4-4 Hydrological Survey

4-4-1 Bago River Basin

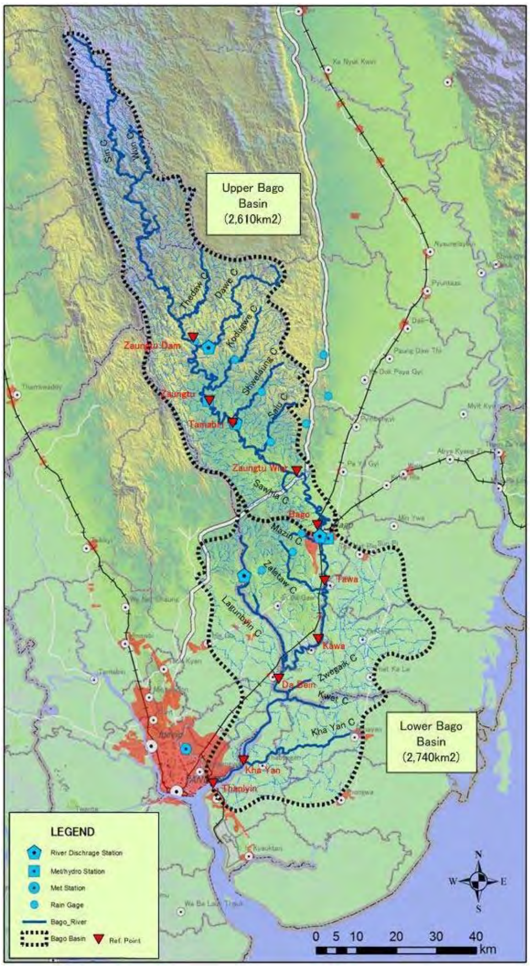


Figure 4-4-1-1 Bago Basin

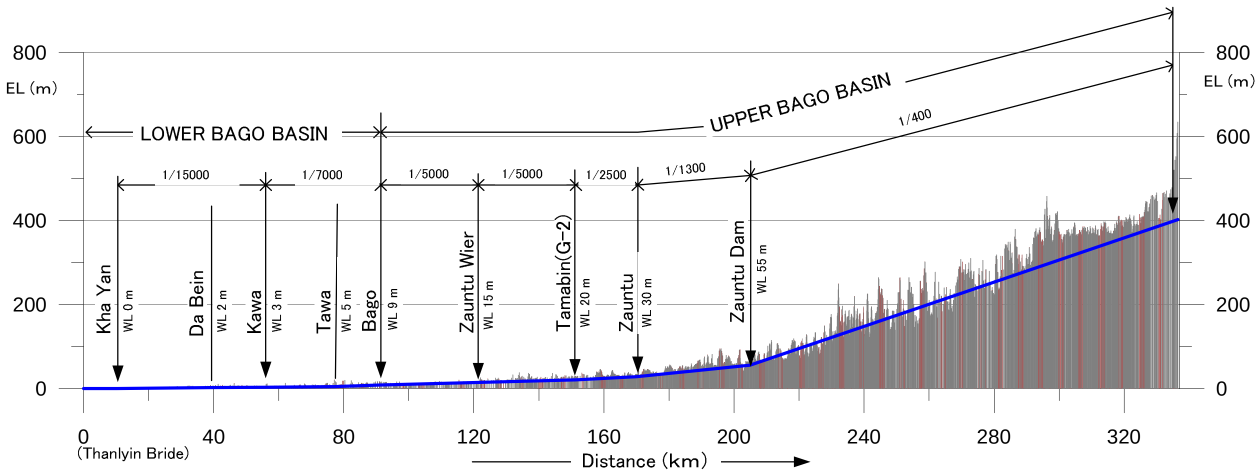
The Bago River is confluent with the Yangon River at Thilawa SEZ (survey area) and reaches the coastal water body. Its head is found 190 km from Yangon, lying on Pegu Yoma (mountain) at an elevation of 630 m. The length of the river-channel reaches, due to including complex meandering sections, over 360 km. However, its tributaries are not broadly developed, so the basin area is relatively small at 5,400 km^2 [1].

The hinterland of the Bago basin is Pegu Yama, mainly consisting of Tertiary layers with a linear structure of NNW-SSE. At the downward reach of the basin, its western side is bordered by the Yangon River basin through the intermediary with Na Moe Yeik Chaung, while at the eastern side, it is restricted by the Sittang River basin, and consequently, the shape of the basin shows a stretching form in a N-S trend (refer to Figure 4-4-1-1).

In view of fluvial geomorphology, the Upper Reach (Upper Bago Basin) is characterized by “Valley Bottom Plain” and Lower Reach (Lower Bago Basin) and is dominated by a “Low-lying Area”. The geographical features of the Upper and Lower Basins are respectively described in the following sub-sections.

1) Upper Reach (Upper Bago Basin): This section is upstream from the Bago bridge (Bago city), and has 2,610 km^2 of catchment. The section between the Bago Bridge and the Zaungtu dam is inlaid with sandy sediments with a highly dissected terrain. The river channel is meandering and is 10 m below the surrounding terraces with 1:5,000 to 1:1,500 of slope as shown in Figure 4-4-1-2.
2) Lower Reach (Lower Bago Basin): This section is located between the Bago bridge and the Thanlyin bridge, covering low land less than 10 m m.s.l. in elevation. Along the river channel, natural levees develop and a flood plain extends behind it. The elevation of the riverbed is lower than the mean sea water level, and seawater intrudes during the dry season. In this section, old canal systems built since the 18th century are used for navigation and irrigation. During flooding and due to the tidal condition, the floodwater comes into the canals from the Sittang river basin.

[1] In comparison with the scale of Japan's rivers, the Bago River’s length of 360 km is almost the same as the longest river, the “Shinano River”, in Japan. However, its catchment area of 5400km^2 is correlative with the 10th largest, the "Anukuma River" in Japan.



Source: JICA Study Team: Figure is made based on SRTM topo-data taken from USGS(http://dds.cr.usgs.gov/srtm/)

Figure 4-4-1-2 Longitudinal Profile along Bago River Basin

4-4-2 Hydrological Stations in Bago Basin

In the Bago Basin, although the temporal observations were made downstream of Bago (10 km section from Bago to Tawa), seven (7) stations were built for the river stage measurement as shown in Table 4-4-2-1. Among them, two (2) stations have been operated by DMH. As for the observation period, the Bago bridge station has been operated for 41 years, since 1972, and the Zaungtu station has been run for 26 years, from 1987. However, at the Bago bridge station, the low water level cannot be measured due to the blockage of intake pipes by the river sediment. Due to the automated (float-type) recorder not being functional, manual reading alone has continued four times a day. The other five (5) stations were constructed by ID and the Survey team. Out of those, four (4) stations were constructed in the main channel, respectively at Dawei Dam, Tama Bin, Bago Old Bridge and Lower Se Tee in order from upstream, while one (1) is set at La Gun Byin Dam, located in the tributary. Water level measurement is made by the automated recorders at four (4) stations excluding the Lower Se Tee station, which has a temporary measurement by a gauge reading.

As for the discharge survey, DMH carried it out in 1987 for the Bago Old Bridge, and ID made it in 2011 and 2012 for around the Bago Bridge. However, the routine river survey at a fixed baseline with the continuous river stage measurement is only for one site, the Bago Old Bridge station, which is currently being observed by the Survey team. List of meteorological and hydrological stations is shown in Table 4-4-2-1 and Location map of meteorological and hydrological stations is shown in Figure 4-4-2-1.

Table 4-4-2-1 List of Meteorological and Hydrological Stations (Location refers to Figure 4-4-2-1)

No	Station Name	Type	Status	Record Available since	Lat (DD)	Lon (DD)	Owner
1	Bago/Bago Bridge	Met/Hydro_M	Ext	1965/1972	17.33	96.50	DMH
2	Zaungtu	Met/Hydro_M	Ext	1987/1987	17.63	96.23	DMH
3	Kabaaye	Met	Ext	1901	16.87	96.18	DMH
4	Zaungtu Dam	RG_M	Ext	1993	17.76	96.20	DHPI
5	La Gun Byin Dam	RG_M/RG_A/WL_A	Ext/Const	2001	17.25	96.31	JICA/ID
6	Alaingni Dam	RG_M	Ext	2003	17.26	96.35	ID
7	Mazin Dam	RG_M	Ext	2000	17.34	96.44	ID
8	Zalataw Dam	RG_M	Ext	1999	17.30	96.42	ID
9	Pyi Pon Gyi Dam	RG_M	Ext	1988	17.64	96.50	ID
10	Baw Ni Dam	RG_M	Ext	1999	17.73	96.49	ID
11	Wa Ga Dok Dam	RG_M	Ext	2008	17.58	96.45	ID
12	Kodugwe Dam	RG_M/RG_A	Ext/Plan	2012	17.72	96.29	ID
13	Salu Dam	RG_M	Ext	2012	17.54	96.37	ID
14	Shewlaung Dam	RG_M	Ext	2012	17.65	96.35	ID
15	Daik-U	RG_M	Ext	-	17.80	96.67	ID
16	Waw	RG_M	Ext	-	17.47	96.68	ID
17	Tha Na Pin	RG_M	Ext	-	17.29	96.58	ID
18	Tawa	RG_M	Ext	-	17.23	96.50	ID
19	Kawa	RG_M	Ext	-	17.85	96.46	ID
20	Nyauglaybin	RG_M	Ext	-	17.95	96.73	ID
21	Myit Kyo	RG_M	Ext	-	17.59	96.82	ID
22	Min Ywa	RG_M	Ext	-	17.35	96.64	ID
23	Shwe Hla	RG_M	Ext	-	17.00	96.41	ID
24	Bago Old Bridge	Hydro(_M/_A)	Const	2013	17.34	96.48	JICA/ID
25	Tama Bin	Hydro	Const	2013	17.58	96.29	JICA/ID
26	Dawei Dam	Hydro	Const	2013	17.75	96.23	JICA/ID
27	Shan Kine Sluice Gate	RG_A	Plan	2013	17.41	96.86	ID
28	Pine Kyone Sluice Gate	RG_A	Plan	2013	17.12	96.49	ID
29	Lower Se-Tee	Hydro（_M）	Const	2012	17.28	96.50	ID

Met: Meteorological Station for the measurement of climatic items including Rain, Temperature, Wind, Humidity, and Pan-Evaporation.

Hydro: Hydrological Station for the measurement of both River Stage and Discharge Rate.

WL_A: Water Level Station for the (automatic) measurement of River Stage or Reservoir WL.

RG_M: Rain Gauge Station (Manual Measurement),RG_A: Rain Gauge Station(Automatic Measurement)

Ext: Existing Station, Const: Constructed by May 2013, Plan: Plan to Construct by May 2014

DMH: Department of Meteorology and Hydrology, ID: Irrigation Department, JICA: Japan International Cooperation Agency,
DHPI: Department of Hydropower Implementation, the Ministry of Electric Power No .(1),
DD: Decimal Degree

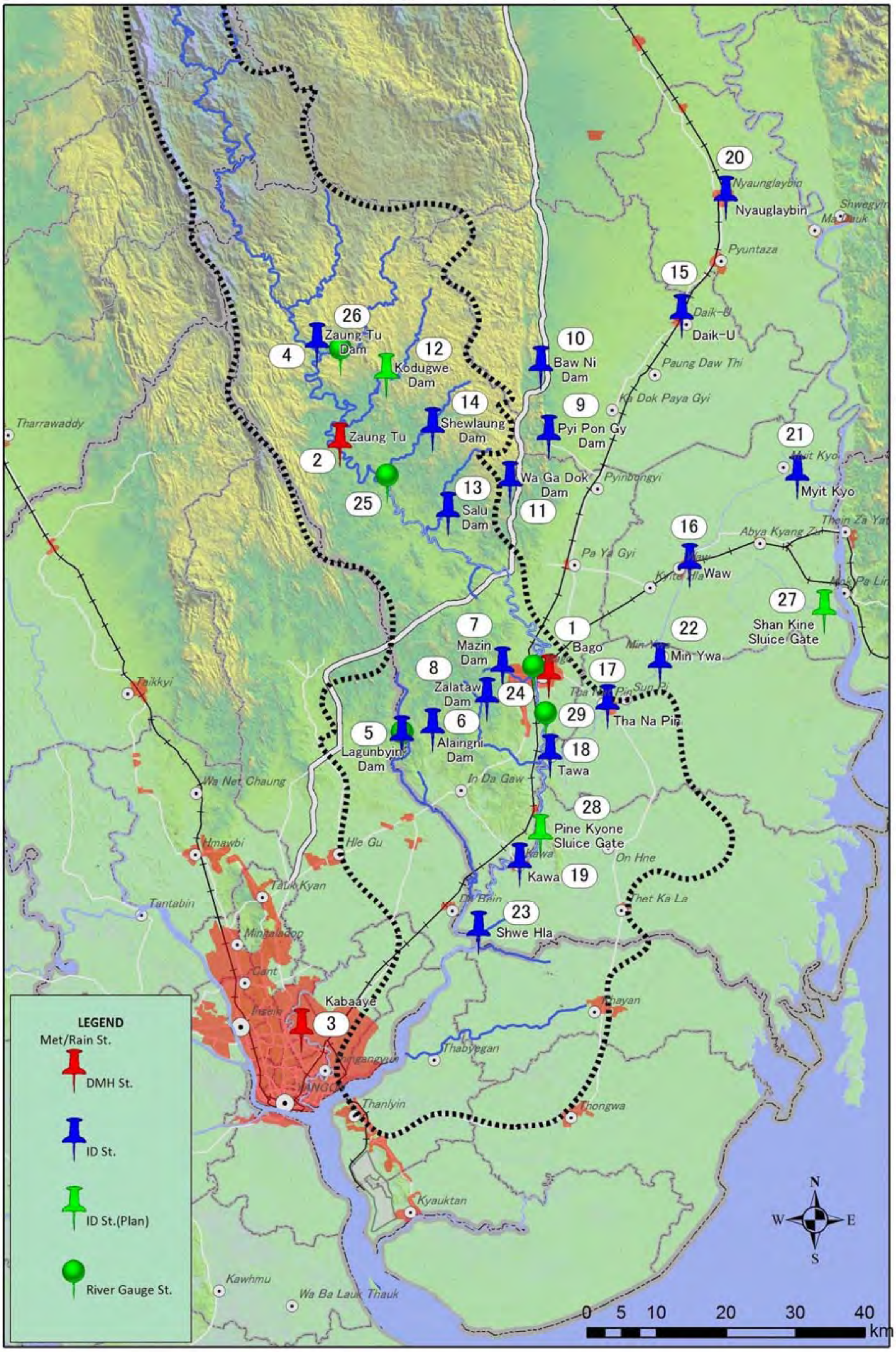


Figure 4-4-2-1 Location map of meteorological and hydrological stations
(Station name refers to Table 4-4-2-1)

4-4-3 Existing Records

In the Bago River Basin, two (2) long-term records are available from the middle and upper reach. As the base station of the middle reach, DMH had installed the Bago Bridge Station in 1972. In the upper reach, the Zaungtu Station was constructed in 1989, and has operated until the present time. Station Name refers to Table 4-4-2-1

(1) River Stage

The river stage observed at the Bago Bridge Station shows that the water level has seasonal changes with the range of 7 meters from 2 meters (Minimum) to 9 meters (Maximum). Ordinarily at the end of May, the water level begins to rise and reach peaks in July and August. By September, coming close to the end of the rainy season, the water level decreases abruptly and reaches the lowest level of 2 to 3 meters as shown in Figure 4-4-3-1.

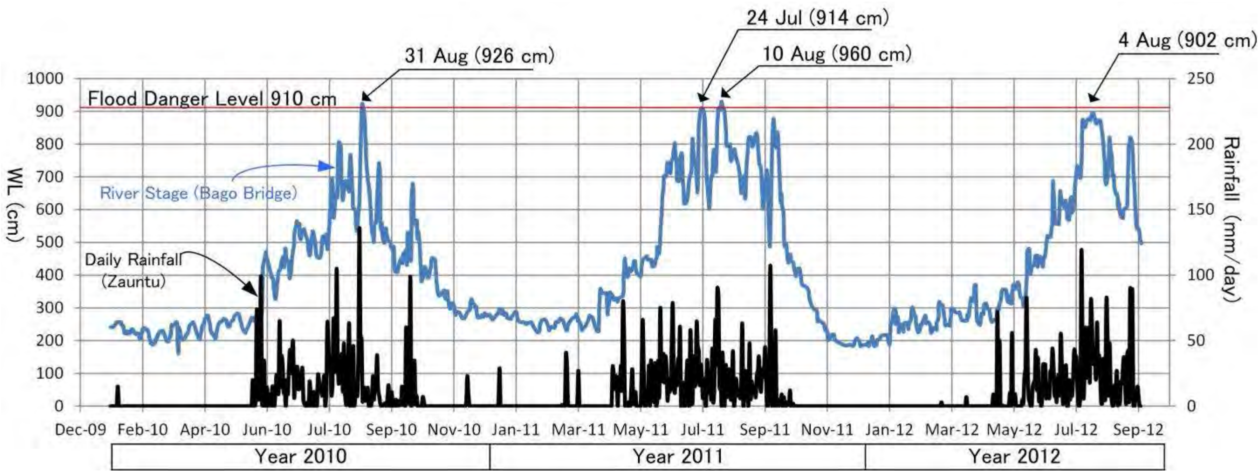


Figure 4-4-3-1 River Stage Hydrograph of Bago Bridge Station

At the Bago Bridge Station, the flood danger level (bank-full stage) is 910 cm by the gage reading. During the last four (4) years, three (3) floods exceeding bank-full stage (910cm) had been observed at 926cm (31 August 2011), 914m (24 July 2011) and 960cm (10 August 2011). However, since three irrigation dams (the Kodugwe, Shwelaung, and Salu dams) had been operated in 2012, the water level does not exceed the flood danger level.

(2) River Discharge

The lower reach of the Bago River is affected by tidal changes and is a capable point to apply the 'Rating Curve Method' on river discharge measurement at the Bago Bridge Station (Catchment Area 2,610 km^2) as is the lowest point in the basin. As for the river discharge survey, it was solely made in 1980 and at a different section far from the current observation line. Although it might be taken during different condition of the channel, this old rating curve is still used up to the present. In this situation, the river discharge is calculated and distributed, as shown in Figure 4-4-3-2.

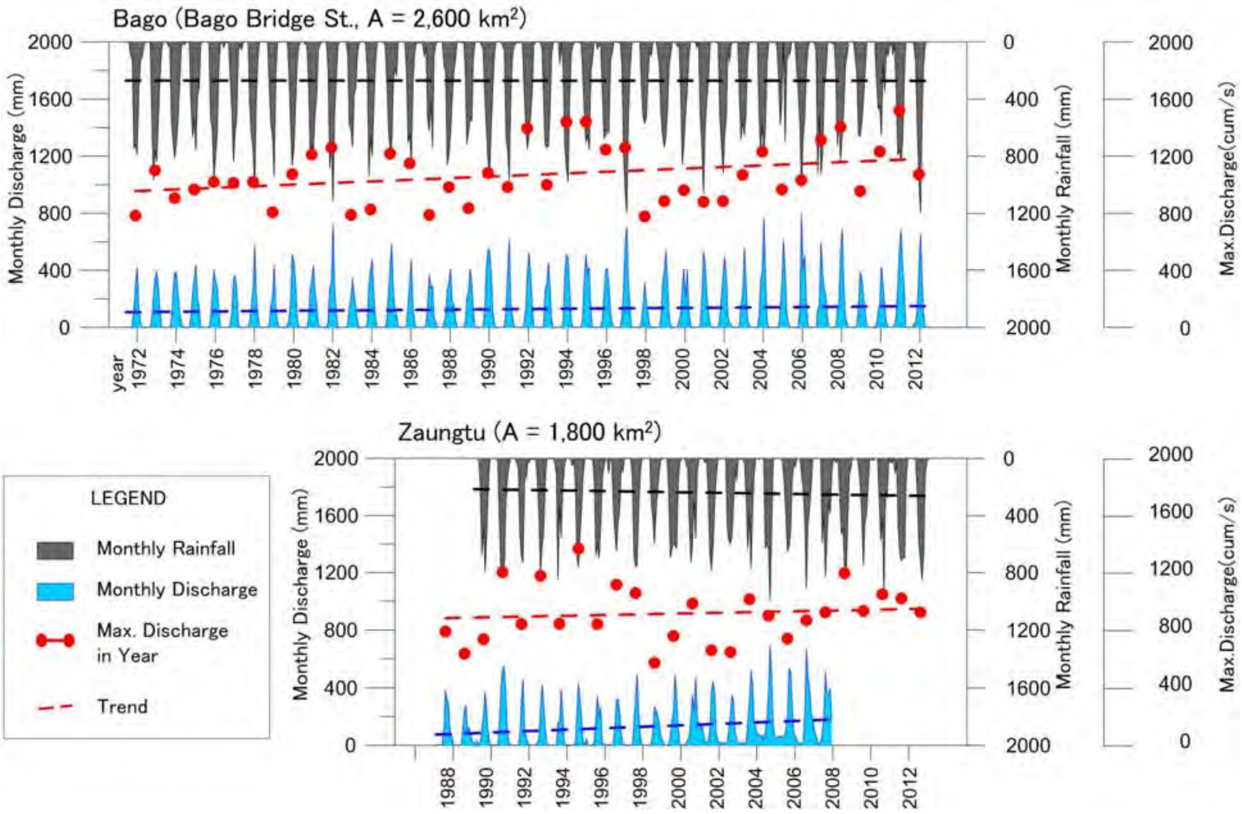


Figure 4-4-3-2 River Discharge at DHM Station (Monthly Discharge of Bago Bridge and Zaungtu Station)

According to the DMH estimation made from 2002 to 2010, the average discharge is accounted to have been 4,050MCM/year[2], converted to 1,490 mm/year with the quotient divided by the catchment area (2,610 km^2). If it compares to 2,860 mm/year of area rainfall at Zaungtu, located in the catchment, half of the rainwater (52%) becomes runoff water and discharges downstream.

However, due to old discharge survey, the river channels may differ from the current and estimation may contain an error. The estimation data is summarized in Table 4-4-3-1.

[2] As result of re-calculation using ID and JICA survey data, average discharge (1972-2012) is 3,950 MCM/year

Table 4-4-3-1 Estimated River Discharge at Bago Bridge Station (DMH,MOTC)

UNIT : MCM

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2002	0	0	0	1	248	610	1,288	1,194	878	80	130	3	4,430
2003	0	0	4	0	187	586	775	1,194	866	185	2	0	3,798
2004	0	0	0	1	247	664	807	1,449	928	181	0	0	4,276
2005	0	0	0	2	116	497	584	1,242	1,187	168	88	40	3,923
2006	0	0	0	12	161	491	1,419	1,256	893	281	42	0	4,554
2007	0	0	2	5	447	439	1,290	1,423	544	285	15	0	4,450
2008	0	1	13	351	478	1,157	1,197	783	210	83	0	0	4,273
2009	0	0	0	8	115	561	920	1,028	684	286	0	0	3,600
2010	0	0	0	0	125	406	614	1,194	282	462	52	46	3,180
2011	-	-	-	-	-	761	1,251	1,465	1,130	647	-	-	(5,254)
2012	-	-	-	-	-	401	1,037	1,455	754	230	-	-	(3,877)
Avg.*1	0	0	2	42	236	601	988	1,196	719	224	37	10	4,054

*1:Avg.(Average) is culuculated by 2002 to 2012, 2011 and 2012 is excluded.

The Zaungtu Station's average annual discharge from 1998 to 2001was recorded at 3,680 MCM/ year. It can convert to 2,080 mm/year and is relevant to 72% for area rainfall. It may be un-realistic high level, and the rating curve should no longer be used for the calculation of current river discharge.

(3) Maximum River Discharge

According to existing record measured by DMH, the maximum annual discharge at Bago Bridge Station stayed around 1,200m^2/sec by1980, but it turned to an increasing trend since 1980. In the last 10 years, it increased to 1,400m^2/sec and more. In particular in 2011, the historical maximum rate of 1,530 m^2/sec (water level: 960cm) was recorded at the Bago Bridge Station as shown in Figure 4-4-3-3. At the Zaungtu station, the river discharge behaves with a different tendency from that of the Bago station due to the Zaungtu dam’s operation. The Zaungtu dam has been operated with the aims of hydropower and flood mitigation. Actually, at the flooding stage, the effect of “peak-cut of discharge” was found on the hydrograph and subsequently the annual maximum discharge shows a decrease trend.

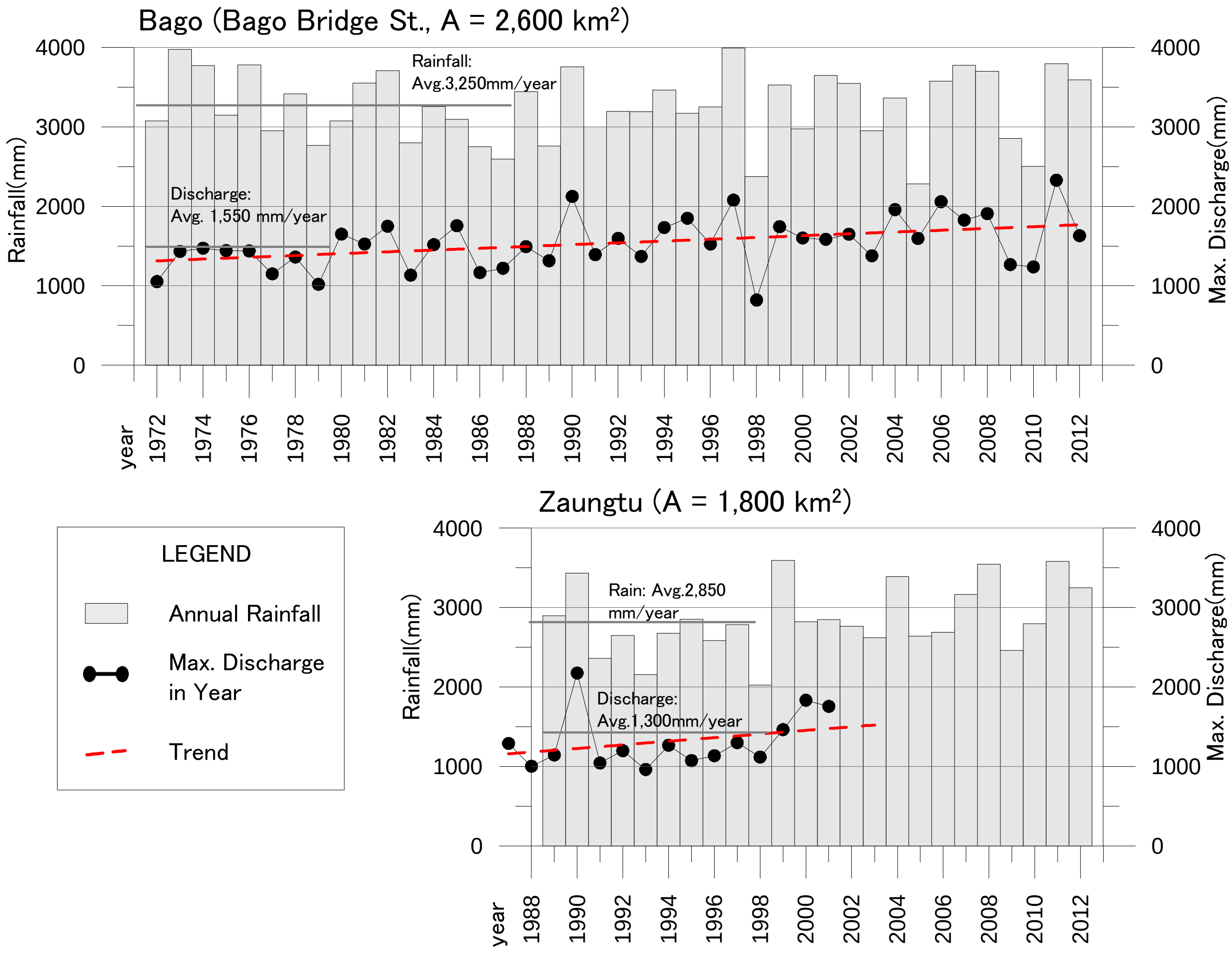


Figure 4-4-3-3 River Discharge at DHM Station (Annual Discharge of Bago Bridge and Zaungtu Station)

4-4-4 River Stage and River Discharge Measurement

To verify the existing data, the four (4) new river gauging stations were installed in 2013's rainy season as shown in Figure 4-4-4-1, Figure 4-2-2-2 and Table 4-4-2-1. The details of the installed gauging station, the progress of observation and the existing records of the nearby station are described as follows.

(1) Installing New Stations

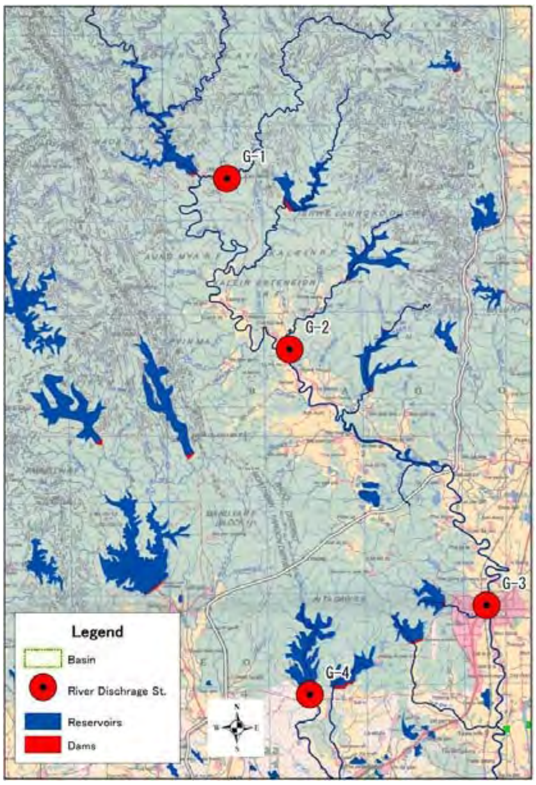


Figure 4-4-4-1 Location Map of River Gauging Station

Among four (4) stations installed in the Survey, thee (3) stations are applied for the measurement of the river stage and discharge, and one(1) station is set in the La Gun Byin reservoir for the measurement of water level changes. As for (3) stations of the river stage measurement, their locations are placed upstream from Bago City due to avoiding the tidal effect. Therefore, as the lowest station, the Bago Old Bridge Station was selected, and the Tamabin and Dawei sites were placed in its upstream. Adjustments of survey lines and station positions in channels are carefully considered through the field survey with the appropriate conditions for the measurement, such as being separated from riverbed deformation, vegetation in the channel, effect of water facility, river construction, abrupt decreasing of discharge in the dry season, as well as the convenience for the measurement work and facility maintenance.

Although there is a delay for getting the approvals from the land owner for the necessary spaces of new stations, all the construction for them was completed by April 2013, before 2013's rainy season. Simultaneously, the leveling survey was also carried out to link gauges with the Myanmar control networks and established benchmark at nearby stations. The summary of the stations are described in Table 4-4-4-1

Table 4-4-4-1 Salient Feature of Hydrological Station

Station Name(St No.)		Lat(D/M/S)	Lon(D/M/S)	BM(EL m)	GDZ(EL m)	Installed
Dawei	G-1	17°44'52"	96°13'52"	BM:41.51	35.64	May2013
Tamabin	G-2	17°34 59"	96°17'29"	BM:23.36	15.77	Mar2013
Bago Old Bridge	G-3	17°20'09"	96°28'52"	BM:09.33	1.45	Jun2013
La Gun Byin	G-4	17°14' 9"	96°18'39"	BM:27.49	14.48	Feb2013

Lat/Lon: Latitude and longitude based on WGS84
BM: Bench Mark Elevation in meter
GDZ: Gage Datum Zero Elevation in meter

1) Bago Old Bridge Station(G3 Station)

The Bago Old Bridge station is located in the intermediate point between the DMH station and ID station. The DMH station was built 200 m downstream whereas ID station is settled 50 m upstream from the Bago Old Bridge station. They are both regarded as the base station in the Bago River Basin. However, as mentioned above, the DMH's gauge is not functioning, in particular for the low water level, because of the plugging up of the conducting pipes by sediment, and ID station is not equipped with any auto-mated instruments; still gauge reading is only available. Even though Bago is the most important location in the basin, the data accuracy and measurement frequency is not enough to study the river regime and formulate the mitigation plan for the flooding and developing plan for water resources. Aiming to improve the condition on hydrological data collection, the Bago Old Bridge station is constructed even beside the ID and DMH station (refer to Figure 4-4-4-2).

Figure 4-4-4-2 Bago Old Bridge (G3) Station (June/2013)

Table 4-4-4-2 Observation Summary of Bago Old Bridge(G3) Station (2013)

Items	Observation Summary (2013)
Catchment Area	2,620 ㎞ ^{2}
Annual Area Rainfall	8,020 MCM/year
Max. Daily Rainfall	106 ㎜（Bago Station）
Min.-Max. Daily Mean River Stage	1.8-8.8 m (2013/1-2014/2)
River Discharge	3,315 MCM/year
Annual Runoff Rate	0.41

The station is main river gage station of Bago River and has large catchment as 2610km^2. The maximum daily discharge measured in flood season was 942m^3/sec (1,005m^3/sec at max. discharge in 10 minutes) while almost zero in dry season. The summary of measurement in 2013 is shown in Table 4-4-4-2.

2) Tamabin (G2) Station

The Tamabin station is located in the middle point of the Bago basin. Downstream from Tamabin, the Zaungtu Weir is located and its reservoir area is extended several kilometers upstream. The station is therefore placed out of the ponding area of the Zaungtu weir, in particular during the rainy season. However in the catchment of the Tamabin station, there is the Zaungtu dam for hydropower and the

Figure 4-4-4-3 Tamabyin(G2) Station（Feb/2013）

Kodugwe and Shwelaung dams for irrigation. Consequently, the observing discharge is affected by their dam operation. Depending on the dam outflow for irrigation water, the changes of discharge from several to several 10 m^3/sec has been observed in the dry season (refer to Figure 4-4-4-3).

Table 4-4-4-3 Observation Summary of Tamabin(G2) Station (2013)

Items	Observation Summary (2013)
Catchment Area	2,024 ㎞ ^{2}
Annual Area Rainfall	6,088 MCM/year
Max. Daily Rainfall	93 ㎜（Zaungtu Station）
Min.-Max. Daily Mean River Stage	16.5-22.1 m (2013/3-2014/2)
River Discharge	2,581 MCM/year
Annual Runoff Rate	0.42

The river stage in dry season was less than one (1) meter while over six (6) meters was observed in rainy season. The summary is shown as Table 4-4-4-3.

3) Dawei (G1) Station

Dawei station was installed at the tributary (Dawei river), and placed at three (3) kilometers upstream of the confluence with the main channel[3]. As the feature plan, the Dawei dam is planned as the water source for SEZ, so the location is selected at an appropriate point able to maintain the useful information for the feature plan(refer to Figure 4-4-4-4).

Figure 4-4-4-4 Dawei(G1) Station (Feb/2013)

At the end of dry season, the river discharge was very few, while in the rainy season it turned to increase up to five (5) meters. The flood peak was also very sharp only with 10 munities. The summary of river flow in 2013 is shown in Table 4-4-4-4.

Table 4-4-4-4 Observation Summary of Dawei(G1) Station (2013)

Items	Observation Summary (2013)
Catchment Area	141 ㎞ ^{2}
Annual Area Rainfall	424 MCM/year
Max. Daily Rainfall	93 ㎜ （Zaungtu Station）
Min.-Max. Daily Mean River Stage	35.6-41.0 m (2013/5-2014/2)

[3] At the point of the Dawei station, the stream is interrupted and dried during April to May and an automated recorder is only installed in the rainy season.

River Discharge	215 MCM/year
Annual Runoff Rate	0.51

4) La Gun Byin G4 Station

Downstream from the La Gun Byin dam, the river channel branches and disperses and an appropriate point therefore was not discovered for clarifying the outflow of the La Gun Byin dam. So the continuous water level of the dam reservoir is measured, and it applies to estimate the reservoir volume using with H-Q curve. Also, the estimated reservoir volume, the dam operation records of intake and overflow are applied for obtaining the inflow for dams. The water level meter is placed on the wall of the intake tower of La Gun Byin (refer to Figure 4-4-4-5).

Figure 4-4-4-5 La Gun Byin G4 Station (Mar/2013)

(2) River Stage Measurement in 2013

The river stage hydrographs of four (4) stations (G1 to G4) are shown in Figure 4-4-4-6. The stage rises from May and reaches the maximum at the August. The seasonal difference of river stage between dry season and rainy season reached five (5) meters at Dawei and Tamabin Station and six(6) meters at Bago Old Bridge. As local condition, a tidal effect is also recognized in particular lower stage than four (4) meters, about one (1) meter's fluctuation was observed effected by daily tidal changes.

As well, the peak was observed at the end of October to November in the hydrographs of river stage. The peak was also traced from the upstream to the downstream. From the upstream station, the flood peak was took place at mid-night of 28th October at Dawei station, the early morning of 29th October and the early morning of 30th October. The time lag between Dawei (G1) and Bago Old Station (G3) was two (2) days.

In other hand, at this timing, the most of dam reservoirs were in almost filled and are no enough room for controlling flood water so the most of discharge might be spilled over to the downstream. In the neighboring areas of Sittaung Basin, this heavy rain caused the inundating damages at Swa and Taungu Township due to rapid rise of river stage without any control by upstream dams.

(3) Rainfall and River Stage in 2013

In 2013, Yangon (Kabaaye) and Bago had normal rainfall, respectively 2,774 mm/year and 3,242 mm/year (average rainfall: 2,780 mm/year of Kabaaye, 3,260 mm/year of Bago) while the Zaungtu Station has a heavy rainfall of 3,008 mm/year than an average (average rainfall: 2,860mm at the Zaungtu station) due to an unseasonable rainfall. It takes 100 mm to 200 mm as a continuous rainfall at the end of dry season and annual total consequently resulted in larger than that of average year. As well, with the climaxes of rainfall, the river stage also moved and the two peaks of river stages were observed in August and October. In Figure 4-4-4-6, the changes of water level (river stages and reservoir water level) and daily rainfall are shown.

At peaks, the maximum discharges were respectively observed as 202 m^3/sec at the Dawei (daily mean of 28/October), 707m^3/sec at the Tamabin (daily mean of 22/August) and 1,005m^3 sec at Bago old Bridge (07:00 of 23/August). If these values compare with 10minutes' discharge, 10 minutes' discharge is 30% larger than daily discharge.

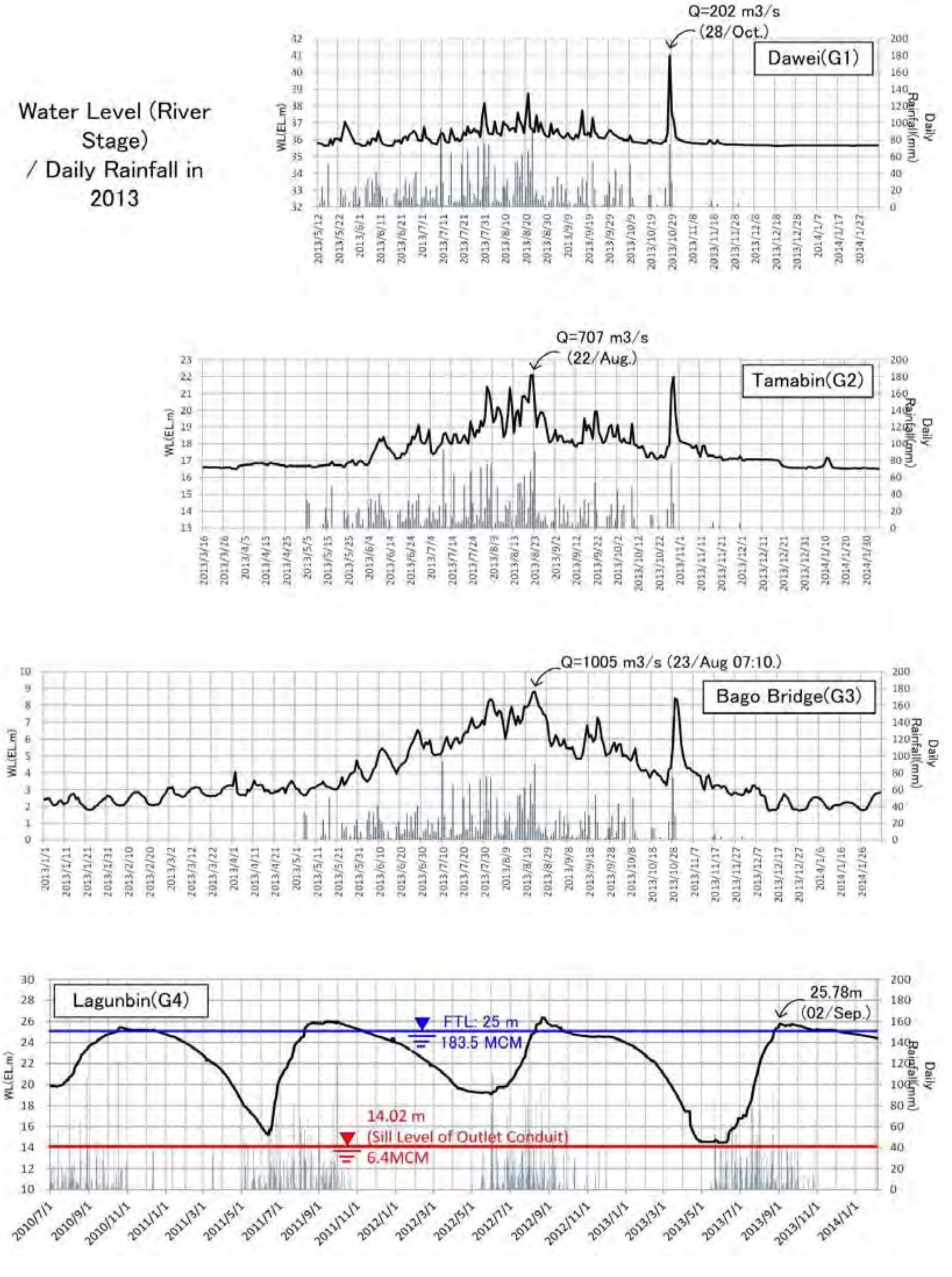


Figure 4-4-4-6 River Stage

(4) River Discharge Measurement in 2013

1) Method of River Discharge Measurement

The Bago River has a large fluctuation of river stages, for instance, Bago Bridge shows two (2) meters in the dry season and nine (9) meters in the rainy season. The river width is also extended from 40 meters to 70 meters and the velocity distribution is complicated. In order to meet the various conditions due to the seasons, the appropriate methods are selected to obtain precise and reliable data.

<u>Portable Electromagnetic Flow-meter</u>: the meter is used for the Low Water Level less than two (2) meters in the main channel and tributaries, as for the Dawei river and its station. As described above, the Bago River behaves as if it's almost dried up and its flow rate is slow, such as less than 0.1 m/sec. So the portable electromagnetic flow-meter is solely used for those measurements in the low water level.

<u>ADCP</u> : Acoustic Doppler Current Profiler (ADCP): ADCP is used for the Middle to High Water level. At the zone of river levels, the depth of the river reaches over 5 meters and the velocity exceeds two (2) meters at the center of the stream while the eddy current occurs at nearby banks. In this condition, ADCP, as a capable devise of the profile measurement, is a more appropriate devise than the portable electromagnetic flow meter.

<u>Float</u>: The Floating method is applied at the time of flooding, supposedly a high-risk of distress of on-boat ADCP survey. Instead, two (2) posts are built upstream and downstream of the bank and the elapsed (flow-) time is measured between posts to estimate the flowing velocity. The survey is made in three (3) survey lines with four (4) measurements respectively and used by four (4) meters of long-float, according to the existing ADCP survey results taken at the same river section.

2) Application of River Discharge Measurement

As stated above, the discharge survey was carried out with three (3) devices according to the river condition in terms of water depth and risk on boat capsizing. Respectively,

- Portable Electromagnetic Flow-meter is used at Low Water Level from October to May,
- ADCP is applied for Middle-High Water Level from June to September without flood time, and
- Float is used at the time of flood when on-boat survey is difficult to proceed with because of a high-risk of sinking of boat.

<u>Portable Electromagnetic Flow-meter</u>: The method applied for the portable electromagnetic

flow-meter is selected as one (1) of two (2) depending on the observing water depth. If water depth is deeper than 75 cm, two (2) points of two-tenths and eight-tenths depth below the surface are measured to estimate the mean velocity while if the water depth is shallower than 75 cm, six-tenths of the total depth below the surface is measured as a close approximation to the mean velocity at the respective observing section. As for the number of observing sections[4], this is also decided by the width of the river and limited to less than 10 % of the river's width. In the case of the Tamabin station measurement in the middle of 20/April/2013, the river's width is 93 meters, so the division is 45 at 5-meter intervals. Totaling an estimated discharge of 45 divisions, four (4) m^3/sec is obtained.

Acoustic Doppler Current Profiler (ADCP): Using ADCP, the velocity distribution and section area of the river channel are able to be simultaneously measured and to estimate the river discharge in the dynamic condition influenced by constantly varying the form of the riverbed. However, for properly uses of ADCP, the water depth of 4 to 5 meters is at least required to maintain observation accuracy. In the case of the measurement on 02/July/2013 at the Bago Bridge Station, the maximum water depth was 7.9 meters and its measurement was made based on 0.5 x 0.5 meters unit in depth (or vertical) direction. Accumulating data in the vertical direction, the measurement continued horizontally along with the ship trail. Simultaneously, the river section and area were also obtained and consequently river discharge was estimated. This measurement showed the given results as 69 meters (229 ft.) of river width, 338 m^2 (4200 ft^2) of river section area, 0.4m/sec (1.4ft/sec) of average velocity and 154 m^3/sec(5494 ft^3/sec) of river discharge as shown in Figure 4-4-4-7.

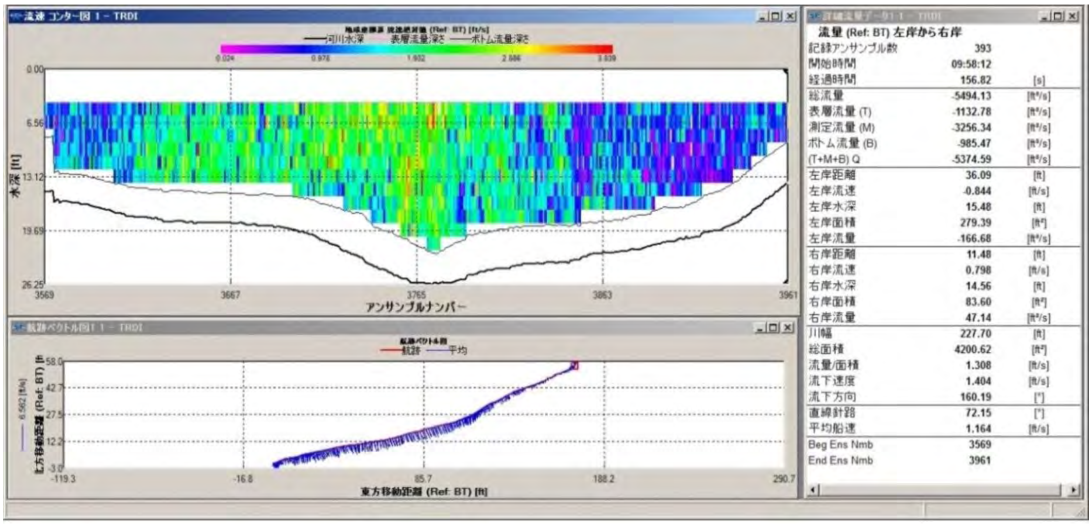


Figure 4-4-4-7 Observation by Acoustic Doppler Current Profiler (ADCP, 02/July/2013, Bago Old Bridge Station)

[4]Velocity also varies across a channel, and measurements must, therefore, be made at several points across the channel. The depth of the river varies across its width, so the usual practice is to divide the cross-section of the stream into a number of vertical sections and measure velocity at each of these. No section should include more than 10-20 percent of the total discharge. Thus, the number of vertical sections is decided depending on the width of the stream.

3) River Discharge in 2013

In the Survey, the discharge measurement has begun together with the construction of the river gauging station. The measurements at the Bago Old Bridge Station and the Tamabin Station were started since the middle of January 2013. While the Dawei Station is located upstream, the measurement was commenced from the middle of February 2013. Since one hydrological year's record is required for the Survey, the measurements of these stations will continue until December 2013. Respectively, 40 measurements in Dawei (G1) Station, 47 in Tamabin (G2) Station and 57 measurements in Bago Old Bridge (G3) Station were carried out in a year 2013.

At the beginning of the measurement of January, the dry season had progressed and the river discharge had drastically deceased, and only released water from reservoirs in turn flowed into the river channel. Especially in the Dawei Station located in tributary, the discharge is measured only at 0.04 m^3/sec at this moment, which has become completely dry in early March. At the Tamabin and Bago Bridge Stations located downstream from the main channel, their discharges are restricted by the outflow from dam reservoirs in their catchments and the flow rates are also respectively 5m^3/sec and 15m^3/sec maximum.

The rainfall commences in May and the succeeding months, followed by the natural discharge in the river channels. Along with increasing the discharge, an irrigation dam also starts to store the water into reservoirs. In the period of May to July, the water level of the river is maintained within the intermediate, measuring at 50 m^3/sec of the monthly average at the Tamabin Station and 50 to 200 m^3/sec at the Bago Bridge Station. At the peak of the rainy season, shown to be from late July to early September, the rain remains longer with heavier intensity, which causes the maximum water level in the main channel. As a monthly average, the 300 to 700 m^3/sec is obtained. In Table 4-4-4-5 to 4-4-4-7, the result of the Discharge Survey is summarized.

