The Republic of Kenya
Rural Electrification Authority

# The Project for Establishment of Rural Electrification Model Using Renewable Energy in the Republic of Kenya

## Project Completion Report
## Volume 3 Attachment 2/2

March 2015

Japan International Cooperation Agency (JICA)

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**March 2015**

**Japan International Cooperation Agency (JICA)**

NIPPON KOEI
Challenging mind, Changing dynamics

KRI International Corporation

# The Project for Establishment of
# Rural Electrification Model
# Using Renewable Energy
# in
# the Republic of Kenya

## Project Completion Report
## Volume 3 Attachment 2/2

# Attachment K

## Materials for Technical Transfer for Micro Hydropower (MHP)

# Guideline for MHP Development

## February 2015

Rural Electrification Authority

Ministry of Energy and Petroleum

Attachment K-1-1

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This guideline was prepared by the Working Group (WG) of MHP, composed of the following, under assistance of REA, MoE&P, and JICA. All figures and tables are prepared by the Working Group otherwise specified.

Working Group of MHP Guideline
Rural Electrification Authority (REA)
Eng. Ephantus Kamweru
Eng. James Muriithi
Ms. Judith Kimeu
Mr. Semekiah Ongong'a
Mr. Anthony Wanjara
And JICA Expert Team

# List of Terms and Abbreviations

| Abbreviation | Description |
|---|---|
| AC | Alternating Current |
| APFR | Automatic Power Factor Regulator |
| AVR | Automatic Voltage Regulator |
| B/C | Cost-Benefit Ratio |
| CAAC | Catchement Area Advisory Committee |
| CAD | Computer-Aided (Computer-Assisted) Detection |
| CD-ROM | Compact Disc Read Only Memory |
| CFD | Computational Fluid Dynamics |
| CH4 | Chemical formula of methane |
| CIF | Cost of Insurance and Freight |
| CO2 | Chemical formula of carbon dioxide |
| CPU | Central Processing Unit |
| CRT | Cathode Ray Tube |
| CV | Curriculum Vitae |
| CVCF | Constant Voltage Constant Frequency |
| DC | Direct Current |
| DEC | District Environmental Committee |
| EA | Environmental Audit |
| IEC | International Electrical Committee |
| IEEJ | Institution of Electrical Engineers in Japan |
| EIA | Environmental Impact Assessment |
| EIA-TAC | Environmental Impact Assessment Technical Advisory Committee |
| EIRR | Economic Internal Rate of Return |
| EMCA | Environmental Management and Coordination Act |
| E-waste | Electronic waste |
| FAX | Facsimile |
| FIDIC | Federation International des Ingenieurs Conseils/<br>International Federation of Consulting Engineers |
| FIRR | Financial Internal Rate of Return |
| FSWL | Full Supply Water Level |
| FV | Future Value |
| H2S | Chemical formula of Hydrogen Sulfide |
| HEC-RAS | Hydrologic Engineering Centers River Analysis System |
| Hg | Chemical formula of Mercury |
| HH | Household |
| IC | Integrated Circuit |
| IPB | Isolated Phase Bus |
| JICA | Japan International Cooperation Agency |
| JET | JICA Expert Team |
| KeNHA | Kenya National Highways Authority |
| KeRRA | Kenya Rural Roads Authority |
| KNBS | Kenya National Bureau of Statistic |
| KP | Kenya Power |
| KS | Kenya Standard |
| KSh. | Kenya Shilling |
| KTDA | Kenya Tea Development Authority |
| LCPDP | Least Cost Power Development Plan |
| LED | Light Emitting Diode |
| L.S. | Lump Sum |
| LPG | Liguefired Petroleum Gas |
| MBC | Metering Billing Collection |
| MEWNR | Ministry of Environment, Water and Natural Resources |
| MHP | Micro Hydro Power, Mini Hydro Power |
| MoE&P | Ministry of Energy and Petroleum |

| | |
|---|---|
| MOL | Minimum Operation Level |
| MWI | Ministry of Water and Irrigation |
| NEDO | New Energy and Industrial Technology Development Organization in Japan |
| NEMA | National Environment Management Authority |
| NGR | Neutral Grounding Resistor |
| NPV | Net Present Value |
| NWMP 2030 | National Water Master Plan 2030 |
| OJT | On the Job Training |
| O&M | Operation and Maintenance |
| PEC | Provincial Environmental Committee |
| PPOA | Public Procurement Oversight Authority |
| PV | Present Value |
| PV | Photovoltaic |
| PVC | Polyvinyl Chloride |
| REA | Rural Electrification Authority |
| SCF | Standard Conversion Factor |
| SEA | Strategic Environmental Assessment |
| SHER | Similar Hydrological Elements Response |
| SSG | Speed Signal Generator |
| STD | Standard Tender Document |
| SWER | Single Wire Earth Return |
| TEL | Telephone |
| ToR | Terms of Reference |
| TV | Television |
| TWL | Tail Water Level |
| USD | United State Dollar |
| ULH-MHP | Ultra Low Head Micro Hydro Power |
| UNIDO | United Nations Industrial Development Organization |
| USEPA | United States Environmental Protection Agency |
| WG | Working Group |
| WRMA | Water Resources Management Authority |
| WRUA | Water Resource Users Association |
| WTP | Willingness to Pay |

# List of Electrical Terminology

| Unit | Description |
|---|---|
| A (Ampere) | Unit of current |
| V (Volt) | Unit of voltage |
| kV (kilovolt) | 1,000 volts |
| W (Watt) | Unit of electric power |
| kW (kilowatt) | 1,000 W |
| MW (Megawatt) | 1,000 kW |
| Wh (Watt-hour) | Unit of energy |
| kWh (kilowatt-hour) | 1,000 Wh |
| MWh (Megawatt-hour) | 1,000 kWh |
| VA (Volt-Ampere) | Unit of apparent power |
| kVA (kilovolt-ampere) | 1,000 VA |
| MVA (Megavolt-ampere) | 1,000 kVA |
| Hz (Hertz) | Unit of frequency |

# EXECUTIVE SUMMARY

## 1 Background

Access to electricity is one of the fundamental infrastructures which lead to improvement of people's living standards. The Government has given a high priority on rural electrification in "Kenya Vision 2030" as one of the key issues. Rural Electrification Authority (REA) was established by the Government in 2007 as an executing agency for rural electrification.

Hydropower is one of the power resources for rural electrification. The total potential of small scale hydropower in Kenya is estimated to be 3,000 MW out of which 30 MW has been exploited. The upsurge in demand for electric energy since 2004 has revealed an exciting potential for growth in exploitation of the small hydropower subsector. However, the development of hydropower has faced with challenges which include insufficient financial resources and lack of technical personnel and lack of hydrological data for carrying out feasibility studies.

The Government of Kenya and Japan International Cooperation Agency (JICA) agreed to implement the "Project for Establishment of Rural Electrification Model using Renewable Energy in Kenya" together with REA and Ministry of Energy and Petroleum (MoE&P) from the year 2012 to 2015.

The project has two main components;

(i) To establish the rural electrification model through pilot projects of solar PV systems in public facilities, and
(ii) To enhance the capacity of REA and MoE&P personnel for micro/mini hydropower (MHP), biomass/biogas and wind technologies.

This guideline was prepared as a tool for one of the capacity development activities.

## 2 Objective of the Guideline

This guideline describes how to implement MHP projects from identification stage to assistance for operation and maintenance stage.

Definitions of micro/mini/small hydro in the guideline are set as follows:

| | |
|---|---|
| ✓ Micro hydro: | Less than 100 kW |
| ✓ Mini hydro: | 100 kW to 1,000 kW (1.0 MW) |
| ✓ Small hydro: | 1,000 kW to 10,000 kW (1.0 MW to 10.0 MW) |

The guideline was prepared for MHP projects whose capacity ranges between 10 to 1,000 kW (Micro hydro and Mini hydro).

The guideline is to be provided to the personnel in Renewable Energy Department of REA, as well as persons who support implementation of REA projects including engineers in power utilities, universities and local consultants, with basic information and knowledge about hydropower technology, in order to utilise it for rural electrification.

## 3 Structure of the Guideline

This guideline was prepared by Working Group (WG) of REA and JICA Expert Team (JET) during the project period. The guideline was prepared based on the existing guidelines and manuals on small scale hydropower development for rural electrification.

In parallel with the making of the guideline, WG executed a simple pre-feasibility study on Asurur MHP in Nandi County. During the study, the contents of the existing guidelines and manuals were reviewed, modified and reflected on the guideline to incorporate actual conditions in Kenya, especially the planning section.

This guideline consists of the following eight (8) chapters. The general description of each chapter is summarized in the table below.

**Table 1 General Description of the Guideline**

| Chapter | General Description |
|---|---|
| 1. General | This chapter briefly explains advantage and disadvantage of MHP and basics of hydropower generation. |
| 2. Identification of the Project | This chapter describes how to identify the potential MHP site and how to evaluate its hydropower potential and power demand by existing data before site investigation. |
| 3. Investigation and Planning | This chapter describes key points for survey including consultation with the local community, power demand forecasting, technical investigations, and procedure of plan formulation. |
| 4. Basic Design | This chapter describes the basic functions and hydraulic design methods of civil structures (structural design methods are not included), the standard types and estimation methods of basic technical features of electrical equipment and distribution facilities. |
| 5. Economic and Financial Evaluation | This chapter explains key indicators for evaluation and difference between economic evaluation and financial evaluation with examples. Estimation of project cost is also explained in detail since it is important for the evaluation. |
| 6. Environmental and Social Consideration | This chapter explains standard procedures for obtaining the environmental licence, solid waste management issues including E-waste, and other management issues for MHP. |
| 7. Construction Supervision | This chapter explains procurement procedures of public works in Kenya and points of construction supervision works by the Client. |
| 8. Operation and Maintenance | This chapter describes the importance of assistance to management board organized by the local community and key points of operation and maintenance works for MHP station and off-grid distribution system. |

## 4 Features of the Guideline

There are many guidelines and manuals on MHP development in the world. The features of this particular guideline may be the following two points:

### (1) Adopting the Results of NWMP 2030

Lack of hydrological data is one of the key challenges for development of MHP. WG also faced difficulty in evaluation of flow duration and definition of reliable discharge in the simple pre-feasibility study on Asurur MHP scheme due to shortage of hydrological data. The same problem might occur for the entire MHP planning process.

To mitigate this problem, WG included the simulated discharge data in “National Water Master Plan 2030 (NWMP 2030)” which was formulated by Ministry of Water & Irrigation (present Ministry of Environment, Water and Natural Resources) with technical cooperation by JICA. In NWMP 2030, rainfall-runoff analysis was conducted in nation-wise, and monthly average naturalized discharges were provided for 204 sub-basins for 20 years period.

By utilizing this data, a reliable discharge at the concerned MHP site is easily estimated without detailed hydrological analysis as preliminary evaluation. Therefore, it may contribute to preliminary identification & planning of MHP scheme.

However, measurement of discharge at the candidate site is essential for detailed planning.

### (2) Adopting the Empirical Equations of Japan

In general, location of intake weir, route of power canal and penstock, location of powerhouse and tailrace, etc. can vary depending on the potential site. In the planning process, the optimum locations of those major structures will be determined by comparing generating energy and construction cost. A comparative study shall be carried out to identify the optimum development plan.

Empirical equations to estimate work quantities were presented in the guideline for comparative evaluation. The empirical equations were developed based on the rich experience and actual records of

MHP projects accumulated in Japan. Using these equations, a comparative study can be easily carried out by temporarily setting some major dimensions.

However, these empirical equations are applicable for comparative study only. A further detailed estimation is required in basic design and/or procurement stages.

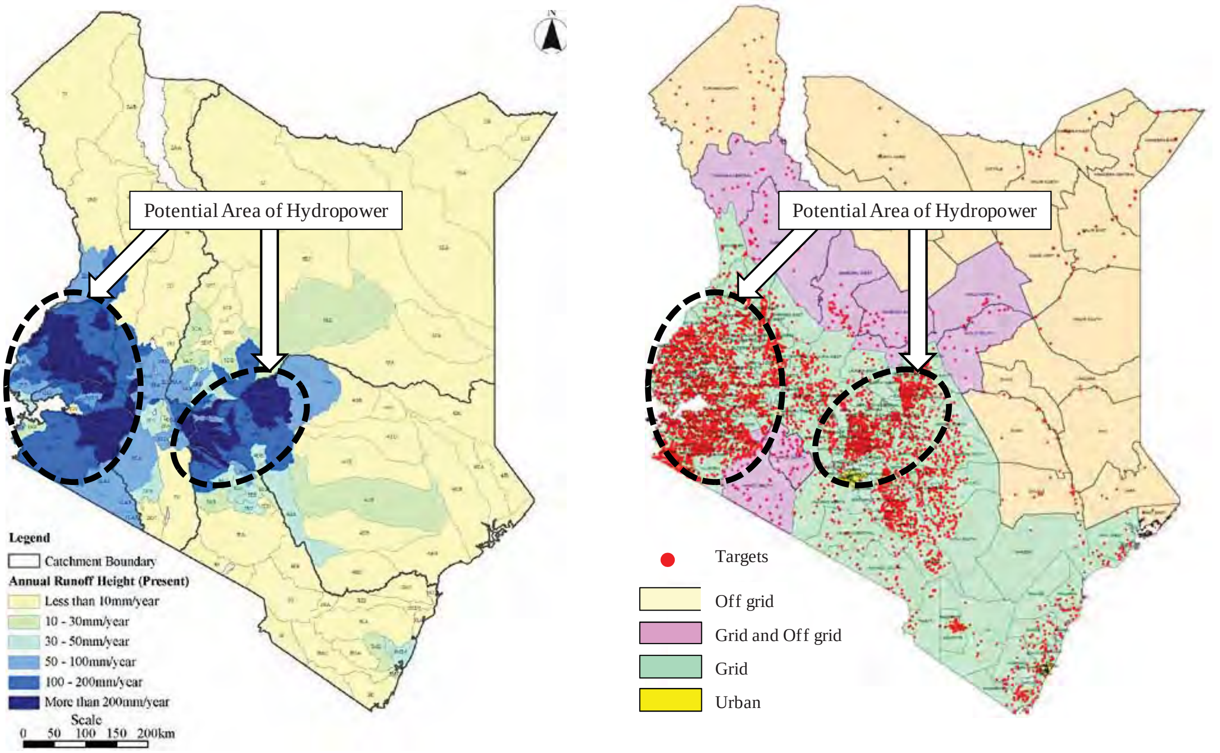
## 5 Overview of MHP Development in Kenya

The potential of hydropower is dependent on the availability of river discharge. As indicated in the figure below, the areas around Mt. Kenya and the Western Kenya region around Kericho (also called water towers) receive annual rainfall of more than 1,500 mm. These two regions are regarded as high potential areas for hydropower development.

REA and Ministry of Energy (Present MoE&P) formulated "Rural Electrification Master Plan (REM 2009)" in August 2009 and areas for rural electrification by grid and off-grid were proposed as indicated in the figure below.

As seen in both figures, the potential areas of hydropower are overlapping with many targets to be electrified by grid. It is likely that electrification by MHP will be developed as off-grid systems in short to medium terms and they will be connected to the main grid in medium to long terms.

Therefore, MHP development shall be conducted, taking into consideration the possibility of grid connection in future and optimal development of finite water resources.



**Potential Area of Hydropower** **Demarcation of Rural Electrification Method**

Source: "Project on the Development of the National Water Master Plan 2030, Sector Report (B) Meteorology and Hydrology, Figure 5.6.1" published by JICA in 2013, and "Rural Electrification Master Plan (REM 2009), Final Report Volume 1 – Main Report, Figure ES-3" on 15 August 2009, Page 24" (both arranged by JET).

**Figure 1 Potential Areas of Hydropower and Proposed Rural Electrification Method in Kenya**

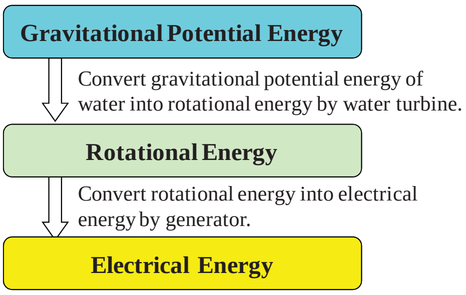
# CHAPTER 1 GENERAL

## 1.1 Basic of Hydropower Generation

Since the latter half of the nineteenth century, hydropower generation has been developed worldwide utilizing natural river water flow. Development of electrification first began with local power generation on a small scale, and then progressively developed into larger scale power generation as power demand increased. Through this process, power transmission lines and distribution networks were formed. Small scale hydropower generation has therefore played an important role in rural electrification

Hydropower generation is a power generation system utilizing gravitational potential energy of water.

Water flows down to a lower level by gravity, releasing gravitational potential energy. In hydropower generation, the water flow down to the water turbine causes the turbine to rotate. The water turbine rotates with a generator, and electricity is generated.



### 1.1.1 Power Output

Power output of hydropower generation is given by the following formula:

$$P = 9.8 \times Q \times H_e \times \eta$$

Where,
$P$: power output (kW)
$Q$: plant discharge ($m^3/s$)
$H_e$: effective head (m)
$\eta$: combined efficiency for turbine and generator ( - )

Each element of the formula is described below.

(1) Plant Discharge

River flow varies daily, monthly and annually. Therefore, the plant discharge also varies depending on the available river flow. Definition of the plant discharge is one of the key issues in MHP planning. Details are explained in Chapter 2.3.

In general, the minimum and maximum plant discharges are defined as follows;

- ✓ Minimum plant discharge: 90 to 95% of dependable discharge at the site.
- ✓ Maximum plant discharge: Depends on peak load demand and available discharge.

(2) Effective Head

The effective head is given as follows:

(Effective head) = (Gross head) – (Head loss)

“Gross head” is the difference between the water level at inlet and water level at outlet.

The potential energy of water flowing down to the turbine is reduced as it passes through the waterway due to: friction, bending, reduction, expansion and branching of waterway, impediments along the waterway such as trashracks, valve, etc. Summation of such losses of potential energy between inlet and outlet is known as “head loss”.

Summation of each head loss can be estimated in the planning stage as follows:

(Total head loss) = (7% of gross head), and/or
(Total head loss) = (Friction loss in power canal) + (2 to 3% of gross head as other losses)

Details of head loss calculation are mentioned in Chapter 4.1.

### (3) Combined Efficiency

The combined efficiency consists of the efficiencies of the turbine and generator. The exact values depend on the manufacturing companies for the turbine and generator. The following standard values can be applied for MHP planning stage.

**Table 1.3.1 Standard Efficiencies for Planning Stage**

| Output | Efficiency of Turbine $\eta_t$ (%) | Efficiency of Generator $\eta_g$ (%) | Combined Efficiency $\eta$ (%) |
|---|---|---|---|
| Less than 100 kW | 79 | 91 | 72 |
| 100 to 300 kW | 81 | 93 | 75 |
| 300 to 1,000 kW | 83 | 94 | 78 |

## 1.1.2 Annual Energy

Annual energy of hydropower generation is given by the following formula:

$$E = \xi \times P \times 24 \times 365 = 8{,}760 \times \xi \times P$$

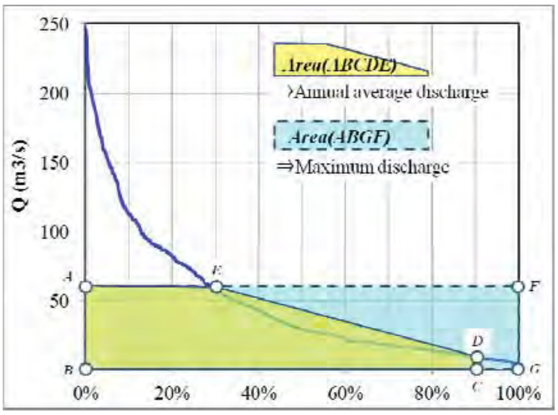
Where, $E$: Annual energy (kWh)
$\xi$: plant factor (kW)
$P$: maximum output (kW)
$H_e$: effective head (m)

The plant factor ($\xi$) is the ratio between available discharge and maximum discharge.

In case of a run-of-river scheme, a flow duration curve is useful in estimating the approximate annual energy. The flow duration curve is a graph in which a series of discharge records are arranged in descending order and discharge is plotted along the ordinate axis and days or percentage is plotted along the abscissa axis. The flow duration curve shows flow duration.

The plant factor is given as follows:

$$\xi = \frac{Area(ABCDE)}{Area(ABGF)}$$



When a larger discharge is selected, a larger scale power facility with a lower plant factor is required. Conversely, when a smaller discharge is selected, a smaller plant facility with a higher plant factor is required.

The optimum maximum discharge should be selected taking into account the revenue to be generated and the initial construction cost, in principle. In addition, it should be selected bearing in mind that the power tariff needs to be properly established.

## 1.2 Required Generator Capacity for Rural Electrification

Power demand in local community is unknown before electrification. The generator capacity is able to be approximated by the following equation based on the assumption explained in Chapter 2.4:

$$P_d = 0.2N$$

Where, $P_d$: required generator capacity (kW)
$N$: community size (number of household)

As a rough estimate, head of at least 20 m and discharge of 1.0 m$^3$/s is enough for rural electrification of communities smaller than 500 households.

### 1.3 Advantage and Disadvantage of MHP

Advantages and disadvantages of MHP development are enumerated below.

Advantages:

- ✓ Hydropower is generated from natural resources. MHP application will contribute to practical use of natural water resources in the country, and minimize procurement cost of importing electricity as well as consumption for power generation,
- ✓ Hydropower could be considered as the safest, cleanest, and cheapest power generation method, in addition to its contribution to CO2 emission reduction, and
- ✓ MHP development will contribute to regional socio - economic activities by providing electric power supply for household use and possibly for industrial use.

Disadvantages:

- ✓ Potential sites depend more significantly on topographic and hydrological conditions rather than power demand,
- ✓ Annual energy generation is highly dependent on river conditions, and the river flow may vary from rainy to dry seasons in the year and from one year to another. It is therefore difficult to accurately estimate river flow discharge, and
- ✓ Operation and maintenance activities required for both small and large scale hydropower stations are the same in principle. Technical correspondence and financial arrangements are required in both instances, but securing the human resources and budget is more difficult for MHP projects.

MHP is one of the major options for rural electrification. However, development of the MHP system shall be studied carefully taking into consideration the above advantage and disadvantages.

### 1.4 Brand New Technology - ULH -MHP

Recently, United Nations Industrial Development Organization (UNIDO) is implementing pilot projects of renewable energy generation technology called “Ultra Low-Head Micro Hydropower (ULH-MHP)” system in many countries including Kenya. The ULH-MHP system is the most up-to-date and commercially available technology developed in this field, innovated a few years ago in Japan.

The ULH-MHP is different from the conventional hydropower technologies. The ULH-MHP system can generate electricity from low water head of less than 5 m and discharge of some 0.5 to 1.0 $m^3/s$ in regulated water such as waterfall of existing water supply and sewage system, power station waterways, drainage from factories, agricultural waterways, stream channels, etc. Hydropower generation in these conditions has not been previously considered feasible.

The ULH-MHP system is a suitable way to generate electricity due to the following advantages:

a) It has less civil works since the equipment comes assembled and is mounted on an already existing canal,
b) The procedure calls for limited environmental concerns and it is easy to install (in the past instances, 3 days in Japan and 7 days in India), and
c) The maintenance is simple and does not require advanced technology.

UNIDO is planning to execute a pilot project of ULH-MHP system in Mwea Irrigation Project to generate up to 130 kW of electricity by installing 13 units of ULH-MHP along the irrigation canals, and the power generated is planned to be channeled to the rice mills for processing the rice.

# CHAPTER 2 IDENTIFICATION OF THE PROJECT

## 2.1 Work Flow of Identification

Work flow of identification of a potential MHP site for rural electrification is summarized below.

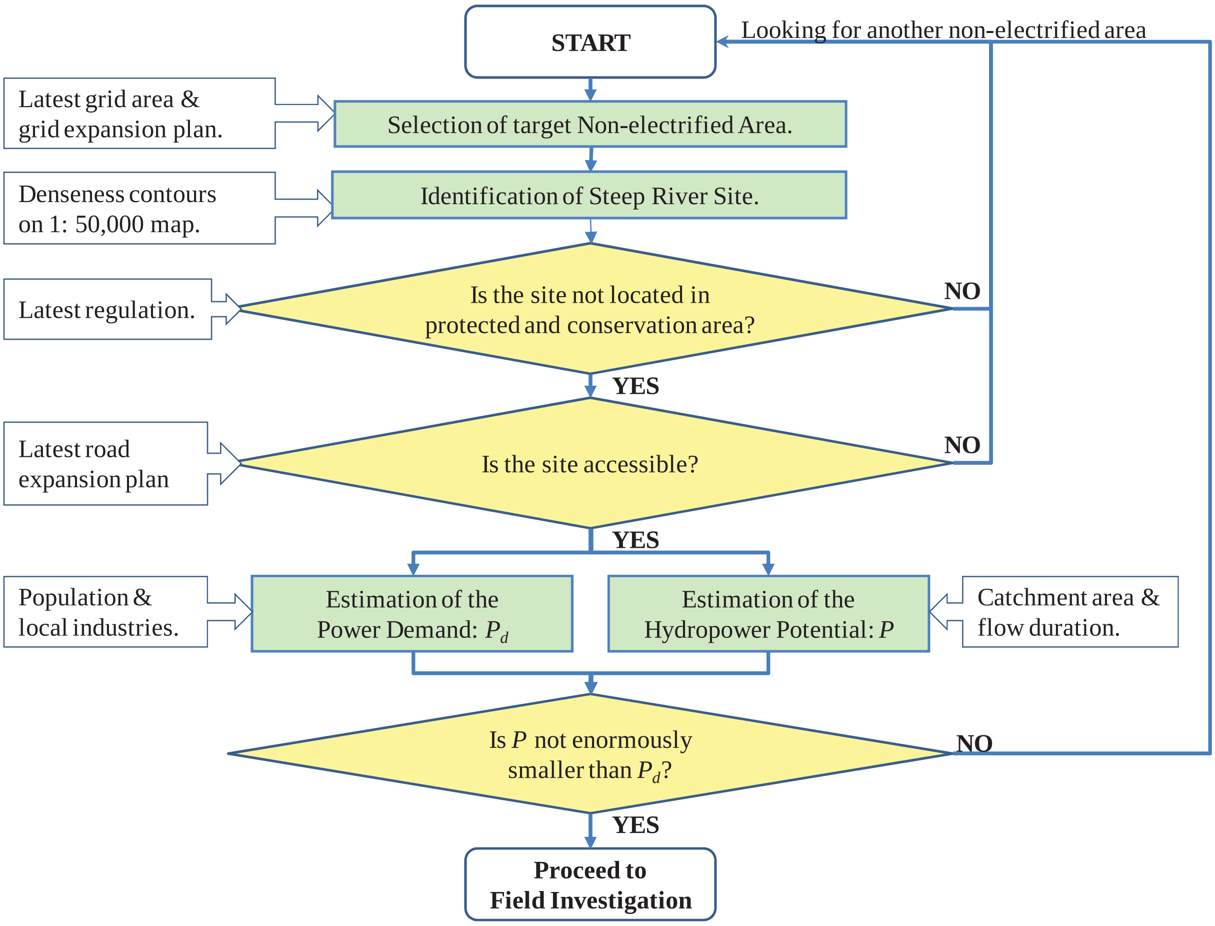


**Figure 2.1.1 Flow Chart of Identification of Potential MHP Site**

Natural conditions, i.e., topography, annual average discharge and hydropower potential, are constant in principle. However, social conditions such as the status of electrification of the area and accessibility change every several years. Furthermore, environmental regulations may possibly be updated over time as well. Confirmation of the current status of non-electrified areas and their surrounding conditions is important for the identification of a MHP project site.

The following information is required to identify promising sites for MHP development schemes:

- ✓ Existing distribution network from Kenya Power (KP)
- ✓ Grid extension plan from REA and KP
- ✓ Least Cost Power Development Plan (LCPDP) from Ministry of Energy and Petroleum (MoE&P)
- ✓ Environmental Acts and laws from Ministry of Environment, Water and Natural Resources (MEWNR).
- ✓ Existing road network and road construction plan from Kenya National Highways Authority (KeNHA) and Kenya Rural Roads Authority (KeRRA)
- ✓ Topographic map (1:50,000) from Land Survey Department under Ministry of Land, Housing and Urban Development, and
- ✓ Population census data from Kenya National Bureau of Statistics (KNBS).

## 2.2 Selection of the Target Non-electrified Area

### 2.2.1 Clarification of Non-electrified Area

Initially, it is necessary to clarify which areas are on-grid, off-grid or connected to an isolated grid. The following information shall be collected and updated regularly (at least once a year).

- ✓ Existing distribution network from REA and KP,
- ✓ Grid extension plan from REA and KP, and
- ✓ Least Cost Power Development Plan (LCPDP) from MoE&P.

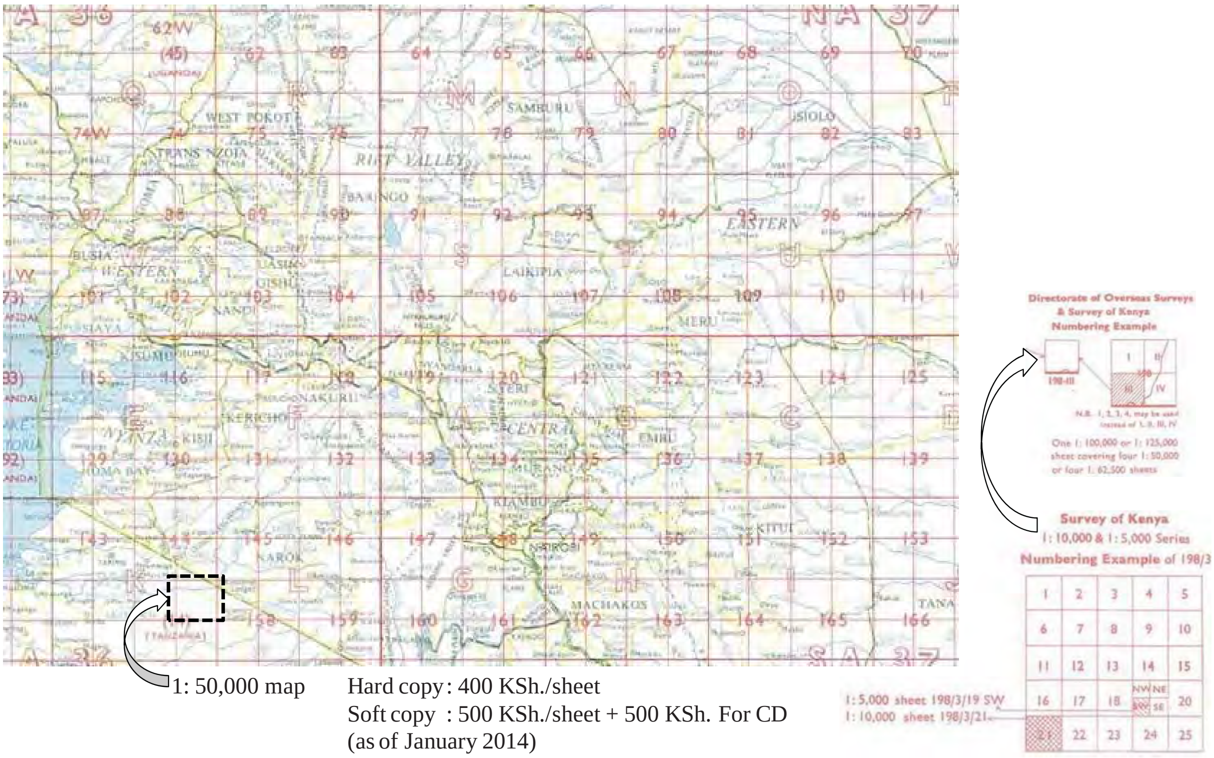
For instance, the above clarification can be carried out within the potential areas of hydropower development mentioned in Executive Summary. When the off-grid area is confirmed, a target non-electrified area shall be selected.

### 2.2.2 Identification of Steep River Site

Once the target non-electrified area is selected, topographic maps with scale of 1: 50,000 are prepared.

(1) Purchasing Topographic Map

Topographic maps are available for purchase from the Land Survey Department under the Ministry of Land, Housing and Urban Development. The index map of the potential areas of hydropower development is shown below.



1: 50,000 map

Hard copy : 400 KSh./sheet
Soft copy : 500 KSh./sheet + 500 KSh. For CD
(as of January 2014)

Source: Land Survey Department under Ministry of Land, Housing and Urban Development (arranged by WG)

**Figure 2.2.1 Index Map of Topographic Map with Scale of 1: 50,000**

(2) Criteria for the Identification

Steep river sites in and around the target area are studied on the topographic maps. A steep river site means that the river site has closely-spaced contour lines. The criteria of identification of steep river sites are as follows:

1) Study area within 5 km of villages in the target area

In general, potential site of MHP shall be identified within 5 km of the target villages due to limitation of efficient distribution.

2) Identify the river sites with intervals less than 200 m

In general, the ratio between head (*H*) and length of waterway (*L*) shall be less than 10 ($L/H < 10$) to secure its economic feasibility. Therefore, river sites with closely-spaced contour lines less than 200 m in length shall be identified.

On the topographic map with a scale of 1: 50,000, ruled lines which are square in shape and 1 km in height and width are provided, and contour lines are drawn at intervals of 20 m in height.

1 km in the map is equivalent to 2 cm on a hard copy. Accordingly, the actual length on the hard copy is as follows:

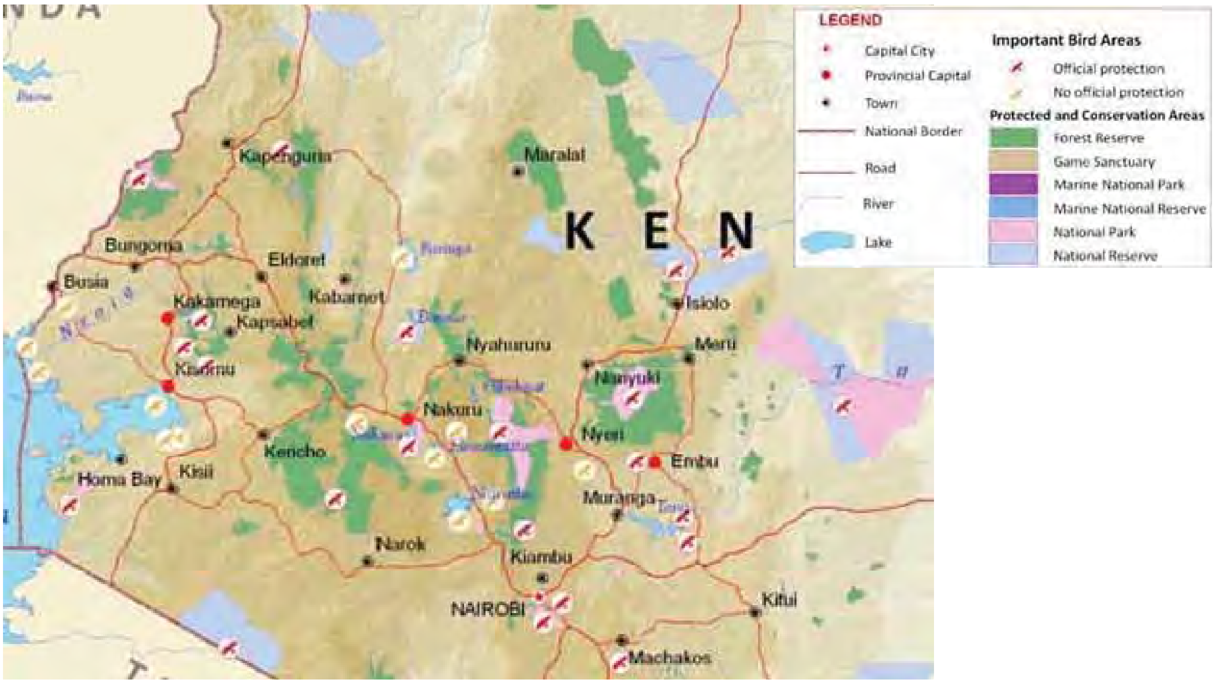
1) Study area within 10 cm of villages in the target area.
2) Identify the river sites with intervals less than 4 mm.

### 2.2.3 Confirmation of Social Conditions around the Site

There are two major issues of confirmation of social conditions at and around the site, i.e., (1) whether a protected area or conservation area exists, and (2) accessibility to the site.

(1) Protected Areas and Conservation Areas

Environmental regulations including areas reserved from any development should be reviewed. In addition, procedures of environmental assessment for project planning and implementation shall be confirmed.



Source: "Kenya State of the Environmental and Outlook 2010" published by NEMA in 2011

Figure 2.2.2 Protected and Conservation Areas

Source: Base Map; National Museums of Kenya (http://www.museums.or.ke/content/view/248/127/) (arranged by JET)

**Figure 2.2.3 Archeological, Cultural Sites and Facilities**

(2) Accessibility to the Site

Accessibility to the potential site shall be possible not only for site investigation but also for future construction.

Accessibility is confirmed using topographic maps and/or the internet (e.g. Google maps). If access roads are not identified on these maps, the latest road network and road construction plan shall be confirmed from Ministry of Land and/or Ministry of Transport and Infrastructure.

## 2.3 Estimation of the Hydropower Potential

### 2.3.1 Measurement of the Catchment Area

The catchment area of the candidate site is indicated and measured on the topographic map with scale of 1: 50,000. The following methods can be applied to measure the catchment area.

(1) Measurement by Visual Estimation

A topographic map provides grid lines at an interval of 1 km, which means that an area of one cell is equivalent to 1 km$^2$. It is therefore possible to measure the catchment area manually using the following steps:

a) Count the number of square cells in the catchment area,
b) Assume the area of each partial cell in the catchment area, across which the boundary of the catchment area passes, and
c) Sum up the area of all the square and partial cells in the catchment area.

An example of measurement by visual estimation is shown below.

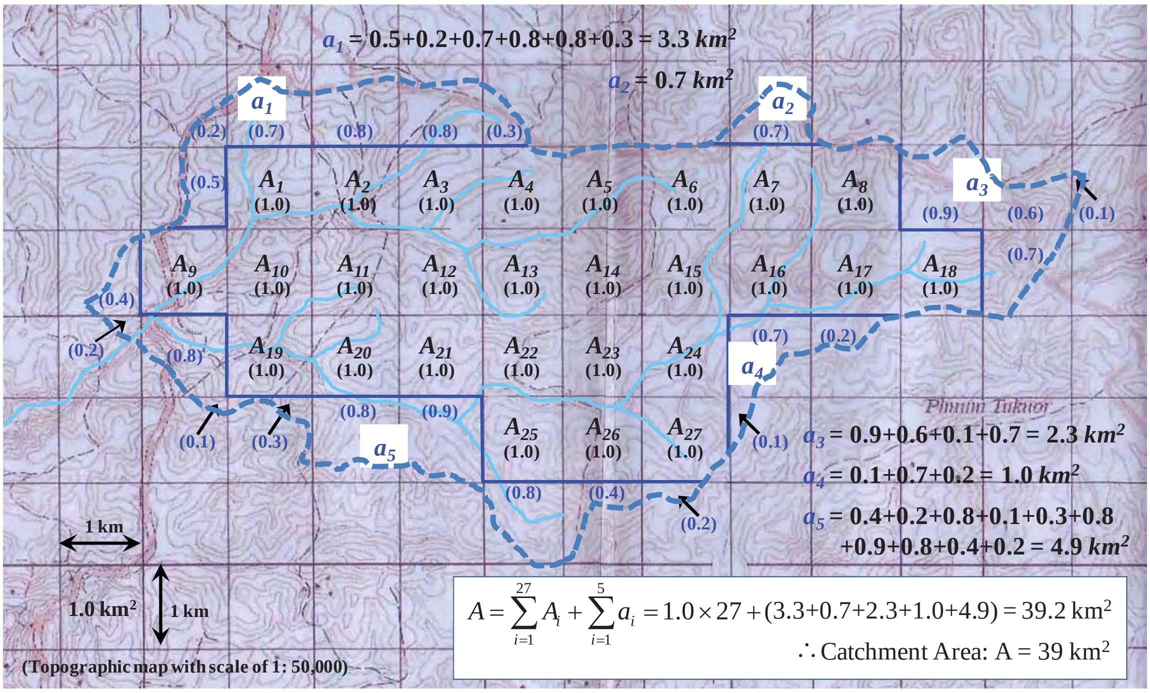
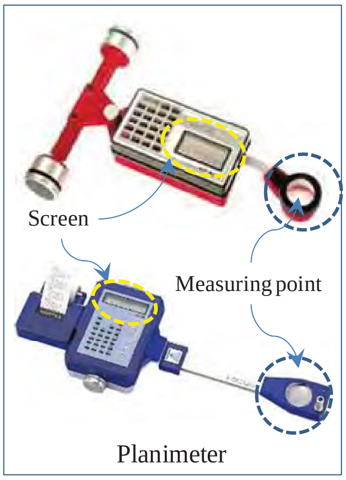


Figure 2.3.1 Example of the Catchment Area Measurement by Visual Estimation

### (2) Measurement by Planimeter



This was the most common method in the past. A planimeter is a device to measure the area of any shape on a plane.

Measurement by Planimeter shall be carried out as follows:

a) Draw the boundary line of the catchment area on the topographic map,
b) Clean up a desk and fix the topographic map onto it using a tape or paperweight,
c) Define a start point on the boundary line of the catchment area,
d) Place the planimeter on the topographic map and adjust the scale following the instruction manual of the planimeter,
e) Fit the measuring point which is generally located at the arm toe of the planimeter,
f) Trace the boundary line of the catchment area by moving the measuring point around on the map, and
g) When the measuring point returns to the start point, record the measured value indicated on the screen of the planimeter.

Repeat the tracing more than three times, and calculate the average of measured values. The catchment area is given by the average value.

### (3) Measurement by CAD Software

This is the most common method at present. The method is able to measure the catchment area more accurately than other methods.

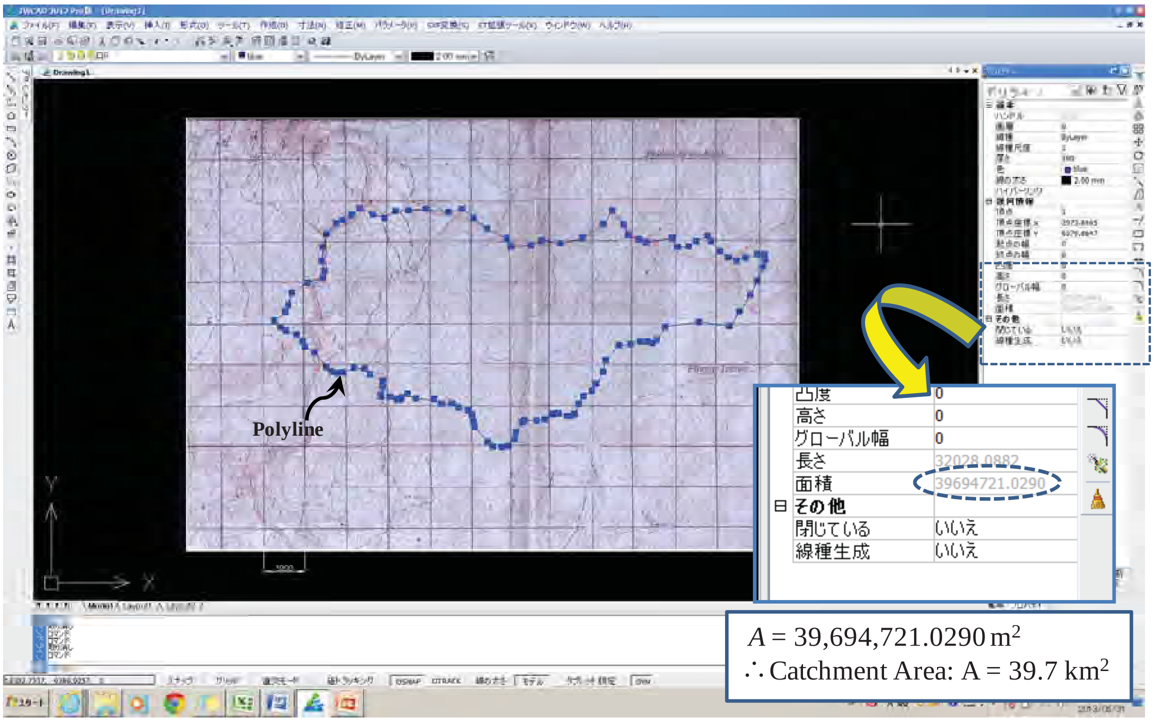
Measurement by CAD software shall be carried out as follows:

a) Convert the topographic map into an image file (bmp, jpg, gif, tif, etc.),
b) Import the topographic map into the CAD file,
c) Adjust the scale of the topographic map,

d) Trace the boundary line of the catchment area by polyline,

e) The CAD file automatically calculates and indicates the area.

An example of measurement by CAD software is shown below.



|  |  |
|---|---|
| 凸度 | 0 |
| 高さ | 0 |
| グローバル幅 | 0 |
| 長さ | 32028.0882 |
| 面積 | 39694721.0290 |
| ⊟ その他 |  |
| 閉じている | いいえ |
| 線種生成 | いいえ |

$A = 39{,}694{,}721.0290\,\mathrm{m}^2$

∴ Catchment Area: $A = 39.7\ \mathrm{km}^2$

**Figure 2.3.2 Example of Catchment Area Measurement by CAD Software**

### 2.3.2 Estimation of Dependable Discharge

Evaluation of river discharge is vital for proper planning and design of hydropower development. In terms of rural electrification with an isolated grid system, the power generation should be available throughout the year.

River discharge varies daily, monthly and annually, and it is therefore necessary to review discharge data over the longest period possible for MHP planning. At least 10 years of daily discharge data is desirable for proper planning.

The dependable discharge for MHP is estimated using the following steps:

- ✓ Estimate the average monthly discharge at the candidate site;
- ✓ Prepare the flow duration curve for the candidate site, and
- ✓ Define the dependable discharge at 90 to 95% of probable discharge.

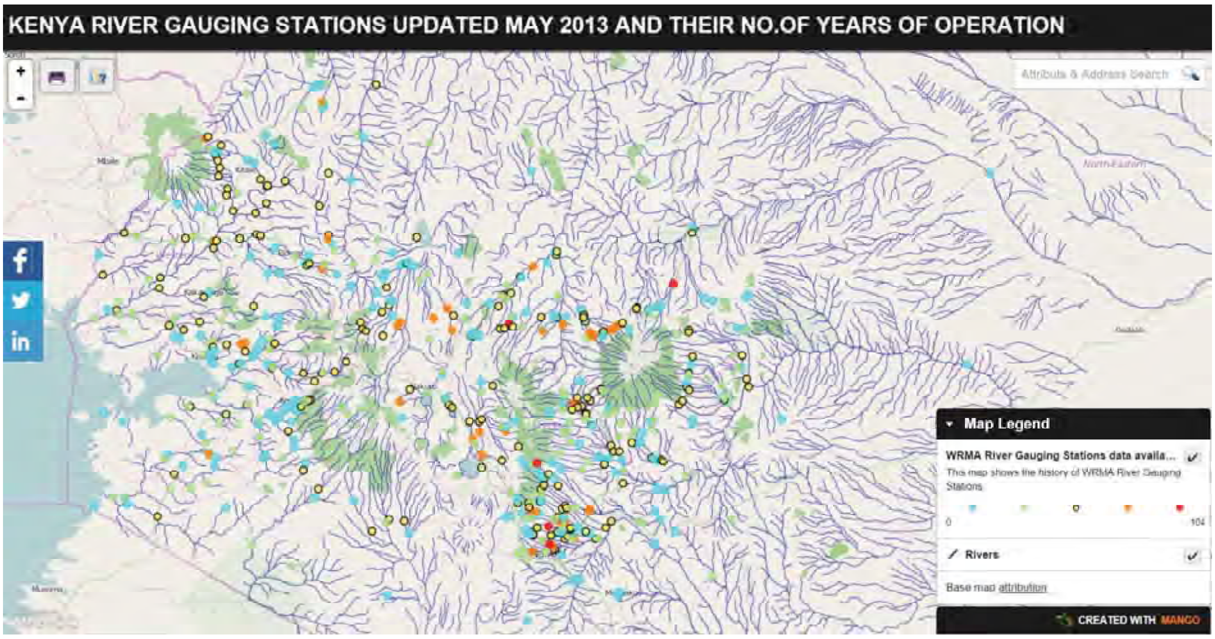
The following data are available for hydrological analysis:

- ✓ Discharge data from Water Resources Management Authority (WRMA),
- ✓ Rainfall data from Kenya Meteorological Department (KMD), and
- ✓ Simulated monthly discharge data by National Water Master Plan 2030 (NWMP 2030).

(1) Estimation from WRMA Discharge DATA

WRMA is executing measurement and compilation of river discharge data. Available data can be confirmed on their website as shown below.

However, observed data of WRMA has uncertainties including many periods for which data is missing. Therefore, it is preferable to collect discharge data at as many gauging stations surrounding the candidate site as possible. Then, collected discharge data are examined as explained hereinafter.


KENYA RIVER GAUGING STATIONS UPDATED MAY 2013 AND THEIR NO.OF YEARS OF OPERATION

This map shows the history of WRMA River Gauging Stations

Source: WRMA website (http://mangomap.com/maps/8325/KENYA)

**Figure 2.3.3 Gauging Stations of WRMA**

1) Confirmation of the Data Homogeneity

The homogeneity of the data is confirmed by the double mass curve. In the double mass curve, the cumulative volume of daily or monthly discharge data at some gauging station is plotted on the horizontal axis and the cumulative volume of discharge data at another gauging station is plotted on the vertical axis. When the records of two gauging stations are homogeneous, the plots form a continuous straight line as shown below.

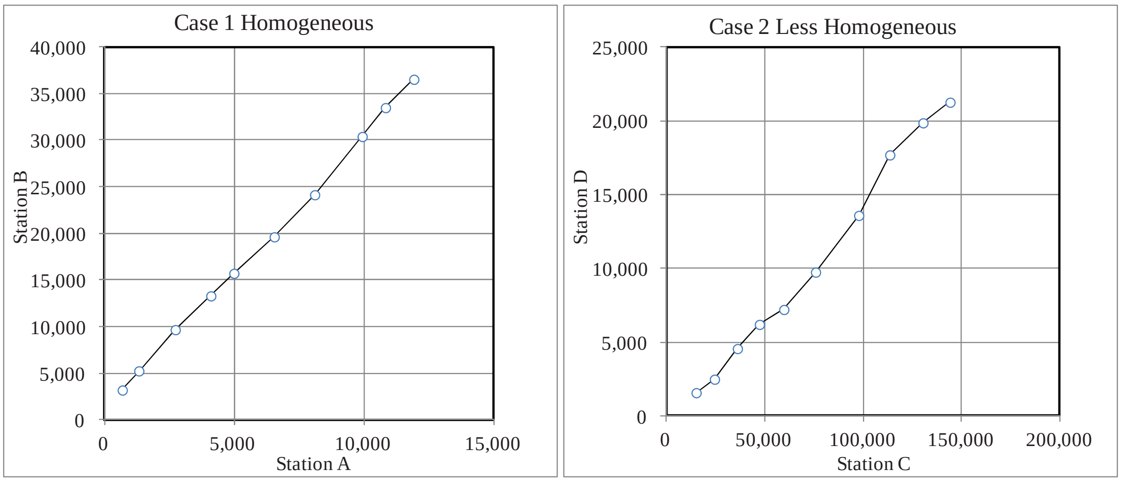


**Figure 2.3.4 Sample of Double Mass Curves**

It is not necessary that the horizontal axis and vertical axis show the discharge volume to determine the data homogeneity. The volume in correlation, for instance, discharge and rainfall, may be used.

2) Confirmation of Data Correlation between each Gauging Station

The correlation of discharge data between each gauging station is evaluated by the correlation coefficient (*R*), given by the following equation.

$$R = \frac{\sum_{i=1}^{n} \times (x_i - x_a) \times (y_i - y_a)}{\sqrt{\sum_{i=1}^{n} (x_i - x_a)^2 \times \sum_{i=1}^{n} (y_i - y_a)^2}}$$

Where,
$R$: correlation coefficient ( - )
$x_i$: monthly discharge at gauging station X ($m^3/s$)
$x_a$: average discharge at station X ($m^3/s$)
$y_i$: monthly discharge at gauging station Y ($m^3/s$)
$y_a$: average discharge at station Y ($m^3/s$)

Value of correlation coefficient (*R*) is variable between minus 1.0 and plus 1.0, and the correlation is evaluated as tabulated below.

| Range of "R" | Correlation |
|---|---|
| -1.0 < R < -0.7 | Strongly negative correlation |
| -0.7 < R < -0.4 | Moderately negative correlation |
| -0.4 < R < -0.2 | Slightly negative correlation |
| -0.2 < R < 0.2 | Little correlation |
| 0.2 < R < 0.4 | Slightly positive correlation |
| 0.4 < R < 0.7 | Moderately positive correlation |
| 0.7 < R < 1.0 | Strongly positive correlation |

### 3) Supplementation of Missing Data

The discharge record often has some data missing; and it needs to be supplemented before conducting hydrological analysis. The supplementation generally is carried out by the linear regression method with the data at the neighboring gauging stations surrounding the candidate site.

The linear regression line is given by the following equations:

$$y = a \times x + b$$

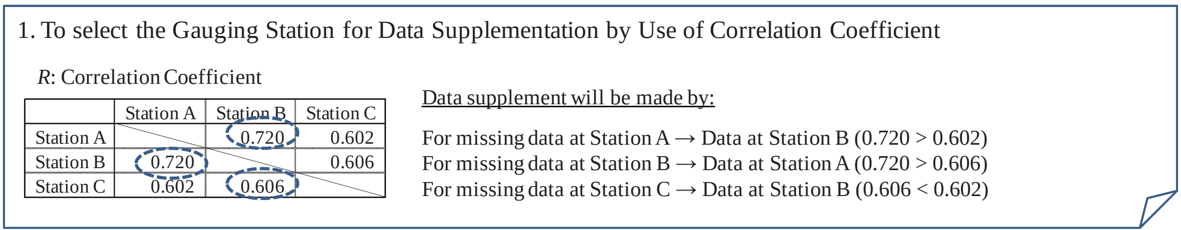
$$a = \frac{\sum_{i=1}^{n} \times (x_i - x_a) \times (y_i - y_a)}{\sum_{i=1}^{n} (x_i - x_a)^2}$$

$$b = y_a - a \times x_a$$

Where,
$Y$: missing discharge ($m^3/s$)
$X$: discharge data of the same time of the above missing discharge ($m^3/s$)
$a$: slope of the linear regression line ( - )
$b$: intercept of the linear regression line ( - )
$x_i$: monthly discharge at gauging station X ($m^3/s$)
$x_a$: average discharge at station X ($m^3/s$)
$y_i$: monthly discharge at gauging station Y ($m^3/s$)
$y_a$: average discharge at station Y ($m^3/s$)

The calculation shall be carried out for available gauging stations. The supplementation of one gauging station data shall be carried out by another gauging station which has the highest correlation coefficient.

The basic procedures of the supplementation of missing data are shown below.



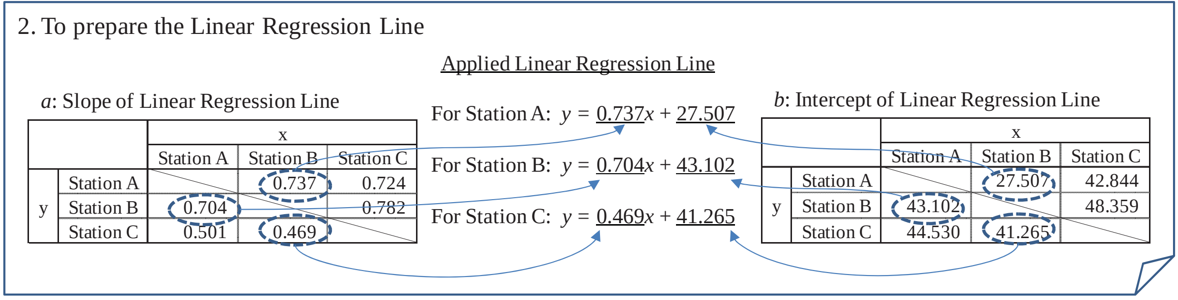
1. To select the Gauging Station for Data Supplementation by Use of Correlation Coefficient

*R*: Correlation Coefficient

| | Station A | Station B | Station C |
|---|---|---|---|
| Station A | | 0.720 | 0.602 |
| Station B | 0.720 | | 0.606 |
| Station C | 0.602 | 0.606 | |

Data supplement will be made by:

For missing data at Station A → Data at Station B (0.720 > 0.602)
For missing data at Station B → Data at Station A (0.720 > 0.606)
For missing data at Station C → Data at Station B (0.606 < 0.602)



2. To prepare the Linear Regression Line

*a*: Slope of Linear Regression Line

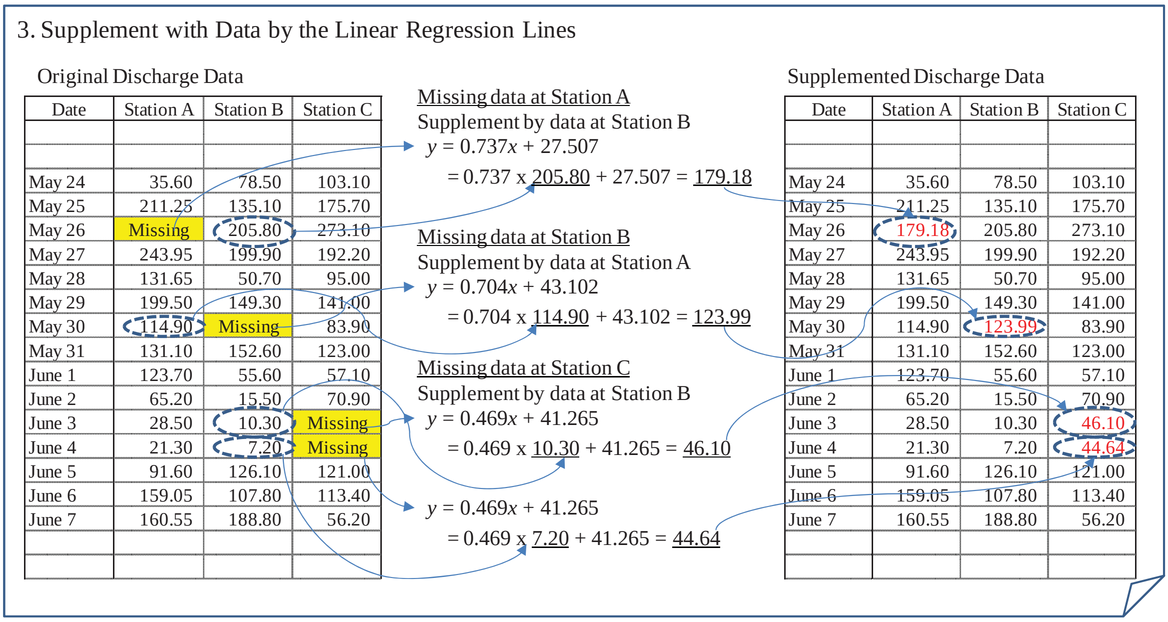
| | | x | | |
|---|---|---|---|---|
| | | Station A | Station B | Station C |
| y | Station A | | 0.737 | 0.724 |
| | Station B | 0.704 | | 0.782 |
| | Station C | 0.501 | 0.469 | |

Applied Linear Regression Line

For Station A: $y = \underline{0.737}x + \underline{27.507}$
For Station B: $y = \underline{0.704}x + \underline{43.102}$
For Station C: $y = \underline{0.469}x + \underline{41.265}$

*b*: Intercept of Linear Regression Line

| | | x | | |
|---|---|---|---|---|
| | | Station A | Station B | Station C |
| y | Station A | | 27.507 | 42.844 |
| | Station B | 43.102 | | 48.359 |
| | Station C | 44.530 | 41.265 | |



3. Supplement with Data by the Linear Regression Lines

Original Discharge Data

| Date | Station A | Station B | Station C |
|---|---|---|---|
| | | | |
| | | | |
| May 24 | 35.60 | 78.50 | 103.10 |
| May 25 | 211.25 | 135.10 | 175.70 |
| May 26 | Missing | 205.80 | 273.10 |
| May 27 | 243.95 | 199.90 | 192.20 |
| May 28 | 131.65 | 50.70 | 95.00 |
| May 29 | 199.50 | 149.30 | 141.00 |
| May 30 | 114.90 | Missing | 83.90 |
| May 31 | 131.10 | 152.60 | 123.00 |
| June 1 | 123.70 | 55.60 | 57.10 |
| June 2 | 65.20 | 15.50 | 70.90 |
| June 3 | 28.50 | 10.30 | Missing |
| June 4 | 21.30 | 7.20 | Missing |
| June 5 | 91.60 | 126.10 | 121.00 |
| June 6 | 159.05 | 107.80 | 113.40 |
| June 7 | 160.55 | 188.80 | 56.20 |
| | | | |
| | | | |

Missing data at Station A
Supplement by data at Station B
$y = 0.737x + 27.507$
$= 0.737 \times \underline{205.80} + 27.507 = \underline{179.18}$

Missing data at Station B
Supplement by data at Station A
$y = 0.704x + 43.102$
$= 0.704 \times \underline{114.90} + 43.102 = \underline{123.99}$

Missing data at Station C
Supplement by data at Station B
$y = 0.469x + 41.265$
$= 0.469 \times \underline{10.30} + 41.265 = \underline{46.10}$

$y = 0.469x + 41.265$
$= 0.469 \times \underline{7.20} + 41.265 = \underline{44.64}$

Supplemented Discharge Data

| Date | Station A | Station B | Station C |
|---|---|---|---|
| | | | |
| | | | |
| May 24 | 35.60 | 78.50 | 103.10 |
| May 25 | 211.25 | 135.10 | 175.70 |
| May 26 | 179.18 | 205.80 | 273.10 |
| May 27 | 243.95 | 199.90 | 192.20 |
| May 28 | 131.65 | 50.70 | 95.00 |
| May 29 | 199.50 | 149.30 | 141.00 |
| May 30 | 114.90 | 123.99 | 83.90 |
| May 31 | 131.10 | 152.60 | 123.00 |
| June 1 | 123.70 | 55.60 | 57.10 |
| June 2 | 65.20 | 15.50 | 70.90 |
| June 3 | 28.50 | 10.30 | 46.10 |
| June 4 | 21.30 | 7.20 | 44.64 |
| June 5 | 91.60 | 126.10 | 121.00 |
| June 6 | 159.05 | 107.80 | 113.40 |
| June 7 | 160.55 | 188.80 | 56.20 |
| | | | |
| | | | |

**Figure 2.3.5 Basic Procedure of the Data Supplementation**

### 4) Estimation of Discharge at the Site

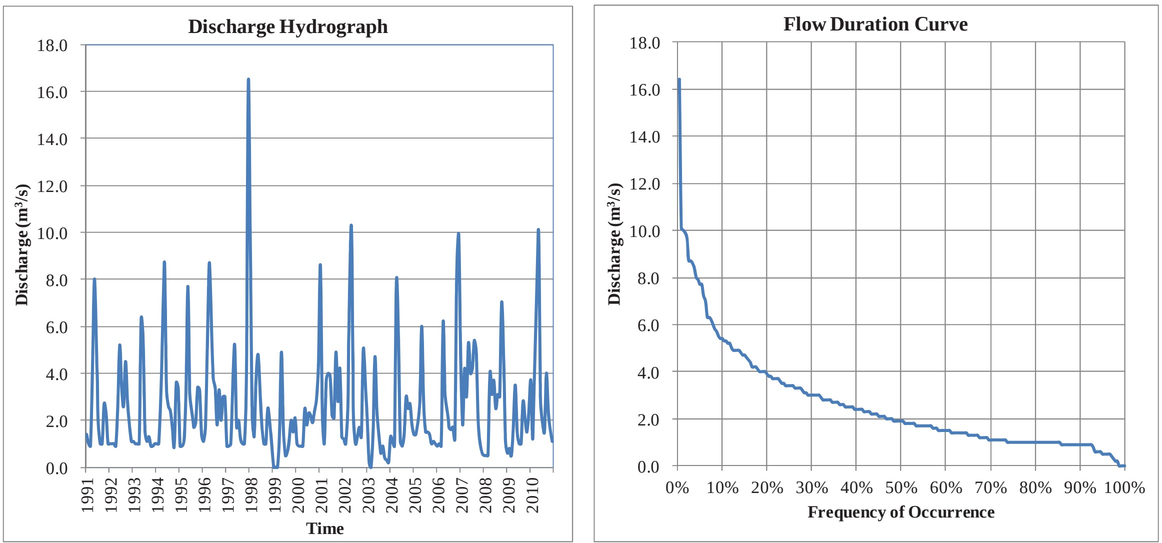
Discharge at the candidate site is estimated based on available discharge at the gauging station (where it is located downstream of the candidate site) as follows:

$$Q = Q_S \times \frac{A}{A_s}$$

Where,

| | |
|---|---|
| $Q$: | discharge at the candidate site ($m^3/s$) |
| $Q_s$: | discharge data at the gauging station ($m^3/s$) |
| $A$: | catchment area of the candidate site ($km^2$) |
| $A_s$: | catchment area of the gauging station ($km^2$) |

Average discharge data is arranged in discharge hydrograph and flow duration curve as shown below.



This is a plot of monthly discharges on the vertical axis and the time series on the horizontal axis. It shows temporal pattern of the historical river flows.

These are the monthly discharges arranged in descending order and plotted along the vertical axis and days or percentage on the horizontal axis. It shows flow duration.

**Figure 2.3.6 Discharge Hydrograph and Flow Duration Curve**

5) Estimation of Dependable Discharge at the Site

The dependable discharge is defined from the flow duration curve, within 90 to 95% of reliable discharge.

It is noted that if there are existing water uses upstream of the site, such as irrigation, domestic consumption, etc., the water amount of use shall be deducted from the estimated monthly average discharge. Water use conditions in upstream basin shall be assumed at this stage, and will be confirmed in site investigation.

### (2) Estimation by KMD Rainfall Data

KMD is executing measurement and compilation of rainfall data. It is preferable to collect rainfall data at as many gauging stations surrounding the candidate site as possible. Then, homogeneity and correlation of collected rainfall data are examined in the same manner as WRMA discharge data.

Monthly discharges at the candidate site are estimated using the following formula:

$$Q_{ave} = \frac{C \times R \times 10^{-3} \times CA \times 10^{6}}{60 \times 60 \times 24 \times D}$$

Where,
$Q_{ave}$: monthly average discharge ($m^3/s$)
$C$: runoff ratio ( - )
$R$: monthly rainfall (mm)
$CA$: catchment area ($km^2$)
$D$: days of each month (31, 30, 29 or 28 days)

The runoff ratio depends on the topographic conditions in the catchment area, and is given as follows:

| **Topographic Condition** | **Runoff Ratio “C”** |
|---|---|
| Flat countryside, arable land or sandy soil | 0.25 – 0.35 |
| Meadow, smooth slope land | 0.35 – 0.45 |
| Hilly area with forest, land rocky | 0.45 – 0.55 |
| Mountainous area, rock land, frozen surface | 0.55 – 0.65 |

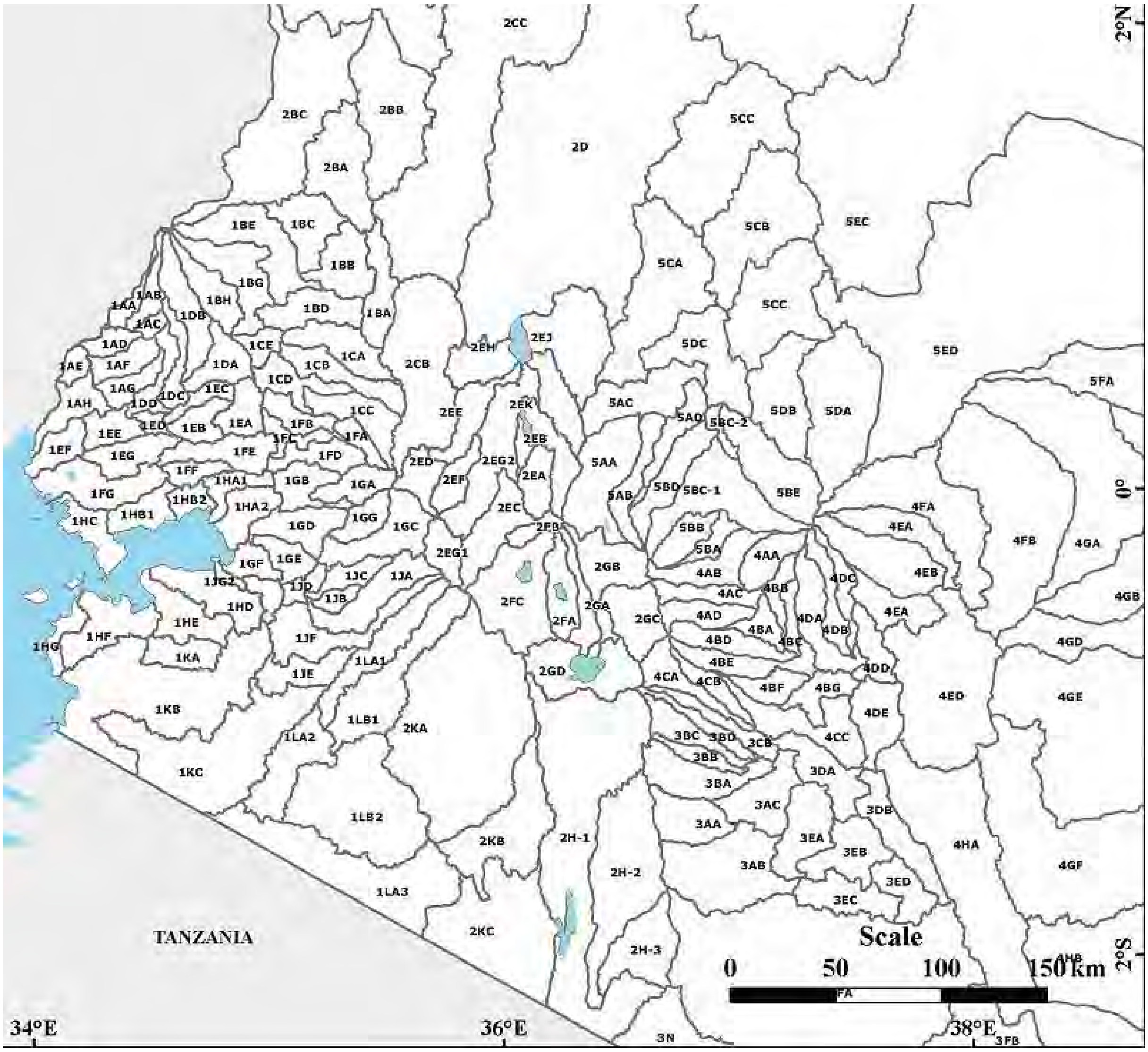
When series of discharge data are prepared, those discharge data are arranged in discharge hydrograph and flow duration curve, and the dependable discharge is defined, in the same manner as WRMA discharge data.

### (3) Simulated Monthly Discharge Data by NWMP 2030

Rainfall-runoff analysis was conducted by JICA in 2013 by the “Project on Development of the National Water Master Plan 2030”, by applying the Similar Hydrological Elements Response model (SHER model) for the entire country. As a result of simulation by SHER model, the monthly average naturalized discharges were provided for 204 sub-basins for the period from 1991 to 2010.

The sub-basins surrounding the potential area of hydropower development are shown in the figure below. The monthly average naturalized river discharges by sub-basins surrounding the potential area are attached in Annex-1. The naturalized river discharge was defined in NWMP 2030 as the river runoff that is not affected by any water use in the catchment area.

The series of discharge data of sub-basins surrounding the candidate site are converted into the discharges at the candidate site by ratio of catchment area. Additionally, those discharge data are arranged to discharge hydrograph and flow duration curve, then the dependable discharge defined, in the same manner as WRMA discharge data.



Source: "National Water Master Plan 2030" conducted by JICA in 2013 (arranged by WG).

**Figure 2.3.7 Sub-basins surrounding the Potential Areas of Hydropower**

### 2.3.3 Amount of the Reserve Discharge by WRMA

The amount of the reserve, consisting of ecological and basic human needs, was determined as the 95% value of the naturalized daily flow for each river in accordance with "Guidelines for Water Allocation (WRMA, 2010)". Therefore, the minimum discharge shall be determined by deducting of 95% reliable discharge.

### 2.3.4 Estimation of Probable Flood Discharge

In general, 50 to 100-year probable flood discharges are used for the design flood discharge of MHP schemes.

Information on regional floods is not available or limited in general. The flood analysis is carried out by several methods, these results compared, and then the design flood discharge determined.

The major analysis methods are explained below.

(1) Statistical Analysis

The statistical analysis is carried out among the annual maximum daily discharge by several frequency curves, such as Gambel's distribution, Pearson distribution, log normal distribution, log Pearson type

III distribution, etc. The frequency curve which is harmonized with the discharge records will be applied.

(2) Rational Formula

The rational formula is commonly applied for the estimation of flood discharge at the catchment area less than 200 km$^2$. The formula is given as follows;

Rational Formula (Lloyd Davies, 1906)

$$Q_P = \frac{1}{3.6} \times f \times R_T \times A$$

Where,
$Q_P$: peak discharge (m$^3$/s)
$f$: runoff coefficient ( - )
$R_T$: average rainfall intensity in flood duration (mm/hr)
$A$: catchment area (km$^2$)

The runoff coefficient is given as follows depending on the land use conditions in the catchment area:

| **Land use Condition** | ***f*** | **Land use Condition** | ***f*** |
|---|---|---|---|
| Steep mountainous area | 0.75 – 0.90 | Irrigated paddy field | 0.70 – 0.80 |
| Tertiary mountainous area | 0.70 – 0.80 | River in highland | 0.75 – 0.85 |
| Undulating land and forest | 0.50 – 0.75 | Small river in plain | 0.45 – 0.75 |
| Flat cultivated land | 0.45 – 0.60 | Large river mostly plain | 0.50 – 0.75 |

The average rainfall intensity is estimated by the following two (2) formulae:

Mononobe Formula

$$R_T = \frac{R_{24}}{24} \times \left(\frac{24}{T}\right)^{2/3}$$

Ito Formula

$$R_T = R_{24} \times \left(\frac{347.1}{t^{1.35} + 1{,}502}\right)$$

Where,
$R_{24}$: probable daily rainfall (mm/day)
$T$: time to concentration of runoff (hr)
$t$: time to concentration of runoff (min)

The flood concentration time ($T$, $t$) is generally estimated by two times, i.e., overland inflow time from the basin to river and river flow time to the site. Those values are given as follows. The required topographic characteristics in the formulae of the catchment area are assumed from the topographic map with scale of 1: 50,000.

Overland Inflow Time [Kerby Formula]

$$T_{OF} = \left(\frac{2}{3} \times 3.28 \times l \times \frac{N}{\sqrt{S}}\right)^{0.467}$$

Where,
$T_{OF}$: overland inflow time (min)
$l$: length between basin crest and top of river (m)
$N$: retardance coefficient ( - )

River Flow Time [Rziha Formula]

$$T_{RF} = \frac{L}{W},$$

Where,
$T_{RF}$: river flow time (s)
$L$: horizontal length of river channel from top of river to the site (m)
$W$: flood velocity (m/s)
$h$: height difference from top of river to the site (m)

The retardance coefficient for overland inflow time is given as follows depending on the land surface conditions in the catchment area:

| **Land Surface Condition** | ***N*** | **Land Surface Condition** | ***N*** |
|---|---|---|---|
| Impervious surface | 0.02 | Forest area with deciduous trees | 0.60 |
| Bare ground (grainy surface) | 0.10 | Forest area with deciduous deposit | 0.80 |
| Bare ground (normal surface) | 0.20 | Forest area with conifer trees | 0.80 |
| Rough grass and cultivated fields | 0.20 | Dense forest area | 0.80 |
| Grass farm and normal grass field | 0.40 | - | - |

### (3) Estimation by Regional Area Flood Curve in NWMP 2030

Regional area flood curves are given by logarithmic function as the results of flood analysis in NWMP 2030. The flood curve is available for 10-year, 25-year, 50-year, and 100-year probable flood in the following 21 sub-basins.

**Table 2.3.1 21 Sub-basins of Regional Area Flood Curve by NWMP 2030**

| Lake Victoria North | Lake Victoria South | Rift Valley |
|---|---|---|
| LVN-2 Yala | LVS-2 Asure | RV-2 Ewaso Ngiro (South) |
| LVN-3 Nzoia | LVS-5 Mara | RV-12 Kedong |
| LVN-6 Malikisi | LVS-6 Migori | RV-14 Lake Naivasha |
| LBN-7 Malaba | LVS-10 Kabondo Awach | RV-19 Lake Bogoria |
|  | LVS-11 Sondu | RV-20 Lake Baringo |
|  | LVS-12 Nyando | **Others** |
|  | LVS-13 Oruba | AT-1 Athi |
|  | LVS-14 Kibos | TN-1 Tana |
|  | LVS-16 Awach Seme | EN-1 Ewaso Ngiro |

Source: “National Water Master Plan 2030” conducted by JICA in 2013 (arranged by WG).

The regional area flood curves are attached in Annex-2. The peak flood discharges are obtained by plugging in the catchment area into the flood curve.

### (4) Confirmation by Creager Envelop Curve

Adequacy of the estimated flood discharges is checked by the Creager envelope curve.

The Creager envelope curve is an empirical formula which indicates the relation between catchment area and estimated or recorded flood peak discharge by the form of specific discharge.

The Creager envelop curve is given by the following formula:

$$Q_P = 0.503 \times C \times \left( \frac{A}{2.59} \right)^{a-1}$$

$$a = 0.894 \times \left( \frac{A}{2.59} \right)^{-0.048}$$

Where,

$Q_P$: Specific peak discharge ($m^3/s/km^2$)

$C$: Creager’s coefficient ( - )

$A$: catchment area ($km^2$)

The Creager coefficient “C” indicates regional characteristics of catchment area. Therefore, it is variable depending on the location of the basin, but nearby basins has similar values. The “C” value, therefore, shall be estimated based on the available flood records and/or design flood discharges in the existing projects to obtain the appropriate value near the basin.

The flood peak specific discharges and the “C” values of hydropower projects in Kenya are compared as shown below.

## Table 2.3.2 Creager's Coefficient of Hydropower Projects in Western Kenya

| Project Name | County | A ($km^2$) | $Q_d$ ($m^3/s$) | $Q_p$ ($m^3/s/km^2$) | C ( - ) | Remarks |
|---|---|---|---|---|---|---|
| *Proposed MHP* | | | | | | |
| Ura Kiegoi 1 | Meru | 59 | 82 | 1.396 | 5.7 | Flood during construction |
| Kazita Githongo | Meru | 155 | 27 | 0.174 | 1.0 | |
| Thiba Kiringa Conf. | Embu | 252 | 204 | 0.812 | 5.9 | |
| Irati-Maragwa Conf. | Muranga | 101 | 101 | 1.001 | 5.0 | |
| Gura-Sagana Conf. | Kirinyaga | 439 | 132 | 0.300 | 2.8 | |
| Zaina Falls-Chania Conf. | Nyeri | 34 | 2.2 | 0.068 | 0.2 | |
| Greater Orobo | Nandi | 50 | 121 | 2.407 | 9.3 | |
| Kiptiget - Itare Conf. | Bomet | 186 | 42 | 0.227 | 1.4 | |
| Ainamoi - Kitio | Kericho | 333 | 75 | 0.227 | 1.9 | |
| Chemosit - Kabianga | Bomet | 1,370 | 310 | 0.227 | 3.8 | |
| Wei Wei - Sighor | Nakuru | 203 | 35 | 0.172 | 1.1 | |
| Embobut - Tot | Elegeyo Marakwet | 34 | 496 | 14.714 | 50.1 | |
| Embobut - Nguruman | Kajiado | 237 | 3.6 | 0.015 | 0.1 | |
| *Large Scale HPP* | | | | | | |
| Sondu/ Miriu | Kisumu | 3,345 | 1,046 | 0.313 | 8.6 | PMF |
| | | | 749 | 0.224 | 6.1 | 1000-years flood |
| Magwagwa | Nyamira | 3,160 | 1,920 | 0.608 | 16.1 | PMF |
| | | | 1,634 | 0.517 | 13.7 | 1000-years flood |

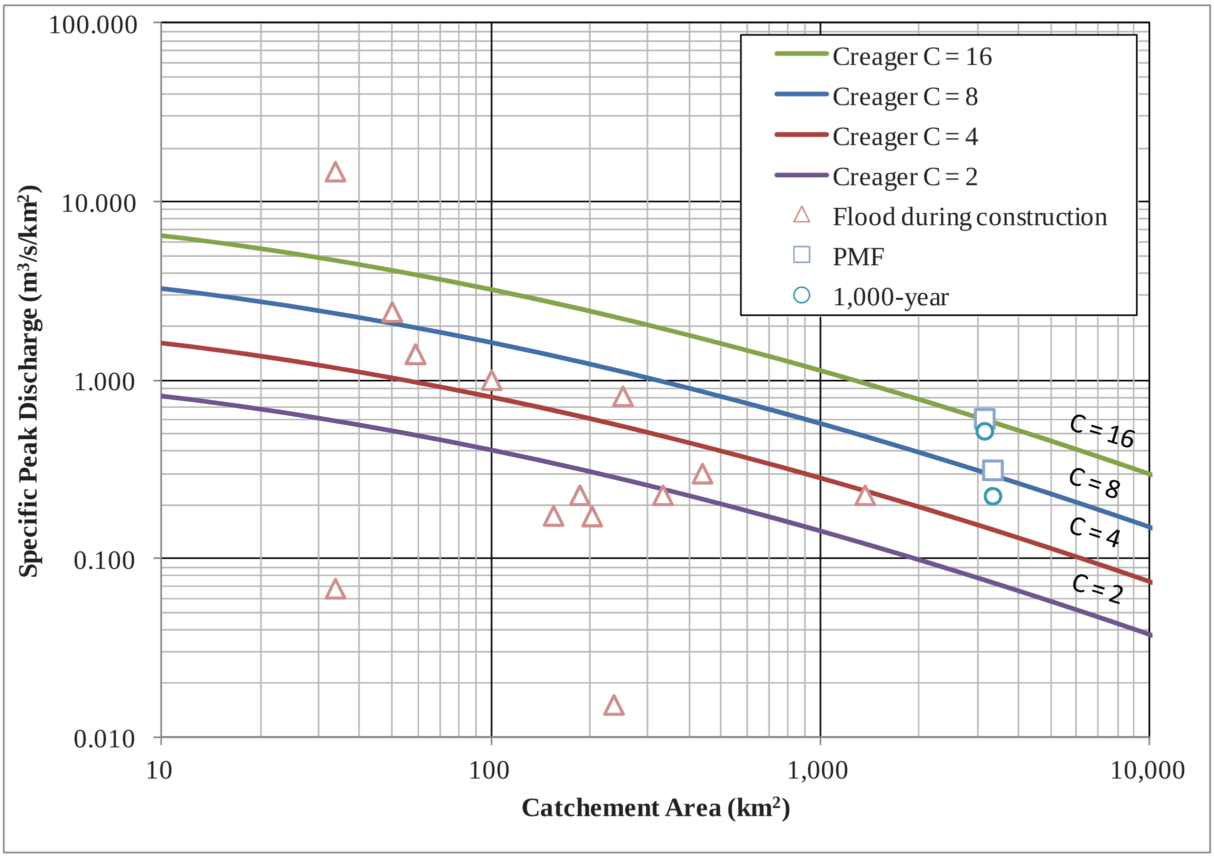


Figure 2.3.8 Creager's Coefficient of Hydropower Projects in Kenya

## 2.4 Estimation of the Power Demand

### 2.4.1 Estimation of required Generator Capacity

Power demand in the local community is unknown before electrification. In general, rural electrification plans are based on assumptions of minimum electric equipment in order to identify promising development schemes.

The generator capacity can be approximated using the following equation based on the assumptions explained hereinafter:

$$P_d = 0.2N$$

Where, $P_d$: required generator capacity (kW)
$N$: community size (number of households)

Community size, i.e., the number of households in the communities in the target area shall be identified based on the population and housing census from Kenya National Bureau of Statistics (KNBS).

(1) Assumption of Power Demand

Assumptions of percentage share and unit demand of each consumer are made as shown below.

**Table 2.4.1 Basic Assumptions of Consumers and Unit Demand**

| User | Share per household or Number per village | Assumed Demand | | | |
|---|---|---|---|---|---|
| | | Lighting | TV | Fan/Heater | Total |
| **Domestic** | | | | | |
| Type A | 20% of total households | - | - | - | 0 |
| Type B | 60% of total households | 20 W x 2 | - | - | 40 |
| Type C | 20% of total households | 20 W x 3 | 200 W x 1 | - | 260 |
| Type D | 1 per 100 households | 40 W x 5 | 200 W x 1 | 200 W x 1 | 600 |
| **Public** | | | | | |
| Primary School | 1 per 100 households | 40 W x 15 | 200 W x 1 | 200 W x 1 | 1,000 |
| Community Hall | 1 per 100 households | 40 W x 15 | - | 200 W x 2 | 1,000 |
| Dispensary | 1 per village > 100 households | 40 W x 5 | - | 200 W x 2 | 600 |
| Streetlight | 1 per 4 households | 40 W x 1 | - | - | 40 |
| **Business** | | | | | |
| Battery Carging Station | 1 per 50 households | - | - | - | 1,200 |
| Posho Mill | 1 per 200 households | - | - | - | 5,000 |

With the basic assumptions outlined above, the power demand of a rural community can be estimated as presented in the table below, for villages of different sizes ranging from 20 to 1,000 households.

## Table 2.4.2 Assumed Consumers and Power Demand

**Assumed Number of Consumers** (Unit: numbers)

| User | Unit | Community Size (Household) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Demand | 1,000 | 800 | 600 | 400 | 300 | 200 | 100 | 50 | 20 |
| **Domestic** | | | | | | | | | | |
| Type A | 0 | 200 | 160 | 120 | 80 | 60 | 40 | 20 | 10 | 4 |
| Type B | 40 | 600 | 480 | 360 | 240 | 180 | 120 | 60 | 30 | 12 |
| Type C | 260 | 200 | 160 | 120 | 80 | 60 | 40 | 20 | 10 | 4 |
| Type D | 600 | 10 | 8 | 6 | 4 | 3 | 2 | 1 | 0 | 0 |
| **Public** | | | | | | | | | | |
| Primary School | 1,000 | 10 | 8 | 6 | 4 | 3 | 2 | 1 | 0 | 0 |
| Community Hall | 1,000 | 10 | 8 | 6 | 4 | 3 | 2 | 1 | 0 | 0 |
| Dispensary | 600 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| Streetlight | 40 | 250 | 200 | 150 | 100 | 75 | 50 | 25 | 12 | 5 |
| **Business** | | | | | | | | | | |
| Battery Carging Station | 500 | 20 | 16 | 12 | 8 | 6 | 4 | 2 | 1 | 0 |
| Posho Mill | 5,000 | 5 | 4 | 3 | 2 | 1 | 1 | 0 | 0 | 0 |
| **Total** | | 1,106 | 885 | 664 | 443 | 332 | 222 | 111 | 53 | 21 |

**Assumed Power Demand** (Unit: kW)

| User | Unit | Community Size (Household) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Demand | 1,000 | 800 | 600 | 400 | 300 | 200 | 100 | 50 | 20 |
| **Domestic** | | | | | | | | | | |
| Type A | 0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Type B | 40 | 24.0 | 19.2 | 14.4 | 9.6 | 7.2 | 4.8 | 2.4 | 1.2 | 0.5 |
| Type C | 260 | 52.0 | 41.6 | 31.2 | 20.8 | 15.6 | 10.4 | 5.2 | 2.6 | 1.0 |
| Type D | 600 | 6.0 | 4.8 | 3.6 | 2.4 | 1.8 | 1.2 | 0.6 | 0.0 | 0.0 |
| **Public** | | | | | | | | | | |
| Primary School | 1,000 | 10.0 | 8.0 | 6.0 | 4.0 | 3.0 | 2.0 | 1.0 | 0.0 | 0.0 |
| Community Hall | 1,000 | 10.0 | 8.0 | 6.0 | 4.0 | 3.0 | 2.0 | 1.0 | 0.0 | 0.0 |
| Dispensary | 600 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.0 | 0.0 |
| Streetlight | 40 | 10.0 | 8.0 | 6.0 | 4.0 | 3.0 | 2.0 | 1.0 | 0.5 | 0.2 |
| **Business** | | | | | | | | | | |
| Battery Carging Station | 500 | 10.0 | 8.0 | 6.0 | 4.0 | 3.0 | 2.0 | 1.0 | 0.5 | 0.0 |
| Posho Mill | 5,000 | 25.0 | 20.0 | 15.0 | 10.0 | 5.0 | 5.0 | 0.0 | 0.0 | 0.0 |
| **Total** | | 147.6 | 118.2 | 88.8 | 59.4 | 42.2 | 30.0 | 12.8 | 4.8 | 1.7 |

### (2) Estimation of required Generator Output

The required generator output ($P_r$) to supply for the power demand derived above can be calculated by the following formula:

$$\begin{aligned} P_r &= P_d + w_1 + w_2 \\ &= P_d \times (1 + 0.2 + 0.1) = 1.3P_d \end{aligned}$$

Where,
$P_r$: required generator output (kW)
$P_d$: power demand (kW)
$w_1$: losses of distribution line, assumed to be 20% of $P_d$
$w_2$: reserved power, assumed to be 10% of $P_d$

The required generator output to meet the corresponding power demand in Table 2.4.2 is calculated using the above equation and presented in the table below as rounded figures.

**Table 2.4.3 Required Generator Capacity by Community Size**

(Unit: kW)

| Item | Community Size (Household) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1,000 | 800 | 600 | 400 | 300 | 200 | 100 | 50 | 20 |
| Assumed Power Demand: $P_d$ | 147.6 | 118.2 | 88.8 | 59.4 | 42.2 | 30.0 | 12.8 | 4.8 | 1.7 |
| Required Generator Output: $P_r$ | 191.9 | 153.7 | 115.4 | 77.2 | 54.9 | 39.0 | 16.6 | 6.2 | 2.2 |
| Selected Generator Capacity $P_g$ | 200 | 160 | 120 | 80 | 60 | 40 | 20 | 10 | 3 |

Accordingly, the generator capacity (kW) can be approximated at 20% of the number of households in the community

### 2.4.2 Estimation of Required Head and Discharge

When a discharge drops through a head, the work done per unit time is called the "theoretical hydropower".

Here, the discharge is defined as the amount of water flow used for power generation, and the head is defined as the height difference between intake and turbine outlet. Theoretical hydropower is calculated using the following equation.

$$P_0 = g \times H \times Q = 9.8HQ$$

Where, $P_0$: theoretical hydropower (kW)
$g$: gravity acceleration (9.8 m/s$^2$)
$H$: static head (m)
$Q$: discharge (m$^3$/s)

In practice, the theoretical hydropower cannot be produced because there are energy losses when converting gravitational potential energy of water into mechanical energy and then further into electrical energy. The relationship between the theoretical hydropower and the required generator capacity can be expressed as follows:

$$P_i = P_0 \times \eta_G \times \eta_T / (1 + m) = 0.65P_0$$

Where, $P_i$: required generator capacity (kW)
$P_0$: theoretical hydropower (kW)
$\eta_G$: combined efficiency, assumed to be 72%
$m$: rate of other losses, assumed to be 10%

The required discharge to obtain the required power is given for various heads as shown below.

**Table 2.4.4 Required Discharge by Available Head**

| Item | | Community Size (Household) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1,000 | 800 | 600 | 400 | 300 | 200 | 100 | 50 | 20 |
| Generator Capacity | (kW) | 200 | 120 | 95 | 80 | 55 | 40 | 20 | 10 | 4 |
| Theoretical Potential | (kW) | 308 | 185 | 146 | 123 | 85 | 62 | 31 | 15 | 6 |
| Available Head (m) | | Required Discahrge (m$^3$/s) | | | | | | | | |
| 30 | | 1.05 | 0.63 | 0.50 | 0.42 | 0.29 | 0.21 | 0.10 | 0.05 | 0.02 |
| 25 | | 1.26 | 0.75 | 0.60 | 0.50 | 0.35 | 0.25 | 0.13 | 0.06 | 0.03 |
| 20 | | 1.57 | 0.94 | 0.75 | 0.63 | 0.43 | 0.31 | 0.16 | 0.08 | 0.03 |
| 15 | | 2.09 | 1.26 | 0.99 | 0.84 | 0.58 | 0.42 | 0.21 | 0.10 | 0.04 |
| 10 | | 3.14 | 1.88 | 1.49 | 1.26 | 0.86 | 0.63 | 0.31 | 0.16 | 0.06 |
| 5 | | 6.28 | 3.77 | 2.98 | 2.51 | 1.73 | 1.26 | 0.63 | 0.31 | 0.13 |
| 3 | | 10.47 | 6.28 | 4.97 | 4.19 | 2.88 | 2.09 | 1.05 | 0.52 | 0.21 |

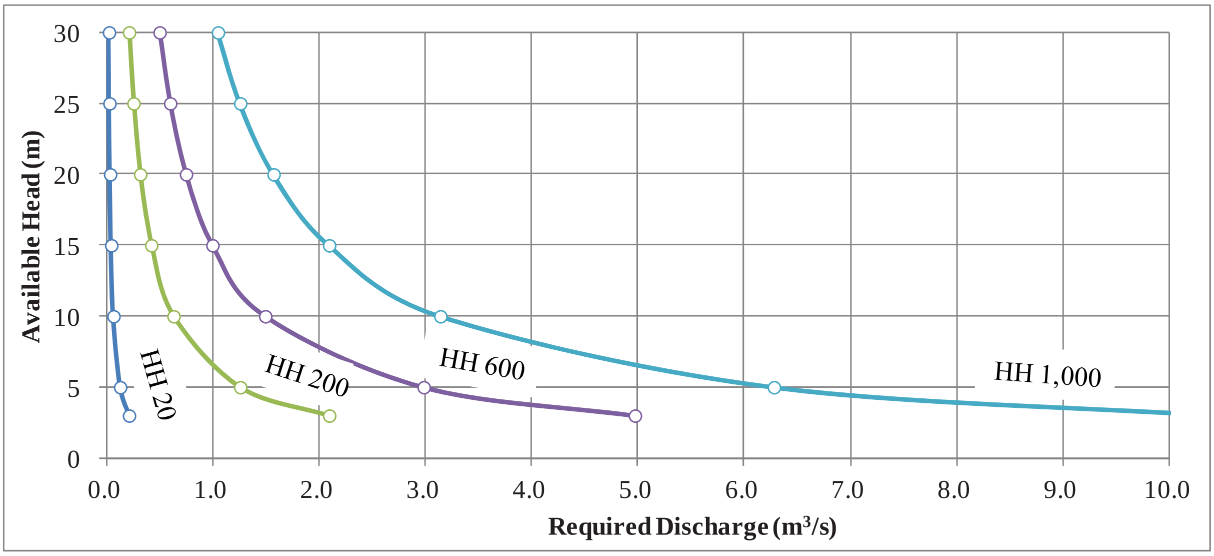


**Figure 2.4.1 Required Head and Discharge**

## 2.5 Comparison between Power Demand and Hydropower Potential

For MHP with an isolated grid system, it is desirable that the power generated is higher than the power demand. Otherwise, a backup power system needs to be provided to meet the full load.

Taking into consideration the development pattern of MHP, the hydropower potential at the candidate site is evaluated as follows:

**Table 2.5.1 Evaluation of the Hydropower Potential**

| Condition | Evaluation | Next Step |
|---|---|---|
| $P_d < P_{90}$ | In case $P_d$ is smaller than $P_{90}$, hydropower potential at the site is enough for electrification of the target area. | Proceed to field investigation. |
| $P_{90} < P_d < P_{50}$ | In case $P_d$ is within the range of $P_{90}$ and $P_{50}$, hydropower potential at the site is not enough for electrification of the target area. Alternative power sources, such as diesel generator, solar, wind, etc., shall be integrated into the MHP. | Proceed to field investigation. |
| $P_{50} < P_d$ | In case $P_d$ is larger than $P_{50}$, hydropower potential at the site is not suitable for electrification of the target area. | Do not proceed with the candidate site. |

Note: $P_d$ means the power demand; $P_{90}$ & $P_{50}$ means the hydropower potential by 90%/50% reliable discharge.

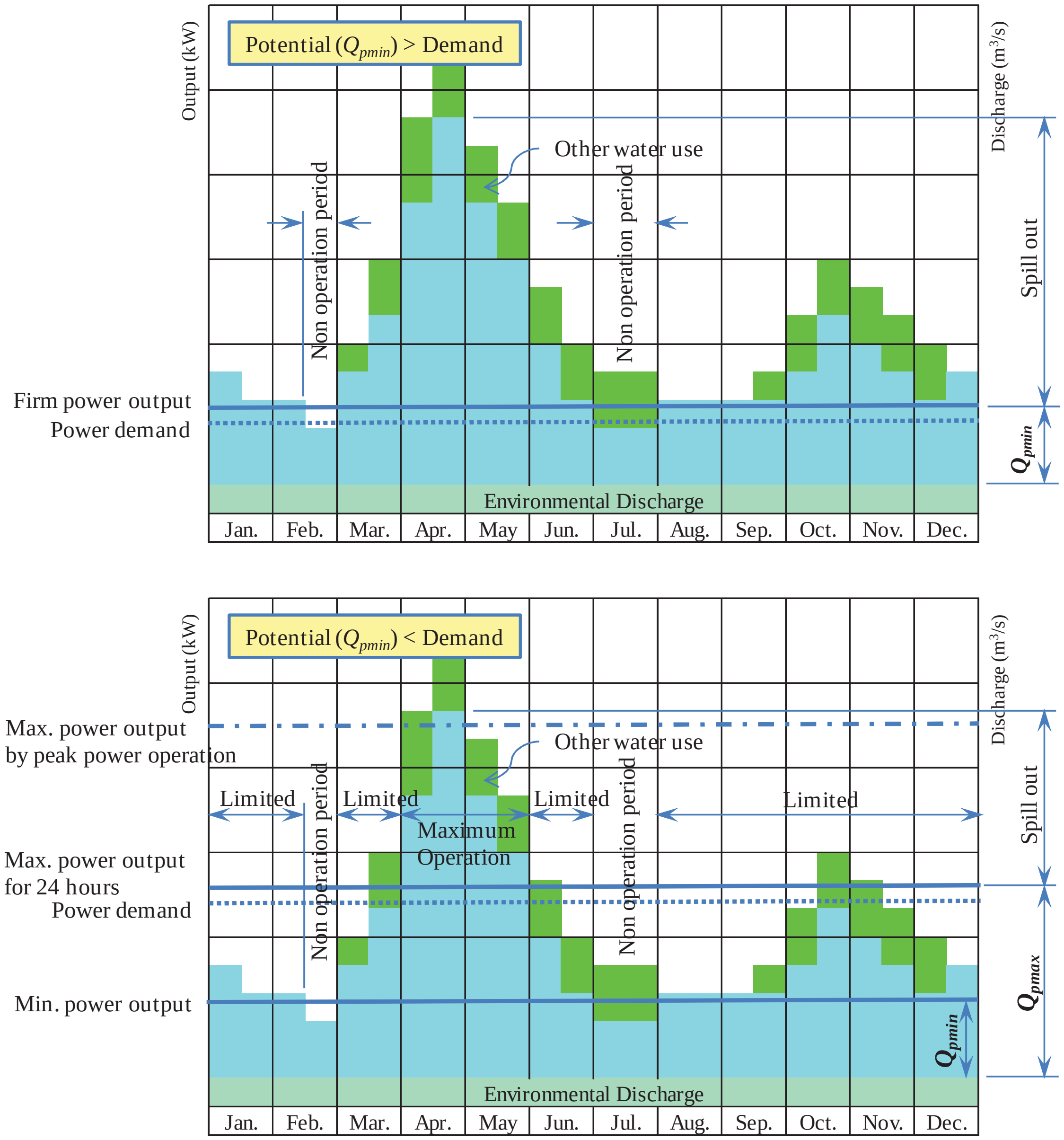


**Figure 2.5.1 Development Pattern**

# CHAPTER 3 INVESTIGATION AND PLANNING

## 3.1 Social Investigation

Initially, MHP was identified based on some assumptions and application of limited data and information. Therefore, the assumptions shall be reviewed for precision through site investigation. The MHP planning shall proceed based on the updated conditions.

The major purposes of site investigation are to conduct:

- ✓ Survey on power demand forecasting, and
- ✓ Survey on hydropower potential,

### 3.1.1 Survey on Power Demand Forecasting

When the planned MHP has been developed successfully, the operation and maintenance will be carried out by a management body organized by local residents. Accordingly, participation of local residents from the planning stage is important for successful development and implementation.

Notwithstanding the above, development of MHP at the target site is not guaranteed at this stage. The purpose of the site survey, the present stage of the MHP plan, and the procedure up to construction shall be explained carefully to local residents in order to avoid exaggerated expectations for electrification.

The social survey at this stage consists of the following activities:

(1) Consultation with Local Community

At first, it is necessary to explain to representatives of the local community the electrification plan and to obtain their approval to access the community area/village for investigation. Essential information to be communicated to the community are as summarized below.

- ✓ Outline of electrification plan,
- ✓ Outline of the hydropower mechanism,
- ✓ Purpose, kinds and period of investigation in the village,
- ✓ Influence of investigation on the residents , if any,
- ✓ Steps of development procedure,
- ✓ Management method after development, and so on.

It is noted that at this stage, the development possibility is still uncertain with equal chance of proceeding or cancellation, and this shall be reiterated during consultations with the local community.

(2) Social Economic Survey

A survey of the attitude of residents towards the proposed electrification is carried out, and their needs for electric energy clarified. The results of the survey will be reflected in the plan and the design.

**Table 3.1.1 Item of Social Economic Survey**

| Category | Item | Content |
|---|---|---|
| I. Key Information Survey | Operational period | Time to begin social economic study<br>(Concurrently with prior consultation) |
| | Target person | District, village, and other local leaders. |
| | Matters for study | Basic information on population, number of households, industries, etc. |
| | Usage and purpose | Basic information collection.<br>Scale of household research and materials for survey |
| II. Workshop (briefing) | Operational period | Before conducting the household research. |
| | Target person | Local representatives of leaders and residents. |
| | Purpose | Explanation of outline of MHP rural electrification.<br>Explanation of household research procedure. |
| III. Household Research | Operational period | After Workshop (briefing) |
| | Target person | About 20% or more of the total number of households. (Reliability and target accuracy of the statistical study are considered.) |
| | Method | Interviews |
| | Main research item | 1. Number and composition of family<br>2. Employment and income.<br>3. Presence and use of electric equipment (current situation).<br>4. Attitude and considerations for electrification.<br>5. Demand level of electrification.<br>6. Amount of energy expenditure (illumination, power and others).<br>7. Amount of payment intention.<br>8. Number of beneficiaries and geographic distribution situation. |

Source: “Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Table 6-4)”, published by JICA in 2011 (arranged by WG).

### (3) Power Demand Survey

In general, there are no time-series data available in the target rural area to be electrified by MHP scheme. Therefore, the power demand for each household is estimated first using the applicable electric appliances and these are summed up for the target area.

It is therefore necessary to conduct a social and economic survey for the target area in advance. The survey is conducted using interviews or a questionnaire sheet. To collect more accurate information, door-to-door interviews are the recommended survey approach. There are several methods for the study and approach. One of the typical methods is introduced here. However different methods could be used depending on the conditions concerned.

#### 1) Classification of Target Village

It is important to prepare a proper questionnaire to meet the current situation of the target village. There are many kinds of non-electrified villages such as a high income villages in which residents own portable generators, or are supported financially by remittances from relatives, etc. If electricity demand for such a village is estimated based on lighting and TV alone, power supply will run short over time because of increasing numbers of electric appliances year by year. It is therefore very important to conduct a tailored social and economic survey for the target village in advance.

Villages are classified into three categories as follows:

Low income village

A low income village is generally seen in a very remote area far away from the city, with limited crop acreage and a larger aging society. Electricity demand in low income villages is generally limited to lighting and TV, and the annual growth rate of electricity consumption is small.

Middle income village

A middle income village is generally seen in a less remote area, with some economic activity such as cultivation of cash crop and livestock keeping. Some households in the village already use automobile batteries to watch TV. In such villages, the annual growth rate of electricity consumption will rapidly increase.

High income village

Some households in a high income village will generally own portable generators and vehicles. If such a village is electrified, people will purchase electric appliances such as refrigerators, washing machines, etc., and electricity supply will run short, which may lead to frustration. In such high income villages, electrification by grid extension is better than an independent power source.

2) Household survey

An interview or questionnaire survey of residents who live in a non-electrified village is necessary. Such households typically have limited access to information because of lack of televisions, etc., and it is therefore important to prepare a simple questionnaire sheet and not to use difficult words such as “disposable income”. It is also necessary to ask questions that are simple to answer because they do not record energy consumption and expenditure.

3) Industry survey

It is envisaged that there are no large industries in non-electrified villages. However, it is necessary to check for existing cottage industries which may be using a portable generator or to check for possible industrial applications for electricity use after electrification.

### 3.1.2 Survey on Future Management Capability

As mentioned above, operation and maintenance of MHP system will be carried out by a management body organized by local residents. Therefore, management capability of the community shall be surveyed.

A public consultation meeting shall be held to explain the following issues:

- ✓ Purpose of survey and electrification planning,
- ✓ Power station and distribution facilities will become the community’s property,
- ✓ Operation and maintenance in view of technical and financial requirements will be managed independently by the communities, in principle,
- ✓ Initial cost for wattmeter and lead-in will be borne by each household,
- ✓ Necessity of cooperation on installation of utility pole and distribution line, etc. in respect to site occupancy, and so on.

Through such a meeting, the implementation body and local residents are able to exchange opinions to achieve mutual understanding.

Major points of the survey at this stage are the reactions and results of the discussion regarding future operation and maintenance by the community itself. When the basic plan of MHP project has been confirmed, further specific preparations shall start.

### 3.1.3 Survey on Environmental and Social Impacts

The possible influences occur due to hydropower development are listed below. A detailed survey will be carried out by environmental specialists registered as lead expert on EIA/EA in NEMA after the feasibility of the project has been confirmed but before making financial arrangements.

However, initial observation is important for the project implementation. Possible environmental and social impacts due to MHP development are listed on the table below.

## Table 3.1.2 Possible Environmental Impact by Hydropower Development

| Item | Possibility |
|---|---|
| **Physical Impact** | |
| River diversion | River runoff between intake weir and outlet decreases because of the diversion for power generation. The project may affect aquatic flare and animals, as well as people using the river flow. |
| Downstream river flow | In case of pond type development, the natural river flow will be regulated at the intake weir, and river flow conditions downstream will be altered. |
| Water pollution | Water pollution will affect drinking water and/or aquatic flare and animals.<br>During construction stage, water pollution due to improper treatment of used water, leakages of fuels for construction equipment are possible.<br>During operation stage, water pollution due to leakages of lubricating oils and other chemical materials for electrical equipment are possible. |
| **Impact on Natural Environment** | |
| Biological environment | The construction of a power plant needs grounds for generation and distribution facilities, and access roads. Tree cutting and clearing are carried out at the operation stage in order to secure the necessary height and passage under the distribution line. |
| Disappearance of organisms living environment | The terrestrial habitat in the inundation area is lost due to the construction of intake weir. The ecosystem will be affected and careful attention should be paid to the area if it is a wildlife habitat for rare and endangered species. In addition, aquatic gene biodiversity will be affected because of reduced opportunities of genetic interaction caused by the weir as migration barrier. Migratory fishes in particular, which move between the upstream and downstream areas or sea, would suffer seriously due to the blockage of migration and reproduction. Open channel of headrace, access roads and temporary roads for construction may possibly obstruct the movement of prowling animals. |
| **Impact on Social Environment** | |
| Resettlement and land occupation | Residents who live in the permanent project area have to move to areas outside the project area. People who live in temporary areas, such as disposal areas, stockyards, contractor’s camp, etc., might have to move temporarily. There may also be cases where areas such as farm lands and important public facilities are inundated. |
| Intangible cultural assets | It might happen that an archaeological site or an ancient dwelling site is unexpectedly discovered during construction. |
| Water use, water right and communal land | In a case where the area affected by river diversion is utilized for inland water fisheries, the project might affect the fisheries. The construction might destroy a landscape and possibly affect the potential development of tourism, such as water fall and/or swale. |
| Increase of disease and electric accident | Malaria disease might break out because an intake weir crates a pond which may become a breeding ground for mosquitoes.<br>Matters of safety for people using electricity for the first time are important in newly electrified villages. |
| Influence to local community | Introduction of electricity to a non-electrified area brings a change to the living conditions of villagers. The amount of kerosene usage decreases drastically by changing from kerosene to electricity, and the business opportunity for kerosene and kerosene lamps sellers is affected. Further, kerosene or LPG refrigerator users may also change to electric ones, similarly affecting business opportunities.<br>Concerning the planned distribution line, there might be a concern that its installation may potentially trigger existing friction between conflict areas and renew fighting. If the project is designed unfairly, it might raise an issue that the electrification will advantage a limited part of the community e.g. higher socioeconomic groups, etc. |
| Traffic accident | Although serious traffic problems might not occur for MHP projects, attention should be paid to cases where the road is used for specific functions of daily life such as access to schools or water facilities, etc. |
| Improvement of residents life | Since the MHP project changes a non-electrification area to an electrified one, positive effects such as improvement of the living conditions of the people may possibly be large. The positive impacts may contribute to health, education, agriculture, development of new small industries, etc. However the users are required to pay the electricity tariff, and a support strategy might be necessary to ensure residents enjoy the potential benefits of MHP by connecting to the power supply. |

Source: “Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Chapter 7.4.2)”, published by JICA in 2011 (arranged by WG).

## 3.2 Technical Investigation

### 3.2.1 Measurement of River Discharge

In general, the existence of either discharge or water level records is limited in the rural areas. When a MHP site is identified, discharge measurement of the river over a period of one year is undesirable due to the following two issues:

Estimation of the reliable discharge

In order to supply the required electric power constantly throughout the year, it is essential that the minimum river discharge in the dry season meets the load requirements. In this context, it is important to measure the river discharge in the dry season for the planning of a MHP station with an off-grid system.

Additionally, if there is an irrigation intake upstream of the planned MHP site, the river discharge is likely to be reduced during the irrigation periods. It will therefore be necessary to check the river discharge at the intake site during the irrigation period.

Estimation of the flood discharge

It is also necessary to observe the flood water levels during the rainy season in order to know the possible maximum water level of floods and to protect the intake and waterway facilities from the floods accordingly.

River discharge fluctuates seasonally and annually, and the discharge measurement shall therefore be undertaken continuously for at least 3 years for MHP planning.

(1) Installation of the Water Level Gauge

The site for discharge measurement and water level observation shall be selected on:

- ✓ A straight river stretch where water depth is uniform and flow conditions are stable without any obstructions (If the river section is irregular, wide or shallow, the accuracy of measurement results will be poor),
- ✓ A uniform slope section of the river to avoid being affected by the change in riverbed level and river width due to scouring or sedimentation. Attention is needed to protect the gauge from damage by floods and flowing debris.

A wooden staff with graduation preferably at 1 cm intervals shall be prepared and firmly placed vertically by concreting its bottom end deep into the ground, at a depth of at least 50 cm. The zero level on the gauge shall be below the lowest water level expected in the dry season. Accordingly, the gauge should be installed in the dry season. The graduated surface shall be faced in such a way that the gauge reader can easily read the water level or clean the gauge surface.

Installation of the gauge

It is also possible to place a graduated staff on a rigid rock surface under the water upon each measurement. In this case, the position for placement of the gauge shall be clearly marked for its easy identification at the next measurement.

The water level observation should be made as many times as possible. It is preferable to read the gauge once a day at a fixed time, 7:00 a.m. for example. The task of gathering such information may be assigned to the local community or inhabitants.

Stepped water level gauge

### (2) Measurement of Discharge

It is preferable that the discharge measurement for the planned MHP scheme is carried out after defining the position of the water level gauge, because the relationship between discharge and water level is important for planning of the scheme and design of the intake weir.

There are two (2) methods available for measurement of the river discharge as discussed below. Both methods estimate the river discharge from the flow areas and the flow velocities in a stream.

#### 1) Measurement by using Float

This is the easiest method, as it does not require any special equipment.

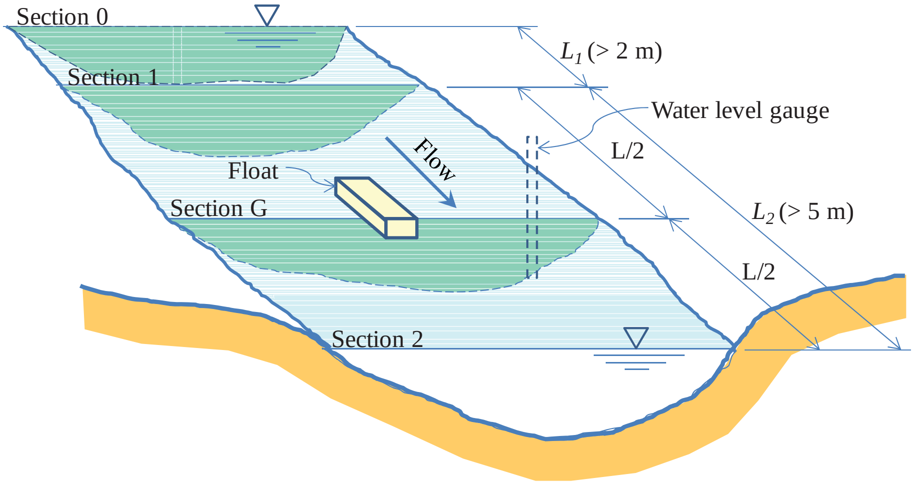
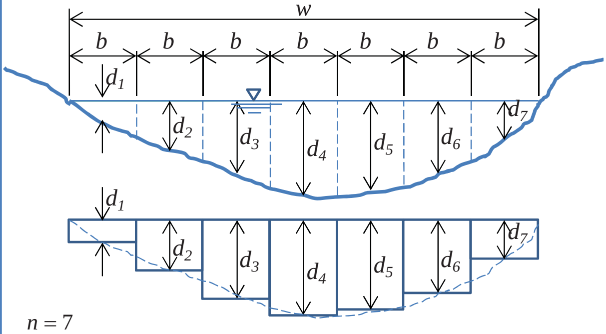


**Figure 3.2.1 Measurement by Float**

Example



$n = 7$

$\therefore b = W/n = W/7$

$$\begin{aligned} A &= d_1 \times b + d_2 \times b + d_3 \times b + d_4 \times b + d_5 \times b + d_6 \times b + d_7 \times b \\ &= b \times (d_1 + d_2 + d_3 + d_4 + d_5 + d_6 + d_7) \\ &= W/7 \times (d_1 + d_2 + d_3 + d_4 + d_5 + d_6 + d_7) \end{aligned}$$

Measurement by float shall be carried out as follows:

a) Define three (3) sections upstream and downstream of the water level gauge section as shown in the above figure,

b) Measure flow area at Section 1, Section G and Section 2 as follows:
  - Divide the river width ($w$) into n (> 2) uniform strips for each section and measure water depth ($d_i$) at the center of each strip for all three sections,
  - Obtain the section area (a) at each section using the following equation:

$$a = w/n \times (d_1 + d_2 + \ldots + d_n)$$

Where,
$a$: section area ($m^2$)
$w$: river width (m)
$n$: number of strips (nos.)
$d_i$: depth at center of each strip (m)

  - Obtain the average section area of the 3 sections,

c) Drop the float at the center of Section 0,

d) Measure the time of float from Section 1 to Section 2 using a stopwatch,

e) Repeat the same procedure 3 more times,

f) Calculate the average flow velocity using the following equation:

$$V_i = L_2 / T_i$$

Where,
$V_i$: flow velocity at i-th measurement (m/s)
$L_2$: distance between Section 1 and Section 2 (m)
$T_i$: arrival time of float from Section 1 to Section 2 (s)

g) Calculate the discharge using the following equation:

$$Q = c \times V \times A$$

Where,
$Q$: discharge ($m^3/s$)
$c$: flow velocity coefficient ( - )
(c=0.65 for shallow stream, c=0.80 for smooth stream, c=0.85 for concrete channel)
$V$: average flow velocity (m/s)
$A$: average cross sectional area ($m^2$)

2) Measurement by using Current Meter

This is the most common method of measuring velocities where the stream is not irregular or turbulentt.

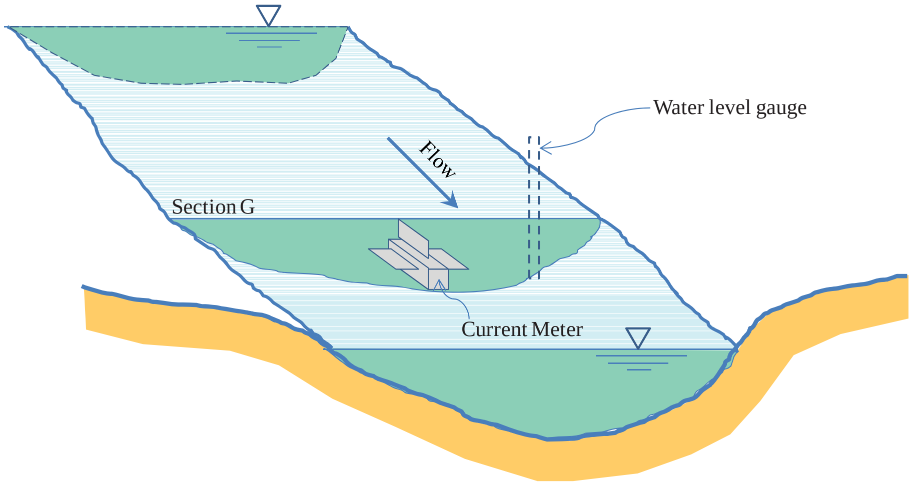
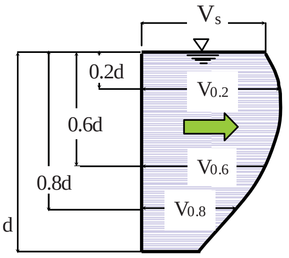


**Figure 3.2.2 Measurement by Current Meter**

Discharge measurement using current meter is conducted by selecting one section beside the gauging staff. Depth and flow area measurement shall be carried out using a similar method to that for float measurement.



