.6	2,301.2	1,764.7	**5,397.6**	12,631.0
	2nd.	10	6,615.0	0.0	**6,615.0**	1,185.9	0.0	1,185.9	1,261.2	0.0	1,261.2	611.8	0.0	611.8	2,517.6	1,440.0	**7,016.5**	13,631.5
	3rd.	11	6,218.3	0.0	**6,218.3**	3,821.2	0.0	3,821.2	1,515.3	0.0	1,515.3	1,185.9	0.0	1,185.9	2,541.2	1,058.8	**10,122.4**	16,340.7
Apr.	1st.	10	2,041.7	0.0	**2,041.7**	2,042.4	0.0	2,042.4	160.0	0.0	160.0	235.3	0.0	235.3	762.4	0.0	**3,200.0**	5,241.7
	2nd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0
	3rd.	10	1,120.0	0.0	**1,120.0**	2,997.6	0.0	2,997.6	0.0	0.0	0.0	282.4	0.0	282.4	225.9	0.0	**3,505.9**	4,625.9
May	1st.	10	2,100.0	0.0	**2,100.0**	6,094.1	0.0	6,094.1	131.8	0.0	131.8	1,204.7	0.0	1,204.7	621.2	0.0	**8,051.8**	10,151.8
	2nd.	10	2,648.3	0.0	**2,648.3**	7,642.4	0.0	7,642.4	329.4	0.0	329.4	1,647.1	0.0	1,647.1	847.1	0.0	**10,465.9**	13,114.2
	3rd.	11	7,151.7	0.0	**7,151.7**	19,237.6	0.0	19,237.6	2,028.2	0.0	2,028.2	5,101.2	0.0	5,101.2	2,720.0	1,548.2	**30,635.3**	37,787.0
Jun.	1st.	10	11,106.7	0.0	**11,106.7**	27,374.1	0.0	27,374.1	2,578.8	0.0	2,578.8	8,009.4	0.0	8,009.4	4,569.4	3,628.2	**46,160.0**	57,266.7
	2nd.	10	11,515.0	0.0	**11,515.0**	23,618.8	0.0	23,618.8	1,435.3	0.0	1,435.3	6,785.9	0.0	6,785.9	4,889.4	4,272.9	**41,002.4**	52,517.4
	3rd.	10	7,501.7	0.0	**7,501.7**	13,011.8	0.0	13,011.8	0.0	0.0	0.0	3,764.7	0.0	3,764.7	4,338.8	4,470.6	**25,585.9**	33,087.5
Jul.	1st.	10	3,593.3	0.0	**3,593.3**	4,941.2	0.0	4,941.2	0.0	0.0	0.0	1,120.0	0.0	1,120.0	3,505.9	4,569.4	**14,136.5**	17,729.8
	2nd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3,002.4	4,790.6	**7,792.9**	7,792.9
	3rd.	11	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2,936.5	5,336.5	**8,272.9**	8,272.9
Aug.	1st.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2,352.9	4,461.2	**6,814.1**	6,814.1
	2nd.	10	0.0	15,131.7	**15,131.7**	0.0	0.0	0.0	0.0	682.4	682.4	0.0	1,364.7	1,364.7	2,743.5	4,352.9	**9,143.5**	24,275.2
	3rd.	11	0.0	43,108.3	**43,108.3**	0.0	0.0	0.0	0.0	2,192.9	2,192.9	0.0	4,385.9	4,385.9	4,738.8	5,534.1	**16,851.8**	59,960.1
Sep.	1st.	10	0.0	49,525.0	**49,525.0**	0.0	3,985.9	3,985.9	0.0	3,698.8	3,698.8	0.0	7,397.6	7,397.6	6,023.5	5,891.8	**26,997.6**	76,522.6
	2nd.	10	0.0	39,281.7	**39,281.7**	0.0	11,068.2	11,068.2	0.0	4,324.7	4,324.7	0.0	8,649.4	8,649.4	7,204.7	6,498.8	**37,745.9**	77,027.5
	3rd.	10	0.0	13,755.0	**13,755.0**	0.0	8,927.1	8,927.1	0.0	3,011.8	3,011.8	0.0	6,023.5	6,023.5	6,150.6	5,101.2	**29,214.1**	42,969.1
Oct.	1st.	10	0.0	9,508.3	**9,508.3**	0.0	4,512.9	4,512.9	0.0	1,444.7	1,444.7	0.0	2,889.4	2,889.4	4,480.0	3,341.2	**16,668.2**	26,176.6
	2nd.	10	0.0	6,836.7	**6,836.7**	0.0	6,917.6	6,917.6	0.0	574.1	574.1	0.0	1,148.2	1,148.2	3,265.9	2,112.9	**14,018.8**	20,855.5
	3rd.	11	0.0	6,813.3	**6,813.3**	0.0	12,880.0	12,880.0	0.0	781.2	781.2	0.0	1,562.4	1,562.4	3,025.9	1,872.9	**20,122.4**	26,935.7
Nov.	1st.	10	0.0	2,788.3	**2,788.3**	0.0	6,160.0	6,160.0	0.0	14.1	14.1	0.0	28.2	28.2	1,143.5	225.9	**7,571.8**	10,360.1
	2nd.	10	0.0	245.0	**245.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.4	0.0	**9.4**	254.4
	3rd.	10	0.0	280.0	**280.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	280.0
Dec.	1st.	10	0.0	303.3	**303.3**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	303.3
	2nd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0
	3rd.	11	0.0	1,750.0	**1,750.0**	0.0	0.0	0.0	0.0	14.1	14.1	0.0	28.2	28.2	174.1	0.0	**216.5**	1,966.5
Annual IWR (m^3/yr.)			*192,990.0*	*190,936.7*	***383,926.7***	*111,967.1*	*54,451.8*	*166,418.8*	*12,296.5*	*19,134.1*	*31,430.6*	*31,821.2*	*38,268.2*	*70,089.4*	*81,129.4*	*78,414.1*	***427,482.4***	*811,409.0*
Max IWR (m^3/dec.)			*40,576.7*	*49,525.0*	***49,525.0***	*27,374.1*	*12,880.0*	*27,374.1*	*2,578.8*	*4,324.7*	*4,324.7*	*8,009.4*	*8,649.4*	*8,649.4*	*7,204.7*	*6,498.8*	***46,160.0***	*77,027.5*

Notes

*1) Gross Irrigation Water Requirement (m^3/dec) = Net Irrigation Water Requirement (m^3/dec) / Irrigation Efficiency (%) * Wet Area Coefficient (%)

*2) Irrigation Efficiency : Rice 100 %

: Upland Cropping 85 % (= 95% (Conveyance Efficiency, "Lined Canal" FAO) * 90% (Field Application Efficiency, "Drip Irrigation" FAO)

*3) Wet Area Coefficient : Rice 100 % (= "Surface Irrigation", JICA)

: Upland Cropping **60 %** (= "Micro Irrigation", JICA)

Legend of Table

Crop Combination		
Crop	Crop	Total
Crop Acreage (ha)		
(Crop Acreage (%))		

Table 4-1-1-21 Gross Irrigation Water Requirement (per Cropping Pattern)

Case-4 : (Wet Area Coefficient = 70%

Gross Irrigation Water Requirement (per Cropping Pattern)

(Unit: m^3/dec)

Month	Decade	Days	Rice Paddy			Upland Cropping												Grand Total
						Maize + Beans			Vegetable 1			Vegetable 2			Vegetable 3	Coffee	Total	
			Rice A	Rice B	Total	Maize	Beans	Sub-total	Carrot	Cabbage	Sub-total	Tomato	Cabbage	Sub-total	Tomato Tree			
			35.0 ha (13 %)			140.0 ha (51 %)			20.0 ha (7 %)			40.0 ha (15 %)			20.0 ha (7 %)	20.0 ha (7 %)	**240.0 ha (87 %)**	275.0 ha (100 %)
Jan.	1st.	10	0.0	151.7	**151.7**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	151.7
	2nd.	10	11,853.3	0.0	**11,853.3**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	11,853.3
	3rd.	11	33,775.0	1,108.3	**34,883.3**	0.0	0.0	0.0	0.0	1,405.5	1,405.5	0.0	2,811.0	2,811.0	0.0	263.5	**4,480.0**	39,363.3
Feb.	1st.	10	40,576.7	350.0	**40,926.7**	0.0	0.0	0.0	170.2	1,158.4	1,328.6	0.0	2,316.9	2,316.9	483.1	1,877.6	**6,006.3**	46,932.9
	2nd.	10	32,270.0	0.0	**32,270.0**	0.0	0.0	0.0	1,372.5	230.6	1,603.1	1,822.7	461.2	2,283.9	2,679.2	3,442.4	**10,008.6**	42,278.6
	3rd.	8	5,670.0	0.0	**5,670.0**	0.0	0.0	0.0	598.4	0.0	598.4	0.0	0.0	0.0	1,548.2	1,581.2	**3,727.8**	9,397.8
Mar.	1st.	10	7,233.3	0.0	**7,233.3**	0.0	0.0	0.0	1,191.4	0.0	1,191.4	362.4	0.0	362.4	2,684.7	2,058.8	**6,297.3**	13,530.6
	2nd.	10	6,615.0	0.0	**6,615.0**	1,383.5	0.0	1,383.5	1,471.4	0.0	1,471.4	713.7	0.0	713.7	2,937.3	1,680.0	**8,185.9**	14,800.9
	3rd.	11	6,218.3	0.0	**6,218.3**	4,458.0	0.0	4,458.0	1,767.8	0.0	1,767.8	1,383.5	0.0	1,383.5	2,964.7	1,235.3	**11,809.4**	18,027.7
Apr.	1st.	10	2,041.7	0.0	**2,041.7**	2,382.7	0.0	2,382.7	186.7	0.0	186.7	274.5	0.0	274.5	889.4	0.0	**3,733.3**	5,775.0
	2nd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0
	3rd.	10	1,120.0	0.0	**1,120.0**	3,497.3	0.0	3,497.3	0.0	0.0	0.0	329.4	0.0	329.4	263.5	0.0	**4,090.2**	5,210.2
May	1st.	10	2,100.0	0.0	**2,100.0**	7,109.8	0.0	7,109.8	153.7	0.0	153.7	1,405.5	0.0	1,405.5	724.7	0.0	**9,393.7**	11,493.7
	2nd.	10	2,648.3	0.0	**2,648.3**	8,916.1	0.0	8,916.1	384.3	0.0	384.3	1,921.6	0.0	1,921.6	988.2	0.0	**12,210.2**	14,858.5
	3rd.	11	7,151.7	0.0	**7,151.7**	22,443.9	0.0	22,443.9	2,366.3	0.0	2,366.3	5,951.4	0.0	5,951.4	3,173.3	1,806.3	**35,741.2**	42,892.8
Jun.	1st.	10	11,106.7	0.0	**11,106.7**	31,936.5	0.0	31,936.5	3,008.6	0.0	3,008.6	9,344.3	0.0	9,344.3	5,331.0	4,232.9	**53,853.3**	64,960.0
	2nd.	10	11,515.0	0.0	**11,515.0**	27,555.3	0.0	27,555.3	1,674.5	0.0	1,674.5	7,916.9	0.0	7,916.9	5,704.3	4,985.1	**47,836.1**	59,351.1
	3rd.	10	7,501.7	0.0	**7,501.7**	15,180.4	0.0	15,180.4	0.0	0.0	0.0	4,392.2	0.0	4,392.2	5,062.0	5,215.7	**29,850.2**	37,351.9
Jul.	1st.	10	3,593.3	0.0	**3,593.3**	5,764.7	0.0	5,764.7	0.0	0.0	0.0	1,306.7	0.0	1,306.7	4,090.2	5,331.0	**16,492.5**	20,085.9
	2nd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3,502.7	5,589.0	**9,091.8**	9,091.8
	3rd.	11	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3,425.9	6,225.9	**9,651.8**	9,651.8
Aug.	1st.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2,745.1	5,204.7	**7,949.8**	7,949.8
	2nd.	10	0.0	15,131.7	**15,131.7**	0.0	0.0	0.0	0.0	796.1	796.1	0.0	1,592.2	1,592.2	3,200.8	5,078.4	**10,667.5**	25,799.1
	3rd.	11	0.0	43,108.3	**43,108.3**	0.0	0.0	0.0	0.0	2,558.4	2,558.4	0.0	5,116.9	5,116.9	5,528.6	6,456.5	**19,660.4**	62,768.7
Sep.	1st.	10	0.0	49,525.0	**49,525.0**	0.0	4,650.2	4,650.2	0.0	4,315.3	4,315.3	0.0	8,630.6	8,630.6	7,027.5	6,873.7	**31,497.3**	81,022.3
	2nd.	10	0.0	39,281.7	**39,281.7**	0.0	12,912.9	12,912.9	0.0	5,045.5	5,045.5	0.0	10,091.0	10,091.0	8,405.5	7,582.0	**44,036.9**	83,318.5
	3rd.	10	0.0	13,755.0	**13,755.0**	0.0	10,414.9	10,414.9	0.0	3,513.7	3,513.7	0.0	7,027.5	7,027.5	7,175.7	5,951.4	**34,083.1**	47,838.1
Oct.	1st.	10	0.0	9,508.3	**9,508.3**	0.0	5,265.1	5,265.1	0.0	1,685.5	1,685.5	0.0	3,371.0	3,371.0	5,226.7	3,898.0	**19,446.3**	28,954.6
	2nd.	10	0.0	6,836.7	**6,836.7**	0.0	8,070.6	8,070.6	0.0	669.8	669.8	0.0	1,339.6	1,339.6	3,810.2	2,465.1	**16,355.3**	23,192.0
	3rd.	11	0.0	6,813.3	**6,813.3**	0.0	15,026.7	15,026.7	0.0	911.4	911.4	0.0	1,822.7	1,822.7	3,530.2	2,185.1	**23,476.1**	30,289.4
Nov.	1st.	10	0.0	2,788.3	**2,788.3**	0.0	7,186.7	7,186.7	0.0	16.5	16.5	0.0	32.9	32.9	1,334.1	263.5	**8,833.7**	11,622.1
	2nd.	10	0.0	245.0	**245.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.0	0.0	**11.0**	256.0
	3rd.	10	0.0	280.0	**280.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	280.0
Dec.	1st.	10	0.0	303.3	**303.3**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	303.3
	2nd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0
	3rd.	11	0.0	1,750.0	**1,750.0**	0.0	0.0	0.0	0.0	16.5	16.5	0.0	32.9	32.9	203.1	0.0	**252.5**	2,002.5
Annual IWR (m^3/yr.)			*192,990.0*	*190,936.7*	***383,926.7***	*130,628.2*	*63,527.1*	*194,155.3*	*14,345.9*	*22,323.1*	*36,669.0*	*37,124.7*	*44,646.3*	*81,771.0*	*94,651.0*	*91,483.1*	***498,729.4***	*882,656.1*
Max IWR (m^3/dec.)			*40,576.7*	*49,525.0*	***49,525.0***	*31,936.5*	*15,026.7*	*31,936.5*	*3,008.6*	*5,045.5*	*5,045.5*	*9,344.3*	*10,091.0*	*10,091.0*	*8,405.5*	*7,582.0*	***53,853.3***	*83,318.5*

Notes

*1) Gross Irrigation Water Requirement (m^3/dec) = Net Irrigation Water Requirement (m^3/dec) / Irrigation Efficiency (%) * Wet Area Coefficient (%)

*2) Irrigation Efficiency	: Rice	100 %	
	: Upland Cropping	85 %	(= 95% (Conveyance Efficiency, "Lined Canal" FAO) * 90% (Field Application Efficiency, "Drip Irrigation" FAO)
*3) Wet Area Coefficient	: Rice	100 %	(= "Surface Irrigation", JICA)
	: Upland Cropping	**70 %**	(= "Micro Irrigation", JICA)

Legend of Table

Crop Combination		
Crop	Crop	Total
Crop Acreage (ha)		
(Crop Acreage (%))		

(b) Simulation of Water Balance / Study on Active Storage Capacity of Reservoir

Active storage capacity or water utilization capacity of reservoir is calculated by water-balance simulation based on inflow to reservoir and outflow from reservoir every ten (10) days as follows:

ⅰ) Conditions of Simulation

1) Inflow to Reservoir

Inflow to reservoir in this simulation is river discharge in base year of 1970 estimated by the tank model method in *"4-1-1. Planning of Water Supply"*, and summarized as shown in (Table 4-1-1-22)."

2) Out flow from Reservoir

Outflow from reservoir consists of irrigation water requirement for rice paddy and upland cropping, and seepage loss as follows:

<u>Irrigation Water Requirement for Rice Paddy</u>

Supply water for rice paddy estimated in "*4-1-1. Planning of Water Supply*" applied as irrigation water requirement for rice paddy, and summarized as shown in(Table 4-1-1-22)

Table 4-1-1-22 Inflow and Supply Water for Rice Paddy

Month	Decade	days	Inflow (m^3)			Supply Water for Rice Paddy (m^3)		
			Decade	Monthly	Cumulative	Decade	Monthly	Cumulative
Jan.	1st.	10	25,360			469		
	2nd.	10	72,709	148,421	148,421	469	1,453	1,453
	3rd.	11	50,352			516		
Feb.	1st.	10	28,891			6,228		
	2nd.	10	23,985	66,683	215,104	6,228	17,438	18,891
	3rd.	8	13,807			4,982		
Mar.	1st.	10	15,623			854		
	2nd.	10	15,438	53,072	268,176	854	2,647	21,538
	3rd.	11	22,011			939		
Apr.	1st.	10	16,119			658		
	2nd.	10	16,074	54,034	322,210	658	1,974	23,512
	3rd.	10	21,841			658		
May	1st.	10	44,967			468		
	2nd.	10	37,214	101,847	424,057	468	1,452	24,964
	3rd.	11	19,666			515		
Jun.	1st.	10	15,397			1,232		
	2nd.	10	13,100	39,543	463,600	1,232	3,695	28,659
	3rd.	10	11,046			1,232		
Jul.	1st.	10	9,062			895		
	2nd.	10	7,129	22,365	485,965	895	2,774	31,433
	3rd.	11	6,174			984		
Aug.	1st.	10	5,407			12,943		
	2nd.	10	5,386	25,142	511,107	12,943	40,122	71,555
	3rd.	11	14,349			14,237		
Sep.	1st.	10	5,593			30,117		
	2nd.	10	5,323	16,215	527,322	30,117	90,350	161,905
	3rd.	10	5,299			30,117		
Oct.	1st.	10	5,278			965		
	2nd.	10	19,278	37,266	564,588	965	2,990	164,895
	3rd.	11	12,710			1,061		
Nov.	1st.	10	20,239			665		
	2nd.	10	17,274	53,591	618,179	665	1,995	166,890
	3rd.	10	16,078			665		
Dec.	1st.	10	24,303			455		
	2nd.	10	25,099	91,005	709,184	455	1,409	168,299
	3rd.	11	41,603			500		
Total			**709,184**	709,184	-	**168,299**	168,299	-

<u>Irrigation Water Requirement for Upland Cropping</u>

Gross irrigation water requirement (GIWR) shown in "(Table 4-1-1-18~4-1-1-21) *Gross Irrigation Water Requirement*" is applied as irrigation water requirement for upland cropping. Annual GIWR for each case (Kw = 40, 50, 60 and 70 %) is summarized as shown in (Table 4-1-1-23).

Table 41-1-23 Annual Irrigation Water Requirement for Upland Cropping

Wetting Area Coefficient Kw (%)	Gross Irrigation Water Requirement GIWR (m^3/year)
40	284,988
50	356,235
60	427,482
70	498,729

Seepage loss from Reservoir

0.05 % of storage volume of reservoir is applied as seepage loss from reservoir.

3) Balance between Rainfall and Evaporation on Reservoir

Rainfall to reservoir and evaporation from reservoir is considered for simulation of water balance, as well as inflow and out flow which mentioned in the above. Water surface area, which is used for calculation for evaporation from reservoir is estimated as 14.96 ha based on H-Q curve at full water surface FWS. 1,390.60 m.

Rainfall to Reservoir (Rd)

Rainfall data observed at Gahororo station in 1970 are applied as rainfall to reservoir.

Evaporation from Reservoir (Eo)

Evaporation from reservoir (Eo) is estimated based on reference Evapotranspiration (ETo) which is calculated by CROWPWAT8.0 and mentioned in (Table 4-1-1-12) and crop coefficient (kc) as follows:

Table 41-1-24 Balance between Rainfall and Evaporation on Reservoir

Crop Coefficient: kc = 1.1 Water Surface Area: A = 14.96 ha (@ FWS.1,390.60m)

Month	Decade	days	Provable Rainfall Rm (mm/month)	Provable Rainfall Rd (mm/decade)	Reference Evapotranspiration ETo (mm/day)	Evaporation Eo = ETo * kc (mm/decade)	Evaporation from Water Surface E = Eo - Rd (mm/decade)	Evaporation from Water Surface Ev = E * A (m^3/decade)	Remarks
Jan.	1st.	10	188.2	60.7	4.01	44.1	-16.6	-2,485	
	2nd.	10		60.7		44.1	-16.6	-2,485	
	3rd.	11		66.8		48.5	-18.3	-2,735	
Feb.	1st.	10	70.7	25.3	4.20	46.2	21.0	3,134	
	2nd.	10		25.3		46.2	21.0	3,134	
	3rd.	8		20.2		37.0	16.8	2,513	
Mar.	1st.	10	91.8	29.6	3.93	43.2	13.6	2,033	
	2nd.	10		29.6		43.2	13.6	2,033	
	3rd.	11		32.6		47.6	15.0	2,248	
Apr.	1st.	10	152.6	50.9	3.38	37.2	-13.7	-2,045	
	2nd.	10		50.9		37.2	-13.7	-2,045	
	3rd.	10		50.9		37.2	-13.7	-2,045	
May	1st.	10	104.9	33.8	3.21	35.3	1.5	219	
	2nd.	10		33.8		35.3	1.5	219	
	3rd.	11		37.2		38.8	1.6	236	
Jun.	1st.	10	4.5	1.5	3.09	34.0	32.5	4,862	
	2nd.	10		1.5		34.0	32.5	4,862	
	3rd.	10		1.5		34.0	32.5	4,862	
Jul.	1st.	10	5.7	1.8	3.39	37.3	35.5	5,305	
	2nd.	10		1.8		37.3	35.5	5,305	
	3rd.	11		2.0		41.0	39.0	5,831	
Aug.	1st.	10	53.5	17.3	4.79	52.7	35.4	5,302	
	2nd.	10		17.3		52.7	35.4	5,302	
	3rd.	11		19.0		58.0	39.0	5,837	
Sep.	1st.	10	20.7	6.9	4.62	50.8	43.9	6,567	
	2nd.	10		6.9		50.8	43.9	6,567	
	3rd.	10		6.9		50.8	43.9	6,567	
Oct.	1st.	10	118.4	38.2	4.68	51.5	13.3	1,991	
	2nd.	10		38.2		51.5	13.3	1,991	
	3rd.	11		42.0		56.6	14.6	2,182	
Nov.	1st.	10	161.7	53.9	3.51	38.6	-15.3	-2,289	
	2nd.	10		53.9		38.6	-15.3	-2,289	
	3rd.	10		53.9		38.6	-15.3	-2,289	
Dec.	1st.	10	161.6	52.1	3.26	35.9	-16.2	-2,428	
	2nd.	10		52.1		35.9	-16.2	-2,428	
	3rd.	11		57.3		39.4	-17.9	-2,684	
Total / Average			1,134.3	1,134.3	3.84	1,541.1	407	60,855	

Notes

*1) Provable Rainfall : 1970, Gahororo Station, Rurenge Sector, Ngoma District

*2) Reference Evapotranspiration : Calculated from Climate Data (Temperature, Humidity, Wind Velocity, Sunshine Hours) by CROPWAT8

*3) Climate Data / Min. Temp. : 1970, Gahororo Station, Rurenge Sector, Ngoma District

Max. Temp. : 1970 & 1974, Gahororo Station, Rurenge Sector, Ngoma District

Humidity : 1974, Kigali International Airport

Wind Velocity : 1974, Kigali International Airport

Sunshine : 1974, Kigali International Airport

*4) Crop Coefficient : kc from water surface of 1.1 is applied based on FAO Irrigation and drainage paper No. 24.

*5) Water Surface Area : 14.96 ha at Full Water Surface (FWS.) EL. 1,390.60 m is applied.

ii) Results of Simulation

The results of simulation are mentioned in (Table 4-1-1-26~4-1-1-29) and required active storage capacity of reservoir is summarized in (Table 4-1-1-25).

Table 4-1-1-25 Design Active Storage Capacity of Reservoir

Wetting Area Coefficient Kw (%)	Storage Volume of Reservoir (m^3)		
	Cumulative Storage Volume		Balance / Required Active Storage Capacity (3) = (1) - (2)
	Maximum (1)	Minimum (2)	
40	332,366	27,363	305,002
50	320,945	-25,592	346,538
60	309,525	-95,540	405,065
70	298,104	-165,487	**463,592**

As the results of simulation mentioned the above, design active storage capacity of reservoir is determined as 450,000 m^3 taking into account Kw = 70%, most severe conditions of wetting area coefficient. In this case, design discharge or intake volume for rice paddy and upland cropping is calculated as follows:

(See "(Table 4-1-1-30) *Design Discharge / Intake Volume*" for the details

Design Discharge / Intake Volume

Rice Paddy : Q = 0.0577m^3/sec

Upland cropping : Q = 0.1760m^3/sec

Table 4-1-1-26 Simulation of Water Balance / Study on Active Storage Capacity of Reservoir

Case-1: Wetting Area Coefficient Kw = 40 %

Cropping Acreage

Crop		Area	
Rice Paddy		35 ha	13 %
Upland Cropping	Maize+Beans	140 ha	51 %
	Vegitable-1	20 ha	7 %
	Vegitable-2	40 ha	15 %
	Vegitable-3	20 ha	7 %
	Coffee	20 ha	7 %
	Sub-total	240 ha	87 %
Total		275 ha	100 %

Efficiencies

Description		Coefficient	Remarks
Irrigation Efficiency	Rice Paddy	100 %	
	Upland Cropping	85 %	= 95% (Conveyance: Lined Canal) * 90% (Field Application: Drip)
Wetting Area	Rice Paddy	100 %	"Suface Irrigation"
	Upland Cropping	**40 %**	"Micro Irrigation"

Reservoir

Description	EL & Volume	Remarks
Full Water Surface	EL. 1,390.60 m	FWS (Water Surface Area: 14.96 ha)
Dead Water Surface	EL. 1,386.50 m	DWS (Water Surface Area: 8.15 ha)
Bottom of Reservoir	EL. 1,380.00 m	ELbttm
Active Storage Capacity	450,000 m3	between FWS and DWS (H=4.10m)
Dead Water Volume	250,000 m3	between DWS and ELbttm (H=6.50m)

Results of Water Balance Study

Month	Decade	days	Inflow (m^3) ①	Outflow (m^3): Rice Supply Water ②	Outflow: Upland Crop Irrigation Water Requirement ③	Outflow: Seepage Loss ④	Outflow: Evaporation from W. Surface ⑤	Outflow: Total ⑥=Σ②-⑤	Balance between In & Outflow (m^3) ⑦=①-⑥	**Cumulative Storage Volume of Reservoir (m^3) ⑧**	Remarks
										0	
Jan.	1st.	10	25,360	469	0	13	-2,485	-2,003	27,363	**27,363**	**Min.**
	2nd.	10	72,709	469	0	36	-2,485	-1,980	74,689	102,053	
	3rd.	11	50,352	516	2,560	25	-2,735	366	49,986	152,039	
Feb.	1st.	10	28,891	6,228	3,432	14	3,134	12,808	16,083	168,122	
	2nd.	10	23,985	6,228	5,719	12	3,134	15,093	8,892	177,014	
	3rd.	8	13,807	4,982	2,130	7	2,513	9,632	4,175	181,188	
Mar.	1st.	10	15,623	854	3,598	8	2,033	6,493	9,130	190,318	
	2nd.	10	15,438	854	4,678	8	2,033	7,573	7,865	198,184	
	3rd.	11	22,011	939	6,748	11	2,248	9,946	12,065	210,248	
Apr.	1st.	10	16,119	658	2,133	8	-2,045	754	15,365	225,613	
	2nd.	10	16,074	658	0	8	-2,045	-1,379	17,453	243,066	
	3rd.	10	21,841	658	2,337	11	-2,045	961	20,880	263,946	
May	1st.	10	44,967	468	5,368	22	219	6,077	38,890	302,835	
	2nd.	10	37,214	468	6,977	19	219	7,684	29,530	**332,366**	**Max.**
	3rd.	11	19,666	515	20,424	10	236	21,185	-1,519	330,847	
Jun.	1st.	10	15,397	1,232	30,773	8	4,862	36,875	-21,478	309,369	
	2nd.	10	13,100	1,232	27,335	7	4,862	33,436	-20,336	289,033	
	3rd.	10	11,046	1,232	17,057	6	4,862	23,157	-12,111	276,922	
Jul.	1st.	10	9,062	895	9,424	5	5,305	15,629	-6,567	270,355	
	2nd.	10	7,129	895	5,195	4	5,305	11,399	-4,270	266,085	
	3rd.	11	6,174	984	5,515	3	5,831	12,334	-6,160	259,926	
Aug.	1st.	10	5,407	12,943	4,543	3	5,302	22,790	-17,383	242,542	
	2nd.	10	5,386	12,943	6,096	3	5,302	24,343	-18,957	223,585	
	3rd.	11	14,349	14,237	11,235	7	5,837	31,315	-16,966	206,619	
Sep.	1st.	10	5,593	30,117	17,998	3	6,567	54,685	-49,092	157,526	
	2nd.	10	5,323	30,117	25,164	3	6,567	61,851	-56,528	100,999	
	3rd.	10	5,299	30,117	19,476	3	6,567	56,163	-50,864	50,135	
Oct.	1st.	10	5,278	965	11,112	3	1,991	14,071	-8,793	41,342	
	2nd.	10	19,278	965	9,346	10	1,991	12,311	6,967	48,309	
	3rd.	11	12,710	1,061	13,415	6	2,182	16,664	-3,954	44,355	
Nov.	1st.	10	20,239	665	5,048	10	-2,289	3,434	16,805	61,160	
	2nd.	10	17,274	665	6	9	-2,289	-1,609	18,883	80,043	
	3rd.	10	16,078	665	0	8	-2,289	-1,616	17,694	97,737	
Dec.	1st.	10	24,303	455	0	12	-2,428	-1,961	26,264	124,002	
	2nd.	10	25,099	455	0	13	-2,428	-1,960	27,059	151,061	
	3rd.	11	41,603	500	144	21	-2,684	-2,019	43,622	194,683	
Total			**709,184**	168,299	284,988	359	60,855	**514,501**	194,683	-	-
									Max. - Min. =	**305,002**	

Notes

*1) Seepage loss from dam body of 0.05 % of storage volume is assumed.

*2) Evaporation from water surface is estimated based on balance of rainfall and evaporation with kc of 1.1 from FAO Irrigation and Drainage Paper No.24.
(See Table "Evaporation from Water Surface of Reservoir, Ngoma 22" for reference.)

*3) Water Supply for Rice Paddy 168,299 m3/yr.

*4) Cumu. Storage Volume : Start at DWS.1,386.50m 0 m3 (Effective Dam Storage Volume)

Table 4-1-1-27 Simulation of Water Balance / Study on Active Storage Capacity of Reservoir
Case-2: Wetting Area Coefficient Kw = 50 %

Cropping Acreage

Crop		Area	
Rice Paddy		35 ha	13 %
Upland Cropping	Maize+Beans	140 ha	51 %
	Vegitable-1	20 ha	7 %
	Vegetable-2	40 ha	15 %
	Vegetable-3	20 ha	7 %
	Coffee	20 ha	7 %
	Sub-total	240 ha	87 %
Total		275 ha	100 %

Efficiencies

Description		Coefficient	Remarks
Irrigation Efficiency	Rice Paddy	100 %	
	Upland Cropping	85 %	= 95% (Conveyance: Lined Canal) * 90% (Field Application: Drip)
Wetting Area	Rice Paddy	100 %	"Suface Irrigation"
	Upland Cropping	**50 %**	"Micro Irrigation"

Reservoir

Description	EL & Volume	Remarks
Full Water Surface	EL. 1,390.60 m	FWS (Water Surface Area: 14.96 ha)
Dead Water Surface	EL. 1,386.50 m	DWS (Water Surface Area: 8.15 ha)
Bottom of Reservoir	EL. 1,380.00 m	ELbttm
Active Storage Capacity	450,000 m3	between FWS and DWS (H=4.10m)
Dead Water Volume	250,000 m3	between DWS and ELbttm (H=6.50m)

Results of Water Balance Study

Month	Decade	days	Inflow (m^3) ①	Outflow (m^3) Rice Supply Water ②	Upland Crop Irrigation Water Requirement ③	Seepage Loss ④	Evaporation from W. Surface ⑤	Total ⑥=Σ②-⑤	Balance between In & Outflow (m^3) ⑦=①-⑥	**Cumulative Storage Volume of Reservoir (m^3) ⑧**	Remarks
										0	
Jan.	1st.	10	25,360	469	0	13	-2,485	-2,003	27,363	27,363	
	2nd.	10	72,709	469	0	36	-2,485	-1,980	74,689	102,053	
	3rd.	11	50,352	516	3,200	25	-2,735	1,006	49,346	151,399	
Feb.	1st.	10	28,891	6,228	4,290	14	3,134	13,666	15,225	166,624	
	2nd.	10	23,985	6,228	7,149	12	3,134	16,523	7,462	174,086	
	3rd.	8	13,807	4,982	2,663	7	2,513	10,165	3,642	177,728	
Mar.	1st.	10	15,623	854	4,498	8	2,033	7,393	8,230	185,958	
	2nd.	10	15,438	854	5,847	8	2,033	8,742	6,696	192,654	
	3rd.	11	22,011	939	8,435	11	2,248	11,634	10,377	203,032	
Apr.	1st.	10	16,119	658	2,667	8	-2,045	1,288	14,831	217,863	
	2nd.	10	16,074	658	0	8	-2,045	-1,379	17,453	235,316	
	3rd.	10	21,841	658	2,922	11	-2,045	1,546	20,295	255,611	
May	1st.	10	44,967	468	6,710	22	219	7,419	37,548	293,159	
	2nd.	10	37,214	468	8,722	19	219	9,428	27,786	**320,945**	**Max.**
	3rd.	11	19,666	515	25,529	10	236	26,291	-6,625	314,321	
Jun.	1st.	10	15,397	1,232	38,467	8	4,862	44,568	-29,171	285,149	
	2nd.	10	13,100	1,232	34,169	7	4,862	40,269	-27,169	257,980	
	3rd.	10	11,046	1,232	21,322	6	4,862	27,421	-16,375	241,605	
Jul.	1st.	10	9,062	895	11,780	5	5,305	17,985	-8,923	232,682	
	2nd.	10	7,129	895	6,494	4	5,305	12,698	-5,569	227,113	
	3rd.	11	6,174	984	6,894	3	5,831	13,712	-7,538	219,574	
Aug.	1st.	10	5,407	12,943	5,678	3	5,302	23,926	-18,519	201,055	
	2nd.	10	5,386	12,943	7,620	3	5,302	25,867	-20,481	180,574	
	3rd.	11	14,349	14,237	14,043	7	5,837	34,124	-19,775	160,799	
Sep.	1st.	10	5,593	30,117	22,498	3	6,567	59,185	-53,592	107,207	
	2nd.	10	5,323	30,117	31,455	3	6,567	68,142	-62,819	44,389	
	3rd.	10	5,299	30,117	24,345	3	6,567	61,032	-55,733	-11,344	
Oct.	1st.	10	5,278	965	13,890	3	1,991	16,849	-11,571	-22,915	
	2nd.	10	19,278	965	11,682	10	1,991	14,648	4,630	-18,285	
	3rd.	11	12,710	1,061	16,769	6	2,182	20,018	-7,308	**-25,592**	**Min.**
Nov.	1st.	10	20,239	665	6,310	10	-2,289	4,696	15,543	-10,049	
	2nd.	10	17,274	665	8	9	-2,289	-1,607	18,881	8,832	
	3rd.	10	16,078	665	0	8	-2,289	-1,616	17,694	26,526	
Dec.	1st.	10	24,303	455	0	12	-2,428	-1,961	26,264	52,791	
	2nd.	10	25,099	455	0	13	-2,428	-1,960	27,059	79,850	
	3rd.	11	41,603	500	180	21	-2,684	-1,983	43,586	123,436	
Total			**709,184**	168,299	356,235	359	60,855	**585,748**	123,436	-	-
									Max. - Min. =	**346,538**	

Notes

*1) Seepage loss from dam body of 0.05 % of storage volume is assumed.

*2) Evaporation from water surface is estimated based on balance of rainfall and evaporation with kc of 1.1 from FAO Irrigation and Drainage Paper No.24.
(See Table "Evaporation from Water Surface of Reservoir, Ngoma 22" for reference.)

*3) Water Supply for Rice Paddy 168,299 m3/yr.

*4) Cumu. Storage Volume : Start at DWS.1,386.50m 0 m3 (Effective Dam Storage Volume)

Table 4-1-1-28 Simulation of Water Balance / Study on Active Storage Capacity of Reservoir
Case-3: Wetting Area Coefficient Kw = 60 %

Cropping Acreage

	Crop	Area	
Rice Paddy		35 ha	13 %
Upland Cropping	Maize+Beans	140 ha	51 %
	Vegitable-1	20 ha	7 %
	Vegitable-2	40 ha	15 %
	Vegetable-3	20 ha	7 %
	Coffee	20 ha	7 %
	Sub-total	240 ha	87 %
Total		275 ha	100 %

Efficiencies

Description		Coefficient	Remarks
Irrigation Efficiency	Rice Paddy	100 %	
	Upland Cropping	85 %	= 95% (Conveyance: Lined Canal) * 90% (Field Application: Drip)
Wetting Area	Rice Paddy	100 %	"Suface Irrigation"
	Upland Cropping	**60 %**	"Micro Irrigation"

Reservoir

Description	EL & Volume	Remarks
Full Water Surface	EL. 1,390.60 m	FWS (Water Surface Area: 14.96 ha)
Dead Water Surface	EL. 1,386.50 m	DWS (Water Surface Area: 8.15 ha)
Bottom of Reservoir	EL. 1,380.00 m	ELbttm
Active Storage Capacity	450,000 m3	between FWS and DWS (H=4.10m)
Dead Water Volume	250,000 m3	between DWS and ELbttm (H=6.50m)

Results of Water Balance Study

Month	Decade	days	Inflow (m^3) ①	Outflow (m^3): Rice Supply Water ②	Outflow: Upland Crop Irrigation Water Requirement ③	Outflow: Seepage Loss ④	Outflow: Evaporation from W. Surface ⑤	Outflow: Total ⑥=Σ②-⑤	Balance between In & Outflow (m^3) ⑦=①-⑥	**Cumulative Storage Volume of Reservoir (m^3)** ⑧	Remarks
										0	
Jan.	1st.	10	25,360	469	0	13	-2,485	-2,003	27,363	27,363	
	2nd.	10	72,709	469	0	36	-2,485	-1,980	74,689	102,053	
	3rd.	11	50,352	516	3,840	25	-2,735	1,646	48,706	150,759	
Feb.	1st.	10	28,891	6,228	5,148	14	3,134	14,524	14,367	165,126	
	2nd.	10	23,985	6,228	8,579	12	3,134	17,953	6,032	171,158	
	3rd.	8	13,807	4,982	3,195	7	2,513	10,698	3,109	174,268	
Mar.	1st.	10	15,623	854	5,398	8	2,033	8,293	7,330	181,598	
	2nd.	10	15,438	854	7,016	8	2,033	9,911	5,527	187,125	
	3rd.	11	22,011	939	10,122	11	2,248	13,321	8,690	195,815	
Apr.	1st.	10	16,119	658	3,200	8	-2,045	1,821	14,298	210,113	
	2nd.	10	16,074	658	0	8	-2,045	-1,379	17,453	227,566	
	3rd.	10	21,841	658	3,506	11	-2,045	2,130	19,711	247,277	
May	1st.	10	44,967	468	8,052	22	219	8,761	36,206	283,483	
	2nd.	10	37,214	468	10,466	19	219	11,172	26,042	**309,525**	**Max.**
	3rd.	11	19,666	515	30,635	10	236	31,397	-11,731	297,794	
Jun.	1st.	10	15,397	1,232	46,160	8	4,862	52,262	-36,865	260,930	
	2nd.	10	13,100	1,232	41,002	7	4,862	47,103	-34,003	226,927	
	3rd.	10	11,046	1,232	25,586	6	4,862	31,686	-20,640	206,287	
Jul.	1st.	10	9,062	895	14,136	5	5,305	20,341	-11,279	195,008	
	2nd.	10	7,129	895	7,793	4	5,305	13,997	-6,868	188,140	
	3rd.	11	6,174	984	8,273	3	5,831	15,091	-8,917	179,223	
Aug.	1st.	10	5,407	12,943	6,814	3	5,302	25,062	-19,655	159,568	
	2nd.	10	5,386	12,943	9,144	3	5,302	27,391	-22,005	137,563	
	3rd.	11	14,349	14,237	16,852	7	5,837	36,933	-22,584	114,979	
Sep.	1st.	10	5,593	30,117	26,998	3	6,567	63,684	-58,091	56,888	
	2nd.	10	5,323	30,117	37,746	3	6,567	74,433	-69,110	-12,222	
	3rd.	10	5,299	30,117	29,214	3	6,567	65,901	-60,602	-72,823	
Oct.	1st.	10	5,278	965	16,668	3	1,991	19,627	-14,349	-87,172	
	2nd.	10	19,278	965	14,019	10	1,991	16,984	2,294	-84,878	
	3rd.	11	12,710	1,061	20,122	6	2,182	23,371	-10,661	**-95,540**	**Min.**
Nov.	1st.	10	20,239	665	7,572	10	-2,289	5,958	14,281	-81,258	
	2nd.	10	17,274	665	9	9	-2,289	-1,606	18,880	-62,379	
	3rd.	10	16,078	665	0	8	-2,289	-1,616	17,694	-44,685	
Dec.	1st.	10	24,303	455	0	12	-2,428	-1,961	26,264	-18,420	
	2nd.	10	25,099	455	0	13	-2,428	-1,960	27,059	8,639	
	3rd.	11	41,603	500	216	21	-2,684	-1,947	43,550	52,189	
Total			**709,184**	168,299	427,482	359	60,855	**656,995**	52,189	-	-
									Max. - Min. =	**405,065**	

Notes

*1) Seepage loss from dam body of 0.05 % of storage volume is assumed.

*2) Evaporation from water surface is estimated based on balance of rainfall and evaporation with kc of 1.1 from FAO Irrigation and Drainage Paper No.24.
(See Table "Evaporation from Water Surface of Reservoir, Ngoma 22" for reference.)

*3) Water Supply for Rice Paddy 168,299 m3/yr.