Table 4-4-4-5 Summary of River Discharge （Dawei G1 Station）

Station ID	Survey No.	Direction *1/	Measurement No	Date (Y/M/D:H:M)	Mean Water Level*2/ (m)	Mean Water Depth (m)	Width (m)	Area (m2)	Mean Velocity (m/sec)	Discharge (m3/sec)	Method*3/	Surveyer	Remarks	Data Relaibility *4/
G1	1	L-R	G1-1-L	2013/1/24 13:00	35.766	0.125	7.930	0.976	0.258	0.255	FL	JICA	Measurement before Installation	x V
G1	1	R-L	G1-1-R	2013/1/24 13:00	35.766	0.125	7.930	0.976	0.258	0.255	FL	JICA	- do -	x V
G1	2	L-R	G1-2-L	2013/2/13 14:00	36.191	0.135	7.500	1.015	0.043	0.043	EF	JICA	- do -	x V
G1	2	R-L	G1-2-R	2013/2/13 14:00	36.191	Nil	-		-	Nil	EF	JICA	- do -	x V
G1	3	L-R	G1-3-L	2013/2/28 10:00	35.841	0.106	6.000	0.635	0.028	0.018	EF	JICA	- do -	x V
G1	3	R-L	G1-3-R	2013/2/28 11:30	35.841	0.100	6.000	0.600	0.024	0.015	EF	JICA	- do -	x V
G1	4	L-R	G1-4-L	2013/3/31 9:30	35.641	0.050	3.000	0.150	0.020	0.003	EF	JICA	- do -	○
G1	4	R-L	G1-4-R	2013/3/31 10:30	35.641	0.052	3.000	0.155	0.020	0.003	EF	JICA	- do -	○
G1	5	L-R	G1-5-L	2013/7/9 12:00	35.961	0.778	19.000	14.790	0.600	8.868	EF	JICA		○
G1	5	R-L	G1-5-R	2013/7/9 12:30	36.011	0.808	19.000	15.350	0.559	8.580	EF	JICA		○
G1	6	L-R	G1-6-L	2013/7/9 16:00	36.286	1.059	20.000	21.175	0.767	16.239	EF	JICA		○
G1	6	R-L	G1-6-R	2013/7/9 16:30	36.256	1.035	20.000	20.693	0.783	16.211	EF	JICA		○
G1	7	L-R	G1-7-L	2013/8/4 11:45	36.151	0.508	13.700	6.955	0.660	4.590	EF	JICA	Unsteady flowing ?	x V
G1	7	R-L	G1-7-R	2013/8/4 11:45	36.151	0.511	13.500	6.900	0.638	4.401	EF	JICA	Unsteady flowing ?	x V
G1	8	L-R	G1-8-L	2013/8/4 16:40	36.291	0.663	14.300	9.475	0.535	5.069	EF	JICA	Unsteady flowing ?	x V
G1	8	R-L	G1-8-R	2013/8/4 16:05	36.291	0.663	14.300	9.475	0.464	4.395	EF	JICA	Unsteady flowing ?	x V
G1	9	L-R	G1-9-L	2013/8/5 7:00	37.541	1.433	18.400	26.360	0.487	12.825	EF	JICA	Unsteady flowing ?	×A
G1	9	R-L	G1-9-R	2013/8/5 16:05	37.541	1.439	18.400	26.480	0.408	10.800	EF	JICA	Unsteady flowing ?	×A
G1	10	L-R	G1-10-L	2013/8/26 14:00	36.771	0.969	24.100	23.345	1.345	31.399	EF	JICA	Unsteady flowing ?	xV
G1	10	R-L	G1-10-R	2013/8/26 13:00	36.771	0.940	24.100	22.645	1.223	27.692	EF	JICA		○
G1	11	L-R	G1-11-L	2013/8/26 14:00	37.186	1.366	24.500	33.475	0.821	27.485	EF	JICA		○
G1	11	R-L	G1-11-R	2013/8/28 16:30	37.141	1.366	24.500	33.475	0.924	30.943	EF	JICA		○
G1	12	L-R	G1-12-L	2013/8/27 7:30	36.516	0.803	23.100	18.555	0.929	17.243	EF	JICA		○
G1	12	R-L	G1-12-R	2013/8/27 8:30	36.516	0.849	23.100	19.605	0.900	17.650	EF	JICA		○
G1	13	L-R	G1-13-L	2013/9/10 13:00	36.111	0.448	21.800	9.770	0.634	6.192	EF	JICA		○
G1	13	R-L	G1-13-R	2013/9/10 13:00	36.111	0.448	21.800	9.770	0.670	6.547	EF	JICA		○
G1	15	L-R	G1-15-L	2013/9/23 16:30	36.161	0.549	21.800	9.740	0.605	7.236	EF	JICA		○
G1	15	R-L	G1-15-R	2013/9/23 16:30	36.161	0.549	21.800	9.740	0.622	7.437	EF	JICA		○
G1	14	L-R	G1-14-L	2013/9/24 9:10	36.081	0.449	21.700	11.960	0.654	6.367	EF	JICA		○
G1	14	R-L	G1-14-R	2013/9/24 9:30	36.081	0.449	21.700	11.960	0.647	6.306	EF	JICA		○
G1	16	L-R	G1-16-L	2013/10/10 9:10	35.861	0.328	16.200	5.310	0.607	3.225	EF	JICA		○
G1	16	R-L	G1-16-R	2013/10/10 8:50	35.861	0.322	16.200	5.215	0.579	3.020	EF	JICA		○
G1	17	L-R	G1-17-L	2013/10/24 9:00	35.731	0.204	17.500	3.575	0.492	1.760	EF	JICA		○
G1	17	R-L	G1-17-R	2013/10/24 8:40	35.731	0.204	17.500	3.575	0.479	1.713	EF	JICA		○
G1	18	L-R	G1-18-L	2013/11/15 13:00	35.741	0.2111	18	3.8	0.5125	1.9475	EF	JICA		○
G1	18	R-L	G1-18-R	2013/11/15 13:20	35.741	0.2122	18	3.82	0.5028	1.9244	EF	JICA		○
G1	19	L-R	G1-19-L	2013/12/1 9:30	35.661	0.1729	11.8	2.04	0.4556	0.9294	EF	JICA		○
G1	19	R-L	G1-19-R	2013/12/1 9:45	35.661	0.1729	11.8	2.04	0.4458	0.9095	EF	JICA		○
G1	20	L-R	G1-20-L	2013/12/23 14:10	35.621	0.1292	12	1.55	0.3487	0.5404	EF	JICA		○
G1	20	R-L	G1-20-R	2013/12/23 13:05	35.621	0.1292	12	1.55	0.3398	0.5267	EF	JICA		○

L-R: Left to Right, R-L:Right to Left *2 Mean Water Level based on elevation *3 FL:Float Method, EF:Electromagnetic FLow Meter,ADCP:Acoustic Doppler Current Profiler

Data is elvaluated with Velocity(xV) and Area(xA), and used only relailabie Data (○)

Table 4-4-4-6 Summary of River Discharge (Tamabin G2 Station)

Station Name	Station ID	Survey No.	Direction *1/	Measurement No	Date (Y/M/D:H:M)	Mean Water Level*2/ (m)	Mean Water Depth (m)	Width (m)	Area (m2)	Mean Velocity (m/sec)	Discharge (m3/sec)	Method*3/	Surveyer	Remarks	Data Relaibility *4/
Tamabin	G2	1	L-R	G2-1-L	2013/1/14 10:00	Nil	Nil	Nil	Nil	Nil	Nil	Nil	JICA		○
Tamabin	G2	1	R-L	G2-1-R	2013/1/14 10:00	16.752	0.457	91.200	41.650	0.047	1.946	EF	JICA		○
Tamabin	G2	2	L-R	G2-2-L	2013/1/29 9:30	16.812	0.530	92.400	48.980	0.026	1.283	EF	JICA		○
Tamabin	G2	2	R-L	G2-2-R	2013/1/29 10:30	16.742	0.501	92.400	46.330	0.019	0.903	EF	JICA		○
Tamabin	G2	3	L-R	G2-3-L	2013/2/13 9:00	16.732	0.370	93.000	34.400	0.078	2.688	EF	JICA		○
Tamabin	G2	3	R-L	G2-3-R	2013/2/13 10:00	16.692	0.361	93.000	33.550	0.046	1.531	EF	JICA		○
Tamabin	G2	4	L-R	G2-4-L	2013/3/1 11:00	16.777	0.505	95.800	48.350	0.059	2.839	EF	JICA		○
Tamabin	G2	4	R-L	G2-4-R	2013/3/1 13:00	16.732	0.462	90.700	41.905	0.026	1.101	EF	JICA		○
Tamabin	G2	5	L-R	G2-5-L	2013/3/15 11:00	16.802	0.497	90.300	44.854	0.056	2.518	EF	JICA		○
Tamabin	G2	5	R-L	G2-5-R	2013/3/15 12:30	16.752	0.488	90.300	44.042	0.051	2.265	EF	JICA		○
Tamabin	G2	6	L-R	G2-6-L	2013/3/30 15:30	16.892	0.598	92.750	55.421	0.035	1.948	EF	JICA		○
Tamabin	G2	6	R-L	G2-6-R	2013/3/30 17:00	16.867	0.608	87.750	53.346	0.034	1.812	EF	JICA		○
Tamabin	G2	7	L-R	G2-7-L	2013/4/1 8:25	16.777	0.500	92.800	46.354	0.049	2.261	EF	JICA		○
Tamabin	G2	7	R-L	G2-7-R	2013/4/1 10:00	16.797	0.520	93.000	48.330	0.052	2.495	EF	JICA		○
Tamabin	G2	8	L-R	G2-8-L	2013/4/13 8:40	17.007	0.701	92.580	64.936	0.063	4.072	EF	JICA		○
Tamabin	G2	8	R-L	G2-8-R	2013/4/13 10:30	17.032	0.717	92.580	66.386	0.064	4.275	EF	JICA		○
Tamabin	G2	9	L-R	G2-9-L	2013/4/28 8:00	16.762	0.511	92.600	47.356	0.051	2.396	EF	JICA		○
Tamabin	G2	9	R-L	G2-9-R	2013/4/28 10:00	16.772	0.504	92.700	46.767	0.049	2.277	EF	JICA		○
Tamabin	G2	10	L-R	G2-10-L	2013/5/13 10:00	16.642	0.372	91.900	34.175	0.047	1.609	EF	JICA		○
Tamabin	G2	10	R-L	G2-10-R	2013/5/13 12:30	16.652	0.381	91.900	35.025	0.049	1.706	EF	JICA		○
Tamabin	G2	11	L-R	G2-11-L	2013/5/31 10:00	17.182	1.022	95.800	97.860	0.492	48.099	EF	JICA		○
Tamabin	G2	11	R-L	G2-11-R	2013/5/31 14:00	17.247	1.042	96.300	100.323	0.495	49.616	EF	JICA		○
Tamabin	G2	12	L-R	G2-12-L	2013/6/14 11:00	17.602	1.175	93.800	110.220	0.736	81.120	EF	JICA		○
Tamabin	G2	12	R-L	G2-12-R	2013/6/14 12:30	17.537	1.102	93.500	103.025	0.734	75.581	EF	JICA		○
Tamabin	G2	13	L-R	G2-13-L	2013/7/10 11:30	18.542	3.269	100.400	328.240	0.202	66.262	EF	JICA	Unsteady flowing ?	×A
Tamabin	G2	13	R-L	G2-13-R	2013/7/10 10:30	18.487	3.409	100.400	342.280	0.189	64.725	EF	JICA	Unsteady flowing ?	×A
Tamabin	G2	14	NA	G2-14-N	2013/7/30 0:00	19.972	3.238	103.900	336.400	1.010	340.000	ADCP	JICA		○
Tamabin	G2	15	NA	G2-15-N	2013/7/31 0:00	21.552	4.585	113.900	522.200	1.130	592.000	ADCP	JICA		○
Tamabin	G2	16	NA	G2-16-N	2013/8/1 0:00	21.172	3.873	115.800	448.500	1.200	537.000	ADCP	JICA		○
Tamabin	G2	17	NA	G2-17-N	2013/8/1 0:00	20.972	3.541	104.800	371.100	1.160	429.000	ADCP	JICA		○
Tamabin	G2	18	NA	G2-18-N	2013/8/25 0:00	19.552	3.540	99.200	351.200	0.854	300.000	ADCP	JICA		○
Tamabin	G2	19	NA	G2-19-N	2013/8/28 0:00	19.112	2.645	99.900	264.200	0.790	209.000	ADCP	JICA		○
Tamabin	G2	20	NA	G2-20-N	2013/8/28 0:00	19.312	3.157	88.400	279.100	0.853	236.000	ADCP	JICA		○
Tamabin	G2	21	NA	G2-21-N	2013/9/8 0:00	18.292	2.698	98.100	264.700	0.647	171.000	ADCP	JICA		○
Tamabin	G2	22	NA	G2-22-N	2013/9/9 0:00	18.042	2.339	100.100	234.100	0.576	135.000	ADCP	JICA		○
Tamabin	G2	23	NA	G2-23-N	2013/9/22 0:00	19.672	3.619	108.000	390.900	0.765	299.000	ADCP	JICA		○
Tamabin	G2	24	NA	G2-24-N	2013/10/9 0:00	19.332	3.370	102.800	346.700	0.673	233.000	ADCP	JICA		○
Tamabin	G2	25	NA	G2-25-N	2013/10/9 0:00	19.552	3.610	108.300	391.100	0.746	292.000	ADCP	JICA		○
Tamabin	G2	26	NA	G2-26-N	2013/10/9	19.792	3.810	108.200	411.600	0.872	359.000	ADCP	JICA		○
Tamabin	G2	27	NA	G2-27-N	2013/10/9	19.922	3.960	108.100	427.800	0.857	367.000	ADCP	JICA		○
Tamabin	G2	28	NA	G2-28-N	2013/10/9	20.032	4.010	111.200	452.300	0.863	390.000	ADCP	JICA		○
Tamabin	G2	24	L-R	G2-24-L	2013/10/23	17.262	0.934	94.500	88.275	0.482	42.583	EF	JICA		○
Tamabin	G2	24	R-L	G2-24-R	2013/10/23	17.262	0.939	94.500	88.775	0.480	42.620	EF	JICA		○
Tamabin	G2	30	L-R	G2-30-L	2013/11/16	17.402	0.894	75.600	67.580	0.430	29.064	EF	JICA		○
Tamabin	G2	30	R-L	G2-30-R	2013/11/16	17.402	0.899	75.600	67.980	0.426	28.964	EF	JICA		○
Tamabin	G2	31	L-R	G2-31-L	2013/12/22	16.757	0.453	62.500	28.325	0.296	8.377	EF	JICA		○
Tamabin	G2	31	R-L	G2-31-R	2013/12/22	16.757	0.460	62.500	28.725	0.295	8.484	EF	JICA		○

*1 L-R: Left to Right, R-L:Right to Left *2 Mean Water Level based on elevation *3 FL:Float Method, EF:Electromagnetic FLow Meter,ADCP:Acoustic Doppler Current Profiler

*4 Data is elvaluated with Velocity(xV) and Area(xA), and used only relailabie Data (○)

Table 4-4-4-7(1/2) Summary of River Discharge (Bago Old Bridge G3 Station - D/S -)

Station Name	Station ID	Survey No.	Direction *1/	Measurement No	Date (Y/M/D:H:M)	Mean Water Level*2/ (m)	Mean Water Depth (m)	Width (m)	Area (m2)	Mean Velocity (m/sec)	Discharge (m3/sec)	Method*3/	Surveyer	Remarks	Data Relaibility *4/
Bago Old Bridge(DS)	G3	1	L	G3-1-L	2013/1/31 8:10	2.380	6.00	66.2	397.16	0.017	6.91	EF	JICA	Surveyline is not on G3	×A
Bago Old Bridge(DS)	G3	1	R	G3-1-R	2013/1/31 9:00	2.380	6.51	26.2	170.61	0.013	2.16	EF	JICA		○
Bago Old Bridge(DS)	G3	2	L	G3-2-L	2013/2/15 8:30	2.690	6.43	68.5	440.58	0.035	15.54	EF	JICA	Surveyline is not on G3	×A
Bago Old Bridge(DS)	G3	2	R	G3-2-R	2013/2/15 9:30	2.680	6.06	68.5	415.23	0.037	15.25	EF	JICA	Surveyline is not on G3	×A
Bago Old Bridge(DS)	G3	3	L	G3-3-L	2013/6/21 14:49	4.397	3.92	63.3	279.47	0.259	72.39	EF	JICA		○
Bago Old Bridge(DS)	G3	3	R	G3-3-R	2013/6/21 14:30	4.297	4.25	63.3	272.07	0.258	70.08	EF	JICA		○
Bago Old Bridge(DS)	G3	4	L	G3-4-L	2013/6/24 9:00	5.447	3.91	66.1	333.86	0.392	130.99	EF	JICA		○
Bago Old Bridge(DS)	G3	4	R	G3-4-R	2013/6/24 10:00	5.447	4.89	66.1	323.32	0.430	139.02	EF	JICA		○
Bago Old Bridge(DS)	G3	5	L	G3-5-L	2013/6/26 9:00	5.927	3.91	66.9	357.38	0.508	181.68	EF	JICA		○
Bago Old Bridge(DS)	G3	5	R	G3-5-R	2013/6/26 7:50	5.897	5.29	66.9	353.90	0.448	158.43	EF	JICA		○
Bago Old Bridge(DS)	G3	6	L	G3-6-L	2013/6/27:08:30	6.142	3.85	68.3	362.40	0.647	234.65	EF	JICA		○
Bago Old Bridge(DS)	G3	6	R	G3-6-R	2013/6/27:09:30	6.142	5.35	68.3	365.59	0.633	231.24	EF	JICA		○
Bago Old Bridge(DS)	G3	7	L	G3-7-L	2013/6/27:16:00	6.392	3.97	68.7	359.99	0.665	239.39	EF	JICA		○
Bago Old Bridge(DS)	G3	7	R	G3-7-R	2013/6/27:17:00	6.442	5.67	68.7	389.69	0.645	251.33	EF	JICA		○
Bago Old Bridge(DS)	G3	8	L	G3-8-L	2013/7/2 0:00	5.657	5.77	66.6	384.55	0.417	160.00	ADCP	JICA	L-R Measurement	○
Bago Old Bridge(DS)	G3	8	R	G3-8-R	2013/7/2 0:00	5.657	5.63	69.4	391.18	0.394	154.00	ADCP	JICA	R-L Measurement	○
Bago Old Bridge(DS)	G3	8	M	G3-8-M	2013/7/2 0:00	5.657	5.82	65.0	378.10	0.418	157.00	ADCP	JICA	Mean of Measurements	○
Bago Old Bridge(DS)	G3	9	M	G3-9-M	2013/7/24 0:00	7.247	6.89	72.6	500.10	0.766	383.00	ADCP	JICA	Mean of Measurements	○
Bago Old Bridge(DS)	G3	10	M	G3-10-M	2013/7/29 0:00	7.087	7.04	66.3	466.80	0.748	349.00	ADCP	JICA	Mean of Measurements	○
Bago Old Bridge(DS)	G3	11	U	G3-11-U	2013/8/1 10:20	8.377	7.46	77.0	574.78	1.372	788.60	FL	JICA	Float Method due to Flood	○
Bago Old Bridge(DS)	G3	12	U	G3-12-U	2013/8/2 9:40	8.557	7.63	77.4	590.75	1.367	807.39	FL	JICA	-do-	○
Bago Old Bridge(DS)	G4	13	M	G4-13-M	2013/8/6 0:00	7.777	7.43	73.7	547.60	0.994	544.00	ADCP	JICA	Mean of Measurements	○
Bago Old Bridge(DS)	G3	13	M	G3-13-M	2013/8/21 0:00	8.257	8.39	75.7	634.90	1.130	718.00	ADCP	JICA	Mean of Measurements	○
Bago Old Bridge(DS)	G3	14	M	G3-14-M	2013/8/22 0:00	8.857	8.01	73.6	589.60	1.180	696.00	ADCP	JICA	Unsteady flow ?	x V
Bago Old Bridge(DS)	G3	12	L	G3-12-L	2013/9/5 11:40	5.997	3.92	65.7	322.78	0.424	136.96	EF	JICA	-do-	x V
Bago Old Bridge(DS)	G3	13	R	G3-13-R	2013/9/5 11:00	6.007	4.94	63.8	315.17	0.438	138.18	EF	JICA	-do-	x V
Bago Old Bridge(DS)	G3	13	L	G3-13-L	2013/9/5 9:00	6.017	3.81	65.1	342.51	0.404	138.29	EF	JICA	-do-	x V
Bago Old Bridge(DS)	G3	14	R	G3-14-R	2013/9/5 10:00	6.017	5.16	61.1	315.29	0.429	135.11	EF	JICA	-do-	x V
Bago Old Bridge(DS)	G3	15	M	G3-15-M	2013/9/21 0:00	5.987	6.32	66.6	420.60	0.855	360.00	ADCP	JICA	-do-	x V
Bago Old Bridge(DS)	G3	15	M	G3-15-M	2013/9/21 0:00	5.987	6.48	66.8	433.10	0.901	433.10	ADCP	JICA	-do-	x V
Bago Old Bridge(DS)	G3	16	M	G3-16-M	2013/10/7 0:00	5.087	5.85	58.8	343.90	0.504	173.00	ADCP	JICA	-do-	x V
Bago Old Bridge(DS)	G3	16	M	G3-16-M	2013/10/7 0:00	5.087	4.97	57.7	286.50	0.519	149.00	ADCP	JICA	-do-	x V
Bago Old Bridge(DS)	G3	17	L	G3-17-L	2013/10/22 13:30	3.747	4.39	63.0	276.45	0.480	132.71	EF	JICA	-do-	x V
Bago Old Bridge(DS)	G3	17	R	G3-17-R	2013/10/22 13:30	3.747	4.37	63.00	275.05	0.491	134.98	EF	JICA	-do-	x V
Bago Old Bridge(DS)	G3	23	L	G3-23-L	2013/11/14 9:00	3.987	4.26	61.0	279.00	0.391	108.99	EF	JICA	-do-	x V
Bago Old Bridge(DS)	G3	23	R	G3-23-R	2013/11/14 10:00	3.967	4.20	61.0	256.50	0.399	102.44	EF	JICA	-do-	x V
Bago Old Bridge(DS)	G3	24	L	G3-24-L	2013/12/2 14:15	3.067	3.18	60.5	192.35	0.198	38.08	EF	JICA		○
Bago Old Bridge(DS)	G3	24	R	G3-24-R	2013/12/2 13:30	3.127	3.19	60.5	192.75	0.183	35.35	EF	JICA		○
Bago Old Bridge(DS)	G3	25	L	G3-25-L	2013/12/26 15:15	1.912	2.61	55.8	145.41	0.044	6.33	EF	JICA		○
Bago Old Bridge(DS)	G3	25	R	G3-25-R	2013/12/26 14:30	1.912	2.48	55.8	138.21	0.038	5.31	EF	JICA		○

*1 L-R: Left to Right, R-L:Right to Left *2 Mean Water Level based on elevation *3 FL:Float Method, EF:Electromagnetic FLow Meter,ADCP:Acoustic Doppler Current Profiler

*4 Data is elvaluated with Velocity(xV) and Area(xA), and used only relailabie Data (○)

Table 4-4-4-7(2/2) Summary of River Discharge (Bago Old Bridge G3 Station - U/S -)

Station Name	Station ID	Survey No.	Direction *1/	Measurement No	Date (Y/M/D:H:M)	Mean Water Level*2/ (m)	Mean Water Depth (m)	Width (m)	Area (m2)	Mean Velocity (m/sec)	Discharge (m3/sec)	Method*3/	Surveyer	Remarks	Data Relaibility *4/
Bago Old Bridge(US)	G3	1	L	G3-1-L	2013/1/18 0:00	2.210	-	-	-	-	Nil	EF	JICA	U/S of Observation Line	○
Bago Old Bridge(US)	G3	1	R	G3-1-R	2013/1/18 17:00	2.100	2.00	43.0	85.90	0.010	0.87	EF	JICA	-do-	○
Bago Old Bridge(US)	G3	2	L	G3-2-L	2013/3/3 7:30	2.940	1.90	65.7	124.92	0.039	2.53	EF	JICA	-do-	XQ
Bago Old Bridge(US)	G3	2	R	G3-2-R	2013/3/3 9:00	2.860	1.85	65.5	121.05	0.045	2.91	EF	JICA	-do-	XQ
Bago Old Bridge(US)	G3	3	L	G3-3-L	2013/3/9 7:45	2.765	1.85	65.0	120.30	0.035	2.27	EF	JICA	-do-	XQ
Bago Old Bridge(US)	G3	3	R	G3-3-R	2013/3/9 9:00	2.735	1.78	64.8	115.55	0.055	3.56	EF	JICA	-do-	XQ
Bago Old Bridge(US)	G3	4	L	G3-4-L	2013/3/20 8:30	2.640	1.68	63.7	107.30	0.036	3.84	EF	JICA	-do-	XQ
Bago Old Bridge(US)	G3	4	R	G3-4-R	2013/3/20 10:30	2.640	1.66	63.7	105.79	0.028	2.96	EF	JICA	-do-	XQ
Bago Old Bridge(US)	G3	5	L	G3-5-L	2013/4/5 7:30	2.670	1.76	65.0	114.65	0.056	6.41	EF	JICA	-do-	○
Bago Old Bridge(US)	G3	5	R	G3-5-R	2013/4/5 8:30	2.670	1.75	65.0	113.95	0.055	6.29	EF	JICA	-do-	○
Bago Old Bridge(US)	G3	6	L	G3-6-L	2013/4/20 7:00	2.800	1.85	65.0	120.10	0.061	3.93	EF	JICA	-do-	○
Bago Old Bridge(US)	G3	6	R	G3-6-R	2013/4/20 10:00	2.800	1.81	65.0	117.50	0.061	3.95	EF	JICA	-do-	○
Bago Old Bridge(US)	G3	7	L	G3-7-L	2013/5/5 9:30	2.385	1.80	65.0	117.20	0.047	5.55	EF	JICA	-do-	○
Bago Old Bridge(US)	G3	7	R	G3-7-R	2013/5/5 8:00	2.380	1.81	65.0	117.60	0.048	5.68	EF	JICA	-do-	○
Bago Old Bridge(US)	G3	8	L	G3-8-L	2013/5/19 9:40	3.030	2.02	65.0	131.25	0.200	26.25	EF	JICA	-do-	○
Bago Old Bridge(US)	G3	8	R	G3-8-R	2013/5/19 10:50	3.030	2.00	65.0	130.00	0.207	26.91	EF	JICA	-do-	○
Bago Old Bridge(US)	G3	9	L	G3-9-L	2013/6/21 13:00	4.597	3.94	71.1	242.97	0.259	63.02	EF	JICA	-do-	○
Bago Old Bridge(US)	G3	9	R	G3-9-R	2013/6/21 11:40	4.597	3.22	71.1	228.97	0.285	65.35	EF	JICA	-do-	○
Bago Bridge(at Brdige)	G3'*5/	1	*	G3'*5/-1-*	2012/6/6 0:00	6.260	5.70	78.0	444.20	0.608	268.18	ADCP	ID	Diffrent Surveyline	－
Bago Bridge(DS)	G3'	2	*	G3'-2-*	2013/7/27 0:00	8.620	6.17	90.2	556.90	1.252	697.12	ADCP	ID	-do-	－
Bago Bridge(US)	G3'	2	*	G3'-2-*	2012/7/27 0:00	8.680	6.61	88.8	587.30	1.159	680.78	ADCP	ID	-do-	－
Bago Bridge(US)	G3'	3	*	G3'-3-*	2012/7/28 0:00	8.460	6.21	91.8	569.90	1.094	622.83	ADCP	ID	-do-	－
Bago Old Bridge(DS)	G3'	4	*	G3'-4-*	2012/8/7 0:00	8.700	6.89	83.9	577.90	1.124	647.84	ADCP	ID	-do-	－
Bago Old Bridge(DS)	G3'	4	*	G3'-4-*	2012/8/7	8.640	6.066	91.300	553.800	1.213	671.966	ADCP	ID	-do-	－
Bago Old Bridge(DS)	G3'	4	*	G3'-4-*	2012/8/7	8.660	6.328	88.940	562.800	1.217	684.858	ADCP	ID	-do-	－
Bago Old Bridge(at Bridg	G3'	5	*	G3'-5-*	2012/9/11	8.180	6.313	89.090	562.400	1.075	604.172	ADCP	ID	-do-	－
Bago Old Bridge(US)	G3'	5	*	G3'-5-*	2012/9/11	8.130	6.331	89.690	567.800	1.062	603.083	ADCP	ID	-do-	－
Bago Old Bridge(US)	G3'	6	*	G3'-6-*	2012/9/21	5.060	3.999	75.240	300.900	0.509	153.241	ADCP	ID	-do-	－
Bago Old Bridge(DS)	G3'	6	*	G3'-6-*	2012/9/21	4.920	3.632	70.160	254.800	0.671	158.130	ADCP	ID	-do-	－
Bago Old Bridge(at Bridg	G3'	7	*	G3'-7-*	2012/10/5	4.540	3.822	67.300	257.200	0.591	151.147	ADCP	ID	-do-	－

*1 L-R: Left to Right, R-L:Right to Left *2 Mean Water Level based on elevation *3 FL:Float Method, EF:Electromagnetic FLow Meter,ADCP:Acoustic Doppler Current Profiler
*4 Data is elvaluated with Velocity(xV) and Area(xA), and used only relailabie Data (○)

4-4-5 Data Verification

The discharge survey was made at three (3) stations with selection of adequate method due upon river conditions; Portable Electromagnetic Flow-Meter for low water level, ADCP for high water level and Float for flooding. Consequently, total 140 records were obtained during 2013 and were verified their reliability by H-A curve, H-V curve and H-Q curve and H-√Q. As a result of verification, over 30 % (14/40) of records of Dawei, less than 10 % (2/47) of Tamabin and 40% (22 /58) of records were judged as ignored data as not-reliable records due to abnormal flowing condition and miss reading/writing. Especially at Bago old bridge station, river flow condition was not stable due to a back-water effect derived from tidal changes. In response to tidal change, the condition of river flow is also frequently changes as is reflecting one (1) meter of river stage. The summary of data verification is shown in Table 4-4-4-5 to 4-4-4-7 and H-A curve, H-V curve and H-Q curve and H-√Q are shown in Figure 4-4-5-1 to 4-4-5-3.

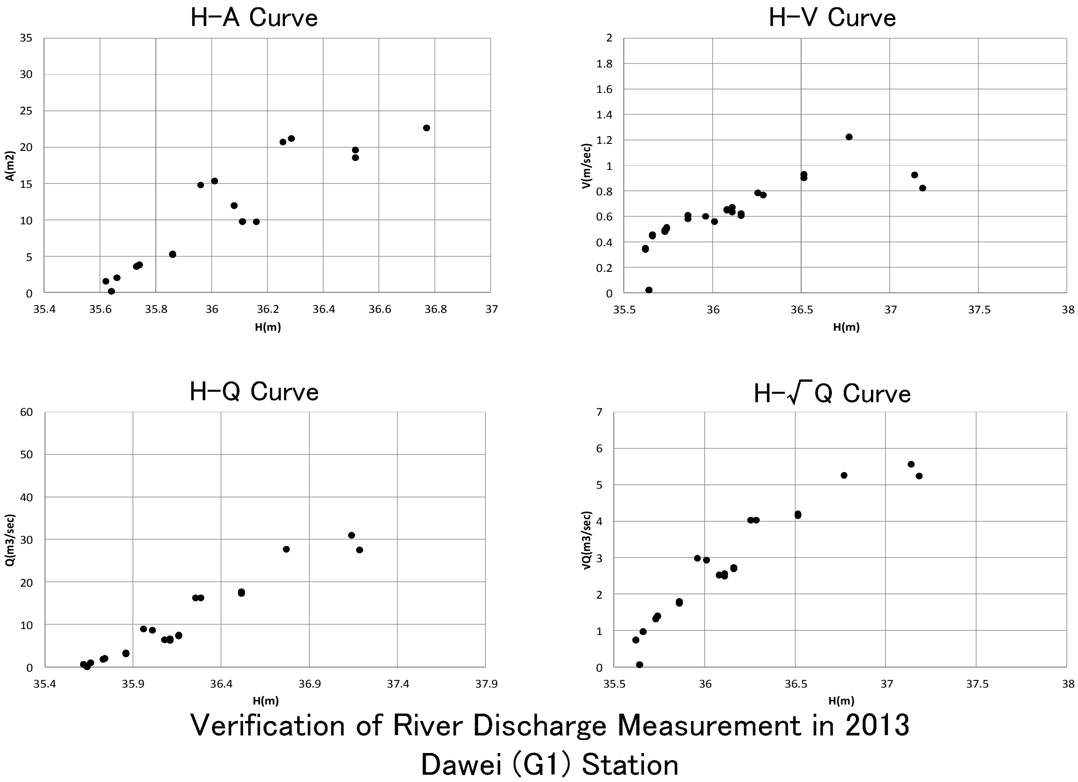
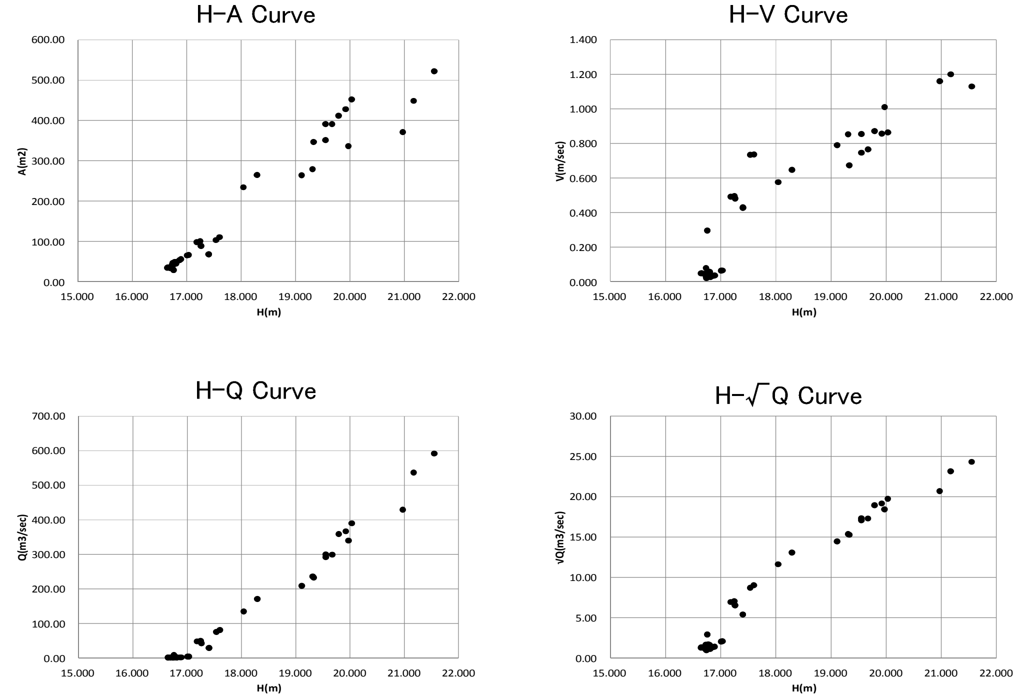
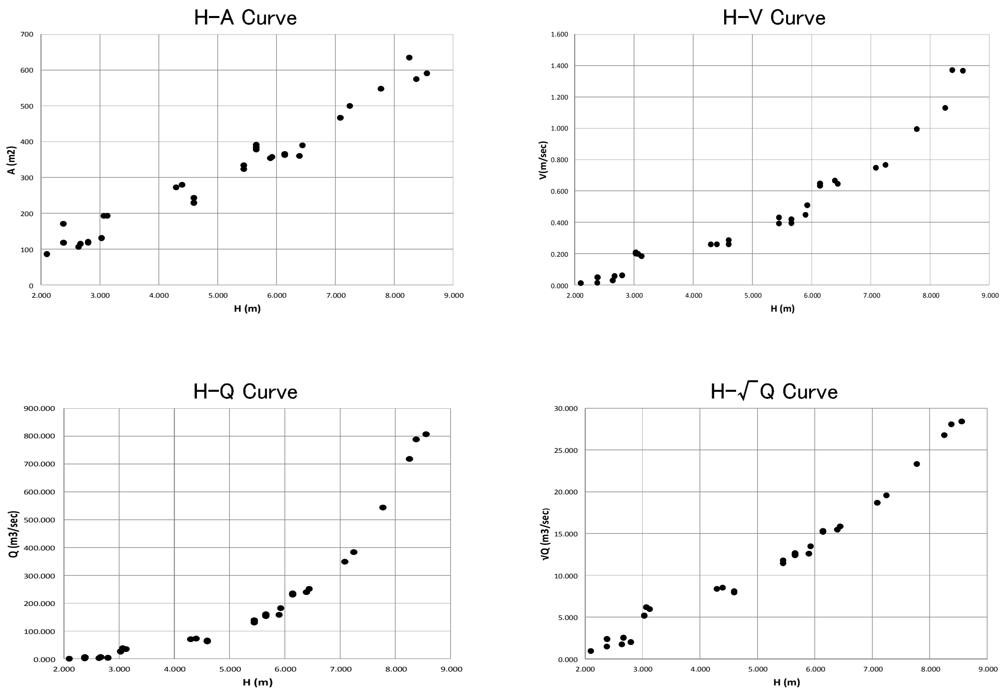


Figure 4-4-5-1 Summary of Verification of Dawei (G1) Station with H-A,H-V,H-Q, and H-√Q curves



Verification of River Discharge Measurement in 2013
Tamabin (G2) Station

Figure 4-4-5-2 Summary of Verification of Tamabin（G2）Station



Verification of River Discharge Measurement in 2013
Bago Old Bridge (G3) Station

Figure 4-4-5-3 Summary of Verification of Bago Old Bridge（G3）Station

4-4-6 Rating Curve

The Rating Curve was finalized with the completed data through one year's hydrological record (Jan 2013 to Feb 2014) with verifying the relation between the water level (H) and discharge (Q) described above subsection.

The quadratic equation is adopted for rating curve. Water level (H) is plotted on the vertical axis while river discharge (Q) is placed on the horizontal axis. Using H and Q, the relation formulae are obtained by the least squares method.

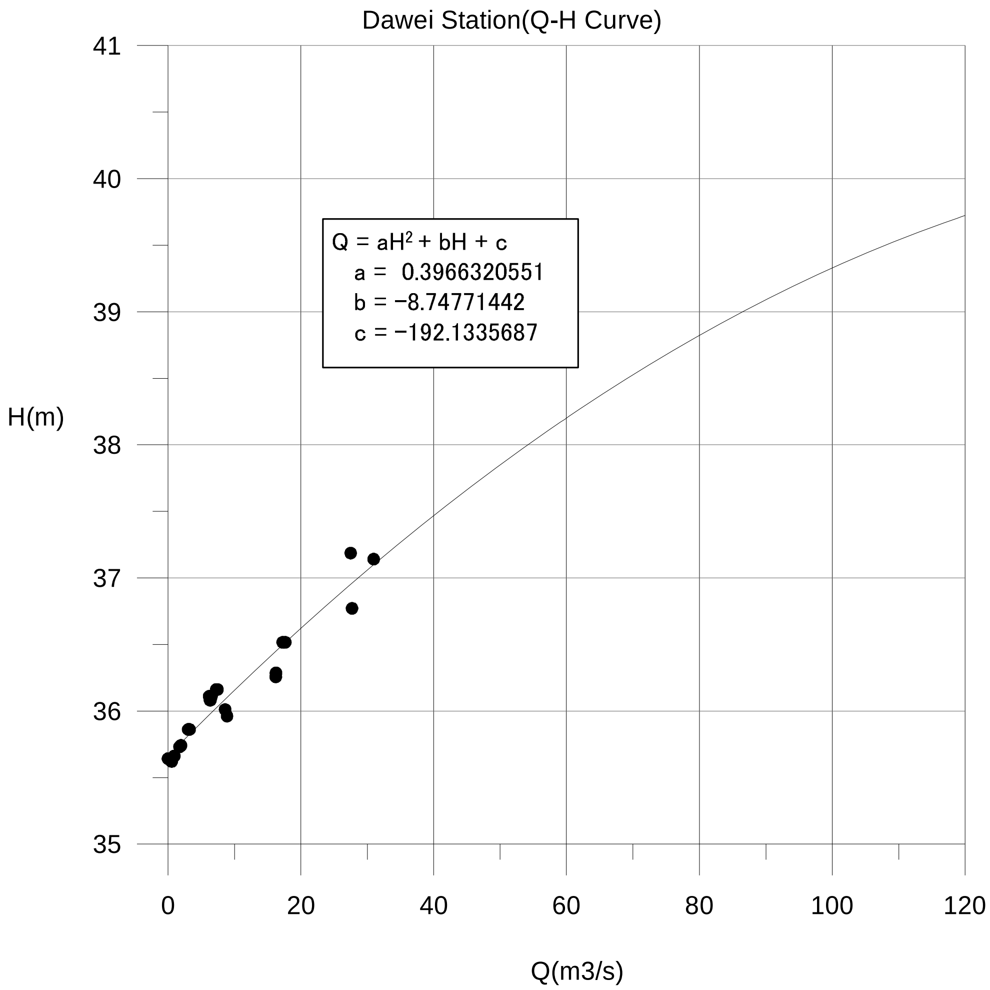
If water level is H (m) and river discharge is Q (m^3/sec), basic formula is applied as,

$$Q = aH^2 + bH + c$$

The discharge (Q) is calculated by above formula within the range of observation value taken in 2013. As well, the constant s (a, b and c) of formula was fixed with the condition that the Q is not negative in particular the low water level. At the adjusting rating curve with formula, the regression was made well with a single and multiple quadratic polynomial curve (R2>90%)[5]. In the case of warning water level at the Bago Bridge Station (910 cm) is given to the curve, flood discharge is accounted as 711m^3/sec.

Rating curves (Water level (H) – river discharge (Q)) for three (3) gauging stations are shown in Figure 4-4-6-1 to 4-4-6-3.

[5] According to the trends of the H-Q Curve and H-$\sqrt{Q}$ Curve, the regression shall be made in the different sections of Low Water level and High Water level (Flood Level). However the data taken from intermediate zone in between them are not enough to clearly decide the limit of sections, so that the single quadratic polynomial curve is provisionally used for the regression of whole water levels.



Fit Results

Fit 2: Polynomial
Equation Y = -192.1335687 - 8.74771442 * X + 0.3966320551 * pow(X,2)

Degree = 2
Number of data points used = 27
Average X = 36.069
Average Y = 8.42589

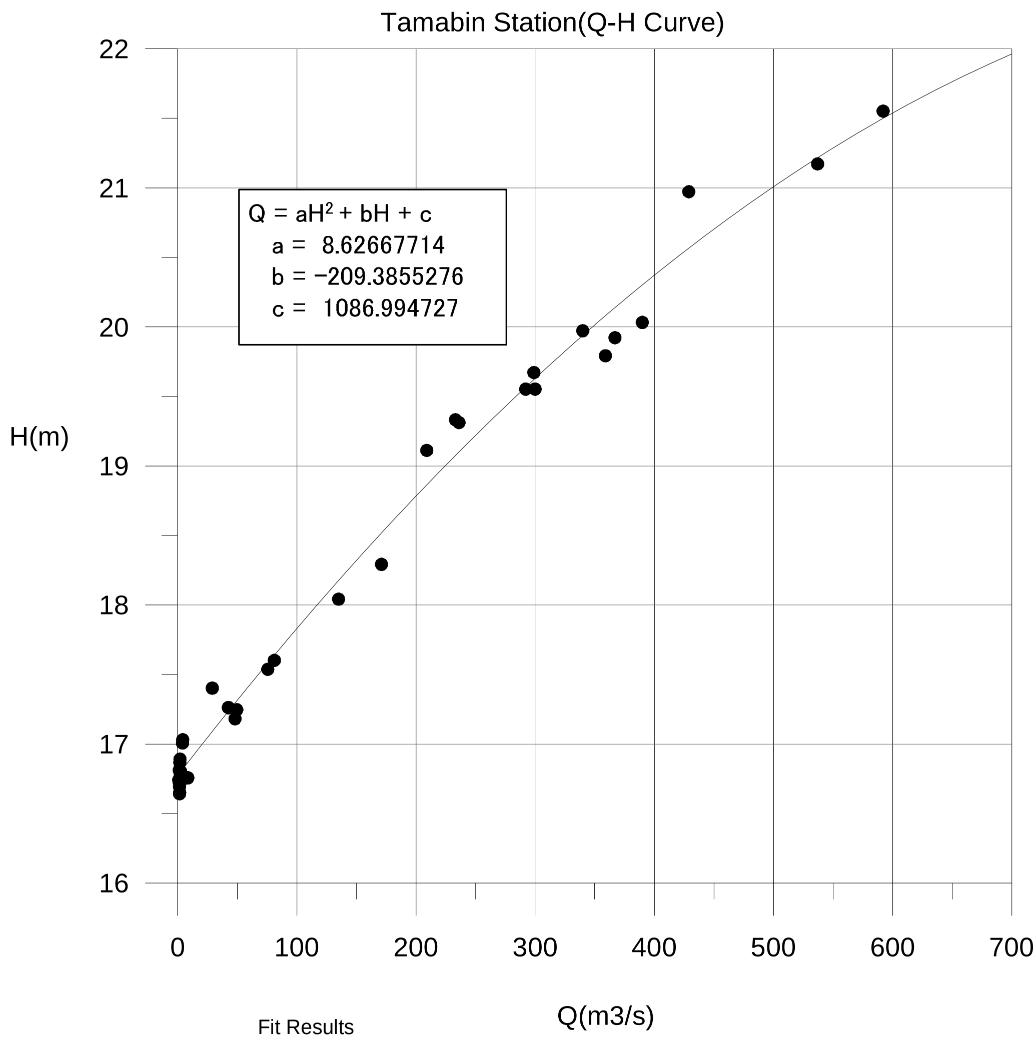
Coefficients:
Degree 0 = -192.1335687
Degree 1 = -8.74771442
Degree 2 = 0.3966320551

Degree: 0
Residual sum of squares = 2154.98
Coef of determination, R-squared = 0

Degree: 1
Residual sum of squares = 126.932
Coef of determination, R-squared = 0.941098

Degree: 2
Residual sum of squares = 126.736
Coef of determination, R-squared = 0.94119

Figure 4-4-6-1 Water level(H)-Discharge(Q) Curve (Dawei（G1）Station)



Fit Results

Fit 2: Polynomial
Equation Y = 1086.994727 - 209.3855276 * X + 8.62667714 * pow(X,2)

Degree = 2
Number of data points used = 44
Average X = 17.9019
Average Y = 121.487

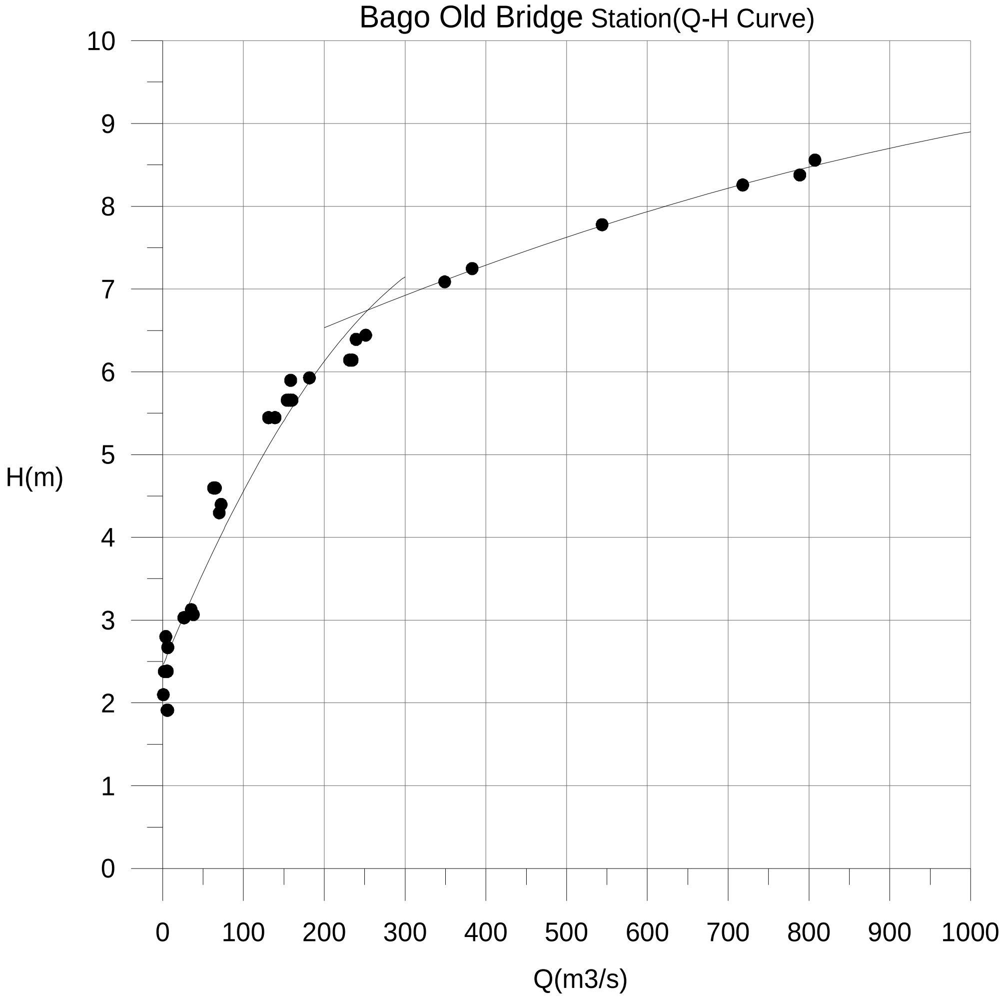
Coefficients:
Degree 0 = 1086.994727
Degree 1 = -209.3855276
Degree 2 = 8.62667714

Degree: 0
Residual sum of squares = 1.19317E+006
Coef of determination, R-squared = 0

Degree: 1
Residual sum of squares = 22928.6
Coef of determination, R-squared = 0.980783

Degree: 2
Residual sum of squares = 13936.1
Coef of determination, R-squared = 0.98832

Figure 4-4-6-2 Water level(H)-Discharge(Q) Curve (Tamabin（G2）Station)



Fit Results

Fit 2: Low Water
Equation Y = 84.69313704 - 65.9506367 * X + 14.07177459 * pow(X,2)

Degree = 2
Number of data points used = 29
Average X = 4.102
Average Y = 85.5738

Coefficients:
Degree 0 = 84.69313704
Degree 1 = -65.9506367
Degree 2 = 14.07177459

Degree: 0
Residual sum of squares = 207961
Coef of determination, R-squared = 2.22045E-016

Degree: 1
Residual sum of squares = 17470.9
Coef of determination, R-squared = 0.915989

Degree: 2
Residual sum of squares = 4074.91
Coef of determination, R-squared = 0.980405

Fit Results

Fit 3: High Water
Equation Y = -238.5134823 - 123.3355161 * X + 28.96228179 * pow(X,2)

Degree = 2
Number of data points used = 6
Average X = 7.88367
Average Y = 598.331

Coefficients:
Degree 0 = -238.5134823
Degree 1 = -123.3355161
Degree 2 = 28.96228179

Degree: 0
Residual sum of squares = 205713
Coef of determination, R-squared = 0

Degree: 1
Residual sum of squares = 1515.18
Coef of determination, R-squared = 0.992634

Degree: 2
Residual sum of squares = 1335.79
Coef of determination, R-squared = 0.993507

Figure 4-4-6-3 Water level(H)-Discharge(Q) Curve (Bago Old Bridge（G3）Station)

4-4-7 Calculation of River Discharge

Using the formula of rating curve, the river charge is calculated from the daily mean river discharge. 2013's daily mean discharge of is shown in Figure 4-4-7-1. In accordance with rainfall pattern, the peak discharge is observed at the end of August and the end of October. As annual maximum, 150m^3/sec of Dawei (G1), 700m^3/sec of Tamabin (G2) and 950m^3/sec of Bago Old Bridge (G3) station are obtained. If these values compare with 10minutes' discharge, 10 minutes' discharge is 30% larger than daily discharge.

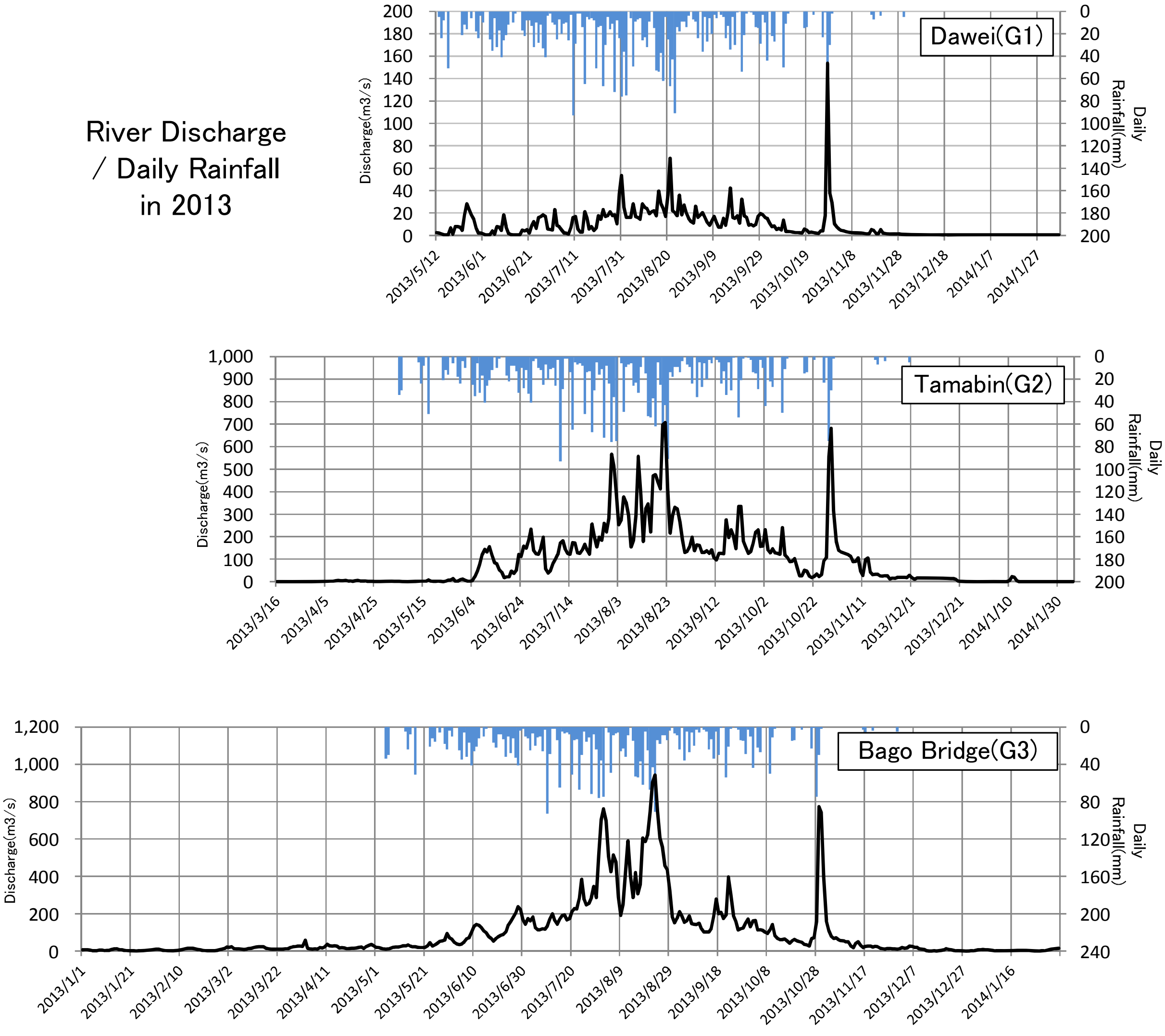


Figure 4-4-7-1 2013 River Discharge of G1, G2 and G3 Station

4-4-8 Comparison with Other Data

(1) DMH Observation Records

70 meters downstream of Bago Old Bridge (G3) station, the existing station was installed and operated by DMH. At the DMH station, the three (3) times measurements have been made and have converted into river discharge. In Figure 4-4-8-1, a comparison between two 2013 results of Bago Old Bridge (G3) and the existing (DMH) station.

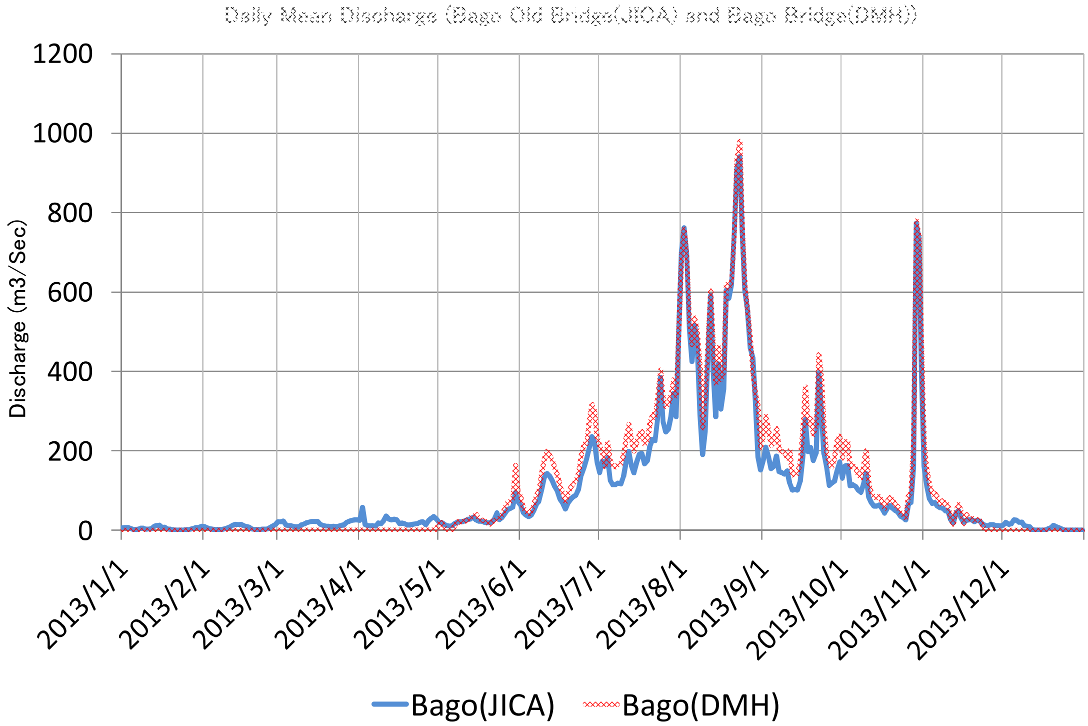


Figure 4-4-8-1 Comparision of River Discharge(Bago Old Bridge/Bago Bridge, 2013)

The difference between them is not large in the high water. However, it became large in low water zone. Since the tidal effect is known as large as one (1) meter in the low water, so it should affect the measurement result and involves some uncertain factors. The difference may conclude how tidal effect evaluates in analysis.

(2) ID Observation Records

The Hydrological branch of the Irrigation Department (MOAI) was constructed at the new river gauging station of the Bago Old Bridge located 70 meters upstream from the Bago Bridge Station (DMH). The new station is called the “Bago Old Bridge Station” or the “Bago Wooden Bridge Station”, and the observation conducted so far includes a daily water level measurement and ADCP survey. In the case of 2011 and 2012, the Hydrological branch made the ADCP survey aiming at the evaluation of the three (3) dams (newly constructed in 2011 at the Salu, Kodugwe and Shwelaung tributaries) in terms of their flood mitigation function. In this survey, since the operation of three (3) dams, no flooding occurs, even during heavier rainfall, other than those of flooded years recorded at Bago city (ID report, Feb.2013[6]). Taking this survey result into account, the Hydrological branch concluded the new three (3) dams have the function of the flood-control capabilities together with irrigation water supply.