Velocity and Depth

Velocity measurement alone may be sufficient for streams where a MHP site is planned under the following conditions:

- ✓ 2-point method: velocity measurement at two points - 20% and 80% of the depth from the surface (0.2d and 0.8d). It is applicable for depth more than 1 m.
- ✓ 1-point method: velocity measurement at one point - 60% of the depth from the surface (0.6d). It is applicable for depth less than 1 m.

The mean velocity is given by the following equation:

2-point method (for depth > 1 m):

$$V_m = 1/2 \times (V_{0.2} + V_{0.8})$$

1-point method (for depth < 1 m):

$$V_m = V_{0.6}$$

Where,
$V_m$: mean flow velocity (m/s)
$V_{0.2}$: velocity at 20% depth from surface (m/s)
$V_{0.6}$: velocity at 60% depth from surface (m/s)
$V_{0.8}$: velocity at 80% depth from surface (m/s)

The discharge of flow can be derived using the following equation:

$$Q = V_m \times A$$

Where,
$Q$: discharge ($m^3/s$)
$A$: cross sectional area ($m^2$)

If the river width is wide, it shall be divided into n (> 2) uniform strips in the same manner as the measurement of flow area, and the velocity measurement shall be made at the center of each strip. In this case, the discharge can be calculated using the following equation:

$$Q = Q_1 + Q_2 + \ldots\ldots + Q_n$$
$$Q_i = V_i \times A_i = V_i \times W/n \times d_i$$

Where,
$Q$: river discharge ($m^3/s$)
$Q_i$: discharge in i-th strip ($m^3/s$)
$A_i$: flow area of i-th strip ($m^2$)
$W$: river width (m)
$n$: number of the strips (nos)
$d_i$: flow depth at center of i-th strip (m)
$V_i$: mean flow velocity at $0.6d_i$ or average of $0.2d_i$ and $0.8d_i$ of center of $i$-th strip (m/s)

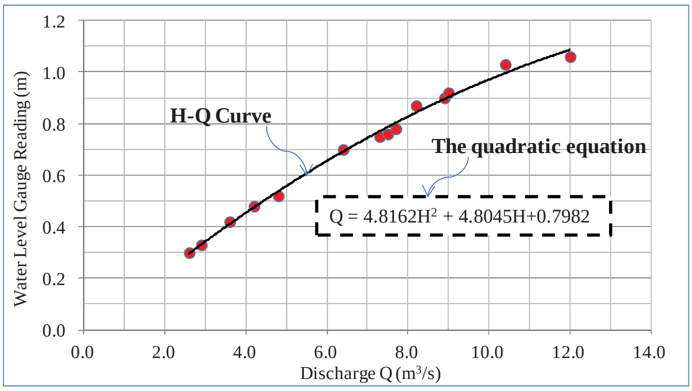
It is essential to check if the current meter has been calibrated prior to measurement.

As a general rule, the current meter should be calibrated once a year in order to obtain reliable velocity. Old current meters without calibration shall not be used. In cases where a calibrated meter is not available, float measurements would give more dependable results.

(3) Preparation of Head-Discharge Curve

When the discharge measurement has been done more than 10 times within the appropriate range, the relationship between discharge and water level is converted to a quadratic equation as shown below.

| Observed Date (D/M/Y) | Time | Weather | H (m) | Q ($m^3/s$) |
|---|---|---|---|---|
| 10 Jan. 2011 | 14:10 | Fine | 0.42 | 3.6 |
| 10 Feb. 2011 | 14:05 | Fine | 0.48 | 4.2 |
| 20 Mar. 2011 | 13:58 | Cloudy | 0.75 | 7.3 |
| 15 Apr. 2011 | 15:50 | Rainy | 1.03 | 10.4 |
| 15 May 2011 | 15:53 | Rainy | 1.06 | 12.0 |
| 17 Jun. 2011 | 14:09 | Cloudy | 0.76 | 7.5 |
| 21 Jul. 2011 | 13:54 | Fine | 0.52 | 4.8 |
| 21 Aug.2011 | 14:03 | Fine | 0.70 | 6.4 |
| 15 Sep. 2011 | 14:00 | Cloudy | 0.78 | 7.7 |
| 18 Oct. 2011 | 14:10 | Cloudy | 0.90 | 8.9 |
| 18 Nov. 2011 | 14:05 | Rainy | 0.92 | 9.0 |
| 14 Dec. 2011 | 14:02 | Fine | 0.87 | 8.2 |
| 12 Jan. 2012 | 14:55 | Fine | 0.33 | 2.9 |
| 10 Feb. 2012 | 14:04 | Fine | 0.30 | 2.6 |



Accumulated data through discharge measurement ⇨ Plotting data & converting to a quadratic equation.
To be updated periodically.

**Figure 3.2.3 Sample of Head-Discharge Rating Curve**

The quadratic equation is known as a “H-Q curve” and/or “Rating Curve”. The discharge can then be estimated by observation of the water level gauge.

However, it is noted that the rating curve should be reviewed periodically for calibration, especially after flood seasons that may result in erosion on the river banks or sedimentation on the riverbed.

### 3.2.2 Measurement of Available Head

Available head shall be confirmed at the site. The head can be measured quickly using simple and less-costly methods in the preliminary planning stage, as explained below.

(1) Survey Method by using Water Hose

A water hose filled with water is placed as shown below. A transparent water hose may be preferable so that the water level inside the hose is visible. Both ends of the hose shall be kept nearly at the same level by fixing to pieces of timber or leveling rods. Measure the height from the water level in the hose to the ground at both ends ($h_1$ and $h_2$). Measure the distance between the two ends ($L$) if the slope is required.

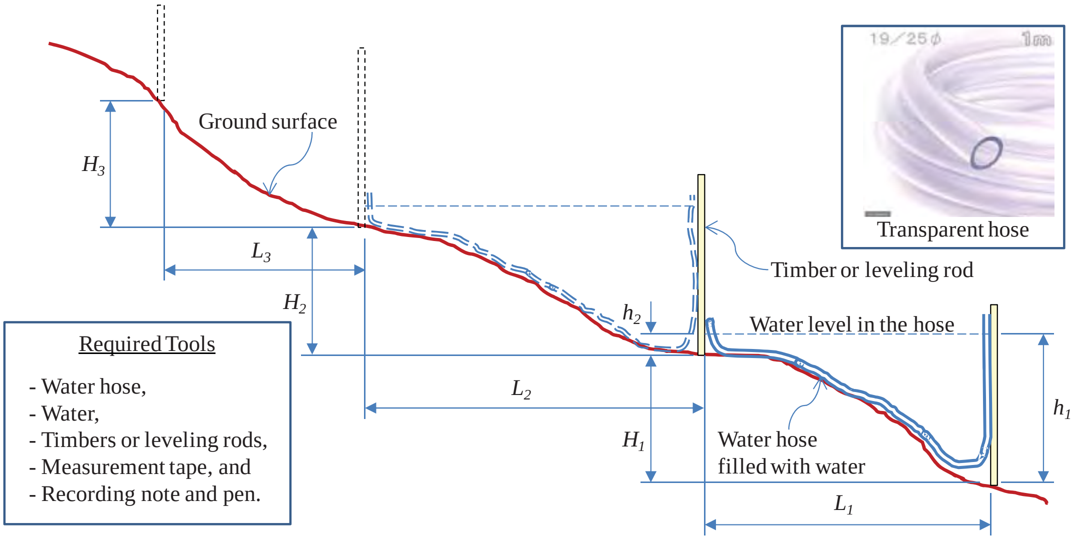


**Figure 3.2.4 Survey Method by using Water Hose**

The head and slope are calculated using the following equations:

$$H = h_2 - h_1$$
$$I = H/L$$

Where,
$H$: height difference between the two point (m)
$h_2$: height at upper point (m)
$h_1$: height at lower point (m)
$I$: slope of the ground surface ( - )
$L$: distance between the two point (m)

Repeat the same procedure until you arrive at the desired place. The gross head is obtained by summing up $H_i$ for $i$ = 1 to n steps ($\sum H = H_1 + H_2 + \ldots\ldots + H_n$).

(2) Survey Method by using Carpenter’s Level

The second option is to measure the height difference using a carpenter’s level and straight board as shown below. In case the length of the straight board is not enough, the level point on ground is confirmed by using additional straight board or rope.

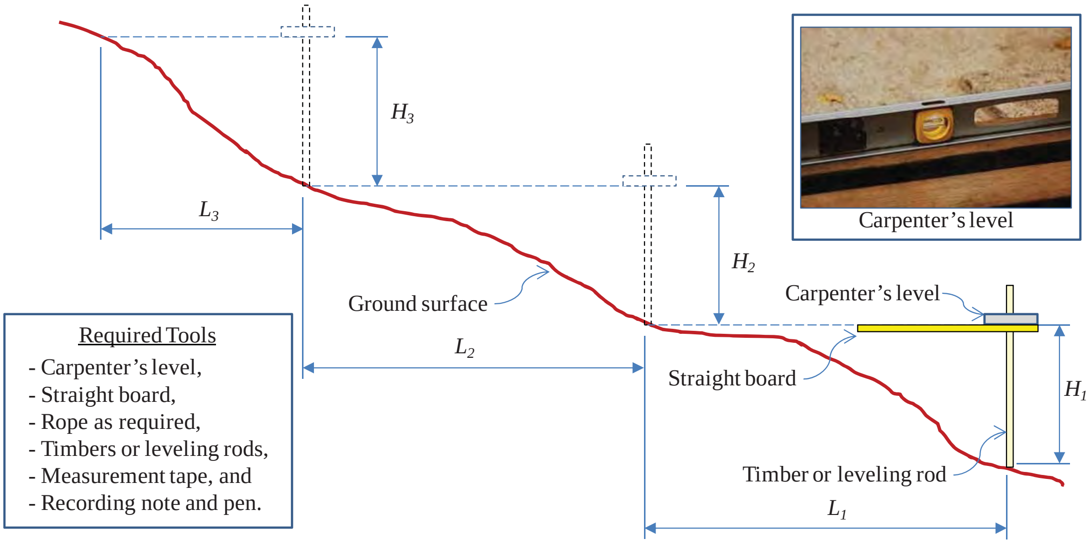


**Figure 3.2.5 Survey Method by using Carpenter’s Level**

Height difference $H_i$ shall be measured progressively to arrive at the desired place. The gross head can be obtained by summing up $H_i$ for $i$ = 1 to n steps ($\sum H = H_1 + H_2 + \ldots\ldots + H_n$).

### (3) Survey Method by using Pressure Meter

The third option is to use a pressure meter and water hose filled with water as shown below.

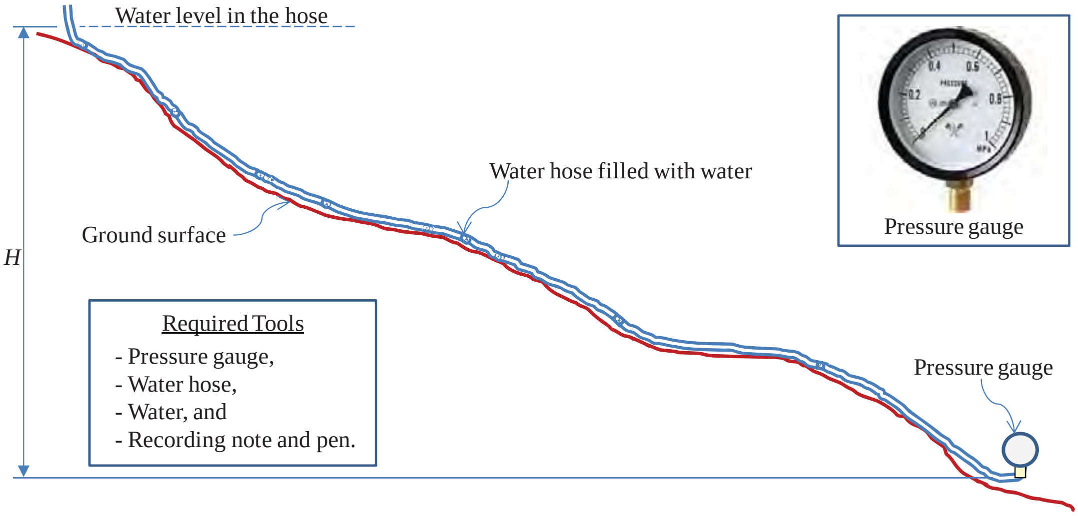


**Figure 3.2.6 Survey Method by using Pressure Gauge**

In case the water hose does not reach the desired place, repeat the same procedure until you arrive at the desired place. The gross head can be obtained by summing up $H_i$ for $i$ = 1 to n steps ($\sum H = H_1+H_2+\ldots\ldots+H_n$).

### (4) Survey Method by using Pocket Distance Meter

The fourth option is to use a combination of a pocket distance meter and an angle measuring device (a hand level with compass, clinometers, etc.) as shown below.

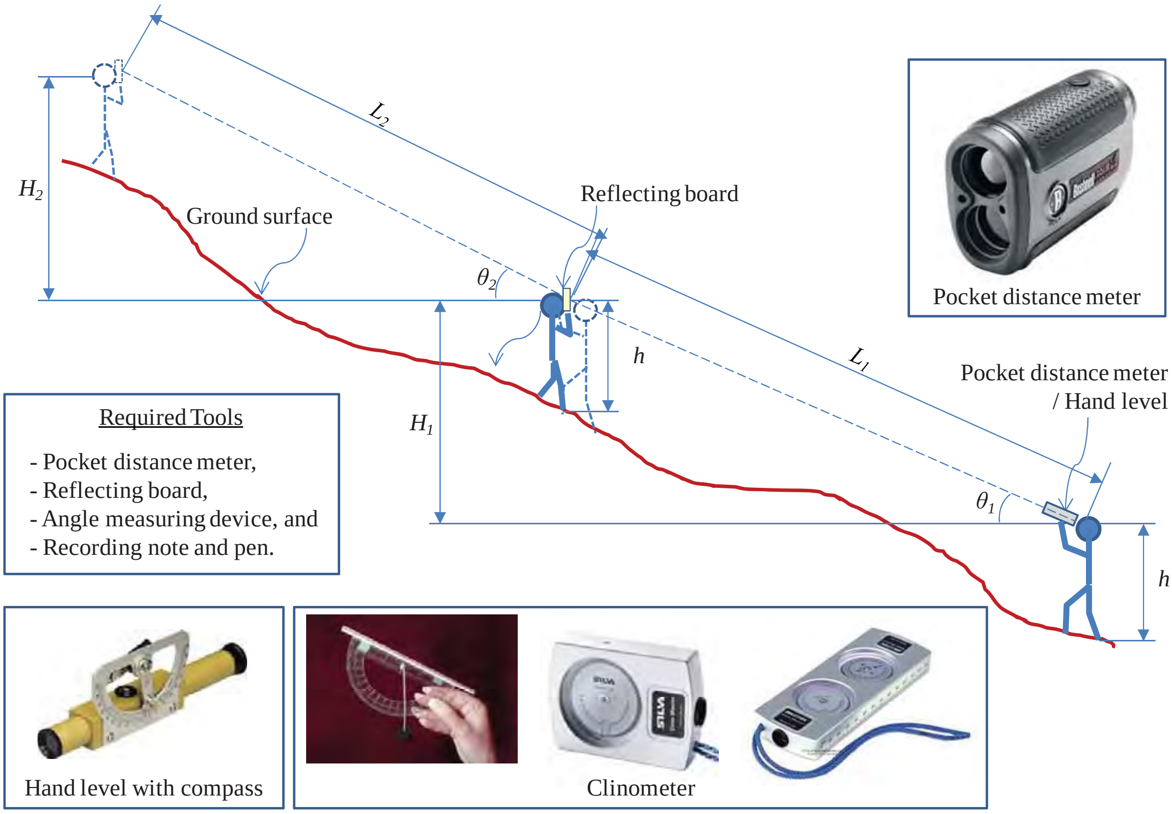


**Figure 3.2.7 Survey Method by using Pocket Distance Meter**

An inclined length ($L$) is measured using the pocket distance meter while the horizontal angle ($\theta$) is measured using the angle measurement device. The height difference can be given by the following equation:

$$H = L \times \sin\theta$$

Where,
$H$: height between the two point (m)
$L$: length between the two point (m)
$\theta$: horizontal angle (degree)

In this case, the two points are required to be visible to each other. The angle measurement should be made by targeting the head of a man standing on the reference point. This is to have the same height of the observer's eye level above the ground for accuracy. The distance measurement should also be done using a reflecting board of about 30 cm square.

### 3.2.3 Observation of Site Topography

The site topography shall be confirmed at site as topographical maps of 1:50,000 are not always of reliable accuracy. The items listed below should be checked. For the sites where further survey is considered to be necessary after the site reconnaissance, topographic survey of the area surrounding the site will be required.

**Table 3.2.1 Check Point of Site Topography**

| Location | Check Point |
|---|---|
| Intake site | River section, width of water surface, gut, riverbed, outcrop, river slope, gradient of bank slope, bank vegetation, etc. |
| Power canal route | Topography, gradient of slope, vegetation of slope, landslide, slope collapses, slope deposits, gulleys, etc. |
| Powerhouse site | Slope situation of penstock route, nature and kind of outcropped rocks, vegetation, river bed at the river outlet, etc. |

### 3.2.4 Observation of Site Geology

The purpose of geological survey is to identify the best placement of installations of system components such as power canal, penstock and powerhouse. A small amount of effort on site geology is easily repaid in cost savings in canal construction, sound penstock and turbine foundations, and safety from canal collapse due to slope instabilities.

(1) Check Point

Since a waterway such as power canal passes mainly on the slope of the terrain, a geological ground surface survey is required in order to inspect the stability of the ground surface. Geological outlines should be grasped by site survey of items such as rock categories of ground surface, strata seen in cliffs and topography.

Use maps and photographs to sketch out the basic geological characteristics of the area. Check points and identification items for the site survey are listed below.

**Table 3.2.2 Check Point of Site Geology**

| Geological Phenomena | Identification |
|---|---|
| Loose slope | Debris, dry mud, lack of vegetation |
| Storm gulley | Debris |
| Flood plain | Local residents' knowledge and experience |
| Landslide, fault | Semi-circular crack or step in hillside |

(2) Test Pit

Generally rocks are covered by top soil on which many grasses and trees grow thick. The geological survey should not be finalized by checking only gullies and outcrops, but should be carried out by removing the top soil if necessary. Since the geology is generally complicated, the geological structure should be grasped broadly for the project area.

Test pitting is enough to confirm the foundation geology of the key structures for MHP schemes. A practical pit size is 1.8 m in length, 1.2 m in width and 5.0 m in depth. It can be dug manually using scoops and picks, and a rope and bucket to lift up the excavated soil without using any further heavy lifting equipment.

A pit log should be prepared for every test pit, as a report of the test pitting, and should contain the pit number, its location, boundaries and depths, description of soil, groundwater table and bedrock surface, and all other additional relevant information, if any.

## 3.3 Plan Formulation

In general, there are many alternative approaches, such as location of intake weir, route of power canal and penstock, and location of powerhouse and tailrace, which can be taken in development at a potential site. A comparative study shall be carried out to identify the optimum development scale and optimum structures' layout.

Prior to the comparative study, power demand of the target area and hydropower potential are reviewed based on the site investigation results.

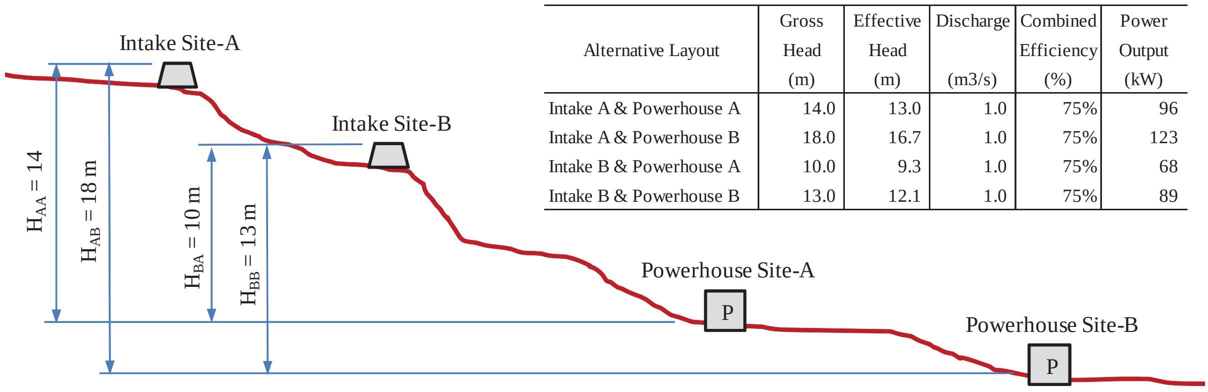
### 3.3.1 Preparation of Alternative Layout

(1) Preparation of Topographic Map

The detailed planning and design shall be conducted based on a topographic map with a scale of 1: 500 or more.

(2) Selection of Alternative Sites of Intake Weir and Powerhouse

Intake weir site and powerhouse site can generally be arranged at several positions depending on the longitudinal profile of the river. The longitudinal profile is created from the topographic map, and alternative sites of intake weir and powerhouse shall be defined to obtain high head within a short horizontal length as shown below.



| Alternative Layout | Gross Head (m) | Effective Head (m) | Discharge (m3/s) | Combined Efficiency (%) | Power Output (kW) |
|---|---|---|---|---|---|
| Intake A & Powerhouse A | 14.0 | 13.0 | 1.0 | 75% | 96 |
| Intake A & Powerhouse B | 18.0 | 16.7 | 1.0 | 75% | 123 |
| Intake B & Powerhouse A | 10.0 | 9.3 | 1.0 | 75% | 68 |
| Intake B & Powerhouse B | 13.0 | 12.1 | 1.0 | 75% | 89 |

**Figure 3.3.1 Sample of Alternative Layouts**

(3) Preparation of Alternative Layout

Alternative sites of intake weir and powerhouse, as well as layouts of civil structures depend on the topographic conditions at the candidate site. Alternative layouts are prepared by taking the following steps:

1). Define the intake weir site near the position selected in the above,
2). Define the penstock line to be arranged along the ridge lines of hills as much as possible, from the powerhouse site near the position selected in the above,
3). Define the powerhouse and the head tank position by adjustment with the penstock line, and
4). Define the power canal alignment to connect the de-silting basin and the head tank along the contour line.

A sample of an alternative layout is shown below. In case the waterway distance on one bank is clearly shorter than on the other bank, it is not necessary to prepare an alternative layout.

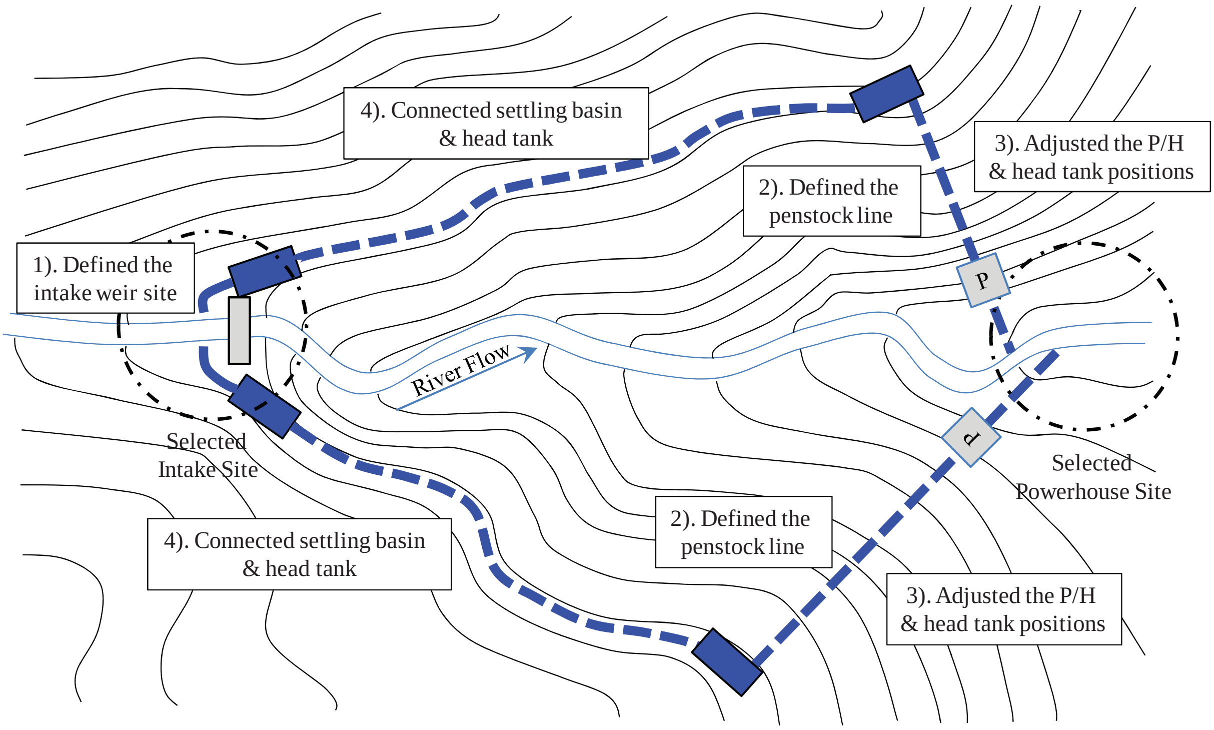


**Figure 3.3.2 Sample Procedure of Preparation of the Alternative Layout**

## (4) Definition of Turbine Center Level

Turbine center level is designed to avoid inundation during flooding. Hydraulic calculation is necessary to estimate flood water level against design flood discharge as explained below. The turbine center level is defined above the flood water level.

### 1) Uniform Flow Calculation

Water level against some discharge can be estimated as uniform flow using the following Manning's equation:

$$Q = \frac{A}{n} \times R^{2/3} \times I^{1/2}$$

Where,

$Q$: discharge (m$^3$/s)
$A$: flow area (m$^2$)
$n$: roughness coefficient ( - )
$R$: hydraulic radius = A/S (m)
$S$: wetted perimeter (m)
$I$: gradient of water surface (= slope of river) ( - )

The river's cross section and gradient in front of the planning site is obtained from the topographic map.

Roughness coefficient is selected from the following values in accordance with the river condition confirmed during site visit.

### Table 3.3.1 Roughness Coefficient of Natural River

| River Conditions and Materials | Roughness Coefficient: n | | |
|---|---|---|---|
| | Min. | Typical | Max. |
| **Small River in the Plains** | | | |
| 1. River channel is straight without weeds and there is no edge. | 0.025 | 0.030 | 0.033 |
| 2. Same as above, but there are stones and weeds often. | 0.030 | 0.035 | 0.040 |
| 3. No weeds but meandering, there are some shoals and brink. | 0.033 | 0.040 | 0.045 |
| 4. Same as above, but there are some stones and/or weeds. | 0.035 | 0.045 | 0.050 |
| 5. Same as above, but change of the cross-section and gradient is less at low water level. | 0.040 | 0.048 | 0.055 |
| 6. Same as 4, but the stones are often further apart. | 0.045 | 0.050 | 0.060 |
| 7. River flow is gentle; there is a deep abyss and weeds. | 0.050 | 0.070 | 0.080 |
| 8. Section where weeds are dense, grove and/or deep abyss appears often. | 0.075 | 0.100 | 0.115 |
| **Mountain River:** There are no plants in the river channels, river bank is steep, shrubs and trees along the river bank are submerged at high water level. | | | |
| 1. Riverbed is gravel and cobble. | 0.030 | 0.040 | 0.050 |
| 2. Riverbed is large boulder. | 0.040 | 0.050 | 0.070 |
| **Large River** | | | |
| 1. Rules section without shrubs and large boulders. | 0.025 | - | 0.060 |
| 2. Course irregular section. | 0.035 | - | 0.100 |

Source: "Planning and Designing Criteria for Agricultural Land Improvement Project" published by Rural Development Bureau in Ministry of Agriculture, Forestry and Fisheries of Japan in 2001.

2) Non-uniform Calculation

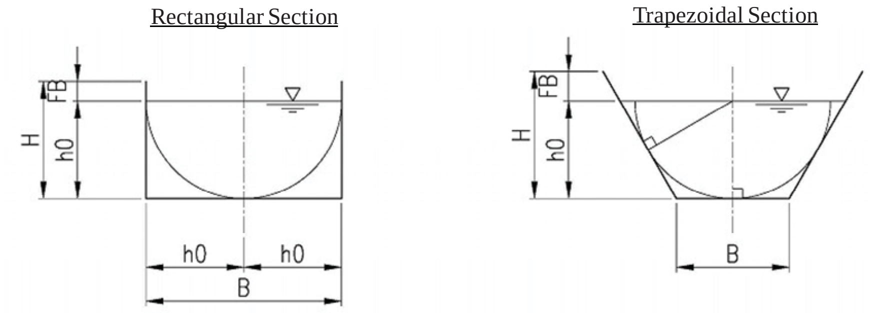
Water level against some discharge can be estimated as non-uniform flow calculation by utilizing free software called "Hydrologic Engineering Centers River Analysis System" (HEC-RAS), developed by US Army Corps of Engineers. The software and user's manual are available on their website free of charge.

Procedures of analysis are described in the user's manual and are briefly itemized below.

1). Create new project,
2). Input geometric data (coordinates of cross sections (station and elevation), downstream reach lengths, Manning's values, main channel bank stations, etc.),
3). Input flow data (discharge), and
4). Run the analysis.

(5) Definition of Dimensions of Power Canal

Dimensions of the power canal are calculated using Manning's formula to determine the economical section against the design maximum discharge. The economical section is that which circumscribes the semicircle of radius equal to the water depth as shown below.


Rectangular Section
Trapezoidal Section

H : height of canal
h0 : design water depth
FB : free board
B : bottom width of canal

Figure 3.3.3 Economical Sections of Open Canal

### (6) Definition of Crest Level of Intake Weir

Crest level of intake weir is defined as follows, and the intake water level is defined as the crest level. The gross head for alternative study is obtained by subtracting the intake water level from the turbine centre level.

$$CL = EL_{RB} + h_{sf} + h0$$

Where,

$CL$: crest level of intake weir (EL.m)
$EL_{RB}$: original riverbed level (EL.m)
$h_{sf}$: depth for sand deposit and flushing (m)
$h0$: design water depth of power canal (m)

### 3.3.2 Estimation of Project Cost

Project cost is estimated based on the empirical methods and equations compiled in the following references:

- ✓ "Guide Manual for Development Aid Programs and Studies of Hydro Electric Power Development" published by New Energy Foundation under Ministry of Economy, Trading and Industry of Japan in December 1996.
- ✓ "Handbook for Estimation of Hydropower Project Costs" published by Agency for Natural Resources under Ministry of Economy, Trading and Industry of Japan in March 2013.

These references describe in an understandable manner the studies involved from the initial planning stage to the feasibility study stage of development projects. It is intended for hydropower engineers and is based on the rich experience in MHP accumulated in Japan.

Estimation of MHP project cost hereinafter is for comparative study only. Further detailed estimation is therefore required in basic design and/or procurement stages.

### (1) Component of Project Cost

Project cost of MHP is estimated using the following components and empirical methods.

**Table 3.3.2 Estimation of Project Cost**

| Description | Estimation Method |
|---|---|
| I. Preparatory Works | Access road: assumed length (km) multiple unit prices.<br>Land compensation: 5% of Item II + Item III.<br>Temporary facilities: 20% of Item II + Item III.<br>Environmental mitigation: 3% of Item II. |
| II. Civil Works | Estimate work quantity of major works of each structure using empirical equations as explained in Table 3.3.3, and the work quantities using multiple unit prices |
| III. Electrical Equipment | Estimate using empirical equation shown in Section (4) based on the maximum power output and effective head. |
| IV. Distribution System | Assumed length (km) multiple unit prices. |
| **Sub-total 1 (Direct Cost)** | Sum of Item I, II, II, and IV. |
| V. Administration and Engineering Cost | 15% of sub-total 1 (Direct cost) |
| VI. Physical Contingency | 10% of sub-total 1 (Direct cost) |
| **Sub-total 2 (Indirect Cost)** | Sum of Item V and VI. |
| **Total** | Sum of Sub-total 1 and Sub-total 2 (direct cost and indirect cost). |

Source: "Guide Manual for Development Aid Programes and Studies of Hydro Electric Power Development" and "Handbook for Estimation of Hydropower Project Costs" (arranged by WG).

### (2) Estimation of Work Quantities of Civil Works

The work quantities of civil works can be estimated using empirical equations in the references listed below.

## Table 3.3.3 Empirical Equations for Estimation of Work Quantities of Civil Works

| Description | Empirical Equation | Remarks |
|---|---|---|
| 1. Intake Weir | | Less than 15 m of height. |
| a. Excavation (m$^3$) | $V_e = 0.181 x (H x L)^{1.92}$ | H: height of the weir (m) |
| b. Concrete (m$^3$) | $V_c = 11.9 x (H^2 x L)^{0.701}$ | L: crest length of the weir (m) |
| c. Re-bar (ton) | $W_r = 0.00893 x V_c^{1.04}$ | Q: design flood discharge (m$^3$/s) |
| d. Sand flush gate (ton) | $W_g = 0.145 x Q^{0.692}$ | |
| e. Others (L.S.) | 30% of sum of the above costs. | Grouting, river diversion, etc. |
| 2. Intake | | Non-pressure type |
| a. Excavation (m$^3$) | $V_e = 637 x (R x Q)^{0.580}$ | R: inner radius of waterway (m) |
| b. Concrete (m$^3$) | $V_c = 43.6 x (R x Q)^{1.01}$ | Q: design plant discharge (m$^3$/s) |
| c. Re-bar (ton) | $W_r = 0.0345 x V_c^{1.05}$ | |
| d. Intake gate (ton) | $W_g = 2.67 x (R x Q)^{0.470}$ | |
| e. Intake screen (ton) | $W_s = 1.04 x (R x Q)^{0.534}$ | |
| f. Others (L.S.) | 25% of sum of the above costs. | River diversion, dust collector, etc. |
| 3. De-silting basin | | |
| a. Excavation (m$^3$) | $V_e = 515 x Q^{1.07}$ | Q: design plant discharge (m$^3$/s) |
| b. Concrete (m$^3$) | $V_c = 392 x Q^{0.882}$ (with slab)<br>$V_c = 188 x Q^{1.04}$ (without slab) | |
| c. Re-bar (ton) | $W_r = 0.150 x V_c^{0.808}$ | |
| d. Drainage gate (ton) | $W_g = 0.910 x Q^{0.613}$ | |
| e. Drainage screen (ton) | $W_g = 0.696 x Q^{1.27}$ | |
| f. Others (L.S.) | 20% of sum of the above costs. | Slope protection, dust collector, etc. |
| 4. Power Canal | | Open type |
| a. Excavation (m$^3$) | $V_c = 1.66 x \{(B x H)^{1/2}\}^{2.40} x L$ | B: inner width of canal (m) |
| b. Concrete (m$^3$) | $V_e = \{H x t x 2 + (B + 2t) x t\} x L$ | H: inner height of canal (m) |
| c. Re-bar (ton) | $W_r = 0.0592 x V_c^{0.896}$ | L: Length of the canal (m)<br>t: thickness of concrete (m) |
| d. Others (L.S.) | 30% of sum of the above costs. | Slope protection, fence, etc. |
| 5. Head Tank | | |
| a. Excavation (m$^3$) | $V_e = 398 x Q^{1.07}$ | Q: design plant discharge (m$^3$/s) |
| b. Concrete (m$^3$) | $V_c = 66.0 x Q^{1.14}$ | |
| c. Re-bar (ton) | $W_r = 0.0724 x V_c$ | |
| d. Others (L.S.) | 40% of sum of the above costs. | Slope protection, gate, screen, etc. |
| 6. Spillway Canal | | |
| a. Excavation (m$^3$) | $V_e = 17.4 x R^{1.01} x L$ | R: inner radius of spillway (m) |
| b. Concrete (m$^3$) | $V_c = 3.38 x R^{1.31} x L$ | L: length of spillway |
| c. Re-bar (ton) | $W_r = 0.0358 x V_c$ | |
| d. Others (L.S.) | 30% of sum of the above costs. | Slope protection, fence, etc. |
| 7. Penstock | | |
| a. Excavation (m$^3$) | $V_e = 12.2 x D^{1.26} x L$ (single lane)<br>$V_e = 10.9 x D^{1.33} x L$ (multi lanes) | D: inner diameter of penstock (m)<br>L: length of penstock (m) |
| b. Concrete (m$^3$) | $V_c = 2.92 x D^{1.26} x L$ (single lane)<br>$V_c = 1.86 x D^{1.48} x L$ (multi lanes) | $H_e$: effective head (m)<br>Q: design plant discharge (m$^3$/s) |
| c. Re-bar (ton) | $W_r = 0.0178 x V_c$ | |
| d. Steel penstock (ton)<br>Q = 1.0 m$^3$/s<br>Q = 2.0 m$^3$/s<br>Q = 3.0 m$^3$/s<br>Q = 4.0 m$^3$/s<br>Q = 5.0 m$^3$/s<br>Q = 6.0 m$^3$/s<br>Q = 7.0 m$^3$/s | <br>$W_p = (0.0003 x H_e + 0.04) x L$<br>$W_p = (0.0006 x H_e + 0.08) x L$<br>$W_p = (0.0009 x H_e + 0.12) x L$<br>$W_p = (0.0012 x H_e + 0.14) x L$<br>$W_p = (0.0014 x H_e + 0.16) x L$<br>$W_p = (0.0017 x H_e + 0.17) x L$<br>$W_p = (0.0020 x H_e + 0.18) x L$ | |
| e. Others (L.S.) | 20% of sum of the above costs. | Grouting, slope protection, etc. |

| | | |
|---|---|---|
| 8. Powerhouse | | Q: design plant discharge ($m^3$/s)<br>$H_e$: effective head (m)<br>n: number of turbine (nos.) |
| a. Excavation ($m^3$) | Surface type:<br>$V_e = 11.4 x (Q x H_e^{2/3} x n^{1/2})^{0.952}$<br>Semi-surface type:<br>$V_e = 38.0 x (Q x H_e^{2/3} x n^{1/2})^{0.952}$ | |
| b. Concrete ($m^3$) | Surface type:<br>$V_c = 6.79 x (Q x H_e^{2/3} x n^{1/2})^{0.824}$<br>Semi-surface type:<br>$V_c = 15.9 x (Q x H_e^{2/3} x n^{1/2})^{0.933}$ | |
| c. Re-bar (ton) | Surface type:<br>$W_r = 0.0326 x V_c^{1.04}$<br>Semi-surface type:<br>$W_r = 0.0764 x V_c^{0.979}$ | |
| d. Others (L.S.) | 50% of sum of the above costs. | Building works, drainage, etc. |
| 9. Tailrace | | Non-pressure type without gate.<br>R: radius of tailrace (m)<br>Q: design plant discharge ($m^3$/s) |
| a. Excavation ($m^3$) | $V_e = 164 x (R x Q)^{0.532}$ | |
| b. Concrete ($m^3$) | $V_c = 36.4 x (R x Q)^{0.353}$ | |
| c. Re-bar (ton) | $W_r = 0.113 x V_c^{0.823}$ | |
| d. Others (L.S.) | 25% of sum of the above costs. | River diversion, slope protection, etc. |
| 10. Miscellaneous (L.S.) | 5% of sum of the above costs (1 to 9). | |

Source: "Guide Manual for Development Aid Programes and Studies of Hydro Electric Power Development" and "Handbook for Estimation of Hydropower Project Costs" (arranged by WG).

It is noted that some civil structures are not required depending on the topographic conditions. For example, intake can be directly connected to the head pond in case of development of a waterfall, and de-silting basin and power canal are not necessary.

The following specific dimensions shall be determined for the estimation of work quantities. For further details, refer to Chapter 4 (Basic design).

**Table 3.3.4 Required Dimensions for Estimation of Work Quantities of Civil Works**

| Category | Required Dimensions | Estimation Method | Remarks |
|---|---|---|---|
| Overall Plan | $Q_p$: design maximum discharge ($m^3$/s) | Determined from flow duration curve | |
| | n: number of turbine (nos.) | Given (2 units as standard). | |
| | $\eta$: combined efficiency (%) | Given (Refer to Table 1.3.1). | |
| | $H_e$: effective head (m) | 93% of gross head. | Various |
| | $P_{max}$: maximum output (kW) | $P_{max} = g x Q x H_e x\eta$ | Various |
| Intake Weir | $Q_s$: design discharge of flush gate ($m^3$/s) | 2-year to 5-year probable flood. | |
| | H: height | | |
| | L: crest length | Assumed from topographic map. | Various |
| Intake Structure | R: radius of portal (m) | Q = A x V, V = 1.0 m/s,<br>A = B x H , R = W/2 | |
| | H: height of portal (m) | | |
| De-silting basin | R: radius of drainage gate (m) | $Q = 0.6 x A x (2 x g x H)^{1/2}$<br>A = B x H , R = W/2 | |
| Power Canal | B: inner width (m) | Calculated using Manning's formula | |
| | H: inner height (m) | Calculated using Manning's formula | |
| | t: concrete thickness (m) | 20% of inner width or height | |
| | L: length of canal (m) | Assumed from topographic map. | Various |
| Spillway Canal | R: radius (m) | Calculated using Manning's formula | |
| | L: length (m) | Assumed from topographic map. | Various |
| Penstock | D: inner diameter (m) | Calculated using Manning's formula | |
| | L: length (m) | Assumed from topographic map. | Various |
| Tailrace | R: radius (m) | Same as intake portal. | |

Notes: Dimension with "Various" in remarks means that the dimension is various by alternative layout. Other dimensions are constant for potential site.

(3) Required Unit Prices for the Estimation

Required unit prices for the estimation of direct cost are listed in the table below. These unit prices shall be updated as required.

**Table 3.3.5 Required Unit Prices for the Estimation**

| Work Item | Unit | Source |
|---|---|---|
| 1. Access Road | KSh./km | Available from REA |
| 2. Excavation | KSh./$m^3$ | Current Construction Costs Handbook published by Cost Planning Unit of the Quantities and Contracts Department, Ministry of Public Works |
| 3. Concrete | KSh./$m^3$ | |
| 4. Re-bar | KSh./ton | |
| 5. Metal works (Gate and screen) | KSh./ton | |
| 6. Steel Penstock | KSh./ton | |
| 7. Distribution Line | KSh./km | Available from REA |

(4) Estimation of Direct Cost of Electrical Equipment

Electrical equipment is defined as all equipment for MHP including inlet valve, turbine, generator, and all attachments of these equipment. The direct cost of electrical equipment is given by the following empirical equation in the references:

$$C_E = 7.09 \times \left( P_{\max} \Big/ \sqrt{H_e} \right)^{0.774} \times F$$

$$F = 1{,}000{,}000 \times 0.333$$

Where,
$C_E$: direct cost of electrical equipment (USD)
$P_{max}$: maximum output (kW)
$H_e$: effective head (m)
$F$: conversion factor from Japanese Yen to US Dollar (USD)

According to the interview results of Kenya Tea Development Agency (KTDA) in 2014, existing small hydropower projects in Kenya procured electrical equipment from Europe and/or India. Direct cost of the equipment from Europe and India is approximately 30% of that in Japan, based on the interview results and experience of JICA expert.

Additionally, the original empirical equation in the references gives direct cost of the equipment in million Japanese Yen. It is therefore necessary to convert the direct cost into USD by dividing by a million and multiplying by 30%.

### 3.3.3 Estimation of Project Benefit

Benefit (B) of a hydropower project is the cost of an alternative thermal power plant that supplies electricity equivalent to the hydropower project, and the cost (C) is derived from the construction cost of the MHP project.

The annualized benefit (B) is estimated based on the fixed cost and variable cost of alternative thermal power using the following formula:

Annualized Benefit (B)

$$B = B_1 + B_2$$

$$B_1 = P_h \times b_1$$

$$B_2 = E \times b_2$$

Where,
$B$: annual benefit of hydropower plant (KSh.)
$B_1$: kW benefit (KSh.)
$B_2$: kWh benefit (KSh.)
$P_h$: effective output (kW)
$E$: annual energy generation (kWh)
$B_1$: kW value (KSh./kW)
$B_2$: kWh value (KSh./kWh)

Effective Output ($P_h$)

$$P_h = 9.8 \times Q_{\min} \times H_e \times \eta$$

$Q_{min}$: minimum plant discharge ($m^3/s$)
$H_e$: effective head (m)
$\eta$: combined efficiency

Annual Energy Generation (E)

$$E = 8{,}760 \times \xi \times P$$

$\xi$: plant factor
$P$: maximum output (kW)

kW value ($b_1$)

$$b_1 = Ct \times \alpha \times \beta$$

$$\alpha = RCF + OM = \frac{i \times (1+i)^n}{(1+i)^n - 1} + OM$$

$$\beta = \frac{(1-H_1)\times(1-H_2)\times(1-H_3)}{(1-T_1)\times(1-T_2)\times(1-T_3)}$$

*Ct*: unit construction cost of alternative thermal power (KSh./kW)
*α*: annual cost factor of alternative thermal power
*RCF* : capital recovery factor
*i* : interest rate (%)
*n* : service line (year)
*OM* : ratio of operation and maintenance cost
*β*: kW adjustment factor ( - )
$H_1$: ratio of station use of hydropower plant
$H_2$: ratio of forced outage of hydropower plant
$H_3$: ratio of scheduled outage of hydropower plant
$T_1$: ratio of station use of alternative thermal power plant
$T_2$: ratio of forced outage of alternative thermal power plant
$T_3$: ratio of scheduled outage of alternative thermal power plant

kWh Value ($b_2$)

$$b_2 = R_h \times P_f = \frac{860}{T_e} \times P_f$$

$R_h$ : heat consumption rate
$P_f$ : unit price of fuel (KSh./kcal)
$T_e$ : thermal efficiency

### 3.3.4 Selection of Optimum Development Plan

Alternative plans are compared in view of economic feasibility by following two indexes.

(1) Benefit-Cost Method

Benefit-Cost method is an economic analysis to compare benefit (B) and cost (C) as follows:

$B/C \geq 1$, or $B - C \geq 0$: MHP is economically better than the thermal power alternative.

$B/C < 1$, or $B - C < 0$: MHP is economically less attractive than the thermal power alternative.

Where an alternative plan shows higher B/C value than others, it is judged that the alternative plan is more economically attractive than the others.

The benefit is applied as mentioned in Chapter 3.3.3, and the cost is applied not only to construction cost but also annualized cost as given by the following formula:

Annualized Cost (C)

$$C = Ch \times \alpha$$

Annual cost factor ($\alpha$)

$$\alpha = RCF + OM = \frac{i \times (1+i)^n}{(1+i)^n - 1} + OM$$

Where,
*RCF* : capital recovery factor
*i* : interest rate (%)
*n* : service line (year) = 50 years
*OM* : ratio of operation and maintenance cost = 1%

The annual cost factor (*α*) varies in accordance with the interest rate, but can be regarded as 10 to 12% in planning stage according to empirical methods.

(2) Generation Cost Method

$$C_G = Ch / E \times \alpha$$

Where,
$C_G$: generation cost (KSh./kWh)
$C_h$: construction cost (KSh.)
*E*: annual energy generation (kWh)
*α*: annual cost factor = 0.10 to 0.12 ( - )

Where an alternative layout shows cheaper generation cost value ($C_G$) than others, it is judged that the alternative plan is economically more attractive than the others. Additionally, the economic soundness of the site or alternative layout can be confirmed by comparison with the present electric tariff.

### (3) Comparative Study

Development scale of a hydropower project varies depending on the discharge and effective head. Therefore, the optimum development plan is selected through comparative study by applying different parameters.

In case of MHP project, the following aspects are often examined;

- ✓ At first, alternative plans with different locations of intake weir and powerhouse (i.e., with different head) are compared, and the intake site and powerhouse site selected, and
- ✓ Alternative plans with different values of maximum and minimum plant discharges are compared on the selected plan (intake site and powerhouse site).

## 3.4 Application of Water Use Permit

There are four major government organizations related to water resources management as listed below:

- ✓ Ministry of Water and Irrigation (MWI) act as the policy maker,
- ✓ Water Resources Management Authority (WRMA) is the regulator at the national and regional levels under MWI,
- ✓ Catchment Area Advisory Committees (CAACs) are advisers of WRMA at catchment level, and
- ✓ Water Resource Users Associations (WRUAs) are the regulators at local level.

The water use activities which need the approval of WRMA are stipulated in the Fifth Schedule of the WRMR 2007. The water use activities are categorized into four from the view point of its scale and impact of the relevant water use activities. These categories are explained as follows:

**Table 3.4.1 Categories of Water Resources Use Activities**

| Category | Description |
|---|---|
| A | ✓ Water use activity deemed by virtue of its scale to have a low risk of impacting the water resource.<br>✓ Applications in this category will be determined by the regional offices. |
| B | ✓ Water use activity deemed by virtue of its scale to have the potential to make a significant impact on the water resource.<br>✓ Permit applications in this category will be determined by the regional offices. |
| C | ✓ Water use activity deemed by virtue of its scale to have a significant impact on the water resource.<br>✓ Permit applications in this category will be determined by the regional offices in consultation with the CAACs. |
| D | ✓ Water use activity which involves either two different catchment areas, or is of a large scale or complexity and which is deemed by virtue of its scale to have a measurable impact on the water resource.<br>✓ Permit applications in this category will be determined by the regional offices in consultation with the CAACs and approval by the WRMA Headquarters. |

Source: Water Resources Management Rules, 2007.

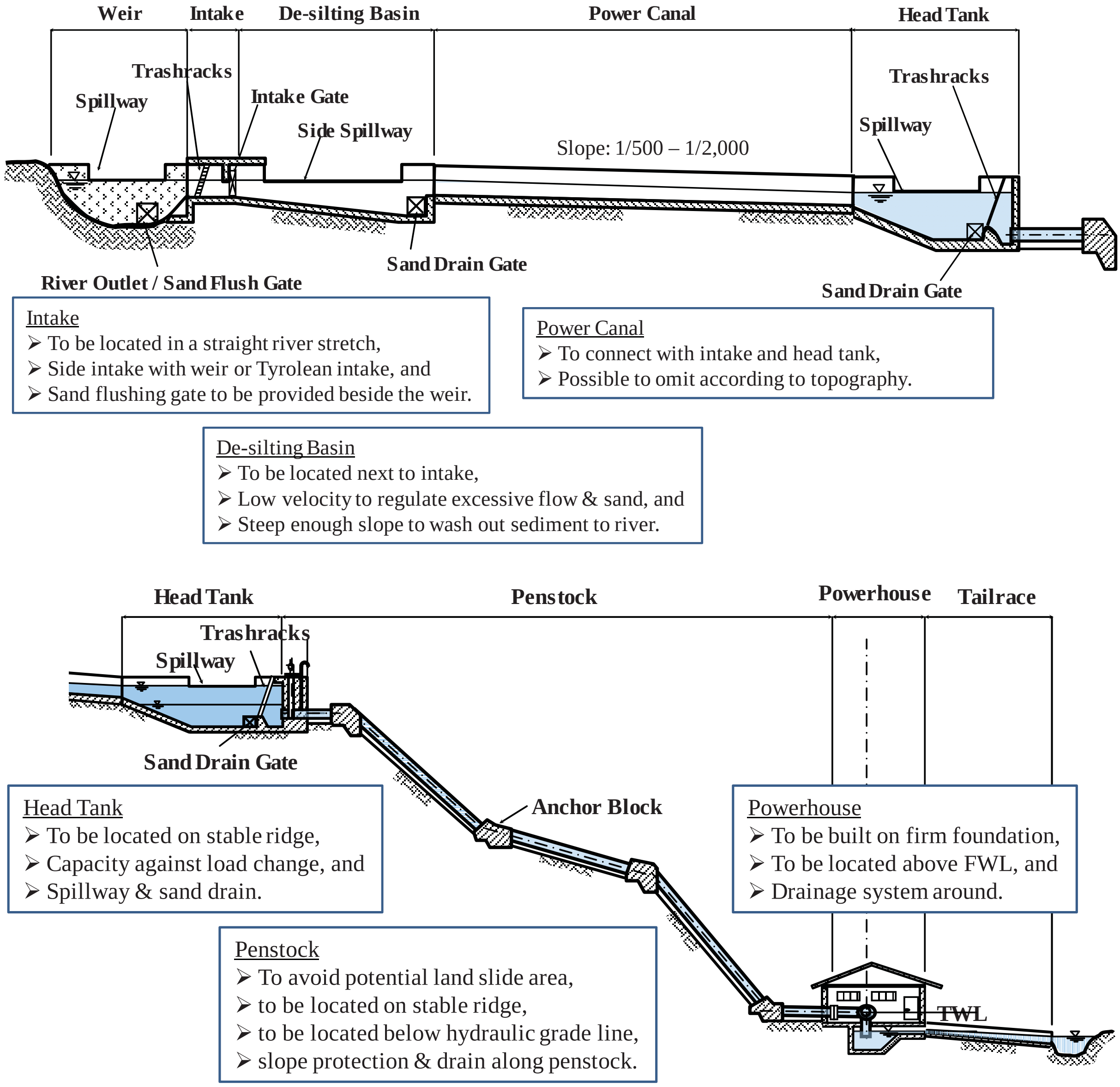
The permit application process for water use is stipulated in Sections 16 to 48 of the WRMR 2007. Any person intending to or currently undertaking any water use activity described above shall obtain approval from the WRMA.

When a MHP project is formulated, the application of water permit is necessary.

# CHAPTER 4 BASIC DESIGN

## 4.1 Civil Structure

The main components of the civil structures are weir, intake, de-silting basin, power canal, head tank, penstock, powerhouse and tailrace. A typical profile of a MHP station is shown below with accompanying technical notes. However, components of the civil structures vary depending on the topographic condition at the candidate site, nature of the work and the design conditions involved.



Intake
- To be located in a straight river stretch,
- Side intake with weir or Tyrolean intake, and
- Sand flushing gate to be provided beside the weir.

Power Canal
- To connect with intake and head tank,
- Possible to omit according to topography.

De-silting Basin
- To be located next to intake,
- Low velocity to regulate excessive flow & sand, and
- Steep enough slope to wash out sediment to river.

Head Tank
- To be located on stable ridge,
- Capacity against load change, and
- Spillway & sand drain.

Powerhouse
- To be built on firm foundation,
- To be located above FWL, and
- Drainage system around.

Penstock
- To avoid potential land slide area,
- to be located on stable ridge,
- to be located below hydraulic grade line,
- slope protection & drain along penstock.

Source: "The Study on Introduction of Renewable Energies in Rural Areas in Myanmar, Final Report Volume 4, Part 4-2 Design Manual – Small Hydros (Figure 1.5.4 & 1.5.5)" conducted by JICA in 2003 (arranged by WG).

**Figure 4.1.1 Typical Profile of MHP**

Based on the experiences in many MHP plants, the major issues relating to the civil components are: i) Sedimentation and ii) Hydraulic characteristics during floods.

Therefore, suitable combinations and layouts according to the specific site conditions need to be properly reflected in the design.

It is rare for dam or tunnel waterway types of layouts to be adopted in MHP. However, existing irrigation dams and/or existing irrigation canals with drops may be utilized for MHP schemes in redevelopment plans. In such cases, penstock pipes can be connected to the intake or the de-silting basin without provision of a power canal.

### 4.1.1 Head Works

This section deals with run-of-river schemes that do not require dam construction, but employ a diversion structure or weir across the river.

Head works commonly consist of weir, intake and de-silting basin. Functions and requirements of the head works design are summarized in the table below.

**Table 4.1.1 Functions and Requirements for Head Works**

| Description | Remarks |
|---|---|
| Hydraulic Functions<br>✓ To ensure design discharge is obtained from the river.<br>✓ To minimize inflow of sediment and flowing debris (leaves) into the power canal.<br>✓ Intake gate to block flood flow entry into the power canal, and to prevent overflow from the power canal from causing catastrophic erosion and damage to the slope and canal foundation. | ✓ Width and height of the gate.<br>✓ Selection of appropriate intake site and, provision of skimmer wall.<br>✓ Intake gate with sufficient height and strength to be provided. |
| Structural Requirements<br>✓ Intake gate to withstand flooding while intake weir is under repair after the flooding season is over. | ✓ Selection of weir type taking topographic, geological and flood conditions into consideration. |
| Issues of the Design<br>✓ Method for determining the normal water levels of intake and head tank.<br>✓ Criteria for determining the gate height and width. | ✓ Uniform flow depth of power canal.<br>✓ Investigation of flood levels at the intake site. |

Source: "The Study on Introduction of Renewable Energies in Rural Areas in Myanmar, Final Report Volume 4, Part 4-3 Design Manual – Village Hydros (Chapter 3.3)" conducted by JICA in 2003 (arranged by WG).

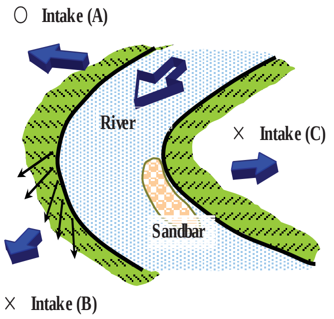
(1) Site Selection

One of the most common problems affecting a MHP scheme is damage to the intake caused by floods. And another is sediment deposited upstream of the intake or flowing into the waterway. The following points are to be considered in locating the intake structures

Intake (A): The best location for an intake is to locate it along a relatively straight stretch of the stream.

Intake (B): Susceptible to severe damage from floods, debris, and erosion.

Intake (C): Sediments tend to accumulate in front of the intake and can enter and/or block it.

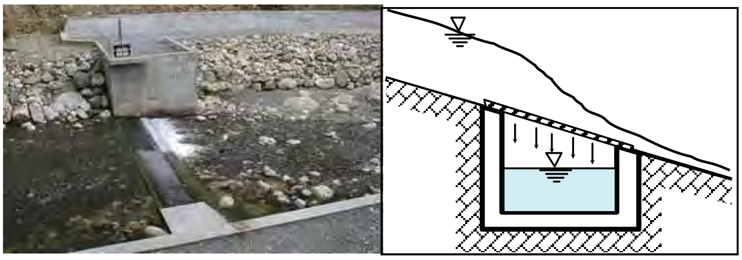


(2) Countermeasures against Sedimentation

Countermeasures against sedimentation are explained below.

1) Tyrolean Intake

The Tyrolean intake is applicable to MHP schemes located on steep rivers containing boulders and pebbles. The characteristics of Tyrolean type intake are as follows:



a) Intake facilities can be minimized.

b) Relatively large amounts of sediment will enter the intake especially during a flood. It is therefore indispensable to install a sand drain facility with enough hydraulic gradient and capacity to drain out the sediment. Periodic sand draining operations are required.

c) It is necessary to carry out cleaning work to remove driftwood or leaves trapped on the screen.

d) An intake discharge of 0.1 to 0.3 $m^3/s/m^2$, a screen slope gentler than 30°, and a screen bar interval of 20 to 30 mm are generally practiced.

2) Sand Flush Gate

A sand flush gate should be located towards one side of the weir to release sediments deposited upstream of the weir. The intake is located at a side of the river just upstream of the weir in order to minimize the volume of sand entering the intake. Sill level of a sand flush gate is generally set at 0.5 to 1.0 m higher than the original riverbed level and 1.0 to 1.5 m lower than the intake floor level.

If slope failures or sediment yield are confirmed in the upstream basin, protection work such as a gabion wall may be effective in controlling the sediment outflow.

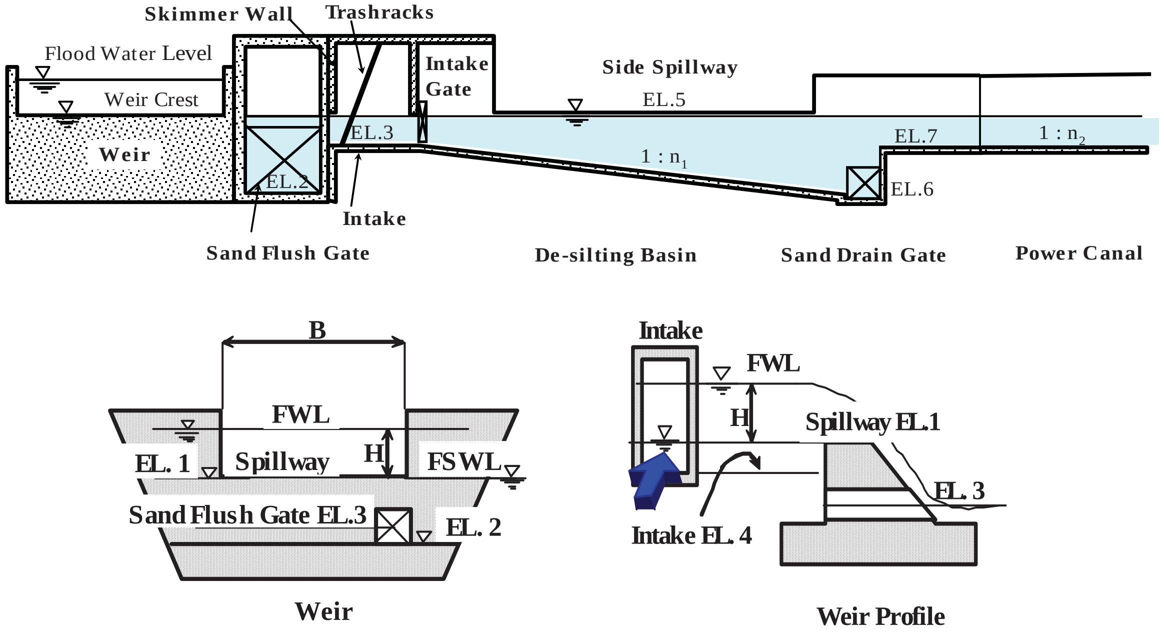
(3) Hydraulic Requirements

Hydraulic requirements generally applied to side intake with concrete weir are summarized below.

**Table 4.1.2 Hydraulic Requirements to Side Intake**

| Item | General Application | Symbol |
|---|---|---|
| Crest level of intake weir | = Full Supply Water Level (FSWL) | EL.1 |
| Sill level of sand flush gate | = Original riverbed + (0.5 to 1.0 m) | EL.2 |
| Floor level of intake | = EL.2 + (1.0 to 1.5 m) | EL.3 |
| Velocity of intake deck | = 0.5 to 1.0 m/s approximately | - |
| Top of intake deck | = Flood Water Level + freeboard (> 1.0 m) | - |
| Top of intake gate | = FSWL = EL.1 | EL.1 |
| Velocity at intake gate | = 1.0 to 1.5 m/s approximately | - |
| Crest level of side spillway | = FSWL – (0 to 10 cm) | EL.5 |
| Slope of de-silting basin | = 1:10 to 1:30 | $n_1$ |
| Velocity of de-silting basin | < 0.3 m/s | - |
| Length of de-silting basin | (2 to 3) x depth x velocity / sedimentation rate<br>= (2 to 3) x depth x 0.3 / 0.1 = (6 to 9) x depth | - |
| Elevation of sand drain | (Sand drain outlet level) > (Water level of the river) | EL.6 |
| Floor level of power canal | = EL.3 | EL.7 |
| Gradient of power canal | = 1:1,000 to 1:2,000 | $n_2$ |
| Velocity in power canal | < 2.0 m/s maximum for lined canal | - |

Source: “The Study on Introduction of Renewable Energies in Rural Areas in Myanmar, Final Report Volume 4, Part 4-2 Design Manual – Small Hydros (Table 2.1.3)” conducted by JICA in 2003 (arranged by WG).



Source: "The Study on Introduction of Renewable Energies in Rural Areas in Myanmar, Final Report Volume 4, Part 4-2 Design Manual – Small Hydros (Chapter 2.1)" conducted by JICA in 2003 (arranged by WG).

**Figure 4.1.2 Schematic Profile of Head Works**

### (4) Estimation of Inflow Discharge into Intake

The weir crest level is normally designed equal to the Full Supply Water Level (FSWL) under the maximum design discharge.

The hydraulic design of weir and intake should be made appropriately to take the proper discharge into the waterway. Since the flow taken from a river is not regulated in a run-of-river scheme, any excess water above the maximum design discharge should be released safely from spillways.

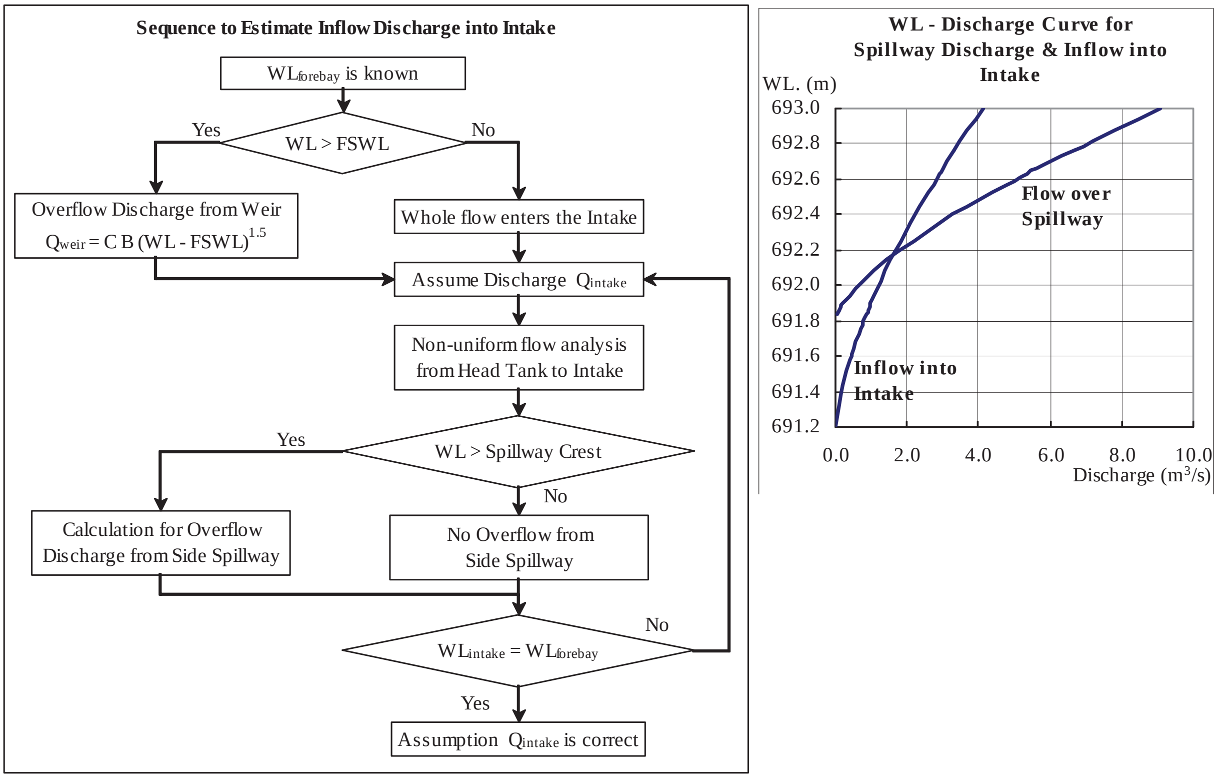
When a weir crest is set equal to the FSWL at the maximum design discharge, the inflow into the intake can be divided into the following cases:

**Table 4.1.3 Flow Condition into Intake**

| (River flow) < (Maximum design discharge) | (River flow) > (Maximum design discharge) |
|---|---|
| ✓ Full flow enters the intake,<br>✓ The water level varies between FSWL (EL.1) and the intake floor level (EL.2),<br>✓ The maximum design discharge flows into the intake at FSWL, and<br>✓ The minimum flow to the downstream basin shall be released from the river outlet at any conditions if need be. | ✓ Water level is above FSWL (EL.1), when partial discharge is spilt over the weir and the remainder, which exceeds the maximum design discharge, enters the waterway,<br>✓ Any excess discharge taken from the intake should be released from a side spillway , which needs to be provided at a suitable location of the waterway, and<br>✓ The intake gate should be closed during a flood to avoid excessive sediment inflow into the waterway. |

Source: "The Study on Introduction of Renewable Energies in Rural Areas in Myanmar, Final Report Volume 4, Part 4-2 Design Manual – Small Hydros (Chapter 2.1)" conducted by JICA in 2003 (arranged by WG).

If a river water level is known from water level gauge readings at the forebay, discharge entering the waterway can be estimated through the sequence described below. Then, a rating curve at the forebay can be prepared.



Source: “The Study on Introduction of Renewable Energies in Rural Areas in Myanmar, Final Report Volume 4, Part 4-2 Design Manual – Small Hydros (Chapter 2.1)” conducted by JICA in 2003 (arranged by WG).

**Figure 4.1.3 Flowchart to Estimate Inflow Discharge into Intake and Sample H-Q Curve**

Overflow discharge from spillway and outflow discharge through sand flush gate can be calculated using the following formulas:

Discharge from a weir spillway:

$$Q_{spill} = 1.84 \times B \times H^{1.5}$$

Where,
$Q_{spill}$: discharge from spillway ($m^3/s$)
$B$: width of spillway (m)
$H$: Overflow depth (water level minus crest level of spillway) (m)

Discharge from a sand flush gate:

For orifice flow:

$$Q = 0.6 \times A \times \sqrt{2 \times g \times H}$$

For pipe flow:

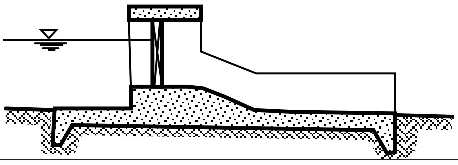
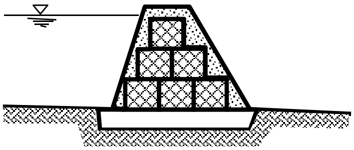
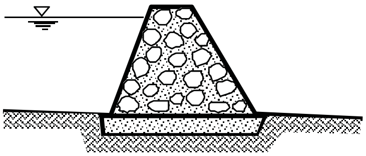
$$Q = A \times \sqrt{\frac{2 \times g \times H}{1 + f_e + f}}$$

Where,
$Q$: discharge through the gate ($m^3/s$)
$A$: section area of the gate ($m^2$)
$f_e$: loss coefficient for entrance ( - )
$f_e = 0.1$ to $0.5$
$f$: loss coefficient for friction ( - )
$f = 124.5n^2 L/D^{(4/3)}$

(5) Major Types of Weirs and Intakes

Major types of weirs and intakes are summarized below.

## Table 4.1.4 Major Types of Weirs

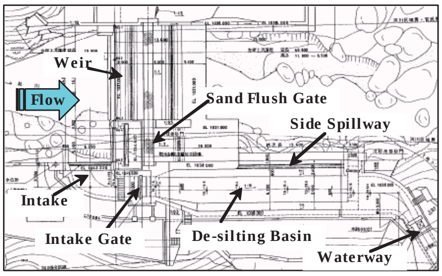
| Type | Characteristics |
|---|---|
| Concrete Gravity<br> | ✓ Applicable on rock foundations,<br>✓ Most commonly applied,<br>✓ Durable and impervious, and<br>✓ Relatively high cost. |
| Floating Concrete Weir<br> | ✓ Applicable on gravel foundations,<br>✓ Needs enough seepage path,<br>✓ Durable, and<br>✓ Relatively high cost. |
| Gabion Covered with Concrete<br> | ✓ Applicable on gravel foundations,<br>✓ Surface protection by concrete, and<br>✓ Relatively low cost. |
| Gabion<br> | ✓ Applicable on gravel foundations,<br>✓ Flexible, and<br>✓ Low cost and easy maintenance. |
| Stone Masonry<br> | ✓ Applicable on gravel foundations, and<br>✓ Low cost and easy maintenance. |

Source: "The Study on Introduction of Renewable Energies in Rural Areas in Myanmar, Final Report Volume 4, Part 4-2 Design Manual – Small Hydros (Table 2.1.1)" conducted by JICA in 2003 (arranged by WG).

It should be noted that the type of weir to be applied should be determined according to the power scale, importance, flood discharge, foundation condition, and maintenance requirements. The use of high quality materials and construction techniques will result in less maintenance and repair work over the lifespan of the scheme.

Major types of intakes are summarized below.

## Table 4.1.5 Major Types of Intakes

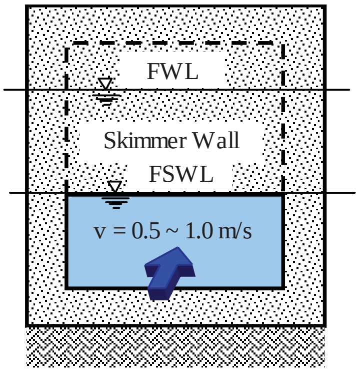
| Type | Characteristics |
|---|---|
| Side Intake with Weir<br><br> | ✓ Most commonly used for run-of-river type power schemes,<br>✓ Sand flush gate is located towards one side of the weir to release sediments deposited upstream of the weir,<br>✓ Intake is located at a side of the river just upstream of the weir/sand flush gate, and<br>✓ Intake gate is provided at upstream section of de-silting basin. It function is to close during sand drain operation or maintenance of the waterway. |
| Tyrolean Type Intake<br> | ✓ Suitable for steep rivers containing boulders,<br>✓ Weir is not necessary,<br>✓ Necessary to remove drift woods or leaves on the screen, and<br>✓ Necessary to remove fine sands which have entered the intake. |
| Intake to utilize Natural Pond<br> | ✓ Applied to natural/artificial ponds to utilize the water for power generation. |

Source: "The Study on Introduction of Renewable Energies in Rural Areas in Myanmar, Final Report Volume 4, Part 4-2 Design Manual – Small Hydros (Table 2.1.2)" conducted by JICA in 2003 (arranged by WG).

The site selected for the head works should be stable and suitable for reliable foundations. All excess water and debris taken from the river need to be minimized in the design of head works, and those entering during a flood flow need to be returned to the river before entering the canal or penstock.

(6) Facilities provided in Intake

The following facilities are provided in the intake:

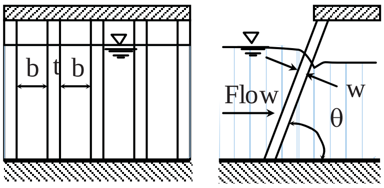


Skimmer Wall

The skimmer wall at the entrance of the inlet may be effective in preventing driftwood or excessive flood flow from entering the intake. It also restricts excessive inflow by ensuring orifice flow when the river water level is higher than the FSWL during a flood.

Intake Gate

An intake gate is provided at the upstream section of the de-silting basin. The gate is to be closed during the sand drain operation or maintenance of the waterway and during floods to avoid excessive sediment inflow. The velocity through the intake gate opening should be limited to about 1.0 m/s.



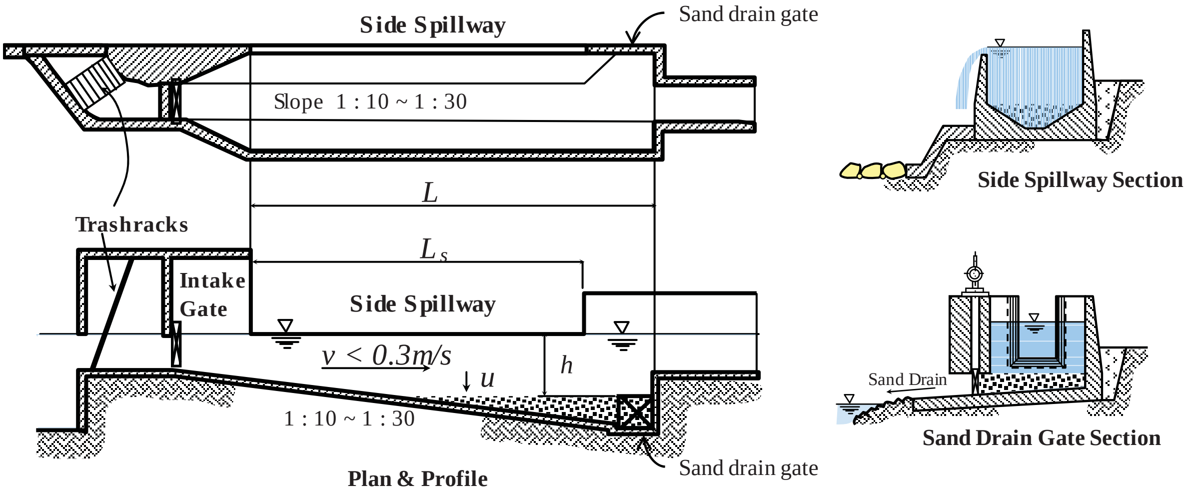
|  |  |
|---|---|
| Thickness | t = 5 ~ 9 mm |
| Width | w = 50 ~ 120 mm |
| Interval | b = 100 ~ 150 mm |
| Inclination | θ = 60 ~ 70º |

Trashrack

Trashracks are provided at the entrance of the intake to prevent trash, leaves, and floating debris from entering the waterway. The screen bars are generally arranged with 5 ~ 9 mm thickness, 50 ~ 120 mm width, 100 ~ 150 mm intervals, and 60 ~ 70ºangle to the horizontal.

### (7) De-silting Basin

General layout of de-silting basin is shown below.



Source: "The Study on Introduction of Renewable Energies in Rural Areas in Myanmar, Final Report Volume 4, Part 4-2 Design Manual – Small Hydros (Chapter 2.2)" conducted by JICA in 2003 (arranged by WG).

**Figure 4.1.4 General Layout of De-silting Basin**

The de-silting basin is designed to settle sand particles bigger than 0.5 to 1.0 mm diameter of which the settling velocity corresponds to 0.1 m/s. Average flow velocity in a de-silting basin is generally 0.3 m/s, and the channel slope is 1/10 to 1/30.

1) Length of De-silting Basin

The length of de-silting basin is given by the following empirical formula:

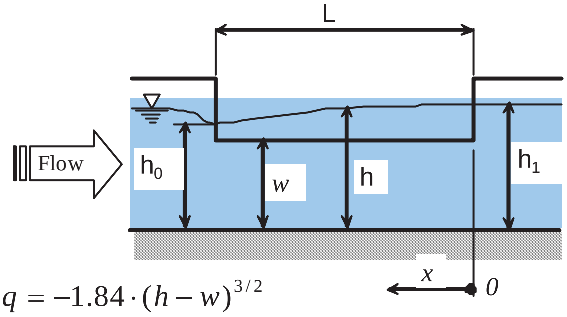
$$L = \alpha \times \frac{v}{u} \times h_s$$

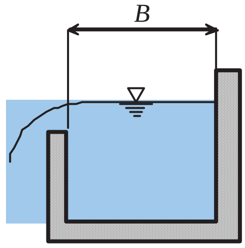
Where,

|  |  |
|---|---|
| $L$: | length of de-silting basin (m) |
| $\alpha$: | coefficient (-) = 2 to 3 |
| $v$: | average velocity in de-silting basin (m/s) = 0.3 m/s |
| $u$: | settling velocity for target sand particle (m/s) = 0.1 m/s |
| $h_s$: | depth of de-silting basin (m) |

2) Length of Spillway

A side spillway should be provided at the de-silting basin to release excess inflow during a flood. The length of spillway required for overflow of the excess discharge and the water surface profile can be computed using the following De-Marchi's equations:





$$q = -1.84 \cdot (h - w)^{3/2}$$

$$L = \frac{\sqrt{2g} \cdot B}{1.84}\{\phi(\frac{h_1}{H}) - \phi(\frac{h_0}{H})\}$$

$$\phi = \frac{2H - 3w}{H - w}(\frac{H - h}{h - w})^{1/2} - 3\tan^{-1}(\frac{H - h}{h - w})^{1/2}$$

Where $q$ : unit overflow discharge ($m^3/s/m$)
$h$ : depth of flow (m)
$B$ : width of channel
$w$ : height of weir (m)
$h_0$ : depth at downstream section (m)
$h_1$ : depth at upstream section (m)
$H = h + Q^2/\{2g\ (B\,h)^2\}$ (m)

Source: "The Study on Introduction of Renewable Energies in Rural Areas in Myanmar, Final Report Volume 4, Part 4-2 Design Manual – Small Hydros (Figure 2.2.4)" conducted by JICA in 2003 (arranged by WG).

It is noted that the outflow path needs to be protected against scouring.

### 4.1.2 Power Canal

This section deals with open canals only, which are the type most commonly applied to MHP schemes.

Functions and requirements of the power canal are summarized in the table below.

**Table 4.1.6 Function and Requirements of Power Canal**

| Description | Remarks |
|---|---|
| Hydraulic Functions<br>✓ To lead the design discharge to the head tank without causing overflow from power canal.<br>✓ To release the excess water, if any, through spillway, or,<br>✓ To confine all the water within power canal by raising the side walls in case the canal flow is blocked. | ✓ Standard hydraulic gradient at or gentler than 1: 1,000 to reduce flow velocity.<br>✓ Spillway and chuteway required at the head tank.<br>✓ Three possible cases are:<br>a. Turbine guide vane is closed,<br>b. Penstock is clogged, and<br>c. Canal is filled and blocked by sliding soils from side slopes. |
| Hydraulic Requirements<br>✓ Flow velocity to be lower than 0.3 m/s so as not to cause canal erosion.<br>✓ Preferably provide a fused spillway section downstream of the intake, in addition to the raised side walls in the option above. | ✓ Low flow velocity is preferable.<br>✓ Chuteway can be shorter compared to that of spillway at the head tank |
| Issues of the Design<br>✓ Sedimentation in power canal.<br>✓ Criteria for determining height and width of the canal.<br>✓ Criteria for determining crest elevation of side walls of power canal.<br>✓ - Criteria for determining crest elevation and length of the side-overflow spillway. | ✓ Canal to be periodically cleared of sediment deposit.<br>✓ A freeboard of 30 cm (= 1 feet) is preferable for earth canal.<br>✓ Overflow crest level can be at the intake water level. |

Source: "The Study on Introduction of Renewable Energies in Rural Areas in Myanmar, Final Report Volume 4, Part 4-3 Design Manual – Village Hydros (Chapter 3.4)" conducted by JICA in 2003 (arranged by WG).

### (1) Route Selection

A route for the power canal needs to be selected after consideration of the topographic features along the canal for the following points:

- ✓ Stability against slope above and/or below the canal, and
- ✓ Specific conditions such as streams, roads, and the existing structures to be crossed.

Selection of the canal route and the design of canals should be made in consideration of the fact that the water level in a canal may rise for any of several possible reasons:

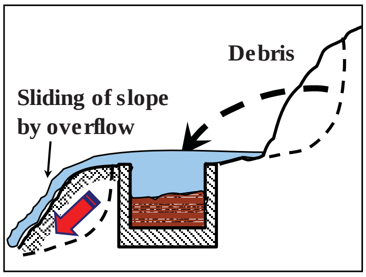
- ✓ When the canal flow is obstructed by a landslide or closure of a gate at the downstream structures,
- ✓ When excess water enters the intake during a flood, and
- ✓ When excess running water is drained into the canal during heavy rain.

When selecting the canal route, the existing structures such as foot pass and irrigation channel can be utilized to minimize the construction cost of the canal as well as for ease of access.

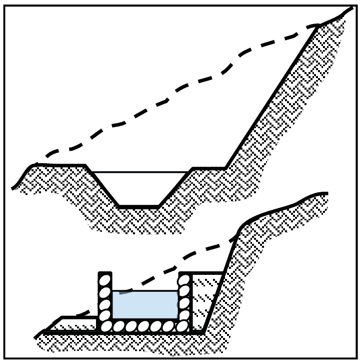
It is noted that the power canal may be possible to omit from the design, depending on the topographic conditions. In this case the penstock may be connected directly to the de-silting basin or the head tank.

### (2) Major Types of Canals

Major types of power canals are summarized below.

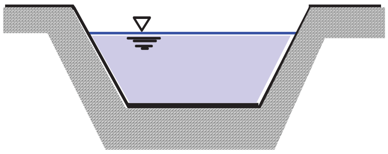
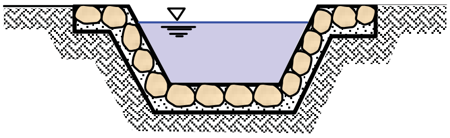
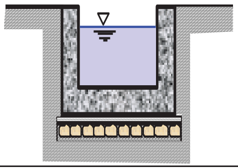


Sliding may be induced by overflow from a canal in which debris enters the canal.



Properly designed lined canal reduces the canal size and the excavation volume to convey the same discharge.

**Table 4.1.7 Major Types of Power Canals**

| Type | Characteristics |
|---|---|
| Earth Canal<br> | ✓ Ease of construction and maintenance,<br>✓ Low cost,<br>✓ Not applicable to pervious and erosive foundation,<br>✓ Velocity < 0.3 m/s,<br>✓ Roughness coefficient n = 0.014 on average,<br>✓ Seepage loss = $1.0 \times 10^{-6}$ $m^3/s/m^2$ (clay) to $8.0 \times 10^{-6}$ $m^3/s/m^2$ (sand) |
| Stone Masonry Canal<br> | ✓ Ease of construction and maintenance,<br>✓ Velocity < 1.5 m/s (dry stone masonry) and velocity < 2.0 m/s (wet stone masonry),<br>✓ Roughness coefficient n = 0.032 (dry stone masonry) and 0.025 (wet stone masonry) |
| Concrete Canal<br> | ✓ Durable,<br>✓ Relatively high cost,<br>✓ Velocity < 3.0 m/s,<br>✓ Roughness coefficient n = 0.015 on average. |

Source: "The Study on Introduction of Renewable Energies in Rural Areas in Myanmar, Final Report Volume 4, Part 4-2 Design Manual – Small Hydros (Chapter 2.3)" conducted by JICA in 2003 (arranged by WG).

Shape of cross section is given as follows:

- ✓ For unlined canals, a trapezoid cross-section is the most common. Side slopes of a canal are 1.0 (V): 0.5 (H) for rock foundation, and 1.0 (V): 2.0 (H) for sandy loam foundation.

- ✓ For lined canals, a rectangular or a trapezoid cross-section is commonly used for stone masonry lining, and a rectangular cross-section for concrete lining.

(3) Canal Dimension

Power canals are to be designed in consideration of 1) flow capacity, 2) velocity, 3) roughness, 4) slope, 5) sectional shape, 6) lining (with or without, material), and 5) maintenance.

The steeper the slope of the canal, the smaller the sectional area required. However the effective head decreases as the slope increases. The best combination of a canal size and a slope should be established within a suitable range of flow velocity.

1) Velocity

The velocity in a canal should be low enough to prevent erosion of the canal, especially if it is unlined, and to keep effective head as high as possible.

<u>Maximum Velocity for Unlined Canal</u>

The maximum permissible velocities for unlined canals are set to avoid erosion, depending on the soil materials as summarized in the table below.

**Table 4.1.8 Standard Maximum Velocity for Unlined Canal**

| **Soil Material** | **Roughness Coefficient “n" ( - )** | **Maximum Velocity (m/s)** | **Permeability (x $10^{-6}$ $m^3/s/m^2$)** |
|---|---|---|---|
| Fine sand | 0.020 – 0.025 | 0.3 – 0.4 | > 8.3 |
| Sandy loam | 0.020 – 0.025 | 0.4 – 0.6 | 2.8 – 8.3 |
| Clayey loam | 0.020 – 0.025 | 0.6 – 0.8 | 1.4 – 2.8 |
| Clay | 0.020 – 0.025 | 0.8 – 2.0 | 0.3 – 1.4 |

Source: “The Study on Introduction of Renewable Energies in Rural Areas in Myanmar, Final Report Volume 4, Part 4-2 Design Manual – Small Hydros (Table 2.3.2)” conducted by JICA in 2003 (arranged by WG).

<u>Maximum Velocity for Lined Canal</u>

The maximum permissible velocities for lined canal are set depending on the wear of abrasion. Velocities above 10 m/s will not damage a concrete lined canal when the water is clear, but velocities above 4 m/s containing sand and gravel may scour the lining.

The maximum velocity in a lined canal is normally lower than 2.0 m/s.

<u>Minimum Velocity</u>

The velocity in a canal should be high enough to prevent sedimentation and to avoid the growth of aquatic plants especially in unlined earth canals.

Minimum velocities are given as follows;

Against sedimentation for flow carrying silty water: $V_{min}$ = 0.3 m/s
Against sedimentation for flow carrying fine sand: $V_{min}$ = 0.3 to 0.5 m/s
Against aquatic plants: $V_{min}$ = 0.7 m/s

2) Longitudinal Slope

A canal slope, depending on the topographic conditions, is generally as follows:

| | |
|---|---|
| 1/500 ~ 1/1,000: | to minimize the canal size in high head plant |
| 1/1,000 ~ 1/1,500: | general application |
| 1/1,500 ~ 1/2,000: | to minimize a head drawdown in low head plant |

3) Roughness Coefficient

Roughness coefficient “n” is an empirical measure of surface roughness of a waterway. The following values are usually applied;

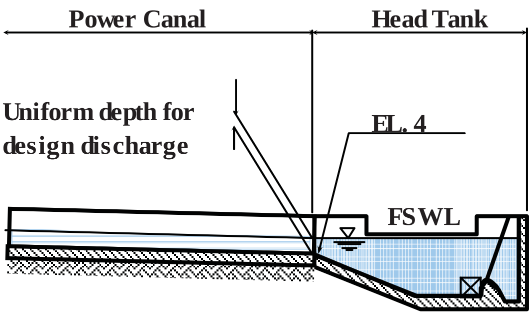
| | |
|---|---|
| Steel: | 0.012 ~ 0.013 |

| | |
|---|---|
| Concrete: | 0.014 ± 0.001 |
| Stone-masonry: | 0.016 ~ 0.020 |

### (4) Water Surface Profile

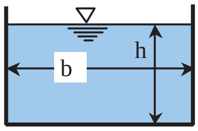
The canal floor elevation at the downstream end (EL.4 in the figure) is commonly selected to provide a uniform flow depth for the maximum design discharge when the water level in the head tank or the regulating pond is at the Full Supply Water Level (FSWL). In this condition, the flow depth in the canal is uniform over the whole stretch, if the canal slope is uniform.

Uniform flow depth in a canal can be calculated using Manning's Formula:



Uniform flow state at the downstream end of the canal at FSWL

$$Q = \frac{A}{n} R^{\frac{2}{3}} I^{\frac{1}{2}} \qquad Q = V \cdot A$$

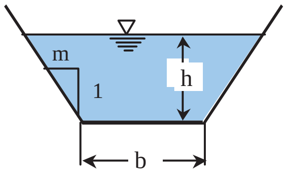


For a rectangular section

$$A = b \cdot h \qquad R = \frac{h}{1 + 2h/b}$$

For a triangular section

$$A = h(b + mh) \qquad R = \frac{h(b + mh)}{b + 2h\sqrt{1 + m^2}}$$



where, Q : discharge ($m^3/s$), n : roughness coefficient, b : width of canal (m)
h : depth of flow (m), R : hydraulic radius (m), I : slope of canal

A non-uniform flow analysis should be carried out in the full section of the waterway starting from the head tank or the regulating pond up to the intake. For the analysis, parameters to be varied include discharge, roughness coefficient, and the initial water level at the head tank. The wall height of the canal is to be designed so that the energy line for the maximum inflow into the canal should be lower than the wall crest.

Non-uniform flow analysis involves solving the following differential equation. The analysis is usually calculated using computer soft ware.

$$\frac{dh}{dx} = \frac{i + \frac{\alpha Q^2}{gA^3} \frac{\partial A}{\partial b} \frac{\partial b}{\partial x} - \frac{n^2}{R^{4/3}} \left(\frac{Q}{A}\right)^2}{1 - \frac{\alpha Q^2}{gA^3} \frac{\alpha A}{\partial h}}$$

### (5) Related Facilities

Design of the following facilities for a canal may be required for the above conditions:

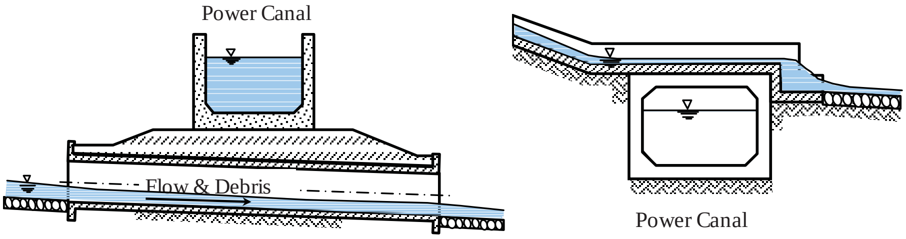
### Table 4.1.9 Required Facilities for Power Canal

| Site Condition | Required Facilities |
|---|---|
| Potential landslide | (a) Box culvert or canal covers (concrete/wood).<br>(b) Slope protection by structural reinforcement of the slope, excavation in a gentler slope, and vegetation such as sodding or planting |
| Crossing of stream or valley | (a) Aqueduct to release excess flow from a flood or debris flow.<br>(b) Siphon to path under the stream.<br>(c) Drainage facilities to collect the running water in the catchment basin and to release it safely to protect the canal from being eroded by the drained flow or invaded by debris. |
| Crossing of roads or existing structures | (a) Box culvert or bridge to connect the existing road.<br>(b) Steel pipe or concrete conduit embedded under the existing structures. |
| Excessive inflow | (a) Side spillway for overflow of excess flow over the maximum design discharge. Appropriate protection work against scouring by the overflow is indispensable.<br>(b) Drainage facilities to avoid excess inflow into the canal. |

Source: "The Study on Introduction of Renewable Energies in Rural Areas in Myanmar, Final Report Volume 4, Part 4-2 Design Manual – Small Hydros (Table 2.3.1)" conducted by JICA in 2003 (arranged by WG).

1) Cross Drain

If a power canal passes through valleys with catchment areas, drain facilities that cross under or over the power canal should be provided to protect the canal structure from impact of running water containing debris during rainfall. Box culverts, concrete pipes, polyethylene pipes, etc. are used as under drains, and open chutes as over drains. Under drains need adequate flow area, since they are likely to be clogged with debris, soil, etc. A minimum inner space of 60 cm is preferable for manual cleaning.



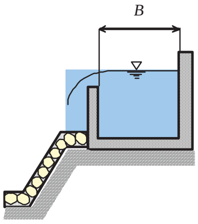
- ➢ Slope steeper than 1/500
- ➢ Size bigger than φ60cm,
- ➢ Enough flow area not to be clogged, and
- ➢ Maintenance for clogging.

Source: "The Study on Introduction of Renewable Energies in Rural Areas in Myanmar, Final Report Volume 4, Part 4-2 Design Manual – Small Hydros (Figure 2.3.12 & 2.3.13)" conducted by JICA in 2003.

Figure 4.1.5 Cross Drain under and Over Power Canal

2) Side Spillway

A side channel spillway is generally provided at the de-silting basin and the head tank. However, it may be necessary to design it in a suitable section of the power canal depending on the design conditions. The outflow path needs to be protected against scouring.



### 4.1.3 Head Tank

A head tank is provided between power canal and penstock pipe to adjust turbine discharge corresponding to the load fluctuation, while a surge tank is required when a pressure tunnel or conduit is applied as headrace. When a penstock pipe is connected directly to a de-silting basin, the de-silting basin may be designed to function as a head tank.

Functions and requirements of the head tank are summarized in the table below.

Head Tank with Spillway

**Table 4.1.10 Function and Requirements of Head Tank**

| Description | Requirements |
|---|---|
| Hydraulic Functions<br>✓ To ensure smooth transition of the water, from free flow in power canal to pressure flow in penstock.<br>✓ To trap flowing debris and leaves using trashracks.<br>✓ To deposit sediments (sill elevation of penstock inlet must be higher than the floor by 30 cm).<br>✓ To release excess water from spillway. | ✓ Adequate water surface area is required to adjust difference in the discharge of power canal and penstock.<br>✓ Trashracks at low flow velocity.<br>✓ Periodic sand flushing/ clearing is required.<br>✓ Spillway can be omitted when side walls of power canal and head tank are raised to confine water within the waterway. |
| Structural Requirements<br>✓ Width of head tank to be determined to have flow velocity slower than 0.2 m/s.<br>✓ Total water surface area of the head tank and power canal to be more than 5 to 10 times of the design discharge.<br>✓ Sand flushing gate and chuteway preferably to be provided. | |
| Issues of the Design<br>✓ Criteria for determining the normal water level (crest elevation of the spillway of the head tank). | ✓ To be equal to the intake water level. |

Source: “The Study on Introduction of Renewable Energies in Rural Areas in Myanmar, Final Report Volume 4, Part 4-3 Design Manual – Village Hydros (Chapter 3.5)” conducted by JICA in 2003 (arranged by WG).

(1) Site Selection

The location of a head tank is generally selected to be on a ridge with firm foundations, depending on the topographical and geological conditions.

Spillway and a sand drain gate should be considered and incorporated into the head tank. When a spillway is provided (it may be omitted under some conditions), the route of the spillway should be properly designed not to cause sliding or erosion of the slope.

(2) Hydraulic Design

1) Required Volume

The capacity of the head tank is determined according to the responsive characteristics of the governors installed in the power plant.

Case 1:

$$V > Q_{\max} \times (120 \sim 180)$$

Case 2:

$$V > Q_{\max} \times 20\sec + A \times 0.8$$

Where,
$V$: Volume of tank ($m^3$)
$A$: Surface area of tank ($m^2$)
$Q_{max}$: Maximum design discharge ($m^3/s$)

Case 1: for mechanical governors and manual operation, and
Case 2: for electric governor, computer governor and dummy load governor.

2) Discharge from Spillway

Spillway discharge can be calculated as follows.

$$Q = 1.84 \times B_s \times H^{1.5}$$

Where,
$Q$: Spill-out discharge ($m^3/s$)
$B_s$: Length of overflow crest (m)
$H$: Overflow depth (m)

3) Discharge from Sand Drain Gate

Discharge capacity of sand drain gate is calculated using the following formulas:

For orifice flow:

$$Q = 0.6 \times A \times \sqrt{2 \times g \times H}$$

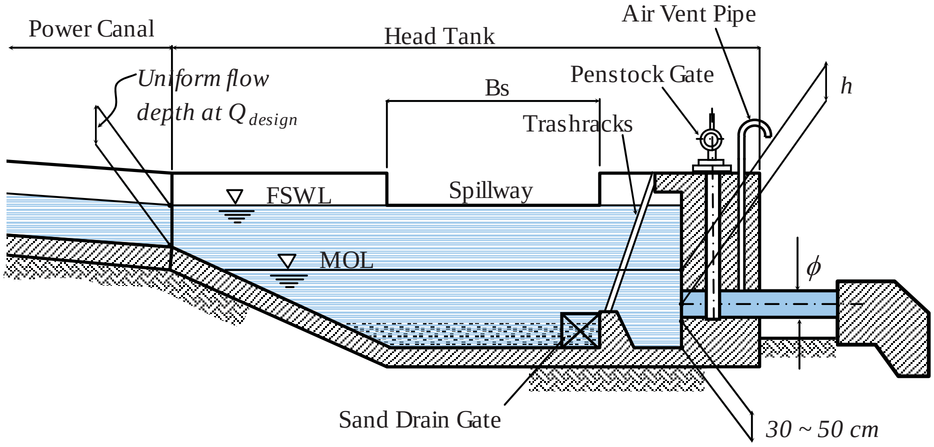
For pipe flow:

$$Q = A \times \sqrt{\frac{2 \times g \times H}{1 + f_e + f_b + f}}$$

$$f_b = \left[0.131 + 0.1632 \times \left(D/R\right)^{3.5}\right] \times \left(\theta/90\right)^{0.5}$$

$$f = 124.5 \times n^2 \times L/D^{4/3}$$

$Q$: Discharge through the gate ($m^3/s$)
$A$: Flow area ($m^2$)
$g$: Gravity acceleration = 9.8 (m/s)
$H$: Overflow depth (m)
$f_e$: Loss coefficient for entrance (m)
$f_b$: Loss coefficient for bend (m)
$f$: Loss coefficient for friction (m)
$D$: Pipe diameter (m)
$R$: Radius of curvature (m)
$\theta$: Bend angle (degree)
$n$: Roughness coefficient of pipe = 0.012 ( - )
$L$: Length of pipe (m)



Source: “The Study on Introduction of Renewable Energies in Rural Areas in Myanmar, Final Report Volume 4, Part 4-2 Design Manual – Small Hydros (Figure 2.4.3)” conducted by JICA in 2003.

**Figure 4.1.6 Typical Profile of Head Tank**

4) Minimum Operation Level

Water depth between the Minimum Operational Level (MOL) and the centre level of the penstock inlet is given by the equation below:

$h > \varphi, \quad \varphi < 1.0\ m$
$h > \varphi^2, \quad \varphi > 1.0\ m$

Where,
$h$: Depth between MOL and penstock center (m)
$\varphi$: Diameter of penstock pipe (m)

5) Air Vent Pipe

An air vent pipe is required when inlet gate is provided at the inlet of the penstock. The diameter of the air vent pipe is given by the following empirical formula:

$$\phi = 0.0068 \times \left(\frac{P^2 \times L}{H}\right)^{0.273}$$

Where,
$\varphi$: Diameter of air vent pipe (m)
$P$: Power output (kW)
$L$: Length of air vent pipe (m)
$H$: Head of penstock (m)

6) Others

The sectional shapes of head tank should be designed to avoid any abrupt changes that can cause the occurrence of a vortex.

Average slope of head tank is 1/15 to 1/50 in order to drain the sediment deposited in the tank through a sand drain gate.

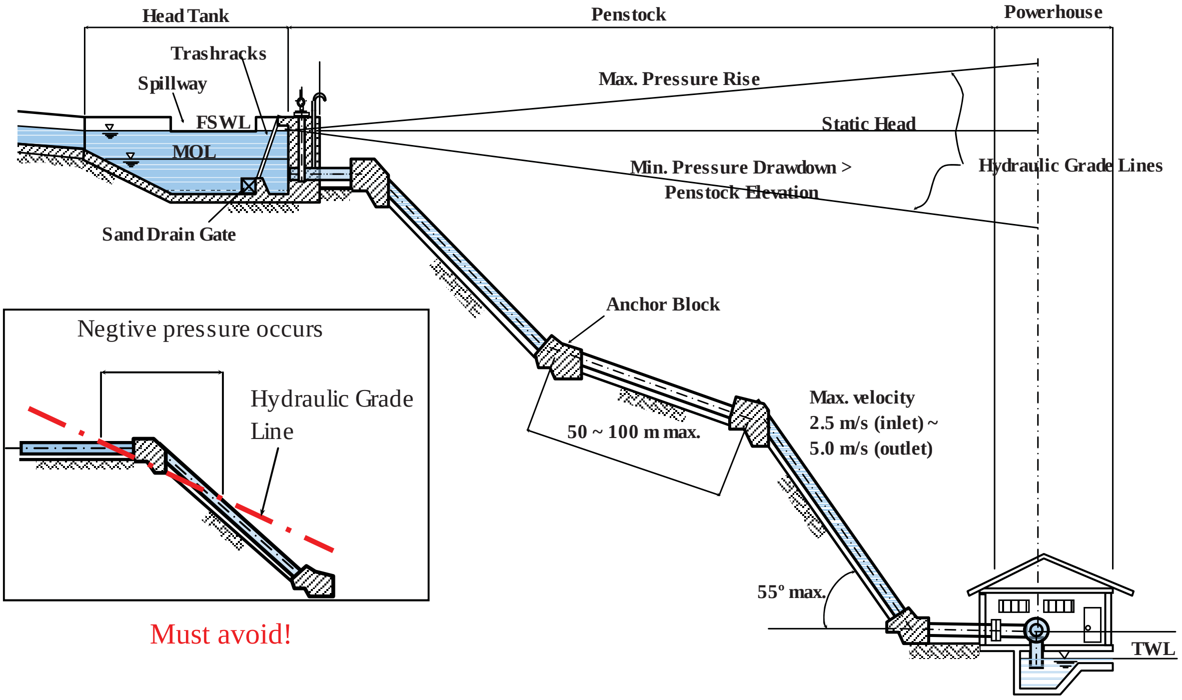
(3) Omission of Spillway

The spillway of the head tank can be omitted when the discharge is regulated at the intake and the following conditions are applied:

1) Deflectors are attached for Pelton or Turgo Impulse type turbines.
2) An outlet valve, branched from the penstock pipe, is provided to release the discharge during load rejection. The valve opening is connected with the closure of the guide vane.
3) A dummy load governor, which is applied to MHP schemes smaller than 300 kW, is provided to respond to load rejection.

### 4.1.4 Penstock

Functions and requirements of the penstock are summarized below.



Source: "The Study on Introduction of Renewable Energies in Rural Areas in Myanmar, Final Report Volume 4, Part 4-2 Design Manual – Small Hydros (Figure 2.6.1)" conducted by JICA in 2003 (arranged by WG).

**Figure 4.1.7 Typical Profile of Penstock**

## Table 4.1.11 Functions and Requirements of Penstock

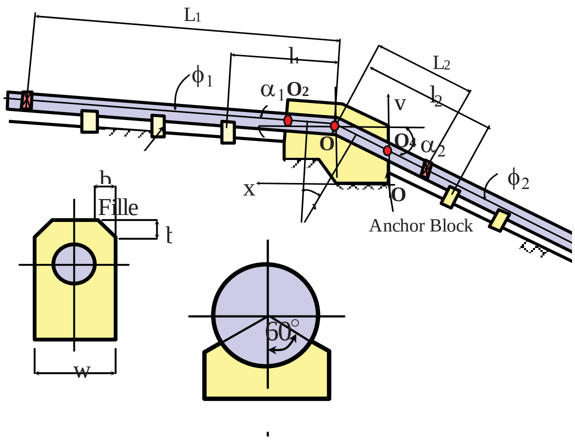
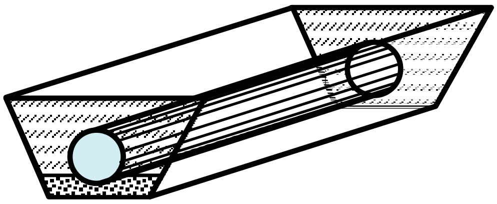
| Description | Remarks |
|---|---|
| Hydraulic Functions<br>✓ To lead the pressured water to the turbine. | |
| Structural Requirements<br>✓ The flow in the penstock pipe should always be pressured flow, that is, the head tank water level should always be above the penstock inlet sill by 2 times of the diameter.<br>✓ To be rigid enough and anchored to avoid vibration. | ✓ Penstock slope to be protected and drains provided to avoid possible erosion by rainwater. |
| Issues of the Design<br>✓ Negative pressure acts on the penstock when the penstock is located above hydraulic grade line.<br>✓ Hydraulic force operates upon bend. | ✓ Alignment of the penstock should be designed for it to be located below the minimum hydraulic grade line during the load rejection.<br>✓ Penstock is fixed by anchor block. |

Source: "The Study on Introduction of Renewable Energies in Rural Areas in Myanmar, Final Report Volume 4, Part 4-3 Design Manual – Village Hydros (Chapter 3.6)" conducted by JICA in 2003 (arranged by WG).

### (1) Major Types of Penstocks

Major types of penstocks are summarized below.

## Table 4.1.12 Functions and Requirements of Penstock

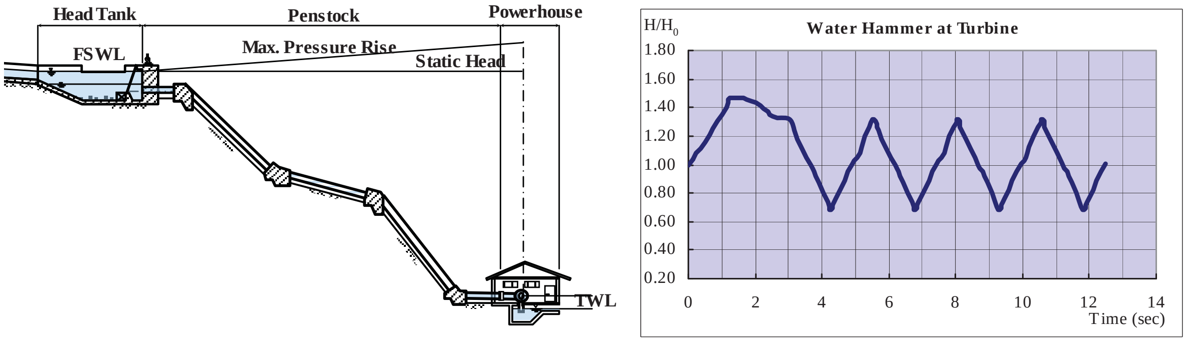
| Type | Features |
|---|---|
| Open Type<br> | ✓ Most commonly applied to small hydro schemes<br>✓ Anchor blocks are provided at bend portions, which should be founded on foundations firm enough to support the blocks with penstock pipes against sliding, overturning and bearing.<br>✓ Interval between anchor blocks should be less than 100 m generally.<br>✓ Saddle piers are provided at 6 m interval.<br>✓ Maximum angle of pipe inclination should be 55°<br>✓ Drainage and slope protection should be considered for the open excavated areas.<br>✓ Expansion joints just below the head tank and between anchors.<br>✓ Bitumen between pipes and anchors/saddles to avoid corrosion. |
| Embedded Type<br> | ✓ Applicable to the following conditions:<br>(a) soft foundations not adequate to support the anchor blocks<br>(b) areas susceptible to landslides or running water<br>(c) gentle slopes to maintain the stability of backfill materials<br>✓ Steel pipes should be galvanized, and double coated with either bitumen or high zinc content paint. |

Source: "The Study on Introduction of Renewable Energies in Rural Areas in Myanmar, Final Report Volume 4, Part 4-2 Design Manual – Small Hydros (Table 2.6.1)" conducted by JICA in 2003 (arranged by WG).

### (2) Water Hammer

Discharge in the penstock changes during the power generation. Discharge is controlled by inlet valve in front of the water turbine in the powerhouse. According to the changes in discharge, the velocity in the penstock also changes, and pressure wave occurs at the inlet vale.

The pressure wave occurs up and down in the penstock, acting on it. This pressure wave is known as "water hammer". It is 10 – 30% of the static water at the inlet valve and disappears at the inlet of penstock (at the head tank).



Source: "The Study on Introduction of Renewable Energies in Rural Areas in Myanmar, Final Report Volume 4, Part 4-2 Design Manual – Small Hydros (Figure 2.6.2)" conducted by JICA in 2003 (arranged by WG).

**Figure 4.1.8 Water Hammer**

### (3) Inner Diameter

In cases where the diameter of the penstock is smaller, the construction cost decreases. On the other hand, energy loss during power generation increases due to the increasing head loss. Conversely, in cases where the diameter of the penstock is larger, energy loss decreases due to the decreasing head loss, but the construction cost increases.

Therefore, the optimum diameter of a penstock is determined by minimizing the total annual cost mainly consisting of the annualized construction cost of the penstock, and decrease of the annual benefit by head loss during generating. The formula for calculating the optimum diameter is shown below.

$$S = Cc + B'$$

The annualized construction cost

$$C_c = C_w \times F_a = C_W \times \left(f_c + C_m\right)$$

The annualized energy loss

$$B' = P_d \times C_t'/kW + E \times C_t/kWh$$

$$P_d = 9.8 \times Q_{\max} \times h_{lg} \times \eta_g$$

$$E = P_d \times T_g$$

$$C_t'/kW = C_t/kW \times f_k \times F_t$$

Where,

$S$: total annual cost of penstock (US$)

$Cc$: annualized construction cost of penstock (US$)

$B'$: decrease of annual benefit by head loss (US&)

$F_a$: annual conversion factor (%)

$f_c$: capital recovery factor (%)

$C_m$: annual operation & maintenance cos (%)

$P_d$: decreasing of effective output in generating (US$)

$Q_{max}$: maximum discharge in generation ($m^3/s$)

$h_{lg}$: head loss in generation (m)

$\eta_g$: total efficiency in generation (%)

$E$: annual energy loss in generating by head loss (US$)

$T$: annual generating hour (hour)

$C_t'/kW$: unit cost of alternative thermal power plant (US$/kW)

$C_t/kW$: fixed unit cost of alternative thermal power plant (US$/kW)

$f_k$: kW adjustment ratio (%)

$F_t$: annual conversion factor of alternative thermal power plant (%)

$C_t/kWh$: variable cost per kWh of alternative thermal power plant (US$/kWh)

### (4) Thickness

Thickness of penstock is given by the following formula:

$$t = \frac{P \times D}{2 \times \sigma_a \times \eta} + \varepsilon$$

Where,
$t$: thickness of steel penstock (mm)
$P$: design pressure at calculation point (N/mm$^2$)
$D$: inner diameter of steel penstock (mm)
$\sigma_a$: allowable tensile stress of steel (N/mm$^2$)
$\eta$: efficiency of welding = 85 (%)
$\varepsilon$: tolerance of steel against corrosion = 20 (mm)

### 4.1.5 Powerhouse

Functions and requirements of the powerhouse are summarized in the table below.

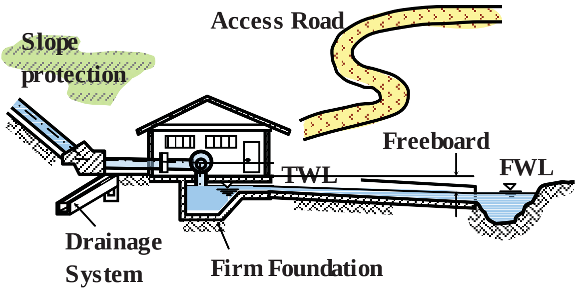
**Table 4.1.13 Functions and Requirements of Powerhouse**

| Description | Remarks |
|---|---|
| Functions<br>✓ To protect generating equipment from rainwater.<br>✓ To provide shelters for operation. | |
| Structural Requirements<br>✓ To be free from flooding.<br>✓ To have space, lighting, toilet facilities, and footpath for operators. | |
| Issues of the Design<br>✓ Criteria for determining the turbine center elevation. | ✓ To select a level free from flood submergence. |

Source: "The Study on Introduction of Renewable Energies in Rural Areas in Myanmar, Final Report Volume 4, Part 4-3 Design Manual – Village Hydros (Chapter 3.7)" conducted by JICA in 2003.

(1) Site Selection

The location of the powerhouse should be selected taking into account the following conditions;



- ✓ Easy access is required for operation and maintenance after completion.
- ✓ Rock foundations are preferable but a well consolidated foundation to support equipment load of 5 ton/m$^2$ will be acceptable.
- ✓ The floor elevation of the powerhouse should be higher than the flood water level of the river downstream, and the slopes surrounding the powerhouse should be stabilized if required.
- ✓ The drainage facilities around the powerhouse should be properly designed to protect the powerhouse from invasion by water rush flow from the slopes and inundation during heavy rain.

(2) Tail Water Level (TWL)

TWL at the powerhouse should be determined so that it will not be affected by the backwater from the river during a flood.

1) Impulse turbine

The water that passes through a runner is directly discharged into the tailrace; and the water flow under the turbine will be turbulent. Therefore, it is necessary to ensure that the clearance between the power plant slab and water surface at the afterbay is at least 30 to 50 cm. The water depth at the tailrace is calculated using the following formula.

$$h_c = \left( \frac{1.1 \times {Q_d}^2}{g \times b^2} \right)^{1/3}$$

Where,
$h_c$: water depth at tailrace (m)
$Q_d$: maximum plant discharge ($m^3/s$)
$g$: gravity acceleration = 9.8 ($m/s^2$)
$b$: width of tailrace canal (m)

The water level at the tailrace should be higher than the design flood water level.

2) Reaction turbine

As a draft tube is used in the reaction turbine, the tail-water level should be designed not to be lower than the outlet of draft tube even during the minimum discharge.

The head between the center of turbine and tail-water level can be used to generate power. So it is possible to set the tail-water level lower than the design flood water level by installing a tailrace channel gate. In this case, the power plant requires a watertight structure and drainage pumps.

### 4.1.6 Tailrace Canal

Functions and requirements of the tailrace canal are summarized in the table below.

**Table 4.1.14 Functions and Requirements of Tailrace Canal**

| Description | Remarks |
|---|---|
| Hydraulic Functions<br>✓ To lead the water back to the river. | |
| Structural Requirements<br>✓ Preferably not to receive backwater and bottom elevation of tailrace. | |
| Issues of the Design<br>✓ Criteria for determining the width and bottom elevation of the tailrace. | ✓ Uniform flow depth above the flood level at the river outlet. |

Source: "The Study on Introduction of Renewable Energies in Rural Areas in Myanmar, Final Report Volume 4, Part 4-3 Design Manual – Village Hydros (Chapter 3.8)" conducted by JICA in 2003.

Tailrace canal is generally not required for MHP schemes, and the powerhouse is selected near the river. In case a tailrace canal is required, it is designed in the same manner as the power canal, in principle.

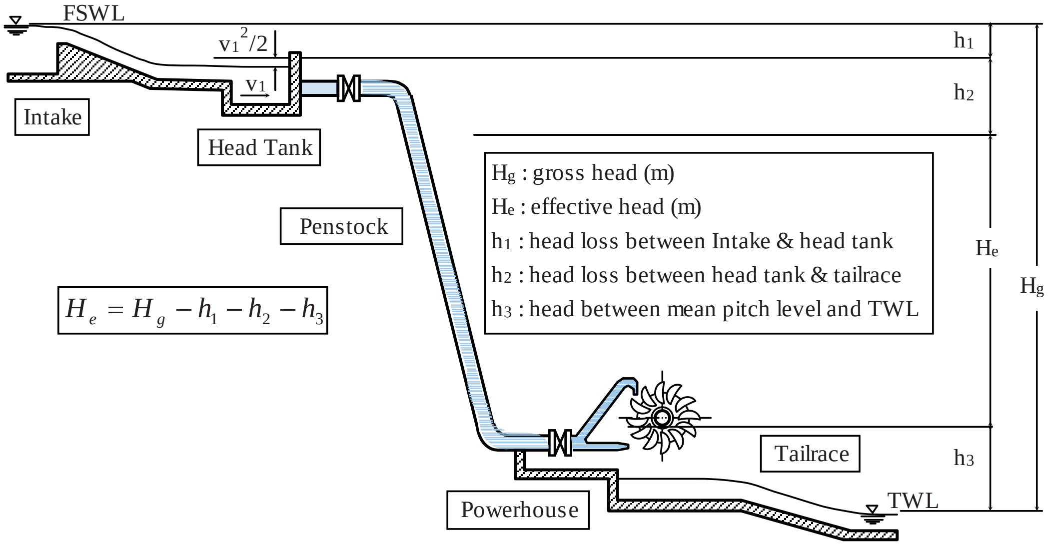
However, normal and flood water levels at the outlet shall be determined and applied as a start condition of the non-uniform flow analysis. The tailrace canal shall be designed to avoid the effect of the backwater from the river as much as possible.