*4) Cumu. Storage Volume : Start at DWS.1,386.50m 0 m3 (Effective Dam Storage Volume)

Table 4-1-1-29 Simulation of Water Balance / Study on Active Storage Capacity of Reservoir
Case-4: Wetting Area Coefficient Kw = 70 %

Cropping Acreage

Crop		Area	
Rice Paddy		35 ha	13 %
Upland Cropping	Maize+Beans	140 ha	51 %
	Vegitable-1	20 ha	7 %
	Vegetable-2	40 ha	15 %
	Vegetable-3	20 ha	7 %
	Coffee	20 ha	7 %
	Sub-total	240 ha	87 %
Total		275 ha	100 %

Efficiencies

Description		Coefficient	Remarks
Irrigation Efficiency	Rice Paddy	100 %	
	Upland Cropping	85 %	= 95% (Conveyance: Lined Canal) * 90% (Field Application: Drip)
Wetting Area	Rice Paddy	100 %	"Surface Irrigation"
	Upland Cropping	**70 %**	"Micro Irrigation"

Reservoir

Description	EL & Volume	Remarks
Full Water Surface	EL. 1,390.60 m	FWS (Water Surface Area: 14.96 ha)
Dead Water Surface	EL. 1,386.50 m	DWS (Water Surface Area: 8.15 ha)
Bottom of Reservoir	EL. 1,380.00 m	ELbttm
Active Storage Capacity	450,000 m3	between FWS and DWS (H=4.10m)
Dead Water Volume	250,000 m3	between DWS and ELbttm (H=6.50m)

Results of Water Balance Study

Month	Decade	days	Inflow (m^3) ①	Outflow (m^3): Rice Supply Water ②	Outflow (m^3): Upland Crop Irrigation Water Requirement ③	Outflow (m^3): Seepage Loss ④	Outflow (m^3): Evaporation from W. Surface ⑤	Outflow (m^3): Total ⑥=Σ②-⑤	Balance between In & Outflow (m^3) ⑦=①-⑥	**Cumulative Storage Volume of Reservoir (m^3)** ⑧	Remarks
										0	
Jan.	1st.	10	25,360	469	0	13	-2,485	-2,003	27,363	27,363	
	2nd.	10	72,709	469	0	36	-2,485	-1,980	74,689	102,053	
	3rd.	11	50,352	516	4,480	25	-2,735	2,286	48,066	150,119	
Feb.	1st.	10	28,891	6,228	6,006	14	3,134	15,382	13,509	163,628	
	2nd.	10	23,985	6,228	10,009	12	3,134	19,382	4,603	168,230	
	3rd.	8	13,807	4,982	3,728	7	2,513	11,230	2,577	170,807	
Mar.	1st.	10	15,623	854	6,297	8	2,033	9,192	6,431	177,238	
	2nd.	10	15,438	854	8,186	8	2,033	11,081	4,357	181,595	
	3rd.	11	22,011	939	11,809	11	2,248	15,008	7,003	188,599	
Apr.	1st.	10	16,119	658	3,733	8	-2,045	2,354	13,765	202,363	
	2nd.	10	16,074	658	0	8	-2,045	-1,379	17,453	219,816	
	3rd.	10	21,841	658	4,090	11	-2,045	2,714	19,127	238,943	
May	1st.	10	44,967	468	9,394	22	219	10,103	34,864	273,807	
	2nd.	10	37,214	468	12,210	19	219	12,917	24,297	**298,104**	**Max.**
	3rd.	11	19,666	515	35,741	10	236	36,502	-16,836	281,268	
Jun.	1st.	10	15,397	1,232	53,853	8	4,862	59,955	-44,558	236,710	
	2nd.	10	13,100	1,232	47,836	7	4,862	53,937	-40,837	195,873	
	3rd.	10	11,046	1,232	29,850	6	4,862	35,950	-24,904	170,969	
Jul.	1st.	10	9,062	895	16,493	5	5,305	22,697	-13,635	157,334	
	2nd.	10	7,129	895	9,092	4	5,305	15,296	-8,167	149,167	
	3rd.	11	6,174	984	9,652	3	5,831	16,470	-10,296	138,871	
Aug.	1st.	10	5,407	12,943	7,950	3	5,302	26,197	-20,790	118,081	
	2nd.	10	5,386	12,943	10,667	3	5,302	28,915	-23,529	94,552	
	3rd.	11	14,349	14,237	19,660	7	5,837	39,741	-25,392	69,160	
Sep.	1st.	10	5,593	30,117	31,497	3	6,567	68,184	-62,591	6,569	
	2nd.	10	5,323	30,117	44,037	3	6,567	80,724	-75,401	-68,832	
	3rd.	10	5,299	30,117	34,083	3	6,567	70,770	-65,471	-134,303	
Oct.	1st.	10	5,278	965	19,446	3	1,991	22,405	-17,127	-151,429	
	2nd.	10	19,278	965	16,355	10	1,991	19,321	-43	-151,472	
	3rd.	11	12,710	1,061	23,476	6	2,182	26,725	-14,015	**-165,487**	**Min.**
Nov.	1st.	10	20,239	665	8,834	10	-2,289	7,220	13,019	-152,468	
	2nd.	10	17,274	665	11	9	-2,289	-1,604	18,878	-133,590	
	3rd.	10	16,078	665	0	8	-2,289	-1,616	17,694	-115,896	
Dec.	1st.	10	24,303	455	0	12	-2,428	-1,961	26,264	-89,631	
	2nd.	10	25,099	455	0	13	-2,428	-1,960	27,059	-62,572	
	3rd.	11	41,603	500	253	21	-2,684	-1,910	43,513	-19,058	
Total			709,184	168,299	498,729	359	60,855	728,242	-19,058	-	-
									Max. - Min. =	**463,592**	

Notes

*1) Seepage loss from dam body of 0.05 % of storage volume is assumed.

*2) Evaporation from water surface is estimated based on balance of rainfall and evaporation with kc of 1.1 from FAO Irrigation and Drainage Paper No.24.
(See Table "Evaporation from Water Surface of Reservoir, Ngoma 22" for reference.)

*3) Water Supply for Rice Paddy 168,299 m3/yr.

*4) Cumu. Storage Volume : Start at DWS.1,386.50m 0 m3 (Effective Dam Storage Volume)

Table 4-1-1-30 Design Discharge / Intake Volume

Cropping Acreage

Crop		Area	
Rice Paddy		35	13%
Upland Cropping	Maize+Beans	140	51%
	Vegitable-1	20	7%
	Vegetable-2	40	15%
	Vegetable-3	20	7%
	Coffee	20	7%
	Sub-total	240	87%
Total		275	100%

Operation Hours

Crop	Operation Hours	Remarks
Rice Paddy	24 hrs	
Upland Cropping	8.5 hrs	

Efficiencies

Description		Coefficient	Remarks
Irrigation Efficiency	Rice Paddy	100 %	-
	Upland Cropping	85 %	-
Wetting Area Coefficient	Rice Paddy	100 %	"Suface Irrigation"
	Upland Cropping	70 %	"Micro Irrigation"

Design Discharge

Month	Decade	Days	Rice Paddy GIWR (m^3/dec)	Rice Paddy Discharge Volume (m^3/sec)	Upland Cropping GIWR (m^3/dec)	Upland Cropping Discharge Volume (m^3/sec)	Grand Total GIWR (m^3/dec)	Grand Total Discharge Volume (m^3/sec)	Remarks
Jan.	1st.	10	152	0.0002	0	0.0000	152	0.0002	
	2nd.	10	11,853	0.0137	0	0.0000	11,853	0.0137	
	3rd.	11	34,883	0.0367	4,480	0.0133	39,363	0.0500	
Feb.	1st.	10	40,927	0.0474	6,006	0.0196	46,933	0.0670	
	2nd.	10	32,270	0.0373	10,009	0.0327	42,279	0.0701	
	3rd.	8	5,670	0.0082	3,728	0.0152	9,398	0.0234	
Mar.	1st.	10	7,233	0.0084	6,297	0.0206	13,531	0.0290	
	2nd.	10	6,615	0.0077	8,186	0.0268	14,801	0.0344	
	3rd.	11	6,218	0.0065	11,809	0.0351	18,028	0.0416	
Apr.	1st.	10	2,042	0.0024	3,733	0.0122	5,775	0.0146	
	2nd.	10	0	0.0000	0	0.0000	0	0.0000	
	3rd.	10	1,120	0.0013	4,090	0.0134	5,210	0.0147	
May	1st.	10	2,100	0.0024	9,394	0.0307	11,494	0.0331	
	2nd.	10	2,648	0.0031	12,210	0.0399	14,859	0.0430	
	3rd.	11	7,152	0.0075	35,741	0.1062	42,893	0.1137	
Jun.	1st.	10	11,107	0.0129	53,853	**0.1760**	64,960	0.1888	
	2nd.	10	11,515	0.0133	47,836	0.1563	59,351	0.1697	
	3rd.	10	7,502	0.0087	29,850	0.0975	37,352	0.1062	
Jul.	1st.	10	3,593	0.0042	16,493	0.0539	20,086	0.0581	
	2nd.	10	0	0.0000	9,092	0.0297	9,092	0.0297	
	3rd.	11	0	0.0000	9,652	0.0287	9,652	0.0287	
Aug.	1st.	10	0	0.0000	7,950	0.0260	7,950	0.0260	
	2nd.	10	15,132	0.0175	10,667	0.0349	25,799	0.0524	
	3rd.	11	43,108	0.0454	19,660	0.0584	62,769	0.1038	
Sep.	1st.	10	49,525	**0.0573**	31,497	0.1029	81,022	0.1603	
	2nd.	10	39,282	0.0455	44,037	0.1439	83,319	**0.1894**	
	3rd.	10	13,755	0.0159	34,083	0.1114	47,838	0.1273	
Oct.	1st.	10	9,508	0.0110	19,446	0.0635	28,955	0.0746	
	2nd.	10	6,837	0.0079	16,355	0.0534	23,192	0.0614	
	3rd.	11	6,813	0.0072	23,476	0.0697	30,289	0.0769	
Nov.	1st.	10	2,788	0.0032	8,834	0.0289	11,622	0.0321	
	2nd.	10	245	0.0003	11	0.0000	256	0.0003	
	3rd.	10	280	0.0003	0	0.0000	280	0.0003	
Dec.	1st.	10	303	0.0004	0	0.0000	303	0.0004	
	2nd.	10	0	0.0000	0	0.0000	0	0.0000	
	3rd.	11	1,750	0.0018	253	0.0008	2,003	0.0026	
Annual			*383,926.7*	-	*498,729.4*	-	*882,656.1*	-	-
Maximum			*49,525.0*	***0.0573***	*53,853.3*	***0.1760***	*83,318.5*	***0.1894***	-

Notes

*1) GIWR (m^3/dec) : Gross Irrigation Water Requirement

*2) Discharge Volume (m^3/sec) = GIWR (m^3/dec) / dec (days) / (3,600 (sec/hr) * Operation Hours (hrs))

4-1-2. Investigation for facility planning

(1) Basic survey for facility planning

(a) Investigation of foundation's permeability

The permeability of the dam foundation is assessed by the field permeability test in test pits. The location of the test pits and their profiles are as shown below. The two test holes for field permeability measurement were excavated on each shelf and six holes in each test pit.

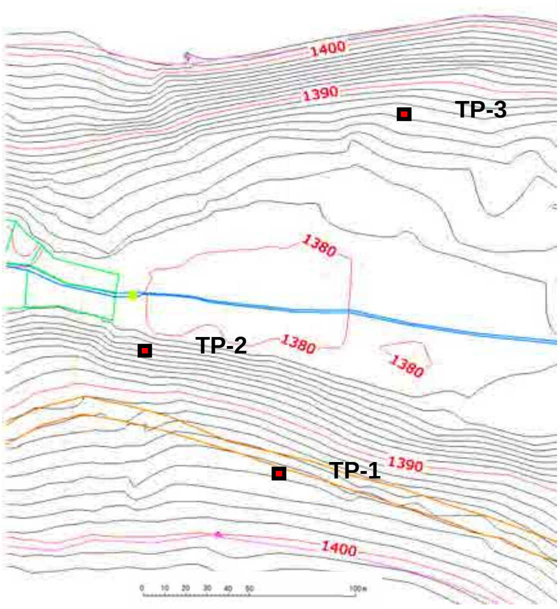


Fig.4-1-2-1Location map of test pit

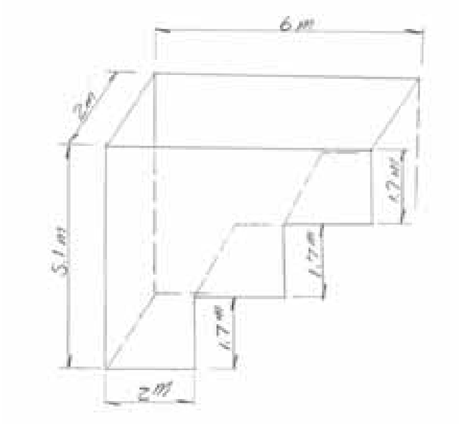


Fig.4-1-2-2 Profile of test pit

ｉ) Test Pit No.1

The test pit wall from the top to the bottom 5.1m deep is composed of uniform reddish-brown sandy clay. The field moisture content of this layer is almost at the optimum moisture content, so that this layer would be able to produce impervious materials for the dam embankment. The excavated soil contains weathered, soft, semi-angular, thin and silver-colored fragments with 2mm to 5mm size in diameter so that the origin of this layer is assumed to be clay stone.

The field permeability test results are as shown below. This layer is considered to be pervious to semi-pervious with the permeability coefficient ranging from k=n×10^{-3}cm/sec to k=n×10^{-4}cm/sec. These values are consistent with high percolation rate in the intake rate survey in the dry fields. The permeability test values conducted in boreholes in 2009 fell in the range of imperviousness, the cause of which would be the mud-cake that was produced through excavation process and covered the wall surface.

Hole for the field permeability test

Silver-colored thin fragment of weathered clay stone

Excavated soil

Table 4-1-2-1 Results of Field Permeability Test (TP-1)

		φ(cm)	r (cm)	H (cm)	H/r	Q(cm3)	time(sec)	Permeability coefficient
TP-1	N0.1	20	10	20	2	300	27	3.6×10-3cm/sec
	No.2	20	10	20	2	300	3	3.3×10-2cm/sec
	No.3	22	11	22	2	221	258	2.3×10-4cm/sec
	No.4	20	10	23	2.3	300	25.7	3.2×10-3cm/sec
	No.5	20	10	22	2.2	300	103	8.5×10-4cm/sec
	No.6	20	10	23	2.3	300	80	1.0×10-3cm/sec

$$k = \frac{Q}{2\pi h^2}\left[\ln\left\{\frac{h}{r_0}+\left(\frac{h^2}{r_0^2}+1\right)^{1/2}\right\}-\left(\frac{r_0^2}{h^2}+1\right)^{1/2}+\frac{r_0}{h}\right]$$

Here; k : Field permeability coefficient (cm/sec)
Q : Constant seepage quantity (cm^3/sec)
h : Water depth in the test hole (cm)
r0 : Radius of the test hole (cm)

Equation for calculating the field permeability coefficient
(Source; Design standard “Dam”, Department of Agriculture and Fishery, Japan)

ii) Test Pit No.2

TP-2

This test pit was excavated on the foot of the left abutment slope and met the ground water at the depth of 1.7m on its way, and the further excavation became impossible. The color of the wall is light yellowish-brown but the component of soil particle size is as same as Test Pit No.1 so that the soil classification is same sandy clay as No.1. The field permeability tests were conducted to the layer beyond the ground water table and their results are also as same as Test Pit No.1 showing the values of k= k=n×10^{-3}cm/sec. In addition, it is expected that the high ground water table confirmed in this test pit would function as a barrier against the seepage passing through the abutment.

Table 4-1-2-2 Results of Field Permeability Test (TP-2)

		Φ(cm)	r (cm)	H (cm)	H/r	Q(cm3)	time(sec)	Permeability coefficient
TP-2	No.1	20	10	24	2.4	300	32	2.2×10-3cm/sec
	No.2	19	9.5	20	2.11	300	24	4.3×10-3cm/sec

iii) Test Pit No.3

This test pit was excavated on the right abutment slope and met the weathered rock layer of clay stone at the depth of 3.6m. This layer was soft enough to be excavated by manpower to the depth of 4m. The bedding planes are closely contacted each other; and the field permeability test values to this layer are classified into semi-pervious. The soil layer, perfectly weathered layer borne from clay stone, is pervious as same as Test Pit No.1 and No.2.

風化岩部分表面

Table 4-1-2-3 Results of Field Permeability Test (TP-3)

		Φ(cm)	r (cm)	H (cm)	H/r	Q(cm3)	time(sec)	Permeability coefficient
TP-3	N0.1	20	10	20	2	300	8	1.2×10-2cm/sec
	No.2	20	10	20	2	300	10	1.0×10-2cm/sec
	No.3	20	10	21	2.1	300	64	1.4×10-3cm/sec
	No.4	20	10	24	2.4	300	59	1.3×10-3cm/sec
	No.5	20	10	22	2.2	300	795.6	1.1×10-4cm/sec
	No.6	20	10	23	2.3	300	804	1.0×10-4cm/sec

(b) Talus Cone Survey

Talus cones did not appear on the test pit walls excavated at the dam site for conducting the field permeability tests. All the test pit walls were composed of the residual soil layer borne from clay stone, so that the slopes submerged in water at the time of the reservoir being full in future are considered to be covered by this residual soil layer. There would be no possibility of land slide as the residual soil layer does not have the stratification, which is common in the sedimentary layers, and is stable mechanically.

The only talus cone observed near the dam site is the soil layer that appears on the cut slope of the newly rehabilitated road on the left bank side. The feature is quite different between the upper soil layer with many gravels and the lower portion composed of silt, i.e. highly weathered clay stone with clear bedding planes. Therefore this upper layer is probable to be the talus cone with the thickness of 0m to 1m according to the undulation of the lower layer's surface.

n addition, there are ditches excavated along contour lines on the right abutment slope at the dam site for preventing rain water from flowing down on the ground surface and helping it seep into the ground. On the walls of these ditches, there are no sedimentary soil layers nor talus cone sedimentation between the top soil and the residual soil layer

Ditch for gathering rain water excavated on the slope

Profile of the cut slope of the newly rehabilitated road

(c) Study on the Possibility of Introducing the Solar Pump System

ｉ) Circumstances around the Solar Pump System

In these days, the solar pump system products that are composed of an integrated combination of the solar energy generation facilities and pumping facilities have been becoming popular in the market and the capacity and quality have been improved. The following specification is one example of these systems with high capacity and high quality.

Solar-operated Submersible Pump System

Characteristics

- flow rate up to 70 m³/h
- lift up to 170 m
- maintenance-free
- excellent efficiency thanks to modern brushless DC motor technology

Application

- drinking water supply
- livestock watering
- pond management
- irrigation
- etc.

Components

Controller PS4000

- controlling of the pump system and monitoring of the operating states
- mounted at surface (no electronic parts submerged)
- two control inputs for well probe (dry running protection), float or pressure switches, remote control etc.
- automatic reset 20 minutes after well probe turns pump off
- protected against reverse polarity, overload and high temperature
- speed control, max. pump speed adjustable to reduce flow rate to c. 30 %
- solar operation: integrated MPPT (Maximum Power Point Tracking), Voc = 375 VDC, Vmp > 238 VDC
- battery operation: low voltage disconnect and restart after battery has recovered
- max. efficiency 92 % (motor + controller)
- enclosure: IP 54 (sealed, weatherproof)
- ambient temperature: –30 to +40° C/–20 to +115° F

Motor ECDRIVE 4000C

- 2-pole, synchronous brushless DC motor
- high life expectancy, electronically commutated, sensorless
- voltage: max. 240 VDC (electronically commutated)
- power: 3.5 kW/4.6 HP, nmax = 3,300 RPM
- no electronics inside motor
- water filled
- IP68, pressure balanced, max. submersion 250 m
- water lubricated dynamic slide bearings, material: carbon/ceramic
- raw earth magnets, sealed in stainless steel and encapsulated in synthetic resin
- unlimited number of starts/stopps per hour
- wetted material: stainless steel (AISI 316), POM, rubber, cable drinking water approved
- max. water temperature: 40° C/105° F

Pump End (PE)

- centrifugal mulistage direct-coupled pump end
- non-return valve
- material: stainless steel (AISI 304), rubber
- dry running protection (optional)
- max. sand content: 50 g/m³, a higher content will wear the pump and reduce its life span considerably
- max. salt content: 300 – 500 ppm at max. 30° C/85° F higher salt contents require lower water temperatures
- pH-value: 6-9
- high life expectancy

Motor and controller can only operate as unit. The motor cannot be operated without controller or with a different controller.

Especially in Africa, there have been many introduction examples of the solar pump system as shown below.

Table 4-1-2-4 Introduction Examples of the Solar Pump System

COUNTRY	LOCATION	SPECIFICATION
Algeria	(1) -	PS1800, H=40m, Q=45m^3/day
Angola	(1) Huambo, Longonjo-Conusse	PS600, H=38m, Q=8m^3/day
	(2) Huambo, Kissala	PS600, H=44m, Q=8m^3/day
	(3) Huambo, Huambo Escola 102	PS600, H=43m, Q=9m^3/day
	(4) Huambo, Mungo-Cassenje	PS600, H=40m, Q=8m^3/day
	(5) Huambo, Cachiungo	PS600, H=44m, Q=8m^3/day
	(6) Huambo, Bailundo	PS600, H=43m, Q=8m^3/day
	(7) Huambo, Talulua	PS600, H=36m, Q=8m^3/day
Burkina Faso	(1) -	PS1800, H=50m, Q=27m^3/day
	(2) Ouagadougou	PS1800, H=50m, Q=50m^3/day
Djibouti	(1) Koussour	PS4000, H=36m, Q=100m^3/day
Egypt	(1) Marsa Alam, Red Sea region	PS200, H=30m, Q=5.7m^3/day
	(2) Al Baharia 2, El Wahat	PS600, H=4m, Q=100m^3/day
	(3) Al Baharia 1, El Wahat	PS600, H=40m, Q=14m^3/day
	(4) Al Fayoum	PS1800, H=5m, Q=250m^3/day
Eritrea	(1) Barentu	PS1200, H=60m, Q=12m^3/day
Ethiopia	(1) Amhara Regional State, Kemisse	PS1800, H=8m, Q=600m^3/day
	(2) Sidamo District, Awasa	PS150, H= -m, Q=8m^3/day
Gambia	(1) Somita	PS4000, H=30m, Q=120m^3/day
	(2) Kuloro	PS4000, H=24m, Q=180m^3/day
	(3) Buginga	PS1800, H=30m, Q=24m^3/day
	(4) Bwiam 1	PS1800, H=30m, Q=50m^3/day
Guinee Bissau	(1) Antula	PS1800, H=50m, Q=22m^3/day
	(2) Cachue, Ingore	PS1200, H=50m, Q=20m^3/day

COUNTRY	LOCATION	SPECIFICATION
	(3) Cacheu, Ingore	PS600, H=30m, Q=10m^3/day
	(4) Cacheu, Ingore	PS200, H=28m, Q=7m^3/day
Ivory Coast	(1) Abidjan	PS600, H=30m, Q=30m^3/day
Kenya	(1) Maili Tisa	PS1800, H=85m, Q=40m^3/day
	(2) Nairobi	PS1800, H=160m, Q=8m^3/day
	(3) Ramada, MDA Health Centre	PS1800, H=250m, Q=24m^3/day
	(4) Masaai Mara 2, Narok	PS4000, H=160m, Q=40m^3/day
	(5) Kitale	PS1800, H=50m, Q=20m^3/day
	(6) Lamu Island	PS600, H= -m, Q= -m^3/day
	(7) Masaai Mara 1, Narok	PS600, H=2m, Q=12m^3/day
	(8) Lewa Wildlife Conservancy	PS1200, H=80m, Q=19m^3/day
	(9) -	PS600, H=10m, Q=6.5m^3/day
Mali	(1) Soussoula	PS1200, H=25m, Q=15m^3/day
	(2) Faraoula	PS1200, H=35m, Q=7m^3/day
	(3) Bamako, Samanko	PS1800, H=82m, Q=28m^3/day PS4000, H=78m, Q=40m^3/day
	(4) Koutiala, Tyanhirisso	PS1200, H=23m, Q=15m^3/day
	(5) Koutiala, Karangasso	PS1200, H=50m, Q=28m^3/day
Mauritania	(1) Chinguitti, Adrar	PS200, H=21m, Q=9m^3/day
Morocco	(1) Figuig	PS1800, H=20m, Q=88m^3/day
	(2) Figuig	PS1800, H=11m, Q=150m^3/day
	(3) Tahla	PS4000, H=30m, Q=210m^3/day
	(4) Figuig	PS1800, H=10m, Q=67m^3/day
	(5) Figuig	PS1800, H=20m, Q=90m^3/day
	(6) Figuig	PS1800, H=9m, Q=170m^3/day
	(7) Figuig	PS600, H=4m, Q=20m^3/day
	(8) Errachidia	PS1800, H=50m, Q=28m^3/day
	(9) Errachidia	PS4000, H=18m, Q=250m^3/day
	(10) Bouarfa, Tendrara	PS1800, H=83m, Q=18m^3/day
	(11) Casablanca, Bensliman	PS1800, H=37m, Q=35m^3/day
	(12) Tinghir, Douar El kasba	PS1800, H=50m, Q=56m^3/day
	(13) Beni Mellal, Tizy Nisly	PS4000, H=110m, Q=40m^3/day
	(14) Meknes, Nzala Bni Amar	PS1800, H=30m, Q=50m^3/day
	(15) Oujda, Figuigu	PS1800, H=25m, Q=25m^3/day
	(16) Sidi Bennour, Oualidia	PS1800, H=42m, Q=40m^3/day
	(17) Douar-Tazamourt, Taroudant	PS4000, H=75m, Q=70m^3/day
	(18) Guercif	PS1800, H=45m, Q=36m^3/day
	(19) Ouad Zem	PS1200, H=80m, Q=12m^3/day
Morocco	(20) Taghdichte, Ouarzazate	PS1800, H=25m, Q=75m^3/day
	(21) Mzouda, Chichaoua	PS4000, H=85m, Q=130m^3/day
	(22) Atlas Mountains	PS1200, H=25m, Q=25m^3/day
	(23) -	PS4000, H= -m, Q= -m^3/day
Namibia	(1) Akutsima	PS1800, H=20m, Q=30m^3/day
Nigeria	(1) Numan, Adamawa	PS1200, H=96m, Q= -m^3/day
Senegal	(1) Thies, Risso	PS150, H=2m, Q=9m^3/day
	(2) Thies, Mboro	PS600, H=15m, Q=20m^3/day
	(3) Niayes, Mbawane	PS200, H=18m, Q=23m^3/day
	(4) Casamanca , Kafountine	PS200, H=20m, Q=10m^3/day
	(5) Sine Saloum, Samba Dia	PS1800, H=25m, Q=30m^3/day
	(6) Sine Saloum , Marlodje	PS600, H=3m, Q=50m^3/day
	(7) St. Louis, Diama	PS200, H=15m, Q=15m^3/day
	(8) Ecovillage, Belvedere	PS200, H=20m, Q=12m^3/day
	(9) Diana, Casamance	PS600, H=13m, Q=25m^3/day
	(10) Tambacounda, Ngen	PS1200, H=30m, Q=25m^3/day
	(11) Casamance , Ziguinchor	PS600, H=35m, Q=18m^3/day
	(12) Fanda, Ziguinchor	PS600, H=17m, Q=12m^3/day
	(13) Djifongor, Casamance	PS200, H=30m, Q=5m^3/day
Senegal	(14) -	PS1800, H= -m, Q= -m^3/day
	(15) -	PS4000, H= -m, Q= -m^3/day
Sierra Leone	(1) Nothern Province, Makeni	PS600, H=50m, Q=11m^3/day
South Africa	(1) Billiton, South Witbank	PS4000, H=20m, Q=400m^3/day
Sudan	(1) River Nile State, Atbara	PS4000, H=90m, Q=150m^3/day
Tanzania	(1) Makambako, Kitandililo	PS200, H=17m, Q=5m^3/day

COUNTRY	LOCATION	SPECIFICATION
		PS200, H=19m, Q=5m^3/day
	(2) Pemba, Chaka Chaka	PS600, H= -m, Q=6.5m^3/day
	(3) Moshi, Ishinde	PS600, H=40m, Q=14m^3/day
Tunisia	(1) Sidi Bouzid, Fayedh	PS4000, H=60m, Q=90m^3/day
	(2) Ellouce Sfax	PS4000, H=48m, Q=115m^3/day
	(3) Mateur, Bizerte	PS600, H=20m, Q=24m^3/day
	(4) Sidi Bouzid, Rgueb	PS1800, H=70m, Q=30m^3/day
Uganda	(1) -	PS1800, H=90m, Q=18m^3/day
	(2) Sembabule	PS4000, H=140m, Q=25m^3/day
	(3) Amuru	PS1800, H=70m, Q=25m^3/day
	(4) -	PS1200, H=60m, Q=25m^3/day
	(5) Moyo	PS600, H=46m, Q=20m^3/day
	(6) Nsambwe	PS200, H=38m, Q= -m^3/day
Zimbabwe	(1) Hatcliffe, Harare	PS1800, H=40m, Q=30m^3/day

H : Total Dynamic Head or Vertical Lift (m)
Q : Flow Rate (m^3/day)

ⅱ) Capacity of the Solar Pump

The following is the diagram of solar pump capacity that is the largest among the ready-made products of which information are gotten at this stage.

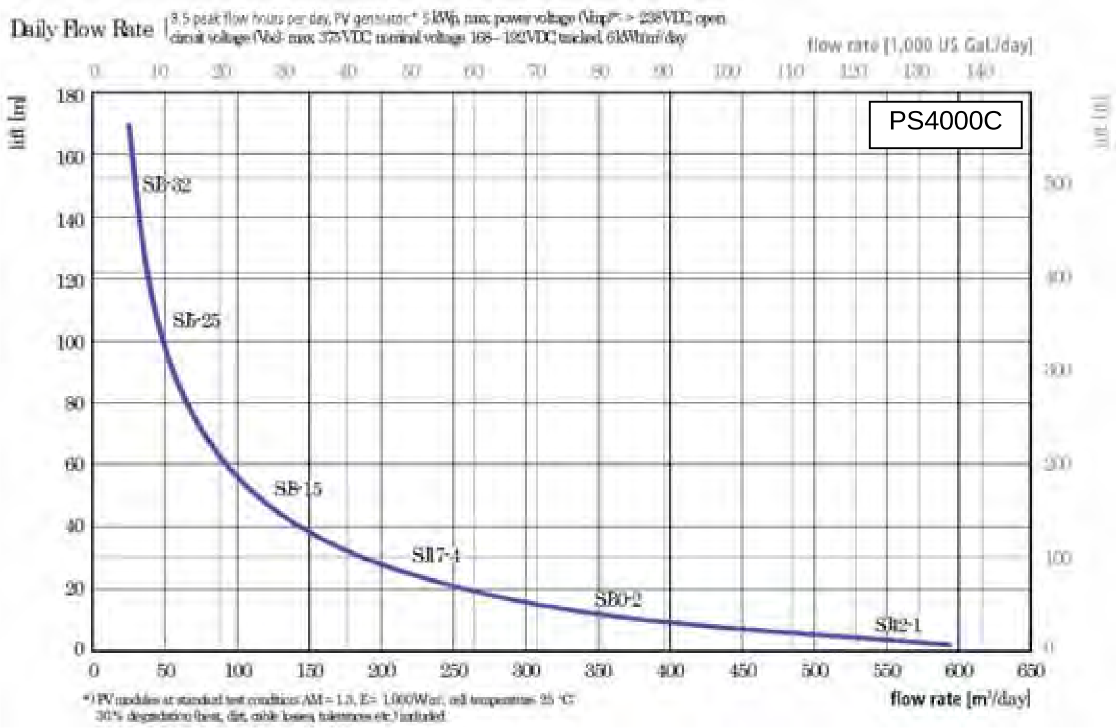


Fig. 4-1-2-3 Capacity of the solar pump

The solar pump capacity is estimated as follows based on the diagram as the ready-made solar pump system is preferable from the view point of economy and the system with larger capacity is preferable for the use in the irrigation project.

Provided the lifting height is 20m and the operation period is 8.5 hours, the capacity becomes about 250m^3/day that corresponds to 8.16 ℓ/sec (=250m^3/8.5hour).

Provided the pumping capacity is in proportion with the solar generation capacity, the average capacity of the solar pump system in fine weather becomes about 80% of the peak capacity according to the characteristics of the solar system shown in the next section. The capacity in fine weather is estimated to be 200m^3/day (=250m^3/day×0.8) and 6ℓ/sec (=8.16ℓ/sec×0.8).

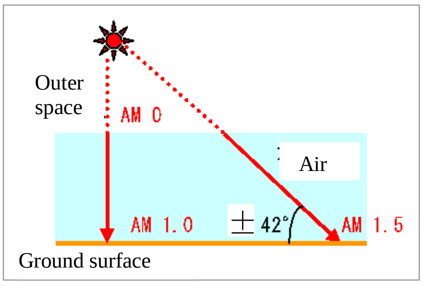
And provided the capacity becomes 70% in cloudy weather of the one in fine weather according to the research result shown in the following section, the capacity in cloudy weather is estimated to be 140m^3/day (=200m^3/day×0.7) and 4.5ℓ/sec (=8.16 ℓ/sec×0.8×0.7).

According to the weather data, the longest duration of sunshine through a year is about 10 hours and the average duration of sunshine through a year is 5.5 hours. The total of the cloudy and fine days after excluding the rainy days are 302 days. Then let us simplify the situation by dividing these 302 days at the proportion of 55% fine and 45% cloudy. Now the average capacity of the solar pump is estimated as follows.

(200m^3/day×55+140m^3/day×45)/100 170m^3/day
(8.16ℓ/sec×0.8×55+8.16 ℓ/sec×0.8×0.7×45)/100 = 5.6ℓ/sec

iii) Characteristics of the solar pump system

It is the characteristic of the solar pump system that the pumping capacity is dependent on the solar generation capacity. The solar generation capacity changes as shown in the following diagram affected by the incident angle of sunshine to the ground surface etc., that is to say the longer the distance of the sunshine proceeding in the air becomes, the smaller the solar generation capacity becomes.



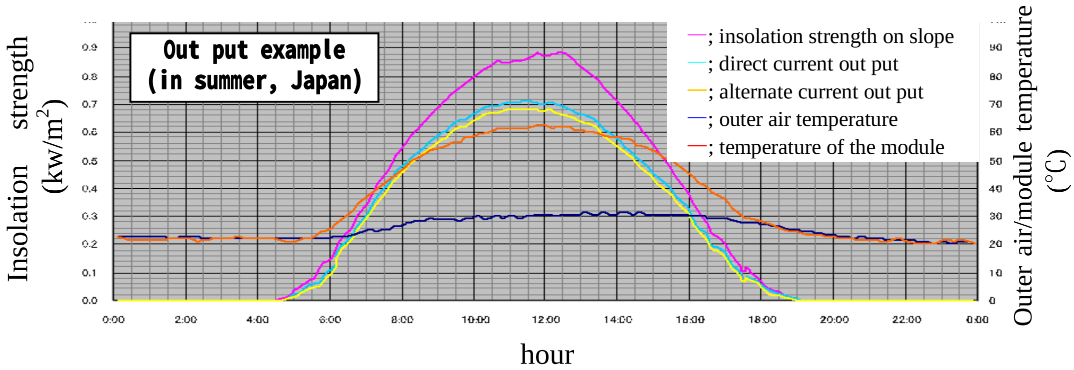


Fig. 4-1-2-4 Output example of solar pump

In terms of the isolation strength, it ascends to about 0.3 kw/m2, which corresponds to about 40% of the maximum, at around 7 AM and descends to this level at around 4 PM in the afternoon; the average isolation strength during these 9 hours from 7 AM to 5 PM would be about 0.55 kw/m2 that corresponds to about 80% of the maximum.

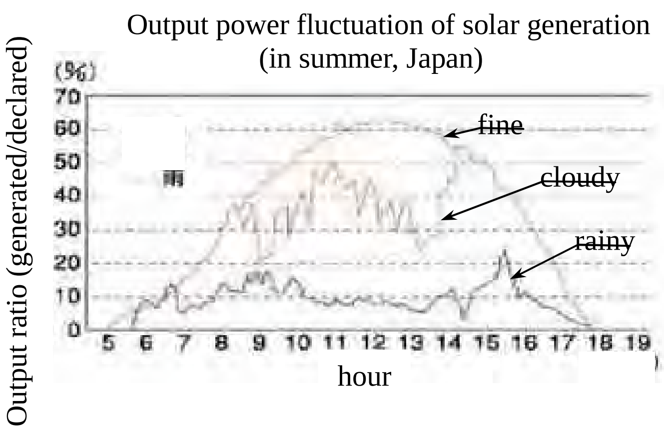


Fig. 4-1-2-5 Output fluctuation of solar generation

iv) Economical comparison with other types of pump

The electric line can not be seen in the dam site but can be seen in the village about 4.2km away from the dam site, so that the comparison is done with the electric pump based on the assumption of the line being extended to the site. It is one option to operate the electric pump by a diesel generator; but the comparison with this case shall not be done as a diesel generator is less economical than the electric pump due to the high cost of fuel.

Table 4-1-2-5 Economical Comparison of Pump

Type	Power	Price (US$)	Operation Cost	Life Time
Electric Pump	3.7KW	22,000	3.7kwh×112Rwf×8.5h×302day×20year =21,275,296Rwf=35,459US$	?
Solar Pump	3.5KW	30,000	No charge	20 years

The electric pump operation cost for 20 years exceeds a little the price of the solar pump. The electric pump has of course the life time, is mortal and must be replaced in considerable years, so that the solar pump is clearly more economical than the electric pump. In reality, it is helpful for the farmers to save the water fee, i.e. not to have to pay the daily electricity fee, under the favor of introducing the solar pump.

v) Judgment to the possibility of introducing the solar pump system

In Rwanda, many ministry/public buildings in districts depend on the electricity by the solar generation system. The solar generation systems spread in Rwanda nowadays are the ones made in China/India that come through Middle East and the ones made in France/Spain/USA that come through Europe. There are more than 10 agent companies in Kigali that deal with solar generation systems in terms of selling, installing, arrangement and maintenance.

Therefore, it is considered to be possible to introduce the solar pump system in Rwanda, in this project, based on its economical advantage, the technological level in Rwanda of being able to perform operation and maintenance works to the solar pump system, and the relatively stable pumping capacity that may be satisfy the irrigation needs totally in spite of the pumping capacity fluctuating hour by hour and day by day.

(2) Comparative study on water supply facilities and intake method for irrigation

(a) Case-1: Dam

i) Available quantity of irrigation water

The function of dams is to store the unsteady river water including floods and to supply irrigation water steadily. The expected quantity of the river in-flow rate at the dam site is 700,000m^3 annually according to the study result in section:3-3-1; and this 700,000m^3 is the available quantity, which is divided into 170,000m^3 for paddy fields' use and 530,000m^3 for dry fields' use.

ii) Facility size

The reservoir capacity necessary for 700,000m^3 of the irrigation operation is 450,000m^3 according to the study result in section 4-1-1. Based on the relationship between the reservoir capacity and the water height (H~Q curve) shown below, the water height corresponding to the quantity 450,000m^3 is

8.5m. Then, the dam height is estimated to be 11.5m by adding empirically 1.5m as the additional height and 1.5m as the foundation excavation.

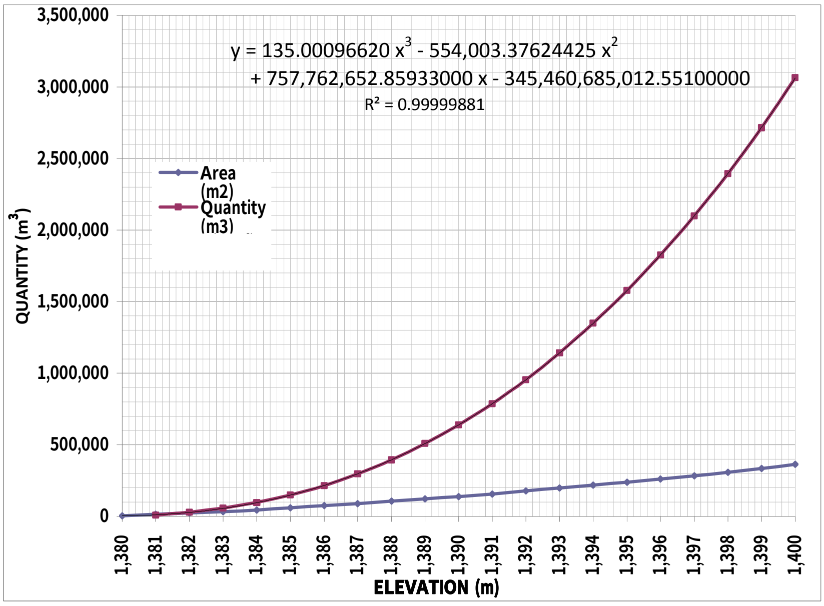


Fig. 4-1-2-6 Reservoir H～Q Curve

The approximate embankment volume of the dam body can be estimated by the following equation.

$$V = \frac{1}{2} \cdot B \cdot H \cdot (L_1 + L_2) + \frac{1}{6} \cdot (m+n) \cdot H^2 \cdot (L_1 + 2L_2)$$

V : Embankment volume of the dam body (m3)

B : Width of the dam crest (m)

H : Dam height (m)

L_1 : Dam crest length (m)

L_2 : Width of the embankment bottom (m)

m : Average inclination of the upstream slope (m)

n : Average inclination of the downstream slope (m)

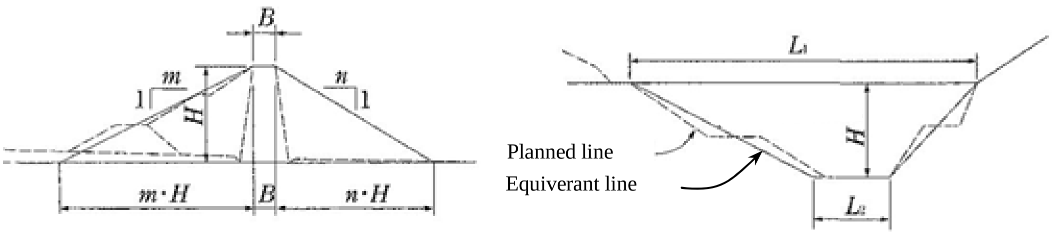


Fig. 4-1-2-7 Dimensional Profile of Dam for Estimation of Embankment Volume

Now, the approximate longitudinal and cross-sectional profile of the dam is as follows.

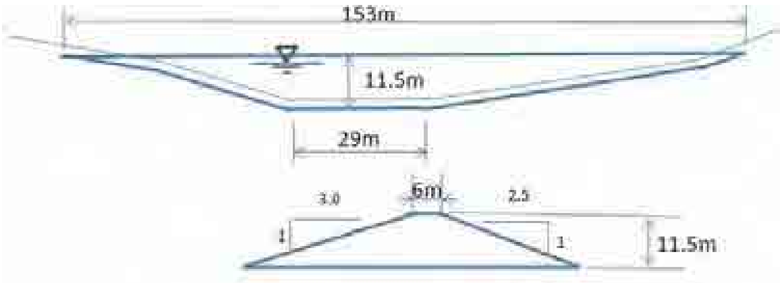


Fig. 4-1-2-8 Longitudinal and Cross-sectional Profile of Dam

B=6.0, H=11.5, L_1=153.0, L_2=29.0, m=3.0, n=2.5

Then,

the embankment volume is : V = $(1/2)\times6.0\times11.5\times(153.0+29.0)+(1/6)\times(3.0+2.5)\times11.50^2\times(153.0+2\times29.0)$

$= 31{,}900m^3$

The approximate construction cost is as follows.

・Foundation excavation ; $\{(1/2)\times(6.0+11.5\times5.5)\times(153.0-29.0)+29.0\times11.5\times5.5\}\times1.5 \times(4{,}500/600)^{US\$/m3}$ = 68,900 US$

・Embankment ; $31{,}900m^3\times(8{,}500/600)\ )^{US\$/m3}$ = 451,900 US$

・Slope protection ; $(1/2)\times(153.0+29.0)\times\{(3\times11.5)^2+11.5^2\}^{1/2}\times0.6\times(1/2)\times(40{,}000/600)^{US\$/m3}$ = 66,200 US$

・Spillway ; L.S. 80,000 US$

・Bottom outlet ; L.S. 75,000 US$

・Intake facilities ; L.S. 60,000 US$

Total ; 802,000 US$

iii) Water supply method

Following two cases come on the table.

① The main canal is connected directly to the bottom outlet. The slopes expanding below the canal line is irrigated by the water supplied gravitationally from the canal. The slopes expanding beyond the canal line is irrigated by the water supplied by the pumps installed on the canal line.

② The whole irrigation water is pumped up on the main canal constructed along the upper perimeter of the project area and delivered to the command area.

The gravitational irrigation area mentioned in Idea-① is estimated as follows.

The width of the command area in the immediately downstream to the dam is zero in case of the water supply being done by the bottom outlet. In the Ngoma-22 valley, the elevation difference between the dam site and the confluence point about 4km downstream is 25m; and the inclination of the ground surface is 6.25/1,000 (=25m/4km). Provided the inclination of the main canal is 1/500 (=2/1,000), the effective inclination difference is 4.25/1,000; and the elevation difference at the exit of the valley 4km far from the dam site is 17m (=4.25×4). Provided the inclination of the slope is 15°averagely, the width corresponding to this elevation difference is 63m (=17m/tan15°). Assuming the shape of the command area on the slope to be triangular between the dam site and the confluence point, it is estimated to be 12.6ha (=(1/2)×4,000m×63m=126,000m2) in one side, 25.2ha in both sides. In the downstream beyond the confluence point, the longitudinal inclination of the river bed is equivalent to the one of the main canal, so that the width of the command area is constant and the command area between the confluence point and the point 4km downstream more is 25.2ha (=63m×4km=25.2ha). The total command area under the gravitational irrigation is 50.4ha.

Accordingly, in the idea-① the secondary/tertiary canal facilities become intricate due to the water supply facilities on the narrow command area below the main canal, solar pump facilities on the main canal line and the secondary/tertiary canal facilities on the slope beyond the main canal.

On the contrary, in the idea-② the irrigation facilities are simplified where the solar pump facilities are concentrated to the dam site and the secondary/tertiary canal facilities extend to downward only from the main canal.

Here to this case, the idea-② is adopted.

The intended area of the solar pump irrigation is 240ha. The pump's irrigation capacity is estimated to be 7.4 (ha/1unit) according to the study result in section 4-1-2 (7). Then the number of pumps needed becomes as follows.

$$240\text{ha} \div 7.4 \text{ ha/unit} = 33^{\text{unit}}$$

The purchase cost of these is: 30,000US$×33=990,000 US$.