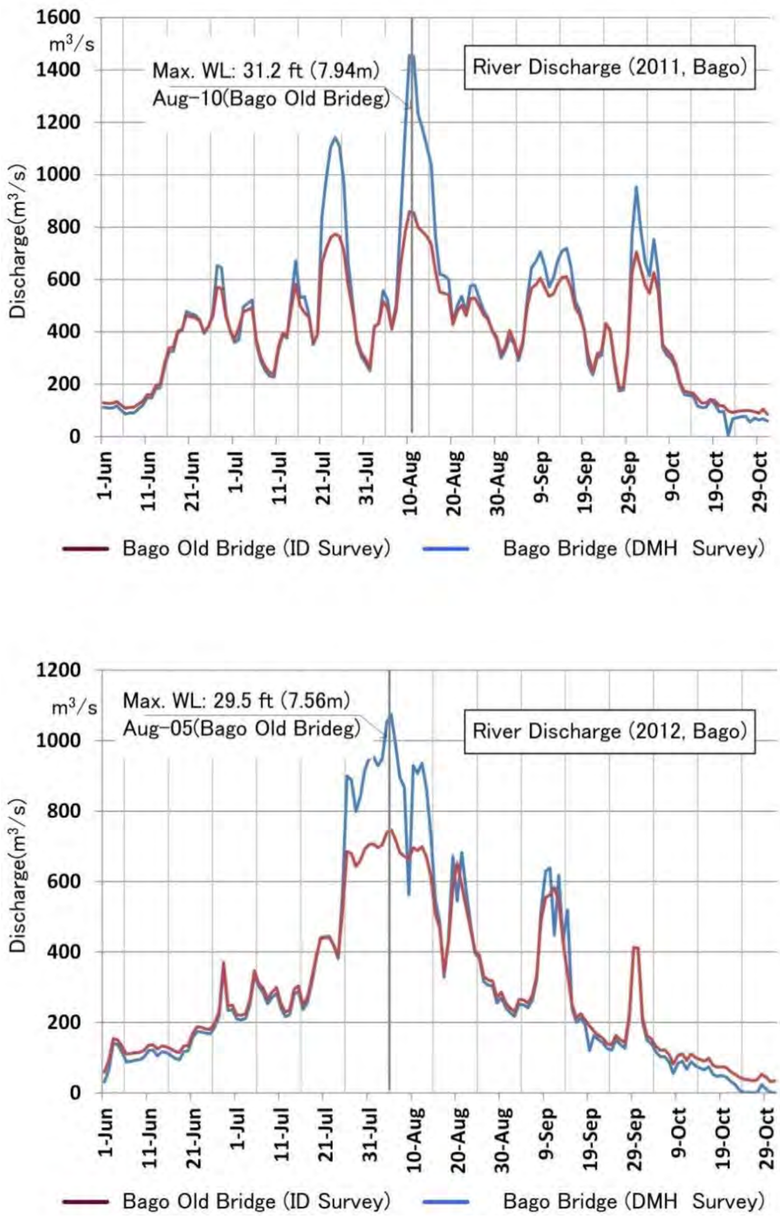


Figure 4-4-8-2 Comparison of River Discharge (Bago Old Bridge/Bago Bridge, 2011~2012)

[6] Report for the Prevention of Flood Bago City (Reason of Flooded and Ebb-tide (Than Win, Hydro Branch ID, Feb 2013))

This survey revealed as well the difference in river discharge between ID and DMH's estimation, especially in the high water level (refer to Figure 4-4-8-2). This is due to the accuracy of the discharge survey, with different tools between the advanced ADCP and the ordinary method.

1) River Discharge（1972～2013）

Assuming not to change the river channel shape since the time of installation, the 40 years' river discharge was calculated from the existing DMH records (river stage) in applying the formula obtained by 2013's survey. As shown in Figure 4-4-8-3, a significant change in chronological order is not recognized in the monthly river discharge as well as monthly mean water level since 1972.

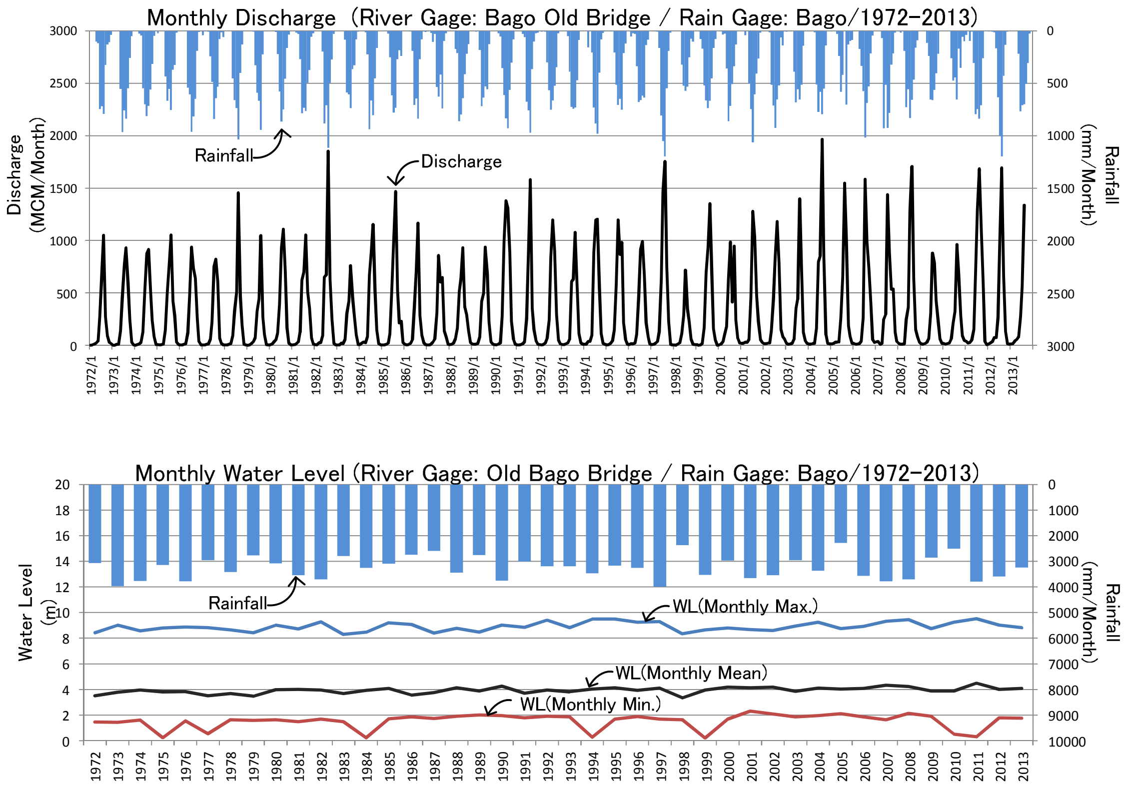


Figure 4-4-8-3 River Discharge（Monthly Total, 1972～2013）

2) Annual Maximum Daily Mean Discharge

Annual maximum daily mean discharge calculated from the Bago Bridge and Zaungtu DMH station are shown in Figure 4-4-8-4. The fluctuation of maximum discharge has increased since 1980's as at the progress of the basin development. On the other hand, In the basin, flood control has become functioning since the construction of Zaungtu (2000), Kodukwe(2012), Shwelaung(2012) and Salu(2012) dam. However, the basin is developing in particular deforest oration and farmland clearing drastically up to the present so has still remained a risk of flooding at the downstream.

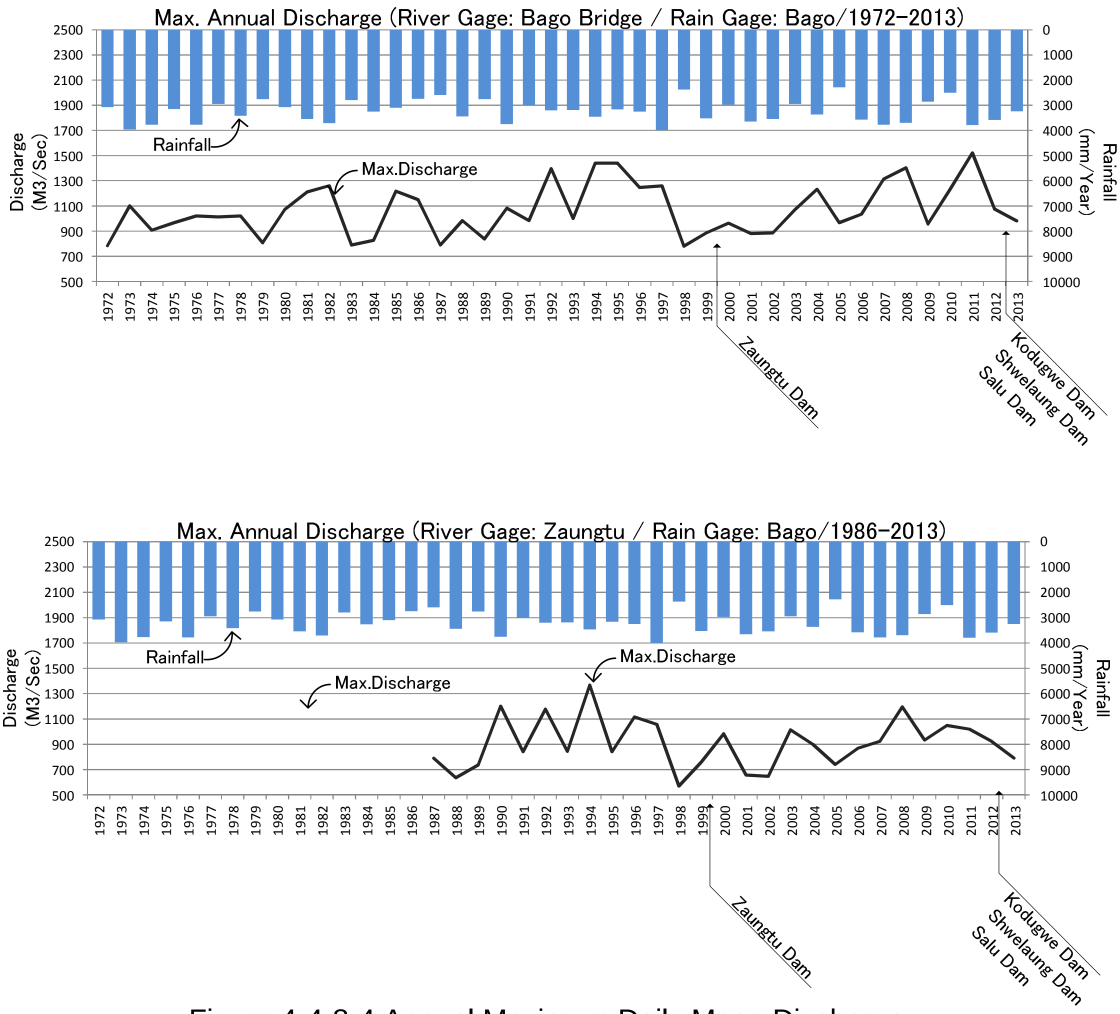


Figure 4-4-8-4 Annual Maximum Daily Mean Discharge
(Bago Bridge and Zaungtu DMH Station)

4-4-9 Water Quality Survey of Surface Water

Table 4-4-9-1 shows water quality test results of the Nga Moe Yeik Reservoir in the Bago River basin and the Sittaung River at Sittaung Bridge. Table 4-4-9-2 shows those of the three reservoirs near SEZ. It is notable that the waters have much iron ion exceeding 1 mg/l in concentration.

Table 4-4-9-1 Water Quality Analysis Result of Nga Moe Yeik Reservoir and Sittaung River

No	Parameter	Symbol	Unit	Sittaung River (Sittaung Bridge)				Ngamoeyeik Reservoir			
				Jul-11	Sep-11	Jan-12	Mar-12	Jun-10	Sep-10	Nov-10	Feb-11
1	Calcium	Ca^{++}	mg/l	9.4	10.4	11.2	15.0	6.4	6.4	7.4	4.8
2	Magnesium	Mg^{++}	mg/l	10.0	10.3	10.7	11.2	8.3	4.9	5.0	17.5
3	Sodium	Na^{+}	mg/l	9.9	9.9	10.3	12.6	5.3	8.7	8.0	32.6
4	Potassium	K^{+}	mg/l	1.6	2.0	1.6	2.0	2.0	2.0	2.0	2.3
5	Carbonate	$CO3^{=}$	mg/l	12.0	12.6	12.0	12.0	ND	ND	ND	ND
6	Bicarbonate	$HCO3^{-}$	mg/l	73.2	73.2	73.2	73.2	6.1	24.4	24.4	24.4
7	Sulphate	$SO4^{=}$	mg/l	0.5	0.5	1.0	0.5	74.9	49.9	60.0	125.8
8	Chloride	CL^{-}	mg/l	10.6	11.3	10.6	10.6	5.0	2.5	6.0	59.2
1	Calcium	Ca^{++}	me/l	0.47	0.52	0.56	0.75	0.32	0.32	0.37	0.24
2	Magnesium	Mg^{++}	me/l	0.82	0.85	0.88	0.92	0.68	0.40	0.41	1.44
3	Sodium	Na^{+}	me/l	0.43	0.43	0.45	0.55	0.23	0.38	0.35	1.42
4	Potassium	K^{+}	me/l	0.04	0.05	0.04	0.05	0.05	0.05	0.05	0.06
5	Carbonate	$CO3^{=}$	me/l	0.40	0.42	0.40	0.40	ND	ND	ND	ND
6	Bicarbonate	$HCO3^{-}$	me/l	1.20	1.20	1.20	1.20	0.10	0.40	0.40	0.40
7	Sulphate	$SO4^{=}$	me/l	0.01	0.01	0.02	0.01	1.56	1.04	1.25	2.62
8	Chloride	CL^{-}	me/l	0.30	0.32	0.30	0.30	0.14	0.07	0.17	1.67
	Total Cations		me/l	1.76	1.85	1.93	2.27	1.28	1.15	1.18	3.16
	Total Anions		me/l	1.51	1.53	1.52	1.51	1.80	1.51	1.82	4.69
9	Total Hardness	T-H	mg/l	64.5	68.5	72.0	83.5	50.0	36.0	39.0	84.0
10	Iron	Fe	mg/l	1.25	1.00	1.20	1.00	-	-	-	-
11	Total Dissolved Solids	TDS	mg/l	115.2	115.8	117.1	131.2	64.6	70.4	86.4	198.4
12	Soluble Sodium Percentage	SSP	%	24.4	23.2	23.3	24.2	18.0	33.0	29.7	44.9
13	Sodium Adsorption Ratio	SAR	-	0.24	0.52	0.53	0.60	0.32	0.63	0.56	1.54
14	Residual Sodium Carbonate	RSC	me/l	0.31	0.25	0.16	0.00	0.00	0.00	0.00	0.00
15	pH	pH		7.15	7.17	7.05	7.25	7.20	7.37	7.52	7.32
16	Electrical Conductivity	Ecw	μS/cm	180	181	183	205	101	110	135	310
17	Turbidity	Turb	NTU	257	375	426	237	2	1	2	10
18	Salinity	Sal	%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
19	Temperature	Temp	C	28.7	28.5	28.8	29.3	30.6	29.0	29.0	28.7
20	Dissolved Oxygen	DO	mg/l	5.43	5.49	5.68	5.49	-	-	-	-
21	USDA Classification			C_1S_1	C_1S_1	C_1S_1	C_1S_1	C_1S_1	C_1S_1	C_1S_1	C_1S_1

ND: No data
Source: Irrigation Department, Ministry of Agriculture and Irrigation

Table 4-4-9-2 Water Quality Analysis Result of Three Reservoirs near SEZ

Reservoir		Zarmani-Inn	Ban Bwe Gone	Thilawa
Item	Unit / Sampling Date	30/07/2004	30/07/2004	30/08/2004
Appearance		Rusty	Slightly Turbide	Rusty
Colour	Platinum, Cobalt Scale	30	54	14
Turbidity	Silica Scale Unit	2.2	8.8	2.2
pH	-	6.5	7.0	8.7
Total Solids	mg/l	90.0	252.0	104.0
Total Hardness	mg/l as CaCo3	14.0	16.0	27.0
Total Alkalinity	mg/l as CaCo3	13.0	14.0	20.0
Calcium	mg/l	2.4	2.4	6.4
Magnesium	mg/l	2.2	2.8	3.1
Chloride	mg/l	58.4	130.4	44.0
Sulphate	mg/l	5.8	11.5	18.2
Total Iron	mg/l	1.6	1.4	1.0

Source: D.H.S.H.D, Ministry of Construction
Analyzed by National Health Laboratory, Ministry of Health

(1) Outline of Survey

1) Location and Purpose

Table 4-4-9-3 shows a list of water quality survey points and purposes. Figure 4-4-9-1 shows the location of quality survey points. Basic physical water quality items, chloride ion concentration and pesticide concentration are surveyed on the Bago River and its tributaries.

2) Survey Item, Method and Frequency

Table 4-4-9-4 shows the contents of the water quality survey. Table 4-4-9-5 shows items and methods of water quality measurement and analysis. As understood from Table 4-4-9-4, the survey was conducted for one (1) year of Nov.2011 to Oct.2013.

Concerning pesticide analysis at four points in the dry and wet seasons, sampling was originally planned at three different depths to a point. However, because the time-series survey revealed there are no significant differences at the various depths, the sampling was changed to be taken at one depth only.

Table 4-4-9-6 shows the target pesticides in the present survey. They are selected based on a list of imported pesticide amounts during 2011-2012, and the WHO drinking water standard guidelines on pesticides are shown in Table 4-4-9-7.

Table 4-4-9-3 List of Water Quality Monitoring Points of Surface Water

Classification	No,	Location	Purpose	Related Water Source
Bago River and its Tributary	S-1	Dawe River near Dawei dam site (plan)	WQ check of planned Dawe reservoir	Dawe Reservoir, Khayan River
	S-2	Bago River (upstream) near Zi daw village	WQ check of Bago River water before diverting to the left bank	Dawe Reservoir, Khayan River
	S-3	Bago River (upstream) upstream of Zaungtu Weir	WQ check of Bago River water at the diverting to the left bank	Dawe Reservoir, Khayan River
	S-4	Bago River (midstream) near wooden Bago bridge in Bago City	WQ check of Bago River mid-stream	Bago River (midstream)
	S-5	Bago River (midstream) near Tawa	Confirmation of saline water condition in Bago River	Bago River (downstream)
	S-6	La Gun Byin reservoir	WQ check of Lagyn Byin reservoir	La Gun Byin Reservoir
	S-7	Head of La Gun Byin main irrigation canal	WQ check of released water from La Gun Byin reservoir	La Gun Byin Reservoir
	S-8	La Gun Byin River (near end) a little upstream of Ngetpawdaw slucce gate	WQ check of La Gun Byin River	La Gun Byin Reservoir
	S-9	Ngamoyeik River (downstream) upstream of Nga Mo Yeik Sluice gate	WQ check of Nga Mo Yeik irrigation canal and river water at present	La Gun Byin Reservoir
	S-10	Khayan River (downstream) upstream of Pagandaung intake gate	WQ check of Khayan River	Dawe Reservoir, Khayan River
	S-11	Bago River(downstream) near Thanlyin Bridge	Confirmation of saline water condition in Bago River	Bago River (downstream)
	S-12	Near confluence of Yangon and Bago rivers	Confirmation of saline water condition in Bago River	Bago River (downstream)
Three Reservoirs near SEZ	R-1	Zamani inn reservoir	WQ check of reservoir	Three Reservoirs near SEZ
	R-2	Thilawa reservoir	WQ check of reservoir	Three Reservoirs near SEZ, New reservoir
	R-3	Ban Bwe Gon Reservoir	WQ check of reservoir	Three Reservoirs near SEZ

Table 4-4-9-4 Contents of Water Quality Survey of Surface Water

Place	Title of Work	Frequency and Duration of Work	Content of work	Measurement /Sampling Points	Sampling (times) 2012: 11	2012: 12	2013: 1	2013: 2	2013: 3	2013: 4	2013: 5	2013: 6	2013: 7	2013: 8	2013: 9	2013: 10
Bago River and its Tributaries	Time-series WQ Survey	2times/ mon at high tide for 12 months	1) Measurement of physical items in-situ 2) Chemical and biological analysis with sampled water. 3) Sampling for arsenic and heavy metals analysis (Samples to be sent to out of Myanmar)	S-1 ~S12at different depths	2	2	2	2	2	2	2	2	2	2	2	2
	Pesticide Water Quality Survey	1 time/ month for 10 months	Sampling (1000ml) and analysis in Japan for 6 pesticide items	S-6	-	-	1	1	1	1	1	1	1	-	-	-
		1 times/seazom		S-3,S-5,S-9,S -10	-	-	-	-	-	1	-	-	1	-	-	-
Three reservoirs near SEZ	4. Sampling for Analysis of Agrochemicals (100ml) (Samples to be sent to out of Myanmar)	4.1 Time-series Survey of Surface Water Monthly for 10 months	1)In-situ measurement of physical items. 2) Sampling for chloride ion analysis (100ml) and measurement in laboratory. 3) Sampling and in-situ measurement for BOD(DO measurement in-situ and after 5days in lob)	R-1 (Zamani-Inn) R-2(Thilawa) R-3(Ban Bwe Gon)	-	-	1	-	-	1	-	-	1	-	-	1
			Sampling (100 ml) and analysis in Japan for 6 pesticide items													

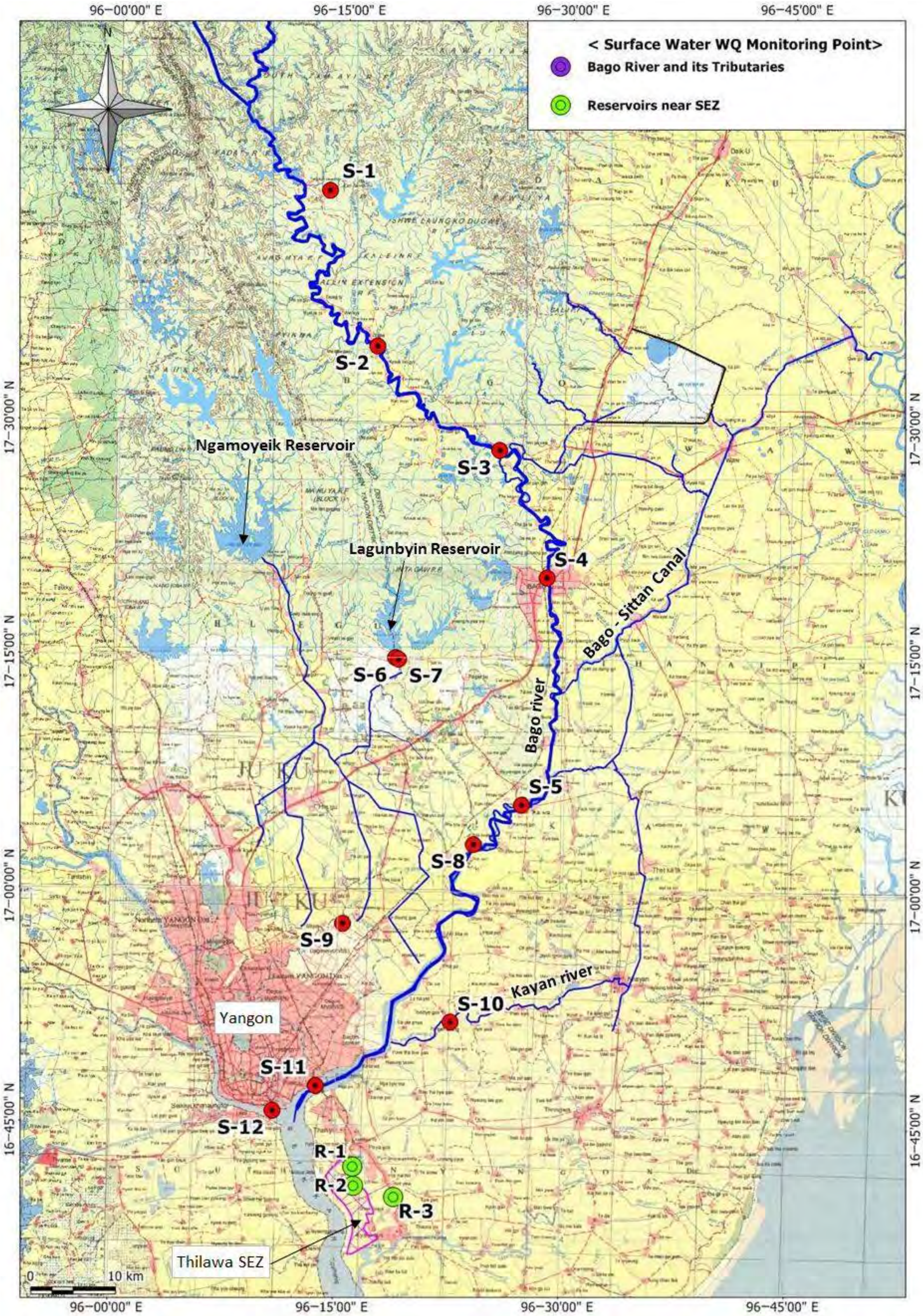


Figure 4-4-9-1 Water Quality Monitoring Location of Surface Water

Table 4-4-9-5 Item and Method of Water Quality Monitoring of Surface Water

Item	Method	Measurement / Analysis Place	Sampling
Odor	By nose	In-situ	-
Taste	By tongue (if possible)		
Turbidity	Digital turbidity & color meter		
Color index	〃		
pＨ	Potable pH meter		
EC	Portable EC meter		
Temperature	Portable EC meter		
BOD	DO measurement with 5 days interval	In-situ and in laboratory.	100ml incubation bottle
Chloride	Portable chloride electrode	In laboratory	100ml bottle
Pesticide 6 items	Instruments certified by Ministry of Health and Labor in Japan	In Japan	1000ml bottle

Table 4-4-9-6 Pesticides to Analyze

Name	WHO Drinking Water Guideline (4th Edition)
2,4 D	0.03 mg/l
Atrazine	0.1 mg/l
Carbofuran	0.007 mg/l
Chlorpyrifos	0.03 mg/l
Dimethoate	0.006 mg/l
Pandimethalin	0.02 mg/l

Table 4-4-9-7 Amount of Pesticide Imported into Myanmar (2011 to 2012) and WHO Drinking Water Guideline (Fourth Edition)

No.	Active Ingredient	Imported Amount (TNE)	WHO Drinking-water Guideline Value/Description	Remarks
1	2,4 D	247	0.03 mg/l	
2	Abamectin 1.8%EC	189		
3	Acephate 75%SP	847		
4	Acetamiprid 16% + Cypermethirin 72%EC	40		
5	Aipha Cypermethrin 5%EC	120		
6	Aiminium Phosphide 56%Tb	139,584		Cereal fumigrant
7	Atrazine 50% SC	20	0.1 mg/l	
8	Benfuracab 20%EC	10		
9	Benomyl	360		
10	Bifenthrin 10%EC	3		
11	Bispyriibac Sodium	26		
12	carbaryl 85%WP	20	Occurs in drinking-water at concentrations below those of health concern	
13	Carbendazim 50%	258		
14	Carbofuran	707	0.007 mg/l	
15	Carbosulfan	154		
16	Cartap 50%SP	31		
17	Cartap Hydrochloride 4%G	60		
18	Chlorothalonil	51	Unlikely occur in drinking water	
19	Chlorpyrifos	1,262	0.03 mg/l	
21	Copper Hydroxide	125		Used near SEZ.
22	Copper Oxychloride	60		
23	Cymoxanil 25%WP	50		
24	Cypermethrin 10%EC	800	Unlikely occur in drinking water	
25	Detamethrin	20	Unlikely occur in drinking water	
26	Difubenzuron	10		
27	Dimethoate 40%EC	454	0.006 mg/l	
28	Dimethomorph	60		
29	D-teramethrin 0.1% + Cyphenothrin 0.3%	11,268		Household insecticide
30	Fenoxaprop-P-ethyl + Ethoxysulfuron	20		
31	Fenopropathrin 20%EC	32		
32	Fenvalerate 20%EC	20		
33	Fipronol	90		
34	Fluazifop- - Butyil 15%EC	10		
35	Formesafen 25%SL	10		
36	Formetanete Hydrochloride 20%SP	5		
37	Gibberellic Acid	125		
38	Glyphosate	397	Occurs in drinking-water at concentrations below those of health concern	
39	Hexaconazale 5%SC	20		
40	Imazethapyr 5%SC	10		
41	Imidacloprid	360		
42	Iprodione 50%WP	30		
43	Isoprothiolane 40%EC	10		
44	Kasugamycin	114		Effective for rice blast. Used near SEZ.
45	Lambda cyhalothrin	655		
46	Malathion	80	Occurs in drinking-water at concentrations below those of health concern	
47	Mancozeb	526		
48	Mepiquat chloride 5% SL	10		
49	Metalaxyl 25%WP	165		
50	Metofluthrin 5%EC	5		
51	NAA 0.3 + NOA 0.3%	20		
52	Nitrophenolate Mixture	40		
53	Orange Oil, Lemon 6%SC	10		
54	Oxadiazon	20		
55	oxyfluorfen 23.5%EC	8		
56	Pandimethalin 33%EC	10	0.02 mg/l	
57	Paraquat	36		
58	Ohenthoate 50%EC	30		
59	Pretilachlor	120		
60	Profenofos 50%EC	200		
61	Propiconazole 25%WP	150		
62	Propineb 70%WP	20		
63	Provalicarb 5.5% + Propineb 61.3%WP	20		
64	Pridaben 20%WP	20		
65	Quibclorac 25%SC	20		
66	Sodium ortho nitrophenolate	4		
67	Sulphur	320		
68	Terbufos 10%GR	10		
69	Thiodicarb 37.5%SC	80		
70	Thiomethoxam 25%WDG	20		
71	Thiophanate methyl	84		
72	Transfluthrin 0.06% + Permethrin + imiprothrin	121		
73	Tri Basic Copper Sulphate	40		
74	Valdamycin	20		
75	Zeta-Cypermethrin	8		

Note: Pesticide use information by Agriculture Department, MOAI

(2) Survey Results

An outline of the survey results with samples taken during Nov. 2012 to Jul. 2013 is shown in the following subsections.

1) Time-series Water Quality Monitoring on the Bago River and its Tributaries

a) Electric Conductivity (EC) and Chloride Ion (Cl^-)Concentration (Figure 4-4-9-2 and Figure 4-4-9-3)

In November 2012, during a transition period from the wet season to the dry season, values corresponding to fresh water were obtained at all points (max. EC - 549μS, max. Cl- concentration – 56 mg/l). During the dry season after the middle of January, EC and chloride concentration increased and saline water intrusion was confirmed at points on the Bago River downstream of the Tawa (S-5, S-8, S-11 and S-12) and Khayan Rivers (S-10). From May 2013, during the wet season, the values decreased, and after late June, the values returned to ones like those for the fresh water.

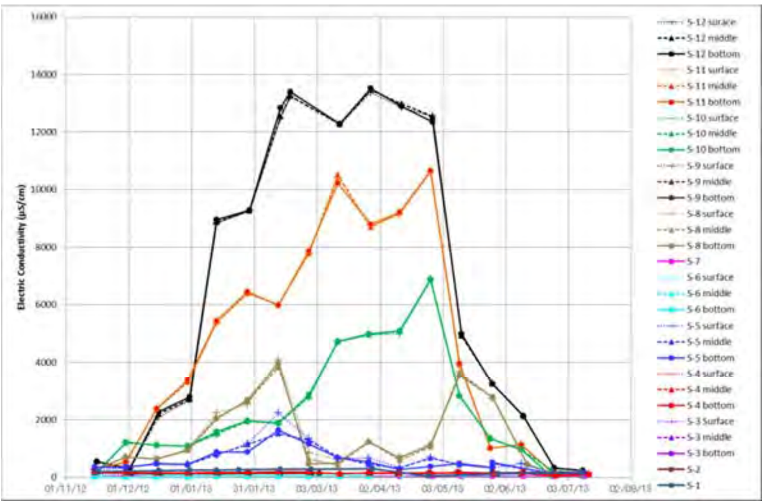


Figure 4-4-9-2 Variation of EC in Bago River and Tributaries

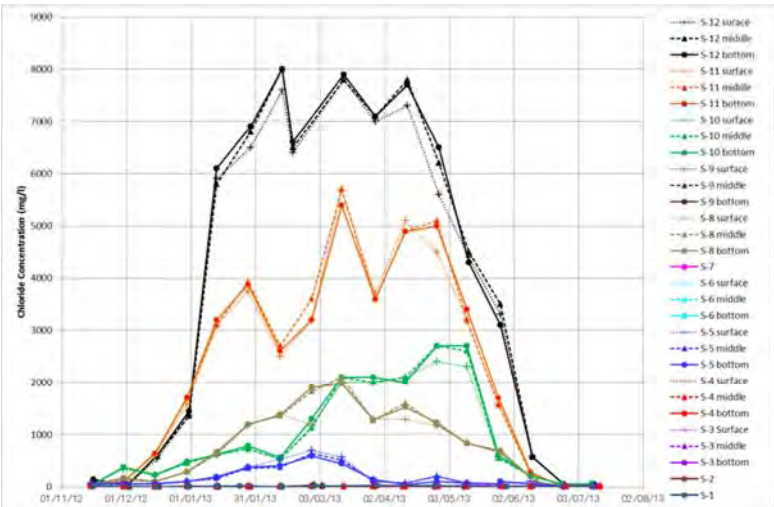


Figure 4-4-9-3 Variation of Chloride (Cl^-) concentration in Bago River and Tributaries

b) Turbidity (Figure 4-4-9-4 and Figure 4-4-9-5)

High turbidity beyond 250 KTU was measured every time at points on the Bago River downstream from Tawa (S-5, S-8, S-11 and S-12). In the Khayan River, turbidity was 50 to 150 KTU until December, but 10 to 20 KTU during the dry season from January to May. At a point of the Bago River in Bago city (S-4), it mostly ranges from 20 to 35 KTU during the dry season. Turbidity less than 10 KTU was almost kept at points along the upstream portion of the Bago River (S-1 ~ S-3), the La Gun Byin reservoir (S-6) and the upstream side of the Ngamoyeik sluice gate (S-9). The water of the La Gun Byin reservoir was always clean in turbidity, staying around 5 KTU[7]. During the wet season after June 2013, turbidity increased at all points.

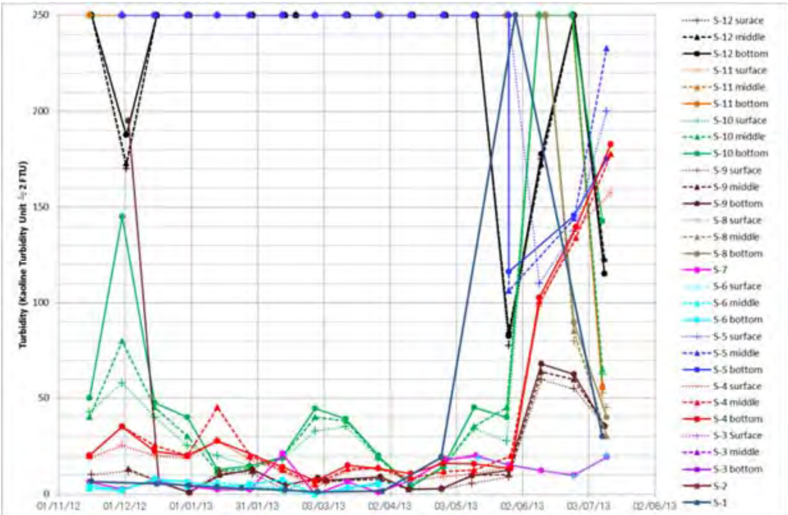


Figure 4-4-9-4 Variation of Turbidity in Bago River and Tributaries (1)

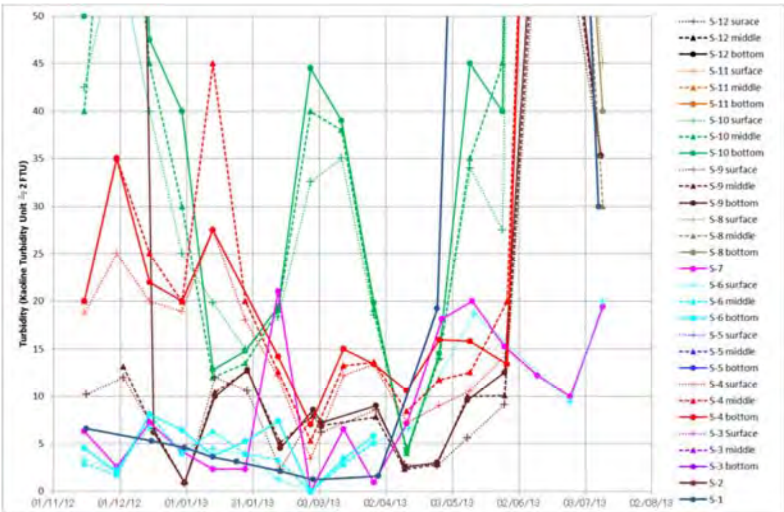


Figure 4-4-9-5 Variation of Turbidity in Bago River and Tributaries (2)

[7] KTU: turbidity unit based on kaolin standard solution; NTU or FTU: ditto based on formazin standard solution, NTU is used only when a specified turbidity meter is applied

c) Color Index (Figure 4-4-9-6)

The color index varies temporally in a similar manner to the turbidity. At the La Gun Byin reservoir, it mostly ranged from 10 to 25 degrees during the dry season but increased to around 50 degrees during the wet season.

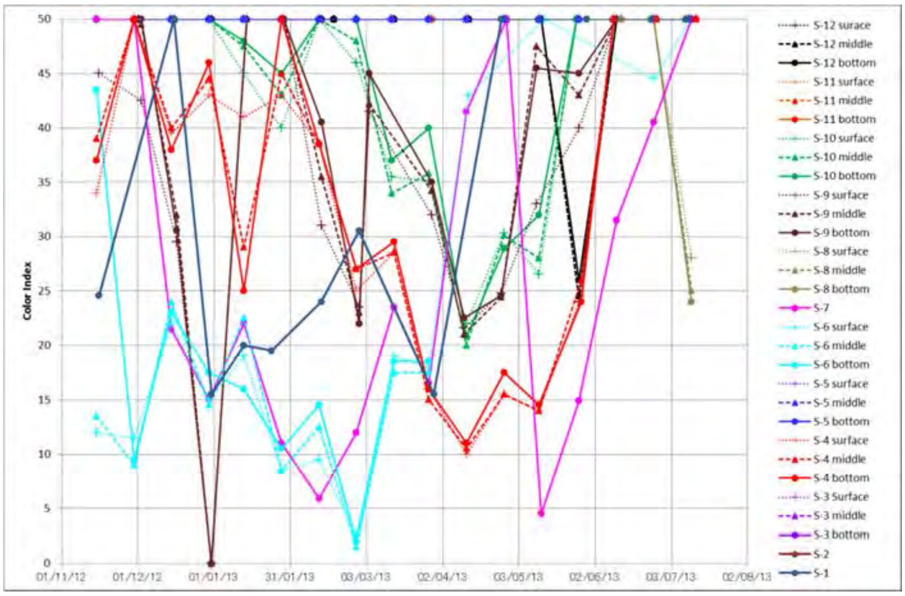


Figure 4-4-9-6 Variation of Color Index in Bago River and Tributaries

d) Water Temperature (Figure 4-4-9-7)

Water temperature mostly ranges from 24 to 30 degrees. It is lower at S-3 and S-8. This may be because the measurement was carried out in early morning.

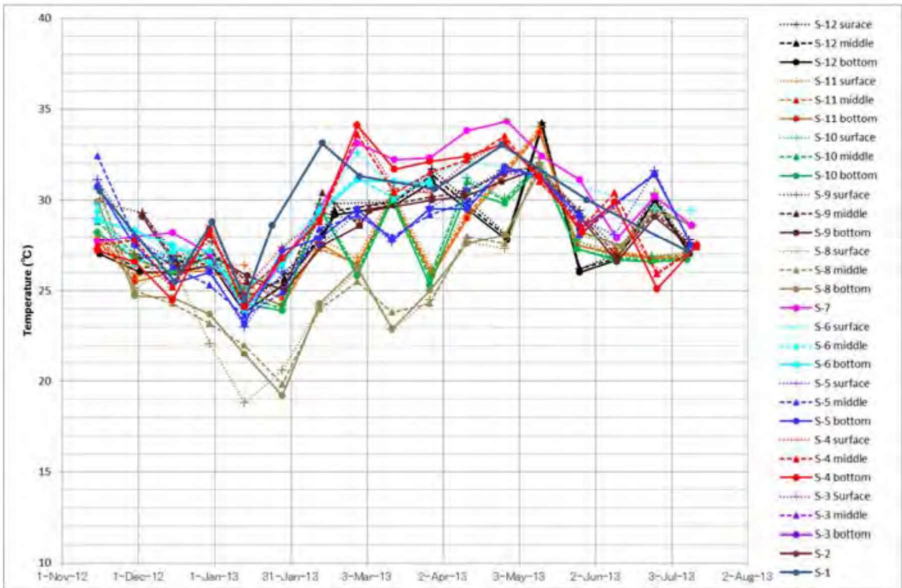


Figure 4-4-9-7 Variation of Water Temperature in Bago River and Tributaries

e) pH (Figure 4-4-9-8)

WHO does not have a pH value guideline for drinking water, but ordinarily drinking water is supplied with a pH of 6.5 to 8.5. The measured value fell out of the range only at S-1, located furthest upstream in the Bago River. It was smaller at the La Gun Byin reservoir (S-6), the upstream side of the Ngamoyeik sluice gate (S-9) and the Khayan River (S10).

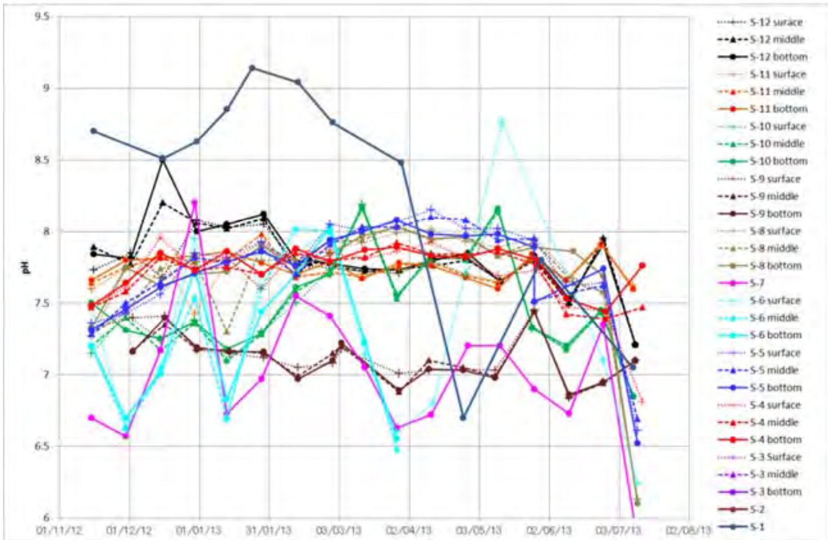


Figure 4-4-9-8 Variation of pH in Bago River and Tributaries

f) DO (Figure 4-4-9-9)

Dissolved oxygen (DO) mostly shows a good value, ranging from 6 to 8 mg/l. At Tawa, midstream in the Bago River (S-5) and at the end of the La Gun Byin River (S-8), the DO at the middle and lower depths shows a low value, like 1 ~ 3 ppm. This implies that water was not refreshed well there.

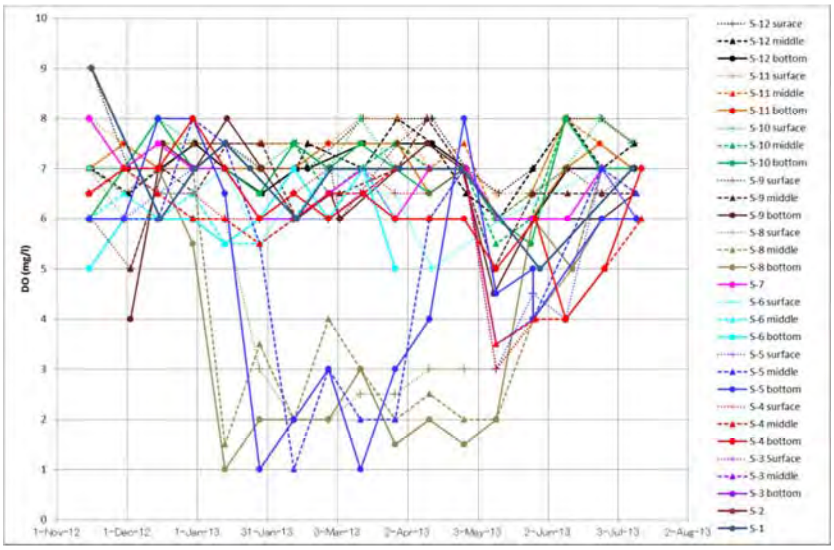


Figure 4-4-9-9 Variation of DO in Bago River and Tributaries

g) BOD (Figure 4-4-9-10)

BOD mostly ranges from 1 to 2 mg/l. In the Tawa on Bago Rivers (S-5), upstream from the Ngamoyeik sluice gate (S-9) and the Khayan River (S-10), it sometimes increased to between 4 and 7. The former two points are located near an urbanized area, and nutritional materials might be flowing into the river. At the La Gun Byin reservoir, the BOD increased when the water level lowered.

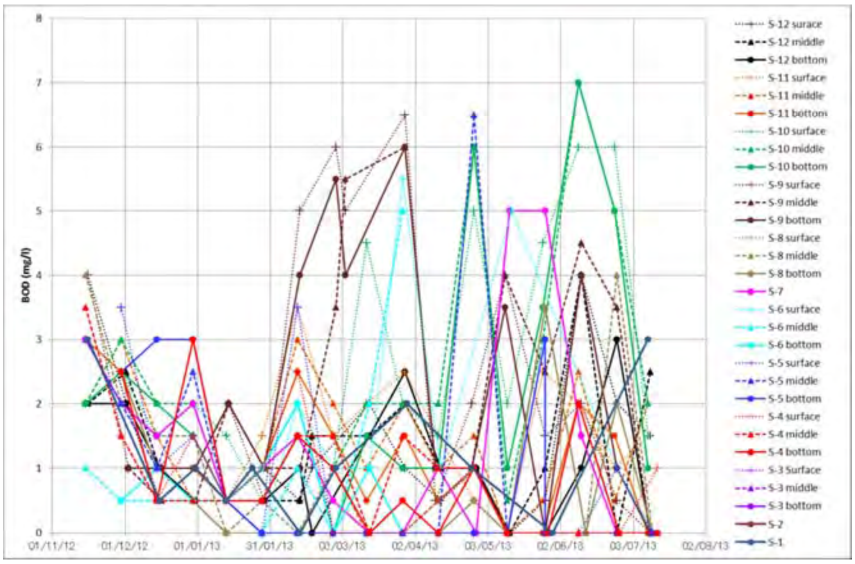


Figure 4-4-9-10 Variation of Water BOD in Bago River and Tributaries

h) Pesticide

Pesticide concentration is checked for the six(6) items of 2.4D, Atrazine, Carbofuran, Chlorpyrifos Dimethoate and Pandimethalin at the points and timings shown in Table 4-4-9-11. The concentrations of these pesticides were all below the detection limit during test period of November 2012 to July 2013[8]

Table 4-4-9-11 Pesticide Monitoring Point and Survey Date

Pesticide Monitoring Point		2013									
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
S-3	Bago River upstrem of Zaungtu Weir				●			●			
S-5	Bago River (midstream) near Tawa				●			●			
S-6	La Gun Byin reservoir	●	●	●	●	●	●	●	●	●	●
S-9	Ngamoyeik River (downstream) upstream of Ngamoyeik Sluce gate				●			●			
S-10	Khayan River upstream of Pagandaung intake gate				●			●			
Remarks		Dry Season					Rainy Season				

[8] Samples for the pesticide were all brought to Japanese Laboratory and tested

2) Seasonal Water Quality Monitoring on the Three Reservoirs near SEZ

The water quality test was made with the eight (8) items of Turbidity, Color Index, EC, pH, DO, BOD, and Chloride (Cl-) for three (3) reservoirs in 2013. The outline is as follows:

Turbidity	0 KTU (Beginning of dry season)
	3 ~ 13 KTU (Late dry and wet seasons)
Color Index	11~43
EC	25~56 μ S
pH	7.2~8.0
DO	7 mg/l
BOD	0.0~1.0 mg/l (Beginning of dry season and Banbuyegon reservoir)
	3.0~5.0 mg/l (Zamani Inn and Thilawa reservoirs in late dry and wet seasons)
Chloride (Cl^-)	2~12 mg/l
Pesticide (6 items)	not detected (less than 1/10 of WHO guideline value)

The water quality is good except for a slightly high color index (due to iron ion), a slightly high Turbidity and BOD in a specific season and reservoir. The Ban Bwe Gon reservoir has better water quality than the others, as shown in Table 4-4-9-12.

Table 4-4-9-12 Water Quality Test Results of Three Reservoir near SEZ, 2013)

Item		Unit	Zamani Reservoir			Thilawa Reservoir			Banbuyegon Reservoir			Remarks
Sample No.			R-1			R-2			R-3			
Total Water Depth		m	2.1	2.1	21	2.6	2.6	2.6	1.1	1.1	1.1	
Samling depth		m	1.0	1.6	1.6	1.0	0.6	0.6	0.5	0.8	0.8	
Date of Site Visit			15/01/13	06/04/13	08/07/13	15/01/13	06/04/13	08/07/13	15/01/13	06/04/13	08/07/13	
Time			11:20	10:15	13:45	12:25	12:00	11:33	13:30	14:50	13:04	
Name of Measurer/Analysist			U Kyaw Kyaw Win / U Nyunt Shwe	U Nyunt Shwe	U Nyunt Shwe	U Kyaw Kyaw Win / U Nyunt Shwe	U Nyunt Shwe	U Nyunt Shwe	U Kyaw Kyaw Win / U Nyunt Shwe	U Nyunt Shwe	U Nyunt Shwe	
Place of Measure /Analysis	Item	Unit	Zamani Reservoir			Thilawa Reservoir			Banbuyegon Reservoir			WHO Guideline (Version 4)
On-site	Odor		-	-	-	-	-	-	-	-	-	
	Taste		-	-	-	-	-	-	-	-	-	
	Turbidity	PTU	0	12.9	11.3	0	4.8	6.3	0	7	2.6	
	Color Index		10.5	35.5	42.5	14	18.5	11	14.5	33	26.5	
	pH		7.46	7.60	7.56	7.25	7.3	7.42	7.20	7.89	7.97	
	EC	μS	48.9	55.7	56.0	22.5	30.0	41.0	25.2	30.2	31.3	
	Temperature	mg/l	25.5	29.7	28.7	24.6	29.8	29	27.7	33.6	29.1	
	DO_0	mg/l	7	7	7	7	7	7	7	7	7	
In Laboratory	DO_5	mg/l	6	3	4	6	2	4	6.5	7	7	
	BOD $=DO_0-DO_5$	mg/l	1	4	3	1	5	3	0.5	0	0	
	Chloride	mg/l	5	5.4	11.8	4.2	4.8	5.3	3.5	< 2	6.8	
In Japan	2,4 D	mg/l	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.03 mg/l
	Atrazine	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.1 mg/l
	Carbofuran	mg/l	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007	0.007 mg/l
	Chlorpyrifos	mg/l	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.03 mg/l
	Dimethoate	mg/l	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	0.006 mg/l
	Pandimethalin	mg/l	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.02 mg/l

4-5 Water Facilities

4-5-1 Reservoir

In the Bago River Basin and adjacent area, including the eastern bank of the Sittang River, there are various scales of reservoirs and 13 large reservoirs, two of which are located at the Zaungtu dam and the Zaungtu weir exit in the main channel with the other 11 being located in the tributaries of the Bago River, three (3) of which are in the east bank, four (4) in the west bank, and the other four (4) are located in the bordering basin of the Sittang River, as shown in Table 4-5-1-1 and Figure 4-5-1-1.

Most of the dams have been constructed for irrigation purposes with the exception of the Zaungtu dam which is for hydropower. In the catchment of the Bago Bridge Station, there are five (5) water facilities: the Zaungtu dam, the Kodukwe dam, the Shwelaung dam, the Salu dam and the Zaungtu weir. These are expected to act as flood regulation dams together with the ponding of irrigation water in the rainy season. The total storage capacity of five (5) reservoirs is accounted as 836 MCM (or the effective storage of 708 MCM) and is correlative with 18%[9]of the total discharge at the Bago Bridge station (3,950MCM/year).

As well as this, four (4) facilities are located in the western bank of the Bago River: the La Gun Byin dam, the Alingni dam, the Magin dam and the Zalataw dam. These are constructed for irrigation purposes. However, the Magin dam currently has turned its purpose to drinking water. As the Magin dam, the La Gun Byin dam is also used as a water source of the Yangon Water Supply together with proper irrigation use.

Other dams of Pyi Pon Gyi, Bawni and Wagadok are located in the neighboring area of the Sittang basin. They were also constructed for supplying irrigation water, and their developing water is planned for use as the water source of a 30-mile greening project.

[9] The effective storage (708MCM/Year) is calculated as 18% for the total discharge amount at the Bago Bridge Station (3,950MCM/Year).