### 4.1.7 Head Loss Calculation

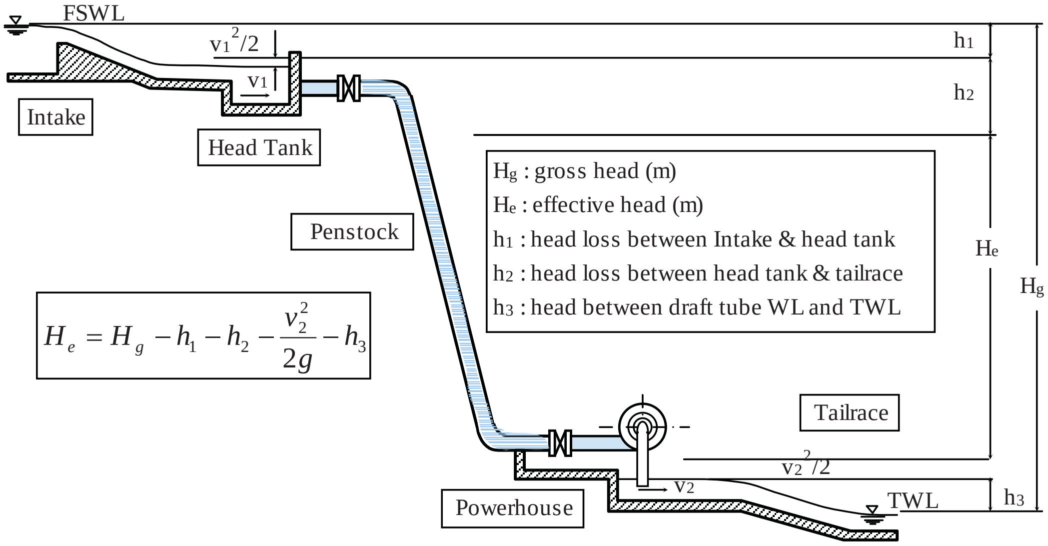
In case of MHP scheme, the effective head to be used to estimate power output can be obtained from the head difference between FSWL at the head tank and TWL at the powerhouse after deducting head losses.

However, effective head changes depending on the type of turbine as shown below:

Impulse Turbine (Pelton, Turgo Impulse and Cross Flow)



Reaction Turbine (Francis, Propeller and Tubular)



Source: "The Study on Introduction of Renewable Energies in Rural Areas in Myanmar, Final Report Volume 4, Part 4-2 Design Manual – Small Hydros (Figure 1.6.3 & 1.6.4)" conducted by JICA in 2003.

**Figure 4.1.9 Effective Head**

The head losses between the head tank and the powerhouse are expressed in a number of equations. The head losses are a summation of nine (9) kinds of head losses defined below. Head losses to be taken into account depend on the plan and profile of penstock.

(1) Velocity Head in Head Tank

$$h_1 = \frac{v_{in}^{\ 2}}{2g}$$

Where,

$h_1$: head loss in head tank (m)

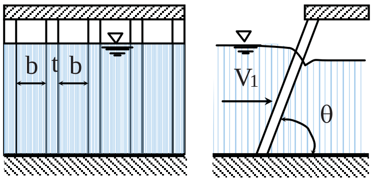
$V_{in}$: flow velocity in head tank (m/s)

$g$: gravity acceleration (m/s$^2$)

## (2) Head Loss at Trashracks

$$h_2 = f_r \times \frac{{v_1}^2}{2g}$$

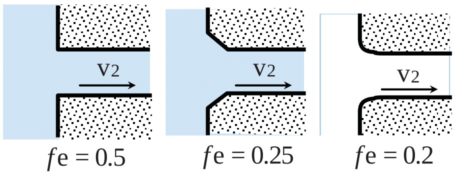
$$f_r = 2.34 \times \sin \vartheta \times (t/b)^{4/3}$$



Where,
$h_2$: head loss of trashracks (m)
$f_r$: head loss coefficient of trashracks ( - )
$v_1$: velocity before trashracks (m/s)
$\theta$: inclination of trashrack (º) $\theta$= 60 to 70º
$t$: thickness of bar (mm)
t = 5 to 9 mm
$b$: space between bars (mm)
$b$ = 100 to 150 mm

## (3) Head Loss at Entrance

$$h_3 = f_e \times \frac{{v_2}^2}{2g}$$



Where,
$h_3$: head loss at entrance (m)
$f_e$: head loss coefficient of entrance ( - )
$v_1$: velocity after entrance (m/s)

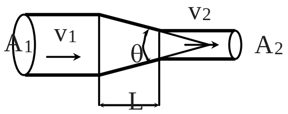
## (4) Head Loss due to Friction

$$h_4 = \frac{124.5 \times n^2}{D^{4/3}} \times L \times \frac{v^2}{2g}$$

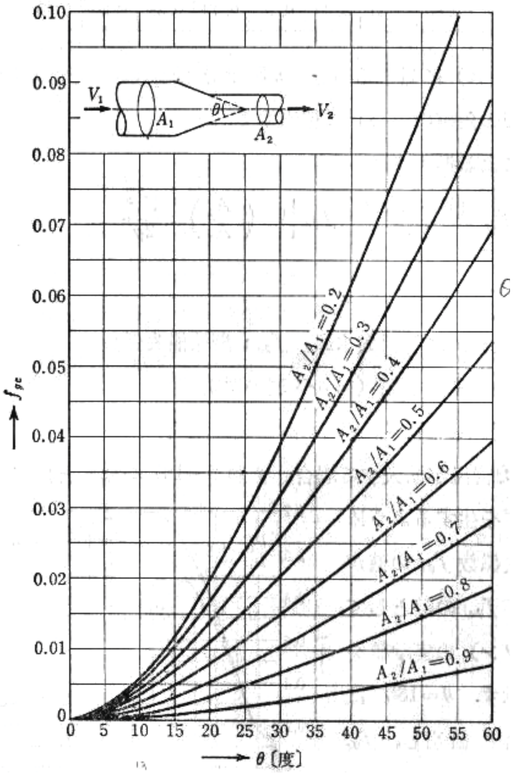
Where,
$h_4$: head loss due to friction (m)
$n$: roughness coefficient of penstock ( - )
= 0.012
$D$: penstock diameter (m)
$L$: penstock length (m)
$v$: velocity in penstock (m/s)

## (5) Head Loss due to Pipe Reducer

$$h_5 = f_{gc} \times \frac{{v_2}^2}{2g}$$



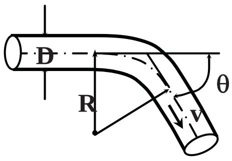
Where,
$h_5$: head loss due to pipe reducer (m)
$f_{gc}$: head loss coefficient of reducer ( - )
$\theta$: reducer angle (º)
$L$: reducer length (m)
$v_1$: velocity before reducer (m/s)
$v_2$: velocity after reducer (m/s)



## (6) Head Loss due to Bend

$$h_6 = f_b \times \frac{v^2}{2g}$$

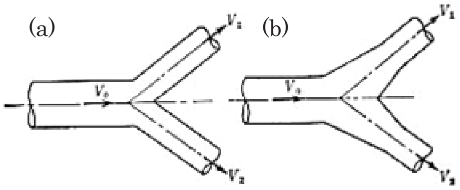
$$f_b = \left[0.131 + 0.1632 \times (D/R)^{3.5}\right] \times (\theta/90)^{0.5}$$



Where,
$h_6$: head loss due to bend (m)
$f_b$: head loss coefficient of bend ( - )
$D$: penstock diameter (m)
$R$: bend radius (m)
$\theta$: bend angle (º)
$v$: velocity in penstock (m/s)

## (7) Head Loss due to Branch

$$h_7 = f_B \times \frac{{v_1}^2}{2g}$$



Where,
$h_7$: head loss due to branch (m)
$f_B$: head loss coefficient of branch ( - )
(a) $f_B$ = 0.75, (b) $f_B$ = 0.50
$v_1$: velocity before branch (m/s)

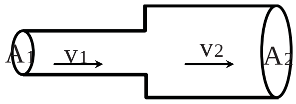
## (8) Head Loss due to Inlet Valve

$$h_8 = f_v \times \frac{v^2}{2g}$$

Where,
$h_8$: head loss due to inlet valve (m)
$f_v$: head loss coefficient of valve ( - )
For sluice valve (full open): $f_v = 0$
For butterfly valve: $f_v = t/d$
$t$: thickness of valve circle end (m)
$d$: diameter of valve circle (m)

## (9) Head Loss due to Enlargement at Outlet

$$h_9 = \left\{1 - \left(\frac{A_1}{A_2}\right)\right\}^2 \times \frac{{v_1}^2}{2g}$$

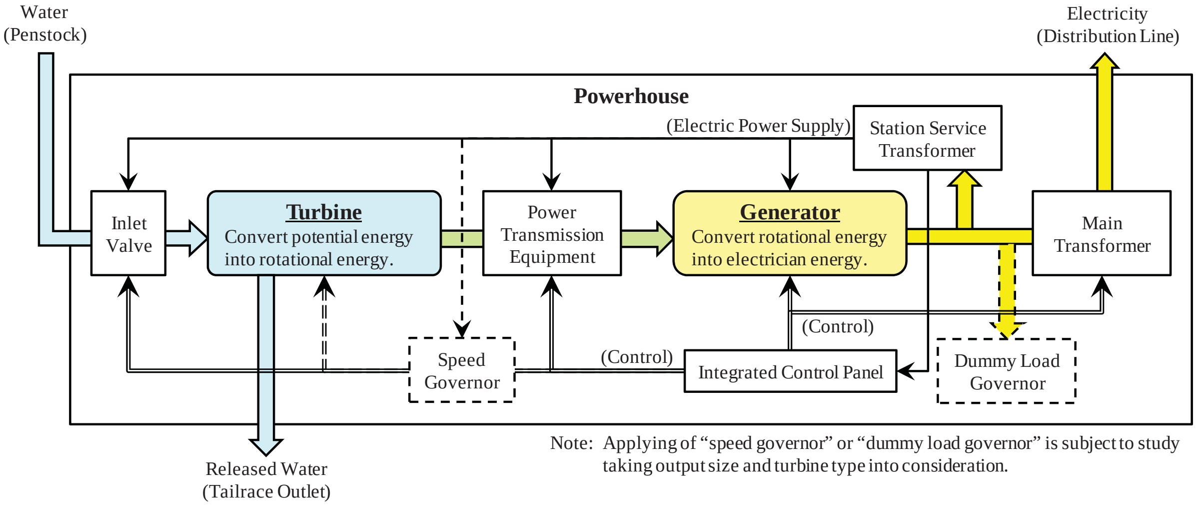


Where,
$h_9$: head loss due to enlargement (m)
$A_1$: flow area before enlargement (m$^2$)
$A_2$: flow area after enlargement (m$^2$)
$v_1$: velocity before enlargement (m/s)

## 4.2 Electrical Equipment

Main components of the electrical equipment are turbine and generator. The turbine converts gravitational potential energy of water into rotational energy, and the generator receives the rotational energy and converts it into electrical energy. To support the operation of turbine and generator a number of equipment are installed in the powerhouse including inlet valve, power transmission equipment, transformers, control panel, governor, etc.

Conceptual diagram of electrical equipment in the powerhouse is shown below.



Note: Applying of "speed governor" or "dummy load governor" is subject to study taking output size and turbine type into consideration.

**Figure 4.2.1 Conceptual Diagram of Electrical Equipment in Powerhouse**

Basically, MHP schemes are similar to general power supply businesses but are at a very small scale. The main requirements for planning and designing electrical equipment in MHP schemes are as follows:

- ✓ Equipment must be designed to be operated easily and safely by villagers because securing the services of an expert to operate high level technology is difficult,
- ✓ In the selection, equipment that have characteristics of small fluctuation in output without requiring special adjustment should be prioritized, and
- ✓ In the selection of equipment, simplicity and durability shall be given priority over efficiency and other functions in order to ensure easy operation, maintain and repair.

Construction budget may be limited, but a MHP scheme should be sustainable and stable. The scheme should be planned to supply stable and high quality electricity, with consideration for future demand increase.

On the other hand, detailed characteristics of electrical equipment vary depending on manufacturers, as they produce electrical equipment based on their individual technical know-how. Some manufactures provide a package of all required equipment for a MHP station known as "Water to Wire System".

Therefore, the explanations in this chapter focus on the standard types and estimation methods based on basic technical features of the turbine and generator, as well as functions of other major equipment for MHP scheme.

### 4.2.1 Turbine

(1) Major Types of Turbines

Turbines are classified into two types according to their water energy utility:

Impulse Turbines

All available water energy is converted by a free jet through a nozzle into rotational energy before water contacts the moving turbine blades (runner peripheral). The energy is then taken from the jet by suitable flow through moving vanes. The vanes are partially filled, with the jet open to the atmosphere throughout its travel through the runner. Losses occur in flow from the reservoir through the penstock to the base of the nozzle.

Reaction Turbines

A portion of the water energy is converted into rotational energy by the water passing through adjustable wicket gates before entering the runner, and the remainder of the energy conversion takes place through the runner. All passages are completely filled with water, including the draft tube from the runner to the downstream water surface. The static water pressure occurs on both sides of the vanes and hence does not do work. All the work done is entirely due to the conversion of water energy into rotational energy.

Both impulse turbines and reaction turbines are comprised of many types. The major types of turbines mainly applied for MHP schemes are summarized below.

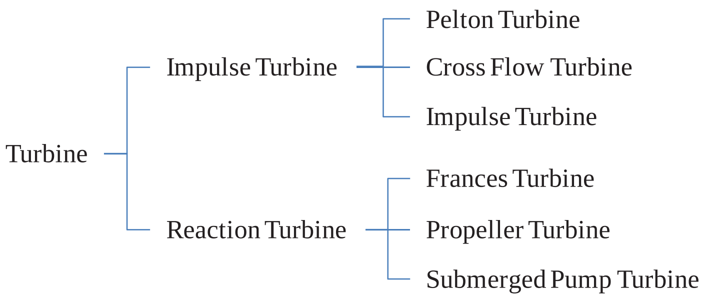


**Figure 4.2.2 Classification Tree of Turbines**

## Table 4.2.1 Major Types of Impulse Turbines

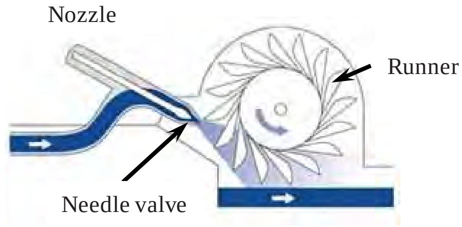
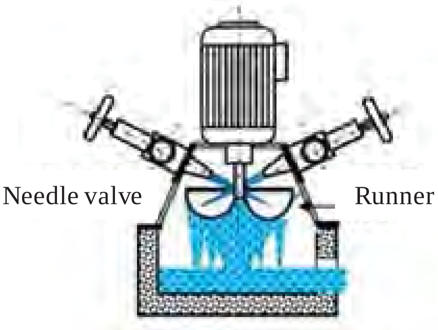
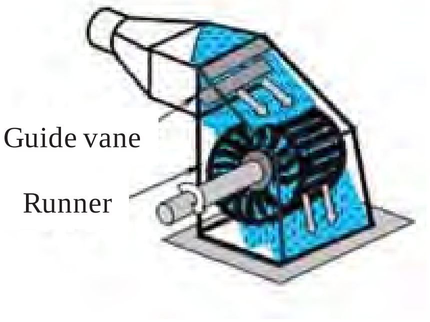
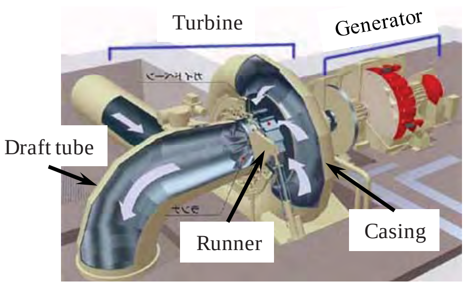
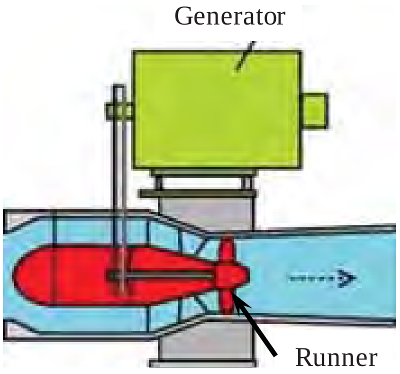
| Type | Characteristics |
|---|---|
| Pelton Turbine<br> <br>Applicable Range:<br>$n_s$ = 12 to 24 (m-kW)<br>$H$ = 75 to 500 (m)<br>$P$ = 300 to 5,000 (kW) | - Water jet from the nozzle strikes the runner. The turned jets over the buckets exert a balanced force that rotates the turbine shaft.<br>- There are one nozzle and two-nozzle types. One-nozzle turbine is applied to high head and low discharge. Two-nozzle turbine is used with relatively large discharge. In general, two-nozzle type is more widely used.<br>- Discharge of the water jet can be adjusted by the needle valve.<br>- A deflector is attached between the top of nozzle and the buckets that enables adjustment of the speed of rotation and immediate interception of water jet flows into the runner.<br>- The structure is rather simple. The turbine is suitable for MHP since pressure rise and speed rise at load rejection can be controlled to lower values by the use of deflector. |
| Turgo Impulse Turbine<br> <br>Applicable Range:<br>$n_s$ = 55 to 65 (m-kW)<br>$H$ = 40 to 300 (m)<br>$P$ = 300 to 5,000 (kW) | - Water jet from the nozzle strikes the runner at an angle of 20 to 25º at the top of the inlet of horizontal vanes each of three or four runner blades. The water jet is discharged roughly towards the direction of the shaft from the outlet side and opposite to that of the inlet.<br>- It has one runner and one or two nozzles.<br>- Water jet enters between the outer circumference of the runner and shaft. Thus, the radius of the radical pitch at which the water jet operates is small in the Turgo Impulse turbine.<br>- It is applicable to relatively large discharge against head compared to Pelton turbine.<br>- The structure of the deflector is simple and durable, which enables the turbine to be stopped by the deflector when the nozzle is fully opened and continuing to discharge. Accordingly, the inlet valve and spillway can be omitted. It can also be applied to river maintenance discharge. |
| Cross Flow Turbine<br> <br>Applicable Range:<br>$n_s$ = 90 to 100 (m-kW)<br>$H$ = 8 to 60 (m)<br>$P$ = 50 to 1,000 (kW) | - The water is led by the guide vane and flows in through the outer side of the runner. It strikes the vanes, passes inside the runner to move the vanes again from the inside, and is then released.<br>- The runner is cylindrical in shape with a long horizontal axis. It includes one (1) or two (2) guide vanes depending on the inlet width.<br>- In the case of a turbine with large maximum discharge, two guide vanes are equipped with vane lengths of either 1/3 and 2/3 of the inflow width. When the discharge is small, i.e., 1/3 of maximum discharge, only the shorter vane is used. If the discharge is more than 1/3 of maximum discharge, only the longer vane is used. If the discharge exceeds 2/3 of maximum discharge, both vanes are used at the same time, which enables operation with small reduction of efficiency against discharge change.<br>- The structure is simple, maintenance is easy, and both equipment and installation costs low. It is therefore widely used in MHP. |

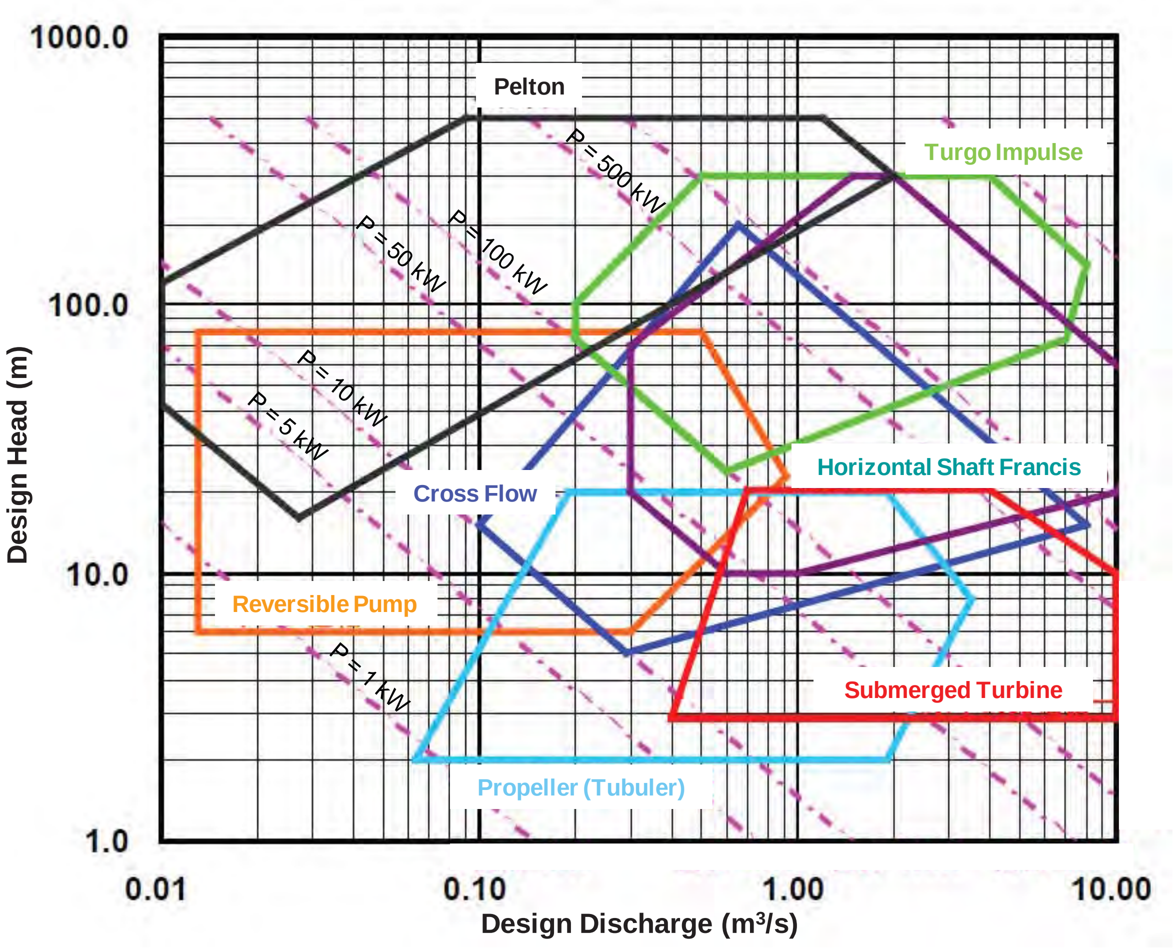
**Table 4.2.2 Major Types of Reaction Turbines**

| Type | Characteristics |
|---|---|
| **Francis Turbine** (Horizontal Shaft)<br> <br>Applicable Range:<br>$n_s$ = 12 to 24 (m-kW)<br>$H$ = 75 to 500 (m)<br>$P$ = 300 to 5,000 (kW) | - They are applied mostly to middle and small scale hydro schemes. They are applicable for a wide range of heads and capacities with high efficiency. Gross head is available down to the tailrace level as a result of draft tube effect that enables a high speed of rotation.<br>- Vertical turbines are mainly applied to medium and small hydro of more than 5,000 kW output. As for horizontal axis Francis turbine less than 5,000 kW output, there are many types according to discharge.<br>- It should not be selected for powerhouses that will experience long operation under low load. |
| **Propeller (Tubular) Turbine**<br> <br>Applicable Range:<br>$n_s$ = 55 to 65 (m-kW)<br>$H$ = 10 to 300 (m)<br>$P$ = 40 to 5,000 (kW) | - It is a tubular shaped horizontal propeller turbine that is applicable under low heads and relatively large discharges.<br>- It can maintain high efficiency against change of head and discharge by rotating both or either runner blades of guide vane.<br>- So far, vertical Kaplan turbine is used in this range of low head and large discharge applications. Horizontal type turbines have advantages in construction, maintenance and operation for MHP and are increasingly being adopted.<br>- There are many types of Tubular turbines. |

### (2) Selection of Turbine

The type of turbine is selected according to design rated head and maximum discharge, taking the range of specific speed of each type into account. A diagram for selecting the applicable turbine type for given discharge and head is shown below.

In the diagram, many types of applicable turbines may be selected for the same discharge and head. In this case, the most appropriate turbine will be selected according to the site conditions and with consideration of size and efficiency and comparison of characteristics.



Source: "Guidebook on Micro Hydropower Introduction" published by NEDO of Japan in 2003 (arranged by WG).

**Figure 4.2.3 Turbine Selection Diagram**

### (3) Specific Speed ($n_s$)

Specific speed is a constant widely used in selection of the turbine type and in preliminary design. The specific speed is defined as the rotating speed of a hypothetical turbine which is geometrically similar, producing a unit output (1 kW) under a unit head (1 m).

The specific speed is given by the following formula:

$$n_s = \frac{N \times \sqrt{P_t}}{H_e^{5/4}} \qquad N = \frac{n_s \times H_e^{5/4}}{\sqrt{P_t}}$$

Where,

| | |
|---|---|
| $n_s$: | specific speed (m-kW) |
| $N$: | revolving speed (min$^{-1}$) |
| $P_t$: | turbine output (kW) |
| $H_e$: | effective head (m) |

The specific speed is proportional to the revolving speed of turbine. In case higher specific speed and higher revolving speed are selected, the turbine and generator will become smaller, as will the powerhouse building. However, the specific speed has equipment strength and limitations to avoid cavitations occurrence as shown below.

**Table 4.2.3 Maximum Specific Speed of Major Turbine Types**

| Impulse Turbine | | Reaction Turbine | |
|---|---|---|---|
| Pelton Turbine | $n_s \leq \frac{4{,}300}{H_e + 200} + 14$ | Francis Turbine | $n_s \leq \frac{23{,}000}{H_e + 30} + 40$ |
| Cross Flow Turbine | $n_s \leq \frac{4{,}000}{H_e + 14} + 16$ | Propeller Turbine | $n_s \leq \frac{21{,}000}{H_e + 16} + 50$ |

Source: "Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Chapter 10.1)" published by JICA in 2011.

(4) Revolving Speed (*N*)

Revolving speed of turbine and generator, without adopting a speed-up gear and/or a direct current generator, is estimated using the following formula;

$$N = \frac{120 \times f}{p} = \frac{120 \times 50}{p} = \frac{6{,}000}{p}$$

Where,
$N$: revolving speed (min$^{-1}$)
$f$: power system frequency (Hz) = 50 Hz
$p$: number of poles (nos.)

It is common for the revolving speed to be chosen among the standard revolving speeds of a generator, originally obtained in the generator design. The upper limit of the revolving speed is calculated using the maximum specific speed of each turbine type, and the revolving speed is selected from the standard revolving speed which is closest to the calculated value.

The standard revolving speed of a Japanese generator is shown below. For MHP station, the number of poles used is generally up to 12.

**Table 4.2.4 Standard Revolving Speed of Generator in Japan**

| Number of Pole (nos.) | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|
| Revolving Speed (min$^{-1}$) | 1,500 | 1,000 | 750 | 600 | 500 | 429 | 375 | 333 | 300 | 250 |

Note: The above revolving speeds are for frequency of 50 Hz.

Source: IEEJ standard JEC-4001 Hydro Turbine and Pump Turbine published by the Institution of Electrical Engineers of Japan (IEEJ), extracted and arranged by WG.

(5) Turbine Efficiency ($\eta_t$)

Turbine efficiency ($\eta_t$) is the ratio of output to input of the turbine.

$$\eta_t = \frac{P_t}{9.8 \times Q_{\max} \times H_e}$$

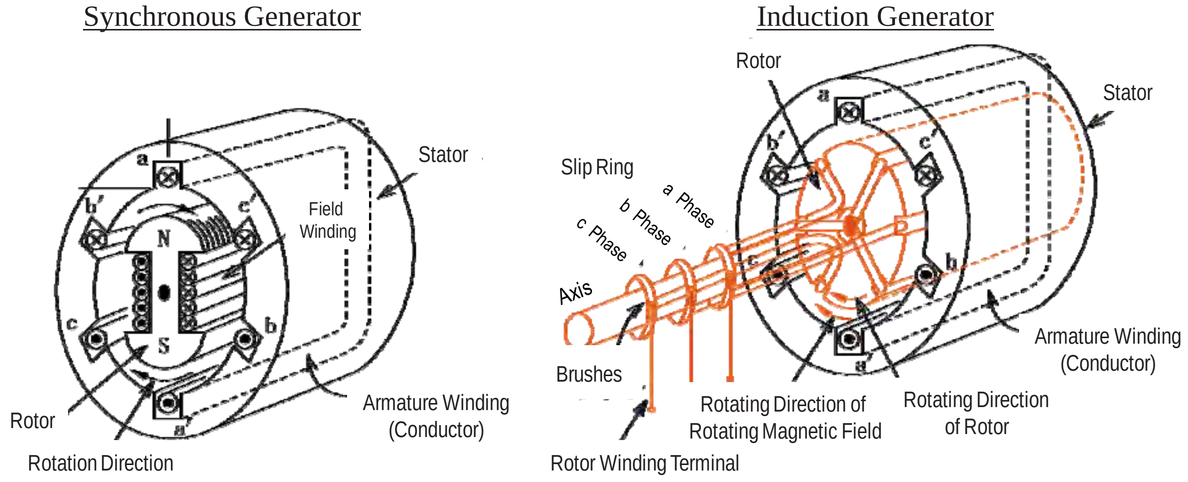
Where,
$P_t$: turbine output (kW)
$Q_{max}$: maximum design discharge (m$^3$/s)
$H_e$: effective head (m)

Generally, the turbine is designed to attain the highest efficiency at around 80% of the maximum discharge. The efficiency decreases depending on the fluctuation of discharge. The efficiency curve is varies depending on the turbine type, the specific speed, and the manufacturer.

### 4.2.2 Generator

(1) Major Types of Generators

There are two types of generators for hydropower, namely synchronous generator and induction generator. The mechanism and characteristics of each type are summarized below.



Synchronous Generator

Induction Generator

Source: “Institution of Electrical Engineers of Japan (IEEJ)” webpage (http://www.jeea.or.jp/course/contents/12125/) (arranged by WG)

**Figure 4.2.4 Mechanism of Synchronous and Induction Generator**

Synchronous Generator

This type induces a voltage in armature coils by rotating magnetic poles. There are several types of exciter systems such as separate excitation, static excitation, and alternate current excitation brushless type. Brushless type generators are often employed in MHP scheme because they are easy to maintain.

It is widely used and generates three-phase alternating current (AC) with low-voltage terminal voltage. For small capacity more than 1,000 kVA, 11,000 V might be applicable.

Revolving speed of the generator is the same as that of the turbine in principle (refer to 4.2.1 (4)).

Induction Generator

This type is a rotating structure composed of armature winding and rotor winding. Electricity is generated through electromagnetic induction between the windings.

Generally, this type of generator cannot generate electricity independently. Operation must be established by supplying an excitation current to the armature winding, from another power source. In addition, the generator causes a rush current which is several times the value of the rated current, when it is connected to the power system on null voltage.

However, it tends to be applied to MHP schemes because of low cost, simple maintenance and easy operation. Induction motors are applied to generators at low cost. In this case, it should be noted that the induction motor is not able to withstand the over speed condition. Because induction generator operates by excitation current from a connected power grid, isolated operation and power factor adjustment are not possible.

To improve the power factor, a parallel condenser is connected to the generator. When load shedding occurs with a large condenser in place, it is necessary to pay attention to the following fact: As the rotational frequency of generator increases, the generator is excited by the leading current of condenser, which eventually causes self-excitation phenomenon with a high voltage.

It is applied to powerhouse less than 1,000 kW connected to power grid in parallel. Generator structure can be simple and low cost by applying a squirrel cage type secondary winding.

The required specification items of each generator type are listed below.

**Table 4.2.5 Required Specifications of Synchronous Generator and Induction Generator**

| Item | Synchronous Generator | Induction Generator |
|---|---|---|
| Direction of shaft | Horizontal | - |
| Axis direction | - | Horizontal |
| Rated | Variable | Continuous |
| Capacity | kVA | kW |
| Voltage | V | V |
| Current | A | A |
| Power factor | 0.8 to 0.5 | Depending on manufacturer. |
| Frequency | Hz | Hz |
| Revolving speed | $\min^{-1}$ | $\min^{-1}$ |
| Slip | - | % |
| Insulation class | F class | F class |
| Type of bearing | With or without thrust bearing. | - |
| Type of excitation | To be specified. | - |
| Short circuit ratio | To be specified in case of large size. | - |

Source: "The Study on Introduction of Renewable Energies in Rural Areas in Myanmar, Final Report Volume 4, Part 4-2 Design Manual – Small Hydros (Chapter 3.2)" conducted by JICA in 2003 (arranged by WG).

(2) Output and Rated Capacity

The output and capacity of a generator is estimated using the following formulae:

Generator Output ($P_g$)

$$P_g = \frac{P_t \times P_{g(temp)}}{P_{g(temp)} + P_{gl}}$$

$$P_{gl} = 0.1628 \times P_{g(temp)}{}^{0.8184}$$

Generator Capacity ($P_g$')

$$P_g' = P_g / P_f$$

$$\eta_g = P_g / P_t$$

Where, $P_g$: generator output (kW)
$P_t$: turbine output (kW)
$P_{g(temp)}$: generator output (temporary value) (kW)
$P_{gl}$: generator loss (kW)
$P_g$': generator rated capacity (kVA)
$P_f$: generator rated power factor ( - )
$\eta_g$: generator efficiency ( - )

Several trial calculations are required to obtain the generator output as explained below.

- ✓ At first, plug in the turbine output ($P_t$) for the temporary generator output ($P_{g(temp)}$), and calculate the generator loss ($P_{gl}$) and generator output ($P_g$),
- ✓ Then, plug in the calculated generator output ($P_g$) for the temporary generator output ($P_{g(temp)}$), and repeat the same calculation until the temporary and the calculated outputs becomes equal ($P_{g(temp)} = P_g$).

Example

Calculation of generator output ($P_g$)

First assumption: $P_t$ = 45 kW, and $P_{g(temp)}$ = 45 kW
Generator loss: $P_{gl} = 0.1628 \text{ x } 45^{0.8184} = 3.7$ (kW)
Generator output: $P_g = 45 \text{ x } 45 / (45 + 3.7) = 41.6 = 42$ (kW)
Second assumption: $P_t$ = 45 (kW), $P_{g(temp)}$ = 42 (kW)
Generator loss: $P_{gl} = 0.1628 \text{ x } 42^{0.8184} = 3.5$ (kW)
Generator output: $P_g = 45 \text{ x } 42 / (42 + 3.5) = 41.5 = 42$ (kW) OK.

Calculation of generator rated capacity ($P_g$')

Generator efficiency: $\eta_g = 42 / 45 = 0.933$
Generator rated power factor: $P_f$ = 0.93 (93%)
Generator rated capacity: $P_g' = 42 / 0.93 = 45$ (kVA)

The generator rated power factor ($P_f$) is generally adopted to be approximately 98% to 85%. However, it is determined in consideration of the characteristics of the load and connected power system.

(3) Voltage and Current

The relationship between generator rated voltage and generator rated current are given by the following formula.

$$I_g = P_g' / \sqrt{3} / E$$

Where,
$I_g$: generator rated current (A)
$P_g$': generator rated capacity (kVA)
$E$: generator rated voltage (kV)

In the case that the generator voltage adopted is higher, the stator coil insulator becomes thicker, the occupation ratio of conductor becomes lower, and total weight of generator becomes larger. As a result, the generator becomes expensive. On the other hand, higher voltage needs lower current and capacities of cables, conductors and breaking devices becomes smaller.

Therefore, comparative study is necessary to obtain an applicable voltage and current. Empirically, the generator rated voltage is adopted as shown below.

| Generator Capacity: | Rated Voltage: |
|---|---|
| Less than 3 MVA | 400 V |
| 3 to 10 MVA | 6.6 kV |
| 10 to 50 MVA | 11 kV |

(4) Excitation System

Excitation system is equipped in a synchronous generator, and serves the function of controlling generator output and generator voltage to be constant by supplying a field current.

Exciter supplies a field current for the rotor in generator to generate magnetic flux. The generated excitation current in the magnetic flux is adjusted by Automatic Voltage Regulator (AVR) to be the constant generator voltage. The power factor of generator voltage is adjusted to be constant by the Automatic Power Factor Regulator (APFR), responding to the voltage fluctuation of the connected power system.

The system is generally adopted in MHP station, except independent operation of the generator.

### 4.2.3 Inlet Valve

Inlet valve is mechanical equipment to control water flow into the turbine. It is installed in front of the turbine inlet at the end of the penstock.

The inlet valve is opened during power generation. When power generation is interrupted, it is closed to shut off water flow before commencement of operation. This may be during inspection and maintenance, or in the case of an emergency involving the turbine. In this case, water inflow to the runner is closed off by a preceding operation of the guide vane or the needle.

In case the diameter of the inlet valve is relatively large and there is a low head and a large discharge, the inlet valve may be omitted by providing a regulating gate at the inlet of the penstock.

In case of automatic operation, there are two types of drives i.e., motor driven and hydraulic oil driven types. Generally, motor drives are more widely adopted. The power source for driving motor is basically direct current (DC), but alternating current (AC) may be applied. Hydraulic oil drives are used for large diameter applications. It is recommended that opening and closing time is set at less than 180 seconds.

The major types of inlet valves mainly applied for MHP schemes are summarized below.

**Table 4.2.6 Major Types of Inlet Valve**

| Type | Characteristics |
|---|---|
| Butterfly Valve<br> | - It is applicable for heads of less than 150 m.<br>- There are horizontal axis type and vertical axis type valves. Horizontal axis type valves have the advantage that the weight of the valve body is easy to support.<br>- The valve diameter is generally 1.1 to 1.2 times the turbine inlet pipe diameter.<br>- The structure is simple. Sealing method is good in rubber seal type valves.<br>- The head loss is rather large compared to other valve types, but this is still applied in relatively small diameter because of the low cost. |
| Through-flow Valve<br>(Double leaf valve)<br> | - It is applicable for heads of less than 200 m.<br>- The structure is the same as Butterfly Valve, but the valve body is thin and is strengthened by combining two pieces in order to reduce head loss.<br>- The valve diameter is 1.1 to 1.2 times the turbine inlet pipe diameter, similar to the Butterfly Valve. |
| Slice Valve<br> | - It is applicable to high heads and small discharges.<br>- It has small head loss.<br>- There are two types of spindles that operate the valve electrically.<br>- One is an inner screw type with a female screw attached to the valve body and a male screw on a spindle is turned for up-down movement.<br>- The other type, the outer screw, turns a female screw at the top of the spindle.<br>- The former is for relatively large diameter applications, but the latter has the advantage of safety and is applied for hydro more frequently. |

Source: "The Study on Introduction of Renewable Energies in Rural Areas in Myanmar, Final Report Volume 4, Part 4-2 Design Manual – Small Hydros (Chapter 3.4)" conducted by JICA in 2003 (arranged by WG).

### 4.2.4 Power Transmission Equipment

Power transmission equipment is mechanical equipment to transmit the rotational energy from the turbine to the generator.

Since it is desirable to directly couple turbine and generator, the turbine speed will be selected to be equal to that of the generator as much as practically possible. However, when it is difficult to select the same speed between turbine and generator or when the turbine speed is very low and therefore requires many magnetic poles of the generator (required to obtain rated frequency at the low speed given, but will be complicated, expensive, and not readily available in the local market), a gear system to increase the revolving speed is required to transmit the turbine output to a generator.

For a MHP scheme, the number of poles used is generally up to 12. For more than 12 poles, the generator size is generally larger and more expensive. Application of speed-up gears paired with application of a 4-6 high speed generator is therefore necessary to increase the turbine speed, especially for cross flow turbine.

Major methods of increasing the revolving speed and the characteristics of each method are explained and are compared as shown below.

Speed Increaser

This is the ideal power transmission mechanism, which is applied to a turbine-generator of more than 30 kW output. Series of gears are contained in oil immersed casing for lubrication and cooling. A transmission efficiency of some 98% is obtained.

A flange coupling is employed for connecting the turbine-speed increaser and speed increaser-generator. The centering between the turbine and generator is difficult since both employ roller bearings. Accordingly, a flexible coupling is used in order not to cause excess stresses on the bearing.

Belt Transmission

Belt transmission is most often applied for small capacity turbine-generator since it is easy to choose the necessary gear ratio.

There are various types of belt transmission such as plane belt, V-belt, and ditched belt. Among these, the V-belt is the most commonly used.

Belt Transmission

**Table 4.2.7 Comparison of Speed Increaser and Belt Transmission**

| Item | Speed Increaser | Belt Transmission |
|---|---|---|
| Gear Ratio | Relatively large, but the ratio shall be selected from the standard goods. | Relatively adjustable as required. |
| Required Space | Relatively narrow. | Relatively huge. |
| Safety | High safety while the rotating portion is completely covered. | Relatively low while the belt is normally exposed. |
| Capacity | Adjustable for large capacity. | Limited due to belt proof strength |
| Economic Efficiency | Relatively expensive | Relatively cheap |
| Serviceability | In principle, it is maintenance free except for regular replacement of grease, etc. | Control of belt tension force, regular cleaning is required. |
| Load to Axis of Turbine and Generator | None | Radial load acts to the axis. Tolerated dose shall be considered. |
| Erection Adjustment | High accuracy is required | There is some tolerance |
| Noise | Relatively large | Relatively small |

### 4.2.5 Governor

(1) Speed Governor

This is electrical equipment to control the revolving speed and output of turbine within the specified value.

The speed governor adjusts the water inflow devices such as guide vanes, needle valves and deflectors, and controls water inflow to synchronous the generator output with the load demand, and the power system frequency keeps the rated value. When operation is disconnected due to a fault or breakdown of the distribution line, the turbine is immediately shutdown by closing the guide vanes to prevent an abnormal rise in speed of the turbine and generator.

Large force is required against the water flow to adjust these devices directly. A hydraulic servomotor is used for medium-small scale hydro, while an electric servomotor is used for MHP scheme since control is accurate and maintenance and inspection are easy.

Detection of the control parameter (such as speed, water level, discharge and output), calculation of the required range for control, and relay of the control signal to the servomotor are conducted by a CPU and electronic circuit.

(2) Dummy Load Governor

This is electrical equipment to control the generator output to be synchronous with load demand within the specified value.

The dummy load governor is a method to adjust the surplus electricity by dummy loads (resistors). Surplus electricity is the difference between the generating output and the power system demand. The dummy load governor detects the differences from change in revolving speed and/or frequency, and adjusts the electricity automatically to be constant.

Advantages of the dummy load governor are:

- ✓ The control characteristics are fine and it can respond to sudden output change even from minimum to maximum,
- ✓ Turbine revolves at the most suitable point depending on the flow discharge control, and mechanical wear of the turbine is therefore mitigated, and
- ✓ Mechanical operation such as a servomotor is not involved.

The dummy load governor is applicable for units less than 200 kW, isolated operation in a small grid and for turbines without a water inlet adjusting mechanism, such as a reversible pump turbine system.

### 4.2.6 Transformer

Transformer is electrical equipment to step-up or step-down voltage. Transformers in power station are classified into the following three types:

- ✓ A main transformer used to step up generator voltage to line voltage,
- ✓ A station service transformer to lower the generator voltage to house voltage, and
- ✓ A station low-voltage transformer to lower the house voltage to equipment voltage.

(1) Main Transformer

Outdoor three-phase transformers are normally used in hydropower station. Regarding the cooling method, a self-cooling type is used in small capacity units. In case the transformer is installed indoors, dry-type is adopted due to the space limitation, in the majority of cases.

The rated capacity of the main transformer is set at a value equal to the rated output of the generator. The primary voltage is normally set at about 5% lower than the rated voltage of the generator. In case the system becomes ultra-high voltage and the power factor approaches 100%, primary voltage is set at the rated generator voltage.

In addition, in a MHP station, in case the voltage of the transmission line and that of the generator are the same, an insulation transformer of the same voltage is installed as a main transformer. This functions to protect the generator from external attack such as a thunder surge from a transmission line and to reduce the short circuit capacity in the power station.

(2) Station Service Transformer and Station Low-Voltage Transformer

Capacity of the station service transformer and station low-voltage transformer are determined to satisfy the required power for plant equipment such as a water supply pump, water drainage pump, lighting for the plant and power supply to a crane for the installation and maintenance works. Dry-type transformer is generally used for a small capacity unit installed indoors to avoid the danger of fire. It is installed in the same place parallel to the metal enclosed switchgears as a safety consideration.

It is noted that impedance of both station service transformer and main transformer are sometimes influenced by the short circuit current of the station service circuit. Appropriate values of impedances and the short circuit current shall be selected.

### 4.2.7 Main Circuit

Main circuit connects electrical equipment in powerhouse. The main circuit is designed taking the following aspects into consideration:

- ✓ Number and capacity of generators,
- ✓ Existence, number and connection method of distribution lines,
- ✓ Receiving method of station power,
- ✓ Restrictions such as space in power station,
- ✓ Construction cost and transportation conditions of transformers and switchgears,
- ✓ Range of power failure caused by in-station accidents, and
- ✓ Safety and ease of repair and maintenance.

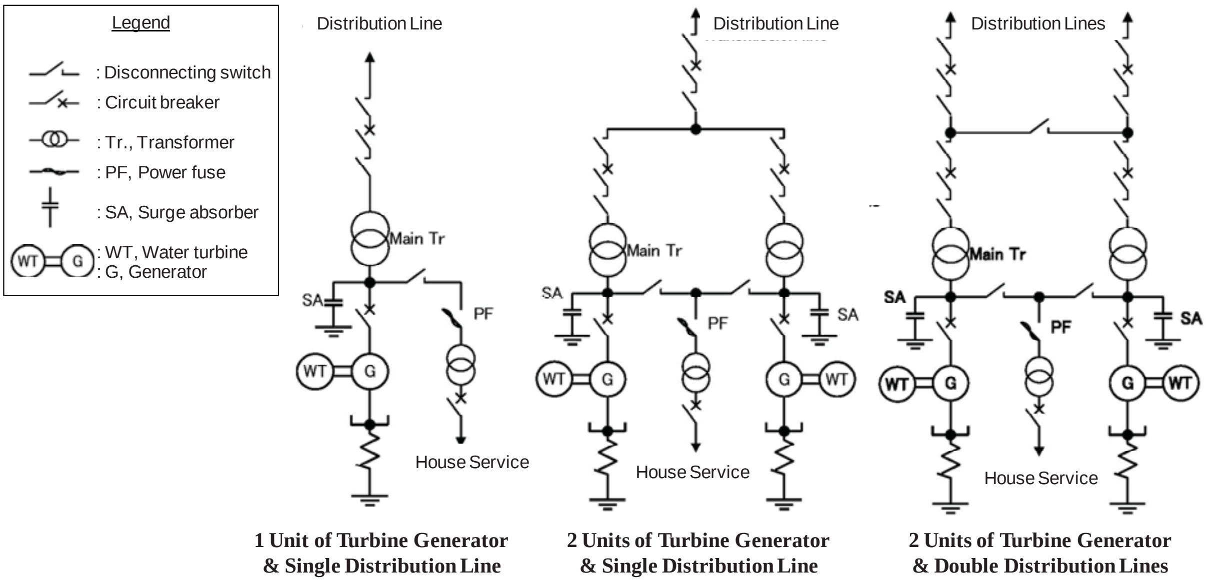
The main circuit consists of the following electrical devices and systems.

### Table 4.2.8 Examples of Major Devices and Systems in Main Circuit

| Name | Function |
|---|---|
| Circuit Breaker | Open and close the load current, short-circuit in interruption and failure, interruption of ground-fault current, etc. |
| Disconnecting Switch | Divide electrical equipment and devices from the main circuit. |
| Instrument Transformer | Measure circuits for high voltage/large current, and supply voltage/current to instruments, relay and watt-hour meter based on the principle of the power transformer. |
| Arrester | Protect electrical equipment and devices from lightening and/or over surging voltage. The arrester includes protective gaps and protective condensers. |
| Metal Enclosed Switchgear | Put away circuit breakers, disconnecting switches and instrument transformers of each power supply (400V, 200V, 100V and a 6.6kV circuit of the power station) in steel boxes for safety and security. |
| Control Panel | Operate, control and protect all electrical equipment in powerhouse. |
| Protective Relay System | Protect electrical equipment against emergency, emergency stop for electrical failure, quick stop for mechanical failure, normal stop in alarm mode, and alarm. |
| Direct Current Power Supply System | Supply a direct current for controlling the control panel, switchboards, and protective relay system. Batteries with chargers are used as a power source. There are two types of batteries, lead acid and alkali. Alkali batteries are adopted more commonly these days because of simplicity of maintenance. |

Source: "Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Chapter 10.4)" published by JICA in 2011 (arranged by WG).

Examples of the main circuit connections are shown below.



Source: "Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Figure 10-36, 10-37 & 10-38)" published by JICA in 2011 (arranged by JICA).

**Figure 4.2.5 Examples of Main Circuit Connections**

### 4.2.8 Integrated Control Panel

An integrated control panel uses a Central Processing Unit (CPU) to perform integrated operations of control, operations of protective equipment, and storage of operation record for the powerhouse. It is contained in a small board.

Examples of the functions included in an integrated control panel are as follows:

**Table 4.2.9 Examples of Functions in an Integrated Control Panel**

| Function | Element |
|---|---|
| Control Functions | Operation sequence, starting speed control, voltage control, power factor control, frequency control, load control, water level control, discharge control, program operation control, etc. |
| Protective Functions | Over current, over voltage, under voltage, bus ground fault, lack of phase fault |
| Display Functions | Voltage, current, power output, power factor, frequency, water level, opening, bearing temperature, faults, etc. |
| Recording Functions | kWh, discharge, historical record of fault , daily operation report, monthly report, annual salary, testing record, etc. |

Source: "The Study on Introduction of Renewable Energies in Rural Areas in Myanmar, Final Report Volume 4, Part 4-2 Design Manual – Small Hydros (Chapter 3.3)" conducted by JICA in 2003 (arranged by WG).

### 4.2.9 Other Equipment

(1) Cooling Water Supply System

Cooling water supply system is provided to cool down the electrical equipment to maintain normal temperature as well as for fire-fighting.

Water for the system is collected from penstock by an automatic valve via a pressure reducer. In the case of a power station with head less than 30 m or higher than 150 m, the water is fed from the tailrace by a water pump.

In the case of MHP station, cooling water supply system is omitted by adopting air-cooling for generator with air duct, plastic packing for main shaft sealing, air-cooling with the heat radiation fin, heat piping of the main bearings, etc. It aims at simplification of the equipment and ease of future maintenance works.

(2) Water Drainage System

A water drainage system is required for the powerhouse. Miscellaneous water flows arise in the powerhouse due to leakages from turbine seals, penstock, casing, rain water from building walls, general service water for maintenance works, etc.

Drainage pit is provided at the lowest level of the powerhouse to collect these miscellaneous water flows in powerhouse. Water flows are led to the drainage pit through drain ditches and drain pipes, and are removed to the outside by manual or drainage pumping.

The capacity of the drainage pit is estimated from time span of arrival time of the station staff and operation time for measures to be effected in the case of an emergency. An oily water separator pit is provided in the drainage pit to separate leaks of lubricating oil and turbine oil from equipment from the rest of the water to avoid direct release of oily water into the river.

(3) Crane

Overhead travelling crane or gantry crane is installed for installation and maintenance works of the water turbine and generator in powerhouse. In case of MHP station; truck crane, small electric hoist, hand-operated hoist and chain block are applicable. The capacity of crane is generally designed to hoist the heaviest equipment. Generator rotor is generally the heaviest among the electrical equipment.

(4) Grounding Wire

Grounding wire mesh is installed in and around the powerhouse area in order to avoid occurrences of step voltage or touch voltage. At the time of a ground fault of transmission line or generator, an electric current flows between the ground fault point and the powerhouse. It is indispensable to connect all the electrical equipment such to a grounding mesh.

## 4.3 Distribution Facilities

### 4.3.1 General

Consideration of the following points is generally required when designing the distribution facilities for a mini-grid. It is necessary for planning and designing the distribution facilities to consider the safety and the life cycle cost. Therefore the facilities for a mini-grid are technically the same as the facilities for the conventional distribution system.

- ✓ The design satisfies the technical standards required for power facilities in Kenya,
- ✓ The design satisfies the safety standards in Kenya,
- ✓ The distribution system supplies electrical power to all consumers at or above the quality of the electrical power standards.
- ✓ The cost of the equipment is minimized over the life cycle of MHP, not only by reducing initial investment cost but also maintenance cost.

### 4.3.2 Distribution Methods

(1) Medium Voltage Distribution Methods

Medium voltage distribution methods can be classified broadly by the neutral grounding method.

These are further classified as single or multiple grounding methods, according to the number of grounding locations. Various neutral grounding methods and their characteristics are tabulated in the next page.

Selection of the neutral grounding method is made primarily on the basis of the distribution voltage and facility conditions. Generally, a non-grounding method is used for 11kV or less, and a neutral point resistively grounding method is used for 20kV or more.

Three-phase loads may be used for the distribution methods listed above. A SWER (Single Wire Earth Return) method can also be used if it is for rural electrification of single-phase load only and the demand is small. The SWER method uses only a single medium voltage conductor, and an earth return system is used for the return circuit. Although the cost of the insulating transformers is high, the cost of the conductor drops as the distance becomes longer. Therefore, this method is used where there are points of load across large areas.

The advantages include low initial investment and low maintenance costs. However, there are many disadvantages such as;

- ✓ Possibility of accidents for the public caused by an electric current passing through large areas of land,
- ✓ A large amount of electromagnetic induction in the communication equipment compared to other distribution methods, and
- ✓ Necessity to change to a single-phase two-wire method or other distribution methods in case the SWER method is unable to handle the load that exceeds a certain volume.

(2) Low Voltage Distribution Methods

Low voltage distribution methods include a single-phase two-wire method, a single-phase three-wire method for a lighting load, and a three-phase three-wire method for a dynamic load. In general, a three-phase four-wire method is used to supply both lighting load and dynamic load. A star-connection three-phase four-wire method is common for the standard of 230/400V. The most suitable method is selected based on the configuration and density of demand in the area.

## Table 4.3.1 Comparison of Grounding Method

<table>
<tr><th colspan="3" rowspan="2">Grounding<br>Item</th><th rowspan="2">Solidly Grounding Method</th><th colspan="3">Resistively Grounding Method</th><th rowspan="2">Arc Suppression Coil Compensated Grounding Method</th><th rowspan="2">Non-grounding Method</th><th rowspan="2">Remarks</th></tr>
<tr><th>40 to 90 Ω</th><th>Around 200 Ω</th><th>500Ω (22kV)<br>950Ω (33kV)</th></tr>
<tr><td rowspan="4"><b>Abnormal Voltage</b></td><td colspan="2">Switching</td><td colspan="6">There is a problem with input surge, and the size is not directly affected by the grounding method.</td><td rowspan="4">There are no grounding methods that are difficult to use for insulation design.</td></tr>
<tr><td rowspan="2">Single-line Grounding Fault</td><td>Steady State</td><td>1.3 times or less</td><td colspan="3">If $R_0/X_1 > 10$, 2.0 times ore less<br>･Impedamce of earth capacity that satisfies conditions of 2.0 times or less.<table><tr><td>$R_N$</td><td>50</td><td>190</td><td>950</td></tr><tr><td>$X_C$</td><td>> 250Ω</td><td>> 300Ω</td><td>> 600Ω</td></tr></table>$X_C$ for model system:<br>City 150 to 1,500Ω<br>Urban 180 to 6,700Ω<br>Rural 3,700 to 10,000Ω</td><td>If overcompensated, $3^{0.5}$ times or less</td><td>If $X_0/X_1 < 10$, 2 times or less</td></tr>
<tr><td>Transient</td><td>1.5 times or less</td><td colspan="3">If $R_0/X_1 > 10$, 3.0 times ore less</td><td>If overcompensated, 2.5 times or less</td><td>If $X_0/X_1 < 10$, 3 times or less</td></tr>
<tr><td colspan="2">One Line Disconnected</td><td>No problem</td><td colspan="3">No problem</td><td><table><tr><td>α</td><td>0.1</td><td>0.2</td><td>0.3</td><td>0.5</td></tr><tr><td>$V_0$</td><td>$5E_a$</td><td>$2.5E_a$</td><td>$1.7E_a$</td><td>$5E_a$</td></tr></table>Where, α<br>α = overcompensation rate<br>$= (3X_L - X_C) / 3X_L$</td><td>No problem</td></tr>
<tr><td><b>Induciton toward Communication Line</b></td><td colspan="2">Single-line Grounding Fault Normary</td><td>Large<br>For multiple groundings, there might be interference from earth branches of load unbalance current.</td><td>Medium<br>No problem</td><td>Small<br>No problem</td><td>Small<br>No problem</td><td colspan="2">Small<br>No problem</td><td rowspan="2">Neutral point solidly grounding cannot be used. Neutral point resistively grounding becomes more difficult to use for lower resistances.</td></tr>
<tr><td colspan="3"><b>Rise in Electrical Potential on Low Voltage side when mixed with Low Voltage</b></td><td>Excessive</td><td>Large</td><td>Medium</td><td>Medium</td><td colspan="2">Small</td></tr>
<tr><td rowspan="3"><b>Grounding Fault Protection</b></td><td colspan="2">Wave Distortion</td><td>No problem</td><td>Small</td><td>Small</td><td>Medium</td><td colspan="2">Large</td><td></td></tr>
<tr><td colspan="2">Applicable Relays</td><td>OC</td><td>3CT + DG</td><td>ZCT + DG<br>3CT + DG might also be used.</td><td>ZCT + DG<br>3CT + DG might also be used.</td><td colspan="2">CT + OCG, GPT+OVG, ZCT+DG<br>ZCT+DG might malfunction depending upon conditios at the fault point, and careful consideration of DG preformance is required.</td><td>Although the development of a relay might be required, resolution of the problem is not difficult.</td></tr>
<tr><td colspan="2">Fault Detection Sensitivity</td><td>Cannot be set very high.</td><td>100-900Ω (10-30%)</td><td>2,000Ω (10%)</td><td>4,500 -8,500Ω (10%)</td><td colspan="2">About 1,000Ω</td><td>Figures shown in ( ) are the minimal detection sensitivity for DG.</td></tr>
</table>

Notes;

$R_0$: zero-phase resistance,
$X_1$: positive-phase resistance,
$V_0$: zero-phase voltage,
OC: over current relay,
OVG: grounding over voltage relay,
3CT: items using residual circuitry for 3 CT units of each phase,
$X_0$: zero-phase reactance,
$X_C$: earth capacity reactance,
OCG: grounding over current relay,
DG: directional grounding fault relay,
ZCT: zero-phase current transformer, and
$X_L$: reactor reactance.

Source: “20kV Distribution Method (Overhead Edition)”, Vol. 3 No.3, published by Electric Technology Research Association in Japan (arranged by WG).

### 4.3.3 Distribution Line Planning

Distribution line planning requires consideration of not only construction but also maintenance in relation to the facility location, topography, the route, and the relationship with other structures.

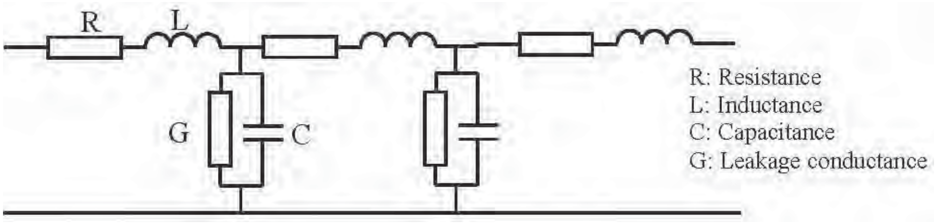
Specifically, the following should be considered when selecting the route:

- ✓ The route preferably follows roadways,
- ✓ There are fewer trees that would require cutting or clearing,
- ✓ The area is not susceptible to natural damages, such as landslides, avalanches, and flooding,
- ✓ Swamps and steep mountainous areas should be avoided,
- ✓ There are fewer river and roadway crossings. When a crossing is required, it can be done at a right angle,
- ✓ The route is straight and level as much as possible between the supports, with equal spans on both sides,
- ✓ The supports can be built on risers firmly when passing through rice paddies and agricultural fields, and so on.

### 4.3.4 Electrical Design

(1) Line Constants

Distribution lines are electric circuits with four line constants, i.e., resistance, inductance, capacitance, and leakage conductance as shown below.



Source: "Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Figure 11-4)" published by JICA in 2011.

**Figure 4.3.1 Line Constants**

These line constants must be known in order to calculate the electric properties of the distribution line. They are determined by the type, thickness, and layout of conductors, and they are mostly unaffected by voltage, current, and power factor. In addition, since the distribution lines have lower voltage and shorter lengths than the transmission lines, only resistance and inductance need to be considered here normally.

(2) Voltage Drop

A voltage drop is the difference between the delivered voltage and the received voltage, occurring when there is a load current on a distribution line. The voltage drop is calculated in order to check the maximum and minimum voltages at each point to finally determine whether it is within a standard range.

Since the load of distribution lines is dispersed in different ways depending on the location, capacity, and type, it is difficult to calculate the voltage drop. Therefore, a usual method for determining an approximate value of voltage drop is to refer to the scattering loss coefficients for common forms of load distribution.

(3) Power Loss

Power loss in distribution lines is primarily a resistive loss in lines, an iron loss (no-load loss) and a copper loss (load loss) in transformers.

The resistive loss in lines and loss in transformer are given by the following formula.

Power loss in distribution line

$$W = I^2 \times r \times L \times N$$

Where,
$W$: power loss of distribution line (W)
$I$: load current (A)
$r$: resistance per km (Ω･km)
$L$: length of distribution line (km)
$N$: number of lines (nos.)

Power Loss in Transformer

$$P = W_i + W_c \times F^2$$

Where,
$P$: power loss in transformer (W)
$W_i$: iron loss (W)
$W_c$: copper loss (W)
$F$: usage rate of transformer

Since the loss in transformers is determined according to the specifications of the transformer itself, power loss in a transformer is one indicator of the quality of the transformer.

### (4) Fault Current

Electric faults can be classified into a grounding fault and a short circuit.

- ✓ A grounding fault occurs when trees or other objects come into contact with lines, or when lightning causes discharge in insulators, resulting in the flow of current into the ground. The grounding fault current value will vary depending on the neutral grounding methods.
- ✓ As for a short circuit, the impedance of electric line becomes nearly zero at the point of the short circuit, and generally the current flows from the power source through the impedance of the line or transformer. Therefore, the value of a short circuit current is huge.

Regardless of which type of fault occures, it is necessary to cope with the faulty current (short circuit current in particular) through the use of protection relays to detect the fault and circuit breakers to cut off the current. This is done in order to prevent the fault from spreading to the entire power system as well as to protect the equipment on the load side.

### (5) Allowable Current

Allowable current is the maximum current that can pass through electric facilities. Physical objects have resistance to electricity, which results in the generation of heat when voltage is applied and current flows through the objects. In the case of electric lines, they may generate sufficient heat to melt the insulation and cause a short circuit, or even possibly start a fire. Therefore, the allowable current is specified for electrical materials, and fuses and circuit breakers are used for protection.

The allowable current varies based on the type of insulating body, electric line laying method and ambient temperature.

### (6) Inductive Interference

Inductive interference is the phenomenon of flowing an electric current in other electric lines or communication lines, thereby causing injury to people and interfering with telecommunications.

#### Electrostatic Induction

In general, there is electrostatic capacitance between conductors located near each other. Such nearby conductors act as a kind of condenser, so that the charge in one of the lines will induce voltage in the other, even if they are not directly connected. This is called electrostatic induction. The size of the voltage occurring in the second conductor is determined based on the mutual electrostatic capacitance and the voltage of the first conductor.

#### Electromagnetic induction

It occurs when a fluctuating magnetic field caused by the current in one conductor intersects with another conductor, resulting in inductive voltage in the second conductor. The size is determined based on the mutual inductance, current and parallel route length of the two conductors.

Normally, inductive interference almost never occurs because distribution voltage is small, and ground current is also small if a non-grounding method is used. However, inductive interference must be considered when distribution voltage is 20 kV or greater, and it must be controlled below the allowable inductive interference value stipulated in the standards.

(7) Insulation Design

Targets for insulation design can be broadly classified as: i) commercial frequency voltage, ii) internal abnormal voltage generated by internal factors, such as switching surges, and iii) external abnormal voltage caused by lightning surges. Since the external abnormal voltage caused by lighting surges is much greater than that of i) or ii), designs resistant to lightning form the basic concept for insulation design in distribution lines.

Arrestors are required to satisfy the following performance to meet the insulation level of the distribution line and protective coordination:

- ✓ The voltage level at which arrestors operate must be higher than the internal abnormal voltage that occurs in the distribution line.
- ✓ The lightning impulse limit voltage of arrestors must be lower than the insulation level of the insulators and equipment in the distribution line, with sufficient margin to allow protective coordination.
- ✓ The continuous cutoff voltage for arrestors must be higher than the maximum voltage occurring in the distribution line circuitry.

### 4.3.5 Mechanical Design

(1) Acting Load

The loads on distribution line supports, electric lines, etc. include wind load, uneven tension between electric lines on both sides, own weight, and the weight of other supporting structures. Since these loads have a compounded effect on distribution lines, they must be classified separately when designing them according to the direction of action. They can generally be categorized into the following three groups:

- ✓ Vertical load
- ✓ Horizontal lateral load, and
- ✓ Horizontal longitudinal load

Since supports for distribution lines are normally strong enough against vertical load, it is necessary to consider during the design stage whether they can withstand horizontal loads in particular.

(2) Support Strength

Support strength refers to the moment of resistance for support against stresses such as the moment of bending. In general, supports must be designed so that the safety factor against a breaking load is equal to the defined number in the standards or greater, and guys and struts must be used to distribute the load.

(3) Guy and Strut Strength

Guys and struts can be used to distribute the load acting on supports for distribution lines. They are necessary to ensure the required safety factor against uneven tension generated when hanging conductors, the combined tension resulting from directional angles with conductors, and also uneven tension due to different span lengths on both sides of the support.

(4) Support Foundation Strength

The support foundations must be set so that the moment of resistance for the ground on which the foundations sit is greater than the moment of rotation caused by external forces under the worst load conditions acting on the support. The strength of the foundations of the support will vary depending on the embedded length, the usage of guy anchors and soil factors based on a type of soil.

(5) Dip in Electric Lines

Although the tension on electric lines themselves is reduced and the safety improved through a greater (deeper) dip in the lines, the height of the supports must be increased to keep the low-hanging lines up from the ground. This results in lateral oscillation caused by wind, increasing the possibility of faults due to tangled lines, etc. Therefore, the dip and tension that satisfy the safety factor must be considered during the design stage.

### 4.3.6 Overhead Distribution Lines

There are overhead and underground distribution lines. Overhead distribution lines are common for mini-grids due to the low construction costs and the possibility of quick recovery in the event of a fault.

(1) Supports

With overhead distribution lines, supports must be used to ensure that the lines remain at a height from the ground that is safe for both motorists and pedestrians. If a support should collapse, there is a high possibility of personal injury and property damage due to the proximity between distribution lines and residential areas. Further, the reconstruction of the collapsed supports involves an additional cost and would require a service interruption in the surrounding area. Therefore, the avoidance of such problems requires the selection of supports that are strong enough against the load acting on them and durable enough for use over a long time.

Different types of supports include reinforced concrete poles, wooden poles, steel poles, and iron poles.

Reinforced concrete poles are economical and strong, and the most commonly used type of support.

Wooden poles are used in areas such as mountainous regions where it is difficult to bring in concrete poles or to construct new poles. These poles require the injection of creosote or other wood preservatives to prevent a reduction in strength due to the decomposition of the wood in the portion of the pole to be embedded in the ground. The strength of wooden poles will vary depending upon the material used.

(2) Guys and Struts

Guys and struts are used in areas where the tension on electric lines acts unevenly on supports, such as at the ends of distribution lines and sections where lines curve. Struts are used where it is not possible to use guys for a land-related reason, and they are installed in the direction opposite to the guys to be installed, if possible.

In general, galvanized steel stranded conductors are used for guys. In addition, anchors that can withstand the guy tension must be embedded in the foundation of guys.

(3) Crossarms

Crossarms are used to mount electric lines on supports. Wooden crossarms are used on wooden poles, and also need to be treated with creosote or other wood preservatives. Metal crossarms are used widely on all types of supports.

(4) Insulators

Insulators are used to maintain insulation and also to mount electric lines when using metal crossarms. Insulators are grouped by voltage and the installation method of electric lines, pin insulators or line post insulators are used for bypass lines and bridle wires, and strain insulators or dead-end insulators are used to mount the ends of electric lines. Although porcelain is generally used for insulators, there are also polymer insulators made of light-weight silicon rubber for use in medium voltage distribution lines.

(5) Conductor

A single conductor is commonly made up of several individual strands. Copper and aluminum are commonly used as conductors due to their low resistance, and there are a variety of structures including bare conductors or the use of insulation, various materials, and steel cores. Since conductors used in overhead distribution lines are often located near residential areas, insulated conductors are normally used for low voltage lines as a safety consideration.

When selecting a conductor, it is necessary to consider a type and sectional area according to the allowable current required, topography of the route, mechanical strength, resistance to corrosion, economical efficiency and other factors.

(6) Transformers

Overhead distribution lines normally have pole transformers to step down the voltage from medium voltage. Most pole transformers are of oil-filled self-cooling type, in which the main transformer unit (core and windings) is immersed in insulating oil. Silicon steel strips are widely used for the core. Grain-oriented silicon steel strips can be used to reduce loss, and amorphous materials are also sometimes used to reduce loss even further. There are two types of transformers, single-phase and three-phase; and wiring methods vary depending on medium or low voltage distribution. Two single-phase transformers with V wiring can be used for a three-phase load, and single-phase transformers with different capacities and V wiring can be used for a combined single- and three-phase load with a three-phase four-wire method.

The primary indicators of transformer performance are no-load current, no-load loss, voltage regulation and efficiency. When selecting a transformer, it is necessary to consider not only the suitable capacity for the load, but also performance indicators such as no-load loss and efficiency.

(7) Switches

Switches can cut off an electric current, and are used to disconnect areas of distribution lines that have a fault, or to limit the range of power outage when repairs to distribution lines are required. Varieties of arc suppressing media are used, such as oil-filled switches, air switches, vacuum switches, and gas switches. The use of oil-filled switches is not recommended for overhead distribution lines in public areas due to possibility of fire if a short circuit occurs. There are also some switches with built-in transformers for controlling the system, arrester components, and a variety of other sensors.

Cutouts are switches with built-in fuses that are installed on the primary side of transformers. If an overload or an internal short circuit occurs at the transformer, they automatically disconnect the transformer from the distribution line and can be used as switches on the primary side. They are also used as switches for branching distribution lines with a small load current. Some also have built-in arresters.

(8) Arresters

Arresters are installed between distribution lines and earth to protect distribution facilities from lightning surges. Many are made of zinc oxide (ZnO) components, non-linear resistive elements. Arresters operate most effectively when installed as near as possible to the equipment to be protected.

### 4.3.7 Others

(1) Service Drops

Service drops are electric lines that branch from distribution lines and supply electricity into customers' homes.

Normally, the point of insertion is the property demarcation point, as well as the obligation demarcation point for maintenance and security between power companies and customers. If watt hour meters are installed on poles to prevent the theft of electricity and the secondary side of a watt hour meter is at the property demarcation point or the obligation demarcation point, the customer will in most cease be required to install electric lines as service drops to his/her residence or business.

It is necessary to select lines, in the same manner as selecting electric lines and cables. That is, with conductors and a sectional area of sufficient mechanical strength for the allowable current, and to keep voltage drops within the allowable range.

Since service drops are installed in residential areas, insulated conductors are normally used as a safety consideration.

### (2) Watt Hour Meters

Watt hour meters measure the amount of electricity used by customers, to calculate electricity rates based on the contracts between the power company and the customers. The type of watt hour meter used, therefore, will vary according to the type of contract.

In case of customers with small-scale demand, whose usage conditions are almost always the same, such as for public street lighting, watt hour meters are not installed. In some instances, load limiters might be used in place of watt hour meters to ensure a more consistent electricity rate when compared with the cost required to calculate the rates by reading meters. Recently prepayment watt hour meters are becoming increasingly popular for the same reason.

# CHAPTER 5 ECONOMIC AND FINANCIAL EVALUATION

## 5.1 Key Comparative Indicators for Evaluation

Evaluation of the efficiency of a MHP project is based on the following four aspects: i) technically sound, ii) socially and environmentally acceptable, iii) economically efficient, and iv) financially viable. The latter two aspects are evaluated on the basis of economic analysis and financial analysis, respectively.

Economic analysis is a way to evaluate the project by comparing the social and economic benefit with the construction cost, from the perspective of public interest or national economy. On the other hand, financial analysis is a way to evaluate the profitability of the project by comparing the revenues accrued to the investment cost from the perspective of business enterprise.

Key comparative indicators for evaluating economic and financial viability of the project are as follows:

- i) Present Value (PV)
- ii) Net Present Value (NPV) (B-C)
- iii) Cost-Benefit Ratio (B/C)
- iv) Internal Rate of Return (IRR)
- v) Unit Energy Cost (kWh Cost)

### (1) Present Value (PV)

In economics, present value is a future amount of money that has been discounted to reflect its current value. The relationship between the present value (PV) and future value (FV) is expressed in terms of the following formula for discounting:

$$FV = PV \times (1 + r)^n$$

$$PV = \frac{FV}{(1 + r)^n}$$

Where, $FV$: future value (currency unit)
$PV$: present value (currency unit)
$r$: discount rate (%)
$n$: year in the future (year)

For example, as shown in the table below, the present value of KSh. 1,000 is expected to rise to KSh. 2,594 in 10 years at the interest rate of 10%. Conversely, KSh. 2,594 after 10 years from now is discounted in value to a present value of KSh. 1,000. The future value of money is therefore considered to be equivalent to a smaller value at present.

On the contrary, this means that a present value has an increased future value, the increase being “interest”. The word “interest” therefore expresses the same idea as the word “discount”. Both the discount rate and market interest rate take inflation and the cost of capital into account. For instance, a bank will quote a market rate of interest because it expects repayments which compensate it for lending the money, and also compensate it for devaluation due to inflation.

The table below shows an example of present value calculation of annual cost.

**Table 5.1.1 Example of Future Amount and Present Value**

| **Year End** | **Future Amount** | | **Present Value** | |
|---|---|---|---|---|
| | Interest rate i = 10% = 0.1 | 1,000 | Discount rate i = 10% = 0.1 | 1,000 |
| 1 | $P$ x $(1+i)^{1}$ = 1,000 x $(1+0.1)^{1}$ = | 1,100 | $P$ / $(1+i)^{1}$ = 1,000 / $(1+0.1)^{1}$ = | 909 |
| 2 | $P$ x $(1+i)^{2}$ = 1,000 x $(1+0.1)^{2}$ = | 1,210 | $P$ / $(1+i)^{2}$ = 1,000 / $(1+0.1)^{2}$ = | 826 |
| 3 | $P$ x $(1+i)^{3}$ = 1,000 x $(1+0.1)^{3}$ = | 1,331 | $P$ / $(1+i)^{3}$ = 1,000 / $(1+0.1)^{3}$ = | 751 |
| 4 | $P$ x $(1+i)^{4}$ = 1,000 x $(1+0.1)^{4}$ = | 1,464 | $P$ / $(1+i)^{4}$ = 1,000 / $(1+0.1)^{4}$ = | 683 |
| 5 | $P$ x $(1+i)^{5}$ = 1,000 x $(1+0.1)^{5}$ = | 1,611 | $P$ / $(1+i)^{5}$ = 1,000 / $(1+0.1)^{5}$ = | 621 |
| 6 | $P$ x $(1+i)^{6}$ = 1,000 x $(1+0.1)^{6}$ = | 1,772 | $P$ / $(1+i)^{6}$ = 1,000 / $(1+0.1)^{6}$ = | 564 |
| 7 | $P$ x $(1+i)^{7}$ = 1,000 x $(1+0.1)^{7}$ = | 1,949 | $P$ / $(1+i)^{7}$ = 1,000 / $(1+0.1)^{7}$ = | 513 |
| 8 | $P$ x $(1+i)^{8}$ = 1,000 x $(1+0.1)^{8}$ = | 2,144 | $P$ / $(1+i)^{8}$ = 1,000 / $(1+0.1)^{8}$ = | 467 |
| 9 | $P$ x $(1+i)^{9}$ = 1,000 x $(1+0.1)^{9}$ = | 2,358 | $P$ / $(1+i)^{9}$ = 1,000 / $(1+0.1)^{9}$ = | 424 |
| 10 | $P$ x $(1+i)^{10}$ = 1,000 x $(1+0.1)^{10}$ = | 2,594 | $P$ / $(1+i)^{10}$ = 1,000 / $(1+0.1)^{10}$ = | 386 |

### (2) Net Present Value (NPV) (B-C)

The MHP project is expected to bring in revenue as well as to incur running costs in subsequent years after its completion. The Net Present Value (NPV) is the present value (PV) of all revenues (benefit) minus the present value of all capital and running costs. It is expressed as follows:

$$NPV = B - C$$
$$= \sum_{t=1}^{n} \frac{B_t}{(1+r)^n} - \sum_{t=1}^{n} \frac{C_t}{(1+r)^n}$$
$$= \sum_{t=1}^{n} \frac{B_t - C_t}{(1+r)^n}$$

Where, $NPV$: net present value (currency unit)
$B_t$: benefit in t-th year (currency unit)
$C_t$: cost in t-th year (currency unit)
$r$: discount rate (%)
$n$: years for evaluation (project life)

### (3) Cost-Benefit Ratio (B/C)

The Cost-Benefit Ratio (B/C), expressed by the below equation is one of the indicators of the efficiency of project. If the B/C is greater than 1.0, it means that the project will earn more than it costs.

$$\frac{B}{C} = \frac{\sum_{t=1}^{n} \frac{B_t}{(1+r)^n}}{\sum_{t=1}^{n} \frac{C_t}{(1+r)^n}}$$

### (4) Internal Rate of Return (IRR)

The Internal Rate of Return (IRR) is the discount rate at which NPV becomes zero. In other words, the IRR is the discount rate at which the NPV of benefit and cost are equal, as expressed below.

$$NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+r)^n} = 0 \qquad \therefore \sum_{t=1}^{n} \frac{B_t}{(1+r)^n} = \sum_{t=1}^{n} \frac{C_t}{(1+r)^n}$$

### (5) Unit Energy Cost (kWh Cost)

Unit Energy Cost (kWh Cost) is an important indicator of financial viability of the MHP project. This indicator provides a guideline for determining the selling price of energy. The unit energy cost is calculated using the following equation:

Energy Cost = ($Ca$ + $Cr$) / E

$$Ca = C \times C_f = \frac{r \times (1+r)^n}{(1+r)^n - 1}$$

$E = P$ x $24$ (hour) x $365$ (days) x $PF$
$= P$ x $8{,}760$ x $\xi$

Where,
$Ca$: annualized construction cost (currency unit)
$C_r$: Annual running (O&M) cost (currency unit)
$C_f$: capital recovery factor (%)
$r$: discount rate (%)
$n$: years for evaluation (project life)
$E$: annual energy (kWh)
$P$: installed capacity (kW)
$\xi$: plant factor (%)

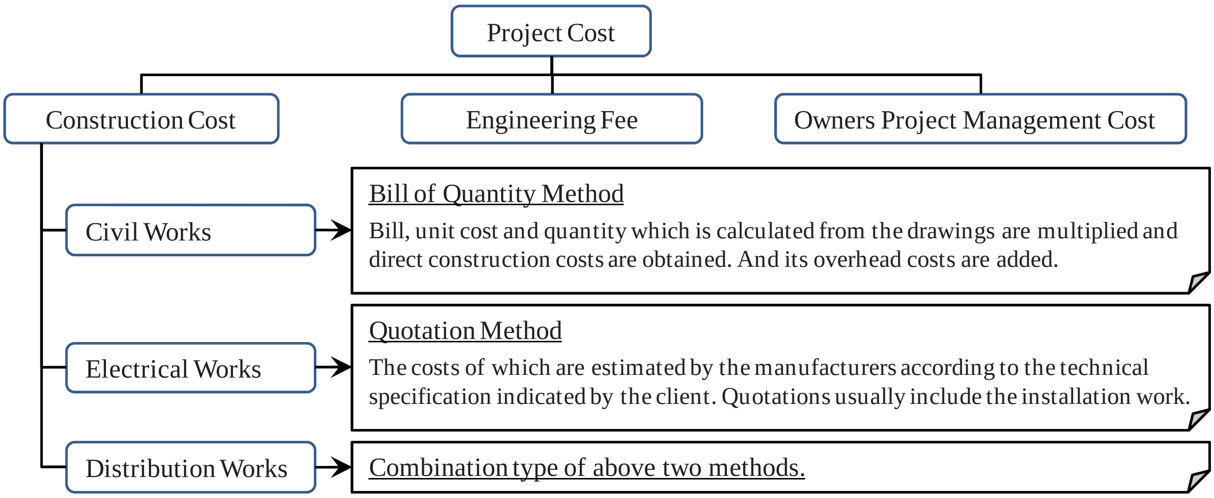
It is noted that the annualized construction cost “Ca” shall be given in terms of a constant annual sum throughout the life of the project. Therefore, the unit energy cost varies according to the discount rate applied and the project life. The annuity equation provides a simple way of converting the initial construction cost into an annual cost.

## 5.2 Estimation of Project Cost

The project cost shall be updated after the basic design and/or detailed design are completed in order to increase the accuracy of the cost estimate.

The project cost consists of construction cost, engineering fee and owners' project management cost. The construction cost of a MHP project is roughly divided into the cost of civil structure, electrical equipment and distribution facility.

Estimation methods of a MHP project cost vary depending on the country and donor/financing organization. However, the following methods are generally adopted:



Bill, unit cost and quantity which is calculated from the drawings are multiplied and direct construction costs are obtained. And its overhead costs are added.

The costs of which are estimated by the manufacturers according to the technical specification indicated by the client. Quotations usually include the installation work.

Source: "Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Figure 12-1)" published by JICA in 2011 (arranged by WG).

**Figure 5.2.1 General Components and Estimation Method of MHP Project**

The estimation of costs should include contingency, which can be determined by surveying current market prices etc., in order to avoid budget shortages during the implementation stage.

The estimation of construction costs specifically requires preparation of estimate data which are clear and logical, to adequately meet any demand for disclosure to a financing or donor organization.

Some assumptions may be made regarding the procurement locations of equipment, materials and suppliers as shown below.

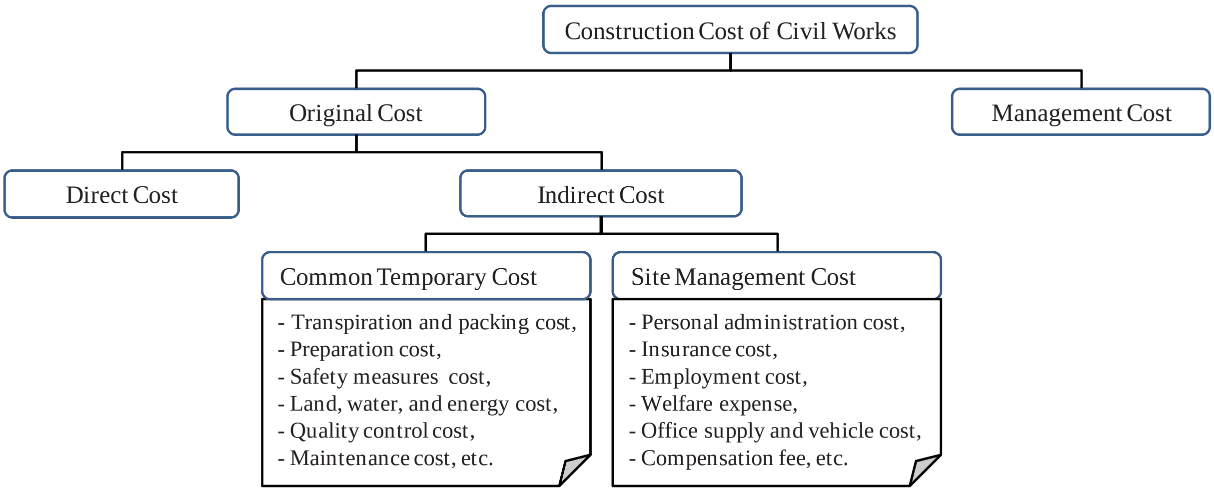
**Table 5.2.1 Assumed Procurement Locations of Equipment, Materials and Suppliers**

| Component | Item | Near the Site | Domestic | Import |
|---|---|---|---|---|
| Civil Works | Sand, gravel, stone | ● | | |
| | Cement | | ● | ● |
| | Steel | | ● | ● |
| | Building materials | ● | ● | ● |
| Electrical Equipment | Turbine | | | ● |
| | Generator | | | ● |
| | Control panel | | | ● |
| Distribution Facilities | Pole | | ● | ● |
| | Electric wire, cable | | ● | ● |
| | Transformer, switch | | ● | ● |
| | Telecommunication system | | ● | ● |

Source: "Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Table 12-1)" published by JICA in 2011.

### 5.2.1 Civil Works

The construction cost of civil works consists of various components as shown below.



Source: “Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Table 12-2)” published by JICA in 2011 (arranged by WG).

**Figure 5.2.2 Components of Construction Cost of Civil Works**

Indirect costs and management costs are generally estimated as a percentage of direct cost, and each set at 10 to 15%.

The direct cost of civil works is estimated by bill of quantity method. The bill of quantity method is based on the unit price of each type of work and requires provisional calculation of the cost as shown in the following equation.

$$Cost = Quantity \times Unit \Pr ice$$

The quantity and unit price are estimated for each work item of construction of civil structures. Quantities are estimated based on drawings, while unit prices are estimated based on current market prices of related materials, equipment, and others.

(1) Quantity

Quantities of civil works vary depending on the geological conditions at the site. Despite this variability, the construction schedule and unit prices are estimated on the basis of these quantities. Quantity calculation of civil works is therefore one of the key issues in the estimation of project cost.

At minimum, quantities should be estimated for the following work items for each permanent structure.

### Table 5.2.2 Major Work Items of Civil Works

| Item | Description |
|---|---|
| Excavation | It is estimated from the sectional area and distance between each cross section in the drawings. Soil portion and rock portion are estimated separately based on the assumed rock line in each cross section. 10 to 15% of the calculated volumes are added as contingency, because excavation volume varies depending on the geological condition. The quantity is estimated by cubic meter ($m^3$). |
| Disposal of Excavated Material | It is estimated as total excavation volume minus reuse volume of excavated material. The quantity is estimated by cubic meter ($m^3$). |
| Backfilling | It is estimated from the drawings, in the same manner as excavation volume. |
| Gabion | It is estimated using the surface area of the area protected by the gabion and the thickness of the gabion indicated in the drawings. The quantity is estimated by cubic meter ($m^3$). |
| Concrete | It is estimated from the sectional area and distance of each element in the drawings. The volume shall be estimated for each strength class specified in the drawings. The quantity is estimated by cubic meter ($m^3$). |
| Formwork | It is estimated from the sectional area of each element in the drawings. The volume shall be estimated for each type of formwork specified in the drawings. Surfaces exposed to water, those exposed to air, and hidden surfaces are estimated separately. The quantity is estimated by cubic meter ($m^3$). |
| Reinforcement Bar | It is estimated from the typical re-bar arrangement or unit weight of concrete (ton/$m^3$) of each structure. The quantity is estimated by weight (ton). |
| Screen and Gate | It is estimated from the volume and unit weight of steel. The volume is calculated from the dimensions indicated in the drawings. 5 to 10% of the calculated volume is added to represent the weight of attached steels. The quantity is estimated by weight (ton). |
| Steel Penstock | It is estimated from the volume and unit weight of steel. The volume is calculated from the diameter, thickness and length of penstock. 5 to 10% of the calculated volume is added to represent the weight of attached steels. The quantity is estimated by weight (ton). |
| Other Metal Works | It may consist of steel pipe, hand rail, fence, etc., and is estimated from the drawings in the same manner as screen and gate. |

For temporary facilities and structures which are required for the construction, the quantities are estimated in the same manner as permanent structures or a lump sum cost is determined. Major temporary facilities and structures and their quantity estimation methods are summarized below.

### Table 5.2.3 Major Temporary Facilities and Structures

| Item | Description |
|---|---|
| Clearing and Grubbing | It is estimated as surface area of temporary facilities from the drawings including cut slope. The quantity is estimated by square meter ($m^2$). |
| Labor Camp | It is estimated based on the number of laborers and required period. The quantity is estimated as lump sum. |
| Care of River | It is estimated based on the size of the river and probable flood discharge at intake site and tailrace site. The quantity is estimated as lump sum. |
| Reclamation of temporary yards | It is estimated in the same manner as permanent structures, with the exception of rent base which will not be used after the construction. |
| Rehabilitation of existing Road | It is estimated from the required width for construction and distance of the existing road. In case rehabilitation of a bridge is required, it will also be included in the estimates. The quantity is estimated by length (km). |

### (2) Unit Price

Unit price of civil works is a summation of the following 6 components:

**Table 5.2.4 Components of Unit Price of Civil Works**

| Item | Description |
|---|---|
| Labor Cost | Cost of laborers directly involved in the construction work: specially skilled persons such as operators, carpenters, reinforcing bar workers, welding operators, and general workers etc. |
| Material Cost | Cost of hiring materials such as cement, sand, aggregates, woods, reinforcement, steel, forms, scaffolds, supports, etc. |
| Machinery Cost | Cost of hiring or leasing construction equipment such as bulldozer, backhoe, dump track, crane etc. |
| Fuel Cost | Cost of fuel and lubricants such as gasoline, diesel oil, electric energy, etc., for construction equipment. |
| Temporary Work Cost | Cost of temporary facilities, equipment, electric energy, water, fences, etc. |
| Transportation Cost | Cost of wrapping and transportation of construction materials and equipment.<br>(In the case of long distance transportation, this category is considered separately.) |

Source: "Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Table 12-4)" published by JICA in 2011.

For cost estimation to be undertaken as described above, special knowledge of construction methods and man-days of work is necessary. In instances where such detailed knowledge is lacking, the first step will be to conduct market price survey. The following recommendations should be considered and taken into account when conducting the market price survey.

Obtain more than Three (3) Quotations

When requesting and receiving cost proposals, details of estimate conditions, time schedule, quantity and specifications should be defined. Further, quotations should show not only the total amount but also the details such as material cost, labor cost and machinery cost. Lastly, at least three quotations should be obtained for comparison.

Select Reliable Procurement Companies

To prevent issues such as inferior quality, delay of delivery date, cancellation due to bankruptcy etc., reliable procurement companies should be selected.

### 5.2.2 Electrical Equipment

The electrical equipment consists of: water turbine, generator, main transformer, switchgears, control equipment, auxiliary equipment, and others. The manufacturing and installation costs are estimated based on the following conditions:

- ✓ Assuming that most of the equipment is to be imported and procured either directly from the manufacture or through an agency,
- ✓ Preparing draft contract documents including technical specifications based on global specifications such as *Federation Internatinale des Ingenierus Conseils/* International Federation of Consulting Engineers – (FIDIC) guideline, and
- ✓ Adopting tenders in package deals rather than numerous separate tenders in general, and
- ✓ Estimating the cost based on the contract performance of the same type of equipment and/or receiving estimates from several manufacturers.

The final cost estimation should not be decided on the basis of price alone. Other factors such as delay of delivery, the performance of equipment and manufacturers and/or suppliers after the installation, convenience of procurement of spare parts, etc., shall also be taken into consideration.

In regards to the specifications, it is noted that the demarcation between contracts, i.e., civil works and distribution works, shall be indicated clearly.

An example of a construction cost list of electrical equipment is shown below.

Table 5.2.5 Example of the Construction Cost List of Electrical Equipment

| Item | Foreign Currency | Local Currency | Total | Remarks |
|---|---|---|---|---|
| **Turbine** | | | | |
| Design and manufacturing | | | | |
| Installation | | | | |
| **Generator** | | | | |
| Design and manufacturing | | | | |
| Installation | | | | |
| **Main Transformer** | | | | |
| Design and manufacturing | | | | |
| Installation | | | | |
| **Switchgears and Control Equipment** | | | | |
| High voltage switchgears | | | | |
| Metal enclosed switchgears | | | | |
| Control equipment | | | | |
| Water level measurement equipment | | | | |
| Transmission line protection system | | | | |
| Tele-control equipment | | | | |
| Main circuit bus | | | | |
| Power and control cable and rack | | | | |
| Installation | | | | |
| **Steel Structure** | | | | |
| **Auxiliary Equipment** | | | | |
| Station service transformers | | | | |
| Crane | | | | |
| DC power system and CVCF | | | | |
| Arrestor | | | | |
| Emergency generator | | | | |
| Grounding Wire | | | | |
| **Spear Parts** | | | | |
| **Other Equipment** | | | | |
| Testing equipment | | | | |
| Plant communication system | | | | |

Source: "Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Table 12-7)" published by JICA in 2011.

### 5.2.3 Distribution Facilities

Distribution facilities consist of supports (poles), conductors, cables, transformers, switches, communication facilities, and so on.

Distribution facilities work is in many cases classified into two portions;

- ✓ Procurement of materials and equipment
  The direct cost is estimated based on quantity and unit prices, and indirect cost is not considered.
- ✓ Installation and construction works of the procured materials and equipment.
  The direct cost is estimated based on quantity and unit prices, and indirect cost is considered including common temporary facilities cost and site management cost.

In the case of a power pole, procurement covers its purchase and transportation to the construction site. Construction work is therefore installation at the site.

(1) Quantity

The quantities shall be estimated for each type of the following main equipment.

### Table 5.2.6 Main Distribution Facilities

| Facility | Unit | Specification |
|---|---|---|
| Middle Voltage Overhead Lines | cct-m | Line type, cross section ($mm^2$) |
| Low Voltage Overhead Lines | cct-m | Line type, cross section ($mm^2$) |
| Middle Voltage Underground Cables | cct-m | Line type, cross section ($mm^2$) |
| Low Voltage Underground Cables | cct-m | Line type, cross section ($mm^2$) |
| Supports | nos. | Type, length, strength. |
| Pole Mounted Transformers | nos. | Single phase or three phase, capacity. |
| Switches | nos. | Type, capacity. |
| Watt-hour Meters | nos. | Single phase or three phase, capacity. |

Source: “Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Table 12-8)” published by JICA in 2011.

In addition, it is necessary to calculate the incidental costs such as those of cutting trees, etc.

(2) Unit Price

The unit prices of distribution facilities consist of the costs outlined below. Surveying current market prices may inform the process of setting unit prices.

### Table 5.2.7 Components of Unit Price of Distribution Facilities

| Procurement Cost | Installation and Construction Cost |
|---|---|
| Material Price | Labor Cost |
| Local Transportation Cost | Material Cost |
| Tax | Machinery Cost |
| Cost of Insurance and Freight (CIF) | Fuel Cost |
| | Temporary Work Cost |
| | Transportation Cost |

Source: “Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Table 12-9)” published by JICA in 2011 (arranged by WG).

### 5.2.4 Planning of Construction Schedule

Hydropower has the advantage of not incurring fuel costs as it utilizes energy from water to run the turbine. For this reason, it is preferable to construct the MHP project and commence generation as quickly as possible. However, even in a short construction period the required safety conditions should be secured in terms of quality and performance.

In practice, the actual construction work is affected by not only natural conditions such as climate, hydrology, topography and geology; but also resource conditions such as laborers’ performance, construction machinery arrangement and equipment procurement procedure.

It is therefore necessary to especially consider the following points for planning the construction schedule:

- ✓ Traffic conditions in each season including the presence of a detour,
- ✓ Difficulty of transportation of construction materials and equipment, and
- ✓ Effect of other conditions on the construction work, such as river discharge, rainfall pattern, etc.

A rough indication of preparation of a basic construction schedule is shown in the following table.

## Table 5.2.8 Example of Construction Schedule

| Item | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Preparation Works | | | | | | | | | | | | | | | | | | |
| Land acuisition and access road | ━ | ━ | | | | | | | | | | | | | | | | |
| 2. Civil Works | | | | | | | | | | | | | | | | | | |
| 1) Head works | | | ━ | ━ | ━ | ━ | | | | | | | | | | | | |
| 2) Power canal, head tank, spillway | | | | | ━ | ━ | ━ | ━ | ━ | ━ | ━ | | | | | | | |
| 3) Penstock | | | | | | | | | | | | | | | | | | |
| Manufacturing and transportation | | | | | | ━ | ━ | ━ | ━ | | | | | | | | | |
| Installation | | | | | | | | | | ━ | ━ | ━ | | | | | | |
| 4) Powerhouse and tailrace | | | | | | | | | | | ━ | ━ | ━ | ━ | ━ | | | |
| 5) Miscellaneous Works | | | - - | - - | - - | - - | - - | - - | - - | - - | - - | - - | - - | - - | - - | - - | - - | - - |
| 3. Electrical Works | | | | | | | | | | | | | | | | | | |
| 1) Design and procuement | | ━ | ━ | ━ | | | | | | | | | | | | | | |
| 2) Manufacturing and transportation | | | | | ━ | ━ | ━ | ━ | ━ | ━ | ━ | | | | | | | |
| 3) Installation | | | | | | | | | | | | ━ | ━ | ━ | | | | |
| 4. Distribution Works | | | | | | | | | | | | | | | | | | |
| 1) Detailed site survey | | ━ | ━ | ━ | | | | | | | | | | | | | | |
| 2) Design and procurment | | | | ━ | ━ | ━ | ━ | ━ | ━ | | | | | | | | | |
| 3) Installation | | | | | | | | ━ | ━ | ━ | ━ | ━ | ━ | ━ | ━ | ━ | ━ | |
| 5. Adjustment and Trial Operation | | | | | | | | | | | | | | | | | ━ | ━ |

Source: "Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Table 12-10)" published by JICA in 2011.

### (1) Rough Indication of Total Construction Period

#### 1) Procurement

A series of procurement procedures such as construction announcement, contractor's estimation, evaluation of proposals and contractor selection generally requires more than six (6) months. However, preparation of tender documents such as technical specifications and drawings for procurement bid, and preparation of contracts are not included in the above period.

#### 2) Contract Negotiation

In a case where negotiation with the first contractor failed, it will generally take around 1 month for the contract to be signed by one of the next negotiating contractors.

#### 3) Construction Period at the Site

It generally takes around one year to one and a half years from the date of the contract to the date of completion or handover to the client. A construction schedule is different from a fund payment schedule, and these two schedules should be prepared separately.

### (2) Civil Works

In the following items, preparation works and temporary works are usually difficult to implement simultaneously with other items.

The entire civil works generally takes around one year to one and a half years, comprised of:

| | |
|---|---|
| i) Preparation works | 1 to 3 months |
| ii) Temporary works | About 1 month |
| iii) Access road | Depends on the site conditions |
| iv) Head works | Half a year to one year<br>(depends on the rainy season and flood conditions) |
| v) Power canal and head tank | Several months (depends on the length of headrace) |
| vi) Penstock | Several months to half a year<br>(manufacturing period should be considered separately) |
| vii) Powerhouse and tailrace | Several months to half a year |

(3) Electrical Works

In the case of a MHP project, the approximate periods outlined below are based on the premise that the turbine and generator are relatively ready-made. The entire period of construction for electrical equipment is approximately one year, in general.

| | |
|---|---|
| i) Design for shop drawings and procurement of materials | Several months |
| ii) Manufacturing and transportation | Several months |
| iii) Erection of turbine and generator | 2 to 3 months |
| iv) Trial operation | 1 to 2 months |

However, for installation work at the project site, it is necessary to adjust the schedule between civil works and distribution works. In addition, civil works and distribution works must be almost complete before electrical works for trial operation.

(4) Distribution Works

The construction period for distribution facilities depends on the distance of the line. In the case of an electrification scale of 500 to 1,000 households and a distance of 50 km for the electricity distribution line, for instance, distribution woks generally take around 8 months to 1 year.

Items of distribution works are undertaken for the following periods:

| | |
|---|---|
| i) Distribution line survey | Several weeks to one month |
| ii) Design for shop drawings and procurement of materials | 2 to 3 months |
| iii) Manufacturing and transportation | 1 to 2 months |
| iv) Construction of poles, distribution of electric wires and installation of watt-hour meters | Several months to half a year |
| v) Trial operation | 1 to 2 months |

## 5.3 Economic Evaluation

### 5.3.1 Economic Project Benefit

Economic analysis evaluates the economic viability of the project, taking into account the effects of the project on the national economy or society as a whole. In this sense, the economic benefit shall be estimated from the perspective of contribution to national income.

Past experiences indicate that when a non-electrified village is electrified, a number of productive opportunities are subsequently identified and initiated by village entrepreneurs. These activities undoubtedly increase the production level of the country, and contribute to economic benefits. They should therefore be added, whenever they are possible to identify.

In a broader perspective, socio-economic benefits of electricity include improved education (e.g. longer reading time), improved manageability of routine household tasks particularly for women, better entertainment and updated information, and improved health. These benefits are generally difficult to measure and quantify. However they can be referred to in the narrative section of economic analysis.

In practice, two methods are applied to estimate the MHP project's benefit from an economic perspective:

> An Alternative Facility Cost Method
>
> This method is often applied to estimate the benefits of medium to large hydropower projects. In this method, the benefit of a hydropower project is defined as the cost of the least-cost thermal plant alternative having comparable electric supply performance as the hydropower that would be saved by implementation. It shall be considered to save the cost of second best alternative under the fixed demand condition. Under this method, the capacity and energy values of hydropower are calculated.

Consumer's Willingness-to-pay (WTP) Method

This method is often applied for MHP projects. Economic benefits are calculated using consumer's average WTP for connection fee and for electricity tariff.

For example, when setting connection fee as US$ 100, only households having more than US$ 100 of WTP will apply for the service. WTP adopted for financial analysis is determined to satisfy WTP of 80% of households. Additionally, the financial benefits are computed based on the actual payments from consumers.

On the other hand, even households having US$ 100 of WTP will pay US$ 70. In this case, the remaining US$ 30 is regarded as consumer surplus of the household. Economic benefit includes not only actual payment of US$ 70 but also consumer surplus of US$ 30.

These benefits in WTP method are calculated as per the following formula:

(1) Benefit from Grid Connection

$$B_{GC} = HH \times R_a \times WTP_{CF}$$

Where,
$B_{GC}$: benefit from grid connection (currency unit)
$HH$: number of total household (HH)
$R_a$: Application ratio (%)
$WTP_{CG}$: WTP for connection fee (currency unit/HH)

(2) Benefit from Electricity Consumption

$$B_{EC} = E \times R_L \times WTP_{ET}$$

Where,
$B_{EC}$: benefit from electricity consumption (currency unit)
$E$: generating energy (MWh/year)
$R_L$: total loss ratio (%) = 10%
$WTP_{ET}$: WTP for electricity tariff (currency unit/kWh)

Both WTP for connection fee and WTP for electricity tariff need to be defined based on the social economic survey.

### 5.3.2 Economic Project Cost

Economic costs need to be adjusted for market distortions caused by government intervention; import duties, sales tax, price control, and transfer payments (taxes and subsidies) for many cost items. They also have to be evaluated with the concept of the opportunity cost.

For economic evaluation, all costs involved in the project have to be measured as economic costs, i.e. the real costs incurred from the viewpoint of national economy. In other words, economic cost estimate is a modification of the project construction cost estimate reflecting an adjustment, to the local currency portion of the project cost from the national economic point of view.

The economic cost is measured as the value in case that resources employed to the project are used for other activities, known as the "shadow" price. The shadow price is represented as the value of the local component of the project cost which could be earned foreign exchange if sold abroad or as the value to the economy of local labourer drawn from another sector, primarily agriculture. Estimating the shadow prices for all the cost items is a difficult task, depending upon a myriad of assumptions about the nature of the labour pool drawn and the market conditions for each category of material. For the purposes of the pre-feasibility or feasibility estimate, a simplified procedure is adopted.

For instance, actual project costs consist of local currency portion and foreign currency portion.

(Economic Project Cost) = (Local Currency Portion) x SCF + (Foreign Currency Portion)

SCF is the standard conversion factor of internal transfer portion.

Economic project costs of MHP project are estimated by the following five groups.

(1) Construction Cost of MHP Station and Distribution System

Costs of civil works are assumed to be 100% of local portion, while costs of electrical equipments are assumed to be 100% of foreign portion. In calculating economic price, the foreign costs are valued at Cost, Insurance and Freight (CIF) price, and local costs (non-tradable costs) are converted into boarder price using the SCF.

(2) Installation Costs of House Wring and Wat-hour Meter for each Customer,

House wiring cost ($C_{HW}$) is estimated by the following assumption;

$$C_{HW} = HH \times R_a \times C_{HW0}$$

Where, $C_{HW}$: house wiring cost (currency unit)
$HH$: number of total household (HH)
$R_a$: Application ratio (%)
$C_{HW0}$: unit cost of house wiring & watt-hour meter (currency unit/HH)

Application ratio means the ration of household in the target area applying for electricity service. It will be defined based on the results of social economic survey.

(3) Operation and Maintenance Cost

Annual O&M costs are assumed to be 2.0% of capital costs (construction cost of MHP station and distribution system), which cover salary of staff, spare parts for routine maintenance, and consumables for operation.

(4) Replacement Costs of Electrical Equipment.

Rehabilitation is supposed to be executed 10 to 15 years after the completion. Rehabilitation costs and replacement cost of electrical equipment are assumed to be 20% of civil work cost and 90% of electrical equipment cost.

### 5.3.3 Example of Economic Evaluation

Economic viability of the project is usually assessed in terms of the economic internal rate of return (EIRR) and the net present value (NPV) by use of the estimated economic project benefits and costs. It has been standard practice for major donors to use EIRR for evaluation of economic viability of projects:

- i) Project with an EIRR of at least 12% can be considered acceptable.
- ii) Projects with an EIRR between 10 and 12% may be accepted if additional unvalued (unquantifiable) benefits are sufficiently demonstrated.
- iii) Projects with an EIRR below 10% are not accepted.

An example of economic evaluation is shown below. In this case, EIRR of the project exceeds 12%. Accordingly, the project is confirmed to be economically viability.

## Table 5.3.1 Example of Economic Evaluation

**COST** Construction Cost

| | Civil Works | | Electrical Equipment | | Distribution Facilities | | Total | |
|---|---|---|---|---|---|---|---|---|
| 1st year | 346,717 | 40% | 29,865 | 15% | 260,988 | 50% | 637,570 | (USD) |
| 2nd year | 520,075 | 60% | 169,234 | 85% | 260,988 | 50% | 950,297 | (USD) |
| Total | 866,792 | 100% | 199,099 | 100% | 521,976 | 100% | 1,587,867 | (USD) |

Economic Cost

| | Civil | | Electrical | | Distribution | | Total | |
|---|---|---|---|---|---|---|---|---|
| SCF | 90% | | 100% | | 95% | | | |
| 1st year | 312,045 | 40% | 29,865 | 15% | 247,939 | 50% | **589,849** | (USD) |
| 2nd year | 468,068 | 60% | 169,234 | 85% | 247,939 | 50% | **885,242** | (USD) |
| Total | 780,113 | 100% | 199,099 | 100% | 495,877 | 100% | **1,475,091** | (USD) |

| | | | |
|---|---|---|---|
| Repairing & Replacement Cost | 20% of the civil works | 156,023 | (USD) |
| | 90% of the electrical equipment | 179,189 | (USD) |
| | Total | **335,212** | (USD) |
| Annual O&M Cost | 2% of the construction cost. | **31,757** | (USD/year) |
| House Wiring Cost | Number of total household | 1,549 | (HH) |
| | Application ratio | 80% | |
| | Number of connection household | 1,239 | (HH) |
| | House wiring & watt-hour meter cost | 60.0 | (USD/HH) |
| | | **74,340** | (USD) |

**BENEFIT** Annual Available Energy

| | | | | | |
|---|---|---|---|---|---|
| Annual generating energy | 1,148 (MWh/year) | Load factor | 50% | |
| Total Loss Ratio | 10% | WTP for onnection fee | **97.74** | (USD/HH) |
| Annual available energy | 1,033 (MWh/year) | WTP for tariff | **27.32** | (USC/kWh) |

**CASH FLOW**

| Year | Cost | | | | Energy | | | | Benefit | | | B-C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Capital Cost (USD) | House Wiring (USD) | O&M (USD) | Cost Total (USD) | Abailable Energy (MWh) | Peak Demand (W/HH) | Energy Demand (MWh) | Sold Energy (MWh) | Electricity Tariff (USD) | Connection Charge (USD) | Benefit Total (USD) | |
| 0 | 589,849 | | | 589,849 | | | | | | | 0 | -589,849 |
| 1 | 885,242 | 74,340 | 31,757 | 991,339 | 1,033 | 90 | 488 | 488 | 133,435 | 121,100 | 254,535 | -736,805 |
| 2 | | | 31,757 | 31,757 | 1,033 | 106 | 575 | 575 | 157,156 | | 157,156 | 125,399 |
| 3 | | | 31,757 | 31,757 | 1,033 | 122 | 662 | 662 | 180,878 | | 180,878 | 149,121 |
| 4 | | | 31,757 | 31,757 | 1,033 | 139 | 754 | 754 | 206,082 | | 206,082 | 174,325 |
| 5 | | | 31,757 | 31,757 | 1,033 | 155 | 841 | 841 | 229,804 | | 229,804 | 198,047 |
| 6 | | | 31,757 | 31,757 | 1,033 | 171 | 928 | 928 | 253,526 | | 253,526 | 221,768 |
| 7 | | | 31,757 | 31,757 | 1,033 | 187 | 1,015 | 1,015 | 277,248 | | 277,248 | 245,490 |
| 8 | | | 31,757 | 31,757 | 1,033 | 196 | 1,064 | 1,033 | 282,221 | | 282,221 | 250,464 |
| 9 | | | 31,757 | 31,757 | 1,033 | 205 | 1,112 | 1,033 | 282,221 | | 282,221 | 250,464 |
| 10 | | | 31,757 | 31,757 | 1,033 | 214 | 1,161 | 1,033 | 282,221 | | 282,221 | 250,464 |
| 11 | | | 31,757 | 31,757 | 1,033 | 223 | 1,210 | 1,033 | 282,221 | | 282,221 | 250,464 |
| 12 | | | 31,757 | 31,757 | 1,033 | 232 | 1,259 | 1,033 | 282,221 | | 282,221 | 250,464 |
| 13 | | | 31,757 | 31,757 | 1,033 | 241 | 1,308 | 1,033 | 282,221 | | 282,221 | 250,464 |
| 14 | | | 31,757 | 31,757 | 1,033 | 250 | 1,357 | 1,033 | 282,221 | | 282,221 | 250,464 |
| 15 | 335,212 | | 31,757 | 366,969 | 1,033 | 259 | 1,406 | 1,033 | 282,221 | | 282,221 | -84,748 |
| 16 | | | 31,757 | 31,757 | 1,033 | 268 | 1,454 | 1,033 | 282,221 | | 282,221 | 250,464 |
| 17 | | | 31,757 | 31,757 | 1,033 | 277 | 1,503 | 1,033 | 282,221 | | 282,221 | 250,464 |
| 18 | | | 31,757 | 31,757 | 1,033 | 286 | 1,552 | 1,033 | 282,221 | | 282,221 | 250,464 |
| 19 | | | 31,757 | 31,757 | 1,033 | 295 | 1,601 | 1,033 | 282,221 | | 282,221 | 250,464 |
| 20 | | | 31,757 | 31,757 | 1,033 | 304 | 1,650 | 1,033 | 282,221 | | 282,221 | 250,464 |

| Present Value | | |
|---|---|---|
| Cost | Benefit | NPV |
| 1,754,491 | 4,752,821 | 2,998,329 |

Discount ratio 10%

| B/C Ratio | EIRR |
|---|---|
| 2.709 | 12.80% |

## 5.4 Financial Evaluation

### 5.4.1 Financial Project Benefit

Benefits of the off-grid type projects are determined as the total expected revenue from sales of energy and revenue from connection fees as follows:

(1) Revenue from Connection Fee

$$B_{CF} = HH \times R_a \times CF$$

Where,
$B_{CF}$: benefit from connection fee (currency unit)
$HH$: number of total household (HH)
$R_a$: Application ratio (%)
$CF$: connection fee (currency unit/HH)

(2) Revenue from Electricity Tariff

$$B_{ET} = E \times R_L \times ET$$

Where,
$B_{EC}$: benefit from electricity tariff (currency unit)
$E$: generating energy (MWh/year)
$R_L$: total loss ratio (%) = 10%
$WTP_{ET}$: electricity tariff (currency unit/kWh)

### 5.4.2 Financial Project Cost

MHP project is a risk because most of the cost must be met at the start of the project. The investor (a private individual, prospective owner, funding agency, or rural development bank) will need to be convinced that such a major investment is safe. It is necessary to convince the investor that the project will produce financially viable results, and it is necessary to identify which proposed schemes are likely to fail and warn the investor of the poor financial potential.

Financial costs shall be estimated based on the current price level. Price escalation shall be taken into account applying annual inflation rates. The O&M cost also shall be inflated to the current price level.

(1) Construction Cost of MHP Station and Distribution System

The estimated construction costs are directly considered as the financial cost of construction costs.

(2) Installation Costs of House Wring and Watt-hour Meter for each Customer,

It is assumed in a manner similar to the economic evaluation.

(3) Operation and Maintenance Cost

It is assumed in a manner similar to the economic evaluation.

(4) Replacement Costs of Electrical Equipment.

It is assumed in a manner similar to the economic evaluation.

### 5.4.3 Example of Financial Evaluation

Financial analysis examines the profitability of project to the operating entity. Financial viability of the project is usually assessed in terms of the financial internal rate of return (FIRR), the net present value (NPV) and benefit-cost ratio (B/C) by use of the estimated project cost and revenue.

An example of financial evaluation is shown below. In this case, all the financial indicators show very bad performance, and accordingly the project are judged to be financially not viable.

# Table 5.4.1 Example of Financial Evaluation

**COST** Construction Cost

| | Civil Works | | Electrical Equipment | | Distribution Facilities | | Total | |
|---|---|---|---|---|---|---|---|---|
| 1st year | 346,717 | 40% | 29,865 | 15% | 260,988 | 50% | **637,570** | (USD) |
| 2nd year | 520,075 | 60% | 169,234 | 85% | 260,988 | 50% | **950,297** | (USD) |
| Total | 866,792 | 100% | 199,099 | 100% | 521,976 | 100% | **1,587,867** | (USD) |

| | | | | |
|---|---|---|---|---|
| Repairing & Replacement Cost | 20% | of the civil works | 173,358 | (USD) |
| | 90% | of the electrical equipment | 179,189 | (USD) |
| | | Total | **352,548** | (USD) |
| Annual O&M Cost | 2% | of the construction cost. | **31,757** | (USD/year) |
| House Wiring Cost | | Number of total household | 1,549 | (HH) |
| | | Application ratio | 80% | |
| | | Number of connection household | 1,239 | (HH) |
| | | House wiring & watt-hour meter cost | 60.0 | (USD/HH) |
| | | | **74,340** | (USD) |

**BENEFIT** Annual Available Energy

| | | | | | |
|---|---|---|---|---|---|
| Annual generating energy | 1,148 | (MWh/year) | Load factor | 50% | |
| Total Loss Ratio | 10% | | Connection fee | **62.1** | (USD/HH) |
| Annual available energy | 1,033 | (MWh/year) | Electricity Tariff | **9.01** | (USC/kWh) |

**CASH FLOW**

| Year | Cost | | | | Energy | | | | Benefit | | | B-C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Capital Cost (USD) | House Wiring (USD) | O&M (USD) | Cost Total (USD) | Abailable Energy (MWh) | Peak Demand (W/HH) | Energy Demand (MWh) | Sold Energy (MWh) | Electricity Tariff (USD) | Connection Charge (USD) | Benefit Total (USD) | |
| 0 | 637,570 | | | 637,570 | | | | | | | 0 | -637,570 |
| 1 | 950,297 | 74,340 | 31,757 | 1,056,395 | 1,033 | 90 | 488 | 488 | 44,006 | 76,942 | 120,948 | -935,447 |
| 2 | | | 31,757 | 31,757 | 1,033 | 106 | 575 | 575 | 51,829 | | 51,829 | 20,072 |
| 3 | | | 31,757 | 31,757 | 1,033 | 122 | 662 | 662 | 59,653 | | 59,653 | 27,895 |
| 4 | | | 31,757 | 31,757 | 1,033 | 139 | 754 | 754 | 67,965 | | 67,965 | 36,208 |
| 5 | | | 31,757 | 31,757 | 1,033 | 155 | 841 | 841 | 75,788 | | 75,788 | 44,031 |
| 6 | | | 31,757 | 31,757 | 1,033 | 171 | 928 | 928 | 83,612 | | 83,612 | 51,854 |
| 7 | | | 31,757 | 31,757 | 1,033 | 187 | 1,015 | 1,015 | 91,435 | | 91,435 | 59,678 |
| 8 | | | 31,757 | 31,757 | 1,033 | 196 | 1,064 | 1,033 | 93,075 | | 93,075 | 61,318 |
| 9 | | | 31,757 | 31,757 | 1,033 | 205 | 1,112 | 1,033 | 93,075 | | 93,075 | 61,318 |
| 10 | | | 31,757 | 31,757 | 1,033 | 214 | 1,161 | 1,033 | 93,075 | | 93,075 | 61,318 |
| 11 | | | 31,757 | 31,757 | 1,033 | 223 | 1,210 | 1,033 | 93,075 | | 93,075 | 61,318 |
| 12 | | | 31,757 | 31,757 | 1,033 | 232 | 1,259 | 1,033 | 93,075 | | 93,075 | 61,318 |
| 13 | | | 31,757 | 31,757 | 1,033 | 241 | 1,308 | 1,033 | 93,075 | | 93,075 | 61,318 |
| 14 | | | 31,757 | 31,757 | 1,033 | 250 | 1,357 | 1,033 | 93,075 | | 93,075 | 61,318 |
| 15 | 352,548 | | 31,757 | 384,305 | 1,033 | 259 | 1,406 | 1,033 | 93,075 | | 93,075 | -291,230 |
| 16 | | | 31,757 | 31,757 | 1,033 | 268 | 1,454 | 1,033 | 93,075 | | 93,075 | 61,318 |
| 17 | | | 31,757 | 31,757 | 1,033 | 277 | 1,503 | 1,033 | 93,075 | | 93,075 | 61,318 |
| 18 | | | 31,757 | 31,757 | 1,033 | 286 | 1,552 | 1,033 | 93,075 | | 93,075 | 61,318 |
| 19 | | | 31,757 | 31,757 | 1,033 | 295 | 1,601 | 1,033 | 93,075 | | 93,075 | 61,318 |
| 20 | | | 31,757 | 31,757 | 1,033 | 304 | 1,650 | 1,033 | 93,075 | | 93,075 | 61,318 |

| Present Value | | |
|---|---|---|
| Cost | Benefit | NPV |
| 1,829,392 | 1,601,096 | -228,296 |

Discount ratio 10%

| B/C Ratio | FIRR |
|---|---|
| 0.875 | -7.27% |

# CHAPTER 6 ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

## 6.1 Environmental Management System in Kenya

### 6.1.1 National Environmental Management Authority (NEMA)

The National Environment Management Authority (NEMA) is the government institution responsible for implementing environment policies, reviewing “EIA Project Reports” and “EIA Study Reports” and issuing environment licenses for development projects in Kenya.