(b) Case-2: Head Work

ⅰ) Available quantity of irrigation water

The function of head works is to divide the river flow and take the divided one in for irrigation use. It is usual to plan the intake rate according to the smaller river flow rate from the view point of supplying irrigation water to the command area steadily for the sake of steady farming management. In this meaning, the available quantity of irrigation water is estimated to be 10 ℓ/sec considering the river flow rate observed during this late February to May and the irrigation water supply to the paddy fields as follows.

Base flow rate during this late February to May (in dry season):	15 ℓ/sec
Irrigation water supply to the downstream paddy fields	: 5 ℓ/sec
Available quantity of irrigation water for the dry fields	: 10 ℓ/sec

The expected available quantity is 315,000m^3 (=10ℓ/sec×86,400sec/day×365day) annually.

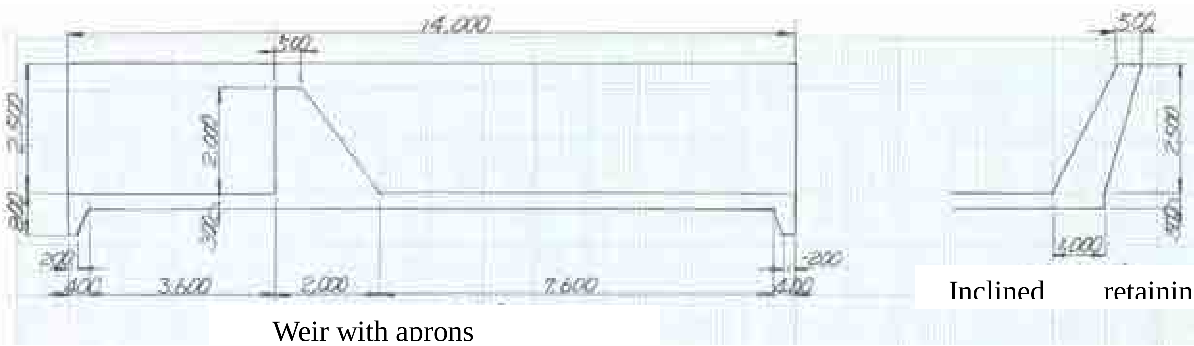


Fig. 4-1-2-9 Cross-sectional Profile of Headwork

The construction cost is estimated approximately as follows.

Excavation；for weir：$(14.0\times30.0\times1.5+0.5\times0.5\times30.0\times2)\times(6{,}500/600)^{US\$/m3}$
=7,000 US$
for retaining wall：$\{(1/2)\times2.0\times3.5\times14.0\times2\}\times(4{,}500/600)^{US\$/m3}$
=700 US$
Wet masonry；for weir and aprons：$\{(1/2)\times(0.5+2.0)\times2.0\times30.0+14.0\times0.3\times30.0+(1/2)$
$\times(0.4+0.2)\times0.5\times30.0\times2\}\times(75{,}000/600)^{US\$/m3}$ =19,500 US$
for retaining wall：$\{(1/2)\times(0.5+1.0)\times2.5+0.3\times1.0\}\times14.0\times2\times(75{,}000/600)^{US\$/m3}$
=7,600 US$
Gate and others；Lump sum 5,000 US$
Total 39,800 US$

iii) Water supply method

In case of head works, the water level is lifted up by the weir, so that the water level at the intake mouth becomes higher and the command area irrigated by gravitational water becomes larger than the bottom outlet case. Provided the water level is lifted up by 1.5m at the intake mouth, the width of the command area at the weir is 5.6m (=1.5m/tan15°) and the intended area for gravitational irrigation from the dam site to the confluence point 4km downstream is calculated to be 14.8ha (= (1/2)×{5.6m+(5.6m+63m)}×4km) in the manner as same as the previous section, and total 29.6ha in both sides. The command area downstream beyond the confluence point is calculated to be 27.4ha (=(5.6m+63m)×4km) as same as before, and the total irrigable area by gravitational water is 57ha.

On the other hand, assuming the average annual irrigation water requirement to be 2,200m^3/ha (530,000m^3/240ha), the command area to 315,000m^3 of the available quantity is 143ha (=315,000^{m3}÷2,200$^{m3/ha}$); and the intended area for the solar pump irrigation is 86ha (=142.5ha－57ha). The pump's irrigation capacity is estimated to be 7.4 (ha/1unit) according to the study result in section 4-1-2 (7). Then the number of pumps needed becomes as follows.

86ha÷7.4 ha/unit=12^{unit}

The purchase cost of these is: 30,000US$×12=360,000 US$.

(c) Case-3: Dam with 10m of lifted up canal

In this case, the lift up function of head works is given to the dam. There would be two ways to give the lift up function to the dam; one is to take the reservoir water in through the intake mouth constructed on a relatively high position on the upstream slope, and the other is to connect the conduit in the bottom outlet to the discharge chamber constructed on a relatively high position on the downstream slope from which the main canal starts. The bottom outlet is essential as the drainage canal during the dam construction, so that to adopt the latter way is rational and economical.

i) Available quantity of irrigation water

The available quantity is 700,000m^3 composed of 170,000m^3 for the paddy fields and 530,000m^3 for the dry fields as same as Case-1.

ii) Facility size

The reservoir water level EL.1390m corresponds to the 10m of lifted up water level. The reservoir capacity corresponding to this water height is 630,000m^3 according to (Fig. 4-1-2-1). Adding 450,000m^3 of quantity for the reservoir operation, the reservoir capacity is 1,080,000m^3, the corresponding water level, full water level to the reservoir, is EL.1392.7m, and the water height is 12.7m. Then, considering the additional height empirically to be 1.5m and the 1.5m of foundation excavation, the dam height becomes 15.7m.

Now, the approximate longitudinal and cross-sectional profile of the dam is as follows.

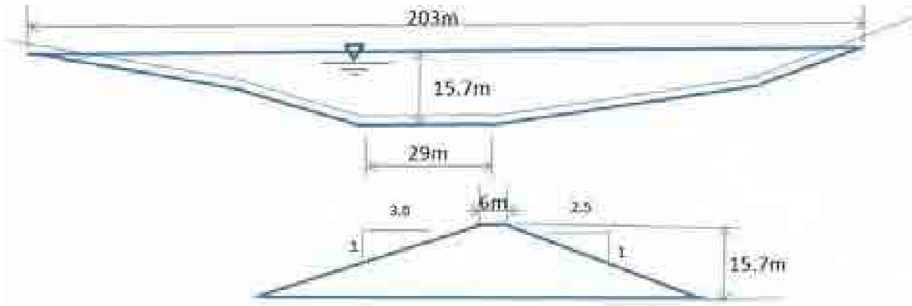


Fig. 4-1-2-10 Longitudinal and Cross-sectional Profile of Dam (w/ 10m lifted up)

$B=6.0,\ H=15.7,\ L_1=203.0,\ L_2=29.0,\ m=3.0,\ n=2.5,$

Then, the embankment volume is:

$$V=(1/2)\times 6.0\times 15.7\times(203.0+29.0)+(1/6)\times(3.0+2.5)\times 15.7^2\times(203.0+2\times 29.0)=69{,}900\ m^3$$

The approximate construction cost is as follows.

・Foundation excavation ; $\{(1/2)\times(6.0+15.7\times5.5)\times(203.0-29.0)+29.0\times15.7\times5.5\}\times1.5\times(4{,}500/600)^{US\$/m3}$ =118,600 US$

・Embankment ; $58{,}800m^3\times(8{,}500/600)\,)^{US\$/m3}$ =990,300 US$

・Slope protection ; $(1/2)\times(203.0+29.0)\times\{(3\times15.7)^2+15.7^2\}^{1/2}\times0.6\times(1/2)\times(40{,}000/600)^{US\$/m3}$ =115,200 US$

・Spillway ; L.S. 100,000 US$

・Bottom outlet ; L.S. 100,000 US$

・Intake facilities ; L.S. 60,000 US$

Total ; 1,484,100 US$

iii) Water supply method

The irrigation water is led through the conduit in the bottom outlet, the connecting pipes that are branched from the end of conduit and connected respectively to the left and the right discharge chamber constructed at the EL.1390m point on the downstream slopes, and the main canals on the both slopes. The command area intended for gravitational irrigation is estimated to be 156.3ha on the right bank slope, 64.2ha on the left bank slope, and 220.5ha in total based on (Fig. 4-1-2-2). Accordingly, the intended area for the solar pump irrigation is 19.5ha (=240ha－220.5ha). The pump's irrigation capacity is estimated to be 7.4 (ha/1unit) according to the study result in section 4-1-2 (7). Then the number of pumps needed becomes as follows.

$19.5ha\div7.4\ ha/unit=3^{unit}$

The purchase cost of these is: 30,000US$×3=90,000 US$.

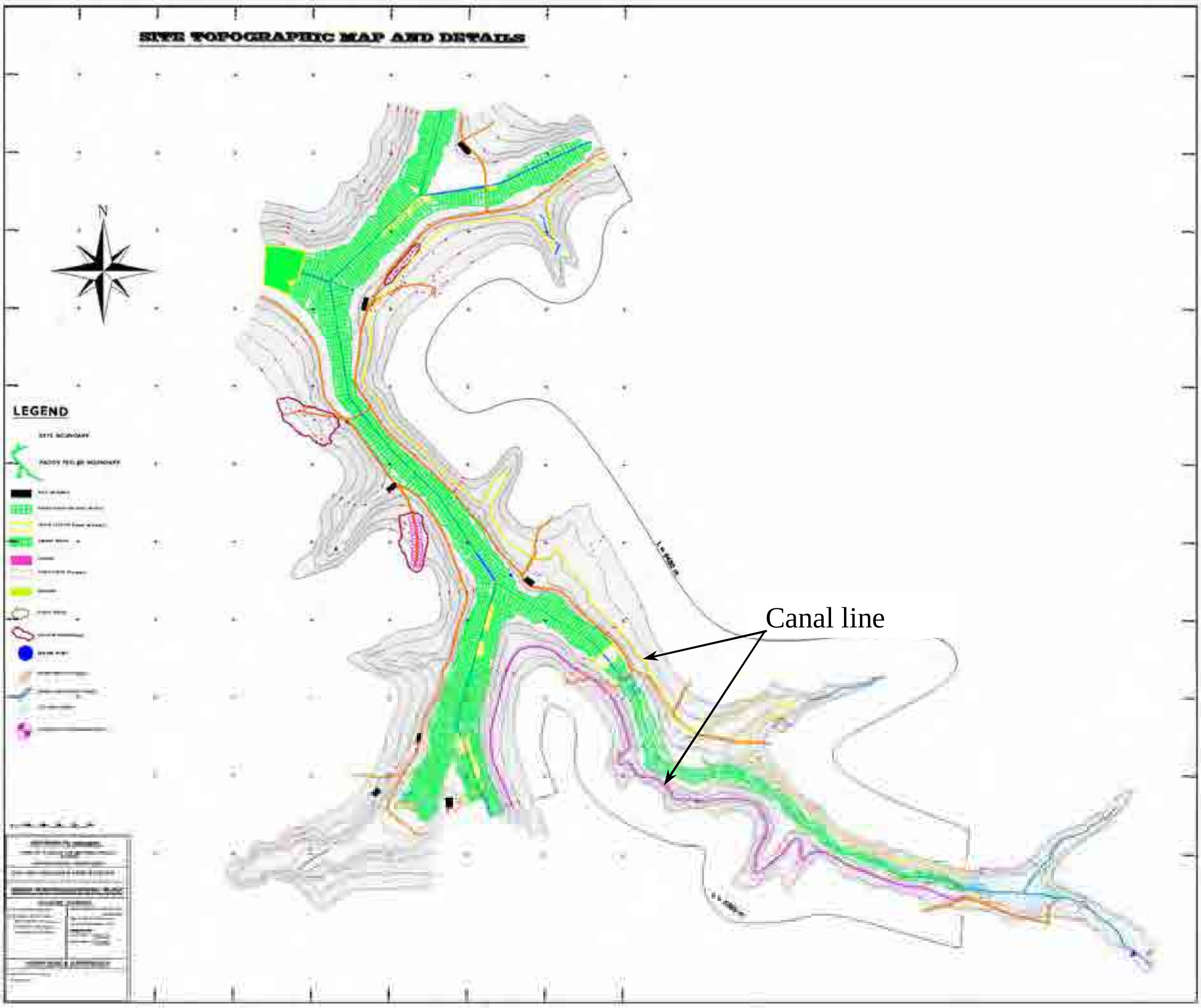


Fig. 4-1-2-11 Canal alignment and the command area (w/ 10m lifted up)

(d) Case-4: Dam with 7.5m of lifted up canal

ⅰ) Available quantity of irrigation water

The available quantity is 700,000m^3 composed of 170,000m^3 for the paddy fields and 530,000m^3 for the dry fields as same as Case-1.

ⅱ) Facility size

The reservoir water level EL.1387.5m corresponds to the 7.5m of lifted up water level. The reservoir capacity corresponding to this water height is 350,000m^3 according to (Fig. 4-1-2-1). Adding 450,000m^3 of quantity for the reservoir operation, the reservoir capacity is 800,000m^3, the corresponding water level, full water level to the reservoir, is EL.1391.2m, and the water height is 11.2m. Then, considering the additional height empirically to be 1.5m and the 1.5m of foundation excavation, the dam height becomes 14.2m and the dam crest elevation is EL.1392.7m.

Now, the approximate longitudinal and cross-sectional profile of the dam is as follows.

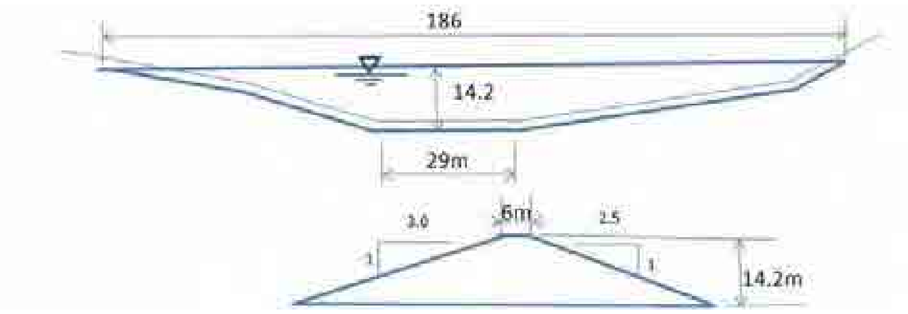


Fig. 4-1-2-12 Longitudinal and Cross-sectional Profile of Dam (w/ 7.5m lifted up)

$B=6.0$, $H=14.2$, $L_1=186.0$, $L_2=29.0$, $m=3.0$, $n=2.5$

Then, the embankment volume is:

$V=(1/2)\times6.0\times14.2\times(186.0+29.0)+(1/6)\times(3.0+2.5)\times14.2^2\times(186.0+2\times29.0)=54{,}300\ m^3$

The approximate construction cost is as follows.

・Foundation excavation；{(1/2)×(6.0+14.2×5.5)×(186.0-29.0)+29.0×14.2×5.5}×1.5×(4,500/600)$^{US\$/m3}$ =99,800 US$

・Embankment ; 54,300m^3×(8,500/600))$^{US\$/m3}$=769,300 US$

・Slope protection ；(1/2)×(186.0+29.0)×{(3×14.2)^2+14.2^2}$^{1/2}$×0.6×(1/2)×(40,000/600) $^{US\$/m3}$ =96,500 US$

・Spillway ；L.S. 95,000 US$

・Bottom outlet ；L.S. 95,000 US$

・Intake facilities ；L.S. 60,000 US$

Total ; 1,215,600 US$

iii) Water supply method

The irrigation water is led through the conduit in the bottom outlet, the connecting pipes that are branched from the end of conduit and connected respectively to the left and the right discharge chamber constructed at the EL.1387.5m point on the downstream slopes, and the main canals on the both slopes. The command area intended for gravitational irrigation is estimated to be 124.6 in total based on (Fig. 4-1-2-3). Accordingly, the intended area for the solar pump irrigation is 115.4ha (=240ha－124.6ha). The pump's irrigation capacity is estimated to be 7.4 (ha/1unit) according to the study result in section 4-1-2 (7). Then the number of pumps needed becomes as follows.

115.4ha÷7.4 ha/unit=16^{unit}

The purchase cost of these is: 30,000US$×16=480,000 US$.

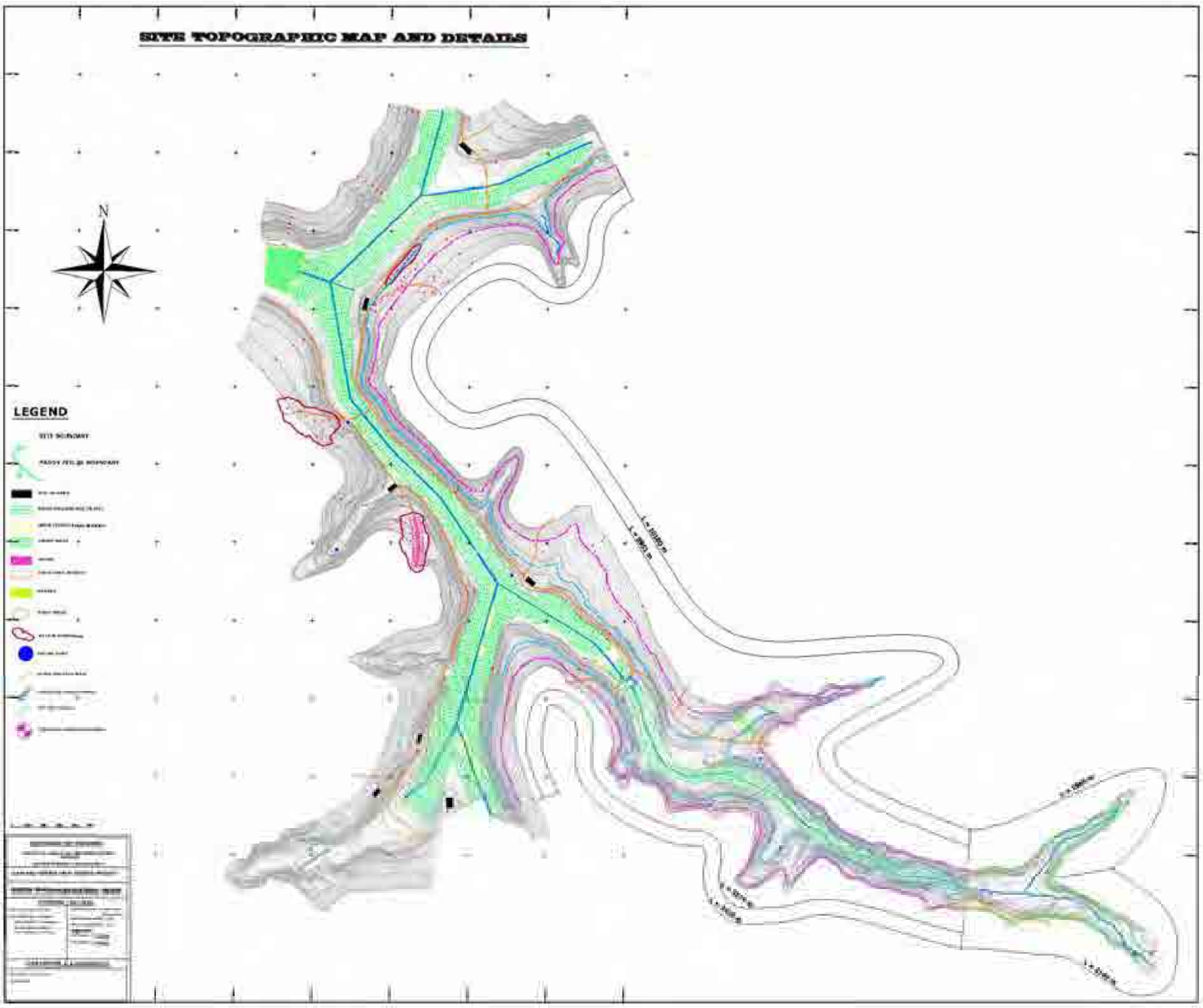


Fig. 4-1-2-13 Canal alignment and the command area (w/ 7.5m lifted up)

(e) Case-5: Dam with 6.5m of lifted up canal

ⅰ) Available quantity of irrigation water

The available quantity is 700,000m^3 composed of 170,000m^3 for the paddy fields and 530,000m^3 for the dry fields as same as Case-1.

ⅱ) Facility size

The reservoir water level EL.1386.5m corresponds to the 6.5m of lifted up water level. The reservoir capacity corresponding to this water height is 250,000m^3 according to (Fig. 4-1-2-1). Adding 450,000m^3 of quantity for the reservoir operation, the reservoir capacity is 700,000m^3, the corresponding water level, full water level to the reservoir, is EL.1390.6m, and the water height is 10.6m. Then, considering the additional height empirically to be 1.5m and the 1.5m of foundation excavation, the dam height becomes 13.6m and the dam crest elevation is EL.1392.1m.

Now, the approximate longitudinal and cross-sectional profile of the dam is as follows.

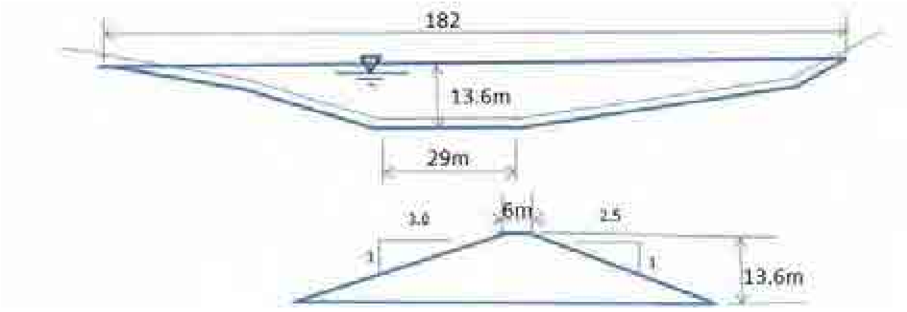


Fig. 4-1-2-14 Longitudinal and Cross-sectional Profile of Dam (w/ 6.5m lifted up)

$B=6.0,\ H=13.6,\ L_1=182.0,\ L_2=29.0,\ m=3.0,\ n=2.5$

Then, the embankment volume is:

$V=(1/2)\times 6.0\times 13.6\times(182.0+29.0)+(1/6)\times(3.0+2.5)\times 13.6^2\times(182.0+2\times 29.0)=49{,}300\ m^3$

The approximate construction cost is as follows.

・Foundation excavation；$\{(1/2)\times(6.0+14.2\times 5.5)\times(186.0-29.0)+29.0\times 14.2\times 5.5\}\times 1.5\times(4{,}500/600)^{US\$/m3}$
=93,900 US$

・Embankment ; $49{,}300m^3\times(8{,}500/600)\ )^{US\$/m3}$
=698,400 US$

・Slope protection ；$(1/2)\times(182.0+29.0)\times\{(3\times 13.6)^2+13.6^2\}^{1/2}\times 0.6\times(1/2)\times(40{,}000/600)^{US\$/m3}$
=90,700 US$

・Spillway ；L.S. 95,000 US$

・Bottom outlet ；L.S. 95,000 US$

・Intake facilities ；L.S. 60,000 US$

Total ; 1,133,000 US$

iii) Water supply method

The irrigation water is led through the conduit in the bottom outlet, the connecting pipes that are branched from the end of conduit and connected respectively to the left and the right discharge chamber constructed at the EL.1386.5m point on the downstream slopes, and the main canals on the both slopes. The command area intended for gravitational irrigation is estimated to be 114.6 in total based on (Fig. 4-1-2-4). Accordingly, the intended area for the solar pump irrigation is 125.4ha (=240ha－114.6ha). The pump's irrigation capacity is estimated to be 7.4 (ha/1unit) according to the study result in section 4-1-2 (7). Then the number of pumps needed becomes as follows.

$125.4ha\div 7.4\ ha/unit=17^{unit}$

The purchase cost of these is: 30,000US$×17=510,000 US$.

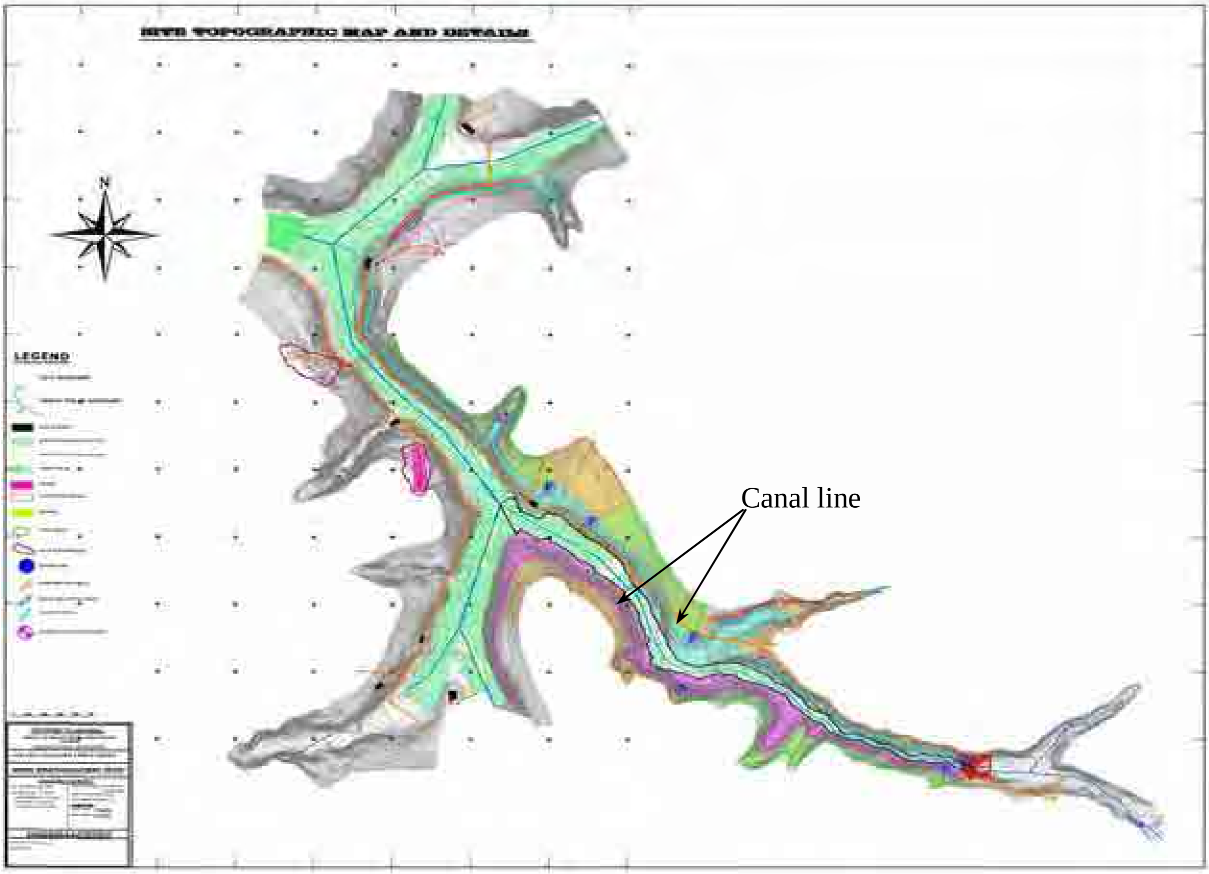


Fig. 4-1-2-15 Canal alignment and the command area (w/ 6.5m lifted up)

(f) Case-6: Dam with 5.0m of lifted up canal

ⅰ) Available quantity of irrigation water

The available quantity is 700,000m^3 composed of 170,000m^3 for the paddy fields and 530,000m^3 for the dry fields as same as Case-1.

ⅱ) Facility size

The reservoir water level EL.1385.0m corresponds to the 5m of lifted up water level. The reservoir capacity corresponding to this water height is 150,000m^3 according to (Fig. 4-1-2-1). Adding 450,000m^3 of quantity for the reservoir operation, the reservoir capacity is 600,000m^3, the corresponding water level, full water level to the reservoir, is EL.1389.7m, and the water height is 9.7m. Then, considering the additional height empirically to be 1.5m and the 1.5m of foundation excavation, the dam height becomes 12.7m and the dam crest elevation is EL.1391.5m.

Now, the approximate longitudinal and cross-sectional profile of the dam is as follows.

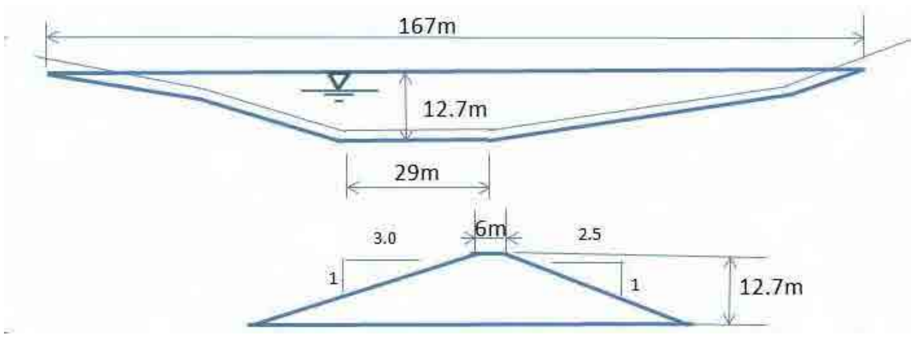


Fig. 4-1-2-16 Longitudinal and Cross-sectional Profile of Dam (w/ 5m lifted up)

$$B=6.0,\ H=12.7,\ L_1=167.0,\ L_2=29.0,\ m=3.0,\ n=2.5$$

Then, the embankment volume is:

$$V=(1/2)\times6.0\times12.7\times(167.0+29.0)+(1/6)\times(3.0+2.5)\times12.7^2\times(167.0+2\times29.0)=\quad 40{,}700\ m^3$$

The approximate construction cost is as follows.

・Foundation excavation；{(1/2)×(6.0+12.7×5.5)×(167.0-29.0)+29.0×12.7×5.5}×1.5×(4,500/600)$^{US\$/m3}$
=81,700 US$
・Embankment ; 40,700m^3×(8,500/600))$^{US\$/m3}$
=576,600 US$
・Slope protection ；(1/2)×(167.0+29.0)×{(3×12.7)^2+12.7^2}$^{1/2}$×0.6×(1/2)×(40,000/600) $^{US\$/m3}$
=78,00 US$
・Spillway ；L.S. 90,000 US$
・Bottom outlet ；L.S. 90,000 US$
・Intake facilities ；L.S. 60,000 US$
Total ; 977,000 US$

iii) Water supply method

The irrigation water is led through the conduit in the bottom outlet, the connecting pipes that are branched from the end of conduit and connected respectively to the left and the right discharge chamber constructed at the EL.1385.0m point on the downstream slopes, and the main canals on the both slopes. The command area intended for gravitational irrigation is estimated to be 72.6 in total based on (Fig. 4-1-2-5). Accordingly, the intended area for the solar pump irrigation is 167.4ha (=240ha－72.6ha). The pump’s irrigation capacity is estimated to be 7.4 (ha/1unit) according to the study result in section 4-1-2 (7). Then the number of pumps needed becomes as follows.

167.4ha÷7.4 ha/unit=23^{unit}

The purchase cost of these is: 30,000US$×23=690,000 US$.

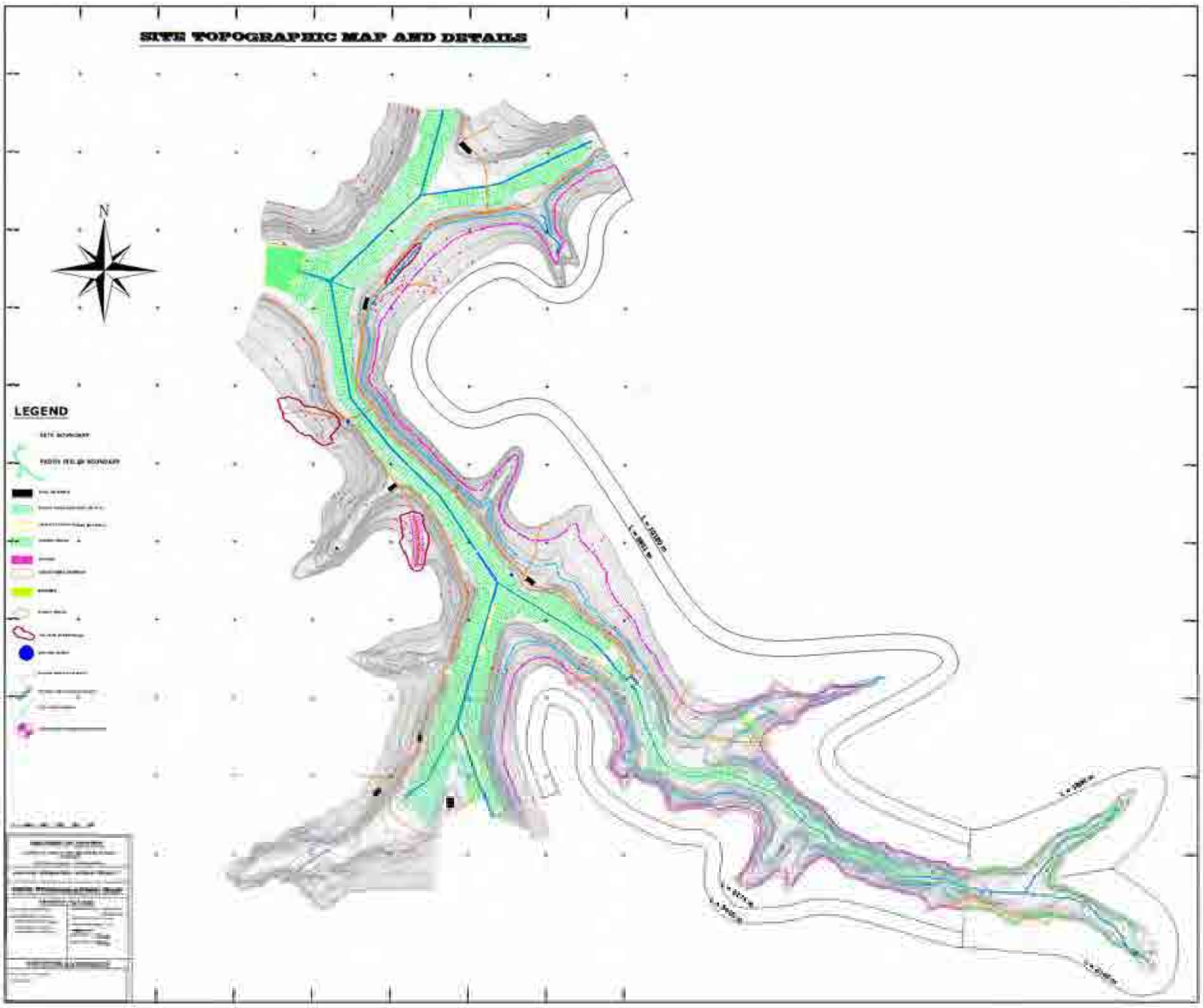


Fig. 4-1-2-17 Canal alignment and the command area (w/ 5.0m lifted up)

(g) Adoption plan

Table 4-1-2-6 Summary Table of Case Studies

Case	Available Quantity (m^3)	Command Area (ha)	Facility Size・Cost (US$)	Solar Pump: unit/cost (US$)
Case-1: Dam	530,000	Gravity；0 Pump;240	Dam height; 11.5m Reservoir; 450,000m^3 Cost; 802,000	Pump; 33 units Cost; 990,000
Case-2: Head work	315,000	Gravity；57 Pump;86	Weir height; 2m Reservoir; Cost; 39,800	Pump; 12 units Cost; 360,000
Case-3: Dam with 10m of lifted up canal	530,000	Gravity ; 220.5 Pump;19.5	Dam height; 15.7m Reservoir;1,080,000m^3 Cost; 1,484,100	Pump; 3 units Cost; 90,000
Case-4: Dam with 7.5m of lifted up canal	530,000	Gravity ; 124.6 Pump;115.4	Dam height; 14.2m Reservoir; 800,000m^3 Cost; 1,215,600	Pump; 16 units Cost; 480,000
Case-5: Dam with 6.5m of lifted up canal	530,000	Gravity ; 114.6 Pump;125.4	Dam height; 13.6m Reservoir; 700,000m^3 Cost; 1,133,000	Pump; 17 units Cost; 570,000

			工事: 1,133,000	
Case-6: Dam with 5.0m of lifted up canal	530,000	Gravity；72.6 Pump;167.4	Dam height; 12.7m Reservoir; 600,000m^3 Cost; 977,000	Pump; 23 units Cost; 690,000

Total Assessment

Case	Assessment
Case-1: Dam	Total Cost;1,792,000 US$ / Dam height; 11.5m / Reservoir capacity; 450,000m^3 / Solar pump; 33 units ・The total construction cost is the highest. ・Degree of dependence on solar pumps is too high. One of the problems in the open channel type canal system is the long conveyance time for sending water. The capacity fluctuation of the solar pump accelerates this disadvantage so that the canal's function would be lowered more. ・The renewal cost for solar pumps becomes large.
Case-2: Head work	Total Cost; 399,800 US$ / Weir height; 2m / Solar pump; 12 units The total construction cost becomes very low. If 15ℓ/sec level of the base flow rate is assured, this plan becomes attractive because of the highest cost-benefit ratio. But in reality, the base flow rate would decrease much more and it would be difficult to perform the stable farming management.
Case-3: Dam with 10m of lifted up canal	Total Cost;1574,100 US$ / Dam height; 15.7m / Reservoir capacity; 1,080,000m^3 / Solar pump; 3 units ・The total construction cost is the cheapest among the dam plans. ・1,080,000m^3 of the reservoir total capacity means that it takes at least two years for the reservoir to be filled with water to the full water level. Such a condition requires the people concerned patience and is contrary to the requirement of early manifestation of the economic effect.
Case-4: Dam with 7.5m of lifted up canal	Total Cost;1,695,600 US$ / Dam height; 14.2m / Reservoir capacity; 800,000m^3 / Solar pump; 16 units ・The total construction cost is the second highest. ・The reservoir total capacity 800,000m^3 is the second largest and it takes two years for the reservoir to be filled with water to the full water level. Such a condition requires the people concerned patience and is contrary to the requirement of early manifestation of the economic effect.
Case-5: Dam with 6.5m of lifted up canal	Total Cost;1,643,000 US$ / Dam height; 13.6m / Reservoir capacity; 700,000m^3 / Solar pump; 17 units ・The total construction cost is the second lowest. ・700,000m^3 of the reservoir total capacity matches with the expected level of the river in-flow rate so that it is possible to obtain the early manifestation of economic effect.
Case-6: Dam with 5.0m of lifted up canal	Total Cost;1,667,000 US$ / Dam height; 12.7m / Reservoir capacity;600,000m^3 / Solar pump; 23 units ・The total construction cost is the third highest. ・Degree of dependence on solar pumps is too high. One of the problems in the open channel type canal system is the long conveyance time for sending water. The capacity fluctuation of the solar pump accelerates this disadvantage so that the canal's function would be lowered more. ・The renewal cost for solar pumps becomes large.

Based on the summarized comparison shown above, it is rational and adequate to adopt Case-5: Dam with 6.5m of lifted up canal.

(3) Comparative study on water conveyance facilities and on-farm irrigation method

(a) On-farm irrigation method

In this project, the micro irrigation method is adopted based on the following reasons.

- The degree of percolation is very high（permeability coefficient: k=n×10^{-2}~10^{-3}cm/sec）in the dry fields of this district. Therefore, the general on-farm irrigation method such as the furrow irrigation would not be able to send irrigation water to the corner of the farm land.（The field tests for furrow irrigation carried out in 2010 confirmed the conditions that the considerable amount of water poured on to the excavated ditch disappeared after proceeding 20m or so.）
- The amount of water is not in abundance but limited. It is the point to use the limited water as much as effectively and bring the effectiveness of productivity improvement to the farmlands as wide as possible. Regarding this point, the micro irrigation method has the highest irrigation effectiveness (refer to the following table).
- The model farming of horticulture has been carried out in PICROPP (Project for Increasing Crop Production with Quality Extension Services) that is precedent to this project, in a part of which the hand irrigation by using jerry cans is adopted for saving irrigation water.

Table 4-1-2-6 (2) Characteristics of on-farm irrigation method

irrigation method	Characteristics
Surface irrigation	The irrigation water is sent along/through ditches by gravity. Low installation cost / Low irrigation effectiveness / Low cost for M & O
Furrow	Horticulture farming / Sugar cane farming / by siphon tube from the canal
Border	Grass farm / flat land
Basin	Fruit farm
Spray irrigation	The irrigation water is sprayed as water drops through nozzles by water pressure. Middium installation cost / Middium irrigation effectiveness / O & M cost is needed such as fuel for the pump operation.
Sprinkler	Alternative for nozzles regarding the spraying radius/pressure / Uniformity in water supply
Center pivot	Grass farm / Cereal farming / round and wide farmland
Side roll	Grass farm / wheel
Hand move	Fruit farm / necessity of manpower / Low cost for facilities
Solid set	Fruit farm / automatization of ratational spraying / High cost for facilities
Micro irrigation	The irrigation water is supplied little by little and frequently from through the emitter under low pressure. High installation cost / High irrigation effectiveness / Automatic horticulture farming / Automatic liquid fertilizer application
Micro-spray	Fruit farm / sprayers under fruit trees / Protection against insect / Sensitive adjustment to the climate change
Micro-sprinkler	Soft/weak vegitables / Frost protection
In-line drip trickle	Fruit farm / Direct water supply around the root / Doube tube for pressure reduction / Tunnel-multi plantation
In-line drip emitter	Horticulture farming / Perforated hose / perforated PVC pipe / Underground pipe irrigation

(Source; Soil management technology in dry fields / www.geocities.jp/soil_water_mitchy11)

Based on the comparison on the following table, the hose irrigation method that is the combination of the hand irrigation method and the hose with a cock and a perforated spraying mouth is adopted as a saving irrigation method and a micro-spraying irrigation method.

Table 4-1-2-7 Comparison of On-farm Irrigation Method

<table>
<tr><th>Method</th><th>Irrigation effectiveness</th><th>Installation /facility cost</th><th>Manpower work</th><th>O & M / Past results</th></tr>
<tr><td>Hose irrigation /perforated mouth</td><td>Considerably high</td><td>Low</td><td>High</td><td>No need of adjustment / Hand irrigation by jerry cans</td></tr>
<tr><td>Micro-sprinkler</td><td>Medium</td><td>High</td><td>Low</td><td>Easy / No experiences</td></tr>
<tr><td>Drip irrigation</td><td>High</td><td>High</td><td>Medium</td><td rowspan="2">・Re-installation/rehabilitation per every plantation
・Clogging of the dripping mouth
・ Experienced but difficult to maintain</td></tr>
<tr><td>Drip emitter</td><td>High</td><td>High</td><td>Low</td></tr>
</table>

(b) Secondary／tertiary canal

The pipe line system is applied to the tertiary canal for the convenience sake of hose connection.

The pipe line system is also applied to the secondary canal considering the frequent connection with the tertiary canal and the water saving by preventing the water flow from becoming uncontrollable at the end of the canal.

(c) Main canal

Based on the following comparison, the open channel canal system made of wet masonry is adopted from the view point of easiness in operation and maintenance works and economic advantage.