Table 4-5-1-1 Sum mary of Reservoirs

Name	Unit	La Gun Byin	Aline Nee	Magin	Zalataw	Pyi Pon Gyi	Bawni	Wagadok	Zaungtu Dam	Zaungtu Weir	Koduk we	Shwe Laung	Salu	Moe Yin Gyi
Purpose [1]		I	I	I	I	I	I	I	P+I	I	I	I	I	I
Construction Period	-	2000.9-2001.11	2002-2003	1999-2000	1998-1999	1987-1988	1998-1999	2007-2008	1994.1-2000.3	1994.1-2000.4	2012	2012	2012	1878,2003-2006
Location/TS	-	Hlegu	Bago	Bago	Bago	Dike U	Dike U	Dike U	Bago	Bago	Bago	Bago	Bago	Waw
Name of Creek	-	Lagunbyin	Alaingni	Magin	Zalataw	Pyi Pon Gyi	Bawni	Wagadok	Bago River	Bago River	Koduk we	Shwe Laung	Salu	Moe Yin Gyi
Catchment Area [2]/	km^2	109	37	28	23	21	65	26	1,120	2,330	163	83	78	155
Average Annual Rainfall [3]/	mm	2,870	2,860	2,870	2,850	2,980	2,870	2,990	(2,700)	(2,700)	2,680	2,820	2,820	-
Average Annual Inflow [4]/	MCM	155	53	-	-	-	-	-	-	-	228	139	124	-
Irrigation Area	ha	8,903	4,047	263	809	1,592	243	-	14,569	14,670				16,187
Reservoir Capacity Necessary to Store	MCM	-	-	-	-	-	-	-	-	-	244	145	130	-
Reservoir Full Tank Level	m	25	25	27	34	48	53	59	-	-	61	60	45	8
Reservoir Full Tank Capacity	MCM	184	48	32	23	137	43	40	400	18	183	123	112	173
Reservoir Water Spread Area at F.T.L.	km^2	27	8	6	6	2	6	6	-	-	27	16	19	104
Free Board	m	-	-	-	-	-	-	-	-	-	2.0	1.7	1.6	-
Dam Crest Level	m	27	-	-	-	-	-	-	-	-	64	63	48	-
Creek Bed Level	m	9	-	-	-	-	-	-	-	-	37	35	21	-
Dam Height	m	19	16	18	15	20	26	26	45	-	27	28	27	3
Dam Length	m	1,579	1,737	1,219	1,391	320	248	1,951	-	-	344	1,433	1,746	43,452
Dam Type	-	Earth	Earth	Earth	Earth	Earth	Earth	Earth	-	-	Earth	Earth	Earth	-
Effective Storage	MCM	177	46	29	22	136	14	-	296	18	171	117	106	-
Number of Saddle Dams	Nos.(ft)	-	-	-	-	-	-	-	-	-	6 (1,081)	9 (928)	11 (3,862)	-
Generation Capacity	-	-	-	-	-	-	-	-	40 (20x2)	-	-	-	-	-

1: "Purpose" ; I: Irrigation, P: Hydraulic Power generation
2: "Catchment Area" is referred from the reports of the ID hydrology section
3: "Average Annual Rainfall" is estimated from isohyets-map based on 2006-2010 records with the exception of the Zaungtu Dam and Weir which applied its own station data
4: "Average Annual Inflow" is referred reports from both the ID and the DHPI
5: Reservoirs are owned by irrigation department except Zaungtu managed by DHPI

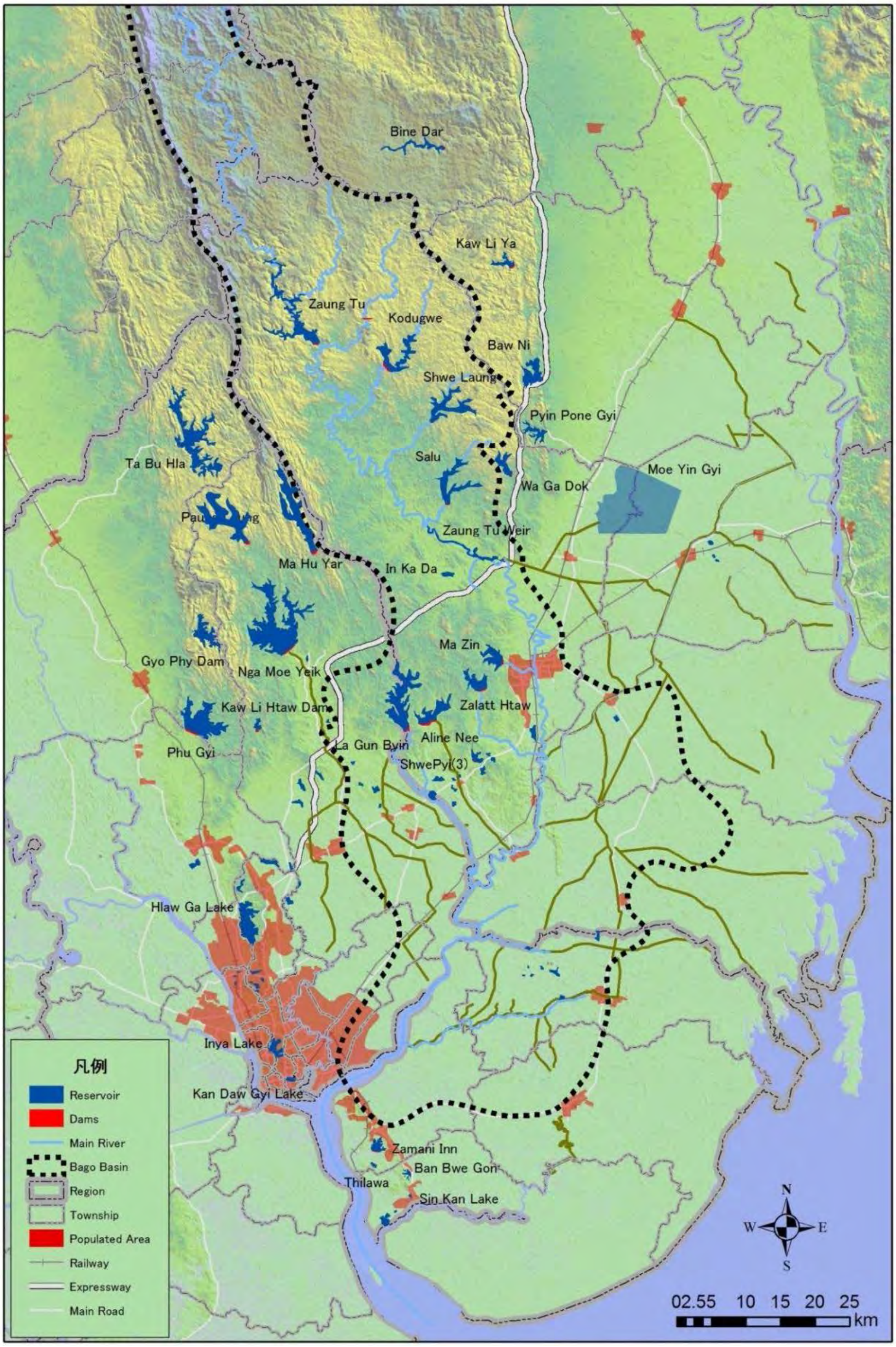


Figure 4-5-1-1 Location of Reservoirs

4-5-2 Irrigation Canals/Drainages and Water Gates

Waterways running in the Bago basin and the east bank of the Sittaung River start from the Zaungtu weir located in the middle course of the Bago River diverting at 10 km downstream and continuing to the Moe Yin Gyi reservoir (Zaungtu-Meo Yin Gyi Canal). Downstream, the canal is divided into Tu-kyite point and Sun Pi, both being connected to the Bago-Sittaung (Bago-Sittaung Drainage/Feeder Canal[10]) Canal. In the same way, water temporarily stored in the Moe Yin Gyi reservoir is also flowing in the Bago-Sittaung Canal at Waw. In the Bago-Sittaung Canal, drainage weirs exist at three locations: Aphyar weir, Min Ywar weir and Bagan Nyaung Pin weir. They function as drainages of the flood water downstream, but in the dry-season, the diverted water at the Bagan Nyaung Pin weir is confluent with the 30-mile canal. As described below, a 30-mile waterway is built by the ID, but its end is reached at Khayan creek in the Yangon district located 45 kilometers south from the Bagan Nyaung Pin weir.

Sittaung Bago and the 30-mile canal is a large-scale canal and have been used for water conveyance and navigation, but is also serving as flood water drainages. As main drainage systems, seven (7) canals have been built on the Sittaung river side with the other four (4) constructed on the Bago river side as a dewatering path for the flood water during the rainy season. At the end of each drainage canal, water gates are provided in order to prevent the inundation of salt water. Out of the four (4) drainages of the Bago river side, three (3), Tawa, Pine Kyone and Khayan, were already constructed. The remaining one (1), the Shwe Hla weir, is in the planning stage. On the other hand, on the Sittaung river side, the facility development has been delayed so far. Out of seven (7) drainages, only two (2), Shan Kine and Kim Mon Chone, were constructed. However, five (5), Winkadat, Kalatsu, Kokko, Mamaul and Tan Din, are still in the planning stage due to technical issues such as a weak foundation and heavy sedimentation.

The Estuary of Sittaung is famous as “the place of tidal bore” in the world. The sites of water gates located there also have the problems of being flooded by salt water inundation, storm surge damage and soil salt damage, as well. Figure 4-5-2-1 and Figure 4-5-2-2 show the location of the drainage canal and water gates, respectively.

[10] The river mouth of the Bago River is known as ‘the laces of tidal bore”, frequently causing the distress of ships and rafts. Aiming to maintain safe and economical transportation, especially for the timber exports, the Bago-Sittaung Canal was constructed in 1878.

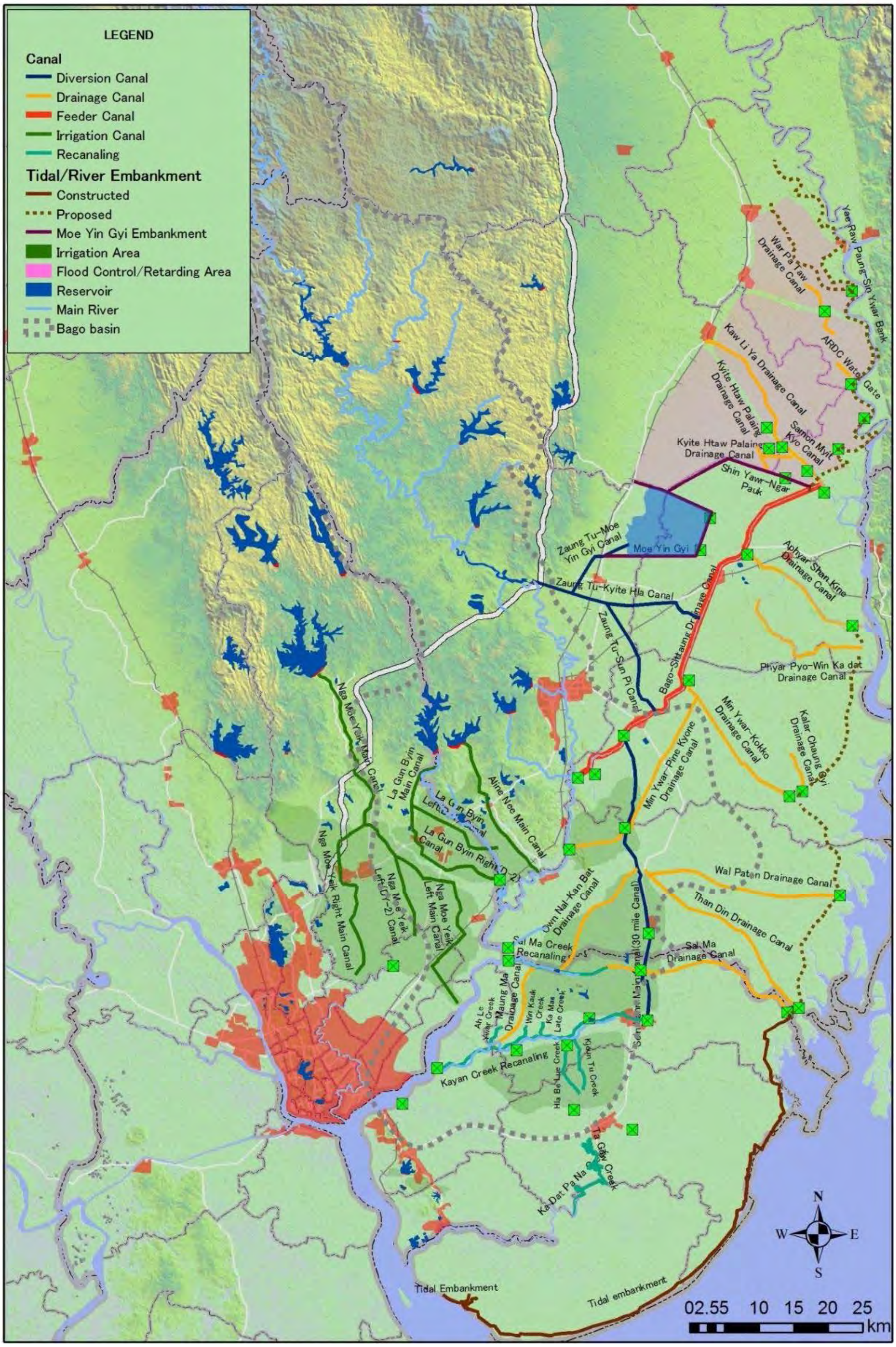


Figure 4-5-2-1 Location map of Drainage Canal

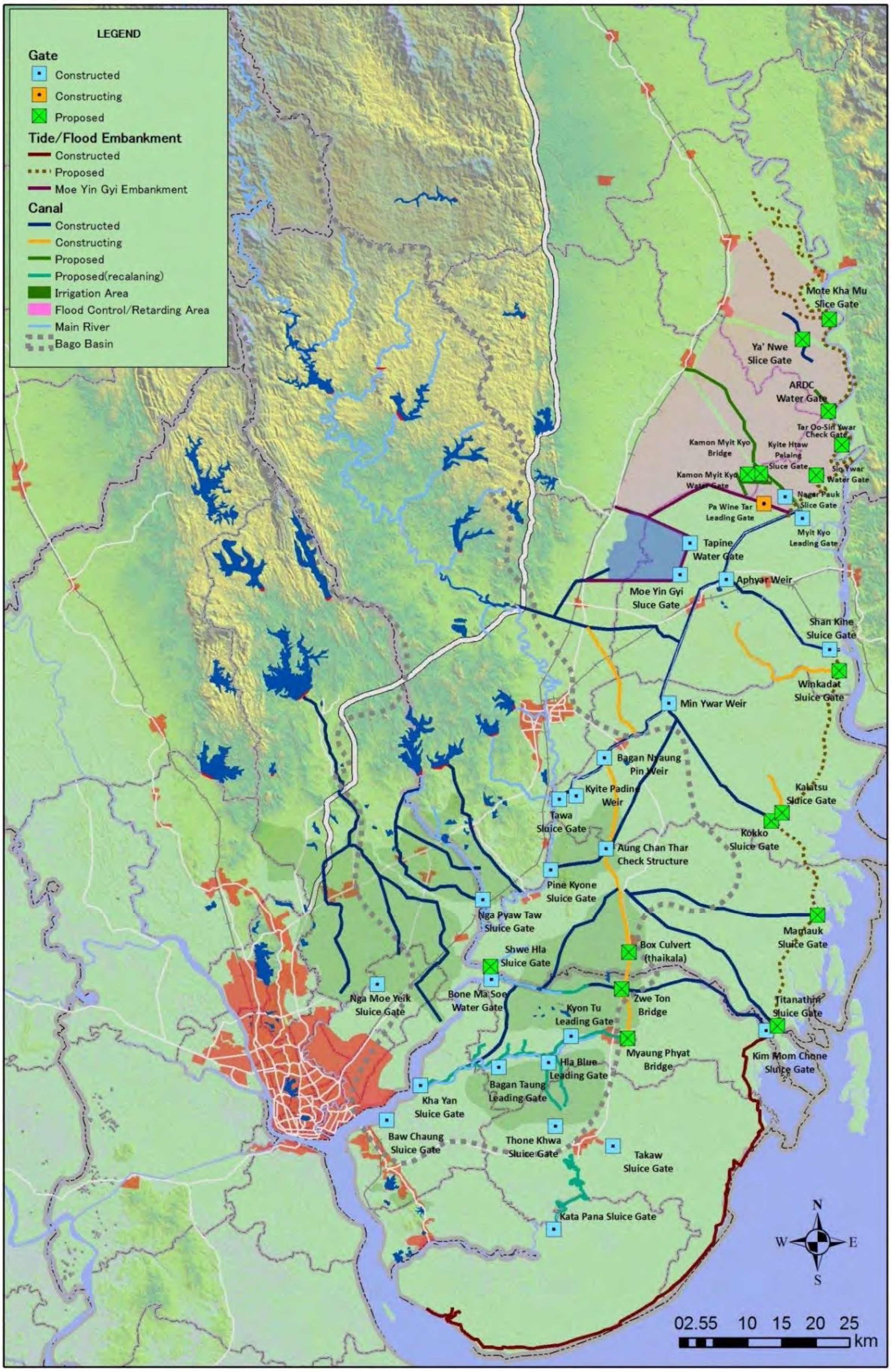


Figure 4-5-2-2 Location map of Water Gate

4-5-3 30 Mile Greening Project

The 30-mile Greening Project (Yangon Region 30-mile Environs [eastern side] Greening and Development Project) aims that the surplus water from dams at the eastern part of Pegu Yoma and water from newly constructed dams is to flow down to the Bago-Sittaung canal and then up to Khayan Chaung. It can help to cultivate the double crop, including paddies at the 30-miles Environs (Eastern side) of the Yangon Region, not only in the rainy season, but also in the dry season, implementing the aim to be green throughout the year.

(1) Project Background

Since the early decade of 1980, the west bank of the Bago River, including the Yangon metropolitan area, has been developed, and a number of dams have been constructed in the Pegu Yoma hills for irrigation, greening, and water supply for the peri-urban and urban water supply of Yangon City. However, on the east bank of the Bago River, the development has been delayed due to the geographical condition, featured as the low flat plain, not an appropriate relief for dam construction, so the water supplying there depends still on a conventional source of rainwater and small ponds which are being apt to cause the chronic drought for the 30-mile Greening Project to develop the large-scale irrigation area for the eastern area that has been left behind in the Yangon metropolitan area. The elimination of the regional disparity between the west city area and suburbs is the beginning of the commencement of the 30-mile Greening Project.

There are few water sources to construct irrigation dams on the eastern side of Bago and the lower plain areas according to geological formation. As the average height is only 13 ft. (4.8m) above sea level, dams can’t be constructed. Therefore, it is considered to supply water for the required cultivating water at the eastern side of Bago by means of flowing down into the Bago-Sittaung canal. It shall need about 400,000 acre-ft. (493 MCM) to supply water for 30,000 acres (12,141 ha) of cultivating fields in the Bago Region and 35,000 acres (14,164 ha) of cultivating fields in the Yangon Region, a total 65,000 acres (26,305 ha).

The 30-mile Greening Project is aiming to supply and secure the water for the vast irrigation area by the long diversion bringing water 100 km from the beneficiary area of the southeastern Yangon -- the eastern bank of the Bago River. The project will be implemented in four phases in the following steps of one (1) to four (4).

<u>Work 1</u>: In carrying out and providing means for getting water, the surplus water from the below-mentioned constructed dams, shown as Table 4-5-3-1, can flow down to the Bago-Sittaung canal through the Napaul Sluice and the Pagaingtar Intake.

Table 4-5-3-1 Reservoirs Planned in Work 1

Sr	Name of Dam	Storage Capacity (acre-ft.)	Irrigation Area (acre)	Extent of Surplus Water (acre-ft.)
1	Kawiliya	165,000 (203 MCM)	24,500 (9,915 ha)	28,000 (35 MCM)
2	Bine Da	374,000 (461 MCM)	46,700 (1,899 ha)	84,000(104 MCM)
3	Baw ni	35,200 (43 MCM)	600 (243 ha)	5,000 (6 MCM)
Total	-	574,200 (708 MCM)	71,800 (29,057 ha)	117,000 (144 MCM)

Work 2: The approximate annual inflow water (32,000) acre-ft. from the constructed Wakadoke dam can fill the Moe Tin Gyi Reservoir and then flow down into the Bago-Sittaung canal through such a reservoir.

Work 3: The storage water from the below-mentioned constructed (3) dams of Zarmani-Inn (Kodukwe), Salu and Shweloung shall deliver to the Zaungti weir and then combined with surplus water (15,000 acre-ft.) from the Zaungtu weir as shownin Table 4-5-3-2. The canal was constructed near the Mayin Village across the Yangon-Mandalay-Highway road. After that, water can be filled into the Bago-Sittaung Canal through Sunpi Chaung near Thanatpin from the Zaungtu Weir.

Table 4-5-3-2 Reservoirs Planned in Work 3

Sr.	Name of Dam	Dam Catchment Area (Sq-mile)	Height of Dam (ft)	Average flow in water annually (acre-ft)
1	Koudukwe	68.7 (178 km^2)	80 (24m)	138,000 (170 MCM)
2	Salu	30 (78 km^2)	75 (23m)	79,000 (97 MCM)
3	Shwelaung	36 (93 km^2)	90 (27m)	95,000 (117 MCM)
4	Zaungtu Weir	-	-	15,000 (18 MCM surplus water)
Total	-	-	-	327,000 (403 MCM)

Work 4: The water flowing into the Bago-Sittaung canal by the above-mentioned three ways, shall be supplied by means of flowing down into Khayan Chaung through Bagan-Nyaung Pin Escape situated on the Bago-Sittaung canal near Thanatpin (refer to Work 4). The constructed Khayan sluice can maintain up to R.L.9.0. The constructed sluices (Tawa, Paing Kyone, Shwe Lay, Kyayan sluice gates) along the Bago River prevent salt-water intrusion, store fresh water and supply water.

Work 5: Khayan Chaung shall be re-excavated and the supplied water from Khayan Chaung shall maintain fresh water through the constructed Thongwa, Takaw, Bawchaung, Kadapana sluice gates via the Bagan Taung, Hla Belu and Kyone Tu intakes. Then fresh water shall be supplied to the Thongwa, Kyauktan and Thanlyin Townships respectively.

The 30-mile Greening project shall be carried out so that water from the Bago-Sittaung canal flows down into Paing Kyone Chaung through the Bagan-Nyaung Pin Escape and then shall flow down along Thanatpin-Khayan-Road through Ohnne. A box culvert shall be constructed beyond Thatkala and then shall flow down to Khayan from the eastern side of Thanatpin Khayan Road.

In doing so, along the main check structure there shall be constructed small creeks which are flowing across the main canal so that it can save water losses in supplying for the dry season. Therefore, there is no need to construct a syphon, flume, etc. and it can be a flow drainage system for rainwater as per the former condition. In conveying though the main canal, the height of the water level shall be controlled at RL 11 ft. (3.3m) and RL 9.0 ft. (0.9 m) in the Shwe Hlay and Khayan sluices respectively, and then it shall supply water in the dry season Therefore, the Yangon Region's 30-mile Environs (eastern side) shall be greened and developed by means of cultivating monsoon paddies as well as having the water supply studied in detail and implemented forward in order to get more greening areas in the dry season.

The summary of related facilities to the 30-mile greening projects: (1) Zaungtu dam, (2) Kodukwe dam, (3)Shweloung dam, (4) Salu dam, (5)Zaungtu weir and (6)Khayan weir are described below.

Figure 4-5-3-1 Zaungtu dam

1) Zaungtu dam

The dam has been constructed since 1994 along with Myanmar's 30-year development plan. However, its construction was delayed due to the technical problems and was completed in 2000 by the supports of the China fund. The dam height is 45 meters and the length is 1,850 meters. The total storage of the reservoir is 400 MCM and the effective storage is 296 MCM with 20MW (10MW x 2) of hydro-power capacity. As for irrigation use, the irrigation water is once controlled at the Zaungtu weir and supplies to the 14,500 ha (plan). The function of flood control is also brought out together with ponding the irrigation water in the rainy season.

2) Kodukwe dam

The dam is located at the middle course of the Kodukwe tributary and was constructed in May 2012 by ID. The height of the dam is 27 meters and the length is 344 meters (with 1,603 meters of six (6) saddle dams). The total storage capacity is 182 MCM (296MCM of effective storage capacity) for the uses of irrigation purpose. The catchment is 163km^2 collecting 228 MCM/year of inflow at 44 % of the runoff

Figure 4-5-3-2 Kodukwe dam

coefficient. Although it is mainly used for irrigation, the other functions of the small scale hydro power plant and flood control are also involved. At the moment, February 2013, 17 m^3/sec of water is being released to maintain the irrigation water for the agricultural land in the down reach.

3) Shwelaung dam

Figure 4-5-3-3 Shwelaung dam

As same as Kodukwe dam, the dam is located in the tributary of the Bago River and was constructed by ID for irrigation use, as well as flood control and small scale hydropower. The inflow amount is 139 MCM/year from the 83km^2 of its catchment. The dam height is 28 meters and dam length is 1,433 meters with total 928 meters of 9 saddle dams. The storage capacity has 123 MCM (effective storage capacity is 117 MCM) and the embankment works were completed in one(1) dry season from 2011 to 2012, and its first operation was examined at the rainy season of 2012. At present, after the rainy season of March 2013, ID is conducting the supplemental construction, including the spillway repairing and the installation of the small scale hydro power plant.

4) Salu dam

Figure 4-5-3-4 Salu dam

The dam was constructed in the Salu tributary that is the most downstream branch in the hilly section. Dam height is 27 meters and dam length is 1,746 meters with 3,862 meters of 11 saddle dams. The total storage capacity is 112 MCM (effective storage is 106 MCM/year) and inflow rate is 124 MCM, collecting from 78 km^2 of the catchment. As the Shwelaung dam, the construction was made during the dry season of 2011/2012, and then the first operation was made during the rainy season of 2012. So far, the incidental fortification for repairing of the access road and the installation of the small scale hydro power plant is followed at the downstream of the dam site.

5) Zaungtu weir

Figure 4-5-3-5 Zaungtu weir

The weir has a function as the regulator with 18 MCM of the storage capacity, for which the released water from Zaungtu (296 MCM/-: total storage/effective storage), Kodukwe (183 MCM/170 MCM), Shwelaung (145/117 MCM) and Salu (112/97 MCM) reservoir. The weir control is to divert the water downstream to the Zaungtu-Sunpi irrigation canal (length: 25km, depth: 3.7m x width: 12.2m). At the down reach, the water flows into the Sittaung-Bago Canal, as supplying water to four (4) irrigation areas planned in the eastern bank of Bago River, then linked to the upstream of Khayan Chaung. The main canal is as long as 45 km long; its excavation was completed by 2012 and its first operation is planned for the dry season of 2013. As for the full construction of all terminal facilities, its completion is planned for 2018 because of the large quantity of supplemental works of check gates, minor canals, etc.

6) Khayan water gate

The Khayan water gate (sluice gate) was constructed at the confluence between the Bago River and Khayan chaung aiming for the storage of river water in the dry season as well as the protection of flood tide. The water conveyed from upstream is once stored in the Khayan Chaung then pumped up to supply the Thongwa, Kyauktan and Thanlyin area. The objectives of Khayan water gate is summarized as follow.

Figure 4-5-3-6 Khayan water gate

- Enhancement of drainage capacity in rainy season
- Provision of supplemental irrigation water at late rainy season
- Provision of irrigation and domestic water using diversion water form 30 mile canals
- Protection of seawater intrusion and sediments caused by tidal change

a) Salient Feature

The Salient feature of Khayan water gate is as shown in Table 4-5-3-3.

Table 4-5-3-3 Salient Future of Khayan Water Gate

Items	Description
Location	Near of Chaungwa old village, Thanlyin Tsp;, Yangon Division
Map/Scale	(94D/5 – 715425), 1inch : 1mile(1:633,583)
Stream of Name	Khayan Chaung
Drainage Area	142 sqmiles (368km^2)
Type of Sluice Gate	Concrete Sluice gate
Size of Sluice Gate	40gates 6' x 6' (1.83 x 1.83 m)
Upstream Length	4,000 ft (1289 m)
Downstream Length	2,500 ft (762m)
Contribution Area	30,000 acres (12,141 km^2)
Project Cost	1247.28 million kyat (1.27 million dollar)
Project Period	April/2004 – June/2005

At north of Thongwa TS, the end of 30 mile canal connects to upstream of Khayan chaung and its water flows down to Khayan water gate. In the dry season, Khayan water gate is closed then river channel is fully ponded and the water is utilized as a local water resource (supposed to be 2 MCM of capacity) for irrigation and domestic supply.

b) Regular Operation at Khayan Sluice Gate

The gate is ordinary closed in the third (3rd) week of October and opened again in the first (1st) week of May. In the dry season of 2012, the water ponded in channel was used for 100 acres of paddy and 10,000 acres of beans. At Khayan water gate, the tidal change is as large as 5.5 meters ranging 4.5 meters (high tide) to -1.0 meter (low tide). Controlling this difference of 5.5 meters, the function of channel storage and necessary irrigation water is maintained.

The rule of operation (Irrigation Department) is as follows.

i) Daily rainfall must be measured daily at 9:00 am, water level at Upstream, Downstream of sluice gate also must be measured daily at 6:00 am, 12:00 pm, 6:00 pm and put into the notice book and submit to the head officer and head office daily. If rainfall over 3 inch, report of the clock water level.
ii) Open and close of sluice gate must be guidance by head officer.
iii) Check and regularly put charging to the phone and report to the head officer immediately if something happened at telephone.
iv) The site gates must be opened and closed carefully with winch for no damage happened and not to danger for workers.

v) The site gates must be opened first as layers of left and right from the center of upper stage. And then, flap gates must be opened from the center to left and right one by one. Flap gates must be opened when all the site gates have already been opened.

vi) At the check gate, to control the fresh water and protect from sand and silt incoming. So, for the result of the end of the rainy season period, the site gates must be closed from the edge of left and right to the center one by one in the third week of October. At the beginning of November, the flap gates must be shut down from the left and right to the center of the one by one when the upstream of check gate reach water level RL +9' .

vii) Upstream flap gate and downstream from silt gate must be opened at beginning of April to remove remain water from the field and the rain water, rained heavily at the early rainy season.

viii) Opening flap gate, closing downstream and downstream silt gate must be cleaned, repainted, rusting, put the lubricant into the hinge of gates must be needed to do carefully at dry seasons.

ix) At downstream, flap gates must be shut down for not incoming water from outside streams and rivers. If necessary, silt gates must be closed temporarily and flap gates must be repaired one by one.

x) Upstream and downstream of sluice gate must be checked daily. If the cracks or something happened on there, must report to head officer. If the sticks and branches are flooded or jammed at the gates, must be removed at once and do not let the animals pass in.

xi) At the maintain water, to check the daily upstream (water conical shape) and downstream (muddy) happened or not.

xii) Longitudinal, horizontal sounding and level checking must be needed to check weekly.

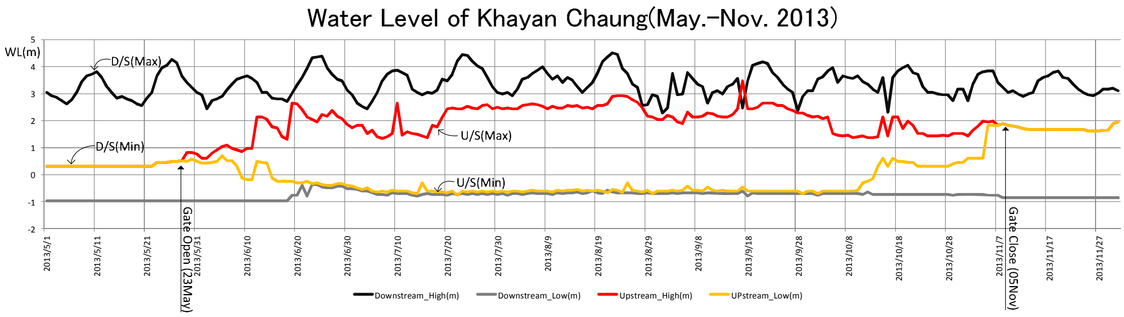
xiii) Along the water inflow/outflow canal and streams (or) rivers bank near sluice gate must be checked that the erosion happened or not, daily.

xiv) Do not fishing and ship sailing in upper 500 ft and lower 500 ft at sluice gate.

xv) If something strange matters happened, must reported at once to head officer.

c) Operation of 2013

The Gate was open on 25th May and closed 5th November during rainy season as shown in Figure 4-5-3-7. In rainy season after May, the gate was operating to control the tidal invasion and sediment deposition and enhance a dewatering. While in the dry season since November by May, river water was stored at WL 2 m (RL 9ft) in maximum and used for irrigation and domestic water by WL 0.35(RL 4 ft).



Source: Irrigation department

Figure 4-5-3-7 Water level of Khayan Chaung in 2013

The Changes of water level in Rainy season is shown Figure 4-5-3-8. The tidal change in August 2013 is large as 5 m. In connection with tide change, the flood water was controlled to drain at the low tide. While in dry season, all gates are closed to keep the water level at 2 m (RL9ft) on January 2014.

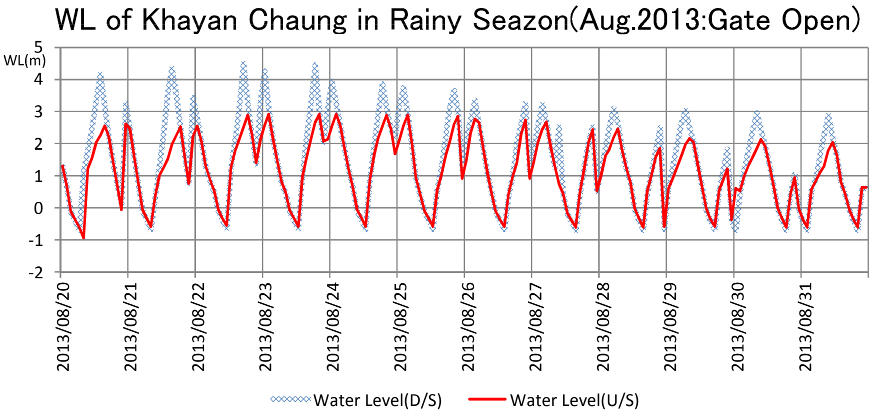


Figure 4-5-3-8 Water level of Khayan Chaung in August 2013

In the dry season since January 2014 as shown in Figure 4-5-3-9, a water level of D/S (Bago river side) shows a fluctuation with a range of 5 meters in response to daily tidal change. While in U/S (Khayan river side), the water level keeps a level to slightly rising by inflow from diverted water and self-discharge (January 2014).

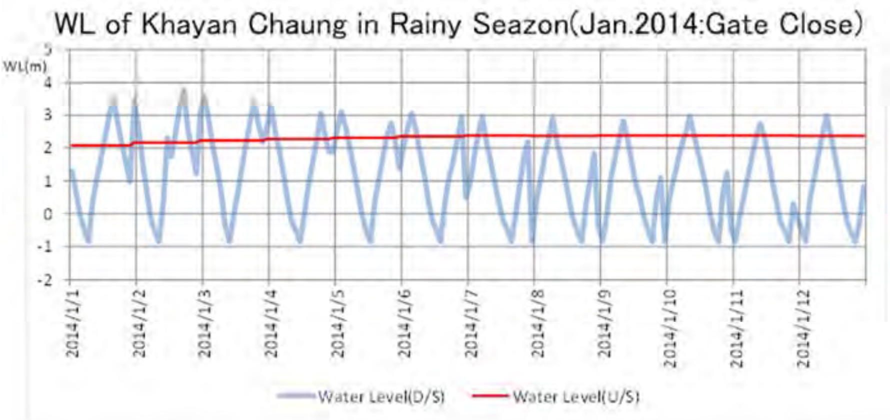


Figure 4-5-3-9 Water level of Khayan Chaung in January 2013

d) Water Quality

In the Khayan chaung, the water quality measurement was done for 1 year from November 2012 to October 2013 with 7 items of filed-test parameters (Turbidity, Color, EC, pH. BOD, Cl) and agricultural chemicals (4 items: 2.4D, Atrazine, Carbofuran, Chlopyrifos, Dimethoate, Pandimethalin). Sample water for filed-test was taken at every high tide from 3 depths of river (surface, middle, and bottom). As for agricultural chemicals, the sampling was made at two times of the end of dry season (April) and dissemination season (July).

As for agricultural chemicals, none of content is found at 2 times (4 items). However, for filed-test parameters, the seasonal change is observed in dry season. In particular EC (Electric Conductivity) and Chloride content, they show a drastic seasonal change between dry season and wet season. 100 μ S/cm of EC in wet season (October) had increased up to 6,000 μ S/cm in the end of dry season(May). Chloride content was also indicated as same manner.

e) Salinization of Khayan river

The factors to cause a salinization of Khayan river are supposed to be

- Natural river discharge is interrupted in the dry season,
- Leakage of seawater from Khayan water gate and
- Seepage from saline soil and shallow aquifer.

At the present, the ID has plans for repairing water gates and investigating saline soil distribution beside river channel to improve a salinization of Khayan river. In addition, the fresh water diverted from 30 mile canal, which test operation has been made since December 2013, is expected to dilute a ponded the saline water in river channel.

f) EC distribution along Khayan Chaung

As shown in Figure 4-5-3-11 of EC distribution, the highest EC was observed at Pagan Daung Bridge located in the middle course of river channel indicating as large as 2,100 μ S/cm (January 2013). In general, the upstream near a confluence with 30 mile canal has low EC (below 1,000 μ S/cm), while the downstream close to Khayan water gate is high EC (1000~2000 μ S/cm).

In view of a relation between EC and Temperature as shown in Figure 4-5-3-10, the water quality type is clearly divided into two types of 'Low EC and High Temperature (representing value: 500 μ S/cm・27℃)' located upstream area (K14-23) and 'High EC and Low Temperature (representing value: 2000 μ S/cm・25.5℃) located downstream area (K1-7)'. If water type is traced in the river

The water type of 'Low EC and High Temperature' traces a diverted water of 30 mile project and ‘High EC and Low Temperature’ is originated from shallow aquifer lying nearby river channel. In other words, the saline groundwater kept in the shallow aquifer seeps in the river channel as river flow is decreasing and water level is lower. In this condition, the fresh water comes in the upstream by the diversion of 30 mile canal project, and replaces saline water by fresh diverted water in the upstream. According to observation records, the interfusing saline water with freshwater is progressed and an area of highest EC located near Pagan Daung Bridge was gradually moved downstream at pace of 2 km/month.

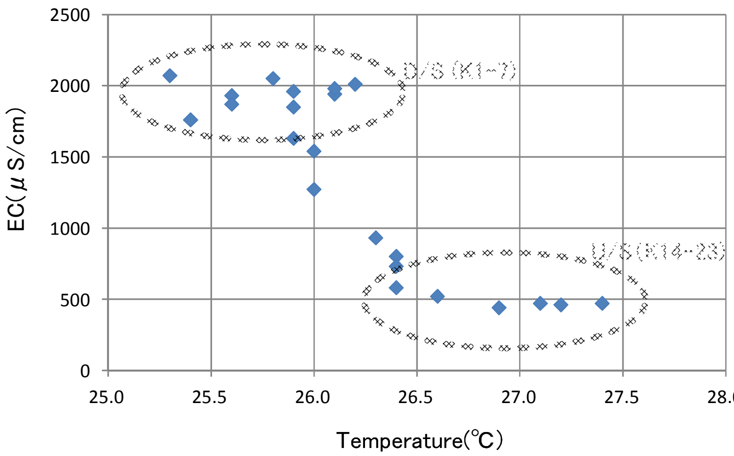
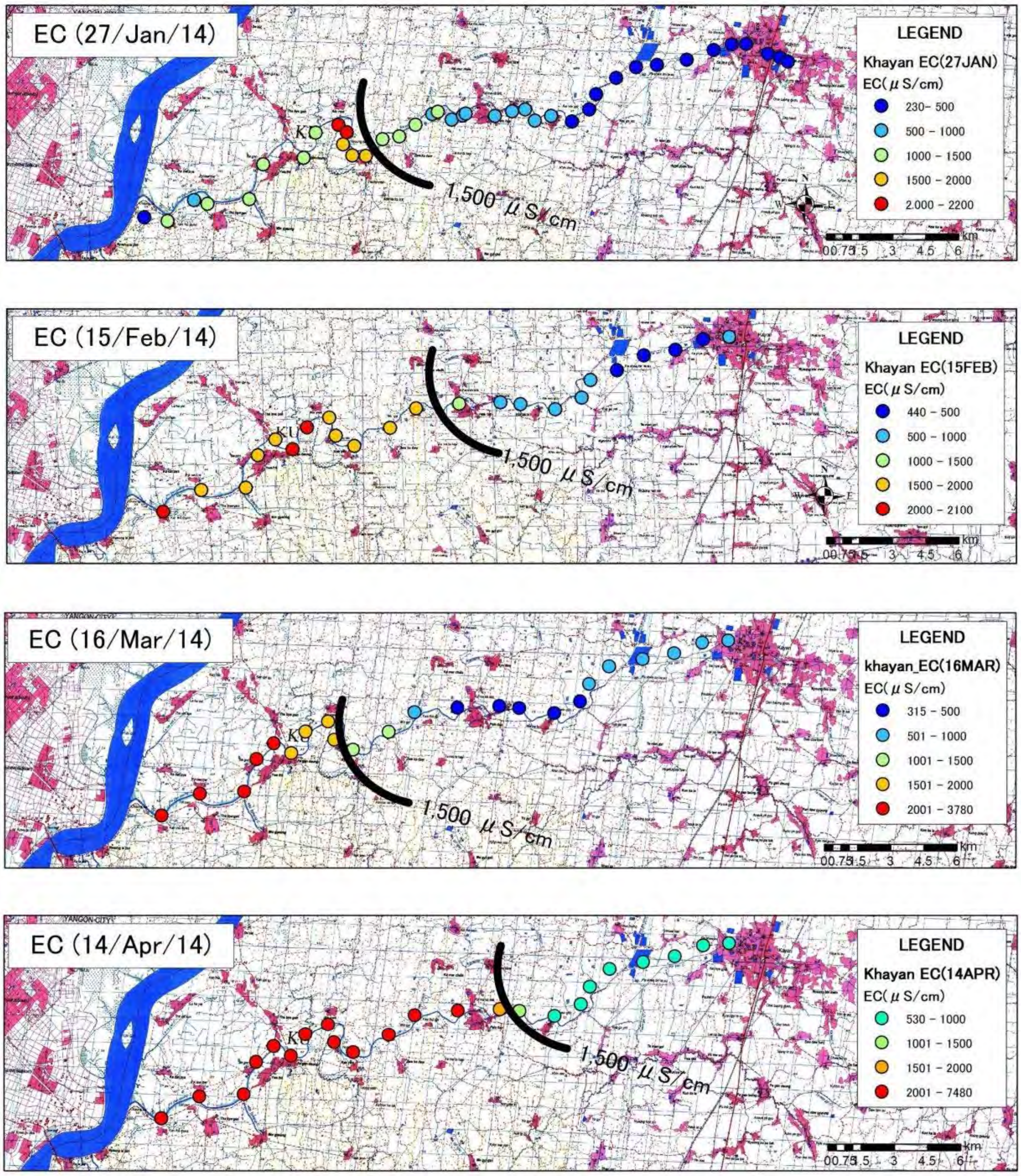


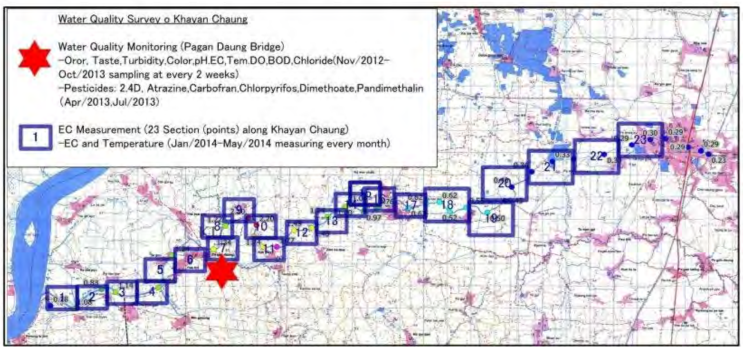
Figure 4-5-3-10 Relation between EC and Temperature

g) Water Resource

The water resources of the Khayan tributary involves both of a stored water in the channel of 200 MCM and the conveyance water from 30 mile canal of 100 ft3/sec (2.7m^3/sec). The in-take is planned near the Khayan Pumping station (WDUD), located at four (4) km upstream of confluence point to Bago River. At the proposed in-take, water quality is a semi-saline water indicating more 2,000μS/cm (Max.6,610 μS/cm at April) in the end of dry season (March-April), and is fresh water showing a less than 1500 μS/cm in rainy season to early dry season (May to February).



Distribution of Electric Conductivity



Location Map of
Water Quality Survey
in Khayan Cahung

Figure 4-5-3-11 Distribution of Electric Conductivity along Khayan Chaung

4-5-4 Reservoirs around Thilawa SEZ

(1) Salient Feature of Three Reservoirs

There are some reservoirs around Thilawa SEZ; the three (3) reservoirs which were constructed as the main surface water resources are enumerated as follows:

Zarmani- Inn Reservoir : It is a reservoir for agricultural purposes, and the reservoir serves for irrigation mainly. In addition, the reservoir water is sold as drinking and domestic water to the nearby industry area and port (refer to Figure 4-5-4-1 left upper).

Ban Bwe Gon Reservoir : It is a reservoir for agricultural purposes. The reservoir water is supplied for irrigation and sold to the Kyauktan Township. A small portion is sold as drinking and domestic water to a nearby port (refer to Figure 4-5-4-1 right upper).

Thilawa Reservoir : This reservoir's water is supplied to nearby factories, is used for irrigation, and is sold to a nearby port (refer to Figure 4-5-4-1 left lower).

Zarmani-Inn Reservoir

Ban Bwe Gon Reservoir

Thilawa Reservoir

Figure 4-5-4-1 View of SEZ Three (3) Reservoirs

The Zarmani-Inn Reservoir is located beside the north-east of SEZ, the Ban Bwe Gon Reservoir is located 3 km east of SEZ, and Thilawa Reservoir lies in SEZ as shown in Figure 4-5-4-2.

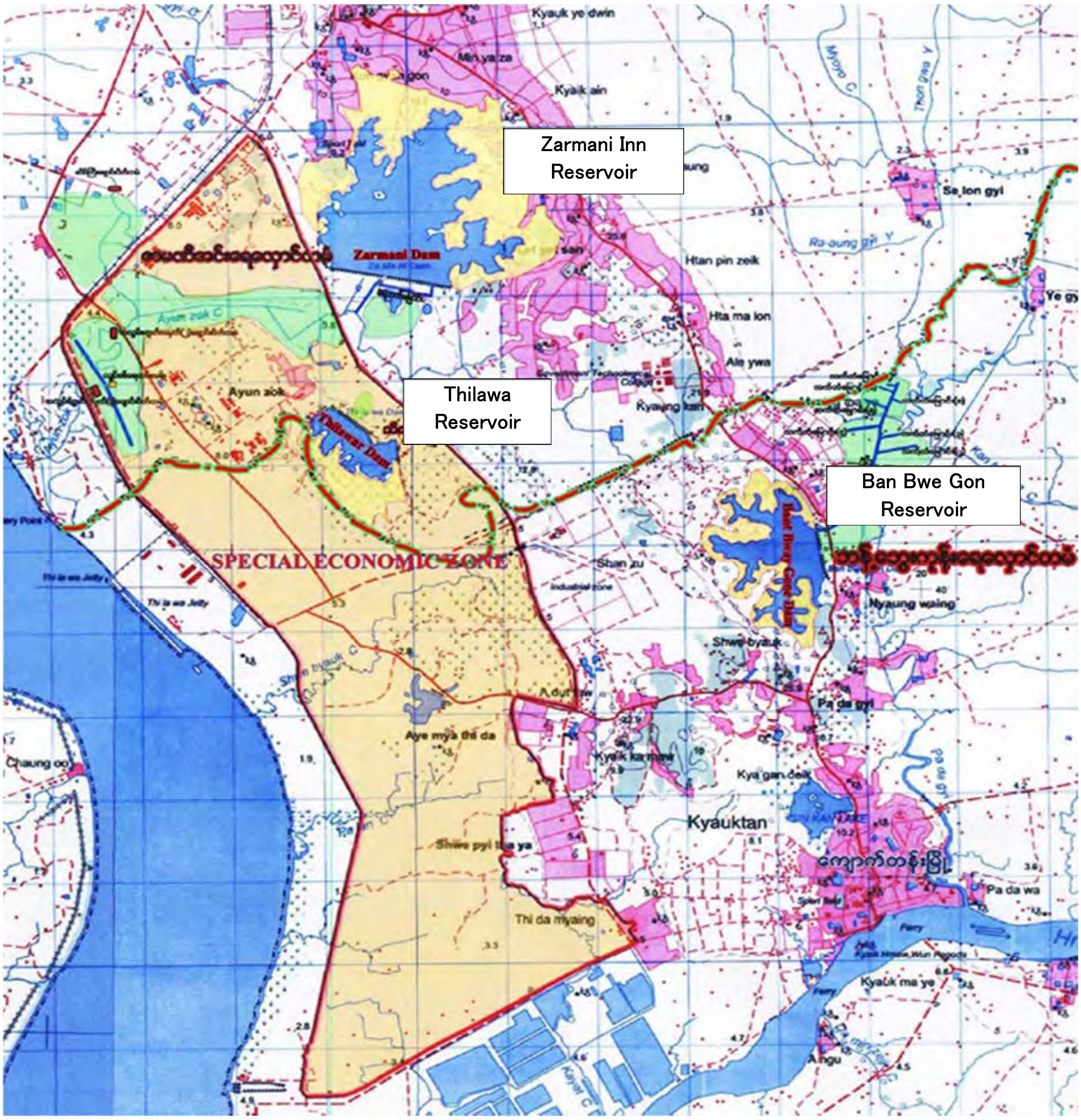


Figure 4-5-4-2 Location Map of SEZ three (3) Reservoirs

These are agricultural water facilities which are all constructed by the Ministry of Agriculture and Irrigation. The Thilawa Reservoir (completed in 1985) which is the oldest of the three reservoirs has already transferred to the Ministry of Industry 1. The Ban Bwe Gon Reservoir (completed in 1994) and the Zarmani-Inn Reservoir (completed in 1995) are managed daily by ID at present. On the other hand, the water rights were transferred from ID to the Yangon Regional Government due to legislative revision (for small and medium-sized irrigation facilities of a less than 5,000-acre irrigation area). Specifications of 3 reservoirs are shown in Table 4-5-4-1.

Table 4-5-4-1 Salient Feature of 3 Reservoirs*1

Specification		Zarmani-Inn	Ban Bwe Gon	Thilawa
Gross Storage Capacity	(1000m^3)	6,616	2,140	1,363
Dead Water Storage Capacity	(1000m^3)	402	185	14
Effective Storage Capacity	(1000m^3)	6,217	1,955	1,349
Full Water Level	(EL m)	7.01	7.92	9.75
Dead Water Level	(EL m)	3.96	4.72	4.88(7.62) *2
Catchment Area	(km^2)	7.25	2.25	0.93
Ability of Water Facility	(m3/sec)	0.765	0.765	-
Water Spread Area	(ha)	281	86	49
Construction Period	(Year Month)	1994-1995(JUN)	1993-1994(JUN)	1984-1985
Project Cost	(10^6 Kyats)	448	199	47

*1 : Information of reservoirs are taken from the document of ID, and added by the result of a site survey.
*2 : In the Thilawa Reservoir, the dead water level is 16 feet, but it is muddy water less than 25 feet deep. Therefore, the lowest water level for taking water is 25 feet.

(2) Situation of Utilization of Reservoir

The situation of utilization (years 2003 – 2011) of the reservoir is summarized in Table 4-5-4-2 by the operational record of the Hydrology Branch of ID and Ministry of Industry 1.

Table 4-5-4-2 Situation of Utilization (years 2003–2011, unit:1000m^3/year)

Purpose	Zarmani-Inn	Ban Bwe Gon	Thilawa*3
Irrigation Water (average) (maximum 1999 - 2011) (minimum 1999 - 2011)	2,455 (5,222) (752)	1,299 (2,620) (1,023)	The amount of Irrigation, Domestic and drinking water (2007 – 2011) 1,371
Domestic, Drinking Water (average : - 2011)*1 (average : 2002 - 2003)*2	9 (23,719)	37 (2,187)	
Average water consumption (①+②) (average : - 2011) *1	2,464	1,336	1,371

*1 : The average except from 2002 to 2003.
*2 : The water from Zarmani-Inn and Ban Bwe Gon was supplied to a nearby construction project in 2002 –

2003; it was different from the normal year.

*3 : In theThilawa reservoir, the operational record before 2006 doesn't remain with the administrator (SHESAKA Factory).

Average water consumption from 1999 to 2011 (except from 2002 to 2003) from each reservoir is 2,464 x 10^3 m^3/year from Zarmani-Inn, 1,336 x 10^3 m^3/year from Ban Bwe Gon and 1,371 x 10^3 m^3/year from the Thilawa Reservoir. It is almost exclusively used as irrigation water (99% from Zarmani-Inn and 97% from Ban Bwe Gon) except from the Thilawa reservoir.

Excluding irrigation usage, the water is supplied to a nearby industy area and the Thilawa Port, but the beneficiaries are limited to a major establishment. The water is sold for 0.09 Kyats/gallon (0.023 USD/m^3≒1.86JPY/m^3). Regarding the sales results of 2011, it is shown in Table 4-5-4-3.

Table 4-5-4-3 Situation of Utilization about Industrial and Domestic Water
(unit : 1000^3m/year)

Zarmani-Inn		Ban Bwe Gon		Thilawa *1	
Establishment	Annual Usage	Establishment	Annual Usage	Establishment	Annual Usage
No.(1) Construction engineering battle lion (Thilawa)	5.309	Demolition of ship factory (Kyuktan)	37.237	6 factories (3,000 pop)	405
Glass Factory(Thanlyin)	3.928			Port	45
Total	9.237	-	37.237	-	450.0

*1 : Because the operational record doesn't remain for the water use of the Thilawa reservoir, the water consumption is assumed from the interview.

(3) Water Level and Reservoir Storage of Reservoir

The change in water level and reservoir storage after constructing the reservoir is shown as follows.

1) Zarmani-Inn Reservoir

The change in the reservoir storage and level after operating the Zarmani-Inn Reservoir is shown as follows: the maximum water level in the 14 years after starting operation was recorded during the rainy season of 2008 when Cyclone Nargis landed in the area. In that year, the water level was exceeded by about 1 meter from the full water level during the 4 months till the end of the rainy season. Because damage to the reservoir itself was also sustained, the reservoir was repaired (bank body protection) during the period when the water level was lowered, from May 2009 to July 2010. This last year was a drought year (2010), and the reservoir emptied completely in March 2010 (Figure 4-5-4-3).

Except for the artificial operating period of the reservoir, the management water level (full water level) was from 23 feet to 26 feet during the normal operation period of fourteen years, and the minimum water level was 14.5 feet. The reservoir storage at this point was 775 acre-feet (955 x 10^3 m^3).

The rehabilitation was made for spillway and embankment from March to April 2014. A new gate was installed on an ex-spillway to raise the full water level up to 26.5 feet（8.08m）. As well, dam embankment was also raised from 27 feet (8.23 m) to29 feet (8.82 m).

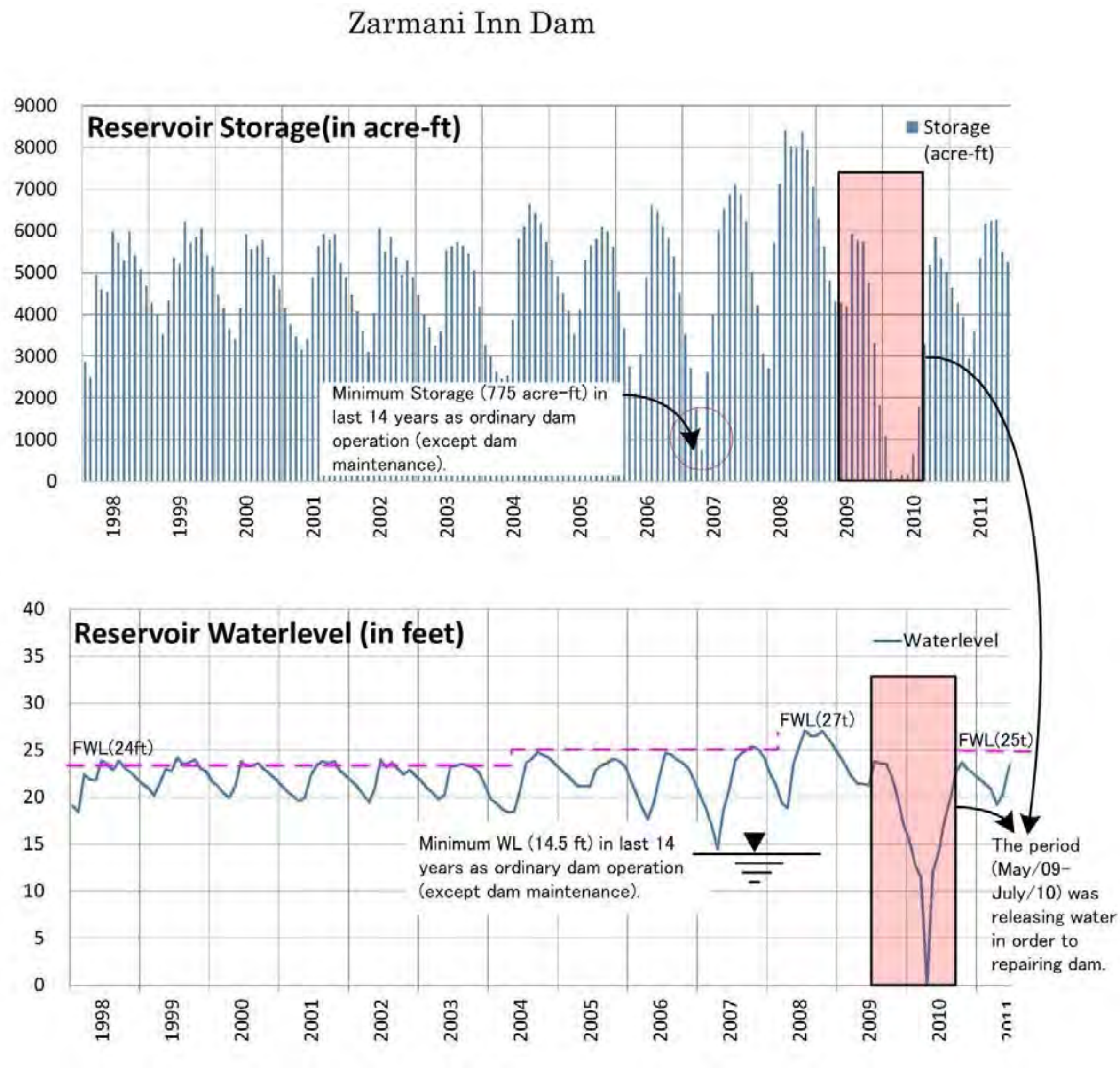


Figure 4-5-4-3 Change of Water Level and Reservoir Storage in Zarmani-Inn Reservoir (1998 – 2011)

2) Thilawa Reservoir

The Thilawa Reservoir has been operated since 1985; the collected operational record at present is for the past five years. According to the record of the past five years, the reservoir has never been at full water level from 2010 to the present in relation to the management water level (full water level, 32 feet). Moreover, in May and June 2012, the water intake trouble (muddy water was mixed in the water) occurred. The minimum water level of the past five and a half years according to the operational record is 25 feet; the reservoir storage is equivalent to 411 acre-feet (507 x 10^3 m^3) (refer to Figure 4-5-4-4).