NEMA’s organizational structure is headed by the Board of Management and Director General. The Authority has further established six departments and one sub-department; among which the following have functions in activities related to EIA: (Source, National Environment Management Authority Strategic Plan 2008-2012, June 2009, NEMA)

- ✓ The Director General appoints members of Environmental Impact Assessment Technical Advisory Committee (EIA-TAC) and prescribes the terms of reference and rules of procedure for the review of EIA related reports received by NEMA.
- ✓ The Compliance and Enforcement Department identifies projects and programmes or types of projects and programmes, and plans and policies for which environmental audits (EA) or environmental monitoring must be conducted under the Act, and ensures that EIAs and EAs are conducted.

### 6.1.2 Environmental Management System at County Level

(1) Decentralization and Administrative Structure Reform (Transitional Period)

Since the new Kenyan Constitution came into force in 2010, decentralization, administrative structure reform and regulatory revisions for “County System” in place of former “Province and District System” have started.

- ✓ As a matter of fact, NEMA issued a public notice with regard to the decentralization of its EIA functions to the county since 1st of July 2012 (See Figure 6.1.1).

As far as reforms of environmental management and EIA review procedures are concerned, the reform processes are in a transition period since January 2014.

- ✓ Due to the fact that the environmental management and EIA procedural reforms have not adequately come into effect in order to conform to the new constitutional dispensation especially on administrative units, the provisions of the current EMCA 1999 and EIA/EA Regulations (Amendment) 2009 are still in force until such a time as they will be reviewed. However, NEMA through an administrative procedure, has done away with District and Provincial offices and effectively replaced them with County offices.
- ✓ The transition period therefore means that the former systems (especially where the relevant laws are concerned) are still in operation alongside the current administrative re-alignment. Therefore, the former local systems of “Provincial Environmental Committee” as well as “District Environmental Committee” are envisaged to be reviewed.

(2) Provincial Environmental Committee (PEC) & District Environmental Committee (DEC)

According to the current EMCA 1999 and EIA/EA Regulations (Amendment) 2009, NEMA operates at provincial and district levels. Namely the Provincial Environmental Committees (PECs) and District Environmental Committees (DECs) are a primary mechanism for NEMA to undertake its functions, which will be altered to County Environmental Committees in order to conform to the new administrative structure of County system.

**NATIONAL ENVIRONMENT MANAGEMENT AUTHORITY**

**PUBLIC NOTICE**

**DECENTRALIZATION OF NEMA FUNCTIONS AND SERVICES**

The National Environment Management Authority (NEMA), effective **1st July 2012** implemented a decentralization programme to counties. This is in adherence to the Constitution of Kenya 2010 provisions for government agencies to devolve their operations and functions to counties to ensure efficient provision of their services. The decentralization will in particular address processing of Environmental Impact Assessment, Environmental Audit, Noise and Excessive Vibration Control and transportation of waste (garbage and sewage) licences.

**SPECIFIC CRITERIA FOR DECENTRALIZATION**

**A. Low impact Environmental Impact Assessment (EIA) projects**

The EIA for the following low impact projects shall be submitted and processed at respective offices of the County Director of Environment:

1. Residential houses (bungalows, maisonettes, flats) in zoned area (of not more than 30 units)
2. Commercial buildings (of not more than 10 storey's) in zoned areas
3. Go-downs for storage of goods only in zoned areas
4. Community based and/or constituency development Fund (CDF) projects such as;
    - i. Water projects, boreholes and water pans
    - ii. Roads (small feeder roads) and bridges
    - iii. Markets
    - iv. Cattle dips
5. Cottage industry/jua kali sector/garages
6. Car and bus parks
7. Restaurants (excluding tourism facilities in or surrounding National parks and game reserves).
8. Expansion of existing facilities for same use especially socially uplifting projects (SUPs) such as schools and dispensaries
9. Afforestation/re-afforestation programmes
10. Sand harvesting, quarrying and brick making
11. Slaughter houses (handling not more than 15 animals a day)
12. Construction of churches and mosques
13. Timber harvesting

**B. Medium and low risk Environmental Audit (EA)reports**

Medium and low impact project audits will be processed at respective offices of County Directors of Environment. These include:

1. Animal feed milling
2. Apartments
3. Colleges
4. Campsites
5. Metal welding
6. Restaurants
7. Schools
8. Tea farms
9. Transport Companies
10. Timber Products
11. Warehouses
12. Stadiums

**C. High impact/risk projects will be processed at NEMA headquarters**

All high impact/risk projects will be processed at NEMA headquarters. These include:

1. Asbestos manufacturing /based industries
2. Battery recycling
3. Airports
4. Airports hangars
5. Base transceiver stations(BTS)
6. Cement factories
7. Chemical factories
8. Distilling and blending spirits
9. Geothermal plants
10. Hydroelectric power generation plants
11. Incinerators
12. Landfills
13. Large scale irrigated agriculture farming (exceeding 50ha)
14. Molasses plants
15. Petroleum refining
16. Paper mills
17. Vegetable oil refineries
18. Steel mills
19. Sewerage works
20. Thermal power generation
21. Tanneries
22. Tourist facilities in protected areas
23. Wood preservation

N.B. All other facilities/projects not included in the high risk category list shall be submitted and processed at the respective offices of the County Director of Environment.

**D. Noise and excessive vibration control licensing**

Noise and excessive vibration control licences and permits shall be issued at the county level for one off activities, where noise emitted is expected to go beyond maximum permissible noise levels. Such one off activities include: weddings and birthday parties, road shows, ceremonies, parties, religious festivals, mobile cinemas among others. The licence is valid for a maximum of seven days and costs Kshs 2,200.

Permits will be issued for the following one off activities: demolition activities, construction sites, fireworks, mines and quarries, firing ranges, specific heavy duty industry. The permit shall be valid for a period of up to three months and costs KShs 5,500.

Commercial activities, discos/ live bands/ pubs, entertainment joints, places of worship among others, shall not be licenced as they are required to sound proof their premises to keep their noise to within permissible noise levels.

**E. Waste transportation licensing**

Licenses to transport garbage and sewage waste shall be issued at the county level. All the other categories of waste management license applications will continue to be received at county level. These will be forwarded to NEMA Headquarters for processing.

**Office contacts of respective County Directors of Environment (CDE) can be found on the NEMA website at www.nema.go.ke.**

For further information, please contact:

**PROF. GEOFFREY WAHUNGU**
**DIRECTOR GENERAL**
**NEMA**
**Popo road, off Mombasa Road**
**P.O. Box 67839- 00200, Nairobi, Kenya**
**Tel: (254 020) 6005522, 020 2101370, 0724 253398, 0735 010237**
**Fax (254 020) 6008997**

**Email: dgnema@nema.go.ke Website: www.nema.go.ke**
**Face book: National Environment Management Authority**
**Report any environmental related corruption to: anticorruption@nema.go.ke**

Source: a Clip DAILY NATION, Monday July 9, 2012.

**Figure 6.1.1 Public Notice on Decentralization of NEMA Functions and Services**

## 6.2 EIA Procedures and Licensing System in Kenya

### 6.2.1 Projects Sectors Subject to EIA

Project Sectors subject to EIA procedures in Kenya are specified in the Environmental Management and Coordination Act of 1999 (EMCA) as “Second Schedule” as shown in Table 6.2.1.

### Table 6.2.1 “Second Schedule” Specified in EMCA (Project Sectors Subject to EIA)

| Sector | Including | |
|---|---|---|
| General | · An activity out of character with its surrounding, any structure of a scale not in keeping with its surroundings | · Major changes in land use |
| Urban development | · Designation of new townships<br>· Establishment of industrial estates<br>· Establishment or expansion of recreational areas | · Establishment or expansion of recreational townships in mountain areas, national parks and game reserves<br>· Shopping centers and complexes |
| Transportation | · All major roads<br>· All roads in scenic, wooded or mountainous areas and wetlands, Railway lines | · Airports and airfields<br>· Oil and gas pipelines<br>· Water transport |
| Dams, rivers and water resources | · Storage dams, barrages and piers<br>· River diversions and water transfer between catchments | · Flood control schemes<br>· Drilling for the purpose of utilizing ground water resources including geothermal energy |
| Aerial spraying | - | - |
| Mining | · Quarrying and open cast extraction of<br>· Precious metal, Gemstones, Metalliferous ores, Coal, Phosphates, Limestone and dolomite | · Stone and slate<br>· Aggregates, sand and gravel, Clay, Exploration for the production of petroleum in any form, Extracting alluvial gold with use of mercury |
| Forestry related activities | · Timber harvesting<br>· Clearance of forest areas | · Reforestation and afforestation |
| Agriculture | · Large scale agriculture<br>· Use of pesticide<br>· Introduction of new crops and animals | · Use of fertilizers<br>· Irrigation |
| Processing and manufacturing industries | · Mineral processing, reduction of ores and minerals<br>· Smelting and refining of ores and minerals<br>· Foundries<br>· Brick and earth wear manufacture<br>· Cement works and lime processing<br>· Glass works<br>· Fertilizer manufacture or processing<br>· Explosive plants<br>· Oil refineries and petrochemical works<br>· Tanning and dressing of hides and skins<br>· Abattoirs and meat processing plants<br>· Chemical works and processing plants<br>· Brewing and malting | · Bulk grain processing plants<br>· Fish processing plants<br>· Pulp and paper mills<br>· Food processing plants<br>· Plants for manufacture or assembly of motor vehicles<br>· Plant for the construction or repair of aircraft or railway equipment<br>· Plants for the manufacture or assembly of motor vehicles<br>· Plants for the manufacture of tanks, reservoirs and sheet metal containers<br>· Plants for manufacture of coal briquettes<br>· Plants for manufacturing batteries |
| Electrical infrastructure | · Electrical generation stations<br>· Electrical transmission lines | · Electrical sub-stations<br>· Pumped storage schemes |
| Management of hydrocarbons | · Storage of natural gas and combustible or explosive fuels | |
| Waste disposal | · Sites for solid waste disposal<br>· Sites for hazardous waste disposal<br>· Sewage disposal works | · Works involving major atmospheric emissions<br>· Works emitting offensive odours |
| Natural conservation areas | · Creation of national parks, game reserves and buffer zones<br>· Establishment of wilderness areas<br>· Formulation or modification of forest management policies<br>· Formulation of modification of water catchment management policies | · Policies for the management of ecosystems especially by use of fire<br>· Commercial exploitation of natural fauna and flora<br>· Introduction of alien species of fauna and flora<br>· Introduction of alien species of fauna and flora into ecosystems |
| Nuclear reactors | - | - |
| Major development in biotechnology | · Introduction and testing of genetically modified organisms | |

Source: Environmental Management and Coordination Act of 1999 (EMCA)

However, “Second Schedule” does not specify the scale and size of each project. Specifically, without reference to scale or size, any project falling under the Second Schedule shall go through the EIA procedures.

### (1) Renewable Energy Projects and Necessity of EIA

Renewable energy projects (PV, MHP, Biogas and Wind power systems) fall under “No. 10 Electrical Infrastructure” in the “Second Schedule” of EMCA. Therefore, all renewable energy projects are naturally subject to the EIA procedures.

(2) Draft NEMA EIA Guidelines and Administration Procedures

In addition, NEMA developed Draft EIA Guidelines and Administration Procedures in November 2002 in response to the National Policy on Environment and EMCA 1999. The NEMA Draft EIA Guidelines provide procedural guidelines for:

- ✓ Implementation of EIA,
- ✓ Monitoring and Environmental Audit (EA),
- ✓ Strategic Environmental Assessment (SEA),
- ✓ Issues of Trans-boundary, Regional and International Conventions, Treaties and Agreements,
- ✓ Steps in EIA studies and Environmental Audits,
- ✓ The contents and format of the study reports to be submitted to NEMA,
- ✓ The EIA study review process and decision-making, and
- ✓ Others.

CHAPTER 7 of the NEMA Draft EIA Guidelines mentions that Lead agencies are mandated by section 58 of the EMCA 1999, in consultation with the Authority, to develop EIA Guidelines to ensure that environmental concerns are integrated into sector development policies, plans, projects or programmes. The sector guidelines shall focus on specific mandates in line with the statutory relationships with the administration of the EIA process.

- ✓ However, such sector guidelines have not been developed by relevant lead agencies with the exception of the petroleum sector (Source, A meeting with NEMA headquarters).
- ✓ In addition, the Draft Guidelines are rendered rather conceptual. Practically, the processes of EIA and licensing shall refer to EIA/EA Regulations (Amendment) 2009.

### 6.2.2 EIA Review Process and Licensing

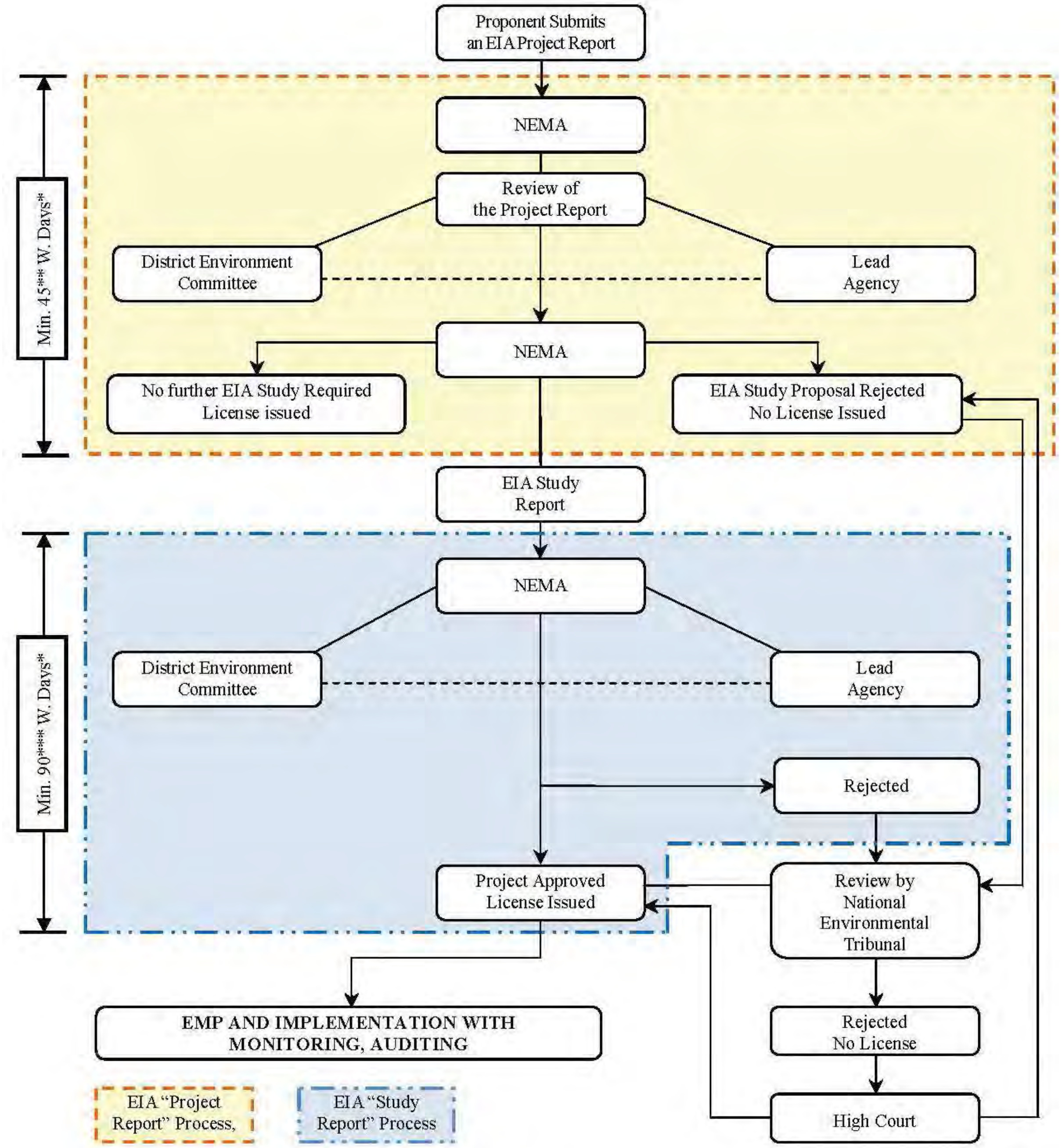
The Environmental Management and Coordination Act of 1999 (EMCA) and EIA/EA Regulations (Amendment) 2009 specify that the EIA Review process consists of the following two steps.

- ✓ EIA “Project Report” Process
- ✓ EIA “Study Report” Process

(1) Overview of the EIA Process

Based on EMCA 1999, EIA/EA Regulations (Amendment) 2009 and discussions with NEMA officials; and considering the decentralization of NEMA’s functions to the County level, Kenya’s EIA procedures can be comprehensively depicted as shown in Figure 6.2.1

Detailed procedures for “EIA Project Report” and “EIA Study Report” will appear afterward (See Figure 6.2.2 and Figure 6.2.3).



*Note; *According to NEMA, "days" in the procedures stands for "Working days"*
***According to NEMA, not "within forty-five days" but "Minimum forty-five days" for the EIA Project Report Review and Licensing period*
****According to NEMA, not "within 90 days" but "Minimum 90 Working days" for the EIA Project Report Review and Licensing period*

Source: NEMA, (modified by the JET based on discussions with NEMA Headquarters officials)

**Figure 6.2.1 Overview of the EIA Process**

(2) EIA "Project Report"

According to EMCA 1999, EIA/EA Regulation (Amendment) 2009 and discussions with NEMA officials; and considering the decentralization of NEMA's functions to the County level, the EIA "Project Report" Process can be summarized as follows and depicted in Figure 6.2.2.

- ✓ The process starts by a project proponent, selecting a consultant who must be licensed and registered with NEMA as a Lead Expert on EIA/EA

- ✓ An EIA “Project Report” shall be prepared by the consultant (Registered Lead Expert on EIA/EA). The following shows contents to be stated in the “Project Report”.

**Table 6.2.2 Contents of the Project Report**

| | |
|---|---|
| · Nature of the project,<br>· Location of the project including the physical area that may be affected by the project's activities,<br>· Activities that shall be undertaken during the project construction, operation and decommissioning phases,<br>· Design of the project,<br>· Materials to be used, products and by-products, including waste to be generated by the project and the methods of their disposal,<br>· Potential environmental impacts of the project and the mitigation measures to be taken during and after implementation of the project, | · Action plan for the prevention and management of possible accidents during the project cycle,<br>· Plan to ensure the health and safety of the workers and neighbouring communities,<br>· Economic and socio-cultural impacts to the local community and the nation in general<br>· Project budget, and<br>· Any other information the Authority may require. |

Prepared by JET

- ✓ The proponent shall submit at least ten copies and one soft copy (CD-ROM) of the EIA “Project Report” to the Authority (NEMA headquarters or its County Office(s)) accompanied by the prescribed fees of 0.05% of the project cost. (50% of the 0.05 of the project cost paid at the time of submission of the EIA “Project Report” and the remainder of 50% paid at the time of collection of license)
- ✓ The Authority shall **within seven (7) days** upon receipt of the project report, where the “Project Report” conforms to the requirements of regulation, distribute a copy of the “Project Report” to Relevant Lead Agencies and Relevant District Environment Committee(s) (DEC(s)) for their review and written comments.
- ✓ The comments of Lead Agencies and DECs shall be submitted to the Authority *within twenty one (21) days* from the date of receipt of the “Project Report” from the Authority, or such other period as the Authority may prescribe.
- ✓ On receipt of the comments or where no comments have been received **by the end of the period of thirty (30) days** from the date of receipt of the “Project Report”, the Authority shall proceed to determine the project report.
- ✓ On determination of the “Project Report”, the decision of the Authority, and the reasons thereof, shall be communicated to the proponent **within forty-five (45) days**[1] of the submission of the “Project Report”.
- ✓ Where the Authority is satisfied that the project will have no significant impact on the environment, or that the project report discloses sufficient mitigation measures, the Authority may issue a license.
- ✓ If the Authority finds that the project will have significant impact on the environment, and the project report discloses no sufficient mitigation measures, the Authority shall require that the proponent undertake an EIA study.
- ✓ A proponent who is dissatisfied with the Authority's decision that an environmental impact assessment study is required, may **within fourteen (14) days** of the Authority's decision, appeal against the decision to the Tribunal.

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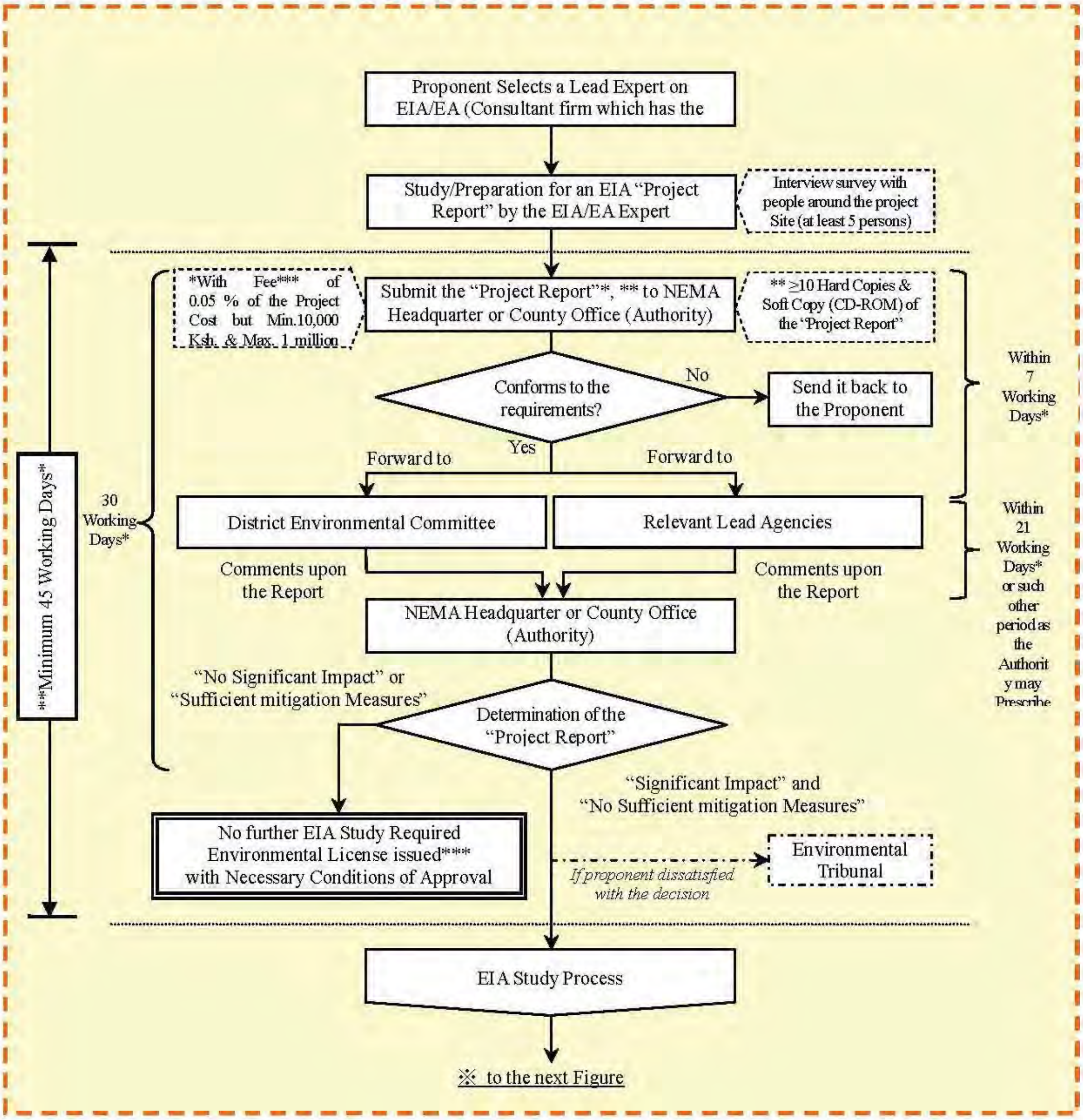
[1] According to NEMA, EIA Project Report Review and Licensing period is not “within forty-five days” but “Minimum forty-five days”.



*Note: *According to NEMA, "days" in the procedures stands for "Working days"*
***According to NEMA, not "within forty-five days" but "Minimum forty-five days" for the EIA Project Report Review and Licensing period*
*** 50% of the 0.05 of the project cost paid at the time of submission of the EIA Project Report and the remainder of 50% paid at the time of collection of license

Source: Prepared by the JET referring to the EIA/EA Regulations (Amendment) 2009 and based on discussions with NEMA headquarters

**Figure 6.2.2 EIA Project Report Review Process and Duration**

### (3) EIA "Study Report"

According to EMCA 1999, EIA/EA Regulation (Amendment) 2009 and discussions with NEMA officials; and considering the decentralization of NEMA's functions to the County level, the <u>EIA "Study Report"</u> Process can be summarized as follows and depicted in Figure 6.2.3.

- ✓ An EIA study shall be conducted in accordance with Terms of Reference (ToR) to be developed during the "Scoping" exercise. The ToR shall subsequently be submitted to be approved **<u>within seven (7) days</u>** by the Authority, Every EIA study shall be carried out by an EIA/EA Lead Expert

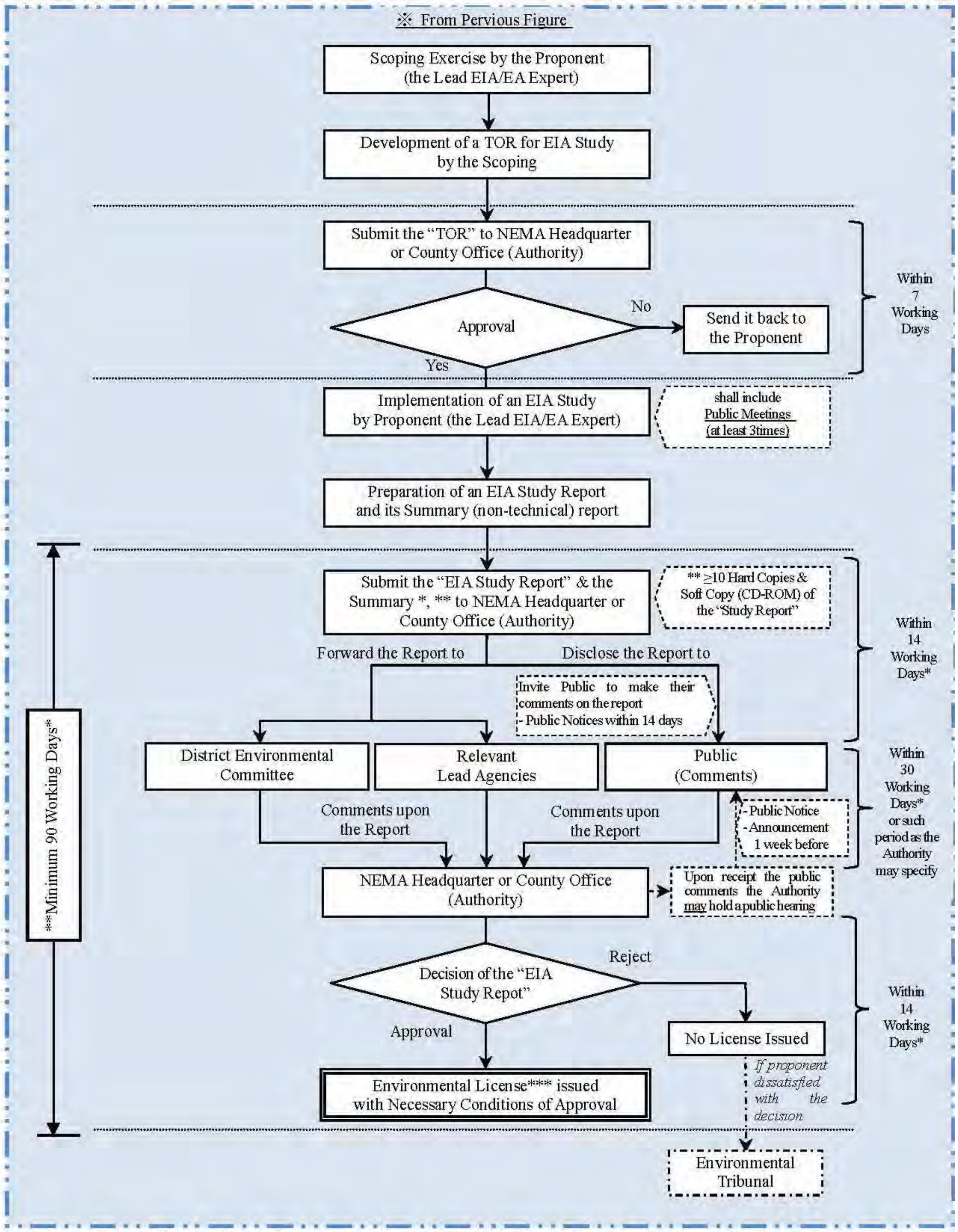
- ✓ During the process of conducting an EIA study, the proponent shall in consultation with the Authority, seek the views of persons who may be affected by the project.
- ✓ Specifically, holding at least three public meetings with the affected parties and communities to explain the project and its effects, and to receive their oral or written comments
- ✓ A proponent shall submit to the Authority, environmental contents of EIA "Study Report" incorporating but not limited to the following information:

**Table 6.2.3 Contents of the Study Report**

| | |
|---|---|
| · Proposed location of the project,<br>· Concise description of the national environmental legislative and regulatory framework, baseline information,<br>· Any other relevant information related to the project, the objectives of the project,<br>· Technology, procedures and processes to be used, in the implementation of the project,<br>· Materials to be used in the construction and implementation of the project,<br>· Products, by-products and waste generated project,<br>· Description of the potentially affected environment,<br>· Environmental effects of the project including the social and cultural effects and the direct, indirect, cumulative, irreversible, short term and long-term effects anticipated,<br>· Alternative technologies and processes available and reasons for preferring the chosen technology and processes,<br>· Analysis of alternatives including project site, design and technologies and reasons for preferring the proposed site, design and technologies, | · Environmental management plan proposing the measures for eliminating, minimizing or mitigating adverse impacts on the environment, including the cost, time frame and responsibility to implement the measures,<br>· Provision of an action plan for the prevention and management of foreseeable accidents and hazardous activities in the cause of carrying out activities or major industrial and other development projects,<br>· Measures to prevent health hazards and to ensure security in the working environment for the employees and for the management of emergencies,<br>· Identification of gaps in knowledge and uncertainties which were encountered in compiling the information,<br>· Economic and social analysis of the project,<br>· Indication of whether the environment of any other state is likely to be affected and the available alternatives and mitigating measures, and<br>· Such other matters as the Authority may require. |

Prepared by JET

- ✓ EIA "Study Report" shall be accompanied by a non-technical summary outlining the key findings, conclusions and recommendations of the study, Proponent shall submit ten copies and a soft copy (CD-ROM) of an EIA "Study Report" to the Authority
- ✓ The Authority shall **within fourteen (14) days** of the receipt of the EIA "Study Report" submit a copy of the report to any Relevant Lead agencies as well as District Environmental Committee(s) (DEC(s)) for their comments.
- ✓ Upon receiving the EIA "Study Report", the lead agencies and DEC(s) shall review the report and shall thereafter send their comments on the "Study Report" to the Authority **within thirty (30) days** or such extended period as the Authority may specify.
- ✓ The Authority shall **within fourteen (14) days** of receiving the EIA "Study Report", invite the public to make oral or written comments on the report, at the expense of the proponent.
- ✓ Upon receipt of these comments, the Authority may hold a public hearing
- ✓ The Authority shall give its decision on EIA "Study Report" **within three (3) months** of receiving an EIA "Study Report"
- ✓ Where the Authority approves an EIA "Study Report" , it shall issue an EIA license on terms and conditions as it may deem necessary
- ✓ A person who is aggrieved by the decision may appeal to the Tribunal against the decision.



Note: *According to NEMA, "days" in the procedures stands for "Working days"
**According to NEMA, not "within 90 days" but "Minimum 90 Working days" for the EIA Project Report Review and Licensing period
*** 50% of the 0.05 of the project cost paid at the time of submission of the EIA Project Report and the remainder of 50% paid at the time of collection of license

Source: Prepared by the JET referring to the EIA/EA Regulations (Amendment) 2009 and based on discussions with NEMA

**Figure 6.2.3 EIA Study Report Review Process and Duration**

### (4) Public Comments and Public Hearing in the EIA Study Report Process

Table 6.2.4 shows differences between “Public Comments” and “Public Hearing” in the course of the EIA Study Report Process. Both public comments and public hearing are means of public consultation.

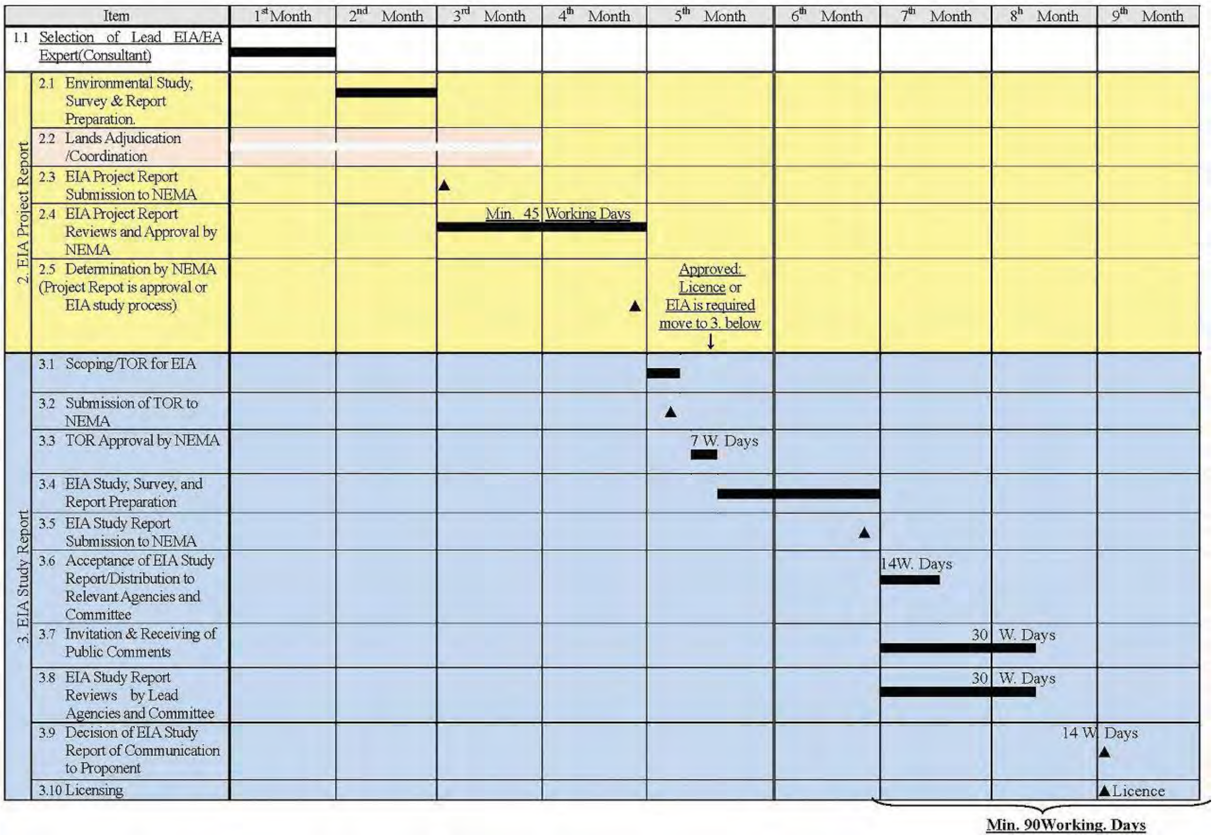
**Table 6.2.4 Public Comments and Public Hearing in EIA Study Report Process**

| Public Comments | Public Hearing |
|---|---|
| - Invitation is done both at the time of conducting EIA and after submission of Study report. | - Conducted only after submission of the EIA study report at NEMA offices |
| - Invitation of public comments must be done as follows.<br>- At least three public meetings for comments must be done by the EIA consultant in the course of the study.<br>- One public comments window after submission of EIA study report at NEMA office. | - Public hearing done only once after submission of EIA study report. |
| - Comments are received both by EIA consultant and NEMA. | - Sessions for public hearing only organized by NEMA and the report of the public hearing only prepared by the presiding NEMA official. |
| - Invitation for public comments is mandatory as per the regulations. | - Conducting public hearing sessions is at the discretion of NEMA based on the nature of the proposed study and adequacy of the study report. |

Prepared by JET

### (5) Possible Schedule of EIA Review Process and Licensing for Renewable Energy Projects

In accordance with the EIA processes noted above, a possible schedule of EIA review and licensing for renewable energy projects can be depicted as a bar-chart as shown in Figure 6.2.4.



Prepared by JET

Figure 6.2.4 Possible Schedule for EIA/Environmental Licenses

(6) Revision of EMCA and EIA/EA Regulation in 2014

In light of the new constitution enacted in 2010, the relevant laws and regulations, especially EMCA 1999 and the EIA/EA regulations 2009 are being reviewed (as of January 2014) to conform to the expectations of the new constitution. Therefore, revised EMCA and EIA/EA regulations may apply to relevant projects after 2014. For more details on any revisions, contact NEMA.

### 6.3 Specific Subject (Solid Waste Management)

Solid waste management issues shall be addressed in compliance with the following laws and regulations in Kenya.

- ✓ Environmental Management and Coordination Act of 1999 (EMCA)
- ✓ Environmental Management and Coordination (Waste Management) Regulations 2006
- ✓ Guidelines for E-Waste Management in Kenya 2010
- ✓ Others (if any)

#### 6.3.1 Construction Stage

All trash and packaging materials which might result from the construction process will be collected by the contractor(s) for adequate disposal, which shall be one of the prerequisites for the contract(s) for the contractor(s) to be employed. In this regard, the solid waste management during constriction stage can be secured as follows.

- ✓ REA is required to instruct contractor(s) to ensure such solid waste management.

#### 6.3.2 Operation Stage

Replacement of used batteries, fluorescent tubes and other electrical appliances shall be managed by each project facility. REA is required to have discussions with each facility, and/or initiate stakeholder meetings in each site to discuss and find solutions for management of such solid waste as follows.

(1) E-waste

The issues of “e-waste management” are prominent. Especially, e-waste components like used batteries, used fluorescent lamps and other used electrical appliances including solar PV panels, inverters and etc. are the core issues as summarized in Table 6.3.1.

**Table 6.3.1 E-waste Components in Renewable Energy Projects**

| E-waste | Hazardous Element |
|---|---|
| Used Lead-acid batteries | Lead and Sulfuric Acid |
| Used Fluorescent tubes | Mercury |
| Used PV panels, Inverters and other appliances | Other heavy metals |

Prepared by JET

(2) Hazardous and Non-Hazardous Elements

Hazardous elements and Non-Hazardous Elements in Table 6.3.1 are regulated by EMCA, especially by the Guidelines for E-Waste Management in Kenya (See Table 6.3.2 and Table 6.3.3).

### Table 6.3.2 Hazardous Elements in Electrical and Electronic Equipment

| Element | For example found in electrical and electronic equipment such as: |
|---|---|
| Americium | Smoke alarms (radioactive source). |
| Mercury | Fluorescent tubes (numerous applications); tilt switches (pinball games, mechanical doorbells, thermostats) |
| Sulfur | Lead-acid batteries |
| PCBs | Prior to ban, almost all 1930s-1970s equipment, including capacitors, transformers, wiring insulation, paints, inks and flexible sealants used PCBs. |
| Cadmium | Light-sensitive resistors, corrosion-resistant alloys for marine and aviation environments and nickel-cadmium batteries. |
| Lead | Old solder, CRT monitor glass, lead-acid batteries and formulations of PVC. |
| Beryllium oxide | Filler in some thermal interface materials such as thermal grease used on heat sinks of CPUs and power transistors, magnetrons, X-ray-transparent ceramic windows, heat transfer fins in vacuum tubes, and gas lasers. |
| Polyvinyl chloride | PVC contains additional chemicals to change the chemical consistency of the product. Some of these additives can leach out of vinyl products e.g. plasticizers that are added to make PVC flexible. |

Source: Guidelines for E-Waste Management in Kenya, December 2010, NEMA

### Table 6.3.3 Non Hazardous Elements in Electrical and Electronic Equipment

| Element | For example found in electrical and electronic equipment such as: |
|---|---|
| Tin | Solder, coatings on component leads. |
| Copper | Copper wire, printed circuit board tracks, component leads. |
| Aluminum | Nearly all electronic goods using more than a few watts of power, including electrolytic capacitors. |
| Iron | Steel chassis, cases, and fixings. |
| Germanium | 1950s-1960s transistorized electronics (bipolar junction transistors). |
| Silicon | Glass, transistor, ICs, printed circuit boards. |
| Nickel | Nickel-cadmium batteries. |
| Lithium | Lithium-ion batteries. |
| Zinc | Plating for steel parts. |
| Gold | Connector plating, primarily in computer equipment. |

Source: Guidelines for E-Waste Management in Kenya, December 2010, NEMA

Possibility of “hazard to health and environment” caused by the hazardous elements shown in Table 6.3.2, is one of the reasons for the necessity of e-waste management.

(3) Handling Procedure of E-waste

Unlike domestic waste which is generated daily, e-waste is generated after the life span of each component of the project facilities has finished.

Specifically, the life span of batteries and fluorescent lamps are about two to several years, while that of electrical appliances including solar PV panels, inverters, etc. are up to 0-25 years for which disposals shall be handled as summarized in Table 6.3.4.

## Table 6.3.4 Handling Procedure of E-waste

| Component | Possible Life Span* (years) | Handling | Remarks |
|---|---|---|---|
| Battery | 3 to 8 | - In order to prevent diffusion of toxic substances in batteries, used ones shall safely be kept without damage (Do not Crash! Do not Take Apart!) until properly disposed.<br>- Used batteries can be sold to licensed e-waste handlers and/or battery producing companies in Kenya. | - Licensed e-waste handlers (See Table 6.3.5) or contact each NEMA county office to get updated information on such handlers.<br>- Battery Producing Companies (See Figure 6.3.1 or contact each NEMA county office).<br>- Purchase Prices are subject to the market trends. |
| Fluorescent Lamp | 2 to 4 | - In order to prevent diffusion of mercury in fluorescent lamps, used ones shall safely be kept without damage (Do not Crash! Do not Take Apart!) until properly disposed.<br>- Used Fluorescent Lamps shall be transported to licensed e-waste handlers in Kenya to be disposed. | - Licensed e-waste handlers (See Table 6.3.5) or contact each NEMA county office to get updated information on such handlers. |
| LED Lamp | 5 | - Used LED Lamps shall be transported to registered e-waste handlers in Kenya to be disposed. | |
| Solar PV Panel | 20 to 25 | - Used solar PV panels shall be transported to registered e-waste handlers in Kenya to be disposed. | |
| Inverter | 5 to 10 | - Used Inverters shall be transported to licensed e-waste handlers in Kenya to be disposed. | |

* Note: Vary depending on the intended use as well as status of use

Prepared by JET

A battery manufacturer already has a program to buy used batteries at KSh. 40 per kilogram

Photo by JET

Figure 6.3.1 Used Battery Purchasing by a Battery Manufacturer

## Table 6.3.5 Licensed E-waste Handlers in Kenya (As of August 2013)

| Handler | Contact | District | Waste Type |
|---|---|---|---|
| East Africa Computer Recyclers Ltd. | P.O. Box 49266-00100, Nairobi<br>Email: eastafricancomputer@yahoo.com<br>07215036515, 0729308221 | Mombasa | Electronic Recycling |
| Waste Electrical and Electronic Equipment Center | P.O. Box 48584-00100, Nairobi<br>Email: infor@weecenter.com<br>0733-986-558, 202060921 | Nairobi | Electronic Recycling |

Source: NEMA (tabulated by JET)

### (4) E-waste Management Structure

Used batteries, fluorescent tubes and other used electrical apparatuses/devices can be handled by organizing an e-waste management sub-committee under the Pilot Project management structure to be set up by each community and/or facility as follows:

a. The structure (sub-committee) to be organized for the e-waste management shall be discussed among stakeholders on the initiative of REA.
b. Each community is to be enlightened that even the electrical apparatuses/devices such as PV panels and inverters which have a longer lifespan eventually need replacement
c. Each community is to be enlightened that those hazardous elements shown in Table 6.3.2 are hazardous to health and environment and some hazardous substances like “lead” in batteries and some non-hazardous elements shown in Table 6.3.3 can be recycled and reused.

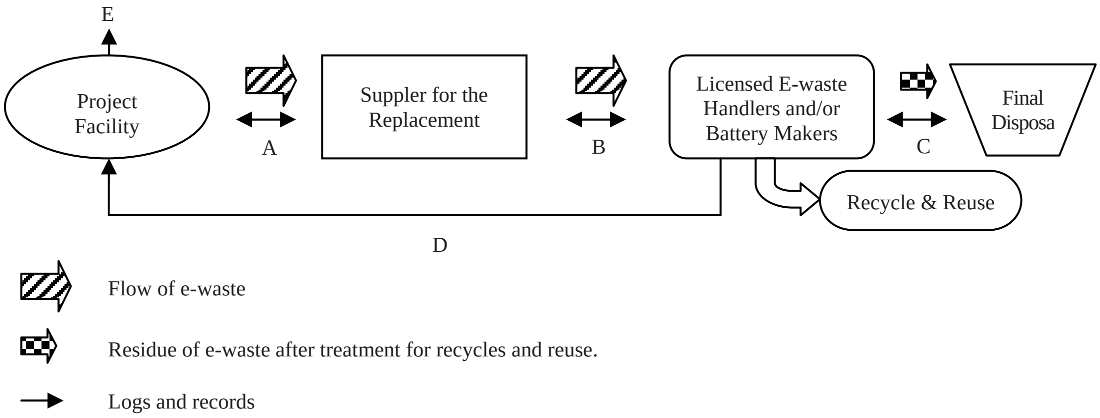
### (5) E-waste Disposal System

Practically, the aforementioned e-wastes shall be transported to the licensed E-waste Handlers and/or battery manufacturers in the following approach:

a. Request suppliers to take away used ones from each facility when carrying out replacements (this shall be set as a condition for carrying out replacements).
b. Being public property of the project, earnings from the sale of used e-waste including batteries shall be remitted using the “m-pesa” system by suppliers receiving earnings from the licensed E-waste Handlers and/or battery manufacturers.
c. The earnings shall be kept in each facility as revenue.
d. In order to ensure proper transportation and treatment, an e-waste manifest system shall be introduced in the e-waste disposal system as shown in Figure 6.3.2 and Table 6.3.6.

* Manifest system: A system to keep all logs from e-waste discharge stage to transportation as well as final treatment in order to prevent illegal dispose of e-waste during the transportation as well as to make sure appropriate final treatment of such waste.

** The following web site of USEPA on Hazardous Waste Manifest System can be referred as reference.
http://www.epa.gov/waste/hazard/transportation/manifest/index.htm



| | |
|---|---|
| A | Keep two logs on e-waste between Generator (facility) and Suppler which will transport e-waste to the (2 logs: one is for the generator and one is for the suppler) |
| B | Keep two logs on the e-waste between the Suppler and Licensed e-waste handler and/or Battery Maker for the treatment of the e-waste (2 logs: one is for the suppler and one is for the Licensed E-waste Handlers and/or Battery Makers) |
| C | Keep two logs on the reside of the e-waste between the Licensed e-waste handler and/or Battery Maker and a final disposal site (2 logs: one is for the Licensed e-waste handler and/or Battery Maker and one is for the final disposal facility like a landfill) |
| D | Send two copies of the logs of B and C to Generator (project facility) by which each project facility can identify the proper transportation, treatment and final disposal of the e-wastes by mail. |
| E | After receiving the copies in D, each facility shall report showing one of the copies to REA, as well as regulatory agency such as Ministry of Education (for Primary Schools) or Ministry of Health (for Dispensaries). |

Prepared by JET

**Figure 6.3.2 Conceptual Diagram of E-waste Manifest system**

## Table 6.3.6 Draft E-waste Manifest Log From

| | | | | |
|---|---|---|---|---|
| | Date: | | No. of Manifest | |
| 1 | Facility<br>(Generator) | Name | Address/TEL/FAX | |
| | | Person –in Charge: | Contact address/TEL | |
| | E-waste | name 1: | Quantity | E-waste |
| | | name 2: | Quantity | |
| | | name 3: | Quantity | |
| | | name 4: | Quantity | |
| | | name 5: | Quantity | |
| 2 | Suppler<br>(Transportation) | Name | Address/TEL/FAX | |
| | | Person –in Charge: | Contact address/TEL | |
| | Received the above listed e-waste from the Facility on date and Sign | | | |
| 3 | Licensed E-waste Handler and/or Battery Maker | Name | Address/TEL/FAX | |
| | | Person –in Charge: | Contact address/TEL | |
| | Received the above listed e-waste from the Suppler on date and Sign | | | |
| | Treated appropriately the e-waste on date and Sign<br>in compliance with the relevant laws and regulations in Kenya, especially the followings<br>✓ Environmental Management and Coordination Act of 1999 (EMCA)<br>✓ Environmental Management and Coordination (Waste Management) Regulations 2006<br>✓ Guidelines for E-Waste Management in Kenya 2010 | | | |
| 4 | Final Disposal | Name | Address/TEL/FAX | |
| | | Person –in Charge: | Contact address/TEL | |
| | Received the residues of above listed e-waste from the Licensed E-waste Handler and/or Battery Maker on date and Sign | | | |
| | Disposed the residues on date and Sign<br>n compliance with the relevant laws and regulations in Kenya, especially the followings<br>✓ Environmental Management and Coordination Act of 1999 (EMCA)<br>✓ Environmental Management and Coordination (Waste Management) Regulations 2006<br>✓ Guidelines for E-Waste Management in Kenya 2010 | | | |

Note: At least eight copies are necessary.

Prepared by JET

## 6.4 Individual Subjects on MHP Project

### (1) Mosquito Emergence Controls

In order to prevent water borne diseases such as malaria, mosquito emergence controls are required for waster body (sluice) dammed (enclosing bunds and dams) for MHP projects as follows:

- ✓ Periodic clean up of rubbish such as branches and leaves, water hyacinth, etc. in the water body.
- ✓ Regular operation of water table control (adjustment of vertical water level, i.e. “Up and Down of the level”. Maintaining the water table at one level may create a suitable water environment for breeding of mosquito larva).

### (2) Wastewater Contamination Control

In order to prevent pollution of waster body (sluice) dammed for the MHP projects, wastewater shall be controlled and managed.

- ✓ Wastewater from surrounding settlements shall be captured and not discharged immediately to the water body.
- ✓ If the quantity of such wastewater is relatively small, leaching pit or septic tank methods can be utilized for wastewater management.
- ✓ If the quantity of such wastewater is relatively large, stabilization pond method (if there is enough space) can be utilized for wastewater management.

### (3) Water Quality Control

In order to avoid anaerobic conditions in the water body (at enclosing bunds and dams) which will create Methane ($CH_4$), Hydrogen sulfide ($H_2S$), methylated inorganic mercury ($Hg \rightarrow CH_4Hg$) (if there is inorganic mercury in the water body), and other compounds in the water, the water quality shall be controlled as follow:.

- ✓ Periodic clean up of rubbish such as branches and leaves, water hyacinth, etc. in the water body.
- ✓ Regular de-sludge of bottom sediment of the water body.

# CHAPTER 7 CONSTRUCTION SUPERVISION

## 7.1 Procurement

### 7.1.1 Procurement Procedure

Procurement should be conducted according to Public Procurement and Disposal Act 2005 and the Public Procurement and Disposal Regulations 2006 as stipulated by Government of Kenya.

MHP projects have components of civil works, electrical equipment, and distribution facility. It is therefore necessary to procure individually or to combine applicable descriptions in the tender document.

The procurement method consists of the following:

1) International open tender

International open tender is applied mainly where there are few or no domestic supplier who have experience of similar projects, and the tender calls for international suppliers. There is no maximum level of expenditure.

2) National open tender

National open tender is mainly for tender among national suppliers. When several national suppliers have experiences of similar projects and sufficient ability to implement, this method will be selected.

3) Restricted tender method

Restricted tender method is the procurement method that relies on the establishment of a list of authorized bidders who will be offered the opportunity to bid for a specific procurement package. The establishment of the list is subject to conditions.

**Table 7.1.1 Types of Procurement and Maximum and Minimum Budgets**

| Type | | Goods | Works | Services |
|---|---|---|---|---|
| International Open Tender | Maximum | The budget allocation | | |
| | Minimum | No minimum | | |
| National Open Tender (Threshold Class A) | Maximum | The budget allocation | | |
| | Minimum | Kshs. 6,000,000 | Kshs. 6,000,000 | Kshs. 3,000,000 |
| National Open Tender (Threshold Class B) | Maximum | The budget allocation | | |
| | Minimum | Kshs. 4,000,000 | Kshs. 4,000,000 | Kshs. 2,000,000 |
| National Open Tender (Threshold Class C) | Maximum | The budget allocation | | |
| | Minimum | Kshs. 3,000,000 | Kshs. 3,000,000 | Kshs. 1,000,000 |

Note: Class A, B, C is classification made by procuring entities.

Source: “Public Procurement and Disposal General Manual” issued by PPOA (arranged by JET).

4) Direct procurement method

Direct procurement does not require the use of competitive bidding. Direct procurement is strictly regulated since it is completely devoid of competition and transparency. It is only applicable in the following cases:

i) When there is only one supplier who can supply the goods, works or services being procured and there is no reasonable alternative or substitute for the goods, works or services, or

ii) Where the goods being produced are urgent and because of the urgency the available methods of procurement are not practical. This type of situations can be regarded as an institutional emergency. In such cases, the circumstances that gave rise to the urgency were not foreseeable and were not the result of dilatory conduct or negligence on the part of the procuring entity.

5) Request for quotations method.

Procuring entities may request for quotations for goods, works and services which are readily available in the market and whose costs are below the set thresholds in schedule one of the regulations. It is mandatory for the procuring entity to have a pre-qualified suppliers list which is maintained for effective use of the "request for quotations" procurement method.

Procurement for public projects applies Standard Tender Document (STD) of Government of Kenya. The following STD would be applicable for MHP projects.

- ✓ Standard tender document for procurement of works (buildings and associated civil engineering works,
- ✓ Standard tender document for procurement of works (electrical and mechanical), and
- ✓ Standard tender document for turnkey projects.

MHP projects have aspects of civil works, building works, electrical works, and procurement of equipment. In the event that procurement is undertaken in a single phase, MHP project category is considered to be a combination of the above categories. It is therefore necessary to select the closest category and undertake modifications as required.

The above STDs are available in the Public Procurement Oversight Authority (PPOA) website. PPOA requires that standard tender documents are used with minor necessary modifications. Use of any other tender documents developed by a procuring entity requires prior approval of the PPOA.

STD generally consists of the following:

| | |
|---|---|
| Section I: | Invitation to Tender |
| Section II: | Instructions to Tenderers |
| Section III: | Conditions of Contract |
| Section IV: | Appendix to Conditions of Contract |
| Section V: | Specifications |
| Section VI: | Drawings |
| Section VII: | Bills of Quantities |
| Section VIII: | Standard Forms |

The above components are based on STD of buildings and associated civil engineering works. However, the contents of other types of STDs are almost same.

Specific description has to be prepared according to the format. Especially, specifications, drawings, bills of quantities, and standard forms have to be prepared according to plan and design. It is also necessary to consider evaluation criteria so that all tenders can be evaluated against the same technical and financial base.

In the specifications, it is necessary to strictly specify quantity and quality requirement, guarantee performance order, guidelines and standards that the supplier shall follow, including user training requirements, reporting obligations, and testing and commissioning. It is necessary to conduct supervision of suppliers and specify the quality requirement in the specifications to ensure high work quality.

For drawings, it is a requirement to include facility and general layouts, plan, profile, typical sections of the permanent civil structures including penstock, major dimensions of gates and valves, powerhouse layout, single line diagram, and related facilities of the MHP station.

For bills of quantities, work and equipment quantities need to be specified in a table. The bills of quantity table will be referred to for inspection prior to commissioning in order to assess if the supplier's work has been completed.

### 7.1.2 Procedure of Procurement

Generally, the procurement procedure will take more than six months. The tendering process consists of the following tasks:

- ✓ Preparation of tender document and specifications,
- ✓ Request for Expression of Interest and Pre-qualification (when pre-qualification is conducted),
- ✓ Invitation to tender or advertisement of procurement,
- ✓ Preparation of tender,
- ✓ Bid opening,
- ✓ Bid evaluation, and
- ✓ Contract negotiation and award.

A tendering schedule should be considered and incorporated in the project implementation schedule. A sample procedure and schedule of a general national tender process is shown in the table below.

**Table 7.1.2 Example of Procurement Schedule**

| Work Items | M1 | | | | M2 | | | | M3 | | | | M4 | | | | M5 | | | | M6 | | | | M7 | | | | M8 | | | | M9 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | W1 | W2 | W3 | W4 | W1 | W2 | W3 | W4 | W1 | W2 | W3 | W4 | W1 | W2 | W3 | W4 | W1 | W2 | W3 | W4 | W1 | W2 | W3 | W4 | W1 | W2 | W3 | W4 | W1 | W2 | W3 | W4 | W1 | W2 | W3 | W4 |
| Preparation of tender document and specification | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| (Request for Expression of Interest and Pre-qualification) | | | | | | | | | 🟦 | 🟦 | 🟦 | 🟦 | | | | | | | | | | | | | | | | | | | | | | | | |
| Invitation to tenderer or advertise of procurement | | | | | | | | | | | | | 🟦 | | | | | | | | | | | | | | | | | | | | | | | |
| Preparation of tender | | | | | | | | | | | | | | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | | | | | | | | | | | | | | | | | | |
| Question and reply about tender | | | | | | | | | | | | | | | 🟦 | 🟦 | 🟦 | | | | | | | | | | | | | | | | | | | |
| Bid opening | | | | | | | | | | | | | | | | | | | 🟦 | | | | | | | | | | | | | | | | | |
| Bid evaluation | | | | | | | | | | | | | | | | | | | | 🟦 | 🟦 | 🟦 | 🟦 | | | | | | | | | | | | | |
| Contract negotiation award | | | | | | | | | | | | | | | | | | | | | | | | 🟦 | 🟦 | | | | | | | | | | | |
| Implementation and contract administration | | | | | | | | | | | | | | | | | | | | | | | | | | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 | 🟦 |

Prepared by JET

If funding is provided by an external donor, concurrence processes are required in addition to the above.

### 7.1.3 Qualification

The method for qualification is described in details in Chapter 5 of “Public Procurement and Disposal General Manual” issued by PPOA.

Eligibility criteria need to be described in the bidding document. For MHP projects, at least three projects with similar technical requirements and budgets should be required of the bidders.

Qualification should include the capability, experience, resources, equipment and facilities to install the MHP station. Qualification criteria may relate to:

i) Technical competencies and resources, including the availability of sufficient manpower, the qualifications and experience of key personnel or managers, available equipment, and manufacturing or construction facilities,
ii) Financial position, including financial soundness, and sufficient turnover or sufficient cash flow,
iii) Experience and satisfactory performance of similar contracts, taking into account relevant factors, including similar or comparable references and litigation record.

A project Manager should be assigned and the bidder required including a CV showing that the identified person has the necessary capability and experience.

Pre-qualification is the process that the bidders first participate in, bidding to prove their qualification. Pre-qualification criteria are the basis for short-listing bidders for tendering. In applying this method, the time and costs constraints versus the size and estimated value of the procurement requirement should be duly considered. Generally, pre-qualification is conducted for projects with potentially numerous contractors and tight competition in the tender process.

## 7.2 Construction Supervision

This chapter describes construction supervision works by the Client, which is different from supervision works by the contractor.

General work items of construction supervision by the Client are summarized below.

**Table 7.2.1 Work Items of Construction Supervision**

| Item | Description |
|---|---|
| 1. Overall management | Overall management of the project internally and external correspondence regarding the project to central government, county government, financing institution, etc. as required. |
| 2. Schedule control | Monitoring the official schedule and actual progress of construction works, adjust the schedule amongst the contractors, update the official schedule as required, etc. |
| 3. Quality control | Monitoring and control of the construction materials, methods, equipment and facilities, check the dimension, shape and form of permanent structures and equipment, etc. based on the technical specifications in the contract. |
| 4. Document control | Filing the correspondences and minutes of meetings, preparing the technical report if necessary, control of the approved drawings, on-site instruction and on-site approval, etc. |
| 5. Payment control | Checking the work performance and quantity calculation sheets for payment, assuming the total budget is based on the construction progress. |
| 6. Variation order | Confirming the necessity of alterations, additions and omissions of works, and availability of project budget, issuing the variation order, etc. |
| 7. Safety and health control | Preparing the emergency communication network chart, monitoring the contractor's activities and natural and social conditions surrounding the project site, responding in case of emergency. |

Source: "Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Table 13-1)" published by JICA in 2011 (arranged by WG).

Prepared by WG of MHP

The construction work for a MHP project is a small scale undertaking, but it is necessary to supervise three (3) main different types of work, i.e., civil structures, electrical equipment and distribution facilities. It is necessary to adjust their design and schedule during the construction period.

Because the supervision of construction work needs complicated technical knowledge, it is often necessary for supervision to be implemented under the leadership of the experts, or be entrusted to a consulting firm.

### 7.2.1 Overall Management

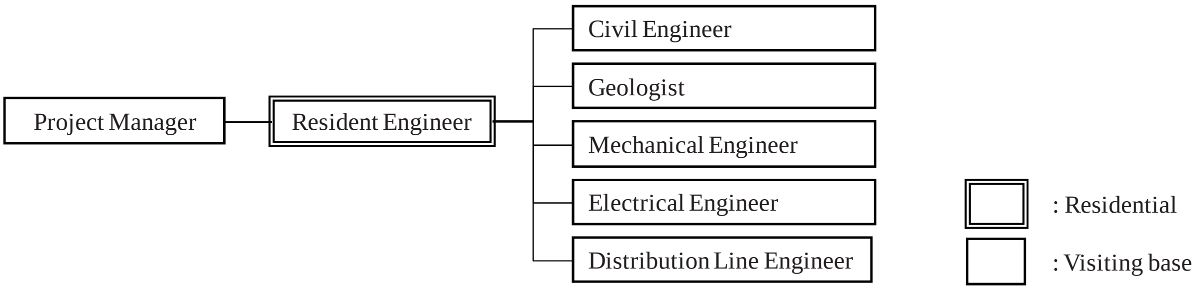
The items related to overall construction management of the project are listed below.

**Table 7.2.2 Items of Overall Management**

| Item | Description |
|---|---|
| 1. Organization management | Organize the management team among the Client, contractors and consultants. |
| 2. Submission control | Manage submissions by the contractors according to the contract. |
| 3. Safety and health control | Establish and operate the management system including basic regulations, regular monitoring items, response manual in case of emergency, etc. |
| 4. Progress report | Define the contents and procedures of reporting by each contractor. |
| 5. Procedure of handover | Prepare the handover procedure from contractor to contractor at milestones and the handover procedure from contractor to client at overall completion. Prepare the project completion report to central government, county government, financing institution, etc., as required. |

Source: "Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Table 13-2)" published by JICA in 2011 (arranged by WG).

A construction supervision team shall be organized for the project. A resident engineer shall be stationed at the site, and at least one personnel and a specialist will visit the site in accordance with the progress of construction work. A sample construction supervision team is shown below.



Source: "Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Figure 13-2)" published by JICA in 2011 (arranged by WG).

**Figure 7.2.1 Sample of Organization of Construction Supervision Team**

### 7.2.2 Schedule Control

This is a task to monitor and control the time schedule in compliance with the actual progress of all the construction activities as explained below.

(1) Management of Construction Schedule

The construction activities will be controlled using the construction schedule. However, actual construction activities often change due to site conditions and/or external factors. The construction schedule, therefore, shall be revised and updated within the contract period.

The construction schedule planned and attached to the contract is the original construction schedule. When the site conditions and/or external factors are different and/or change from the assumed conditions, the construction schedule will be revised and officially adopted as the revised construction schedule.

The work progress is monitored using either the original or the revised construction schedule, by indicating the actual work progress on the construction schedule, and comparing them against each other periodically. In case the actual progress falls behind the schedule, the supervision team shall clarify the reasons and implement countermeasures to catch-up to the schedule.

(2) Management of Key Dates and Milestones

In the construction schedule, some important dates such as starting date of concrete placement, delivery date of the turbine, etc. are set as milestones, and designated as "Key Dates" which have to be adhered to contractually.

If a key date is rescheduled backward or forward, it will influence not only its work but also that of subsequent relevant works. Therefore, the schedules and actual work progress shall be continuously confirmed and the concerned parties notified.

(3) Adjustment of Construction Schedules among Contractors

Civil works, electrical works and distribution works are mutually related to each other for completion of the construction work. Especially, for works which relate to the key dates, it is necessary to confirm the actual progress against the construction schedule at all times. The supervision team shall hold regular meetings in order to adjust the construction schedule of each contractor. In general, regular meetings are organized as follows:

- ✓ Weekly Meeting: It is normally held on the last weekday to clarify the results of the week and the plan of the coming week, and to adjust the related work schedule as required.
- ✓ Monthly Meeting: It is normally held at the end of the month to clarify the results of the month and the plan of the coming month, and to adjust the related work schedule as required.

### 7.2.3 Quality Control

This is a task to monitor and control the quality, such as strength, shape, efficiency, etc., of the permanent structures and equipment as explained below.

(1) Management of Construction Materials

The quality of construction materials, such as filling materials, aggregates, cement, concrete, reinforcement bar, rock bolts, etc., which are used for the permanent structures shall be controlled. The technical requirement and test method of each material will be specified in the technical specifications in the contract, in accordance with Kenya Standard (KS) and/or related international standards. Construction materials for temporary works are not included.

The supervision team shall define the procedure, inspection sheets and required documents to be prepared by the contractor, before the commencement of construction works.

(2) Management of Construction Method

The construction method of each structure is proposed by the contractor for approval. The construction supervision team shall check the construction method in view of validity and safety.

(3) Management of Construction Equipment and Facilities

The construction equipment and facilities used for the construction works are proposed by the contractor for approval. The construction supervision team shall check the quality, quantity, performance, and maintenance plan.

(4) Management of Dimension, Shape and Form

The dimension, shape and form of the permanent structures shall be checked to determine whether permanent structures have been constructed in line with the drawings and the specifications.

In case of concrete structures, it is desirable to check the dimensions and shapes two times, i.e., the form setting condition before concrete placement, and the concrete after its placement.

### 7.2.4 Documents Control

This is a task to record the instructions of the Client and performance of the contractor as explained below.

(1) Letters between the Client and Contractors

Communications between the Client and contractors are to be established by official letters, in principle. These letters shall be issued and filed properly.

1) Numbering of letters

Numbering of letters should be defined before issuing the first letter. Items such as number of letter, issuing place and date, sending address and name of person should be simple and clear in order to organize the record of letters.

2) Letter control

Issuing and receiving of letters should be recorded, and the records should be filled separately. The followings are basic points for writing a letter.

- ✓ One letter shall be for one subject,
- ✓ Name of the relevant structure should be indicated in the captioned title, and
- ✓ Reference number, if necessary, should be indicated alongside the issuing date in the caption.

(2) Minutes of Meetings

Minutes of meetings should be filed after confirmation by concerned parties.

- ✓ Joint Meeting: Client, supervisor and all individual contractors participate in the joint meeting periodically to discuss mainly the construction program.
- ✓ Coordination Meeting: Supervisor meets contractors in turn mainly for the coordination of the programs which are related to one another, and
- ✓ Meeting between persons in charge mainly to discuss daily practical issues.

(3) Technical Reports

These are reports showing clarifications and analysis of special technical issues of the project. Technical reports are prepared by the contractor and/or the consultant and submitted to the Client, as required.

(4) Drawings

Drawings indicate the location, dimensions, materials, etc. of the permanent structures and equipment to be constructed and installed by the contractors. The original drawings are generally included in the contract document.

However, additional drawings are further required for construction as explained below.

1) Drawings issued by Supervisor

The drawings issued by supervisor are called Approval-for-Construction Drawings. They are usually revised versions of the original drawings to suit actual site conditions as required.

It is recommended that a numbering system for the drawings be defined before starting construction. Basically, new number is added at the end of the number of the tender drawing, and the record of revision mentioned there as well.

2) Drawings submitted by the Contractors

The contractor prepares the shop drawings which indicate details of construction works (re-bar bending details, arrangement of anchor bars, etc.). The contractor submits these drawings to the Client for approval before the commencement of related construction activities. The person in charge on behalf of the Client checks and approves these drawing.

The following items should be defined before starting construction work.

- ✓ Format -size and title- of drawings,
- ✓ Number of drawings submitted to the Client and number of the drawing approved by the Client and returned to Contractor,
- ✓ Procedure for submitting drawings for approval,
- ✓ Final signatory on behalf of the Client, and so on.

3) As-built drawings

As-built drawings are compilations of all drawings used for construction activities. These are important for the project operation and maintenance, as well as rehabilitation in future.

Generally, as-built drawings are prepared and submitted by the contractor according to the contract.

(5) Onsite Instructions

Construction supervisor issues onsite instructions. The instructions should mention the payment terms and influence on the construction program. It is recommended that there should be the number, the name of structure and the issuing date and year in the instruction form.

The original is kept by the contractor while the Client and supervisor keep individual copies.

(6) Onsite Approval

The contractor makes a request for inspection; which describes the objective structure, inspection date and inspection contents. Whether the Client might sign it or not depends on the Client's availability and daily presence to conduct the inspection. This should be discussed and decided preferably before the construction work begins.

The supervisor approves the inspection and maintains the original inspection form in his records, while the contractor keeps the copy.

### 7.2.5 Payment Control

In instances where a "progress payment" method is adopted in the contract, it is necessary to confirm the progress of the construction works by the amount of work done and measurement of performance.

(1) Work Performance Investigation

Set up the standard of work performance management in advance. Make a graph for work performance management, comparing measured value according to work performance measurement sheet against the designed one. Thereafter, manage the construction performance to go well with the design.

Generally, the following items are controlled and supervised.

- ✓ Base Line Survey: The contractor carries out a base line survey in the presence of the supervisor,
- ✓ Work Performance Measurement: Dimensions of the structures whose construction has been completed by the time of the inspection are measured and confirmed, and
- ✓ Calculation Sheet: Quantities written in the calculation sheet are checked against the data of the work performance measurement and baseline survey.

(2) Inspection at the Time of Accomplishment of Milestone

It is one of the "progress payment" methods in which a certain amount of payment is paid to the contractor when a milestone has been accomplished.

Examples milestones which can be set are as follows:

- ✓ A certain percentage of the costs is paid when concrete placing work is commenced at the intake weir.
- ✓ A certain percentage of the costs is paid when 30% of foundation concrete has been placed at the intake weir.

Methods of inspection and confirmation are the same as mentioned before.

### 7.2.6 Variation Order

It often becomes necessary to modify the original design, especially civil structures, in accordance with the actual site conditions and/or adjustments to other works during the construction. The design changes shall be carried out according to the procedure for design change stipulated in the contract.

The variations include 3 actions; alterations, additions, and omissions. These include variations of work volume, alterations of characteristics, quality and types of the work, modifications of the levels, base lines, positions and sizes of the structures, variations of the construction order, work additions, and work omissions.

In case the project's procurement budget was provided by a financial institution, it is also necessary to confirm and report the variations to the financial institution concerned, for approval.

### 7.2.7 Safety and Health Management

Construction sites have a lot of hazards which may cause accidents. Moreover, MHP development projects are often located in remote areas. Once an accident or any other fatal disaster occurs, significant time and effort is required to deal with the occurrence. It is therefore necessary to take steps to manage all kinds of situations in order to prevent accidents.

In the first instance, an emergency communication network chart shall be prepared in the early stages of the construction. The network chart shall include essential parties such as the Client, the contractors, police station, hospital, representatives of local residents, etc. and for each the name and telephone number of the contact person.

The supervision team shall oversee and ensure that the contractor is properly executing safety and health control, and also provide instructions for reinforcement and/or improvement, if necessary.

- ✓ Monitoring of safety measures on the construction site by periodic site patrol,
- ✓ Monitoring of disposal status of construction waste by periodic site patrol,
- ✓ Monitoring of natural conditions, especially water pollution due to construction activities, by periodic patrol and water quality inspection,
- ✓ Monitoring of social conditions, especially traffic conditions caused by construction activities, by periodic patrol,
- ✓ Confirmation of the points of reinforcement and improvement at weekly and/or monthly meetings.

The supervisor shall also instruct the contractor to undertake the following items:

- ✓ Convening a daily morning safety assembly before work begins to confirm the daily tasks, and confirm awareness of the precautions and perform physical exercise,
- ✓ Indicating safety targets (priority safety issues corresponding to the progress and characteristics of the ongoing work should be set up on a monthly basis to raise awareness amongst the laborers.), and
- ✓ Preparation of a daily safety report; which should be perused by the supervisor as needed.

## 7.3 Civil Works

### 7.3.1 Inspection Items for Construction Supervision

Major inspection items of civil works are summarized in the table below.

**Table 7.3.1 Major Inspection Items of Civil Works**

| Inspection Items | Description | Timing |
|---|---|---|
| 1. Confirmation of right of way and reference survey points. | Joint inspection for confirmation of borders and reference points by land owners, contractor and supervisor. | Before commencement of construction works. |
| 2. Confirmation of temporary accommodations and areas. | Joint inspection for confirmation of borders and areas by land owners, contractor and supervisor. | Before mobilization of the contractor. |
| 3. Care of River Flow. | Construction work under conditions of river flow, diversion and care of river flow is necessary.<br><Related Structure><br>Headwork, powerhouse and tailrace outlet. | As required during the construction period in accordance with the progress of works. |
| 4. Confirmation of Foundation Conditions. | Joint inspection for confirmation of the foundation ground conditions to avoid differential settlement.<br><Related Structure><br>Headwork, headpond, penstock, powerhouse and other buildings. | After excavation and before concrete placement. |
| 5. Protection of Water Leakage. | Joint inspection for sealing condition of each gate and stoplog.<br><Related Structure><br>Intake, power canal, silting basin, headpond, and tailrace outlet. | During construction and after installation of gate and stoplog. |
| 6. Leveling control. | Reference point management.<br><Related Structure><br>Headwork, power canal, and powerhouse. | During construction period. |
| 7. Steel penstock | Factory inspection and site inspection of welding. | Before delivery of the steel, during and after erection at the site. |
| 8. Connection points with electrical works | Arrangement and confirmation of electrical works at connection points (anchor bars, opening, etc.) in powerhouse. | Before and during erection works. |
| 9. Care of roads | Public road and project maintenance road shall be cared for properly. | During construction period. |

Source: “Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Table 13-6)” published by JICA in 2011 (arranged by WG).

### 7.3.2 Procedure of Approval and Confirmation on Site

Inspection, approval and confirmation of the construction activities are carried out in a number of stages, in order of importance.

If inspection, approval and confirmation of all construction activities are carried out using the same methods, the procedure will become too detailed and result in significant amount of work and time consumption for both the contractor and the supervision team. As a result, the construction period will be long and the construction costs expensive.

**Table 7.3.2 Procedure for Approval and Confirmation**

| Grade | Form | Application | Process by Supervisor | Example |
|---|---|---|---|---|
| A | Covering letter with the transmittal | ✓ Approval item by supervisor written in the contract document.<br>✓ Milestone for payment<br>✓ Design change,<br>✓ Minutes of meeting of important issue, etc. | Supervisor signs the transmittal at the time of approval. If some defects are found, re-submission is required. Finally, a copy is returned to the contractor. | Approval of major construction materials (concrete, re-bar, etc.), commencement of works (excavation of waterway, etc.) |
| B | Application for Approval | ✓ Approval item which is a relatively minor issue written in the contract document.<br>✓ Minutes of meeting,<br>✓ Other issues not mentioned above but required by the contractor. | Stamp of approval is sealed on the application form, and a copy is returned to the contractor. | Approval of construction materials, approval of concrete placement, etc. excluding milestones. |
| C | Covering letter only | Issues which are written in the specification as submissions. | Receipt stamp is sealed on the letter, and a copy is returned to the contractor. | Submission of weekly and monthly reports. |
| D | Verbal communication | Confirmation at the site without approval. | Send the person responsible for checking and confirming to the site. If some issues arise, minutes of the meeting are prepared by the contractor and submitted for approval. | Concrete test at laboratory, confirmation of land border, etc. |

Source: "Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Table 13-9)" published by JICA in 2011.

## 7.4 Electrical Equipment

Construction management for electrical equipment is partially performed under the same rules for the civil works, with some differences. In principle, rules for the civil works will similarly be applied to electrical equipment including: design documents, approval documents, final documents, completion documents and manual of equipment.

In regards to payment, it is stipulated in the contract how to authorize payment for fabrication and installation. Further, it is common for payment to be authorized upon witnessing equipment tests at the factory, upon delivery or on the installation date at the construction site, and on acceptance of the commissioning test. In the case of MHP projects, the construction costs of electrical equipment may be paid in a lump sum at the time of acceptance of the commissioning test, for example.

Two key points of construction supervision for electrical equipment are:

<u>Interface with the Civil Works</u>

The civil contractor and electrical equipment supplier are generally different service providers. Coordination between the two contractors is one of the most important aspects of construction management and supervision.

Some openings and embedded metals shall be prepared in the concrete to allow electrical equipment to be fixed, including:

- ✓ Blockouts in the concrete floor and foundation metal,
- ✓ Location of anchor bars embedded in concrete for electrical apparatus,
- ✓ Space for cables to be installed after the civil works, etc.

The concrete works are executed by the civil contractor. Therefore, required information and materials shall be clarified before approval of working drawings for the civil contractor. These requirements will be reflected in the approved drawings for the civil contractor.

Rigorous Execution of Inspections and Tests

Control of the turbine efficiency and generator efficiency, and the error allowance of fabrication and installation are important to maintain the quality of electrical equipment. Inspections, tests and measurements procedures specified in the technical specifications to control them should be executed by the designer, or submitted for approval by the contractor. It is important to carry out such inspections, tests and measurements correctly in the factory and at the construction site for quality control of electrical equipment.

### 7.4.1 Acceptance of the Turbine Efficiency

Turbine efficiency is an important parameter for a hydropower generation scheme. To ensure the planned turbine efficiency, the following measures are generally adopted for procurement of the turbine:

Performance Order

The guaranteed level of efficiency of the turbine is stipulated in the procurement specifications and/or the tender specifications. In case the actual efficiency of the turbine does not achieve the guaranteed efficiency, the supplier has an obligation to pay the penalties.

Model Test Before Fabrication

Execution of the model test of the turbine is stipulated in the contract documents in order to confirm performance parameters such as efficiency, runaway speed, cavitations characteristics, etc. The model test is executed in the factory upon completion of fluid design and before the commencement of fabrication of the turbine based on international standards prescribed by IEC (International Electrical Committee) or equivalents.

However, the model test is too expensive and therefore influences construction costs of the MHP project. Therefore, there are instances where a turbine model test can be omitted in a MHP project. Instead, the efficiency can be confirmed and ensured by using the following alternatives:

- ✓ Confirmation by Computational Fluid Dynamics (CFD) analysis,
- ✓ In case of application of a completed type of turbine developed in series, or a reverse pump turbine, confirmation can be done using performance data generated during product development by the manufacturer.

### 7.4.2 Acceptance of the Generator Efficiency

Generator efficiency is also an important parameter to control the economy of a hydropower scheme, and the efficiency stipulated in the contract is guaranteed by supplier.

There are two measurement methods to confirm the generator efficiency as follows:

- ✓ Measurement in the factory with generator assembled, and carrying out a revolving test,
- ✓ Measurement on site using an actual machine at the time of a filed acceptance test.

The test methods are prescribed by international standards such as IEC, and are applied as well.

For a MHP project, the revolving test carried out in the factory may be omitted with the aim of reducing cost, and it is common to measure efficiency using an actual generator on site.

### 7.4.3 Shop Test

A shop test is important for checking whether generation apparatus is produced according to the specifications, the contract, and the approved drawings. Confirmation of the factory test data and all witness tests must be carried out carefully to perform quality control impeccably.

An example of a witness test is shown below. When purchasing a finished product or a general purpose product, witness tests may be omitted. However, it is necessary for the manufacturer to submit factory test data for the supervisor to confirm.

**Table 7.4.1 Major Items of Witness Test for Generation Equipment**

| Inspection Equipment | Test Item |
|---|---|
| Turbine | ✓ Model turbine test,<br>✓ Dimension measurements of draft tube liners,<br>✓ Dimension measurements and nondestructive test of a spiral casing,<br>✓ Nondestructive test of a runner (before finishing machining),<br>✓ Nondestructive test of a runner (after finishing machining),<br>✓ Nondestructive test of guide vanes (before finishing machining),<br>✓ Dimension measurements of guide vanes,<br>✓ Dimension measurements and nondestructive test of a top cover, a bottom cover and a guide ring,<br>✓ Turbine main shaft alignment test and nondestructive test,<br>✓ Turbine temporary assembly test,<br>✓ Governor performance test,<br>✓ Performance tests for turbine auxiliary equipment, etc. |
| Generator | ✓ Dimension measurements and nondestructive test of a top and bottom bracket,<br>✓ Dimension measurements and nondestructive test of guide bearings and thrust bearing,<br>✓ Generator main shaft alignment test and nondestructive test,<br>✓ Combination and revolving balance alignment test of rotor spoke, turbine and generator main shaft,<br>✓ Dimension measurements and withstand voltage test of stator coils,<br>✓ Dimension measurements and withstand voltage test of rotor coils,<br>✓ Dimension measurements and withstand voltage test of a stator,<br>✓ Dimension measurements and withstand voltage test of a rotor,<br>✓ Performance test and withstand voltage test of an exciter,<br>✓ Dimension measurements, withstand voltage test and performance test of a Neutral Grounding Resistor (NGR), etc. |
| Main Transformer | ✓ Dimension measurements,<br>✓ Withstand voltage test,<br>✓ Measurements of various fixed number, etc. |
| Control panels, Switch Gears, etc. | ✓ Dimension measurements<br>✓ Performance test (open-close test, interlock system test, sequence test, etc.)<br>✓ Withstand voltage test, etc. |

Source: “Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Table 13-10)” published by JICA in 2011.

### 7.4.4 Site Test (Acceptance Test)

The site test is performed in order to determine the acceptance of the generation apparatus. Attention shall be paid to performance of the power plant, purchase conditions, and construction quality in particular. As for factory test data, measurements at the time of installation at the site and site test data are necessary as initial values for comparative observation of changes due to aging of the generation facilities.

The major items of site tests are listed below.

## Table 7.4.2 Major Items of Acceptance Test for Generation Equipment

| Inspection Equipment | Test Item |
|---|---|
| Turbine | ✓ General structural inspection,<br>✓ First revolving test,<br>✓ Bearing running in test,<br>✓ Revolving balance alignment test,<br>✓ Protection system test,<br>✓ Load rejection stop test,<br>✓ Emergency stop test,<br>✓ Quick stop test,<br>✓ Quick stop test by power source (oil pressure, voltage) drop of guide vane servomotor,<br>✓ Load test (continuous operation test with full output),<br>✓ Remote control and supervision test (includes alarm test), etc. |
| Generator | ✓ General structural inspection,<br>✓ First revolving test,<br>✓ Bearing running in test,<br>✓ Revolving balance alignment test,<br>✓ Measurements of insulation resistance and withstand voltage test,<br>✓ Measurements of various fixed number of the generator,<br>✓ Check of phase sequence,<br>✓ No-load saturation test,<br>✓ 3 phase short-circuit test,<br>✓ Calculation of short-circuit ratio and voltage regulation,<br>✓ Measurements of deviation factor of voltage waveform,<br>✓ Operation test combined with excitation system,<br>✓ Shaft voltage/current measurements,<br>✓ Protection system test,<br>✓ Load rejection stop test,<br>✓ Emergency stop test,<br>✓ Quick stop test,<br>✓ Load test (continuous operation test with full output),<br>✓ Remote control and supervision test (includes alarm test), etc. |
| Main Transformer | ✓ General structural inspection,<br>✓ Measurements of various fixed number of the transformer,<br>✓ Measurements of insulation resistance,<br>✓ Withstand voltage test, etc. |
| Control panels, Switch Gears, etc. | ✓ General structural inspection,<br>✓ Performance test (open-close test, interlock system test, sequence test, etc.),<br>✓ Withstand voltage test,<br>✓ Remote control and supervision test (includes alarm test), etc. |

Source: “Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Table 13-11)” published by JICA in 2011.

## 7.5 Distribution Facilities

### 7.5.1 Inspection Items for Construction Supervision

The major inspection items of distribution facilities are summarized in the table below.

Table 7.5.1 Major Inspection Items of Distribution Facilities

| No. | Inspection Items | Description | Timing |
|---|---|---|---|
| 1 | Pole positions and wiring routes | To confirm pole positions with land owner, contractor and supervisor. | Before the construction. |
| 2 | Supporting structures | To plumb the pole up,<br>To check the pole length in ground,<br>To check foundation | During and after the installation. |
| 3 | Guys | To check the linkage of anchor, and<br>To check the height of guy wire. | During and after the installation. |
| 4 | Grounding | To check the depth of grounding electrode and grounding wire installation method, and<br>To check the grounding resistance. | During and after the installation. |
| 5 | Cross arms | To check the installation condition of cross arm, arm tie and band. | During and after the installation. |
| 6 | Insulators | To check the type and installation method. | During and after the installation. |
| 7 | Conductors | To check the dip,<br>To check ground height and distance between conductor and surrounding object,<br>To check fixing condition, and<br>To measure the insulation resistance. | During and after the installation. |
| 8 | Transformers | To check the installation condition | During and after the installation. |
| 9 | Switches | To check the installation condition, and<br>To check the fuse value of cutout. | During and after the installation. |
| 10 | Watt-hour meters | To check the place and height,<br>To check the wiring, and<br>To measure the insulation resistance. | After the installation. |

Source: “Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Table 13-12)” published by JICA in 2011.

### 7.5.2 Quality of Construction Materials

Quality control of materials for distribution facilities should be chosen from witness test at the factory, while quality inspection and sampling test should be according to the level of importance and quantity.

### 7.5.3 Procedures of Approval and Confirmation on Site

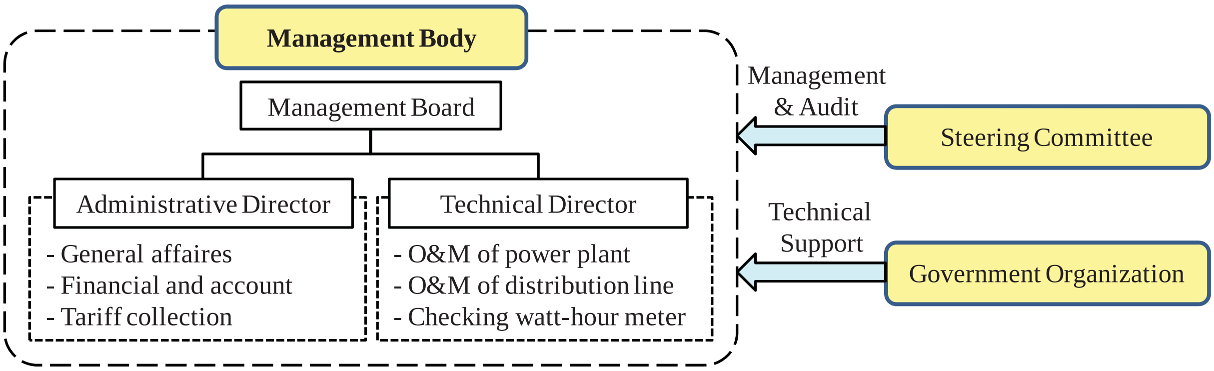
Inspection, approval and confirmation of construction activities are carried out in various stages depending on the level of importance and construction stage, in the same way as the civil works.

# CHAPTER 8 OPERATION AND MAINTENANCE

## 8.1 Establishment of Management Body

It is expected that electricity consumers of a MHP station in a remote area are less than 1,000 households and some enterprises. This scale is too small to be managed by Government and/or parastatals. As a result, the operation and maintenance of a MHP station has to be executed by local residents.

The management body of a MHP station shall be prepared simultaneously with the construction stage of the MHP project. Organization of the management body constituted by the local community may be as follows:



Source: "Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Table 14-1)" published by JICA in 2011 (arranged by WG).

**Figure 8.1.1 Example of Organization of Management Body**

Each component of the organization functions as follows:

### (1) Steering Committee

The steering committee is responsible for project management in general. Its members consist of officials from local authorities, beneficiaries of the rural electrification, supervisors of the electricity project, and representatives from the agencies financially supporting the construction of the project, if any.

The steering committee is responsible for:

- ✓ Establishing management policies,
- ✓ Assigning and removing officers executing the management,
- ✓ Setting an electricity tariff (submitting an electricity tariff to a higher institution, if any, for approval),
- ✓ Approving important repair and renovation plans.,
- ✓ Financial audit, etc.

The steering committee should hold a meeting every quarter of the year to supervise and guide the operations.

### (2) Technical Support Organization

Since the MHP project will be operated by staff members with inadequate technical experience, it is important to arrange for additional support to be provided by a special organization such as a public electricity corporation which specializes in operation and maintenance of electricity facilities.

The technical support organization is responsible for;

- ✓ Handling trouble-shooting at the initial stage, upon commencement of operation,
- ✓ Regular checks and repairs,
- ✓ Instructions for replenishment of spare parts, etc.

If the above responsibilities are neglected, the equipment may be out of order often and the life span of the MHP station will become considerably shorter. Therefore it is desirable to enter into an umbrella agreement with the organization to get technical support from the construction stage.

### (3) Management Body

Members of the management board are appointed by the steering committee to execute the operation and maintenance of MHP.

The management body consists of two departments: administrative and technical. The major tasks of each department are as listed below and explained in Chapter 8.3.

1) Administrative Department

- ✓ Personnel and labor affairs (employment, pay control, working control),
- ✓ General affairs (Meetings, document control, control of office equipment &consumables, safety control, miscellaneous affairs),
- ✓ Budget control (Business planning, fiscal budget, control of revenues and expenses),
- ✓ Accounting (Bookkeeping, account settlement, asset management),
- ✓ Fund administration (Cashier, fund administration),
- ✓ Customer management (Customer management, bill collection),
- ✓ Procurement (Contract for construction work, contract for maintenance work, purchases),
- ✓ Inventory control (Warehouse control, control of inventory goods and fuels), etc.

In implementing the above tasks, responsibilities shall be simplified and implemented in order of a priority to be established.

2) Technical Department

- ✓ Operating the MHP station as well as maintaining and controlling the facilities,
- ✓ Maintaining and checking the distribution facilities as well as controlling and repairing spare parts,
- ✓ Understanding well about the operation conditions of the MHP station and giving instructions for startup or shutdown,
- ✓ Checking watt-hour meters, etc.

The constitution of the management body will depend on the scale of consumers as shown below.

**Table 8.1.1 Approximate Numbers of Members of Management**

| Position | Unit | Appropriate Number of Staff | | | |
|---|---|---|---|---|---|
| Scale of consumers | Nos. | Less than 200 | 200 – 500 | 500 – 1,000 | More than 1,000 |
| Scale of MHP | kW | Less than 40 | 40 – 100 | 100 – 300 | More than 300 |
| 1. Director | Person | 1 | 1 | 1 | 1 |
| 2. Deputy director | Person | – | – | 1 | 2 |
| 3. Administrator | Person | 1 | 2 | 2 | 4 |
| 4. Plant Operator | Person | 2 | 4 | 4 | 5 |
| 5. Distribution staff | Person | 2 | 2 | 2 | 3 |
| Total | Person | 6 | 8 | 10 | 15 |

Source: "Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Table 14-1)" published by JICA in 2011.

## 8.2 Financial Management

The financial management of a MHP station is important to achieve the sustainable operation of the power generating service. The financial conditions require a balance between income from electricity tariff and the expenditures of MHP station and distribution system.

For sound management, it is important to set an electricity tariff that will not cause a deficit. It is desirable to employ a tariff system that ensures fairness and transparency and is simple and easy to operate based on the explanation of necessary expenditures to residents.

### 8.2.1 Necessary Expenditure

The following expenses are generally taken into account for MHP operation.

**Table 8.2.1 Required Expenses of MHP Operation**

| Category | Description |
|---|---|
| 1. Personnel Expenses | Calculate personnel costs -salaries and allowances of persons in charge of office management, operators and other employees. |
| 2. Administrative Expenses | Calculate all the administrative expenses excluding the personnel expenses of the management body but including expenses for the office's electricity use, administrative commodities and others.<br>It is estimated that administrative expenses amount to about 60 to 120% of personnel expenses. |
| 3. O&M Expenses of Facilities | Calculate the expenses for power facilities' maintenance needed for normal operation including the costs of machinery tools, oils, spare parts, etc. |
| 4. Cost Depreciation | This is a cost associated with changes in the properties of equipment e.g. its value distributed over their life span. |
| 5. Reserved Fund for Overhaul | Accumulate a fund to inspect and overhaul the electrical components and equipment. Since the inspection and overhaul will be conducted every several years by manufacturers, a large budget is needed. |
| 6. Others | Calculate expenses for taxes, insurances, loyalty, etc. |

Source: "Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Chapter 14.2)" published by JICA in 2011 (arranged by WG).

Regarding the cost depreciation, it is normally supported by aid or a subsidy in the case of rural electrification projects because of the following reasons:

- ✓ Electricity tariff set with cost depreciation will become quite expensive,
- ✓ An expensive tariff makes it difficult for customers to afford electrification, and
- ✓ Rural electrification of households is not attained even if the power source has been developed.

Therefore, it is recommended that the electricity tariff is set without the cost depreciation of fixed assets to make it affordable for subscribers.

If the cost depreciation is not calculated and reflected in the electricity tariff, the facilities renewal costs will not be accumulated. In other words, if the facilities break down, power generation will stop and the areas will be un-electrified as before. In order to prevent such a problem, a reserved fund for overhaul should be taken into account.

### 8.2.2 Electricity Tariff

Generally, the electricity tariff is divided into the following two charges:

| | |
|---|---|
| Fixed charge: | a charge not related with the amount of electricity consumed. |
| Consumption charge: | a charge related with the amount of electricity consumed. |

In case of small scale rural electrification projects, a fixed charge is commonly accepted to save for operation and maintenance costs of the MHP station. In case of relatively large scale electrification projects, a fixed charge is sometimes called a basic charge and depends on the capacity of the watt-hour meter.

The average electricity tariff per kWh shall be set above the cost price per kWh to be sold or consumed. The power demand is expected to be unstable for about one year after the commencement of power generation. Therefore, the amount of energy consumption used to estimate the electricity tariff should be adopted based on the value two or three years after the commencement of power generation.

A sample breakdown of the unit generation cost, which is basic data for setting the electricity tariff, is shown below.

**Table 8.2.2 Sample of Breakdown of the Unit Generation Cost**

| Item | Unit | Middle Scale | Large Scale |
|---|---|---|---|
| **Condition of Electrification** | | | |
| 1. Number of household | nos. | 300 | 1,000 |
| 2. Distance of distribution line | km | 15 | 35 |
| 3. Monthly energy consumption per household | kWh/month | 15 | 40 |
| 4. Installed capacity | kW | 55 | 300 |
| 5. Annual energy consumption | MWh/year | 54 | 480 |
| 6. Monthly energy consumption | MWh/month | 5 | 40 |
| 7. Number of employees | person | 6 | 12 |
| **Cost Estimation on Monthly Bases** | | | |
| 1. Employment cost | L.S. | 300 | 1,020 |
| 2. Overhead cost | L.S. | 300 | 1,020 |
| 3. O&M cost | L.S. | 200 | 200 |
| 4. Depreciation cost | L.S. | 0 | 0 |
| 5. Provision for Overhaul | 10% | 80 | 224 |
| 6. Other expenses | 5% | 40 | 112 |
| **Total** | | 920 | 2,576 |
| **Unit Cost per kWh** | US Cent/kWh | 20.4 | 6.4 |
| **Monthly Expenses for Electric Energy per Household** | US$/month | 3.1 | 2.6 |

Source: “Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Table 14-4)” published by JICA in 2011.

### 8.2.3 User Charges

Generally, an electricity user is required to pay the following charges at the time of connection.

**Table 8.2.3 Required Expenses of MHP Operation**

| Category | Description |
|---|---|
| 1. Cost of Service Drop Installation | Where a watt-meter is installed on a power pole, a service drop from the power pole to the subscribed house is needed. The line extension shall be around several meters to tens of meters, depending on the location. |
| 2. Cost of Indoor Wiring Work | It is the cost of indoor wiring with smaller cords and installing a circuit breaker box. |
| 3. Cost of Watt-meter Installation | It is the cost of equipment to measure kWh which a subscriber consumes. In some cases, it is installed at the expense of the management body. |
| 4. Deposit | There are cases where a deposit equivalent to one-or-two months’ electricity fee is needed as a guarantee for the payment of electricity bills. The management body may use it for operation expenses in the initial period of electrification. |

Source: “Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Chapter 14.2)” published by JICA in 2011 (arranged by WG).

### 8.2.4 Billing System

The normal billing system for rural electrification is Metering-Billing-Collection (MBC).

A series of procedures need to be established for MBC including: application from subscribers, subscription contract singing, checking electricity consumed at subscribers’ houses, and issuing and paying electricity bills.

In cases where subscribers fail to pay their bills, measures for coping with non-payment should be taken into consideration. It is important not only from an income perspective but also as a discipline aspect of management, which is also part of the management of the accounting system.

### 8.2.5 Balance Sheet

The manager shall monitor the financial conditions of the MHP station by simple balance calculation between the income from the electricity tariff and expenses of the MHP station, in order to maintain sound management.

The balance calculation indicates the comparison of estimates and actual achievements. In case there are differences between the estimates and actual achievements, it is necessary to explore the reasons, and take them into consideration for improvement in management. These improvements may include: mitigation of losses, adjustment of maintenance and/or repair schedule, etc., and adjustments should be used to calculate estimates for the next few months and for the next year.

An example of a simple balance calculation sheet is shown below. It should be noted that the entire financial balance of account needs to be calculated with a detailed breakdown of all incomes and expenditures.

**Table 8.2.4 Example of Balance Calculation Sheet**

| | | |
|---|---|---|
| Monthly Provision | 10% | of revenue |
| Miscellaneous | 5% | of salary + overhead + O&M cost |
| Tariff Rate | 22 | cent/kWh |

| | Electricity | | | Revenue | | | Expenditure | | | | | | | Cost per kWh | Profit | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | Generation kWh | Consumption kWh | Loss % | Invoice | Revenue | Loss % | Salary | Overhead | O&M | Misc. | Sub-total | Provision for Overhaul | Total | $/kWh | $ | % |
| Jan | 5,869 | 4,850 | 17% | 1,067 | 1,014 | 5% | 300 | 300 | 200 | 40 | 840 | 101 | 941 | 0.17 | 73 | 7% |
| Feb | 6,081 | 5,110 | 16% | 1,124 | 1,069 | 5% | 300 | 300 | 200 | 40 | 840 | 107 | 947 | 0.16 | 122 | 11% |
| Mar | 6,344 | 5,200 | 18% | 1,144 | 1,087 | 5% | 300 | Record | | 40 | 840 | 109 | 949 | 0.16 | 138 | 13% |
| Apr | 5,924 | 5,020 | 15% | 1,104 | 1,049 | 5% | 300 | 300 | 200 | 40 | 840 | 105 | 945 | 0.17 | 104 | 10% |
| May | 6,000 | 5,000 | 17% | 1,100 | 1,045 | 5% | 300 | | | 40 | 840 | 105 | 945 | 0.17 | 100 | 10% |
| Jun | 6,000 | 5,000 | 17% | 1,100 | 1,045 | 5% | 300 | Plan | | 40 | 840 | 105 | 945 | 0.17 | 100 | 10% |
| Jul | 6,000 | 5,000 | 17% | 1,100 | 1,045 | 5% | 300 | 300 | 200 | 40 | 840 | 105 | 945 | 0.17 | 100 | 10% |
| Aug | 6,000 | 5,000 | 17% | 1,100 | 1,045 | 5% | 300 | 300 | 200 | 40 | 840 | 105 | 945 | 0.17 | 100 | 10% |
| Sep | 6,000 | 5,000 | 17% | 1,100 | 1,045 | 5% | 300 | 300 | 200 | 40 | 840 | 105 | 945 | 0.17 | 100 | 10% |
| Oct | 6,000 | 5,000 | 17% | 1,100 | 1,045 | 5% | 300 | 300 | 200 | 40 | 840 | 105 | 945 | 0.17 | 100 | 10% |
| Nov | 6,000 | 5,000 | 17% | 1,100 | 1,045 | 5% | 300 | 300 | 200 | 40 | 840 | 105 | 945 | 0.17 | 100 | 10% |
| Dec | 6,000 | 5,000 | 17% | 1,100 | 1,045 | 5% | 300 | 300 | 200 | 40 | 840 | 105 | 945 | 0.17 | 100 | 10% |
| | 72,218 | 60,180 | 17% | 13,240 | 12,579 | 5% | 3,600 | 3,600 | 2,400 | 480 | 10,080 | 1,262 | 11,342 | 0.17 | 1,237 | 9.8% |

| | | |
|---|---|---|
| Electricity | (a) Energy generation (kWh/month): | Value at the end of generator |
| | (b) Energy consumption (kWh/month) | Value at the User end, watt-hour meter value |
| | (c) Distribution Losses | Technical energy loss by distribution line |
| Revenue | (d) Amount of invoice (Monetary Unit) | Corresponding to item (b), monthly sales of energy. |
| | (e) Amount of revenue (Monetary Unit) | Corrected amount by due date of the month to be revised when the payment is made. |
| | (f) Recovery rate (%) | When the payment is made, table shall be revised. |
| Expenditure | (g) Salary (Monetary Unit) | Monthly salary cost |
| | (h) Administration cost (Monetary Unit) | Expenses for operation of the office |
| | (i) Operation and maintenance cost (Monetary Unit) | Spare parts, repair, maintenance cost |
| | (j) Other cost (Monetary Unit) | Taxes, royalty |
| | (k) Deposit (Monetary Unit) | Reserve fund for overhaul |
| | (l) Total | (g)+(h)+(i)+(j)+(k) |
| Generation and Profit | (m) Unit cost per kWh (Monetary Unit/kWh) | (l)/(b) |
| | (n) Monthly balance (Monetary Unit) | (l) – (b) |
| | (o) Profit-earning ratio (%) | Monthly Basis |

Source: "Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Chapter 14.2)" published by JICA in 2011 (arranged by WG).

### 8.2.6 Management During Initial Stage

Customers of a new distribution system increase over time. Especially, customer numbers increase from the initial stage up to 1 to 2 years after the commencement of power generation. This means that income from the electricity tariff also increases over time.

As a result, revenue from the electricity tariff does not meet the operation expenditures of the MHP station and distribution system at the initial stage in most cases, and it is necessary to put some financial measures in place.

The following measures can be undertaken:

i) To allocate the security deposits from subscribers (paid upon signing-up) to operation funds for the time being,
ii) To borrow from a lending institution, and
iii) To obtain financial assistance from an aid agency and/or a governmental institution.

i) and ii) above are liabilities which need to be compensated and repaid. Allotted to these repayable sources are shares of the profits and/or surplus generated by the management body.

In the case of a further lack, electricity tariff system needs to be revised.

## 8.3 Operation and Maintenance

In order to supply electricity to customers for 24 hours continuously at all times, functions of the MHP station and distribution system shall be maintained in good condition for proper power generation. Furthermore, customer support is required.

Administrative and technical activities are essential to realize uninterrupted proper power generation and supply. Essential issues of operation and maintenance activities are explained hereafter. However, actual activities shall be adjusted for each MHP station and distribution system.

### 8.3.1 Administrative Works

Required administrative works are summarized in the table below.

## Table 8.3.1 Major Administrative Works for a MHP Station

| Component | Item | Activities |
|---|---|---|
| General Affairs | Labor Management | Work management for technical staff, such as work shift. |
| | Operational Coordination | Providing places and opportunities for coordination amongst those in charge. |
| | Safety control | Managing the safety of electric power facilities from a technical point of view. |
| | Document Control | Storage and compilation of operation plans and records such as;<br>- Daily/weekly/monthly/annual plans and reports,<br>- Maintenance and repair plans and records,<br>- Accident and emergency response records, etc. |
| Med-term Planning | Repair Plan | Plan for repair for up to 5 years and estimate of the budget. |
| | Inspection Plan | Plan for periodic inspections according to facilities and equipment and estimate of the budget. |
| | Replacement Plan | Plan for tools and parts replacement to maintain the performance and quality of equipment, parts and oil of facilities, and estimate of the budget. |
| Asset Management | Equipment ledger | Technical division is responsible for reporting in a case where any change happens due to a disaster or a repair. |
| | Inventory Book of Parts | Technical division is responsible for reporting a utilization schedule of parts and their prospects. |
| Complaint and Request Response | Accidental Service Interruption | Since the working group that supervises the equipment causing the fault handles the restoration. |
| | Abnormal Voltage | Since the working group that supervises the equipment causing abnormal voltage takes charge of the investigation and countermeasures. |
| | Malfunction of Watt-hour Meters | Responses to complaints and requests to the malfunction of watt-hour meters, such as problems with the circular plate. |
| | Check of Watt-hour Meters | It is important to check a watt- hour meter in a case where a large error is suspected. |
| Customer support | Technical review of Application | It is to check the need for additional distribution facilities in the case of the increase in electronic products of current customers. |
| | Connection Setup | Construction work in response to customer's application for electric power receiving, such as setting a watt- hour meter and a service drop for new customers or replacement of a watt- hour meter in response to current customers. |
| | Meter Reading | Read a number of watt- hour meters every month or at agreed intervals. |
| | Issue of Invoice | Issue the invoice to customers based on the meter reading. |
| | Temporary Connection and Removal | Set up and remove a watt-hour meter in the case of a temporary use of electricity, such as construction work. |
| | Removal of Watt-hour Meters | Remove watt-hour meters when customers stop the use of electricity such as service cancellation. |

Source: "Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Chapter 15.1)" published by JICA in 2011 (arranged by WG).

### 8.3.2 Civil Structures

In order to realize the planned functions of the MHP station, the civil structures shall be operated and maintained properly. The major operation activities for civil structures are gate operation and inspection.

In fact, many hydropower stations experience reduction of power generation capability because of degradation of maintenance due to lack of budgets and/or insufficient takeovers, and so on. That would cause inattention to fundamental maintenance activities, and/or delays in detection of damages or defects.

In order to avoid such situations, maintenance activities shall be systematically executed, reported and recorded even if no damages or defects are identified, in order to ensure timely actions and sustainable maintenance activities in the long term.

All operation and maintenance activities shall be recorded, filed and kept in the station. The records shall consist of the following information:

- ✓ Names of staff involved, date and time, weather conditions, locations,
- ✓ Identified indications, damages and/or defects with photographs as required,
- ✓ Regular maintenance activities such as cleaning of drain ditch, repainting of steel cover, replacement of security light lamp, and so on.

### (1) Operation

The following major operations are required:

<u>Regular Operation</u>

- ✓ Clearing floating debris on water surface of river in front of the intake, along the power canal, the head pond, etc.,
- ✓ Flushing sediments at the intake weir, the de-silting basin and/or the head pond, etc.,

<u>Special Operation</u> (as required)

- ✓ Draining or re-filling water from or to the penstock.

The above operations will be carried out with gates and valves installed in the civil structure. In case the integrated control system is installed in the power station, regular operation is executed by the system. If not, operation of the gates shall be executed by the station staff.

#### 1) Regular Operation

Generally, the following gates are installed in the civil structures:

- ✓ Intake Gate and Tailrace Gate

  These gates are opened during power generation, and closed during inspection of the turbine and generator and/or in case of emergency.
- ✓ Sand Flush Gate and Drainage Gates

  The sand flush gate is installed at intake weir, and drainage gates are installed at de-silting basin and/or head pond. These are installed for sand drainage operations. Sedimentation progress dependings on each MHP site, as well as each structure. Appropriate frequency of operation shall be determined through the monitoring of sedimentation after commencement of power generation in each MHP station.

Detailed operation rules for each gate will vary depending on the scale of the gate, and the rules might be prepared by the contractor. In general, there are two basic regulations of gate operation:

- ✓ A gate opening speed has limitation in order to avoid any adverse effects of a quick water rise in the downstream reach.
- ✓ A gate opening height has limitation in order to avoid damage to gate bottom lips caused by cavitations phenomenon.

#### 2) Special Operation

Water draining operations are necessary for special inspections or in case problems appear along the waterway. Conversely, water filling operations are required to resume the power generation. In principle, these operations shall be carefully performed during daytime in order to avoid any accidents.

Water draining or filling operations are for replacement of water and air in the penstock. Special attention shall be paid to control incoming and outgoing air in the penstock to avoid the following worst-case damages:

- ✓ Crushing of the penstock due to shortage of air supply during water draining operation,

- ✓ Destruction of the penstock valve due to air pressure during water filling operation,

In order to avoid any damage during these operations, the operations shall be carried out slowly, steadily, and step by step to minimize impacts to the penstock. Therefore, fluctuation of static water head in the penstock shall be limited in both operations as follows:

- ✓ Fluctuation of static water head: 30m in elevation per hour.

(2) Maintenance

Maintenance work shall be executed under the concept of “Preventive Maintenance” to achieve sustainable operation and safety of the power station. Continous routine inspection, maintenance, and monitoring activities for civil structures are indispensable for checking problems, and planning timely solutions to them, as necessary.

Maintenance activities are categorised as follows:

1) Regular Inspection

Regular inspection is defined as patrol of civil structures and surrounding facilities to check the conditions to determine whether they are maintained in good condition or have any defects or damages.

Regular inspection shall be carried out on a weekly or monthly basis. Furthermore, extra inspections shall be carried out in case of any unusual events, such as big floods, strong earthquakes, heavy rains, etc.

In case any damage is observed during the regular inspection, it shall be reported to the station manager.

2) Regular Maintenance

Regular maintenance is defined as repair or cleaning work when any defects are observed in civil structures during the regular inspection. It includes such work as cleaning of drain ditches, replacing of lamps, etc.

Regular maintenance shall be carried out whenever required.

3) Special Maintenance

Special maintenance is defined as repair or rehabilitation work.

The station manager shall review damages or defects from the point of view of safety and function of the structure, in order to judge the necessity of special maintenance and to decide proper measures - technical, financial and environmental.

The station manager shall arrange for specialists, as required, to obtain appropriate advice to make the above judgment.

In case repair and rehabilitation work requires stoppage of power generation, special maintenance shall be performed with careful preparation by all parties concerned, whenever it is required.

4) Special Inspection

Special inspection is defined as inspection of the power canal and penstock, and requires stoppage of power generation. Therefore, special inspections shall be conducted based on careful consideration and preparation except in the case of an emergency. Time schedule, participating specialists, equipment, etc. shall be determined for each case.

Major items of the inspection and maintenance are summarized in the table below.

**Table 8.3.2 Inspection and Maintenance Items for Civil Structures**

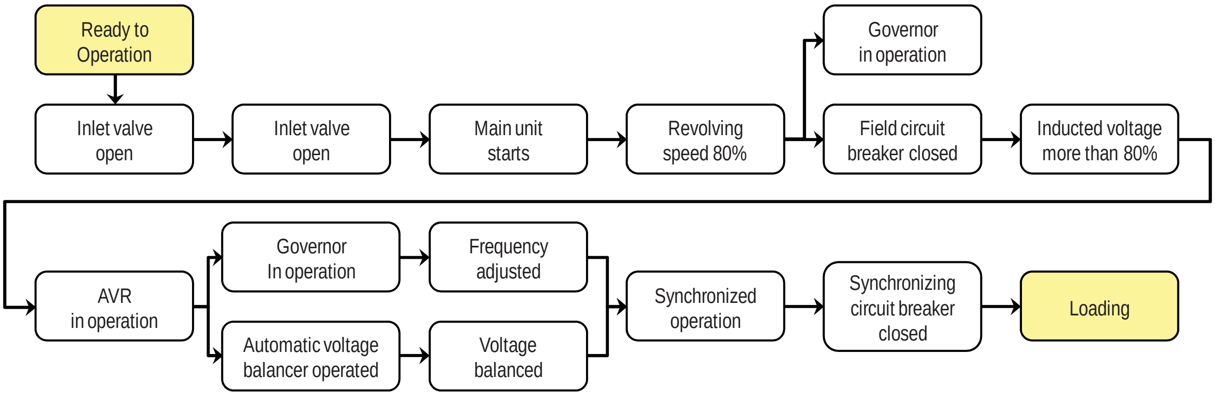
| Items | Details |
|---|---|
| Condition of Security Facilities | Security facilities such as gates, fences, and security lights, etc., shall be maintained properly. Any holes in the fence shall be repaired, and blown-out lamps shall be replaced immediately. |
| Condition of Cable Duct Covers | Covers of pits, manholes, ducts, etc., shall be maintained in closed condition to protect the installed cables against deterioration. Any foreign materials shall be cleaned out. |
| Condition of Drainage Facilities | Deposits in drainage facilities shall be removed regularly. |
| Condition of Slopes | In case any deformations and/or unusual leakages of water are observed, monitoring shall be continued and special maintenance planned as required. |
| Condition of exposed Concrete Structures | In case the following damages and/or defects are observed, appropriate repair and/or monitoring shall be undertaken, reviewed by specialists, and special maintenance planned as required:<br>✓ Settlement, heaving, deflections or lateral or out-of-alignment movement at construction or contraction joints,<br>✓ Development of cracks on concrete surface,<br>✓ Development of cavitations due to high velocity water flow,<br>✓ Abnormal leakage or seepage from construction or contraction joints,<br>✓ Change of drain conditions from embedded drain holes, and so on. |
| Condition of Structures under the Water | Condition of structures under the water; i.e., intake, de-silting basin, power canal, head tank, penstock, and tailrace outlet, cannot be confirmed under stoppage of power generation without draining the water. It is recommended that special inspections are carried out when the power generation is stopped. |

### 8.3.3 Electrical Equipment

Electrical equipment shall be maintained to generate electric power efficiently and properly.

In recent years, the operation of power generation is executed as automatic control by utilizing computer technology. An integrated control panel performs integrated operation of controls including: starting speed control, voltage control, power factor control, frequency control, load control, water level control, discharge control, program operation control, etc.

For example, generator start operation requires the following control. The integrated control panel performs all operations including such starting operation automatically.



Source: "Guideline and manual for hydropower development Vol. 2, Small Scale Hydropower (Figure 10-40)" published by JICA in 2011 (arranged by WG).

**Figure 8.3.1 Example of Start-up Procedure of Power Generation**

Accordingly, the major operation and maintenance activities for electrical equipment are explained below.

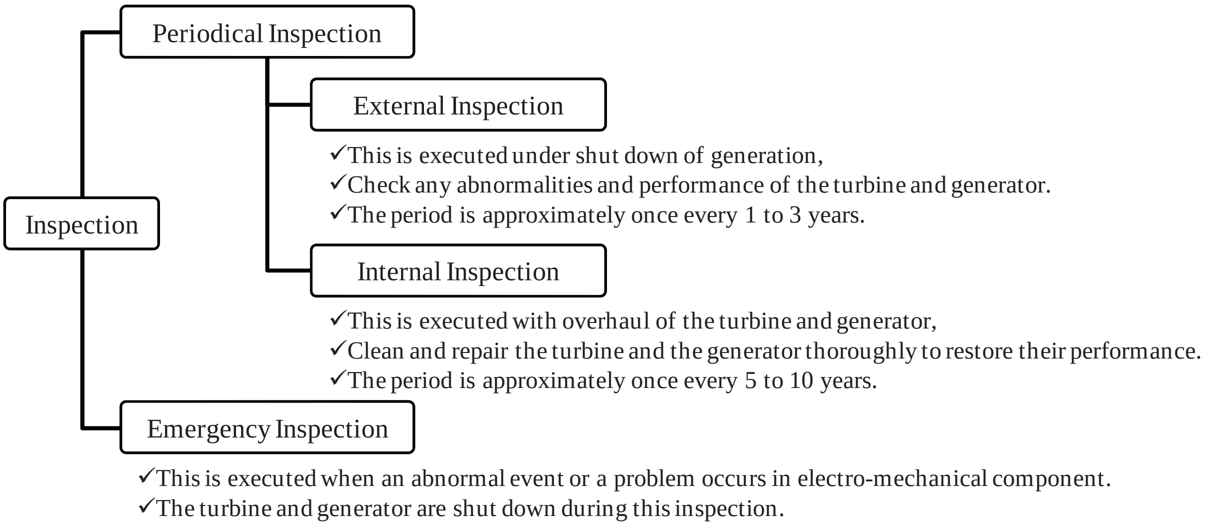
(1) Regular Patrol

The regular patrol is to check for general abnormalities of the equipment and to check the operational conditions of electrical components. The key detection factors are abnormal noise, smell and vibration.

The regular patrol is to be conducted daily or weekly, setting a patrol course and check list beforehand, and recording the readings of indicators such as a meter, pressure gauge, oil gauge, and opening angle meter.

(2) Inspection

The inspections of electrical equipment can be classified as shown below.



External Inspection

✓This is executed under shut down of generation,
✓Check any abnormalities and performance of the turbine and generator.
✓The period is approximately once every 1 to 3 years.

Internal Inspection

✓This is executed with overhaul of the turbine and generator,
✓Clean and repair the turbine and the generator thoroughly to restore their performance.
✓The period is approximately once every 5 to 10 years.

Emergency Inspection

✓This is executed when an abnormal event or a problem occurs in electro-mechanical component.
✓The turbine and generator are shut down during this inspection.

Source: "Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Chapter 15.3)" published by JICA in 2011 (arranged by WG).

**Figure 8.3.2 Inspections for Electrical Equipment**

It is recommended that the inspection cycle is set based on the inspection results and the operation conditions. For example, from cavitations measurement of turbine runner to be carried out once annually for 1 to 3 years, repair works are set to coincide with the time of internal inspection depending on the progress and damage due to cavitations.

Major items of the periodic inspection are summarized in the table below.