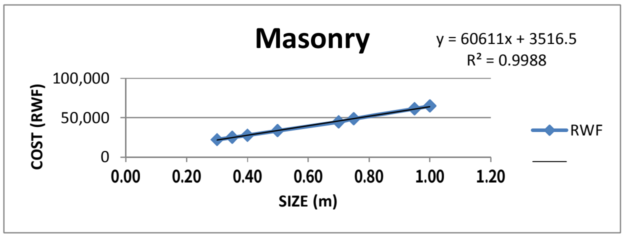
Table 4-1-2-8 Comparison of Main Canal

<table>
<tr><th>Type</th><th>Operation and maintenance</th><th>Economy</th><th>Function</th></tr>
<tr><td>Pipe line</td><td>Daily maintenance is not required; but once the problem such as sedimentation happens to occur, the treatment to such is very difficult.</td><td>Φ500mm
HDPE Pipe；
231 US$/km (4.20)</td><td>No gap in time between the start of sending water and the receiving of sent water.</td></tr>
<tr><td>Open channel / reinforced concrete</td><td>Easy to be maintained. The high velocity of the water flow due to the small coefficient of roughness reduces the event of sedimentation in the channel.</td><td>0.50m wide
open channel;
197 US$/km (3.58)</td><td rowspan="2">It takes long time for the sent water to reach the end of the canal line.</td></tr>
<tr><td>Open channel /wet masonry</td><td>Easy to be maintained. A relatively large coefficient of roughness increases the event of sedimentation, but the maintenance work itself is easy.</td><td>0.50m wide
open channel;
55 US$/km (1.00)</td></tr>
</table>

（Source of unit price; adopted unit price in Nyanza-23）

Masonry

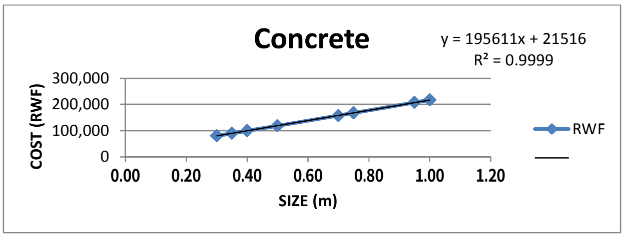
Size(m)	RWF	US$	YEN
1.00	64,700	107	8,555
0.95	61,475	102	8,129
0.75	48,665	80	6,435
0.70	44,770	74	5,920
0.50	33,550	55	4,436
0.40	27,785	46	3,674
0.35	25,010	41	3,307
0.30	22,200	37	2,936



Size(m)	RWF
0.90	58,066
0.85	55,036
0.80	52,005
0.75	48,975
0.60	39,883

Concrete

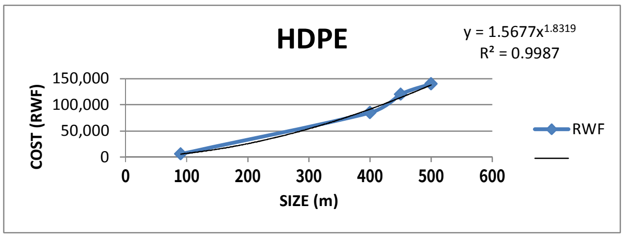
Size(m)	RWF	US$	YEN
1.00	217,700	360	28,787
0.95	207,725	343	27,468
0.75	167,915	278	22,204
0.70	157,270	260	20,796
0.50	119,050	197	15,742
0.40	99,785	165	13,195
0.35	90,260	149	11,935
0.30	80,700	133	10,671



Size(m)	RWF
0.90	197,566
0.85	187,785
0.80	178,005
0.75	168,224
0.60	138,883

HDPE

Size(m)	RWF	US$	YEN
500	140,000	231	18,512
450	120,000	198	15,868
400	85,000	140	11,240
90	6,000	10	793



Size(m)	RWF
100	7,229
125	10,879
200	25,735
250	38,730
300	54,088
600	192,557
700	255,387
800	326,162

Fig. 4-1-2-18 Comparison diagram of the canal type and unit prices depending on sizes

(4) General design of water supply facilities

(a) Dam

ⅰ) Dam axis

The following two cases of dam axis location, the downstream axis and the upstream axis, would come to the surface as candidates in this dam site. Here, the downstream axis is adopted based on the following comparison results, of which advantage is the capability of storing the more water in the reservoir by the less embankment volume.

Table 4-1-2-9 Comparison of the dam axis location

Item	Upstream dam axis	Downstream dam axis
Catchment area	8.68 km^2	8.8 km^2
Reservoir capacity	400,000m^3	600,000m^3
Dam crest elevation	EL.1390m (to do the comparison under the same condition)	
Dam crest length	225m	145m
Embankment volume	37,000m^3	30,000m^3
Dam height	10.0m	11.5m

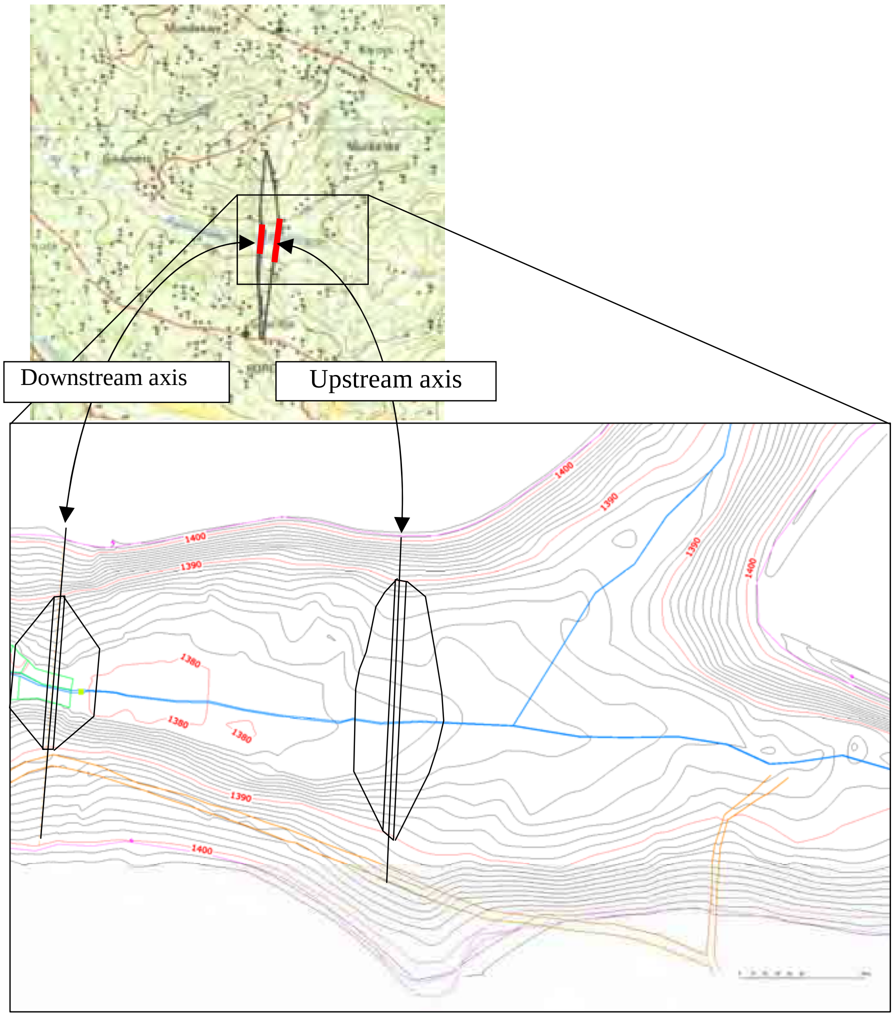


Fig. 4-1-2-19 Location map of dam axises ii) Design flood discharge

The following table shows the result of exceedence probability analysis to the maximum daily precipitation records from 1960 to 1993 in Gahororo weather station.

Table 4-1-2-10 Analysis result of exceedence probability to the maximum daily precipitation

Occurrence period					Probability expectance
T year	ξ	1/a・ξ	averageY +1/a・ξ	x+b	x
2	0.0000	0.0000	1.6747	47.3	51.932
3	0.3045	0.0539	1.7285	53.5	58.175
4	0.4769	0.0844	1.7590	57.4	62.068
5	0.5951	0.1053	1.7799	60.2	64.900
6	0.6858	0.1213	1.7960	62.5	67.167
7	0.7547	0.1335	1.8082	64.3	68.946
10	0.9062	0.1603	1.8350	68.4	73.038
20	1.1630	0.2057	1.8804	75.9	80.578
50	1.4520	0.2568	1.9315	85.4	90.063
100	1.6450	0.2910	1.9656	92.4	97.048

The design flood discharge is estimated based on the maximum flood discharge with 50 year probability expectance considering 50 years of the dam duration period and the downstream site condition with no household. The maximum daily precipitation with 50 years exceedence probability is 90.06mm according to the analysis result. The peak flow rate to this precipitation is estimated by the following equation called "rational formula" and adopted as the design flood discharge.

$Q_A = (1/3.6) \cdot r_e \cdot A$

$r_e = f_p \cdot r$

Q_A ; Peak flood discharge (m^3/sec)

r_e ; Effective rainfall intensity during the period of flood concentration (mm/h)

A ; Catchment area (km^2), A=8.8 km^2

f_p ; Peak runoff coefficient

r ; Probability rainfall intensity (mm/h)

The period of flood concentration is estimated to be 2.5 hours on the safe side based on the record of rainfall/river flow rate observation at the dam site.

It is assumed that this rainfall 90.06mm is concentrated in 2.5 hours and fp (Peak runoff coefficient) is 2.5% considering the observed and estimated value 1.39% of the runoff ratio of the direct runoff to the daily rainfall on 24th of April.

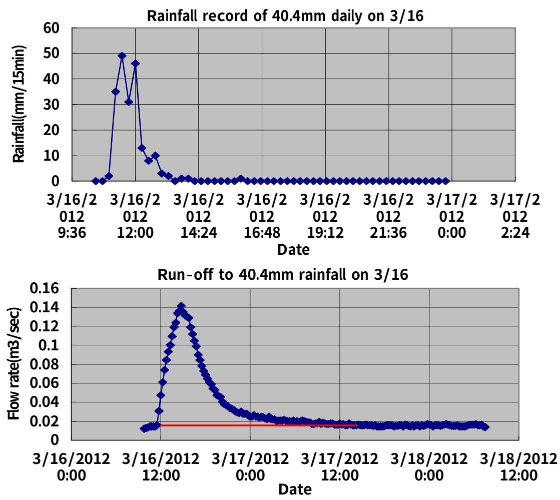


Fig. 4-1-2-20 Rainfall and Runoff on Mar. 16, '12

Then: $r = 90.06/2.5 = 36.0$ mm/h

$re = 0.025 \times 36$ mm/h $= 0.9$ mm/h

$Q_A = (1/3.6) \cdot r_e \cdot A = (1/3.6) \times 0.9 \times 8.8 = 2.2\ m^3/sec$

2.2m^3/sec is adopted as the design flood discharge.

This quantity of flow rate corresponds to about 7 times of $0.3m^3$/sec which is observed at the dam site and caused by 57.8mm of the maximum daily rainfall during this survey period. The daily rainfall 57.8mm corresponds to 1/3 probability expectance value 58.175mm and 0.6 (=57.8/97.048) times of 1/100 probability expectance value 97.048mm.

Now let us confirm the river flow condition on 24th of April when the maximum daily rainfall was recorded. According to the river flow gauge record on this day, $0.3m^3$/sec of river flow rate was flowing down over the observation weir 1.3m long at the depth of about 25cm. At the dam site, the river bed width is about 30m; and the paddy fields cover the whole river bed. In case of the flood with $2.2m^3$/sec scale flowing into the dam site, the flood water would be spread over the paddy fields but would not rush down in a rapid flow condition as the paddy fields function as a retarding basin.

ii) F.W.L. (Full Water Level) and H.W.L. (Flood Water Level)

(a) Full water level

The full water level of the reservoir is defined as follows.

F.W.L.=Water head for sending water to the discharge chamber

+ Water depth equivalent to 450,000m3 of the reservoir operating capacity

According to the study result in section 4-1-2 (2), each water level corresponding to Case-5

(Dam with 6.5m of lifted up canal), the adopted case, becomes as follows.

Dead water level: EL.1386.5m / Full water level: EL.1390.6m

(b) Spillway overflow depth

Considering the relationship between the weir height and the improvement ratio of the coefficient of discharge, the overflow depth is designed to be as same as the weir height, i.e. P/Hd=1.0 (P: weir height, Hd: overflow depth). The front wall of the weir is designed to be perpendicular for the convenience sake of construction. Then the coefficient of discharge is 2.14 corresponding to P/Hd=1.0.

The relationship between the overflow depth and the weir length under the design flood discharge: 2.2 m^3/sec can be obtained by applying the discharge quantity formula of overflow weir: $Q=C \cdot L \cdot H^{3/2}$.

Table 4-1-2-11 Spillway overflow depth

Q: design floo discharge (m3/sec)	C: coefficient of discharge	L: weir length (m)	H: overflow depth (m)
2.2	2.14	3.0	0.490
2.2	2.14	4.0	0.404
2.2	2.14	5.0	0.348
2.2	2.14	6.0	0.308

Based on the calculation above, the dimension of the weir is designed to be 5m of the weir length, 0.35m of the weir height and 0.35m of the overflow depth. And H.W.L. becomes EL.1390.95m (=EL.1390.6m+0.35m).

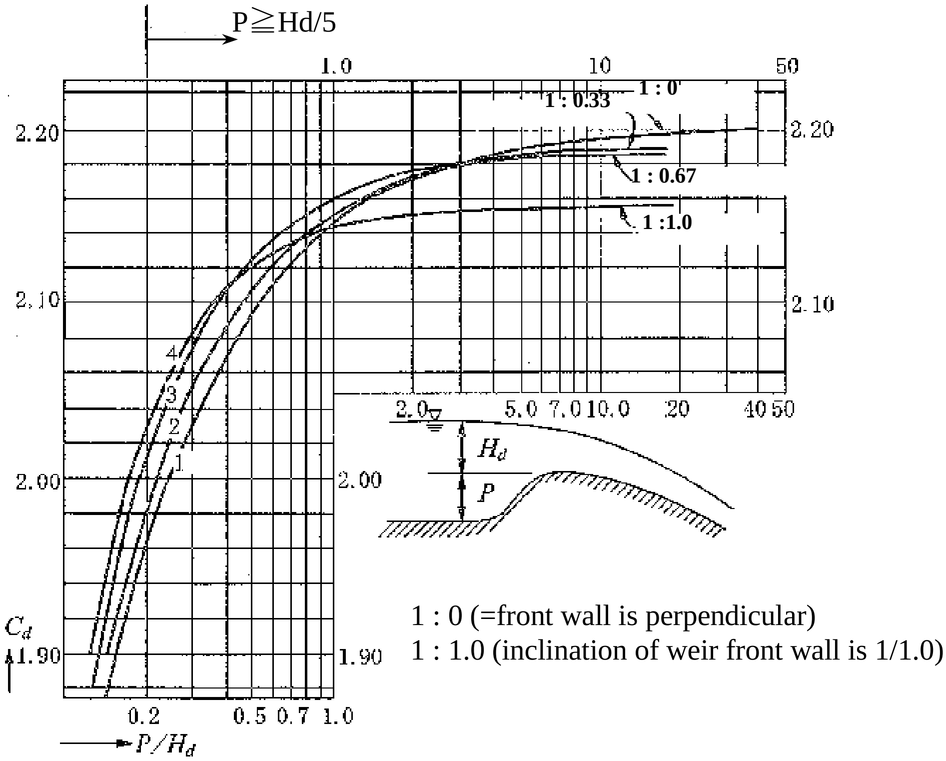


Fig.4-1-2-21 Spillway overflow depth

iii) Dam type and the additional height of the dam body

The homogeneous type is adopted based on the following reasons.

- The dam height is lower than 15m and the dam is classified into small dams.
- In case of small dams, the homogeneous type is preferable for the convenience sake of construction.
- The wide bottom of the impervious embankment given by the homogeneous dam body is effective to reduce the seepage quantity through the foundation.

In the homogeneous dam's case, specifications of the dam body are defined as follows.

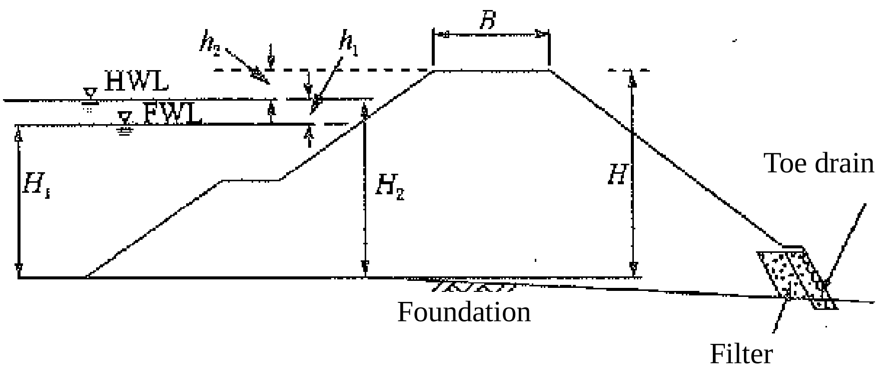


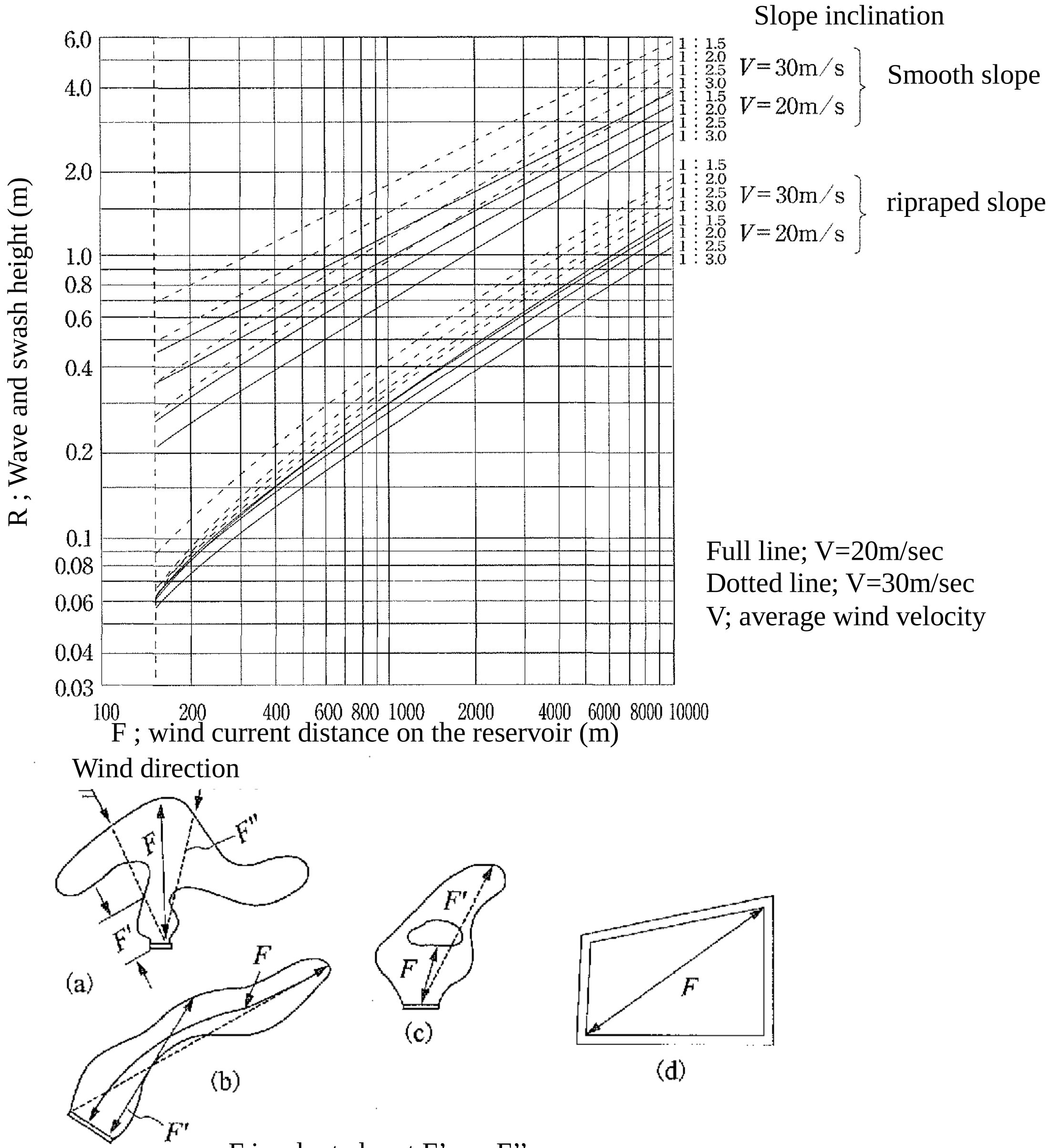
Fig. 4-1-2-22 Specifications of Dam Body

H; dam height
B; dam crest width
HWL; high water level (the maximum water level at the time of the design flood overflowing the spillway weir)
FWL; full water level (the maximum water level at the time of daily storage behavior)
H_1; water depth at the time of FWL
H_2; water depth at the time of HWL
h_1; overflow depth at the time of the design flood overflowing the spillway weir
h_2; margin/additional height of the reservoir crest to HWL
h_2 is given as follows.

In case of R≦1.0m・・・・・・・h_2=0.05 H_2+1.0
or h_2=1.0 (only to the case of H being lower than 5m, by judging the damage level at the time of failure)

In case of R＞1.0m・・・・・・・h_2=0.05 H_2+R

Here, R is the wave height that includes the height of wave swash on the slope, and estimated by the following diagram usually.



F is adopted, not F' nor F''

Fig. 4-1-2-23 Wind wave height

But Rwanda is situated in the equatorial calm zone so that the average wind velocity does not exceed 10m/sec as shown below as the observation record in Kigali. Therefore R is considered to be less than 1.0m and the additional height is estimated to be 1.1m as follow.

$$h_2 = 0.05 \cdot H_2 + 1.0$$
$$= 0.005 \times \{EL.1390.95mm^{H.W.L.} - (EL.1380m^{Foundation} - 1.5m^{Excavation})\} + 1.0m$$
$$= 1.06m \quad 1.1m$$

Frequency of wind velocity and direction in Kigali(%) (Data number: 8,056)

	DIRECTION								
SPEED (m/s)	NE	E	SE	S	SW	W	NW	N	TOT-V
1-2	5.6	5.2	4.8	9.2	2.2	2.7	4.9	6.9	41.6
3-5	4.3	4.3	2.8	4.6	.7	.5	1.1	4.0	22.2
6-7	.3	.4	.1	.1	.0	.1	.1	.3	1.3
8-10	.1	.0	.0	.0	.0	.0	.0	.0	.2
> 10	.0	.0	.0	.0	.0	.0	.0	.0	.0

ⅳ) Sediment

Something like sediment was scarcely found on the bottom of the Ngoma-22 river when carrying out the river flow rate observation at the dam site bridge point, the river confluence point and the downstream check gate point. The color of river water becomes light yellow to grayish due to silt particles but does become murky or muddy. Almost all the ground surfaces are covered with vegetation; sometimes naked ground surface appears, but such surface is composed of lateritic soil layer with gravels which is tough against erosive actions of rain water.

Considering such circumstances, the least quantity of sediment among the ones calculated by three or four kinds of method shall be adopted to the design.

Sediment: $Qsd = D \cdot A \cdot Y$

Here, D ; sediment yield (specific sediment rate, specific degradation) in m^3/km^2 per year

A ; catchment area : A=8.8 km2

Y ; durable years of the reservoir : 50 years is applied generally in Rwanda.

Sediment yield D is estimated as follows by three kinds of method.

Gresillons (France) ; $D = 700(P/500)^{-0.22} \cdot A^{-0.1}$ P: annual rainfall

$= 700 \cdot (1000/500)^{-0.22} \cdot 8.8^{-0.1}$

$= 122.6\ m^3/km^2/year$

Gottshalk (USA) ; $D = 260 \cdot A^{-0.1}$

$= 260 \times 8.8^{-0.1}$

$= 209.2\ m^3/km^2/year$

Puech (West Africa); $50 < D < 200\ m^3/km^2/year$

$D = 70\ m^3/km^2/year$

Based on these sediment yield values, sediment volumes are estimated as follows.

Equation/Method	Evaluated value	Adopted value
Gresillons	54,000 m^3	30,000 m^3
Gottshalk	92,000 m^3	
Puech	30,000 m^3	

30,000 m^3 is adopted as the design sediment.

Now this quantity of 30,000 m^3 is very small compared with the dead reservoir capacity of 250,000m3 and is the cumulative quantity through 50 years so that this quantity does not effect the reservoir operation at all. Therefore this quantity of sediment is treated as a part of the dead reservoir capacity.

ⅳ) Dam crest elevation and the dam height

The dam crest elevation and the dam height is as follows based on the study results above.

- Dam crest elevation = EL. 1390.95mm$^{\mathrm{H.W.L}}$+1.1m = EL.1392.05m
- Dam eight = EL.1392.05m－(EL.1380m$^{\mathrm{foundation}}$－1.5m$^{\mathrm{Excavation}}$) = 13.55m

ⅴ) Foundation treatment against seepage

The foundation of the dam body is composed of the pervious to semi-pervious soil layer and the semi-pervious highly weathered clay stone layer. The foundation treatment work is necessary for the leakage through foundation layers to be reduced. As the general foundation treatment method, there are two kinds; one is the grouting method and the other is the blanket method. The former is the method to reduce the leakage quantity by choking cracks in a rock formation by cement milk, and the latter is to reduce the leakage quantity by making the seepage length long and the hydraulic gradient small. Fundamentally the former method is effective only to the rock foundation with cracks and not effective to the foundation of soil layers or highly weathered rock layers because the particle size of cement is larger than the diameter of voids in soil layers and the cement particle can not choke these voids. In this meaning, the foundation treatment method applicable to this dam is the grouting method only; there is no other method applicable except for some special one.

Design of the horizontal blanket
[Basic equations]
The length and the thickness of the horizontal blanket is decided by the following equations

$$q_f = \frac{k \cdot h \cdot d}{x_r + x_d} \qquad x_r = \frac{e^{2ax} - 1}{a\,(e^{2ax} + 1)} \qquad a = \sqrt{\frac{k_1}{t \cdot k \cdot d}}$$

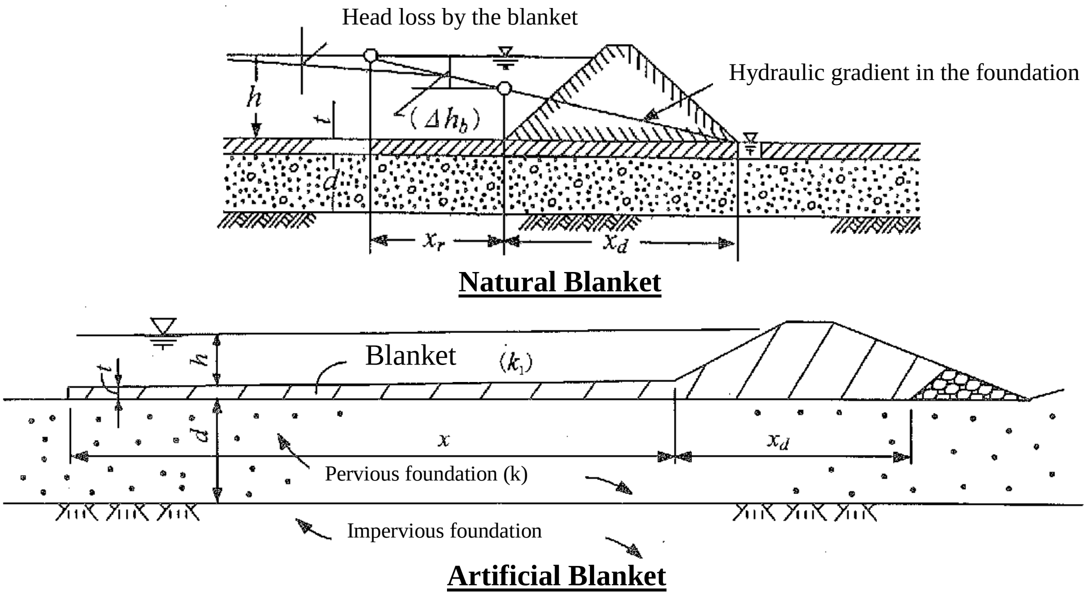


Fig. 4-1-2-23 Specifications of blanket method

Here, q_f; seepage quantity through the foundation layer (m^3/sec)
h; differential between the reservoir water level and the downstream water level (m)
x_r; effective seepage length (m)
x_d; bottom length of the dam body (m)
x; required length of the blanket (m)
k; permeability coefficient of the foundation layer (m/sec)
k_1; permeability coefficient of the blanket and the dam body (m/sec)
t; thickness of the blanket (m)
d; thickness of the foundation layer (m)

[Analysis model of the foundation]

According to the results of the field permeability tests, the permeability coefficient of the foundation layers is estimated as follows.

Soil layer; $k=6.0\times10^{-3}$cm/sec

Highly weathered clay stone layer; $k=1.0\times10^{-4}$cm/sec

The differential of the permeability coefficient between these two layers is 60 times. The soil layer's one is 60 times larger than the latter's one; and the latter layer, highly weathered clay stone layer, is assumed to be an impervious layer relatively to the upper soil layer. Therefore, the horizontal blanket is to be designed as the structure placed on the pervious soil layer with the average permeability coefficient $k=6.0\times10^{-3}$cm/sec.

The thickness of the soil layer is estimated to be 6m considering the thickness 7.5m grasped by the borehole drilled at the river bed, and the planned excavation depth to the dam foundation.

Table 4-1-2-12 Summary of Results of Field Permeability Test

Pit	Hole No.	Permeability coefficient	test depth	ground condition	mean value
TP-1	N0.1	3.6×10^{-3}cm/sec	1.7m	earth	6.0×10^{-3}cm/sec
	No.2	3.3×10^{-2}cm/sec	1.7m	earth	
	No.3	2.3×10^{-4}cm/sec	3.4m	earth	
	No.4	3.2×10^{-3}cm/sec	3.4m	earth	
	No.5	8.5×10^{-4}cm/sec	5.1m	earth	
	No.6	1.0×10^{-3}cm/sec	5.1m	earth	
TP-2	No.1	2.2×10^{-3}cm/sec	1.0m	earth	
	No.2	4.3×10^{-3}cm/sec	1.0m	earth	
TP-3	N0.1	1.2×10^{-2}cm/sec	1.7m	earth	
	No.2	1.0×10^{-2}cm/sec	1.7m	earth	
	No.3	1.4×10^{-3}cm/sec	3.4m	earth～highly weathered	
	No.4	1.3×10^{-3}cm/sec	3.4m		
	No.5	1.1×10^{-4}cm/sec	4.2m	highly weathered	1.0×10^{-4}cm/sec
	No.6	1.0×10^{-4}cm/sec	4.2m	highly weathered	

BH-1 (Left Abutment)				BH-2 (River Bed)				BH-3 (Right Abutment)			
Depth (m)	Remarks	permeability rate	SPT test	Depth (m)	Remarks	permeability rate	SPT test	Depth (m)	Remarks	permeability rate	SPT test
1.0				1.0				1.0			
2.0	Reddish brown sandy clay with small gravels			2.0			12	2.0			17
3.0		1.5 Lu		3.0		3.2 Lu		3.0	Yellowish brown sandy clay with small gravels		
4.0				4.0	Yellowish brown sandy clay with small gravels		20	4.0			58
5.0				5.0			15	5.0			
6.0				6.0			38	6.0			
7.0	Highly weathered clay stone		N>50	7.0				7.0			
8.0		1.0 Lu		8.0		1.0 Lu		8.0	Highly weathered caly stone		
9.0				9.0				9.0			
10.0				10.0				10.0			
11.0				11.0							
				12.0	Highly weathered clay stone		N>50				
				13.0		Lu<1.0					
				14.0							
				15.0							

[Length of the horizontal blanket : x]

To the cases of the blanket thickness: 1.0m, 1.5m, 2.0m, 2.5m, the seepage quantity q_f is calculated to the given value of x by the former basic equations. The calculated result is shown in the following table and summarized as the graph below.

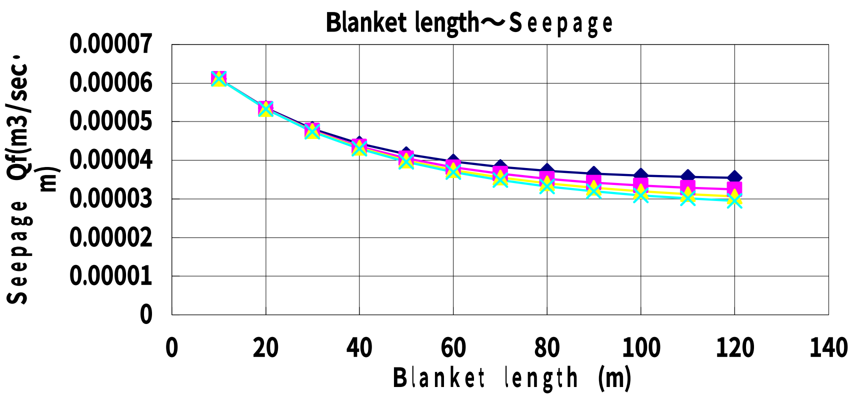


Fig. 4-1-2-24 Blanket length - Seepage

Here, the allowable leakage quantity is assumed to be 0.05% of the total reservoir capacity per day. Then the allowable quantity becomes as follows.

$$700{,}000\text{m}^3 \times 0.05/100 = 350\text{m}^3/\text{day}$$

Considering this allowable leakage quantity, 2m of the blanket thickness and 50m of the blanket length is adopted.

The leakage quantity per meter to these dimensions is $3.51\times10^{-5}\text{m}^3/\text{sec}$ as shown in the table and becomes 3.0m^3 by day.

$$qf = 3.51\times10^{-5}\text{m}^3/\text{sec} = 3.51\times10^{-5}\ \text{m}^3/\text{sec}\times 86400\text{sec/day} = 3.0\text{m}^3/\text{day}$$

When counting the leakage quantity all through the longitudinal dam crest length, the total leakage quantity per day is estimated to be 316.5m3/day which is less than the allowable one.

$$Q = 3.0\text{m}^3/(\text{day}\cdot\text{m})\times 29\text{m}+(1/2)\times(182\text{m}-29\text{m})\times 3.0\text{m}^3/(\text{day}\cdot\text{m}) = 316.5\text{m}^3/\text{day}$$

Table 4-1-2-13 Leakage quantity ~ Blanket thickness & length

t(m)	k (m/sec)	d (m)	k1(m/sec)	a	x(m)	e2ax	xr(m)	qf(m3/sec)
1	0.00006	6	0.0000001	0.016667	10	1.395612	9.908425	6.11758E-05
1	0.00006	6	0.0000001	0.016667	20	1.947734	19.29076	5.35524E-05
1	0.00006	6	0.0000001	0.016667	30	2.718282	27.72703	4.81565E-05
1	0.00006	6	0.0000001	0.016667	40	3.793668	34.96698	4.43238E-05
1	0.00006	6	0.0000001	0.016667	50	5.29449	40.93571	4.15946E-05
1	0.00006	6	0.0000001	0.016667	60	7.389056	45.69565	3.96477E-05
1	0.00006	6	0.0000001	0.016667	70	10.31226	49.39204	3.82572E-05
1	0.00006	6	0.0000001	0.016667	80	14.39192	52.20370	3.72631E-05
1	0.00006	6	0.0000001	0.016667	90	20.08554	54.30890	3.65519E-05
1	0.00006	6	0.0000001	0.016667	100	28.03162	55.86658	3.60429E-05
1	0.00006	6	0.0000001	0.016667	110	39.12128	57.00907	3.56786E-05
1	0.00006	6	0.0000001	0.016667	120	54.59815	57.84165	3.54176E-05
1.5	0.00006	6	0.0000001	0.013608	10	1.312804	9.938725	6.11477E-05
1.5	0.00006	6	0.0000001	0.013608	20	1.723455	19.52038	5.33896E-05
1.5	0.00006	6	0.0000001	0.013608	30	2.262559	28.43742	4.77513E-05
1.5	0.00006	6	0.0000001	0.013608	40	2.970297	36.46747	4.36045E-05
1.5	0.00006	6	0.0000001	0.013608	50	3.899419	43.48739	4.05278E-05
1.5	0.00006	6	0.0000001	0.013608	60	5.119174	49.46685	3.823E-05
1.5	0.00006	6	0.0000001	0.013608	70	6.720474	54.44838	3.65057E-05
1.5	0.00006	6	0.0000001	0.013608	80	8.822667	58.52242	3.52071E-05
1.5	0.00006	6	0.0000001	0.013608	90	11.58244	61.80417	3.42263E-05
1.5	0.00006	6	0.0000001	0.013608	100	15.20547	64.41557	3.3484E-05
1.5	0.00006	6	0.0000001	0.013608	110	19.96181	66.4734	3.29214E-05
1.5	0.00006	6	0.0000001	0.013608	120	26.20595	68.08259	3.24945E-05
2.0	0.00006	6	0.0000001	0.011785	10	1.265797	9.953959	6.11336E-05
2.0	0.00006	6	0.0000001	0.011785	20	1.602243	19.63768	5.33068E-05
2.0	0.00006	6	0.0000001	0.011785	30	2.028115	28.80949	4.75418E-05
2.0	0.00006	6	0.0000001	0.011785	40	2.567183	37.27868	4.32253E-05
2.0	0.00006	6	0.0000001	0.011785	50	3.249533	44.91769	3.99534E-05
2.0	0.00006	6	0.0000001	0.011785	60	4.11325	51.66343	3.745E-05
2.0	0.00006	6	0.0000001	0.011785	70	5.206542	57.50979	3.55212E-05
2.0	0.00006	6	0.0000001	0.011785	80	6.590427	62.49496	3.40268E-05
2.0	0.00006	6	0.0000001	0.011785	90	8.342145	66.68722	3.28641E-05
2.0	0.00006	6	0.0000001	0.011785	100	10.55946	70.17172	3.19564E-05
2.0	0.00006	6	0.0000001	0.011785	110	13.36614	73.03993	3.12461E-05
2.0	0.00006	6	0.0000001	0.011785	120	16.91883	75.38201	3.06891E-05
2.5	0.00006	6	0.0000001	0.010541	10	1.234688	9.963127	6.11251E-05
2.5	0.00006	6	0.0000001	0.010541	20	1.524455	19.70888	5.32566E-05
2.5	0.00006	6	0.0000001	0.010541	30	1.882227	29.03844	4.74138E-05
2.5	0.00006	6	0.0000001	0.010541	40	2.323963	37.78688	4.29911E-05
2.5	0.00006	6	0.0000001	0.010541	50	2.86937	45.83279	3.95943E-05
2.5	0.00006	6	0.0000001	0.010541	60	3.542778	53.10167	3.69564E-05
2.5	0.00006	6	0.0000001	0.010541	70	4.374226	59.5634	3.48899E-05
2.5	0.00006	6	0.0000001	0.010541	80	5.400805	65.22571	3.32603E-05
2.5	0.00006	6	0.0000001	0.010541	90	6.668311	70.12538	3.19682E-05
2.5	0.00006	6	0.0000001	0.010541	100	8.233285	74.31913	3.09394E-05
2.5	0.00006	6	0.0000001	0.010541	110	10.16554	77.87527	3.01176E-05
2.5	0.00006	6	0.0000001	0.010541	120	12.55127	80.86694	2.94593E-05

vi) Typical cross-section of the dam and the slop blanket

The width of the dam crest is provided with 6m on the safe side considering the additional dam height being not so high and the water surface coming up near the dam crest.

The upstream slope and the downstream slope is provide with the inclination of 1 : 3.0 and 1 : 2.5 respectively considering the stability of the dam body and the bottom width of the embankment being effective to reduce the seepage quantity.

The coffer dam is provided on the upstream river bed 50m away from the upstream slope toe of the dam body. The height of the coffer dam is 2m and the bottom is penetrated into the foundation by 3m which is expected to cut the ground water flow and give the dry work condition to the construction of horizontal blanket behind.

The berm is provided at EL.1386.0m on the upstream slope of the dam body. The upper slope to the berm, where the water level comes up and down, is protected by the riprap work.

The vertical drain is provided in the dam body, downstream side, to intercept the seepage flow and prevent the downstream toe from being saturated.

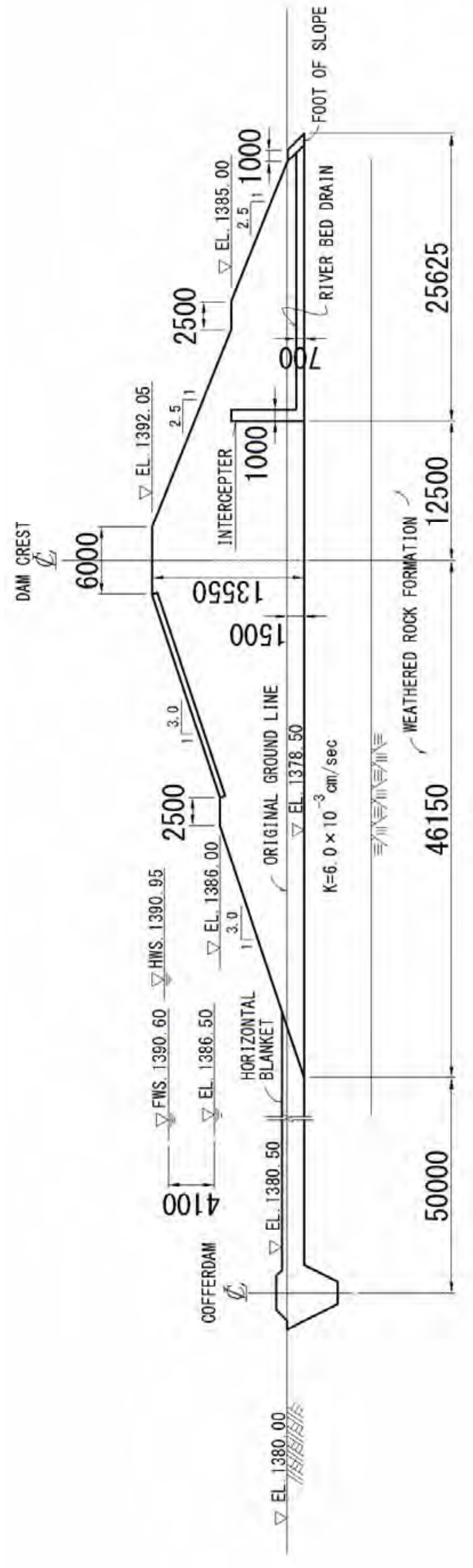
The river bed drain is provided widely on the downstream foundation to prevent the seepage flow from seeping out concentrated.

The berm is provided at EL.1385.0m on the downstream slope of the dam body for the convenience sake of maintenance. The downstream slope is protected by the planting works.

The dam crest is protected by soil cement to avoid the rain erosion and the ant invasion.

The slope blanket is provided with the same structural formation as the dam body from the view point of the stability of the embankment slope and the protection against erosion.

The crest and the excavated slope on which the embankment is loaded is provided with 4m in width and the inclination of 1 : 2.5 respectively intending to shape the embankment thickness to be about 50% of the water depth on the given point of the upstream slope for the stability sake against the force that is brought from the ground water behind and pushes the embankment from behind.



Typical cross-section of slop blanket

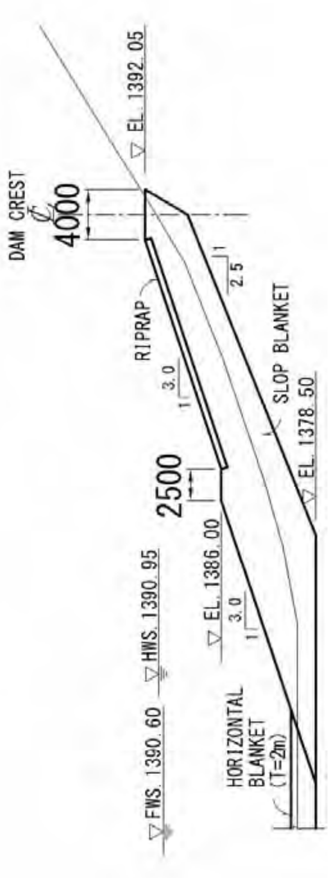


Fig. 4-1-2-25 Typical cross-section of Dam

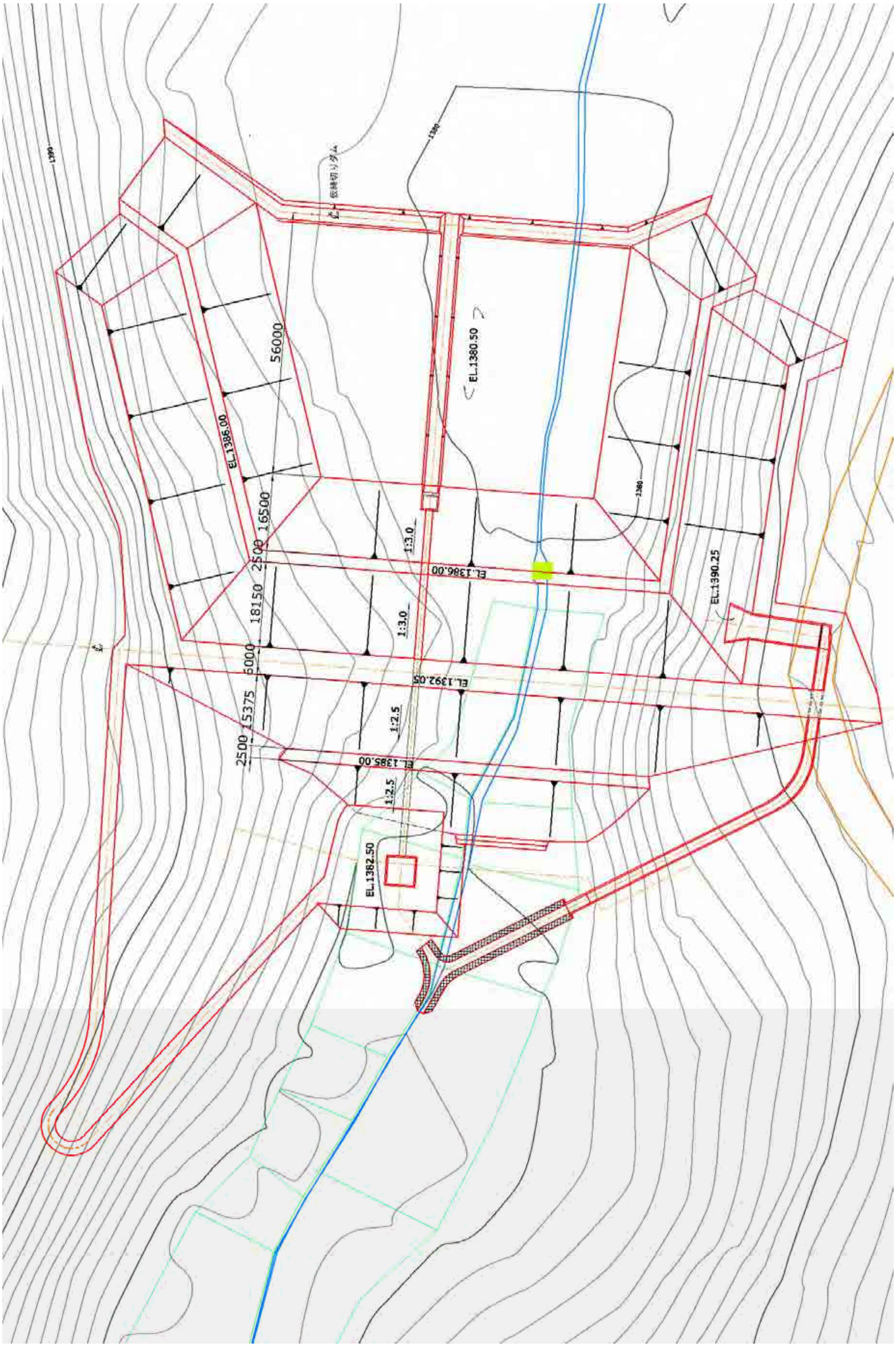


Fig. 4-1-2-26 General Plan of the Dam

(b) Spillway

ⅰ) Installation location

The spillway is composed of the approach and weir section, the transition section, the chute section, and the stilling basin section. The following table shows the comparison result of the installation location on which abutment the spillway should be placed. The conclusion is the left abutment is suitable.