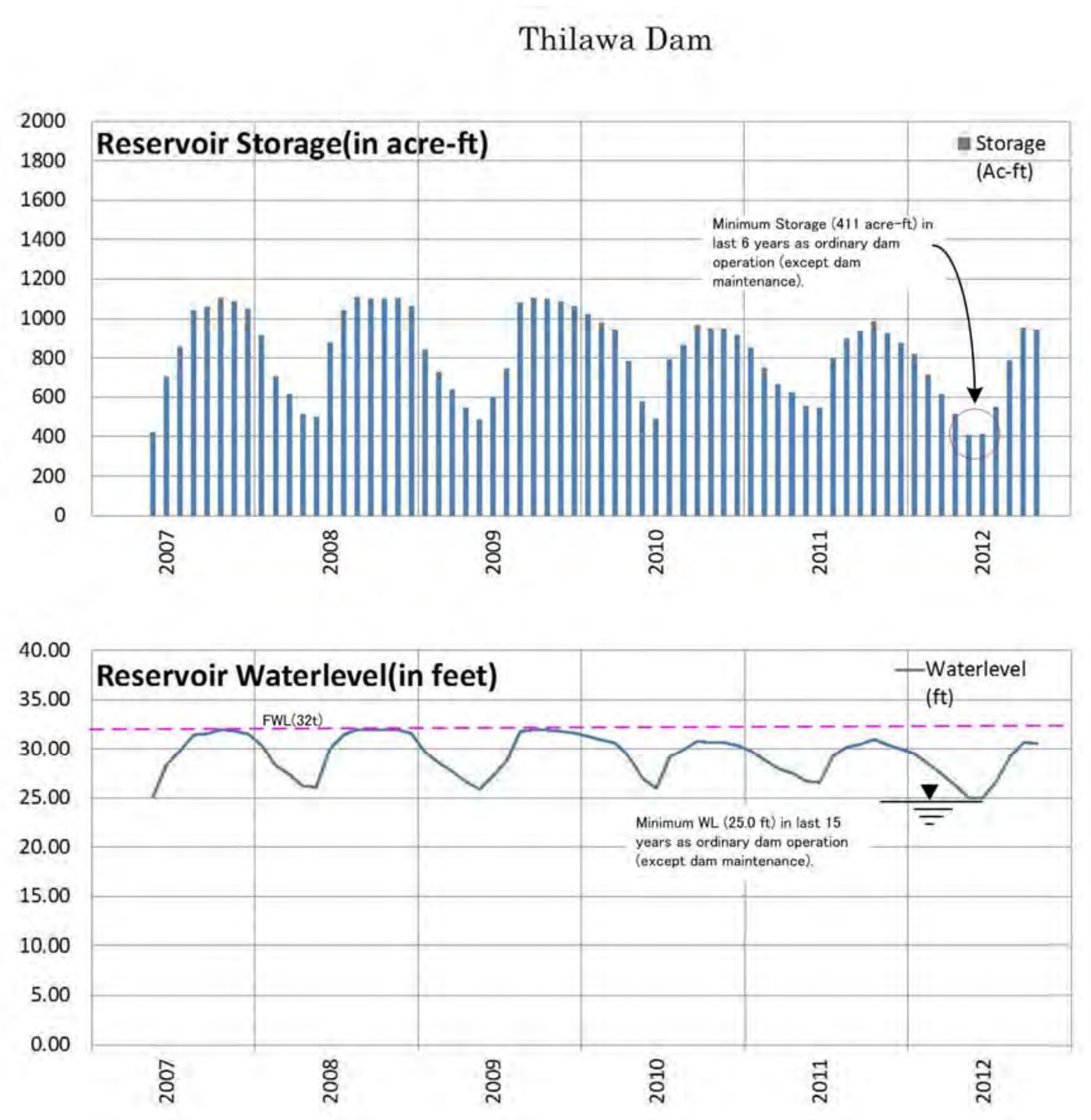


Figure 4-5-4-4 Change of Water Level and Reservoir Storage in Thilawa Reservoir (2007 – 2012)

3) Ban Bwe Gon Reservoir

The Ban Bwe Gon Reservoir has been operated since 1996. The management water level is set from 26 feet to 28 feet in the normal operation except for one year after construction and for emergency operation such as a dam repair in 2011. The minimum water level in the past sixteen years is 17.7 feet, and the reservoir storage is 371 acre-feet ($457*10^3m^3$) (refer to Figure 4-5-4-5).

In April 2014 a new gate was installed on an ex-spillway to raise the full water level from 26 feet (7.92m) to 28 feet (8.53m).

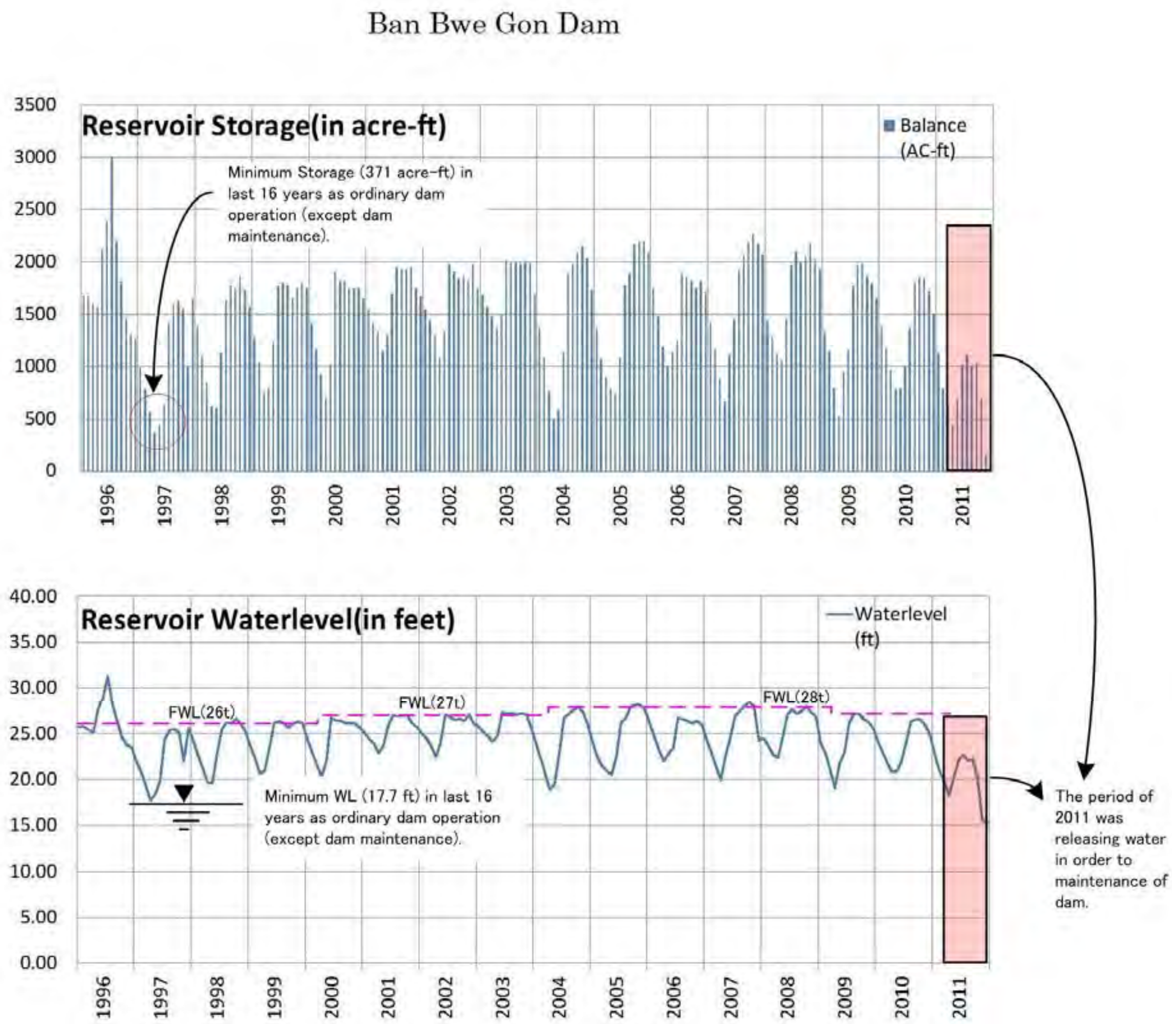


Figure 4-5-4-5 Change of Water Level and Reservoir Storage in Ban Bwe Gon Reservoir (2007 – 2012)

(4) Simulation of Surplus Water Resources from Reservoirs

It was judged that it was difficult to get a surplus of water from the Thilawa Reservoir because the water level didn't reach the full water level during the past three years after 2010 and water intake trouble (muddy water was mixed in the water) occurred at the end of the dry season in 2011.

On the other hand, the Zarmani-Inn and Ban Bwe Gon Reservoirs were judged as being possible to allot the surplus water to new use, because their capacity remained at 553 x 10^3m^3 (955 x 10^3m^3 of reservoir storage – 402 x 10^3m^3 of dead storage capacity) and 272 x 10^3m^3 (457 x 10^3m^3 of reservoir storage – 185 x 10^3m^3 of dead storage capacity) at the end of the dry season during the dry year (probability 1/15 years).

To clear the amount of surplus water from their reservoirs and figure out the limit of the amount, a reservoir operating simulation was carried out. 1) Water balance and inflow on the Zarmani-Inn and Ban Bwe Gon Reservoirs and 2) the result of the simulation are shown below.

1) Water balance and inflow in the reservoir

The current water balance of the Zarmani-Inn and Ban Bwe Gon Reservoirs is as follows.

a) Zarmani-Inn Reservoir

The inflow into the reservoir is estimated by the amount of the contents (①～⑤ and ⑥ in the Table 4-5-4-4) : add the amount of intake water (① and ② in the Table 4-5-4-4), losses (③ evaporation, leaked water, planned discharge etc.), overflow (④ in the Table 4-5-4-4) and the increase and decrease of the reservoir storage in the period (⑥ in the Table 4-5-4-4) : of water balance of the reservoir.

In the Zarmani-Inn Reservoir case, except from 2002 to 2003 which seems to have been the emergency operation of the reservoir, the average inflow of the normal period of fourteen years is 12,721 x 10^3 m^3, 1.9 times of 6,616 x 10^3 m^3 of the gross storage capacity. And runoff percentage is 0.69, because the average rainfall during the same period (from 1996 to 2010) of the Yangon meteorological observatory is 2,547 mm/year, and the rainfall is calculated at 18,465 x 10^3 m^3/year from 7.25 km^2 of the catchment area.

Table 4-5-4-4 Calculation of Water Balance and Inflow in Zarmani-Inn Reservoir
(unit : 1000m³)*1

Year	Intake and Overflow (outflow)					⑥ Increase and decrease in the reservoir storage	⑦ inflow into the reservoir (⑤＋⑥)
	① Irrigation	② Domestic *3	③ Losses (Evaporation , leakage, etc.)	④ Overflow	⑤ Outflow (①+②+③ +④)		
1996	0	0	2,705	8,092	10,797	2,110	12,907
1997	0	0	6,507	9,948	16,455	-4,911	11,544
1998	0	0	5,185	4,495	9,680	1,611	11,291
1999	2,871	0	2,638	9,770	15,279	589	15,868
2000	2,571	0	2,605	6,604	11,780	-671	11,109
2001	5,222	0	2,551	2	7,775	335	8,110
2002*2	(2,898	(44,453)	(2,574)	(406)	(50,331)	(0)	(50,331)
2003*2	(4,969	(2,984)	(3,154)	(0)	(11,107)	(-875)	(10,232)
2004	1,955	0	2,886	718	5,559	4,925	10,484
2005	1,943	0	2,657	1,192	5,792	-139	5,653
2006	4,946	0	2,592	11,825	19,363	-1,375	17,988
2007	4,238	0	2,449	13,654	20,341	2,124	22,465
2008	4,395	0	4,634	1,115	10,144	1,021	11,165
2009	2,213	0	17,325	4,437	23,975	-6,463	17,512
2010	752	0	3,349	1,209	5,310	3,946	9,256
2011	3,266	0	2,460	7,879	13,605	-866	12,739
平均	2,455	0	4,325	5,781	12,561	160	12,721

*1 : It is culled from the document of ID
*2 : The water from Zarmani-Inn and Ban Bwe Gon was supplied to a nearby construction project in 2002 – 2003; it was different from the normal year. Therefore, the value of ( ) was excluded from the calculation of the average value to judge that inflow into the reservoir during the year had unreliable values.
*3 : Drinking and domestic water after the period from 2004 to 2011 was allocated to "③ Losses" because the value was slight.

b) Ban Bwe Gon Reservoir

In the Ban Bwe Gon Reservoir case, the average inflow of the normal period of fourteen years is 5,365 x 10^3 m^3, 2.5 times the 2,140 x 10^3 m^3 of the gross storage capacity (refer to Table 4-5-4-5). Runoff percentage is 0.94, because the average rainfall during the same period (from 1996 to 2010) of the Yangon meteorological observatory is 2,547 mm/year, and the rainfall is calculated at 5,730 x 10^3 m^3/year from 2.25 km^2 of the catchment area.

Table 4-5-4-5 Calculation of Water Balance and Inflow in Ban Bwe Gon Reservoir
(unit : 1000m³)*1

Year	Intake and Overflow (outflow)					⑥ Increase and decrease in the reservoir storage	⑦ inflow into the reservoir (⑤＋⑥)
	① Irrigation	② Domestic *3	③ Losses (Evaporation, leakage, etc.)	④ Overflow	⑤ Outflow (①+②+③+④)		
1996	0	0	762	3,647	4,409	-578	3,831
1997	989	0	720	3,088	4,797	474	5,271
1998	563	0	1,693	904	3,160	-100	3,060
1999	1,290	1,379	855	0	3,524	229	3,753
2000	1,304	0	819	3,402	5,525	-126	5,399
2001	1,023	0	766	6,785	8,574	25	8,599
2002*2	(853)	(4,237)	(793)	(5,808)	(11,691)	(101)	(11,792)
2003*2	(378)	(137)	(964)	(12,618)	(14,097)	(-56)	(14,041)
2004	2,620	0	4,784	628	8,032	35	8,067
2005	1,032	0	740	6,124	7,896	450	8,346
2006	1,363	0	840	2,711	4,914	-460	4,454
2007*2	(1,048)	(0)	(814)	(13,591)	(15,453)	(431)	(15,884)
2008	1,485	0	1,021	2,061	4,567	-174	4,393
2009	1,562	0	751	7,598	9,911	-335	9,576
2010	1,106	0	900	1,505	3,511	-191	3,320
2011	2,553	0	580	221	3,354	-1,676	1,678
Average	1,299	106	1,172	2,975	5,552	-187	5,365

*1 : It is culled from the document of ID
*2 : The water from Zarmani-Inn and Ban Bwe Gon was supplied to a nearby construction project in 2002 – 2003; it was different from the normal year because it carried out the disabled discharge in order to maintain the reservoir in 2007. Therefore, the value of ( ) was excluded from the calculation of the average value to judge that inflow into the reservoir in the year had unreliable values.

2) Result of Operating Simulation

The operating simulation of the reservoirs was carried out using the monthly balance of reservoirs since dams supplied the water to users. As a resource, the inflow into the reservoir during the same period for irrigation, drinking and domestic water of existing water rights was deducted at first, and by increasing the amount of newly used water on this value sequentially, it was traced how the water level of the reservoir decreased.

Here, the value at the point when the water level of the reservoir exceeds the dead water level due to adding new usable water is defined as “Newly available water”. In other words, in the simulation of the past years, newly available water indicates the amount of water that can be taken continuously according to the calculation from the reservoir.

The result of simulation of Zarmani-Inn and Ban Bwe Gon Reservoirs are summarized as follows.

a) Zarmani-Inn Reservoir

The calculation of the Zarmani-Inn Reservoir is set with three (3) conditions as shown in Table 4-5-4-6. According to the condition, the available water amount of industrial use is calculated.

Table 4-5-4-6 Condition of Zarmani-Inn Reservoir Operation

Case	Control Water level(FTL)	Irrigation Supply	Domestic Supply	Local Factory	Water Supply to Navy	Remarks
Case 1	EL 23t -26 ft	Average 3,017TCM with Max.5,222 TCM	Average 3,388 TCM with Max. 44,453 TCM	Average 2.9 TCM with Max. of 4.1 TCM	Average 3.9 TCM with Max. of 5.4TCM	Water utilization given Case 1 is modified from the existing records of water utilization 1998 -2011[*1].
Case 2	EL 26.5 ft	-do -	-do -	-do -	-do -	FWL is changed after dam rehabilitation made in Feb.-Apr. 2014.
Case 3	EL 26.5 ft	78.9 TCM (constant)	-do -	-do -	-do -	Water utilization follows a feature plan which irrigation area decreases by 26 from 240 acre.

*1: The existing data are used for 1999-2011 but the average is applied for 1998.

i) Case 1

Case 1 is calculated based on previous condition of water use included 240 acre (97ha) of irrigation. The condition of water amount of industrial use is set from 1,000 m^3/day to 3,000m^3/day. According to the trial calculation, 2,400 m^3/day of surplus water is obtained at the lowest water level (April 2004) just above the dead water level, as shown in Figure 4-5-4-6.

ii) Case 2

Case 2 uses with the condition after dam rehabilitation, which increased dam height and constructed the 2 feet fallen shutter made in March 2014. Consequently, full tank level (FTL) rose up to 26.5 feet from the previous level of 23 feet[11]. As the result of calculation, 5,030 m^3/day is obtained as a surplus water as shown in Figure 4-5-4-7. Out of 5,030 m^3/day, 2,630 m^3/day is regarded as a newly developed water by the rehabilitation (refer to Figure 4-5-4-7).

[11] Design crest level of spill way is 20'. But it was raised up to 25'with sand bag since 2004. With newly rehabilitation FTL is again set higher than 26.5'.

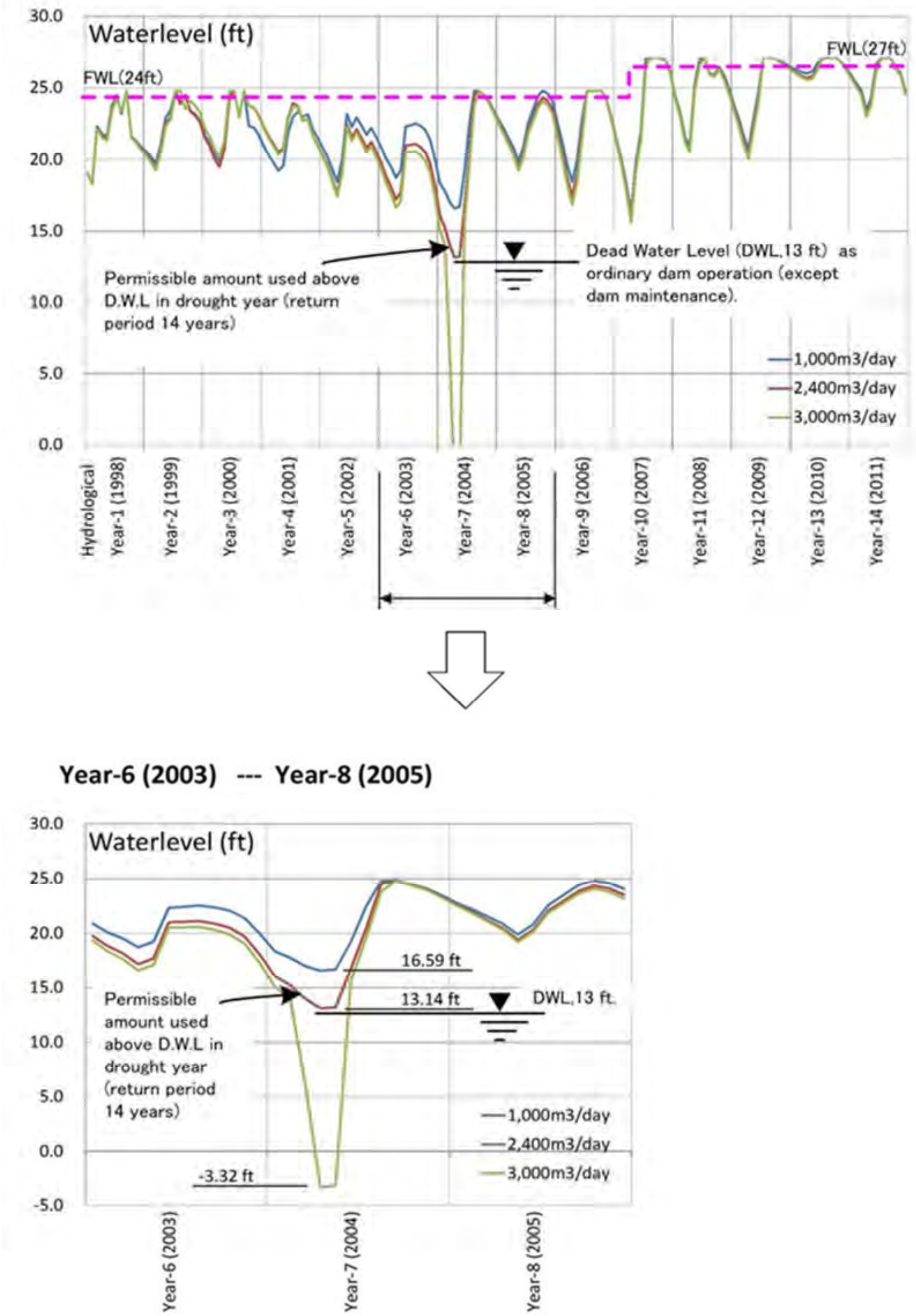


Figure 4-5-4-6 Result of Operating Simulation in Zarmani-Inn Reservoir (Case1)

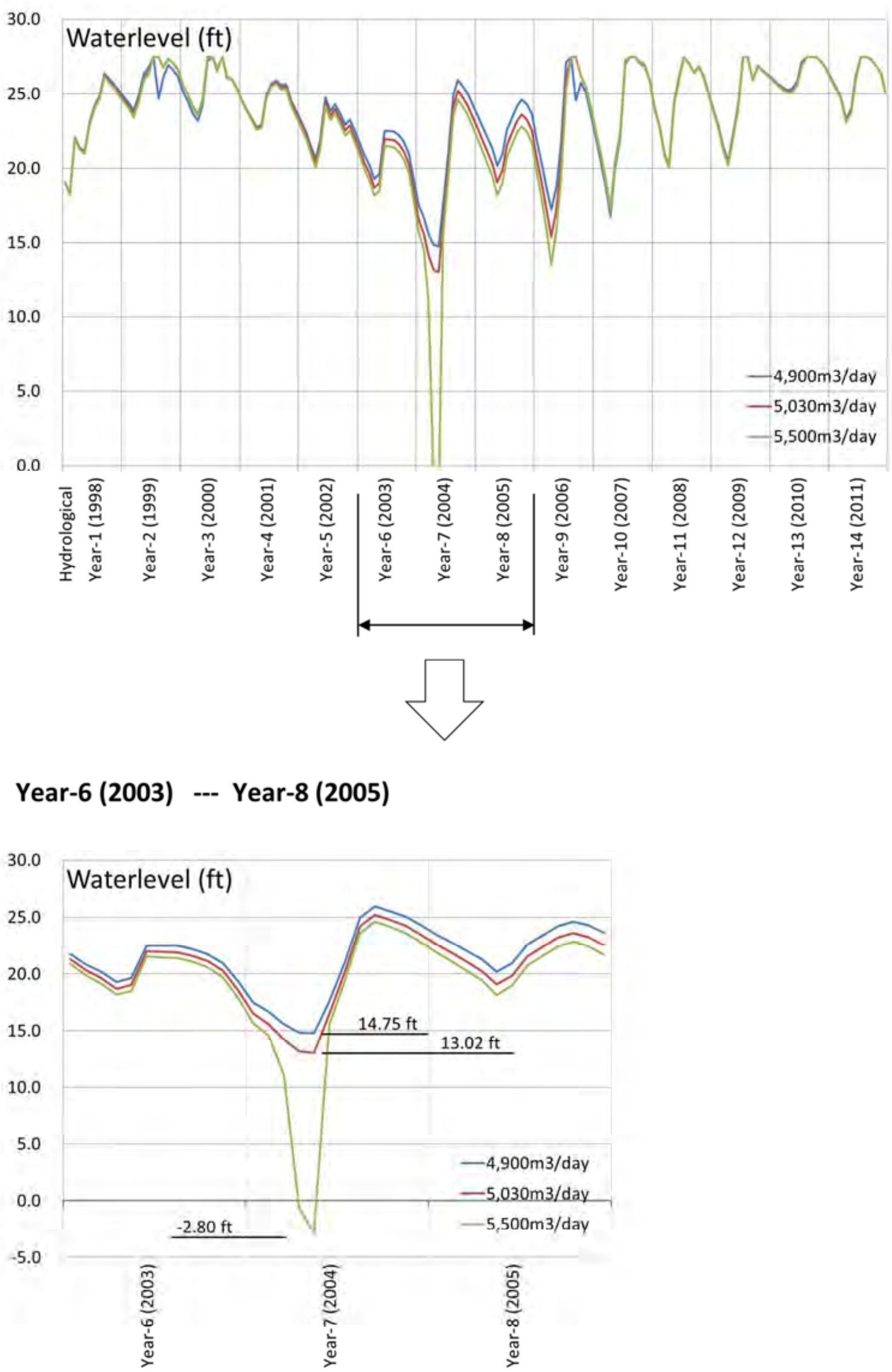
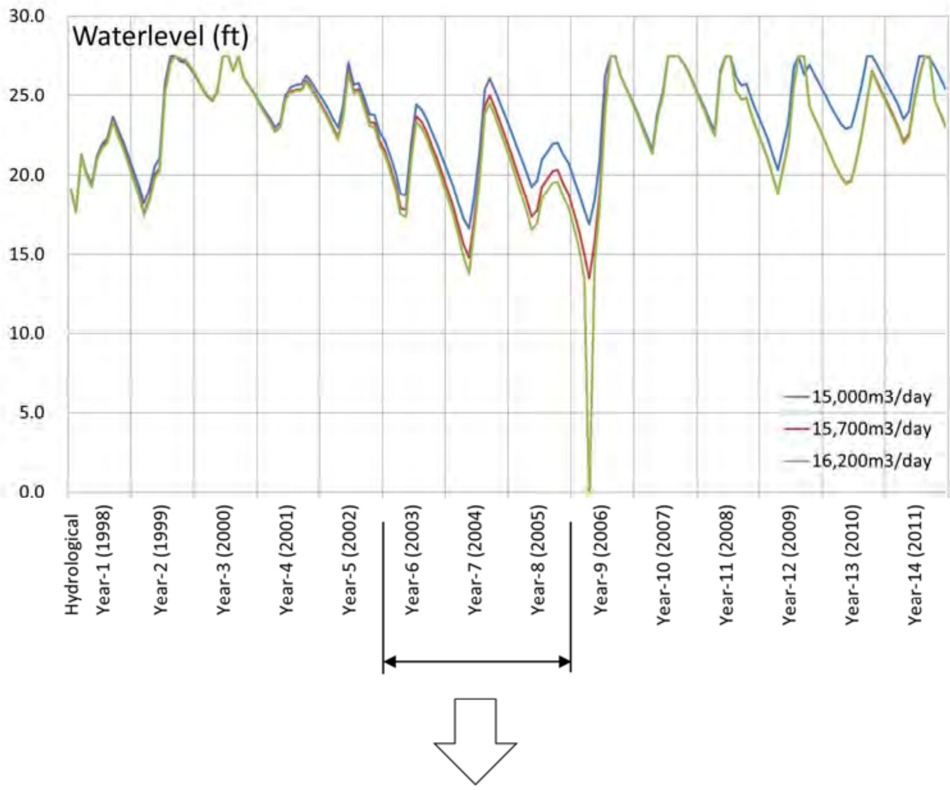


Figure 4-5-4-7 Result of Operating Simulation in Zarmani-Inn Reservoir (Case2)



Year-7 (2004) --- Year-9 (2006)

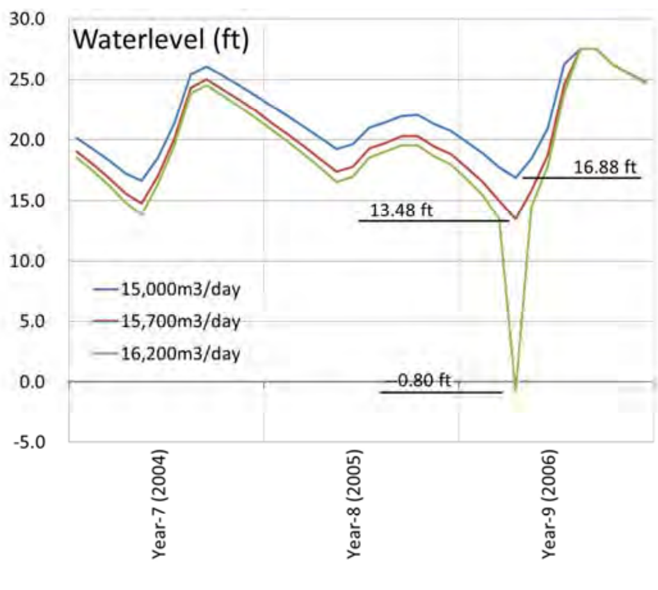


Figure 4-5-4-8 Result of Operating Simulation in Zarmani-Inn Reservoir (Case3)

iii) Case 3

Case 3 was made with a future plan of water allocation and based on rehablitated dam structure (26.5 feet of FWL). According to new plan of water allocation, 240 acre (97ha) of summer paddy irrigation is quited and insteadely supply water to an upland farm irrigation of 26 Acre(10.5ha) outside SEZ. As the result of calculation as shown in Figure 4-5-4-8, the available water for industrial use is account to 15,700 m^3/day.

Using Case 3 result and dam reservoir balance, water resources and its allocation are summarized as Table 4-5-4-7.

Table 4-5-4-7 Water Resource and Allocation of Zarmani-Inn Reservoir

Water Resources	Water recourses/utilizable/allocable water		
	MCM/a	MGD	Remarks
①Total Surface Water Resource	12.7	7.7	Total inflow to reservoir
②Loss	4.3	2.6	Evapotranspiration and seepage, 1.5m/sq.km(reservoir area)
③Utilizable Water	8.4	5.1	③=①-④
④Uncontrolled Flooding	2.5	1.5	Spilled water from dam spill way
⑤Allocable Water Resource	5.9	3.5	⑤=③-⑥
⑥Environmental Flow	0.0	0.0	Equivalent to 9mm/sq.km(catchment area)
⑦Irrigation Use	0.1	0.0	Irrigation Area 11 ha(26acre)
⑧Industry Use	5.8	3.5	Thilawa SEZ
⑨Electricity Generation	0.0	0.0	None
⑩Domestic Supply	0.0	0.0	None

b) Ban Bwe Gon Reservoir

The calculation of the Ban Bwe Gon Reservoir is made with two (2) cases as shown in Table 4-5-4-8. Using the conditions, the available water amount is calculated.

Table 4-5-4-8 Condition of Ban Bwe Gon Reservoir Operation

Case	Control Water level(FTL)	Irrigation Supply	Domestic supply	Local Factory	Water Supply to Navy	Remarks
Case 1	EL 26 ft	Average 1,278 TCM with Max.2,620 TCM	Average 387 TCM with Max. 4,237 TCM	-	-	Water utilization given Case 1 is same as the existing records of water utilization 1997 -2011.
Case 2	EL 28 ft	-do -	-do -	-do -	-do -	FWL is changed after dam rehabilitation made in Feb.-Apr. 2014.

i) Case 1

The calculation condition of the Ban Bwe Gon Reservoir was set at a condition from 500 m^3/day to 2,000 m^3/day. In the calculating period, the month which the water level fell below the dead water level was April 2000, and the amount of surplus water at this point is 1,400m^3/day. In the result of the simulation, the newly available water in the Ban Bwe Gon Reservoir is 1,400 m^3/day (refer to Figure 4-5-4-9).

ii) Case 2

Case 2 is applied by the rehabilitated condition with the new gate risen up to 28 feet. As the result of the simulation, the newly available water in the Ban Bwe Gon Reservoir is 2,000 m^3/day (refer to Figure 4-5-4-10).

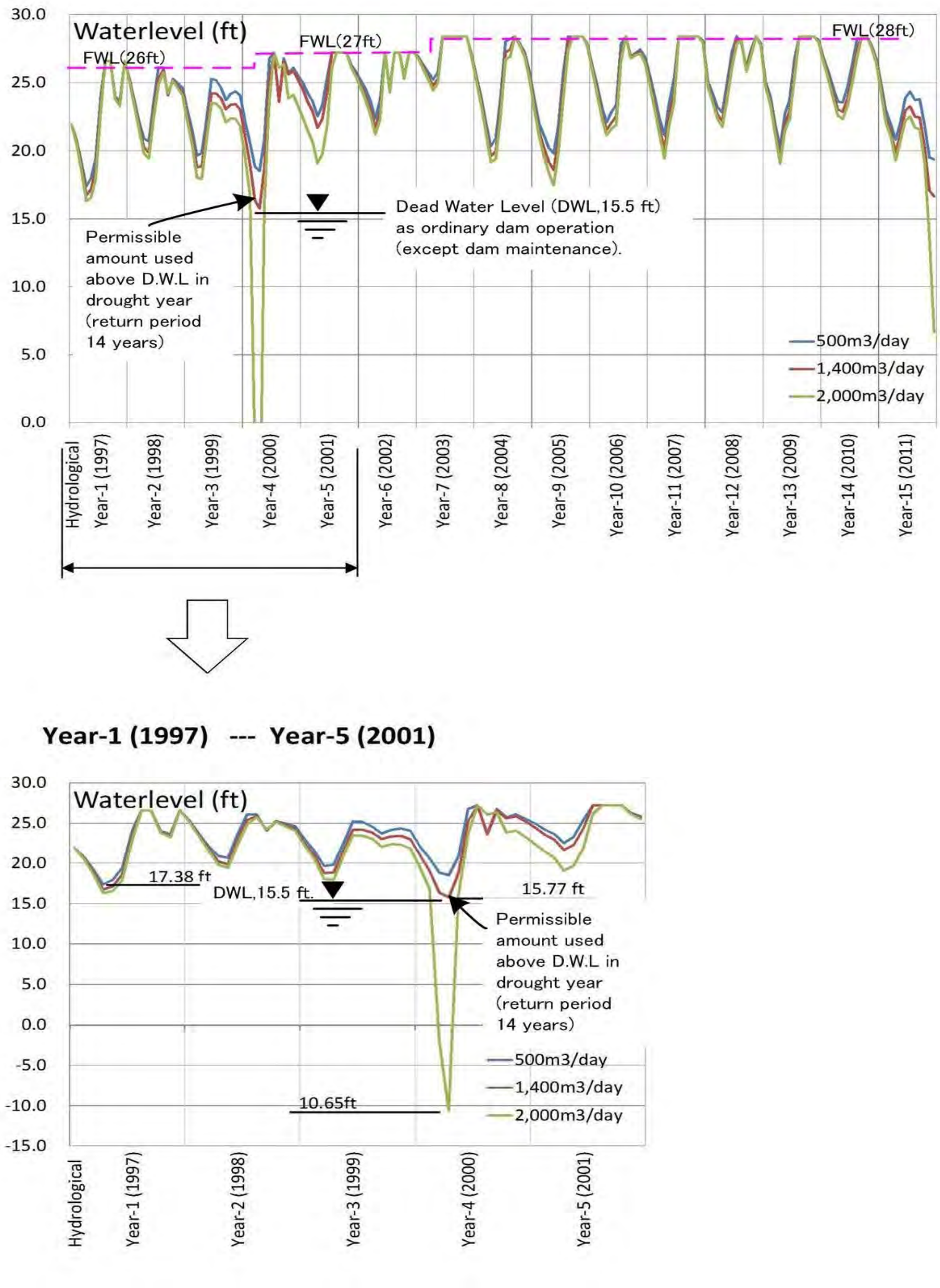


Figure 4-5-4-9 Result of Operating Simulation in Ban Bwe Gon Reservoir (Case1)

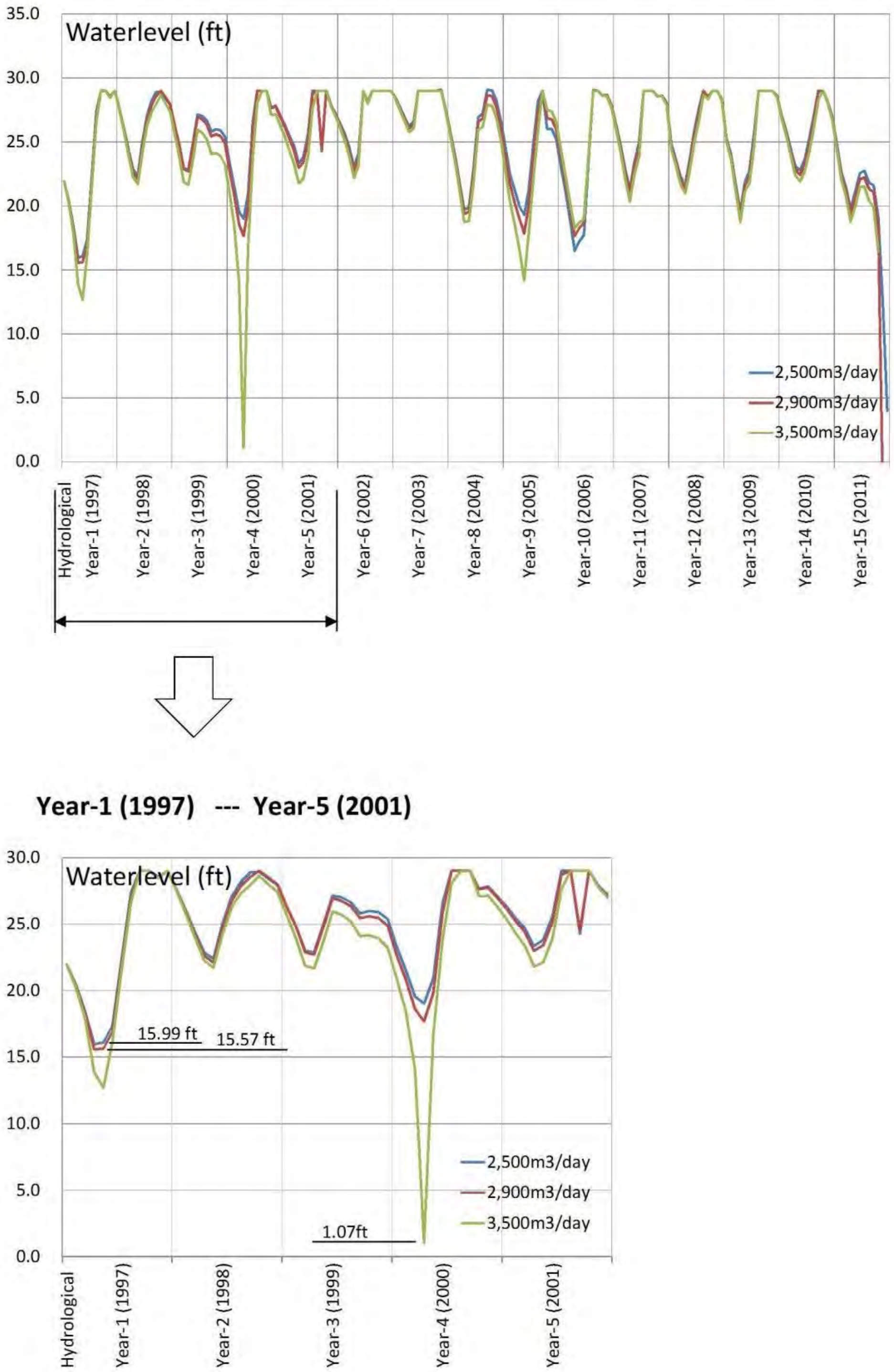


Figure 5-4-10 Result of Operating Simulation in Ban Bwe Gon Reservoir (Case2)

(5) Water Resource of 3 Reservoirs

The amount of water resources and consumption of 3 reservoirs are summarized in Table 4-5-4-9.

Table 4-5-4-9 Water Resources of 3 Reservoirs
(unit: 1000m^3/year, figure in parentheses is m^3 / day)

Contents	Zarmani-Inn	Ban Bwe Gon	Thilawa	Total
① Vested water right (for Irrigation)	2,455 (6,730)	1,299 (3,560)	921 (2,520)	4,675 (12,810)
② Vested water right (Industry, Drinking and Domestic)	9 (20)	37 (100)	450 (1,230)	496 (1,360)
③ Total of vested water right (①+②)	2,464 (6,750)	1,336 (3,660)	1,371 (3,750)	5,171 (14,170)
④ Surplus water resources in current use	876 (2,400)	511 (1,400)	0 (0)	1,387 (3,800)
⑤ Newly developed water resources	960 (2,630)	548 (1,500)	0 (0)	1,508 (4,130)
⑥ Available water resources without re-allocation from vested water (④+⑤)	1,834 (5,030)	2,395 (2,900)	1,371 (0)	8,066 (7,930)

Note: As for the vested water right, it refers the operation records of Irrigation Department. Surplus water source amount, Newly developed water resources amount was estimated by reservoir simulation made by Study Team on the basis of the Irrigation Department survey data. the Details of each items (①~⑥) are as follows.

① Vested water right (irrigation water): Quantity of irrigation water used in/around SEZ, supplied from Zarmani-Inn reservoir based on the reservoir operation record of 1996- 2010.

② Vested water right (industrial and domestic water): Quantity of industrial and domestic water used outside SEZ, supplied from Zarmani-Inn reservoir based on t the reservoir operation record of 1996- 2010.

③ Total of vested water right: Total amount of ①Vested water right (irrigation) and ②Vested water right (industrial and domestic water).

④ Surplus water source amount: The amount of water left in the Zarmani-Inn reservoir in the current utilization of 1996 -2010.

⑤ Newly developed water resources: The amount of water newly developed by the rehabilitation of reservoir.

⑥ Available water resources without re-allocation form vested water: Total amount of ④Surplus water source amount: and ⑤Available water resources without re-allocation from vested water.

The estimation was made based on existing operation record and with a consideration of current dam rehabilitation which is increasing dam reservoir volume. As the result of the simulation, 5,030 m^3/day from the Zarmani-Inn and 2,900 m^3/day from the Ban Bwe Gon Reservoir were obtained and their total is 7,930 m^3/day of available water. However, water supply from Ban Bwe Gon Reservoir to SEZ is thought to be difficult because there is strong demand of vested water right for existing irrigation land.

According to the information in the site, irrigation water will be reduced by 78,900m^3/year as an upland farming used only in dry season from October to April. If this water will be changed to an industrial use, the 15,700 m^3/day of water can supply to SEZ.

4-5-5 La Gun Byin and Aligni Reservoir

(1) General Condition of Reservoir

The La Gun Byin Reservoir was constructed by ID in 2000, and it is located 70 km north of Thilawa SEZ. The reservoir is for irrigation, with 18.9 m of dam height and 1578.8 m of crest length, and with 183.5 MCM of gross storage capacity (177.0 MCM of effective storage capacity). It is expected to be used for 8,903 ha of irrigation by the plan (2002), but the current irrigated area is 3,561 ha. It is estimated by ID that there is a considerable amount of surplus water in the reservoir, because water consumption is smaller than the effective storage capacity and the inflow.

The outline location of the La Gun Byin Reservoir, the main irrigation canal and the irrigated area is shown in Figure 4-5-5-1.

(2) Salient Feature of Reservoir

The Salient feature specifications of the La Gun Byin Reservoir are shown in Table 4-5-5-1.

To the east of the reservoir, the Aline Nee Reservoir adjoins it, and both reservoirs are connected by an opened link canal (refer to Figure 4-5-5-1), and the stored water is moved in both directions in accordance with respective water level. In the Aline Nee Reservoir, there is no spillway, and all flood water is released from the La Gun Byin Reservoir..

Table 4-5-5-1 Salient Feature of La Gun Byin Reservoir

No.	Subject	La Gun Byin
1.	Location	Border of Yangon Division and Bago Division, Near Tha me ka lay Village
2.	Map Reference	94 C/7 L 718932
3.	Name of Chaung	La Gun Byin chaung
4.	Catchment area	42 Square-mile (108.78 km^2)
5.	Average annual rain fall (Inch)	100 inch (2,500 mm)
6.	Average Annual Inflow (Ac-ft)	126,000 Ac-ft (155.418 MCM)
7.	Type of Dam	Earth Dam
8.	Height of Dam	62 ft (18.89m)
9.	Length of Dam	5,180 ft (1578.8m)
10.	Storage Capacity of Full Tank (Ac-ft)	148,800 Ac-ft (183.512 MCM)
11.	Dead Storage Capacity (Ac-ft)	5,250 Ac-ft (6.476 MCM)
12.	Water Spread Area of F.T.L (Acre)	6,700 Acre (27km^2)
13.	Type of Conduit	Reinforce Cement Concrete

14.	Size of Conduit	4 ft x 6 ft (2) hole (1,219 x 1,829 mm)
15.	Length of Conduit (Ft)	244 ft (74.37m)
16.	Conduit Design Discharge(Cuft/sec)	500 Cuft/sec
17.	Type of Spillway	Reinforce Cement Concrete(Broad Crest)
18.	Width of Spillway (Ft)	50 ft (15.24 m)
19.	Spillway Design Discharge (Cuft/sec)	900 Cuft/sec (25m^3/sec)
20.	Irrigable Area (Acre)	8,800Acre (3,560 ha) – Plan in 2002 4,000 Acre (1,618 ha) – in 2012

Source: Irrigation department

(3) Water Intake Facilities and Irrigation Canal of the reservoir

Irrigation water from the reservoir flows into a main irrigation canal (earth canal with partial lining) by a division works which was installed about 2.9 km downstream, into the La Gun Byin River from the intake facility (capability; 14.2 m^3/sec) of the reservoir. From the main canal, the irrigation water is divided into the beneficiaries' area through a two-branch canal. The end of the main canal is linked to the main irrigation canal from the Nga Moe Yeik Reservoir, and it is always closed now.

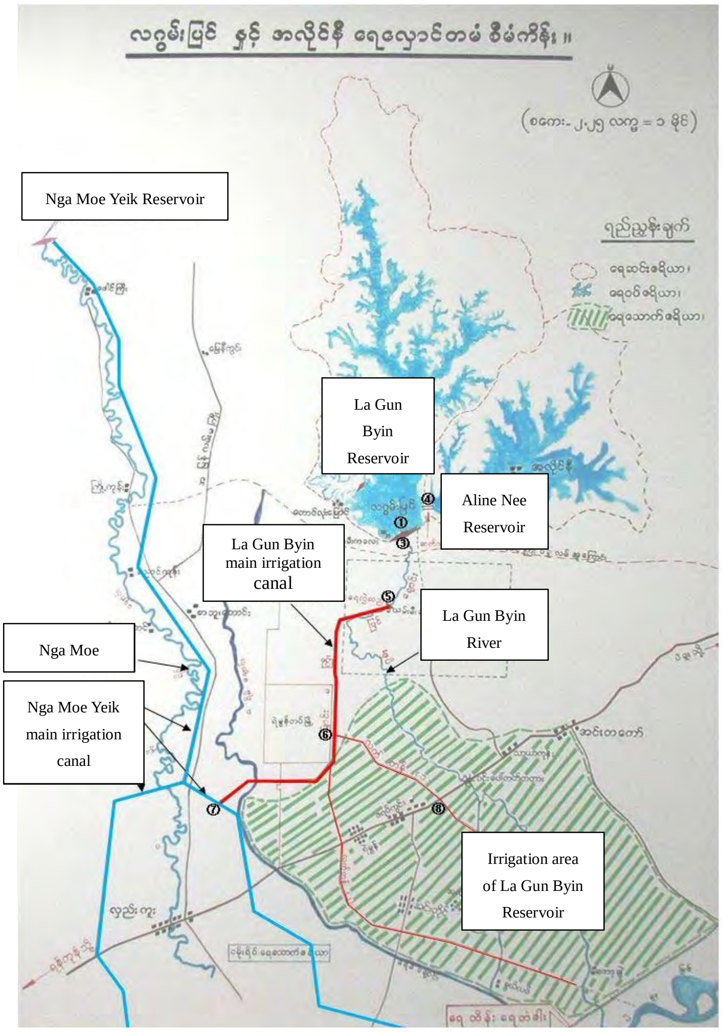


Figure 4-5-5-1 The outline location of the La Gun Byin Reservoir, main irrigation canal and irrigated area

(4) Reservoir Balance

The water balance consisting of inflow, domestic supply, irrigation water, evaporation loss and released water is estimated by ID based on dam operation records since 2006 as shown in Table 4-5-5-2 and Figure 4-5-5-2. Total inflow is 285 MCM. Among 285 MCM of inflow, 103 MCM is lost by evapotranspiration and 71 MCM is uncontrolled floodwater as it is spilled over the dam. The Remaining 111 MCM is utilizable water. As for environmental flow, it cannot be decided with reasonable considerations due to lack of environmental information on water quality, sediment, saline intrusion, habitat of aquatic spices, groundwater recharge, riverine and riparian, and culture of this tributary and so on. However, it does not require much quantity in view of a natural river condition and the minimum flow level. The river flow is often dried-up even for two (2) to three (3) months in the dry season as shown in Table 4-5-5-3. In consideration of this river resume and discharge records, the value of monthly mean minimum discharge for 10 years may be sufficient for an environmental flow. In the dam operation records for 7 years, 14 MCM/year is recorded as a monthly mean minimum discharge. However, a spill over occurs in four (4) months of a year and this can replaced an environmental flow. An environmental flow in turn is required for eight (8) months in a year. Taking a total amount of as much as 8 MCM/year as necessary environmental flow into account, 103 MCM (111 MCM: Utilizable water – 8MCM : Environmental flow) is obtained as Allocable water for irrigation, industry and water supply and other demands.

Table 4-5-5-2 Annual Water balance of La Gun Byin Dam (2006-2012)

Year	①Inflow	OUT(MCM)						Storage Carry-over
		② Domestic Supply	② Irrigation Water	③ Evaporation Loss	④ Spilled Water	⑤ Released Water	⑥Total (②+③+④+⑤)	
2006	320	112	0	75	136	0	323	-3
2007	330	151	0	123	69	0	343	-13
2008	230	127	0	90	8	0	225	4
2009	249	0	0	130	40	85	254	-5
2010	227	0	78	76	16	43	213	14
2011	357	0	93	135	150	0	377	-20
2012	284	0	52	95	77	44	268	16
Avg.	285	56	32	103	71	25	286	-8

Source: Irrigation department

Table 4-5-5-3 Monthly Water balance of La Gun Byin Dam (2011-2012)

Year	① Inflow	OUT(MCM)						Storage Carry-over
		② Domestic Supply	② Irrigation Water	③ Evaporation Loss	④ Spilled Water	⑤ Released Water	⑥Total (②+③+④+⑤)	
2010								
Oct	29.0	0.0	0.0	8.3	8.5	3.7	20.5	8.52
Nov	18.9	0.0	0.0	12.0	5.2	3.9	21.1	-2.21
Dec	12.2	7.4	0.0	3.4	2.4	5.0	18.2	-5.93
2011								
Jan.	2.8	0.0	13.9	10.7	0.0	0.0	24.6	-21.7
Feb	0.0	0.0	14.1	14.9	0.0	0.0	29.0	-29.0
Mar	1.3	0.0	14.7	22.2	0.0	0.0	36.9	-35.7

Apr	0.0	0.0	18.1	37.2	0.0	0.0	55.3	-55.3
May	0.8	0.0	12.4	10.5	0.0	0.0	22.9	-22.1
Jun	71.0	0.0	4.3	3.2	0.0	0.0	7.5	63.5
Jul	86.8	0.0	0.0	2.5	0.0	0.0	2.5	84.2
Aug	76.2	0.0	0.0	3.4	39.0	0.0	42.4	33.7
Sep	84.9	0.0	0.0	7.6	69.1	0.0	76.7	8.2
Oct	29.6	0.0	0.0	7.4	39.3	0.0	46.7	-17.1
Nov	3.4	0.0	6.9	6.7	2.1	0.0	15.8	-12.3
Dec	0.0	0.0	8.0	8.8	0.0	0.0	16.8	-16.8
Total	357	0	93	135	150	0	377	-20

In the ID irrigation plan (La Gun Byin Irrigation Project), 5,200ha of irrigation area was planned and 93MCM of irrigation water is required for maintaining the service area. The water thus allocable to other users remains at 39 MCM (103MCM - 64MCM = 39MCM). However, the actual use of water (as of 2010) for irrigation, accounting for 36 MCM (2,000 ha) and 28 MCM is abundant without use. Totaling 39 MCM of allocable water and 28 MCM of abundant water, 67 MCM (40MGD) can be used for other purpose. By the adjustment consultation made between relevant organizations, the allocation plan, which supplies 17 MCM (10 MGD) to SEZ and 50 MCM (30 MGD) to YCDC, had been confirmed. Water allocation of the La Gun Byin dam reservoir is shown in Table 4-5-5-4.