## Table 8.3.3 Inspection Items of Periodic Inspection for Electrical Equipment

| Component | Inspection Items | Details |
|---|---|---|
| **External Inspection** | | |
| Turbine | Turbine internal | ✓ Inspect and measure for abrasion, cracks, erosion and rust on the runner, guide vane and casing interior.<br>✓ Measure the runner gap and guide vane gap.<br>✓ Check the bearing lubricant quality<br>* Test: automatic start/stop |
| Inlet Valve | Inlet valve internal | ✓ Measure leakage. Inspect for abrasion and erosion and erosion. Measure sheet surface clearance.<br>✓ Inspect position indicator conditions. |
| Speed Governor | Mechanism | ✓ Inspect for abrasion of movable parts. Loose wiring/lever and strainer overhaul. |
| | Controller | ✓ Inspect the conditions of the printed circuit board and position transducer. Measure the insulation resistance. |
| Oil Pressure Supply and Lubrication oil System | Performance | ✓ Measure load operation time. |
| | Oil filtration | ✓ Test oil quality. |
| Water Supply and Drainage System | Strainer overhaul | ✓ Inspect abrasion and erosion. |
| Generator | Generator internal | ✓ Inspect for loose electric circuit terminals, discoloured, peeled or loose coil, abrasion and damage to slip ring, loose and rusted revolving part.<br>✓ Measure brush contact pressure and insulation resistance of electric circuit. |
| | Brake equipment | ✓ Inspect for shoe abrasion loss and operation condition. |
| | Neutral grounding resistor | ✓ Measure resistance and insulation resistance. |
| Control Panels, etc. | | ✓ Performance test of all relays. |
| **Internal Inspection** | | |
| Turbine | Overhaul | ✓ Measure abrasion loss at each part of turbine.<br>✓ Inspect the sliding area and packing for damage and fine cracks on turbine.<br>✓ Measure the damage and gap on the sliding surface of bearing.<br>✓ Calibrate the cooling water pipe pressure resistance, thermometer and oil gauge.<br>* Replace worn parts<br>* Test: load rejection, vibration measurement, stroke output, automatic start/stop. |
| Inlet Valve | Overhaul | ✓ Inspect damage to movable part and sliding area.<br>✓ Inspect for abrasion and erosion.<br>✓ Inspect for damage to the packing and the sealing condition. Replace worn parts. |
| Speed Governor | Overhaul | ✓ Overhaul movable part and Speed Signal Generator (SSG).<br>✓ Replace worn parts.<br>* Test: characteristics measurement and load rejection. |
| Oil Pressure Supply and Lubrication oil System | Overhaul | ✓ Inspect for abrasion and damage to internal movable part and sliding area, and motor insulation resistance. |
| | Performance test | ✓ Measure pump discharge and grease feed volume<br>✓ Performance test of sensors, detectors, and protection relays |
| Water Supply and Drainage System | Overhaul | ✓ Inspect for abrasion and damage to internal movable part and sliding area, and motor insulation resistance. |
| | Performance test | ✓ Measure water supply and drain volume. |
| Generator | Rotor lifting | ✓ Inspect for loose rotor core and winding.<br>✓ Measure winding deterioration.<br>✓ Inspect loose wedge, flaking varnish, and rust. |
| | Overhaul | ✓ Brake equipment, bearings and air cooler overhaul.<br>* Measure shaft current.<br>* Exciter characteristic test. |
| Control Panels, etc. | | ✓ Performance test of all relays |

Source: "Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Table 15-5)" published by JICA in 2011.

(3) Spare Parts

Spare parts shall be stored in the powerhouse for quick correction and recovery from abnormalities and breakdowns. The variety and quantity of spare parts are determined according to: their frequency of breakdown, the manufacturing period, the importance level, and so on. The storage location is determined on the basis of the haul distance and other conditions.

Examples of spare parts for a MHP station are shown below.

**Table 8.3.4 Common Spare Parts for Electrical Equipment**

| Component | Part Name | Quantity | Remarks |
|---|---|---|---|
| Turbine Main Unit | Main bearing metal | For 1 unit | |
| | Guide vane weak point pin | For 1 unit | |
| | Searing packing | For 1 unit | |
| | Runner | For 1 unit | The replaced parts can be utilized as auxiliary parts after repair of damaged parts. |
| | Guide vane | For 1 unit | |
| | Nozzle tip | For 1 unit | |
| | Bucket | For 1 unit | |
| Governor | Printed circuit board | 1 each | |
| | Moving coil | 1 | |
| | Various springs | 1 each | |
| Oil Pressure Supply and Lubrication Oil System | Oil pressure lubricant pump | 1 unit | In case the auxiliary system is not installed only. |
| | Un-loader spring | 1 | |
| | Safety valve spring | 1 | |
| Air compressor | Pressure reduction valve | 1 | |
| Automatic control system | Solenoid for electromagnetic valve | 1 | In case the auxiliary system is not installed only. |
| Generator Main Unit | Thrust bearing metal | For 1 unit | |
| | Guide bearing metal | For 1 unit | |
| | Stator coil | 5 to 10 | |
| | Brush holder | For 1 unit | |
| Exciter | Printed circuit board | 1 each | |
| | Field breaker coil | 1 | |
| | Semiconductor rectifier | For 1 phase | |
| Transformer | Bushing | For 1 phase | Not stored if available from other stocks. |
| | Bushing board | 1 | |
| Switchgear, Breaker | Bushing | For 1 phase | Not stored if available from other stocks. |
| | Fixed and movable contact | For 1 phase | |
| | Switching coil | 1 each | |
| Switchgear, Disconnecting switch | Switching coil | 1 each | |
| Control Panel | Printed circuit board | 1 each | |
| Generator Main Circuit | Current transformer (per model) | 1 each | Not stored if available from other stocks. |
| | Instrument transformer (per model) | 1 each | |

Source: "Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Table 15-6)" published by JICA in 2011.

### 8.3.4 Distribution Facilities

Distribution facilities shall be maintained efficiently and properly in order to operate the system safely and prevent accidents.

To realize this objective, major operation and maintenance works for the distribution facilities are required as explained below. All results of operation and maintenance activities should be described in the defined form and reported to the person in charge.

### (1) Scheduled Outage

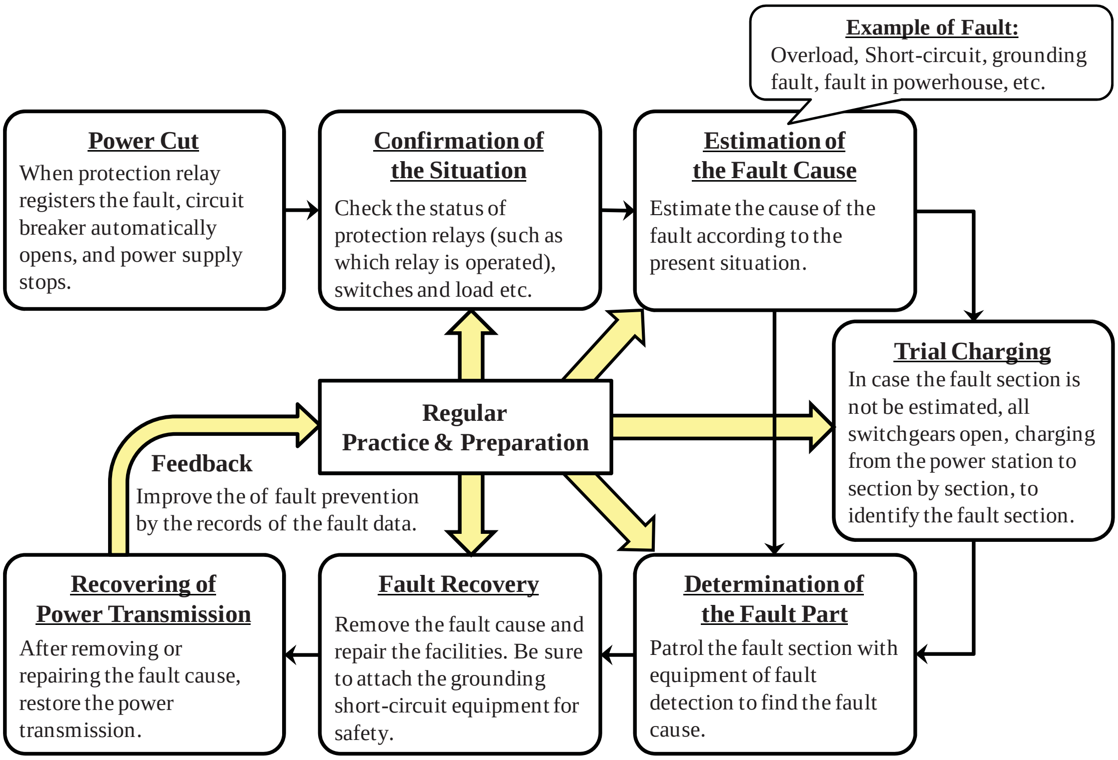
Planned outages are necessary to check distribution facilities and conduct repairs. A planned outage shall be planned and executed taking the followings into consideration:

- ✓ The procedure for installation and operation of the switches and grounding short-circuit equipment etc. shall be decided in detail at the initial stage,
- ✓ The safety of works shall be ensured,
- ✓ The outage period shall be minimized to mitigate inconveniences to customers, and
- ✓ The executing date and times shall be communicated to the affected consumers in advance.

### (2) Fault Recovery

In case electricity failure occurs, it is preferable to restore power as soon as possible. The fault will often be accompanied by damage to the equipment, and the safety of the community and workers shall be considered adequately.

The basic procedure of accident restoration works is shown below. As shown in the figure, regular practice of accident restoration and preparation of materials and tools are essential for early fault recovery.



**Example of Fault:**
Overload, Short-circuit, grounding fault, fault in powerhouse, etc.

**Power Cut**
When protection relay registers the fault, circuit breaker automatically opens, and power supply stops.

**Confirmation of the Situation**
Check the status of protection relays (such as which relay is operated), switches and load etc.

**Estimation of the Fault Cause**
Estimate the cause of the fault according to the present situation.

**Trial Charging**
In case the fault section is not be estimated, all switchgears open, charging from the power station to section by section, to identify the fault section.

**Regular Practice & Preparation**

**Feedback**
Improve the of fault prevention by the records of the fault data.

**Recovering of Power Transmission**
After removing or repairing the fault cause, restore the power transmission.

**Fault Recovery**
Remove the fault cause and repair the facilities. Be sure to attach the grounding short-circuit equipment for safety.

**Determination of the Fault Part**
Patrol the fault section with equipment of fault detection to find the fault cause.

Source: "Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Chapter 15.4)" published by JICA in 2011 (arranged by WG).

**Figure 8.3.3 Basic Procedure of Accident Restoration Works**

### (3) Measurement

Regular measurement of voltage, current, and ground resistance, etc. of the system at peak and off-peak is important to check the status of the distribution line and conduct maintenance. When they are out of the permissible ranges it is also necessary to take measures to restore them to the acceptable ranges.

A watt- hour meter should be set up on the secondary side of the transformer in order to detect both technical losses and non-technical losses such as stolen electricity. Whether electricity is being stolen can be determined by comparing the indication of the meter to the total amount of power supplied by the transformer.

(4) Maintenance

Periodic patrol and annual inspection of distribution facilities are the major maintenance activities.

- ✓ Periodic Patrol (weekly or monthly)
  General patrol of the entire distribution facilities to clear out flying obstacles, broken facilities, fallen trees, obstructive building constructions, etc.
- ✓ Annual Inspection (yearly)
  Detailed inspection to identify signs of degradation and damage in the distribution system.

Basically, these patrols and inspections are carried out without interruption of power supply. Lastly, the maintenance check sheets shall be prepared in advance.

## 8.4 Assistance for Management Board

In case of MHP development in rural areas, a new management body should be established and operated by local residents. The members of the management body might not have any experience or knowledge of electrical utility services.

Therefore, assistance for management board should include training of their staff who have minimum ability to operate and maintain the electricity utility service, which is essential to commence power generation and successful electrification.

### 8.4.1 Assistance before Commencement of Power Generation

Once an electrical supply service is commenced, it is difficult to commit a significant amount of time for the training as the number of staff in the management board is limited. Therefore, it is necessary to conduct the training before the commencement of supply services and simultaneous with the planning or construction stage of MHP project.

To develop human resource capacities of the staff of management board, the assistance program shall include:

- ✓ “On the job training (OJT)” through the practice of management, operation, and maintenance of the existing hydropower plant, and
- ✓ Technical training carried out by experts working for parastatals or aid agencies related to electric power generation.

The following items should be effectively considered for planning and putting into practice the assistance program.

i) To arrange for opportunities for staff to be involved in the construction work in order to increase their understanding of facilities and mechanisms, and to gain experience in operation and troubleshooting
ii) To arrange for opportunities for staff to attend lectures in training centers of parastatals and/or vocational training schools in order to learn basic electrical knowledge and safety matters before actual operation.
iii) To establish a monitoring system to check the learning and skills level of staff after the commencement of operation.
iv) To establish and implement periodic auditing of management and operations by related government authorities.

Major items to provide guidance and training of the management board are summarized below:

**Table 8.4.1 Major Assistance Items of Management Board**

| Responsible Person | Assistance Item | Description |
|---|---|---|
| Representative and Manager | Establishment of management body and joint steering committee. | To provide technical guidance on development of rules and on how to operate the organization when the management body is established, and help it establish joint steering committee. |
| | Arrangements to obtain the business license. | To provide technical guidance on how to prepare an application form for electricity business license, and to help them become capable of obtaining the license. |
| | Start-up of power supply business. | To check management of power utilization during test operation, advise on points for improvement, and help the local staff continuously carry out their own management. |
| Administrative Staff | Outline and functions of power facilities. | To help the trainees learn the basics of power plant facilities and understand the roles of the staff through lectures, including visits to the site. |
| | Lecture on electricity charge system | To hold a lecture on the concept of electricity charge and its system so that the trainees can learn the background of the work of 3) and 4). |
| | Development of office management manuals | To help the trainees complete the office management manuals based on the draft prepared in advance and establish the work flow through workshops. |
| | Guidance on work procedures | To help the trainees memorize the work procedures such as recording energy consumption, issuing and sending invoices, and collection of electricity charges, etc., through lectures and field practice. |
| Technical Staff | Outline and functions of power plant facilities | To help the trainees learn the basics of power plant facilities and understand the roles of the staff through lectures, including visits to the site. |
| | Guidance on functions and structures of facilities | To help the trainees understand the functions and structures of the civil structures, electrical equipment and distribution facilities through lectures and field visits. |
| | Preparation of operation and maintenance manuals | To help the trainees complete the manuals based on the draft prepared in advance and establish the work flow through workshops. |
| | Guidance on inspection, maintenance and repairing | To help the trainees learn how to conduct daily inspection, mainly through field practice, and be capable of judging repair necessity. |
| | Guidance on documentation of maintenance | To help the trainees become capable of filling in inspection sheets, mainly through field practice. |

Source: “Guideline and Manual for Hydropower Development, Vol. 2 Small Scale Hydropower (Chapter 16.2)” published by JICA in 2011.

### 8.4.2 Assistance after Commencement of Power Generation

Assistance after the commencement of the power supply service is also necessary because of the following reasons:

- ✓ Initial troubles during operation will often occur within the first one year,
- ✓ Some contradictions among the regulations and/or manuals which are apparent, as well as problems which had not been anticipated, occur within a few years,
- ✓ In case of hydropower generation, the manner of operation varies between rainy seasons and dry seasons and depends on the natural river flow. At the same time, power demand also changes with the seasons,
- ✓ Repeated training on actual situations is required to improve staff capacities to conduct inspection, operation and maintenance, troubleshooting etc., and
- ✓ The status of power generation, charge collection and expenses shall be audited to determine whether the management board is executing their responsibilities properly.

Taking into consideration the above situations, elaborate assistance by experts is indispensable for 2 to 3 years after the commencement of power supply service. Major items to guide and train the management board are similar to the items required before the commencement of power generation. Coaching is carried out practically.

Simultaneous with the coaching; documents such as regulations, workflow, manual, etc., shall be reviewed based on the actual situations, and modified as required.

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# Annex-1

## Simulated Monthly Surface Water by Sub-basin in NWMP 2030

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

# Annex-1 Simulated Monthly Surface Water by Sub-basin in NWMP 2030

## Table of Contents

Source: "National Water Master Plan 2030", Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

# 1. Lake Victoria North Catchment Area (LVNCA)

## 1AA, 1AB, 1AC, 1AD, 1AE, 1AF, 1AG and 1AH

Sub-basin: **1AA** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 1.34 | 0.89 | 0.93 | 3.48 | 10.70 | 4.90 | 3.56 | 3.37 | 2.90 | 6.39 | 3.05 | 1.52 |
| 1992 | 0.92 | 0.74 | 0.81 | 0.79 | 4.11 | 3.55 | 4.32 | 3.41 | 3.72 | 7.17 | 3.57 | 1.81 |
| 1993 | 1.24 | 1.06 | 1.02 | 0.86 | 5.29 | 4.75 | 2.69 | 2.08 | 4.31 | 4.03 | 2.70 | 1.42 |
| 1994 | 0.88 | 0.74 | 0.78 | 1.00 | 11.29 | 4.82 | 2.83 | 3.92 | 3.73 | 2.48 | 7.62 | 3.66 |
| 1995 | 1.06 | 0.73 | 0.81 | 1.33 | 5.77 | 3.71 | 3.23 | 3.80 | 6.64 | 3.78 | 3.80 | 1.77 |
| 1996 | 0.95 | 0.88 | 1.10 | 7.43 | 9.77 | 6.72 | 4.65 | 3.43 | 8.58 | 6.71 | 3.57 | 2.77 |
| 1997 | 1.10 | 0.71 | 0.76 | 4.24 | 9.37 | 3.52 | 3.24 | 3.45 | 2.01 | 6.63 | 11.61 | 7.12 |
| 1998 | 9.12 | 3.42 | 1.61 | 3.37 | 9.29 | 5.50 | 6.00 | 5.10 | 5.01 | 8.73 | 8.00 | 1.70 |
| 1999 | 1.00 | 0.78 | 1.34 | 9.29 | 11.48 | 4.53 | 3.81 | 5.52 | 5.53 | 13.48 | 4.24 | 2.68 |
| 2000 | 1.28 | 0.80 | 0.78 | 0.75 | 2.70 | 2.99 | 2.91 | 3.73 | 3.01 | 5.57 | 4.63 | 2.66 |
| 2001 | 1.41 | 1.00 | 0.88 | 3.96 | 6.88 | 3.94 | 2.67 | 2.70 | 2.45 | 3.22 | 5.87 | 1.78 |
| 2002 | 0.87 | 0.70 | 0.74 | 0.84 | 10.67 | 3.45 | 1.65 | 1.02 | 0.85 | 1.17 | 2.36 | 2.96 |
| 2003 | 2.94 | 0.88 | 0.80 | 3.38 | 14.82 | 6.72 | 5.75 | 3.51 | 5.26 | 2.16 | 1.72 | 1.29 |
| 2004 | 0.94 | 0.74 | 0.78 | 1.82 | 6.71 | 2.70 | 1.71 | 2.73 | 3.18 | 3.91 | 6.97 | 2.43 |
| 2005 | 1.17 | 0.71 | 0.72 | 0.84 | 7.99 | 5.60 | 3.86 | 1.97 | 2.11 | 3.55 | 3.33 | 1.17 |
| 2006 | 0.76 | 0.66 | 1.07 | 11.38 | 7.05 | 4.98 | 3.06 | 3.86 | 6.90 | 5.33 | 9.64 | 8.67 |
| 2007 | 3.22 | 1.78 | 1.36 | 1.89 | 8.30 | 5.66 | 5.95 | 6.74 | 7.49 | 5.04 | 3.12 | 1.17 |
| 2008 | 0.76 | 0.65 | 0.70 | 2.44 | 6.36 | 7.55 | 2.88 | 5.13 | 9.63 | 9.58 | 7.76 | 1.85 |
| 2009 | 0.82 | 0.72 | 0.71 | 2.45 | 11.56 | 4.71 | 2.39 | 2.39 | 5.86 | 4.84 | 3.00 | 2.75 |
| 2010 | 5.37 | 1.34 | 5.00 | 7.92 | 9.88 | 6.27 | 6.49 | 4.00 | 9.43 | 11.37 | 5.72 | 2.74 |

Sub-basin: **1AB** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 3.20 | 2.34 | 2.41 | 7.04 | 15.75 | 9.96 | 9.82 | 10.45 | 8.65 | 13.98 | 6.96 | 3.58 |
| 1992 | 2.34 | 1.89 | 2.05 | 2.06 | 6.47 | 8.03 | 9.73 | 9.26 | 8.44 | 15.78 | 7.44 | 3.70 |
| 1993 | 2.83 | 3.20 | 3.01 | 2.37 | 11.79 | 10.01 | 6.54 | 5.86 | 10.02 | 8.79 | 5.97 | 3.26 |
| 1994 | 2.18 | 1.85 | 1.95 | 2.08 | 18.45 | 11.02 | 7.30 | 10.34 | 8.44 | 5.03 | 13.55 | 7.40 |
| 1995 | 2.62 | 1.86 | 2.06 | 2.33 | 9.59 | 7.75 | 7.59 | 9.45 | 13.22 | 8.20 | 8.11 | 3.94 |
| 1996 | 2.38 | 2.23 | 2.79 | 13.22 | 18.37 | 13.21 | 9.48 | 9.09 | 16.21 | 11.11 | 7.28 | 5.24 |
| 1997 | 2.56 | 1.78 | 1.86 | 8.22 | 17.75 | 7.36 | 7.98 | 9.34 | 4.59 | 9.38 | 19.86 | 11.12 |
| 1998 | 17.96 | 8.17 | 4.61 | 7.25 | 17.48 | 11.84 | 14.60 | 12.69 | 11.08 | 18.02 | 16.56 | 4.08 |
| 1999 | 2.49 | 1.93 | 3.04 | 15.25 | 20.16 | 9.90 | 8.93 | 10.87 | 8.85 | 23.78 | 8.77 | 4.19 |
| 2000 | 2.56 | 1.90 | 1.93 | 1.86 | 5.86 | 7.19 | 7.42 | 8.92 | 7.71 | 12.51 | 7.94 | 5.00 |
| 2001 | 2.98 | 2.24 | 2.25 | 7.50 | 12.55 | 9.15 | 7.36 | 7.58 | 5.99 | 7.64 | 13.58 | 4.51 |
| 2002 | 2.23 | 1.76 | 1.89 | 2.09 | 15.58 | 7.63 | 4.45 | 3.30 | 2.65 | 3.54 | 3.92 | 4.78 |
| 2003 | 6.48 | 2.17 | 1.97 | 5.23 | 29.72 | 13.69 | 13.62 | 9.14 | 11.92 | 4.92 | 3.30 | 2.72 |
| 2004 | 2.17 | 1.78 | 1.88 | 4.72 | 14.64 | 6.27 | 4.16 | 6.90 | 6.13 | 6.23 | 12.06 | 5.85 |
| 2005 | 3.30 | 1.94 | 1.85 | 2.43 | 15.83 | 10.74 | 9.27 | 5.01 | 6.42 | 7.14 | 6.85 | 2.73 |
| 2006 | 1.86 | 1.60 | 2.45 | 19.02 | 12.95 | 10.43 | 7.10 | 10.38 | 15.06 | 10.36 | 18.87 | 15.42 |
| 2007 | 6.96 | 3.74 | 3.42 | 5.11 | 15.80 | 12.80 | 14.23 | 16.85 | 18.63 | 11.06 | 5.77 | 2.73 |
| 2008 | 1.91 | 1.63 | 1.75 | 3.70 | 11.78 | 16.37 | 6.94 | 12.24 | 13.89 | 16.95 | 13.77 | 4.02 |
| 2009 | 2.06 | 1.79 | 1.76 | 3.62 | 20.46 | 10.11 | 5.48 | 7.51 | 12.08 | 10.90 | 6.17 | 5.12 |
| 2010 | 10.81 | 3.36 | 10.24 | 17.01 | 20.83 | 12.55 | 13.90 | 8.98 | 18.42 | 21.91 | 11.68 | 6.38 |

Sub-basin: **1AC** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 0.03 | 0.00 | 0.00 | 0.00 | 2.97 | 1.71 | 1.20 | 1.10 | 0.67 | 1.85 | 1.04 | 0.07 |
| 1992 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 1.06 | 1.23 | 0.90 | 2.57 | 1.44 | 0.24 |
| 1993 | 0.00 | 0.00 | 0.00 | 0.00 | 0.20 | 1.76 | 0.78 | 0.57 | 1.79 | 1.25 | 0.67 | 0.03 |
| 1994 | 0.00 | 0.00 | 0.00 | 0.00 | 2.05 | 2.28 | 1.10 | 1.52 | 1.45 | 0.44 | 1.86 | 1.59 |
| 1995 | 0.03 | 0.00 | 0.00 | 0.00 | 0.55 | 1.45 | 1.04 | 1.08 | 2.11 | 1.21 | 1.22 | 0.40 |
| 1996 | 0.00 | 0.00 | 0.00 | 2.69 | 5.15 | 3.03 | 1.74 | 1.12 | 3.08 | 2.55 | 1.46 | 0.79 |
| 1997 | 0.02 | 0.00 | 0.00 | 0.29 | 4.71 | 1.30 | 1.45 | 1.45 | 0.51 | 1.65 | 4.83 | 2.45 |
| 1998 | 3.83 | 1.21 | 0.25 | 0.40 | 4.14 | 2.68 | 3.50 | 2.26 | 2.19 | 3.87 | 3.54 | 0.31 |
| 1999 | 0.00 | 0.00 | 0.00 | 4.20 | 5.01 | 2.20 | 1.62 | 2.28 | 2.00 | 6.30 | 1.91 | 0.21 |
| 2000 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.61 | 0.91 | 0.96 | 0.78 | 1.51 | 1.21 | 0.62 |
| 2001 | 0.06 | 0.00 | 0.00 | 0.36 | 2.52 | 1.19 | 0.40 | 0.26 | 0.18 | 0.29 | 1.03 | 0.22 |
| 2002 | 0.00 | 0.00 | 0.00 | 0.00 | 1.19 | 1.69 | 0.43 | 0.02 | 0.00 | 0.00 | 0.00 | 0.02 |
| 2003 | 0.95 | 0.01 | 0.00 | 0.00 | 7.05 | 3.13 | 3.05 | 1.20 | 2.28 | 0.72 | 0.13 | 0.00 |
| 2004 | 0.00 | 0.00 | 0.00 | 0.00 | 2.12 | 0.92 | 0.26 | 0.54 | 0.62 | 0.69 | 1.69 | 0.86 |
| 2005 | 0.10 | 0.00 | 0.00 | 0.00 | 2.15 | 2.29 | 1.17 | 0.27 | 0.33 | 0.68 | 0.91 | 0.05 |
| 2006 | 0.00 | 0.00 | 0.00 | 4.49 | 2.92 | 2.10 | 1.34 | 1.46 | 3.10 | 1.76 | 4.04 | 3.81 |
| 2007 | 1.40 | 0.28 | 0.03 | 0.15 | 3.09 | 2.93 | 2.65 | 2.90 | 3.11 | 2.32 | 1.18 | 0.06 |
| 2008 | 0.00 | 0.00 | 0.00 | 0.01 | 2.34 | 3.93 | 1.06 | 1.81 | 3.45 | 4.26 | 3.06 | 0.46 |
| 2009 | 0.00 | 0.00 | 0.00 | 0.01 | 4.82 | 2.47 | 0.87 | 0.54 | 2.03 | 1.93 | 0.69 | 0.38 |
| 2010 | 1.82 | 0.26 | 1.79 | 3.43 | 3.88 | 2.52 | 2.84 | 1.32 | 3.93 | 5.66 | 2.92 | 0.99 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

Sub-basin: **1AD** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 1.74 | 1.00 | 1.09 | 3.53 | 17.13 | 6.36 | 4.47 | 2.79 | 1.82 | 3.21 | 4.11 | 1.77 |
| 1992 | 1.02 | 0.81 | 0.88 | 0.88 | 2.65 | 5.01 | 5.46 | 3.70 | 3.63 | 6.89 | 5.55 | 3.03 |
| 1993 | 1.96 | 1.37 | 1.14 | 0.98 | 5.22 | 6.38 | 3.10 | 1.93 | 3.94 | 4.04 | 3.09 | 1.70 |
| 1994 | 0.99 | 0.79 | 0.91 | 2.77 | 15.32 | 6.80 | 4.02 | 3.92 | 4.43 | 3.15 | 8.61 | 6.31 |
| 1995 | 1.32 | 0.85 | 1.09 | 2.86 | 8.66 | 6.01 | 4.27 | 3.11 | 5.95 | 5.80 | 5.49 | 2.86 |
| 1996 | 1.25 | 1.49 | 2.05 | 11.31 | 13.21 | 8.34 | 5.70 | 3.74 | 9.63 | 9.69 | 5.39 | 4.02 |
| 1997 | 1.45 | 0.80 | 0.80 | 3.33 | 12.97 | 4.93 | 4.37 | 3.85 | 2.73 | 9.04 | 14.68 | 10.75 |
| 1998 | 11.37 | 4.58 | 2.00 | 3.24 | 12.50 | 6.43 | 6.29 | 3.64 | 4.41 | 8.75 | 9.41 | 2.18 |
| 1999 | 1.20 | 0.91 | 1.56 | 12.26 | 15.17 | 6.55 | 4.71 | 5.52 | 8.84 | 18.18 | 6.18 | 5.13 |
| 2000 | 2.05 | 0.99 | 0.90 | 0.86 | 2.43 | 3.14 | 2.41 | 2.77 | 2.77 | 4.40 | 6.40 | 5.06 |
| 2001 | 2.44 | 1.53 | 1.13 | 5.10 | 9.66 | 5.39 | 2.72 | 1.88 | 2.03 | 2.73 | 4.09 | 1.94 |
| 2002 | 0.95 | 0.74 | 0.81 | 1.22 | 13.71 | 5.23 | 2.20 | 1.19 | 1.03 | 2.06 | 5.72 | 3.88 |
| 2003 | 4.13 | 1.07 | 0.95 | 3.94 | 17.12 | 8.69 | 7.24 | 3.29 | 5.14 | 3.01 | 2.73 | 2.05 |
| 2004 | 1.33 | 0.94 | 0.96 | 1.72 | 8.00 | 3.28 | 1.89 | 2.34 | 3.27 | 6.52 | 9.00 | 3.68 |
| 2005 | 1.27 | 0.74 | 0.77 | 0.98 | 7.36 | 7.31 | 4.53 | 2.27 | 1.61 | 2.90 | 4.37 | 1.41 |
| 2006 | 0.82 | 0.70 | 1.38 | 13.49 | 9.66 | 5.72 | 3.30 | 2.98 | 6.28 | 6.19 | 10.92 | 11.99 |
| 2007 | 4.88 | 2.82 | 1.56 | 1.99 | 9.22 | 6.90 | 4.52 | 6.03 | 6.45 | 6.32 | 4.66 | 1.52 |
| 2008 | 0.83 | 0.70 | 0.75 | 2.43 | 8.16 | 8.48 | 3.42 | 4.53 | 16.20 | 11.76 | 11.86 | 2.73 |
| 2009 | 0.92 | 0.84 | 0.75 | 2.71 | 13.86 | 5.60 | 2.88 | 1.54 | 3.47 | 5.07 | 4.01 | 2.71 |
| 2010 | 6.68 | 1.68 | 4.87 | 7.09 | 9.73 | 6.74 | 6.61 | 3.57 | 7.78 | 12.16 | 7.39 | 3.18 |

Sub-basin: **1AE** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 0.99 | 0.63 | 0.72 | 2.03 | 9.07 | 3.32 | 1.94 | 1.03 | 0.79 | 1.39 | 1.91 | 1.22 |
| 1992 | 0.69 | 0.51 | 0.55 | 0.54 | 2.49 | 2.20 | 2.04 | 1.44 | 1.70 | 2.78 | 2.33 | 1.63 |
| 1993 | 1.18 | 0.81 | 0.69 | 0.64 | 2.23 | 2.84 | 1.37 | 0.77 | 0.95 | 1.39 | 1.34 | 1.00 |
| 1994 | 0.64 | 0.50 | 0.58 | 1.84 | 6.73 | 2.63 | 1.64 | 1.28 | 1.46 | 1.77 | 4.04 | 2.93 |
| 1995 | 0.79 | 0.52 | 0.75 | 2.19 | 4.09 | 2.49 | 1.60 | 1.12 | 2.40 | 2.63 | 2.37 | 1.21 |
| 1996 | 0.77 | 0.79 | 1.20 | 3.35 | 4.11 | 3.16 | 2.38 | 1.60 | 3.18 | 3.44 | 2.31 | 1.50 |
| 1997 | 0.76 | 0.48 | 0.50 | 0.78 | 3.92 | 1.99 | 1.44 | 1.25 | 1.01 | 4.61 | 6.14 | 5.28 |
| 1998 | 4.35 | 2.00 | 0.97 | 1.51 | 4.84 | 2.25 | 1.38 | 0.89 | 0.97 | 2.27 | 3.11 | 1.06 |
| 1999 | 0.71 | 0.58 | 0.74 | 4.75 | 5.55 | 2.45 | 1.71 | 2.02 | 3.73 | 7.96 | 2.46 | 3.69 |
| 2000 | 1.22 | 0.61 | 0.56 | 0.52 | 0.75 | 0.91 | 0.80 | 0.94 | 1.03 | 1.68 | 3.55 | 2.72 |
| 2001 | 1.42 | 0.92 | 0.70 | 2.06 | 4.25 | 2.63 | 1.33 | 0.90 | 1.10 | 1.55 | 2.20 | 1.04 |
| 2002 | 0.59 | 0.47 | 0.52 | 1.56 | 6.58 | 1.97 | 0.89 | 0.65 | 0.57 | 1.19 | 2.84 | 1.72 |
| 2003 | 1.38 | 0.58 | 0.54 | 2.31 | 5.33 | 3.02 | 2.23 | 1.19 | 1.51 | 1.19 | 1.69 | 1.29 |
| 2004 | 0.87 | 0.61 | 0.61 | 0.82 | 2.55 | 1.29 | 0.89 | 1.08 | 1.78 | 3.39 | 4.15 | 1.61 |
| 2005 | 0.62 | 0.43 | 0.46 | 0.49 | 2.28 | 2.87 | 1.97 | 1.16 | 0.93 | 1.81 | 2.07 | 0.80 |
| 2006 | 0.50 | 0.45 | 0.68 | 4.02 | 3.55 | 1.78 | 1.12 | 1.04 | 1.71 | 3.01 | 3.88 | 4.53 |
| 2007 | 2.06 | 1.54 | 0.86 | 0.94 | 3.30 | 2.26 | 1.42 | 2.00 | 1.92 | 2.09 | 1.93 | 0.81 |
| 2008 | 0.50 | 0.42 | 0.45 | 0.77 | 2.36 | 2.59 | 1.24 | 1.41 | 6.56 | 4.90 | 5.01 | 1.30 |
| 2009 | 0.57 | 0.52 | 0.47 | 1.08 | 4.96 | 1.94 | 1.25 | 0.73 | 1.34 | 2.15 | 2.16 | 1.62 |
| 2010 | 2.35 | 0.79 | 2.05 | 2.28 | 3.30 | 2.16 | 1.51 | 1.04 | 1.60 | 3.26 | 2.64 | 1.26 |

Sub-basin: **1AF** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 2.64 | 1.82 | 1.96 | 5.08 | 15.81 | 7.13 | 4.64 | 3.27 | 2.58 | 4.35 | 4.18 | 2.46 |
| 1992 | 1.79 | 1.47 | 1.60 | 1.55 | 2.11 | 4.27 | 5.68 | 4.09 | 4.42 | 7.00 | 5.62 | 3.49 |
| 1993 | 2.62 | 2.05 | 1.90 | 1.67 | 5.16 | 6.39 | 3.60 | 3.30 | 5.05 | 4.85 | 3.75 | 2.41 |
| 1994 | 1.70 | 1.43 | 1.53 | 2.44 | 13.50 | 7.26 | 4.47 | 4.38 | 4.24 | 3.50 | 8.62 | 6.57 |
| 1995 | 2.07 | 1.45 | 1.73 | 3.16 | 8.34 | 5.93 | 4.93 | 3.67 | 6.49 | 6.31 | 6.65 | 3.40 |
| 1996 | 2.04 | 2.20 | 3.63 | 13.14 | 15.21 | 9.45 | 6.48 | 4.06 | 11.00 | 11.03 | 6.16 | 4.96 |
| 1997 | 2.25 | 1.43 | 1.46 | 3.02 | 12.87 | 6.07 | 5.09 | 4.99 | 3.15 | 8.60 | 15.29 | 12.04 |
| 1998 | 12.72 | 5.30 | 2.75 | 4.98 | 12.86 | 7.82 | 7.65 | 4.78 | 5.94 | 9.96 | 10.47 | 2.91 |
| 1999 | 2.02 | 1.62 | 2.76 | 13.20 | 15.81 | 7.30 | 5.13 | 6.58 | 8.90 | 18.51 | 7.20 | 5.17 |
| 2000 | 2.61 | 1.68 | 1.58 | 1.51 | 2.91 | 3.34 | 3.11 | 3.67 | 3.19 | 5.15 | 6.09 | 5.33 |
| 2001 | 3.25 | 2.29 | 1.95 | 7.11 | 10.77 | 5.62 | 3.26 | 2.54 | 2.62 | 3.18 | 4.36 | 2.32 |
| 2002 | 1.57 | 1.34 | 1.42 | 1.49 | 11.67 | 6.04 | 2.69 | 1.91 | 1.70 | 2.35 | 5.90 | 4.75 |
| 2003 | 4.36 | 1.65 | 1.54 | 3.74 | 18.34 | 10.00 | 7.86 | 5.00 | 6.09 | 3.58 | 3.23 | 2.46 |
| 2004 | 1.95 | 1.53 | 1.63 | 3.01 | 7.91 | 3.93 | 2.49 | 3.03 | 3.82 | 6.22 | 8.95 | 3.89 |
| 2005 | 1.99 | 1.31 | 1.35 | 1.52 | 7.37 | 7.87 | 4.90 | 3.01 | 2.76 | 4.04 | 4.30 | 2.03 |
| 2006 | 1.40 | 1.23 | 1.81 | 14.72 | 10.62 | 7.03 | 4.17 | 3.56 | 6.77 | 6.54 | 12.15 | 12.97 |
| 2007 | 5.30 | 3.14 | 2.13 | 3.04 | 10.34 | 7.51 | 5.76 | 6.76 | 7.80 | 7.68 | 5.65 | 2.28 |
| 2008 | 1.47 | 1.25 | 1.33 | 3.49 | 8.82 | 9.26 | 4.38 | 6.20 | 15.29 | 12.83 | 12.08 | 3.43 |
| 2009 | 1.60 | 1.47 | 1.38 | 3.51 | 13.93 | 6.72 | 3.79 | 2.40 | 4.95 | 5.63 | 3.99 | 3.66 |
| 2010 | 6.15 | 2.51 | 7.01 | 7.47 | 10.44 | 7.92 | 6.76 | 4.93 | 7.80 | 12.65 | 8.40 | 4.05 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

Sub-basin: **1AG** (Unit: $m^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 1.62 | 0.91 | 0.95 | 4.28 | 13.29 | 5.58 | 2.97 | 1.91 | 1.53 | 2.66 | 3.17 | 1.41 |
| 1992 | 0.78 | 0.57 | 0.61 | 0.59 | 1.14 | 3.41 | 4.55 | 2.90 | 2.98 | 4.77 | 3.93 | 2.31 |
| 1993 | 1.55 | 1.13 | 0.95 | 0.73 | 3.49 | 5.18 | 2.65 | 1.98 | 3.70 | 3.39 | 2.56 | 1.39 |
| 1994 | 0.72 | 0.53 | 0.58 | 1.46 | 11.02 | 5.75 | 3.03 | 2.63 | 3.05 | 2.24 | 6.53 | 5.17 |
| 1995 | 1.04 | 0.58 | 0.84 | 2.13 | 7.05 | 4.53 | 3.80 | 2.53 | 4.55 | 5.14 | 5.41 | 2.61 |
| 1996 | 1.12 | 1.41 | 2.33 | 12.04 | 12.55 | 7.69 | 4.53 | 2.68 | 9.13 | 9.76 | 4.74 | 4.07 |
| 1997 | 1.27 | 0.56 | 0.54 | 1.63 | 10.71 | 4.78 | 3.64 | 3.32 | 2.14 | 5.21 | 12.21 | 10.44 |
| 1998 | 10.71 | 3.91 | 1.69 | 3.63 | 10.96 | 5.78 | 5.43 | 3.31 | 4.05 | 7.93 | 8.70 | 1.91 |
| 1999 | 1.05 | 0.74 | 1.41 | 9.88 | 13.05 | 5.65 | 3.54 | 4.09 | 6.86 | 13.83 | 5.83 | 3.72 |
| 2000 | 1.59 | 0.77 | 0.61 | 0.57 | 1.63 | 2.17 | 2.03 | 2.46 | 2.17 | 3.71 | 4.16 | 4.13 |
| 2001 | 2.26 | 1.44 | 1.00 | 5.62 | 9.08 | 4.59 | 2.31 | 1.55 | 1.66 | 2.19 | 3.14 | 1.38 |
| 2002 | 0.65 | 0.49 | 0.52 | 0.78 | 10.41 | 5.04 | 1.63 | 0.95 | 0.81 | 1.55 | 5.06 | 3.87 |
| 2003 | 3.41 | 0.81 | 0.63 | 2.17 | 15.32 | 8.29 | 6.14 | 3.60 | 4.75 | 2.54 | 2.12 | 1.44 |
| 2004 | 0.95 | 0.66 | 0.70 | 1.81 | 6.06 | 2.98 | 1.49 | 1.77 | 2.39 | 4.98 | 7.11 | 2.93 |
| 2005 | 1.05 | 0.51 | 0.49 | 0.68 | 5.66 | 6.57 | 3.75 | 2.20 | 2.12 | 2.67 | 3.02 | 1.15 |
| 2006 | 0.53 | 0.43 | 0.93 | 13.21 | 9.17 | 5.96 | 3.15 | 2.32 | 4.41 | 4.50 | 10.07 | 11.23 |
| 2007 | 4.34 | 1.96 | 1.17 | 1.87 | 8.36 | 5.98 | 3.95 | 4.84 | 6.11 | 6.14 | 4.52 | 1.37 |
| 2008 | 0.59 | 0.46 | 0.47 | 2.29 | 7.73 | 7.64 | 3.20 | 4.58 | 13.37 | 10.26 | 10.35 | 2.52 |
| 2009 | 0.71 | 0.67 | 0.51 | 2.16 | 11.58 | 5.25 | 2.70 | 1.42 | 3.21 | 4.42 | 2.78 | 2.22 |
| 2010 | 4.55 | 1.44 | 4.96 | 5.64 | 8.54 | 6.34 | 5.49 | 3.45 | 5.99 | 9.85 | 6.62 | 2.85 |

Sub-basin: **1AH** (Unit: $m^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 0.97 | 0.47 | 0.50 | 5.67 | 15.23 | 5.37 | 2.40 | 1.04 | 0.69 | 1.84 | 2.32 | 1.28 |
| 1992 | 0.48 | 0.24 | 0.22 | 0.24 | 2.78 | 3.06 | 3.14 | 1.71 | 2.99 | 4.55 | 3.78 | 2.50 |
| 1993 | 2.08 | 0.90 | 0.61 | 0.44 | 4.93 | 4.92 | 1.51 | 0.67 | 1.61 | 2.55 | 2.18 | 1.06 |
| 1994 | 0.44 | 0.22 | 0.30 | 3.48 | 13.33 | 4.42 | 2.35 | 2.08 | 2.21 | 2.95 | 8.55 | 4.46 |
| 1995 | 0.61 | 0.29 | 0.54 | 5.27 | 7.84 | 3.61 | 2.46 | 1.20 | 4.95 | 5.60 | 5.06 | 1.66 |
| 1996 | 0.81 | 0.95 | 2.86 | 9.51 | 9.15 | 6.22 | 4.01 | 1.67 | 8.13 | 8.69 | 3.95 | 2.84 |
| 1997 | 0.71 | 0.25 | 0.18 | 1.05 | 8.34 | 3.63 | 2.11 | 1.97 | 1.07 | 7.70 | 13.34 | 12.16 |
| 1998 | 9.53 | 2.63 | 0.87 | 4.01 | 9.69 | 3.75 | 1.79 | 0.97 | 2.32 | 5.33 | 5.93 | 1.04 |
| 1999 | 0.55 | 0.38 | 0.42 | 9.31 | 12.58 | 3.84 | 2.37 | 3.48 | 7.33 | 14.34 | 4.58 | 6.65 |
| 2000 | 1.22 | 0.43 | 0.28 | 0.23 | 0.60 | 0.94 | 0.78 | 1.44 | 1.40 | 3.51 | 7.02 | 4.60 |
| 2001 | 2.38 | 1.32 | 0.67 | 6.62 | 8.31 | 4.91 | 1.63 | 1.04 | 1.99 | 2.69 | 4.17 | 0.99 |
| 2002 | 0.37 | 0.20 | 0.23 | 3.65 | 12.22 | 2.78 | 0.82 | 0.47 | 0.40 | 1.62 | 7.28 | 3.05 |
| 2003 | 2.43 | 0.44 | 0.30 | 5.81 | 10.96 | 5.78 | 3.75 | 1.10 | 1.92 | 1.36 | 2.62 | 1.37 |
| 2004 | 0.76 | 0.45 | 0.45 | 1.57 | 5.07 | 1.97 | 1.01 | 1.50 | 3.35 | 6.93 | 8.60 | 1.85 |
| 2005 | 0.51 | 0.18 | 0.14 | 0.25 | 5.63 | 5.48 | 2.82 | 1.57 | 1.38 | 3.60 | 3.13 | 0.68 |
| 2006 | 0.23 | 0.17 | 0.54 | 11.08 | 8.05 | 3.55 | 1.76 | 1.28 | 3.55 | 4.66 | 8.93 | 11.24 |
| 2007 | 3.27 | 2.43 | 0.89 | 2.57 | 8.41 | 4.24 | 1.78 | 2.98 | 2.87 | 4.27 | 3.18 | 0.80 |
| 2008 | 0.28 | 0.17 | 0.15 | 3.09 | 6.43 | 4.40 | 1.84 | 3.54 | 16.16 | 9.47 | 10.43 | 1.36 |
| 2009 | 0.35 | 0.33 | 0.18 | 3.06 | 10.77 | 2.92 | 1.84 | 0.70 | 3.03 | 4.15 | 3.10 | 3.00 |
| 2010 | 4.12 | 0.57 | 4.61 | 4.27 | 7.19 | 3.70 | 2.01 | 1.23 | 3.29 | 7.10 | 4.43 | 1.60 |

## 1BA, 1BB, 1BC, 1BD, 1BE, 1BG & 1BH

Sub-basin: **1BA** (Unit: $m^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 1.75 | 1.45 | 1.21 | 1.93 | 1.26 | 6.86 | 10.34 | 15.96 | 6.93 | 2.94 | 2.76 | 1.99 |
| 1992 | 0.93 | 0.61 | 0.63 | 0.68 | 6.39 | 5.63 | 8.54 | 11.45 | 6.30 | 10.06 | 7.89 | 2.81 |
| 1993 | 2.75 | 7.28 | 2.44 | 1.08 | 17.40 | 8.53 | 5.11 | 4.22 | 3.58 | 1.65 | 1.41 | 2.78 |
| 1994 | 1.09 | 0.63 | 0.62 | 2.43 | 16.67 | 12.25 | 8.91 | 12.81 | 4.21 | 1.41 | 9.12 | 4.99 |
| 1995 | 1.26 | 0.67 | 0.73 | 0.96 | 4.55 | 2.36 | 5.93 | 6.23 | 7.58 | 5.22 | 6.08 | 2.68 |
| 1996 | 1.45 | 0.89 | 1.02 | 3.97 | 3.02 | 13.56 | 13.36 | 9.63 | 8.67 | 2.61 | 1.82 | 2.46 |
| 1997 | 0.92 | 0.60 | 0.60 | 10.90 | 8.93 | 2.17 | 13.11 | 11.84 | 2.10 | 3.03 | 17.30 | 11.28 |
| 1998 | 18.42 | 5.35 | 1.93 | 1.67 | 12.00 | 4.09 | 11.69 | 6.34 | 3.27 | 7.91 | 6.14 | 1.83 |
| 1999 | 0.82 | 0.58 | 0.79 | 2.67 | 12.33 | 2.99 | 4.66 | 4.07 | 3.55 | 11.43 | 5.77 | 3.46 |
| 2000 | 1.11 | 0.65 | 0.62 | 0.58 | 3.37 | 3.57 | 7.59 | 9.00 | 4.96 | 9.65 | 5.15 | 3.07 |
| 2001 | 1.53 | 2.15 | 1.15 | 10.35 | 9.69 | 9.21 | 7.19 | 11.84 | 6.32 | 3.39 | 14.71 | 3.25 |
| 2002 | 1.15 | 0.70 | 0.75 | 0.86 | 8.87 | 2.34 | 1.60 | 1.76 | 1.21 | 2.20 | 3.99 | 6.77 |
| 2003 | 5.75 | 1.14 | 0.70 | 6.09 | 23.10 | 7.95 | 6.88 | 12.40 | 6.06 | 1.44 | 0.83 | 0.89 |
| 2004 | 0.72 | 0.57 | 0.59 | 8.07 | 17.77 | 2.96 | 3.62 | 13.74 | 3.55 | 3.56 | 13.86 | 4.08 |
| 2005 | 1.82 | 1.08 | 0.92 | 1.91 | 22.49 | 9.89 | 7.07 | 5.40 | 10.02 | 3.58 | 1.88 | 0.99 |
| 2006 | 0.66 | 0.57 | 0.67 | 8.52 | 6.17 | 2.39 | 5.78 | 12.69 | 4.85 | 4.62 | 20.50 | 13.42 |
| 2007 | 5.11 | 2.80 | 1.60 | 6.21 | 10.16 | 18.50 | 12.99 | 14.14 | 12.13 | 3.63 | 1.72 | 0.84 |
| 2008 | 0.65 | 0.56 | 0.60 | 2.55 | 3.03 | 4.93 | 5.61 | 10.79 | 9.31 | 14.56 | 16.46 | 2.18 |
| 2009 | 0.83 | 0.65 | 0.61 | 0.61 | 5.73 | 3.02 | 1.59 | 1.48 | 1.10 | 2.11 | 2.82 | 2.62 |
| 2010 | 7.26 | 1.29 | 14.47 | 16.06 | 16.66 | 6.31 | 5.20 | 4.64 | 8.23 | 6.64 | 5.04 | 1.56 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

Sub-basin: **1BB** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 6.07 | 4.86 | 4.71 | 6.13 | 5.34 | 22.43 | 39.21 | 53.54 | 24.65 | 15.12 | 10.78 | 7.04 |
| 1992 | 4.48 | 3.71 | 4.03 | 4.28 | 21.57 | 20.61 | 32.51 | 41.68 | 25.14 | 34.70 | 23.47 | 8.68 |
| 1993 | 8.76 | 20.17 | 7.87 | 4.64 | 54.13 | 29.84 | 17.65 | 14.99 | 13.97 | 7.70 | 6.62 | 7.90 |
| 1994 | 4.50 | 3.74 | 3.93 | 8.36 | 53.92 | 42.96 | 32.55 | 43.26 | 14.92 | 5.93 | 26.00 | 14.90 |
| 1995 | 5.07 | 3.75 | 4.11 | 5.11 | 14.44 | 9.65 | 25.46 | 23.75 | 25.24 | 20.06 | 21.80 | 8.46 |
| 1996 | 5.35 | 3.99 | 4.53 | 10.29 | 11.19 | 39.12 | 35.33 | 30.22 | 31.81 | 9.38 | 8.00 | 8.39 |
| 1997 | 4.44 | 3.57 | 3.86 | 38.32 | 30.05 | 8.98 | 37.72 | 36.93 | 7.42 | 9.64 | 45.07 | 32.72 |
| 1998 | 54.33 | 20.54 | 8.50 | 9.71 | 42.00 | 15.51 | 42.49 | 24.68 | 13.69 | 31.22 | 23.07 | 6.73 |
| 1999 | 4.39 | 3.66 | 4.73 | 7.65 | 35.01 | 12.63 | 18.81 | 14.56 | 11.45 | 40.63 | 20.60 | 11.32 |
| 2000 | 4.80 | 3.70 | 3.94 | 3.78 | 17.29 | 12.08 | 25.61 | 30.90 | 20.28 | 35.09 | 17.07 | 9.15 |
| 2001 | 5.55 | 6.07 | 4.51 | 23.81 | 32.79 | 34.59 | 26.61 | 38.97 | 22.22 | 14.56 | 48.00 | 10.64 |
| 2002 | 4.84 | 3.79 | 4.03 | 4.23 | 27.27 | 8.04 | 6.16 | 7.34 | 5.57 | 9.70 | 11.11 | 17.13 |
| 2003 | 18.30 | 4.51 | 3.89 | 19.52 | 77.99 | 31.63 | 30.38 | 39.52 | 22.84 | 5.94 | 4.19 | 4.19 |
| 2004 | 3.90 | 3.42 | 3.74 | 23.27 | 55.43 | 11.38 | 11.86 | 42.79 | 12.25 | 11.07 | 38.72 | 12.68 |
| 2005 | 6.23 | 4.29 | 4.17 | 4.82 | 58.80 | 32.42 | 25.23 | 17.74 | 29.60 | 12.35 | 7.11 | 4.62 |
| 2006 | 3.88 | 3.54 | 3.94 | 22.04 | 20.07 | 8.19 | 15.60 | 40.44 | 21.35 | 13.92 | 56.41 | 42.21 |
| 2007 | 15.84 | 9.02 | 5.85 | 17.02 | 32.24 | 54.83 | 40.92 | 49.83 | 46.81 | 14.77 | 6.59 | 4.40 |
| 2008 | 4.07 | 3.62 | 3.98 | 9.08 | 8.06 | 21.73 | 20.20 | 39.13 | 28.07 | 39.07 | 52.36 | 7.76 |
| 2009 | 4.44 | 3.78 | 4.02 | 3.90 | 16.97 | 10.23 | 6.61 | 6.80 | 5.85 | 9.79 | 9.39 | 7.88 |
| 2010 | 22.12 | 5.19 | 37.74 | 46.36 | 56.90 | 22.10 | 21.09 | 17.30 | 26.31 | 21.56 | 15.29 | 5.91 |

Sub-basin: **1BC** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 2.20 | 1.70 | 1.68 | 2.64 | 3.80 | 10.56 | 18.63 | 23.01 | 13.41 | 12.58 | 8.74 | 3.67 |
| 1992 | 1.98 | 1.53 | 1.67 | 1.63 | 3.35 | 7.93 | 15.42 | 18.86 | 13.88 | 17.07 | 9.26 | 3.60 |
| 1993 | 2.65 | 5.02 | 3.81 | 1.95 | 16.99 | 14.54 | 8.42 | 6.78 | 9.05 | 6.91 | 4.11 | 2.68 |
| 1994 | 1.81 | 1.52 | 1.65 | 1.36 | 14.65 | 18.26 | 13.23 | 19.36 | 10.73 | 4.58 | 8.97 | 6.58 |
| 1995 | 2.31 | 1.57 | 1.73 | 1.47 | 3.23 | 5.02 | 14.27 | 13.32 | 13.96 | 11.01 | 10.28 | 4.30 |
| 1996 | 2.33 | 1.65 | 1.64 | 2.12 | 5.27 | 9.17 | 7.05 | 9.45 | 15.82 | 7.77 | 4.69 | 3.85 |
| 1997 | 1.98 | 1.48 | 1.56 | 7.83 | 15.08 | 5.47 | 9.68 | 12.82 | 4.81 | 2.65 | 8.88 | 8.34 |
| 1998 | 16.83 | 9.80 | 5.88 | 4.54 | 16.41 | 10.20 | 16.64 | 13.75 | 10.19 | 16.77 | 15.24 | 4.58 |
| 1999 | 2.08 | 1.49 | 1.56 | 1.48 | 6.03 | 6.40 | 8.58 | 7.70 | 5.99 | 15.03 | 9.92 | 4.31 |
| 2000 | 2.06 | 1.47 | 1.55 | 1.46 | 4.20 | 4.34 | 7.78 | 13.71 | 12.72 | 17.39 | 8.57 | 4.28 |
| 2001 | 2.11 | 1.81 | 1.65 | 2.55 | 10.46 | 16.31 | 14.24 | 15.25 | 10.22 | 10.70 | 22.23 | 6.77 |
| 2002 | 2.34 | 1.57 | 1.68 | 1.68 | 8.28 | 4.93 | 3.93 | 3.99 | 3.47 | 3.53 | 3.11 | 2.45 |
| 2003 | 5.62 | 1.95 | 1.54 | 2.86 | 29.67 | 16.18 | 21.62 | 14.29 | 14.28 | 4.76 | 2.46 | 2.02 |
| 2004 | 1.57 | 1.37 | 1.48 | 2.34 | 14.22 | 5.70 | 4.48 | 11.07 | 6.66 | 4.80 | 9.02 | 6.26 |
| 2005 | 3.16 | 1.77 | 1.51 | 1.54 | 10.73 | 12.97 | 11.99 | 7.82 | 7.91 | 6.67 | 4.39 | 2.10 |
| 2006 | 1.48 | 1.32 | 1.41 | 1.84 | 5.29 | 5.02 | 4.65 | 13.05 | 13.67 | 8.20 | 15.95 | 14.79 |
| 2007 | 5.83 | 2.95 | 2.58 | 3.45 | 9.93 | 17.00 | 15.39 | 25.41 | 26.23 | 11.66 | 3.33 | 1.84 |
| 2008 | 1.48 | 1.31 | 1.42 | 1.25 | 1.74 | 7.59 | 8.28 | 18.21 | 10.07 | 8.84 | 13.42 | 3.96 |
| 2009 | 1.71 | 1.35 | 1.41 | 1.40 | 2.71 | 4.27 | 2.83 | 4.74 | 6.23 | 7.27 | 5.04 | 2.83 |
| 2010 | 6.73 | 2.19 | 4.50 | 11.98 | 27.06 | 11.32 | 11.07 | 9.37 | 11.14 | 11.82 | 7.89 | 3.11 |

Sub-basin: **1BD** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 5.14 | 4.44 | 4.74 | 5.61 | 6.42 | 9.48 | 12.89 | 17.86 | 15.35 | 12.95 | 9.23 | 6.54 |
| 1992 | 5.01 | 4.25 | 4.67 | 4.48 | 6.68 | 8.43 | 12.06 | 16.62 | 13.15 | 15.37 | 11.32 | 6.34 |
| 1993 | 5.36 | 5.63 | 5.84 | 4.61 | 9.27 | 12.28 | 8.84 | 7.78 | 9.48 | 8.10 | 5.82 | 5.24 |
| 1994 | 4.59 | 4.18 | 4.41 | 3.75 | 13.57 | 15.03 | 13.34 | 16.67 | 12.63 | 7.09 | 9.32 | 8.79 |
| 1995 | 5.08 | 4.11 | 4.50 | 4.13 | 6.82 | 7.01 | 8.82 | 12.50 | 14.19 | 9.58 | 8.66 | 5.94 |
| 1996 | 4.77 | 4.03 | 4.33 | 4.95 | 6.26 | 8.73 | 10.72 | 13.10 | 14.31 | 8.52 | 5.61 | 5.01 |
| 1997 | 4.36 | 3.83 | 4.19 | 4.80 | 15.12 | 6.79 | 9.46 | 12.61 | 6.42 | 4.92 | 10.68 | 12.24 |
| 1998 | 14.80 | 9.99 | 6.94 | 6.10 | 15.52 | 10.61 | 12.32 | 18.05 | 11.86 | 13.96 | 13.69 | 6.57 |
| 1999 | 4.76 | 3.99 | 4.36 | 4.06 | 11.10 | 8.30 | 8.81 | 9.92 | 8.38 | 12.19 | 9.70 | 6.22 |
| 2000 | 4.69 | 3.90 | 4.25 | 4.09 | 4.47 | 5.66 | 8.95 | 11.44 | 12.43 | 12.89 | 8.90 | 5.97 |
| 2001 | 4.70 | 4.11 | 4.24 | 4.22 | 7.88 | 11.88 | 12.69 | 13.71 | 12.39 | 9.62 | 17.23 | 8.35 |
| 2002 | 4.83 | 3.99 | 4.23 | 4.13 | 9.95 | 7.53 | 6.31 | 6.15 | 5.34 | 5.06 | 4.73 | 4.41 |
| 2003 | 8.48 | 4.24 | 4.04 | 3.09 | 23.16 | 12.11 | 12.57 | 10.93 | 14.31 | 6.53 | 4.47 | 4.28 |
| 2004 | 4.03 | 3.58 | 3.93 | 3.93 | 13.67 | 7.75 | 6.48 | 10.22 | 8.68 | 7.63 | 9.65 | 8.47 |
| 2005 | 5.32 | 3.92 | 3.97 | 3.96 | 8.01 | 12.97 | 10.37 | 9.14 | 8.99 | 8.04 | 5.71 | 4.25 |
| 2006 | 3.87 | 3.57 | 3.80 | 5.22 | 10.32 | 8.05 | 7.92 | 15.49 | 14.14 | 9.63 | 14.15 | 15.72 |
| 2007 | 10.30 | 6.76 | 6.29 | 6.13 | 9.90 | 12.88 | 16.50 | 19.19 | 22.52 | 11.75 | 5.51 | 4.44 |
| 2008 | 4.16 | 3.71 | 4.08 | 3.78 | 4.41 | 7.83 | 8.28 | 13.34 | 12.50 | 11.94 | 17.95 | 6.46 |
| 2009 | 4.38 | 3.77 | 4.08 | 3.98 | 6.90 | 8.29 | 5.89 | 7.98 | 9.44 | 10.15 | 7.82 | 5.73 |
| 2010 | 12.00 | 5.14 | 7.13 | 13.96 | 25.20 | 12.22 | 13.24 | 10.13 | 16.92 | 14.38 | 9.31 | 5.65 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

Sub-basin: **1BE** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 3.43 | 2.29 | 2.03 | 4.75 | 7.87 | 24.14 | 43.11 | 52.49 | 31.88 | 31.52 | 22.32 | 7.59 |
| 1992 | 2.84 | 1.86 | 1.97 | 2.07 | 4.64 | 14.09 | 29.66 | 42.29 | 32.09 | 40.80 | 22.25 | 7.17 |
| 1993 | 4.68 | 8.60 | 7.99 | 3.03 | 30.44 | 32.79 | 18.49 | 13.70 | 19.23 | 15.53 | 9.03 | 4.83 |
| 1994 | 2.28 | 1.73 | 1.83 | 0.79 | 29.26 | 39.38 | 27.51 | 43.13 | 26.64 | 9.28 | 18.90 | 16.32 |
| 1995 | 3.91 | 1.94 | 2.16 | 1.62 | 5.85 | 10.90 | 31.12 | 34.28 | 32.37 | 25.71 | 23.58 | 9.15 |
| 1996 | 3.80 | 2.16 | 1.94 | 3.76 | 14.00 | 19.30 | 13.55 | 17.25 | 35.39 | 19.76 | 9.72 | 6.45 |
| 1997 | 2.49 | 1.56 | 1.60 | 7.15 | 38.89 | 12.76 | 18.88 | 29.27 | 10.95 | 4.19 | 16.27 | 18.60 |
| 1998 | 33.83 | 23.51 | 15.58 | 11.29 | 38.06 | 26.41 | 31.49 | 33.17 | 24.27 | 38.54 | 39.15 | 10.82 |
| 1999 | 3.18 | 1.73 | 1.69 | 0.96 | 9.66 | 13.54 | 18.48 | 18.04 | 13.27 | 30.28 | 23.82 | 8.65 |
| 2000 | 3.03 | 1.61 | 1.60 | 1.51 | 3.48 | 7.60 | 14.15 | 26.90 | 29.40 | 37.67 | 19.89 | 8.24 |
| 2001 | 3.04 | 2.29 | 1.80 | 2.71 | 18.19 | 37.00 | 31.02 | 34.39 | 24.11 | 23.25 | 53.43 | 16.72 |
| 2002 | 3.97 | 1.86 | 2.05 | 2.15 | 16.74 | 11.31 | 8.40 | 8.78 | 7.81 | 7.20 | 5.80 | 2.92 |
| 2003 | 10.52 | 3.01 | 1.52 | 0.39 | 65.46 | 34.15 | 49.69 | 29.19 | 33.96 | 10.65 | 4.37 | 3.05 |
| 2004 | 1.75 | 1.34 | 1.39 | 1.61 | 23.52 | 13.09 | 8.27 | 16.57 | 15.14 | 9.86 | 18.07 | 14.17 |
| 2005 | 5.92 | 2.54 | 1.45 | 1.66 | 16.37 | 30.51 | 28.87 | 17.25 | 14.15 | 15.89 | 10.18 | 3.32 |
| 2006 | 1.38 | 1.10 | 1.21 | 1.58 | 11.30 | 12.95 | 11.55 | 27.36 | 33.14 | 21.19 | 37.39 | 34.90 |
| 2007 | 12.02 | 5.33 | 4.20 | 6.04 | 22.05 | 35.81 | 35.37 | 59.09 | 63.97 | 29.96 | 6.96 | 2.53 |
| 2008 | 1.49 | 1.21 | 1.30 | 1.03 | 1.81 | 12.85 | 17.86 | 41.87 | 25.00 | 18.39 | 29.16 | 8.57 |
| 2009 | 2.13 | 1.34 | 1.26 | 1.33 | 4.63 | 9.96 | 5.60 | 9.86 | 14.81 | 17.92 | 11.77 | 4.88 |
| 2010 | 14.69 | 3.88 | 6.10 | 24.57 | 65.73 | 26.84 | 25.34 | 22.44 | 25.41 | 29.12 | 20.56 | 6.39 |

Sub-basin: **1BG** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 6.47 | 5.30 | 5.60 | 11.82 | 20.92 | 26.41 | 33.94 | 42.74 | 29.03 | 38.87 | 19.52 | 10.02 |
| 1992 | 6.17 | 5.00 | 5.48 | 5.55 | 12.28 | 20.01 | 31.74 | 33.19 | 28.28 | 40.78 | 18.32 | 8.64 |
| 1993 | 6.95 | 9.58 | 9.17 | 6.10 | 29.55 | 27.71 | 17.04 | 13.92 | 23.02 | 19.52 | 11.50 | 7.56 |
| 1994 | 5.63 | 5.00 | 5.33 | 4.88 | 35.17 | 30.02 | 24.82 | 38.35 | 26.74 | 13.43 | 28.90 | 15.45 |
| 1995 | 6.54 | 5.01 | 5.58 | 5.23 | 12.31 | 16.87 | 26.55 | 30.15 | 34.02 | 23.02 | 19.16 | 9.22 |
| 1996 | 6.22 | 5.06 | 5.42 | 7.89 | 17.39 | 18.26 | 16.10 | 25.37 | 30.59 | 18.41 | 11.60 | 7.83 |
| 1997 | 5.51 | 4.66 | 5.10 | 12.78 | 33.59 | 13.86 | 16.73 | 22.81 | 10.48 | 7.41 | 22.12 | 17.59 |
| 1998 | 29.79 | 17.23 | 11.84 | 10.28 | 35.77 | 23.28 | 24.57 | 33.22 | 26.25 | 40.68 | 34.11 | 10.57 |
| 1999 | 5.95 | 4.68 | 5.14 | 5.54 | 25.16 | 18.57 | 19.86 | 20.46 | 16.15 | 32.29 | 16.82 | 8.81 |
| 2000 | 5.74 | 4.58 | 4.98 | 4.81 | 8.14 | 14.69 | 20.02 | 28.35 | 24.38 | 36.32 | 17.21 | 9.55 |
| 2001 | 6.54 | 5.10 | 5.28 | 7.44 | 20.15 | 31.84 | 31.08 | 27.43 | 21.06 | 27.91 | 46.31 | 14.05 |
| 2002 | 6.28 | 4.78 | 5.33 | 5.72 | 27.49 | 15.16 | 12.77 | 12.61 | 9.91 | 9.88 | 7.99 | 7.33 |
| 2003 | 14.26 | 5.74 | 5.01 | 7.27 | 56.49 | 28.81 | 36.96 | 25.91 | 30.39 | 12.54 | 6.84 | 5.85 |
| 2004 | 5.01 | 4.35 | 4.75 | 5.91 | 26.62 | 14.61 | 11.26 | 18.14 | 17.20 | 13.76 | 20.87 | 15.43 |
| 2005 | 8.64 | 5.36 | 4.93 | 5.60 | 27.15 | 24.39 | 24.83 | 16.20 | 16.56 | 15.04 | 11.64 | 6.04 |
| 2006 | 4.72 | 4.28 | 4.76 | 12.95 | 25.14 | 20.15 | 16.88 | 33.20 | 34.17 | 22.75 | 34.50 | 29.52 |
| 2007 | 14.85 | 9.20 | 8.73 | 10.82 | 23.58 | 28.58 | 33.00 | 54.63 | 57.14 | 25.48 | 8.40 | 5.46 |
| 2008 | 4.75 | 4.19 | 4.63 | 4.67 | 6.50 | 27.58 | 18.35 | 34.18 | 24.38 | 23.41 | 29.54 | 8.85 |
| 2009 | 5.06 | 4.30 | 4.59 | 5.00 | 19.89 | 18.00 | 9.88 | 20.92 | 24.74 | 26.74 | 14.57 | 9.79 |
| 2010 | 20.67 | 7.17 | 9.75 | 34.35 | 58.11 | 24.37 | 31.24 | 21.99 | 39.56 | 37.59 | 19.63 | 9.94 |

Sub-basin: **1BH** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 4.47 | 3.46 | 3.62 | 9.36 | 16.54 | 17.38 | 19.29 | 24.66 | 19.29 | 25.63 | 12.75 | 6.36 |
| 1992 | 3.88 | 3.13 | 3.40 | 3.34 | 8.40 | 13.06 | 19.31 | 20.18 | 17.25 | 26.74 | 12.39 | 5.69 |
| 1993 | 4.46 | 5.91 | 5.33 | 3.80 | 19.68 | 18.18 | 11.42 | 9.79 | 16.48 | 13.66 | 8.25 | 4.91 |
| 1994 | 3.45 | 3.03 | 3.20 | 3.15 | 22.05 | 19.98 | 15.39 | 22.24 | 17.63 | 9.18 | 20.11 | 10.52 |
| 1995 | 4.06 | 3.00 | 3.26 | 3.28 | 10.44 | 11.74 | 15.03 | 18.64 | 22.54 | 14.34 | 12.46 | 5.88 |
| 1996 | 3.72 | 3.13 | 3.41 | 8.75 | 16.94 | 15.55 | 12.67 | 15.58 | 22.32 | 14.39 | 9.00 | 5.81 |
| 1997 | 3.49 | 2.78 | 2.99 | 8.27 | 23.68 | 10.32 | 11.62 | 14.43 | 6.70 | 6.49 | 20.59 | 12.97 |
| 1998 | 21.69 | 11.47 | 6.99 | 8.25 | 25.13 | 16.65 | 18.58 | 22.89 | 18.48 | 27.34 | 24.48 | 6.78 |
| 1999 | 3.73 | 2.87 | 3.32 | 8.69 | 23.04 | 14.37 | 13.90 | 14.98 | 11.76 | 25.79 | 11.96 | 5.63 |
| 2000 | 3.52 | 2.79 | 2.99 | 2.86 | 6.33 | 10.39 | 13.68 | 17.26 | 15.80 | 22.69 | 11.83 | 6.42 |
| 2001 | 4.30 | 3.18 | 3.24 | 6.98 | 14.85 | 18.48 | 17.82 | 16.90 | 12.33 | 16.64 | 27.66 | 8.73 |
| 2002 | 3.72 | 2.81 | 3.00 | 3.31 | 19.81 | 11.41 | 8.51 | 7.49 | 5.65 | 6.35 | 5.32 | 6.18 |
| 2003 | 10.13 | 3.41 | 2.96 | 5.24 | 39.44 | 20.62 | 23.21 | 16.36 | 20.60 | 8.38 | 4.44 | 3.62 |
| 2004 | 3.00 | 2.55 | 2.74 | 4.80 | 18.68 | 10.42 | 7.45 | 12.63 | 10.72 | 9.16 | 14.99 | 9.88 |
| 2005 | 5.53 | 3.16 | 2.86 | 3.63 | 20.53 | 16.70 | 15.37 | 9.54 | 11.00 | 9.98 | 8.37 | 3.71 |
| 2006 | 2.71 | 2.41 | 2.86 | 16.04 | 19.12 | 15.21 | 11.77 | 21.21 | 23.03 | 16.11 | 24.34 | 20.79 |
| 2007 | 10.75 | 6.30 | 5.88 | 8.27 | 18.06 | 19.59 | 22.55 | 32.76 | 35.99 | 18.05 | 6.23 | 3.55 |
| 2008 | 2.84 | 2.46 | 2.69 | 3.15 | 8.12 | 22.43 | 12.21 | 20.89 | 18.13 | 19.22 | 20.67 | 5.84 |
| 2009 | 3.06 | 2.59 | 2.68 | 3.45 | 19.77 | 13.73 | 7.63 | 15.17 | 18.59 | 18.32 | 9.78 | 7.45 |
| 2010 | 15.05 | 4.87 | 10.31 | 24.97 | 37.07 | 18.63 | 22.23 | 14.87 | 29.14 | 29.84 | 15.72 | 8.32 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

# 1CA, 1CB, 1CC, 1CD & 1CE

Sub-basin: **1CA** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 5.45 | 4.81 | 4.96 | 7.05 | 6.05 | 10.30 | 16.43 | 16.00 | 12.08 | 7.88 | 6.12 | 5.76 |
| 1992 | 4.71 | 4.00 | 4.37 | 4.30 | 9.21 | 7.80 | 10.78 | 16.83 | 11.38 | 11.14 | 10.78 | 6.27 |
| 1993 | 5.51 | 6.21 | 5.80 | 4.51 | 8.28 | 10.74 | 7.99 | 7.64 | 7.67 | 5.98 | 4.92 | 4.73 |
| 1994 | 4.32 | 3.95 | 4.20 | 5.42 | 20.70 | 14.53 | 15.96 | 15.56 | 10.00 | 5.80 | 6.59 | 7.08 |
| 1995 | 4.79 | 3.98 | 4.48 | 4.46 | 10.28 | 7.24 | 8.51 | 11.06 | 11.92 | 7.44 | 6.89 | 5.85 |
| 1996 | 4.86 | 4.10 | 4.71 | 8.01 | 6.84 | 12.08 | 16.14 | 14.04 | 12.31 | 6.90 | 4.90 | 4.72 |
| 1997 | 4.27 | 3.78 | 4.15 | 7.43 | 12.95 | 5.79 | 12.32 | 13.97 | 5.71 | 5.49 | 14.31 | 15.11 |
| 1998 | 19.63 | 10.17 | 6.35 | 5.86 | 14.89 | 9.27 | 15.59 | 16.58 | 9.35 | 11.03 | 9.91 | 5.88 |
| 1999 | 4.69 | 4.03 | 4.71 | 6.01 | 12.55 | 6.76 | 7.66 | 9.48 | 7.78 | 12.35 | 9.33 | 7.79 |
| 2000 | 5.10 | 4.05 | 4.34 | 4.16 | 4.65 | 5.01 | 6.82 | 10.52 | 9.98 | 9.13 | 7.27 | 5.32 |
| 2001 | 4.70 | 4.57 | 4.42 | 5.26 | 8.22 | 10.87 | 11.65 | 14.34 | 12.49 | 6.85 | 12.50 | 7.10 |
| 2002 | 4.90 | 4.12 | 4.29 | 4.23 | 11.40 | 6.70 | 5.59 | 5.66 | 4.97 | 4.60 | 4.36 | 8.95 |
| 2003 | 11.65 | 4.56 | 4.19 | 4.38 | 21.59 | 10.41 | 8.64 | 11.96 | 10.79 | 5.59 | 4.30 | 4.26 |
| 2004 | 4.12 | 3.66 | 4.02 | 6.47 | 20.48 | 7.27 | 6.79 | 11.71 | 7.72 | 8.08 | 8.32 | 6.77 |
| 2005 | 4.78 | 3.93 | 4.18 | 4.29 | 11.87 | 11.11 | 8.29 | 10.42 | 12.17 | 7.18 | 4.75 | 4.17 |
| 2006 | 4.00 | 3.70 | 4.00 | 6.88 | 9.97 | 6.78 | 8.30 | 19.38 | 12.77 | 7.64 | 15.61 | 19.71 |
| 2007 | 10.85 | 8.17 | 6.60 | 7.58 | 10.52 | 17.58 | 18.62 | 17.78 | 21.50 | 9.64 | 5.83 | 4.74 |
| 2008 | 4.42 | 3.93 | 4.31 | 4.27 | 4.80 | 6.74 | 7.75 | 13.11 | 13.65 | 17.20 | 23.10 | 6.64 |
| 2009 | 4.73 | 4.06 | 4.36 | 4.21 | 5.65 | 6.21 | 5.42 | 6.14 | 6.15 | 7.33 | 7.25 | 6.28 |
| 2010 | 13.02 | 5.73 | 12.40 | 12.88 | 22.56 | 11.12 | 10.81 | 12.17 | 14.69 | 10.45 | 7.12 | 5.25 |

Sub-basin: **1CB** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 5.25 | 4.38 | 4.43 | 9.40 | 6.63 | 14.24 | 21.00 | 17.66 | 13.61 | 7.76 | 5.75 | 5.35 |
| 1992 | 3.80 | 3.06 | 3.30 | 4.44 | 12.96 | 8.34 | 14.24 | 21.67 | 14.32 | 13.29 | 11.90 | 5.73 |
| 1993 | 5.00 | 6.05 | 5.02 | 3.53 | 9.26 | 13.48 | 8.47 | 8.61 | 8.90 | 5.99 | 4.73 | 4.14 |
| 1994 | 3.40 | 3.03 | 3.28 | 8.28 | 26.95 | 17.87 | 20.59 | 19.32 | 11.29 | 5.36 | 6.30 | 6.65 |
| 1995 | 3.85 | 3.12 | 3.97 | 4.77 | 14.23 | 8.18 | 11.23 | 14.33 | 15.22 | 7.47 | 7.23 | 5.67 |
| 1996 | 4.11 | 3.40 | 4.35 | 10.03 | 7.19 | 14.35 | 18.45 | 16.48 | 14.34 | 6.76 | 4.23 | 4.10 |
| 1997 | 3.40 | 2.94 | 3.22 | 11.00 | 14.96 | 5.49 | 15.49 | 14.87 | 5.18 | 5.53 | 17.55 | 17.27 |
| 1998 | 22.20 | 12.44 | 6.04 | 5.41 | 17.01 | 10.28 | 19.61 | 21.28 | 10.14 | 12.58 | 10.91 | 5.13 |
| 1999 | 3.75 | 3.16 | 4.25 | 6.26 | 13.47 | 6.57 | 8.82 | 12.22 | 9.10 | 16.10 | 9.89 | 8.72 |
| 2000 | 4.34 | 3.21 | 3.40 | 3.25 | 4.35 | 4.68 | 7.87 | 12.92 | 11.67 | 9.92 | 7.30 | 4.56 |
| 2001 | 4.05 | 4.69 | 3.75 | 4.96 | 8.48 | 12.79 | 14.13 | 16.79 | 14.19 | 6.69 | 13.66 | 6.76 |
| 2002 | 4.19 | 3.38 | 3.50 | 3.78 | 16.44 | 6.70 | 5.24 | 5.59 | 4.99 | 3.93 | 3.69 | 18.32 |
| 2003 | 14.39 | 3.97 | 3.35 | 3.89 | 27.33 | 12.27 | 9.97 | 16.84 | 12.85 | 5.43 | 3.60 | 3.50 |
| 2004 | 3.35 | 2.95 | 3.22 | 8.40 | 23.50 | 7.45 | 7.27 | 14.42 | 8.17 | 9.34 | 8.04 | 6.29 |
| 2005 | 4.16 | 3.32 | 3.55 | 3.87 | 13.48 | 12.17 | 8.59 | 12.14 | 14.68 | 6.98 | 4.09 | 3.33 |
| 2006 | 3.13 | 2.91 | 3.48 | 9.81 | 11.41 | 7.16 | 10.29 | 26.92 | 16.34 | 7.70 | 14.71 | 21.72 |
| 2007 | 12.29 | 8.74 | 6.62 | 8.65 | 12.09 | 22.50 | 22.29 | 23.59 | 29.21 | 10.48 | 5.42 | 3.94 |
| 2008 | 3.54 | 3.13 | 3.44 | 4.07 | 5.13 | 8.66 | 10.26 | 17.48 | 17.14 | 18.84 | 24.34 | 6.16 |
| 2009 | 3.88 | 3.28 | 3.47 | 3.47 | 5.87 | 6.83 | 5.40 | 6.67 | 6.67 | 9.62 | 8.86 | 6.67 |
| 2010 | 16.30 | 5.68 | 13.65 | 12.79 | 28.57 | 13.02 | 14.72 | 16.70 | 18.36 | 12.16 | 7.06 | 4.60 |

Sub-basin: **1CC** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 9.28 | 7.80 | 8.34 | 15.79 | 13.96 | 23.17 | 26.86 | 20.85 | 17.70 | 11.98 | 10.21 | 9.29 |
| 1992 | 7.99 | 6.83 | 7.43 | 8.09 | 19.72 | 15.30 | 24.79 | 29.37 | 23.46 | 21.14 | 17.08 | 10.49 |
| 1993 | 9.55 | 10.84 | 9.98 | 7.81 | 17.21 | 22.32 | 14.28 | 15.82 | 14.64 | 10.79 | 10.72 | 9.73 |
| 1994 | 7.96 | 7.04 | 7.54 | 15.98 | 36.06 | 23.72 | 25.22 | 25.88 | 15.70 | 9.65 | 12.63 | 12.24 |
| 1995 | 8.36 | 7.11 | 8.84 | 10.72 | 20.81 | 13.17 | 18.49 | 18.58 | 20.39 | 12.63 | 13.06 | 10.50 |
| 1996 | 8.58 | 7.34 | 8.72 | 16.28 | 13.49 | 20.42 | 23.80 | 24.13 | 20.14 | 11.16 | 8.97 | 9.75 |
| 1997 | 8.14 | 6.92 | 7.50 | 24.02 | 20.45 | 10.13 | 23.67 | 17.86 | 9.82 | 11.37 | 28.26 | 23.47 |
| 1998 | 30.22 | 18.91 | 10.84 | 9.09 | 21.29 | 15.43 | 26.23 | 25.99 | 14.34 | 17.73 | 16.86 | 9.86 |
| 1999 | 8.32 | 7.20 | 8.96 | 12.03 | 17.51 | 10.92 | 17.89 | 22.20 | 15.06 | 24.49 | 14.94 | 15.03 |
| 2000 | 9.04 | 7.29 | 7.86 | 7.52 | 9.01 | 10.45 | 17.82 | 20.00 | 16.62 | 17.72 | 12.14 | 9.35 |
| 2001 | 9.32 | 11.03 | 8.55 | 11.51 | 17.09 | 21.73 | 21.28 | 21.83 | 18.08 | 11.64 | 19.90 | 11.21 |
| 2002 | 8.90 | 7.68 | 8.10 | 8.02 | 23.60 | 10.74 | 9.84 | 12.82 | 11.98 | 8.78 | 8.32 | 23.60 |
| 2003 | 20.93 | 8.00 | 7.74 | 9.65 | 36.32 | 17.60 | 14.48 | 26.25 | 19.52 | 11.23 | 8.32 | 8.18 |
| 2004 | 7.82 | 6.90 | 7.56 | 19.32 | 27.09 | 12.38 | 14.57 | 22.75 | 13.08 | 16.15 | 15.58 | 12.79 |
| 2005 | 9.95 | 7.93 | 8.70 | 10.11 | 25.88 | 18.17 | 15.88 | 17.77 | 21.75 | 11.88 | 9.22 | 8.02 |
| 2006 | 7.62 | 7.03 | 7.83 | 20.33 | 15.70 | 12.45 | 19.55 | 32.83 | 20.90 | 11.53 | 18.75 | 26.57 |
| 2007 | 16.98 | 12.60 | 11.48 | 16.03 | 19.78 | 31.69 | 32.12 | 33.27 | 37.39 | 15.81 | 10.67 | 8.87 |
| 2008 | 8.29 | 7.37 | 8.12 | 14.84 | 13.53 | 15.90 | 19.73 | 26.50 | 23.34 | 24.45 | 26.37 | 11.06 |
| 2009 | 8.73 | 7.62 | 8.19 | 7.92 | 13.06 | 12.23 | 10.22 | 11.98 | 12.68 | 17.35 | 14.01 | 12.40 |
| 2010 | 22.86 | 10.34 | 19.47 | 17.78 | 34.73 | 18.95 | 20.51 | 21.60 | 24.24 | 18.16 | 12.37 | 9.71 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

Sub-basin: **1CD** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 15.54 | 13.35 | 13.86 | 23.52 | 26.04 | 37.04 | 54.43 | 49.26 | 37.34 | 31.34 | 19.84 | 16.90 |
| 1992 | 13.14 | 11.05 | 12.06 | 12.94 | 29.37 | 28.74 | 46.79 | 56.05 | 41.16 | 42.27 | 32.14 | 17.97 |
| 1993 | 15.47 | 17.03 | 15.78 | 12.40 | 31.75 | 38.45 | 25.16 | 25.37 | 28.78 | 19.87 | 15.18 | 13.64 |
| 1994 | 12.07 | 10.98 | 11.73 | 20.37 | 71.27 | 48.23 | 56.35 | 55.51 | 34.58 | 18.37 | 24.71 | 22.30 |
| 1995 | 13.42 | 11.07 | 12.80 | 13.63 | 38.92 | 28.60 | 34.93 | 40.92 | 42.21 | 24.24 | 23.05 | 18.10 |
| 1996 | 13.68 | 11.62 | 13.67 | 27.78 | 24.37 | 38.24 | 47.79 | 43.30 | 39.71 | 22.20 | 15.11 | 14.14 |
| 1997 | 12.12 | 10.53 | 11.52 | 30.35 | 45.20 | 18.30 | 41.61 | 40.52 | 17.16 | 16.98 | 47.28 | 42.01 |
| 1998 | 55.01 | 30.11 | 17.87 | 16.22 | 51.15 | 32.76 | 53.66 | 57.52 | 31.34 | 39.72 | 31.50 | 16.37 |
| 1999 | 12.79 | 10.95 | 13.56 | 22.74 | 42.68 | 23.70 | 29.46 | 40.31 | 28.80 | 47.05 | 27.38 | 21.84 |
| 2000 | 13.85 | 11.00 | 11.84 | 11.37 | 18.47 | 19.80 | 27.78 | 39.06 | 34.08 | 32.94 | 22.36 | 15.99 |
| 2001 | 14.51 | 15.47 | 12.93 | 16.94 | 28.47 | 38.03 | 40.01 | 43.70 | 39.46 | 23.03 | 38.88 | 20.54 |
| 2002 | 13.60 | 11.38 | 11.89 | 12.12 | 46.27 | 21.77 | 19.27 | 21.52 | 17.98 | 14.67 | 14.21 | 37.89 |
| 2003 | 37.30 | 12.90 | 11.68 | 13.35 | 77.39 | 38.40 | 34.31 | 47.26 | 38.33 | 18.98 | 12.59 | 12.17 |
| 2004 | 11.61 | 10.26 | 11.20 | 21.34 | 60.28 | 22.82 | 22.38 | 39.83 | 25.60 | 27.93 | 26.54 | 20.66 |
| 2005 | 14.16 | 11.24 | 12.00 | 13.97 | 40.80 | 34.81 | 25.63 | 31.61 | 36.39 | 20.92 | 14.05 | 11.64 |
| 2006 | 10.99 | 10.18 | 11.65 | 35.03 | 33.86 | 23.84 | 30.16 | 65.92 | 47.19 | 23.72 | 40.68 | 55.79 |
| 2007 | 33.90 | 25.49 | 20.55 | 24.64 | 32.75 | 54.12 | 57.45 | 65.28 | 76.94 | 30.28 | 16.83 | 12.96 |
| 2008 | 11.90 | 10.57 | 11.61 | 16.19 | 19.79 | 31.39 | 30.44 | 46.97 | 46.71 | 47.99 | 62.02 | 18.15 |
| 2009 | 12.66 | 10.90 | 11.68 | 12.61 | 27.85 | 22.05 | 18.02 | 26.05 | 24.26 | 27.76 | 23.48 | 20.09 |
| 2010 | 43.94 | 16.72 | 36.07 | 39.33 | 73.39 | 38.91 | 43.38 | 42.06 | 57.34 | 39.38 | 22.01 | 15.10 |

Sub-basin: **1CE** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 3.97 | 3.49 | 3.72 | 5.97 | 9.64 | 8.62 | 9.83 | 11.65 | 9.47 | 14.68 | 6.79 | 4.85 |
| 1992 | 3.93 | 3.38 | 3.72 | 3.53 | 5.14 | 7.85 | 13.60 | 10.80 | 9.95 | 13.53 | 7.26 | 4.78 |
| 1993 | 4.05 | 3.78 | 4.01 | 3.62 | 10.37 | 10.35 | 7.05 | 6.46 | 9.11 | 6.76 | 4.64 | 3.97 |
| 1994 | 3.66 | 3.38 | 3.59 | 3.47 | 12.09 | 10.80 | 10.97 | 14.02 | 10.69 | 6.57 | 8.83 | 6.33 |
| 1995 | 3.90 | 3.28 | 3.57 | 3.22 | 8.41 | 9.35 | 9.57 | 11.31 | 12.18 | 7.00 | 5.91 | 4.61 |
| 1996 | 3.73 | 3.28 | 3.49 | 4.70 | 5.50 | 6.47 | 6.59 | 7.18 | 9.00 | 6.77 | 4.83 | 4.01 |
| 1997 | 3.54 | 3.13 | 3.45 | 4.70 | 11.67 | 5.31 | 7.05 | 6.80 | 4.49 | 4.19 | 8.28 | 6.73 |
| 1998 | 6.65 | 4.74 | 3.89 | 3.57 | 11.69 | 8.55 | 9.30 | 14.16 | 9.23 | 12.38 | 8.79 | 4.35 |
| 1999 | 3.55 | 3.08 | 3.39 | 5.00 | 11.22 | 7.47 | 7.66 | 10.13 | 8.33 | 11.74 | 6.18 | 4.01 |
| 2000 | 3.50 | 3.04 | 3.34 | 3.22 | 5.75 | 6.97 | 8.89 | 10.08 | 8.69 | 10.10 | 6.04 | 4.63 |
| 2001 | 4.14 | 3.55 | 3.49 | 3.64 | 5.63 | 7.68 | 9.18 | 8.15 | 8.67 | 7.78 | 9.66 | 5.28 |
| 2002 | 3.55 | 3.10 | 3.27 | 3.35 | 12.38 | 6.81 | 5.97 | 5.54 | 4.74 | 4.71 | 4.38 | 5.70 |
| 2003 | 8.37 | 3.43 | 3.33 | 3.15 | 16.17 | 10.37 | 11.44 | 9.73 | 11.25 | 5.96 | 3.70 | 3.41 |
| 2004 | 3.24 | 2.89 | 3.16 | 3.32 | 8.50 | 6.00 | 5.56 | 8.25 | 7.13 | 6.62 | 6.02 | 5.51 |
| 2005 | 3.89 | 3.01 | 3.13 | 3.38 | 7.65 | 8.67 | 5.73 | 5.09 | 5.70 | 5.19 | 4.09 | 3.26 |
| 2006 | 3.06 | 2.84 | 3.11 | 8.67 | 9.47 | 7.93 | 7.48 | 12.65 | 12.32 | 7.34 | 6.39 | 9.33 |
| 2007 | 7.42 | 5.22 | 5.03 | 5.05 | 6.68 | 9.22 | 9.94 | 14.50 | 15.16 | 7.61 | 3.85 | 3.26 |
| 2008 | 3.08 | 2.76 | 3.04 | 3.25 | 4.90 | 10.62 | 6.90 | 10.16 | 10.21 | 7.91 | 10.00 | 4.10 |
| 2009 | 3.15 | 2.78 | 3.02 | 3.97 | 11.49 | 7.68 | 4.98 | 9.21 | 9.80 | 8.18 | 5.32 | 4.68 |
| 2010 | 9.55 | 3.83 | 5.61 | 11.89 | 15.82 | 9.68 | 12.79 | 7.73 | 19.41 | 13.76 | 6.72 | 4.46 |

## 1DA, 1DB, 1DC & 1DD

Sub-basin: **1DA** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 7.44 | 6.56 | 7.21 | 12.03 | 25.79 | 14.86 | 16.77 | 19.24 | 16.01 | 24.55 | 12.22 | 8.33 |
| 1992 | 6.93 | 6.00 | 6.58 | 6.71 | 8.67 | 16.23 | 26.33 | 17.44 | 17.25 | 24.49 | 13.84 | 9.19 |
| 1993 | 7.43 | 6.77 | 7.46 | 6.87 | 21.86 | 19.53 | 12.09 | 12.28 | 18.90 | 12.68 | 8.78 | 7.19 |
| 1994 | 6.53 | 5.94 | 6.46 | 9.56 | 29.48 | 20.88 | 22.22 | 24.89 | 19.77 | 11.52 | 18.73 | 13.55 |
| 1995 | 7.15 | 5.83 | 6.42 | 7.52 | 19.80 | 21.39 | 19.00 | 18.42 | 21.69 | 13.53 | 14.58 | 10.15 |
| 1996 | 6.94 | 6.73 | 7.51 | 19.25 | 21.59 | 17.90 | 13.93 | 11.83 | 19.66 | 17.06 | 10.39 | 8.97 |
| 1997 | 6.83 | 5.66 | 6.21 | 12.90 | 28.45 | 11.77 | 15.76 | 15.39 | 9.59 | 9.57 | 19.80 | 14.39 |
| 1998 | 16.21 | 9.82 | 7.77 | 7.62 | 27.30 | 19.69 | 19.74 | 20.93 | 17.68 | 25.65 | 18.02 | 8.08 |
| 1999 | 6.55 | 5.62 | 8.66 | 20.07 | 26.77 | 17.22 | 15.18 | 21.13 | 18.36 | 28.22 | 12.99 | 7.45 |
| 2000 | 6.54 | 5.59 | 6.09 | 6.08 | 14.97 | 14.02 | 15.16 | 15.67 | 14.68 | 17.74 | 11.61 | 9.71 |
| 2001 | 8.79 | 7.09 | 6.78 | 10.30 | 17.24 | 14.17 | 14.37 | 12.53 | 13.28 | 12.85 | 16.28 | 9.70 |
| 2002 | 6.48 | 5.63 | 5.94 | 7.05 | 26.91 | 14.64 | 12.39 | 10.67 | 9.28 | 9.79 | 11.65 | 15.18 |
| 2003 | 15.49 | 6.37 | 6.13 | 5.37 | 38.86 | 22.83 | 25.89 | 20.65 | 21.47 | 12.14 | 7.19 | 6.58 |
| 2004 | 6.26 | 5.44 | 5.91 | 8.29 | 20.13 | 11.80 | 9.82 | 13.86 | 13.31 | 12.40 | 12.37 | 10.80 |
| 2005 | 7.59 | 5.66 | 5.88 | 8.29 | 19.21 | 17.13 | 10.94 | 9.59 | 9.90 | 9.42 | 8.11 | 6.26 |
| 2006 | 5.62 | 5.18 | 7.12 | 31.13 | 21.18 | 17.34 | 14.04 | 20.01 | 25.57 | 12.80 | 14.76 | 22.66 |
| 2007 | 14.44 | 9.45 | 8.44 | 11.08 | 16.91 | 20.47 | 19.31 | 28.65 | 28.53 | 16.74 | 9.65 | 6.59 |
| 2008 | 5.77 | 5.11 | 5.72 | 9.78 | 17.75 | 23.35 | 13.39 | 21.57 | 23.32 | 17.95 | 20.88 | 8.23 |
| 2009 | 5.94 | 5.39 | 5.64 | 12.14 | 26.50 | 15.63 | 9.98 | 14.89 | 18.65 | 14.49 | 9.81 | 8.84 |
| 2010 | 19.07 | 8.14 | 13.52 | 22.19 | 27.54 | 22.15 | 24.21 | 16.21 | 34.74 | 28.46 | 14.77 | 9.52 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

Sub-basin: **1DB** (Unit: $m^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 12.16 | 10.03 | 10.70 | 20.55 | 30.91 | 26.05 | 27.12 | 30.55 | 25.11 | 34.44 | 19.71 | 13.08 |
| 1992 | 10.55 | 9.09 | 9.96 | 9.82 | 17.37 | 20.12 | 28.74 | 27.01 | 24.20 | 37.48 | 20.67 | 13.15 |
| 1993 | 11.48 | 12.64 | 12.13 | 10.28 | 30.11 | 26.41 | 19.39 | 19.08 | 27.00 | 22.70 | 16.55 | 11.91 |
| 1994 | 10.00 | 8.99 | 9.55 | 9.53 | 37.85 | 30.20 | 23.56 | 31.11 | 24.76 | 16.18 | 30.38 | 19.86 |
| 1995 | 10.82 | 8.78 | 9.71 | 10.22 | 23.51 | 21.78 | 23.47 | 26.58 | 31.74 | 22.27 | 21.79 | 13.75 |
| 1996 | 10.38 | 9.56 | 11.21 | 27.69 | 38.80 | 31.30 | 23.77 | 24.18 | 34.38 | 27.51 | 18.45 | 15.27 |
| 1997 | 10.49 | 8.52 | 9.20 | 19.96 | 40.75 | 20.16 | 22.50 | 25.02 | 14.23 | 17.98 | 38.62 | 25.04 |
| 1998 | 36.82 | 20.64 | 14.66 | 18.58 | 38.94 | 29.05 | 35.04 | 33.47 | 29.20 | 40.41 | 37.26 | 13.61 |
| 1999 | 10.38 | 8.73 | 10.95 | 29.36 | 43.79 | 25.96 | 24.14 | 27.33 | 22.54 | 46.45 | 22.62 | 12.78 |
| 2000 | 10.19 | 8.62 | 9.30 | 8.95 | 18.02 | 19.85 | 22.37 | 25.39 | 21.82 | 31.06 | 19.37 | 14.20 |
| 2001 | 11.38 | 9.43 | 9.99 | 19.52 | 27.17 | 24.77 | 22.89 | 22.26 | 18.00 | 22.50 | 32.93 | 14.47 |
| 2002 | 9.85 | 8.51 | 9.10 | 9.46 | 32.17 | 21.32 | 15.69 | 13.74 | 11.69 | 13.31 | 13.04 | 15.94 |
| 2003 | 19.15 | 9.20 | 9.12 | 13.94 | 61.62 | 33.49 | 35.28 | 26.42 | 30.85 | 16.02 | 11.25 | 10.38 |
| 2004 | 9.41 | 8.19 | 8.88 | 15.52 | 32.04 | 18.52 | 14.18 | 21.10 | 17.11 | 16.68 | 25.72 | 16.66 |
| 2005 | 12.39 | 8.81 | 8.94 | 10.87 | 34.66 | 26.66 | 23.10 | 15.52 | 18.84 | 17.94 | 16.11 | 10.17 |
| 2006 | 8.66 | 7.85 | 9.49 | 39.70 | 31.86 | 26.76 | 20.66 | 29.00 | 35.20 | 24.88 | 37.91 | 34.11 |
| 2007 | 20.03 | 12.58 | 12.66 | 17.30 | 32.40 | 31.85 | 33.99 | 41.91 | 46.47 | 28.09 | 15.24 | 10.40 |
| 2008 | 8.89 | 7.82 | 8.56 | 12.01 | 24.28 | 39.58 | 20.30 | 32.12 | 29.89 | 33.92 | 31.73 | 12.98 |
| 2009 | 9.17 | 8.14 | 8.58 | 12.14 | 40.25 | 25.34 | 16.16 | 23.36 | 28.56 | 26.77 | 16.70 | 15.11 |
| 2010 | 25.53 | 11.63 | 23.92 | 38.29 | 47.21 | 30.20 | 34.44 | 23.57 | 42.62 | 47.60 | 27.42 | 17.84 |

Sub-basin: **1DC** (Unit: $m^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 5.58 | 4.58 | 4.78 | 7.32 | 15.27 | 11.11 | 8.72 | 9.31 | 9.25 | 11.01 | 9.28 | 5.85 |
| 1992 | 4.78 | 4.12 | 4.53 | 4.29 | 4.21 | 6.86 | 12.14 | 10.39 | 9.18 | 11.75 | 10.43 | 6.53 |
| 1993 | 5.16 | 4.39 | 5.12 | 4.38 | 8.20 | 11.55 | 8.05 | 7.30 | 11.44 | 9.09 | 6.79 | 5.18 |
| 1994 | 4.49 | 4.05 | 4.31 | 3.63 | 14.44 | 13.79 | 9.85 | 11.43 | 11.37 | 7.01 | 9.82 | 10.90 |
| 1995 | 5.07 | 3.97 | 4.47 | 4.32 | 10.79 | 10.26 | 10.16 | 9.06 | 11.68 | 9.91 | 10.26 | 7.56 |
| 1996 | 4.93 | 4.89 | 5.54 | 15.90 | 20.23 | 14.86 | 9.87 | 7.44 | 14.73 | 15.53 | 9.05 | 8.11 |
| 1997 | 5.10 | 3.92 | 4.20 | 4.33 | 20.93 | 9.34 | 9.99 | 10.33 | 7.26 | 6.14 | 15.65 | 13.86 |
| 1998 | 15.61 | 8.53 | 6.09 | 5.93 | 17.89 | 13.02 | 14.55 | 11.73 | 12.15 | 15.55 | 16.38 | 6.48 |
| 1999 | 4.76 | 3.99 | 5.23 | 14.03 | 20.68 | 11.69 | 9.94 | 11.44 | 12.17 | 19.40 | 12.23 | 5.94 |
| 2000 | 4.76 | 3.94 | 4.23 | 4.07 | 5.73 | 7.67 | 8.24 | 7.73 | 8.57 | 9.95 | 8.36 | 7.23 |
| 2001 | 5.74 | 4.83 | 4.61 | 7.67 | 13.35 | 8.94 | 7.30 | 6.60 | 7.04 | 6.42 | 8.76 | 6.44 |
| 2002 | 4.38 | 3.84 | 4.02 | 4.05 | 11.95 | 11.03 | 7.15 | 5.58 | 5.35 | 5.59 | 7.64 | 6.14 |
| 2003 | 10.77 | 4.39 | 4.17 | 2.59 | 26.36 | 15.37 | 16.12 | 10.66 | 14.33 | 8.33 | 5.32 | 4.67 |
| 2004 | 4.26 | 3.71 | 4.03 | 4.41 | 12.63 | 8.10 | 5.91 | 6.45 | 7.23 | 8.13 | 8.72 | 7.84 |
| 2005 | 5.29 | 3.81 | 3.93 | 4.37 | 10.28 | 13.06 | 8.21 | 6.82 | 6.17 | 6.85 | 6.34 | 4.55 |
| 2006 | 3.84 | 3.52 | 4.11 | 19.36 | 16.25 | 12.32 | 9.09 | 9.31 | 13.36 | 9.63 | 12.92 | 18.00 |
| 2007 | 11.18 | 5.35 | 5.06 | 5.40 | 12.97 | 13.39 | 12.13 | 14.70 | 16.97 | 13.69 | 8.72 | 5.02 |
| 2008 | 4.01 | 3.52 | 3.83 | 5.39 | 12.39 | 16.73 | 8.42 | 12.10 | 16.14 | 14.86 | 16.09 | 6.75 |
| 2009 | 4.18 | 3.79 | 3.88 | 5.62 | 17.26 | 12.37 | 7.65 | 6.20 | 10.58 | 10.53 | 6.65 | 4.98 |
| 2010 | 10.54 | 5.48 | 8.61 | 12.82 | 17.53 | 13.44 | 14.03 | 9.37 | 15.63 | 19.94 | 13.53 | 7.61 |

Sub-basin: **1DD** (Unit: $m^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 6.42 | 5.20 | 5.56 | 9.41 | 18.56 | 12.09 | 8.31 | 7.79 | 7.86 | 9.10 | 9.12 | 6.26 |
| 1992 | 5.28 | 4.56 | 4.99 | 4.91 | 5.17 | 7.33 | 10.88 | 9.24 | 8.68 | 10.68 | 10.19 | 7.16 |
| 1993 | 6.03 | 5.07 | 5.71 | 4.95 | 8.45 | 11.24 | 8.07 | 7.54 | 10.80 | 9.14 | 7.35 | 5.91 |
| 1994 | 4.99 | 4.50 | 4.91 | 4.91 | 14.99 | 13.77 | 9.07 | 9.25 | 9.80 | 7.12 | 10.74 | 11.40 |
| 1995 | 5.48 | 4.46 | 5.32 | 5.98 | 12.24 | 10.24 | 9.90 | 8.16 | 10.59 | 10.80 | 11.41 | 8.15 |
| 1996 | 5.59 | 5.74 | 6.86 | 20.21 | 22.99 | 16.21 | 10.38 | 7.56 | 16.31 | 18.55 | 10.34 | 9.85 |
| 1997 | 5.83 | 4.37 | 4.67 | 5.38 | 20.78 | 10.71 | 10.05 | 10.04 | 7.54 | 8.04 | 18.48 | 17.35 |
| 1998 | 18.40 | 9.54 | 6.74 | 7.87 | 19.56 | 13.37 | 14.44 | 10.54 | 11.45 | 15.63 | 17.40 | 6.97 |
| 1999 | 5.59 | 4.62 | 6.31 | 15.68 | 23.01 | 12.57 | 9.78 | 10.77 | 13.24 | 21.48 | 13.42 | 7.68 |
| 2000 | 5.74 | 4.54 | 4.83 | 4.69 | 6.41 | 7.38 | 7.70 | 7.52 | 7.91 | 9.46 | 8.83 | 8.50 |
| 2001 | 6.62 | 5.46 | 5.33 | 10.01 | 15.56 | 9.81 | 7.14 | 6.35 | 6.71 | 6.47 | 7.83 | 6.18 |
| 2002 | 4.82 | 4.31 | 4.65 | 5.11 | 14.00 | 11.65 | 6.88 | 5.60 | 5.49 | 6.42 | 9.69 | 7.67 |
| 2003 | 10.24 | 4.70 | 4.72 | 4.71 | 26.86 | 16.53 | 15.10 | 10.19 | 13.38 | 8.38 | 6.17 | 5.52 |
| 2004 | 5.00 | 4.26 | 4.77 | 5.82 | 12.91 | 8.36 | 6.12 | 6.40 | 7.08 | 9.51 | 10.85 | 8.09 |
| 2005 | 5.60 | 4.20 | 4.53 | 4.92 | 10.83 | 13.49 | 8.83 | 7.26 | 6.78 | 7.30 | 7.14 | 5.23 |
| 2006 | 4.38 | 4.04 | 5.06 | 21.03 | 18.25 | 13.33 | 9.13 | 7.98 | 11.65 | 9.56 | 15.20 | 20.32 |
| 2007 | 11.60 | 5.83 | 5.52 | 6.16 | 14.62 | 13.33 | 11.08 | 12.35 | 15.08 | 14.09 | 10.06 | 5.76 |
| 2008 | 4.58 | 4.06 | 4.46 | 6.66 | 14.14 | 16.50 | 8.77 | 11.70 | 19.31 | 17.32 | 18.09 | 7.63 |
| 2009 | 4.77 | 4.44 | 4.46 | 6.65 | 18.74 | 12.83 | 8.12 | 6.06 | 9.26 | 10.40 | 7.02 | 5.94 |
| 2010 | 10.23 | 5.88 | 10.14 | 12.26 | 16.83 | 13.55 | 13.03 | 9.17 | 13.59 | 19.10 | 14.58 | 8.25 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

# 1EA, 1EB, 1EC, 1ED, 1EE, 1EF & 1EG

Sub-basin: **1EA** (Unit: $m^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 13.02 | 11.24 | 12.28 | 22.35 | 39.75 | 23.86 | 24.30 | 25.33 | 20.78 | 29.33 | 19.37 | 13.98 |
| 1992 | 12.01 | 10.45 | 11.46 | 11.06 | 13.41 | 32.71 | 36.92 | 25.51 | 27.39 | 28.77 | 18.76 | 14.98 |
| 1993 | 12.82 | 12.23 | 13.42 | 12.35 | 33.10 | 27.57 | 17.84 | 18.36 | 24.03 | 16.63 | 13.38 | 12.19 |
| 1994 | 11.38 | 10.41 | 11.40 | 25.24 | 39.24 | 27.31 | 32.15 | 31.34 | 25.24 | 16.53 | 27.56 | 20.70 |
| 1995 | 12.23 | 10.34 | 12.78 | 18.97 | 29.83 | 29.65 | 30.34 | 22.78 | 26.27 | 21.59 | 24.26 | 17.03 |
| 1996 | 12.59 | 12.80 | 15.37 | 32.96 | 29.00 | 25.10 | 21.05 | 18.65 | 26.66 | 22.14 | 15.58 | 15.46 |
| 1997 | 12.37 | 10.23 | 10.95 | 22.10 | 33.05 | 18.76 | 23.54 | 22.32 | 15.42 | 13.65 | 23.58 | 22.53 |
| 1998 | 26.42 | 15.43 | 13.24 | 13.55 | 37.33 | 25.56 | 23.96 | 21.65 | 21.51 | 30.63 | 22.37 | 12.86 |
| 1999 | 11.26 | 9.89 | 12.89 | 25.92 | 30.77 | 22.82 | 21.81 | 30.88 | 26.30 | 33.21 | 17.19 | 13.03 |
| 2000 | 11.45 | 9.86 | 10.76 | 10.37 | 20.14 | 19.40 | 22.23 | 23.29 | 20.45 | 24.25 | 16.48 | 16.76 |
| 2001 | 18.33 | 15.21 | 12.52 | 20.53 | 27.74 | 24.43 | 24.80 | 19.13 | 21.86 | 21.05 | 21.58 | 15.54 |
| 2002 | 11.73 | 10.16 | 11.24 | 14.75 | 41.14 | 20.85 | 18.92 | 21.82 | 18.01 | 17.21 | 21.14 | 23.13 |
| 2003 | 22.22 | 10.92 | 10.80 | 11.50 | 46.24 | 31.78 | 33.47 | 37.94 | 26.72 | 19.99 | 12.41 | 12.26 |
| 2004 | 11.54 | 10.03 | 10.79 | 16.81 | 29.51 | 17.33 | 15.52 | 20.70 | 20.60 | 21.07 | 19.23 | 16.17 |
| 2005 | 12.91 | 10.51 | 11.74 | 17.34 | 27.22 | 22.27 | 17.89 | 18.17 | 17.07 | 14.25 | 11.80 | 10.82 |
| 2006 | 10.16 | 9.41 | 11.60 | 42.89 | 27.11 | 22.51 | 21.10 | 26.22 | 29.50 | 17.08 | 21.28 | 28.27 |
| 2007 | 20.49 | 14.58 | 14.18 | 19.09 | 23.08 | 26.75 | 25.92 | 42.80 | 41.36 | 22.46 | 16.13 | 11.86 |
| 2008 | 10.60 | 9.39 | 10.30 | 19.17 | 26.95 | 28.53 | 22.84 | 29.58 | 30.29 | 23.80 | 27.39 | 13.23 |
| 2009 | 10.70 | 10.02 | 10.38 | 18.12 | 29.40 | 18.21 | 16.48 | 20.74 | 23.22 | 20.74 | 15.34 | 15.17 |
| 2010 | 25.03 | 13.53 | 20.68 | 25.07 | 33.62 | 29.40 | 28.70 | 24.18 | 35.55 | 29.28 | 17.80 | 13.27 |

Sub-basin: **1EB** (Unit: $m^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 11.21 | 9.71 | 10.65 | 18.40 | 31.36 | 17.39 | 14.45 | 16.29 | 15.75 | 19.90 | 15.78 | 11.65 |
| 1992 | 10.31 | 9.00 | 9.88 | 9.56 | 10.79 | 22.22 | 23.41 | 16.90 | 16.99 | 17.99 | 14.12 | 12.11 |
| 1993 | 10.78 | 9.84 | 10.99 | 10.30 | 19.73 | 18.99 | 13.91 | 13.27 | 16.63 | 13.34 | 11.19 | 10.32 |
| 1994 | 9.74 | 8.96 | 9.85 | 16.91 | 26.73 | 18.43 | 18.37 | 18.13 | 16.81 | 12.83 | 19.19 | 16.07 |
| 1995 | 10.21 | 8.78 | 11.05 | 15.32 | 20.65 | 19.60 | 20.58 | 15.13 | 17.59 | 17.12 | 18.91 | 13.71 |
| 1996 | 10.60 | 11.02 | 13.16 | 27.89 | 24.48 | 20.01 | 14.70 | 12.38 | 21.36 | 20.31 | 13.20 | 13.52 |
| 1997 | 10.48 | 8.75 | 9.49 | 13.20 | 24.45 | 15.18 | 16.31 | 16.03 | 12.47 | 11.20 | 16.55 | 19.22 |
| 1998 | 21.90 | 12.18 | 10.91 | 13.36 | 27.22 | 18.53 | 17.04 | 14.57 | 15.47 | 23.37 | 18.61 | 10.90 |
| 1999 | 9.88 | 8.67 | 10.44 | 19.47 | 23.56 | 16.60 | 15.08 | 16.71 | 19.22 | 23.58 | 14.13 | 11.08 |
| 2000 | 9.93 | 8.59 | 9.39 | 9.06 | 12.13 | 12.92 | 14.62 | 14.88 | 13.90 | 16.46 | 12.66 | 13.48 |
| 2001 | 14.23 | 11.73 | 10.74 | 18.13 | 21.84 | 16.07 | 16.78 | 13.54 | 14.99 | 16.10 | 16.41 | 12.42 |
| 2002 | 9.88 | 8.71 | 9.59 | 13.55 | 28.86 | 16.41 | 13.15 | 13.82 | 12.46 | 14.13 | 18.91 | 15.64 |
| 2003 | 16.02 | 9.01 | 9.35 | 9.30 | 31.07 | 23.07 | 23.30 | 26.20 | 19.02 | 14.71 | 10.53 | 10.28 |
| 2004 | 9.75 | 8.55 | 9.36 | 11.47 | 18.68 | 13.61 | 11.40 | 12.62 | 13.83 | 16.22 | 14.59 | 12.38 |
| 2005 | 10.26 | 8.56 | 9.35 | 11.22 | 18.92 | 16.49 | 13.25 | 14.56 | 14.60 | 11.51 | 9.63 | 9.30 |
| 2006 | 8.86 | 8.23 | 9.62 | 32.79 | 21.79 | 18.53 | 14.61 | 15.83 | 19.21 | 13.50 | 18.30 | 23.28 |
| 2007 | 15.01 | 10.20 | 10.40 | 12.68 | 18.28 | 17.85 | 16.03 | 25.33 | 27.42 | 18.53 | 14.30 | 10.33 |
| 2008 | 9.21 | 8.18 | 8.97 | 11.53 | 21.93 | 19.50 | 14.49 | 20.45 | 23.68 | 19.30 | 22.14 | 11.44 |
| 2009 | 9.35 | 8.77 | 9.11 | 12.99 | 21.67 | 14.58 | 13.01 | 12.58 | 16.18 | 16.08 | 11.63 | 10.83 |
| 2010 | 15.80 | 10.67 | 16.13 | 18.04 | 23.21 | 19.69 | 18.41 | 16.43 | 20.93 | 20.44 | 15.09 | 11.44 |

Sub-basin: **1EC** (Unit: $m^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 6.71 | 5.77 | 6.33 | 8.88 | 16.83 | 10.07 | 9.76 | 10.58 | 9.28 | 11.48 | 8.96 | 6.86 |
| 1992 | 6.24 | 5.52 | 6.08 | 5.87 | 6.19 | 10.60 | 14.19 | 10.51 | 10.15 | 11.76 | 9.22 | 7.48 |
| 1993 | 6.65 | 6.03 | 6.49 | 6.06 | 12.22 | 11.34 | 8.30 | 7.87 | 10.83 | 8.45 | 6.92 | 6.29 |
| 1994 | 5.98 | 5.53 | 5.91 | 8.59 | 16.46 | 11.78 | 12.23 | 12.63 | 11.20 | 7.95 | 11.25 | 9.57 |
| 1995 | 6.30 | 5.43 | 6.22 | 7.49 | 12.27 | 12.38 | 12.16 | 9.90 | 11.11 | 10.24 | 10.70 | 8.30 |
| 1996 | 6.41 | 6.29 | 7.21 | 15.24 | 14.42 | 11.63 | 9.22 | 8.03 | 12.27 | 12.05 | 7.98 | 7.78 |
| 1997 | 6.37 | 5.38 | 5.85 | 8.72 | 15.22 | 8.89 | 10.43 | 10.08 | 7.62 | 7.07 | 11.00 | 10.46 |
| 1998 | 11.97 | 7.50 | 6.58 | 6.90 | 15.40 | 11.64 | 11.33 | 9.56 | 10.26 | 13.93 | 11.10 | 6.64 |
| 1999 | 6.05 | 5.33 | 6.51 | 12.46 | 14.74 | 10.26 | 9.91 | 10.85 | 11.73 | 15.15 | 8.94 | 6.73 |
| 2000 | 6.09 | 5.32 | 5.83 | 5.62 | 8.43 | 8.74 | 9.07 | 9.24 | 8.56 | 10.06 | 7.97 | 7.85 |
| 2001 | 7.66 | 6.43 | 6.32 | 9.50 | 12.34 | 9.41 | 9.39 | 8.10 | 8.30 | 8.80 | 9.19 | 7.19 |
| 2002 | 5.96 | 5.35 | 5.70 | 6.12 | 15.69 | 9.88 | 8.54 | 8.22 | 7.47 | 8.06 | 9.95 | 9.96 |
| 2003 | 9.77 | 5.58 | 5.76 | 5.86 | 18.90 | 13.70 | 14.12 | 13.55 | 11.30 | 8.78 | 6.38 | 6.21 |
| 2004 | 5.92 | 5.21 | 5.70 | 6.57 | 11.44 | 8.20 | 7.14 | 8.07 | 8.39 | 9.29 | 8.82 | 7.82 |
| 2005 | 6.35 | 5.25 | 5.73 | 6.65 | 11.08 | 10.09 | 8.13 | 7.85 | 7.54 | 6.96 | 6.14 | 5.72 |
| 2006 | 5.45 | 5.06 | 5.83 | 17.93 | 12.59 | 10.72 | 8.93 | 10.01 | 12.81 | 8.59 | 10.60 | 13.08 |
| 2007 | 9.17 | 6.63 | 6.47 | 7.87 | 10.86 | 11.40 | 9.95 | 15.35 | 15.26 | 10.95 | 8.16 | 6.18 |
| 2008 | 5.62 | 5.01 | 5.51 | 7.25 | 12.14 | 12.37 | 9.05 | 12.41 | 14.55 | 11.17 | 12.81 | 6.83 |
| 2009 | 5.69 | 5.22 | 5.55 | 7.81 | 13.88 | 9.20 | 7.73 | 7.65 | 9.83 | 9.40 | 7.11 | 6.77 |
| 2010 | 10.54 | 6.52 | 9.26 | 10.96 | 13.52 | 12.44 | 12.21 | 9.99 | 14.29 | 13.70 | 9.40 | 7.13 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