Table 4-1-2-14 Location of Spillway

Abutment / Locasion	Upstream side slope	Downstream side slope
Left	Gentle slope. The amount of soil excavated from the construction of the approach and weir section and the transition section becomes small.the area of the cut slope becomes small.	Gentle slope. The amount of soil excavated from the construction of the chute section becomes small.the area of the cut slope becomes small.
Right	Steep slope. The amount of soil excavated from the construction of the approach and weir section and the transition section becomes large. The area of the cut slope becomes large.	Steep slope. The amount of soil excavated from the construction of the chute section becomes large. The area of the cut slope becomes large.

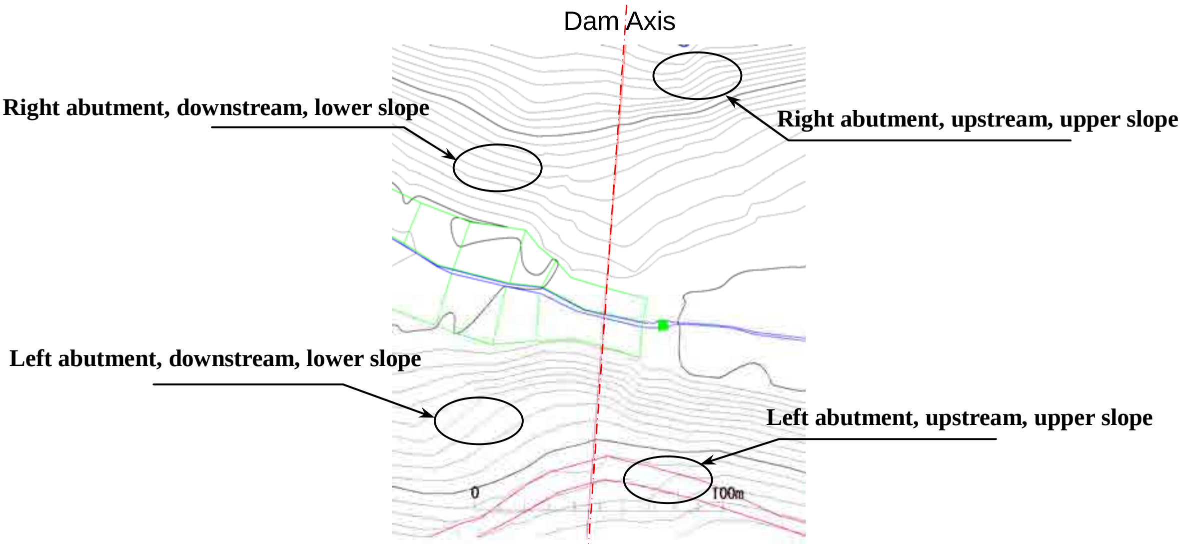


Fig. 4-1-2-27 Location of Spillway

ⅱ) Spillway type

The slope blanket is placed on the abutment upstream slope so that the approach section is located on the slope blanket. In this case, it is rational for the discharge water to be led to the orthogonal direction for the sake of structure's simplicity. And the discharge water must be led finally into the downstream river, so that this discharge flow must be turned toward the downstream direction; and the side weir type spillway is suitable because this type can turn the flow-in direction at a right angle.

Table 4-1-2-15 Type of Spillway

Spillway type	Flow condition		Capacity to floods, etc.	
	Adjustment section	Transition section	Discharge capacity to floods	Foundation of the structure
Channel flow-in type	From the front	Unsteady flow condition	Very small	Ground or embankment
Front weir type	From the front over the weir	Flow down in the channel in the critical flow condition	Small to medium	Ground or embankment
Side weir type	From the side over the weir		Medium to large	Ground

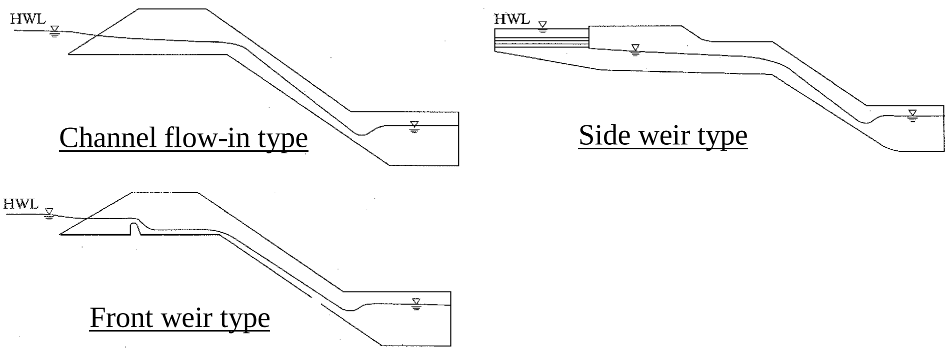


Fig. 4-1-2-28 Type of Spillway

iii) Storage effect

The characteristics of the floods in the Ngoma-22 river are as follows according to the observation result of the rainfall gauge station and the river flow rate gauge station.

① very small runoff ratio of the floods as the direct runoff
② short period of flood concentration
③ large increasing ratio of floods to their peak

Regarding ②, ③, followings would be their causes.

- Short distance between the dam site and the perimeter of the catchment area
- Fan-shaped eroded valleys that formulate the catchment area
- Water gathering system of the fan-shaped eroded valley where rain water falling on the slope gathers together at its bottom and flows out all at once toward downstream

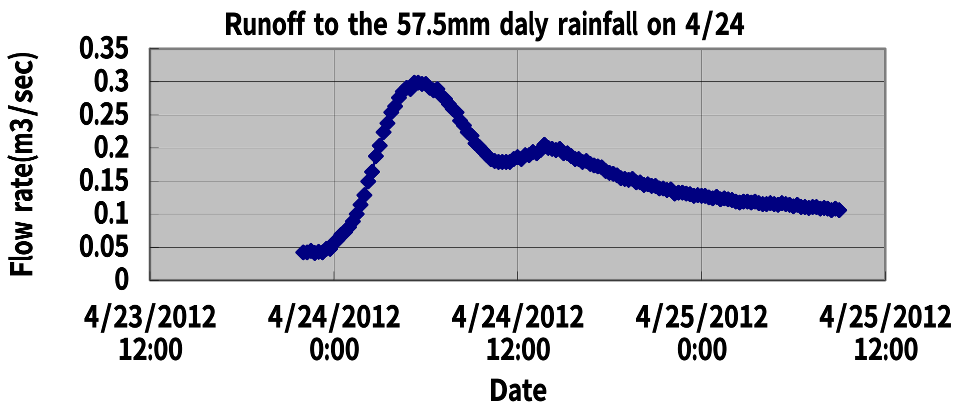


Fig. 4-1-2-29 Runoff to the daily rainfall on Apr. 24, ‘12

Therefore, reducing of reservoir surface rising by floods through the storage effect, where the floods flow into the reservoir gradually and the reservoir surface rises up gradually together with the floods being discharged over the spillway weir, is not considered; but it is considered that the peak flood rate reaches the spillway all at once.

*Japanese standard (Design Guideline of Small Reservoirs) allows to consider the storage effect only to the case that the ratio of the reservoir surface area to the catchment area is more than 1/40 (=0.025). In this reservoir's case, this ratio is less than 0.025 as follows.

$$(1.50\times10^5)/(8.8\times10^6)=0.017\ (<0.025)$$

ⅳ) Design flood discharge, weir length/height and overflow depth

According to the result in the previous section (4), (a), these are as follows.

・Design flood discharge; $2.2m^3$/sec
・Weir length; 5.0m
・Weir height; 0.35m
・Overflow depth; 0.35m

ⅴ) Alignment and longitudinal setting

The alignment of the spillway route is planned as follows considering the following the aspects.

- Location of the transition section to the dam body and the slope blanket
- Orthogonality between the approach channel section and the slope direction of the blanket
- Orthogonality between the route of chute section and the contour line of the downstream abutment slope
- Smooth connection between the downstream river and the discharge section
- Insert of the curve section between the chute section and the transition section, not on the chute section to avoid the rise of the water surface due to the eccentric flow

Fig. 4-1-2-30 General Plan of Spillway

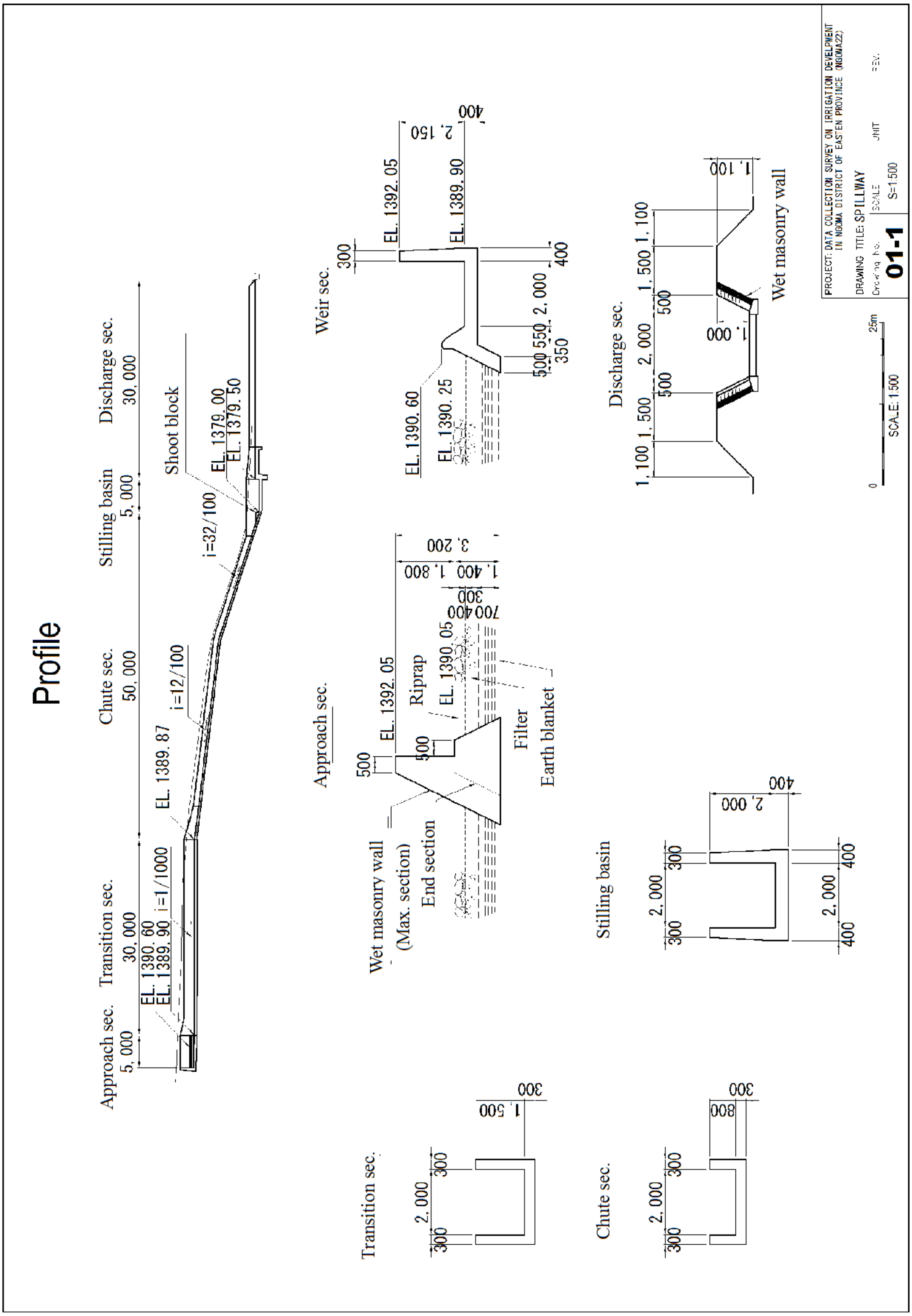


Fig. 4-1-2-31 General Profile of Spillway

(5) General plan of supplemental water resource

(a) Fundamental policy and plan

Followings are the fundamental policies and plans based on the assumption that the quantity fluctuation of the ground water is little.

- Cut off the valley by “a water-stop work” at the downstream to the spring, the small stream, the swamp, etc. that is found in the field survey.
- Carry out the field permeability test and confirm the existence of the pervious first layer and semi-pervious second layer at the bottom of the valley. (The highly weathered clay stone layer that is the second layer in the foundation at the dam site is confirmed to be semi-pervious and recognizable to be impervious relatively to the first layer through the field permeability tests.)
- Excavate the pervious layer and make a trench on the foundation.
- Fill back the trench with the excavated materials through compaction works after adjusting the moisture content of the materials at the optimum moisture condition.
- Penetrate the bottom of the backfill by one or two meter into the semi-pervious second layer.
- This backfill shall stop the ground water flow through the first pervious layer and lift up the ground water level and let the ground water appear on the ground surface.
- A weir shall be constructed to catch the ground water lifted up and the stream flow.
- The weir shall be made of soil cement with a wide bottom considering an economical advantage, the placement on the compacted soil, and the decentration of load.
- The surface of the weir shall be covered by wet masonry works and protected from erosion.
- A water-way shall be provided at the center of the weir to discharge the stream water at the floods.
- A sediment basin shall be provided to prevent this pond from being buried by sediment.

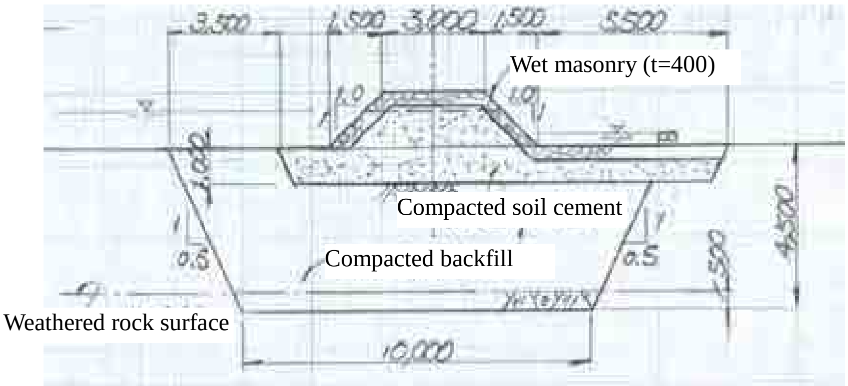


Fig. 4-1-2-32 Typical cross-section of water-stop work

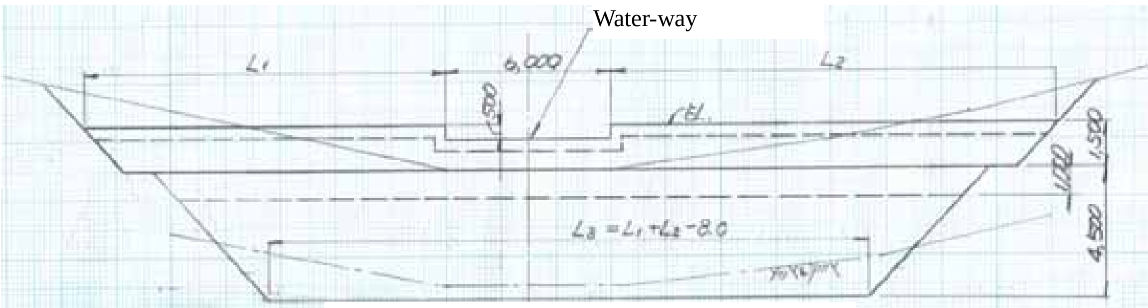


Fig. 4-1-2-33 Longitudinal profile

(b) Water-stop work at each valley

In terms of the Dry Valley and the valley of Downstream of Right Bank, the water-stop work shall function also as a regulation pond of the irrigation canal because these valleys are the most suitable spots for providing a regulation pond in the canal alignment plan and the suitable location for water-stop work overlaps with the canal alignment.

The pond shall be designed as an excavated-type pond with a maximum excavation depth of 3m to get the reservoir capacity. As for the valley of Downstream of Confluence, the pond has no relationship with the canal plan so that the pond shall be designed as an excavated-type pond with a maximum excavation depth of 1m or so.

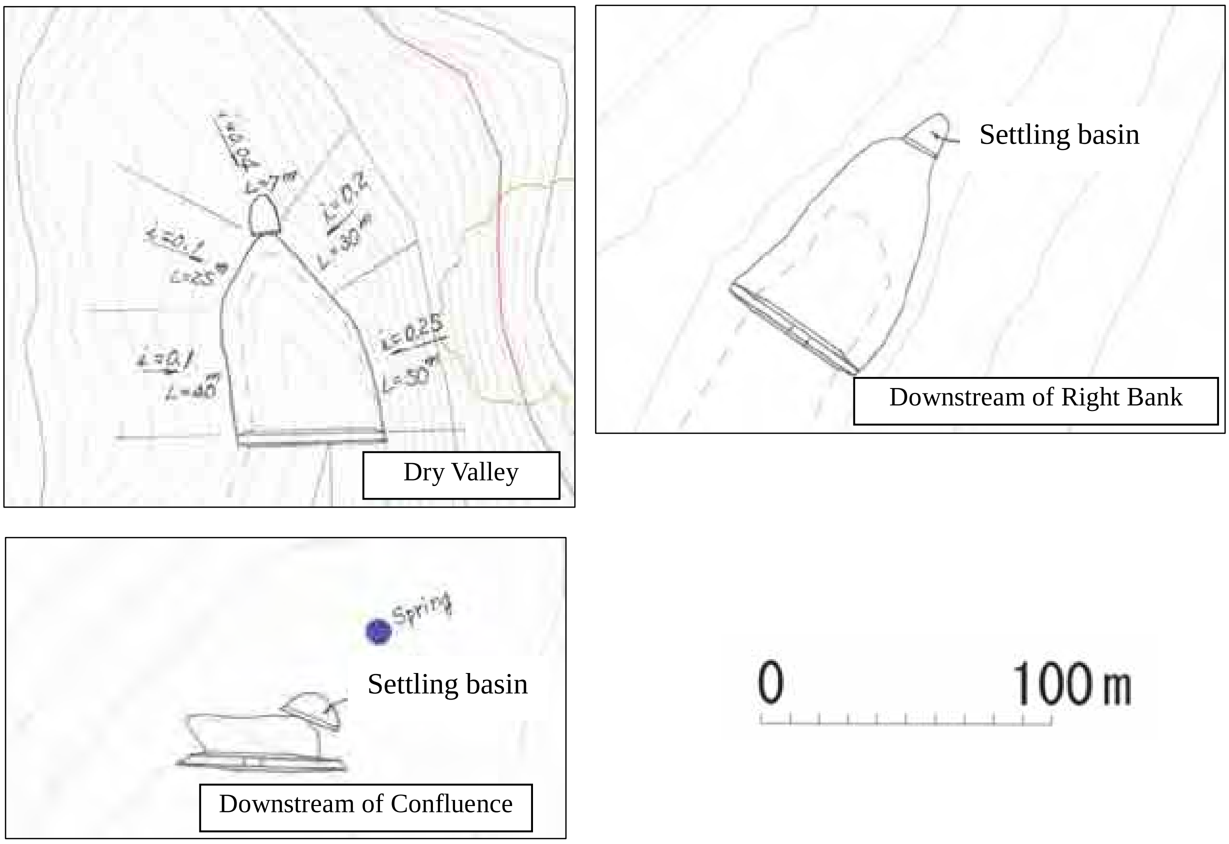


Fig. 4-1-2-34 Plan of water-stop work

Table 4-1-2-16 Specifications of water-stop work

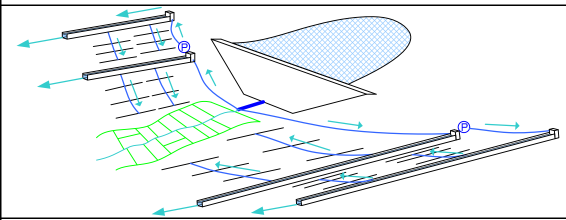
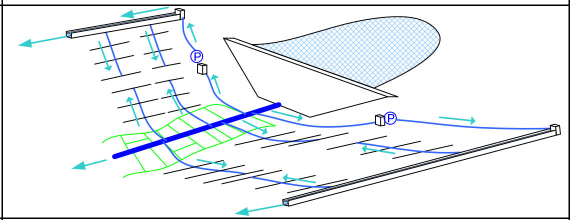
Location	Crest EL.	Crest Length	L1	L2	L3	Pond Capacity
Dry Valley	EL.1397.0	35.5m	13.2m	16.3m	21.5m	1,300m^3
Downstream of Right bank	EL.1378.0	51.0m	24.0m	21.0m	37.0m	3,000m^3
Downstream of Confluence	EL.1370.5	53.0m	19.0m	28.0m	39.0m	470m^3

(6) General design of intake facilities

ⅰ) Design of intake facilities

The type of the intake facility is considered the next table.

Table 4-1-2-17 The type of intake facilities

	Plan A	Plan B
Image		
Explanation	Link up the main canal to the bottom outlet, irrigated the slope of the farmland by gravity from main canal and the pump irrigate upper slope.	Install the main pipe along the river from the bottom outlet, to supply water to the left and right farmland by the pipeline.

However, the second plan is half length of the main canal than the plan A, but construction of the main canal extension compared to the plan A, a longer extension of the pipeline. The cost of the pipeline is over four (4) times bigger than the open canal, and it is economically disadvantaged. In addition, In order to laying the pipeline along the river, it is necessary to set up a temporary road and road management, 1) reduction of a paddy field area, 2) construction costs pay anywhere from a measure to deal with the soft ground, and then we choose the first plan.

(a) Bottom outlet

Bottom outlet has been adopted interoperability and ease of operation and adjustment of flow rate, even Nyanza-23, Link up the main canal to the bottom outlet, irrigate the slop of the farmland by gravity from main canal and make the irrigation pump set up a water pump upper slope on the main canal.

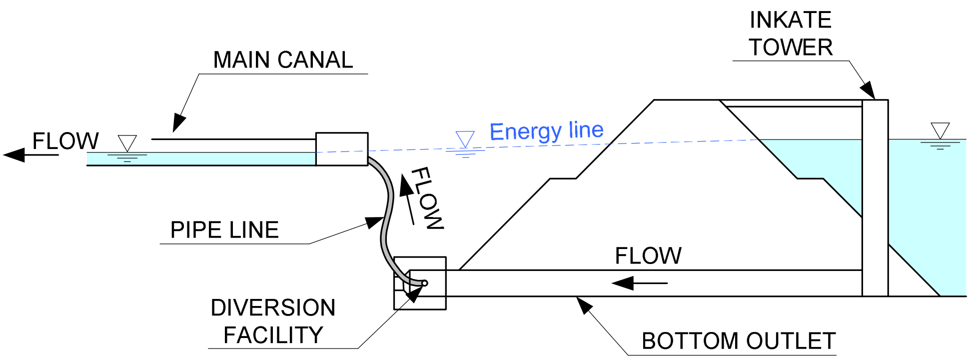


Fig. 4-1-2-35 Image of diversion of the main canal

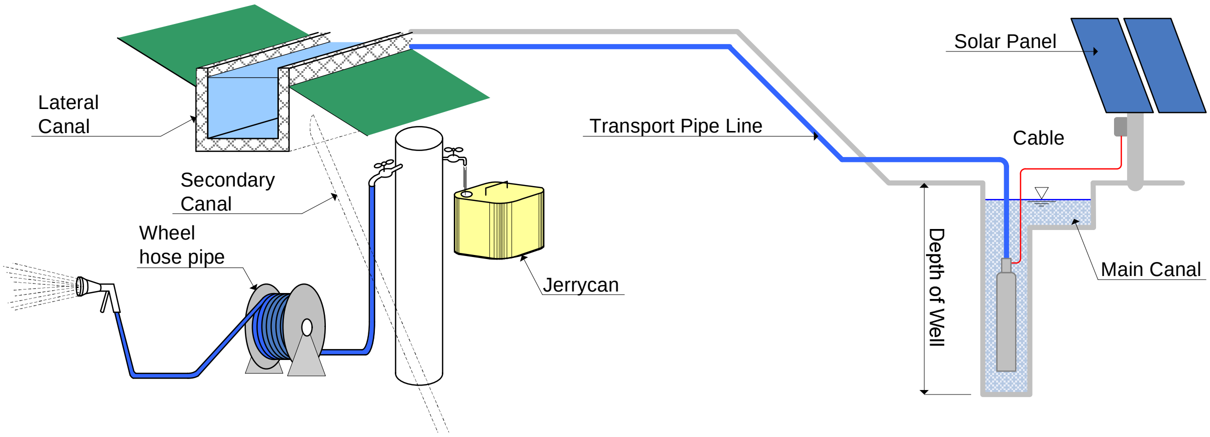


Fig. 4-1-2-36 Image of pump up facilities

(b) Intake

The type of the intake is considered 1) intake tower, 2) inclined conduit, and 1) easy maintenance and simple facility structure, 2) impact of the dam body is small, it is advantageous for the subsidence, therefor the type is intake tower.

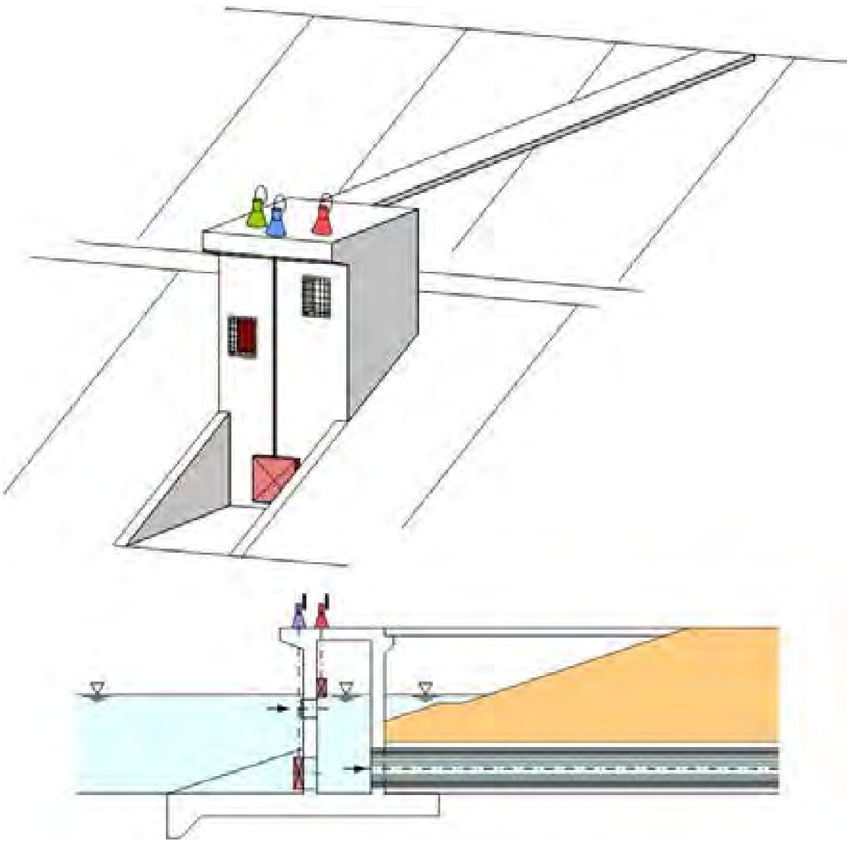


Fig. 4-1-2-37 Image of the intake facilities

ⅱ) Design condition

Design flow rate of the gutter bottom in this design is 0.234 m^3/s for planning water and 0.015 m^3/s flow rate of the base (dry season) when temporary drainage.

Here, as the bottom outlet checks the ability to flow over the base flow, in this report is calculated by

0.015 m^3/s flow rate at the time of temporary drainage. (The flow capacity for 0.234 m^3/s of the water plan was calculated the hydraulic pipe line below.

Design discharge Bottom outlet : Q =0.015 m^3/s

iii) Hydraulic computation

Hydraulic computation of bottom outlet is calculated by the Manning's formula.

$$Q = V \cdot A$$

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

Where, Q : Discharge(m^3/s)

V : Average velocity(m/s)

R : Hydraulic radius(m)＝A/P

〔A : Cross sectional area of flow(m^2) , P : Wetted perimeter(m)〕

I : Canal slope

n : Coefficient of roughness

Table 4-1-2-18 Coefficient of roughness

Materials and conditions of canal	Coefficient of roughness		
	Minimum value	Standard value	Maximum value
Concrete (cast-in-place flume, culvert, etc.)	0.012	0.015	0.016
Concrete (shotcrete)	0.016	0.019	0.023
Concrete (with precast flume, pipe, etc.)	0.012	0.014	0.016
Concrete (reinforced concrete pipe)	0.011	0.013	0.014
Concrete block masonry	0.014	0.016	0.017
Cement (mortar)	0.011	0.013	0.015
Steel (locked bar or welded)	0.010	0.012	0.014
Steel (revet)	0.013	0.016	0.017
Smooth steel surface (not painted)	0.011	0.012	0.014
Smooth steel surface and pipe (painted)	0.012	0.013	0.017
Corrugated surface (steel sheet)	0.021	0.025	0.030
Cast iron (not painted)	0.011	0.014	0.016
Cast iron sheet and pipr (painted)	0.010	0.013	0.014
Polyvinyl chloride pipe		0.012	
fiber reinforced plastic mortar pipe		0.012	
Ceramic pipe	0.011	0.014	0.017
Earth lining		0.025	
Asphalt (smooth surface)		0.014	
Asphalt (rough stone)		0.017	
Masonry (rough stone wet masonry)	0.017	0.025	0.030
Masonry (rough stone dry masonry)	0.023	0.032	0.035
Rock tunnel with no lining on overall cross-sectional area	0.030	0.035	0.040
Rock tunnel with no lining expect concrete placed on the bott	0.020	0.025	0.030
Vegetation coverage (turfing)	0.030	0.040	0.050

Minimum pipe diameter of the bottom outlet is designed by "Small reservoir design guideline 3.5.3 Design of bottom outlet, p.105", and then the minimum pipe diameter was φ800mm to account for maintenance. The type of pipe was selected a steel and it has been adopted in Nianza-23. In addition, the slope plan, I=1/1,000 from the slope gradient and construction limits on the local landform.

・Result of uniform flow of the temporary drainage pipe

Water depth(m)	Discharge (m^3/s)	Velcity (m/s)	Flow area(m^2)	Wetted perimeter(m)	Hydraulic radius(m)	Fr number	Coefficient of rughness
0.100	0.015	0.415	0.036	0.577	0.063	0.507	0.012

From the above results, there is no problem with the physical structure and hydrological flow, to adopt the φ800mm steel pipe.

(7) General design of canal／on-farm irrigation facilities

Main irrigation canal is water division by the pipeline from the intake facility. Therefore, the pipeline is calculated hydraulic accounting with a water pressure. In addition, the open channel is calculated by Manning's formula.

ⅰ) Design condition

Design discharge Bottom outlet : Q =0.234 m^3/s (Q=$Q$1+$Q$2+$Q$3)

Paddy : $Q$1=0.058 m^3/s

Main irrigation canal of right bank : $Q$2=0.116 m^3/s

Main irrigation canal of left bank : $Q$3=0.060 m^3/s

Intake water level of dam lowest water level : LWL=1387.5 m

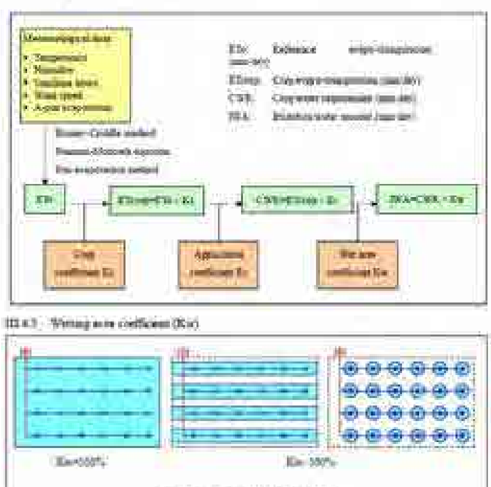
Main irrigation canal base level : EL=1387.0 m

Irrigation time : 8.5 hours/day (From the catalog)

Table 4-1-2-19 Irrigation requirement per hectare

Item	Value	Remark
Irrigation requirement (m^3/sec/ha)	0.000317	Calculated value by CROPWAT8.0
Conveyance efficiency(*ec*)	95%	FAO Annex I:Irrigation efficiencies
Field application efficiency(*ea*)	90%	ditto
Wet area coefficient(*Kw*)	40%	※
Crop water requirement(*CWR*) (m^3/sec/ha)	0.000733	0.000317×(24hr/8.5hr)×1/(95%×90%)×40%

※ PROJECT ON DEVELOPMENT OF EFFICIENT IRRIGATION TECHNIQUES AND EXTENSION IN SYRIA (JICA) August,2007 DESIGN STANDARD OF EFFICIENT IRRIGATION SYSTEM AND ON-FARM IRRIGATION MANAGEMENT p.37,p.51


III.4.2 Crop water requirement (CWR)

Crop water requirement (CWR) is defined as the depth of water that is equivalent to the water amount consumed by evapo-transpiration. It can be estimated according to the following procedure.

1. Reference evapo-transpiration (ETo) is calculated with the correlation equations such as Blaney Criddle, Pan evaporation or Penman Monteith method from meteorological data.
2. The crop factor including the variety and growing stage should be considered when estimating crop evapo-transpiration (ETcrop). Differences in evapo-transpiration between the proposed crops and the reference grass are integrated into crop coefficient (Kc). Crop evapo-transpiration (ETcrop) is calculated by multiplying ETo by crop coefficient (Kc).
3. A certain amount of water is lost by evaporation, seepage, deep percolation, etc during the irrigation process. These should be considered when estimating crop water requirement (CWR). Difference between the water amount consumed by crop growing and the water amount to be supplied from water source is expressed by application coefficient (Ec). Crop water requirement is calculated by dividing crop evapo-transpiration (ETcrop) by application coefficient (Ec).
4. Micro irrigation forms the localized wet zone which differs from the whole wet zone formed by sprinkler irrigation. The difference should be considered when estimating irrigation water amount (IWA). The ratio of wet area to whole area can be expressed by wet area coefficient (Kw). Irrigation water amount (IWA) is calculated by multiplying crop water requirement (CWR) by wet area coefficient (Kw).

III.4.3 Wetting area coefficient (Kw)

The shape of wet area is different depending on the irrigation method and the arrangement of the emitters and so on. Sprinkler and surface irrigation create whole wet area. On the contrary, GR and Micro irrigation create localized wet area. GR irrigation method forms the partial wet zones with a certain width along the drip tubes, and Micro irrigation forms the isolated wet area around trees.

The ratio of wet area to whole area is expressed by wetting area coefficient (Kw). In case of surface irrigation and sprinkler irrigation, Kw-value is 100%. On the other hand, Kw-value of GR irrigation varies from 70 to 100% according to the spacing of the drip tubes, the discharge of the drippers and soil type. Kw-value of Micro irrigation varies 40 to 70 % in accordance with spacing of the trees, specification of the emitters and soil type as well.

Table 4.5 Wetting area coefficient Kw

Irrigation method	Kw (%)	Remarks
Surface irrigation	100	
Sprinkler irrigation	100	
GR irrigation	70-100	GR : Drip tube
Micro irrigation	40~70	Micro emitter, Micro sprinkler

IRRIGATION NETWORK PLAN

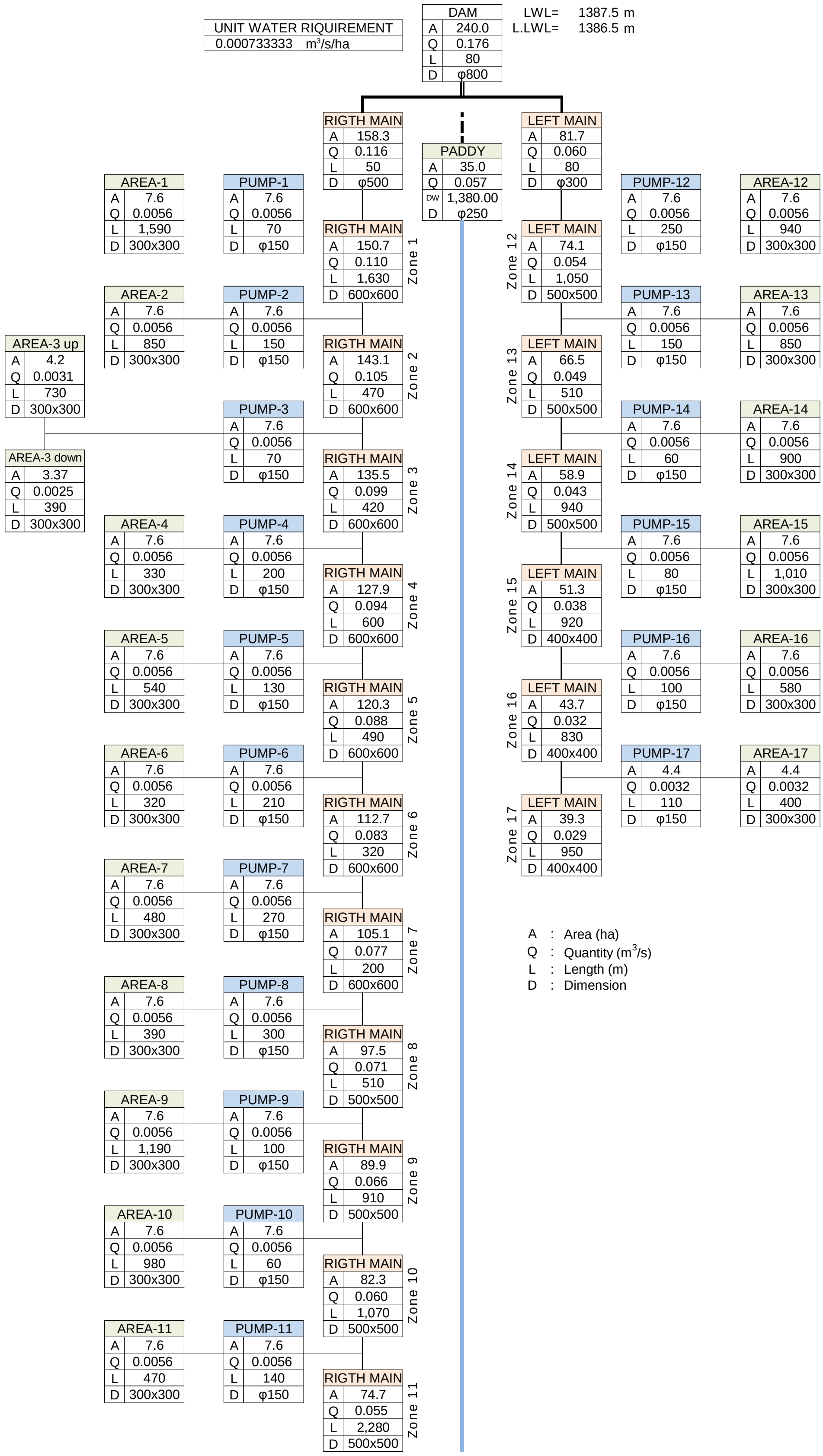


Fig. 4-1-2-38 Irrigation Network Plan

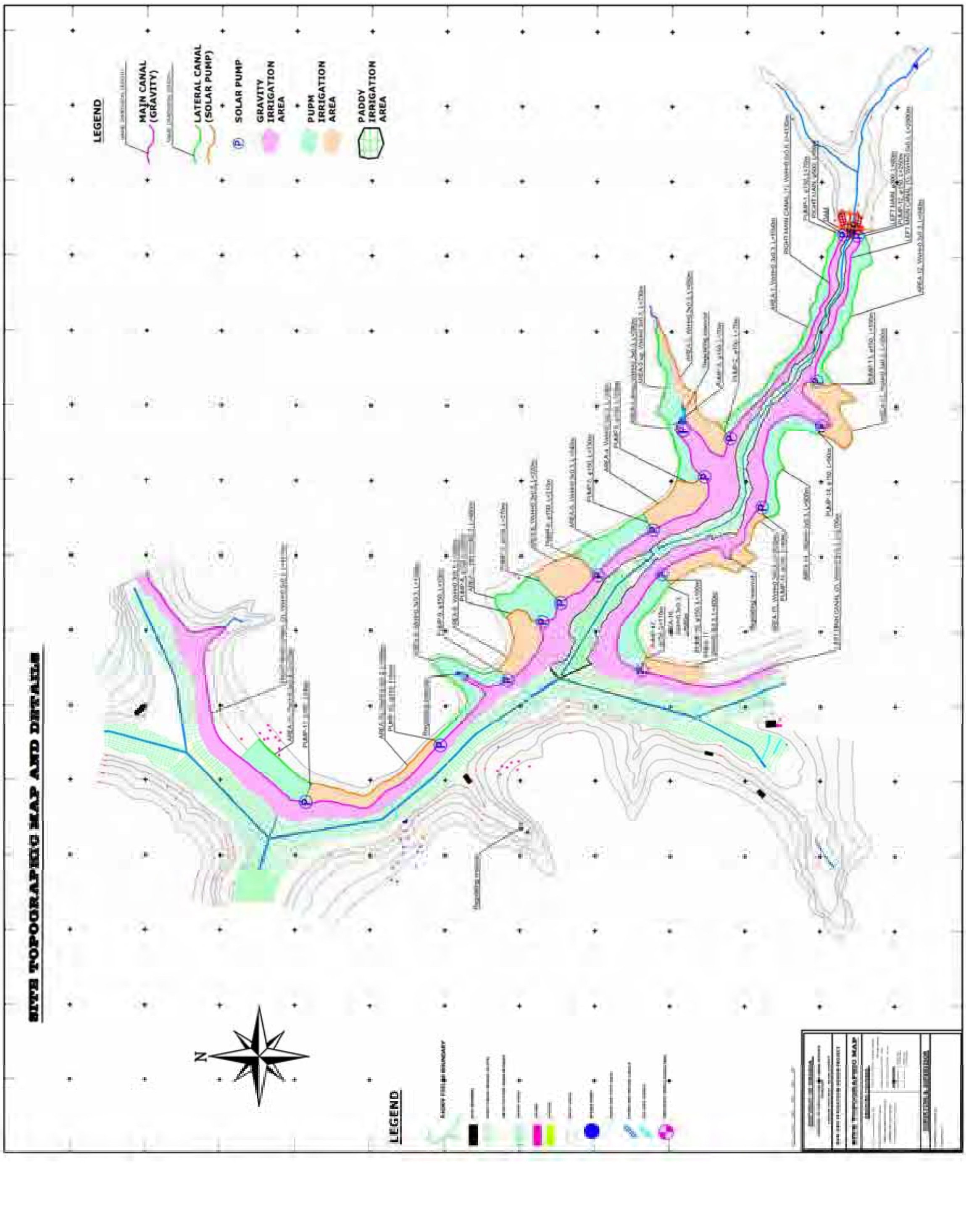


Fig. 4-1-2-39 General Plan of irrigation facilities

ⅱ) Hydraulic computation

(a) Pipeline

・Friction loss

Hazen-williams formula shown below is applied to estimate the loss head of the pipeline. In addition, the minimum allowable flow rate more than V=0.3 m/s so that there is no deposition of suspended sediment, the maximum allowable flow rate equal to or less than V=2.0 m/s which is the desired value.

$$V = 0.849 \cdot C \cdot R^{0.63} \cdot I^{0.54}$$

From the following formula is derived for a pipe.

$$V = 0.355 \cdot C \cdot D^{0.63} \cdot I^{0.54}$$
$$Q = 0.279 \cdot C \cdot D^{2.63} \cdot I^{0.54}$$
$$D = 1.626 \cdot C^{-0.38} \cdot Q^{0.38} \cdot I^{-0.21}$$
$$I = h_f/L = 10.67 \cdot C^{-1.85} \cdot D^{-4.87} \cdot Q^{1.85}$$

V : Mean Velocity (m/s) D : Diameter (m)
C : Velocity Coefficient(Average of next table)
hf : Friction Loss (m)
R : Hydraulic Radius (m) Q : Discharge (m^3/s)
I : Hydraulic Gradient L : Length (m)

Table 4-1-2-20 Coefficient of roughness

Type of pipe (Condition of the inner surface)	Coefficient of roughness (C) Maximum value	Minimum value	Standard value
Cast iron pipe (not painted)	150	80	100
Steel pipe (not painted)	150	90	100
Coal tar painted pipe (cast iron)	145	80	100
Liquid and tar epoxy painted pipe (steel)*			
φ800 or lager	-	-	130
φ700～600	-	-	120
φ500～350	-	-	110
φ300 or smallr	-	-	100
Mortar liningpipr (steel,cast iron)	150	120	130
Centrifugal reinforced concrete pipe	140	120	130
Rolled reinforced concrete pipe	140	120	130
Prestressed concrete pipes-core type	140	120	130
Asbestos cement pipe	160	140	140
Rigid polyvinyl chloride pipe**	160	140	150
Polyethylene pipe **	170	130	150
Fiber reinforced plastic mortar pipe **	160	-	150

Remark) * Painting methods shall conform to JWWA-115-1974, or to JWWA K 135-1989, and it is desirable to have paint thickness in the range 0.3 to 0.5 mm. Also, for liquid and tar epoxy painted pipe which nominal diameter is less than 800 mm, when the inside of field welded areas are not painted, values in this table shall be applied. However, the coefficient of velocity value of 130 (C = 130) can be applied if painting for the inside of field welded areas is performed under adequate supervisions.