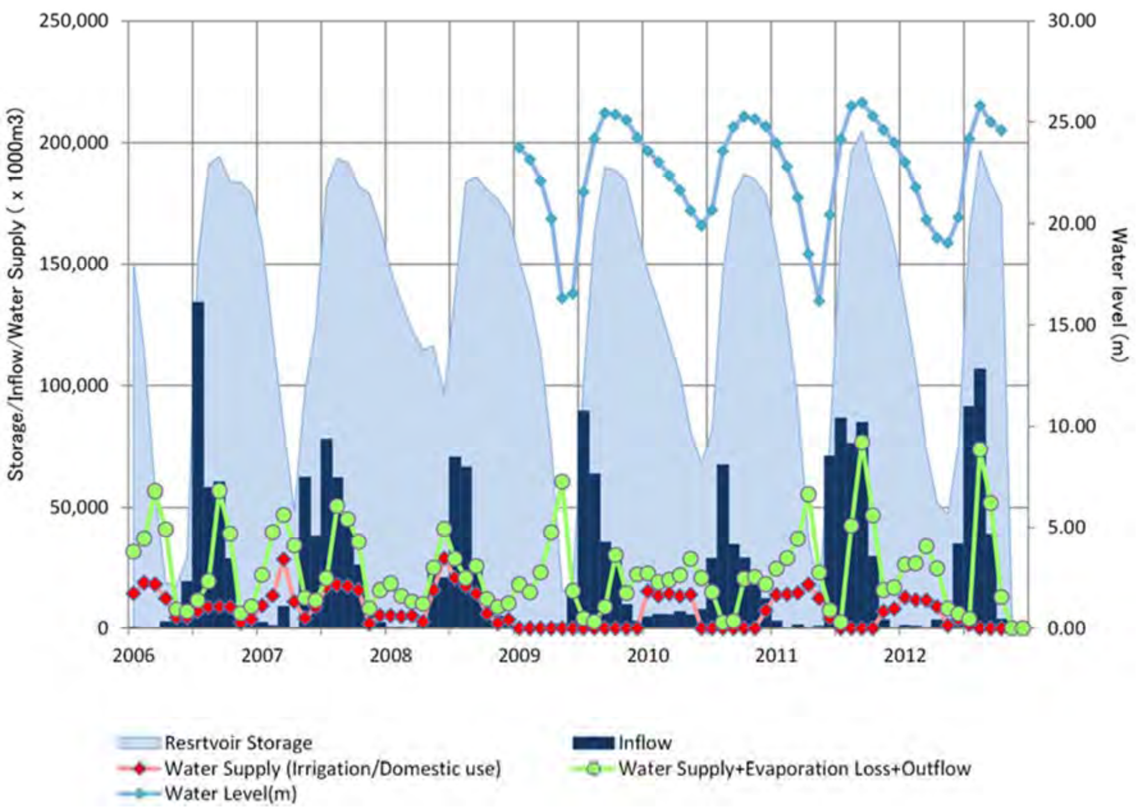


Figure 4-5-5-2 Water Level and Inflow of La Gun Byin Dam (2006-2012)

Table 4-5-5-4 Water Allocation of La Gun Byin Dam Reservoir

Water Resources	Water recourses/utilizable/allocable water		
	MCM/a	MGD	Remarks
①Total Surface Water Resource	285	172	Total inflow to reservoir
②Loss	103	62	Evapotranspiration and seepage, 3.8m/sq.km(reservoir area)
③Utilizable Water	111	67	③=①-④
④Uncontrolled Flooding	71	43	Spilled water from dam spill way
⑤Allocable Water Resource	103	62	⑤=③-⑥
⑥Environmental Flow	8	5	Equivalent to 9mm/sq.km(catchment area)
⑦Irrigation Use	36	22	Irrigation Area 2000ha, Water allocation is 38% for original Plan(5200ha)
⑧Industry Use	17	10	Thilawa SEZ
⑨Electricity Generation	0	0	None
⑩Domestic Supply	50	30	Yangon Water Supply

(5) Water Quality

The water sample was taken from the outlet of the La Gun Byin reservoir at the beginning and end of the dry season. Items of water quality test were 24, selected from the drinking water standard in Japan. As shown in Table 4-5-5-5, water quality is indicated as adoptable as raw water although Odor, Color, Turbidity, Manganese and Iron are deflected from the Japanese drinking water standards.

Table 4-5-5-5 Water Quality Test of La Gun Byin Dam Reservoir

No	Items	Unit	Standard Value	Sampling Date	
				Wet season 2013/12/2	Dry season 2014/4/11
1	Odor	—	Not abnormal	dusty	dusty
2	pH Value	—	5.8-8.6	6.2(20℃)	6.5(20℃)
3	Cadmium	mg/L	0.01	< 0.0003	< 0.0003
4	Cyanide ion and Cyanogens Chloride	mg/L	0.01	< 0.001	< 0.001
5	Lead	mg/L	0.01	< 0.001	< 0.001
6	Chromium(VI)	mg/L	0.05	< 0.005	< 0.005
7	Arsenic	mg/L	0.01	< 0.001	< 0.001
8	Mercury	mg/L	0.0005	< 0.00005	< 0.00005
9	Selenium	mg/L	0.01	< 0.001	< 0.001
10	Nitrate and Nitrite	mg/L	10	< 0.02	< 0.02
11	Fluoride	mg/L	0.8	< 0.05	< 0.05
12	Boron	mg/L	1	< 0.02	< 0.02
13	Copper	mg/L	1	< 0.001	< 0.001
14	Zinc	mg/L	1	0.016	0.009
15	Color	degree	5	2.4	15
16	Turbidity	degree	2	19	6.2

17	Total residue	mg/L	500	36	58
18	Organic surface active agent	mg/L	5	1.3	2.4
19	Manganese	mg/L	0.05	1.3	0.34
20	Iron	mg/L	0.2	8.4	2.6
21	Sodium	mg/L	200	1.1	1.4
22	Aluminum	mg/L	200	0.03	0.03
23	Calcium, Magnesium(Hardness)	mg/L	300	6	4.7
24	Chloride Ion	mg/L	200	1	1.1

4-5-6 Dawei Dam Plan

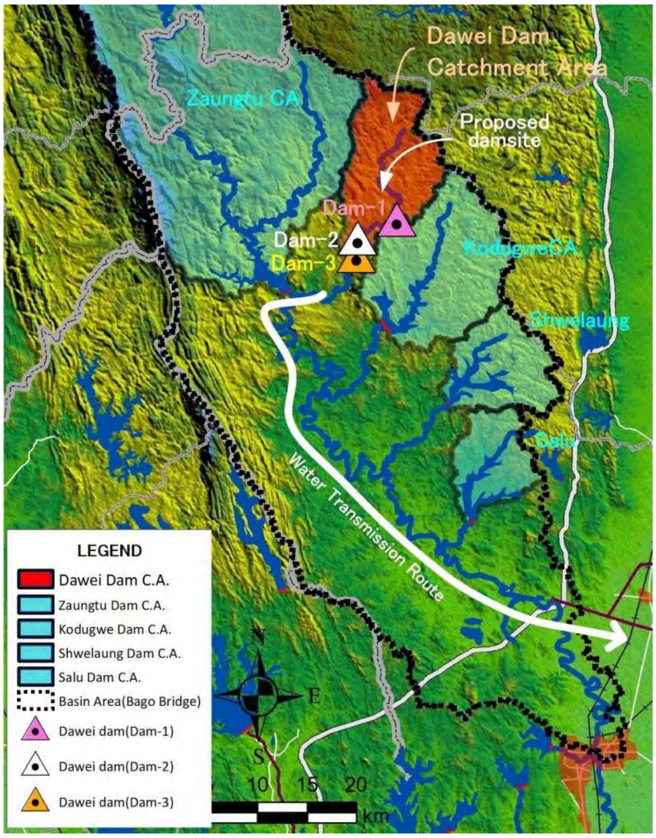


Figure 4-5-6-1 Location of Dawei Dam Basin

The Dawei Reservoir is planned for the Dawei Branch River meeting downstream from the existing Zaungtu Reservoir. At this time, there are three candidates for the construction site, which are located on a narrow section of the tributary as shown in Figure 4-5-6-1.

The possible sites are located 9km (dam-1 site), 13km (dam-2site) and 16km (dam-3 site) from the meeting point on the river.

The candidate location of the dam axis for the Dawei dam is shown in Figure 4-5-6-2, and the plan salient data for the candidate dam axes are shown on Table 4-5-6-1. The total storage capacity is a large amount of reservoir storage which is from 130 MCM to 170 MCM, and the dam height is assumed to be from 23 m to 28 m.

Table 4-5-6-1 Main Plan Specifications aboutCandidates of Dam Axis in Dawei Reservoir

Plan	Plan Salient Data				
	Catchment Area(km^2)	Estimated Inflow (MCM)	Storage Capacity (MCM)	Dam Height (m)	Catchment Area (km^2)
Dam-1	89.7	128.2	133.2	22. 6	90
Dam-2	112.8	161.1	167.2	25.3	113
Dam-3	117.3	167.6	173.9	27.4	123

Source: Irrigation department

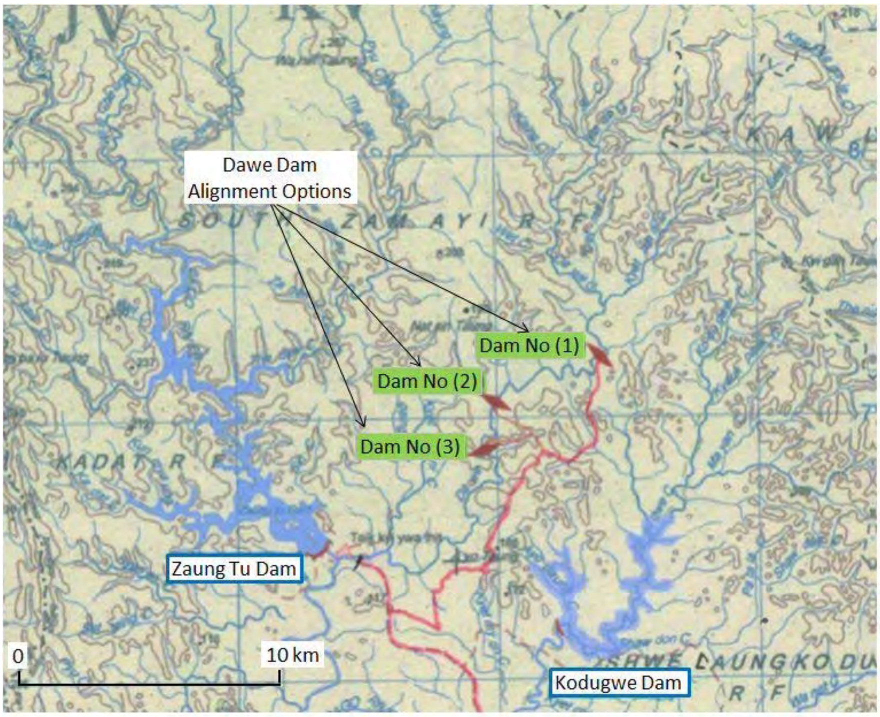


Figure 4-5-6-2 Planned Dawei Dam Sites

(1) Water Resource

As the result of simulation with the SWAT basin model (refer to chapter 6: Water Resource and Basin Water Balance) made for 30 years from 1984 to 2013, 200 MCM/year of mean discharge is estimated as Dawei dam inflow as shown in Table 4-5-6-2. The annual variation is also calculated as is the minimum at 122MCM and maximum at 277 MCM/year.

Table 4-5-6-2 Estimated River Discharge of Dawei Chaung at Proposed dam site-3 (Dam No (3) site)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1984	0.0	0.0	0.0	0.0	1.1	27.8	39.8	68.3	57.2	15.8	0.7	0.0	210.7
1985	0.0	0.0	0.0	0.0	4.3	60.2	75.2	77.2	34.7	11.2	2.0	0.0	264.8
1986	0.0	0.0	0.0	0.0	0.2	8.4	50.5	67.3	17.6	6.9	0.4	0.2	151.5
1987	0.0	0.0	0.0	0.0	0.2	4.2	58.4	64.1	44.9	13.0	2.5	0.0	187.4
1988	0.0	0.0	0.0	0.0	0.2	37.5	30.0	42.2	24.7	2.3	0.0	0.0	137.0
1989	0.0	0.0	0.0	0.0	1.1	26.5	40.3	68.5	56.9	15.4	0.7	0.0	209.3
1990	0.0	0.0	0.0	0.0	4.2	57.6	74.5	76.8	34.9	11.0	2.0	0.0	261.0
1991	0.0	0.0	0.0	0.0	0.2	8.0	49.0	66.2	17.6	6.1	0.3	0.3	147.6
1992	0.0	0.0	0.0	0.0	0.3	5.3	58.8	64.0	45.6	12.0	1.8	0.0	187.8
1993	0.0	0.0	0.0	0.0	0.1	40.1	30.9	42.4	24.6	2.1	0.0	0.0	140.3
1994	0.0	0.0	0.2	0.1	0.9	28.6	68.6	47.0	29.9	7.8	0.1	0.0	183.1

1995	0.0	0.0	0.0	0.0	0.6	26.6	51.3	61.1	47.2	12.4	1.6	0.0	200.8
1996	0.0	2.3	0.1	0.0	2.5	22.4	56.0	44.8	27.9	7.8	4.0	0.0	167.7
1997	0.0	0.0	0.0	0.0	0.5	22.1	66.3	67.1	33.8	13.0	0.1	0.0	202.9
1998	0.0	0.0	0.0	0.0	1.8	12.9	56.9	29.8	16.5	4.4	0.0	0.0	122.3
1999	0.0	0.0	0.0	3.2	29.9	55.9	54.5	53.6	57.2	14.8	3.2	0.0	272.4
2000	0.0	0.0	0.1	0.2	4.9	49.6	57.3	22.7	47.3	9.9	0.1	0.0	192.1
2001	0.0	0.0	0.1	0.0	1.3	31.4	72.1	54.8	30.7	8.4	0.1	0.0	198.9
2002	0.0	0.0	0.0	0.0	7.2	33.1	53.1	50.9	26.2	3.6	5.7	2.8	182.6
2003	0.0	0.0	0.0	0.0	1.6	28.3	33.7	73.9	36.0	8.1	0.0	0.0	181.6
2004	0.0	0.0	0.0	0.0	12.5	48.3	54.4	94.5	53.1	2.6	0.0	0.0	265.4
2005	0.0	0.0	0.0	0.1	1.1	6.7	43.2	63.7	41.6	15.8	1.1	0.8	174.0
2006	0.1	0.0	0.0	0.4	1.2	16.3	80.0	41.4	30.3	21.1	0.2	0.0	190.9
2007	0.0	0.0	0.0	0.0	15.3	23.5	76.2	48.3	24.5	37.6	5.3	0.0	230.6
2008	0.1	0.2	0.0	2.7	26.6	34.6	63.1	84.7	40.7	7.5	6.3	0.0	266.4
2009	0.0	0.0	0.0	0.2	0.6	7.5	59.4	45.4	29.6	15.4	1.2	0.0	159.3
2010	0.1	0.0	0.0	0.0	2.8	21.6	33.6	86.1	28.2	21.4	1.2	0.2	195.2
2011	0.4	0.0	1.2	0.1	15.2	46.3	67.3	67.2	58.1	21.3	0.2	0.0	277.3
2012	0.0	0.0	0.0	0.0	1.6	16.2	59.5	87.2	61.0	14.0	0.2	0.0	239.7
2013	0.0	0.0	0.0	0.0	1.0	9.7	57.5	78.8	34.4	25.7	3.9	0.0	211.0
Average	0.0	0.1	0.1	0.2	4.7	27.2	55.7	61.3	37.1	12.3	1.5	0.1	200.4

The 1/10's (10 years' return period) in exceedance probability is calculated as 257 MCM/year, while in non-exceedance probability147MCM/year is obtained. In Figure 4-5-6-3 monthly variation is shown.

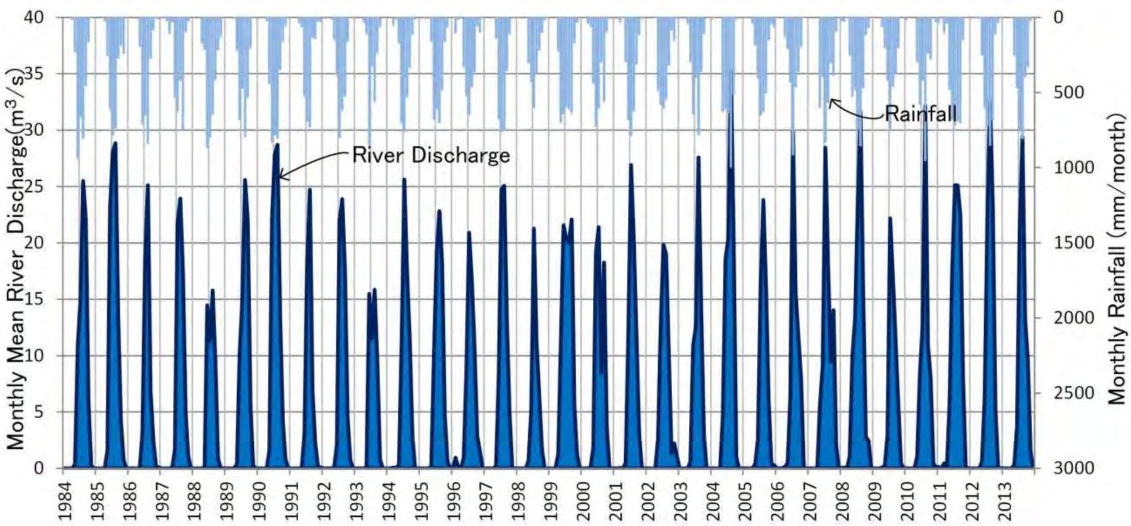


Figure 4-5-6-3 Estimated Discharge at Dawei Dam Site 3 (lower dam)

In the dam plan, 200 MCM/year of mean discharge is regarded as "Total Surface Water Resource". The other water allocation is planned flowing allocation items as below.

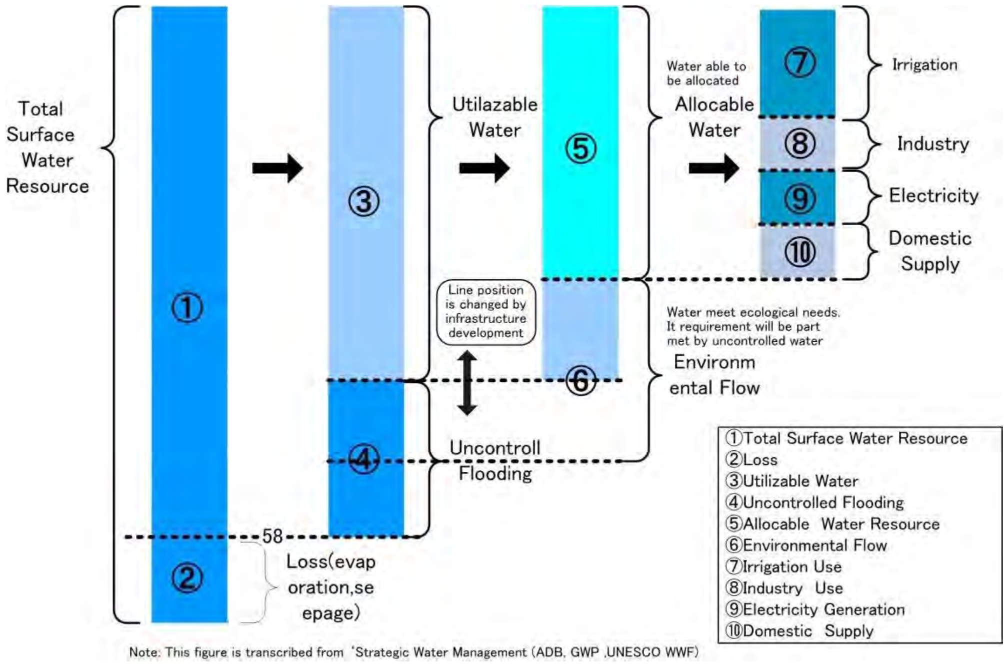


Figure 4-5-6-4 Conceptual Diagram of Water Allocation

Based on allocation items as shown in Figure 4-5-6-4, a reservoir operation was made with 30 years' inflow estimated by SWAT simulation.

Table 4-5-6-4 Condition of Reservoir Operation

Items	Condition of reservoir operation	
Total reservoir storage	150	MCM
Dead water storage	20	MCM
Water loss from reservoir	16.5	MCM
Environmental flow	1	MCM
Irrigation area	Using Reaming Amount	-
Demand for industrial water	28.5	MCM
Demand for electricity generation	−	MCM
Demand for domestic Supply	100,000	person

The allocation of developing water is evaluated by operating simulation with giving reservoir inflow[12] and the condition given as Table 4-5-6-4. Taking the condition that provides the priority to industrial (28.5MCM:78,000m^3/day) and domestic use (100,000@100lit./person) and a remaining amount is used for irrigation at 1/10's drought year for summer paddy. In Figure 4-5-6-5, 30 years' simulation of reservoir operation is shown.

[12] Effective storage of Dawei Reservoir is 130 MCM (full tank level capacity:150 MCM, dead water level capacity: 20 MCM). In order to confirm availability of developing reservoir capacity, estimation was made using with reservoir operating simulation. In the estimation, industrial demand is expected in SEZ's full development stage and domestic use is assumed for rural people living nearby irrigable area as simulation condition.

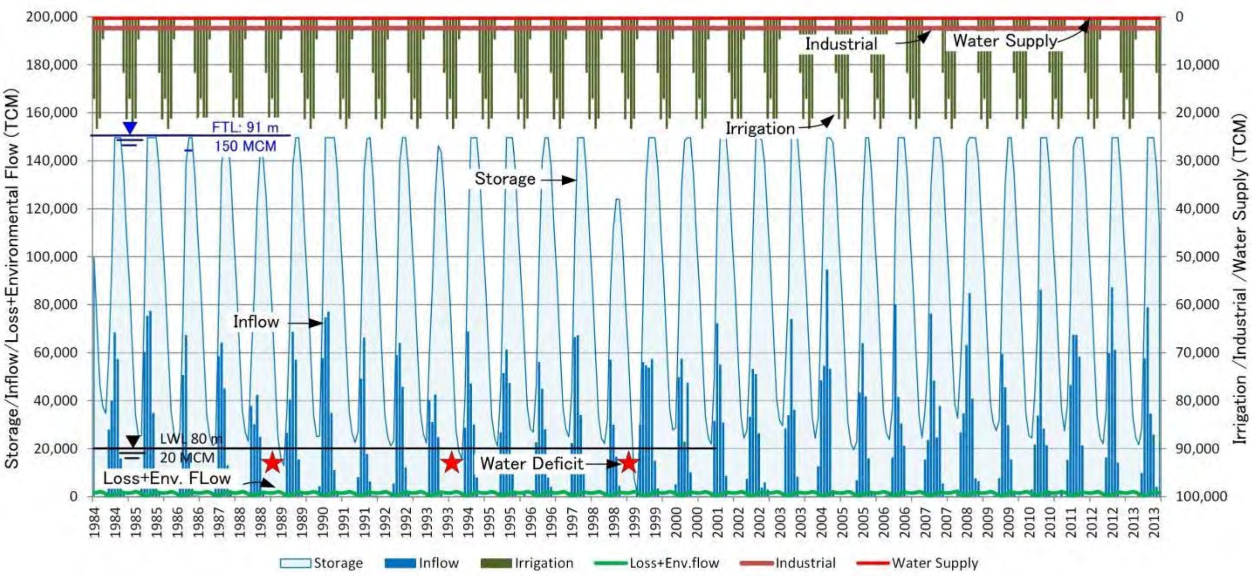


Figure 4-5-6-5 Result of Reservoir Operating Simulation (Dam-3 Site)

As the result of the simulation, a plan of water allocation which fulfills the SEZ demand is obtained as shown in Table 4-5-6-5.

Table 4-5-6-5 Water Allocation Plan of Dawei Proposed Reservoir

Water Resources	Water recourses/utilizable/allocable water		
	MCM/a	MGD	Remarks
①Total Surface Water Resource	200	121	Total inflow to reservoir
②Loss	17	10	Evapotranspiration and seepage, 2.4mm(0.7-3.5mm/day, based on Kodugwe Reservoir)
③Utilizable Water	131	79	③=①-④
④Uncontrolled Flooding	69	42	Spilled water from dam spill way
⑤Allocable Water Resource	130	79	⑤=③-⑥
⑥Environmental Flow	1	0	Equivalent to base flow in the dry season
⑦Irrigation Use	99	60	Irrigation Area 5,400ha(13,500 acre)
⑧Industry Use	29	17	Thilawa SEZ - excluded Class A (78,000m^3/day since 2025)
⑨Electricity Generation	0	0	None
⑩Domestic Supply	4	2	Pop 100,000@100lit/day

4-5-7 Rainwater Utilization adjacent to SEZ

In the adjacent area to SEZ, many of houses have the roof catchment system for collecting the rainwater which is used as supplemental water resources instead of the main water sources of the public water supply system, groundwater wells and ponds. To evaluate the availability of rainwater utilization, in particular for the items of the available period and its amount, the simulation was made using with the climate records of the rainfall and evapotranspiration. The method, data, and conditions applied are described in the following items.

(1) Method Applied for Rainwater Resources

The calculation was begun with the separation of the runoff, which is subtracting the loss (Evaporation loss + Initial loss of rainfall) from the rainfall actually occurring on the roof. The height of rainfall is then multiplied by the roof catchment area (50 m^2, 100 m^2, 150 m^2) to obtain the rainwater amount. So, the respective rainwater amount is supplied to the different storage amounts of the tanks (2 m^3, 3 m^3, 5 m^3, 7 m^3, 10 m^3) ,which is subtracted by the consuming amount according to the daily house use. This daily calculation is repeatedly made over the years, and the available amounts and durations are obtained for the given simulations cases.

(2) Condition of Calculation

The calculation period, types of inputting data and other conditions are as follows:

- The calculation period: 32 years of 1980 to 2012
- Rainfall: Daily rainfall at Kabaye Station(Yangon)
- Evapotranspiration: Monthly Potential Evapotranspiration (refer to Table 4-5-7-1 FAO ClimWAT database[13])
- Water use[14]:Unit of supply amount of 100lit/person x 4.3person /house(0.43 m^3/day)
- Initial loss:2 mm (assessed value)

[13] http://www.fao.org/nr/water/infores_databases_climwat.html

[14] Unit of supply amount and family make-up adjoining to SEZ is referred from the Interim Report on the Preparatory Survey Project on the Improvement of Water and Sewerage System in Yangon, May 2013

Table 4-5-7-1 Potential Evapotranspiration of Yangon Area (ET0)

Month	Temp Max (℃)	Temp Min (℃)	Hum (%)	Win (km/day)	Sun (hrs)	Rad (MJ/m²/day)	ET0 (mm/day)	Water Demand (m³)
JAN	31.8	18.1	62.5	77.8	8.13	17.70	3.38	0.43
FEB	34.1	19.3	59.1	95.0	9.08	20.75	4.23	0.43
MAR	35.7	21.7	62.8	103.7	8.54	21.72	4.78	0.43
APR	36.8	24.3	64.2	121.0	8.79	23.01	5.47	0.43
MAY	33.2	24.9	76.0	112.3	5.26	17.70	4.23	0.43
JUN	30.1	24.5	85.2	95.0	2.41	13.31	3.06	0.43
JUL	29.5	24.1	88.3	103.7	1.73	12.26	2.76	0.43
AUG	29.3	24.0	87.9	95.0	2.02	12.59	2.78	0.43
SEP	30.2	24.1	86.2	77.8	3.63	14.56	3.11	0.43
OCT	31.4	24.1	81.9	69.1	5.85	16.65	3.49	0.43
NOV	32.0	22.4	75.4	77.8	6.73	16.28	3.39	0.43
DEC	31.4	19.4	69.1	86.4	7.31	16.07	3.21	0.43

(3) Result of calculation

As stated above, three (3) cases of roof catchment areas (50 m^2, 100 m^2 and 150 m^2) and five cases of the tank storages (2 m^3,3 m^3,5 m^3,7 m^3,10 m^3) were applied for the simulation and to evaluate the available duration as shown in Figure 4-5-7-1. As a result of the simulation on the above cases, the available period is taken as about 6.5 months from the beginning of May to the middle of November, even in the longest case with 150m^2 of roof area and 10m^3 of storage tank. If the case of year-round utilization is planned, a huge-volume tank has to be required for each house[15]. This is vital as in the area near SEZ, most of the houses have a long drought period after November until the next rainy season.

In the adjacent area to SEZ, the average roof area is about 100m^2 and the average capacity of the storage tank is 2-3 m^3. This case is just found at the marginal zone as is the economical scale of the facility, and the most of existing systems are used properly from an economical point of view.

[15] If the all the demand for a house is covered by the rainwater for all year round, a storage tank larger than 90m^3 is required which may not be economically feasible.

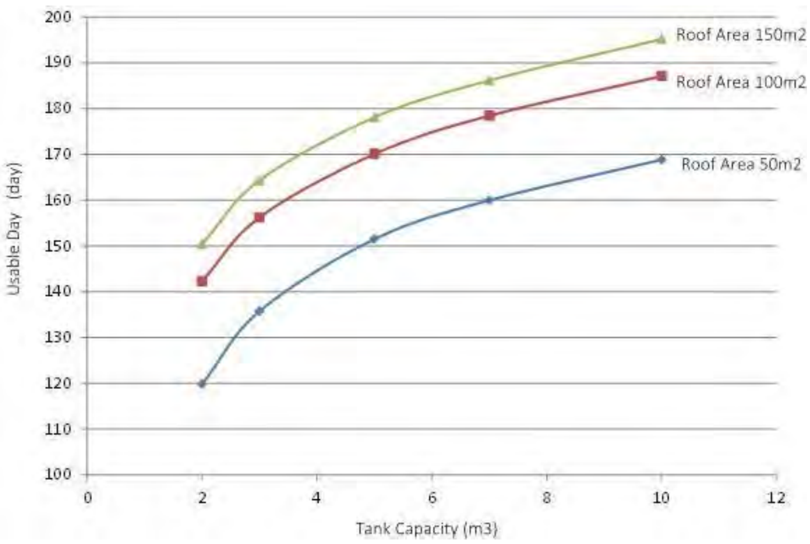


Figure 4-5-7-1 Annual Available Period of Rainwater Utilization (Tank Capacity- Usable Day)

The water budget for this case indicates the runoff rate is 78%[16] (≒runoff: 2,166 mm /rainfall: 2,785 mm). In addition, out of the 217 m^3 of rainwater collected from the roof, 69 m^3 (30% of the runoff) is stored and utilized for 160 days from the beginning of May to the beginning of October, as shown in Table 4-5-7-2.

[16]According to the Guideline published from the American Society of Civil Engineering, the standard runoff rate for the roof-top is in the rage of 0.75 to 0.95.

Table 4-5-7-2 Water Budget in Rainwater Utilization (Roof area:100m^2 ,Tank Capacity:3m^3)

Year	Rainfall (mm)	Runoff (mm)	Runoff (m^3)	Usable Water Amount (m^3)	Annual Usable Day (day)	Deficit Water Amount (m^3)
1980	2,717	2,099	210	65	145	-93
1981	2,636	2,018	202	67	150	-90
1982	2,703	2,135	213	62	140	-95
1983	2,795	2,162	216	76	172	-81
1984	2,379	1,802	180	64	146	-93
1985	3,291	2,600	260	76	173	-81
1986	2,799	2,194	219	63	141	-94
1987	2,553	1,995	200	69	156	-88
1988	2,540	1,869	187	66	146	-92
1989	2,557	1,997	200	69	160	-88
1990	2,803	2,168	217	72	165	-85
1991	2,115	1,568	157	49	107	-108
1992	2,439	1,801	180	68	152	-90
1993	2,824	2,236	224	64	146	-93
1994	3,072	2,421	242	70	156	-87
1995	2,552	1,963	196	70	161	-87
1996	3,087	2,408	241	79	178	-79
1997	3,050	2,441	244	66	153	-91
1998	2,436	1,869	187	64	144	-93
1999	3,523	2,760	276	85	195	-72
2000	2,577	1,945	195	72	162	-85
2001	2,817	2,125	212	79	175	-78
2002	3,090	2,469	247	72	160	-85
2003	2,310	1,715	171	63	145	-94
2004	2,712	2,107	211	60	137	-97
2005	2,738	2,103	210	71	162	-85
2006	2,836	2,187	219	68	154	-89
2007	3,586	2,947	295	75	172	-82
2008	3,051	2,377	238	79	180	-78
2009	3,060	2,493	249	65	146	-92
2010	2,428	1,901	190	69	153	-88
2011	3,058	2,427	243	81	183	-76
2012	2,778	2,189	219	63	142	-95
Average	2,785	2,166	217	69	156	-88
Min.	2,115	1,568	157	49	107	-108
Max	3,586	2,947	295	85	195	-72

4-5-8 New Reservoir in the Thilawa SEZ area

In order to examine a further utilization of rainwater in the SEZ, the possibility of a new reservoir in the Thilawa SEZ is considered. Facility scale (reservoir) is also examined from the climate records such as rainfall, evapotranspiration. In the following sub-sections, applied method and input data, calculation condition and results are described.

1) Calculation method

The calculation was started with the separation of the runoff, which is subtracting the loss (Evaporation loss + Initial loss of rainfall) from the rainfall. This remaining amount is added to reservoir storage, and is subtracted by the consuming amount on a daily basis. This daily calculation is repeatedly made over the years, and the necessary catchment area and facility scale are obtained.

2) Condition of Calculation

The calculation period, types of inputting data and other conditions are as follows:

- The calculation period: 32 years of 1980 to 2012
- Rainfall: Daily rainfall at Kabaye Station(Yangon)
- Evapotranspiration: Monthly Potential Evapotranspiration (refer to Table 4-5-7-1 FAO ClimWAT database[17])
- Water use: 4000m^3/day (every day through year)
- leakage loss:0.3 mm/day (assumed value for SEZ low plain area)

3) Result of Calculation

The effective rainfall, which is deducted a reservoir loss from rainfall, is 2,350 mm/year as an annual average for 30 years. However, in the draught year of 1991 for 30 years, the effective rainfall remains in 1,750 mm/year. In the case of utilizing 4,000m^3/day from this rain water, the necessary reservoir scale is 70 ha (area) x 2.5 m (depth). This scale is large as those of Ban Bwe Gon (reservoir area 86 ha). As well, the ponding time is expected to be several years up to full water level and at least the stable operation cannot be done for one year after completion of construction. The plan therefore involves two risks, of which are its large scale of facility and a preparation time for operation.

[17] http://www.fao.org/nr/water/infores_databases_climwat.html

4-6 Water Resource and Basin Water Balance

Using simulation model, water balance was analyzed for major area of the Bago River Basin. The analytical tool applied is SWAT, the acronym for 'Soil and Water Assessment Tool', a river basin, or watershed, scale model developed for USDA Agricultural Research Service. It has been properly developed to predict impact of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land use and management conditions over long periods of time.

In the analysis, SWAT was used for the evaluation of water balance, in particular surface water resource for providing Thilawa SEZ. As well, with the analysis, the general information of a replenishment water amount was preliminary estimated for the Bago River Basin.

The physical processes to analyze the water balance are briefly summarized in the following sub-section.

4-6-1 Soil and Water Assessment Tool (SWAT)

Soil and Water Assessment Tool (SWAT) is continuous-time, quasi-distributed and process based model have been developed in USDA-ARS (Agriculture Research Service, United States Department of Agriculture) since 1990s. It can operate on a daily time step and is designed to predicted the water flow and capable of continuous simulation over long time period. Major model components are weather, hydrology, soil and land use. The potential pathways of water movement dealt by SWAT are shown in Figure 4-6-1-1.

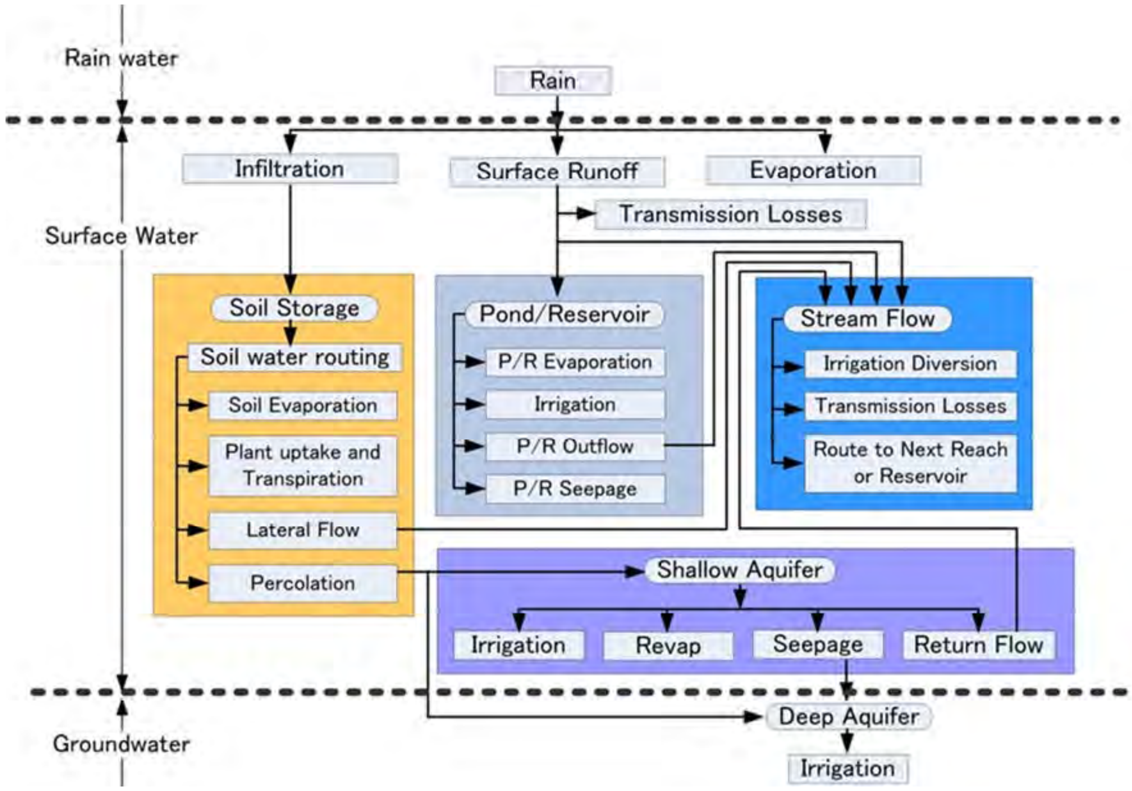


Figure 4-6-1-1 Potential Pathways of Water Movement Dealt in SWAT

At the use of model, basin is divided plural sub-basins and further sub-divided into Hydrologic Response Units (HRUs). HRU is characterized by homogeneous land use, soil type and topography (land slope) and are presented as a percentage of sub-basin area, being not contiguous and spatially identified in SWAT simulation.

Water balance is originally driven by climatic data such as daily precipitation, maximum and minimum temperature, solar radiation, humidity, wind speed. As the result, the SWAT simulates the hydrologic process including surface runoff, infiltration, evapotranspiration, lateral flow, tile drainage, and redistribution of water within the soil profile, consumptive use through pumping, return flow and recharge by seepage from surface water bodies, ponds, and tributary channels[1].

4-6-2 Catchments Delineation

The model area applied is about 6,950 km^2 and extends over three (3) large watersheds as shown in Figure 4-6-2-2

1) <u>Upper reaches of Bago Bridge</u> located Dawei (proposed) dam, Kodukwe dam, Shwelaung dam, Salu dam, Zaungtu dam and Zaungtu Weir,

2) <u>Lower Reaches and Lower Left Bank</u> placed with Sittang-Bago canal, 30 mile greening canal and Khayan tributary and

3) <u>Lower Reach of Right Bank</u> involving the La Gun Byin and Aligni dam.

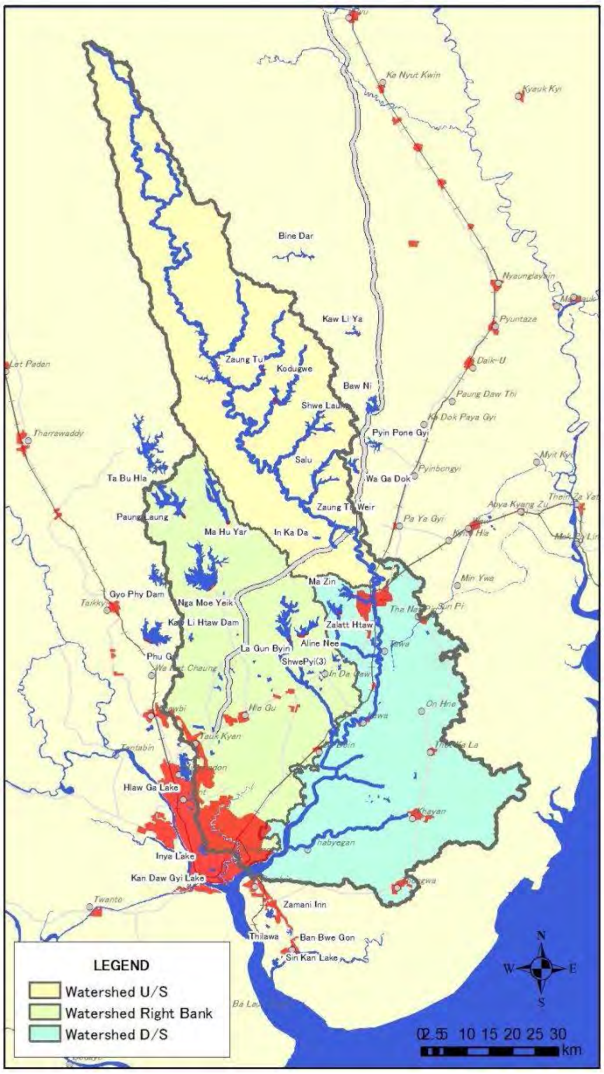


Figure 4-6-2-2 SWAT Model Basin

[1]Process of SWAT Calculation

No matter what type of problem studied, in particular surface discharge or groundwater discharge, with SWAT, water balance is the driving force behind everything that happens in the watershed. To accurately predict even the groundwater recharge, the hydrologic cycle as simulated by the model must conform to what is happening in the watershed. Simulation of the hydrologic cycle of a watershed can be separated into two major divisions. The first division is the land phase of the hydrologic cycle. The land phase of the hydrologic cycle controls the amount of water to the main channel in each catchment. The second division is the water or routing phase of the hydrologic cycle which can be defined as the movement of water through the channel network of the watershed to the outlet.

At the study, the analysis is made with GIS application called as ArcSWAT ArcGIS 2012, which is an interface for SWAT program being able to prepare the necessary data set for SWAT run.

4-6-3 Sub-basin Division

At the beginning of modeling, a model area should be partitioned into sub-basins (Called as ‘catchments’ in SWAT). The use of catchments in the simulation is particularly beneficial when different areas of the watershed are dominated by water uses enough in properties to impact hydrology.

The sub-basin division was made with Watershed Delineation Tools able to delineate sub-basins based on automatic procedure using Digital Elevation Model (DEM). In the analysis, 3 arc-second data (SRTM-3[2]) is used for delineation of sub-basins. The SRTM-3 of model area is processed with ArcGIS Spatial Analyst function to calculate flow direction and flow accumulation grid as shown in Figure 4-6-3-1

[2] SRTM data were processed from raw C-band radar signals at NASA’s Jet Propulsion Laboratory (JPL). This version was edited or finished by the NGA(National Geospatial-Intelligence Agency) to delineate and flatten water bodies, better define coastlines, remove spikes and wells, and fill small voids. They are two types of SRTM-1 and SRTM-3. SRTM-1 is 1 arc-second resolution (about 30 m) and 3arc-second is about 90 m. In the analysis for basin delineation, SRTM 3 is applied (https://lta.cr.usgs.gov/SRTM2).

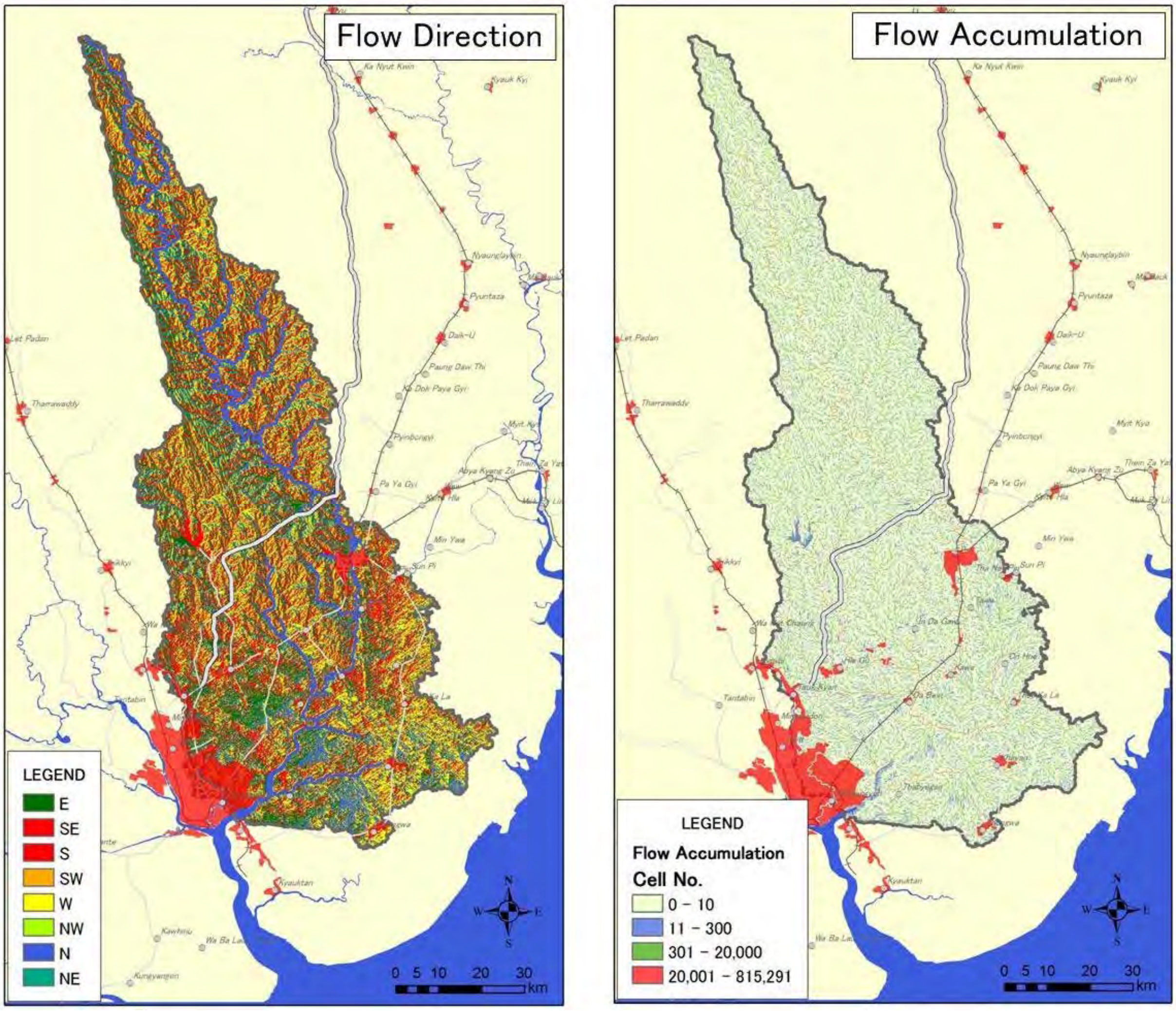
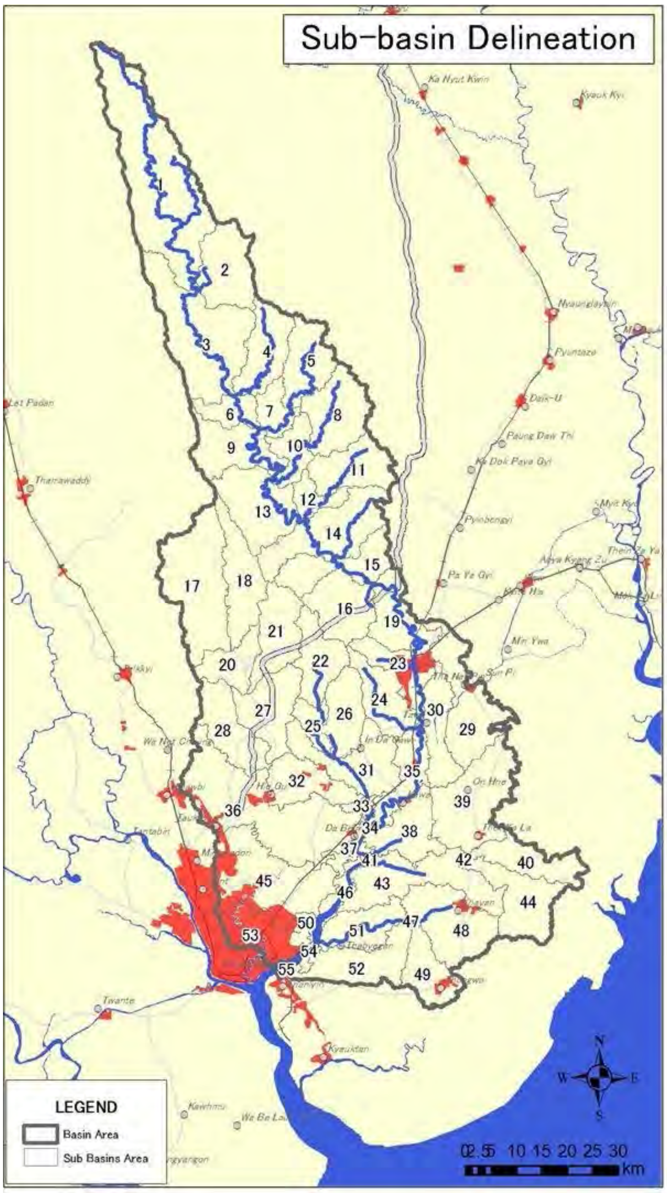


Figure 4-6-3-1 Flow Direction and Flow Accumulation

After flow direction and flow accumulation were completed, the defining the streams and watersheds with giving outlet as well as monitoring points at the river mouth is calculated. Using the algorism of automatic delineation and segmentation of river basin, the model area was divided into 55 sub-basins with various areas ranging from 1 to 480 km^2 as shown in Figure 4-6-3-2.



No. Subbasin	Area (km2)	Elevation (m)	Dam/Reservoir
1	480	357	
2	148	205	
3	312	217	
4	129	139	
5	123	115	Dawei Proposed Dam
6	57	118	Zaungtu Dam
7	58	86	Dawei G1 St.
8	155	93	Kodukwe Dam
9	139	106	
10	72	69	
11	128	79	Shwelaung Dam
12	48	46	
13	175	68	
14	203	50	Tamabin G2 St./Salu Dam
15	125	39	Zaungtu Weir
16	137	36	
17	275	81	Ngamoyeik Dam/Paung Laung Dam
18	143	81	Ma Hu Yar Dam
19	129	22	Bago Old Bridge G2 St.
20	84	40	
21	129	47	
22	114	43	Lagunbin Dam
23	90	24	Mazin Dam
24	113	30	Zalataw Dam
25	45	22	
26	105	28	Aligni Dam
27	141	26	
28	130	34	
29	195	8	
30	108	8	
31	161	14	
32	114	10	
33	17	7	
34	3	8	
35	100	11	
36	393	12	
37	32	7	
38	121	7	
39	227	7	
40	112	7	
41	3	5	
42	2	6	
43	210	3	
44	150	5	
45	274	5	
46	40	5	
47	1	5	
48	184	5	
49	103	5	
50	24	5	
51	108	4	
52	144	4	
53	109	4	
54	18	3	
55	11	3	

Area of Sub-basins

Figure 4-6-3-2 Sub-basin Delineation for Bago River Basin

4-6-4 Preparation of Input Information

As the preparation of SWAT run, the meteorological and hydrological information were prepared as input information. In general, input information for each sub-basin is to be grouped into the following categories:

1) Hydrologic response units or HRUs
2) Land use map and soil taxonomy map
3) Climate data;
4) Hydrologic data

- Discharge at main channel, or reach
- Dams/Ponds / wetlands
- Draining the catchments etc.

Input information (1 – 3), the actual data applied to the analysis is described in following sub-sections.

4-6-5 HRU (Hydrological Response Unit) Analysis

HRU (Hydrological Response Unit) is a basic computational unit assumed to be homogeneous in hydrologic response to land cover change, which has the same soil type and land use form. To characterize HRU, Landcover, Soil and Slope dataset are overlay on the GIS layer and determine the land cover/soil/slope class combinations and distribution for the respective sub basins. Applied data set (land cover/soil/slope) and combined result are described in following subsections.

(1) Land Cover

Land cover data set used is GLCNMO version 2[3] of 500m x 500m resolution produced by the Global Mapping Project coordinated by the International Steering Committee for Global Mapping(ISCGM) as shown in Figure 4-6-5-1. The classification is based on LCCS (Land Cover Classification System) developed by FAO and 14 types are classified in the Model area composing of 5 types of forest, 3 types of meadow and 3types of agricultural lands and others. At the moment of 2008, most dominant land type is 60% of cropland-paddy field while 9% of forest area. Prior to loading the model, these land types are defined as SWAT land cover classes. Using the comparison table shown in Table 4-6-5-1, the distribution of land cover type taken from MOIS imagery is converted and loaded to SWAT.

Table 4-6-5-1 Correlation Table between LCCS and SWAT Landcover Classification

LCCS(FAO)		SWAT Land Cover		Area
Code	LCCS(FAO)	Code	SWAT Land Cover	
1	Broadleaf Evergreen Forest	FRSE	Forest-Evergreen	213
2	Broadleaf Deciduous Forest	FRSD	Forest-Deciduous	273
3	Needle leaf Evergreen Forest	FRSE	Forest-Evergreen	42
4	Mixed Forest	FRST	Forest-Mixed	8
5	Tree Open	FRST	Forest-Mixed	1,577
6	Shrub	FRST	Forest-Mixed	421
7	Herbaceous	PAST	Pasture	175
8	Sparse Vegetation	PAST	Pasture	6
9	Cropland	AGRL	Agricultural Land-Generic	1,560
10	Paddy field	RICE	Rice	1,135
11	Cropland /Other Vegetation Mosaic	AGRL	Agricultural Land-Generic	1,475
12	Bare area, consolidated (gravel, rock)	BARR	Barren	3

[3] http://www.iscgm.org/csgtm/index.html

13	Urban	URBN	Residential	21
14	Water Bodies	WATR	Water	42
Total				6,951

(2) Soil Type

The soil type data is referred from the existing Soil Map of Yangon and Bago region prepared by MAS (Myanmar Agriculture Service). The maps are combined into a series of map and clipped it by Bago basin area with ArcSWAT tools. As shown in Figure 4-6-5-2 and Table 4-6-5-2, four types of soil are recognized in the Bago basin. They are Meadow, Lateritic, Forest and Saline Meadow Soil and are indicated as different characteristics as described in Table 4-6-5-2. For respective soil type, the physical property is given as initial data as indicated in Table 4-6-5-3.