Sub-basin: **1ED** (Unit: $m^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 2.70 | 2.18 | 2.37 | 4.87 | 8.06 | 4.60 | 3.40 | 3.25 | 3.17 | 3.64 | 3.84 | 2.68 |
| 1992 | 2.30 | 2.00 | 2.20 | 2.12 | 2.28 | 3.56 | 5.44 | 3.77 | 3.80 | 4.14 | 3.75 | 3.11 |
| 1993 | 2.84 | 2.41 | 2.53 | 2.22 | 4.28 | 5.00 | 3.38 | 2.80 | 3.93 | 3.48 | 2.89 | 2.50 |
| 1994 | 2.20 | 1.99 | 2.13 | 2.68 | 7.75 | 4.84 | 3.76 | 3.86 | 4.13 | 3.19 | 4.86 | 4.38 |
| 1995 | 2.34 | 1.97 | 2.40 | 3.28 | 5.75 | 4.38 | 4.56 | 3.42 | 4.24 | 4.96 | 5.04 | 3.62 |
| 1996 | 2.54 | 2.52 | 2.98 | 8.65 | 7.29 | 5.59 | 3.80 | 2.99 | 6.68 | 7.16 | 3.79 | 4.01 |
| 1997 | 2.50 | 1.97 | 2.12 | 2.42 | 7.45 | 4.16 | 4.01 | 3.60 | 3.04 | 2.96 | 6.09 | 6.62 |
| 1998 | 6.81 | 3.30 | 2.57 | 3.38 | 7.56 | 4.65 | 4.27 | 3.53 | 4.03 | 5.95 | 5.61 | 2.77 |
| 1999 | 2.36 | 2.00 | 2.30 | 5.01 | 8.07 | 4.45 | 3.68 | 3.61 | 5.31 | 6.91 | 4.49 | 3.36 |
| 2000 | 2.53 | 2.00 | 2.14 | 2.06 | 2.63 | 2.89 | 3.16 | 3.49 | 3.25 | 4.10 | 3.52 | 3.77 |
| 2001 | 3.24 | 2.81 | 2.53 | 5.38 | 6.18 | 4.50 | 3.49 | 2.94 | 3.04 | 3.54 | 3.74 | 2.79 |
| 2002 | 2.21 | 1.96 | 2.09 | 2.72 | 7.62 | 4.33 | 2.89 | 2.58 | 2.72 | 3.48 | 5.54 | 3.93 |
| 2003 | 4.29 | 2.11 | 2.15 | 2.66 | 9.03 | 5.99 | 5.48 | 4.02 | 4.67 | 3.44 | 2.75 | 2.47 |
| 2004 | 2.24 | 1.94 | 2.14 | 2.76 | 4.84 | 3.47 | 2.73 | 2.80 | 3.06 | 4.82 | 4.75 | 3.36 |
| 2005 | 2.41 | 1.91 | 2.05 | 2.39 | 4.88 | 5.00 | 3.47 | 3.31 | 3.21 | 3.12 | 2.76 | 2.26 |
| 2006 | 2.02 | 1.86 | 2.26 | 9.05 | 6.81 | 5.27 | 3.50 | 3.31 | 4.17 | 3.59 | 5.75 | 7.85 |
| 2007 | 4.26 | 2.64 | 2.46 | 3.12 | 5.64 | 4.80 | 3.53 | 4.73 | 5.61 | 5.17 | 4.02 | 2.51 |
| 2008 | 2.10 | 1.85 | 2.02 | 3.29 | 5.74 | 5.34 | 3.49 | 4.84 | 8.75 | 5.80 | 6.99 | 3.00 |
| 2009 | 2.14 | 1.96 | 2.06 | 2.82 | 6.66 | 4.01 | 3.07 | 2.54 | 3.47 | 4.12 | 2.99 | 2.73 |
| 2010 | 4.21 | 2.36 | 3.99 | 4.21 | 6.18 | 4.55 | 4.77 | 3.47 | 4.72 | 5.87 | 4.53 | 3.00 |

Sub-basin: **1EE** (Unit: $m^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 1.80 | 1.50 | 1.47 | 10.40 | 15.30 | 8.47 | 3.25 | 1.71 | 2.42 | 1.44 | 3.43 | 1.39 |
| 1992 | 1.80 | 1.19 | 1.50 | 1.31 | 0.70 | 2.12 | 4.26 | 3.01 | 3.88 | 4.04 | 5.85 | 4.13 |
| 1993 | 4.73 | 1.80 | 1.84 | 1.45 | 4.21 | 9.18 | 3.64 | 0.96 | 3.06 | 3.56 | 2.95 | 1.76 |
| 1994 | 1.62 | 1.27 | 1.52 | 0.00 | 14.01 | 10.74 | 3.83 | 2.74 | 5.18 | 3.37 | 9.47 | 7.87 |
| 1995 | 1.68 | 1.41 | 1.16 | 3.95 | 13.01 | 6.46 | 4.41 | 2.19 | 5.81 | 10.48 | 10.94 | 5.53 |
| 1996 | 2.08 | 1.67 | 2.34 | 18.77 | 16.00 | 11.85 | 5.04 | 1.85 | 15.09 | 21.44 | 7.05 | 7.72 |
| 1997 | 1.67 | 1.20 | 1.62 | 0.00 | 14.14 | 7.25 | 4.30 | 2.93 | 2.72 | 2.13 | 15.56 | 22.67 |
| 1998 | 16.29 | 5.05 | 1.87 | 3.68 | 17.05 | 6.72 | 2.80 | 2.47 | 4.60 | 8.43 | 10.66 | 2.74 |
| 1999 | 1.19 | 1.62 | 1.07 | 3.51 | 22.68 | 7.58 | 3.46 | 2.59 | 9.75 | 12.95 | 10.68 | 8.61 |
| 2000 | 2.52 | 1.44 | 1.29 | 1.46 | 0.59 | 1.25 | 1.41 | 1.10 | 3.43 | 4.81 | 6.69 | 8.55 |
| 2001 | 4.31 | 3.39 | 1.35 | 10.43 | 14.46 | 10.63 | 4.03 | 2.33 | 3.64 | 4.24 | 5.63 | 3.02 |
| 2002 | 1.68 | 1.24 | 1.61 | 3.76 | 16.00 | 6.81 | 2.01 | 1.14 | 1.95 | 3.19 | 13.03 | 6.30 |
| 2003 | 8.04 | 1.57 | 1.70 | 3.64 | 19.18 | 11.17 | 7.69 | 0.88 | 4.32 | 2.53 | 2.81 | 1.55 |
| 2004 | 1.46 | 1.42 | 1.52 | 1.72 | 7.19 | 4.35 | 2.25 | 1.40 | 3.12 | 11.20 | 11.82 | 5.84 |
| 2005 | 1.66 | 1.44 | 1.53 | 1.05 | 5.04 | 11.36 | 4.61 | 3.63 | 1.86 | 3.76 | 4.50 | 1.61 |
| 2006 | 1.26 | 1.22 | 1.49 | 16.22 | 19.73 | 10.60 | 3.60 | 2.42 | 3.48 | 3.37 | 9.41 | 24.14 |
| 2007 | 10.74 | 3.80 | 1.93 | 3.77 | 12.77 | 8.45 | 2.87 | 2.30 | 4.80 | 7.88 | 5.90 | 1.68 |
| 2008 | 1.52 | 1.35 | 1.29 | 4.67 | 9.73 | 8.69 | 3.24 | 6.31 | 29.01 | 13.28 | 19.02 | 4.13 |
| 2009 | 1.61 | 1.27 | 1.63 | 2.13 | 12.99 | 7.48 | 2.73 | 0.32 | 2.96 | 5.53 | 3.66 | 2.44 |
| 2010 | 7.26 | 1.29 | 3.63 | 4.60 | 12.82 | 6.71 | 4.39 | 1.22 | 3.89 | 6.98 | 9.24 | 3.22 |

Sub-basin: **1EF** (Unit: $m^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 0.00 | 0.00 | 0.00 | 7.79 | 17.04 | 6.96 | 0.00 | 0.00 | 1.45 | 0.00 | 1.49 | 0.16 |
| 1992 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 5.32 | 1.74 |
| 1993 | 2.47 | 0.00 | 0.00 | 0.00 | 0.00 | 7.70 | 0.66 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1994 | 0.00 | 0.00 | 0.00 | 0.00 | 17.16 | 10.18 | 0.04 | 0.00 | 4.60 | 0.21 | 10.75 | 10.12 |
| 1995 | 0.00 | 0.00 | 0.00 | 2.84 | 15.30 | 4.48 | 0.05 | 0.00 | 3.28 | 8.26 | 8.97 | 3.27 |
| 1996 | 0.00 | 0.00 | 0.57 | 18.94 | 15.86 | 12.59 | 2.34 | 0.00 | 10.51 | 21.66 | 5.55 | 5.73 |
| 1997 | 0.00 | 0.00 | 0.00 | 0.00 | 11.40 | 2.64 | 0.52 | 0.00 | 0.74 | 0.00 | 22.62 | 33.99 |
| 1998 | 19.49 | 2.80 | 0.00 | 1.62 | 17.94 | 2.76 | 0.00 | 0.00 | 0.12 | 0.86 | 9.38 | 0.51 |
| 1999 | 0.00 | 0.00 | 0.00 | 0.13 | 27.73 | 4.00 | 0.87 | 0.00 | 9.61 | 15.27 | 11.25 | 10.54 |
| 2000 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.76 | 0.00 | 6.52 | 7.24 |
| 2001 | 2.70 | 1.57 | 0.00 | 6.83 | 13.13 | 8.24 | 0.00 | 0.00 | 0.68 | 0.17 | 5.15 | 1.42 |
| 2002 | 0.00 | 0.00 | 0.00 | 0.00 | 20.27 | 3.20 | 0.00 | 0.00 | 0.00 | 0.00 | 12.40 | 0.00 |
| 2003 | 8.28 | 0.00 | 0.00 | 0.00 | 20.84 | 6.67 | 5.15 | 0.00 | 4.09 | 0.00 | 0.27 | 0.00 |
| 2004 | 0.00 | 0.00 | 0.00 | 0.00 | 5.01 | 0.56 | 0.00 | 0.00 | 0.57 | 10.12 | 14.20 | 4.17 |
| 2005 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.92 | 1.32 | 1.16 | 0.00 | 2.85 | 3.80 | 0.00 |
| 2006 | 0.00 | 0.00 | 0.00 | 11.90 | 19.71 | 6.05 | 0.00 | 0.00 | 0.00 | 1.68 | 8.08 | 31.40 |
| 2007 | 11.50 | 1.25 | 0.00 | 1.42 | 16.08 | 7.10 | 0.17 | 0.00 | 0.52 | 5.95 | 4.41 | 0.00 |
| 2008 | 0.00 | 0.00 | 0.00 | 0.08 | 7.78 | 8.12 | 0.00 | 3.10 | 34.83 | 14.88 | 22.13 | 1.74 |
| 2009 | 0.00 | 0.00 | 0.00 | 0.00 | 16.30 | 5.98 | 0.05 | 0.00 | 0.28 | 4.25 | 1.97 | 0.33 |
| 2010 | 7.38 | 0.00 | 0.00 | 3.80 | 15.85 | 2.36 | 1.10 | 0.00 | 0.65 | 5.86 | 7.26 | 0.00 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

Sub-basin: **1EG** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 3.98 | 2.36 | 2.60 | 18.99 | 22.73 | 12.79 | 6.61 | 4.67 | 4.07 | 4.73 | 7.14 | 3.93 |
| 1992 | 2.39 | 1.83 | 2.00 | 2.03 | 2.57 | 7.05 | 10.10 | 5.94 | 7.36 | 8.18 | 7.53 | 6.60 |
| 1993 | 7.82 | 4.53 | 3.52 | 2.37 | 10.56 | 14.84 | 6.87 | 3.63 | 5.47 | 5.03 | 4.37 | 3.44 |
| 1994 | 2.21 | 1.83 | 2.30 | 6.12 | 22.76 | 14.44 | 8.36 | 6.44 | 8.22 | 5.70 | 16.08 | 11.34 |
| 1995 | 2.68 | 2.15 | 3.38 | 11.33 | 19.27 | 11.31 | 10.04 | 5.13 | 8.46 | 15.52 | 17.72 | 9.28 |
| 1996 | 4.63 | 4.32 | 5.95 | 31.91 | 21.27 | 16.25 | 8.17 | 4.44 | 18.96 | 27.19 | 9.26 | 12.07 |
| 1997 | 3.32 | 1.94 | 2.00 | 3.71 | 17.01 | 11.13 | 8.12 | 5.45 | 4.03 | 3.66 | 15.36 | 32.27 |
| 1998 | 25.45 | 7.19 | 3.00 | 7.26 | 25.69 | 11.14 | 6.16 | 4.46 | 5.83 | 12.49 | 12.26 | 4.19 |
| 1999 | 2.77 | 1.97 | 2.45 | 8.34 | 26.59 | 11.25 | 6.12 | 5.58 | 12.94 | 17.16 | 11.58 | 11.55 |
| 2000 | 4.59 | 2.05 | 2.06 | 1.97 | 3.07 | 3.12 | 3.90 | 5.21 | 5.09 | 8.13 | 7.53 | 11.99 |
| 2001 | 9.34 | 8.20 | 4.18 | 18.04 | 19.65 | 16.14 | 8.27 | 5.08 | 6.67 | 10.47 | 10.25 | 5.07 |
| 2002 | 2.55 | 1.94 | 2.23 | 11.10 | 25.67 | 10.29 | 4.03 | 3.34 | 4.33 | 7.12 | 21.29 | 12.98 |
| 2003 | 11.25 | 2.58 | 2.50 | 8.33 | 25.91 | 17.18 | 12.52 | 6.62 | 7.67 | 5.61 | 4.90 | 3.63 |
| 2004 | 2.65 | 2.07 | 2.42 | 5.18 | 11.45 | 7.59 | 4.75 | 4.23 | 5.62 | 16.04 | 16.71 | 8.55 |
| 2005 | 3.48 | 2.04 | 2.35 | 3.61 | 12.14 | 14.94 | 7.25 | 6.50 | 6.60 | 6.44 | 5.94 | 2.79 |
| 2006 | 2.00 | 1.81 | 2.78 | 28.79 | 25.09 | 16.37 | 7.24 | 5.67 | 6.92 | 5.46 | 17.56 | 31.70 |
| 2007 | 14.24 | 6.74 | 4.64 | 9.33 | 19.52 | 13.64 | 5.63 | 7.26 | 10.45 | 11.69 | 8.98 | 3.57 |
| 2008 | 2.16 | 1.79 | 2.09 | 8.67 | 16.96 | 13.34 | 6.64 | 11.89 | 37.74 | 19.87 | 25.96 | 6.41 |
| 2009 | 2.33 | 2.09 | 2.08 | 5.12 | 19.53 | 9.90 | 4.62 | 3.19 | 5.01 | 8.73 | 5.58 | 6.06 |
| 2010 | 11.12 | 2.87 | 8.78 | 9.55 | 19.93 | 10.33 | 6.76 | 4.12 | 6.83 | 10.89 | 11.70 | 5.28 |

## 1FA, 1FB, 1FC, 1FD, 1FE, 1FF & 1FG

Sub-basin: **1FA** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 1.13 | 0.77 | 0.78 | 3.92 | 4.27 | 7.83 | 8.08 | 5.52 | 4.77 | 2.94 | 1.83 | 1.01 |
| 1992 | 0.55 | 0.38 | 0.39 | 0.49 | 3.76 | 5.01 | 9.30 | 10.06 | 8.95 | 7.14 | 4.94 | 1.76 |
| 1993 | 1.82 | 2.95 | 1.36 | 0.60 | 6.56 | 8.32 | 4.33 | 4.44 | 3.74 | 1.79 | 3.07 | 1.82 |
| 1994 | 0.65 | 0.41 | 0.46 | 4.04 | 13.01 | 7.23 | 6.93 | 8.32 | 4.17 | 1.25 | 4.13 | 2.36 |
| 1995 | 0.68 | 0.45 | 1.62 | 2.81 | 5.04 | 3.56 | 5.19 | 4.69 | 5.84 | 2.85 | 3.38 | 1.40 |
| 1996 | 0.84 | 0.63 | 1.46 | 3.88 | 3.69 | 4.99 | 6.12 | 8.37 | 6.04 | 1.88 | 1.73 | 1.97 |
| 1997 | 0.78 | 0.43 | 0.41 | 8.23 | 5.69 | 2.32 | 6.41 | 3.94 | 1.33 | 2.66 | 10.09 | 7.38 |
| 1998 | 9.77 | 5.56 | 1.57 | 0.91 | 5.40 | 3.94 | 7.31 | 6.95 | 3.19 | 4.38 | 4.87 | 1.22 |
| 1999 | 0.58 | 0.41 | 0.76 | 2.33 | 3.48 | 2.11 | 5.47 | 8.15 | 4.10 | 7.84 | 3.66 | 3.94 |
| 2000 | 0.90 | 0.45 | 0.44 | 0.40 | 0.56 | 1.38 | 5.63 | 5.78 | 4.26 | 5.54 | 2.63 | 1.20 |
| 2001 | 2.19 | 1.90 | 0.75 | 3.72 | 5.45 | 7.15 | 6.57 | 6.18 | 4.31 | 2.66 | 5.69 | 1.93 |
| 2002 | 1.16 | 0.74 | 0.84 | 1.29 | 8.37 | 1.95 | 1.40 | 4.72 | 2.98 | 1.10 | 1.18 | 7.69 |
| 2003 | 4.78 | 0.76 | 0.46 | 2.04 | 12.26 | 4.80 | 3.61 | 9.76 | 6.10 | 2.33 | 0.91 | 0.81 |
| 2004 | 0.56 | 0.43 | 0.47 | 6.35 | 6.45 | 3.06 | 4.08 | 7.27 | 3.59 | 4.10 | 5.12 | 4.21 |
| 2005 | 1.70 | 1.11 | 1.52 | 2.45 | 9.39 | 5.29 | 4.58 | 4.65 | 7.29 | 2.39 | 1.45 | 0.64 |
| 2006 | 0.45 | 0.39 | 0.51 | 6.28 | 4.45 | 3.63 | 6.61 | 10.01 | 6.10 | 1.86 | 5.35 | 7.72 |
| 2007 | 4.02 | 2.72 | 1.90 | 4.09 | 6.34 | 9.78 | 10.57 | 11.52 | 11.95 | 3.95 | 1.50 | 0.74 |
| 2008 | 0.51 | 0.43 | 0.49 | 4.35 | 3.11 | 4.17 | 5.80 | 10.22 | 7.68 | 5.85 | 5.48 | 1.54 |
| 2009 | 0.66 | 0.52 | 0.47 | 0.47 | 2.26 | 2.09 | 1.61 | 2.82 | 3.71 | 5.53 | 2.97 | 2.73 |
| 2010 | 6.40 | 2.00 | 4.73 | 4.63 | 11.25 | 5.84 | 5.92 | 5.77 | 7.91 | 5.56 | 2.70 | 1.31 |

Sub-basin: **1FB** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 6.07 | 5.08 | 6.31 | 14.51 | 20.42 | 21.74 | 21.25 | 15.35 | 14.12 | 14.57 | 10.40 | 6.58 |
| 1992 | 5.13 | 4.20 | 4.52 | 4.65 | 13.20 | 19.60 | 28.79 | 26.00 | 25.67 | 21.12 | 13.98 | 7.67 |
| 1993 | 6.37 | 7.79 | 6.87 | 5.34 | 21.19 | 23.45 | 11.86 | 12.31 | 14.27 | 8.34 | 10.28 | 7.81 |
| 1994 | 5.06 | 4.25 | 5.45 | 15.73 | 33.56 | 21.30 | 23.53 | 25.42 | 16.72 | 8.02 | 17.59 | 12.71 |
| 1995 | 5.64 | 4.51 | 7.41 | 11.16 | 19.57 | 15.70 | 19.58 | 17.71 | 18.28 | 13.06 | 13.80 | 8.80 |
| 1996 | 6.24 | 6.35 | 10.18 | 18.96 | 17.79 | 18.47 | 18.97 | 19.08 | 19.91 | 11.55 | 9.31 | 9.50 |
| 1997 | 5.95 | 4.48 | 4.42 | 23.22 | 21.59 | 10.38 | 21.37 | 14.96 | 8.16 | 10.15 | 26.54 | 20.74 |
| 1998 | 25.53 | 13.94 | 8.35 | 6.93 | 23.49 | 16.74 | 23.19 | 20.22 | 14.86 | 17.47 | 16.35 | 6.71 |
| 1999 | 5.03 | 4.18 | 6.60 | 13.56 | 19.39 | 12.64 | 20.20 | 29.56 | 17.81 | 26.41 | 12.85 | 10.70 |
| 2000 | 5.63 | 4.32 | 4.55 | 4.30 | 10.57 | 13.27 | 19.89 | 19.67 | 16.81 | 18.61 | 11.44 | 8.38 |
| 2001 | 12.68 | 9.94 | 5.92 | 12.97 | 19.23 | 22.14 | 19.64 | 17.07 | 16.26 | 11.72 | 15.41 | 7.97 |
| 2002 | 6.48 | 4.85 | 6.85 | 7.67 | 27.65 | 10.91 | 9.42 | 17.92 | 12.77 | 7.85 | 9.66 | 16.12 |
| 2003 | 16.59 | 5.28 | 4.63 | 9.68 | 40.00 | 21.40 | 18.69 | 26.99 | 20.43 | 12.53 | 6.14 | 6.65 |
| 2004 | 5.55 | 4.63 | 5.04 | 20.03 | 25.00 | 11.85 | 11.77 | 17.68 | 14.33 | 15.15 | 16.75 | 11.33 |
| 2005 | 7.31 | 6.28 | 9.39 | 10.93 | 23.82 | 16.99 | 14.77 | 13.07 | 14.74 | 9.77 | 7.61 | 5.13 |
| 2006 | 4.42 | 3.98 | 6.17 | 27.23 | 15.77 | 13.87 | 18.45 | 23.55 | 19.40 | 9.70 | 17.50 | 22.83 |
| 2007 | 14.08 | 10.62 | 10.71 | 12.89 | 20.41 | 24.34 | 29.18 | 37.06 | 39.24 | 15.27 | 8.34 | 5.68 |
| 2008 | 4.76 | 4.27 | 6.88 | 20.38 | 15.77 | 20.56 | 19.22 | 22.37 | 20.09 | 18.26 | 18.75 | 7.06 |
| 2009 | 4.94 | 4.57 | 4.51 | 7.46 | 19.08 | 11.25 | 10.95 | 15.91 | 17.26 | 16.08 | 11.42 | 10.28 |
| 2010 | 20.63 | 9.15 | 15.72 | 15.21 | 29.86 | 21.41 | 20.15 | 16.19 | 25.30 | 20.87 | 10.86 | 7.16 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

Sub-basin: **1FC** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 3.88 | 3.28 | 3.47 | 8.12 | 11.80 | 11.74 | 10.45 | 7.49 | 6.81 | 8.48 | 6.80 | 4.24 |
| 1992 | 3.37 | 2.93 | 3.26 | 3.07 | 5.76 | 11.48 | 15.52 | 12.25 | 14.68 | 10.80 | 7.77 | 4.87 |
| 1993 | 3.84 | 3.82 | 4.53 | 3.51 | 11.47 | 13.12 | 6.85 | 6.31 | 8.09 | 5.16 | 5.08 | 4.84 |
| 1994 | 3.46 | 3.00 | 3.33 | 7.90 | 17.06 | 10.95 | 10.56 | 12.60 | 9.67 | 5.24 | 9.38 | 8.64 |
| 1995 | 3.75 | 2.98 | 4.29 | 5.36 | 11.59 | 8.66 | 10.21 | 8.93 | 9.87 | 7.77 | 7.98 | 5.87 |
| 1996 | 4.12 | 3.91 | 5.07 | 11.67 | 10.54 | 9.96 | 9.28 | 8.91 | 11.35 | 7.20 | 5.58 | 6.66 |
| 1997 | 4.10 | 2.99 | 3.19 | 10.45 | 13.11 | 5.66 | 10.58 | 7.54 | 5.33 | 4.53 | 13.66 | 12.14 |
| 1998 | 13.38 | 7.35 | 5.35 | 4.12 | 11.86 | 9.03 | 9.88 | 9.31 | 7.86 | 9.42 | 9.15 | 4.62 |
| 1999 | 3.31 | 2.86 | 3.49 | 7.31 | 11.10 | 7.02 | 10.73 | 16.41 | 11.31 | 13.17 | 8.12 | 5.76 |
| 2000 | 3.76 | 2.89 | 3.16 | 3.05 | 5.07 | 7.58 | 10.50 | 10.82 | 9.20 | 10.12 | 7.14 | 5.86 |
| 2001 | 6.91 | 6.88 | 3.94 | 7.10 | 11.75 | 12.32 | 10.27 | 8.64 | 8.52 | 7.29 | 7.67 | 5.32 |
| 2002 | 3.97 | 3.25 | 4.03 | 4.57 | 15.84 | 6.49 | 5.68 | 9.28 | 8.60 | 5.18 | 5.81 | 6.73 |
| 2003 | 10.37 | 3.48 | 3.13 | 3.95 | 21.53 | 12.71 | 10.74 | 13.45 | 12.13 | 8.08 | 4.25 | 4.24 |
| 2004 | 3.66 | 3.07 | 3.27 | 9.98 | 14.96 | 6.31 | 6.12 | 8.67 | 8.12 | 9.16 | 8.87 | 6.51 |
| 2005 | 4.69 | 3.90 | 5.02 | 7.22 | 11.67 | 10.24 | 7.74 | 7.32 | 6.41 | 5.64 | 4.84 | 3.47 |
| 2006 | 3.06 | 2.87 | 3.63 | 15.65 | 9.79 | 7.58 | 9.76 | 11.15 | 9.09 | 5.89 | 7.89 | 12.45 |
| 2007 | 9.17 | 5.19 | 6.11 | 6.79 | 11.46 | 13.07 | 15.17 | 19.58 | 20.14 | 8.89 | 5.67 | 3.82 |
| 2008 | 3.18 | 2.84 | 3.18 | 12.61 | 10.16 | 11.57 | 10.10 | 11.98 | 10.37 | 9.75 | 9.83 | 4.65 |
| 2009 | 3.27 | 3.02 | 3.03 | 4.56 | 9.90 | 7.39 | 6.18 | 8.39 | 10.76 | 9.21 | 6.49 | 5.68 |
| 2010 | 11.27 | 4.98 | 7.93 | 8.91 | 14.81 | 11.93 | 10.76 | 8.07 | 12.76 | 11.74 | 6.98 | 4.50 |

Sub-basin: **1FD** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 5.88 | 4.68 | 5.39 | 14.75 | 18.28 | 23.26 | 20.42 | 11.11 | 10.57 | 11.98 | 9.11 | 5.47 |
| 1992 | 4.48 | 3.68 | 3.96 | 4.01 | 12.66 | 20.01 | 27.80 | 26.36 | 28.49 | 21.70 | 14.40 | 7.61 |
| 1993 | 6.14 | 7.26 | 6.66 | 4.89 | 21.89 | 25.49 | 12.13 | 11.74 | 12.45 | 7.53 | 12.85 | 10.03 |
| 1994 | 5.12 | 3.95 | 4.97 | 15.05 | 34.23 | 19.56 | 16.54 | 22.19 | 14.38 | 7.05 | 17.12 | 11.56 |
| 1995 | 5.09 | 4.11 | 7.11 | 9.78 | 18.19 | 13.49 | 15.62 | 14.02 | 16.51 | 12.28 | 12.68 | 7.53 |
| 1996 | 5.79 | 5.42 | 8.38 | 17.63 | 16.63 | 14.96 | 16.97 | 18.59 | 19.22 | 10.12 | 9.73 | 11.34 |
| 1997 | 5.89 | 4.11 | 3.96 | 25.64 | 21.66 | 9.17 | 19.21 | 11.27 | 6.89 | 9.29 | 30.98 | 23.67 |
| 1998 | 27.90 | 14.33 | 8.02 | 5.84 | 17.98 | 14.37 | 19.53 | 17.98 | 12.55 | 13.47 | 16.02 | 6.48 |
| 1999 | 4.67 | 3.80 | 5.54 | 10.73 | 15.83 | 11.03 | 19.42 | 29.16 | 17.53 | 24.99 | 13.71 | 12.62 |
| 2000 | 5.49 | 3.98 | 4.15 | 3.86 | 7.67 | 11.47 | 21.05 | 19.62 | 14.70 | 18.71 | 11.87 | 8.29 |
| 2001 | 13.41 | 9.94 | 5.36 | 13.67 | 19.90 | 22.45 | 17.90 | 15.91 | 14.09 | 11.40 | 14.83 | 7.43 |
| 2002 | 6.78 | 4.85 | 7.17 | 7.64 | 25.37 | 9.12 | 7.52 | 16.47 | 13.00 | 7.36 | 8.34 | 12.31 |
| 2003 | 16.22 | 4.68 | 4.13 | 10.03 | 37.66 | 18.71 | 13.47 | 23.19 | 21.58 | 12.61 | 5.93 | 6.36 |
| 2004 | 5.13 | 4.20 | 4.52 | 24.93 | 24.79 | 11.16 | 12.35 | 17.32 | 13.12 | 13.29 | 18.20 | 12.77 |
| 2005 | 7.89 | 6.28 | 9.51 | 11.03 | 23.70 | 17.87 | 14.90 | 11.56 | 14.44 | 10.15 | 8.35 | 4.91 |
| 2006 | 4.14 | 3.68 | 5.00 | 26.63 | 15.23 | 12.91 | 19.20 | 20.28 | 14.77 | 8.39 | 17.20 | 23.38 |
| 2007 | 14.41 | 9.78 | 10.37 | 12.81 | 24.04 | 26.55 | 32.22 | 35.01 | 35.26 | 14.61 | 7.97 | 5.32 |
| 2008 | 4.45 | 3.97 | 5.60 | 24.20 | 14.16 | 16.94 | 17.40 | 21.48 | 17.72 | 17.37 | 15.34 | 6.60 |
| 2009 | 4.66 | 4.18 | 4.19 | 5.47 | 15.87 | 10.83 | 8.78 | 13.52 | 18.90 | 16.55 | 11.63 | 11.08 |
| 2010 | 21.06 | 8.83 | 15.36 | 15.92 | 29.93 | 20.44 | 15.50 | 12.41 | 22.09 | 20.35 | 11.55 | 7.73 |

Sub-basin: **1FE** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 9.94 | 7.86 | 7.95 | 27.69 | 45.62 | 28.89 | 19.80 | 16.83 | 17.29 | 25.55 | 21.19 | 10.58 |
| 1992 | 7.37 | 5.97 | 6.48 | 6.27 | 11.77 | 34.80 | 37.51 | 24.64 | 30.28 | 24.63 | 17.29 | 11.80 |
| 1993 | 9.44 | 8.60 | 10.57 | 9.04 | 32.97 | 32.48 | 15.96 | 13.28 | 19.63 | 12.42 | 9.65 | 8.75 |
| 1994 | 6.97 | 5.94 | 7.73 | 27.86 | 46.38 | 28.65 | 25.70 | 26.75 | 22.89 | 12.92 | 28.16 | 24.03 |
| 1995 | 8.34 | 6.41 | 10.65 | 19.83 | 36.49 | 26.07 | 29.08 | 18.98 | 21.98 | 23.77 | 27.04 | 16.49 |
| 1996 | 9.96 | 11.43 | 16.46 | 45.44 | 33.89 | 29.45 | 20.61 | 15.40 | 28.78 | 26.23 | 14.24 | 18.38 |
| 1997 | 9.12 | 6.35 | 6.33 | 17.26 | 39.06 | 17.05 | 22.37 | 17.75 | 12.42 | 9.17 | 23.89 | 42.36 |
| 1998 | 40.03 | 15.18 | 11.05 | 14.49 | 40.19 | 25.51 | 19.90 | 15.85 | 15.80 | 28.66 | 23.45 | 9.80 |
| 1999 | 7.22 | 5.95 | 7.74 | 25.05 | 37.33 | 19.76 | 21.58 | 31.70 | 29.59 | 31.66 | 17.60 | 13.01 |
| 2000 | 8.47 | 6.09 | 6.41 | 6.12 | 12.37 | 16.46 | 20.13 | 21.05 | 18.90 | 22.96 | 17.17 | 20.09 |
| 2001 | 24.32 | 17.94 | 10.13 | 23.87 | 32.89 | 27.94 | 22.96 | 17.90 | 21.93 | 23.57 | 22.22 | 13.99 |
| 2002 | 8.82 | 6.86 | 9.44 | 22.41 | 52.01 | 19.91 | 14.30 | 19.66 | 17.82 | 15.38 | 25.99 | 21.39 |
| 2003 | 25.82 | 7.80 | 6.78 | 9.77 | 56.07 | 34.25 | 31.82 | 35.86 | 30.35 | 19.34 | 10.17 | 10.21 |
| 2004 | 8.86 | 7.29 | 7.47 | 20.88 | 35.29 | 15.42 | 11.45 | 15.41 | 19.78 | 25.15 | 21.20 | 15.15 |
| 2005 | 10.69 | 8.39 | 10.28 | 17.61 | 28.33 | 26.48 | 16.36 | 17.62 | 16.14 | 11.79 | 9.60 | 7.42 |
| 2006 | 6.20 | 5.66 | 7.72 | 50.23 | 31.87 | 24.30 | 19.91 | 21.67 | 22.41 | 15.41 | 27.10 | 42.14 |
| 2007 | 25.73 | 12.47 | 13.97 | 18.41 | 28.71 | 29.01 | 27.26 | 44.74 | 44.39 | 22.98 | 14.81 | 8.70 |
| 2008 | 6.75 | 5.86 | 5.96 | 21.71 | 30.92 | 32.52 | 21.80 | 30.82 | 34.25 | 31.07 | 32.57 | 11.75 |
| 2009 | 7.11 | 7.18 | 6.64 | 14.48 | 30.55 | 17.79 | 13.79 | 15.11 | 23.49 | 22.67 | 14.27 | 13.58 |
| 2010 | 26.42 | 11.21 | 21.18 | 25.78 | 43.85 | 27.66 | 24.73 | 19.34 | 33.05 | 27.44 | 17.28 | 10.72 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

Sub-basin: **1FF** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 0.72 | 0.12 | 0.01 | 7.45 | 12.62 | 6.43 | 2.36 | 1.15 | 1.32 | 3.27 | 4.72 | 0.71 |
| 1992 | 0.01 | 0.00 | 0.00 | 0.00 | 0.02 | 6.52 | 6.82 | 3.21 | 4.61 | 3.95 | 2.25 | 1.04 |
| 1993 | 0.51 | 0.47 | 0.30 | 0.27 | 7.33 | 7.10 | 2.35 | 0.72 | 1.88 | 0.63 | 0.12 | 0.01 |
| 1994 | 0.00 | 0.00 | 0.01 | 6.21 | 12.04 | 5.80 | 4.00 | 3.28 | 2.95 | 0.80 | 6.01 | 5.01 |
| 1995 | 0.13 | 0.00 | 0.03 | 5.22 | 9.26 | 5.47 | 5.23 | 2.09 | 2.53 | 4.82 | 7.26 | 2.67 |
| 1996 | 0.52 | 1.25 | 3.56 | 13.46 | 9.00 | 6.59 | 3.28 | 1.02 | 4.55 | 6.77 | 2.15 | 4.17 |
| 1997 | 0.32 | 0.00 | 0.00 | 0.70 | 9.25 | 3.18 | 2.93 | 1.64 | 0.71 | 0.01 | 2.44 | 16.68 |
| 1998 | 12.15 | 1.99 | 0.39 | 3.23 | 9.81 | 4.98 | 2.70 | 1.00 | 0.69 | 4.15 | 4.16 | 0.38 |
| 1999 | 0.00 | 0.00 | 0.01 | 5.59 | 9.41 | 3.58 | 2.36 | 4.40 | 5.70 | 6.03 | 2.57 | 2.19 |
| 2000 | 0.34 | 0.00 | 0.00 | 0.00 | 0.02 | 1.13 | 2.18 | 2.18 | 1.89 | 3.27 | 2.51 | 5.53 |
| 2001 | 6.37 | 3.73 | 0.76 | 5.60 | 7.09 | 5.55 | 3.41 | 2.07 | 4.18 | 5.61 | 5.00 | 1.95 |
| 2002 | 0.10 | 0.00 | 0.01 | 7.91 | 13.69 | 3.74 | 1.15 | 1.16 | 1.41 | 1.96 | 7.69 | 4.54 |
| 2003 | 4.74 | 0.16 | 0.00 | 1.53 | 13.12 | 6.70 | 5.58 | 6.65 | 6.06 | 2.56 | 0.54 | 0.40 |
| 2004 | 0.09 | 0.07 | 0.01 | 2.68 | 7.94 | 2.00 | 0.54 | 0.65 | 2.55 | 5.68 | 4.43 | 2.37 |
| 2005 | 0.84 | 0.16 | 0.01 | 2.17 | 7.38 | 5.43 | 2.00 | 2.24 | 2.25 | 1.01 | 0.35 | 0.01 |
| 2006 | 0.00 | 0.00 | 0.00 | 11.25 | 7.99 | 5.71 | 2.85 | 2.44 | 2.60 | 1.79 | 8.47 | 12.70 |
| 2007 | 5.66 | 1.89 | 1.78 | 3.69 | 6.29 | 5.56 | 3.12 | 7.56 | 8.04 | 4.15 | 2.05 | 0.11 |
| 2008 | 0.00 | 0.00 | 0.00 | 0.61 | 7.53 | 6.87 | 2.71 | 4.92 | 8.58 | 8.51 | 9.14 | 1.40 |
| 2009 | 0.01 | 0.01 | 0.00 | 0.54 | 7.68 | 2.79 | 0.93 | 0.45 | 1.89 | 3.76 | 1.29 | 1.71 |
| 2010 | 4.66 | 0.78 | 3.92 | 7.04 | 12.22 | 4.25 | 2.96 | 1.54 | 5.06 | 4.85 | 2.51 | 0.71 |

Sub-basin: **1FG** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 0.00 | 0.00 | 0.00 | 30.18 | 24.55 | 9.76 | 1.51 | 0.00 | 0.00 | 0.00 | 3.39 | 0.00 |
| 1992 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.47 | 0.00 | 1.14 | 1.55 | 3.92 | 1.95 |
| 1993 | 6.54 | 0.00 | 0.00 | 0.00 | 7.73 | 14.24 | 0.84 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1994 | 0.00 | 0.00 | 0.00 | 0.00 | 40.23 | 12.71 | 0.73 | 2.90 | 4.56 | 0.49 | 26.01 | 16.42 |
| 1995 | 0.00 | 0.00 | 0.00 | 17.74 | 32.07 | 6.53 | 2.79 | 0.00 | 3.89 | 14.76 | 19.79 | 5.52 |
| 1996 | 0.00 | 0.00 | 9.25 | 49.02 | 25.14 | 21.43 | 3.25 | 0.00 | 14.47 | 27.47 | 7.19 | 12.20 |
| 1997 | 0.00 | 0.00 | 0.00 | 0.00 | 11.85 | 3.53 | 0.68 | 0.00 | 0.00 | 0.00 | 31.81 | 70.87 |
| 1998 | 40.77 | 0.93 | 0.00 | 11.19 | 30.55 | 3.12 | 0.00 | 0.00 | 0.00 | 0.00 | 4.28 | 0.00 |
| 1999 | 0.00 | 0.00 | 0.00 | 9.11 | 38.99 | 4.00 | 0.00 | 0.00 | 15.06 | 20.23 | 10.70 | 17.31 |
| 2000 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 9.14 | 12.37 |
| 2001 | 13.38 | 9.13 | 0.00 | 20.22 | 19.65 | 16.09 | 0.22 | 0.00 | 4.08 | 6.03 | 13.71 | 0.82 |
| 2002 | 0.00 | 0.00 | 0.00 | 15.36 | 39.53 | 2.44 | 0.00 | 0.00 | 0.00 | 0.00 | 28.93 | 8.60 |
| 2003 | 10.15 | 0.00 | 0.00 | 6.21 | 28.73 | 10.45 | 5.22 | 0.00 | 1.59 | 0.00 | 0.92 | 0.00 |
| 2004 | 0.00 | 0.00 | 0.00 | 0.00 | 10.99 | 0.91 | 0.00 | 0.00 | 0.93 | 16.41 | 28.48 | 2.74 |
| 2005 | 0.00 | 0.00 | 0.00 | 0.00 | 7.58 | 13.86 | 0.00 | 0.62 | 5.97 | 4.61 | 3.41 | 0.00 |
| 2006 | 0.00 | 0.00 | 0.00 | 35.51 | 29.00 | 10.85 | 0.00 | 1.51 | 0.00 | 1.41 | 25.38 | 52.63 |
| 2007 | 16.90 | 2.98 | 0.00 | 14.54 | 35.86 | 14.85 | 0.00 | 0.00 | 1.36 | 7.00 | 5.25 | 0.00 |
| 2008 | 0.00 | 0.00 | 0.00 | 10.09 | 19.28 | 13.06 | 0.00 | 10.58 | 54.61 | 28.98 | 37.88 | 1.16 |
| 2009 | 0.00 | 0.00 | 0.00 | 2.24 | 33.14 | 4.53 | 0.00 | 0.00 | 1.52 | 4.46 | 2.36 | 7.25 |
| 2010 | 12.86 | 0.00 | 7.56 | 11.84 | 31.10 | 0.71 | 0.00 | 0.00 | 0.00 | 10.14 | 4.65 | 0.00 |

## 2. Lake Victoria South Catchment Area (LVSCA)

## 1GA, 1GB, 1GC, 1GD, 1GE & 1GG

Sub-basin: **1GA** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 6.64 | 4.14 | 4.17 | 20.03 | 19.62 | 25.25 | 24.25 | 15.12 | 13.43 | 12.35 | 7.97 | 3.38 |
| 1992 | 2.24 | 1.83 | 1.85 | 2.87 | 15.49 | 21.49 | 29.97 | 37.55 | 30.31 | 22.07 | 13.92 | 5.60 |
| 1993 | 6.01 | 10.04 | 5.35 | 2.96 | 24.81 | 25.80 | 14.70 | 12.74 | 11.32 | 6.17 | 7.94 | 9.27 |
| 1994 | 3.01 | 1.90 | 4.76 | 20.36 | 44.09 | 23.03 | 19.77 | 25.28 | 11.28 | 3.88 | 14.52 | 8.82 |
| 1995 | 2.74 | 2.01 | 7.28 | 10.43 | 19.90 | 12.41 | 16.43 | 13.32 | 17.59 | 12.94 | 13.32 | 5.08 |
| 1996 | 3.07 | 4.29 | 7.26 | 21.14 | 14.79 | 15.08 | 18.98 | 25.89 | 19.53 | 6.83 | 6.19 | 9.22 |
| 1997 | 3.24 | 1.95 | 1.82 | 29.84 | 20.87 | 6.08 | 17.72 | 10.56 | 4.68 | 4.52 | 35.25 | 22.70 |
| 1998 | 30.43 | 14.32 | 5.20 | 5.47 | 23.23 | 16.43 | 24.41 | 19.88 | 11.29 | 16.79 | 14.48 | 3.91 |
| 1999 | 2.37 | 1.80 | 5.75 | 15.74 | 18.33 | 8.75 | 16.66 | 24.07 | 14.77 | 22.50 | 10.63 | 11.03 |
| 2000 | 3.28 | 1.98 | 1.90 | 1.78 | 6.13 | 10.02 | 22.43 | 20.61 | 10.95 | 19.55 | 12.75 | 6.90 |
| 2001 | 15.04 | 7.93 | 3.32 | 23.82 | 23.06 | 23.22 | 19.31 | 15.67 | 13.08 | 10.60 | 22.56 | 7.89 |
| 2002 | 5.67 | 3.34 | 8.02 | 8.09 | 33.11 | 6.55 | 5.37 | 17.22 | 9.32 | 5.76 | 15.00 | 19.13 |
| 2003 | 18.18 | 2.88 | 2.03 | 14.13 | 42.26 | 16.73 | 11.72 | 29.86 | 18.00 | 8.09 | 3.71 | 4.84 |
| 2004 | 3.44 | 2.41 | 2.42 | 34.45 | 21.50 | 8.46 | 11.47 | 22.52 | 10.48 | 11.70 | 18.84 | 16.75 |
| 2005 | 6.24 | 4.22 | 7.16 | 12.17 | 29.15 | 17.01 | 13.31 | 13.63 | 24.05 | 7.35 | 4.89 | 2.51 |
| 2006 | 1.96 | 1.67 | 6.54 | 38.58 | 17.72 | 13.65 | 20.91 | 26.52 | 16.80 | 6.05 | 26.15 | 37.11 |
| 2007 | 17.73 | 14.90 | 8.31 | 16.04 | 30.01 | 24.82 | 28.12 | 31.45 | 31.67 | 10.84 | 4.47 | 2.60 |
| 2008 | 2.10 | 1.87 | 3.66 | 22.94 | 11.25 | 15.04 | 19.24 | 39.92 | 27.26 | 20.21 | 17.17 | 5.39 |
| 2009 | 2.58 | 2.19 | 2.05 | 4.34 | 15.04 | 7.93 | 5.12 | 6.40 | 22.87 | 14.07 | 10.72 | 13.63 |
| 2010 | 28.56 | 6.83 | 18.95 | 19.15 | 40.89 | 20.03 | 15.86 | 14.51 | 25.20 | 17.91 | 10.57 | 6.39 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

Sub-basin: **1GB** (Unit: $m^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 4.52 | 1.75 | 4.16 | 21.80 | 22.43 | 26.07 | 17.51 | 3.80 | 3.71 | 14.22 | 5.62 | 1.87 |
| 1992 | 0.97 | 0.65 | 0.63 | 1.20 | 14.29 | 25.41 | 23.40 | 27.63 | 29.11 | 19.63 | 8.41 | 2.66 |
| 1993 | 2.12 | 2.29 | 3.46 | 2.01 | 27.47 | 24.95 | 5.97 | 3.62 | 5.51 | 2.52 | 5.88 | 11.92 |
| 1994 | 1.68 | 0.77 | 6.38 | 29.69 | 39.28 | 17.26 | 13.38 | 20.07 | 8.48 | 2.95 | 21.91 | 9.08 |
| 1995 | 1.47 | 0.89 | 2.51 | 15.08 | 23.67 | 9.51 | 11.01 | 11.62 | 13.45 | 18.08 | 11.42 | 3.29 |
| 1996 | 3.15 | 6.81 | 15.95 | 36.14 | 19.12 | 14.64 | 21.95 | 16.16 | 20.64 | 7.63 | 12.33 | 6.97 |
| 1997 | 1.79 | 0.83 | 0.66 | 22.24 | 23.23 | 5.63 | 15.07 | 4.74 | 2.45 | 2.53 | 41.91 | 43.33 |
| 1998 | 35.86 | 9.96 | 5.85 | 9.21 | 24.21 | 11.09 | 6.95 | 9.18 | 10.76 | 15.28 | 8.74 | 1.97 |
| 1999 | 1.03 | 0.66 | 1.50 | 9.92 | 22.22 | 10.90 | 14.52 | 28.39 | 17.32 | 24.01 | 7.94 | 11.21 |
| 2000 | 2.14 | 0.93 | 0.79 | 0.67 | 2.74 | 4.92 | 18.12 | 16.81 | 7.85 | 17.29 | 16.55 | 7.44 |
| 2001 | 26.89 | 5.96 | 2.10 | 25.15 | 24.39 | 22.99 | 14.34 | 11.74 | 11.02 | 6.72 | 12.99 | 3.87 |
| 2002 | 6.26 | 1.86 | 13.83 | 14.14 | 37.54 | 5.17 | 2.80 | 11.08 | 6.89 | 4.52 | 23.59 | 16.65 |
| 2003 | 20.74 | 1.52 | 0.85 | 17.35 | 45.58 | 20.20 | 9.10 | 15.69 | 16.23 | 8.80 | 2.48 | 7.56 |
| 2004 | 3.48 | 1.69 | 1.18 | 45.49 | 25.39 | 4.14 | 4.06 | 9.47 | 8.24 | 6.03 | 15.78 | 8.50 |
| 2005 | 5.31 | 5.63 | 11.06 | 10.06 | 15.20 | 11.80 | 7.59 | 5.33 | 6.55 | 4.51 | 5.05 | 1.20 |
| 2006 | 0.61 | 0.43 | 2.77 | 39.49 | 13.51 | 10.03 | 11.50 | 8.57 | 10.49 | 3.10 | 32.40 | 42.77 |
| 2007 | 17.11 | 8.53 | 12.51 | 12.65 | 40.49 | 25.45 | 28.37 | 31.30 | 35.78 | 7.12 | 2.41 | 1.12 |
| 2008 | 0.78 | 0.69 | 1.66 | 32.62 | 11.37 | 18.65 | 16.19 | 22.52 | 21.07 | 21.21 | 13.32 | 2.14 |
| 2009 | 0.94 | 0.92 | 0.73 | 2.43 | 11.06 | 5.05 | 4.26 | 4.30 | 31.91 | 11.23 | 14.94 | 11.88 |
| 2010 | 28.54 | 4.58 | 22.95 | 18.02 | 38.88 | 20.72 | 8.20 | 7.28 | 23.94 | 17.42 | 8.06 | 4.78 |

Sub-basin: **1GC** (Unit: $m^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 21.07 | 11.70 | 9.58 | 34.48 | 37.58 | 40.33 | 36.21 | 34.19 | 29.72 | 24.43 | 21.04 | 8.64 |
| 1992 | 6.31 | 5.36 | 5.62 | 14.35 | 28.22 | 28.57 | 39.47 | 55.28 | 45.17 | 34.03 | 23.98 | 13.78 |
| 1993 | 18.85 | 31.20 | 14.64 | 9.11 | 40.11 | 39.22 | 30.25 | 19.83 | 17.55 | 11.60 | 9.56 | 11.40 |
| 1994 | 6.28 | 4.99 | 9.73 | 22.78 | 62.66 | 38.73 | 40.71 | 44.76 | 20.41 | 10.00 | 19.61 | 16.03 |
| 1995 | 6.60 | 5.46 | 16.34 | 20.50 | 38.76 | 28.57 | 29.76 | 23.18 | 32.10 | 31.42 | 28.61 | 12.51 |
| 1996 | 9.12 | 13.96 | 13.39 | 37.18 | 24.47 | 24.46 | 35.43 | 35.13 | 37.38 | 17.31 | 12.25 | 17.36 |
| 1997 | 7.00 | 5.10 | 5.23 | 12.62 | 31.38 | 10.95 | 24.48 | 20.90 | 9.44 | 7.14 | 43.21 | 39.05 |
| 1998 | 43.42 | 27.12 | 11.00 | 17.69 | 43.61 | 26.58 | 43.29 | 43.60 | 26.33 | 43.67 | 21.93 | 8.38 |
| 1999 | 6.07 | 5.01 | 9.00 | 22.76 | 30.98 | 14.48 | 16.80 | 36.49 | 22.30 | 32.02 | 18.68 | 12.61 |
| 2000 | 6.64 | 5.05 | 5.17 | 5.21 | 13.10 | 14.06 | 23.44 | 34.69 | 18.30 | 24.95 | 28.88 | 23.26 |
| 2001 | 41.77 | 18.00 | 9.68 | 46.67 | 41.64 | 36.29 | 29.97 | 25.51 | 22.07 | 29.49 | 50.75 | 20.23 |
| 2002 | 13.95 | 7.96 | 18.61 | 18.12 | 69.38 | 15.51 | 12.86 | 26.37 | 15.84 | 11.83 | 35.72 | 36.89 |
| 2003 | 29.53 | 7.07 | 5.74 | 32.92 | 72.94 | 31.72 | 19.24 | 41.26 | 28.34 | 16.03 | 12.21 | 15.95 |
| 2004 | 10.96 | 7.55 | 7.20 | 48.40 | 37.73 | 13.75 | 11.85 | 26.39 | 19.34 | 19.24 | 21.13 | 18.89 |
| 2005 | 11.42 | 8.28 | 15.52 | 25.28 | 38.46 | 30.37 | 21.88 | 32.28 | 41.69 | 14.46 | 9.82 | 6.40 |
| 2006 | 5.37 | 4.63 | 10.72 | 53.86 | 38.58 | 21.41 | 32.09 | 37.83 | 25.12 | 14.41 | 52.58 | 75.70 |
| 2007 | 39.93 | 31.22 | 15.16 | 26.34 | 40.33 | 38.19 | 35.45 | 45.29 | 51.43 | 22.74 | 10.04 | 6.61 |
| 2008 | 5.72 | 5.17 | 7.57 | 27.83 | 24.51 | 21.86 | 26.69 | 60.20 | 44.43 | 39.35 | 36.50 | 12.42 |
| 2009 | 6.63 | 6.32 | 5.79 | 9.55 | 16.39 | 12.93 | 9.16 | 7.82 | 18.91 | 20.01 | 15.66 | 31.45 |
| 2010 | 40.61 | 12.38 | 37.28 | 38.85 | 64.92 | 25.87 | 26.96 | 27.82 | 36.40 | 34.25 | 19.54 | 15.46 |

Sub-basin: **1GD** (Unit: $m^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 12.60 | 4.37 | 9.38 | 22.05 | 23.78 | 21.47 | 12.46 | 8.08 | 5.65 | 10.84 | 5.73 | 4.78 |
| 1992 | 5.01 | 5.02 | 5.27 | 6.19 | 12.47 | 14.25 | 11.99 | 21.37 | 17.39 | 10.76 | 6.25 | 4.09 |
| 1993 | 4.87 | 6.62 | 4.52 | 5.15 | 16.32 | 13.70 | 7.26 | 4.65 | 4.67 | 5.05 | 4.83 | 9.61 |
| 1994 | 4.96 | 4.76 | 13.16 | 25.97 | 30.36 | 12.33 | 10.85 | 10.90 | 5.07 | 4.66 | 14.35 | 5.66 |
| 1995 | 4.86 | 4.64 | 6.07 | 12.98 | 16.31 | 10.43 | 7.84 | 7.79 | 10.86 | 20.15 | 8.90 | 4.04 |
| 1996 | 5.12 | 12.02 | 13.73 | 31.28 | 16.52 | 14.56 | 18.87 | 9.00 | 12.94 | 5.44 | 10.96 | 8.52 |
| 1997 | 4.74 | 4.52 | 5.40 | 8.80 | 14.78 | 4.45 | 8.85 | 4.89 | 4.63 | 5.53 | 24.82 | 38.20 |
| 1998 | 29.29 | 7.99 | 5.22 | 13.49 | 17.71 | 13.22 | 7.63 | 9.10 | 7.66 | 16.26 | 5.54 | 5.14 |
| 1999 | 5.25 | 4.84 | 8.27 | 17.08 | 20.19 | 8.98 | 6.99 | 13.79 | 9.46 | 14.21 | 5.27 | 9.67 |
| 2000 | 4.60 | 4.67 | 5.15 | 5.21 | 6.52 | 7.56 | 11.54 | 12.91 | 4.44 | 10.04 | 17.22 | 9.35 |
| 2001 | 35.91 | 5.95 | 5.14 | 26.68 | 22.31 | 13.16 | 8.27 | 5.71 | 6.62 | 10.47 | 16.74 | 7.02 |
| 2002 | 9.29 | 4.08 | 17.96 | 12.21 | 34.86 | 5.72 | 4.56 | 8.00 | 4.46 | 6.01 | 35.51 | 16.50 |
| 2003 | 18.13 | 4.01 | 5.21 | 20.42 | 33.62 | 14.44 | 6.01 | 10.66 | 7.32 | 6.41 | 4.47 | 9.04 |
| 2004 | 6.10 | 4.23 | 5.60 | 40.70 | 19.48 | 4.78 | 4.87 | 6.69 | 6.87 | 4.66 | 8.10 | 6.37 |
| 2005 | 4.73 | 5.39 | 11.83 | 9.85 | 11.28 | 10.08 | 6.93 | 8.78 | 8.39 | 4.46 | 4.67 | 5.19 |
| 2006 | 5.15 | 4.81 | 7.30 | 27.47 | 15.36 | 10.32 | 11.33 | 10.70 | 8.10 | 6.60 | 37.33 | 47.85 |
| 2007 | 21.45 | 15.09 | 12.07 | 15.38 | 32.40 | 17.77 | 15.93 | 17.75 | 25.72 | 6.04 | 0.00 | 0.00 |
| 2008 | 0.00 | 0.00 | 0.00 | 3.64 | 3.68 | 3.88 | 0.18 | 12.84 | 14.45 | 14.25 | 9.02 | 0.00 |
| 2009 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.37 | 0.52 | 1.76 | 4.99 |
| 2010 | 12.74 | 0.00 | 15.75 | 17.24 | 33.06 | 6.28 | 2.20 | 0.58 | 6.25 | 4.08 | 0.91 | 0.00 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

Sub-basin: **1GE** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 2.08 | 0.06 | 0.05 | 0.57 | 20.47 | 18.48 | 2.04 | 0.05 | 0.05 | 0.30 | 0.24 | 0.02 |
| 1992 | 0.01 | 0.01 | 0.01 | 0.01 | 0.09 | 0.97 | 0.32 | 0.51 | 0.65 | 6.92 | 0.44 | 0.07 |
| 1993 | 0.13 | 0.02 | 0.01 | 0.01 | 0.72 | 5.49 | 0.93 | 0.06 | 0.05 | 0.05 | 0.05 | 0.06 |
| 1994 | 0.05 | 0.04 | 0.08 | 7.78 | 20.94 | 5.76 | 5.84 | 7.47 | 0.85 | 0.06 | 3.85 | 3.78 |
| 1995 | 0.05 | 0.04 | 0.05 | 0.27 | 2.65 | 6.74 | 0.10 | 0.08 | 0.17 | 21.57 | 4.78 | 0.12 |
| 1996 | 0.07 | 2.97 | 14.11 | 35.75 | 16.99 | 11.11 | 12.89 | 0.23 | 5.78 | 0.14 | 10.08 | 4.44 |
| 1997 | 0.05 | 0.04 | 0.04 | 0.04 | 0.07 | 0.06 | 0.06 | 0.05 | 0.05 | 0.04 | 1.02 | 11.40 |
| 1998 | 29.75 | 5.59 | 0.06 | 1.04 | 14.32 | 1.24 | 0.06 | 0.05 | 0.05 | 1.12 | 0.04 | 0.01 |
| 1999 | 0.01 | 0.01 | 0.01 | 0.01 | 0.06 | 0.21 | 0.03 | 4.35 | 0.50 | 0.82 | 0.03 | 0.38 |
| 2000 | 0.05 | 0.04 | 0.04 | 0.04 | 0.22 | 0.03 | 0.10 | 0.44 | 0.03 | 0.33 | 1.09 | 0.62 |
| 2001 | 26.28 | 1.42 | 0.06 | 12.43 | 15.81 | 6.83 | 0.07 | 0.13 | 0.10 | 0.16 | 13.80 | 0.07 |
| 2002 | 0.37 | 0.05 | 1.28 | 8.10 | 36.09 | 0.08 | 0.05 | 0.05 | 0.04 | 0.05 | 16.40 | 11.64 |
| 2003 | 11.50 | 0.05 | 0.05 | 8.05 | 37.91 | 4.01 | 0.07 | 0.15 | 0.08 | 0.02 | 0.01 | 0.22 |
| 2004 | 0.02 | 0.02 | 0.01 | 17.32 | 15.94 | 0.05 | 0.05 | 0.05 | 0.05 | 0.07 | 0.06 | 0.06 |
| 2005 | 0.05 | 0.06 | 0.12 | 0.31 | 0.35 | 0.04 | 0.04 | 0.03 | 0.04 | 0.01 | 0.01 | 0.00 |
| 2006 | 0.00 | 0.00 | 0.00 | 0.63 | 0.64 | 0.06 | 0.08 | 0.02 | 0.18 | 0.04 | 24.73 | 4.33 |
| 2007 | 0.74 | 2.64 | 8.25 | 10.82 | 21.11 | 14.75 | 6.86 | 7.63 | 15.65 | 0.08 | 0.05 | 0.04 |
| 2008 | 0.04 | 0.04 | 0.04 | 0.06 | 0.08 | 0.29 | 0.07 | 0.55 | 1.27 | 0.99 | 6.85 | 0.06 |
| 2009 | 0.04 | 0.04 | 0.04 | 0.04 | 0.05 | 0.04 | 0.04 | 0.04 | 0.05 | 0.06 | 0.07 | 0.46 |
| 2010 | 0.78 | 0.02 | 1.45 | 1.36 | 23.18 | 4.78 | 3.48 | 0.39 | 4.48 | 2.91 | 0.18 | 0.07 |

Sub-basin: **1GG** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 10.41 | 3.85 | 4.22 | 22.41 | 19.39 | 19.70 | 17.28 | 11.71 | 10.82 | 10.63 | 7.35 | 1.83 |
| 1992 | 1.08 | 0.85 | 0.86 | 5.09 | 13.82 | 15.27 | 17.22 | 28.38 | 21.95 | 14.75 | 9.17 | 3.41 |
| 1993 | 5.01 | 8.24 | 3.68 | 2.87 | 20.28 | 17.55 | 11.04 | 6.90 | 6.85 | 3.53 | 2.78 | 5.78 |
| 1994 | 1.47 | 0.83 | 6.45 | 16.00 | 32.50 | 17.42 | 15.76 | 18.16 | 6.67 | 2.27 | 10.19 | 5.96 |
| 1995 | 1.31 | 0.93 | 7.17 | 9.77 | 17.12 | 11.90 | 11.26 | 9.29 | 13.68 | 13.45 | 11.33 | 3.42 |
| 1996 | 2.06 | 6.70 | 6.39 | 20.40 | 11.41 | 12.20 | 15.85 | 14.90 | 15.60 | 5.17 | 4.70 | 7.70 |
| 1997 | 1.55 | 0.80 | 0.67 | 9.69 | 14.43 | 3.46 | 10.26 | 6.92 | 2.06 | 1.41 | 24.02 | 16.51 |
| 1998 | 20.22 | 10.22 | 2.79 | 8.31 | 19.74 | 13.96 | 16.63 | 14.14 | 10.54 | 19.12 | 8.46 | 1.71 |
| 1999 | 1.06 | 0.79 | 5.09 | 16.84 | 18.70 | 6.60 | 8.17 | 14.92 | 9.48 | 15.52 | 6.32 | 5.68 |
| 2000 | 1.52 | 0.78 | 0.71 | 0.79 | 7.37 | 8.11 | 14.69 | 15.41 | 6.19 | 12.68 | 13.17 | 7.92 |
| 2001 | 21.41 | 6.71 | 3.01 | 23.32 | 21.54 | 17.97 | 11.42 | 8.82 | 8.28 | 12.34 | 22.20 | 7.46 |
| 2002 | 5.59 | 2.06 | 10.25 | 9.21 | 30.52 | 5.40 | 3.61 | 10.34 | 5.33 | 5.12 | 21.51 | 15.71 |
| 2003 | 14.11 | 1.48 | 0.89 | 16.61 | 31.61 | 14.39 | 7.92 | 17.77 | 11.31 | 6.07 | 3.35 | 5.80 |
| 2004 | 3.57 | 1.62 | 1.31 | 28.56 | 17.59 | 5.28 | 4.87 | 12.77 | 7.86 | 7.01 | 10.92 | 8.23 |
| 2005 | 3.97 | 2.20 | 8.34 | 11.53 | 18.25 | 14.41 | 8.90 | 11.04 | 17.00 | 4.90 | 2.77 | 1.07 |
| 2006 | 0.76 | 0.62 | 7.13 | 33.49 | 18.41 | 10.52 | 15.74 | 17.95 | 10.64 | 5.49 | 25.90 | 38.55 |
| 2007 | 17.60 | 16.02 | 5.92 | 13.76 | 23.55 | 17.67 | 16.94 | 19.80 | 24.66 | 8.04 | 2.11 | 1.11 |
| 2008 | 0.86 | 0.76 | 2.71 | 16.77 | 10.35 | 10.84 | 11.35 | 30.65 | 22.37 | 18.07 | 14.63 | 3.27 |
| 2009 | 1.20 | 1.30 | 0.99 | 4.83 | 9.88 | 4.70 | 2.79 | 2.02 | 15.37 | 9.74 | 7.53 | 14.34 |
| 2010 | 19.21 | 5.15 | 17.69 | 17.28 | 33.87 | 13.25 | 10.94 | 10.81 | 15.48 | 13.38 | 7.48 | 6.22 |

## 1HA1, 1HA2, 1HB1, 1HB2, 1HD, 1HE & 1HG

Sub-basin: **1HA1** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 3.72 | 2.37 | 2.50 | 10.59 | 21.33 | 13.95 | 4.85 | 2.66 | 2.51 | 7.29 | 5.98 | 2.61 |
| 1992 | 2.58 | 2.37 | 2.57 | 2.25 | 6.93 | 13.46 | 9.12 | 7.01 | 11.71 | 7.54 | 4.65 | 3.01 |
| 1993 | 2.97 | 2.42 | 2.57 | 2.65 | 16.98 | 14.35 | 4.08 | 2.86 | 3.41 | 2.51 | 2.44 | 2.63 |
| 1994 | 2.60 | 2.37 | 7.41 | 14.78 | 23.39 | 8.52 | 6.91 | 6.56 | 4.46 | 2.52 | 9.22 | 9.14 |
| 1995 | 2.35 | 2.13 | 2.89 | 8.18 | 20.71 | 7.69 | 6.30 | 4.62 | 4.85 | 9.09 | 8.51 | 3.67 |
| 1996 | 2.97 | 4.15 | 14.14 | 22.66 | 16.95 | 9.86 | 9.14 | 4.82 | 8.64 | 5.25 | 7.71 | 8.05 |
| 1997 | 2.41 | 2.20 | 2.60 | 8.91 | 13.95 | 4.35 | 5.24 | 3.16 | 2.61 | 2.62 | 9.12 | 43.81 |
| 1998 | 26.00 | 5.23 | 3.51 | 9.88 | 12.88 | 8.67 | 4.46 | 2.78 | 2.61 | 6.71 | 4.90 | 2.61 |
| 1999 | 2.49 | 2.32 | 2.42 | 10.61 | 10.26 | 5.38 | 6.46 | 17.34 | 9.63 | 9.80 | 4.75 | 7.09 |
| 2000 | 2.58 | 2.27 | 2.44 | 2.34 | 6.57 | 4.73 | 6.13 | 5.85 | 4.99 | 6.53 | 7.42 | 11.68 |
| 2001 | 22.96 | 5.37 | 2.65 | 9.62 | 10.84 | 10.22 | 5.85 | 5.71 | 12.75 | 7.44 | 10.83 | 3.61 |
| 2002 | 3.30 | 2.41 | 6.08 | 19.93 | 27.06 | 5.08 | 2.77 | 3.54 | 4.29 | 3.46 | 12.92 | 10.01 |
| 2003 | 9.62 | 2.18 | 2.51 | 13.95 | 25.13 | 8.88 | 6.29 | 11.13 | 10.31 | 4.61 | 2.52 | 3.94 |
| 2004 | 3.38 | 2.73 | 2.35 | 20.52 | 15.61 | 2.96 | 2.47 | 3.66 | 7.77 | 6.61 | 6.97 | 4.82 |
| 2005 | 3.80 | 3.32 | 4.99 | 6.99 | 16.14 | 7.11 | 4.10 | 4.05 | 3.68 | 2.64 | 2.81 | 2.59 |
| 2006 | 2.47 | 2.32 | 2.44 | 16.08 | 8.09 | 6.46 | 4.63 | 4.37 | 4.29 | 3.32 | 21.84 | 26.52 |
| 2007 | 12.51 | 4.35 | 11.18 | 7.85 | 14.28 | 10.42 | 11.20 | 14.46 | 12.83 | 5.04 | 2.64 | 1.52 |
| 2008 | 1.31 | 1.17 | 1.39 | 10.38 | 8.40 | 9.63 | 6.82 | 8.29 | 7.88 | 18.81 | 12.61 | 2.96 |
| 2009 | 1.62 | 1.85 | 1.43 | 4.38 | 9.42 | 3.98 | 2.69 | 2.73 | 7.28 | 5.75 | 3.98 | 6.47 |
| 2010 | 10.03 | 3.02 | 12.35 | 18.65 | 26.70 | 7.16 | 4.99 | 4.09 | 10.37 | 6.19 | 4.13 | 2.94 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

Sub-basin: **1HA2** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 0.12 | 0.03 | 0.01 | 0.17 | 4.44 | 4.03 | 0.11 | 0.02 | 0.01 | 0.01 | 0.02 | 0.01 |
| 1992 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 0.21 | 0.09 | 0.73 | 0.27 | 0.12 | 0.03 |
| 1993 | 0.02 | 0.02 | 0.01 | 0.00 | 0.94 | 1.81 | 0.07 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 |
| 1994 | 0.00 | 0.00 | 0.00 | 0.91 | 4.34 | 0.82 | 0.13 | 0.18 | 0.06 | 0.01 | 0.10 | 0.51 |
| 1995 | 0.03 | 0.01 | 0.00 | 0.01 | 1.65 | 0.77 | 0.05 | 0.02 | 0.01 | 1.42 | 0.54 | 0.06 |
| 1996 | 0.02 | 0.05 | 3.88 | 16.84 | 2.84 | 1.04 | 1.10 | 0.13 | 0.29 | 0.11 | 1.07 | 1.96 |
| 1997 | 0.04 | 0.01 | 0.01 | 0.01 | 0.03 | 0.03 | 0.01 | 0.01 | 0.00 | 0.00 | 0.02 | 38.59 |
| 1998 | 14.31 | 0.42 | 0.07 | 0.65 | 1.21 | 0.15 | 0.08 | 0.02 | 0.01 | 0.01 | 0.00 | 0.00 |
| 1999 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.81 | 0.91 | 0.93 | 0.08 | 0.80 |
| 2000 | 0.05 | 0.02 | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.11 | 0.65 | 1.49 |
| 2001 | 18.01 | 0.33 | 0.05 | 0.62 | 0.84 | 0.68 | 0.06 | 0.06 | 0.73 | 0.44 | 0.98 | 0.05 |
| 2002 | 0.03 | 0.04 | 0.20 | 2.79 | 18.43 | 0.10 | 0.03 | 0.01 | 0.01 | 0.00 | 2.00 | 0.99 |
| 2003 | 1.20 | 0.06 | 0.03 | 8.31 | 8.09 | 0.37 | 0.08 | 0.12 | 0.27 | 0.07 | 0.01 | 0.01 |
| 2004 | 0.01 | 0.01 | 0.00 | 10.46 | 7.95 | 0.07 | 0.02 | 0.01 | 0.01 | 0.01 | 0.03 | 0.09 |
| 2005 | 0.06 | 0.13 | 0.07 | 0.25 | 0.80 | 0.44 | 0.04 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 |
| 2006 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 19.30 | 13.06 |
| 2007 | 5.74 | 0.15 | 3.10 | 0.79 | 5.87 | 1.15 | 0.64 | 1.07 | 0.77 | 0.11 | 0.03 | 0.01 |
| 2008 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.34 | 4.82 | 1.19 | 0.06 |
| 2009 | 0.02 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 |
| 2010 | 0.49 | 0.05 | 1.40 | 4.58 | 11.00 | 0.22 | 0.10 | 0.03 | 0.57 | 0.16 | 0.02 | 0.01 |

Sub-basin: **1HB1** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 1.11 | 0.19 | 0.00 | 9.02 | 9.33 | 6.98 | 2.67 | 0.63 | 0.14 | 0.15 | 1.49 | 0.87 |
| 1992 | 0.07 | 0.00 | 0.00 | 0.00 | 0.01 | 0.87 | 3.90 | 1.54 | 1.96 | 2.46 | 2.11 | 1.88 |
| 1993 | 2.39 | 1.22 | 0.32 | 0.06 | 3.44 | 7.15 | 2.75 | 0.42 | 0.32 | 0.08 | 0.13 | 0.01 |
| 1994 | 0.00 | 0.00 | 0.01 | 2.98 | 14.87 | 7.28 | 3.19 | 1.92 | 2.26 | 0.70 | 6.17 | 8.41 |
| 1995 | 0.72 | 0.01 | 0.09 | 6.51 | 13.72 | 5.77 | 3.41 | 1.04 | 0.85 | 3.25 | 8.77 | 5.10 |
| 1996 | 1.70 | 1.21 | 4.52 | 18.47 | 12.32 | 9.06 | 3.99 | 0.87 | 2.03 | 10.07 | 3.90 | 6.61 |
| 1997 | 0.82 | 0.04 | 0.00 | 0.01 | 7.86 | 3.76 | 2.47 | 0.95 | 0.20 | 0.01 | 4.91 | 30.69 |
| 1998 | 18.56 | 2.78 | 0.51 | 3.02 | 12.19 | 4.39 | 1.70 | 0.30 | 0.01 | 0.37 | 1.01 | 0.13 |
| 1999 | 0.00 | 0.00 | 0.00 | 3.56 | 13.20 | 4.26 | 1.45 | 1.48 | 3.07 | 5.28 | 3.95 | 5.74 |
| 2000 | 1.23 | 0.03 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.44 | 1.90 | 7.22 |
| 2001 | 8.63 | 6.10 | 1.49 | 6.16 | 7.57 | 6.70 | 2.89 | 1.35 | 2.11 | 5.46 | 6.20 | 2.92 |
| 2002 | 0.43 | 0.04 | 0.01 | 9.06 | 16.62 | 4.01 | 0.68 | 0.18 | 0.13 | 0.20 | 7.00 | 6.44 |
| 2003 | 5.70 | 0.48 | 0.01 | 3.51 | 12.60 | 6.34 | 3.67 | 1.58 | 2.22 | 1.07 | 0.81 | 0.51 |
| 2004 | 0.16 | 0.03 | 0.01 | 0.37 | 5.32 | 2.16 | 0.84 | 0.17 | 0.42 | 3.22 | 8.09 | 4.00 |
| 2005 | 1.22 | 0.20 | 0.01 | 0.63 | 5.93 | 6.42 | 1.89 | 1.24 | 2.04 | 1.89 | 1.97 | 0.25 |
| 2006 | 0.00 | 0.00 | 0.00 | 11.22 | 11.99 | 6.33 | 2.52 | 1.47 | 0.84 | 0.58 | 7.91 | 20.92 |
| 2007 | 9.64 | 2.98 | 2.34 | 4.56 | 13.36 | 7.68 | 2.32 | 1.67 | 1.74 | 2.14 | 2.17 | 0.53 |
| 2008 | 0.01 | 0.00 | 0.00 | 3.82 | 8.29 | 6.93 | 2.07 | 3.23 | 13.49 | 12.20 | 11.88 | 2.46 |
| 2009 | 0.09 | 0.04 | 0.00 | 0.93 | 10.18 | 3.94 | 0.86 | 0.10 | 0.35 | 1.60 | 0.92 | 2.15 |
| 2010 | 4.49 | 0.59 | 3.16 | 6.95 | 16.01 | 3.47 | 0.85 | 0.03 | 0.46 | 1.36 | 1.80 | 0.69 |

Sub-basin: **1HB2** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 1.13 | 0.48 | 0.23 | 5.48 | 9.10 | 6.30 | 1.68 | 0.41 | 0.24 | 0.81 | 2.70 | 0.70 |
| 1992 | 0.12 | 0.03 | 0.03 | 0.15 | 1.40 | 6.72 | 3.71 | 1.56 | 2.58 | 2.63 | 1.49 | 0.88 |
| 1993 | 0.74 | 0.39 | 0.24 | 0.43 | 5.91 | 5.62 | 1.60 | 0.45 | 0.32 | 0.10 | 0.06 | 0.08 |
| 1994 | 0.02 | 0.00 | 3.47 | 7.01 | 10.83 | 4.15 | 2.33 | 1.56 | 0.89 | 0.24 | 2.87 | 4.16 |
| 1995 | 0.45 | 0.13 | 0.37 | 4.11 | 10.50 | 3.62 | 2.64 | 0.91 | 0.59 | 3.33 | 4.94 | 1.69 |
| 1996 | 0.77 | 1.09 | 5.25 | 11.57 | 7.31 | 5.26 | 2.71 | 0.83 | 1.46 | 2.40 | 2.09 | 3.79 |
| 1997 | 0.54 | 0.13 | 0.01 | 2.30 | 7.66 | 2.04 | 1.32 | 0.54 | 0.17 | 0.09 | 1.54 | 22.14 |
| 1998 | 12.54 | 1.73 | 0.77 | 4.64 | 5.34 | 3.70 | 1.67 | 0.37 | 0.11 | 0.40 | 0.64 | 0.13 |
| 1999 | 0.05 | 0.04 | 0.17 | 7.32 | 6.93 | 2.39 | 1.27 | 3.44 | 3.34 | 3.35 | 1.53 | 2.98 |
| 2000 | 0.78 | 0.16 | 0.05 | 0.07 | 1.83 | 1.21 | 1.01 | 0.64 | 0.43 | 0.79 | 2.02 | 6.06 |
| 2001 | 10.03 | 3.17 | 0.92 | 3.56 | 3.81 | 3.03 | 1.30 | 1.06 | 4.67 | 3.97 | 4.89 | 1.49 |
| 2002 | 0.69 | 0.30 | 1.01 | 9.92 | 12.30 | 2.35 | 0.66 | 0.34 | 0.24 | 0.24 | 5.25 | 4.11 |
| 2003 | 3.17 | 0.36 | 0.12 | 4.67 | 9.85 | 3.28 | 2.05 | 3.33 | 4.01 | 1.34 | 0.53 | 0.56 |
| 2004 | 0.59 | 0.47 | 0.21 | 4.19 | 6.26 | 1.00 | 0.30 | 0.23 | 0.88 | 2.73 | 3.13 | 2.02 |
| 2005 | 1.29 | 0.60 | 0.53 | 1.81 | 6.31 | 3.42 | 1.09 | 0.88 | 0.85 | 0.35 | 0.34 | 0.06 |
| 2006 | 0.01 | 0.01 | 0.05 | 7.27 | 5.37 | 3.47 | 1.46 | 0.85 | 0.61 | 0.57 | 8.27 | 13.08 |
| 2007 | 6.48 | 2.09 | 3.42 | 3.52 | 5.57 | 3.72 | 1.99 | 3.64 | 2.75 | 1.44 | 0.50 | 0.10 |
| 2008 | 0.02 | 0.01 | 0.01 | 2.11 | 5.17 | 5.02 | 1.43 | 2.52 | 4.01 | 8.90 | 6.78 | 1.17 |
| 2009 | 0.22 | 0.42 | 0.13 | 2.18 | 6.03 | 1.67 | 0.48 | 0.16 | 0.33 | 0.94 | 0.54 | 2.26 |
| 2010 | 3.66 | 0.80 | 4.53 | 7.64 | 12.43 | 2.12 | 0.79 | 0.30 | 1.90 | 2.23 | 1.20 | 0.56 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

Sub-basin: **1HD** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 4.91 | 2.27 | 0.39 | 11.43 | 17.08 | 26.47 | 8.72 | 1.60 | 3.91 | 10.79 | 9.68 | 2.68 |
| 1992 | 0.58 | 0.11 | 0.09 | 8.34 | 16.38 | 17.29 | 15.75 | 6.98 | 13.25 | 20.51 | 11.06 | 6.75 |
| 1993 | 12.36 | 8.88 | 2.11 | 0.65 | 22.27 | 28.73 | 9.12 | 1.74 | 1.90 | 0.57 | 0.74 | 2.48 |
| 1994 | 0.27 | 0.01 | 8.29 | 31.06 | 35.86 | 18.74 | 14.84 | 8.51 | 7.97 | 4.75 | 26.18 | 16.49 |
| 1995 | 1.88 | 0.25 | 7.73 | 13.28 | 25.50 | 23.24 | 16.34 | 4.36 | 2.84 | 9.84 | 18.94 | 8.23 |
| 1996 | 5.99 | 13.50 | 15.78 | 34.16 | 25.62 | 16.26 | 14.69 | 4.74 | 17.85 | 12.52 | 10.96 | 13.12 |
| 1997 | 2.49 | 0.21 | 0.01 | 1.68 | 23.71 | 7.44 | 3.63 | 4.30 | 4.27 | 0.59 | 16.15 | 55.80 |
| 1998 | 36.80 | 7.86 | 1.65 | 10.09 | 24.38 | 14.49 | 7.98 | 2.72 | 3.55 | 13.47 | 8.95 | 0.99 |
| 1999 | 0.09 | 0.01 | 0.07 | 17.03 | 18.12 | 10.84 | 5.76 | 10.73 | 10.91 | 24.60 | 9.02 | 12.56 |
| 2000 | 2.83 | 0.10 | 0.11 | 5.87 | 27.22 | 8.74 | 9.08 | 6.74 | 6.72 | 9.08 | 19.09 | 23.35 |
| 2001 | 31.39 | 13.29 | 2.04 | 18.25 | 19.24 | 23.38 | 6.24 | 3.37 | 10.32 | 16.32 | 25.39 | 5.95 |
| 2002 | 3.69 | 2.50 | 7.22 | 19.76 | 49.45 | 10.29 | 2.26 | 1.30 | 1.90 | 1.13 | 23.28 | 11.60 |
| 2003 | 13.27 | 1.23 | 0.13 | 12.04 | 43.79 | 15.37 | 9.49 | 6.72 | 10.91 | 7.28 | 4.65 | 7.84 |
| 2004 | 3.34 | 1.62 | 2.13 | 26.53 | 25.21 | 7.46 | 1.43 | 1.98 | 12.30 | 9.96 | 8.86 | 10.38 |
| 2005 | 5.07 | 1.40 | 1.54 | 13.13 | 14.64 | 14.38 | 7.01 | 3.08 | 7.48 | 3.25 | 1.72 | 0.10 |
| 2006 | 0.00 | 0.00 | 0.34 | 29.00 | 29.04 | 11.07 | 5.16 | 1.48 | 1.40 | 1.44 | 22.61 | 33.95 |
| 2007 | 31.28 | 13.44 | 10.09 | 11.84 | 15.72 | 21.83 | 10.18 | 5.56 | 6.51 | 3.08 | 0.70 | 0.15 |
| 2008 | 0.02 | 0.00 | 0.02 | 13.01 | 11.40 | 8.05 | 5.18 | 12.76 | 14.33 | 19.02 | 17.79 | 4.33 |
| 2009 | 0.33 | 0.42 | 0.14 | 7.50 | 21.28 | 12.58 | 3.57 | 2.45 | 7.01 | 6.17 | 1.98 | 12.79 |
| 2010 | 18.25 | 2.55 | 16.72 | 25.49 | 49.41 | 13.41 | 7.30 | 3.18 | 18.83 | 13.37 | 6.61 | 7.91 |

Sub-basin: **1HE** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 2.68 | 0.50 | 0.01 | 6.76 | 18.35 | 17.27 | 7.15 | 0.30 | 0.34 | 4.99 | 11.38 | 3.71 |
| 1992 | 0.46 | 0.01 | 0.01 | 1.29 | 16.20 | 13.52 | 12.67 | 4.70 | 7.29 | 16.24 | 9.22 | 6.48 |
| 1993 | 9.14 | 7.71 | 2.26 | 0.70 | 18.01 | 20.32 | 6.67 | 1.12 | 1.72 | 1.40 | 1.42 | 1.35 |
| 1994 | 0.01 | 0.00 | 1.21 | 24.28 | 27.58 | 14.05 | 10.47 | 5.07 | 4.96 | 2.81 | 25.16 | 16.76 |
| 1995 | 1.47 | 0.01 | 2.38 | 12.13 | 20.82 | 14.64 | 12.86 | 3.12 | 0.60 | 2.10 | 13.79 | 8.42 |
| 1996 | 2.43 | 3.61 | 11.42 | 24.33 | 25.62 | 11.45 | 9.18 | 2.52 | 18.64 | 14.26 | 8.63 | 11.23 |
| 1997 | 2.78 | 0.24 | 0.01 | 0.03 | 23.18 | 7.06 | 2.35 | 1.20 | 2.26 | 0.27 | 14.25 | 48.65 |
| 1998 | 28.57 | 4.60 | 0.48 | 5.91 | 21.87 | 14.72 | 6.43 | 1.19 | 1.01 | 8.17 | 7.06 | 0.69 |
| 1999 | 0.01 | 0.00 | 0.01 | 11.34 | 22.69 | 9.55 | 4.15 | 5.26 | 5.85 | 19.55 | 9.75 | 11.70 |
| 2000 | 2.20 | 0.01 | 0.01 | 0.02 | 24.96 | 6.87 | 6.32 | 2.65 | 2.83 | 8.03 | 14.23 | 18.68 |
| 2001 | 20.87 | 8.80 | 0.75 | 12.26 | 20.24 | 24.24 | 4.07 | 0.73 | 2.92 | 15.21 | 22.84 | 4.97 |
| 2002 | 1.37 | 0.51 | 3.18 | 23.73 | 41.04 | 8.77 | 1.67 | 0.10 | 0.02 | 0.23 | 18.77 | 8.79 |
| 2003 | 11.17 | 0.84 | 0.01 | 5.55 | 38.26 | 13.74 | 9.74 | 3.58 | 9.46 | 6.93 | 5.10 | 6.06 |
| 2004 | 1.60 | 0.13 | 0.35 | 8.34 | 20.89 | 7.95 | 1.32 | 0.01 | 5.05 | 10.79 | 12.53 | 11.19 |
| 2005 | 4.57 | 0.46 | 0.01 | 6.65 | 16.70 | 12.15 | 5.18 | 2.45 | 7.40 | 4.32 | 1.61 | 0.01 |
| 2006 | 0.00 | 0.00 | 0.01 | 27.12 | 27.52 | 9.60 | 2.71 | 0.29 | 0.01 | 0.01 | 9.73 | 26.50 |
| 2007 | 24.86 | 10.81 | 4.71 | 5.39 | 13.89 | 21.50 | 7.51 | 2.82 | 2.78 | 1.99 | 0.89 | 0.01 |
| 2008 | 0.01 | 0.00 | 0.00 | 9.48 | 11.98 | 7.16 | 4.64 | 11.47 | 11.39 | 14.27 | 15.82 | 2.86 |
| 2009 | 0.01 | 0.01 | 0.01 | 1.58 | 25.83 | 13.47 | 3.14 | 0.50 | 2.34 | 4.03 | 1.39 | 12.07 |
| 2010 | 16.62 | 1.04 | 5.81 | 20.34 | 41.03 | 9.33 | 4.66 | 0.27 | 12.97 | 11.70 | 7.62 | 6.65 |

Sub-basin: **1HG** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 0.10 | 0.03 | 0.01 | 4.09 | 9.55 | 4.46 | 0.97 | 0.07 | 0.01 | 0.03 | 2.45 | 1.10 |
| 1992 | 0.11 | 0.00 | 0.00 | 0.43 | 5.85 | 1.52 | 1.49 | 0.25 | 0.12 | 0.53 | 1.65 | 6.53 |
| 1993 | 4.04 | 2.35 | 0.57 | 0.02 | 2.10 | 3.42 | 0.71 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 |
| 1994 | 0.00 | 0.00 | 0.10 | 8.39 | 14.15 | 4.72 | 1.99 | 0.72 | 0.91 | 0.23 | 6.55 | 6.13 |
| 1995 | 0.59 | 0.02 | 0.12 | 5.74 | 9.96 | 3.36 | 1.16 | 0.15 | 0.01 | 0.01 | 1.39 | 2.01 |
| 1996 | 0.30 | 0.02 | 0.14 | 5.29 | 13.61 | 3.31 | 1.24 | 0.08 | 3.57 | 5.89 | 2.44 | 2.60 |
| 1997 | 0.52 | 0.02 | 0.00 | 3.44 | 12.02 | 1.28 | 0.33 | 0.02 | 0.00 | 0.59 | 11.42 | 25.31 |
| 1998 | 19.53 | 1.31 | 0.10 | 1.20 | 10.53 | 4.43 | 1.05 | 0.04 | 0.01 | 0.01 | 0.00 | 0.00 |
| 1999 | 0.00 | 0.00 | 0.00 | 1.18 | 12.28 | 2.64 | 0.27 | 0.01 | 0.00 | 0.01 | 0.59 | 4.91 |
| 2000 | 0.68 | 0.00 | 0.00 | 0.01 | 1.89 | 0.86 | 0.43 | 0.02 | 0.00 | 0.01 | 0.02 | 1.92 |
| 2001 | 4.93 | 2.19 | 0.30 | 4.92 | 5.97 | 3.77 | 0.63 | 0.03 | 0.00 | 0.01 | 0.85 | 1.07 |
| 2002 | 0.04 | 0.00 | 0.00 | 7.90 | 19.01 | 3.20 | 0.55 | 0.02 | 0.00 | 0.00 | 0.05 | 0.94 |
| 2003 | 2.20 | 0.14 | 0.00 | 6.27 | 20.14 | 6.43 | 3.41 | 0.73 | 1.80 | 1.41 | 1.95 | 1.87 |
| 2004 | 0.19 | 0.01 | 0.02 | 0.04 | 7.59 | 2.87 | 0.53 | 0.01 | 0.01 | 0.15 | 7.73 | 4.98 |
| 2005 | 1.08 | 0.06 | 0.17 | 2.70 | 9.93 | 3.88 | 1.11 | 0.44 | 4.25 | 3.30 | 2.79 | 0.15 |
| 2006 | 0.00 | 0.00 | 0.39 | 21.15 | 14.99 | 3.61 | 0.80 | 0.12 | 0.01 | 0.01 | 4.21 | 15.25 |
| 2007 | 10.52 | 3.05 | 1.01 | 1.44 | 10.72 | 10.26 | 1.94 | 0.54 | 0.44 | 0.94 | 1.75 | 0.79 |
| 2008 | 0.05 | 0.00 | 0.01 | 11.54 | 6.26 | 4.04 | 3.48 | 6.35 | 6.67 | 6.30 | 10.54 | 1.09 |
| 2009 | 0.04 | 0.01 | 0.00 | 6.91 | 18.16 | 5.87 | 1.01 | 0.05 | 0.02 | 0.07 | 0.10 | 7.11 |
| 2010 | 5.63 | 0.31 | 0.78 | 7.23 | 16.75 | 2.37 | 0.71 | 0.01 | 0.29 | 1.91 | 2.39 | 2.21 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

# 1JA, 1JB, 1JC, 1JD, 1JE, 1JF, 1JG1 & 1JG2

Sub-basin: **1JA** (Unit: $m^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 22.81 | 15.99 | 11.22 | 34.92 | 39.60 | 51.34 | 29.06 | 27.44 | 31.92 | 28.49 | 25.11 | 12.68 |
| 1992 | 9.37 | 7.78 | 8.86 | 18.97 | 34.88 | 31.30 | 37.54 | 34.81 | 41.36 | 39.14 | 26.01 | 18.04 |
| 1993 | 26.07 | 34.83 | 17.37 | 11.15 | 38.13 | 42.48 | 27.21 | 16.60 | 14.91 | 12.15 | 14.21 | 16.41 |
| 1994 | 9.52 | 7.18 | 18.57 | 44.39 | 70.34 | 38.91 | 36.10 | 39.39 | 28.28 | 17.93 | 40.00 | 25.97 |
| 1995 | 10.38 | 9.90 | 29.57 | 32.17 | 50.86 | 38.64 | 34.84 | 21.10 | 28.71 | 33.60 | 36.40 | 20.47 |
| 1996 | 20.80 | 30.05 | 31.63 | 62.68 | 30.90 | 27.82 | 35.13 | 27.73 | 37.39 | 22.64 | 16.34 | 26.88 |
| 1997 | 11.69 | 7.92 | 7.60 | 14.06 | 34.15 | 15.38 | 29.82 | 25.53 | 14.54 | 13.27 | 50.62 | 44.09 |
| 1998 | 48.43 | 24.86 | 13.77 | 19.53 | 45.02 | 29.63 | 33.31 | 28.76 | 25.16 | 44.47 | 25.31 | 11.70 |
| 1999 | 9.61 | 7.94 | 13.24 | 34.30 | 33.36 | 17.97 | 15.85 | 25.82 | 23.19 | 27.15 | 19.95 | 19.75 |
| 2000 | 11.15 | 7.61 | 7.96 | 10.10 | 17.58 | 16.24 | 21.26 | 30.00 | 19.29 | 19.31 | 32.83 | 34.54 |
| 2001 | 56.77 | 25.38 | 13.85 | 40.67 | 33.78 | 29.60 | 26.04 | 21.76 | 20.10 | 30.96 | 49.05 | 20.43 |
| 2002 | 15.09 | 11.13 | 19.50 | 21.49 | 75.31 | 18.12 | 15.48 | 23.78 | 17.91 | 12.08 | 30.00 | 29.72 |
| 2003 | 27.27 | 9.90 | 8.27 | 34.97 | 70.25 | 32.39 | 18.42 | 32.01 | 29.39 | 20.10 | 16.55 | 19.41 |
| 2004 | 14.59 | 13.04 | 18.47 | 54.83 | 49.05 | 18.19 | 12.94 | 18.04 | 19.65 | 18.90 | 16.73 | 16.32 |
| 2005 | 11.67 | 9.57 | 15.98 | 32.45 | 34.06 | 31.01 | 22.86 | 22.17 | 29.40 | 16.45 | 13.01 | 9.27 |
| 2006 | 7.58 | 6.50 | 11.79 | 53.85 | 45.34 | 19.30 | 25.98 | 25.85 | 18.56 | 14.24 | 48.99 | 71.15 |
| 2007 | 43.60 | 29.46 | 22.09 | 27.43 | 34.13 | 36.60 | 25.71 | 35.29 | 45.73 | 22.65 | 12.40 | 9.26 |
| 2008 | 7.92 | 7.21 | 8.81 | 30.08 | 27.08 | 21.18 | 20.18 | 35.08 | 32.44 | 34.65 | 36.98 | 14.69 |
| 2009 | 8.93 | 9.30 | 8.33 | 12.56 | 26.01 | 17.41 | 11.53 | 10.11 | 15.55 | 19.17 | 14.50 | 30.50 |
| 2010 | 39.87 | 15.15 | 43.30 | 39.28 | 59.96 | 23.18 | 20.49 | 18.94 | 25.37 | 36.10 | 21.44 | 23.04 |

Sub-basin: **1JB** (Unit: $m^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 5.64 | 3.45 | 2.01 | 8.26 | 10.43 | 13.63 | 5.77 | 6.11 | 7.02 | 7.51 | 5.89 | 2.39 |
| 1992 | 1.58 | 1.24 | 1.50 | 5.04 | 8.65 | 7.06 | 9.00 | 7.34 | 10.06 | 9.79 | 5.43 | 3.10 |
| 1993 | 5.09 | 6.06 | 2.79 | 1.84 | 10.29 | 10.39 | 6.31 | 3.18 | 2.73 | 2.21 | 3.00 | 3.59 |
| 1994 | 1.69 | 1.13 | 4.68 | 13.40 | 19.09 | 8.05 | 7.84 | 8.39 | 7.08 | 4.68 | 11.79 | 6.19 |
| 1995 | 1.82 | 1.90 | 7.70 | 8.44 | 12.78 | 9.84 | 8.04 | 3.94 | 5.77 | 9.95 | 10.02 | 4.85 |
| 1996 | 5.47 | 9.42 | 9.16 | 16.38 | 7.91 | 5.89 | 7.65 | 4.89 | 7.89 | 5.45 | 4.22 | 6.81 |
| 1997 | 2.22 | 1.33 | 1.22 | 2.29 | 7.20 | 3.14 | 5.74 | 4.83 | 2.56 | 2.50 | 13.40 | 10.29 |
| 1998 | 12.14 | 4.45 | 2.40 | 4.44 | 10.47 | 6.30 | 7.15 | 4.46 | 4.49 | 10.56 | 5.47 | 2.10 |
| 1999 | 1.72 | 1.43 | 3.84 | 10.13 | 9.75 | 4.55 | 3.21 | 4.58 | 4.83 | 6.73 | 3.95 | 4.14 |
| 2000 | 2.00 | 1.23 | 1.32 | 2.03 | 5.78 | 4.48 | 5.28 | 6.71 | 4.07 | 4.55 | 7.51 | 8.80 |
| 2001 | 16.25 | 5.87 | 2.70 | 8.32 | 7.64 | 7.46 | 5.54 | 3.83 | 3.54 | 8.07 | 11.15 | 4.25 |
| 2002 | 3.11 | 2.16 | 3.74 | 5.12 | 17.94 | 3.83 | 3.40 | 5.62 | 4.01 | 2.41 | 7.42 | 5.45 |
| 2003 | 5.29 | 1.68 | 1.34 | 8.89 | 15.36 | 7.06 | 3.68 | 5.88 | 6.74 | 4.82 | 3.73 | 3.97 |
| 2004 | 2.85 | 2.51 | 4.02 | 13.48 | 11.66 | 3.66 | 2.57 | 3.59 | 4.53 | 4.21 | 3.31 | 2.86 |
| 2005 | 1.94 | 1.55 | 4.00 | 8.13 | 7.03 | 7.73 | 5.41 | 3.91 | 5.02 | 2.97 | 2.58 | 1.48 |
| 2006 | 1.17 | 0.99 | 2.53 | 15.26 | 11.15 | 4.63 | 7.02 | 5.02 | 3.35 | 2.87 | 11.55 | 17.11 |
| 2007 | 8.92 | 6.61 | 5.08 | 6.90 | 8.42 | 8.59 | 5.08 | 6.53 | 11.31 | 5.10 | 2.38 | 1.58 |
| 2008 | 1.26 | 1.14 | 1.84 | 8.54 | 6.45 | 5.05 | 3.70 | 6.51 | 7.16 | 8.13 | 7.58 | 3.03 |
| 2009 | 1.58 | 2.05 | 1.53 | 3.34 | 6.57 | 3.59 | 2.37 | 2.19 | 4.96 | 4.68 | 3.00 | 7.38 |
| 2010 | 7.79 | 2.97 | 8.98 | 9.08 | 14.72 | 4.98 | 4.47 | 3.67 | 4.52 | 7.83 | 4.19 | 4.57 |

Sub-basin: **1JC** (Unit: $m^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 12.85 | 7.88 | 6.20 | 18.04 | 21.84 | 23.13 | 13.05 | 13.68 | 14.34 | 15.24 | 12.79 | 6.45 |
| 1992 | 5.05 | 4.49 | 4.95 | 12.39 | 17.74 | 15.07 | 17.61 | 17.78 | 19.90 | 18.85 | 11.56 | 7.70 |
| 1993 | 10.58 | 12.05 | 7.28 | 5.72 | 22.09 | 19.30 | 14.04 | 8.59 | 8.02 | 6.69 | 7.64 | 8.32 |
| 1994 | 5.23 | 4.28 | 7.00 | 20.65 | 34.38 | 15.86 | 16.91 | 18.14 | 12.85 | 8.82 | 18.89 | 11.99 |
| 1995 | 5.27 | 4.92 | 13.44 | 14.78 | 22.34 | 18.75 | 14.87 | 9.93 | 14.02 | 19.28 | 18.32 | 9.82 |
| 1996 | 9.47 | 15.01 | 14.96 | 27.06 | 15.39 | 12.59 | 16.49 | 11.85 | 16.17 | 11.46 | 9.37 | 13.20 |
| 1997 | 5.83 | 4.26 | 4.59 | 7.81 | 14.35 | 7.38 | 12.73 | 10.17 | 6.05 | 5.68 | 25.02 | 19.41 |
| 1998 | 23.43 | 10.81 | 6.68 | 10.68 | 20.12 | 13.77 | 15.78 | 11.57 | 11.33 | 21.65 | 11.67 | 5.90 |
| 1999 | 5.04 | 4.31 | 7.11 | 17.36 | 20.07 | 10.01 | 8.25 | 12.65 | 10.61 | 15.45 | 9.23 | 8.18 |
| 2000 | 5.21 | 4.27 | 4.44 | 4.63 | 11.30 | 10.33 | 12.29 | 14.94 | 9.25 | 12.09 | 14.14 | 15.57 |
| 2001 | 27.85 | 10.73 | 6.51 | 17.70 | 18.33 | 17.13 | 12.15 | 10.14 | 9.17 | 17.05 | 22.37 | 10.00 |
| 2002 | 8.19 | 5.81 | 9.69 | 10.63 | 32.36 | 8.90 | 8.64 | 13.11 | 8.87 | 6.85 | 17.90 | 14.06 |
| 2003 | 12.06 | 4.76 | 4.63 | 18.46 | 29.93 | 14.72 | 9.35 | 13.03 | 14.22 | 10.25 | 8.68 | 9.55 |
| 2004 | 7.04 | 5.93 | 6.62 | 23.22 | 19.53 | 7.85 | 6.81 | 9.54 | 10.29 | 9.68 | 9.04 | 7.23 |
| 2005 | 5.56 | 5.14 | 10.10 | 14.74 | 15.99 | 15.06 | 11.61 | 12.69 | 12.98 | 7.49 | 6.78 | 4.90 |
| 2006 | 4.51 | 3.95 | 6.32 | 26.39 | 19.98 | 10.95 | 15.58 | 12.64 | 9.70 | 8.29 | 23.47 | 31.29 |
| 2007 | 16.91 | 13.35 | 9.62 | 13.81 | 17.72 | 17.43 | 13.70 | 15.95 | 23.95 | 11.74 | 6.55 | 4.99 |
| 2008 | 4.72 | 4.36 | 6.06 | 16.55 | 13.76 | 12.02 | 9.95 | 16.94 | 16.14 | 18.24 | 15.84 | 7.44 |
| 2009 | 4.99 | 5.33 | 4.76 | 7.30 | 11.45 | 7.80 | 6.22 | 5.89 | 12.20 | 10.72 | 8.07 | 16.09 |
| 2010 | 14.90 | 6.58 | 16.07 | 17.62 | 27.65 | 11.67 | 11.81 | 10.54 | 12.56 | 16.92 | 9.36 | 9.43 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

Sub-basin: **1JD** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 8.53 | 5.88 | 5.07 | 10.35 | 12.21 | 15.31 | 9.39 | 8.92 | 10.65 | 11.84 | 11.01 | 5.89 |
| 1992 | 5.07 | 4.47 | 4.85 | 8.71 | 11.28 | 9.60 | 11.31 | 9.55 | 11.86 | 14.70 | 10.57 | 6.69 |
| 1993 | 8.94 | 7.34 | 5.62 | 4.82 | 13.43 | 13.19 | 10.36 | 6.51 | 5.91 | 5.41 | 5.94 | 6.62 |
| 1994 | 5.08 | 4.25 | 6.93 | 14.84 | 20.57 | 10.21 | 12.55 | 16.76 | 15.57 | 9.26 | 19.61 | 15.75 |
| 1995 | 5.49 | 4.98 | 10.28 | 10.17 | 18.36 | 23.98 | 18.82 | 7.75 | 9.10 | 14.22 | 23.02 | 11.05 |
| 1996 | 9.37 | 14.11 | 19.08 | 46.52 | 21.19 | 13.67 | 13.66 | 8.52 | 11.55 | 9.02 | 7.57 | 9.39 |
| 1997 | 5.34 | 4.36 | 4.69 | 6.03 | 10.18 | 5.99 | 7.57 | 7.23 | 5.38 | 5.04 | 14.02 | 13.87 |
| 1998 | 14.18 | 6.73 | 5.51 | 7.60 | 12.22 | 8.29 | 8.57 | 6.55 | 6.87 | 12.47 | 7.62 | 5.29 |
| 1999 | 4.78 | 4.26 | 5.34 | 10.65 | 11.36 | 7.27 | 6.29 | 8.31 | 7.70 | 10.58 | 6.40 | 6.88 |
| 2000 | 5.14 | 4.34 | 4.66 | 5.40 | 10.23 | 7.11 | 8.24 | 9.29 | 6.58 | 7.92 | 9.60 | 10.20 |
| 2001 | 16.23 | 7.66 | 5.44 | 10.48 | 9.85 | 9.55 | 7.89 | 6.93 | 6.91 | 10.07 | 12.53 | 6.77 |
| 2002 | 6.38 | 5.12 | 6.89 | 7.68 | 17.76 | 6.55 | 6.21 | 8.05 | 6.46 | 5.62 | 11.57 | 8.35 |
| 2003 | 8.01 | 4.58 | 4.68 | 11.03 | 17.07 | 8.59 | 6.77 | 7.92 | 8.55 | 7.32 | 6.46 | 7.33 |
| 2004 | 5.80 | 5.19 | 5.54 | 14.59 | 11.86 | 5.90 | 5.51 | 6.45 | 7.61 | 6.95 | 6.37 | 5.91 |
| 2005 | 5.07 | 4.60 | 7.08 | 9.42 | 8.80 | 9.22 | 7.66 | 7.22 | 7.92 | 5.84 | 5.59 | 4.76 |
| 2006 | 4.51 | 4.03 | 5.35 | 15.05 | 12.18 | 7.09 | 9.08 | 7.11 | 6.59 | 5.98 | 13.49 | 16.63 |
| 2007 | 11.00 | 7.85 | 7.81 | 9.11 | 10.53 | 10.59 | 8.15 | 8.83 | 12.23 | 7.67 | 5.47 | 4.91 |
| 2008 | 4.67 | 4.29 | 5.34 | 10.57 | 8.24 | 7.56 | 6.73 | 9.28 | 9.55 | 10.68 | 9.37 | 5.91 |
| 2009 | 4.84 | 4.71 | 4.74 | 5.86 | 8.32 | 6.14 | 5.49 | 5.53 | 8.37 | 7.01 | 5.82 | 9.66 |
| 2010 | 9.22 | 5.33 | 10.20 | 11.46 | 15.89 | 7.82 | 7.83 | 7.20 | 8.04 | 9.77 | 6.41 | 6.82 |

Sub-basin: **1JE** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 7.91 | 5.94 | 6.30 | 18.28 | 12.82 | 26.28 | 9.78 | 5.69 | 10.38 | 10.99 | 8.41 | 4.24 |
| 1992 | 3.22 | 1.95 | 2.58 | 9.94 | 13.47 | 13.78 | 14.29 | 8.39 | 15.22 | 19.58 | 11.99 | 8.27 |
| 1993 | 12.78 | 17.81 | 8.00 | 4.37 | 13.89 | 18.22 | 8.01 | 3.65 | 3.87 | 3.41 | 6.45 | 6.13 |
| 1994 | 2.78 | 1.92 | 21.49 | 29.43 | 27.09 | 19.63 | 14.52 | 10.24 | 9.31 | 6.80 | 23.68 | 14.15 |
| 1995 | 4.69 | 4.79 | 19.89 | 17.60 | 24.71 | 18.62 | 17.43 | 6.14 | 7.31 | 10.00 | 15.66 | 8.06 |
| 1996 | 14.76 | 25.01 | 18.17 | 33.89 | 15.71 | 11.11 | 16.21 | 9.69 | 23.11 | 13.11 | 7.97 | 13.43 |
| 1997 | 5.65 | 2.88 | 1.80 | 7.64 | 27.72 | 6.96 | 9.87 | 12.79 | 9.98 | 7.21 | 25.96 | 36.05 |
| 1998 | 26.50 | 10.57 | 6.30 | 17.74 | 27.27 | 15.52 | 11.81 | 7.29 | 8.68 | 17.99 | 16.27 | 4.89 |
| 1999 | 4.73 | 3.29 | 13.39 | 26.53 | 11.05 | 7.51 | 5.81 | 9.54 | 11.16 | 15.24 | 8.78 | 12.36 |
| 2000 | 5.69 | 2.41 | 2.91 | 10.86 | 14.10 | 8.16 | 10.28 | 10.60 | 7.99 | 7.49 | 21.67 | 22.22 |
| 2001 | 34.52 | 14.99 | 5.58 | 21.36 | 14.25 | 15.48 | 10.34 | 5.88 | 9.76 | 13.88 | 22.38 | 6.97 |
| 2002 | 5.93 | 4.25 | 8.18 | 12.13 | 38.60 | 8.04 | 4.37 | 6.07 | 5.10 | 2.97 | 10.83 | 8.85 |
| 2003 | 10.52 | 4.09 | 2.67 | 14.76 | 31.82 | 11.81 | 6.94 | 11.92 | 10.97 | 8.48 | 5.27 | 7.27 |
| 2004 | 6.40 | 6.45 | 14.35 | 32.77 | 30.27 | 9.67 | 4.36 | 6.15 | 10.72 | 8.32 | 6.41 | 9.41 |
| 2005 | 5.77 | 3.26 | 6.47 | 18.46 | 11.38 | 15.52 | 8.58 | 3.37 | 4.84 | 4.49 | 3.46 | 2.15 |
| 2006 | 1.71 | 1.49 | 6.84 | 31.38 | 25.49 | 6.64 | 5.27 | 3.90 | 3.21 | 3.23 | 19.92 | 37.84 |
| 2007 | 27.10 | 13.61 | 13.63 | 12.75 | 16.26 | 19.81 | 6.66 | 6.78 | 9.83 | 5.91 | 3.60 | 3.39 |
| 2008 | 2.54 | 2.02 | 4.41 | 19.98 | 10.70 | 6.30 | 5.89 | 11.37 | 14.77 | 11.80 | 15.36 | 5.57 |
| 2009 | 2.75 | 4.38 | 3.11 | 12.63 | 22.68 | 10.52 | 5.46 | 6.17 | 9.95 | 8.26 | 4.73 | 14.69 |
| 2010 | 24.32 | 8.65 | 25.61 | 22.49 | 36.63 | 11.51 | 6.40 | 4.95 | 11.99 | 17.20 | 9.56 | 17.17 |

Sub-basin: **1JF** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 21.94 | 16.62 | 12.22 | 36.73 | 36.57 | 68.47 | 32.85 | 24.55 | 39.08 | 32.96 | 27.56 | 13.89 |
| 1992 | 10.77 | 8.27 | 9.36 | 24.89 | 35.61 | 35.02 | 38.51 | 29.56 | 46.65 | 55.21 | 39.12 | 22.61 |
| 1993 | 32.51 | 43.57 | 20.10 | 12.90 | 39.86 | 66.15 | 33.87 | 15.55 | 13.92 | 12.15 | 18.22 | 18.23 |
| 1994 | 10.33 | 7.67 | 29.11 | 63.41 | 81.37 | 59.64 | 47.06 | 42.98 | 37.57 | 24.99 | 63.45 | 44.88 |
| 1995 | 13.90 | 12.36 | 42.10 | 42.88 | 80.49 | 69.55 | 57.49 | 21.73 | 25.94 | 34.31 | 49.02 | 26.93 |
| 1996 | 31.30 | 48.32 | 55.97 | 115.52 | 53.36 | 36.03 | 45.40 | 29.15 | 53.23 | 32.13 | 20.76 | 30.09 |
| 1997 | 13.40 | 8.82 | 8.20 | 18.30 | 48.05 | 18.29 | 31.28 | 33.23 | 18.54 | 17.74 | 56.75 | 70.28 |
| 1998 | 82.23 | 26.71 | 15.09 | 26.31 | 67.61 | 40.15 | 35.18 | 24.11 | 23.48 | 50.62 | 39.27 | 13.89 |
| 1999 | 10.99 | 9.11 | 16.01 | 43.23 | 31.30 | 19.13 | 17.00 | 24.77 | 27.19 | 34.63 | 21.63 | 27.44 |
| 2000 | 14.27 | 8.74 | 10.65 | 21.54 | 24.95 | 19.06 | 25.20 | 30.73 | 21.15 | 18.26 | 41.97 | 45.39 |
| 2001 | 69.71 | 33.00 | 15.89 | 50.09 | 41.17 | 42.29 | 35.02 | 22.44 | 26.11 | 32.27 | 62.32 | 22.70 |
| 2002 | 16.46 | 12.57 | 20.59 | 26.86 | 104.55 | 23.41 | 16.14 | 25.54 | 18.45 | 11.80 | 26.55 | 25.47 |
| 2003 | 27.74 | 11.68 | 9.53 | 37.40 | 78.75 | 30.00 | 19.13 | 32.70 | 29.46 | 24.30 | 17.65 | 22.78 |
| 2004 | 17.71 | 16.80 | 27.49 | 71.82 | 83.95 | 24.64 | 14.06 | 18.90 | 23.96 | 20.90 | 17.96 | 21.33 |
| 2005 | 14.64 | 10.42 | 17.02 | 39.43 | 29.55 | 35.80 | 24.04 | 15.30 | 25.00 | 19.75 | 14.58 | 10.11 |
| 2006 | 8.40 | 7.34 | 18.04 | 69.17 | 55.53 | 19.15 | 22.95 | 19.05 | 15.25 | 13.34 | 51.07 | 77.81 |
| 2007 | 53.70 | 29.65 | 32.39 | 34.57 | 43.46 | 51.77 | 23.40 | 29.38 | 39.65 | 20.94 | 12.64 | 10.87 |
| 2008 | 9.14 | 8.04 | 13.61 | 38.71 | 27.35 | 19.34 | 19.04 | 32.44 | 34.49 | 33.13 | 39.38 | 16.07 |
| 2009 | 10.06 | 11.75 | 9.99 | 20.92 | 40.96 | 22.44 | 15.04 | 16.92 | 23.80 | 21.44 | 14.64 | 31.59 |
| 2010 | 49.55 | 21.04 | 53.66 | 49.01 | 73.80 | 26.23 | 19.14 | 17.75 | 28.21 | 38.58 | 22.67 | 32.72 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

Sub-basin: **1JG1** (Unit: $m^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 4.35 | 2.56 | 0.75 | 6.26 | 9.71 | 13.88 | 5.40 | 2.99 | 5.84 | 6.03 | 6.06 | 1.38 |
| 1992 | 1.24 | 1.85 | 2.45 | 5.96 | 9.07 | 6.98 | 9.04 | 5.56 | 10.25 | 10.50 | 6.45 | 2.85 |
| 1993 | 5.63 | 7.17 | 1.73 | 0.33 | 10.74 | 19.28 | 8.77 | 2.07 | 1.37 | 0.52 | 1.18 | 1.97 |
| 1994 | 1.37 | 2.15 | 5.81 | 17.16 | 21.64 | 13.07 | 11.65 | 9.86 | 9.65 | 4.36 | 17.41 | 12.58 |
| 1995 | 1.32 | 1.13 | 7.10 | 7.03 | 18.20 | 19.81 | 15.38 | 4.18 | 3.61 | 10.18 | 14.94 | 6.31 |
| 1996 | 5.93 | 11.10 | 14.94 | 35.62 | 17.61 | 10.39 | 10.43 | 4.66 | 11.30 | 7.72 | 5.08 | 8.48 |
| 1997 | 1.32 | 1.76 | 2.61 | 2.68 | 10.86 | 2.99 | 2.89 | 4.25 | 2.26 | 0.83 | 11.12 | 21.24 |
| 1998 | 25.11 | 6.09 | 1.70 | 3.18 | 14.77 | 7.99 | 5.81 | 3.34 | 3.24 | 10.50 | 7.44 | 1.23 |
| 1999 | 2.61 | 2.38 | 2.79 | 8.43 | 7.44 | 4.72 | 2.64 | 4.67 | 5.92 | 10.08 | 3.65 | 4.65 |
| 2000 | 1.27 | 2.59 | 2.04 | 2.87 | 11.38 | 3.85 | 5.04 | 5.49 | 4.64 | 4.27 | 8.32 | 12.17 |
| 2001 | 28.20 | 11.31 | 2.22 | 10.98 | 11.44 | 12.01 | 6.02 | 4.17 | 4.10 | 8.52 | 18.72 | 4.60 |
| 2002 | 2.54 | 1.77 | 2.82 | 4.36 | 30.02 | 6.15 | 2.16 | 2.84 | 2.98 | 1.18 | 9.78 | 4.69 |
| 2003 | 6.59 | 0.80 | 1.91 | 7.38 | 26.92 | 9.18 | 4.72 | 4.19 | 6.80 | 4.19 | 3.01 | 4.39 |
| 2004 | 2.01 | 1.37 | 1.94 | 17.25 | 19.57 | 4.43 | 1.43 | 1.87 | 4.31 | 5.41 | 2.94 | 3.01 |
| 2005 | 1.57 | 1.30 | 1.56 | 8.02 | 5.88 | 6.76 | 4.99 | 2.77 | 4.45 | 2.29 | 1.57 | 1.49 |
| 2006 | 2.70 | 2.28 | 1.20 | 15.29 | 13.27 | 4.15 | 5.20 | 2.52 | 2.26 | 1.53 | 11.55 | 17.83 |
| 2007 | 19.06 | 8.70 | 6.28 | 9.06 | 11.25 | 15.84 | 7.31 | 4.60 | 8.76 | 4.62 | 1.43 | 0.57 |
| 2008 | 0.73 | 0.80 | 0.40 | 7.94 | 5.99 | 3.64 | 2.25 | 5.93 | 7.46 | 8.39 | 7.81 | 2.37 |
| 2009 | 0.62 | 0.64 | 0.86 | 1.51 | 7.24 | 4.74 | 1.91 | 1.82 | 4.44 | 4.12 | 1.69 | 4.21 |
| 2010 | 10.06 | 1.01 | 8.82 | 12.70 | 25.87 | 8.95 | 7.01 | 3.59 | 8.40 | 9.74 | 4.87 | 3.77 |