** For pipes which nominal diameter are 150 mm or smaller, the coefficient of velocity value of 140 (C = 140) shall be used as a standard.

・Hydraulic calculations summary

For calculation of hydraulic schematic, 1) oblique length of the pipeline, 2) valve, 3) bend, 4) flow, 5) head loss that occurs in addition to friction loss, such as spills, recorded as 15% of the friction head loss was calculated.

Tube diameter was determined as the water level, including the depth of the water that was obtained by the calculation of open channel hydraulic height and the bottom of the trunk canal water level required.

Table 4-1-2-21 Calculation of hydraulic schematic

Name	C	D (m)	Q (m^3/s)	Hf (m)	L (m)	ΣHf (m)	ΣHf (m)	V (m/s)	Head of water level (m) ①	Required water level (m) ②=③+④	Grand level (m) ③	water depth of canal (m) ④	Water head difference (m) ⑤=①-②	Judge
NGOMA22				Another loss15%										
LWL of DAM									1387.500					
Bottom outlet	100	0.800	0.234	0.000494155	80.0	0.040	0.040	0.466	1387.460					
Main canal of Rigth									1387.460					
	150	0.500	0.116	0.000628575	50.0	0.031	0.031	0.591	1387.429	1387.35	1387.00	0.35	0.079	≧0 OK
Main canal of Left									1387.460					
	150	0.300	0.060	0.002234049	80.0	0.179	0.179	0.849	1387.282	1387.20	1387.00	0.25	0.082	≧0 OK

④ : Refer to "d" of Hydraulic calculations (Zone1, Zone12)

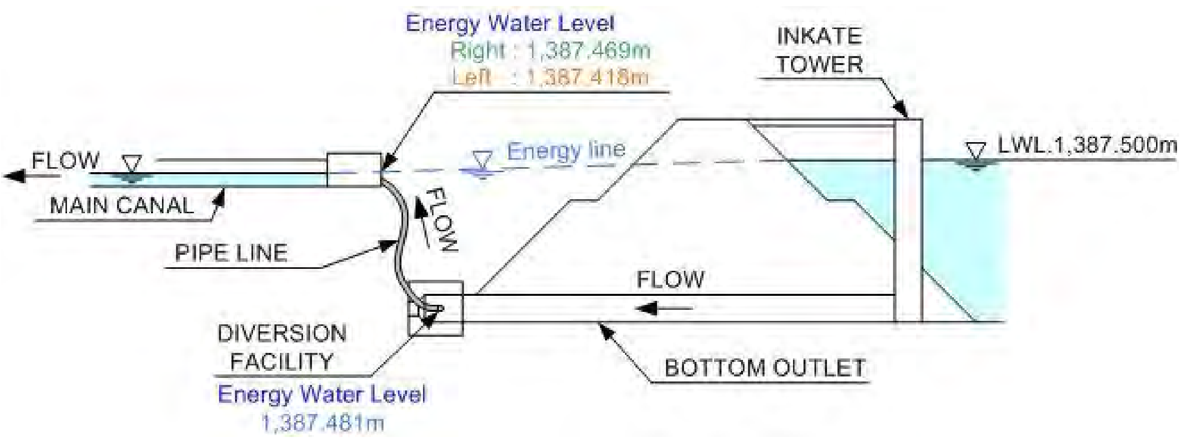


Fig. 4-1-2-40 Hydraulic calculations

(b) Open canal

Hydraulic calculation of open canal to determine the scale as calculated using Manning's formula. In addition, the maximum allowable flow rate equal to or less than V=2.5 m/s from the structural durability against wear and scouring.

High-margin is determined from the following equation, and Planning is safe even if the flow rate of 1.2 times the design flow in order to cope with unforeseen circumstances.

$$\boldsymbol{Q = V \cdot A}$$

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

$Fb1 = 0.07 \cdot d + hv + 0.1$ (subcritical flow)

$Fb2 = C \cdot V \cdot d^{1/2}$ (supercritical flow)

ここに、Q ：Discharge(m^3/s)

d ：Water depth(m)

V ：Mean Velocity(m/s)

R ：Hydraulic Radius(m)＝*A*/*P*

〔*A*：Cross sectional area of flow(m^2)，*P*：Wetted perimeter(m)〕

I ：Canal slope

n ：Coefficient of roughness

C ：Coefficient

Square *C*=0.1

Trapezium *C*=0.13

Fb：Freeboard(m)

hv：Velocity Head(m)

d ：Water depth(m)

Table 4-1-2-22 Coefficient of roughness

Materials and conditions of canal	Coefficient of roughness		
	Minimum value	Standard value	Maximum value
Concrete (cast-in-place flume, culvert, etc.)	0.012	0.015	0.016
Concrete (shotcrete)	0.016	0.019	0.023
Concrete (with precast flume, pipe, etc.)	0.012	0.014	0.016
Concrete (reinforced concrete pipe)	0.011	0.013	0.014
Concrete block masonry	0.014	0.016	0.017
Cement (mortar)	0.011	0.013	0.015
Steel (locked bar or welded)	0.010	0.012	0.014
Steel (revet)	0.013	0.016	0.017
Smooth steel surface (not painted)	0.011	0.012	0.014
Smooth steel surface and pipe (painted)	0.012	0.013	0.017
Corrugated surface (steel sheet)	0.021	0.025	0.030
Cast iron (not painted)	0.011	0.014	0.016
Cast iron sheet and pipr (painted)	0.010	0.013	0.014
Polyvinyl chloride pipe		0.012	
fiber reinforced plastic mortar pipe		0.012	
Ceramic pipe	0.011	0.014	0.017
Earth lining		0.025	
Asphalt (smooth surface)		0.014	
Asphalt (rough stone)		0.017	
Masonry (rough stone wet masonry)	0.017	0.025	0.030
Masonry (rough stone dry masonry)	0.023	0.032	0.035
Rock tunnel with no lining on overall cross-sectional area	0.030	0.035	0.040
Rock tunnel with no lining expect concrete placed on the botto	0.020	0.025	0.030
Vegetation coverage (turfing)	0.030	0.040	0.050

・Hydraulic calculations summary

Right bank of main irrigation canal (Zone1)

Condition	*B*	*d*	*A*	*P*	*R*	$R^{2/3}$	*n*	*i*	*V*	*Q*	*Qa*	*hv*	*Fr*	Fb_1	Fb_2	*Fb*	*d+Fb*	*H*
Q	0.500	0.427	0.213	1.353	0.158	0.292	0.025	0.00200	0.522	0.111	0.111	0.014	0.255	0.144	—	0.144	0.570	0.600
	0.600	0.349	0.210	1.299	0.161	0.296	0.025	0.00200	0.530	0.111	0.111	0.014	0.287	0.139	—	0.139	0.488	0.500
	0.700	0.299	0.210	1.299	0.161	0.296	0.025	0.00200	0.530	0.111	0.111	0.014	0.310	0.135	—	0.135	0.435	0.500
1.2Q	0.500	0.494	0.247	1.487	0.166	0.302	0.025	0.00200	0.540	0.133	0.133	0.015	0.246	0.149	—	0.149	0.643	0.700
	0.600	0.402	0.241	1.404	0.172	0.309	0.025	0.00200	0.553	0.133	0.133	0.016	0.279	0.144	—	0.144	0.545	0.600
	0.700	0.342	0.240	1.385	0.173	0.311	0.025	0.00200	0.556	0.133	0.133	0.016	0.303	0.140	—	0.140	0.482	0.500

Right bank of main irrigation canal (Zone2)

Condition	*B*	*d*	*A*	*P*	*R*	$R^{2/3}$	*n*	*i*	*V*	*Q*	*Qa*	*hv*	*Fr*	Fb_1	Fb_2	*Fb*	*d+Fb*	*H*
Q	0.500	0.408	0.204	1.316	0.155	0.289	0.025	0.00200	0.516	0.105	0.105	0.014	0.258	0.142	—	0.142	0.550	0.600
	0.600	0.335	0.201	1.270	0.158	0.293	0.025	0.00200	0.523	0.105	0.105	0.014	0.289	0.137	—	0.137	0.472	0.500
	0.700	0.288	0.201	1.275	0.158	0.292	0.025	0.00200	0.523	0.105	0.105	0.014	0.311	0.134	—	0.134	0.422	0.500
1.2Q	0.500	0.473	0.236	1.445	0.164	0.299	0.025	0.00200	0.535	0.126	0.126	0.015	0.249	0.148	—	0.148	0.620	0.700
	0.600	0.385	0.231	1.370	0.169	0.305	0.025	0.00200	0.546	0.126	0.126	0.015	0.281	0.142	—	0.142	0.527	0.600
	0.700	0.329	0.230	1.358	0.170	0.306	0.025	0.00200	0.548	0.126	0.126	0.015	0.305	0.138	—	0.138	0.467	0.500

Right bank of main irrigation canal (Zone3)

Conditin	*B*	*d*	*A*	*P*	*R*	$R^{2/3}$	*n*	*i*	*V*	*Q*	*Qa*	*hv*	*Fr*	Fb_1	Fb_2	*Fb*	*d+Fb*	*H*
Q	0.500	0.389	0.194	1.277	0.152	0.285	0.025	0.00200	0.510	0.099	0.099	0.013	0.261	0.140	—	0.140	0.529	0.600
	0.600	0.321	0.192	1.241	0.155	0.288	0.025	0.00200	0.516	0.099	0.099	0.014	0.291	0.136	—	0.136	0.457	0.500
	0.700	0.276	0.193	1.252	0.154	0.288	0.025	0.00200	0.515	0.099	0.099	0.014	0.313	0.133	—	0.133	0.409	0.500
1.2Q	0.500	0.450	0.225	1.401	0.161	0.296	0.025	0.00200	0.529	0.119	0.119	0.014	0.252	0.146	—	0.146	0.596	0.600
	0.600	0.369	0.221	1.337	0.165	0.301	0.025	0.00200	0.539	0.119	0.119	0.015	0.284	0.141	—	0.141	0.509	0.600
	0.700	0.316	0.221	1.332	0.166	0.302	0.025	0.00200	0.540	0.119	0.119	0.015	0.307	0.137	—	0.137	0.453	0.500

Right bank of main irrigation canal (Zone4)

Condition	*B*	*d*	*A*	*P*	*R*	$R^{2/3}$	*n*	*i*	*V*	*Q*	*Qa*	*hv*	*Fr*	Fb_1	Fb_2	*Fb*	*d+Fb*	*H*
Q	0.500	0.374	0.187	1.247	0.150	0.282	0.025	0.00200	0.505	0.094	0.094	0.013	0.264	0.139	—	0.139	0.513	0.600
	0.600	0.309	0.185	1.218	0.152	0.285	0.025	0.00200	0.510	0.095	0.094	0.013	0.293	0.135	—	0.135	0.444	0.500
	0.700	0.267	0.187	1.233	0.151	0.284	0.025	0.00200	0.508	0.095	0.094	0.013	0.314	0.132	—	0.132	0.399	0.400
1.2Q	0.500	0.432	0.216	1.365	0.158	0.293	0.025	0.00200	0.524	0.113	0.113	0.014	0.254	0.144	—	0.144	0.577	0.600
	0.600	0.354	0.213	1.309	0.162	0.298	0.025	0.00200	0.533	0.113	0.113	0.014	0.286	0.139	—	0.139	0.494	0.600
	0.700	0.305	0.213	1.310	0.163	0.298	0.025	0.00200	0.534	0.114	0.113	0.015	0.309	0.136	—	0.136	0.441	0.500

Right bank of main irrigation canal (Zone5)

Condition	*B*	*d*	*A*	*P*	*R*	$R^{2/3}$	*n*	*i*	*V*	*Q*	*Qa*	*hv*	*Fr*	Fb_1	Fb_2	*Fb*	*d+Fb*	*H*
Q	0.500	0.355	0.177	1.210	0.147	0.278	0.025	0.00200	0.498	0.088	0.088	0.013	0.267	0.137	—	0.137	0.492	0.500
	0.600	0.293	0.176	1.186	0.148	0.280	0.025	0.00200	0.501	0.088	0.088	0.013	0.296	0.133	—	0.133	0.427	0.500
	0.700	0.253	0.177	1.206	0.147	0.278	0.025	0.00200	0.498	0.088	0.088	0.013	0.316	0.130	—	0.130	0.383	0.400
1.2Q	0.500	0.411	0.206	1.322	0.155	0.289	0.025	0.00200	0.517	0.106	0.106	0.014	0.258	0.142	—	0.142	0.553	0.600
	0.600	0.337	0.202	1.275	0.159	0.293	0.025	0.00200	0.525	0.106	0.106	0.014	0.288	0.138	—	0.138	0.475	0.600
	0.700	0.289	0.203	1.279	0.158	0.293	0.025	0.00200	0.524	0.106	0.106	0.014	0.311	0.134	—	0.134	0.424	0.500

Right bank of main irrigation canal (Zone6)

Condition	B	d	A	P	R	$R^{2/3}$	n	i	V	Q	Qa	hv	Fr	Fb_1	Fb_2	Fb	d+Fb	H
Q	0.500	0.338	0.169	1.176	0.144	0.274	0.025	0.00200	0.491	0.083	0.083	0.012	0.270	0.136	—	0.136	0.474	0.500
	0.600	0.280	0.168	1.161	0.145	0.276	0.025	0.00200	0.494	0.083	0.083	0.012	0.298	0.132	—	0.132	0.413	0.500
	0.700	0.243	0.170	1.185	0.143	0.274	0.025	0.00200	0.490	0.083	0.083	0.012	0.318	0.129	—	0.129	0.372	0.400
1.2Q	0.500	0.392	0.196	1.285	0.153	0.286	0.025	0.00200	0.511	0.100	0.100	0.013	0.261	0.141	—	0.141	0.533	0.600
	0.600	0.323	0.194	1.245	0.155	0.289	0.025	0.00200	0.517	0.100	0.100	0.014	0.291	0.136	—	0.136	0.459	0.600
	0.700	0.278	0.194	1.255	0.155	0.288	0.025	0.00200	0.516	0.100	0.100	0.014	0.313	0.133	—	0.133	0.411	0.500

Right bank of main irrigation canal (Zone7)

Condition	B	d	A	P	R	$R^{2/3}$	n	i	V	Q	Qa	hv	Fr	Fb_1	Fb_2	Fb	d+Fb	H
Q	0.500	0.319	0.160	1.138	0.140	0.270	0.025	0.00200	0.483	0.077	0.077	0.012	0.273	0.134	—	0.134	0.453	0.500
	0.600	0.265	0.159	1.130	0.141	0.271	0.025	0.00200	0.484	0.077	0.077	0.012	0.300	0.131	—	0.131	0.396	0.400
	0.700	0.230	0.161	1.159	0.139	0.268	0.025	0.00200	0.479	0.077	0.077	0.012	0.319	0.128	—	0.128	0.357	0.400
1.2Q	0.500	0.367	0.183	1.233	0.149	0.281	0.025	0.00200	0.502	0.092	0.092	0.013	0.265	0.139	—	0.139	0.505	0.600
	0.600	0.303	0.182	1.206	0.151	0.283	0.025	0.00200	0.507	0.092	0.092	0.013	0.294	0.134	—	0.134	0.437	0.600
	0.700	0.261	0.183	1.222	0.150	0.282	0.025	0.00200	0.504	0.092	0.092	0.013	0.315	0.131	—	0.131	0.392	0.400

Right bank of main irrigation canal (Zone8)

Condition	B	d	A	P	R	$R^{2/3}$	n	i	V	Q	Qa	hv	Fr	Fb_1	Fb_2	Fb	d+Fb	H
Q	0.400	0.389	0.156	1.178	0.132	0.259	0.025	0.00200	0.464	0.072	0.072	0.011	0.238	0.138	—	0.138	0.527	0.600
	0.500	0.303	0.152	1.107	0.137	0.266	0.025	0.00200	0.476	0.072	0.072	0.012	0.276	0.133	—	0.133	0.436	0.500
	0.600	0.253	0.152	1.105	0.137	0.266	0.025	0.00200	0.476	0.072	0.072	0.012	0.302	0.129	—	0.129	0.382	0.400
1.2Q	0.400	0.450	0.180	1.300	0.138	0.268	0.025	0.00200	0.479	0.086	0.086	0.012	0.228	0.143	—	0.143	0.593	0.600
	0.500	0.348	0.174	1.196	0.145	0.277	0.025	0.00200	0.495	0.086	0.086	0.012	0.268	0.137	—	0.137	0.485	0.500
	0.600	0.288	0.173	1.176	0.147	0.278	0.025	0.00200	0.498	0.086	0.086	0.013	0.296	0.133	—	0.133	0.421	0.500

Right bank of main irrigation canal (Zone9)

Condition	B	d	A	P	R	$R^{2/3}$	n	i	V	Q	Qa	hv	Fr	Fb_1	Fb_2	Fb	d+Fb	H
Q	0.400	0.362	0.145	1.124	0.129	0.255	0.025	0.00200	0.456	0.066	0.066	0.011	0.242	0.136	—	0.136	0.498	0.500
	0.500	0.284	0.142	1.067	0.133	0.260	0.025	0.00200	0.466	0.066	0.066	0.011	0.279	0.131	—	0.131	0.414	0.500
	0.600	0.237	0.142	1.074	0.132	0.260	0.025	0.00200	0.465	0.066	0.066	0.011	0.305	0.128	—	0.128	0.364	0.400
1.2Q	0.400	0.419	0.168	1.238	0.135	0.264	0.025	0.00200	0.472	0.079	0.079	0.011	0.233	0.141	—	0.141	0.560	0.600
	0.500	0.326	0.163	1.151	0.141	0.271	0.025	0.00200	0.486	0.079	0.079	0.012	0.272	0.135	—	0.135	0.460	0.500
	0.600	0.270	0.162	1.141	0.142	0.272	0.025	0.00200	0.487	0.079	0.079	0.012	0.299	0.131	—	0.131	0.401	0.500

Right bank of main irrigation canal (Zone10)

Condition	B	d	A	P	R	$R^{2/3}$	n	i	V	Q	Qa	hv	Fr	Fb_1	Fb_2	Fb	d+Fb	H
Q	0.400	0.335	0.134	1.070	0.125	0.250	0.025	0.00200	0.448	0.060	0.060	0.010	0.247	0.134	—	0.134	0.469	0.500
	0.500	0.264	0.132	1.028	0.128	0.254	0.025	0.00200	0.455	0.060	0.060	0.011	0.283	0.129	—	0.129	0.393	0.400
	0.600	0.221	0.133	1.042	0.127	0.253	0.025	0.00200	0.453	0.060	0.060	0.010	0.308	0.126	—	0.126	0.347	0.400
1.2Q	0.400	0.388	0.155	1.177	0.132	0.259	0.025	0.00200	0.464	0.072	0.072	0.011	0.238	0.138	—	0.138	0.526	0.600
	0.500	0.303	0.152	1.106	0.137	0.266	0.025	0.00200	0.475	0.072	0.072	0.012	0.276	0.133	—	0.133	0.436	0.500
	0.600	0.252	0.151	1.105	0.137	0.266	0.025	0.00200	0.476	0.072	0.072	0.012	0.302	0.129	—	0.129	0.382	0.400

Right bank of main irrigation canal (Zone11)

Condition	B	d	A	P	R	$R^{2/3}$	n	i	V	Q	Qa	hv	Fr	Fb_1	Fb_2	Fb	d+Fb	H
Q	0.400	0.313	0.125	1.025	0.122	0.246	0.025	0.00200	0.440	0.055	0.055	0.010	0.251	0.132	—	0.132	0.444	0.500
	0.500	0.247	0.124	0.994	0.124	0.249	0.025	0.00200	0.445	0.055	0.055	0.010	0.286	0.127	—	0.127	0.374	0.400
	0.600	0.208	0.125	1.015	0.123	0.247	0.025	0.00200	0.442	0.055	0.055	0.010	0.310	0.124	—	0.124	0.332	0.400
1.2Q	0.400	0.362	0.145	1.124	0.129	0.255	0.025	0.00200	0.456	0.066	0.066	0.011	0.242	0.136	—	0.136	0.498	0.500
	0.500	0.284	0.142	1.067	0.133	0.260	0.025	0.00200	0.466	0.066	0.066	0.011	0.279	0.131	—	0.131	0.414	0.500
	0.600	0.237	0.142	1.074	0.132	0.260	0.025	0.00200	0.465	0.066	0.066	0.011	0.305	0.128	—	0.128	0.364	0.400

Left bank of main irrigation canal (Zone12)

Condition	B	d	A	P	R	$R^{2/3}$	n	i	V	Q	Qa	hv	Fr	Fb_1	Fb_2	Fb	d+Fb	H
Q	0.400	0.309	0.123	1.017	0.121	0.245	0.025	0.00200	0.438	0.054	0.054	0.010	0.252	0.131	—	0.131	0.440	0.500
	0.500	0.244	0.122	0.989	0.124	0.248	0.025	0.00200	0.444	0.054	0.054	0.010	0.287	0.127	—	0.127	0.371	0.400
	0.600	0.205	0.123	1.010	0.122	0.246	0.025	0.00200	0.440	0.054	0.054	0.010	0.310	0.124	—	0.124	0.329	0.400
1.2Q	0.400	0.358	0.143	1.115	0.128	0.254	0.025	0.00200	0.455	0.065	0.065	0.011	0.243	0.136	—	0.136	0.493	0.500
	0.500	0.277	0.138	1.054	0.131	0.258	0.025	0.00200	0.462	0.064	0.065	0.011	0.281	0.130	—	0.130	0.407	0.500
	0.600	0.234	0.141	1.069	0.132	0.259	0.025	0.00200	0.463	0.065	0.065	0.011	0.305	0.127	—	0.127	0.362	0.400

Left bank of main irrigation canal (Zone13)

Condition	B	d	A	P	R	$R^{2/3}$	n	i	V	Q	Qa	hv	Fr	Fb_1	Fb_2	Fb	d+Fb	H
Q	0.400	0.285	0.114	0.971	0.118	0.240	0.025	0.00200	0.429	0.049	0.049	0.009	0.257	0.129	—	0.129	0.415	0.500
	0.500	0.227	0.113	0.953	0.119	0.242	0.025	0.00200	0.433	0.049	0.049	0.010	0.290	0.125	—	0.125	0.352	0.400
	0.600	0.191	0.115	0.982	0.117	0.239	0.025	0.00200	0.427	0.049	0.049	0.009	0.312	0.123	—	0.123	0.314	0.400
1.2Q	0.400	0.331	0.132	1.061	0.125	0.249	0.025	0.00200	0.446	0.059	0.059	0.010	0.248	0.133	—	0.133	0.464	0.500
	0.500	0.260	0.130	1.021	0.128	0.253	0.025	0.00200	0.453	0.059	0.059	0.010	0.284	0.129	—	0.129	0.389	0.500
	0.600	0.218	0.131	1.037	0.126	0.252	0.025	0.00200	0.451	0.059	0.059	0.010	0.308	0.126	—	0.126	0.344	0.400

Left bank of main irrigation canal (Zone14)

Condition	B	d	A	P	R	$R^{2/3}$	n	i	V	Q	Qa	hv	Fr	Fb_1	Fb_2	Fb	d+Fb	H
Q	0.400	0.259	0.104	0.918	0.113	0.234	0.025	0.00200	0.418	0.043	0.043	0.009	0.262	0.127	—	0.127	0.386	0.400
	0.500	0.206	0.103	0.913	0.113	0.234	0.025	0.00200	0.418	0.043	0.043	0.009	0.294	0.123	—	0.123	0.330	0.400
	0.600	0.174	0.105	0.949	0.110	0.230	0.025	0.00200	0.411	0.043	0.043	0.009	0.315	0.121	—	0.121	0.295	0.300
1.2Q	0.400	0.300	0.120	1.001	0.120	0.243	0.025	0.00200	0.435	0.052	0.052	0.010	0.254	0.131	—	0.131	0.431	0.500
	0.500	0.237	0.119	0.975	0.122	0.246	0.025	0.00200	0.440	0.052	0.052	0.010	0.288	0.126	—	0.126	0.364	0.500
	0.600	0.200	0.120	0.999	0.120	0.243	0.025	0.00200	0.435	0.052	0.052	0.010	0.311	0.124	—	0.124	0.323	0.400

Left bank of main irrigation canal (Zone15)

Condition	B	d	A	P	R	$R^{2/3}$	n	i	V	Q	Qa	hv	Fr	Fb_1	Fb_2	Fb	d+Fb	H
Q	0.300	0.323	0.097	0.947	0.102	0.219	0.025	0.00200	0.392	0.038	0.038	0.008	0.220	0.130	—	0.130	0.454	0.500
	0.400	0.234	0.094	0.869	0.108	0.227	0.025	0.00200	0.405	0.038	0.038	0.008	0.268	0.125	—	0.125	0.359	0.400
	0.500	0.185	0.092	0.869	0.106	0.224	0.025	0.00200	0.401	0.037	0.038	0.008	0.298	0.121	—	0.121	0.306	0.400
1.2Q	0.300	0.379	0.114	1.059	0.107	0.226	0.025	0.00200	0.404	0.046	0.046	0.008	0.210	0.135	—	0.135	0.514	0.600
	0.400	0.272	0.109	0.943	0.115	0.237	0.025	0.00200	0.424	0.046	0.046	0.009	0.260	0.128	—	0.128	0.400	0.400
	0.500	0.216	0.108	0.933	0.116	0.238	0.025	0.00200	0.425	0.046	0.046	0.009	0.292	0.124	—	0.124	0.341	0.400

Left bank of main irrigation canal (Zone16)

Condition	B	d	A	P	R	$R^{2/3}$	n	i	V	Q	Qa	hv	Fr	Fb_1	Fb_2	Fb	d+Fb	H
Q	0.300	0.281	0.084	0.862	0.098	0.212	0.025	0.00200	0.380	0.032	0.032	0.007	0.229	0.127	—	0.127	0.408	0.500
	0.400	0.206	0.082	0.812	0.102	0.218	0.025	0.00200	0.389	0.032	0.032	0.008	0.274	0.122	—	0.122	0.328	0.400
	0.500	0.166	0.083	0.833	0.100	0.215	0.025	0.00200	0.385	0.032	0.032	0.008	0.302	0.119	—	0.119	0.286	0.300
1.2Q	0.300	0.324	0.097	0.947	0.102	0.219	0.025	0.00200	0.392	0.038	0.038	0.008	0.220	0.130	—	0.130	0.454	0.500
	0.400	0.237	0.095	0.875	0.109	0.228	0.025	0.00200	0.407	0.039	0.038	0.008	0.267	0.125	—	0.125	0.363	0.400
	0.500	0.188	0.094	0.876	0.107	0.226	0.025	0.00200	0.404	0.038	0.038	0.008	0.298	0.122	—	0.122	0.310	0.400

Left bank of main irrigation canal (Zone17)

Condition	B	d	A	P	R	$R^{2/3}$	n	i	V	Q	Qa	hv	Fr	Fb_1	Fb_2	Fb	d+Fb	H
Q	0.300	0.260	0.078	0.819	0.095	0.208	0.025	0.00200	0.373	0.029	0.029	0.007	0.234	0.125	—	0.125	0.385	0.400
	0.400	0.191	0.076	0.782	0.098	0.212	0.025	0.00200	0.380	0.029	0.029	0.007	0.277	0.121	—	0.121	0.312	0.400
	0.500	0.155	0.078	0.810	0.096	0.209	0.025	0.00200	0.374	0.029	0.029	0.007	0.304	0.118	—	0.118	0.273	0.300
1.2Q	0.300	0.302	0.091	0.905	0.100	0.216	0.025	0.00200	0.386	0.035	0.035	0.008	0.224	0.129	—	0.129	0.431	0.500
	0.400	0.220	0.088	0.840	0.105	0.222	0.025	0.00200	0.398	0.035	0.035	0.008	0.271	0.123	—	0.123	0.344	0.400
	0.500	0.177	0.089	0.855	0.104	0.221	0.025	0.00200	0.395	0.035	0.035	0.008	0.300	0.120	—	0.120	0.298	0.300

iii) Terminal irrigation facilities

Terminal irrigation will be selected "micro irrigation" of wheel hose and Jerry cans.

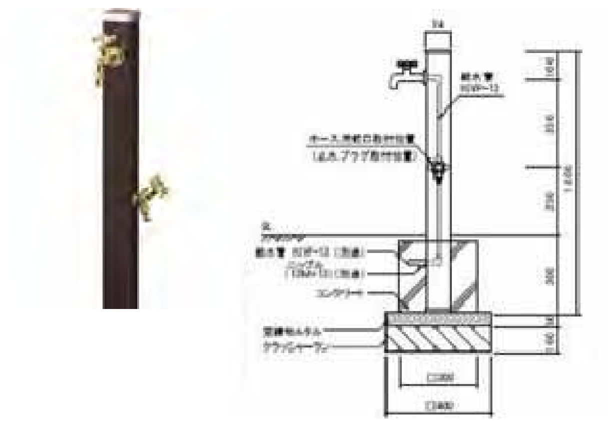


Fig. 4-1-2-41 Water tap

Fig. 4-1-2-42 Wheel hose pipe

The water tap will be installed in six (6) units per hectare. In addition, the wheel house will be installed in twelve (12) units per hectare to set up two units per place with a water tap.

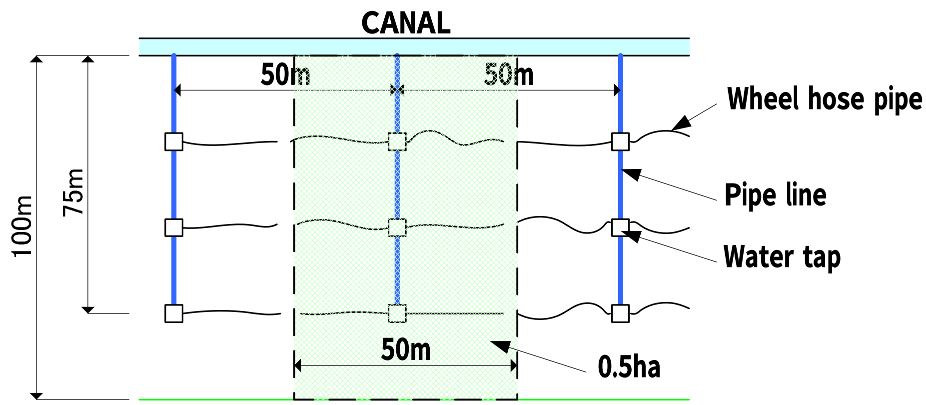


Fig. 4-1-2-43 Layout of water tap

(8) Study of regulating reservoir

The main canal length approximately 5 km on the left bank and right bank side length of approximately 9 km are relatively short. In addition, the main canal to consider the introduction of the regulating reservoir in order to adjust the supply and demand due to supply-driven water management valves and gate operation is assumed.
Such as keeping a good balance between supply and demand balances of water supply management of the regulating reservoir is a purpose, something organic and flexible with the functionality of the canal as much as possible to prevent an imbalance of water distribution and water distribution operational discharge caused invalid in order to establish.

The regulating reservoir of this project has the following utility.

① It is possible to reduce the loss of water for operation management of the water distribution becomes smooth.
② Increase the degree of freedom of irrigation in increasing the elasticity of the end capacity of irrigation water distribution throughout the organization.
③ Equalization of water distribution and leveling of the water reached.
④ To add the function of spillway to deal with contingencies or rainwater inflow mistake gate operation.

Installation location for the facility to use complex auxiliary water source becomes economically advantageous to take advantage of this.

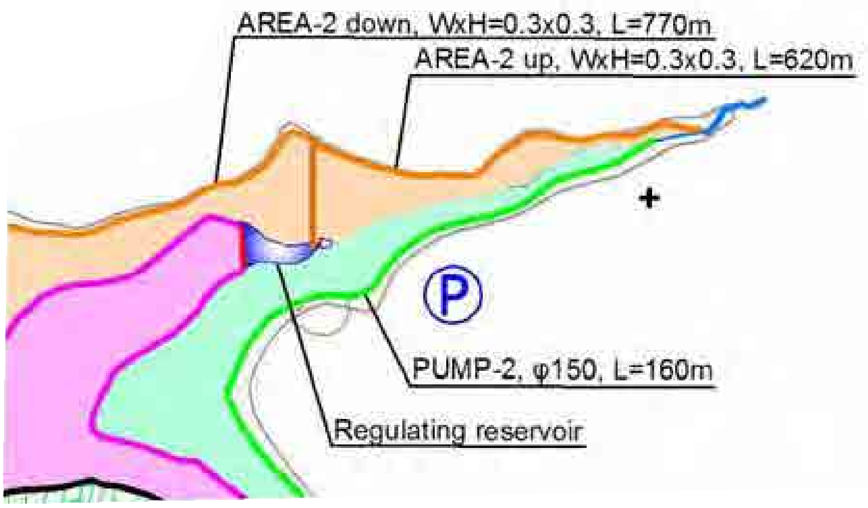
ｉ) Study of capacity

To ensure the required capacity of the regulating reservoir is more than enough capacity to ensure the minute delay from the upstream reaches. Therefore, the required capacity obtained by arrival time × flow rate calculations. In addition, capacity plan is pond digging depth of about 1 ~ 3 m.

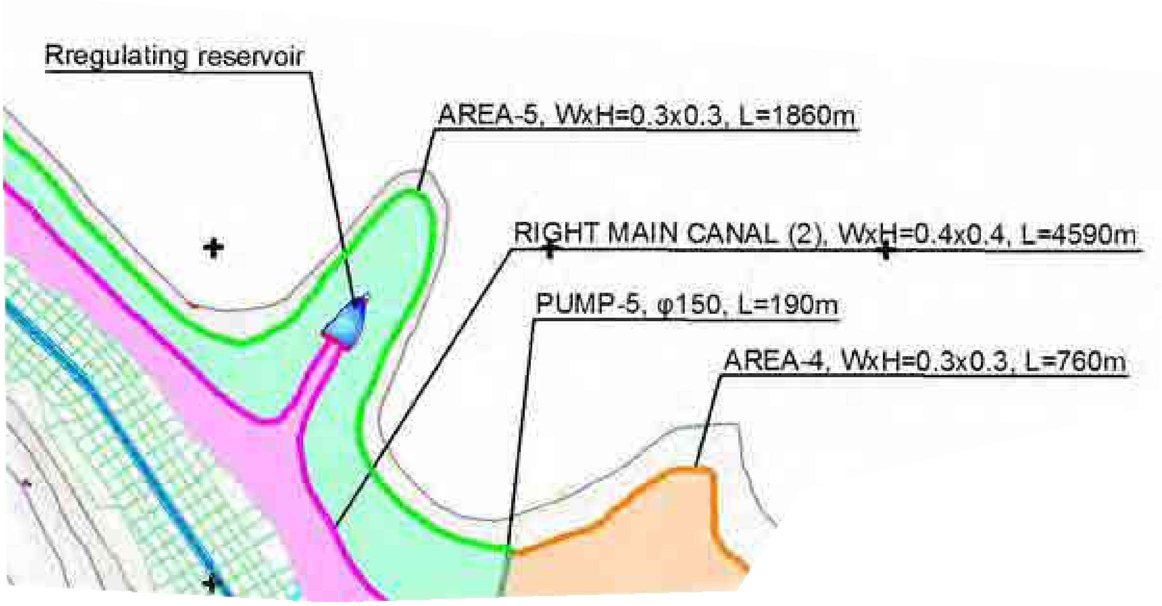
Table 4-1-2-23 Capacity of regulation reservoir

	Zone	Discharge (m^3/s)	Velocity (m/s)	Length (m)	Reaching time (sec)	Volume (m^3)	Required capacity (m^3)	Capacity plan (m^3)
Dried up valley	1	0.111	0.530	1,630	3,075	644		
	2	0.105	0.523	470	899	181	825	< 4,000 OK
Valley of the right bank downstream	3	0.099	0.516	420	814	157		
	4	0.095	0.510	600	1,176	218		
	5	0.088	0.501	490	978	172		
	6	0.083	0.494	320	648	109		
	7	0.077	0.484	200	413	66		
	8	0.072	0.476	510	1,071	162		
	9	0.066	0.466	910	1,953	277	1,161	< 3,000 OK
Valley of the left bank	12	0.054	0.444	1,050	2,365	289		
	13	0.049	0.433	510	1,178	134		
	14	0.043	0.418	940	2,249	232		
	15	0.038	0.405	397	980	92	747	< 800 OK

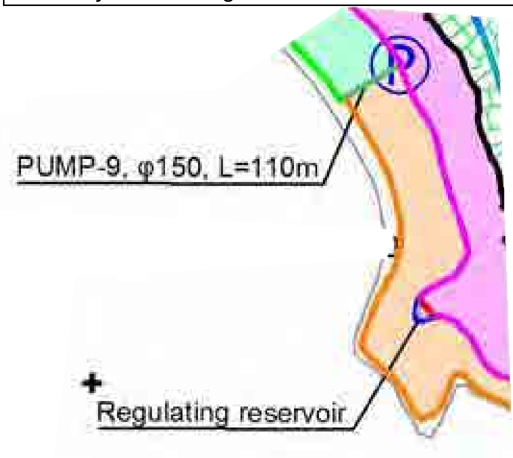
Auxiliary water supply facilities and the capacity of the regulating reservoir was planned from the above table is made sufficiently secure.



Dried valley



Valley of the right bank downstream



Valley of the left bank

Fig. 4-1-2-44 Location map of regulation reservoir

(9) Improvement plan of the downstream paddy fields

(a) Existing conditions

ⅰ) Supply and demand balance of the irrigation water

According to the interview survey result conducted to the farmers who cultivate paddy fields in the Ngoma-22 valley, a half of the farmers are satisfied with the existing water supply conditions and the other half feel the water supply is not enough. The latter farmers also answered that the period was July, August, January and February when they felt the water supply was not enough. The survey results shall be summarized that a half of farmers think the shortage of irrigation water occurs in July, August, January and February when the rice nursery season and the dry season overlap together.

ⅱ) Intake method／irrigation method

In the upstream region where paddy fields extend in a row on the both river bank, the river water is led directly into the paddy field through the intake mouth that is set by cutting off the river bank about 0.5m to 1.0m wide. At this time, the river water level is lifted up by a barricade of twigs stuck into the river bed and an armful of grass caught on the twigs at the downstream of this intake mouth. The irrigation water taken into the paddy field is led through the water way at the foot of the ridge and to the adjacent paddy field through a cut-off about 0.2m wide that is set on the ridge; and this way of irrigation is called “the ridge-through method”. The ridge-through irrigation is repeated averagely two times; and the irrigation water returns to the river from the end ridge of the third paddy field. The inner water way at the foot of the ridge is one of the characteristics in this area; and paddy rice is not planted in this water way.

In the region where the plural rows of paddy fields appear, the intake method composed of a weir and an earthen canal that lead the irrigation water toward the hill side appears. As for the weirs, their scales become larger together with their locations becoming downstream; but there are no permanent ones. And an earthen canal does not keep its shape, i.e. sometimes changes into inner water way and sometimes come out of the paddy field and becomes an earthen canal. The irrigation water taken into paddy fields is delivered to other paddy fields case by case; sometimes it is led by the ridge-through irrigation method next by next and sometimes it is led from the outer earthen canal, but at the last the irrigation water turns back to the river after passing through three or four or several paddy fields.

ⅲ) Conditions in the paddy fields

1) Paddy field bed and its percolation

The paddy fields were developed on the marshland so that its bed is composed of the alluvial deposits and is soft. The softness level is not so high because it is possible to walk in the paddy field with not so much effort but low enough for the wooden boards about 1.5cm thick to be pushed into by hand about 60cm deep at the time of the field percolation test after the ridge improvement.

The soil of the paddy field bed is the silty clay with dark grayish brown to light grayish brown; and its percolation is estimated to be 20.1mm/day to 7.2mm/day based on the field percolation tests and considered to be low enough when comparing with the average value in Japan as shown to the right.

Table 4-1-2-24 Unit volume of water for different soil texture classification

Soil series classification				Water requirement average rate (mm/day)	
Wet and dry classification	Soil texture		Number of soil series		
Ill-drained paffy field	Strength clay		1, 2, 10, 20, 30, 31	11	14
	Clay		3, 11, 21, 32,33	12	
	Loam		4, 12,22,34,35	14	
	Sandy soil		5,13,36,37	17	
Semi ill-draied paddy field	Strength clay		40, 41	14	16
	Clay		42	14	
	Loam		43	17	
	Sandy soil		44	19	
Well-drained paddy field	Strength clay		60, 80, 81	17	26
	Clay		50, 51, 61, 82	19	
	Loam		52, 53, 62, 63, 83	23	
	Sandy soil		54, 64, 65, 84	26	
	Black soil	Clay	70, 72	21	
		Loam	71, 73	29	
	Gravel and gravelly loam	Sat gravelly	93, 95	32	
		Sat gravel	90, 91	34	
		All layers of sand and gravel	92, 94	38	

(Source; Handbook of Agricultural Engineering, Japan)

2) Ridges

Ridges are made of the mixture of grass and clayey silt. The strength of the clayey silt is very low and it can't exist as a solid block due to its semi-liquid like condition when it meets water; but grass leaves prevent such deformation from appearing, where the ridges stand like walls strengthened by fibers, and it is a surprise to see ridges about 20cm wide and 50cm to 60cm high standing on its own. The structure of the ridges is rational as a light weight and strengthened wall on the soft ground, but not adequate as a separate wall to control the water depth in the paddy fields. According to the field percolation tests, about 90mm/day of water level descending was observed that was understood to be caused by the horizontal leakage through ridges.

(b) Necessity of improvement of paddy fields conditions

1) Intake facilities

After the completion of the reservoir, the river flow rate would be reduced to be about 50% of original one. At that time, it would be probable that the existing intake method of the river water being lifted up by a temporary weir does not function. Therefore, it is necessary to construct check gates as a permanent intake facility.

2) Improvement of ridges

Under the existing conditions, it becomes necessary to supply the irrigation water much more than the primary water requirement (ETc + vertical percolation) to maintain the water level in the paddy fields because of the horizontal leakage (average 90mm/day, field percolation test) through ridges being too much compared to the vertical percolation (average 13.6mm/day, field percolation test); and it is impossible to control the irrigation water management effectively in the water supply unit, so that the irrigation water is not delivered equally.

It is necessary to reduce the horizontal leakage through ridges as the reduction of horizontal leakage through ridges to less than 5mm/day would decrease the water supply to the paddy fields much, would make it possible not only to decrease the river flow rate much at the dam site for the precedent water supply to the dry fields but also to actualize the efficient and stable water supply/distribution to the paddy fields.

3) Canals

Under the existing conditions, the earthen canals that are constructed toward the hill side or along the hill foot for the intake purpose of the irrigation water in case of the plural rows of paddy fields appearing on the both river bank are not complete in the cross-sectional shape and the longitudinal gradation. It is necessary to provide the lined canals with less loss of water, higher water conveyance capacity and high workability in maintenance.