Table 4-6-5-2 Soil Characteristics in Bago Basin

No	Soil Type			Description
	*1	*2	*3	
2	Meadow & Meadow Alluvial Soil	Glesol/Gleysol Fluvic/Humic Gleysol/Calcaric Glaysol	2.Meadow & Meadow Alluvial Soil	There are different subtypes of Meadow soils. The meadow soils or paddy soils are widely occurring in the different parts of Myanmar in river plains, delta and low coastal plains and valleys. All types of Meadow Soils have thick solum and are mostly having clayey texture. They are most suitable for addy cultivation. The Meadow soils of the Dry zone in the upper Myanmar have the characteristic light colors. There are Meadow soils with neutral reaction, whereas, some have the alkaline reaction. The Meadow Carbonate soils can also be found in that region. Although they are deficient in plant nutrients, they can be used for pulses and vegetables, The Meadow soils in the mountainous region with high rainfall and Meadow soils of the lower Myanmar have yellow brown color with acid to neutral soil reaction, the meadow soils which occur near the river plains with occasional tidal floods are non-carbonate. They usually contain large amount of salts. They contain more plant nutrients than the Meadow soils of Upper Myanmar. Regardless of the more content of iron, the soils can be utilized for rice and vegetables.
6	Lateritic Soil	Plinthic Ferrasol	6.Lateritic Soil	These soils occur mostly in the lower Myanmar in the lower slopes of the hills of Pegu Yoma, Rakhine Yoma and Donna hill range. They are found on well-drained low uplands and at the foot of low hills. They usually occur at the elevation not higher than 300 feet above sea level. They are formed under the influence of the tropical forests under the conditions of wet tropical monsoon climate with 80-200 inches of rainfall. Morphologically, yellow or yellow brown and reddish brown colors characterize them. The yellow and red colors of the soils are due to the presence of iron with oxidation and reduction processes. In some places the horizons of pisolithic laterite are found at the depth of 18 to 20 inches, whereas, in other places they are not found even at the depth below 4 and 5 feet. The humus content of these soils in forest area is high, but can be less in the deforested areas. The soil reaction is acidic in the upper horizon and can be more acidic at the lower horizons. The available plant nutrients are very low in these soils. These soils are suitable for plantation crops such as rubber, oil palm, orchards such as durian and mango or reforestation for soil conservation.

7	Red Brown Forest Soil	Rhodic Ferralsol	7.Red Brown Forest Soil	The Red Brown Forest soils are the typical soils of tropical evergreen forest of Myanmar. They occur on the well-drained hill slopes at the elevation between 1000 and 4000 feet above sea level. These soils also occur in the northern hilly region and on the hill slopes of Rakhine mountain range, Taninthari and Donna range. These soils are formed under the influence of tropical evergreen forests with the annual rainfall of about 80 to 200 inches. Some are also found at the low uplands. The soils are well structured and have a good drainage. The soil is slightly acid with the pH value ranging from 5.5 to 6.5. Usually these soils have medium to heavy loamy texture. The soils contain moderate amount of plant available nutrients. These soils can be regarded as forest land of good productivity; however, the soils on the lower elevation are suitable for gardens and plantation.
11	Saline Swampy Meadow Gley Soil	Gley - Gleysol	11.Saline Swanpy Meadow Gley Soil	These soils occur in Ayeyarwady Delta and along the river bands of the Gulf of Motama and the marine flat lowlands influenced by the tidal sea water, hich is always salty. Due to high salinity and whole year tidal sea water, the land can only be utilized for prawn breeding and mangrove firewood forests.

Note *1:Soil type name used in local usage
*2:Soil type correlate to International name
*3:Soil name used in MAS Soil Map

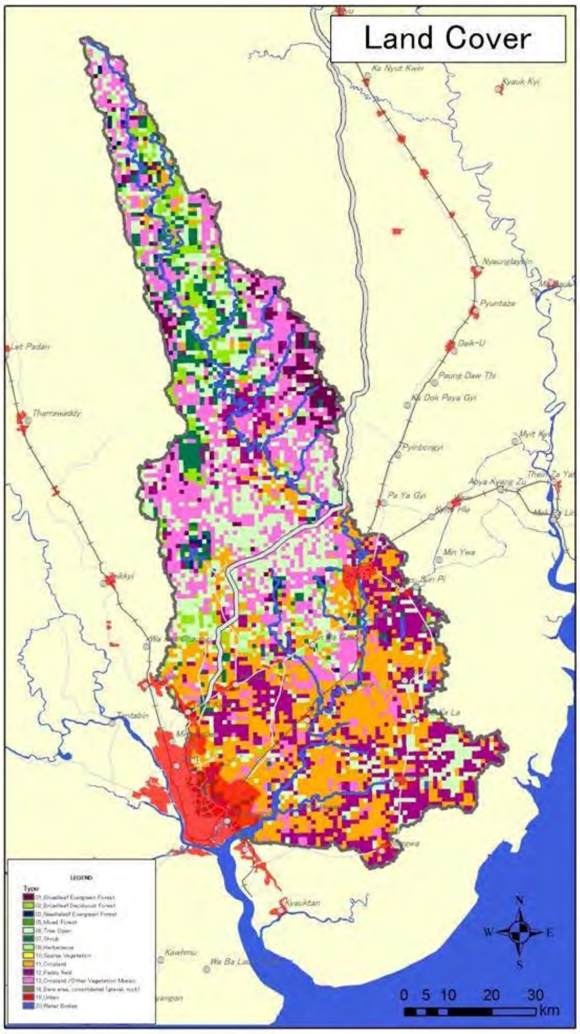


Figure 4-6-5-1 Landcover

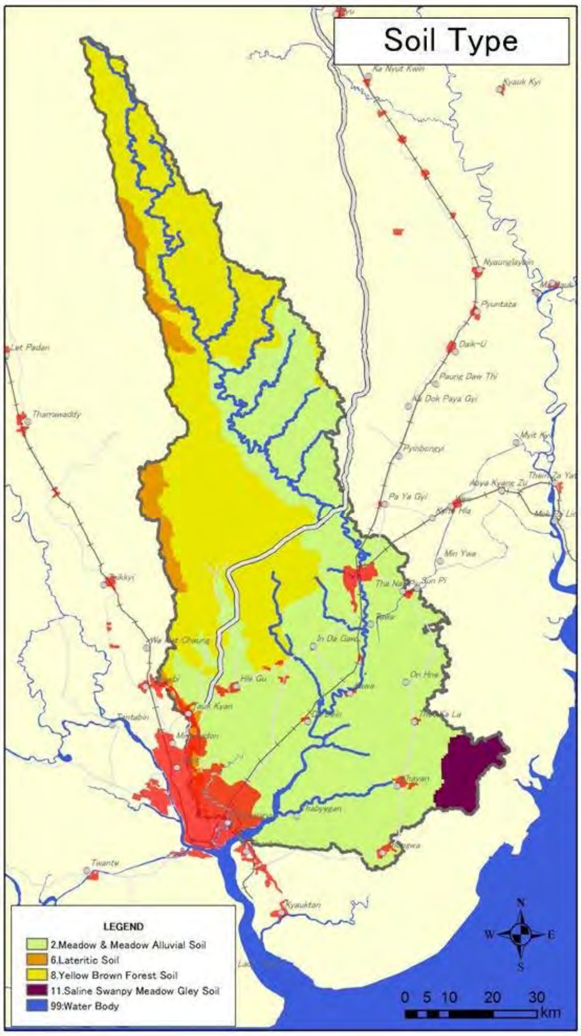


Figure 4-6-5-2 Soil Type

Table 4-6-5-3 Initial Value of Soil Physical / Chemical Characteristics

TITLE	SYMBOL	NLAYERS	HYDGRP	SOL_ZMX	ANION	SOL_CRK	TEXTURE	SOIL LAYER	SOL_Z	SOL_BD	SOL_AWC	SOL_CBN	SOL_K	CLAY	SILT	SAND	ROCK	SOL_ALB	USLE_K	SOL_EC	SOL_CAL	SOL_PH
Alluvial Soil	L	3	B	1500	0.5	0.5	L	1	250	1.2	0.2	1	7.6	14	33	53	5	0.1	0.3	0	0	7
								2	900	1.4	0.15	1	5.7	14	33	53	5	0.1	0.3	0	0	7
								3	1500	1.6	0.1	1	3.8	14	33	53	5	0.1	0.3	0	0	7
Meadow Soils/Meadow Alluvial Soils/Meadow Swampy Soils	SiL	3	B	1500	0.5	0.5	SiL	1	250	1.2	0.2	1	7.6	14	73	13	5	0.1	0.3	0	0	7
								2	900	1.4	0.15	1	5.7	14	73	13	5	0.1	0.3	0	0	7
								3	1500	1.6	0.1	1	3.8	14	73	13	5	0.1	0.3	0	0	7
Lateric Soil	LCoS	3	A	1500	0.5	0.5	LCoS	1	250	1.2	0.2	1	11.4	8	7	85	10	0.1	0.3	0	0	7
								2	900	1.4	0.15	1	9.5	8	7	85	10	0.1	0.3	0	0	7
								3	1500	1.6	0.1	1	7.6	8	7	85	10	0.1	0.3	0	0	7
Red Brown Forest Soil	LFS	3	A	1500	0.5	0.5	LFS	1	250	1.2	0.2	1	11.4	8	13	79	7	0.1	0.3	0	0	7
								2	900	1.4	0.15	1	9.5	8	13	79	7	0.1	0.3	0	0	7
								3	1500	1.6	0.1	1	7.6	8	13	79	7	0.1	0.3	0	0	7
Saline Swampy Meadow Gley Soil	SCL	3	C	1500	0.5	0.5	SCL	1	250	1.2	0.2	1	3.8	17	10	73	5	0.1	0.3	0	0	7
								2	900	1.4	0.15	1	2.6	17	10	73	5	0.1	0.3	0	0	7
								3	1500	1.6	0.1	1	1.3	17	10	73	5	0.1	0.3	0	0	7

Title	Unit	Description	Title	Unit	Description
NLAYERS	na	Number of layers in the soil.	SOL_CBN	[%]	Organic carbon content .
HYDGRP	na	Soil Hydrologic Group	CLAY	[%]	Clay content.
SOL_ZMX	[mm]	Maximum rooting depth of soil profile.	SILT	[%]	Silt content.
ANION_EXCL	[fraction]	Fraction of porosity (void space) from which anions are excluded.	SAND	[%]	Sand content.
SOL_CRK	[fraction]	Crack volume potential of soil.	ROCK	[%]	Rock fragment content.
TEXTURE	na	Texture of soil layer.	SOL_ALB	na	Moist soil albedo.
SOL_Z	[mm]	Depth from soil surface to bottom of layer.	USLE_K	na	USLE equation soil erodibility (K) factor.
SOL_BD	[g/cm3]	Moist bulk density.	SOL_EC	[dS/m]	[Not currently active] Electrical conductivity.
SOL_AWC	[mm/mm]	Available water capacity of the soil layer.	SOL_CAL	[%]	Calcium carbonate content
SOL_K	[mm/hr]	Saturated hydraulic conductivity.	SOL_PH	na	Soil pH

(3) Slope

Using with DEM, the slope is calculated in Model area. It can take wide range from even (=0%) to steep terrain (>50 %). However, it is generally composed of gentle slope which is less than 3% of gradient as shown in Figure 4-6-5-3. In particular, the flat area less than 1% extends widely the lower reach of basin. With a slope clarification bounded by 1%, 3% and 5%, HRU analysis was made by slope classes in addition to land use and soils.

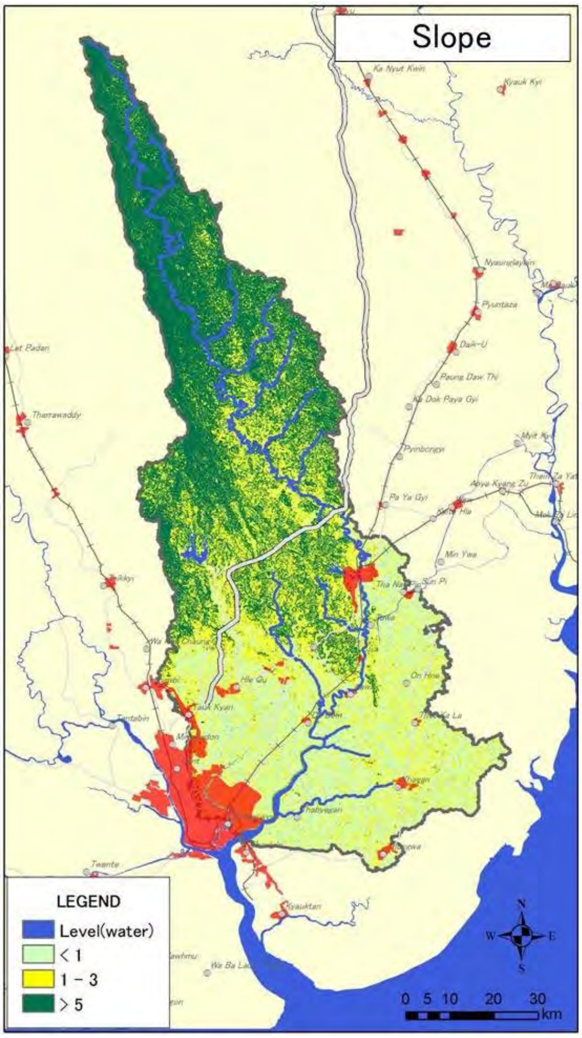


Figure 4-6-5-3 Slope

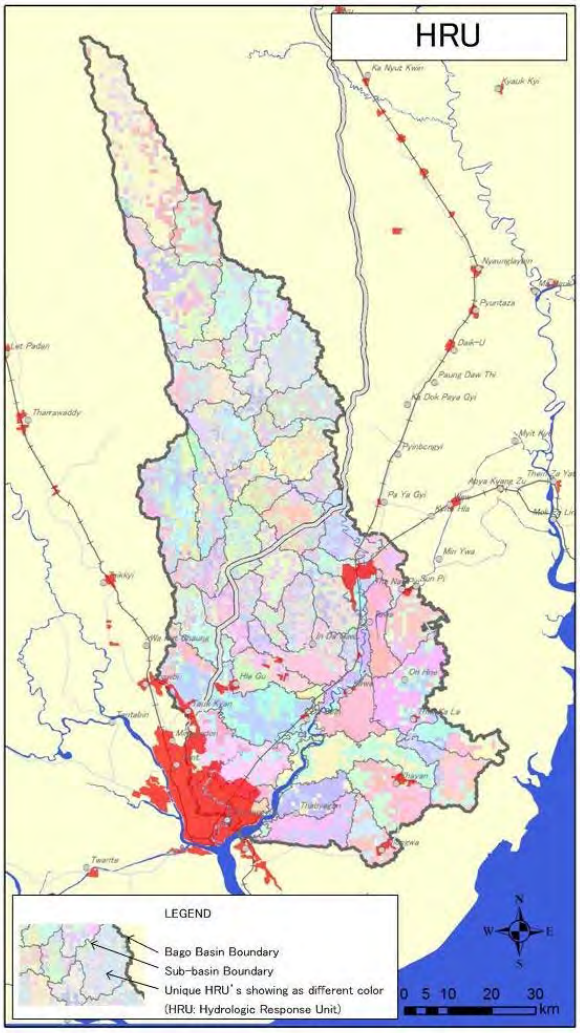


Figure 4-6-5-4 HRU

(4) HRU Distribution

The slope data are classified and overlaid it on landcover and soil distribution, Hydrologic Response Unit (HRUs) is determined in the sub-basin. Subdividing sub-basins, HRU, have a unique landcover and soil combinations, enables the model to reflect different in evapotranspiration and other hydrologic conditions for different land covers/crops and soils. Runoff will predicted separately for each HRU and routed to obtain the total runoff of sub-basin. For the analysis of Bago basin, 1,140 HRUs are classified as unique properties In the Figure 4-6-5-4, the applied distribution of HRUs are shown.

(5) Climate data

The climatic data to the SWAT are most essential because it provide the moisture and energy that drive all other process simulated in the model area. The climatic process modeled in SWAT consists of six (6) items: rainfall, air temperature, solar radiation, wind speed and relative humidity. Depending on the method used to calculate potential evapotranspiration, wind speed and relative humidity are used for its estimation. Out of six (6) climatic items, the solar radiation has not been measured and has to be calculated based on weather generate table. The stations used for Model are six (6) as shown in Figure 4-6-5-5.

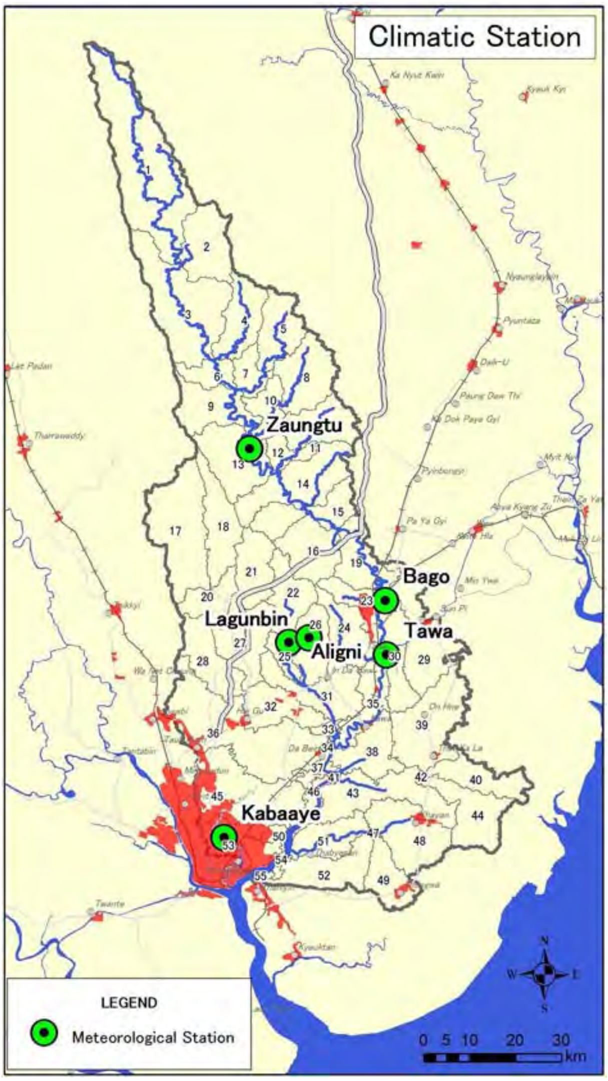
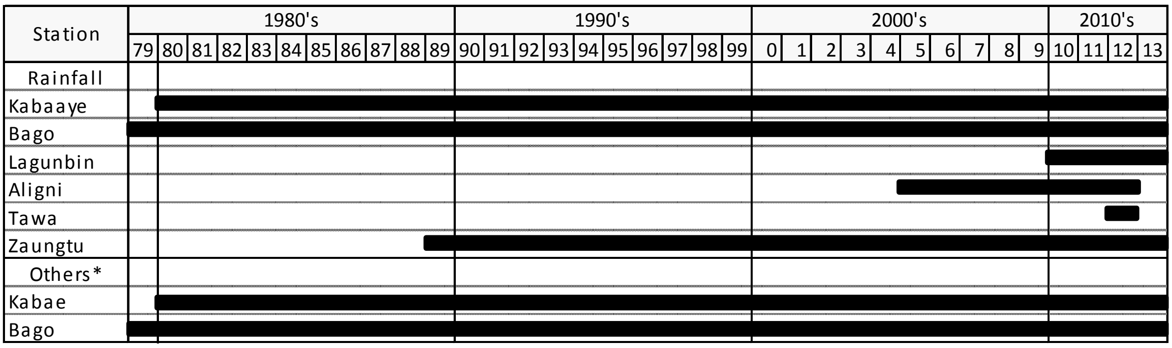


Figure 4-6-5-5 Climatic Station

(6) Climatic Data for SWAT

SWAT requires daily values of precipitation, maximum and minimum temperature, solar radiation, relative humidity and wind speed. As the input data, rainfall data are applied for six(6) station and other climatic data of temperature, humidity and wind speed are prepared for two stations. The period of input data for respective station is shown in Figure 4-6-5-6.



*Others: Daily Max./Min Temperature, Daily Mean Humidity, Daily Mean Windspeed

Figure 4-6-5-6 Climatic data used for SWAT

(7) Weather Generator

If the measurement value does not exist, the model automatically generates the climatic data to fill in gaps in measure records. The function of SWAT (WXGEN) creates the predicted value from monthly average data summarized over number of years. The occurrence of rain on a given day has a major impact on relative humidity, temperature and solar radiation for the day. The weather generator first independently generated precipitation for the day. Once the total amount of rainfall for the day is generated, the distribution of rainfall within the day is computed by deducting the daily infiltration. Others of Max/Min temperature, solar radiation and relative humidity are then generated based on the presence or absence of rain for the day. Finally wind speed is generated independently. The weather generated table as shown in Table 4-6-5-4.

Table 4-6-5-4 Monthly Statistical Parameter Applied for SWAT Weather Generator

STATION: Kabaaye WLATITUDE: 16.87° WELEV: 17m
WLONGITUDE: 96.18° RAIN_YRS: 33year

Month	TMP MX	TM PMN	TMPSTD MX	TMPSTD MN	PC MM	PCP STD	PCP SKW	PR W1	PR W2	PCP D	RAINHH MX	SOLAR AV	DEW PT	WND AV
1	33.2	16.2	1.6	2.3	1.8	1.1	20.0	0.0	0.1	0.3	7.0	17.8	20.5	1.6
2	35.5	17.8	1.7	2.1	3.7	2.1	20.0	0.0	0.3	0.2	12.0	18.5	21.2	1.7
3	36.7	20.6	2.0	2.2	14.8	3.7	9.3	0.0	0.5	1.0	10.0	24.7	23.2	2.0
4	38.8	23.2	2.4	1.8	32.2	8.8	14.8	0.1	0.3	2.2	40.0	24.5	24.4	2.4
5	35.5	23.7	3.5	1.9	328.5	22.7	6.3	0.3	0.7	15.7	75.0	21.3	25.4	2.4
6	32.0	22.5	1.8	1.8	560.6	21.6	1.8	0.7	0.8	25.7	32.0	20.1	25.4	2.3
7	31.2	22.1	1.7	1.8	600.0	21.7	1.8	0.6	0.9	27.4	37.0	19.7	25.2	2.1
8	30.3	22.2	1.8	1.6	578.2	20.6	1.8	0.7	0.9	27.8	29.0	18.6	25.2	2.0
9	32.7	22.8	1.8	1.6	398.0	20.0	3.7	0.6	0.8	22.1	53.0	19.8	25.3	1.9
10	33.9	22.1	2.0	1.5	192.6	13.4	3.7	0.3	0.6	13.6	27.0	19.6	25.4	1.7
11	34.0	20.1	1.8	2.5	56.4	10.0	10.9	0.1	0.5	4.1	37.0	18.9	23.8	1.8
12	34.0	17.0	1.5	2.5	6.8	2.1	13.1	0.0	0.3	0.6	9.0	17.8	21.4	1.8

STATION: Bago WLATITUDE: 17.3° WELEV: 11.3m
WLONGITUDE: 96.5° RAIN_YRS: 33year

Month	TMP MX	TM PMN	TMPSTD MX	TMPSTD MN	PC MM	PCP STD	PCP SKW	PR W1	PR W2	PCP D	RAINHH MX	SOLAR AV	DEW PT	WND AV
1	31.0	16.4	1.5	2.2	2.1	1.1	20.0	0.0	0.3	0.5	7.0	17.2	20.7	1.2
2	34.0	17.3	1.9	2.2	2.4	1.4	20.0	0.0	0.4	0.2	8.0	19.9	22.5	1.3
3	36.0	20.7	2.5	2.2	15.8	3.8	9.8	0.0	0.4	1.1	12.0	24.2	24.9	1.3
4	38.0	22.8	2.3	2.1	41.1	7.3	8.1	0.1	0.3	2.5	20.0	24.0	25.9	1.3
5	33.0	22.7	3.9	2.4	308.8	19.3	3.9	0.3	0.7	15.7	49.0	19.8	25.5	1.3
6	31.0	22.2	1.7	2.5	600.0	22.9	1.4	0.8	0.9	26.8	43.0	17.7	25.0	1.3
7	30.0	22.5	1.5	1.9	600.0	25.4	1.8	0.7	0.9	27.8	40.0	17.2	24.9	1.2
8	30.0	22.6	1.5	1.7	600.0	26.0	2.7	0.6	0.9	26.9	55.0	16.5	24.9	1.2
9	31.0	22.8	1.7	1.8	470.7	21.4	2.2	0.5	0.8	22.6	41.0	17.8	25.2	1.2
10	32.0	23.4	1.7	1.2	185.0	13.3	3.8	0.3	0.5	12.0	26.0	18.9	25.5	1.3
11	32.0	20.9	1.5	2.6	48.8	7.9	9.0	0.1	0.5	3.6	29.0	18.4	23.8	1.3
12	31.0	17.7	1.4	2.3	7.9	2.9	15.0	0.0	0.3	0.6	12.0	17.2	21.3	1.3

Statistical parameters required for SWAT Weather Generator

Data Type	Unit	Description
STATION	na	Weather Station name.
WLATITUDE	[Degrees]	Latitude of weather station used to create statistical parameters.
WLONGITUDE	[Degrees]	Longitude of weather station.
WELEV	[m]	Elevation of weather station.
RAIN_YRS	[Numeric]	The number of years of maximum monthly 0.5 h rainfall data.
TMPMX	[deg c]	Average maximum air temperature for month .
TMPMN	[deg c]	Average minimum air temperature for month.
TMPSTDMX	[deg c]	Standard deviation for maximum air temperature in month .
TMPSTDMN	[deg c]	Standard deviation for minimum air temperature in month.
PCPMM	[mm/dd]	Average amount of precipitation falling in month.
PCPSTD	[mm/dd]	Standard deviation for daily precipitation in month.
PCPSKW	na	Skew coefficient for daily precipitation in month.
PR_W1_	[fration]	Probability of a wet day following a dry day in the month.
PR_W2_	[fration]	Probability of a wet day following a wet day in the month.
PCPD	[days]	Average number of days of precipitation in month.
RAINHHMX	[mm]	Maximum 0.5 hour rainfall in entire period of record for month.
SOLARAV	[MJ/m2-day]	Average daily solar radiation in month .
DEWPT	[deg c]	Average dew point temperature in month.
WNDAV	[m/s]	Average wind speed in month.

4-6-6 Calibration Data

Hydrologic observation data prepared for a verification of the models are six (6) points of Zaungtu dam, Kodugwe dam, Dawei Station (G1) , Tamabin Station (G2), Bago Bridge Station and La Gun Byin Dam. The reservoirs and ponds and wetlands, in particular storage change of reservoirs was not able to use for SWAT since completed data is not collected throughout simulation period. The drainage data from the Bago basin was not applied as SWAT simulation.

4-6-7 Model Calibration

(1) Sensitivity Analysis and Parameter Calibration

Model calibration to determinate the model parameter is made through the correlation between model outputs and observation records. The period of calibration selected was from 1984 to 2013, and the records used were monthly river discharge. Prior to calibrating the model, Sensitivity Analysis was made to obtain sensitive factors from around 60 parameters, as shown in Table 4-6-7-3. At the beginning of calibration, Auto Calibration tool is applied to look up a best value (minimum difference between calculated and observed value) for sensitive parameters. Unless the best fitting from Auto Calibration resulted in enough coincidence of the values, manual adjustment was applied by trial runs. In the sensitivity analysis, CN2 (Initial SCS Curve Number II value) which defines runoff response to precipitation was selected as 1st susceptible order, and as second function, SOL_Awc (Available water capacity) was followed. As for others, GWQMN (Threshold water depth in the shallow aquifer for flow), SOL_K (Saturated hydraulic conductivity) and SOL_Z (Soil depth) and others were taken as major sensitive factors as shown in Table 4-6-7-1.

Table 4-6-7-1 Result of Sensitivity Analysis

Parameters	Order	Parameters	Order	Parameters	Order
CN2	1	SLSUBBSN	8	GW_REVAP	15
SOL_AWC	2	SLOPE	9	REVAPMN	16
GWQMN	3	CH_K2	10	TLAPS	17
SOL_Z	4	SOL_ALB	11	GW_DELAY	18
SOL_K	5	CH_N	12	RCHRG_DP	19
ALPHA_BF	6	EPCO	13	BLAI	20
SURLAG	7	ESCO	14		

Although these effective parameters of top five (5) were once decided as initial value based on the result of existing soil surveys and land use maps. However, the values were changed by recommended values as best fit from Auto Calibration process. By both of the auto calibration and manual trials, the model parameters were consequently verified with the target of 5 percent error in annual discharge amount.

The calibration result for the sensitive parameters is shown in Table 4-6-7-2 and 4-6-7-3. CN2 initially set by HRU's condition determined by land-cover, soil type and slope (HRUs' attributes), and was modified manually with adjusting for observed river discharge. The CN2 is then determined as various values with wide range from low discharge of CN2:36 to high rate of CN2:81. Lowest CN2 is found in Mixed Forest (FRST) covered by lateritic soil (LT) and highest CN2 is observed in paddy field (RICE), extending on Meadow & Meadow Alluvial Soil (MD) and Saline Swampy Meadow Grey Soil (SM).

For the soil depth (SOL_Z), the total 1,500 mm is applied composed of 3 layers: 250 mm, 650 mm and 600 mm from the surface (1st layer) to bottom (3rd layer). As well, the threshold for groundwater recharge (GWQMN) was determined in the range of 0 to 70 mm.

Applying the optimum adjustment for five (5) calibration points in monthly basis, the model parameters were decided. In Figure 4-6-7-1 to 4-6-7-4, the result of model calibration at five (5) calibration points: Zaungtu dam, Dawei (G1 station), Kodukwe dam and Tamabin (G2 station) and Bago Bridge Station and La Gun Byin dam (G4 station) are shown.

The calibration of Bago Bridge Station was made 25 years since 1984. However, in particular flood peak in 1997 and last decade, difference was large unable to be adjusted.

For daily calibration, it was also tried to be carried out within a reliable error less than 5 %. However, acceptable result had not been obtained due to poor relationship between precipitation and river discharge in daily basis. It may be resulted from local climatic condition like as showery rainfall which took place near river gage station.

Table 4-6-7-2 Parameter Calibration

Order	Parameters	AGRL			FRST			FRSE		FRSD	RICE		WATER
		BF	MD	LT	BF	MD	LT	BF	MD	BF	MD	SM	
1	CN2(Bago Main)	69	75	60	54	66	32	50	63	59	81	81	92
	CN3(La Gun Byin)	77	83	66	60	73	35	92	63	59	81	81	92
	CN4(Dawei)	69	82	-	54	73	-	49	63	59	81	81	92

Order	Parameters	Layer 1	Layer 2	Layer 3
2	SOL_AWC	0.8	0.7	0.5
3	GWQMN	50/70(sub5,7)	50/70(sub5,7)	150
4	SOL_Z	250	900	1500
5	SOL_K(BF)	95	71	48
	SOL_K(MD)	12	8	4
	SOL_K(LT)	219	165	94

Order	Parameters	Sub-basins/HRUs	Explanation	
3	GWQMN	50/70(sub5,7)	Landcover	
6	ALPHA_BF	0.3	AGRL:	Agricultural Land-Generic
7	SURLAG	4	FRST:	Forest-Mixed
8	SLSUBBSN	18 -121	FRSE:	Forest-Evergreen
9	SLOPE	0.002-0.19	WATR	Water
10	CH_K2	0	FRSD:	Forest-Deciduous
11	SOL_ALB	0.1	RICE:	Rice

12	CH_N	0.014-0.1	Soil Type
13	EPCO	1	BF: Red Brown Forest Soil
14	ESCO	0.95	MD: Meadow & Meadow Alluvial Soil
15	GW_REVAP	0.1	LT: Lateritic Soil
16	REVAPMN	1	SM: Saline Swampy Meadow Grey Soil
17	TLAPS	0.006	
18	GW_DELAY	4/5/20/31	
19	RCHRG_DP	0.1/0.15/0.27/0.5	
20	BLAI	0-5	

Table 4-6-7-3 Explanation of SWAT Common Parameter

Par	Name	Type	Description	Location
1	ALPHA_BF	Sub	Baseflow alpha factor [days]	*.gw
2	GW_DELAY	Sub	Groundwater delay [days]	*.gw
3	GW_REVAI	Sub	Groundwater "revap" coefficient	*.gw
4	RCHRG_DF	Sub	Deep aquifer percolation fraction	*.gw
5	REVAPMN	Sub	Threshold water depth in the shallow aguifer for "revap" [mm]	*.gw
6	GWQMN	Sub	Threshold water depth in the shallow aguifer for flow [mm]	*.gw
7	CANMX	Sub	Maximum canopy storage [mm]	*.hru
8	GWNO3	Sub	Concentration of nitrate in groundwater contribution [mg N/l]	*.gw
10	CN2	Sub	Initial SCS CN II value	*.mgt
15	SOL_K	Sub	Saturated hydraulic conductivity [mm/hr]	*.sol
16	SOL_Z	Sub	Soil depth [mm]	*.sol
17	SOL_AWC	Sub	Available water capacity [mm H20/mm soil]	*.sol
18	SOL_LABP	Sub	Initial labile P concentration [mg/kg]	*.chm
19	SOL_ORGN	Sub	Initial organic N concentration [mg/kg]	*.chm
20	SOL_ORGF	Sub	Initial organic P concentration [mg/kg]	*.chm
21	SOL_NO3	Sub	Initial NO_3 concentration [mg/kg]	*.chm
22	SOL_ALB	Sub	Moist soil albedo	*.sol
23	SLOPE	Sub	Average slope steepness [m/m]	*.hru
24	SLSUBBSN	Sub	Average slope length [m]	*.hru
25	BIOMIX	Sub	Biological mixing efficiency	*.mgt
26	USLE_P	Sub	USLE support practice factor	*.mgt
27	ESCO	Sub	Soil evaporation compensation factor	*.hru
28	EPCO	Sub	Plant uptale compensation factor	*.hru
30	SPCON	Bas	Lin. Re-entrainment parameter for channel sediment routing	*.bsn
31	SPEXP	Bas	Exp. Re-entrainment parameter for channel sediment routing	*.bsn
33	SURLAG	Bas	Surface rumoff lag time [days]	*.bsn
34	SMFMX	Bas	Melt factor for snow on June 21 [mm H2O/℃-day]	*.bsn
35	SMFMN	Bas	Melt factor for snow on Decemner 21 [mm H2O/℃-day]	*.bsn
36	SETMP	Bas	Snowfall temperature [℃]	*.bsn
37	SMTMP	Bas	Snow melt base temperature [℃]	*.bsn
38	TIMP	Bas	Snow pack temperature lag factor	*.bsn
41	NPERCO	Bas	Nitrogen percolation coefficient	*.bsn
42	PPERCO	Bas	Phosphorus percolation coefficient	*.bsn
43	PHOSKD	Bas	Phosphorus soil partitioning coefficient	*.bsn
50	CH_EROD	Sub	Channel erodibility factor	*.rte
51	CH_N	Sub	Manning's nvalue for main channel	*.rte
52	TLAPS	Sub	Temperature lapse rate [℃/km]	*.sub
53	CH_COV	Sub	Channel cover factor	*.rte
54	CH_K2	Sub	Channel effective hydraulic conductivyty [mm/hr]	*.rte
60	USLE_C	Sub	Minimum USLE cover factor	crop.dat
61	BLAI	Sub	Maximum potential leaf area index	crop.dat

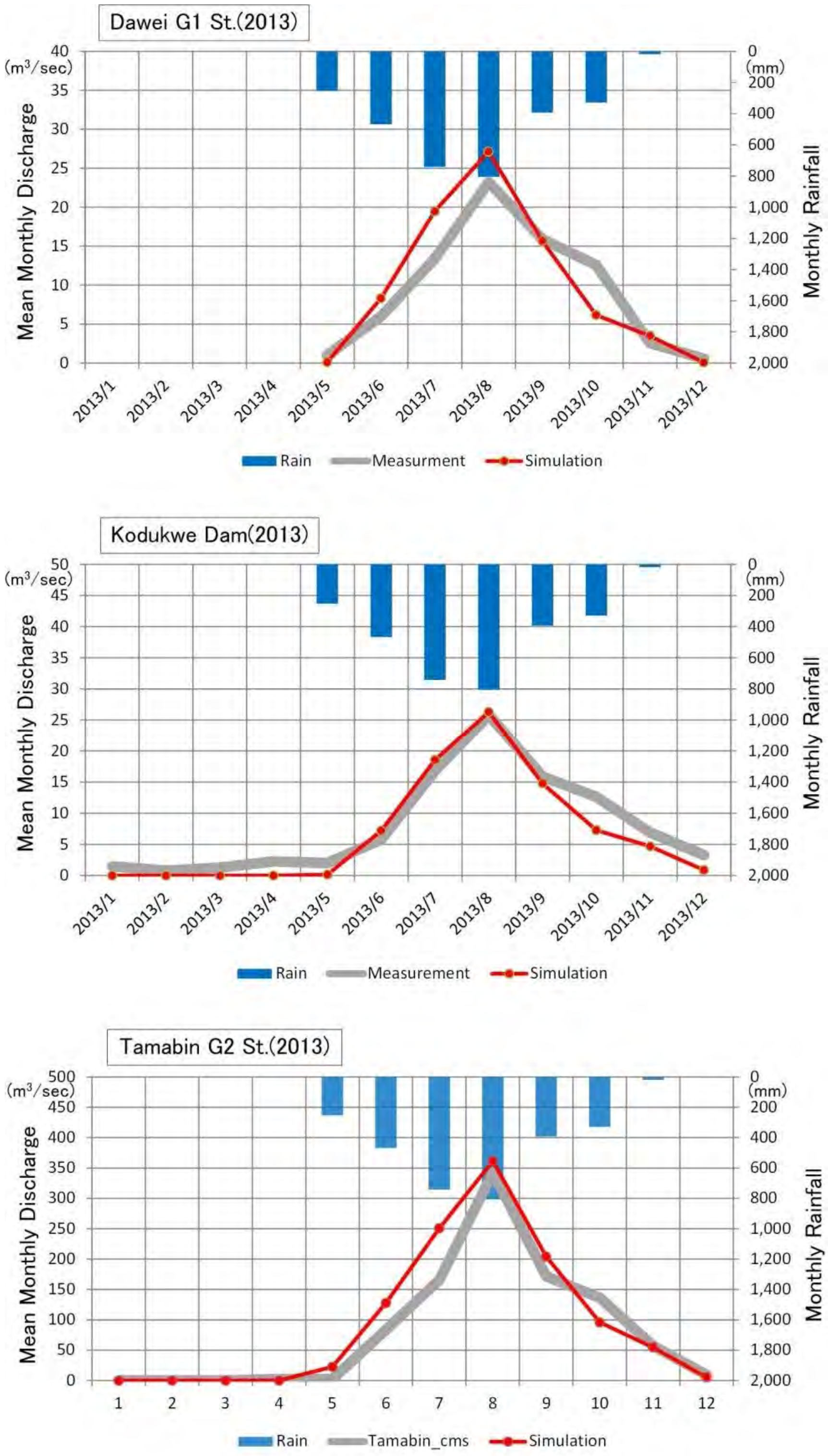


Figure 4-6-7-1 Calibration Result (Dawei, Kodugwe and Tamabin）

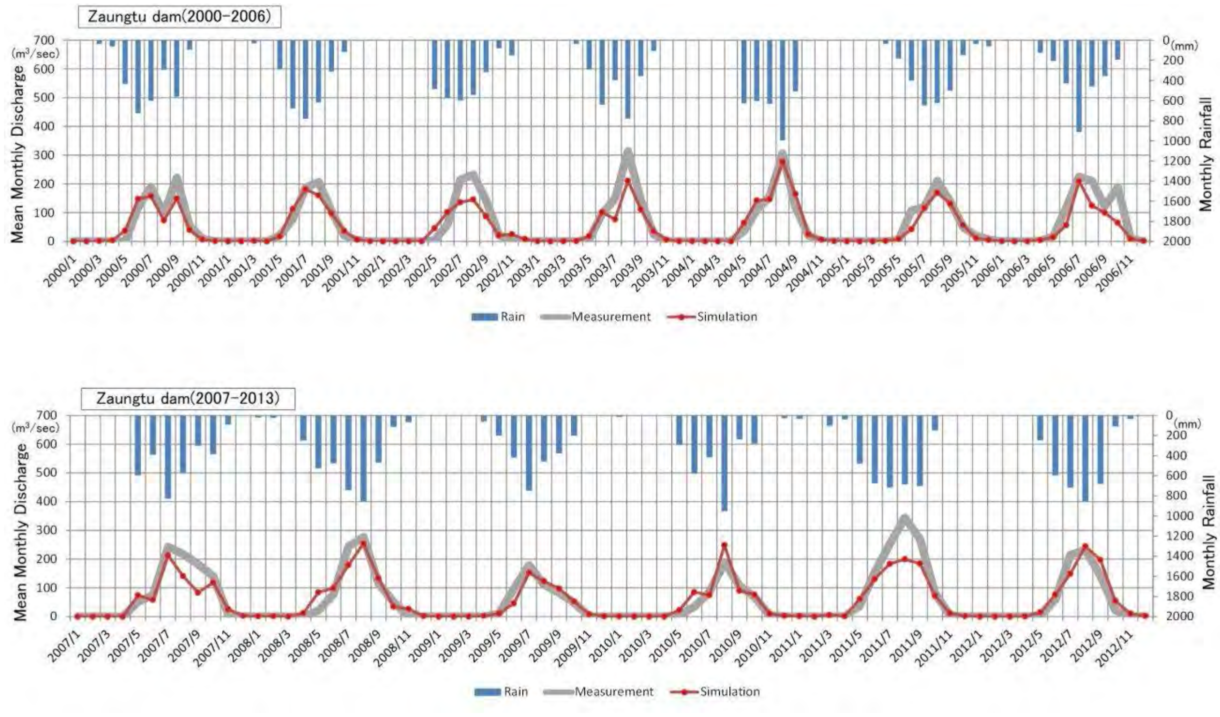


Figure 4-6-7-2 Calibration Result (Zaungtu)

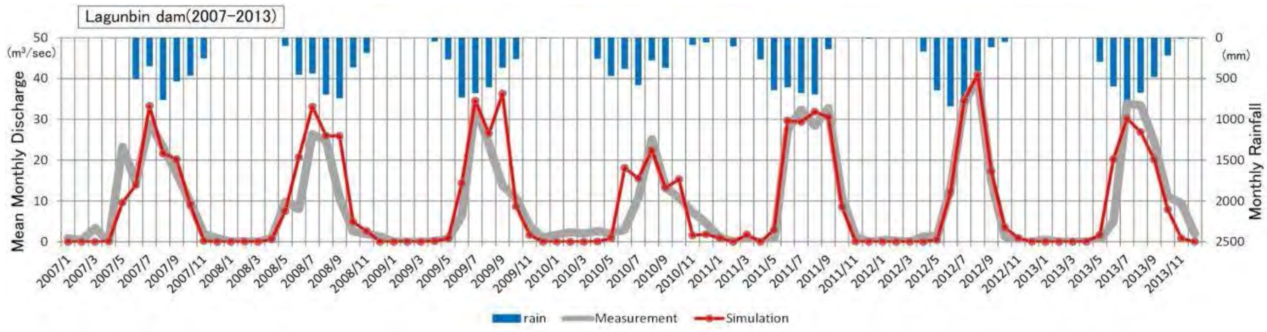


Figure 4-6-7-3 Calibration Result (La Gun Byin)

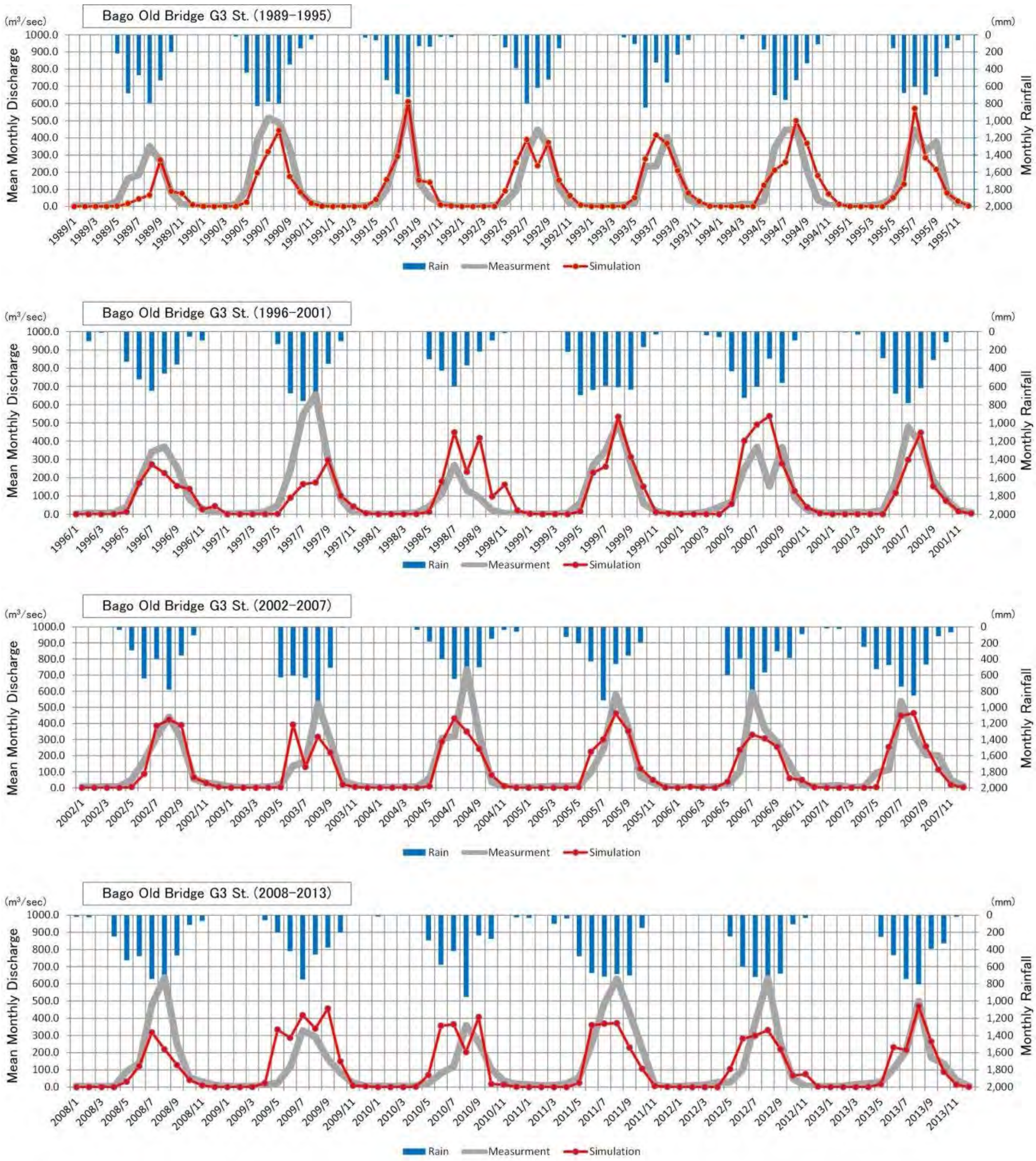


Figure 4-6-7-4 Calibration Result (Bago Bridge)

4-6-8 Model Output

With normal precipitation, it may be intercepted and held in the vegetation canopy or fall to the soil surface, or later lost by evaporation. By the heavy rain, water flows overland as runoff and moves quickly toward a stream channel and contributes to short-term stream response. At the upper reach of river course, especially lain by Red Brown Forest soils or Lateritic soil, some water begins to infiltrate into the subsurface. However, the down reach covered by Meadow & Meadow Alluvial soil in low alluvial plain, most of rainwater is run-off into channels and frequently flooding over in the alluvial low land due to the low infiltration rate, shallow water table and the backwater by tidal effect. At the lower reach, water are held in temporary ponds, and soil layer, the half of water is evapotranspiration and rest of water may slowly make its way to the surface-water system via underground paths. Along with the potential pathways of water movement in the project area, flowing outputs (1) - (7) are selected and post-processed among SWAT’s options.

(1) Area Rainfall
(2) Potential Evapotranspiration
(3) Actual Evapotranspiration
(4) Percolation
(5) Surface Runoff
(6) Base flow
(7) Water Yield

(1) Area Rainfall

Area rainfall was calculated using with the 6 stations. The area rainfall for the Bago basin was obtained as a range of 2,787 mm/year to 3,202 with an average of 2,880 mm/year in 30 years (1984-2013) for the basin. The rainfall for respective sub-basins is shown in Figure 4-6-8-1.

(2) Potential Evapotranspiration

Potential evapotranspiration is the rate at which evapotranspiration would occur from a large area covered with growing vegetation which has access to an unlimited supply of soil water. The calculation was made with the Penman-Monteith method, and had a range of 1,422 to 2,668 mm/year an average of 1,541 mm/year was obtained, as shown in Figure 4-6-8-2.

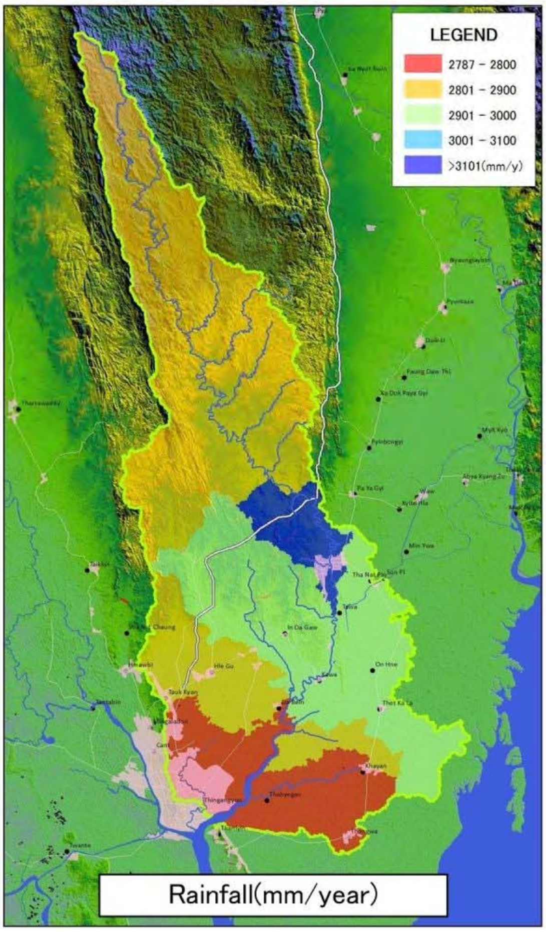


Figure 4-6-8-1 Area Rainfall

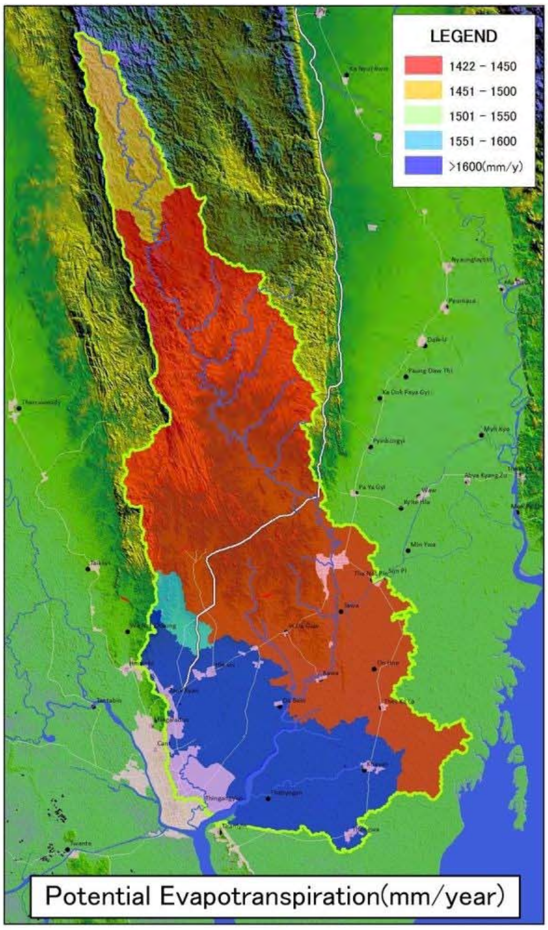


Figure 4-6-8-2 Potential Evapotranspiration

(3) Actual Evapotranspiration

The calculated value of evapotranspiration includes evaporation from rivers and lakes, bare soil, and vegetative surfaces; evaporation from within the leaves of plants (transpiration). The model computed evaporation from soils and plants separately. Potential soil water evaporation was estimated as a function of potential evapotranspiration and leaf area index. Actual soil water evaporation was estimated by using exponential functions of soil depth and water content. Plant transpiration was simulated as a linear function of potential evapotranspiration and leaf area index. As the result of the calculations, 765 to 1868 mm/year of actual evapotranspiration was taken, as shown in Figure 4-6-8-3.

(4) Percolation

Percolation was calculated for a soil layer in the profile. Water is allowed to percolate if the water content exceeds the field capacity water contents for that layer. Water that moves past the lowest depth of the soil profile by percolation enters and flows through the vadose zone in to the shallow aquifer. The lag between the time that water exits the soil profile and enters the shallow aquifer will depend on the depth to the water table and the hydraulic properties of the geologic formations in the vadose zone and groundwater zones. In the calculation, the percolation amount was obtained as 476 to 1,653 mm/year with an average of 977 mm/year in 30 years since 1984 as shown in Figure 4-6-8-4.

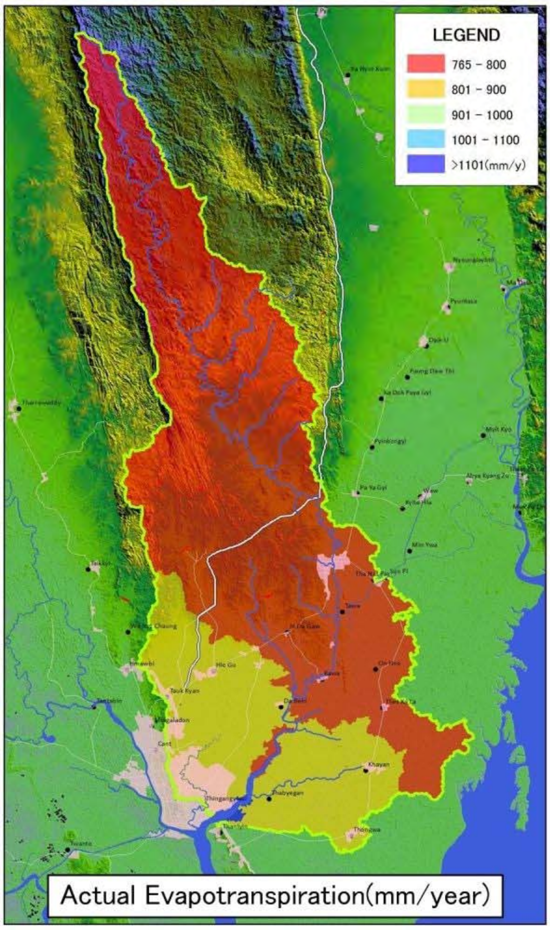


Figure 4-6-8-3 Actual Evapotranspiration

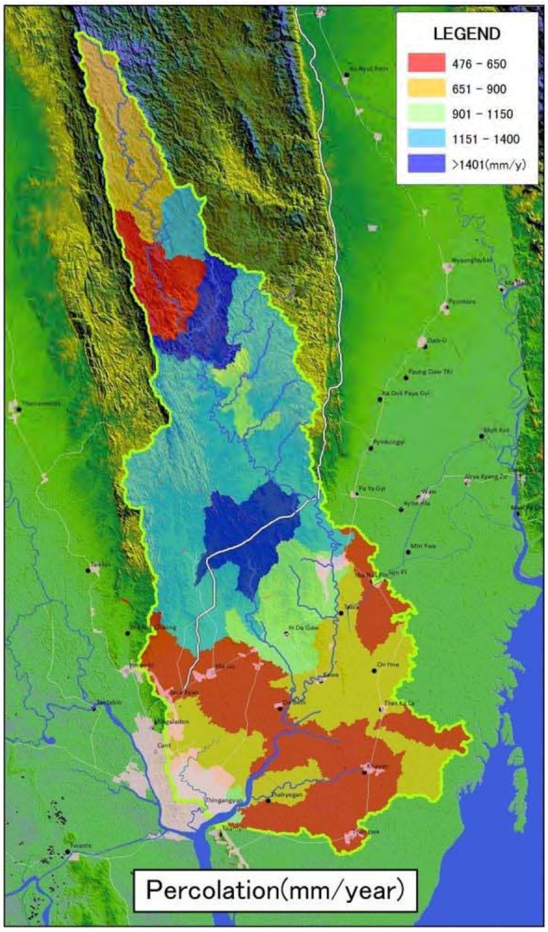


Figure 4-6-8-4 Percolation

(5) Runoff Volume

Surface runoff occurs whenever the rate of rainwater to the ground surface exceeds the rate of infiltration. When rain is initially applied to a dry soil, the infiltration rate is usually very high. However, it will decrease as the soil become wetter. When the rainwater is higher than infiltration rate, surface depressions begin to fill. If the rain continues to be higher than the infiltration rate once all surface depressions have filled, surface runoff will begin. In the analysis, surface runoff was calculated with the SCS Curve Number method and is estimated as 271 mm/year to 1,730 mm/year with an average of 1,029 mm/year for 30 years, as shown in Figure 4-6-8-5.