Sub-basin: **1JG2** (Unit: $m^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 2.59 | 1.74 | 1.80 | 3.40 | 5.75 | 7.50 | 2.25 | 2.91 | 3.27 | 3.08 | 2.54 | 1.62 |
| 1992 | 1.83 | 2.14 | 2.20 | 3.39 | 3.59 | 4.33 | 3.53 | 2.89 | 6.03 | 4.60 | 2.48 | 1.42 |
| 1993 | 2.58 | 3.92 | 1.95 | 1.47 | 5.59 | 5.77 | 2.23 | 1.61 | 1.53 | 1.40 | 1.81 | 1.58 |
| 1994 | 2.09 | 2.73 | 4.01 | 8.41 | 10.61 | 5.97 | 4.39 | 3.71 | 3.41 | 1.66 | 6.96 | 4.30 |
| 1995 | 1.77 | 1.41 | 4.05 | 3.30 | 8.01 | 5.80 | 4.29 | 1.28 | 2.32 | 5.86 | 4.04 | 2.18 |
| 1996 | 2.27 | 4.07 | 4.56 | 9.97 | 5.82 | 3.80 | 4.60 | 2.45 | 4.89 | 2.23 | 1.88 | 3.31 |
| 1997 | 1.71 | 2.09 | 3.36 | 3.24 | 5.20 | 1.43 | 2.33 | 1.89 | 1.74 | 1.73 | 5.57 | 13.10 |
| 1998 | 9.50 | 2.42 | 1.78 | 2.92 | 5.85 | 3.06 | 2.68 | 2.30 | 2.13 | 5.50 | 2.38 | 1.91 |
| 1999 | 2.18 | 2.67 | 3.24 | 4.58 | 3.09 | 1.55 | 1.50 | 3.37 | 2.11 | 3.28 | 1.47 | 2.73 |
| 2000 | 1.64 | 3.38 | 2.44 | 1.46 | 5.43 | 1.71 | 2.00 | 2.25 | 1.74 | 1.76 | 5.16 | 7.28 |
| 2001 | 12.65 | 3.32 | 1.81 | 5.11 | 4.02 | 3.51 | 2.01 | 1.53 | 2.58 | 4.03 | 6.29 | 1.84 |
| 2002 | 1.64 | 1.50 | 1.86 | 3.68 | 11.50 | 1.96 | 1.63 | 2.14 | 1.85 | 1.61 | 5.37 | 2.55 |
| 2003 | 3.04 | 1.49 | 2.34 | 6.67 | 9.05 | 3.29 | 1.35 | 3.48 | 2.15 | 1.65 | 1.89 | 2.01 |
| 2004 | 1.56 | 2.04 | 2.13 | 9.98 | 7.50 | 1.92 | 1.62 | 1.98 | 1.95 | 2.29 | 1.65 | 1.98 |
| 2005 | 1.50 | 1.66 | 2.13 | 3.89 | 2.68 | 3.25 | 1.84 | 2.06 | 2.16 | 2.06 | 1.64 | 2.69 |
| 2006 | 3.58 | 2.61 | 2.01 | 6.30 | 6.83 | 1.72 | 2.92 | 2.10 | 1.58 | 1.75 | 7.03 | 11.11 |
| 2007 | 7.28 | 3.28 | 2.55 | 3.43 | 4.10 | 5.01 | 1.61 | 2.55 | 4.57 | 1.67 | 0.79 | 0.52 |
| 2008 | 0.42 | 0.26 | 0.00 | 0.50 | 1.55 | 0.83 | 0.22 | 0.81 | 2.06 | 3.73 | 2.77 | 1.02 |
| 2009 | 0.47 | 0.63 | 0.41 | 0.02 | 2.57 | 1.54 | 0.74 | 0.48 | 0.45 | 0.87 | 0.73 | 0.00 |
| 2010 | 4.13 | 0.00 | 2.57 | 5.74 | 8.72 | 1.17 | 0.89 | 0.37 | 2.73 | 1.13 | 1.16 | 0.42 |

## 1KA, 1KB & 1KC

Sub-basin: **1KA** (Unit: $m^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 2.24 | 1.82 | 3.21 | 8.60 | 11.20 | 13.28 | 4.19 | 1.18 | 2.74 | 7.19 | 7.18 | 3.11 |
| 1992 | 1.83 | 0.64 | 0.47 | 9.41 | 11.48 | 8.72 | 8.54 | 3.56 | 5.76 | 13.09 | 6.25 | 7.51 |
| 1993 | 7.60 | 6.61 | 2.38 | 1.48 | 14.93 | 13.70 | 3.79 | 2.42 | 2.91 | 2.77 | 3.15 | 2.58 |
| 1994 | 0.61 | 0.07 | 6.39 | 15.17 | 16.92 | 10.42 | 8.37 | 4.11 | 4.03 | 3.66 | 17.51 | 10.91 |
| 1995 | 1.83 | 0.93 | 8.19 | 6.96 | 11.65 | 10.18 | 9.03 | 2.25 | 2.08 | 3.72 | 10.37 | 5.09 |
| 1996 | 3.31 | 8.28 | 7.33 | 13.30 | 17.22 | 7.54 | 6.25 | 3.70 | 15.37 | 11.10 | 6.69 | 7.70 |
| 1997 | 3.01 | 0.93 | 0.04 | 4.59 | 18.26 | 4.18 | 2.34 | 4.13 | 3.29 | 1.25 | 11.34 | 29.21 |
| 1998 | 19.11 | 4.05 | 2.10 | 9.21 | 16.55 | 12.01 | 5.39 | 2.19 | 4.40 | 7.57 | 5.94 | 1.30 |
| 1999 | 0.63 | 0.16 | 3.29 | 14.26 | 14.97 | 7.56 | 3.43 | 5.13 | 4.45 | 15.14 | 7.25 | 7.63 |
| 2000 | 2.15 | 0.23 | 0.26 | 7.16 | 17.91 | 5.91 | 6.78 | 3.19 | 4.44 | 5.67 | 10.03 | 11.08 |
| 2001 | 10.48 | 4.78 | 1.07 | 13.26 | 16.55 | 17.38 | 2.79 | 1.17 | 4.31 | 8.93 | 13.10 | 3.32 |
| 2002 | 3.45 | 1.31 | 5.39 | 11.92 | 28.51 | 7.62 | 2.11 | 1.54 | 1.82 | 2.23 | 11.38 | 5.47 |
| 2003 | 6.80 | 1.07 | 0.21 | 5.43 | 24.10 | 10.93 | 6.48 | 3.90 | 6.85 | 6.22 | 4.24 | 4.25 |
| 2004 | 1.57 | 0.93 | 3.07 | 7.14 | 13.95 | 7.10 | 1.63 | 1.75 | 8.06 | 6.30 | 8.00 | 9.02 |
| 2005 | 2.95 | 1.03 | 2.39 | 8.46 | 10.72 | 8.97 | 3.67 | 2.53 | 6.89 | 2.56 | 1.25 | 0.15 |
| 2006 | 0.00 | 0.00 | 4.44 | 21.65 | 19.46 | 6.41 | 2.23 | 1.09 | 1.39 | 1.54 | 9.27 | 16.55 |
| 2007 | 18.19 | 8.87 | 3.18 | 4.73 | 8.93 | 15.17 | 5.39 | 2.42 | 4.17 | 2.84 | 2.16 | 1.32 |
| 2008 | 0.42 | 0.03 | 1.36 | 13.27 | 8.04 | 4.98 | 5.53 | 9.68 | 9.07 | 9.34 | 10.77 | 2.19 |
| 2009 | 0.52 | 0.81 | 0.37 | 11.48 | 19.17 | 11.44 | 3.14 | 3.12 | 4.83 | 3.55 | 2.27 | 11.42 |
| 2010 | 11.59 | 1.39 | 6.59 | 12.51 | 28.34 | 9.02 | 3.61 | 1.95 | 14.45 | 10.27 | 5.09 | 9.30 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

Sub-basin: **1KB** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 21.26 | 17.14 | 25.31 | 68.84 | 72.01 | 83.17 | 27.69 | 12.16 | 19.61 | 35.01 | 36.42 | 18.41 |
| 1992 | 12.31 | 5.52 | 6.68 | 45.77 | 65.52 | 41.32 | 46.79 | 22.04 | 35.16 | 73.30 | 38.31 | 55.00 |
| 1993 | 47.66 | 44.27 | 18.13 | 12.22 | 96.79 | 74.29 | 23.18 | 12.55 | 14.39 | 14.47 | 18.93 | 15.22 |
| 1994 | 7.48 | 4.40 | 55.11 | 98.00 | 114.28 | 61.72 | 49.77 | 26.68 | 24.67 | 18.44 | 85.18 | 60.46 |
| 1995 | 14.83 | 12.31 | 51.28 | 44.68 | 78.66 | 57.25 | 50.21 | 16.40 | 18.85 | 27.53 | 62.37 | 26.99 |
| 1996 | 30.89 | 66.45 | 51.66 | 91.11 | 97.22 | 38.52 | 37.31 | 22.23 | 78.66 | 55.59 | 30.12 | 45.80 |
| 1997 | 21.51 | 8.97 | 3.39 | 34.75 | 131.22 | 22.22 | 15.78 | 24.29 | 20.46 | 9.28 | 70.31 | 218.99 |
| 1998 | 163.32 | 36.88 | 20.31 | 70.34 | 116.76 | 72.23 | 31.59 | 15.64 | 22.30 | 40.06 | 37.54 | 11.73 |
| 1999 | 8.77 | 5.31 | 36.10 | 97.17 | 83.15 | 40.77 | 20.16 | 28.14 | 26.25 | 64.30 | 41.53 | 46.88 |
| 2000 | 17.29 | 5.21 | 4.78 | 38.05 | 89.39 | 31.20 | 41.33 | 25.22 | 23.94 | 27.96 | 54.82 | 65.68 |
| 2001 | 72.50 | 34.67 | 12.62 | 89.79 | 92.05 | 86.78 | 21.25 | 13.22 | 26.69 | 38.79 | 62.50 | 21.54 |
| 2002 | 20.25 | 11.17 | 23.37 | 55.28 | 188.91 | 49.10 | 15.42 | 13.01 | 11.51 | 6.91 | 40.12 | 24.31 |
| 2003 | 33.16 | 9.60 | 4.54 | 32.94 | 142.03 | 48.86 | 29.26 | 23.51 | 30.68 | 28.04 | 16.43 | 19.75 |
| 2004 | 13.49 | 10.96 | 22.71 | 44.81 | 106.97 | 41.24 | 11.59 | 12.92 | 33.02 | 27.07 | 29.01 | 46.87 |
| 2005 | 22.75 | 10.75 | 17.16 | 50.02 | 58.07 | 54.01 | 25.35 | 11.59 | 26.92 | 17.68 | 14.07 | 4.71 |
| 2006 | 2.42 | 2.04 | 22.80 | 142.60 | 119.94 | 31.42 | 15.77 | 9.44 | 9.88 | 10.91 | 63.07 | 131.93 |
| 2007 | 118.47 | 55.75 | 25.77 | 29.58 | 66.07 | 102.96 | 30.14 | 17.84 | 25.78 | 18.58 | 14.44 | 10.48 |
| 2008 | 5.60 | 2.32 | 6.24 | 87.31 | 48.01 | 29.65 | 32.93 | 62.83 | 59.78 | 51.53 | 89.76 | 16.15 |
| 2009 | 5.33 | 7.76 | 5.00 | 69.27 | 141.50 | 65.60 | 20.94 | 16.90 | 27.05 | 23.84 | 14.14 | 69.68 |
| 2010 | 79.01 | 13.51 | 53.94 | 95.27 | 183.03 | 49.31 | 22.50 | 11.01 | 58.52 | 60.27 | 32.47 | 61.42 |

Sub-basin: **1KC** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 33.24 | 30.11 | 39.04 | 79.41 | 54.03 | 81.55 | 32.52 | 11.88 | 7.46 | 9.51 | 21.88 | 13.71 |
| 1992 | 9.01 | 5.14 | 5.56 | 12.29 | 47.92 | 29.00 | 34.89 | 16.11 | 14.86 | 47.35 | 37.92 | 41.19 |
| 1993 | 43.45 | 47.44 | 24.82 | 11.92 | 74.52 | 47.81 | 19.55 | 8.03 | 6.74 | 7.37 | 8.31 | 8.31 |
| 1994 | 6.31 | 5.37 | 43.08 | 92.13 | 84.29 | 56.86 | 43.54 | 21.98 | 16.97 | 9.08 | 41.56 | 55.47 |
| 1995 | 19.76 | 16.33 | 49.89 | 37.66 | 70.21 | 32.53 | 37.46 | 17.01 | 13.50 | 24.34 | 49.58 | 24.67 |
| 1996 | 33.09 | 99.02 | 56.18 | 104.10 | 60.33 | 36.40 | 29.58 | 17.75 | 65.95 | 47.94 | 22.14 | 36.69 |
| 1997 | 26.01 | 10.03 | 4.89 | 26.02 | 133.07 | 21.79 | 12.46 | 9.74 | 11.73 | 6.62 | 37.34 | 203.55 |
| 1998 | 133.25 | 56.16 | 31.90 | 81.53 | 113.04 | 65.60 | 25.96 | 10.10 | 8.60 | 18.89 | 34.76 | 13.91 |
| 1999 | 10.43 | 6.03 | 61.77 | 102.87 | 52.22 | 30.78 | 17.28 | 15.56 | 16.33 | 42.30 | 47.90 | 45.74 |
| 2000 | 21.16 | 7.01 | 5.66 | 22.14 | 82.40 | 33.76 | 43.11 | 27.67 | 17.83 | 19.37 | 47.28 | 72.08 |
| 2001 | 70.04 | 46.31 | 20.14 | 100.76 | 87.69 | 71.87 | 21.97 | 13.22 | 10.38 | 22.92 | 58.42 | 26.75 |
| 2002 | 16.74 | 11.68 | 12.08 | 36.62 | 161.37 | 46.14 | 17.72 | 9.76 | 5.81 | 4.54 | 8.02 | 15.31 |
| 2003 | 29.03 | 8.88 | 5.05 | 8.44 | 86.82 | 33.62 | 17.52 | 10.87 | 13.29 | 11.10 | 7.96 | 6.70 |
| 2004 | 5.54 | 4.53 | 6.26 | 16.55 | 106.18 | 38.35 | 12.18 | 8.57 | 10.89 | 22.20 | 18.15 | 33.21 |
| 2005 | 28.55 | 12.53 | 14.36 | 48.78 | 41.02 | 46.65 | 30.53 | 10.25 | 10.55 | 10.73 | 9.72 | 5.50 |
| 2006 | 3.89 | 3.38 | 10.51 | 100.48 | 91.07 | 27.52 | 13.86 | 8.30 | 7.23 | 7.11 | 55.21 | 137.16 |
| 2007 | 110.17 | 58.02 | 29.37 | 27.98 | 58.46 | 89.97 | 30.56 | 19.55 | 22.60 | 19.16 | 12.59 | 11.23 |
| 2008 | 7.57 | 5.03 | 5.96 | 71.65 | 44.92 | 27.08 | 23.56 | 50.28 | 59.18 | 43.46 | 74.97 | 19.62 |
| 2009 | 7.31 | 7.70 | 5.88 | 56.80 | 117.88 | 57.22 | 22.89 | 13.94 | 23.54 | 31.33 | 18.03 | 68.28 |
| 2010 | 86.31 | 20.77 | 72.85 | 94.36 | 160.55 | 46.61 | 25.95 | 12.05 | 42.01 | 68.06 | 39.19 | 62.11 |

## 1LA1, 1LA2, 1LA3, 1LB1 & 1LB2

Sub-basin: **1LA1** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 13.09 | 10.36 | 7.48 | 26.29 | 26.76 | 50.67 | 23.41 | 18.51 | 24.46 | 17.80 | 16.48 | 7.12 |
| 1992 | 4.64 | 3.28 | 3.67 | 5.76 | 21.42 | 26.86 | 27.71 | 22.22 | 25.91 | 28.62 | 20.01 | 15.72 |
| 1993 | 24.52 | 43.18 | 15.75 | 6.28 | 16.22 | 25.97 | 14.72 | 8.30 | 7.08 | 5.68 | 8.83 | 11.04 |
| 1994 | 4.75 | 3.07 | 18.18 | 49.91 | 57.46 | 41.51 | 26.14 | 26.08 | 17.74 | 9.89 | 37.64 | 24.76 |
| 1995 | 6.75 | 5.70 | 31.06 | 35.58 | 59.64 | 30.39 | 29.56 | 13.48 | 17.99 | 21.00 | 25.46 | 13.62 |
| 1996 | 20.53 | 35.96 | 35.98 | 75.75 | 27.28 | 25.13 | 35.86 | 26.19 | 42.21 | 23.08 | 12.45 | 25.67 |
| 1997 | 8.68 | 4.54 | 3.12 | 16.32 | 41.43 | 12.70 | 32.44 | 24.12 | 16.85 | 14.45 | 51.00 | 69.55 |
| 1998 | 65.10 | 29.03 | 12.82 | 23.26 | 57.58 | 32.23 | 27.22 | 22.31 | 18.06 | 37.98 | 23.85 | 8.01 |
| 1999 | 6.58 | 4.39 | 10.35 | 40.78 | 22.08 | 9.91 | 8.25 | 18.40 | 18.30 | 15.45 | 14.14 | 20.74 |
| 2000 | 9.08 | 4.08 | 3.80 | 5.63 | 11.08 | 8.44 | 10.89 | 19.32 | 12.24 | 10.17 | 33.01 | 37.75 |
| 2001 | 67.68 | 31.69 | 12.21 | 40.62 | 27.65 | 20.80 | 19.89 | 15.58 | 15.98 | 21.53 | 45.69 | 14.58 |
| 2002 | 10.35 | 7.52 | 15.64 | 18.64 | 91.52 | 16.77 | 9.89 | 16.42 | 10.68 | 5.70 | 19.40 | 24.11 |
| 2003 | 21.27 | 6.61 | 4.20 | 30.94 | 72.03 | 27.46 | 11.24 | 28.43 | 23.38 | 12.78 | 9.84 | 13.29 |
| 2004 | 9.42 | 10.69 | 25.37 | 67.29 | 64.70 | 19.99 | 8.60 | 12.48 | 14.44 | 12.29 | 9.24 | 12.85 |
| 2005 | 7.77 | 5.52 | 9.15 | 30.97 | 32.42 | 23.71 | 15.33 | 11.44 | 19.78 | 10.15 | 7.68 | 5.08 |
| 2006 | 3.21 | 2.59 | 5.90 | 52.17 | 46.82 | 12.10 | 11.15 | 13.17 | 9.91 | 7.45 | 37.70 | 75.15 |
| 2007 | 57.30 | 27.80 | 26.00 | 28.51 | 32.92 | 40.72 | 17.18 | 26.36 | 32.92 | 13.68 | 6.85 | 4.97 |
| 2008 | 3.72 | 3.24 | 3.60 | 26.44 | 22.03 | 13.16 | 11.49 | 21.07 | 23.00 | 26.11 | 34.10 | 9.64 |
| 2009 | 4.32 | 4.74 | 3.89 | 7.30 | 31.28 | 15.04 | 6.52 | 4.68 | 6.11 | 9.39 | 7.92 | 24.30 |
| 2010 | 48.13 | 14.37 | 53.54 | 42.30 | 65.24 | 21.25 | 12.50 | 9.91 | 18.58 | 35.79 | 20.04 | 28.93 |

Source: "National Water Master Plan 2030", Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

Sub-basin: **1LA2** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 21.27 | 19.33 | 21.15 | 22.81 | 22.16 | 34.68 | 18.94 | 7.82 | 9.79 | 7.42 | 7.80 | 6.55 |
| 1992 | 6.53 | 5.38 | 6.37 | 6.13 | 11.80 | 11.30 | 13.10 | 9.72 | 11.41 | 13.92 | 14.10 | 13.12 |
| 1993 | 17.32 | 32.59 | 15.99 | 7.56 | 11.85 | 12.28 | 8.61 | 6.48 | 5.92 | 5.75 | 5.59 | 5.90 |
| 1994 | 6.02 | 4.73 | 9.68 | 31.02 | 33.11 | 32.98 | 18.63 | 11.35 | 9.23 | 6.57 | 14.26 | 21.26 |
| 1995 | 10.29 | 8.72 | 25.25 | 18.32 | 27.44 | 14.80 | 13.96 | 8.14 | 7.21 | 10.21 | 9.85 | 7.20 |
| 1996 | 15.77 | 31.68 | 23.76 | 50.07 | 21.95 | 15.71 | 18.43 | 11.96 | 25.34 | 15.99 | 7.84 | 15.76 |
| 1997 | 7.80 | 6.40 | 5.65 | 7.41 | 51.47 | 11.63 | 12.54 | 10.96 | 9.06 | 7.83 | 15.34 | 64.61 |
| 1998 | 44.79 | 27.66 | 14.06 | 21.84 | 44.41 | 26.19 | 12.00 | 10.60 | 7.91 | 11.82 | 11.87 | 8.31 |
| 1999 | 6.63 | 6.13 | 20.72 | 42.32 | 13.98 | 8.26 | 6.42 | 7.73 | 10.06 | 15.13 | 16.74 | 19.92 |
| 2000 | 11.75 | 6.10 | 6.44 | 14.12 | 27.83 | 15.62 | 17.66 | 13.41 | 11.85 | 10.01 | 22.68 | 38.77 |
| 2001 | 55.78 | 30.43 | 12.17 | 37.10 | 34.35 | 31.75 | 14.51 | 9.72 | 10.13 | 17.84 | 30.89 | 14.40 |
| 2002 | 10.14 | 8.12 | 10.30 | 13.68 | 66.53 | 19.85 | 9.04 | 6.99 | 7.74 | 6.62 | 12.77 | 12.51 |
| 2003 | 16.90 | 6.99 | 6.18 | 11.43 | 30.87 | 17.36 | 8.04 | 9.88 | 10.76 | 6.95 | 6.16 | 6.45 |
| 2004 | 5.53 | 5.49 | 13.63 | 32.51 | 44.41 | 21.12 | 7.65 | 6.90 | 12.44 | 13.27 | 8.99 | 13.21 |
| 2005 | 11.03 | 7.19 | 8.75 | 26.14 | 19.29 | 20.90 | 14.09 | 6.53 | 7.48 | 7.23 | 6.08 | 6.09 |
| 2006 | 5.23 | 4.65 | 5.42 | 35.97 | 44.50 | 14.67 | 7.87 | 6.22 | 5.70 | 6.58 | 14.51 | 60.03 |
| 2007 | 59.04 | 27.59 | 20.04 | 18.91 | 22.26 | 33.31 | 13.68 | 10.58 | 13.77 | 9.18 | 5.81 | 6.40 |
| 2008 | 6.28 | 5.61 | 5.70 | 20.36 | 22.97 | 12.75 | 8.87 | 16.54 | 21.74 | 17.81 | 25.83 | 10.92 |
| 2009 | 6.44 | 5.88 | 6.44 | 14.10 | 37.70 | 24.62 | 10.39 | 7.28 | 9.92 | 10.38 | 6.51 | 10.21 |
| 2010 | 45.95 | 11.40 | 34.27 | 39.03 | 62.61 | 21.11 | 10.89 | 6.13 | 14.46 | 27.67 | 20.55 | 24.56 |

Sub-basin: **1LA3** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 10.61 | 10.46 | 11.24 | 40.84 | 73.42 | 61.63 | 23.32 | 7.30 | 6.24 | 6.16 | 5.51 | 5.35 |
| 1992 | 5.62 | 5.00 | 4.91 | 8.04 | 24.50 | 11.78 | 11.28 | 8.27 | 7.39 | 9.07 | 12.42 | 12.21 |
| 1993 | 57.67 | 93.47 | 33.04 | 11.99 | 19.82 | 19.35 | 9.80 | 6.12 | 6.08 | 5.39 | 5.65 | 6.16 |
| 1994 | 5.11 | 5.31 | 11.80 | 42.43 | 54.01 | 35.00 | 21.00 | 11.41 | 6.99 | 6.53 | 7.76 | 13.01 |
| 1995 | 8.76 | 8.81 | 48.39 | 20.89 | 44.61 | 15.45 | 9.61 | 6.23 | 6.61 | 8.01 | 8.70 | 7.42 |
| 1996 | 11.04 | 68.06 | 50.12 | 115.84 | 31.02 | 28.47 | 36.80 | 19.09 | 37.97 | 23.30 | 9.93 | 17.38 |
| 1997 | 11.65 | 6.89 | 5.55 | 52.41 | 146.14 | 20.48 | 14.53 | 11.47 | 7.27 | 6.42 | 46.08 | 170.85 |
| 1998 | 124.72 | 88.37 | 36.44 | 52.64 | 98.44 | 48.89 | 15.67 | 9.27 | 7.97 | 7.75 | 7.58 | 7.72 |
| 1999 | 6.68 | 6.11 | 59.68 | 109.61 | 29.25 | 9.69 | 5.21 | 5.97 | 5.48 | 3.68 | 4.17 | 7.44 |
| 2000 | 8.47 | 5.10 | 5.91 | 4.34 | 6.48 | 5.06 | 4.71 | 4.19 | 3.76 | 3.57 | 6.44 | 22.68 |
| 2001 | 134.56 | 54.14 | 18.23 | 46.63 | 40.00 | 27.46 | 14.15 | 10.67 | 6.67 | 7.65 | 17.06 | 12.65 |
| 2002 | 16.94 | 15.85 | 23.58 | 16.70 | 175.45 | 23.09 | 7.46 | 4.61 | 5.74 | 7.11 | 8.79 | 31.60 |
| 2003 | 48.90 | 12.78 | 8.56 | 10.48 | 93.12 | 29.82 | 10.51 | 8.57 | 7.22 | 6.31 | 6.09 | 6.75 |
| 2004 | 6.15 | 6.47 | 7.03 | 31.26 | 76.86 | 19.93 | 6.45 | 4.09 | 3.75 | 3.75 | 3.13 | 3.57 |
| 2005 | 3.71 | 3.50 | 3.62 | 11.33 | 28.97 | 27.56 | 11.20 | 5.88 | 5.64 | 4.48 | 5.45 | 5.69 |
| 2006 | 5.45 | 4.49 | 6.25 | 83.81 | 61.43 | 14.19 | 5.83 | 4.96 | 5.38 | 5.35 | 10.51 | 97.90 |
| 2007 | 92.00 | 55.58 | 27.53 | 18.30 | 21.00 | 23.69 | 9.87 | 6.17 | 5.90 | 3.92 | 3.01 | 3.01 |
| 2008 | 2.97 | 2.80 | 3.26 | 34.99 | 27.07 | 8.41 | 4.64 | 4.37 | 4.86 | 4.40 | 6.09 | 4.79 |
| 2009 | 3.01 | 2.65 | 2.96 | 2.91 | 8.56 | 16.34 | 6.86 | 3.97 | 3.28 | 3.34 | 2.89 | 2.15 |
| 2010 | 36.67 | 17.18 | 43.81 | 48.57 | 64.29 | 19.14 | 6.71 | 3.51 | 3.52 | 5.68 | 14.97 | 33.96 |

Sub-basin: **1LB1** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 18.10 | 13.99 | 12.12 | 33.02 | 34.04 | 65.12 | 30.23 | 18.71 | 24.95 | 18.29 | 17.19 | 8.68 |
| 1992 | 6.34 | 4.77 | 5.22 | 6.16 | 20.40 | 29.16 | 31.59 | 25.30 | 27.03 | 30.57 | 25.31 | 20.51 |
| 1993 | 38.11 | 62.36 | 25.06 | 9.35 | 15.55 | 28.96 | 16.93 | 9.57 | 7.22 | 5.73 | 6.54 | 9.41 |
| 1994 | 5.78 | 4.36 | 28.18 | 67.13 | 66.89 | 55.28 | 32.10 | 28.31 | 20.81 | 11.21 | 43.37 | 34.19 |
| 1995 | 10.99 | 9.14 | 43.72 | 44.43 | 96.50 | 41.93 | 40.92 | 18.17 | 21.31 | 21.49 | 25.95 | 16.03 |
| 1996 | 27.21 | 52.00 | 52.72 | 145.45 | 39.03 | 34.72 | 52.51 | 35.35 | 59.31 | 29.04 | 14.20 | 29.37 |
| 1997 | 12.02 | 6.28 | 4.53 | 22.06 | 67.74 | 16.42 | 34.11 | 32.00 | 20.01 | 14.60 | 66.84 | 125.24 |
| 1998 | 130.33 | 66.32 | 22.68 | 30.84 | 91.12 | 52.30 | 27.53 | 21.85 | 17.99 | 33.48 | 27.51 | 9.96 |
| 1999 | 7.95 | 5.70 | 20.42 | 56.98 | 22.49 | 10.82 | 8.20 | 13.15 | 19.34 | 15.38 | 14.70 | 28.43 |
| 2000 | 13.60 | 5.75 | 5.44 | 8.25 | 12.98 | 8.61 | 8.71 | 12.37 | 12.92 | 9.20 | 36.08 | 49.42 |
| 2001 | 85.64 | 38.44 | 14.29 | 46.88 | 28.96 | 17.32 | 19.32 | 19.63 | 16.44 | 22.19 | 47.73 | 16.94 |
| 2002 | 13.53 | 10.62 | 20.09 | 23.38 | 110.26 | 18.89 | 10.14 | 13.47 | 10.59 | 6.37 | 19.29 | 30.31 |
| 2003 | 34.57 | 10.60 | 6.52 | 32.71 | 103.52 | 38.18 | 14.83 | 30.48 | 29.77 | 15.24 | 10.71 | 12.69 |
| 2004 | 9.74 | 11.10 | 33.29 | 102.63 | 125.64 | 29.85 | 10.94 | 12.12 | 15.19 | 13.06 | 9.45 | 13.45 |
| 2005 | 10.16 | 6.45 | 9.59 | 36.30 | 36.93 | 29.67 | 18.15 | 13.92 | 19.27 | 10.89 | 8.01 | 5.99 |
| 2006 | 4.46 | 3.73 | 7.61 | 70.31 | 60.76 | 15.16 | 10.01 | 11.47 | 10.49 | 7.53 | 39.62 | 100.18 |
| 2007 | 72.22 | 39.85 | 35.59 | 33.93 | 40.81 | 57.44 | 21.55 | 28.00 | 35.36 | 16.51 | 8.53 | 6.56 |
| 2008 | 5.03 | 4.54 | 5.26 | 33.73 | 25.95 | 14.06 | 11.33 | 18.87 | 24.90 | 28.54 | 44.21 | 13.85 |
| 2009 | 6.00 | 6.10 | 5.24 | 8.87 | 36.73 | 20.20 | 8.56 | 5.54 | 5.61 | 7.01 | 6.20 | 20.37 |
| 2010 | 70.80 | 22.19 | 70.28 | 52.35 | 74.11 | 23.76 | 12.57 | 11.65 | 17.79 | 45.81 | 28.60 | 37.54 |

Source: "National Water Master Plan 2030", Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

Sub-basin: **1LB2** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 9.40 | 8.64 | 9.22 | 29.76 | 33.25 | 45.86 | 12.17 | 0.66 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1992 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.01 | 2.58 | 4.65 |
| 1993 | 31.78 | 51.15 | 16.71 | 3.14 | 7.68 | 7.75 | 1.64 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1994 | 0.00 | 0.00 | 0.01 | 18.98 | 34.34 | 28.49 | 12.62 | 3.70 | 0.98 | 0.00 | 0.00 | 5.17 |
| 1995 | 3.56 | 3.45 | 37.37 | 11.09 | 35.70 | 7.32 | 3.68 | 0.69 | 0.63 | 1.13 | 0.76 | 0.15 |
| 1996 | 2.96 | 56.56 | 35.02 | 78.90 | 16.44 | 15.00 | 25.95 | 8.77 | 24.96 | 13.11 | 1.96 | 6.17 |
| 1997 | 3.65 | 0.34 | 0.00 | 14.97 | 90.09 | 7.68 | 4.50 | 3.18 | 0.44 | 0.00 | 13.66 | 97.75 |
| 1998 | 88.39 | 129.46 | 52.20 | 83.80 | 195.61 | 103.06 | 16.84 | 3.12 | 0.38 | 2.22 | 5.83 | 0.77 |
| 1999 | 0.00 | 0.00 | 41.03 | 82.16 | 20.70 | 3.46 | 0.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2000 | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 5.32 |
| 2001 | 91.14 | 35.53 | 6.82 | 28.37 | 20.46 | 17.72 | 9.20 | 5.51 | 3.90 | 11.75 | 31.87 | 8.29 |
| 2002 | 9.64 | 7.54 | 11.86 | 8.70 | 121.55 | 22.09 | 3.03 | 0.00 | 0.00 | 0.00 | 0.01 | 4.42 |
| 2003 | 25.38 | 3.18 | 0.09 | 0.00 | 57.65 | 14.49 | 2.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2004 | 0.00 | 0.00 | 0.00 | 12.00 | 59.95 | 11.42 | 0.59 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2005 | 0.00 | 0.00 | 0.00 | 0.02 | 5.83 | 16.08 | 4.62 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2006 | 0.00 | 0.00 | 0.00 | 45.04 | 43.58 | 5.58 | 0.19 | 0.00 | 0.00 | 0.00 | 0.06 | 71.86 |
| 2007 | 63.17 | 35.60 | 16.28 | 10.08 | 13.35 | 20.56 | 3.57 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2008 | 0.00 | 0.00 | 0.00 | 1.49 | 13.97 | 1.55 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 |
| 2009 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 5.03 | 1.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2010 | 14.24 | 10.55 | 40.48 | 31.96 | 50.75 | 9.07 | 0.74 | 0.00 | 0.00 | 0.01 | 17.37 | 30.25 |

## 3. Rift Valley Catchment Area (RVCA)

### 2BA, 2BB & 2BC

Sub-basin: **2BA** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 1.01 | 0.07 | 0.00 | 0.00 | 0.00 | 9.79 | 51.21 | 81.58 | 29.99 | 21.25 | 11.58 | 3.62 |
| 1992 | 1.54 | 0.21 | 0.00 | 0.00 | 1.45 | 17.39 | 47.74 | 74.89 | 41.46 | 33.57 | 18.07 | 4.71 |
| 1993 | 2.42 | 2.26 | 1.36 | 0.26 | 67.53 | 54.10 | 25.11 | 17.01 | 18.17 | 6.48 | 2.90 | 1.47 |
| 1994 | 0.23 | 0.00 | 0.00 | 0.00 | 45.34 | 67.94 | 54.47 | 82.07 | 21.76 | 6.40 | 11.02 | 5.83 |
| 1995 | 1.90 | 0.42 | 0.01 | 0.00 | 0.00 | 0.00 | 30.95 | 30.87 | 29.97 | 26.05 | 26.99 | 5.81 |
| 1996 | 2.48 | 0.79 | 0.04 | 0.00 | 0.00 | 16.89 | 22.26 | 27.10 | 55.40 | 11.94 | 11.28 | 9.57 |
| 1997 | 2.34 | 0.68 | 0.02 | 33.18 | 40.28 | 5.61 | 40.49 | 38.60 | 7.25 | 4.01 | 37.84 | 26.23 |
| 1998 | 70.95 | 25.55 | 7.46 | 2.98 | 36.08 | 17.57 | 74.19 | 38.30 | 17.85 | 42.25 | 30.08 | 5.70 |
| 1999 | 2.66 | 0.82 | 0.04 | 0.00 | 11.66 | 15.69 | 26.79 | 12.83 | 8.99 | 63.80 | 36.24 | 9.21 |
| 2000 | 3.22 | 1.19 | 0.16 | 0.00 | 15.21 | 5.82 | 29.20 | 47.47 | 38.06 | 62.95 | 27.52 | 8.63 |
| 2001 | 3.53 | 1.69 | 0.56 | 2.24 | 43.41 | 59.36 | 42.02 | 60.26 | 30.95 | 23.51 | 71.15 | 11.58 |
| 2002 | 4.02 | 1.65 | 0.35 | 0.00 | 7.16 | 0.88 | 0.62 | 0.11 | 0.02 | 0.72 | 2.13 | 4.69 |
| 2003 | 7.54 | 0.73 | 0.06 | 2.94 | 118.37 | 68.66 | 84.17 | 66.64 | 45.05 | 8.30 | 3.74 | 1.66 |
| 2004 | 0.29 | 0.00 | 0.00 | 0.04 | 49.67 | 9.27 | 9.21 | 58.37 | 14.11 | 7.06 | 28.04 | 9.02 |
| 2005 | 3.80 | 1.62 | 0.43 | 0.00 | 32.76 | 39.07 | 25.68 | 15.95 | 39.28 | 13.75 | 4.68 | 2.30 |
| 2006 | 0.64 | 0.01 | 0.00 | 0.00 | 0.19 | 0.41 | 0.76 | 31.30 | 25.81 | 9.02 | 55.01 | 45.39 |
| 2007 | 12.79 | 4.09 | 1.88 | 0.52 | 20.79 | 79.07 | 56.76 | 120.36 | 114.32 | 32.32 | 9.03 | 3.89 |
| 2008 | 1.14 | 0.09 | 0.00 | 0.00 | 0.00 | 12.18 | 24.80 | 63.26 | 25.96 | 27.32 | 54.24 | 8.14 |
| 2009 | 3.40 | 1.28 | 0.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2010 | 0.00 | 0.00 | 0.92 | 27.84 | 73.80 | 38.50 | 39.56 | 27.82 | 37.90 | 27.63 | 16.50 | 4.96 |

Sub-basin: **2BB** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 1.62 | 0.11 | 0.00 | 0.00 | 0.00 | 15.73 | 82.34 | 131.17 | 48.22 | 34.17 | 18.63 | 5.81 |
| 1992 | 2.47 | 0.34 | 0.00 | 0.00 | 2.33 | 27.97 | 76.77 | 120.41 | 66.67 | 53.98 | 29.05 | 7.57 |
| 1993 | 3.89 | 3.63 | 2.19 | 0.42 | 108.58 | 86.99 | 40.38 | 27.34 | 29.22 | 10.42 | 4.66 | 2.36 |
| 1994 | 0.37 | 0.00 | 0.00 | 0.00 | 72.91 | 109.25 | 87.59 | 131.95 | 34.99 | 10.29 | 17.71 | 9.37 |
| 1995 | 3.06 | 0.67 | 0.01 | 0.00 | 0.00 | 0.00 | 49.76 | 49.63 | 48.18 | 41.88 | 43.40 | 9.35 |
| 1996 | 3.99 | 1.27 | 0.07 | 0.00 | 0.00 | 27.15 | 35.79 | 43.57 | 89.07 | 19.20 | 18.14 | 15.39 |
| 1997 | 3.77 | 1.09 | 0.03 | 53.35 | 64.76 | 9.03 | 65.10 | 62.06 | 11.65 | 6.44 | 60.84 | 42.17 |
| 1998 | 114.08 | 41.08 | 12.00 | 4.79 | 58.01 | 28.25 | 119.29 | 61.58 | 28.70 | 67.94 | 48.36 | 9.16 |
| 1999 | 4.28 | 1.32 | 0.07 | 0.00 | 18.75 | 25.23 | 43.07 | 20.62 | 14.46 | 102.58 | 58.26 | 14.81 |
| 2000 | 5.18 | 1.91 | 0.26 | 0.00 | 24.46 | 9.36 | 46.95 | 76.33 | 61.20 | 101.21 | 44.25 | 13.87 |
| 2001 | 5.68 | 2.72 | 0.90 | 3.61 | 69.80 | 95.44 | 67.56 | 96.90 | 49.77 | 37.80 | 114.41 | 18.63 |
| 2002 | 6.46 | 2.66 | 0.56 | 0.00 | 11.52 | 1.42 | 1.00 | 0.18 | 0.03 | 1.16 | 3.43 | 7.54 |
| 2003 | 12.12 | 1.18 | 0.09 | 4.73 | 190.32 | 110.40 | 135.34 | 107.15 | 72.43 | 13.34 | 6.02 | 2.67 |
| 2004 | 0.46 | 0.00 | 0.00 | 0.07 | 79.87 | 14.91 | 14.80 | 93.86 | 22.69 | 11.36 | 45.08 | 14.50 |
| 2005 | 6.12 | 2.61 | 0.69 | 0.00 | 52.67 | 62.82 | 41.29 | 25.65 | 63.15 | 22.10 | 7.52 | 3.71 |
| 2006 | 1.03 | 0.02 | 0.00 | 0.00 | 0.30 | 0.66 | 1.22 | 50.33 | 41.50 | 14.51 | 88.45 | 72.98 |
| 2007 | 20.57 | 6.57 | 3.02 | 0.84 | 33.42 | 127.14 | 91.27 | 193.52 | 183.82 | 51.97 | 14.51 | 6.26 |
| 2008 | 1.84 | 0.14 | 0.00 | 0.00 | 0.00 | 19.59 | 39.88 | 101.71 | 41.74 | 43.93 | 87.21 | 13.08 |
| 2009 | 5.47 | 2.05 | 0.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2010 | 0.00 | 0.00 | 1.48 | 44.76 | 118.66 | 61.90 | 63.61 | 44.72 | 60.94 | 44.42 | 26.53 | 7.97 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

Sub-basin: **2BC** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 0.82 | 0.00 | 0.00 | 0.00 | 0.00 | 31.99 | 61.65 | 82.38 | 42.73 | 47.99 | 21.84 | 6.29 |
| 1992 | 0.71 | 0.00 | 0.00 | 0.00 | 0.00 | 13.17 | 42.00 | 60.08 | 40.92 | 49.00 | 20.41 | 5.07 |
| 1993 | 1.28 | 3.98 | 4.69 | 0.23 | 55.37 | 53.71 | 25.42 | 17.81 | 23.16 | 12.16 | 5.85 | 1.43 |
| 1994 | 0.00 | 0.00 | 0.00 | 0.00 | 48.95 | 74.02 | 61.21 | 121.94 | 39.06 | 10.76 | 23.89 | 11.48 |
| 1995 | 1.13 | 0.00 | 0.00 | 0.00 | 0.00 | 6.71 | 54.48 | 40.76 | 34.80 | 30.60 | 28.32 | 7.38 |
| 1996 | 1.01 | 0.00 | 0.00 | 0.00 | 11.36 | 27.26 | 14.77 | 27.55 | 65.97 | 26.23 | 16.48 | 10.79 |
| 1997 | 2.22 | 0.07 | 0.00 | 20.29 | 76.02 | 16.14 | 37.28 | 44.87 | 11.27 | 2.95 | 41.42 | 29.63 |
| 1998 | 92.24 | 38.16 | 16.22 | 7.50 | 54.87 | 29.97 | 69.74 | 48.75 | 32.19 | 68.60 | 66.79 | 14.78 |
| 1999 | 3.64 | 0.43 | 0.00 | 0.00 | 16.47 | 29.97 | 42.27 | 26.94 | 17.61 | 74.07 | 47.82 | 14.51 |
| 2000 | 3.81 | 0.45 | 0.00 | 0.00 | 1.13 | 11.39 | 24.42 | 46.82 | 45.45 | 76.48 | 31.90 | 12.74 |
| 2001 | 3.60 | 1.13 | 0.03 | 0.00 | 38.20 | 76.33 | 67.35 | 80.94 | 43.42 | 44.03 | 102.39 | 20.89 |
| 2002 | 5.15 | 0.85 | 0.00 | 0.00 | 17.32 | 7.78 | 5.48 | 5.67 | 5.80 | 5.02 | 4.26 | 1.38 |
| 2003 | 9.96 | 1.31 | 0.00 | 0.00 | 143.56 | 84.19 | 123.74 | 78.85 | 61.27 | 14.63 | 4.62 | 1.18 |
| 2004 | 0.02 | 0.00 | 0.00 | 0.00 | 31.84 | 11.62 | 8.12 | 30.70 | 13.59 | 8.38 | 23.23 | 10.97 |
| 2005 | 3.98 | 0.34 | 0.00 | 0.00 | 25.51 | 40.81 | 34.80 | 19.26 | 44.81 | 24.13 | 12.93 | 3.08 |
| 2006 | 0.11 | 0.00 | 0.00 | 0.00 | 2.33 | 10.50 | 10.51 | 38.04 | 38.05 | 18.40 | 78.18 | 80.67 |
| 2007 | 21.83 | 5.84 | 2.19 | 1.48 | 31.18 | 77.11 | 78.84 | 205.94 | 218.06 | 56.99 | 12.76 | 3.03 |
| 2008 | 0.27 | 0.00 | 0.00 | 0.00 | 0.00 | 11.63 | 25.08 | 72.75 | 32.65 | 30.40 | 58.82 | 15.91 |
| 2009 | 3.86 | 0.61 | 0.00 | 0.00 | 0.00 | 2.39 | 2.68 | 4.16 | 9.37 | 14.60 | 6.32 | 1.84 |
| 2010 | 13.66 | 2.00 | 4.18 | 32.70 | 95.55 | 49.88 | 57.48 | 52.48 | 60.29 | 47.62 | 25.41 | 7.66 |

## 2CB

Sub-basin: **2CB** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 9.10 | 4.99 | 1.91 | 13.74 | 10.35 | 80.11 | 122.19 | 135.61 | 83.11 | 12.96 | 9.42 | 5.50 |
| 1992 | 1.58 | 0.09 | 0.05 | 0.08 | 31.63 | 11.01 | 60.99 | 105.75 | 48.70 | 53.98 | 61.50 | 12.44 |
| 1993 | 14.49 | 71.00 | 13.47 | 4.09 | 74.96 | 117.42 | 55.71 | 33.67 | 13.67 | 5.36 | 1.58 | 0.20 |
| 1994 | 0.07 | 0.03 | 0.01 | 49.01 | 232.51 | 138.44 | 136.52 | 191.27 | 45.84 | 12.63 | 18.72 | 19.62 |
| 1995 | 4.92 | 1.62 | 0.16 | 1.63 | 27.35 | 8.57 | 45.20 | 37.36 | 90.95 | 16.38 | 25.71 | 10.09 |
| 1996 | 4.83 | 2.07 | 0.74 | 9.32 | 4.15 | 86.79 | 181.35 | 171.47 | 106.74 | 19.14 | 8.97 | 5.23 |
| 1997 | 1.65 | 0.07 | 0.04 | 99.30 | 92.06 | 7.88 | 155.94 | 138.94 | 13.97 | 10.12 | 177.70 | 199.06 |
| 1998 | 223.32 | 92.62 | 18.27 | 9.36 | 92.08 | 30.47 | 99.75 | 100.63 | 22.43 | 51.60 | 48.82 | 8.27 |
| 1999 | 3.80 | 0.70 | 0.09 | 1.68 | 32.86 | 3.91 | 12.83 | 20.56 | 20.42 | 54.78 | 24.59 | 32.38 |
| 2000 | 4.59 | 1.12 | 0.09 | 0.04 | 0.02 | 0.00 | 0.00 | 9.15 | 9.36 | 9.76 | 9.88 | 5.82 |
| 2001 | 1.51 | 3.89 | 0.16 | 21.05 | 35.68 | 69.94 | 90.49 | 134.41 | 71.66 | 14.27 | 133.75 | 22.02 |
| 2002 | 7.01 | 3.24 | 0.71 | 0.16 | 95.66 | 7.40 | 4.02 | 1.48 | 0.42 | 0.09 | 0.04 | 79.31 |
| 2003 | 85.39 | 4.77 | 1.85 | 1.38 | 237.78 | 41.07 | 32.58 | 190.22 | 61.03 | 10.85 | 5.02 | 1.89 |
| 2004 | 0.09 | 0.04 | 0.01 | 42.90 | 201.16 | 16.99 | 11.94 | 86.79 | 17.34 | 30.89 | 40.34 | 15.40 |
| 2005 | 6.13 | 2.19 | 0.41 | 0.12 | 127.63 | 90.39 | 37.48 | 67.98 | 182.41 | 20.54 | 8.59 | 4.18 |
| 2006 | 1.05 | 0.05 | 0.03 | 20.23 | 35.96 | 13.10 | 81.72 | 163.23 | 53.23 | 14.99 | 195.71 | 244.79 |
| 2007 | 82.07 | 41.11 | 13.62 | 86.62 | 72.39 | 298.47 | 228.65 | 267.14 | 273.53 | 60.19 | 23.72 | 10.68 |
| 2008 | 4.94 | 1.32 | 0.07 | 0.04 | 0.02 | 0.01 | 6.78 | 151.94 | 147.69 | 176.13 | 237.97 | 23.60 |
| 2009 | 11.59 | 5.10 | 2.09 | 0.06 | 0.04 | 0.01 | 0.01 | 0.01 | 0.00 | 0.01 | 0.01 | 0.06 |
| 2010 | 44.05 | 2.09 | 158.78 | 163.35 | 297.47 | 88.05 | 88.00 | 116.25 | 130.25 | 68.51 | 28.80 | 8.36 |

## 2EA, 2EB, 2EC, 2ED, 2EE, 2EF, 2EG1, 2EG2, 2EH & 2EK

Sub-basin: **2EA** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 0.11 | 0.02 | 0.00 | 0.13 | 0.19 | 0.58 | 2.89 | 7.51 | 6.57 | 1.65 | 0.68 | 0.24 |
| 1992 | 0.05 | 0.00 | 0.00 | 0.00 | 0.03 | 0.21 | 1.98 | 7.42 | 8.52 | 5.05 | 2.27 | 1.61 |
| 1993 | 2.59 | 6.82 | 1.82 | 0.29 | 0.58 | 1.97 | 2.85 | 2.42 | 1.25 | 0.43 | 0.11 | 0.09 |
| 1994 | 0.01 | 0.00 | 0.00 | 0.00 | 2.23 | 3.91 | 7.86 | 9.29 | 3.01 | 0.64 | 0.58 | 0.70 |
| 1995 | 0.09 | 0.00 | 0.11 | 0.10 | 0.51 | 0.46 | 1.39 | 1.28 | 2.78 | 2.18 | 6.35 | 1.70 |
| 1996 | 0.45 | 0.04 | 0.00 | 0.00 | 0.00 | 0.26 | 6.83 | 10.58 | 8.98 | 1.91 | 0.65 | 0.55 |
| 1997 | 0.05 | 0.00 | 0.00 | 3.26 | 11.97 | 2.01 | 9.17 | 9.09 | 1.55 | 0.72 | 8.01 | 11.19 |
| 1998 | 15.11 | 8.45 | 2.20 | 0.74 | 10.45 | 5.74 | 7.26 | 8.00 | 5.32 | 7.17 | 2.97 | 0.96 |
| 1999 | 0.13 | 0.00 | 0.00 | 0.00 | 0.04 | 0.03 | 0.35 | 2.01 | 2.04 | 0.71 | 0.46 | 0.38 |
| 2000 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 1.05 | 0.62 | 0.68 | 0.75 |
| 2001 | 0.36 | 0.26 | 0.09 | 2.82 | 5.75 | 4.46 | 5.68 | 13.14 | 9.03 | 1.63 | 4.25 | 2.04 |
| 2002 | 0.60 | 0.16 | 0.21 | 0.16 | 8.28 | 1.79 | 1.03 | 1.17 | 0.73 | 0.21 | 0.40 | 1.80 |
| 2003 | 4.46 | 0.55 | 0.05 | 0.06 | 13.09 | 5.25 | 3.93 | 17.18 | 7.11 | 1.49 | 0.61 | 2.53 |
| 2004 | 0.75 | 0.30 | 0.05 | 0.60 | 4.49 | 1.29 | 0.77 | 2.82 | 1.52 | 0.63 | 0.80 | 0.73 |
| 2005 | 0.19 | 0.02 | 0.00 | 0.00 | 0.24 | 3.46 | 5.53 | 10.09 | 13.92 | 3.01 | 1.00 | 0.26 |
| 2006 | 0.01 | 0.00 | 0.00 | 0.00 | 0.27 | 0.26 | 1.36 | 2.54 | 2.06 | 0.73 | 2.93 | 9.93 |
| 2007 | 7.77 | 3.19 | 0.94 | 0.75 | 2.03 | 11.52 | 17.15 | 20.15 | 26.76 | 5.19 | 2.70 | 0.85 |
| 2008 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.92 | 6.79 | 8.15 | 10.26 | 1.78 |
| 2009 | 0.23 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 |
| 2010 | 4.83 | 3.21 | 11.58 | 16.47 | 18.82 | 6.21 | 2.67 | 9.24 | 13.41 | 5.91 | 2.62 | 0.62 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

Sub-basin: **2EB** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 0.15 | 0.01 | 0.00 | 0.01 | 0.05 | 0.90 | 4.77 | 12.44 | 10.89 | 2.74 | 1.12 | 0.40 |
| 1992 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 2.88 | 12.28 | 14.12 | 8.37 | 3.76 | 2.67 |
| 1993 | 4.30 | 11.29 | 3.02 | 0.48 | 0.95 | 3.26 | 4.72 | 4.02 | 2.07 | 0.71 | 0.13 | 0.05 |
| 1994 | 0.00 | 0.00 | 0.00 | 0.00 | 3.69 | 6.48 | 13.02 | 15.40 | 4.98 | 1.07 | 0.97 | 1.16 |
| 1995 | 0.13 | 0.00 | 0.01 | 0.02 | 0.67 | 0.69 | 2.27 | 2.13 | 4.60 | 3.60 | 10.51 | 2.81 |
| 1996 | 0.75 | 0.05 | 0.00 | 0.00 | 0.00 | 0.06 | 11.25 | 17.52 | 14.88 | 3.17 | 1.08 | 0.91 |
| 1997 | 0.07 | 0.00 | 0.00 | 5.40 | 19.83 | 3.33 | 15.20 | 15.06 | 2.57 | 1.20 | 13.27 | 18.54 |
| 1998 | 25.02 | 13.99 | 3.64 | 1.23 | 17.30 | 9.51 | 12.02 | 13.25 | 8.81 | 11.87 | 4.92 | 1.59 |
| 1999 | 0.19 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.07 | 3.11 | 3.38 | 1.17 | 0.74 | 0.59 |
| 2000 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.08 | 1.03 | 1.11 | 1.25 |
| 2001 | 0.57 | 0.40 | 0.03 | 4.58 | 9.52 | 7.39 | 9.41 | 21.77 | 14.96 | 2.71 | 7.05 | 3.38 |
| 2002 | 1.00 | 0.26 | 0.32 | 0.27 | 13.69 | 2.96 | 1.71 | 1.94 | 1.20 | 0.31 | 0.63 | 2.87 |
| 2003 | 7.38 | 0.91 | 0.05 | 0.01 | 21.68 | 8.70 | 6.51 | 28.46 | 11.78 | 2.46 | 1.02 | 4.19 |
| 2004 | 1.24 | 0.50 | 0.05 | 0.93 | 7.43 | 2.13 | 1.28 | 4.68 | 2.53 | 1.03 | 1.33 | 1.21 |
| 2005 | 0.29 | 0.00 | 0.00 | 0.00 | 0.05 | 5.70 | 9.16 | 16.71 | 23.06 | 4.99 | 1.65 | 0.42 |
| 2006 | 0.01 | 0.00 | 0.00 | 0.00 | 0.03 | 0.12 | 2.20 | 4.18 | 3.41 | 1.21 | 4.85 | 16.45 |
| 2007 | 12.88 | 5.28 | 1.55 | 1.25 | 3.37 | 19.09 | 28.42 | 33.37 | 44.32 | 8.60 | 4.48 | 1.40 |
| 2008 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 8.09 | 11.25 | 13.51 | 17.00 | 2.96 |
| 2009 | 0.37 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2010 | 7.79 | 5.32 | 19.18 | 27.29 | 31.18 | 10.28 | 4.42 | 15.31 | 22.22 | 9.78 | 4.34 | 1.03 |

Sub-basin: **2EC** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 0.02 | 0.00 | 0.00 | 0.00 | 0.02 | 0.03 | 3.09 | 6.35 | 7.61 | 3.02 | 1.41 | 0.21 |
| 1992 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.04 | 3.57 | 10.42 | 11.42 | 7.29 | 6.02 | 4.97 |
| 1993 | 4.45 | 12.14 | 5.83 | 0.71 | 1.73 | 4.59 | 4.89 | 3.11 | 1.28 | 0.14 | 0.01 | 0.00 |
| 1994 | 0.00 | 0.00 | 0.00 | 0.00 | 0.07 | 3.21 | 7.96 | 15.44 | 8.25 | 1.47 | 1.44 | 1.20 |
| 1995 | 0.03 | 0.00 | 0.00 | 0.02 | 3.34 | 2.93 | 5.16 | 4.17 | 10.48 | 7.53 | 10.66 | 3.45 |
| 1996 | 0.79 | 0.01 | 0.00 | 0.00 | 0.01 | 0.24 | 4.29 | 7.72 | 12.37 | 5.32 | 1.57 | 1.90 |
| 1997 | 0.07 | 0.00 | 0.00 | 0.05 | 9.32 | 3.12 | 9.37 | 13.51 | 4.04 | 1.44 | 10.23 | 22.32 |
| 1998 | 17.24 | 11.74 | 4.21 | 1.66 | 9.56 | 9.61 | 8.09 | 8.66 | 8.33 | 11.41 | 6.73 | 1.92 |
| 1999 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 0.03 | 0.05 | 0.49 | 1.31 |
| 2000 | 0.14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.03 | 0.36 | 1.78 |
| 2001 | 0.76 | 0.90 | 0.16 | 5.79 | 7.91 | 3.29 | 5.42 | 18.86 | 14.02 | 5.55 | 11.95 | 6.27 |
| 2002 | 1.31 | 0.22 | 0.32 | 0.25 | 15.41 | 4.52 | 2.35 | 2.77 | 1.42 | 0.13 | 0.35 | 2.76 |
| 2003 | 8.96 | 1.07 | 0.01 | 0.01 | 22.11 | 16.30 | 6.29 | 12.57 | 14.91 | 4.54 | 2.14 | 1.48 |
| 2004 | 0.46 | 0.19 | 0.00 | 1.29 | 5.68 | 2.77 | 0.85 | 1.48 | 0.95 | 0.47 | 0.60 | 0.54 |
| 2005 | 0.12 | 0.01 | 0.00 | 0.00 | 0.03 | 0.07 | 0.76 | 4.62 | 13.31 | 6.19 | 2.57 | 0.75 |
| 2006 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.03 | 0.04 | 0.43 | 1.83 | 0.64 | 3.27 | 13.35 |
| 2007 | 20.28 | 8.88 | 2.50 | 2.47 | 6.79 | 11.66 | 17.13 | 27.21 | 29.57 | 11.60 | 4.10 | 0.66 |
| 2008 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 3.56 | 6.63 | 8.54 | 19.71 | 4.80 |
| 2009 | 0.35 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2010 | 1.87 | 2.10 | 12.19 | 27.47 | 27.04 | 13.52 | 6.23 | 12.67 | 26.11 | 19.11 | 11.09 | 2.59 |

Sub-basin: **2ED** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 0.13 | 0.01 | 0.00 | 0.01 | 0.03 | 0.21 | 7.93 | 17.61 | 24.69 | 6.93 | 4.83 | 1.49 |
| 1992 | 0.04 | 0.00 | 0.00 | 0.01 | 0.29 | 0.36 | 7.76 | 23.25 | 21.14 | 12.87 | 12.70 | 6.71 |
| 1993 | 6.17 | 19.39 | 11.02 | 1.14 | 7.09 | 16.81 | 15.33 | 12.58 | 6.29 | 2.37 | 0.48 | 0.01 |
| 1994 | 0.00 | 0.00 | 0.00 | 0.03 | 8.51 | 18.28 | 27.38 | 37.40 | 17.76 | 2.44 | 2.73 | 3.34 |
| 1995 | 0.12 | 0.00 | 0.01 | 0.02 | 6.36 | 5.48 | 13.10 | 10.73 | 18.11 | 10.63 | 12.41 | 3.67 |
| 1996 | 0.86 | 0.02 | 0.01 | 0.01 | 0.00 | 0.86 | 10.80 | 24.07 | 29.90 | 10.47 | 2.32 | 3.94 |
| 1997 | 0.27 | 0.01 | 0.00 | 3.36 | 17.02 | 3.89 | 17.32 | 19.96 | 5.57 | 1.21 | 12.46 | 28.99 |
| 1998 | 25.25 | 19.93 | 6.94 | 2.77 | 15.82 | 10.33 | 27.70 | 32.69 | 22.57 | 21.35 | 13.40 | 2.71 |
| 1999 | 0.05 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 | 1.07 | 7.42 | 6.61 | 7.09 | 3.69 |
| 2000 | 0.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.12 | 0.67 | 0.44 | 3.95 | 6.66 |
| 2001 | 3.00 | 2.88 | 0.33 | 9.24 | 14.03 | 10.00 | 16.71 | 31.07 | 24.27 | 7.55 | 22.24 | 12.42 |
| 2002 | 2.37 | 0.48 | 0.79 | 0.49 | 17.36 | 6.74 | 3.32 | 5.29 | 3.41 | 0.34 | 0.27 | 2.42 |
| 2003 | 12.70 | 1.47 | 0.02 | 0.04 | 33.96 | 19.56 | 7.66 | 23.48 | 25.85 | 5.02 | 1.33 | 0.80 |
| 2004 | 0.02 | 0.00 | 0.00 | 0.56 | 7.92 | 2.61 | 1.24 | 6.76 | 5.14 | 4.64 | 3.95 | 4.15 |
| 2005 | 1.73 | 0.11 | 0.01 | 0.02 | 5.09 | 14.57 | 10.07 | 20.17 | 38.47 | 13.92 | 4.01 | 0.89 |
| 2006 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 5.90 | 11.63 | 3.15 | 5.72 | 27.16 |
| 2007 | 34.86 | 12.56 | 3.48 | 5.23 | 13.09 | 27.80 | 31.50 | 45.29 | 42.90 | 18.88 | 6.06 | 0.84 |
| 2008 | 0.02 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.06 | 28.43 | 35.12 | 20.95 | 26.59 | 7.04 |
| 2009 | 0.45 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 |
| 2010 | 5.62 | 2.41 | 15.90 | 34.72 | 44.13 | 22.86 | 15.79 | 26.96 | 41.50 | 26.40 | 14.35 | 3.89 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

Sub-basin: **2EE** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 0.23 | 0.02 | 0.00 | 0.00 | 0.42 | 9.02 | 23.36 | 24.30 | 23.77 | 4.05 | 3.68 | 0.69 |
| 1992 | 0.00 | 0.00 | 0.00 | 0.00 | 2.18 | 4.23 | 21.72 | 27.87 | 17.66 | 12.79 | 10.53 | 3.21 |
| 1993 | 4.89 | 16.40 | 4.56 | 0.00 | 10.72 | 21.91 | 15.98 | 11.33 | 6.26 | 1.97 | 0.00 | 0.00 |
| 1994 | 0.00 | 0.00 | 0.00 | 1.03 | 45.07 | 32.54 | 35.41 | 45.45 | 12.23 | 1.91 | 1.98 | 4.04 |
| 1995 | 0.03 | 0.00 | 0.01 | 0.53 | 10.85 | 4.96 | 13.27 | 8.09 | 16.93 | 5.48 | 7.11 | 1.77 |
| 1996 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 5.42 | 24.42 | 40.54 | 27.51 | 5.78 | 1.16 | 2.68 |
| 1997 | 0.03 | 0.00 | 0.00 | 23.81 | 31.57 | 2.64 | 33.56 | 33.22 | 4.27 | 0.62 | 26.13 | 39.35 |
| 1998 | 39.98 | 19.44 | 4.55 | 1.35 | 16.66 | 6.94 | 36.09 | 36.56 | 11.98 | 16.09 | 9.89 | 1.52 |
| 1999 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.13 | 3.65 | 11.94 | 8.13 | 7.07 | 7.11 | 3.31 |
| 2000 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.29 | 5.37 | 5.38 | 5.99 | 5.40 |
| 2001 | 1.60 | 2.81 | 0.00 | 10.04 | 11.43 | 13.05 | 19.81 | 27.16 | 21.93 | 4.30 | 27.34 | 7.33 |
| 2002 | 0.95 | 0.01 | 0.00 | 0.00 | 20.83 | 3.24 | 1.31 | 5.80 | 3.80 | 0.04 | 0.00 | 13.11 |
| 2003 | 14.99 | 0.58 | 0.00 | 0.42 | 55.87 | 11.09 | 5.24 | 48.19 | 19.81 | 2.80 | 0.24 | 4.85 |
| 2004 | 0.41 | 0.02 | 0.00 | 8.60 | 22.16 | 3.14 | 2.62 | 16.77 | 4.47 | 7.88 | 5.84 | 8.08 |
| 2005 | 2.31 | 0.00 | 0.00 | 0.13 | 21.64 | 21.66 | 9.77 | 34.55 | 57.77 | 8.38 | 2.12 | 0.12 |
| 2006 | 0.00 | 0.00 | 0.00 | 1.24 | 4.53 | 2.49 | 11.11 | 24.75 | 14.08 | 1.94 | 10.37 | 45.35 |
| 2007 | 24.61 | 9.55 | 2.58 | 9.94 | 14.83 | 65.39 | 52.97 | 68.94 | 72.99 | 16.92 | 11.14 | 2.01 |
| 2008 | 0.22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.61 | 59.36 | 36.20 | 24.10 | 36.41 | 4.87 |
| 2009 | 0.52 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2010 | 22.58 | 3.31 | 35.46 | 40.69 | 80.59 | 22.15 | 22.76 | 32.21 | 40.50 | 17.96 | 9.45 | 2.45 |

Sub-basin: **2EF** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 0.09 | 0.00 | 0.00 | 0.01 | 0.02 | 0.14 | 5.17 | 11.50 | 16.11 | 4.52 | 3.16 | 0.97 |
| 1992 | 0.03 | 0.00 | 0.00 | 0.00 | 0.19 | 0.23 | 5.06 | 15.18 | 13.80 | 8.40 | 8.29 | 4.38 |
| 1993 | 4.03 | 12.65 | 7.19 | 0.74 | 4.63 | 10.97 | 10.00 | 8.21 | 4.10 | 1.54 | 0.31 | 0.01 |
| 1994 | 0.00 | 0.00 | 0.00 | 0.02 | 5.55 | 11.93 | 17.87 | 24.40 | 11.59 | 1.59 | 1.78 | 2.18 |
| 1995 | 0.08 | 0.00 | 0.01 | 0.01 | 4.15 | 3.57 | 8.55 | 7.00 | 11.82 | 6.94 | 8.10 | 2.39 |
| 1996 | 0.56 | 0.01 | 0.00 | 0.01 | 0.00 | 0.56 | 7.05 | 15.71 | 19.52 | 6.83 | 1.51 | 2.57 |
| 1997 | 0.17 | 0.00 | 0.00 | 2.20 | 11.11 | 2.54 | 11.31 | 13.03 | 3.64 | 0.79 | 8.13 | 18.92 |
| 1998 | 16.48 | 13.01 | 4.53 | 1.81 | 10.33 | 6.74 | 18.08 | 21.34 | 14.73 | 13.93 | 8.75 | 1.77 |
| 1999 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.70 | 4.84 | 4.31 | 4.63 | 2.41 |
| 2000 | 0.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.08 | 0.44 | 0.29 | 2.58 | 4.35 |
| 2001 | 1.96 | 1.88 | 0.21 | 6.03 | 9.15 | 6.53 | 10.91 | 20.27 | 15.84 | 4.92 | 14.52 | 8.11 |
| 2002 | 1.55 | 0.31 | 0.51 | 0.32 | 11.33 | 4.40 | 2.17 | 3.45 | 2.22 | 0.22 | 0.18 | 1.58 |
| 2003 | 8.29 | 0.96 | 0.01 | 0.02 | 22.16 | 12.77 | 5.00 | 15.33 | 16.87 | 3.28 | 0.87 | 0.52 |
| 2004 | 0.01 | 0.00 | 0.00 | 0.36 | 5.17 | 1.70 | 0.81 | 4.41 | 3.35 | 3.03 | 2.58 | 2.71 |
| 2005 | 1.13 | 0.07 | 0.01 | 0.01 | 3.32 | 9.51 | 6.57 | 13.17 | 25.11 | 9.08 | 2.62 | 0.58 |
| 2006 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 3.85 | 7.59 | 2.06 | 3.73 | 17.72 |
| 2007 | 22.75 | 8.19 | 2.27 | 3.41 | 8.55 | 18.15 | 20.56 | 29.56 | 27.99 | 12.32 | 3.96 | 0.55 |
| 2008 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 18.55 | 22.92 | 13.67 | 17.36 | 4.60 |
| 2009 | 0.29 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2010 | 3.67 | 1.57 | 10.38 | 22.66 | 28.80 | 14.92 | 10.31 | 17.59 | 27.08 | 17.23 | 9.37 | 2.54 |

Sub-basin: **2EG1** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 3.70 | 3.84 | 4.35 | 1.16 | 0.49 | 0.03 |
| 1992 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.14 | 6.67 | 5.11 | 2.92 | 2.78 | 1.98 |
| 1993 | 1.77 | 6.50 | 2.09 | 0.06 | 0.80 | 3.60 | 2.83 | 1.98 | 0.81 | 0.11 | 0.00 | 0.00 |
| 1994 | 0.00 | 0.00 | 0.00 | 0.00 | 1.51 | 6.98 | 8.85 | 12.94 | 4.72 | 1.07 | 0.69 | 0.75 |
| 1995 | 0.00 | 0.00 | 0.00 | 0.00 | 3.47 | 1.46 | 3.38 | 2.29 | 5.34 | 3.03 | 3.80 | 0.90 |
| 1996 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.22 | 4.20 | 6.87 | 8.45 | 2.72 | 0.67 | 0.72 |
| 1997 | 0.00 | 0.00 | 0.00 | 0.28 | 9.15 | 1.51 | 8.68 | 10.80 | 2.47 | 0.68 | 6.15 | 12.09 |
| 1998 | 11.74 | 6.82 | 2.33 | 0.89 | 5.48 | 3.69 | 6.33 | 9.86 | 5.25 | 6.62 | 3.35 | 0.87 |
| 1999 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.31 | 1.06 | 1.03 | 1.48 | 0.90 |
| 2000 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.21 | 1.39 | 1.32 |
| 2001 | 0.29 | 0.52 | 0.01 | 4.27 | 3.36 | 1.37 | 4.01 | 8.63 | 6.81 | 2.41 | 6.99 | 2.77 |
| 2002 | 0.45 | 0.02 | 0.00 | 0.00 | 8.47 | 1.30 | 0.65 | 1.54 | 0.94 | 0.01 | 0.00 | 3.19 |
| 2003 | 3.86 | 0.21 | 0.00 | 0.00 | 15.31 | 6.37 | 2.63 | 12.61 | 7.20 | 2.14 | 0.87 | 2.65 |
| 2004 | 0.60 | 0.18 | 0.00 | 1.40 | 3.79 | 1.23 | 0.19 | 0.97 | 0.92 | 0.45 | 0.73 | 0.82 |
| 2005 | 0.27 | 0.00 | 0.00 | 0.00 | 0.34 | 2.07 | 1.71 | 8.66 | 15.21 | 3.95 | 1.58 | 0.45 |
| 2006 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.35 | 0.59 | 2.62 | 1.97 | 0.43 | 3.31 | 8.52 |
| 2007 | 9.91 | 4.18 | 1.11 | 1.13 | 3.49 | 10.55 | 13.10 | 20.69 | 22.89 | 6.84 | 4.71 | 1.38 |
| 2008 | 0.39 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 7.40 | 7.50 | 7.25 | 11.67 | 2.43 |
| 2009 | 0.31 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2010 | 2.15 | 1.07 | 9.22 | 15.63 | 21.71 | 7.46 | 5.08 | 8.83 | 13.88 | 8.90 | 4.34 | 1.35 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

Sub-basin: **2EG2** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 12.33 | 12.82 | 14.53 | 3.88 | 1.64 | 0.09 |
| 1992 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.47 | 22.27 | 17.05 | 9.74 | 9.29 | 6.61 |
| 1993 | 5.89 | 21.70 | 6.97 | 0.04 | 2.47 | 12.03 | 9.45 | 6.59 | 2.71 | 0.36 | 0.00 | 0.00 |
| 1994 | 0.00 | 0.00 | 0.00 | 0.00 | 5.03 | 23.29 | 29.53 | 43.16 | 15.74 | 3.58 | 2.29 | 2.50 |
| 1995 | 0.00 | 0.00 | 0.00 | 0.00 | 11.58 | 4.87 | 11.27 | 7.64 | 17.81 | 10.10 | 12.67 | 3.00 |
| 1996 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.70 | 14.00 | 22.94 | 28.20 | 9.08 | 2.24 | 2.40 |
| 1997 | 0.00 | 0.00 | 0.00 | 0.92 | 30.53 | 5.04 | 28.98 | 36.03 | 8.26 | 2.27 | 20.53 | 40.34 |
| 1998 | 39.18 | 22.77 | 7.78 | 2.97 | 18.29 | 12.30 | 21.12 | 32.91 | 17.51 | 22.10 | 11.19 | 2.90 |
| 1999 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.01 | 3.52 | 3.44 | 4.95 | 3.02 |
| 2000 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.69 | 4.65 | 4.39 |
| 2001 | 0.90 | 1.73 | 0.00 | 14.09 | 11.22 | 4.58 | 13.37 | 28.79 | 22.73 | 8.04 | 23.32 | 9.24 |
| 2002 | 1.50 | 0.02 | 0.00 | 0.00 | 28.27 | 4.34 | 2.18 | 5.14 | 3.12 | 0.00 | 0.00 | 10.46 |
| 2003 | 12.88 | 0.64 | 0.00 | 0.00 | 51.07 | 21.25 | 8.76 | 42.08 | 24.04 | 7.15 | 2.91 | 8.84 |
| 2004 | 1.99 | 0.57 | 0.00 | 4.64 | 12.65 | 4.10 | 0.62 | 3.23 | 3.08 | 1.49 | 2.43 | 2.75 |
| 2005 | 0.91 | 0.00 | 0.00 | 0.00 | 1.13 | 6.92 | 5.72 | 28.91 | 50.77 | 13.18 | 5.28 | 1.51 |
| 2006 | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 | 1.17 | 1.98 | 8.73 | 6.56 | 1.44 | 11.03 | 28.44 |
| 2007 | 33.08 | 13.95 | 3.69 | 3.76 | 11.66 | 35.19 | 43.71 | 69.03 | 76.38 | 22.81 | 15.70 | 4.60 |
| 2008 | 1.29 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 24.70 | 25.04 | 24.19 | 38.95 | 8.11 |
| 2009 | 1.04 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2010 | 7.17 | 3.56 | 30.78 | 52.14 | 72.44 | 24.91 | 16.96 | 29.46 | 46.33 | 29.71 | 14.48 | 4.50 |

Sub-basin: **2EH** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 0.66 | 0.22 | 0.02 | 0.01 | 0.01 | 2.78 | 5.43 | 9.87 | 7.13 | 1.27 | 0.36 | 0.02 |
| 1992 | 0.00 | 0.00 | 0.00 | 0.00 | 0.69 | 1.04 | 5.78 | 7.37 | 2.32 | 1.43 | 2.33 | 1.24 |
| 1993 | 0.57 | 5.17 | 1.46 | 0.37 | 1.78 | 10.93 | 4.78 | 2.76 | 1.07 | 0.28 | 0.01 | 0.00 |
| 1994 | 0.00 | 0.00 | 0.00 | 8.56 | 24.72 | 13.29 | 12.45 | 25.92 | 3.66 | 1.33 | 0.42 | 0.52 |
| 1995 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.21 | 1.40 | 8.19 | 1.72 | 1.48 | 1.12 |
| 1996 | 0.40 | 0.03 | 0.01 | 0.01 | 0.01 | 0.80 | 15.05 | 20.55 | 9.32 | 2.05 | 0.78 | 0.22 |
| 1997 | 0.00 | 0.00 | 0.00 | 17.12 | 10.44 | 1.14 | 18.58 | 20.60 | 1.74 | 0.56 | 15.19 | 16.65 |
| 1998 | 22.81 | 5.96 | 2.02 | 0.73 | 7.49 | 3.98 | 12.70 | 13.19 | 3.55 | 2.26 | 2.14 | 1.15 |
| 1999 | 0.29 | 0.01 | 0.00 | 0.63 | 2.96 | 0.81 | 0.53 | 1.14 | 2.06 | 1.02 | 0.95 | 0.47 |
| 2000 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.41 | 1.69 | 0.80 | 0.44 | 0.37 |
| 2001 | 0.06 | 0.01 | 0.00 | 1.87 | 2.95 | 2.33 | 5.98 | 13.62 | 5.75 | 1.52 | 7.99 | 1.98 |
| 2002 | 0.78 | 0.18 | 0.01 | 0.00 | 8.77 | 1.17 | 0.53 | 0.04 | 0.00 | 0.00 | 0.00 | 4.29 |
| 2003 | 4.98 | 0.55 | 0.05 | 0.95 | 32.97 | 2.75 | 4.27 | 32.39 | 6.76 | 1.41 | 0.39 | 5.32 |
| 2004 | 0.70 | 0.11 | 0.01 | 6.73 | 18.07 | 1.67 | 0.86 | 3.32 | 1.48 | 1.45 | 3.14 | 2.02 |
| 2005 | 0.57 | 0.04 | 0.00 | 0.00 | 9.62 | 6.83 | 4.57 | 14.09 | 30.86 | 2.85 | 1.16 | 0.29 |
| 2006 | 0.02 | 0.00 | 0.00 | 2.36 | 1.90 | 1.26 | 8.48 | 8.03 | 2.48 | 1.07 | 21.25 | 21.48 |
| 2007 | 6.75 | 3.67 | 1.56 | 6.68 | 2.57 | 31.47 | 25.46 | 35.27 | 40.81 | 4.75 | 6.67 | 1.66 |
| 2008 | 0.57 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 1.18 | 13.24 | 12.68 | 12.24 | 23.62 | 2.05 |
| 2009 | 0.64 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2010 | 4.39 | 0.07 | 23.21 | 18.47 | 40.64 | 7.25 | 5.84 | 10.82 | 12.97 | 5.29 | 3.17 | 1.44 |

Sub-basin: **2EK** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.67 | 2.75 | 0.14 | 0.06 | 0.03 |
| 1992 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.13 | 0.22 | 0.20 | 0.17 | 0.10 |
| 1993 | 1.10 | 5.51 | 1.03 | 0.06 | 0.09 | 1.98 | 1.54 | 1.00 | 0.17 | 0.02 | 0.00 | 0.00 |
| 1994 | 0.00 | 0.00 | 0.00 | 0.00 | 5.98 | 6.56 | 11.85 | 11.45 | 2.66 | 0.25 | 0.06 | 0.18 |
| 1995 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.03 | 0.13 | 0.09 | 0.23 | 0.16 |
| 1996 | 0.06 | 0.01 | 0.00 | 0.00 | 0.00 | 0.05 | 10.84 | 15.29 | 10.45 | 1.33 | 0.16 | 0.05 |
| 1997 | 0.01 | 0.00 | 0.00 | 6.99 | 14.39 | 1.10 | 13.65 | 14.74 | 1.57 | 0.25 | 10.45 | 13.38 |
| 1998 | 18.42 | 6.53 | 1.35 | 0.42 | 12.55 | 4.74 | 8.80 | 11.85 | 4.87 | 4.80 | 1.80 | 0.45 |
| 1999 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2000 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.11 | 0.04 | 0.02 | 0.02 |
| 2001 | 0.01 | 0.00 | 0.00 | 0.03 | 0.12 | 0.17 | 0.78 | 8.48 | 6.08 | 0.17 | 0.76 | 0.18 |
| 2002 | 0.06 | 0.02 | 0.03 | 0.04 | 5.88 | 1.03 | 0.27 | 0.05 | 0.02 | 0.00 | 0.00 | 0.00 |
| 2003 | 0.01 | 0.00 | 0.00 | 0.00 | 24.47 | 4.00 | 2.65 | 25.02 | 8.39 | 1.32 | 0.81 | 32.03 |
| 2004 | 2.65 | 1.06 | 0.43 | 0.57 | 7.10 | 0.74 | 0.10 | 0.53 | 0.29 | 0.07 | 0.07 | 0.23 |
| 2005 | 0.02 | 0.00 | 0.00 | 0.00 | 0.11 | 5.77 | 8.69 | 28.87 | 31.52 | 4.13 | 1.56 | 0.72 |
| 2006 | 0.23 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.05 | 0.01 | 1.95 | 13.77 |
| 2007 | 8.15 | 3.43 | 0.54 | 0.41 | 0.74 | 13.40 | 20.47 | 21.26 | 34.83 | 5.68 | 12.31 | 2.51 |
| 2008 | 0.84 | 0.31 | 0.12 | 0.01 | 0.00 | 0.00 | 0.00 | 3.69 | 6.39 | 7.38 | 10.58 | 1.00 |
| 2009 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2010 | 1.68 | 0.26 | 7.91 | 18.37 | 32.21 | 6.23 | 2.35 | 7.52 | 11.14 | 2.88 | 1.26 | 0.23 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

## 2FB

Sub-basin: **2FB** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 0.08 | 0.02 | 0.00 | 0.04 | 0.08 | 0.59 | 1.04 | 0.74 | 0.86 | 0.53 | 0.32 | 0.12 |
| 1992 | 0.01 | 0.00 | 0.00 | 0.00 | 0.02 | 0.31 | 1.25 | 1.70 | 1.75 | 1.11 | 0.82 | 0.69 |
| 1993 | 0.58 | 1.89 | 0.69 | 0.10 | 0.14 | 0.32 | 0.39 | 0.27 | 0.17 | 0.03 | 0.01 | 0.00 |
| 1994 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.24 | 0.72 | 0.69 | 0.24 | 0.32 | 0.41 |
| 1995 | 0.06 | 0.00 | 0.00 | 0.03 | 0.28 | 0.33 | 0.74 | 0.38 | 0.73 | 0.60 | 1.35 | 0.81 |
| 1996 | 0.24 | 0.03 | 0.00 | 0.00 | 0.01 | 0.24 | 0.80 | 1.09 | 1.53 | 0.83 | 0.41 | 0.46 |
| 1997 | 0.07 | 0.00 | 0.00 | 0.00 | 1.07 | 0.43 | 0.46 | 0.62 | 0.34 | 0.21 | 1.65 | 2.09 |
| 1998 | 2.06 | 1.24 | 0.56 | 0.27 | 2.84 | 1.57 | 0.84 | 0.53 | 0.47 | 0.77 | 0.74 | 0.43 |
| 1999 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.07 | 0.09 | 0.07 | 0.12 |
| 2000 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.13 | 0.24 |
| 2001 | 0.10 | 0.06 | 0.02 | 0.50 | 1.04 | 0.55 | 0.68 | 1.54 | 0.92 | 0.59 | 0.95 | 0.71 |
| 2002 | 0.20 | 0.04 | 0.04 | 0.08 | 2.42 | 0.59 | 0.42 | 0.41 | 0.14 | 0.05 | 0.29 | 0.51 |
| 2003 | 1.18 | 0.18 | 0.01 | 0.00 | 2.12 | 1.83 | 0.93 | 1.10 | 1.75 | 0.69 | 0.54 | 0.44 |
| 2004 | 0.17 | 0.09 | 0.01 | 0.33 | 1.11 | 0.49 | 0.31 | 0.44 | 0.32 | 0.23 | 0.24 | 0.19 |
| 2005 | 0.06 | 0.00 | 0.00 | 0.00 | 0.10 | 0.62 | 0.67 | 0.88 | 1.56 | 0.91 | 0.64 | 0.19 |
| 2006 | 0.01 | 0.00 | 0.00 | 0.00 | 0.04 | 0.14 | 0.21 | 0.25 | 0.32 | 0.10 | 0.19 | 1.05 |
| 2007 | 1.54 | 1.06 | 0.34 | 0.34 | 1.08 | 1.31 | 1.37 | 1.33 | 2.15 | 1.02 | 0.40 | 0.08 |
| 2008 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.37 | 0.95 | 1.14 | 1.68 | 0.57 |
| 2009 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2010 | 0.29 | 0.30 | 1.22 | 2.55 | 2.88 | 1.18 | 0.42 | 0.95 | 2.51 | 2.60 | 1.82 | 0.38 |

## 2GA, 2GB, 2GC & 2GD

Sub-basin: **2GA** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 0.27 | 0.01 | 0.00 | 0.65 | 1.25 | 7.26 | 5.47 | 2.84 | 3.09 | 1.69 | 1.21 | 0.33 |
| 1992 | 0.02 | 0.00 | 0.00 | 0.00 | 1.62 | 2.84 | 6.84 | 7.05 | 6.51 | 4.78 | 4.21 | 3.94 |
| 1993 | 5.60 | 14.71 | 4.12 | 0.66 | 0.55 | 1.55 | 1.24 | 0.70 | 0.34 | 0.04 | 0.00 | 0.00 |
| 1994 | 0.00 | 0.00 | 0.00 | 0.00 | 0.15 | 2.80 | 3.08 | 4.21 | 2.56 | 1.14 | 3.80 | 4.85 |
| 1995 | 0.77 | 0.04 | 0.60 | 0.69 | 1.87 | 1.69 | 4.56 | 1.66 | 2.49 | 1.68 | 5.27 | 2.69 |
| 1996 | 0.82 | 0.07 | 0.01 | 0.00 | 0.00 | 2.22 | 4.76 | 4.72 | 7.64 | 3.29 | 1.65 | 1.78 |
| 1997 | 0.17 | 0.00 | 0.00 | 1.05 | 5.94 | 1.10 | 1.33 | 1.66 | 0.69 | 0.46 | 6.74 | 7.61 |
| 1998 | 15.18 | 9.91 | 3.94 | 1.89 | 14.57 | 9.36 | 4.17 | 2.02 | 1.80 | 2.33 | 2.03 | 0.79 |
| 1999 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 1.02 | 1.20 | 0.27 | 0.22 | 0.42 |
| 2000 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.84 | 0.24 | 0.71 | 0.73 |
| 2001 | 0.21 | 0.14 | 0.04 | 2.69 | 3.38 | 1.83 | 2.55 | 4.15 | 2.02 | 1.70 | 3.96 | 1.79 |
| 2002 | 0.61 | 0.15 | 0.12 | 0.30 | 11.96 | 3.07 | 2.20 | 1.53 | 0.42 | 0.03 | 1.00 | 2.28 |
| 2003 | 2.83 | 0.36 | 0.00 | 0.00 | 10.53 | 7.31 | 4.17 | 6.12 | 5.82 | 2.02 | 2.05 | 1.55 |
| 2004 | 0.36 | 0.17 | 0.01 | 1.52 | 5.23 | 1.79 | 1.09 | 1.54 | 0.71 | 0.43 | 0.67 | 0.44 |
| 2005 | 0.09 | 0.00 | 0.00 | 0.00 | 1.51 | 2.42 | 1.31 | 2.45 | 4.77 | 2.69 | 2.12 | 0.44 |
| 2006 | 0.00 | 0.00 | 0.00 | 0.11 | 2.41 | 0.77 | 0.75 | 1.03 | 0.85 | 0.20 | 0.89 | 3.59 |
| 2007 | 4.77 | 3.40 | 0.94 | 1.07 | 3.18 | 6.02 | 4.27 | 3.98 | 6.52 | 1.95 | 0.78 | 0.09 |
| 2008 | 0.00 | 0.00 | 0.00 | 0.00 | 0.40 | 0.24 | 0.47 | 2.05 | 2.27 | 2.81 | 3.11 | 0.80 |
| 2009 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2010 | 2.78 | 0.61 | 4.58 | 7.94 | 12.06 | 4.92 | 1.48 | 3.73 | 7.13 | 11.28 | 7.24 | 1.76 |

Sub-basin: **2GB** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 1.98 | 0.71 | 0.18 | 4.80 | 6.84 | 26.96 | 15.30 | 10.97 | 10.29 | 6.79 | 5.53 | 2.44 |
| 1992 | 0.99 | 0.18 | 0.00 | 0.00 | 10.96 | 13.64 | 24.02 | 23.24 | 21.44 | 16.56 | 12.93 | 12.98 |
| 1993 | 18.84 | 35.71 | 6.68 | 1.61 | 3.65 | 9.58 | 6.34 | 3.91 | 2.84 | 1.38 | 0.94 | 1.37 |
| 1994 | 0.64 | 0.03 | 0.00 | 0.28 | 9.08 | 14.53 | 11.81 | 14.25 | 7.99 | 5.36 | 19.58 | 14.06 |
| 1995 | 2.28 | 0.55 | 3.71 | 4.36 | 10.41 | 9.51 | 17.57 | 5.32 | 9.50 | 10.08 | 27.03 | 8.73 |
| 1996 | 3.17 | 0.94 | 0.74 | 1.15 | 2.17 | 14.93 | 21.12 | 17.47 | 23.92 | 9.37 | 5.73 | 7.56 |
| 1997 | 1.43 | 0.22 | 0.00 | 6.14 | 25.92 | 4.52 | 7.50 | 8.29 | 4.38 | 5.56 | 36.14 | 25.35 |
| 1998 | 46.21 | 24.13 | 7.74 | 9.43 | 56.02 | 24.65 | 12.47 | 7.34 | 8.03 | 11.35 | 9.35 | 4.28 |
| 1999 | 1.25 | 0.16 | 0.00 | 0.00 | 0.77 | 0.92 | 1.53 | 5.99 | 8.43 | 3.25 | 2.90 | 5.42 |
| 2000 | 2.18 | 0.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.37 | 2.67 | 1.97 | 4.88 | 5.63 |
| 2001 | 2.98 | 2.54 | 1.72 | 19.82 | 19.83 | 10.38 | 13.82 | 16.66 | 9.94 | 9.02 | 19.24 | 6.46 |
| 2002 | 3.18 | 1.48 | 1.61 | 3.26 | 47.19 | 7.18 | 5.91 | 6.21 | 2.45 | 1.79 | 10.67 | 15.25 |
| 2003 | 13.51 | 2.26 | 0.43 | 0.04 | 48.33 | 19.80 | 11.80 | 25.63 | 16.24 | 6.24 | 8.41 | 6.80 |
| 2004 | 2.49 | 1.79 | 1.12 | 11.24 | 24.66 | 6.79 | 5.02 | 7.92 | 3.68 | 3.03 | 6.94 | 4.15 |
| 2005 | 2.09 | 0.81 | 0.27 | 0.39 | 8.35 | 13.54 | 7.11 | 11.85 | 22.61 | 10.37 | 7.06 | 2.40 |
| 2006 | 0.52 | 0.02 | 0.57 | 3.72 | 14.08 | 4.38 | 4.93 | 6.02 | 5.04 | 2.39 | 10.71 | 21.78 |
| 2007 | 18.20 | 10.85 | 3.04 | 6.16 | 13.54 | 29.42 | 15.13 | 18.53 | 29.40 | 6.88 | 4.03 | 1.57 |
| 2008 | 0.45 | 0.05 | 0.00 | 1.66 | 3.10 | 1.63 | 1.77 | 9.60 | 13.60 | 19.15 | 15.61 | 4.48 |
| 2009 | 0.98 | 0.17 | 0.00 | 0.00 | 0.00 | 0.21 | 0.43 | 0.06 | 0.06 | 0.02 | 2.30 | 1.47 |
| 2010 | 14.34 | 5.89 | 24.85 | 27.84 | 36.65 | 10.60 | 4.15 | 17.68 | 27.77 | 36.19 | 17.30 | 4.37 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

Sub-basin: **2GC** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 3.14 | 0.75 | 0.56 | 8.33 | 24.02 | 30.05 | 10.89 | 3.97 | 5.07 | 8.98 | 9.68 | 3.63 |
| 1992 | 1.34 | 0.21 | 0.01 | 2.34 | 34.95 | 19.64 | 18.48 | 13.10 | 12.47 | 16.44 | 16.13 | 15.40 |
| 1993 | 21.44 | 25.43 | 6.69 | 2.43 | 15.12 | 15.13 | 6.36 | 2.87 | 1.61 | 0.77 | 1.18 | 5.20 |
| 1994 | 1.95 | 0.58 | 0.63 | 12.96 | 39.90 | 21.94 | 11.14 | 8.73 | 7.52 | 12.83 | 40.94 | 18.65 |
| 1995 | 3.16 | 1.20 | 11.36 | 9.96 | 21.83 | 14.81 | 19.26 | 5.17 | 6.95 | 6.46 | 24.15 | 11.69 |
| 1996 | 5.05 | 2.55 | 3.56 | 8.24 | 10.12 | 23.72 | 16.13 | 11.11 | 17.63 | 9.22 | 9.05 | 10.55 |
| 1997 | 2.05 | 0.35 | 0.01 | 17.26 | 33.40 | 6.71 | 8.11 | 8.23 | 4.89 | 12.12 | 49.60 | 26.55 |
| 1998 | 44.23 | 29.02 | 9.57 | 24.75 | 51.89 | 27.08 | 9.55 | 3.91 | 3.76 | 7.61 | 8.69 | 5.72 |
| 1999 | 1.46 | 0.20 | 0.01 | 0.04 | 4.76 | 4.24 | 4.11 | 6.32 | 10.37 | 4.60 | 6.24 | 18.00 |
| 2000 | 5.86 | 1.03 | 0.10 | 0.00 | 0.00 | 0.06 | 0.27 | 1.49 | 1.85 | 2.79 | 8.94 | 11.14 |
| 2001 | 10.33 | 7.20 | 5.79 | 34.79 | 33.99 | 11.15 | 10.81 | 9.65 | 5.88 | 11.72 | 20.90 | 8.33 |
| 2002 | 5.13 | 2.38 | 4.35 | 11.43 | 59.42 | 8.94 | 5.84 | 4.08 | 2.18 | 4.45 | 24.12 | 16.91 |
| 2003 | 17.34 | 2.96 | 0.53 | 1.94 | 62.43 | 22.37 | 8.61 | 9.81 | 11.29 | 7.06 | 14.31 | 8.52 |
| 2004 | 2.18 | 1.33 | 1.08 | 18.28 | 37.70 | 7.78 | 3.26 | 1.78 | 0.82 | 0.97 | 10.71 | 6.63 |
| 2005 | 2.88 | 1.34 | 0.70 | 1.27 | 12.01 | 13.61 | 5.53 | 3.66 | 13.09 | 8.82 | 8.08 | 2.63 |
| 2006 | 0.38 | 0.02 | 0.38 | 5.84 | 19.26 | 6.24 | 3.12 | 2.28 | 1.73 | 1.17 | 11.13 | 20.43 |
| 2007 | 17.70 | 6.17 | 2.41 | 11.76 | 22.21 | 35.26 | 9.01 | 15.04 | 15.74 | 8.56 | 10.56 | 3.97 |
| 2008 | 1.21 | 0.38 | 0.18 | 11.61 | 10.28 | 4.15 | 2.09 | 2.63 | 7.25 | 18.41 | 16.19 | 5.84 |
| 2009 | 0.95 | 0.14 | 0.00 | 0.00 | 0.00 | 1.12 | 0.71 | 0.23 | 0.14 | 0.20 | 4.28 | 2.62 |
| 2010 | 11.04 | 3.49 | 18.17 | 21.46 | 27.01 | 8.48 | 2.61 | 3.52 | 12.44 | 20.45 | 16.31 | 4.80 |

Sub-basin: **2GD** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 4.44 | 1.06 | 0.80 | 11.78 | 33.88 | 42.40 | 15.37 | 5.60 | 7.15 | 12.67 | 13.65 | 5.13 |
| 1992 | 1.89 | 0.30 | 0.01 | 3.34 | 49.36 | 27.70 | 26.07 | 18.48 | 17.60 | 23.20 | 22.75 | 21.73 |
| 1993 | 30.26 | 35.88 | 9.44 | 3.43 | 21.36 | 21.36 | 8.98 | 4.05 | 2.27 | 1.08 | 1.68 | 7.35 |
| 1994 | 2.76 | 0.82 | 0.89 | 18.35 | 56.31 | 30.95 | 15.71 | 12.31 | 10.61 | 18.11 | 57.76 | 26.31 |
| 1995 | 4.46 | 1.69 | 16.05 | 14.06 | 30.81 | 20.90 | 27.16 | 7.30 | 9.80 | 9.14 | 34.08 | 16.50 |
| 1996 | 7.12 | 3.60 | 5.02 | 11.64 | 14.29 | 33.50 | 22.76 | 15.67 | 24.88 | 13.00 | 12.78 | 14.88 |
| 1997 | 2.90 | 0.50 | 0.01 | 24.48 | 47.12 | 9.47 | 11.45 | 11.62 | 6.89 | 17.13 | 69.99 | 37.45 |
| 1998 | 62.40 | 40.94 | 13.50 | 34.95 | 73.21 | 38.20 | 13.47 | 5.52 | 5.31 | 10.74 | 12.27 | 8.07 |
| 1999 | 2.07 | 0.28 | 0.01 | 0.06 | 6.73 | 5.98 | 5.81 | 8.95 | 14.63 | 6.51 | 8.81 | 25.43 |
| 2000 | 8.28 | 1.45 | 0.14 | 0.00 | 0.00 | 0.13 | 0.38 | 2.10 | 2.61 | 3.95 | 12.63 | 15.74 |
| 2001 | 14.62 | 10.16 | 8.20 | 49.13 | 47.95 | 15.72 | 15.26 | 13.61 | 8.30 | 16.54 | 29.49 | 11.75 |
| 2002 | 7.23 | 3.37 | 6.14 | 16.19 | 83.86 | 12.62 | 8.24 | 5.75 | 3.08 | 6.31 | 34.04 | 23.88 |
| 2003 | 24.46 | 4.18 | 0.75 | 2.78 | 88.11 | 31.55 | 12.15 | 13.85 | 15.93 | 9.97 | 20.20 | 12.03 |
| 2004 | 3.07 | 1.87 | 1.52 | 25.84 | 53.21 | 10.98 | 4.59 | 2.50 | 1.16 | 1.36 | 15.14 | 9.37 |
| 2005 | 4.08 | 1.89 | 0.99 | 1.79 | 16.98 | 19.20 | 7.80 | 5.17 | 18.46 | 12.44 | 11.40 | 3.70 |
| 2006 | 0.53 | 0.02 | 0.55 | 8.26 | 27.17 | 8.80 | 4.40 | 3.22 | 2.44 | 1.65 | 15.75 | 28.83 |
| 2007 | 24.97 | 8.70 | 3.39 | 16.63 | 31.34 | 49.76 | 12.71 | 21.22 | 22.21 | 12.08 | 14.90 | 5.60 |
| 2008 | 1.70 | 0.53 | 0.26 | 16.41 | 14.51 | 5.86 | 2.95 | 3.72 | 10.24 | 26.00 | 22.84 | 8.25 |
| 2009 | 1.35 | 0.19 | 0.00 | 0.00 | 0.01 | 1.64 | 1.00 | 0.32 | 0.20 | 0.29 | 6.04 | 3.70 |
| 2010 | 15.61 | 4.93 | 25.66 | 30.27 | 38.11 | 11.96 | 3.69 | 4.98 | 17.56 | 28.86 | 23.00 | 6.77 |

## 2KA

Sub-basin: **2KA** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 2.59 | 1.79 | 0.40 | 11.78 | 51.74 | 77.11 | 28.09 | 8.97 | 8.19 | 4.33 | 3.88 | 1.46 |
| 1992 | 0.60 | 0.10 | 0.13 | 0.50 | 10.56 | 8.40 | 12.36 | 12.16 | 12.43 | 10.22 | 9.42 | 9.06 |
| 1993 | 65.81 | 127.40 | 46.16 | 9.38 | 16.31 | 33.99 | 13.47 | 4.00 | 1.30 | 0.23 | 0.38 | 1.60 |
| 1994 | 0.22 | 0.00 | 2.69 | 24.54 | 90.43 | 54.57 | 29.39 | 19.92 | 11.27 | 3.22 | 13.73 | 18.93 |
| 1995 | 4.61 | 2.66 | 23.82 | 24.14 | 91.16 | 25.57 | 21.04 | 8.75 | 11.43 | 10.84 | 12.24 | 6.75 |
| 1996 | 7.44 | 19.47 | 33.00 | 120.39 | 27.77 | 55.64 | 73.10 | 36.62 | 44.75 | 17.66 | 5.31 | 10.68 |
| 1997 | 3.84 | 1.25 | 0.07 | 31.33 | 168.00 | 25.84 | 26.97 | 25.59 | 9.87 | 4.44 | 71.12 | 164.70 |
| 1998 | 178.94 | 138.82 | 39.03 | 36.44 | 107.31 | 65.25 | 17.44 | 7.39 | 5.16 | 7.74 | 5.37 | 1.29 |
| 1999 | 0.34 | 0.16 | 10.38 | 80.15 | 26.35 | 5.49 | 1.38 | 2.80 | 4.43 | 2.79 | 3.10 | 6.97 |
| 2000 | 1.90 | 0.24 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 1.87 | 2.17 | 1.27 | 6.16 | 11.99 |
| 2001 | 105.20 | 80.74 | 24.36 | 65.09 | 45.43 | 13.06 | 9.73 | 13.88 | 9.87 | 9.80 | 23.50 | 10.40 |
| 2002 | 16.86 | 14.04 | 32.35 | 19.87 | 231.51 | 28.55 | 7.30 | 3.91 | 1.75 | 0.42 | 5.92 | 43.12 |
| 2003 | 99.79 | 18.90 | 5.96 | 18.74 | 251.44 | 61.42 | 16.38 | 14.14 | 23.47 | 6.53 | 2.64 | 2.84 |
| 2004 | 1.41 | 1.72 | 6.29 | 83.04 | 135.94 | 27.59 | 5.86 | 2.63 | 2.44 | 1.92 | 1.64 | 2.59 |
| 2005 | 1.16 | 0.86 | 1.11 | 6.06 | 18.83 | 28.58 | 8.78 | 4.36 | 6.28 | 2.86 | 1.44 | 0.57 |
| 2006 | 0.01 | 0.00 | 1.08 | 89.60 | 101.62 | 16.58 | 4.58 | 3.23 | 2.49 | 1.01 | 17.42 | 133.10 |
| 2007 | 133.05 | 106.06 | 44.66 | 33.32 | 32.82 | 53.57 | 19.29 | 16.23 | 25.90 | 11.70 | 2.78 | 1.10 |
| 2008 | 0.26 | 0.15 | 0.40 | 31.05 | 28.16 | 6.53 | 2.44 | 4.45 | 5.30 | 7.01 | 22.92 | 7.77 |
| 2009 | 1.33 | 0.80 | 0.11 | 0.17 | 5.00 | 6.99 | 2.04 | 0.25 | 0.01 | 0.00 | 0.00 | 1.75 |
| 2010 | 55.06 | 22.70 | 76.48 | 77.40 | 95.18 | 25.21 | 5.93 | 1.86 | 5.41 | 40.33 | 48.79 | 28.29 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

## 4. Athi River Catchment Area (ATCA)

### 3AA

Sub-basin: **3AA** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 6.33 | 3.65 | 3.51 | 4.49 | 15.70 | 9.63 | 4.37 | 3.54 | 3.21 | 3.36 | 3.70 | 5.33 |
| 1992 | 4.89 | 3.48 | 3.39 | 11.19 | 25.31 | 5.60 | 4.20 | 3.44 | 3.17 | 3.25 | 3.90 | 4.83 |
| 1993 | 18.52 | 25.00 | 7.09 | 4.06 | 4.16 | 3.60 | 3.40 | 3.30 | 3.17 | 3.27 | 3.66 | 4.96 |
| 1994 | 3.74 | 3.62 | 3.64 | 5.51 | 9.80 | 5.35 | 3.77 | 3.43 | 3.22 | 3.70 | 14.58 | 13.03 |
| 1995 | 5.78 | 4.36 | 12.21 | 9.19 | 17.99 | 6.16 | 3.86 | 3.38 | 3.18 | 3.40 | 4.16 | 4.14 |
| 1996 | 3.64 | 3.22 | 3.61 | 5.98 | 4.81 | 5.30 | 4.08 | 3.38 | 3.22 | 3.23 | 4.18 | 5.19 |
| 1997 | 3.51 | 2.91 | 3.18 | 18.09 | 26.15 | 6.13 | 3.79 | 3.45 | 3.18 | 3.83 | 17.46 | 33.73 |
| 1998 | 34.11 | 31.41 | 17.15 | 15.82 | 34.67 | 19.28 | 7.17 | 5.32 | 3.89 | 3.77 | 3.67 | 3.86 |
| 1999 | 3.75 | 3.27 | 4.42 | 9.05 | 7.31 | 4.04 | 3.65 | 3.57 | 3.55 | 3.59 | 4.69 | 22.72 |
| 2000 | 7.30 | 3.65 | 3.65 | 3.87 | 4.07 | 3.80 | 3.68 | 3.57 | 3.42 | 3.57 | 3.97 | 4.81 |
| 2001 | 30.33 | 11.65 | 11.33 | 24.18 | 13.09 | 7.60 | 4.72 | 3.87 | 3.62 | 3.68 | 5.27 | 4.96 |
| 2002 | 4.21 | 3.56 | 4.88 | 4.44 | 28.19 | 6.46 | 4.03 | 3.70 | 3.58 | 3.79 | 5.14 | 12.00 |
| 2003 | 12.54 | 4.53 | 3.93 | 4.54 | 34.07 | 12.55 | 5.13 | 3.89 | 3.64 | 3.70 | 4.62 | 4.62 |
| 2004 | 4.26 | 3.93 | 4.17 | 9.88 | 25.40 | 5.61 | 3.98 | 3.68 | 3.53 | 3.78 | 4.29 | 4.65 |
| 2005 | 4.38 | 4.14 | 4.45 | 5.49 | 18.02 | 13.25 | 5.30 | 3.92 | 3.54 | 3.69 | 4.12 | 3.95 |
| 2006 | 3.67 | 3.37 | 4.17 | 4.90 | 6.14 | 4.13 | 3.65 | 3.61 | 3.56 | 3.57 | 4.56 | 7.68 |
| 2007 | 10.43 | 5.69 | 4.27 | 4.24 | 4.60 | 4.00 | 3.60 | 3.51 | 3.39 | 3.47 | 3.41 | 3.54 |
| 2008 | 3.82 | 3.36 | 3.66 | 5.24 | 5.63 | 3.76 | 3.60 | 3.49 | 3.49 | 3.99 | 5.61 | 4.35 |
| 2009 | 3.61 | 3.38 | 3.60 | 3.73 | 4.12 | 3.88 | 3.78 | 3.44 | 3.24 | 3.61 | 3.83 | 4.17 |
| 2010 | 9.83 | 4.81 | 11.07 | 23.29 | 34.40 | 8.96 | 4.28 | 3.54 | 3.36 | 3.62 | 4.29 | 4.44 |

### 3BA, 3BB, 3BC & 3BD

Sub-basin: **3BA** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 3.18 | 1.38 | 0.89 | 2.30 | 10.56 | 5.89 | 1.47 | 0.90 | 0.67 | 0.73 | 1.70 | 2.56 |
| 1992 | 1.18 | 0.88 | 0.74 | 5.81 | 15.47 | 2.40 | 1.68 | 0.80 | 0.57 | 0.57 | 2.29 | 3.07 |
| 1993 | 8.32 | 12.77 | 3.03 | 1.35 | 2.09 | 1.51 | 0.90 | 0.60 | 0.56 | 0.60 | 1.76 | 4.12 |
| 1994 | 1.29 | 1.25 | 1.03 | 3.96 | 8.04 | 2.75 | 1.24 | 0.96 | 0.70 | 1.60 | 13.44 | 8.93 |
| 1995 | 2.58 | 1.97 | 6.38 | 6.70 | 10.82 | 2.59 | 0.98 | 0.68 | 0.55 | 0.77 | 2.71 | 2.61 |
| 1996 | 1.55 | 0.97 | 1.30 | 3.51 | 1.65 | 2.90 | 1.56 | 0.77 | 0.73 | 0.58 | 2.92 | 5.21 |
| 1997 | 1.22 | 0.49 | 0.55 | 11.70 | 15.83 | 2.73 | 1.09 | 0.82 | 0.62 | 1.88 | 15.34 | 25.11 |
| 1998 | 22.01 | 19.06 | 8.93 | 11.75 | 23.55 | 11.20 | 3.16 | 1.87 | 1.02 | 1.05 | 1.13 | 1.44 |
| 1999 | 1.05 | 0.66 | 2.25 | 5.26 | 4.70 | 1.43 | 0.82 | 0.76 | 0.93 | 0.77 | 2.69 | 17.49 |
| 2000 | 4.52 | 1.03 | 0.86 | 1.56 | 1.74 | 1.35 | 0.95 | 0.76 | 0.64 | 0.84 | 1.82 | 2.65 |
| 2001 | 14.24 | 6.78 | 5.52 | 14.78 | 7.05 | 3.31 | 1.23 | 0.86 | 0.91 | 0.86 | 3.64 | 2.05 |
| 2002 | 1.32 | 0.89 | 3.18 | 2.20 | 25.88 | 2.98 | 1.05 | 0.84 | 0.94 | 1.20 | 3.64 | 8.24 |
| 2003 | 7.52 | 1.39 | 0.97 | 2.62 | 27.14 | 5.98 | 1.69 | 0.91 | 0.86 | 0.86 | 3.20 | 2.37 |
| 2004 | 1.60 | 1.46 | 1.50 | 8.49 | 18.74 | 2.19 | 0.98 | 0.79 | 0.70 | 1.06 | 2.40 | 2.34 |
| 2005 | 1.88 | 1.88 | 1.69 | 2.36 | 10.87 | 10.01 | 2.38 | 1.03 | 0.74 | 0.85 | 2.16 | 1.34 |
| 2006 | 0.83 | 0.65 | 1.93 | 5.70 | 8.94 | 2.26 | 0.94 | 0.78 | 1.01 | 0.80 | 4.00 | 8.02 |
| 2007 | 6.77 | 1.50 | 1.34 | 2.63 | 4.93 | 3.71 | 1.46 | 0.87 | 0.81 | 0.83 | 0.88 | 0.89 |
| 2008 | 1.35 | 1.15 | 0.94 | 4.23 | 3.97 | 1.24 | 1.02 | 0.78 | 1.03 | 1.76 | 3.89 | 1.41 |
| 2009 | 0.86 | 1.18 | 1.06 | 1.65 | 2.02 | 1.44 | 1.27 | 0.74 | 0.60 | 1.52 | 2.06 | 2.04 |
| 2010 | 6.17 | 2.30 | 6.72 | 17.01 | 18.12 | 4.39 | 1.19 | 0.73 | 0.73 | 1.06 | 2.43 | 1.78 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

Sub-basin: **3BB** (Unit: $m^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 2.32 | 1.27 | 1.12 | 2.22 | 8.18 | 4.35 | 1.39 | 1.07 | 0.89 | 0.95 | 1.77 | 2.33 |
| 1992 | 1.22 | 1.06 | 0.93 | 5.39 | 10.80 | 1.95 | 1.62 | 0.98 | 0.82 | 0.83 | 2.20 | 2.62 |
| 1993 | 6.25 | 8.53 | 2.28 | 1.34 | 1.97 | 1.43 | 1.00 | 0.86 | 0.81 | 0.84 | 1.80 | 3.28 |
| 1994 | 1.23 | 1.37 | 1.17 | 3.75 | 5.88 | 2.23 | 1.29 | 1.10 | 0.93 | 1.69 | 9.41 | 5.72 |
| 1995 | 2.03 | 1.88 | 5.05 | 5.12 | 7.91 | 2.11 | 1.10 | 0.90 | 0.82 | 1.06 | 2.45 | 2.26 |
| 1996 | 1.40 | 1.15 | 1.47 | 2.95 | 1.69 | 2.52 | 1.48 | 0.96 | 0.93 | 0.85 | 2.73 | 3.40 |
| 1997 | 1.17 | 0.76 | 0.80 | 9.27 | 10.18 | 2.09 | 1.14 | 1.01 | 0.86 | 1.99 | 11.17 | 15.19 |
| 1998 | 13.50 | 12.56 | 6.44 | 7.84 | 16.16 | 7.58 | 2.52 | 1.67 | 1.13 | 1.14 | 1.27 | 1.47 |
| 1999 | 1.16 | 0.88 | 2.19 | 4.19 | 3.45 | 1.34 | 0.99 | 0.95 | 1.09 | 0.96 | 2.91 | 11.92 |
| 2000 | 3.08 | 1.09 | 1.02 | 1.61 | 1.73 | 1.38 | 1.08 | 0.95 | 0.90 | 1.02 | 1.87 | 2.36 |
| 2001 | 10.92 | 4.59 | 4.63 | 9.95 | 5.07 | 2.74 | 1.27 | 1.04 | 1.08 | 1.04 | 3.24 | 1.69 |
| 2002 | 1.35 | 1.04 | 2.85 | 2.82 | 16.59 | 2.23 | 1.13 | 1.00 | 1.11 | 1.34 | 3.24 | 6.11 |
| 2003 | 5.18 | 1.33 | 1.11 | 2.64 | 18.36 | 4.20 | 1.53 | 1.05 | 1.03 | 1.04 | 2.94 | 1.96 |
| 2004 | 1.60 | 1.46 | 1.53 | 6.83 | 13.43 | 1.82 | 1.09 | 0.96 | 0.92 | 1.25 | 2.26 | 2.10 |
| 2005 | 1.78 | 1.75 | 1.71 | 2.26 | 8.79 | 6.60 | 1.96 | 1.13 | 0.94 | 1.04 | 2.06 | 1.38 |
| 2006 | 1.01 | 0.88 | 1.87 | 4.30 | 5.96 | 1.82 | 1.06 | 1.00 | 1.15 | 0.99 | 3.39 | 5.27 |
| 2007 | 4.13 | 1.41 | 1.36 | 2.39 | 3.50 | 2.86 | 1.37 | 1.03 | 1.00 | 1.01 | 1.03 | 1.03 |
| 2008 | 1.45 | 1.21 | 1.21 | 3.75 | 2.98 | 1.25 | 1.15 | 0.98 | 1.20 | 1.82 | 3.35 | 1.34 |
| 2009 | 1.07 | 1.28 | 1.19 | 1.67 | 1.97 | 1.47 | 1.35 | 0.94 | 0.84 | 1.59 | 1.94 | 2.00 |
| 2010 | 4.72 | 1.95 | 5.32 | 10.98 | 13.20 | 3.24 | 1.23 | 0.94 | 0.94 | 1.23 | 2.26 | 1.73 |

Sub-basin: **3BC** (Unit: $m^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 9.43 | 6.27 | 6.11 | 6.98 | 28.26 | 16.27 | 8.21 | 6.73 | 5.96 | 6.01 | 6.39 | 8.09 |
| 1992 | 6.83 | 5.40 | 5.78 | 13.87 | 32.71 | 10.76 | 8.77 | 6.74 | 5.89 | 6.05 | 7.95 | 13.57 |
| 1993 | 22.24 | 21.07 | 9.76 | 7.24 | 12.86 | 11.04 | 7.71 | 6.31 | 5.71 | 5.80 | 5.85 | 10.76 |
| 1994 | 7.40 | 5.90 | 6.05 | 13.91 | 27.32 | 11.20 | 8.53 | 7.06 | 6.25 | 6.96 | 33.54 | 18.64 |
| 1995 | 8.97 | 6.76 | 15.26 | 18.57 | 27.36 | 10.77 | 7.84 | 6.62 | 5.91 | 5.96 | 7.90 | 11.56 |
| 1996 | 8.75 | 6.44 | 6.92 | 11.76 | 11.69 | 15.79 | 10.14 | 7.26 | 6.47 | 5.98 | 7.95 | 14.94 |
| 1997 | 7.12 | 5.30 | 5.67 | 24.35 | 30.68 | 9.90 | 8.04 | 7.05 | 5.92 | 7.84 | 39.26 | 37.94 |
| 1998 | 36.98 | 35.75 | 17.59 | 26.38 | 49.31 | 26.56 | 11.54 | 8.61 | 6.99 | 6.88 | 6.94 | 7.41 |
| 1999 | 6.74 | 5.76 | 6.49 | 11.20 | 16.61 | 8.45 | 6.83 | 6.45 | 6.20 | 6.23 | 8.63 | 35.19 |
| 2000 | 11.49 | 6.39 | 6.36 | 6.31 | 7.17 | 6.70 | 6.50 | 6.21 | 5.91 | 6.06 | 6.24 | 9.00 |
| 2001 | 30.67 | 14.03 | 12.96 | 28.24 | 25.10 | 10.51 | 7.54 | 6.70 | 6.15 | 6.25 | 9.54 | 10.12 |
| 2002 | 7.75 | 6.23 | 9.30 | 17.79 | 50.15 | 10.17 | 7.11 | 6.51 | 6.11 | 6.36 | 13.02 | 22.92 |
| 2003 | 16.24 | 7.04 | 6.51 | 7.79 | 55.88 | 18.73 | 8.82 | 7.03 | 6.61 | 6.58 | 11.17 | 10.67 |
| 2004 | 7.29 | 6.60 | 6.82 | 22.10 | 39.37 | 8.95 | 6.93 | 6.41 | 6.08 | 6.29 | 6.77 | 8.58 |
| 2005 | 7.67 | 6.42 | 6.61 | 7.37 | 29.45 | 18.68 | 9.45 | 7.10 | 6.32 | 6.28 | 6.75 | 6.79 |
| 2006 | 6.14 | 5.63 | 6.23 | 11.33 | 19.54 | 8.44 | 6.60 | 6.14 | 5.86 | 5.94 | 9.25 | 18.13 |
| 2007 | 13.20 | 6.51 | 6.36 | 8.92 | 17.48 | 18.39 | 9.54 | 8.75 | 8.44 | 8.39 | 8.85 | 7.59 |
| 2008 | 6.81 | 5.93 | 6.18 | 15.96 | 13.57 | 7.52 | 6.52 | 6.14 | 5.79 | 7.57 | 15.15 | 9.08 |
| 2009 | 6.19 | 5.35 | 5.75 | 5.60 | 6.03 | 5.86 | 5.74 | 5.54 | 5.30 | 5.59 | 5.75 | 6.33 |
| 2010 | 12.23 | 7.58 | 14.27 | 26.52 | 31.68 | 11.07 | 6.53 | 5.71 | 5.37 | 5.51 | 5.81 | 6.07 |