(c) Improvement plan of the paddy fields

1) Intake facilities

Such check gate as shown below shall be installed.

In addition, one of the subjects in the next stage would be how to place a heavy structure on the soft foundation, to apply piles to its foundation or not.

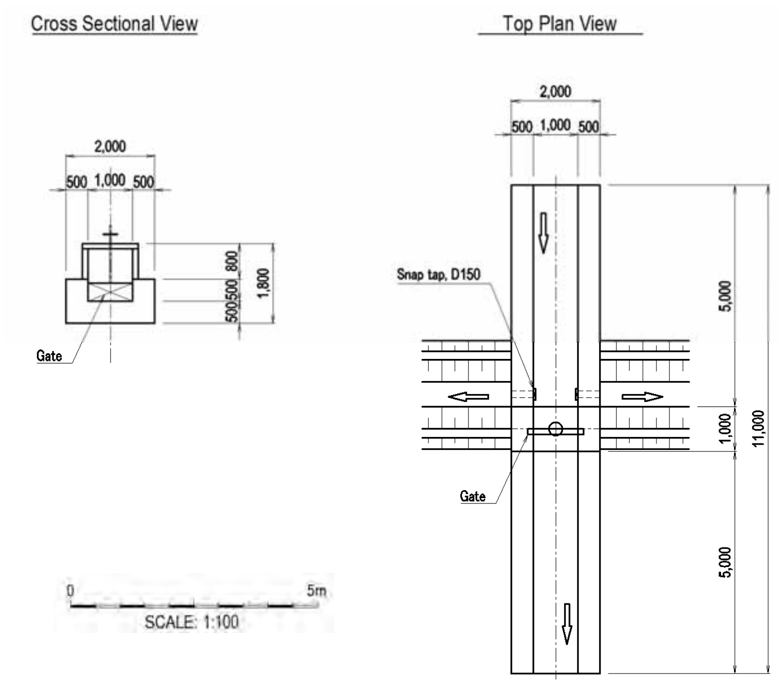


Figure 4-1-2-45 Weir plan

2) Improvement of ridge

It is not adequate to replace the existing ridge with an improved one because it is impossible to carry out the compaction work of soils on the soft foundation and is very difficult to remove the soft foundation and carry out the compaction work of soils while draining the ground water from the view point of construction works' scale and the environmental destruction by the construction works. The problem is the highly pervious condition of ridges, so that the cutoff wall method shall be applied to decrease the leakage quantity through ridges. This cutoff wall method is composed of the impervious wall/walls stuck into the foundation along the ridge at one side or at both sides. The advantage of this method is to

Water-stop polyethylene board

reduce the leakage through the ridge's foundation by the effect of penetrated walls. As the wall materials, there are many kinds, but the water-stop polyethylene board popular in Japanese market shall be suitable considering the durability and the economical conditions, i.e. high price of wood in Rwanda.

3) Canals

Considering less loss of water, higher water conveyance capacity and high workability in maintenance, such canals as shown below, lined with wet masonry, shall be installed. In addition, the subjects in the next stage would be as follows.

- To formulate the canal system
- To systematize the paddy fields, canal systems and the check gates
- How to improve the existing canal conditions, where canals repeat to go into the paddy fields and come out of the paddy fields, under consideration of land problems for the canal construction.

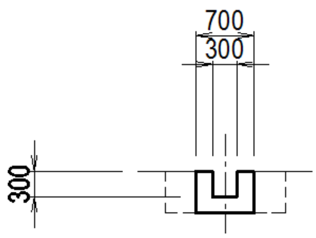


Figure 4-1-2-46 Typical section of irrigation canal

4-1-3. Execution scheme and cost estimation

(1) Construction quantity

Table 4-1-3-1 Construction quantity

Description	Unit	i) Temporary work and general work			ii) Dam body			Total
		Road maintenance and improvement of dam site	Temporary for dam	General temporary construction	Main body	Slope blanket	Horizontal blanket	
Protection retaining wall of excavation slope	m	1000.0						1,000.0
Drain development (triple soil-cement lining)	m	2500.0						2,500.0
Roadbed development (recompression of cut-and-cove	m^3	4000.0						4,000.0
Subbase development (cement improved soil)	m^3	1600.0						1,600.0
Paving gravel	m^3	3200.0						3,200.0
Vegetation of slope protection	m^2	4000.0			2943.0			6,943.0
Dewatering (temporary coffering)	unit		1					1
Excavation of connecting canal of bottom outlet	m^3		100.0					100.0
Temporary road	m		1,000.0					1,000.0
Preparation of site	unit			1				1
Site office construction	unit			1				1
Field test room	unit			1				1
Clearing and grubbing, deforestation	m^2			30,000.0				30,000.0
Excavation	m^3				11,175.0	14,611.0	4,871.0	30,657.0
River bed drain, Intercepter	m^3				1,285.0			1,285.0
Foot of slope	m^3				30.0			30.0
Riprap/ filter	m^3				1,211.0	1,854.0		3,065.0
Banking	m^3				48,721.0	29,221.0	8,522.0	86,464.0
Protection crest (soil-cement)	m^3				295.0	343.0		638.0

Description	Unit	iii) Spillway						Total
		Guide portion	Intake portion	Connecting canal portion	Chute portion	Stilling basin portion	wasteway portion	
Masonry wall	m^3	154.6						154.6
Earth blanket	m^3	47.0						47.0
Riprap filter	m^3	56.0						56.0
Excavation	m^3		72.0	336.0	401.0	40.0		849.0
back-filling	m^3		18.0	134.0	131.0	26.0		309.0
Reinforced concrete	m^3		16.6	50.0	63.0	13.04		142.64
Vegetation of slope protection	m^2		5.0	60.0	100.0			165.0
back-filling	m^3						145.0	145.0
Bank protection (wet stone masonry)	m^2						67.0	67.0
Bottom protection (wet stone masonry)	m^3						18.0	18.0

Description	Unit	iv) Intake facilities						Total
		(e-1) Intake Tower	(e-2) Bottom Outlet	(e-3) Outlet Valve Chanber				
Rainforced concrete								
including formwork	m^3	218	216	138				572
Steel pipe								
φ800	m		80					80
Needle type valve								
500mm	piece			1				1
300mm	piece			1				1
Butterfly type valve								
500mm	piece			1				1
300mm	piece			3				3

Description	Unit	V） Irrigation facilities							Total
		(f-1) Pipe Line	(f-2) H0.60xB0.60	(f-3) H0.50xB0.50	(f-4) H0.40xB0.40	(f-5) H0.30xB0.30	(f-6) Weir(1/2)	(f-7) Weir(2/2)	
HDPE									
φ500	m	50							50
φ300	m	80							80
φ150	m	2,450							2,450
Pump	unit	17							17
Secondry canal									
HDPE φ90	m	36,000							36,000
Water tap	unit	1,440							1,440
Earth work									
Excavation work	m^3		3,618	7,706	2,133	7,246	726	8,237	29,666
Backfilling work	m^3		2,234	4,871	1,377	4,788	242	4,233	17,745
Structuer									
Wet masonry	m^3		1,170	2,763	864	3,364	33	2,974	11,168
Gate	unit						22		22
Snap tap	unit						44		44
Levee borad	m							35,000	35,000

(2) Approximate construction cost

Table 4-1-3-2 Approximate construction cost

Description	Unit	Quantity	Unit Cost (RWF)	Cost (RWF)	Remarks
ⅰ) Temporary work and general work	ls	1.0		467,485,000	
ⅱ) Dam body	ls	1.0		1,099,675,600	
ⅲ) Spillway	ls	1.0		67,042,000	
ⅳ) Intake facilities	ls	1.0		266,256,000	
ⅴ) Irrigation facilities	ls	1.0		2,315,325,000	
ⅵ) Total			RWF	4,215,783,600	indirect construction cost included
			US$	6,968,237	1 US$=605 RWF
			Yen	557,458,988	1 US$=80 Yen

(3) Execution scheme

(a) Construction method

ⅰ) Temporary works

[Rehabilitation of the existing road]

The wide road has constructed by manpower on the left bank slope of the hill, but cars can not go to the dam site due to the partially soft conditions of the road surface during or immediately after the rainfall. In addition, the cut slopes are not stable and collapses occur repeatedly and gully erosions proceed at the time of heavy rainfall; and these are the source of murky waters. To improve these conditions, rehabilitation works shall be done that are the provisions of gravel pavement to the road surface, slope protection works to the cut slope, the drainage ditch and the planting works onto the embankment surface.

[Temporary road]

The borrow area for the embankment materials shall be opened on the gentle slope of the upstream hill and the gentle slope toe of the right bank hill. Then the temporary road for conveyance of embankment materials between the dam construction site and these borrow areas shall become necessary. And considering the ground condition in the river bed area to be soft, the ground improvement work by mixing cement powder shall be executed. The road surface shall be protected by the gravel pavement also.

[Dewatering]

The drainage channel connected to the in-let mouth of the intake tower shall be provided as a part of intake structures. The river water shall be led onto this drainage channel during the construction period.

ⅱ) Construction of intake facilities

The intake structure is composed of, from the upstream, the drainage channel, the intake tower, the bottom out-let and diversion facilities. These are the first structures to be constructed as they are provided under the embankment on the river bed foundation. The bottom out-let shall be constructed at the toe of the right bank slope of the hill so that the ground water shall seep out along the slope toe, which shall be treated by the drainage earthen channel excavated apart enough from the bottom out-let foundation.

ⅲ) Dam construction

The construction works proceed in order, at first the foundation excavation, then the embankment of coffer dam, the embankment of horizontal blanket, the embankment of left and right bank slope blanket, and the dam embankment. The embankment works of these slope blankets and the dam shall be conducted simultaneously. The total embankment volume of these is 86,500m^3, which shall be finished within about 5 months under each one set of heavy equipments arrangement on the dam and the slope blankets.

Compaction capacity；Q=(V×W×D×E)／N

Here

V；velocity of the compaction machine V=3.5km/hr=3,500m/hr

W；effective width of compaction work per one time W=1.2m

D；finish thickness D=0.2m

E；work efficiency E=0.55

N；passing time of the compaction machine N=8 回

Q=(3,500×1.2×0.2×.55)／8=58 m3/hr

Provided working time per one day: 6 hours, then capacity per day; Qd=58×6=348 m3/day

Capacity by 2 parties of heavy equipments;

Qd’=696 m3/day

Working days needed for 86,500m3 of compaction; 86,500m3 ／ 696m3/day=124 day

Conversion to months;

124 day／26 day/month = 4.8months

ⅳ) Spillway construction

The spillway construction can be carried out together with the dam embankment works. The construction period is estimated approximately to be 3 months.

ⅴ) Construction of irrigation facilities

The main canal construction shall be divided into 5 sections. In each section, the works shall be carried out simultaneously from the upstream end and the downstream end. Provided the capacity of the work execution per day is 15m, the construction period shall be about 4 months. The installation of solar pump system and other related works shall be done together with the main canal construction works.

(b) Execution Schedule

Table 4-1-3-3 Execution Schedule

Month / Item	1	2	3	4	5	6	7	8	9	10	11	12
Rehabilittion of existing road												
Site preparation												
Site office												
Site Laoratory												
Cut down and cleaning												
Temporary road												
Intake structures												
Foundation excavation												
Coffer dam												
Hoizontal blanket												
Slope blanket												
Dam embankment												
Riprap												
Crest protection work												
Slope planting works												
Spillway construction												
Main canal construction												
Secondary canal construction												
Installation of solar pump system												
Tertiary canal construction												
others												
Site cleaning												

(Note)
In case of the construction works for land-husbandry being done by Rwandan side, the works must be finished till the start of dam construction.

4-2. Cropping plan

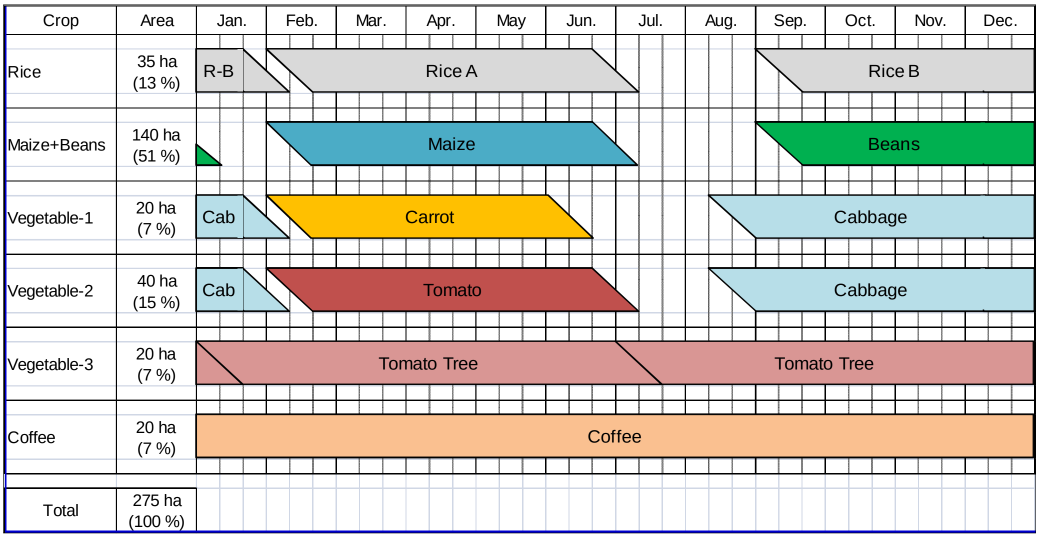
4-2-1. Basic principle

The farming plan of this Project is provided based on the basic principles of the following:

- Marketing : Planting crop are higher irrigation effect and profitable.
- Productivity: readily introduced crop should be selected taking current technical level on cultivation into consideration.
- Food security: cropping of maize is recommended as measures of procuring food supply in cases that food supply is influenced in this area, also as an efficient cash crop with high marketability.

Cropping plan has been formulated based firstly upon the basic principles mentioned above and secondly in consultation with Remera sector agricultural office. Cropping rates in this plan comprise Rice: 35ha（13%）, Maize+Beans: 140ha（ 51%）, Vegetable 1: 20ha（ 7%）, Vegetable 2: 40ha（15%）, Vegetable 3: 20ha（7%）, Coffee: 20ha（7%）. The cropping plan is illustrated in (Table 4-2-1-1).

Table 4-2-1-1 Cropping Plan



The reasons of selecting crops for individual land uses are given in the following:

(1) Rice

- Marketability

Rwandese Government recommends rice cultivation as a national policy. Rice is not self-sufficient same as Maize, Wheat. It is possible to sell at stable price.

- Productivity

According to the questionnaire in 61 households, 56 farmers cultivate rice and all do it by double cropping. 13 farmers have measured areas of their paddy fields, paddy yield is 4t/ha on the average (Paddy base).

・The present state of cultivation and farmers' techniques

Currently 35ha is cultivated under rice. Three varieties have been cultivated, Pekin, Indobanure and Kigori. 2 times of fertilizer application are practiced per cultivation after weeding. Considering current situation, though area expansion cannot be anticipated, improvement in the efficiency of fertilization through land consolidation and yield increase by the optimization of water management can be expected.

・The validity of the plan

Currently Rice has cultivated twice in Season-A and Season-B. RiceB has cultivated in Season-A RiceA has cultivated Season-B Considering current situation, Cropping plan is reasonable.

(2) Maize + Beans

・Marketability

Maize can be marketed during late June ~early July. Higher benefit is gained from stable and high-yielding cultivation by irrigation and provision of relevant system that enables timely marketing by utilizing post-harvesting storage facility.

・Productivity

This pattern aims at maintaining and promoting productivity by employing coupled rotation system of gramineae crop (Maize)→ legumineae crop（Beans）. Since leguminous crops have ability of fixing air nitrogen, and incorporating these into rotation system leads to an improved plant-nutritional balance in cultivated soils thereby enhancing yield and quality of the harvested maize. St the same time, such a rotation system can prevent the hazard problem of declining yields and quality induced by continuous mono-cropping. Introduction of this cropping practice of "Maize +Beans" is expected in the area where sorghum is currently cultivated. Sorghum has low yield response to irrigation while maize can easily and highly realize the effect of maize

・The present state of cultivation and farmers' techniques

Cropped area under maize is estimated at 5% of current area of agricultural land use. Out of 61 households sampled in the questionnaire study, 11 households cultivated maize, of which 7 households knew their acreage under maize. Yield of maize harvested by these 7 households ranges 0.12t/ha-1.1t/ha, averaged at a low level of 0.5t/ha. Farm households with low maize yield employed rotations with maize-sorghum, or sorghum-maize, namely the combination of gramineae - gramineae. On the other hand, those with higher maize yield followed rotation system of beans-maize, namely legumineae – gramineae. Only a household among these 11 practiced fertilizer application. Such yield levels per ha reported here remains much lower than as compared with the world average maize yield in 1999, namely 4.4t/ha. For further improving maize yield it seems necessary to enhance soil fertility by a mixed cropping with green manure leguminous crop, mucuna, alteration of cropping pattern with pertinent rotation system (for example cropping maize after cropping leguminous one), soil improvement with compost etc, optimization of planting density to rectify current tendency of too dense cropping (the interval width of cropping ridge is made at 70cm, that between stands adjusted at 30cm), and fertilizer application (NPK-80-80-80kg/ha).

・The validity of the plan

Maize: Currently Maize has cultivated in Season-A. This cropping plan, Maize has cultivated in Season-B. Irrigation for maize cultivation in dry season is carried out one for sowing time. and several times for growing period.

Beans: Currently Beans has cultivated in Season-A, Season-B. This cropping plan, Beans has cultivated in Season-A. Irrigation for Beans cultivation in dry season is carried out one for sowing time. and several times for growing period The supporting service for irrigation (water management) .tecnic and agricultureextension should strengthened.

(3) Vegetable 1 : (Carrot +Cabbage), Vegetable 2 : (Tomato+Cabbage)

・<u>Marketability</u>

Cabbage : by adjusting harvesting season to February, marketing in the period of bullish market price can be realized. There is a possibility to convert cropping of cabbage in lowland after rice is harvested. Tomato and carrot : Consumer’s preference of these vegetables is high, so the unit price is stable all the year around.

・<u>Productivity</u>

Cabbage and tomato are currently produced by farmers in the scheduled beneficiary are, though their acreages are very small (Picture-1 and 2). Needs of farmers for these vegetables are high. As regards cultivation techniques, mixed cropping as observe in Picture-1 is not desirable. Tomato plant has a photo- taxis (preferring sunlight), so cultivation under full sunshine is desirable. Therefore, mixed cropping with banana may lead to cropping in the shade giving detrimental effect on plant development. The mixed cropping may stem from farmer’s wisdom to utilize land intensively, but as far as tomato cultivation is concerned, sunny plots are more desirable. The plant enters into flowering stage, partly blossoming yellow flowers, perhaps a variety of mini-tomato with low plant height. Cabbage has already entered into head formation stage, without any cultivation problem up till now. Information has been obtained that cultivation of carrot is practiced in Ngoma area.

Tomato

Cabbage

・<u>The validity of the plan</u>

Cabbage: Currently Cabbage has cultivated in Season-A-B. sowing time on November, harvested on April. This cropping plan, Cabbage has cultivated in Season-A. Irrigation for Cabbage cultivation in dry season is carried out one for sowing time. and several times for growing period. The supporting service for irrigation (water management) and agriculture extension should strengthened.

Carrot: Currently Carrot has cultivated in Season-A. This cropping plan, Carrot has cultivated in Season-B. Irrigation for Carrot cultivation in dry season is carried out one for sowing time. and several times for growing period The supporting service for irrigation (water management) . and agriculture extension should strengthened.

Tomato: Currently Tomato has cultivated in Season-A-B. This cropping plan, Tomato has cultivated in Season-B. Irrigation for Tomato cultivation in dry season is carried out one for sowing time. and several times for growing period The supporting service for irrigation (water management) and agriculture extension should strengthened.

(4) Vegetable 3 : Tree Tomato

・Marketability

This crop has high preference and the price is kept stable throughout the year. It is marketed as raw food, but processing into juice and jam is also easy with high commodity value. Agricultural officer in Rulenge sector also recommends the cultivation.

・Productivity

After transplanting it bears fruits resembling to tomato fruit, harvest is possible for 4 ~ 5 years after planting. This is popularly cultivated in Rwanda

・Current state of cultivation and technical level

This is planted in a village 1km away from the planned construction site of Ngoma Dam. No problem is considered to be raise from its cultivation.

・The validity of the plan

Currently Tree Tomato is common fruit in study area. Considering current situation, cropping plan is reasonable.

Fruit of Tree Tomato

Tree Tomato

4-2-2. Site of cultivation

Candidate site of irrigation is located in a river valley surrounded by three hilly areas, namely, Remera sector and Gikomero Village (elevation: 1,525m) at the north, Remera sector、Gitobe Village（elevation: 1,675m）at the east、Rulenge sector（elevation: 1,500m）at he south, extending 3 km to southeast from the scheduled dam site with a width of 60-200m. The width of the site is gradually broadened from the upstream side, (Fig.4-2-2-1:A), once narrowed at mid-stream (Fig. B) and again expanded (Fig.C). Prior to the selection of cropping site, soil survey was conducted at these three points. (Table 4-2-2-1).

Upstream site (Map:A slope gradient 5° date of the study April 25th plot of preceding crop: sweet potato)

Plant root distributed as deep as 100 cm including I and II layers. From the observed state, effective root sphere is estimated at 100cm.

Mid-stream site (Map:B slope gradient 10° date of the study April 1st parcel of sorghum)

Plant roots are occupying as deep as 37 cm where Ⅰ layer lies. From this observation, effective root sphere is estimated at 37cm.

Downstream site (Map:C flat plain, precedent crop: Beans + Maize)

Plant root distributed as deep as 50 cm including I and II layers. From the observed state, root sphere

Table 4-2-2-1 Result of soilprofile

Upper basin (Map A：inclined at angle of 5 ° ：25th of April：preceding crop "Sweet Potato")													
Stratigraph	Depth(cm)	Compactness(mm)	Soil color	Soil Texture	Stone Area	Stone Shape	Stone Size	Plasticity	Adhesiveness	Porosity	Porosity (diameter)	Dry and Wet (soil)	Root
I	40	4.0	blackish brown (7.5YR 3/2)	loam	Exist	columnar forms	small (5%)	Medium	Medium	Rich	Medium	Wet	Rich
II	40	13.8	dull dark reddish-brown (5YR 4/3)	clay loam	Exist	columnar forms	small (6%)	Medium	Medium	Rich	Medium	Wet	Rich
III	＜80	17.1	dull dark reddish-brown (5YR 4/4)	clay loam	-	-	-	Medium	Medium	Rich	Very small	Wet	Include
Middle basin (Map B：inclined at angle of 10 ° ：1st of April： "Sorghum")													
Stratigraph	Depth(cm)	Compactness(mm)	Soil color	Soil Texture	Stone Area	Stone Shape	Stone Size	Plasticity	Adhesiveness	Porosity	Porosity (diameter)	Dry and Wet (soil)	Root
I	37	14.0	dull dark reddish-brown (5YR 4/4)	Silt loam soil	-	-	-	Weak	Weak	Rich	Medium	Half Wet	Rich
II	32	25.0	light brown (7.5YR 5/6)	clay loam	Rich	columnar forms, half horn-shaped	small (D：5%)	Medium	Strong	Include	Very small	Wet	-
III	＜69	28.0	light dark reddish-brown (5YR 5/6)	light clay	Rich	columnar forms	small (D：5%)	Strong	Strong	Nuavailable	Very small	Half Wet	-
Lower basin (Map C：flatland：25th of April：preceding crop "Beans+Maize")													
Stratigraph	Depth(cm)	Compactness(mm)	Soil color	Soil Texture	Stone Area	Stone Shape	Stone Size	Plasticity	Adhesiveness	Porosity	Porosity (diameter)	Dry and Wet (soil)	Root
I	22	8.4	dark reddish brown (2.5YR 3/4)	clay loam	Rich	horn-shaped	small (D：5%)	Weak	Medium	Rich	Medium	Wet	Rich
II	28	19.1	greyish brown (5YR 4/2)	clay loam	Rich	horn-shaped	Include (D：5-10%)	Medium	Medium	Include	Medium	Wet	Include
III	＜50	21.7	light dark reddish-brown (5YR 4/4)	clay loam	Rich	horn-shaped	Include (D：5-10%)	Medium	Medium	Nuavailable	Very small	Wet	-

Note of the table)

Division of soil layers: Soil profile comprises number of soil layers with different color/ hardness / soil texture. They are named from the top soil Ist layer, IInd layer, IIIrd layer etc. and the soil profile is described by layer.

Soil hardness: This is measured by soil hardness (compactness) meter. This value serves as an indicator of soil compactness in which plant roots develop.

Soil color: Soils with dark/ blackish hue are generally rich in humus, on the other hand, those with reddish hue are oxidative but those with bluish/ greenish color are reductive.

Soil textures: This means soil particle size composition except gravel or art of fine particle sizes. They are indicated by the weight ratio of sand, silt (fine sand) and clay.

Gravel observed in the soil profile: They are classified into identified (5% or less), contained (5-10%), rich (10-20%) and exceedingly rich (20-50%).

Plasticity and adhesiveness are the items related to the readiness of cultivation.

Plasticity: none (wetted soil cannot be made a bar even if it were puddle with finger tips), weak (it can be managed to process into a bar), medium (it can be made into a bar/ string with a diameter of 2mm), strong (it can be extended into a bar/string with a diameter of 1mm).

Adhesiveness: none (when wetted soil is paddled with finger tips, the soil does not adhere to them, weak (soil adheres to one of the paddled finger, medium (it adheres to both fingers), strong (it strongly adheres to them, when two paddling fingers begin to separate, the paddled soil stretches longer).

Soil porosity is an important soil character in relation to water permeability in soil, elongation of roots etc, it is measured by naked eye observation by breaking soil clods.

Quantity of soil pore: none, observable (1~3 pores/ 2.5cm^2), contained (4 -14 pores/ 2.5cm^2), rich (15 or more)

pore(diameter) : fine (0.1-0.5 ㎜) , small (0.5-2mm) , medium (2-5mm), large (5mm or larger)

Humidity of soil: judged by feeling of hand when gripping soil clods with a palm. Dry (when gripping soil clods by palm, no humidity remain on the surface of gripped palm), semi-moist (when gripping soil clods by palm, some feeling of wetness is felt), moist (wetness remains on the gripped palm surface, when strongly crash soil clod between thumb and index finger water oozes out).

According to a standard of diagnosing soil physical characteristics for vegetable cultivation, effective root sphere for cultivation is termed as 40-50cm or deeper for fruit vegetables, accompanied with the range of proper hardness of less than 20mm. In the case of leafy ones the value is equal to or deeper than 30cm with the same hardness, or less than 20mm. On the inclined plot at the point B with slope gradient 10°, the effective root sphere has the depth of 37cm. because upland plots with the slope gradient 0-25° are distributed in the candidate beneficiary area, it is conceivable that the effective root sphere becomes shallower than this value on the inclined upland plots with their slope steeper than 10°. To cope with this, it is required to make the effective root sphere thicker for vegetable cultivation. For this purpose, terracing of the plots should be provided for increasing the depth of the effective root sphere. On the other hand, delicate measures are also required in a way that in providing terraces, attention should be paid not to strip and waste top soil and if top soil is stripped it has to be kept in other deposit yard(s) and after the terracing is completed the deposited soil should be return over the surface of the terraces.

Keeping what is mentioned above in mind, it was planned that vegetable plots are selected beside rice fields where soils with deeper effective root sphere is distributed, maize plots of maize that is a deep-rooted crop are placed on the second step of sloped area and the plots of coffee as an orchard crop are placed on the third step (Fig.4-2-2-1)。

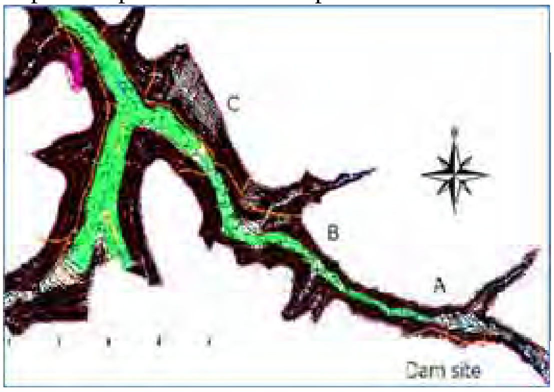


Fig.4-2-2-1 Location Map of soilprofile

Picture-5. Soil profile in upstream

Picture-6. Soil profile in middle stream

Picture-7. Soil profile in down stream

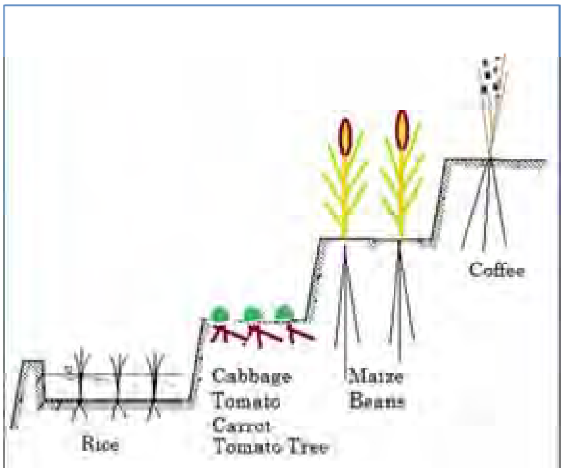


Fig. 4-2-2-2 Place to plant

4-3-3. Characteristics of each crop

(1) Rice/gramineae

This specie belongs to aquatic plants. Culture under submerged condition has such characteristics as nutritional supply contained/ dissolved in water, free from continuous mono-culture hazard by the action that water leaches out harmful substances in soils etc. Besides, rice field plays secondary role of recharging groundwater by percolated/ infiltrated water. Rice is placed as a recommended crop in Rwanda. Also, it is ranked as a cash crop in this Project area (Table 4-2-3-1).

(2) Maize＋Beans

・Maize（gramineae）

This specie belongs to gramineae. Cultural characteristics include low fertilizer requirement but high yielding, high-temperature crop but broader adaptability, broader variation found in female cob and content of seed grain leading to larger diversity in its utilization and heterogamous property. It has a great advantage as a rotation crop component on upland/ horticultural cropping system that is a typical character of gramineae crops. This specie is also ranked as one of recommended crops in Rwanda. Referring to market price of rice in 2011, unit price kept a high level of 200 RWF per kg in last September, thus well-planned sale is possible if storage facility is fully available.

・Beans（leguminous crop）

Beans plays important role as crops for maintaining and promoting soil fertility often utilized post-planting rotation crops after harvesting maize, a gramineae crop. In this Project area, self-consumption rate of pulses account for a high rate, 42% of the production (Table 4-2-3-1).

(3) Vegetable 1（Carrot+Cabbage）, Vegetable 2（Tomato+Cabbage）

・Cabbage（cruciferae）

At present, cabbage is cultivated in very small scale beside lowland rice field in the scheduled dam site. Farmers have an earnest desire to cultivate this crop (according to the result of preparatory study in 2009). As the optimum growth atmospheric temperature is 20℃, this area really suits its cultivation. Market price recorded in last year indicated the market price of cabbage in last April~ May reached a high level of 150Rwf/ kg.. Therefore, it is planned to compose cropping pattern so that cabbage can be marketed in this period. If profitability of cabbage can be elevated surpassing that of rice double cropping, possibility will arise from the introduction of cabbage cropping after harvesting rice.

・Tomato（Solanaceae）

Plant of tomato can recover from moisture shortage soon after watering even though it wilts to considerable extent when soil moisture approaches permanent wilting point and can restore vigorous growth again. It is well-known that the state of root development/ distribution varies with irrigation, roots are densely developed near the ground surface in the case of abundantly irrigated plots with special ly higher distribution of hairy roots and lateral development, whereas in drier plots roots do not much distributed in the ground surface. Water saving irrigation can be applied to tomato and high desire is shown by farmers (according to the result of preparatory study in 2009)

・Carrot（Umbelliferae）

Optimum atmospheric temperature for seed germination ranges 15-25℃ while that for growth is 18-21℃. For the root growth soil water content of 70-80% of soil field capacity serves as an optimum, but at less than 30% its growth becomes difficult. The optimum temperature for root coloring ranges 16-21℃. It is said that in carrot cultivation the state of germination may decide 70-80% of its success.

(4) Vegetable 3 System（Tree Tomato）

・Tree Tomato (tamarillo = *Cyphomandra betacca* Sendt.)/ Solanaceae

This plant is a perennial tree called tree tomato. After transplanting it bears sweet fruits and can be harvested for 4-5 after planting.

It is cultivated in Rwanda and sector agricultural officer recommended to adopt this crop.

Table 4-2-3-1 Allocation of products

	Domestic-consumption	Sale
Rice	26%	70%
Sorghum	18%	82%
Maize	35%	65%
Beans	42%	58%
Irish potato	89%	11%

CHAPTER 5 FINANCIAL AND ECONOMIC ANALYSIS

5-1. Premises of financial and economic analysis

Financial and economic analysis aim at comparing project cost-benefits and evaluating development projects in a tangible way. Generally, evaluation by financial analysis gives relevance of the proposed project from the viewpoint of project agency and it is calculated by market prices. On the other hand, economic evaluation is made with economic prices to estimate the effect of the benefits at national and regional levels derived from the project.

The guideline of economic evaluation for LWH (Hill-side Irrigation Program with Land-husbandry, Water Harvesting and Hillside-irrigation) has been provided in Annex 11. Economic analysis of this project will be made in accordance with the contents given in this TOR. This contains a common economic evaluation. Namely, this analysis consists of financial analysis with market prices and economic one with economic prices through the calculation of such indicators as IRR(Internal Rate of Return), B/C(Benefit/Cost Ratio) and NPV(Net Present Value). In this context, the criteria for selecting project sites in LWH has proposed that those sites that have EIRR at the level of 12% or higher should be selected, and this can be considered as the opportunity cost of the capital input into irrigation sector in Rwanda. The economic analysis will be performed under the conditions given below.

5-1-1. Project life (period)

Project life (period) is generally determined by those who analyze the project taking account of the economic life of such physical inputs used for the investment as facility, machinery, equipment, materials etc. and the duration of predictable future outcome of the project. The project period of LWH has been assumed at 50 years. In this economic analysis, the project period is thus assumed at 50 years. At the same time, the economic life of solar electricity generation panels and water pumps is assumed at 20 years. This assumption will lead to a necessity of replacing panels and pumps thereby generating replacing (renewal) cost of these inputs during the project period. Though the implementation period of the project is scheduled for a year, around one year has to be added after the completion of dam construction owing to the necessary water storage test, thus two years are required from the beginning of the construction to the initiation of water use, followed by the generation of the benefit that starts from the third year of the project period. Thus, the initial two years of the project period are termed as the construction period, then the rest 48 years as the beneficial period. It follows that operation and maintenance cost is to be counted from the next year (the 3rd year) of the completion of the construction works.

5-1-2. Conversion factors

For the calculation of the cost of tradable goods, a standard conversion factor (hereinafter referred to as DCF) of 0.95 is to be applied. This value is derived from the statistic records of trade and tariffs of Rwanda. The estimation of SCF is given in (Table 5-1-2-1).[1]

[1] The economic price is to be determined under fully-competitive marketing activities. In real society, the international market is deemed the market closest to fully-competitive. Whereas, market prices of traded goods in a country is judged biased/ distorted from international market prices due to the effect of tariffs etc. Therefore, as indicated in table 2-1-8, SCF is estimated in order to convert from market prices into economic or imaginal ones.

Table 5-1-2-1 Estimation of the standard conversion factor(SCF)

(Unit：million US$)

Item	2009	2010	2011	Average
(1) Import	1246.80	1389.38	1629.90	1422.03
(2) Export	191.00	253.70	387.70	277.47
(3) Import Tax	78.08	97.33	115.78	97.06
(4) Export Tax	0.00	0.00	0.00	0.00
(5) Export Subsidy	0.00	0.00	0.00	0.00
(6)＝(1)＋(2)	1437.80	1643.08	2017.60	1699.49
(7)＝(1)＋(2)＋(3)－(4)＋(5)	1515.88	1740.41	2133.38	1796.56
(8)SCF＝(6)÷(7)	0.95	0.94	0.95	0.95

Data: BNR, Statistical year book, MINEFIN
Import / Export Amount：BNR
Import tax：MINFIN Revenue data
Exchange rate：Rwanda Statistics and Figures in Year 2011

5-1-3. Unit prices used for the project evaluation

Financial prices of agricultural products have been determined by crop-wise price statistic records obtained from MINAGRI (market prices) and those collected through the interviews with farmers (farm-gate ones). Since a presumption has been placed in a way that the assumed and proposed project gives benefits to the beneficial farmers, farm-gate (financial) prices are assumed for the market (financial) ones to be used in the financial analysis. After the project implementation, it can be estimated that the disparity between farm-gate prices and market prices are gradually rectified through the effect by establishing marketing cooperatives etc. Market prices are to be converted into economic prices by applying SCF thereto. The unit prices to be used for project evaluation are listed in (Table 5-1-3-1).

Table 5-1-3-1 List of unit prices to be used for project evaluation (as of April 2012)

Item	Price Unit	Financial Price	Economic Price	Remark
Products				
Sorghum	Rwf/kg	200	190	SCF
Sweet potato	Rwf/kg	60	57	SCF
Cassava	Rwf/kg	50	48	SCF
Rice	Rwf/kg	250	238	SCF
Maize	Rwf/kg	200	190	SCF
Haricot bean	Rwf/kg	330	314	SCF
Banana	Rwf/kg	50	48	SCF
Cabbage	Rwf/kg	130	124	SCF
Tomato	Rwf/kg	300	285	SCF
Carrot	Rwf/kg	450	428	SCF
Tree Tomato	Rwf/kg	850	808	SCF
Coffee (Washed)	Rwf/kg	600	570	SCF
Seeds/Seedlings				
Sorghum	Rwf/kg	180	171	SCF
Sweet potato	Rwf/vine	150	150	non-tradable
Cassava	Rwf/nos	10	9	SCF
Rice	Rwf/kg	500	475	SCF
Maize	Rwf/kg	300	285	SCF
Haricot bean	Rwf/kg	300	285	SCF
Banana	Rwf/kg	300	285	SCF
Cabbage	Rwf/kg	800	760	SCF
Tomato	Rwf/kg	20,000	19,000	SCF
Carrot	Rwf/kg	800	760	SCF
Tree Tomato	Rwf/kg	1,000	950	SCF
Coffee (parchment)	Rwf/seedling	25	24	SCF
Fertilizers			-	
NPK1/	Rwf/kg	480	456	no tariff
DAP2/	Rwf/kg	480	456	no tariff
Urea	Rwf/kg	410	390	no tariff
DSP3/	Rwf/kg	500	475	no tariff
CAN4/	Rwf/kg	400	380	no tariff
Manure	Rwf/kg	5	5	non-tradable
Pesticides			-	
Thiodan	Rwf/liter	11,000	10,450	SCF
Ridomil	Rwf/kg	10,000	9,500	SCF
Dithane	Rwf/kg	1,600	1,520	SCF
Dimethoate	Rwf/liter	6,000	5,700	SCF
Kitazine	Rwf/liter	8,500	8,075	SCF
			-	
Materials			-	
Multing grass	Rwf/kg	500	500	non-tradable
Farm Labor	man-day	800	600	Labor conversion factor

Note: Tools such as hoes, saw, shovels re coneerted by SCF to economic price.
Economic price of local materials is equivalent to market price
Parchment：Washed with water to remove the flash pulp
1/Nitrogen and phosphorous acid and potassium 2/Ammonium phosphate
3/Sodium hydrogenphosphate **4/Calcium nitrate**

5-1-4. Wages of agricultural labor

Because skilled labor is procured in competitive markets, market prices of wage for the skilled labor should nearly be equal to economic ones. On the contrary, since un-skilled labor is available even in un-competitive markets, the price of its wage should be converted into economic ones by multiplying with a labor-conversion factor. Agricultural labor is considered as an un-skilled one. In this economic evaluation, wage level of skilled labor is estimated at 800RWF, and Labor Conversion Factories assumed at 0.6, thus agricultural labor wage is assumed at 480RWF.

5-1-5. Taxes

Because such taxes as Land Tax etc. belong to a kind of transferable cost items, it should be eliminated from economic prices. As to value-added tax (VAT), it is considered in production costs (market prices) but also excluded from economic ones.

5-2. Project cost

As components of the project cost, those of the facility for water source, water conveyance, on-farm irrigation facilities and operation/ maintenance are to be estimated. The project cost is subdivided into two portions, i.e., foreign currency (F/C) and local currency (L/C), where F/C portion is concerted into economic price by applying SCF. The composition of the project cost is shown in (Table 5-2-2-1). The construction period in this project is estimated at one year, while the cost of operation and maintenance is incurred every year after the construction is completed where an average operation/ maintenance cost is accounted.

5-2-1. Rate of physical contingencies

As to contingency costs, physical contingency equivalent to 5% of the project cost is to be assumed for both F/C and L/C portions to prepare for un-foreseeable cost increment arising from alteration of design/ specifications at the initial stage of investment.

5-2-2. Annual allocation of investment for each year during the construction period

Though the construction period of this project is assumed at one year, around 2 years are actually required from the initiation of the construction works to the actual use of the facilities by the beneficiaries on account of carrying out water storage test just after the completion of the dam. However, no allocation of the construction cost is intended during this required period.

Table 5-2-2-1 Project cost

Financial price

Item	Unit	Cost	F/C	L/C
Preparation, Mobilization	L.S.	467,485,000	233,742,500	233,742,500
Dam	L.S.	1,099,675,600	549,837,800	549,837,800
Spillway	L.S.	67,042,000	33,521,000	33,521,000
Outlet Works	L.S.	266,256,000	213,004,800	53,251,200
Irrigation Facirity	L.S.	2,315,325,000	1,157,662,500	1,157,662,500
Base Cost		4,215,783,600	2,187,768,600	2,028,015,000
Rate of physical contingencies	5%	210,789,180	109,388,430	101,400,750
Total	Rwf	4,426,572,780	2,297,157,030	2,129,415,750
(US$) *1)	Us$	7,316,649		
Ha/US$	275Ha	26,606		

*1) US$1.00＝Rwf 605

Economic price

Item	Unit	Cost	F/C	L/C
Preparation, Mobilization	L.S.	455,797,875	222,055,375	233,742,500
Dam	L.S.	1,072,183,710	522,345,910	549,837,800
Spillway	L.S.	65,365,950	31,844,950	33,521,000
Outlet Works	L.S.	255,605,760	202,354,560	53,251,200
Irrigation Facirity	L.S.	2,257,441,875	1,099,779,375	1,157,662,500
Base Cost		4,106,395,170	2,078,380,170	2,028,015,000
Rate of physical contingencies	5%	205,319,759	103,919,009	101,400,750
Total	Rwf	4,311,714,929	103,919,009	101,400,750
(US$) *1)	Us$	7,126,802		
Ha/US$	275Ha	25,916		

*1) US$1.00＝Rwf 605

5-3. Economic benefits of the project

The following two kinds of benefits are considered as tangible economic benefits brought about by the project.

1) Increment of crop yield per unit area (hereinafter referred to as “unit yield”) brought about by stable supply of irrigation water

Unit yield increase by stable supply of irrigation water is determined based on the information obtained from the on-going “Agricultural Productivity Promotion Project in Eastern Province”, and also through the interview to Sector agricultural officer. Besides, actual performance realized by irrigation farming in neighboring countries is referred to for this determination. Unit yield increase and expected production quantities by crop are tabulated in (table 5-3-1). The cropping plan is illustrated in (Table 4-2-1-1).

Table 5-3-1 Unit yield increase and expected crop production quantities

Crop	Production of Unit Yield (Unit：ton/ha)		Beneficial Area (Unit:ha)	Proposed Production (unit:ton)
	Without	With		
Rice	4.0	6.0	70	420
Maize	1.0	5.5	140	770
Beans	0.8	2.5	140	350
Cabbage	8.0	17.0	60	1,020
Tomato	5.0	22.0	40	880
Carrot	3.0	22.0	20	440
Treetomato	2.5	3.5	20	70
Coffee	3.0	4.0	20	80

Source: JICA Study Team

Basis of Yield and Validity of Each Crops

Rice: Proposed yield are future projection of irrigated and technical improve agriculture, technology and are quoted from on-going “Agricultural Productivity Promotion Project in Eastern Province” project

Maize: The world average yield is 4.8ton/ha without irrigation by FAO. Proposed yield are 5.5ton/ha future projection of irrigated and fertilization management by technical improve agriculture,

Beans: The average yield is 3ton/ha in Japan with irrigation.. Proposed yield are 2.5ton/ha future projection of irrigated and fertilization management by technical improve agriculture,

Cabbage: The world average yield is 22ton/ha with irrigation by FAO. Proposed yield are 17ton/ha future projection of irrigated. The average yield is 16ton/ha in Kenya with irrigation.