(6) Base flow

Depending on topography, the infiltration/percolation water is moved upward from the water table into the capillary fringe, a zone above the groundwater table that is saturated. In the analysis, the water amount from the shallow aquifer that returns to the reach during one year was calculated as base flow. It takes 195 mm/year to 1,091 mm/year with an average of 597 mm/year[4] as shown in Figure 4-6-8-6.

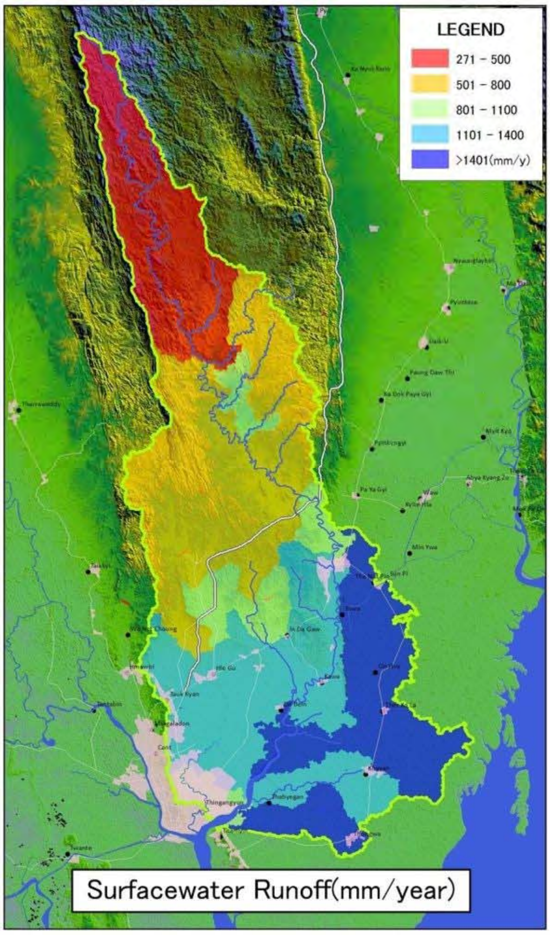


Figure 4-6-8-5 Surface Runoff

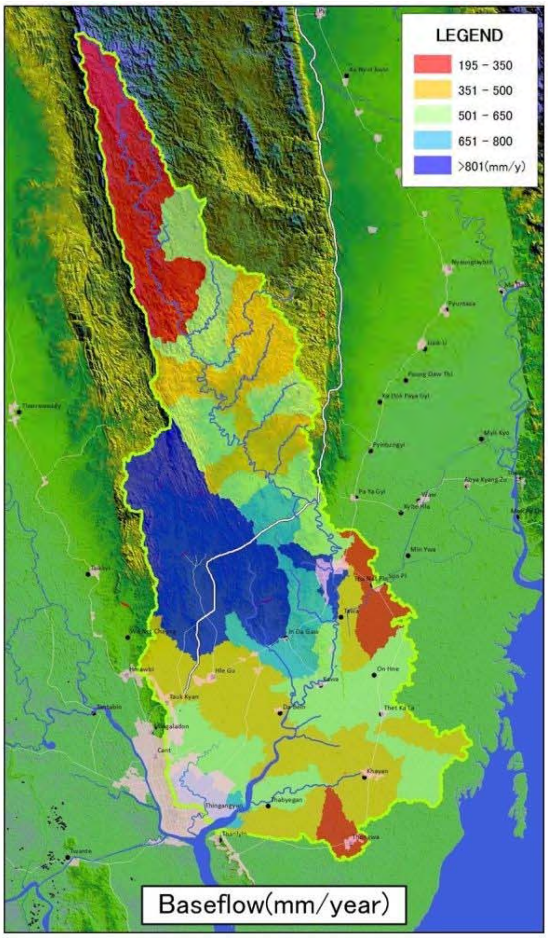


Figure 4-6-8-6 Base Flow

(7) Available Water yield

Flow in a basin is classified as overland and channelized. The primary difference between the two flow processes is that water storage and its influence on flow rates is considered in channelized flow. Main channel processes modeled by SWAT include the movement of water in the stream network. Open channel; flow is defined as channel flow with a free surface, such as flow in river or partially full

[4] Unit of runoff and base flow is indicated as height, as is 'runoff height(mm)' and 'base flow height(mm)', which divided by catchment area in order to comparison with rainfall and evapotranspiration.

pipe. SWAT uses Manning's equation to define the rate and velocity of flow. Water is routed through the channel network using the valuable storage routing method. SWAT treats the volume of out flow calculated with valuable storage routing method as the net amount of water removed from the reach. As transmission losses, evaporation, and other water losses for the reach segment are calculated, the amount of outflow to the next reach segment is reduced by the amount of the loss. When outflow and all losses are summed, the total amount (called the Water yield in SWAT) will equal the value obtained from the valuable storage routine method. Maximum rate is shown in the downstream of Bago city of 2,163mm/year while the minimum rate is found near Zaungtu Village of 1,150mm/year. The basin average is 1,710mm/year. In Figure 4-6-8-7, the distribution of water yield is shown.

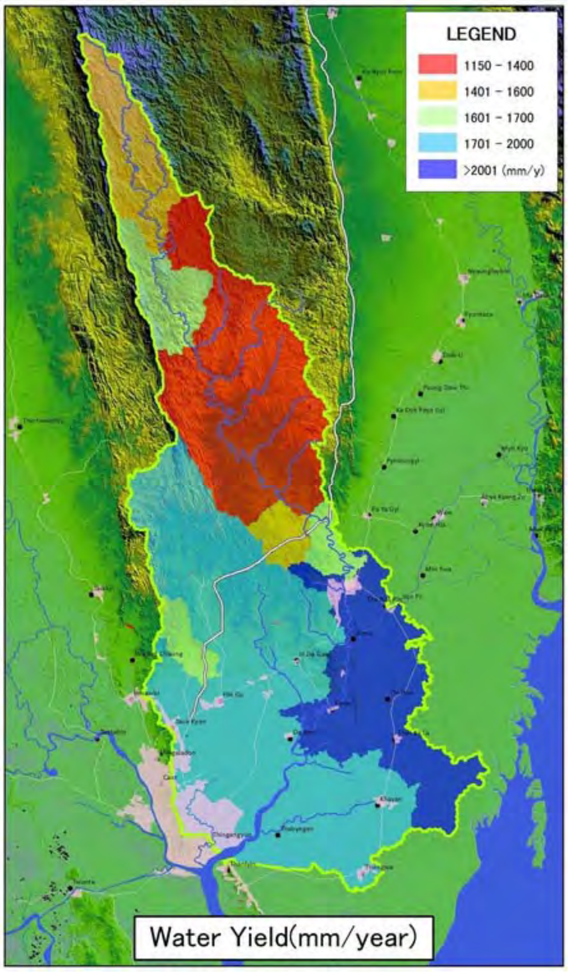


Figure 4-6-8-7 Water Yield

4-6-9 Basin Water Balance

(1) Water Balance

In Table 4-6-9-1, water balance calculated is shown, as the average for 30 years from 1984 to 2013 and annual average of 2010 which is the dry year for 1/10 years (3rd driest in 30 years).

Of the balance, at an average for 30 years, rainfall is 2,880 mm/year, and 797 mm/year is lost by evapotranspiration and 1,508 mm/year flows into channels. The remaining 398 mm is recharged into the aquifer and re-evapotranspiration from groundwater through deep-rooted plants.

In the case of a dry year, (2010 was the 3rd driest year in 30 years, which is regarded as 1/10 years' dry year), its rainfall is 2,595 mm/year, and out of this, 824 mm/year and 1,394 mm/year are respectively allocated to evapotranspiration and surface water discharge (water yield). Others of 377 mm/year turn into subsurface system and are lost by re-evapotranspiration directly from aquifer.

Table 4-6-9-1 Basin Water Balance

Year	Area Rainfall	Surface Runoff	Lateral Flow	Base Flow	Percola -tion	ET*1	PET*2	Water Yield	GW. Recharge*3	Order of Water Yield
	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	-
1984	3,102	1,015	184	639	1,089	815	1,495	1,837	450	24
1985	2,718	959	140	487	849	778	1,531	1,586	354	8

1986	2,456	677	132	462	805	814	1,492	1,272	371	2
1987	2,183	585	114	375	693	803	1,469	1,074	307	1
1988	2,873	1,006	153	510	904	810	1,482	1,670	394	16
1989	2,812	910	165	569	967	775	1,467	1,643	393	13
1990	3,159	1,066	196	636	1,093	799	1,504	1,898	462	25
1991	2,528	762	134	513	858	771	1,483	1,409	348	4
1992	2,622	806	147	524	898	775	1,479	1,478	370	7
1993	2,649	940	123	525	858	737	1,481	1,587	325	9
1994	2,969	1,043	144	613	994	778	1,469	1,800	392	23
1995	2,874	969	157	566	950	792	1,470	1,691	391	18
1996	2,824	969	141	527	900	810	1,478	1,637	377	12
1997	2,806	963	161	545	935	759	1,504	1,669	379	15
1998	2,534	802	114	515	836	768	1,508	1,430	336	6
1999	3,653	1,379	206	772	1,270	793	1,437	2,358	502	30
2000	2,906	962	162	595	1,007	780	1,461	1,720	406	20
2001	2,905	879	167	601	1,022	835	1,532	1,647	423	14
2002	3,282	1,244	161	610	1,029	832	1,555	2,015	436	28
2003	2,755	912	149	537	915	798	1,530	1,598	359	10
2004	2,940	973	192	568	1,003	773	1,562	1,733	434	21
2005	2,613	818	148	449	797	808	1,544	1,414	391	5
2006	2,859	906	158	626	1,044	786	1,480	1,690	382	17
2007	3,038	1,061	177	551	977	813	1,566	1,790	435	22
2008	3,285	1,101	193	666	1,139	844	1,529	1,960	481	27
2009	2,883	1,021	138	543	904	819	1,551	1,702	362	19
2010	2,595	794	155	445	811	824	1,615	1,394	377	3
2011	3,618	1,379	206	745	1,241	810	1,539	2,329	479	29
2012	3,152	1,121	181	600	1,015	819	1,559	1,902	431	26
2013	2,801	873	163	580	974	784	1,471	1,615	402	11
Average	2,880	963	159	563	959	797	1,508	1,685	398	-

ET*1: Actual Evapo-transpiration
PET*2: Potential Evapo-transpiration
GW. Recharge*3: Groundwater Recharge and Evapo-transpiration from Ground water

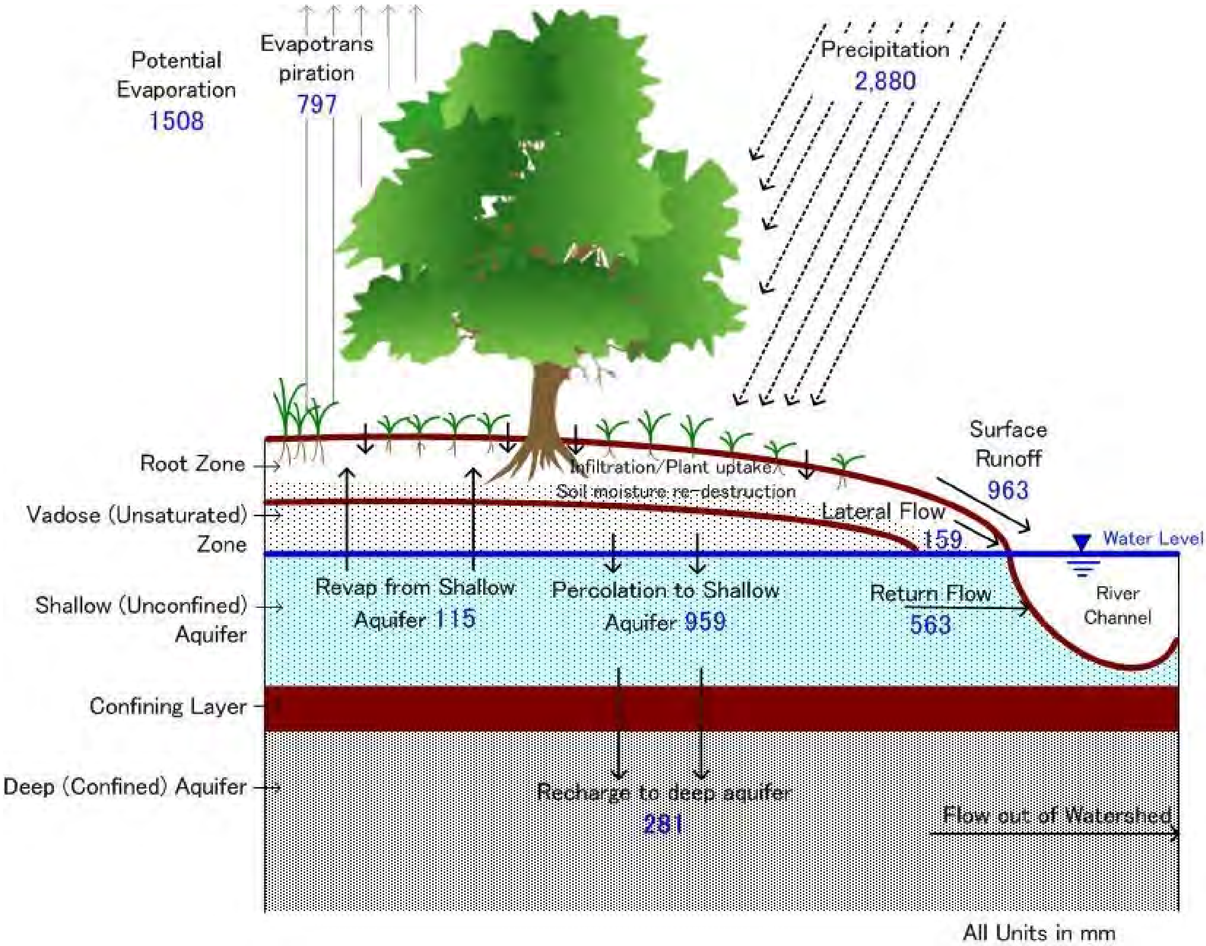


Figure 4-6-9-1 Basin Water Balance (1984-2013)

In the basin water balance, a runoff coefficient of the whole Bago Basin is calculated as 58%, which is 1,685mm/year of river inflow (surface runoff 963mm+lateral flow 159 mm+baseflow 563 mm) divided by 2,880mm/year of rainfall. This rate can compare to observation records (52% of Bago Bridge Station in the mid-stream, 60% of Dawei Station in the up-stream) as same level. As well, the ID's design guideline (60%: slightly permeable and bare land, 50%: slightly permeable and partly cultivated or covered with vegetation) is also set as same level. As for 797 mm/year of Evapotranspiration, its value is not far from other analysis based on satellite information[5] (750mm in the mid-stream). The groundwater recharge, obtained as 281mm by SWAT, is also same level as

[5] MODIS Global Evapotranspiration Project (MOD16) http://www.ntsg.umt.edu/project/mod16

result of Tank model analysis made in a similar condition of soil and geology[6]. In comparison with other results of analysis, this SWAT result is judged as enough accuracy to understand the water balance of the Bago Basin.

4-6-10 Water Yield of Sub-Baisn

As described in above subsection, basin water balance are calculated based on each sub-basins' balance. A sample of water yield of each basin is shown in Figure 4-6-10-1.

[6] In tank model analysis in the Study, the height of groundwater recharge was calculated as wide range of 60 mm/year to 600 mm/year. In the case of Pegu formation, which is same condition as a hilly area of the Bago basin, 320mm/year of groundwater recharge is obtained.

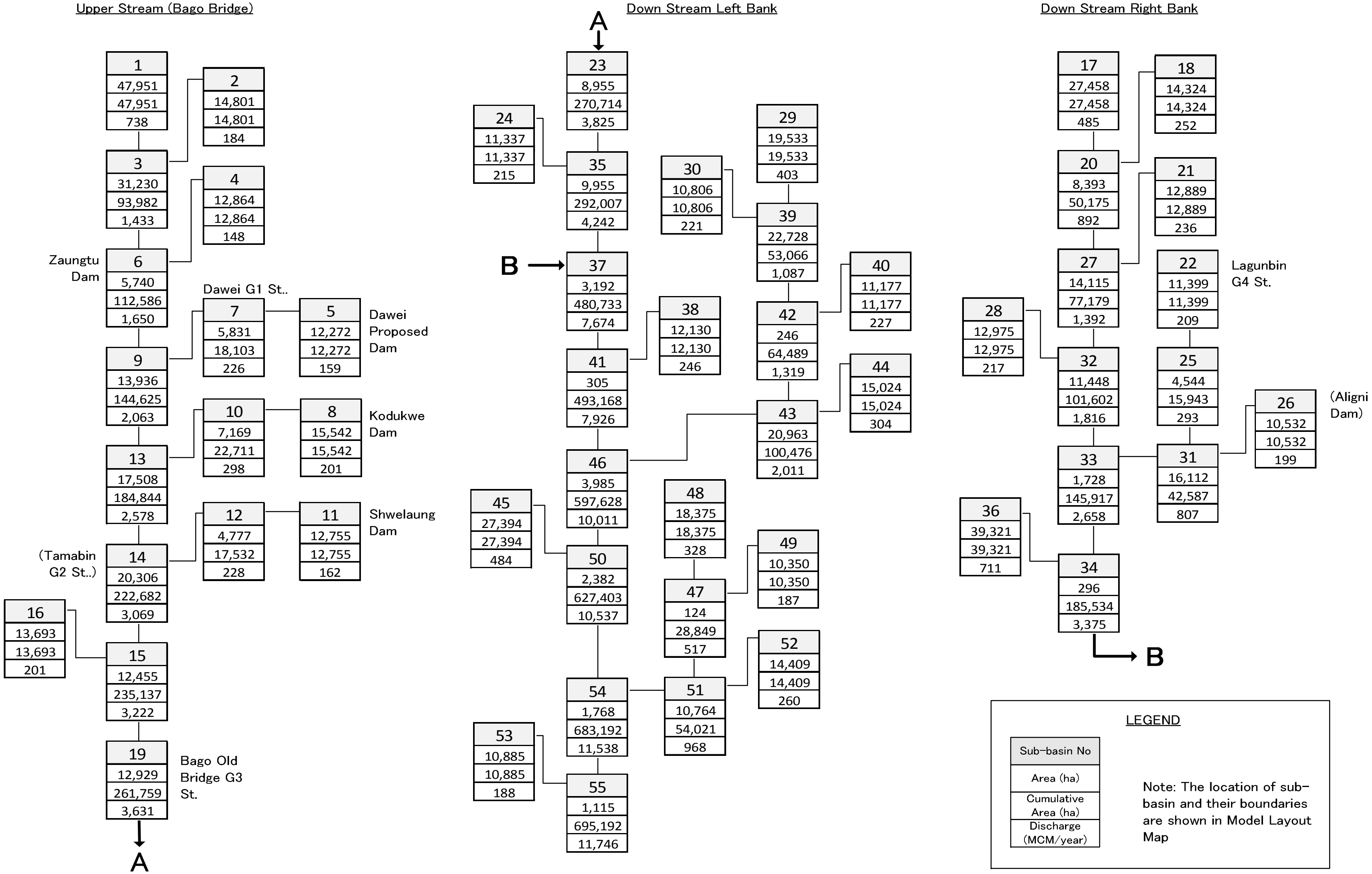


Figure 4-6-10-1 River Discharge for Sub-basins

4-7 Monitoring System and Database

4-7-1 Monitoring items

The water resources monitoring and its database establishment is made for SEZ and the adjoining area (Thanlyin, Kyauktan, Thongwa and Khayan Townships), the Bago basin, the bordering area between and Bago River (eastern bank) and Sittaung River (western bank of River Mouse). The monitoring items are of rainfall, water level, river discharge, water quality, riverbed sediment, operation and management record of dams, weirs, gates and sea phenomena (refer to Figure 4-7-1-1) in order to utilize for a future plan and management on the Bago basin. Standing on this view, the necessary number of observatories (and an observation framework) is described below.

Rainfall: Due to the scale of the observing area covered by the Bago basin (5,350 km^2) and to maintain the necessary accuracy for area rainfall(average rainfall) as basic information of basin water resources, the density of rain gauges are ideally desired to be 50km^2/site[7], which is corresponding to at least 107 sites for the area. But, actually in the Bago basin, its half is in the inaccessible area laid by the mountainous to hilly forest without any roads. Consequently, half of the ideal number of 50 sites is considered as the monitoring plan, while in plan areas, the existing rain gauges have been installed along with 23 sites of dams and weirs and are functioning as manual stations with the graduated cylinders. In the plan, these 23 stations are to be changed to the automated tipping bucket rain gauge and new stations are also made in between the existing stations. In addition, the telemeter system is also considered, especially in hilly to mountainous areas.

River Discharge: The Bago River, regarded as the main subject for monitoring, is deeply intruded by tide. It can be traced over 80 km inland from the River Mouse, and the applied method for river discharge is also different due to whether or not the tide affects the river flow. For the un-tidal section, the Rating Curve Method can be applied, the same as for existing stations. So, the monitoring points follow those of existing stations, adding the improvement of accuracy with frequent observation. As for the tidal section, there is none of the existing station due to the burden of high cost[8]. New monitoring point(s) therefore shall be established. In conjunction with the change of the water use situation in the future, the adequate location of an observatory is selected in the section of SEZ to Bago city. For the flow rate of the tributaries, many dams and weirs exist, enabling measurements using those water facilities.

[7] The Japanese Ministry of Land, Infrastructure, Transport and Tourism Technical Criteria for River Works: Practical Guide for Survey, Chapter 2 hydrology and hydraulic observation, Sub-section 2 rainfall observation (2.3.1) /

Hashimoto T. (1977), Study on the estimation of the accuracy and reliability of area rainfalls by sample design method, Report No. 149 of Public Works Research Institute, Ministry of Land, Infrastructure, Transport and Tourism.

[8] The Japanese Ministry of Land, Infrastructure, Transport and Tourism Technical Criteria for River Works: Practical Guide for Survey, Chapter 2 hydrology and hydraulic observation, Sub-section4 river discharge survey (4.11.1).

Water Level: The water level is observed at the river discharge points. Furthermore, at facilities such as dams and weirs, of which are available points for estimating river discharge (≒outflow), the water level is also monitored. The measurement devices are planned to use the pressure type water level logger.

Water Quality (surface water): Water quality points are considered, giving future water use and including the existing 12 points made by the Survey (refer to Figure 4-4-9-1) and the new points locating the border area between the Bago and Sittaung Rivers as well as the diversion route from the water source to the beneficiary (SEZ and adjoining area).

River Bed Sediment: Sediment monitoring sites are installed respectively for the river sections (hill, alluvial, and river-mouth) and the River Discharge stations are used in combination with the sediment monitoring points.

Dam/Weir: The monitoring is subjected to the management and operation records of dams, weirs, gates, etc. constructed by ID and DHPI.

Sea Phenomena: The seawater levels (the water level at River Mouse), interfered by tidal changes and waves, and is measured, as it is closely related to river flow upstream. In particular, the monitoring point is to be planned at the estuary of the Sittaung River known as “a place of tidal bore”, resulting in large tidal changes.

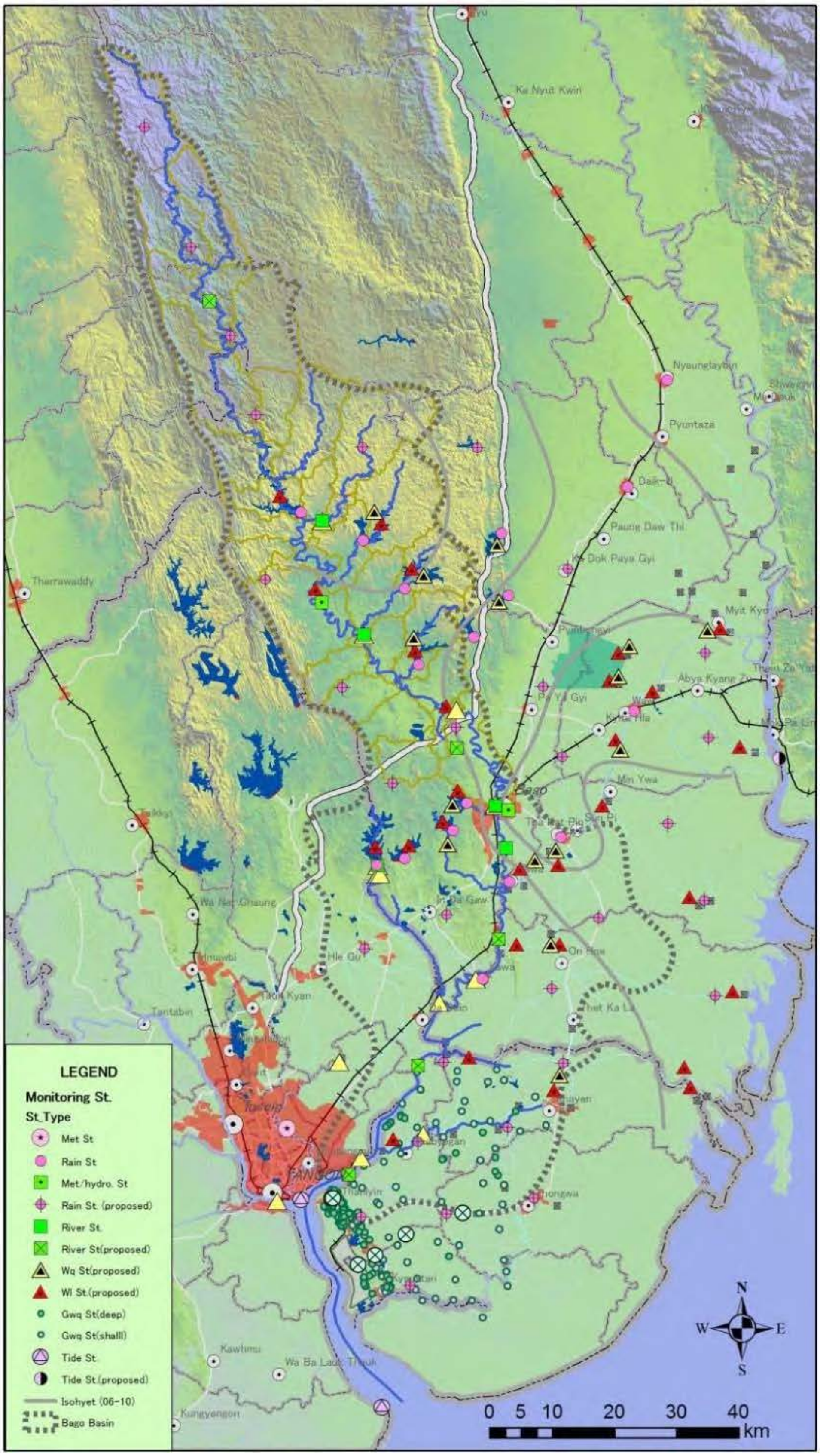


Figure 4-7-1-1 Monitoring Points

4-7-2 Data Base

In the Survey, information and data accumulated in ID was not fully surveyed and the detail of their data modeling cannot be described. The collected data are classified as three (3) types:

1) Existing data collected from relevant sections of respective organizations and agencies

2) Observation data surveyed in the Study (data is used for groundwater/hydrological analysis)

3) Processed tables and figures and secondary data arranged from 1) and 2) data.

As for 1) and 3) data, the data type and format are not unified and various data are mixed together and stored in different ID sections and branches respectively. In current situation ID has an obstacle on data and document management. Therefore, ID expects to introduce new data collection/management/shearing system capable to easy access and browse various data. In the Study, as preparation for future data management plan, the collected data were grouped into three (3) categories of (a) Hydrological survey/Water source, (b) Water supply/Water use and (c) Water facility with 22 sub-areas as a recommended database structure, as shown in Table 4-7-2-1.

Table 4-7-2-1 Data base Structure

Categories of Data Modeling	Sub-areas Symbol	Sub-areas
Hydrological Observation And Water points	HO-00	Water Point (or Water measure Point)
	HO-01	Meteorological Observation (or Meteorology)
	HO-02	River Discharge(or River)
	HO-03	Spring Discharge(or Spring)
	HO-04	Observation Well
	HO-05	Ground Water Level survey (or Ground Water Level)
	HO-06	Geophysical Survey (or Geophysics)
	HO-07	Water Chemistry survey
	HO-08	Chemical analysis (or Chemistry)
	HO-09	Well construction
	HO-10	Pumping Test
Water Supply And Water Demand	WS-00	Water Supply Point
	WS-01	Water Service
	WS-02	Water Production
	WS-03	Well Inventory Survey
	WS-04	Irrigation Survey
	WS-05	Agricultural Survey (or Village Survey)
	WS-06	Environmental and Social Survey
Water Facility	WF-00	Water Facility Project
	WF-01	Water Facility Point
	WF-02	Dam
	WF-03	Pump Station (or Pipe line)
	WF-04	Irrigation Network
	WF-05	Drainage Network

	WF-06	Sub Basin
3 Areas	22 sub-subject	

In the future database establishment in the ID, the database structure is recommended to be applied for data classification, and various data is to be stored and registered in certain rule. In conjunction with the rule, the collected data in the Study were also arranged in to 22 sub-areas for a future implementation of data base management system.

(1) Observation and Operation Framework

The operation and management of hydrological monitoring and database are expected to manage by the present framework of ID. At the present time, hydrological measurement and facility maintenance are conducted by related organizations in ID; Hydrology Branch, Investigation Branch, Construction Circles, Region/States Maintenance Office, Design Branch and Planning and Works Branch. The manual measurements for rainfall and river stage are carried out by construction circle and maintenance office due to the most of station is installed in existing water facility. In the construction duration, construction circle has responsible to install the rain gauge and successive measurement. After construction, maintenance office has role to follow measurement of rainfall and river stage. In the most of major water facility, the O/M staffs are engaged full time in the field and has task for daily maintenance and necessary observation (in daily or hourly reading in flood period). All the measurement data are then sending to planning and works branch and feedback to related organizations. While for river discharge survey and auto-mated measurements, which requires a skill and knowledge to operate the equipment, hydrology branch is exclusively in-charged. The water quality survey is done by plural organizations of Hydrology Branch, Investigation Branch and Irrigation Technology Center. As for river bottom sediment, its survey is carried out by Investigation branch. Further for leveling survey necessary to station's installation, it was done by topo-survey team under the Design branch. At the current measurement works, these ID’s framework for hydrological measurement is well functioned without any serious problems as far. The future monitoring plan in Bago basin is also recommended to manage by existing ID’s framework.

As for the database management system, ID has keen to intention to introduce the system. However, there are basic obstacles on the network condition within ID, communication lines to outside and experience of ID staff, and it must be required a long term plan to clear those for actual implementation. In the current situation, the data collected in the Study was not structuralized for data base and only classified into sub-areas with keeping original data formats and types.

(2) Database Management System

As a tool for basin management, Data-Base Management System (DBMS) may be considered in the future. An idea of Schematic diagram of DBMS is shown in Figure 4-7-2-1.

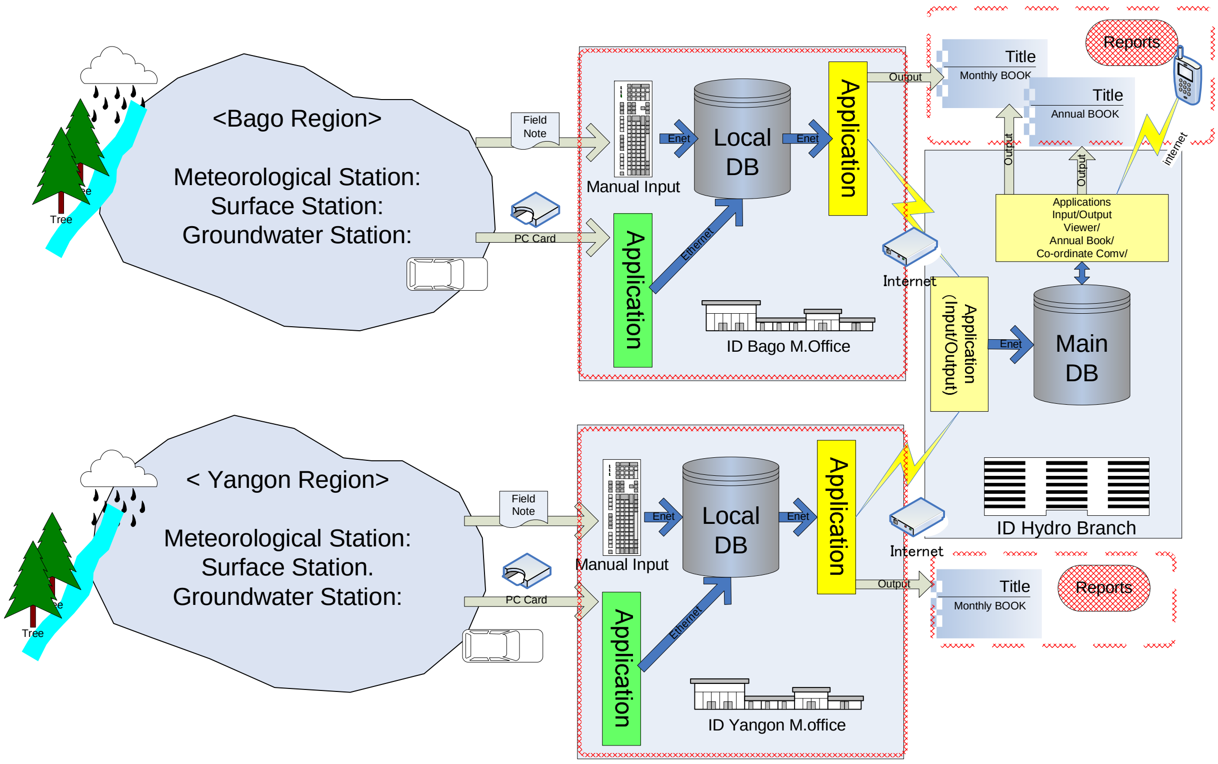


Figure 4-7-2-1 Data Base Operation and Management

In the future operation of the monitoring system and database, the regional office (Yangon and Bago Region Maintenance Office) has conducted the (a) checking of the observation equipment, (b) collecting of the measurement data, (c) initial verification (correcting outlier caused by equipment/reading error etc.) and (d) inputting of data to the Local Database (Local DB). The Local DB is installed in each regional office; however, it has the same structure and format as those of the Main data base (Main DB) used in the headquarters. Using wide area network (WAN) through the Internet or leased line, the Local DB is linked to the Main DB. The data inputted into the Local DB are simultaneously transferred to the Main DB in headquarters. The secondary verification then follows on the data and is registered (or re-registered) to the Main DB. Registered data is to be fed back to the Local DB on a regular basis. At the same time, the public moiety, a capable part to be opened as repositories, is opened outside. The opened material is the monthly and annual report, and is provided through the Internet with a PC or mobile phone.

CHAPTER 5

WATER DEMAND FORECASTING

CHAPTER 5 THE WATER DEMAND FORECASTING

5-1 Precondition of the Forecasting on the Water Demand

5-1-1 Industry Targeted

On the occasion of the forecasting of the water demand from the survey area, the composition element of the amount of the water demand is defined. According to the Water Resources White Paper compiled by the Ministry of the Land Infrastructure and Transportation of Government of Japan in 2012, the relationship between the water resources potential and the water demand are shown below as a pattern diagram:

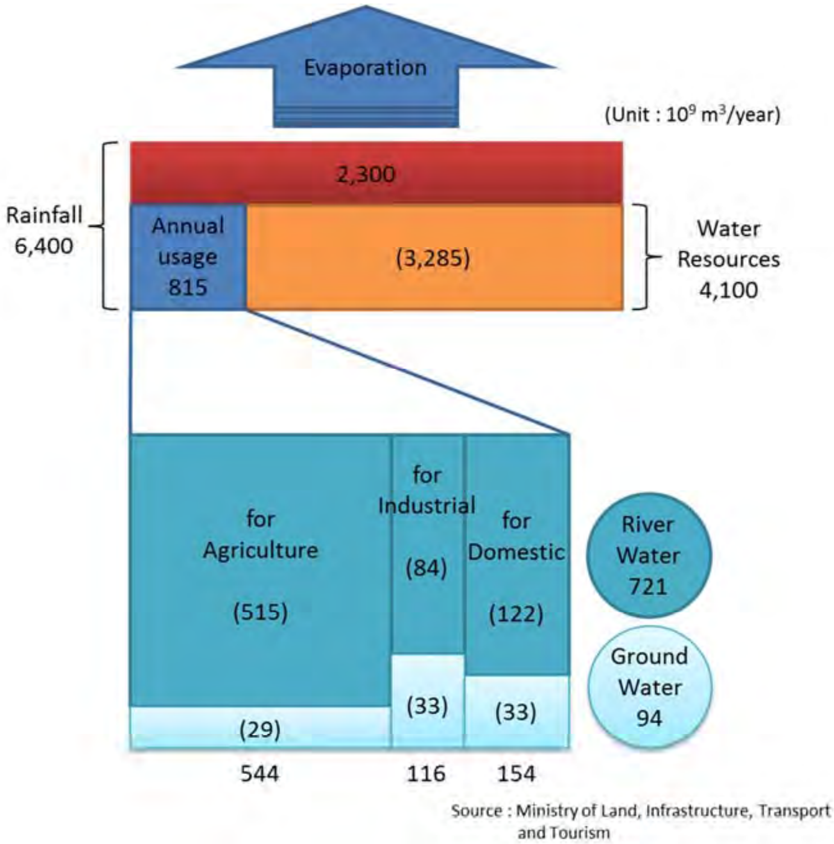


Figure 5-1-1 Water Resources Potential and Water Demand in Japan

According to the result of an analysis based on the statistical data in the last thirty (30) years, on the occasion of the water demand forecasting, the following three (3) items of the water demand should be considered for rationale estimation of the forecasting:

- Water for Agriculture
- Water for Industry
- Water for Domestic use

Nowadays Japan is not an agrarian country, but the water for agriculture still shares the biggest water user at 67%.

Therefore in this paper, three items (mentioned above) shall be considered for the forecasting.

5-2 Forecasting on the Water Demand for Agriculture

5-2-1 Present Situation of the Agriculture in the Target Area

Agriculture shares the first priority in the structure of the GDP of 27.8% in Myanmar, and even as it is going toward a manufacturing industry nation in the future, agriculture is the main industry at this moment. Since the natural resources of the Earth and the Water are essential components for agriculture, an agricultural field is the biggest user of the water resource.

From the "Five-Year Plan of Action from 2011-2012 to 2015-2016 of the Department Agriculture" the target is mentioned in the paragraph below.

- Increasing the crop yield per acre
- Expanding sown area
- Systematically applying quality seeds, chemical fertilizers and pesticides
- Educating for Good Agriculture Practices
- Conducting the agricultural research and development
- Training and educating for human resource development

To realize the expanding sown area, the application of quality seeds and increasing the crop yield per acre, the water demand will certainly be increased. To keep a sustainable water supply for an agricultural activity, additional water resource development will be a major issue.

5-2-2 Future Agriculture in the Target Area

(1) Present irrigated ratio

Considering the population movement, requiring the increase of food production and promotion of the policy of the rice export for obtaining foreign currency, the promotion of agriculture is exceedingly a priority political issue. Consequently, it can be said that the biggest user of the water resources will still be an agricultural field in the future. And the water resources demand depends on the implementation ratio of the irrigation system for sustainable agriculture in Myanmar.

According to "Myanmar Agriculture in Brief (Ministry of Agriculture and Irrigation, August 2012, P37)", the Irrigation ratio in Myanmar is reported at 16.7% throughout the country. The irrigation ratio in the target area is reported below as a result of interviews conducted.

	Yangon District	Survey Area (4 Township)
Administrative Area (km^2)	5,030.9	2,665.3
Cultivate Area (ha)	357,337	190,513
Irrigated Area (ha)		0
Irrigated Ratio (%)		0

(2) Implementation ratio of the irrigation system in 2040

The "Five-Year Plan of the Department Agriculture" couldn't be found through the survey activities in the Headquarters. The "Agriculture Sector Development Objectives", which is a part of the "National Comprehensive Development Plan (2011-2031) compiled by the Ministry of National Planning and Economic Development", mentioned the numerical target for a five year period as shown below.

Table 5-2-1 Five-Year Plan of Department Agriculture

Year	Dam/Reservoirs	Beneficiary Area (million acre)	Irrigated Area (million acre)
2011/12	415	33.93	5.65
2012/13	421	33.94	5.72
2013/14	424	33.52	5.76
2014/15	433	33.85	5.80
2015/16	443	36.67	5.82

The implementation ratio of the irrigation system in 2011/12 is estimated as shown below.

5.65 (million acre) / 33.93 (million acre) = 16.65 (%)

The target ratio of the irrigation system in 2015/16 is estimated as shown below.

5.82 (million acre) / 36.67 (million acre) = 17.29 (%)

Following this implementation plan until target year of the plan in 2040, during thirty years (30) from 2011 to 2040, an increase of the irrigation ratio can be estimated as shown below.

$(17.29 - 16.65) \times (2040 - 2010) / 5 = 3.84$ (%)

Consequently, the mean implementation ratio of the irrigation system in 2040 will be assumed as shown below.

$16.65 + 3.84 = 20.49$ (%)

(3) Cultivated area

Since there is no the agricultural development plan, the cultivated area in 2040 can't assumed based on the official materials. It can be assumed as follows:

- Tanlyin township and Kyauktan township has possibility and potential of the regional development. The cultivated area in 2040 will be decreased around 30%,
- Thongwa township and Kyauktan township will be same compare with present situation.

Table 5-2-2 Transition of Cultivated Area (in 2040)

Unit; ha

	Thanlyin	Kyauktan	Thongwa	Khayan
Cultivating area	24,762	62,883	58,805	44,063
Decreasing ratio	30%	30%	0%	0%
Cultivating area in 2040	17,333	44,018	58,805	44,063

5-2-3 Forecasting of the Irrigation Water Demand

On the forecasting of the irrigation water demand, the following model shall be assumed based on the national agricultural policy and improvement policy of the irrigation system.

- The cultivated area in the survey area has possibility to be increased by following the population growth in the survey area, based on the self-sufficiency of the rice. The other side, it has possibility of the progress of urbanization for Thanlyin and Thauktan township. The cultivated area in 2040 is obtained as mention in Table 5-2-2.
- Since one of the political targets of the Government is stated as an increase of agricultural production, the implementation of an irrigation system is set at 20.49 (%).
- The sown area of the paddy will be increased in order to correspond with an increase of the population of the cultivated area in Thongwa and Khayan township. Thanlyin and Kyauktan township will be developed in progress of urbanization.
- The required water resources in 2040 shall be estimated by applying the above-mentioned formula based on the sown area assumed for the summer paddy.

Table 5-2-3 Forecasting of Irrigation Water Demand

	Thanlyin	Kyauktan	Thongwa	Kayan	Total
Cultivated area (ha)	17,333	44,018	58,805	44,063	164,219
Summer paddy (ha)	3,552	9,019	12,049	9,029	33,649
Required water demand ($10^6 m^3$)	64.9	164.9	220.4	165.2	615.4

Summer paddy area = (cultivated area) × (Implementation ratio of Irrigation system 20.49%)

According to the estimation shown above, the water demand for agriculture in 2040 can be forecasted at 615,400,000 m^3. The additional water resource development should be considered to cover the survey area by irrigation system to meet the national plan.

The Irrigation Department has an aggressive water resources development plan in the Bago river basin. It had no reply to the survey team regarding the question for the possibility of the above-mentioned value of the water requirement in their development plan.

It should be considered that the study for the future water requirement on the irrigation field will be done with higher accurate improvement plan of the irrigation system by the Irrigation Department.

5-3 Forecasting on the Water Demand for Industry

5-3-1 Present Situation of Water Utilization of Industy in the Target Area

(1) Existing small scale reservoir

Thilawa reservoir is only using for the industry use. There is no reservoir operation record under management of the Irrigation Department. According to the interview at the site, the total amount of the supply water is 450,000 m^3/year for the factory located at nearby the Thilawa reservoir.

(2) Groundwater

According to the result of the inventory survey of the existing wells, it can find the big user of the groundwater of 12m^3/day or more to meet the number of the factories in the Thanlyin township of 47, compare with normal user of 1 m^3/day larger of smaller. The big users in the four township can be summarized as follows based on the existing wells of 12,409.

Table 5-3-1 Estimation of Amount of Groundwater for Industry Use

	Thanlyin	Kyauktan	Thongwa	Kayan	Total
Number of well	10,563	1,703	64	79	12.409
Yield of ground water (m^3/day)	13,639	2,451	215	586	16,891
Number > 12m^3/day	56	11	5	20	92
Max. Yield (m^3/day)	72.0	35.0	40.8	35.7	-
Average Yield (m3/day)	42.0	29.7	26.4	23.9	-
Number of factories	47	15	0	0	62
Total amount of Yield (m^3/day)	1,974	446	-	-	2,420

Total amount of the present groundwater for industrial use in Thanlyin and Kyauktan township for the industry use is estimated 2,420 m^3/day.

5-3-2 Required Water Demand of Industry use for the Four Township in 2040

(1) Small scale reservoir

The JICA survey team inquired to the Irrigation Department, which is in charge of the daily maintenance of the Thilawa reservoir, regarding the reservoir operation, the Irrigation Department has no future plan on this mater. Therefore, the industrial use of the small scale reservoir in 2040 will be kept of 450,000 m^3/year.

(2) Groundwater

In case of the estimation of the future water demand for the industrial use of the gourndwater, the number of factory in the Thanlyin and Kyauktan township will be doble based on the present situation and the Thongwa and Khayan township will be same number of Kyauktan of the present situation.

Table 5-3-2 Estimation of Groundwater for Industry Use (in 2040)

	Thanlyin	Kyauktan	Thongwa	Kayan	Total
Estimated number of factories	94	30	15	15	154
Required demand (m^3/day)	3,948	892	446	446	5,732
Annual demand (m^3/year)	1,441,020	325,580	162,790	162,790	2,092,180

5-3-3 Required Water Demand from the Thilawa SEZ

The water demand volume for the industrial activities in the Thilawa SEZ in the future developing stage are mentioned in the report of the JICA study on the Infrastructural Improvement for the Thilawa SEZ as follows.

The Thilawa SEZ consists of the total areas of 2,400 (ha). The Japanese investors will share the area of 420 (ha) classified as class-A, and the remaining 1,980 (ha) will be shared by local investors. The total required water for the industrial activities is summarized as follows.

Table 5-3-3 Total Required Water for Industrial Activities

Stage of the Development	Class-A	Others	Total
2015	6,000 – 10,000 m^3/year	-	6,000 – 10,000 m^3/year
2018	42,000 m^3/year	-	42,000 m^3/year
2025	42,000 m^3/year	78,000 m^3/year	120,000 m^3/year

The annual water demand of the Thilawa SEZ in 2040 will be estimated as shown below.

$$120{,}000\ (m^3/\text{day}) \times 365\ (\text{day}) = 43{,}800{,}000\ m^3$$

5-3-4 Required Water Demand for Industry

The required water demand for industry is summarized below.

Water utilization of small scale reservoir	450,000 m^3/year
Water demand for Industry in the target area	2,092,000 m^3/year
Water demand for Thilawa SEZ	43,800,000 m^3/year
Total	46,342,,000 m^3/year

5-4 Forecasting on the Water Demand for Domestic Use

5-4-1 Present Situation and Future image of the Domestic Use in the Target Area

According to the report of “The master plan study for The Project for the Improvement of Water Supply, Sewerage and Drainage System in Yangon City (JICA)” (May, 2013), the target ratio of the diffusion rate of the public water supply system in the Thanlyin and Kyauktan township were set at 40%. There was no mention for the Thongwa and Khayan township. For the estimation of the future water demand of two township, the diffusion rate are set at 10%.

Estimation of the domestic use water in the target area of four (4) townships will be carried out by applying the target ratio to the diffusion rate of the public water supply system and the prospect of the future population movement.

5-4-2 Population Movement in the Target Area

According to the above-mentioned report, the water supplied population of the Thalyin and Kyauktan township in 2040 was estimated as bellows. The water supplied population of the Thongwa and Khayan township are estimated based on the national growth ratio of population of 1.1% in reset year. (Statistical Yearbook (2011))

Concerning the population of the target area in 2012, the following data was reported by the administrative office for each township. The estimated population of each township in 2040 can be shown as follows by applying the annual population ratio of 1.1%.

Table 5-4-1 Estimated Population of Each Township (in 2040)

	Thanlyin	Kyauktan	Thongwa	Kayan	Total
Population (2011)	181,959	48,473	162,884	159,204	552,520
40% Water supplied Population (2040)	497,508	61,382	-	-	558,890
Gross Population (2040)	1,243,770	153,455	-	-	-
10% Water supplied Population (2040)	746,262	92,073	221,264	216,265	1,275,864

Source; The master plan study for The Project for the Improvement of Water Supply, Sewerage and Drainage System in Yangon City (JICA) 2013

5-4-3 Forecasting on the Water Demand for Domestic Use

The following formula will be applied to estimate the forecasting for the water demand for domestic use.

Water Demand = (Population)×(Water Service Coverage Rate)

×(Unit Water Supply Volume) / (1 - leakage ratio of water)

The water demand for the domestic use in the target area will be estimated as follows.

Table 5-4-2 Water Demand for Domestic Use in Target Area (1/2)

Items	Thanlyin		Kyauktan		Sub-total
Population (2040)	1,243,770		153,455		1,397,225
Water service coverage rate (%)	40	10	40	10	-
Water supply service population	497,	746,262	61,382	92,073	1,397,225
Unit water supply volume（ℓ）	150	150	150	150	-
Leakage ratio（10%）	10	10	10	10	-
Daily water demand　(m^3/day)	33,1	12,438	4,092	1,535	51,232
Annual water demand（m^3/year）	12,1	4,539,870	1,493,580	560,275	18,699,680

Table 5-4-3 Water Demand for Domestic Use in Target Area (2/2)

Items	Tongwa	Khayan	Sub-total
Population (2040)	221,264	216,265	437,529
Water service coverage rate (%)	10	10	-
Water supply service population	22,126	21,627	43,753
Unit water supply volume（ℓ）	150	150	-
Leakage ratio（10%）	10	10	-
Daily water demand　(m^3/day)	369	360	729
Annual water demand（m^3/year）	134,685	131,400	266,085

Note:Water service coverage and Unit water supply volume are shown in the report of the “Preparatory Survey Report on the Project for the Improvement of Water Supply, Sewerage and Drainage System in Yangon City (JICA)” (May, 2013)

The gross annual water demand is 18,965,765 m^3.

The gross annual water demand for the domestic use in the survey area can be estimated 19.0×106 m^3.

5-5 Future Water Demand in the Target Area

The future water demand in the target area for 2040 shall be summarized as follows based on the estimations above.

Table 5-5-1 Future Water Demand in Target Area (in 2040)

	Thanlyin	Kyauktan	Thongwa	Kayan	Total
Agriculture(10^6 m^3)	64.9	164.9	220.4	165.2	615.4
Industry (10^6 m^3)	-	-	-	-	46.3
Domestic Use (10^6 m^3)	16.7	2.1	0.1	0.1	19.0
Total (10^6 m^3)	-	-	-	-	680.7

Accordingly, the annual water demand for the target area for 2040 is estimated to be 680 million m^3 (680 MCM).

The various kinds of preconditions were set for the estimation of the water demand for the agriculture, industry and domestic use. For the making of the future regional water resource development plan, it should be collect more accurate estimation of the water demand.

5-6 Consideration from View Point of the Water Resources Potential

5-6-1 Groundwater Resource Potential

According to the evaluation on the analysis for the possibility of the groundwater development, following items were summarized as metioned in chapter 5-2.

- Daily average recharged volume of the groundwater is estimated of 47,000 m^3/day. Annual volume can be estimated of 17,155,000 m^3/year. It can’t meet to the required capacity of 680,000,000 m^3/year, which was estimated in chapter 5.5. It shares only 2.5% of the required capacity.

Moreover,

- According to the result of the inventory survey of the exsisting wells, groundwater resource of 17,000 m^3/day are developed already in the survey area.

- The ridge which is located between Thanlyin and Kyauktan is taking the groundwater with over pumping phenomenon.

Consequently, some possibility of the groundwater development in the survey area can be estimated as below with condition of prohibit strong pumping up of the groundwater at specific area.

47,000 (m^3/day) – 17,000 (m^3/day) = 30,000 (m^3/day)

The annual water demand for the irrigation purpose is estimated of 615.4 million m^3. It is equivalent to 1,686,000 m^3/day. It is 562 times of 30,000 m^3/day, which is available groundwater. The groundwater can't be main water resource for the future water demand.

The groundwater development is not suit for the future main water resource in the survey area, based on the above-mentioned considerations.

5-6-2 Surface Water Resource Potential

The basin water balance study was carried out by the analysis system of the SWAT simulation model. The detailed study was shown in section 4-6 of chapter 4 in the main report. According to the result of the analysis, the main points were summarized as bellows.

- Annual runoff discharge volume at the Bago Old Bridge is 3,631 MCM.
- Annual runoff discharge volume at the Thanlyin Bridge is 11,746 MCM.

The discharge volume at the Thanlyin Bridge which is located at 60km downstream from the Bago Bridge are 3.2 times as high than the discharge at the Bago Bridge. It is enough discharge volume, but the water quality is not suitable for the industrial use. The water quality at the Bago Bridge is not confirmed the saline intrusion, the other side, the river discharge at the Thanlyin Bridge is tidal river discharge. Therefore, from aspect of the available water of the surface water, the annual discharge volume of 3,631 MCM at the Bago River Bridge is the potential volume for the future surface water resource to meet the required water demand for the huge wide plane area in the Western Bago Area.

5-6-3 Issues for the Water Resource Development from Aspect of the Water Balance

According to the result of the analysis for the groundwater resource potential and the surface water resource potential, the annual amount of the available water resource for the water resource development in the survey area including the Thilawa SEZ is 3,631 MCM at the Bago Old Bridge to meet the required volume of 680 MCM assumed for the future water requirement.

Since the irrigation water shares 90% of 680 MCM, which is the annual water demand in the survey area, the future water demand will be change depend on the future agriculture policy which will be made by the union government and the regional government. The survey area locates in the influenced area of the Yangon Economic Zone. Furthermore, the industrial water demand is also an important factor for the forecasting of the future water demand. It is essential activity to watch the movement of the economic development in the Yangon urban area for the grasp of the future water demand.