Tomato: The world average yield is 27ton/ha with irrigation by FAO. Proposed yield are 22ton/ha future projection of irrigated and fertilization management by technical improve agriculture,

Carrot: The world average yield is 23ton/ha with irrigation by FAO. Proposed yield are 22ton/ha future projection of irrigated and fertilization management by technical improve agriculture,

Tree tomato: Proposed yield are 3.5ton/ha future projection of irrigated and fertilization management by technical improve agriculture,

Coffee: Proposed yield are 3.5ton/ha future projection of irrigated and fertilization management by technical improve agriculture,

2) Improved agricultural income through crop conversion owing to the supply of irrigation water (conversion from self-consumed to cash crops)

In the process of estimating project benefits, currently cultivated crop species are deemed as the crops without –poject then net-profits of both current and planned crops are estimated and the difference between these is considered as increased benefit with-project.

Table 5-3-2 Gross benefit, production cost and increased benefit

Crop	Production (unit：ton/ha)		Economic Price (000 Rwf/ton)	Gross Income (Unit000Rwf/ton)		Production Cost (Unit:000Rwf/ton)		Net income (unit:000Rwf/ton)	
	Without	With		Without	With	Without	With	Without	With
Rice	4.0	6.0	250	1,000	1,500	331	491	669	1,009
Maize	1.0	5.5	200	200	1,100	117	146	83	954
Beans	0.8	2.5	330	264	825	196	307	68	518
Cabbage	8.0	17.0	130	1,040	2,210	340	576	700	1,634
Tomato	5.0	22.0	300	1,500	6,600	1,273	1,526	227	5,074
Carrot	3.0	22.0	428	1,284	9,416	622	941	662	8,475
Treetomato	2.5	3.5	850	2,125	2,975	3,514	714	-1,389	2,261
Coffee	3.0	4.0	600	1,800	2,400	1,706	1,514	94	886

Source:JICA Study team

3) As regards cultivated land within the basin of the planned reservoir

Currently, about 10.5ha out of the planned area at full storage (high water level) of 15ha are cultivated. For the cultivated land within the area of the reservoir, duly compensation for land, transfer and cropping is conceivable. As regards compensation for land and transfer, the coping method was not identified in this study. It will be examined in the next EIA. As to cropping compensation, it is evaluated and calculated as a negative benefit.

4) Family labor

Because market prices are used in financial analysis, family labor is not tangibly evaluated in this analysis.

5) Estimated Annual Benefit

Estimated Annual Increment with project is illustrated in (Table 5-3-3)

Table 5-3-3 Estimated annual Increment with project

Year	Cropping Area (ha)	Annual Increment (000Rwf)		Increment /ha (Rwf)	
		Financial Price	Economic Price	Financial Price	Economic Price
1	275	168,874	292,055	614,087	1,062,018
2	275	770,204	541,105	2,800,742	1,967,655
3	275	932,324	639,105	3,390,269	2,324,018
4	275	1,005,414	703,885	3,656,051	2,559,582
5	275	1,005,414	703,885	3,656,051	2,559,582
6	275	1,005,414	703,885	3,656,051	2,559,582
7	275	1,005,414	703,885	3,656,051	2,559,582
8	275	1,005,414	703,885	3,656,051	2,559,582
9	275	1,005,414	703,885	3,656,051	2,559,582
10	275	1,005,414	703,885	3,656,051	2,559,582
11	275	1,005,414	703,885	3,656,051	2,559,582
12	275	1,005,414	703,885	3,656,051	2,559,582
13	275	1,005,414	703,885	3,656,051	2,559,582
14	275	1,005,414	703,885	3,656,051	2,559,582
15	275	1,005,414	703,885	3,656,051	2,559,582
16	275	1,005,414	703,885	3,656,051	2,559,582
17	275	1,005,414	703,885	3,656,051	2,559,582
18	275	1,005,414	703,885	3,656,051	2,559,582
19	275	1,005,414	703,885	3,656,051	2,559,582
20	275	1,005,414	703,885	3,656,051	2,559,582
21	275	1,005,414	703,885	3,656,051	2,559,582
22	275	1,005,414	703,885	3,656,051	2,559,582
23	275	1,005,414	703,885	3,656,051	2,559,582
24	275	1,005,414	703,885	3,656,051	2,559,582
25	275	1,005,414	703,885	3,656,051	2,559,582
26	275	1,005,414	703,885	3,656,051	2,559,582
27	275	1,005,414	703,885	3,656,051	2,559,582
28	275	1,005,414	703,885	3,656,051	2,559,582
29	275	1,005,414	703,885	3,656,051	2,559,582
30	275	1,005,414	703,885	3,656,051	2,559,582
31	275	1,005,414	703,885	3,656,051	2,559,582
32	275	1,005,414	703,885	3,656,051	2,559,582
33	275	1,005,414	703,885	3,656,051	2,559,582
34	275	1,005,414	703,885	3,656,051	2,559,582
35	275	1,005,414	703,885	3,656,051	2,559,582
36	275	1,005,414	703,885	3,656,051	2,559,582
37	275	1,005,414	703,885	3,656,051	2,559,582
38	275	1,005,414	703,885	3,656,051	2,559,582
39	275	1,005,414	703,885	3,656,051	2,559,582
40	275	1,005,414	703,885	3,656,051	2,559,582
41	275	1,005,414	703,885	3,656,051	2,559,582
42	275	1,005,414	703,885	3,656,051	2,559,582
43	275	1,005,414	703,885	3,656,051	2,559,582
44	275	1,005,414	703,885	3,656,051	2,559,582
45	275	1,005,414	703,885	3,656,051	2,559,582
46	275	1,005,414	703,885	3,656,051	2,559,582
47	275	1,005,414	703,885	3,656,051	2,559,582
48	275	1,005,414	703,885	3,656,051	2,559,582
49	275	1,005,414	703,885	3,656,051	2,559,582
50	275	1,005,414	703,885	3,656,051	2,559,582

Source: JICA Study team

5-4. Financial and economic evaluation of the project

Internal rate of return (IRR), investment efficiency or benefit cost ratio (B/C) and net present value (NPV) are calculated by means of the above estimated project cost and benefits. The discount rate of 12% has been applied to the calculation of B/C and NPV. Provided that the economic internal rate of return exceeds the opportunity cost of the investment indicated for LWH, or 12% and that NPV gives a positive value, the additional benefits produced by the project outweighs the additional investment thereof. (Table5-4-1) indicates the result of estimation.

Table 5-4-1 Result of project evaluation

IRR		B/C(i = 12%)1/		NPV(000Rwf) (i = 12%)	
Economic	Financial	Economic	Financial	Economic	Financial
12.1%	15.7%	1.01	1.36	23	1,552

Note:1/:12%of discount ate is charaged on LWH Gaide Line

Source: JICA Study team

5-5. Sensitivity analysis

The sensitivity analysis is provided for quantitatively (and at constant period) analyzing impact to the effect of the project by socio-economic environmental changes surrounding it. This analysis includes 1) in the case that the project cost is increased by 10% from the estimated amount, 2) in the case that the project benefit is decreased by 10% from the estimated amount of benefit, 3) in the case of combined impact by 10% increase of the cost and 10% decrease of the benefit, and further 4) in the case of actual yield levels realized at 10% less than the planned level, and also 5) in the case of realized unit price levels of the crops at 10% less than the planned price levels in terms of the eroding factors of benefit development. (Table 5-5-1) gives the result of the sensitivity analysis on EIRR. Even in the case that the project cost is increased by 10% and that benefit reaches 10% less than the planned level, the values exceed 12% or the opportunity cost of the investment, implying that the economic performance of the proposed project is favorable. The result also suggests that the realized lower yield than the projected level give more grave impact than the case of the realized lower unit prices than the planned levels in terms of the causative factor of discouraging benefits.

Table 5-5-1 Sensitivity analysis on economic internal rate of return(EIRR)(unit:%)

ERR	**Project cost + 10% (a)**	**Benefit - 10% (b)**	**Project cost +10% Benefit -10% (a+b)**	**Yeld Levels of the crops -10%**	**Price Levels of the crops -10%**
12.1	11.1	10.9	10.0	10.4	10.6

Source: JICA Study team

5-6. Benefits predictable in future

The benefits that are tangibly difficult in evaluating in currency value at present, but in future it is predicted that they will be included in the cost-benefit analysis are put in order in the following (table.5-6-1).

Table 5-6-1 Benefits predictable in future

Benefit			Beneficially			
			Resident	Water Users	DamSite Users	Inland Fishers
Rural Area	Economic	Inland Fisher			+	+
		Eco-Tourism	+		+	
	Envilomen t	Improved Lakeside Landscape Aground the Dam	+		+	
		Improveed eco-System		+		+

Source: JICA Study Team

The definition of "major beneficiary groups" is as follows:

Residents: those who live in the range that the project effect brought about by this project reaches,

Water users: farm households utilizing water stored in the dam as irrigation water,

Dam site users: those who visit dam site engaged in such activities as tourism

Inland fishermen: those who are engaged in inland fishery in the dam

The definition of "benefits" is as follows:

Promotion of inland fishery: effect generated by promoting inland fishery that utilizes the reservoir,

Promotion of eco-tourism: Accompanying with the increase of those who utilize the dam, an effect is generated from increased demand for sale of local specialty goods/ souvenirs and for business serving foods and drinks in and around the dam,

Improved lakeside landscape around the dam: As better scenery of improved landscape develops, the effect of appreciating it by visitors and better atmosphere or living environment for inhabitants will be generate,

Improved eco-system for birds and plants: Accompanied by the improved growth environment for aquatic plants a diversified eco-system including birds, fish, insects, plants that line up on food-chain proliferates and get diversified in favorable habitat conditions, thus generating an environmental betterment effect.

CHAPTER 6 CHINESE DAM SURVEY

6-1. Existing condition survey

At the early stage of the survey to Ngoma-22, the possibility of the Ngoma-22 project's downscaling and the minimal cost-benefit ratio due to insufficiency of available river water and the suitable operation area was predicted. This survey was conducted to examine if the rehabilitation of the existing dam was feasible in line with comparison to Ngoma-22 project. We come up with the conclusion that it is feasible same as a site of LWH project.

6-1-1. Dam and appurtenant structures

(1) Dam

Table 6-1-1-1 Dimension of Chinese dam

Item	Contents	Item	Contents
Catchment area	29.4 km^2	Dam height	14m (estimation)
Reservoir surface at F.W.L.	95,000 m^2 (based on satellite image)	Crest length	157.8m
Gross capacity	Approximately 400,000m^3	Crest width	4.5m
Dam type	Homogeneous type	Upstream slope	1:2.4
Dam crest elevation	EL.1,380 m (measured by GPS)	Downstream slope	1:2.0

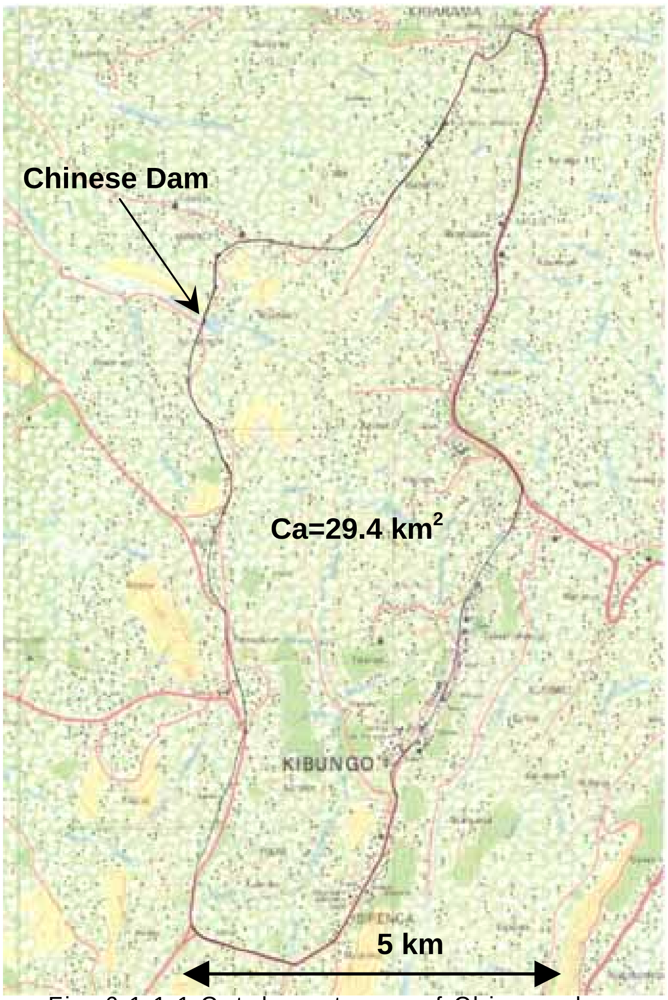


Fig. 6-1-1-1 Catchment area of Chinese dam

(2) Appurtenant structures and others

Elevation of the overflow portion of the spillway；EL. 1374.8 m (by handy GPS)

Structural formation of the intake conduit;

- Structure of steel pipe enwrapped by concrete, but there is nobody who confirmed it.

Reservoir operation;

- The discharge from the reservoir is done in February, March, April, July, August, November and December.
- The gate operator conducts the daily gate operation work following the request from the agronomist and farmers.
- There is no reservoir/gate operation guideline.
- There has never occurred the problem that the reservoir became empty and the discharge could not be done in the dry season.

Circumstances in terms of the reservoir operation in these years;

- The reservoir water levels are kept below the full water level during from July till October, but haven ever become low more than 2m to the full water level. In other seasons, the reservoir is kept full.

Observation of the river flow rate;

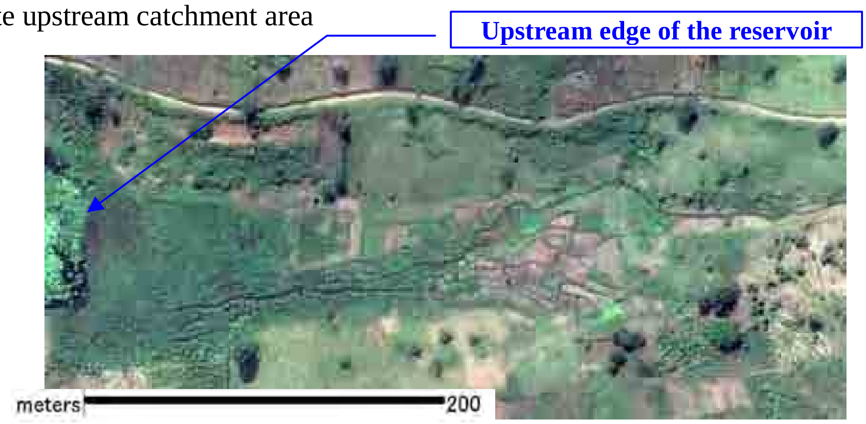
Table 6-1-1-2 River flow rate measurement by the electromagnetic flow-meter

Date	At the downstream of the dam	Ngoma-22 branch river at the upstream of the confluence
25/3/2012	108?/sec	69.8?/sec
1/4/2012	116?/sec	71.3?/sec
8/4/2012	119?/sec	73.5?/sec
19/4/2012	99?/sec	68.3?/sec
25/4/2012	32.6?/sec∗	236?/sec
1/5/2012	518?/sec	210?/sec
12/5/2012	462?/sec	218?/sec

∗taken out for irrigation at the upstream

6-1-2. Field Survey in the immediate upstream catchment area and the command area

(1) Immediate upstream catchment area

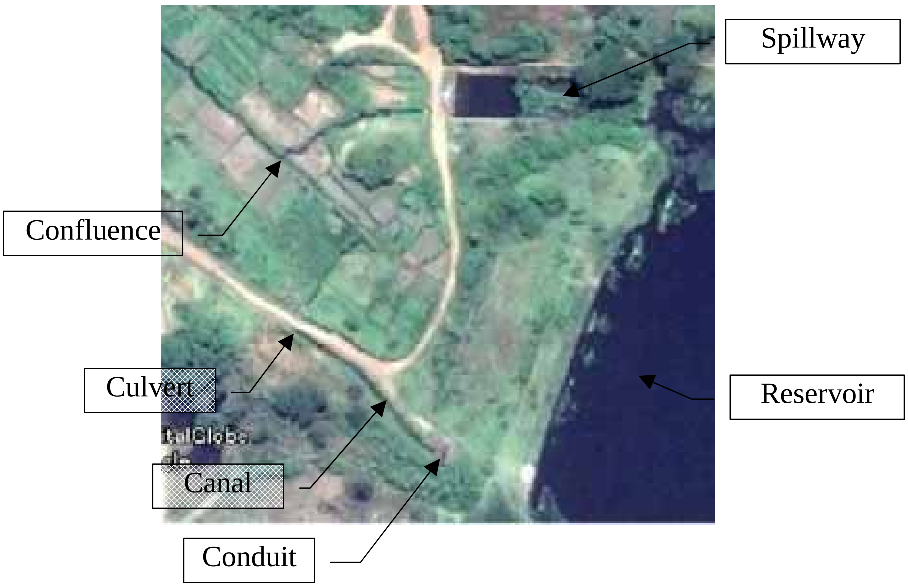


・The upstream end of the reservoir meets the land with a linear line.

・The land use of the river bed is composed of a patch work of farmlands and weed-grown areas.

・ The valley becomes narrow at about 500m upstream form the reservoir upstream end and the inclination of the river bed seems to be relatively steep so that the water surface in case of the reservoir water level rising by 2m or 3m would not reach this narrow portion. The submerged area caused by water level rising is roughly estimated to be 20,000 m^2 (longitudinal length:500m ×average width:40m).

(2) Command area survey (survey date; 1st of April)



ϕ600mm steel pipe, corroded a little

Discharge channel ends up at 50m downstream from the gate house and flows down to the river bed.

Confluence of streams from the spillway and from the discharge channel at about 60m downstream

River flow rate observation point at the downstream of the confluence

Canals along the foot of the hill recognized on the satellite imagery are buried under the grass in the field.

Differential about 1m between the water surface and the paddy field level causes anxiety to intake works

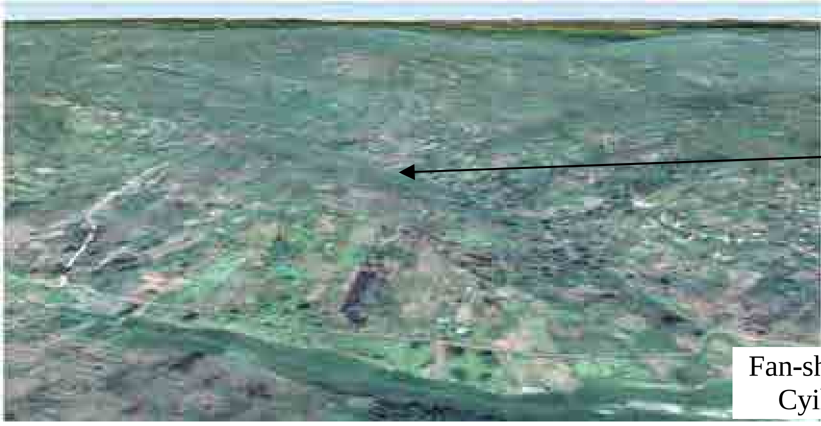
Notch on the ridge as an intake mouth

A tree trunk for a temporary weir to lift up water level at 500m downstream

Cultivation conditions on the marshland, at 500m downstream, left bank

Natural forest on the steep slope at 500m downstream, right bank

On the left bank, Cyihishire valley at about 1km downstream / A small stream at the exit of the valley /



Promising spot for ground water gathering system

Fan-shaped eroded formation in Cyihishire valley

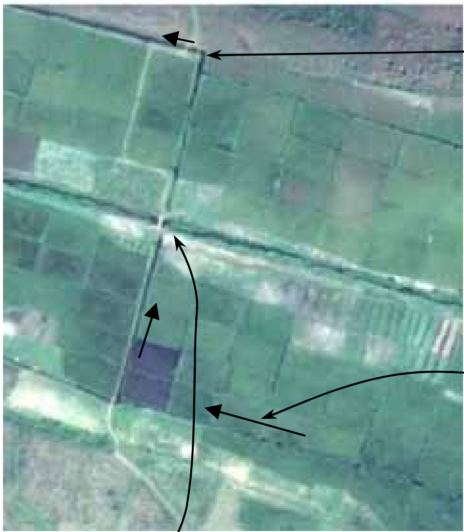
Natural forest

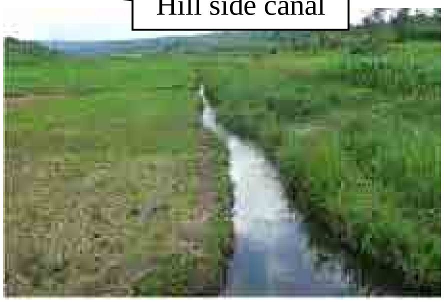
The canal along the hill foot becomes not clear after the natural forest.

A valley on the left bank, at about 2.5kmdownstream, a stream at the exit of the valley with no flow

A check gate at about 4km downstream, not under operation

Intake mouth to the canal at the immediately upstream of the check gate





The hill side canal on the left bank interflows with the main river behind the cooperative's building. There is a check gate at the confluence.

Hill side canal keeps going along the hill foot on the right bank. But no water in the canal and not under use.

(3) Confirmation of the canal conditions (Survey date; 8th of May)

(a) River conditions

The river itself is not enough maintained. The flow is interfered by weeds and waterweeds.


Flow-down conditions of the river at the midstream

(b) Check gate

There are two check gates made of concrete at about 4km downstream and behind the cooperative's building. As for the canal that receive the lifted up water, the canal in the former case lies at the higher elevation than the intake mouth so that the irrigation water can not be conveyed by this system. The canal in the latter case is chocked up at the dead end with luxuriant weeds. There is no check gate in the section from the dam site to the point 4km downstream.


(c) Canal conditions (only done to the left bank side)

The canal exists along the foot of the hill for 1km distance from the downstream of the dam till the end of the natural forest, but buried under weeds and not maintained.


At about 1.5km downstream, a wide and well-maintained canal appears, but the bed inclination is reverse, so that there is no flow in the canal.

The hill side canal is not provided in the midstream region where the valley is narrow.

It is said that at about 4km downstream, there was a hill side canal, which was rehabilitated in 1999 to 2000, along the foot of the hill on the both bank side. But the canal is buried completely; and it is difficult to imagine the canal that once exited.

(d) Summarization

- Once the maintenance works shall be done to the canals, a large portion of them would become available.
- There is no canal destroyed by a landslide or a collapse of a steep cliff.
- In the region from the midstream to the downstream, there is a hill side canal lying on a relatively high position beyond the river water level. To supply the irrigation water onto this canal, it is necessary to construct a functional check gate in the upstream/midstream region.

(4) Interview survey on the existing irrigation water conditions

Irrigation water	Number of farmers	Percentage
Enough	24	57%
Not enough	18	43%
Total	**42**	**100%**

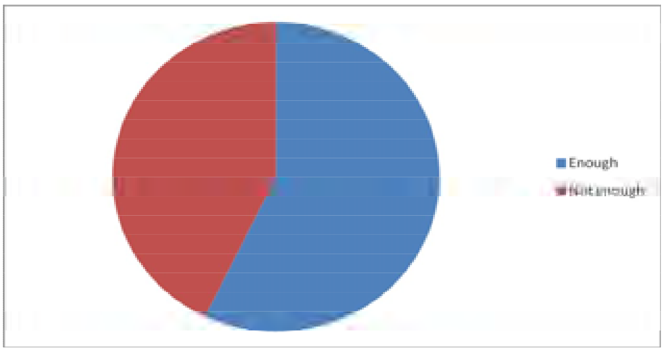


Fig. 6-1-2-1 Existing conditions of irrigation water

Followings are the causes of lack of irrigation water that were pointed out by the interviewed farmers.

- Poor and irrational irrigation water management
- Lack of maintenance to the canals

In addition, farmers pointed out the followings as the affections brought from the shortage of irrigation water.

- Disease of rice
- Low yield

6-1-3. Room and significance for the rehabilitation of Chinese Dam

(1) Room for rehabilitation

(a) Small scale rehabilitation

The existing crest height of Chinese Dam is about 1380m above sea level (EL.1380m, by handy GPS). To this, the full water level of the reservoir is about EL.1374.8m; and there is about 5m differential between these. When considering the dam height to be 14m or so, 2m would be enough as the additional dam height. In this meaning, it is able to set up the full water surface at the higher elevation by 3m or so. At that time, the additional reservoir capacity would be about 300,000m^3 (=(95,000m^2+α)×3m). The total reservoir capacity would become 700,000m^3 that is about twice of the existing one and makes it possible to carry out the irrigation development project with as same scale as Ngoma-22 project.

(b) Large scale rehabilitation

The catchment area of Chinese Dam is 29.4km^2 that is about 4 times larger than 8.8km^2, the catchment area of Ngoma-22. According to observation result at the downstream of the dam site, the river flow rate of Chinese Dam is about 2 times larger than the one at the confluence point (on the Ngoa-22 river immediately upstream of the confluence). Considering the river flow rate at the confluence point being about 2 times larger than the one at the Ngoma-22 dam site in the rainy season, the river flow rate at Chinese Dam becomes about 4 times larger than the one at the Ngoma-22 dam site. Therefore, the irrigation development scheme with about 2,800,000m^3 of available quantity of irrigation water comes to the surface. As for the dam, the dam site would be moved to the upstream side; and the dam would be constructed as a new one. And the alternative to this would be composed of the new dam with the reservoir capacity of 2,100,000m^3 at the upstream and the rehabilitated dam with the reservoir capacity of 700,000m^3 at the downstream.

(2) Significance of rehabilitation

(a) Economical significance

The irrigation conditions in the paddy fields would be improved as the result of rehabilitation, which would bring the higher yield of rice and higher income to the farmers. And also, the irrigation water for the dry fields would be obtained as the result of rehabilitation, which makes it possible to expand the LWH project to this area, to proceed the agricultural modernization and economical development in this district.

(b) Social significance

Sense of unfairness regarding irrigation water one of the causes of which is the lack of irrigation facilities or the poor functions of irrigation facilities is widespread among farmers and becomes a barrier against establishing the cooperative relationship in this region. Once the dam is rehabilitated and the irrigation facilities are provided and function, all the situations would begin to move toward the establishment of the social cooperative relationship.

And also, in case of the dry field irrigation being under operation, employment chances as irrigation workers would be borne and society conditions would be improved and stabilized.

6-2. General rehabilitation plan of Chinese Dam

6-2-1. General rehabilitation plan

(1) Concept of rehabilitation

The concept is to rehabilitate the existing intake facilities of the dam, to improve the existing facilities or develop newly facilities needed for the paddy field irrigation, and to make it possible for the paddy fields to be irrigated completely.

The reservoir capacity shall be increased by making the existing full water surface higher by 3m; and the dry field irrigation shall become possible by using this newly developed water and by developing the irrigation facilities needed.

(2) Construction plan of rehabilitation

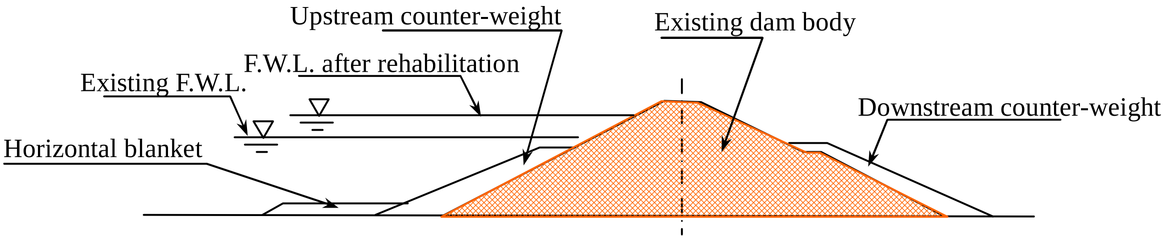
(a) Dam

ｉ) Embankments for the counter-weight on the upstream slope and the downstream slope

It is necessary to give the dam body the same level of stability against the sliding failure as before. To satisfy this requirement, an embankment shall be added onto the upstream and downstream slope of the dam body as a counter-weight that resists against the sliding failure.

ii) Horizontal blanket

It is necessary to give the dam body the same level of stability against the hydraulic failure, i.e. the piping phenomenon. To satisfy this requirement, the horizontal blanket shall be added to the upstream slope toe of the dam body to make the hydraulic gradient along the foundation surface same



as before.

Fig. 6-2-1-1 Concept of the existing embankment rehabilitation

iii) Removal of the existing riprap and its rehabilitation

The existing riprap shall be removed from the area on which the counter-weight embankment is added; and the slope surface of the counter-weight embankment shall be protected by the riprap.

iv) Arrangement of the downstream slope, removal and provision of the slope toe masonry

The existing planting work for slope protection, the slope toe masonry and the drainage channel shall be removed for the downstream counter-weight embankment and provided after its completion.

(b) Spillway

i) Arrangement of the flow-in range of the spillway and the construction of over-flow weir

An over-flow gravity weir 3m high shall be constructed on the floor of the spillway flow-in portion. The upstream ground surface shall be covered by the earth blanket so as to reduce the hydraulic gradient along the foundation surface of the weir against the water head at the upstream side.

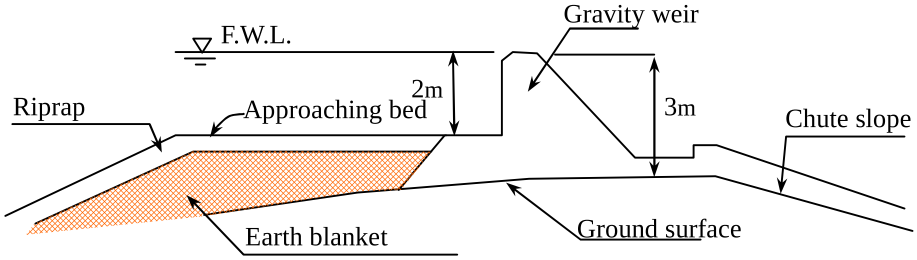


Fig. 6-2-1-2 Arrangement of the flow-in range of the spillway and the over-flow weir

iii) Arrangement of the chute portion

The existing chute slope is not shaped and protected. This portion shall be shaped as a chute channel and provided with a concrete channel considering the drop height to be increased.

(c) Intake facilities

ⅰ) Reconstruction of the intake facilities

The existing intake facilities are aged and do not function well. The discharge gate is damaged and must be repaired; but it is very difficult to repair it because of the lack of way for closing the conduit or emptying the reservoir. Therefore, the existing facilities must be removed and replaced with new ones. These construction works for renewal shall be done by the open cut method; at this time, the position of the conduit shall be moved toward the river bed and be lowered so as to increase the available quantity of reservoir water for irrigation use. Followings would be the construction works done at that time.

- Intake tower
- Bottom out-let with a conduit and valves
- Discharge chamber

ⅱ) Installation of intake facilities for dry fields irrigation

Two discharge chambers shall be constructed on the downstream both slopes; and the irrigation water shall be led to this chamber through the conduit and a pipe based on the same design philosophy as the one in Ngoma-22.

(d) Irrigation facilities

As same as in Ngoma-22, the irrigation facilities shall be installed following the plan of the gravity irrigation from the main canal and the pump irrigation from and through the main canal and the solar pump system.

6-2-2. Execution scheme and cost estimation

(1) Temporary works

(a) Coffer dam

A coffer dam 1m or 2m high shall be constructed for the earth works of the upstream counter-weight embankment and the horizontal blanket

(b) Foundation excavation

The sediment soil layer shall be removed from the foundation of the upstream counter-weight embankment and the horizontal blanket.

(c) Drainage work by pumping during the construction period

During the construction term, the flow-in river water shall be drained by pumping from the upstream of the coffer dam to the downstream through the cut-channel for the bottom out-let construction work. After the completion of the bottom out-let, the drainage shall be done through the conduit of the bottom out-let.

(d) Temporary road

The temporary road to connect the embankment site with the borrow area shall be constructed along the foot of the left bank slope in the reservoir.

(2) Execution schedule

Table 6-2-2-1 Execution schedule of Chinese dam

Item \ Month	1	2	3	4	5	6	7	8	9	10	11	12
Temporary/General												
Site preparation												
Site office												
Temporary road												
Intake facilities												
Open cut excavation												
Removal of existiong facilities												
Renewal of intake facilities												
Foundation excavation												
Coffer dam												
Horizaintal blanket												
Counter-weight embankmnt												
Recovery embankment												
Riprap												
Dam crest protection												
Slope protection												
Spillway construction												
Main canal construction												
Secondary canal construction												
Solar pump installation												
Tertiary canal construction												
others												
Site cleaning												

(3) Approximate construction quantity (Chinese Dam rehabilitation)

Table 6-2-2-2 Approximate construction quantity (Chinese Dam rehabilitation)

Description	Calculation	Unit	Quantity
Temporary/General			
Site preparation		L.s.	1
Site office		L.s.	1
Temporary road	500	m	500
Dewatering	operation of the submerged pump	L.s.	1
Intake facilities			
Open cut excavation	{1.0×(2.4+2.0)/3}×12.0^3+{4.5×1.0+5.0×(2.4+2.0)/2}×12.0^2 +4.5×5.0×12.0 = 5,036	m3	5,036
Removal of existing faclities	1	L.s.	1
Renewal of intake facilities	1	L.s.	1
Dam			
Foundation excavation	120.0×30.0×1.5 = 5,400	m^3	5,400
Coffer dam	120.0×1/2×(3.0+6.0)×2.0 = 1,080	m^3	1,080
Horizontal blanket	120.0×20.0×2.0 = 4,800	m^3	4,800
Counter-weight embankment	1/2×(3.0+6.0)×7.0×120.0×2 = 7,560	m^3	7,560
recovery of the open cut	= 5,036	m^3	5,036
Riprap	1/2×(19.0+29.0)×7.0×2.6×0.6 = 262	m^3	262
Planting works to the slope	1/2×(19.0+29.0)×7.0×2.236+1/2×(120.0+80.)×7.0×2.236+3.0×120.0 = 2,301	m^2	2,301
Spillway			
Gravity weir and chute channel	1/2×(1.0+4.0)×3.0×5.0×1.5+1.0×0.3×10.0×2+5.0×0.3×10.0 = 77	m^3	77
Earth blanket	10.0×30.0×2.0 = 600	m^3	600
Riprap	10.0×30.0×0.6 = 180	m^3	180
Irrigation facilities	1	L.s.	1

(4) Approximate construction cost (Chinese Dam rehabilitation)

Table 6-2-2-3 Approximate construction cost (Chinese Dam rehabilitation)

Approximate construction cost

Description	Unit	Quantity	Unit Cost (RWF)	Cost (RWF)	Remarks
Temporary/General works					
Site preparation	L.s.			7,500,000	
Site office	L.s.			30,000,000	
Temporary road	m	1000.0	147,000	147,000,000	7.0×1.0×1.0×13,000(セメント
Dewatering	L.s.	1.0		13,500,000	24 hours operation for 3 months
Sub total				198,000,000	
Intake facilities					
open cut excavation	m^3	5036.0	4,500	22,662,000	
Removal of existing facilities	L.Ss.	1.0		15,000,000	
Renewal of intake facilities	L.s.	1.0		266,256,000	
Sub total				303,918,000	
Dam					
Foundation excavation	m^3	5400.0	6,500	35,100,000	
Coffer dam	m^3	1080.0	8,500	9,180,000	
Horizontal blanket	m^3	4800.0	8,500	40,800,000	
Counter-weight embankment	m^3	7560.0	8,500	64,260,000	
Recovery of the open cut	m^3	5036.0	8,500	42,806,000	
Riprap	m^3	262.0	40,000	10,480,000	
Planting works on the slope	m^2	2301.0	1,500	3,451,500	
Sub toal				206,077,500	
Spillway					
Gravity weir and chute channel	m^3	77.0	75,000	5,775,000	
Earth blanket	m^3	600.0	8,500	5,100,000	
Riprap	m^3	180.0	40,000	7,200,000	
Sub total				18,075,000	
Irrigation faclities	L.s.	1.0		2,113,427,500	as same as Ngoma-22
小計				2,113,427,500	
Approximate construction cost				2,839,498,000	

6-2-3. Investigation plan

Followings are the investigation plan necessary for studying how to rehabilitate the Chinese Dam.

Table 6-2-3-1 Chinese dam investigation plan

Chinese Dam Investigation Plan		
Item	Quantity	Note
Borehole drilling	3 holes, 20m×3=60m	
Standard penetration test	12 times/hole×3=36 times	
Permeability test in the hole	4 times/hole×3=12 times	
Test pit excavation	3 pits, D=3m×3=9m	
Field permeability test	2 pits/m×3m×3test pit=18	Pit method
Test piece sampling	3 pieces	undisturbed sample
Unit weight measurement	3	
moisture content test	3	
particle size distribution test	3	
Specific gravity test	3	
Atterburg limit test	3	
Direct shear test	3	
Standard compaction test	3	

CHAPTER 7 ADEQUACY OF COOPERATION AND THE ADEQUATE SCOPE AND SCALE OF THE COOPERATION

7-1. Adequacy of cooperation

It is judged to be adequate to execute this project under the Japan grant aid scheme based on the following reasons.

① The government of Rwanda has several programs supergrade to this project that are 1) Rwanda Vision 2020, 2) Economic Development and Poverty Reduction Strategy, 2008-2012: EDPRS 2008-2012, 3) National Agriculture Policy (NAP): 2004, 4) Strategic Plan for Agricultural Transformation in Rwanda 2004: SPAT, and 5) Land-husbandry, Water harvesting and Hillside-irrigation: LWH. In these programs, the main and common targets are the reduction of poverty, the economic development and the food security. This project was formulated and has been reconsidered under the scheme of LWH program, accords with the contents of the mid to long term development programs above, and contributes for these programs to accomplish their purposes.

② According to the papers, the philosophy or targets of LWH program is/are improvement of farmlands, accommodation of farmlands, execution of market-oriented agriculture through hillside irrigation, and strengthening of the technical or institutional capacity of staff or related organizations. And the Government intends to construct 101 irrigation purpose reservoirs throughout the country. One of the main targets of this project is to introduce the market-oriented vegetable farming through the hillside irrigation, which accords with the target of the LWH program mentioned above.

③ Japan Government made a public commitment in the forth Tokyo International Conference on African Development to support African countries concentrated in the fields of 1) increase of food production and improvement of agricultural productivity, 2) improvement of utilization and management of water resources and lands, 3) development of water-related infrastructures, 4) reduction of hazard risks and 5) accommodation of safe water resources. This project aims at the development of water resources through a dam construction and the modernization of agriculture so that it can contribute the achievement of all the items of the commitment above.

④ This project has suggested not only the fundamental technology in terms of the reservoir planning and the design of homogeneous dam with horizontal blanket, but also the new idea of introducing the solar pump system for the hillside irrigation and the utilization of shallow ground water by stopping its flow at the neck of the valley, so that it would be able to become a model case of hillside irrigation project in Rwanda. Followings are also included in these suggestions.

i) Setting up the utilization plan of the limited water resources for the paddy field irrigation and the dry field irrigation based on the water balance study through the catchment area and the command area. (Limited condition was confirmed by the Tank Model runoff analysis to the observed rainfall and river flow rate record at the site.)

ii) Clarification of the precedent water supply to the dry field irrigation being possible through rationalizing and saving the irrigation water use in the paddy field, the study of which was done based on the field survey on the existing paddy field conditions. (Stable water supply and fair distribution of irrigation water would be preferable for the farmers to be benefited from the stable rice production and would be able to contribute to the Water Users Union activities in terms of the easy collection of water fee and the farmers' cooperation to the maintenance works of the irrigation facilities.)

iii) Suggestion of the utilization method of ground water as the supplemental water resource considering the limited quantity of the river flow rate that came out from the runoff analysis based on the observation record.

iv) Suggestion of the introduction of the solar pump system which is relatively low cost and is going to come into wide use based on the recognition that the command area irrigated by gravitational water supply is limited and is not enough to satisfy the planning concept because of the topographical conditions, specific to Rwanda and the topographical survey result brought to surface more clearly, of the narrow valley lying between hills.

7-2. Scope and scale of the cooperation

7-2-1. Scope of the cooperation

The scope of the cooperation in this project is to develop the facilities/structures ranging from the dam to on-farm irrigation equipments. In this project, one of the main schemes is the saving irrigation by means of micro-irrigation method so that the materials such as the hose inevitable for execution of micro-irrigation are included in the scope of cooperation. And the paddy fields that expand on the downstream river bed from the dam site are included in the command area. Then it becomes necessary to control and manage the water supply quantity to the paddy fields and avoid the water wasted. To control and manage the water, it is necessary to improve/rehabilitate the existing ridges that have no ability of keeping water. Therefore, development/rehabilitation of the facilities for the paddy field irrigation, including the rehabilitation of ridges, is included in the scope of cooperation. It is the common recognition among authorities and donors concerned that the land-husbandry and the hillside irrigation are inseparable, that they should be implemented at the same time and that the increase of productivity brought from the land-husbandry should be counted as a part of benefit of the hillside irrigation; but this time the land-husbandry is considered not to need the technological assistance of Japan and is not included in the scope of cooperation.

7-2-2. Scale

At this moment, the facilities for utilizing ground water as a water resource for irrigation is not included in this construction design due to the difficulty of estimating its available quantity though its utilization is recognized to be possible and effective. The planned command area 275ha might be increased at the stage of ground water utilization plan taking form.

7-2-3. Problems in future

(1) Problems in this project (short-term problems)

(a) Review of the available river in-flow rate

It is necessary to review the available river in-flow rate based on the annual observation record that includes the one in the dry season, July and August.

In addition, it is necessary to study the available quantity of ground water taking its conditions in dry seasons into account.

(b) Review of the design flood discharge to the dam

At this moment, referring to the observation record of river flow rate during February to April, the design flood discharge to the dam is estimated as the peak flood rate calculated by the rational formula to the maximum daily precipitation with 50 years exceedence probability. It is also necessary to review this result referring to the annual observation record of river flow rate by applying the more analytical methods such as the Tank Model Method or the Storage Function Method.

(c) Execution of the stability analysis of the dam body, Hydraulic and structural design of the spillway

At this moment, the cross-sectional shape of the dam body is decided empirically, so that at the next stage it must be decided based on the stability analysis of the dam body.

And also, the spillway must be designed based on the hydraulic and structural analysis.

(d) Wetting area coefficient

At this moment, the wetting area coefficient is estimated to be 0.7 that ranges from 0.4 to 0.7 in the papers regarding the saving irrigation. This value must be reviewed based on the result of the field conformation survey on the saving irrigation that is going to be conducted in the site.

(e) Effective reservoir capacity 450,000m^3

It is of course for the effective reservoir capacity 450,000m3 to be reviewed based on the newly applied available quantity of the river water, but also the adequate effective reservoir capacity must be examined based on the long-term simulation analysis on the reservoir operation.

(f) Improvement of the paddy field conditions

It is necessary to carry out the further survey and examination of adequate and effective improvement method from or to the paddy field conditions in terms of the leakage restraint through ridges and the installation of check gate structures.

(g) Land Husbandry

It is recommended in terms of Land Husbndry works in command areas of this project that the compost shall be concentrated on the farming lands with poor fertility ad high prmeability by Rwandan government authorities.

(2) Mid to long term problem

After the completion of this project, technical support programs are essential to let the project effectiveness appear as clearly or highly as possible and make the project effectiveness as durable as possible. The themes or the fields of these support programs would be as follows.

(a) Technical support for dry field farming

It is the first experience for the farmers in this district to conduct the irrigated dry field farming. And the hose irrigation method introduced as the on-farm irrigation method in this project is the first experience for them. On the other hand, the yield increase plays an important role to increase the farmers' income according to the result of economic analysis on farming (sensitivity analysis). Therefore, it is crucial for the future dry field farming how to get high yield of products by applying fertilizer and irrigation water adequately; to this, the Rwandan Government shall be requested to provide technical supports.

(b) Technical support for paddy field farming

The rice farming in this district has about 20 years history, but this history is the one of fighting or resisting against the low temperature that is brought from about 1500m of the high altitude in spite of this country being situated in the tropical area. Therefore, there are many problems to challenge such as the introducing of suitable variety of rice by means of breed improvement, and the selecting/introducing of suitable farming method from the special or radical ones, for example the intermittent irrigation method, the non-plowing irrigation method and the organic farming method. To these, the Rwandan Government shall be requested to provide technical supports.

(c) Support for strengthening the farmers' organization and technical support to operation and management of irrigation facilities

The establishment of cooperation system in the local community is inevitable to perform the operation and maintenance works to the irrigation facilities such as the dam and the canals. This establishment of cooperation system would be done at the same time of the accomplishment of the Water User's Association and the cooperative being strengthened institutionally; this means the establishment or the accomplishment must be achieved by the farmers' voluntary activities. Not only to these, the Rwandan Government shall be requested to provide technical supports but also at the same time to the operation of irrigation facilities such as operation and management of the solar pump system, the intake gate of the dam, intake gate at the regulation pond, and the check gate along the river.