Sub-basin: **3BD** (Unit: $m^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 3.37 | 2.25 | 2.18 | 2.26 | 13.03 | 5.76 | 2.92 | 2.33 | 2.08 | 2.12 | 2.08 | 2.42 |
| 1992 | 2.34 | 1.90 | 2.05 | 6.81 | 13.21 | 3.86 | 3.04 | 2.38 | 2.06 | 2.09 | 2.20 | 5.10 |
| 1993 | 10.11 | 8.41 | 3.33 | 2.46 | 4.36 | 4.16 | 2.80 | 2.22 | 2.02 | 2.06 | 2.06 | 4.80 |
| 1994 | 2.79 | 2.05 | 2.09 | 5.64 | 10.94 | 3.87 | 2.90 | 2.34 | 2.08 | 2.18 | 15.50 | 7.36 |
| 1995 | 3.16 | 2.31 | 5.73 | 8.25 | 10.81 | 3.79 | 2.66 | 2.29 | 2.07 | 2.11 | 2.61 | 5.25 |
| 1996 | 3.33 | 2.23 | 2.35 | 4.38 | 4.21 | 6.57 | 3.53 | 2.54 | 2.13 | 2.08 | 2.39 | 6.62 |
| 1997 | 2.56 | 1.89 | 2.04 | 12.97 | 13.04 | 3.45 | 2.76 | 2.39 | 2.08 | 2.45 | 18.56 | 17.48 |
| 1998 | 17.28 | 15.32 | 7.32 | 11.38 | 20.73 | 9.43 | 3.73 | 2.88 | 2.37 | 2.32 | 2.25 | 2.30 |
| 1999 | 2.27 | 2.03 | 2.29 | 5.07 | 6.74 | 3.02 | 2.38 | 2.25 | 2.15 | 2.21 | 3.65 | 15.77 |
| 2000 | 4.03 | 2.31 | 2.30 | 2.22 | 2.28 | 2.17 | 2.20 | 2.18 | 2.11 | 2.16 | 2.14 | 3.31 |
| 2001 | 13.69 | 5.02 | 5.33 | 12.26 | 9.26 | 3.61 | 2.64 | 2.32 | 2.16 | 2.21 | 3.19 | 4.03 |
| 2002 | 2.72 | 2.17 | 3.15 | 8.11 | 21.92 | 3.85 | 2.62 | 2.32 | 2.18 | 2.24 | 4.71 | 10.57 |
| 2003 | 5.68 | 2.47 | 2.33 | 2.43 | 26.07 | 6.89 | 3.19 | 2.46 | 2.24 | 2.26 | 2.94 | 4.24 |
| 2004 | 2.61 | 2.23 | 2.33 | 9.90 | 15.71 | 3.36 | 2.54 | 2.31 | 2.18 | 2.25 | 2.29 | 3.40 |
| 2005 | 3.00 | 2.29 | 2.29 | 2.36 | 13.07 | 7.53 | 3.48 | 2.54 | 2.21 | 2.22 | 2.19 | 2.24 |
| 2006 | 2.18 | 2.02 | 2.22 | 6.67 | 9.25 | 2.99 | 2.34 | 2.20 | 2.10 | 2.14 | 5.44 | 8.27 |
| 2007 | 5.28 | 2.36 | 2.33 | 3.88 | 7.66 | 7.12 | 3.42 | 2.74 | 2.74 | 2.63 | 3.12 | 2.90 |
| 2008 | 2.48 | 2.14 | 2.18 | 7.67 | 4.78 | 2.70 | 2.29 | 2.16 | 2.04 | 2.16 | 5.28 | 3.30 |
| 2009 | 2.26 | 1.94 | 2.10 | 2.04 | 2.16 | 2.07 | 2.05 | 2.02 | 1.94 | 2.04 | 2.23 | 2.77 |
| 2010 | 6.58 | 2.86 | 6.81 | 11.94 | 13.72 | 4.06 | 2.46 | 2.13 | 1.99 | 2.04 | 2.12 | 2.38 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

## 3CB & 3DA

Sub-basin: **3CB** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 7.05 | 5.81 | 6.25 | 6.57 | 15.49 | 10.32 | 7.34 | 6.42 | 5.94 | 6.09 | 6.20 | 6.80 |
| 1992 | 6.48 | 5.56 | 5.98 | 7.83 | 19.52 | 7.66 | 7.42 | 6.38 | 5.81 | 5.95 | 6.52 | 7.88 |
| 1993 | 13.16 | 14.81 | 6.71 | 6.55 | 8.64 | 8.49 | 6.98 | 6.11 | 5.71 | 5.92 | 6.22 | 7.11 |
| 1994 | 6.36 | 5.85 | 6.15 | 7.30 | 15.30 | 7.99 | 7.13 | 6.36 | 5.86 | 6.37 | 22.16 | 13.00 |
| 1995 | 6.69 | 6.17 | 8.28 | 10.87 | 14.96 | 8.05 | 6.86 | 6.28 | 5.83 | 6.11 | 6.77 | 8.62 |
| 1996 | 7.66 | 6.05 | 6.69 | 9.02 | 8.53 | 10.35 | 8.07 | 6.56 | 5.91 | 5.85 | 6.17 | 10.55 |
| 1997 | 6.44 | 5.27 | 5.76 | 20.67 | 20.14 | 6.74 | 6.85 | 6.43 | 5.77 | 6.56 | 27.36 | 27.65 |
| 1998 | 28.60 | 23.86 | 11.22 | 18.38 | 30.28 | 15.18 | 7.55 | 7.45 | 6.58 | 6.64 | 6.52 | 6.74 |
| 1999 | 6.60 | 5.80 | 6.77 | 7.33 | 11.00 | 7.50 | 6.61 | 6.36 | 6.19 | 6.32 | 6.81 | 23.01 |
| 2000 | 8.30 | 6.11 | 6.40 | 6.45 | 6.62 | 6.32 | 6.34 | 6.18 | 5.95 | 6.19 | 6.25 | 7.18 |
| 2001 | 18.18 | 9.91 | 8.13 | 18.08 | 14.12 | 8.12 | 6.90 | 6.45 | 6.16 | 6.29 | 6.99 | 7.80 |
| 2002 | 6.95 | 6.03 | 7.73 | 13.53 | 34.62 | 7.38 | 6.77 | 6.41 | 6.21 | 6.47 | 7.33 | 14.90 |
| 2003 | 10.48 | 6.42 | 6.51 | 6.76 | 35.31 | 11.26 | 7.70 | 6.68 | 6.29 | 6.43 | 7.48 | 8.68 |
| 2004 | 6.98 | 6.22 | 6.67 | 13.97 | 23.72 | 7.17 | 6.69 | 6.41 | 6.12 | 6.46 | 6.64 | 7.47 |
| 2005 | 7.22 | 6.17 | 6.61 | 6.65 | 17.45 | 12.65 | 7.20 | 6.61 | 6.09 | 6.27 | 6.40 | 6.40 |
| 2006 | 6.19 | 5.65 | 6.54 | 8.62 | 15.10 | 6.61 | 6.31 | 6.11 | 5.95 | 6.00 | 8.39 | 14.35 |
| 2007 | 11.37 | 5.84 | 6.59 | 7.40 | 12.45 | 10.71 | 7.85 | 6.91 | 6.66 | 6.60 | 7.20 | 7.05 |
| 2008 | 6.71 | 5.95 | 6.15 | 11.02 | 9.63 | 6.75 | 6.27 | 5.99 | 5.85 | 6.31 | 8.35 | 7.38 |
| 2009 | 6.13 | 5.57 | 5.99 | 6.04 | 6.30 | 5.91 | 5.99 | 5.69 | 5.44 | 5.97 | 6.13 | 6.27 |
| 2010 | 8.63 | 5.23 | 10.21 | 19.86 | 18.50 | 7.76 | 6.34 | 5.78 | 5.51 | 5.78 | 6.18 | 6.30 |

Sub-basin: **3DA** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 4.40 | 1.26 | 2.72 | 0.00 | 0.76 | 2.38 | 3.43 | 4.28 | 3.98 | 4.01 | 3.43 | 2.46 |
| 1992 | 2.66 | 2.87 | 3.98 | 0.00 | 11.46 | 1.27 | 2.87 | 4.00 | 4.01 | 4.01 | 3.28 | 3.42 |
| 1993 | 19.78 | 18.94 | 3.10 | 0.10 | 1.37 | 3.26 | 3.87 | 4.25 | 3.97 | 4.00 | 3.56 | 5.19 |
| 1994 | 1.72 | 2.52 | 3.99 | 2.91 | 7.52 | 1.62 | 2.91 | 4.07 | 3.98 | 3.56 | 26.22 | 17.28 |
| 1995 | 2.62 | 0.06 | 0.91 | 2.80 | 4.00 | 1.44 | 4.11 | 4.10 | 3.99 | 3.87 | 2.56 | 0.94 |
| 1996 | 1.01 | 3.04 | 3.69 | 0.30 | 1.50 | 2.91 | 3.65 | 4.16 | 3.93 | 4.22 | 5.26 | 11.51 |
| 1997 | 1.22 | 3.44 | 3.88 | 13.77 | 19.52 | 2.60 | 1.85 | 4.12 | 4.04 | 3.32 | 26.09 | 55.29 |
| 1998 | 60.78 | 24.51 | 5.77 | 15.35 | 20.93 | 6.80 | 1.16 | 2.34 | 3.95 | 3.98 | 3.77 | 3.89 |
| 1999 | 3.99 | 3.76 | 2.89 | 5.75 | 3.97 | 1.61 | 3.99 | 4.06 | 4.10 | 4.06 | 2.54 | 24.41 |
| 2000 | 5.45 | 0.94 | 4.29 | 3.41 | 3.79 | 3.61 | 4.02 | 4.23 | 4.03 | 4.20 | 3.14 | 2.06 |
| 2001 | 10.87 | 6.07 | 1.08 | 20.75 | 3.81 | 1.18 | 3.85 | 3.99 | 3.98 | 4.01 | 1.64 | 1.94 |
| 2002 | 0.90 | 2.67 | 1.10 | 0.00 | 28.04 | 2.45 | 2.20 | 4.16 | 4.02 | 3.88 | 1.77 | 16.29 |
| 2003 | 7.55 | 1.13 | 3.71 | 2.71 | 35.69 | 3.83 | 1.58 | 4.19 | 4.02 | 3.90 | 2.19 | 0.82 |
| 2004 | 2.28 | 3.21 | 3.83 | 3.86 | 8.30 | 1.10 | 3.87 | 4.02 | 4.06 | 4.10 | 3.01 | 1.15 |
| 2005 | 0.48 | 1.86 | 3.40 | 2.97 | 2.22 | 7.09 | 1.67 | 4.33 | 3.72 | 4.13 | 3.47 | 4.10 |
| 2006 | 4.07 | 3.84 | 3.63 | 5.66 | 10.41 | 1.32 | 3.45 | 4.25 | 3.84 | 4.09 | 10.84 | 18.23 |
| 2007 | 16.30 | 0.54 | 3.07 | 4.22 | 6.86 | 2.19 | 2.54 | 3.91 | 3.72 | 3.91 | 3.66 | 3.96 |
| 2008 | 3.90 | 3.51 | 3.71 | 2.06 | 2.01 | 3.24 | 3.89 | 4.30 | 3.86 | 3.50 | 1.97 | 3.72 |
| 2009 | 4.16 | 3.55 | 4.33 | 3.58 | 3.67 | 3.94 | 4.08 | 4.13 | 3.97 | 3.54 | 3.79 | 2.67 |
| 2010 | 3.73 | 1.90 | 13.27 | 19.51 | 5.04 | 2.07 | 3.11 | 4.27 | 3.86 | 3.70 | 3.50 | 3.83 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

## 5. Tana River Catchment Area (TNCA)

## 4AA, 4AB, 4AC & 4AD

Sub-basin: **4AA** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 8.43 | 3.49 | 3.16 | 3.28 | 42.10 | 9.42 | 4.01 | 3.39 | 3.04 | 3.05 | 4.14 | 7.28 |
| 1992 | 4.19 | 2.97 | 3.01 | 3.04 | 16.56 | 9.80 | 4.03 | 3.24 | 2.89 | 2.93 | 6.37 | 21.74 |
| 1993 | 16.61 | 11.05 | 5.05 | 7.17 | 16.92 | 6.00 | 3.61 | 3.06 | 2.85 | 2.91 | 3.41 | 9.24 |
| 1994 | 4.09 | 3.08 | 2.97 | 12.51 | 39.42 | 5.94 | 4.13 | 3.41 | 2.96 | 3.21 | 32.53 | 10.40 |
| 1995 | 4.83 | 4.74 | 7.70 | 11.53 | 33.51 | 5.63 | 3.48 | 3.10 | 2.92 | 8.20 | 18.81 | 11.45 |
| 1996 | 5.73 | 3.51 | 3.16 | 3.58 | 11.44 | 9.87 | 4.48 | 3.29 | 2.92 | 2.91 | 2.80 | 3.91 |
| 1997 | 3.21 | 2.62 | 2.83 | 16.96 | 23.59 | 4.92 | 3.96 | 3.11 | 2.78 | 20.58 | 54.48 | 24.30 |
| 1998 | 28.14 | 14.04 | 7.48 | 18.34 | 30.91 | 7.36 | 4.15 | 3.49 | 3.18 | 3.18 | 3.18 | 3.92 |
| 1999 | 3.37 | 2.83 | 3.09 | 4.15 | 19.76 | 4.60 | 3.34 | 3.10 | 2.93 | 3.00 | 4.28 | 19.91 |
| 2000 | 8.87 | 3.90 | 3.18 | 2.95 | 3.07 | 2.92 | 2.93 | 2.91 | 2.80 | 2.87 | 2.76 | 4.18 |
| 2001 | 7.42 | 5.50 | 3.49 | 17.15 | 21.60 | 4.35 | 3.29 | 2.94 | 2.75 | 2.81 | 7.01 | 8.32 |
| 2002 | 3.91 | 2.82 | 2.87 | 7.84 | 30.60 | 4.81 | 3.33 | 2.89 | 2.71 | 2.79 | 18.75 | 10.82 |
| 2003 | 7.56 | 3.14 | 2.87 | 7.27 | 32.46 | 10.45 | 3.66 | 3.08 | 2.92 | 5.08 | 19.59 | 16.11 |
| 2004 | 5.25 | 3.59 | 3.07 | 5.72 | 12.79 | 3.49 | 2.96 | 2.81 | 2.67 | 2.76 | 19.51 | 9.54 |
| 2005 | 3.83 | 2.67 | 2.77 | 2.69 | 14.86 | 12.57 | 3.98 | 3.12 | 2.80 | 2.80 | 4.63 | 4.51 |
| 2006 | 3.01 | 2.53 | 2.91 | 18.75 | 23.88 | 3.93 | 2.93 | 2.74 | 2.59 | 5.28 | 36.75 | 17.28 |
| 2007 | 15.45 | 3.82 | 3.23 | 12.10 | 15.94 | 12.74 | 3.97 | 4.61 | 3.91 | 4.36 | 9.00 | 5.39 |
| 2008 | 4.46 | 3.22 | 2.86 | 7.71 | 7.72 | 4.23 | 3.01 | 2.75 | 2.60 | 3.59 | 9.32 | 4.37 |
| 2009 | 3.10 | 2.59 | 2.66 | 2.53 | 8.51 | 3.88 | 2.78 | 2.58 | 2.46 | 2.55 | 10.54 | 6.50 |
| 2010 | 4.69 | 2.78 | 14.89 | 28.77 | 26.26 | 4.08 | 2.89 | 2.67 | 2.53 | 2.58 | 7.12 | 5.27 |

Sub-basin: **4AB** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 8.68 | 5.15 | 5.06 | 6.08 | 47.38 | 16.29 | 8.13 | 6.46 | 5.47 | 5.20 | 5.74 | 8.01 |
| 1992 | 6.35 | 4.62 | 4.84 | 4.79 | 22.35 | 13.88 | 9.45 | 6.93 | 5.68 | 5.64 | 11.33 | 23.15 |
| 1993 | 20.39 | 15.38 | 7.84 | 6.54 | 19.78 | 11.41 | 6.92 | 5.28 | 4.69 | 4.73 | 4.55 | 5.04 |
| 1994 | 5.08 | 4.58 | 4.71 | 12.36 | 47.78 | 11.82 | 8.98 | 6.89 | 5.77 | 6.22 | 33.51 | 14.14 |
| 1995 | 8.57 | 7.45 | 11.98 | 9.86 | 35.96 | 10.10 | 7.83 | 5.88 | 5.25 | 8.44 | 22.00 | 12.69 |
| 1996 | 8.74 | 5.60 | 5.38 | 6.90 | 13.50 | 15.89 | 8.50 | 6.12 | 5.54 | 5.22 | 5.14 | 9.44 |
| 1997 | 5.78 | 4.35 | 4.57 | 21.28 | 33.53 | 8.84 | 7.87 | 5.87 | 4.74 | 20.67 | 62.79 | 28.96 |
| 1998 | 36.07 | 24.38 | 10.48 | 21.40 | 44.75 | 15.23 | 8.03 | 6.02 | 5.22 | 5.15 | 5.06 | 5.59 |
| 1999 | 5.19 | 4.48 | 4.91 | 4.73 | 15.59 | 7.62 | 5.59 | 5.07 | 4.74 | 4.79 | 4.68 | 13.66 |
| 2000 | 8.91 | 5.11 | 4.88 | 4.59 | 4.76 | 4.56 | 4.62 | 4.58 | 4.40 | 4.52 | 4.36 | 4.89 |
| 2001 | 8.55 | 8.46 | 6.17 | 30.16 | 30.06 | 8.47 | 6.20 | 5.45 | 4.60 | 4.60 | 9.43 | 10.09 |
| 2002 | 6.36 | 4.78 | 4.92 | 8.70 | 39.00 | 8.13 | 5.76 | 4.81 | 4.40 | 4.56 | 21.11 | 15.50 |
| 2003 | 13.83 | 5.27 | 4.66 | 7.96 | 48.35 | 16.51 | 7.00 | 6.01 | 6.50 | 8.85 | 21.43 | 15.05 |
| 2004 | 6.88 | 5.14 | 4.86 | 8.25 | 24.11 | 6.76 | 5.06 | 4.61 | 4.31 | 4.45 | 15.69 | 13.31 |
| 2005 | 7.14 | 4.44 | 4.47 | 4.28 | 15.41 | 16.78 | 6.84 | 5.06 | 5.38 | 5.78 | 8.49 | 6.94 |
| 2006 | 4.73 | 4.05 | 4.69 | 14.27 | 27.32 | 6.89 | 4.86 | 4.45 | 4.14 | 4.32 | 36.14 | 19.63 |
| 2007 | 15.64 | 6.56 | 5.36 | 11.48 | 20.45 | 21.87 | 7.88 | 11.45 | 9.10 | 11.28 | 14.27 | 7.62 |
| 2008 | 5.62 | 4.33 | 4.42 | 8.75 | 10.47 | 6.87 | 4.82 | 4.39 | 4.13 | 5.19 | 13.76 | 6.99 |
| 2009 | 4.81 | 3.91 | 4.16 | 3.98 | 4.29 | 4.26 | 4.12 | 4.03 | 3.87 | 3.98 | 5.27 | 5.92 |
| 2010 | 7.39 | 4.80 | 15.36 | 25.64 | 29.87 | 7.36 | 4.78 | 4.24 | 4.01 | 4.17 | 12.89 | 7.53 |

Sub-basin: **4AC** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 10.16 | 6.75 | 7.00 | 9.46 | 43.03 | 18.90 | 10.33 | 8.45 | 7.69 | 8.58 | 9.25 | 9.20 |
| 1992 | 7.81 | 6.16 | 6.59 | 7.77 | 24.80 | 16.74 | 11.76 | 9.26 | 8.29 | 9.66 | 12.56 | 22.28 |
| 1993 | 20.95 | 17.15 | 10.13 | 8.68 | 21.52 | 14.45 | 9.23 | 7.39 | 6.64 | 6.61 | 6.68 | 9.02 |
| 1994 | 7.39 | 6.54 | 6.91 | 14.66 | 45.03 | 14.84 | 11.09 | 9.29 | 8.17 | 10.30 | 32.85 | 16.76 |
| 1995 | 10.31 | 8.83 | 13.81 | 11.92 | 34.79 | 13.61 | 11.04 | 8.05 | 7.84 | 8.53 | 20.12 | 14.29 |
| 1996 | 10.89 | 7.93 | 8.23 | 10.86 | 14.79 | 17.87 | 10.89 | 8.43 | 9.16 | 8.06 | 8.69 | 11.19 |
| 1997 | 7.37 | 5.91 | 6.29 | 26.49 | 35.74 | 11.28 | 10.38 | 8.74 | 7.08 | 19.67 | 56.47 | 28.14 |
| 1998 | 34.24 | 26.54 | 13.37 | 22.72 | 43.00 | 19.79 | 10.63 | 8.18 | 7.56 | 8.22 | 8.99 | 8.78 |
| 1999 | 7.43 | 6.24 | 6.79 | 6.68 | 18.31 | 9.82 | 7.91 | 7.58 | 8.25 | 7.33 | 8.56 | 18.67 |
| 2000 | 11.08 | 6.77 | 6.67 | 6.37 | 7.10 | 6.86 | 6.77 | 6.73 | 6.36 | 6.77 | 8.39 | 10.13 |
| 2001 | 13.25 | 11.13 | 8.94 | 30.31 | 32.29 | 10.92 | 8.80 | 8.24 | 6.94 | 8.33 | 12.58 | 11.25 |
| 2002 | 8.76 | 6.84 | 7.98 | 11.59 | 41.76 | 10.67 | 8.01 | 7.05 | 6.52 | 8.26 | 24.79 | 16.50 |
| 2003 | 16.36 | 7.15 | 6.52 | 9.24 | 46.88 | 19.61 | 9.34 | 8.54 | 8.72 | 9.18 | 20.79 | 16.55 |
| 2004 | 8.70 | 6.81 | 6.87 | 12.29 | 26.78 | 9.03 | 7.13 | 6.54 | 6.11 | 6.63 | 16.42 | 15.03 |
| 2005 | 9.02 | 6.35 | 6.52 | 6.68 | 17.46 | 18.41 | 8.83 | 7.05 | 8.28 | 7.97 | 9.34 | 7.96 |
| 2006 | 6.31 | 5.60 | 6.22 | 10.12 | 25.01 | 8.85 | 6.80 | 6.33 | 5.91 | 6.21 | 29.78 | 20.36 |
| 2007 | 18.11 | 8.18 | 7.09 | 12.76 | 22.31 | 24.53 | 10.31 | 14.26 | 11.47 | 12.75 | 17.02 | 9.84 |
| 2008 | 7.60 | 6.06 | 6.30 | 13.23 | 13.56 | 8.71 | 6.77 | 6.42 | 6.73 | 10.35 | 14.25 | 9.08 |
| 2009 | 6.48 | 5.40 | 5.77 | 5.53 | 6.19 | 6.37 | 5.90 | 5.65 | 5.40 | 5.67 | 8.00 | 7.34 |
| 2010 | 9.44 | 6.26 | 14.57 | 26.39 | 31.95 | 9.11 | 6.46 | 6.03 | 7.21 | 9.07 | 11.72 | 8.39 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

Sub-basin: **4AD** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 10.79 | 6.91 | 7.22 | 10.46 | 56.55 | 22.69 | 11.65 | 9.07 | 8.08 | 9.52 | 11.25 | 11.68 |
| 1992 | 8.52 | 6.29 | 6.65 | 10.66 | 41.08 | 20.02 | 13.95 | 10.40 | 9.17 | 11.19 | 18.81 | 28.27 |
| 1993 | 26.55 | 20.36 | 11.23 | 9.98 | 32.52 | 17.58 | 10.40 | 7.80 | 6.87 | 6.77 | 7.18 | 13.19 |
| 1994 | 8.72 | 6.97 | 7.18 | 24.99 | 58.79 | 17.45 | 13.17 | 10.34 | 9.06 | 13.64 | 49.65 | 20.77 |
| 1995 | 11.05 | 9.57 | 16.91 | 17.10 | 45.25 | 15.59 | 13.36 | 8.75 | 8.41 | 8.70 | 25.09 | 17.60 |
| 1996 | 12.57 | 9.02 | 9.48 | 15.98 | 22.64 | 21.62 | 12.13 | 9.21 | 10.37 | 8.79 | 9.77 | 16.35 |
| 1997 | 8.07 | 6.05 | 6.34 | 38.74 | 45.56 | 13.01 | 12.81 | 10.28 | 7.71 | 26.53 | 71.49 | 35.31 |
| 1998 | 44.29 | 34.68 | 15.45 | 33.89 | 53.84 | 23.63 | 11.59 | 8.63 | 8.00 | 9.16 | 11.03 | 11.15 |
| 1999 | 8.05 | 6.39 | 6.88 | 7.09 | 27.29 | 10.88 | 8.44 | 8.07 | 9.27 | 7.76 | 10.69 | 30.22 |
| 2000 | 12.29 | 6.97 | 6.73 | 6.47 | 8.43 | 8.05 | 7.27 | 7.03 | 6.51 | 7.08 | 9.15 | 14.02 |
| 2001 | 22.08 | 13.66 | 9.97 | 43.22 | 42.58 | 12.58 | 9.87 | 9.11 | 7.40 | 9.43 | 18.22 | 14.23 |
| 2002 | 9.98 | 7.41 | 8.87 | 21.35 | 59.96 | 11.83 | 8.54 | 7.40 | 6.79 | 9.13 | 36.74 | 21.66 |
| 2003 | 19.29 | 7.55 | 6.64 | 13.01 | 64.77 | 24.79 | 10.15 | 8.98 | 10.00 | 12.26 | 29.36 | 18.16 |
| 2004 | 8.92 | 7.08 | 7.09 | 19.35 | 37.85 | 10.04 | 7.36 | 6.64 | 6.19 | 6.77 | 22.87 | 17.54 |
| 2005 | 9.49 | 6.58 | 6.74 | 6.99 | 24.51 | 21.04 | 9.70 | 7.37 | 8.68 | 8.39 | 11.49 | 9.49 |
| 2006 | 6.48 | 5.61 | 6.25 | 10.85 | 28.68 | 9.68 | 7.11 | 6.42 | 5.96 | 6.31 | 34.29 | 23.62 |
| 2007 | 19.57 | 8.44 | 7.07 | 20.22 | 30.99 | 33.48 | 12.16 | 20.50 | 14.72 | 19.06 | 21.93 | 11.22 |
| 2008 | 8.27 | 6.36 | 6.53 | 22.08 | 17.14 | 9.82 | 7.13 | 6.77 | 7.39 | 13.91 | 20.72 | 10.60 |
| 2009 | 6.59 | 5.37 | 5.73 | 5.51 | 6.38 | 7.13 | 6.10 | 5.68 | 5.40 | 5.82 | 9.72 | 8.06 |
| 2010 | 12.22 | 7.02 | 18.93 | 31.35 | 38.01 | 9.55 | 6.36 | 5.82 | 6.16 | 8.07 | 12.46 | 9.20 |

## 4BA, 4BB, 4BC, 4BD, 4BE, 4BF & 4BG

Sub-basin: **4BA** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 3.40 | 1.38 | 1.15 | 1.10 | 19.63 | 5.87 | 1.95 | 1.36 | 1.14 | 1.08 | 1.07 | 1.50 |
| 1992 | 1.41 | 1.03 | 1.09 | 1.28 | 17.63 | 7.03 | 2.12 | 1.35 | 1.10 | 1.04 | 2.92 | 8.22 |
| 1993 | 8.57 | 6.54 | 2.40 | 1.76 | 11.74 | 4.07 | 1.82 | 1.21 | 1.06 | 1.07 | 0.96 | 1.79 |
| 1994 | 1.51 | 1.10 | 1.07 | 9.28 | 23.11 | 4.00 | 2.03 | 1.35 | 1.11 | 1.03 | 22.94 | 6.28 |
| 1995 | 2.30 | 1.68 | 2.83 | 9.33 | 23.93 | 4.04 | 1.66 | 1.26 | 1.08 | 0.52 | 5.32 | 5.01 |
| 1996 | 2.75 | 1.43 | 1.20 | 1.70 | 4.84 | 5.08 | 1.93 | 1.22 | 1.05 | 1.06 | 0.91 | 1.13 |
| 1997 | 1.09 | 0.94 | 1.02 | 18.51 | 17.02 | 2.88 | 1.70 | 1.18 | 1.04 | 4.02 | 32.60 | 15.06 |
| 1998 | 14.26 | 8.57 | 3.69 | 10.87 | 22.04 | 6.08 | 2.12 | 1.36 | 1.12 | 1.14 | 1.02 | 1.16 |
| 1999 | 1.13 | 1.00 | 1.09 | 1.00 | 7.59 | 2.44 | 1.33 | 1.10 | 1.05 | 1.07 | 2.12 | 12.60 |
| 2000 | 4.04 | 1.44 | 1.12 | 1.04 | 1.04 | 1.04 | 1.05 | 1.04 | 1.00 | 1.02 | 0.93 | 1.18 |
| 2001 | 3.36 | 2.63 | 1.34 | 8.21 | 16.92 | 2.72 | 1.39 | 1.12 | 0.99 | 1.00 | 1.82 | 3.32 |
| 2002 | 1.53 | 1.04 | 1.07 | 7.35 | 29.66 | 2.95 | 1.43 | 1.09 | 1.00 | 0.89 | 11.91 | 5.76 |
| 2003 | 4.20 | 1.34 | 1.06 | 1.79 | 26.24 | 7.43 | 1.79 | 1.20 | 1.13 | 0.68 | 7.19 | 6.79 |
| 2004 | 2.14 | 1.22 | 1.09 | 1.42 | 8.31 | 1.84 | 1.17 | 1.03 | 0.97 | 0.97 | 7.18 | 6.32 |
| 2005 | 2.19 | 1.06 | 1.01 | 0.95 | 12.74 | 9.84 | 2.18 | 1.25 | 0.97 | 0.98 | 1.03 | 1.33 |
| 2006 | 1.03 | 0.91 | 0.96 | 1.99 | 16.16 | 2.52 | 1.24 | 1.01 | 0.94 | 0.87 | 15.45 | 9.31 |
| 2007 | 8.56 | 1.72 | 1.14 | 3.87 | 10.28 | 8.32 | 2.04 | 1.93 | 1.64 | 1.35 | 5.11 | 2.45 |
| 2008 | 1.67 | 1.12 | 0.96 | 4.45 | 5.58 | 2.13 | 1.20 | 1.01 | 0.92 | 0.86 | 1.62 | 1.48 |
| 2009 | 1.04 | 0.87 | 0.93 | 0.90 | 1.40 | 1.46 | 0.99 | 0.91 | 0.87 | 0.88 | 1.83 | 1.90 |
| 2010 | 1.51 | 1.07 | 2.55 | 12.48 | 20.26 | 2.67 | 1.19 | 0.94 | 0.87 | 0.86 | 1.08 | 1.60 |

Sub-basin: **4BB** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 5.08 | 3.29 | 3.45 | 6.11 | 36.47 | 11.83 | 5.25 | 4.24 | 3.72 | 3.90 | 7.99 | 7.05 |
| 1992 | 4.05 | 3.03 | 3.24 | 12.69 | 35.37 | 11.27 | 6.65 | 4.31 | 3.63 | 5.56 | 16.13 | 18.72 |
| 1993 | 18.01 | 12.04 | 5.21 | 6.44 | 27.23 | 10.45 | 4.86 | 3.59 | 3.16 | 3.18 | 4.00 | 11.51 |
| 1994 | 4.15 | 3.18 | 3.18 | 24.02 | 38.36 | 8.55 | 6.77 | 5.03 | 4.05 | 10.29 | 39.82 | 12.16 |
| 1995 | 5.07 | 5.22 | 10.04 | 16.56 | 34.31 | 8.78 | 6.10 | 4.05 | 3.43 | 3.72 | 16.22 | 10.67 |
| 1996 | 6.47 | 4.89 | 5.47 | 13.69 | 16.85 | 11.26 | 5.23 | 3.72 | 4.06 | 3.39 | 7.14 | 10.52 |
| 1997 | 3.54 | 2.73 | 2.94 | 35.60 | 31.66 | 6.96 | 6.87 | 5.06 | 3.29 | 17.01 | 47.89 | 24.24 |
| 1998 | 28.78 | 23.48 | 8.54 | 25.96 | 36.45 | 14.58 | 5.07 | 3.95 | 3.52 | 3.82 | 8.32 | 5.93 |
| 1999 | 3.84 | 3.02 | 3.23 | 6.53 | 23.28 | 4.84 | 3.62 | 3.29 | 3.33 | 3.19 | 12.44 | 24.91 |
| 2000 | 5.45 | 3.03 | 3.08 | 2.95 | 6.61 | 3.87 | 3.25 | 3.02 | 2.82 | 2.88 | 4.53 | 10.40 |
| 2001 | 20.07 | 7.61 | 5.52 | 31.31 | 29.76 | 5.82 | 3.91 | 3.61 | 2.98 | 2.93 | 15.38 | 7.81 |
| 2002 | 4.76 | 3.14 | 5.37 | 23.33 | 47.44 | 5.37 | 3.61 | 3.07 | 2.84 | 4.16 | 29.18 | 14.07 |
| 2003 | 9.89 | 3.19 | 2.97 | 10.99 | 48.89 | 14.95 | 4.16 | 4.12 | 4.55 | 7.39 | 21.45 | 8.79 |
| 2004 | 3.75 | 3.02 | 3.03 | 15.56 | 27.05 | 4.24 | 3.15 | 2.94 | 2.79 | 3.26 | 17.06 | 10.72 |
| 2005 | 4.08 | 2.79 | 2.86 | 2.81 | 23.61 | 12.91 | 4.24 | 3.11 | 2.99 | 3.11 | 6.70 | 4.31 |
| 2006 | 2.82 | 2.49 | 2.66 | 4.50 | 16.69 | 3.79 | 2.97 | 2.63 | 2.47 | 2.52 | 19.88 | 13.79 |
| 2007 | 9.76 | 3.06 | 2.70 | 15.87 | 22.24 | 21.50 | 6.84 | 14.07 | 7.74 | 14.84 | 14.28 | 5.61 |
| 2008 | 3.84 | 2.89 | 2.89 | 20.62 | 10.92 | 4.08 | 3.00 | 2.95 | 2.64 | 9.52 | 12.95 | 4.90 |
| 2009 | 2.71 | 2.29 | 2.47 | 2.37 | 3.96 | 3.36 | 2.51 | 2.38 | 2.27 | 2.32 | 5.74 | 3.48 |
| 2010 | 6.83 | 2.79 | 11.11 | 20.03 | 26.77 | 3.89 | 2.52 | 2.34 | 2.23 | 2.28 | 5.16 | 3.63 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

Sub-basin: **4BC** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 9.71 | 5.14 | 4.69 | 1.93 | 3.70 | 5.80 | 4.49 | 4.21 | 4.04 | 3.97 | 0.00 | 1.70 |
| 1992 | 4.27 | 4.08 | 4.46 | 0.00 | 0.00 | 8.39 | 3.26 | 3.90 | 3.86 | 2.06 | 0.00 | 2.10 |
| 1993 | 3.27 | 6.67 | 5.90 | 3.57 | 0.00 | 2.88 | 4.03 | 4.25 | 4.22 | 4.38 | 3.31 | 0.00 |
| 1994 | 4.25 | 4.06 | 4.29 | 0.00 | 9.59 | 5.52 | 2.76 | 3.07 | 3.36 | 0.00 | 5.67 | 6.48 |
| 1995 | 5.09 | 3.15 | 0.57 | 2.88 | 13.76 | 4.85 | 2.74 | 3.98 | 4.12 | 3.91 | 1.48 | 6.22 |
| 1996 | 5.51 | 3.14 | 2.50 | 0.00 | 0.00 | 4.13 | 4.34 | 4.21 | 3.27 | 4.10 | 0.05 | 0.00 |
| 1997 | 3.86 | 3.89 | 4.35 | 0.00 | 1.88 | 4.02 | 1.62 | 2.51 | 3.86 | 0.00 | 17.93 | 10.57 |
| 1998 | 5.87 | 0.00 | 6.09 | 3.41 | 24.64 | 4.87 | 5.46 | 4.64 | 4.32 | 4.12 | 0.00 | 2.07 |
| 1999 | 4.02 | 3.99 | 4.49 | 1.07 | 0.00 | 5.63 | 4.62 | 4.45 | 4.04 | 4.36 | 0.00 | 3.12 |
| 2000 | 10.66 | 5.55 | 4.74 | 4.45 | 1.01 | 3.41 | 4.17 | 4.36 | 4.27 | 4.41 | 2.50 | 0.00 |
| 2001 | 0.00 | 0.35 | 2.04 | 0.00 | 3.68 | 4.95 | 4.12 | 3.73 | 3.95 | 4.17 | 0.00 | 2.89 |
| 2002 | 3.53 | 3.63 | 1.76 | 0.00 | 12.70 | 6.32 | 4.50 | 4.28 | 4.11 | 2.92 | 0.00 | 2.08 |
| 2003 | 3.33 | 4.17 | 4.26 | 0.00 | 0.00 | 3.95 | 4.72 | 3.60 | 2.64 | 0.00 | 0.00 | 12.56 |
| 2004 | 6.83 | 4.51 | 4.44 | 0.00 | 0.00 | 4.17 | 4.28 | 4.19 | 4.04 | 3.77 | 0.94 | 7.48 |
| 2005 | 5.33 | 3.90 | 4.19 | 3.99 | 0.00 | 9.04 | 5.41 | 4.51 | 3.91 | 3.90 | 0.38 | 3.33 |
| 2006 | 4.23 | 3.92 | 4.22 | 9.57 | 20.08 | 6.64 | 4.55 | 4.38 | 4.18 | 4.77 | 17.59 | 11.95 |
| 2007 | 15.20 | 5.48 | 4.97 | 0.00 | 1.38 | 0.00 | 2.28 | 0.00 | 0.00 | 0.00 | 0.00 | 3.44 |
| 2008 | 4.51 | 4.03 | 4.16 | 0.00 | 5.52 | 5.11 | 4.43 | 4.03 | 3.98 | 0.00 | 0.00 | 2.95 |
| 2009 | 4.37 | 3.95 | 4.23 | 4.14 | 6.52 | 5.66 | 4.45 | 4.22 | 4.05 | 4.20 | 4.06 | 6.54 |
| 2010 | 1.68 | 3.91 | 1.14 | 11.97 | 15.38 | 6.61 | 4.79 | 4.43 | 4.21 | 4.32 | 2.11 | 4.79 |

Sub-basin: **4BD** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 9.83 | 6.37 | 6.64 | 10.66 | 60.88 | 20.97 | 9.64 | 7.91 | 7.03 | 7.31 | 13.83 | 12.47 |
| 1992 | 7.59 | 5.80 | 6.23 | 21.08 | 61.99 | 20.22 | 11.89 | 7.99 | 6.84 | 9.82 | 27.14 | 31.74 |
| 1993 | 30.82 | 21.62 | 9.69 | 11.37 | 45.55 | 18.28 | 8.94 | 6.78 | 6.03 | 6.09 | 7.27 | 19.59 |
| 1994 | 7.66 | 6.01 | 6.06 | 40.24 | 65.45 | 15.32 | 11.98 | 9.04 | 7.45 | 17.33 | 68.91 | 21.80 |
| 1995 | 9.29 | 9.32 | 17.24 | 28.77 | 60.47 | 15.77 | 10.89 | 7.52 | 6.47 | 6.78 | 27.28 | 18.69 |
| 1996 | 11.64 | 8.76 | 9.71 | 23.09 | 28.04 | 19.34 | 9.38 | 6.91 | 7.41 | 6.35 | 12.14 | 18.03 |
| 1997 | 6.59 | 5.19 | 5.60 | 61.40 | 54.61 | 12.42 | 12.00 | 9.05 | 6.16 | 27.94 | 81.18 | 43.37 |
| 1998 | 50.28 | 39.89 | 15.23 | 43.93 | 63.44 | 25.82 | 9.45 | 7.41 | 6.63 | 7.14 | 14.22 | 10.57 |
| 1999 | 7.14 | 5.72 | 6.15 | 11.33 | 39.02 | 8.90 | 6.77 | 6.22 | 6.23 | 6.04 | 20.72 | 43.81 |
| 2000 | 10.38 | 5.77 | 5.88 | 5.63 | 11.48 | 7.11 | 6.12 | 5.73 | 5.38 | 5.49 | 7.97 | 17.59 |
| 2001 | 33.05 | 13.28 | 9.61 | 51.52 | 51.07 | 10.52 | 7.18 | 6.64 | 5.59 | 5.54 | 25.47 | 13.80 |
| 2002 | 8.52 | 5.82 | 9.43 | 39.93 | 85.24 | 9.92 | 6.74 | 5.80 | 5.40 | 7.36 | 48.77 | 24.29 |
| 2003 | 17.35 | 5.94 | 5.62 | 18.22 | 84.28 | 26.06 | 7.71 | 7.48 | 8.19 | 12.51 | 35.40 | 15.38 |
| 2004 | 6.96 | 5.65 | 5.72 | 25.69 | 45.88 | 7.90 | 5.94 | 5.56 | 5.28 | 5.98 | 28.58 | 19.09 |
| 2005 | 7.66 | 5.25 | 5.41 | 5.31 | 40.56 | 23.66 | 7.92 | 5.87 | 5.60 | 5.82 | 11.49 | 7.81 |
| 2006 | 5.34 | 4.75 | 5.08 | 7.99 | 29.82 | 7.28 | 5.62 | 5.03 | 4.73 | 4.83 | 34.05 | 24.73 |
| 2007 | 18.39 | 5.81 | 5.17 | 26.35 | 38.00 | 36.29 | 11.78 | 23.45 | 13.27 | 24.37 | 23.84 | 9.81 |
| 2008 | 6.98 | 5.34 | 5.30 | 34.01 | 19.36 | 7.48 | 5.59 | 5.50 | 4.97 | 15.92 | 21.47 | 8.70 |
| 2009 | 5.08 | 4.33 | 4.68 | 4.52 | 7.17 | 6.17 | 4.74 | 4.51 | 4.30 | 4.42 | 9.94 | 6.37 |
| 2010 | 11.67 | 5.12 | 18.38 | 34.23 | 46.85 | 7.43 | 4.80 | 4.45 | 4.23 | 4.33 | 8.91 | 6.54 |

Sub-basin: **4BE** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 12.62 | 7.42 | 7.29 | 9.70 | 50.51 | 21.77 | 10.99 | 8.76 | 7.70 | 8.29 | 12.35 | 12.70 |
| 1992 | 8.89 | 6.33 | 6.72 | 19.32 | 60.66 | 21.76 | 12.53 | 8.63 | 7.42 | 9.57 | 20.76 | 27.50 |
| 1993 | 29.36 | 25.27 | 12.32 | 10.35 | 40.20 | 19.92 | 11.03 | 7.70 | 6.65 | 6.61 | 7.26 | 21.12 |
| 1994 | 9.75 | 6.84 | 6.77 | 34.38 | 58.67 | 16.83 | 12.23 | 9.45 | 8.37 | 13.59 | 68.01 | 25.21 |
| 1995 | 10.97 | 8.66 | 15.75 | 28.47 | 58.28 | 18.20 | 11.63 | 8.49 | 7.18 | 6.09 | 21.10 | 19.62 |
| 1996 | 13.42 | 9.77 | 10.76 | 23.62 | 24.50 | 20.99 | 11.21 | 8.22 | 8.66 | 7.46 | 12.49 | 20.16 |
| 1997 | 8.16 | 5.84 | 6.16 | 59.37 | 54.64 | 14.20 | 12.99 | 10.50 | 7.14 | 19.86 | 76.52 | 49.95 |
| 1998 | 54.54 | 43.12 | 17.76 | 44.01 | 64.45 | 29.32 | 11.90 | 8.76 | 7.76 | 8.62 | 12.84 | 11.42 |
| 1999 | 8.09 | 6.45 | 6.93 | 12.40 | 37.24 | 11.36 | 7.89 | 7.29 | 8.18 | 7.34 | 21.69 | 47.41 |
| 2000 | 14.35 | 6.97 | 6.70 | 6.48 | 11.95 | 8.62 | 7.30 | 6.86 | 6.28 | 6.36 | 10.88 | 17.53 |
| 2001 | 38.33 | 16.53 | 10.56 | 47.19 | 49.12 | 12.70 | 8.41 | 7.67 | 6.54 | 6.74 | 21.48 | 16.36 |
| 2002 | 9.93 | 7.31 | 10.52 | 41.72 | 95.59 | 13.24 | 8.13 | 6.89 | 6.39 | 8.23 | 38.76 | 26.33 |
| 2003 | 19.70 | 7.62 | 6.61 | 14.55 | 85.52 | 27.79 | 9.82 | 7.97 | 9.24 | 9.49 | 28.67 | 16.63 |
| 2004 | 8.33 | 6.63 | 6.75 | 26.42 | 47.93 | 10.48 | 7.16 | 6.45 | 6.05 | 6.43 | 19.42 | 21.16 |
| 2005 | 10.40 | 6.60 | 6.62 | 7.47 | 40.92 | 26.02 | 10.38 | 7.18 | 6.84 | 6.99 | 9.61 | 8.86 |
| 2006 | 6.23 | 5.50 | 5.82 | 5.18 | 24.11 | 9.84 | 6.84 | 5.96 | 5.53 | 5.49 | 26.29 | 25.95 |
| 2007 | 21.67 | 7.45 | 6.28 | 24.62 | 37.42 | 35.26 | 13.11 | 20.18 | 14.40 | 20.41 | 22.34 | 11.93 |
| 2008 | 8.96 | 6.88 | 6.47 | 33.44 | 20.38 | 9.97 | 7.10 | 6.82 | 6.22 | 13.77 | 19.94 | 11.51 |
| 2009 | 6.22 | 5.10 | 5.43 | 5.24 | 5.95 | 5.95 | 5.39 | 5.21 | 5.00 | 5.10 | 6.19 | 6.88 |
| 2010 | 10.67 | 6.72 | 12.82 | 32.28 | 44.22 | 10.87 | 5.96 | 5.19 | 4.90 | 4.97 | 5.41 | 6.86 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

Sub-basin: **4BF** (Unit: $m^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 8.62 | 6.41 | 6.75 | 6.79 | 17.73 | 8.63 | 7.06 | 6.71 | 6.39 | 6.55 | 6.30 | 6.74 |
| 1992 | 6.64 | 5.79 | 6.35 | 9.88 | 24.34 | 8.39 | 6.88 | 6.51 | 6.18 | 6.33 | 6.89 | 11.15 |
| 1993 | 14.18 | 12.90 | 7.42 | 6.42 | 9.46 | 7.37 | 6.57 | 6.28 | 6.00 | 6.15 | 5.93 | 8.47 |
| 1994 | 6.67 | 5.74 | 6.02 | 14.38 | 16.34 | 7.21 | 6.42 | 6.12 | 5.82 | 6.03 | 29.62 | 11.46 |
| 1995 | 6.92 | 5.84 | 7.22 | 15.54 | 20.03 | 7.46 | 6.49 | 6.23 | 5.94 | 6.09 | 7.64 | 10.85 |
| 1996 | 7.14 | 5.72 | 6.21 | 7.52 | 7.08 | 6.84 | 6.17 | 5.91 | 5.64 | 5.78 | 6.04 | 9.63 |
| 1997 | 6.11 | 5.20 | 5.68 | 28.01 | 17.87 | 6.89 | 6.18 | 5.94 | 5.67 | 5.88 | 28.80 | 27.18 |
| 1998 | 27.04 | 16.96 | 9.95 | 18.37 | 28.14 | 13.38 | 7.69 | 6.91 | 6.46 | 6.58 | 6.32 | 6.49 |
| 1999 | 6.44 | 5.78 | 6.36 | 9.84 | 11.55 | 6.74 | 6.42 | 6.30 | 6.05 | 6.20 | 9.00 | 22.57 |
| 2000 | 8.19 | 5.95 | 6.30 | 6.03 | 6.18 | 5.94 | 6.09 | 6.05 | 5.81 | 5.97 | 5.74 | 6.12 |
| 2001 | 13.18 | 7.79 | 7.25 | 18.74 | 13.94 | 6.72 | 6.20 | 6.01 | 5.75 | 5.90 | 7.27 | 7.48 |
| 2002 | 6.22 | 5.50 | 6.08 | 20.30 | 37.94 | 7.13 | 6.33 | 6.10 | 5.84 | 5.99 | 11.20 | 14.09 |
| 2003 | 8.27 | 5.70 | 6.03 | 6.50 | 38.19 | 8.69 | 6.62 | 6.27 | 5.96 | 6.10 | 6.40 | 8.15 |
| 2004 | 6.41 | 5.52 | 5.99 | 12.40 | 18.12 | 6.56 | 6.15 | 6.01 | 5.76 | 5.91 | 7.02 | 8.44 |
| 2005 | 6.83 | 5.44 | 5.82 | 5.59 | 21.43 | 12.01 | 6.61 | 6.00 | 5.66 | 5.79 | 5.56 | 5.71 |
| 2006 | 5.66 | 5.26 | 5.59 | 7.51 | 17.37 | 6.44 | 5.81 | 5.63 | 5.39 | 5.53 | 16.08 | 15.18 |
| 2007 | 11.52 | 5.62 | 5.77 | 10.83 | 14.00 | 8.86 | 6.20 | 5.79 | 5.46 | 5.58 | 5.37 | 5.52 |
| 2008 | 5.47 | 4.91 | 5.39 | 10.33 | 8.79 | 5.65 | 5.47 | 5.36 | 5.14 | 5.28 | 5.13 | 5.25 |
| 2009 | 5.19 | 4.66 | 5.12 | 4.93 | 5.50 | 5.20 | 5.05 | 4.98 | 4.78 | 4.91 | 5.17 | 5.58 |
| 2010 | 6.85 | 5.18 | 10.28 | 16.25 | 17.16 | 6.25 | 5.26 | 5.03 | 4.80 | 4.92 | 4.81 | 5.01 |

Sub-basin: **4BG** (Unit: $m^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 6.35 | 4.13 | 3.73 | 2.25 | 4.13 | 8.12 | 4.50 | 3.84 | 3.53 | 3.10 | 2.82 | 3.60 |
| 1992 | 3.77 | 3.02 | 3.23 | 0.00 | 19.32 | 7.88 | 4.38 | 3.77 | 3.37 | 2.47 | 3.12 | 3.58 |
| 1993 | 7.36 | 14.37 | 5.59 | 3.10 | 2.92 | 4.97 | 4.08 | 3.45 | 3.14 | 3.14 | 2.24 | 3.59 |
| 1994 | 3.88 | 3.15 | 3.15 | 0.07 | 13.62 | 6.81 | 3.99 | 3.40 | 3.31 | 1.47 | 20.34 | 10.77 |
| 1995 | 4.88 | 2.98 | 3.62 | 3.06 | 17.84 | 6.49 | 4.24 | 3.66 | 3.14 | 0.48 | 4.27 | 3.99 |
| 1996 | 4.46 | 3.13 | 3.00 | 3.54 | 1.34 | 5.00 | 3.54 | 3.18 | 2.86 | 2.93 | 0.99 | 4.91 |
| 1997 | 3.54 | 2.79 | 2.92 | 8.69 | 20.61 | 4.88 | 3.81 | 3.46 | 3.12 | 0.00 | 15.28 | 34.65 |
| 1998 | 33.12 | 13.44 | 5.98 | 11.64 | 23.33 | 10.53 | 5.46 | 4.15 | 3.43 | 3.40 | 2.50 | 3.68 |
| 1999 | 3.21 | 2.79 | 2.98 | 2.04 | 4.63 | 4.48 | 3.44 | 3.12 | 2.95 | 3.01 | 0.00 | 15.25 |
| 2000 | 7.09 | 3.72 | 3.34 | 2.99 | 2.66 | 3.11 | 2.95 | 2.88 | 2.73 | 2.78 | 1.60 | 2.92 |
| 2001 | 2.84 | 5.67 | 2.76 | 7.22 | 15.08 | 4.84 | 3.61 | 3.29 | 2.91 | 2.81 | 0.56 | 4.88 |
| 2002 | 3.12 | 2.90 | 2.47 | 0.00 | 50.54 | 5.42 | 3.85 | 3.19 | 2.91 | 1.67 | 2.47 | 5.74 |
| 2003 | 7.42 | 3.64 | 3.17 | 0.00 | 30.09 | 9.96 | 4.28 | 2.80 | 3.31 | 0.12 | 2.36 | 5.57 |
| 2004 | 3.18 | 2.68 | 2.81 | 0.03 | 9.81 | 4.39 | 3.27 | 2.97 | 2.74 | 2.31 | 0.28 | 6.13 |
| 2005 | 4.43 | 2.97 | 2.91 | 2.53 | 0.10 | 14.94 | 4.39 | 3.27 | 2.55 | 2.68 | 2.08 | 3.44 |
| 2006 | 2.74 | 2.43 | 2.49 | 0.20 | 10.19 | 4.66 | 3.31 | 2.86 | 2.62 | 2.23 | 4.77 | 13.96 |
| 2007 | 15.14 | 3.95 | 3.26 | 3.39 | 9.34 | 7.13 | 3.54 | 2.63 | 3.67 | 0.23 | 4.37 | 3.09 |
| 2008 | 2.83 | 2.46 | 2.27 | 0.00 | 6.11 | 3.91 | 2.79 | 2.62 | 2.41 | 1.28 | 2.39 | 3.37 |
| 2009 | 2.53 | 2.18 | 2.35 | 2.20 | 1.82 | 2.68 | 2.41 | 2.29 | 2.19 | 2.17 | 1.46 | 2.72 |
| 2010 | 2.42 | 2.70 | 1.99 | 14.05 | 11.89 | 5.19 | 3.32 | 2.72 | 2.42 | 2.25 | 1.47 | 3.09 |

## 4CA, 4CB & 4CC

Sub-basin: **4CA** (Unit: $m^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 20.72 | 16.11 | 17.32 | 21.04 | 51.84 | 32.17 | 21.68 | 18.71 | 17.35 | 19.53 | 21.80 | 21.00 |
| 1992 | 17.33 | 14.21 | 15.26 | 28.88 | 53.37 | 26.72 | 23.27 | 19.07 | 17.37 | 21.18 | 28.58 | 33.31 |
| 1993 | 37.38 | 30.40 | 21.12 | 18.94 | 39.81 | 27.57 | 20.12 | 16.92 | 15.34 | 15.25 | 16.61 | 28.49 |
| 1994 | 17.44 | 14.46 | 15.20 | 36.05 | 56.64 | 24.83 | 21.85 | 19.13 | 17.41 | 24.46 | 62.43 | 31.51 |
| 1995 | 19.16 | 15.94 | 27.28 | 31.08 | 45.39 | 24.94 | 22.63 | 17.94 | 16.50 | 16.47 | 27.93 | 26.28 |
| 1996 | 20.71 | 17.69 | 19.44 | 29.62 | 30.53 | 30.95 | 22.08 | 18.39 | 19.25 | 17.09 | 24.62 | 29.32 |
| 1997 | 16.28 | 13.10 | 13.94 | 46.59 | 51.62 | 21.58 | 22.31 | 20.52 | 15.98 | 29.41 | 68.49 | 47.95 |
| 1998 | 55.85 | 50.56 | 27.80 | 48.21 | 63.16 | 37.30 | 22.85 | 19.88 | 18.92 | 20.17 | 23.76 | 22.63 |
| 1999 | 18.49 | 15.29 | 16.60 | 22.96 | 39.01 | 19.88 | 17.86 | 17.67 | 18.52 | 16.86 | 28.96 | 48.43 |
| 2000 | 21.63 | 15.01 | 15.52 | 15.03 | 20.03 | 17.15 | 16.24 | 15.60 | 14.38 | 14.89 | 19.26 | 26.43 |
| 2001 | 44.81 | 22.40 | 21.70 | 50.94 | 50.23 | 21.31 | 18.43 | 17.63 | 15.48 | 17.16 | 31.79 | 22.50 |
| 2002 | 18.99 | 15.30 | 20.84 | 39.96 | 78.38 | 20.95 | 17.36 | 16.17 | 15.06 | 18.11 | 41.09 | 35.26 |
| 2003 | 27.34 | 15.56 | 15.21 | 21.88 | 81.70 | 33.54 | 19.47 | 18.56 | 18.86 | 19.37 | 35.83 | 22.37 |
| 2004 | 16.62 | 14.73 | 15.73 | 41.02 | 54.73 | 19.20 | 16.38 | 15.35 | 14.40 | 15.58 | 22.94 | 23.67 |
| 2005 | 17.34 | 14.26 | 15.09 | 16.42 | 40.11 | 27.27 | 18.39 | 15.49 | 16.25 | 15.76 | 17.61 | 16.02 |
| 2006 | 13.47 | 12.07 | 12.79 | 15.76 | 27.53 | 15.85 | 13.87 | 12.88 | 12.06 | 12.30 | 23.58 | 28.63 |
| 2007 | 22.28 | 13.07 | 12.79 | 29.32 | 38.41 | 40.18 | 20.94 | 27.36 | 23.28 | 26.95 | 26.05 | 18.19 |
| 2008 | 15.43 | 13.26 | 14.38 | 38.68 | 24.04 | 16.18 | 14.58 | 14.25 | 13.98 | 24.26 | 29.78 | 18.34 |
| 2009 | 13.10 | 11.17 | 12.00 | 11.46 | 12.09 | 12.17 | 11.64 | 11.20 | 10.62 | 10.90 | 11.88 | 12.05 |
| 2010 | 19.95 | 12.46 | 21.85 | 31.58 | 37.63 | 16.38 | 12.10 | 11.15 | 10.68 | 12.07 | 14.93 | 12.72 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

Sub-basin: **4CB** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 14.01 | 10.86 | 11.58 | 12.96 | 33.88 | 19.12 | 13.40 | 12.05 | 11.10 | 12.07 | 12.93 | 13.09 |
| 1992 | 11.30 | 9.46 | 10.23 | 20.36 | 34.90 | 16.34 | 13.67 | 11.46 | 10.45 | 12.30 | 15.50 | 21.36 |
| 1993 | 24.17 | 19.91 | 13.38 | 12.27 | 25.38 | 17.44 | 12.80 | 10.87 | 9.99 | 10.06 | 11.10 | 18.78 |
| 1994 | 11.48 | 9.50 | 9.93 | 23.06 | 34.42 | 14.71 | 13.07 | 11.65 | 10.58 | 13.70 | 41.38 | 20.40 |
| 1995 | 12.56 | 10.55 | 16.63 | 22.40 | 31.35 | 15.47 | 12.97 | 11.19 | 10.26 | 10.51 | 16.92 | 18.27 |
| 1996 | 13.61 | 11.35 | 12.17 | 19.13 | 19.42 | 18.79 | 13.32 | 11.12 | 10.89 | 10.22 | 13.76 | 19.81 |
| 1997 | 10.58 | 8.63 | 9.28 | 36.48 | 33.44 | 13.82 | 13.51 | 12.33 | 10.01 | 17.39 | 46.55 | 33.74 |
| 1998 | 36.55 | 33.80 | 18.71 | 32.52 | 43.27 | 24.23 | 14.88 | 13.21 | 12.47 | 12.93 | 14.84 | 13.66 |
| 1999 | 12.16 | 10.38 | 11.36 | 16.80 | 26.59 | 13.14 | 11.69 | 11.44 | 11.48 | 11.00 | 19.10 | 34.38 |
| 2000 | 14.55 | 10.19 | 10.68 | 10.33 | 13.59 | 10.88 | 10.60 | 10.22 | 9.59 | 9.77 | 12.36 | 15.21 |
| 2001 | 32.22 | 15.05 | 14.16 | 32.26 | 30.37 | 13.40 | 11.44 | 10.93 | 10.01 | 10.41 | 18.29 | 15.05 |
| 2002 | 12.02 | 9.89 | 13.05 | 29.21 | 49.68 | 13.58 | 11.25 | 10.64 | 10.05 | 11.82 | 25.15 | 24.56 |
| 2003 | 17.28 | 10.26 | 10.37 | 14.54 | 53.23 | 20.90 | 12.54 | 11.83 | 11.64 | 12.41 | 21.00 | 15.27 |
| 2004 | 11.27 | 9.94 | 10.52 | 26.60 | 34.98 | 12.41 | 10.91 | 10.43 | 9.87 | 10.65 | 14.06 | 15.98 |
| 2005 | 11.93 | 9.54 | 10.12 | 10.72 | 30.24 | 18.42 | 12.05 | 10.25 | 9.96 | 9.93 | 10.77 | 10.16 |
| 2006 | 9.13 | 8.30 | 8.76 | 11.32 | 20.34 | 10.30 | 9.04 | 8.55 | 8.07 | 8.18 | 17.82 | 19.66 |
| 2007 | 14.76 | 8.44 | 8.56 | 19.02 | 25.20 | 23.98 | 13.25 | 15.88 | 13.51 | 16.45 | 16.95 | 12.26 |
| 2008 | 10.57 | 9.11 | 9.77 | 26.34 | 16.09 | 10.49 | 9.72 | 9.39 | 8.78 | 13.41 | 18.62 | 12.06 |
| 2009 | 8.88 | 7.66 | 8.26 | 7.89 | 8.37 | 8.10 | 7.85 | 7.65 | 7.27 | 7.41 | 7.96 | 8.55 |
| 2010 | 13.10 | 8.36 | 14.18 | 22.49 | 26.33 | 10.48 | 8.02 | 7.53 | 7.13 | 7.24 | 7.39 | 7.85 |

Sub-basin: **4CC** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 14.39 | 8.96 | 8.16 | 7.59 | 15.94 | 12.42 | 8.94 | 8.16 | 7.80 | 7.72 | 7.53 | 8.33 |
| 1992 | 8.18 | 7.09 | 7.78 | 6.33 | 32.42 | 11.35 | 8.70 | 8.00 | 7.58 | 7.20 | 7.86 | 11.48 |
| 1993 | 24.11 | 30.29 | 12.31 | 8.47 | 8.32 | 8.18 | 8.11 | 7.73 | 7.38 | 7.57 | 6.96 | 12.25 |
| 1994 | 9.59 | 7.29 | 7.47 | 9.90 | 25.03 | 10.99 | 8.38 | 7.58 | 7.31 | 6.63 | 44.36 | 26.59 |
| 1995 | 11.14 | 7.92 | 10.18 | 14.06 | 21.03 | 10.16 | 8.22 | 7.75 | 7.28 | 7.06 | 7.72 | 11.70 |
| 1996 | 9.77 | 7.00 | 7.50 | 9.40 | 7.58 | 7.99 | 7.60 | 7.19 | 7.15 | 7.16 | 6.19 | 16.52 |
| 1997 | 8.48 | 6.61 | 7.14 | 31.37 | 36.08 | 11.24 | 8.21 | 7.55 | 7.22 | 5.51 | 42.59 | 71.69 |
| 1998 | 74.03 | 36.01 | 17.96 | 31.21 | 46.44 | 22.15 | 11.42 | 8.99 | 7.84 | 8.24 | 7.37 | 8.37 |
| 1999 | 8.03 | 7.19 | 7.99 | 11.98 | 15.51 | 9.03 | 8.12 | 7.66 | 7.74 | 7.76 | 5.08 | 36.87 |
| 2000 | 15.87 | 8.30 | 8.04 | 7.55 | 7.56 | 7.61 | 7.69 | 7.67 | 7.33 | 7.57 | 6.56 | 7.93 |
| 2001 | 18.23 | 14.75 | 11.06 | 39.41 | 18.79 | 9.43 | 8.03 | 7.73 | 7.35 | 7.45 | 7.33 | 10.05 |
| 2002 | 8.18 | 7.18 | 7.54 | 10.94 | 67.73 | 11.93 | 8.57 | 7.80 | 7.40 | 7.10 | 8.12 | 23.14 |
| 2003 | 16.10 | 8.02 | 7.75 | 5.54 | 66.13 | 14.66 | 9.08 | 7.71 | 7.65 | 7.07 | 7.55 | 9.64 |
| 2004 | 8.03 | 6.96 | 7.56 | 12.17 | 25.64 | 9.70 | 8.00 | 7.65 | 7.30 | 7.18 | 7.00 | 11.45 |
| 2005 | 9.57 | 7.32 | 7.51 | 6.97 | 17.75 | 20.68 | 9.51 | 7.79 | 7.12 | 7.29 | 6.95 | 7.54 |
| 2006 | 7.28 | 6.74 | 7.24 | 12.84 | 24.45 | 9.96 | 7.81 | 7.31 | 6.98 | 7.14 | 19.02 | 30.65 |
| 2007 | 28.87 | 8.59 | 7.95 | 13.29 | 22.39 | 13.36 | 8.13 | 7.34 | 7.50 | 6.47 | 7.47 | 7.38 |
| 2008 | 7.23 | 6.44 | 6.38 | 7.76 | 11.90 | 7.74 | 7.05 | 6.99 | 6.74 | 6.26 | 6.66 | 7.77 |
| 2009 | 6.90 | 6.16 | 6.77 | 6.52 | 6.89 | 6.59 | 6.68 | 6.63 | 6.38 | 6.56 | 6.65 | 7.50 |
| 2010 | 11.98 | 9.34 | 23.46 | 37.48 | 20.00 | 10.58 | 7.45 | 6.82 | 6.47 | 6.56 | 6.33 | 6.77 |

## 4DA, 4DB, 4DC & 4DD

Sub-basin: **4DA** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 20.82 | 12.94 | 12.68 | 12.20 | 42.77 | 19.42 | 13.51 | 12.29 | 11.41 | 11.52 | 11.70 | 15.80 |
| 1992 | 12.84 | 10.11 | 10.78 | 10.61 | 49.56 | 22.99 | 13.50 | 11.74 | 10.70 | 10.71 | 15.09 | 29.57 |
| 1993 | 26.45 | 27.49 | 16.14 | 14.83 | 27.39 | 15.22 | 11.84 | 10.85 | 10.14 | 10.25 | 9.94 | 17.72 |
| 1994 | 11.71 | 9.50 | 9.77 | 30.92 | 49.10 | 16.55 | 12.66 | 11.07 | 10.08 | 10.54 | 75.18 | 25.33 |
| 1995 | 14.21 | 11.33 | 14.36 | 32.58 | 65.35 | 17.09 | 12.77 | 11.62 | 10.71 | 10.93 | 28.91 | 23.50 |
| 1996 | 15.49 | 11.14 | 11.24 | 13.73 | 18.70 | 16.32 | 11.79 | 10.40 | 9.74 | 9.83 | 9.39 | 10.92 |
| 1997 | 9.70 | 8.43 | 9.19 | 44.11 | 39.60 | 13.88 | 11.25 | 10.19 | 9.50 | 21.30 | 73.80 | 62.91 |
| 1998 | 67.38 | 30.57 | 20.11 | 40.43 | 78.27 | 26.73 | 16.33 | 13.68 | 12.19 | 12.02 | 11.61 | 12.80 |
| 1999 | 11.65 | 10.03 | 10.96 | 13.53 | 28.28 | 13.13 | 11.26 | 10.74 | 10.16 | 10.26 | 12.98 | 44.61 |
| 2000 | 19.05 | 11.27 | 10.94 | 10.27 | 10.29 | 9.72 | 9.84 | 9.68 | 9.18 | 9.36 | 8.96 | 11.48 |
| 2001 | 13.68 | 10.89 | 9.48 | 24.01 | 37.15 | 12.85 | 10.44 | 9.63 | 8.93 | 9.05 | 15.45 | 17.01 |
| 2002 | 10.92 | 8.67 | 8.98 | 37.21 | 100.76 | 15.15 | 11.44 | 10.31 | 9.53 | 9.57 | 24.09 | 18.41 |
| 2003 | 14.68 | 9.33 | 9.63 | 10.72 | 69.91 | 21.23 | 12.22 | 10.77 | 9.81 | 9.76 | 21.56 | 22.09 |
| 2004 | 12.40 | 9.38 | 9.70 | 12.44 | 20.42 | 10.37 | 9.54 | 9.16 | 8.70 | 8.87 | 39.84 | 22.25 |
| 2005 | 12.26 | 9.09 | 9.47 | 8.87 | 24.97 | 24.55 | 11.85 | 9.87 | 8.98 | 9.00 | 9.44 | 10.93 |
| 2006 | 8.96 | 7.92 | 8.35 | 18.25 | 38.27 | 12.02 | 9.43 | 8.90 | 8.32 | 8.44 | 49.51 | 40.77 |
| 2007 | 40.64 | 12.02 | 10.58 | 18.81 | 29.24 | 23.59 | 11.67 | 10.32 | 9.37 | 9.33 | 13.11 | 12.72 |
| 2008 | 10.96 | 8.95 | 8.95 | 20.89 | 17.53 | 10.22 | 9.10 | 8.74 | 8.19 | 8.60 | 11.49 | 9.62 |
| 2009 | 8.30 | 7.29 | 7.84 | 7.58 | 16.60 | 10.27 | 8.04 | 7.56 | 7.22 | 7.39 | 14.94 | 12.43 |
| 2010 | 9.33 | 7.49 | 14.14 | 38.40 | 43.35 | 12.97 | 9.50 | 8.61 | 7.94 | 7.90 | 9.69 | 10.38 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

Sub-basin: **4DB** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 11.22 | 5.36 | 4.84 | 4.94 | 29.35 | 8.96 | 5.37 | 4.60 | 4.14 | 4.21 | 11.90 | 10.08 |
| 1992 | 6.07 | 3.81 | 3.68 | 6.52 | 34.19 | 9.48 | 4.73 | 3.83 | 3.37 | 3.29 | 13.77 | 23.54 |
| 1993 | 15.78 | 14.43 | 7.01 | 10.40 | 16.67 | 6.06 | 4.11 | 3.54 | 3.15 | 3.07 | 7.88 | 12.92 |
| 1994 | 4.59 | 3.01 | 2.77 | 29.14 | 28.71 | 6.59 | 4.35 | 3.67 | 3.00 | 9.04 | 58.86 | 14.90 |
| 1995 | 5.52 | 3.85 | 8.23 | 19.61 | 37.20 | 6.95 | 4.49 | 3.99 | 3.61 | 5.53 | 23.29 | 17.53 |
| 1996 | 7.12 | 4.84 | 4.15 | 10.99 | 12.44 | 8.43 | 4.86 | 3.63 | 3.08 | 2.96 | 5.18 | 8.05 |
| 1997 | 3.43 | 2.40 | 2.45 | 36.97 | 24.14 | 5.21 | 3.56 | 2.98 | 2.67 | 21.29 | 52.21 | 33.12 |
| 1998 | 35.08 | 17.77 | 11.84 | 25.16 | 45.54 | 13.66 | 7.39 | 5.94 | 5.19 | 4.95 | 7.10 | 7.35 |
| 1999 | 5.21 | 4.05 | 4.45 | 9.95 | 16.81 | 5.79 | 4.26 | 3.85 | 3.50 | 3.44 | 12.59 | 36.66 |
| 2000 | 9.25 | 4.38 | 3.80 | 3.44 | 3.38 | 3.09 | 3.02 | 2.86 | 2.61 | 2.55 | 8.43 | 11.45 |
| 2001 | 7.93 | 4.90 | 2.91 | 22.34 | 23.63 | 4.75 | 3.12 | 2.66 | 2.35 | 2.28 | 14.47 | 8.64 |
| 2002 | 3.83 | 2.37 | 2.21 | 46.00 | 53.08 | 5.81 | 3.58 | 3.07 | 2.76 | 2.78 | 21.29 | 10.91 |
| 2003 | 6.03 | 2.88 | 2.61 | 10.79 | 45.70 | 8.83 | 3.99 | 3.35 | 3.15 | 6.02 | 21.49 | 13.37 |
| 2004 | 5.03 | 3.25 | 2.95 | 10.32 | 11.72 | 3.60 | 2.72 | 2.42 | 2.18 | 2.22 | 34.70 | 12.51 |
| 2005 | 4.14 | 2.44 | 2.36 | 2.39 | 17.73 | 12.33 | 4.47 | 3.16 | 2.64 | 2.53 | 8.92 | 5.52 |
| 2006 | 2.87 | 2.13 | 2.43 | 14.85 | 28.91 | 4.21 | 2.30 | 1.85 | 1.61 | 2.45 | 46.46 | 25.93 |
| 2007 | 24.50 | 4.04 | 2.86 | 10.33 | 17.94 | 11.02 | 3.85 | 3.08 | 2.75 | 4.37 | 15.80 | 6.23 |
| 2008 | 5.21 | 3.36 | 2.42 | 20.45 | 8.18 | 3.25 | 2.40 | 2.13 | 1.88 | 4.07 | 10.33 | 3.48 |
| 2009 | 2.02 | 1.95 | 1.60 | 3.10 | 12.17 | 3.51 | 1.63 | 1.24 | 1.12 | 1.17 | 14.32 | 5.91 |
| 2010 | 2.77 | 1.49 | 8.16 | 29.06 | 22.51 | 3.94 | 1.83 | 1.42 | 1.20 | 1.13 | 4.68 | 3.19 |

Sub-basin: **4DC** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 11.05 | 5.49 | 5.00 | 5.09 | 27.47 | 9.00 | 5.53 | 4.77 | 4.31 | 4.38 | 12.07 | 10.09 |
| 1992 | 6.23 | 3.97 | 3.86 | 6.68 | 28.76 | 9.24 | 4.89 | 4.01 | 3.54 | 3.48 | 13.94 | 22.37 |
| 1993 | 14.76 | 13.68 | 7.09 | 10.29 | 15.88 | 6.19 | 4.28 | 3.72 | 3.32 | 3.25 | 8.09 | 13.05 |
| 1994 | 4.76 | 3.18 | 2.96 | 25.10 | 26.59 | 6.59 | 4.49 | 3.83 | 3.17 | 9.24 | 52.31 | 14.22 |
| 1995 | 5.65 | 3.99 | 8.23 | 17.70 | 33.83 | 6.94 | 4.65 | 4.16 | 3.78 | 5.76 | 22.50 | 16.85 |
| 1996 | 7.24 | 4.99 | 4.32 | 10.71 | 12.08 | 8.46 | 5.03 | 3.81 | 3.26 | 3.15 | 5.39 | 8.19 |
| 1997 | 3.61 | 2.57 | 2.63 | 32.91 | 22.46 | 5.27 | 3.70 | 3.13 | 2.81 | 21.22 | 46.10 | 29.32 |
| 1998 | 31.08 | 16.53 | 11.54 | 23.75 | 41.49 | 13.06 | 7.49 | 6.10 | 5.35 | 5.12 | 7.28 | 7.52 |
| 1999 | 5.39 | 4.21 | 4.63 | 10.13 | 16.62 | 5.96 | 4.44 | 4.03 | 3.68 | 3.62 | 12.80 | 33.21 |
| 2000 | 9.21 | 4.53 | 3.99 | 3.62 | 3.57 | 3.27 | 3.21 | 3.05 | 2.80 | 2.74 | 8.64 | 11.60 |
| 2001 | 8.10 | 5.05 | 3.10 | 20.51 | 21.86 | 4.85 | 3.28 | 2.82 | 2.51 | 2.45 | 14.63 | 8.58 |
| 2002 | 4.01 | 2.54 | 2.40 | 34.04 | 42.45 | 5.70 | 3.67 | 3.17 | 2.87 | 2.89 | 20.85 | 10.48 |
| 2003 | 6.16 | 3.04 | 2.80 | 10.84 | 41.11 | 8.54 | 4.14 | 3.52 | 3.32 | 6.23 | 21.03 | 12.99 |
| 2004 | 5.20 | 3.41 | 3.13 | 10.24 | 11.36 | 3.76 | 2.90 | 2.60 | 2.36 | 2.41 | 32.85 | 12.00 |
| 2005 | 4.27 | 2.60 | 2.55 | 2.57 | 15.95 | 11.52 | 4.15 | 2.87 | 2.36 | 2.25 | 8.66 | 5.22 |
| 2006 | 2.58 | 1.87 | 2.15 | 14.29 | 26.73 | 4.33 | 2.47 | 2.02 | 1.78 | 2.64 | 42.08 | 23.83 |
| 2007 | 22.80 | 4.13 | 3.03 | 9.73 | 17.13 | 10.63 | 4.00 | 3.26 | 2.93 | 4.57 | 15.83 | 6.31 |
| 2008 | 5.26 | 3.52 | 2.61 | 18.97 | 8.09 | 3.35 | 2.51 | 2.25 | 1.99 | 4.20 | 10.44 | 3.59 |
| 2009 | 2.15 | 2.05 | 1.72 | 3.23 | 12.26 | 3.61 | 1.75 | 1.36 | 1.24 | 1.29 | 14.44 | 6.01 |
| 2010 | 2.88 | 1.60 | 7.61 | 26.52 | 20.57 | 3.98 | 1.97 | 1.57 | 1.34 | 1.28 | 4.84 | 3.33 |

Sub-basin: **4DD** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 2.05 | 1.18 | 0.86 | 0.70 | 0.38 | 1.23 | 0.81 | 0.71 | 0.66 | 0.65 | 0.48 | 0.78 |
| 1992 | 0.82 | 0.64 | 0.67 | 0.02 | 5.01 | 2.29 | 1.19 | 0.83 | 0.69 | 0.67 | 0.52 | 2.89 |
| 1993 | 4.43 | 5.55 | 2.06 | 1.04 | 1.13 | 1.05 | 0.79 | 0.71 | 0.65 | 0.66 | 0.24 | 0.97 |
| 1994 | 0.79 | 0.70 | 0.60 | 0.00 | 3.94 | 1.93 | 1.19 | 0.86 | 0.69 | 0.33 | 10.64 | 4.42 |
| 1995 | 1.74 | 0.94 | 0.82 | 0.00 | 4.77 | 1.73 | 1.05 | 0.78 | 0.68 | 0.12 | 1.05 | 1.72 |
| 1996 | 1.68 | 1.07 | 0.79 | 0.74 | 0.59 | 0.89 | 0.75 | 0.67 | 0.65 | 0.65 | 0.35 | 0.92 |
| 1997 | 0.75 | 0.54 | 0.65 | 4.05 | 5.24 | 1.62 | 1.01 | 0.75 | 0.67 | 0.00 | 9.41 | 15.97 |
| 1998 | 13.24 | 6.14 | 2.57 | 5.00 | 11.45 | 3.54 | 1.82 | 1.09 | 0.80 | 0.73 | 0.57 | 0.79 |
| 1999 | 0.72 | 0.63 | 0.66 | 0.25 | 1.60 | 1.20 | 0.85 | 0.72 | 0.67 | 0.68 | 0.00 | 5.35 |
| 2000 | 2.39 | 1.16 | 0.90 | 0.65 | 0.70 | 0.66 | 0.67 | 0.68 | 0.64 | 0.67 | 0.36 | 0.88 |
| 2001 | 0.70 | 0.84 | 0.70 | 0.00 | 5.03 | 1.53 | 0.96 | 0.75 | 0.72 | 0.62 | 0.26 | 1.40 |
| 2002 | 1.21 | 0.79 | 0.66 | 0.00 | 16.77 | 1.92 | 1.16 | 0.81 | 0.69 | 0.67 | 0.54 | 1.98 |
| 2003 | 1.87 | 1.02 | 0.80 | 0.00 | 4.86 | 2.47 | 1.26 | 0.84 | 0.71 | 0.35 | 0.53 | 1.38 |
| 2004 | 1.27 | 0.87 | 0.75 | 0.26 | 1.03 | 0.72 | 0.68 | 0.66 | 0.64 | 0.63 | 2.56 | 3.83 |
| 2005 | 1.69 | 0.92 | 0.78 | 0.68 | 0.00 | 1.96 | 0.97 | 0.75 | 0.66 | 0.65 | 0.49 | 0.81 |
| 2006 | 0.65 | 0.62 | 0.63 | 0.18 | 1.32 | 1.24 | 0.90 | 0.65 | 0.64 | 0.51 | 6.14 | 6.54 |
| 2007 | 9.00 | 1.66 | 1.03 | 0.93 | 2.30 | 1.69 | 1.06 | 0.77 | 0.67 | 0.46 | 0.67 | 0.79 |
| 2008 | 0.68 | 0.73 | 0.64 | 0.05 | 1.36 | 0.83 | 0.71 | 0.65 | 0.67 | 0.55 | 0.56 | 0.75 |
| 2009 | 0.65 | 0.58 | 0.65 | 0.40 | 0.67 | 0.75 | 0.67 | 0.68 | 0.57 | 0.65 | 0.34 | 0.86 |
| 2010 | 0.70 | 0.63 | 1.29 | 6.42 | 3.11 | 1.79 | 1.05 | 0.72 | 0.66 | 0.63 | 0.48 | 0.74 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

## 4EA, 4EB, 4EC & 4ED

Sub-basin: **4EA** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 24.76 | 11.20 | 11.74 | 27.93 | 92.04 | 18.06 | 11.93 | 11.07 | 10.31 | 21.99 | 42.37 | 45.76 |
| 1992 | 18.75 | 10.75 | 10.86 | 24.31 | 59.27 | 18.25 | 11.75 | 10.92 | 10.24 | 10.44 | 71.45 | 118.88 |
| 1993 | 68.17 | 52.85 | 14.41 | 31.81 | 70.01 | 14.30 | 11.67 | 10.89 | 10.25 | 10.46 | 46.02 | 62.27 |
| 1994 | 14.02 | 10.76 | 10.80 | 52.30 | 48.77 | 13.15 | 11.69 | 11.08 | 10.32 | 45.69 | 211.01 | 70.08 |
| 1995 | 15.23 | 11.03 | 24.94 | 86.20 | 97.28 | 13.54 | 11.68 | 11.16 | 10.51 | 22.87 | 75.96 | 65.75 |
| 1996 | 24.45 | 12.06 | 16.13 | 23.60 | 28.86 | 22.87 | 11.89 | 11.18 | 10.39 | 10.55 | 42.73 | 30.51 |
| 1997 | 12.10 | 9.88 | 10.55 | 105.64 | 78.82 | 12.51 | 11.40 | 10.74 | 10.19 | 94.69 | 176.11 | 121.55 |
| 1998 | 138.36 | 49.58 | 29.95 | 75.46 | 110.21 | 25.38 | 13.25 | 12.02 | 11.15 | 11.13 | 41.60 | 18.21 |
| 1999 | 13.16 | 10.31 | 22.62 | 31.83 | 37.43 | 12.38 | 11.41 | 10.94 | 10.38 | 10.63 | 69.12 | 111.23 |
| 2000 | 20.28 | 11.19 | 11.20 | 10.87 | 11.17 | 10.52 | 10.67 | 10.59 | 10.22 | 10.54 | 59.21 | 58.25 |
| 2001 | 28.19 | 13.91 | 11.41 | 80.38 | 38.36 | 12.33 | 11.39 | 10.84 | 10.27 | 10.55 | 79.60 | 35.66 |
| 2002 | 16.54 | 11.22 | 19.46 | 117.64 | 92.34 | 12.61 | 11.39 | 10.81 | 10.29 | 20.49 | 95.55 | 51.79 |
| 2003 | 19.37 | 10.80 | 11.04 | 74.53 | 95.59 | 17.81 | 11.99 | 11.16 | 10.45 | 28.40 | 104.41 | 45.85 |
| 2004 | 23.87 | 12.31 | 11.57 | 50.59 | 37.24 | 11.97 | 11.17 | 10.72 | 10.24 | 16.99 | 135.25 | 54.87 |
| 2005 | 14.10 | 10.92 | 11.04 | 11.03 | 42.00 | 25.35 | 11.81 | 11.07 | 10.38 | 10.56 | 54.88 | 20.27 |
| 2006 | 12.21 | 10.48 | 11.35 | 51.40 | 74.71 | 12.60 | 11.28 | 10.72 | 10.21 | 16.79 | 167.74 | 82.41 |
| 2007 | 71.34 | 11.88 | 11.53 | 32.05 | 57.70 | 19.75 | 12.08 | 11.37 | 10.57 | 18.97 | 65.47 | 26.97 |
| 2008 | 25.18 | 11.51 | 11.96 | 53.14 | 19.12 | 11.45 | 10.88 | 10.61 | 10.19 | 17.42 | 45.56 | 12.33 |
| 2009 | 12.30 | 10.83 | 10.82 | 14.36 | 32.44 | 11.57 | 10.77 | 10.49 | 9.99 | 19.36 | 72.70 | 32.36 |
| 2010 | 16.20 | 10.73 | 32.73 | 76.59 | 45.33 | 12.30 | 11.11 | 10.62 | 10.09 | 10.23 | 31.59 | 16.75 |

Sub-basin: **4EB** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 35.36 | 14.93 | 17.22 | 26.17 | 115.33 | 26.92 | 16.15 | 15.62 | 14.56 | 37.23 | 61.31 | 56.04 |
| 1992 | 23.64 | 13.57 | 14.62 | 37.78 | 98.69 | 25.88 | 15.41 | 14.79 | 14.24 | 16.62 | 94.01 | 126.53 |
| 1993 | 71.30 | 63.31 | 20.80 | 45.00 | 87.81 | 20.29 | 15.72 | 15.07 | 14.36 | 15.14 | 59.57 | 69.52 |
| 1994 | 17.91 | 13.79 | 14.93 | 101.24 | 77.37 | 18.53 | 17.02 | 15.06 | 13.96 | 69.04 | 246.52 | 74.66 |
| 1995 | 19.80 | 15.84 | 41.11 | 91.51 | 141.03 | 19.73 | 16.68 | 16.44 | 15.40 | 29.74 | 102.62 | 83.39 |
| 1996 | 31.35 | 17.14 | 22.99 | 43.61 | 42.94 | 29.30 | 17.05 | 15.46 | 14.39 | 15.07 | 55.29 | 41.25 |
| 1997 | 15.36 | 12.89 | 15.59 | 151.57 | 97.61 | 17.31 | 15.28 | 14.82 | 14.00 | 131.70 | 196.74 | 144.06 |
| 1998 | 156.57 | 68.08 | 41.11 | 110.83 | 151.36 | 39.59 | 20.60 | 18.85 | 17.59 | 17.78 | 49.40 | 26.84 |
| 1999 | 18.71 | 15.35 | 29.29 | 43.56 | 56.28 | 18.24 | 16.74 | 16.41 | 15.56 | 16.38 | 89.72 | 139.46 |
| 2000 | 32.32 | 15.50 | 16.05 | 17.64 | 16.31 | 15.16 | 15.46 | 15.39 | 14.67 | 15.09 | 88.85 | 73.56 |
| 2001 | 37.20 | 20.86 | 16.36 | 106.01 | 64.39 | 16.50 | 15.24 | 14.99 | 14.08 | 15.13 | 109.02 | 45.17 |
| 2002 | 20.33 | 13.87 | 19.72 | 137.41 | 124.63 | 16.93 | 15.36 | 15.23 | 14.45 | 26.55 | 119.50 | 57.97 |
| 2003 | 24.70 | 13.51 | 16.69 | 85.31 | 146.70 | 27.15 | 15.82 | 16.09 | 14.71 | 37.96 | 121.57 | 60.34 |
| 2004 | 26.04 | 15.16 | 15.66 | 65.04 | 49.02 | 15.54 | 14.95 | 14.70 | 14.08 | 27.51 | 154.15 | 52.70 |
| 2005 | 18.01 | 13.93 | 14.75 | 19.50 | 57.76 | 40.55 | 15.75 | 14.54 | 13.64 | 17.47 | 71.24 | 27.44 |
| 2006 | 15.35 | 12.94 | 18.02 | 73.16 | 109.25 | 15.87 | 13.84 | 13.66 | 13.17 | 25.57 | 210.23 | 103.71 |
| 2007 | 94.67 | 14.71 | 15.81 | 39.38 | 78.40 | 35.72 | 15.82 | 16.32 | 14.06 | 24.81 | 87.11 | 34.22 |
| 2008 | 30.55 | 14.97 | 17.30 | 75.46 | 28.64 | 13.90 | 14.06 | 13.81 | 12.97 | 34.62 | 66.27 | 16.42 |
| 2009 | 15.75 | 12.80 | 13.07 | 23.79 | 46.32 | 15.34 | 12.50 | 12.48 | 11.64 | 24.05 | 82.71 | 36.80 |
| 2010 | 19.04 | 12.52 | 43.53 | 111.70 | 66.80 | 14.44 | 12.82 | 12.72 | 11.82 | 14.08 | 54.25 | 22.40 |

Sub-basin: **4EC** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 20.17 | 13.65 | 13.76 | 13.41 | 30.69 | 17.78 | 14.44 | 13.40 | 12.55 | 12.91 | 18.37 | 21.39 |
| 1992 | 16.24 | 12.16 | 12.66 | 12.90 | 38.62 | 17.20 | 13.71 | 12.69 | 11.89 | 12.08 | 22.92 | 41.20 |
| 1993 | 28.09 | 26.09 | 16.70 | 16.22 | 26.77 | 15.58 | 13.38 | 12.56 | 11.83 | 12.03 | 13.15 | 25.55 |
| 1994 | 14.66 | 11.82 | 11.95 | 34.34 | 31.32 | 15.55 | 13.35 | 12.40 | 11.53 | 16.27 | 83.68 | 29.02 |
| 1995 | 15.58 | 12.41 | 15.05 | 27.69 | 47.51 | 16.11 | 13.84 | 13.09 | 12.32 | 12.66 | 32.18 | 30.80 |
| 1996 | 17.66 | 13.41 | 13.49 | 17.36 | 16.84 | 15.39 | 13.18 | 12.37 | 11.67 | 11.89 | 12.44 | 19.03 |
| 1997 | 12.98 | 10.73 | 11.54 | 49.08 | 34.04 | 14.27 | 12.75 | 12.08 | 11.44 | 29.79 | 72.57 | 60.48 |
| 1998 | 59.16 | 32.07 | 21.09 | 43.49 | 64.24 | 23.68 | 17.15 | 15.22 | 13.99 | 14.09 | 14.54 | 16.47 |
| 1999 | 14.42 | 12.37 | 13.63 | 16.83 | 23.96 | 15.07 | 13.69 | 13.13 | 12.46 | 12.69 | 22.56 | 51.46 |
| 2000 | 19.11 | 13.09 | 13.31 | 12.50 | 12.69 | 12.11 | 12.36 | 12.20 | 11.67 | 11.92 | 17.59 | 25.63 |
| 2001 | 17.83 | 13.54 | 12.58 | 32.86 | 30.76 | 14.15 | 12.73 | 12.11 | 11.45 | 11.66 | 25.34 | 20.52 |
| 2002 | 14.61 | 11.70 | 11.89 | 45.14 | 56.92 | 14.95 | 13.09 | 12.38 | 11.70 | 11.93 | 25.07 | 24.05 |
| 2003 | 16.69 | 11.75 | 12.11 | 17.41 | 58.91 | 17.54 | 13.58 | 12.62 | 11.81 | 12.04 | 30.01 | 27.86 |
| 2004 | 15.85 | 12.07 | 12.31 | 16.39 | 21.00 | 13.02 | 12.13 | 11.67 | 11.09 | 11.38 | 48.58 | 23.91 |
| 2005 | 14.14 | 11.22 | 11.75 | 11.19 | 18.72 | 18.44 | 13.01 | 11.75 | 10.92 | 11.07 | 14.65 | 15.85 |
| 2006 | 12.11 | 10.44 | 10.94 | 19.10 | 39.18 | 13.65 | 11.72 | 11.02 | 10.41 | 10.61 | 65.94 | 41.84 |
| 2007 | 40.88 | 12.97 | 12.42 | 15.56 | 25.18 | 18.89 | 13.27 | 12.20 | 11.31 | 11.52 | 20.59 | 16.70 |
| 2008 | 14.58 | 11.97 | 11.76 | 26.01 | 17.44 | 12.07 | 11.43 | 11.07 | 10.52 | 10.97 | 16.96 | 13.10 |
| 2009 | 11.24 | 9.80 | 10.47 | 10.20 | 15.57 | 11.60 | 10.38 | 10.08 | 9.62 | 9.92 | 17.55 | 16.15 |
| 2010 | 12.19 | 10.02 | 16.01 | 39.56 | 26.37 | 12.94 | 10.97 | 10.30 | 9.71 | 9.88 | 11.38 | 12.04 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

Sub-basin: **4ED** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 38.54 | 22.37 | 19.42 | 23.65 | 29.48 | 25.48 | 18.85 | 17.34 | 16.37 | 16.14 | 20.00 | 29.31 |
| 1992 | 21.09 | 16.13 | 16.87 | 11.42 | 54.51 | 25.04 | 19.39 | 17.40 | 16.19 | 15.38 | 31.22 | 105.92 |
| 1993 | 97.49 | 87.37 | 33.03 | 24.31 | 28.93 | 22.96 | 19.19 | 17.43 | 16.23 | 16.47 | 18.27 | 41.28 |
| 1994 | 23.23 | 17.39 | 17.06 | 16.18 | 41.42 | 23.70 | 18.31 | 16.90 | 16.14 | 16.45 | 203.81 | 125.51 |
| 1995 | 32.37 | 20.58 | 22.57 | 35.74 | 73.92 | 27.15 | 20.26 | 17.95 | 16.31 | 14.71 | 34.59 | 64.60 |
| 1996 | 31.64 | 21.25 | 19.08 | 20.62 | 16.32 | 19.21 | 17.19 | 16.50 | 15.61 | 16.02 | 18.31 | 33.20 |
| 1997 | 19.97 | 15.56 | 16.29 | 60.86 | 82.19 | 25.33 | 19.67 | 17.50 | 16.15 | 19.59 | 210.73 | 394.43 |
| 1998 | 427.47 | 163.90 | 58.49 | 166.90 | 246.43 | 60.07 | 30.25 | 21.89 | 18.08 | 17.62 | 22.73 | 22.09 |
| 1999 | 18.18 | 15.43 | 16.78 | 18.20 | 27.09 | 20.36 | 17.79 | 16.93 | 16.16 | 16.63 | 22.29 | 127.83 |
| 2000 | 38.54 | 21.84 | 19.24 | 16.94 | 16.49 | 16.45 | 16.52 | 16.42 | 15.83 | 16.16 | 16.51 | 33.48 |
| 2001 | 18.74 | 21.00 | 16.40 | 25.31 | 46.30 | 21.22 | 17.92 | 16.94 | 15.94 | 16.13 | 31.46 | 42.62 |
| 2002 | 26.78 | 19.68 | 17.70 | 37.85 | 169.50 | 29.67 | 21.39 | 17.91 | 16.28 | 15.34 | 34.48 | 86.81 |
| 2003 | 42.04 | 21.89 | 18.93 | 11.88 | 101.42 | 36.51 | 22.10 | 17.37 | 16.66 | 13.33 | 54.90 | 120.76 |
| 2004 | 44.61 | 23.39 | 19.91 | 18.51 | 28.53 | 18.73 | 16.89 | 16.29 | 15.52 | 15.85 | 135.39 | 103.60 |
| 2005 | 30.56 | 20.70 | 18.60 | 16.21 | 1.49 | 31.36 | 17.83 | 16.35 | 15.15 | 15.74 | 22.92 | 24.68 |
| 2006 | 17.55 | 15.18 | 15.86 | 27.45 | 46.04 | 22.34 | 18.09 | 16.47 | 15.44 | 15.15 | 187.64 | 153.97 |
| 2007 | 187.86 | 28.39 | 21.54 | 16.05 | 34.41 | 25.53 | 19.14 | 16.20 | 16.59 | 12.85 | 18.44 | 18.90 |
| 2008 | 18.15 | 16.19 | 15.96 | 22.03 | 27.80 | 17.96 | 16.26 | 15.74 | 15.07 | 13.66 | 19.44 | 18.61 |
| 2009 | 15.99 | 14.05 | 15.32 | 14.35 | 14.74 | 15.29 | 15.26 | 15.08 | 14.58 | 14.94 | 14.94 | 21.12 |
| 2010 | 17.94 | 15.77 | 27.77 | 85.96 | 38.02 | 24.05 | 18.30 | 16.26 | 14.93 | 15.01 | 18.11 | 20.17 |

## 4FA & 4FB

Sub-basin: **4FA** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 41.10 | 14.48 | 17.23 | 48.63 | 158.93 | 39.31 | 15.05 | 12.62 | 11.17 | 22.47 | 52.60 | 75.35 |
| 1992 | 29.95 | 13.20 | 11.72 | 23.95 | 69.36 | 25.01 | 13.57 | 11.89 | 11.11 | 14.04 | 108.19 | 269.38 |
| 1993 | 146.10 | 111.75 | 22.39 | 38.67 | 130.55 | 23.53 | 14.46 | 12.42 | 11.44 | 12.77 | 73.46 | 137.70 |
| 1994 | 23.52 | 13.01 | 12.49 | 39.72 | 68.20 | 18.27 | 13.86 | 12.22 | 11.54 | 50.69 | 453.18 | 171.81 |
| 1995 | 26.62 | 14.71 | 23.02 | 151.03 | 189.44 | 20.91 | 14.96 | 13.67 | 12.18 | 30.67 | 114.04 | 123.46 |
| 1996 | 45.48 | 17.79 | 17.95 | 22.43 | 25.37 | 31.63 | 15.93 | 12.86 | 11.39 | 12.78 | 53.25 | 52.49 |
| 1997 | 14.68 | 10.70 | 12.60 | 133.79 | 184.35 | 17.67 | 13.40 | 12.18 | 11.24 | 131.79 | 417.89 | 299.04 |
| 1998 | 338.28 | 100.23 | 47.12 | 119.91 | 230.52 | 38.72 | 18.89 | 15.65 | 13.69 | 13.75 | 59.15 | 27.87 |
| 1999 | 17.57 | 12.46 | 25.93 | 44.56 | 54.01 | 16.57 | 13.93 | 13.04 | 12.25 | 13.24 | 91.38 | 229.93 |
| 2000 | 37.05 | 14.54 | 13.26 | 15.80 | 13.11 | 12.14 | 12.41 | 12.34 | 11.75 | 12.15 | 70.62 | 90.94 |
| 2001 | 33.18 | 19.47 | 14.68 | 100.71 | 66.58 | 17.06 | 13.26 | 12.25 | 11.17 | 12.08 | 113.29 | 67.40 |
| 2002 | 26.44 | 13.72 | 31.37 | 217.07 | 240.48 | 18.78 | 13.90 | 12.65 | 12.00 | 25.83 | 147.34 | 101.59 |
| 2003 | 37.92 | 13.43 | 14.72 | 104.16 | 178.25 | 33.13 | 15.34 | 13.36 | 12.18 | 31.75 | 184.22 | 109.80 |
| 2004 | 50.19 | 20.61 | 14.89 | 67.63 | 67.70 | 15.70 | 13.23 | 12.33 | 11.65 | 28.25 | 267.64 | 160.81 |
| 2005 | 24.28 | 14.53 | 13.16 | 16.70 | 39.82 | 41.88 | 15.23 | 13.08 | 11.81 | 14.59 | 74.07 | 32.37 |
| 2006 | 15.56 | 12.05 | 14.25 | 63.33 | 106.02 | 17.27 | 12.76 | 11.92 | 11.39 | 28.58 | 292.51 | 160.26 |
| 2007 | 169.85 | 18.95 | 16.55 | 42.37 | 101.14 | 24.02 | 14.77 | 13.26 | 11.94 | 22.19 | 84.02 | 42.16 |
| 2008 | 41.28 | 17.02 | 15.95 | 63.71 | 34.67 | 13.90 | 12.19 | 11.60 | 10.83 | 26.05 | 53.04 | 17.38 |
| 2009 | 18.10 | 13.94 | 11.30 | 17.27 | 39.59 | 15.38 | 11.33 | 10.79 | 9.80 | 44.57 | 118.15 | 54.38 |
| 2010 | 24.52 | 13.95 | 41.99 | 100.44 | 65.03 | 15.73 | 12.34 | 11.77 | 10.24 | 12.57 | 51.56 | 25.52 |

Sub-basin: **4FB** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 23.77 | 8.46 | 4.67 | 21.35 | 77.19 | 24.91 | 8.11 | 4.80 | 4.17 | 2.34 | 11.10 | 34.59 |
| 1992 | 17.31 | 7.46 | 4.53 | 0.00 | 26.40 | 14.43 | 6.56 | 4.50 | 3.91 | 2.42 | 55.07 | 198.34 |
| 1993 | 84.39 | 70.66 | 14.96 | 7.07 | 56.97 | 15.10 | 6.92 | 4.52 | 4.01 | 3.21 | 19.04 | 101.06 |
| 1994 | 16.38 | 6.12 | 4.31 | 0.00 | 33.47 | 12.51 | 5.54 | 4.26 | 4.03 | 5.61 | 415.06 | 131.21 |
| 1995 | 18.94 | 7.08 | 6.52 | 81.88 | 137.31 | 14.86 | 6.41 | 4.89 | 4.22 | 0.00 | 58.68 | 77.18 |
| 1996 | 23.60 | 11.50 | 4.75 | 8.47 | 3.20 | 9.13 | 5.35 | 4.44 | 3.84 | 3.98 | 3.74 | 37.94 |
| 1997 | 8.97 | 4.27 | 3.49 | 49.35 | 154.01 | 13.37 | 6.66 | 4.99 | 4.32 | 37.60 | 367.25 | 263.44 |
| 1998 | 232.49 | 58.75 | 20.16 | 65.02 | 120.77 | 21.13 | 9.49 | 5.38 | 4.31 | 4.07 | 19.88 | 17.31 |
| 1999 | 8.08 | 4.49 | 2.28 | 10.10 | 29.09 | 10.06 | 5.09 | 4.21 | 3.98 | 4.13 | 40.26 | 173.44 |
| 2000 | 24.96 | 7.77 | 4.92 | 4.13 | 3.86 | 4.31 | 4.22 | 4.07 | 3.92 | 4.08 | 19.00 | 70.72 |
| 2001 | 12.54 | 12.80 | 3.79 | 37.40 | 44.11 | 10.72 | 5.48 | 4.37 | 3.93 | 3.95 | 48.11 | 46.22 |
| 2002 | 16.07 | 7.74 | 5.01 | 109.59 | 229.81 | 16.75 | 7.20 | 4.93 | 4.33 | 0.00 | 73.48 | 61.57 |
| 2003 | 23.59 | 7.47 | 4.42 | 27.08 | 121.71 | 24.17 | 8.12 | 4.14 | 4.50 | 0.00 | 103.67 | 75.42 |
| 2004 | 26.25 | 11.02 | 5.74 | 23.95 | 37.71 | 9.62 | 4.97 | 4.16 | 3.91 | 0.00 | 201.01 | 97.09 |
| 2005 | 15.35 | 7.27 | 4.85 | 3.16 | 0.00 | 28.52 | 8.10 | 4.81 | 3.68 | 3.31 | 24.07 | 24.41 |
| 2006 | 8.07 | 4.19 | 4.03 | 21.39 | 67.48 | 12.51 | 5.64 | 4.13 | 3.60 | 0.55 | 232.64 | 85.70 |
| 2007 | 98.78 | 13.57 | 6.24 | 0.46 | 48.41 | 14.75 | 6.56 | 3.77 | 4.63 | 0.00 | 16.79 | 21.80 |
| 2008 | 20.05 | 11.61 | 4.68 | 29.81 | 26.77 | 8.41 | 4.52 | 4.06 | 3.70 | 1.33 | 10.88 | 10.99 |
| 2009 | 5.16 | 4.36 | 3.58 | 1.95 | 7.25 | 8.62 | 4.72 | 3.83 | 3.63 | 0.00 | 90.14 | 37.91 |
| 2010 | 15.12 | 6.23 | 3.44 | 59.11 | 32.36 | 11.07 | 5.08 | 3.91 | 3.61 | 3.22 | 9.15 | 15.70 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

## 4GA

Sub-basin: **4GA** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 21.48 | 11.61 | 8.75 | 9.96 | 28.48 | 23.09 | 11.67 | 8.69 | 7.51 | 5.77 | 5.12 | 8.82 |
| 1992 | 9.27 | 6.78 | 7.05 | 0.00 | 9.88 | 9.75 | 7.55 | 7.07 | 6.64 | 5.82 | 11.68 | 129.33 |
| 1993 | 76.31 | 52.66 | 18.79 | 8.30 | 15.98 | 13.77 | 9.64 | 7.95 | 7.19 | 6.54 | 0.01 | 44.61 |
| 1994 | 16.24 | 9.24 | 7.97 | 0.00 | 14.91 | 9.74 | 7.31 | 6.91 | 6.68 | 0.00 | 502.66 | 136.51 |
| 1995 | 26.25 | 11.97 | 9.40 | 66.41 | 153.67 | 26.69 | 12.96 | 9.66 | 8.02 | 2.80 | 24.12 | 56.40 |
| 1996 | 22.47 | 13.30 | 8.75 | 9.39 | 5.40 | 10.33 | 8.07 | 7.55 | 6.97 | 7.17 | 0.00 | 15.34 |
| 1997 | 8.81 | 6.83 | 7.11 | 8.39 | 118.91 | 20.54 | 11.71 | 9.10 | 7.88 | 0.00 | 524.07 | 480.76 |
| 1998 | 204.71 | 48.43 | 22.27 | 22.06 | 64.29 | 22.46 | 13.52 | 9.81 | 8.32 | 8.07 | 5.61 | 9.92 |
| 1999 | 8.12 | 7.04 | 5.92 | 4.44 | 10.65 | 8.79 | 7.76 | 7.52 | 7.22 | 7.45 | 14.17 | 124.88 |
| 2000 | 26.11 | 11.97 | 9.70 | 8.24 | 7.71 | 7.72 | 7.69 | 7.52 | 7.15 | 7.44 | 0.76 | 40.41 |
| 2001 | 13.48 | 14.31 | 8.18 | 0.63 | 27.04 | 11.89 | 9.01 | 8.07 | 7.38 | 7.34 | 7.26 | 28.48 |
| 2002 | 15.85 | 10.36 | 7.66 | 32.48 | 192.23 | 25.13 | 12.88 | 9.48 | 8.13 | 3.56 | 34.69 | 43.96 |
| 2003 | 24.24 | 11.50 | 9.05 | 3.33 | 87.42 | 26.91 | 13.73 | 9.28 | 8.44 | 1.77 | 29.76 | 47.77 |
| 2004 | 19.98 | 12.25 | 9.55 | 1.87 | 20.14 | 10.78 | 8.46 | 7.86 | 7.25 | 3.22 | 100.93 | 79.12 |
| 2005 | 18.77 | 10.80 | 9.25 | 7.50 | 0.00 | 20.73 | 8.57 | 7.68 | 6.92 | 6.69 | 3.91 | 12.23 |
| 2006 | 7.92 | 6.48 | 7.42 | 3.87 | 38.22 | 14.44 | 9.55 | 8.07 | 7.07 | 5.20 | 187.32 | 100.11 |
| 2007 | 69.10 | 18.79 | 11.69 | 2.13 | 16.31 | 12.57 | 9.33 | 7.45 | 7.87 | 3.52 | 9.05 | 8.60 |
| 2008 | 8.45 | 8.91 | 7.25 | 6.72 | 20.48 | 10.78 | 8.27 | 7.64 | 7.05 | 4.97 | 8.04 | 9.02 |
| 2009 | 7.20 | 6.65 | 6.87 | 5.16 | 7.86 | 8.02 | 7.23 | 6.98 | 6.64 | 1.49 | 67.42 | 40.80 |
| 2010 | 19.97 | 11.22 | 5.46 | 42.53 | 34.00 | 15.01 | 9.73 | 8.07 | 7.25 | 6.82 | 5.60 | 11.27 |

## 6. Ewaso Ngiro Catchment Area (ENCA)

## 5AA & 5AB

Sub-basin: **5AA** (Unit: m$^3$/s)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 0.86 | 11.65 | 0.64 | 3.57 | 1.63 | 5.20 | 8.95 | 21.85 | 18.05 | 2.96 | 1.51 | 1.03 |
| 1992 | 0.73 | 0.58 | 0.62 | 1.22 | 7.92 | 1.93 | 6.85 | 15.72 | 15.66 | 10.59 | 5.68 | 5.04 |
| 1993 | 7.94 | 15.99 | 3.03 | 0.98 | 2.02 | 5.50 | 5.37 | 4.53 | 2.50 | 1.13 | 0.64 | 0.62 |
| 1994 | 0.59 | 0.55 | 0.58 | 0.63 | 13.39 | 6.89 | 11.65 | 13.62 | 4.27 | 1.16 | 1.71 | 2.87 |
| 1995 | 0.81 | 0.55 | 1.27 | 0.90 | 4.57 | 1.61 | 5.97 | 4.11 | 6.16 | 4.36 | 17.78 | 3.99 |
| 1996 | 1.19 | 0.62 | 0.61 | 0.57 | 0.58 | 14.78 | 17.76 | 14.90 | 16.88 | 2.88 | 1.24 | 1.06 |
| 1997 | 0.64 | 0.53 | 0.57 | 18.97 | 25.51 | 3.29 | 11.97 | 10.27 | 2.72 | 2.37 | 22.81 | 25.36 |
| 1998 | 39.48 | 16.03 | 4.00 | 1.64 | 38.35 | 12.05 | 11.84 | 12.51 | 9.77 | 14.28 | 5.87 | 2.37 |
| 1999 | 0.83 | 0.60 | 0.99 | 2.41 | 2.99 | 0.88 | 4.54 | 7.47 | 4.75 | 1.22 | 1.08 | 1.28 |
| 2000 | 0.77 | 0.54 | 0.59 | 0.57 | 0.58 | 0.56 | 0.64 | 4.40 | 4.52 | 1.21 | 1.44 | 1.76 |
| 2001 | 1.35 | 0.97 | 0.72 | 13.50 | 13.44 | 8.32 | 9.22 | 21.06 | 17.94 | 2.81 | 7.24 | 4.90 |
| 2002 | 1.28 | 0.71 | 1.56 | 3.27 | 33.53 | 3.09 | 2.12 | 4.04 | 2.15 | 0.83 | 1.62 | 7.15 |
| 2003 | 11.95 | 1.23 | 0.73 | 4.83 | 41.51 | 7.55 | 6.58 | 30.97 | 11.68 | 2.58 | 2.13 | 4.39 |
| 2004 | 5.01 | 2.27 | 0.89 | 7.30 | 14.22 | 2.07 | 1.99 | 12.03 | 3.77 | 1.46 | 3.54 | 2.90 |
| 2005 | 0.98 | 0.56 | 0.58 | 0.56 | 12.76 | 13.42 | 8.92 | 9.55 | 20.38 | 4.66 | 2.02 | 1.02 |
| 2006 | 0.65 | 0.56 | 3.47 | 4.86 | 3.96 | 1.21 | 6.02 | 7.73 | 7.29 | 1.94 | 17.52 | 19.07 |
| 2007 | 16.14 | 3.72 | 1.57 | 1.77 | 4.15 | 22.87 | 28.78 | 29.10 | 39.02 | 7.94 | 3.28 | 1.23 |
| 2008 | 0.75 | 0.59 | 0.62 | 1.52 | 1.31 | 0.70 | 2.01 | 12.65 | 12.73 | 16.62 | 16.19 | 2.70 |
| 2009 | 0.93 | 0.61 | 0.63 | 0.59 | 2.01 | 2.59 | 0.72 | 0.59 | 0.56 | 0.57 | 1.77 | 1.86 |
| 2010 | 21.79 | 4.95 | 14.94 | 24.76 | 28.28 | 8.52 | 3.17 | 16.96 | 25.23 | 10.85 | 5.46 | 1.48 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

Sub-basin: **5AB** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 0.35 | 16.80 | 0.22 | 1.60 | 0.60 | 2.83 | 3.50 | 16.54 | 13.51 | 0.54 | 0.38 | 0.33 |
| 1992 | 0.25 | 0.19 | 0.19 | 0.49 | 5.01 | 0.71 | 3.70 | 6.59 | 5.10 | 4.01 | 2.03 | 2.41 |
| 1993 | 3.32 | 6.21 | 0.60 | 0.25 | 0.27 | 1.39 | 1.31 | 0.89 | 0.42 | 0.27 | 0.21 | 0.20 |
| 1994 | 0.19 | 0.17 | 0.18 | 0.19 | 4.63 | 2.82 | 3.84 | 4.22 | 0.98 | 0.31 | 0.36 | 1.08 |
| 1995 | 0.30 | 0.20 | 0.26 | 0.23 | 1.84 | 0.51 | 2.98 | 0.97 | 1.26 | 3.65 | 8.06 | 1.09 |
| 1996 | 0.35 | 0.20 | 0.19 | 0.18 | 0.18 | 4.92 | 7.48 | 5.77 | 5.81 | 0.55 | 0.27 | 0.23 |
| 1997 | 0.19 | 0.16 | 0.18 | 8.01 | 10.56 | 0.69 | 4.28 | 3.46 | 0.83 | 0.93 | 11.01 | 12.34 |
| 1998 | 19.24 | 4.60 | 0.75 | 0.35 | 19.87 | 4.68 | 4.51 | 4.23 | 3.03 | 5.39 | 2.01 | 0.69 |
| 1999 | 0.29 | 0.21 | 0.28 | 1.02 | 1.72 | 0.39 | 1.69 | 2.88 | 1.30 | 0.34 | 0.27 | 0.32 |
| 2000 | 0.27 | 0.20 | 0.20 | 0.19 | 0.20 | 0.19 | 0.20 | 0.30 | 0.75 | 0.31 | 0.24 | 0.26 |
| 2001 | 0.32 | 0.28 | 0.25 | 7.22 | 4.51 | 2.77 | 3.92 | 7.35 | 5.52 | 0.54 | 3.49 | 1.78 |
| 2002 | 0.36 | 0.23 | 0.33 | 2.97 | 15.58 | 0.73 | 0.58 | 1.99 | 0.62 | 0.29 | 0.43 | 4.33 |
| 2003 | 4.46 | 0.33 | 0.25 | 4.67 | 22.14 | 2.29 | 2.20 | 13.29 | 3.17 | 0.52 | 0.67 | 1.83 |
| 2004 | 3.76 | 0.96 | 0.38 | 4.20 | 6.05 | 0.58 | 0.50 | 6.17 | 0.96 | 0.38 | 1.64 | 0.88 |
| 2005 | 0.36 | 0.23 | 0.22 | 0.21 | 7.21 | 5.49 | 2.54 | 2.28 | 8.44 | 0.99 | 0.52 | 0.34 |
| 2006 | 0.24 | 0.21 | 1.68 | 3.37 | 2.08 | 0.51 | 1.86 | 3.75 | 2.76 | 0.55 | 9.33 | 7.83 |
| 2007 | 6.07 | 0.53 | 0.32 | 0.33 | 1.45 | 10.65 | 9.25 | 10.19 | 12.69 | 1.50 | 0.70 | 0.38 |
| 2008 | 0.30 | 0.24 | 0.24 | 0.65 | 0.81 | 0.36 | 0.66 | 5.11 | 5.68 | 7.15 | 4.42 | 0.54 |
| 2009 | 0.28 | 0.21 | 0.23 | 0.22 | 0.26 | 0.44 | 0.25 | 0.23 | 0.22 | 0.22 | 0.65 | 1.08 |
| 2010 | 8.73 | 1.30 | 5.71 | 7.05 | 9.44 | 2.13 | 0.83 | 7.65 | 8.32 | 4.24 | 2.08 | 0.48 |

## 5BA, 5BB, 5BC1, 5BD & 5BE

Sub-basin: **5BA** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 1.67 | 17.01 | 0.37 | 0.44 | 11.45 | 5.04 | 0.93 | 12.67 | 11.30 | 0.38 | 0.37 | 0.43 |
| 1992 | 0.39 | 0.33 | 0.37 | 0.48 | 3.93 | 2.77 | 1.07 | 0.72 | 0.47 | 0.48 | 1.29 | 4.73 |
| 1993 | 4.04 | 3.57 | 0.88 | 0.53 | 1.99 | 1.50 | 0.54 | 0.36 | 0.34 | 0.35 | 0.34 | 0.41 |
| 1994 | 0.36 | 0.33 | 0.35 | 0.57 | 12.16 | 2.64 | 0.85 | 0.50 | 0.39 | 0.37 | 6.43 | 2.65 |
| 1995 | 0.85 | 0.57 | 1.18 | 0.81 | 7.22 | 1.49 | 0.65 | 0.40 | 0.35 | 1.59 | 8.27 | 2.15 |
| 1996 | 1.02 | 0.38 | 0.35 | 0.34 | 0.46 | 1.99 | 1.19 | 0.59 | 0.58 | 0.37 | 0.34 | 0.45 |
| 1997 | 0.35 | 0.30 | 0.33 | 1.69 | 7.94 | 1.02 | 0.84 | 0.49 | 0.34 | 4.80 | 19.10 | 8.83 |
| 1998 | 11.51 | 5.06 | 1.63 | 2.97 | 12.34 | 2.76 | 0.97 | 0.73 | 0.52 | 0.41 | 0.42 | 0.43 |
| 1999 | 0.37 | 0.33 | 0.36 | 0.37 | 3.71 | 0.86 | 0.38 | 0.36 | 0.35 | 0.36 | 0.36 | 1.73 |
| 2000 | 1.53 | 0.45 | 0.35 | 0.34 | 0.35 | 0.33 | 0.34 | 0.34 | 0.33 | 0.34 | 0.33 | 0.35 |
| 2001 | 0.53 | 0.63 | 0.40 | 4.00 | 7.92 | 0.95 | 0.51 | 0.45 | 0.34 | 0.34 | 1.15 | 2.03 |
| 2002 | 0.52 | 0.31 | 0.33 | 0.42 | 8.96 | 1.13 | 0.45 | 0.34 | 0.32 | 0.33 | 2.66 | 2.56 |
| 2003 | 3.27 | 0.45 | 0.33 | 1.81 | 14.56 | 4.00 | 0.64 | 0.86 | 0.96 | 0.67 | 4.67 | 4.76 |
| 2004 | 1.19 | 0.67 | 0.37 | 0.79 | 5.46 | 0.69 | 0.39 | 0.36 | 0.32 | 0.33 | 3.34 | 2.71 |
| 2005 | 0.78 | 0.32 | 0.33 | 0.34 | 3.22 | 5.27 | 0.74 | 0.42 | 0.79 | 0.73 | 1.06 | 0.71 |
| 2006 | 0.34 | 0.30 | 0.56 | 3.64 | 7.81 | 0.80 | 0.35 | 0.33 | 0.32 | 0.37 | 10.51 | 4.52 |
| 2007 | 4.61 | 0.69 | 0.39 | 1.17 | 3.82 | 5.15 | 1.17 | 1.81 | 1.58 | 0.97 | 2.18 | 0.80 |
| 2008 | 0.44 | 0.32 | 0.33 | 0.64 | 1.36 | 0.60 | 0.34 | 0.32 | 0.31 | 0.48 | 2.71 | 0.90 |
| 2009 | 0.36 | 0.29 | 0.31 | 0.30 | 0.48 | 0.46 | 0.32 | 0.31 | 0.30 | 0.33 | 1.71 | 1.12 |
| 2010 | 1.47 | 0.42 | 4.26 | 6.00 | 7.54 | 1.15 | 0.38 | 0.34 | 0.36 | 0.35 | 2.52 | 1.48 |

Sub-basin: **5BB** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 2.02 | 17.24 | 0.65 | 1.85 | 21.24 | 9.44 | 2.33 | 13.21 | 11.73 | 0.72 | 1.28 | 1.79 |
| 1992 | 1.02 | 0.60 | 0.64 | 2.76 | 11.89 | 4.50 | 3.72 | 3.38 | 2.36 | 3.54 | 5.59 | 8.87 |
| 1993 | 8.58 | 8.65 | 1.59 | 0.81 | 4.47 | 3.72 | 1.23 | 0.66 | 0.61 | 0.62 | 0.61 | 0.74 |
| 1994 | 0.66 | 0.58 | 0.61 | 2.06 | 23.85 | 5.98 | 2.36 | 1.39 | 1.19 | 1.40 | 13.77 | 4.72 |
| 1995 | 1.25 | 0.79 | 3.10 | 1.90 | 15.11 | 2.47 | 2.76 | 1.09 | 1.03 | 8.24 | 17.57 | 4.48 |
| 1996 | 1.71 | 0.65 | 0.61 | 0.59 | 0.76 | 6.06 | 3.53 | 2.18 | 4.51 | 1.40 | 1.01 | 2.47 |
| 1997 | 0.77 | 0.54 | 0.59 | 10.35 | 17.84 | 1.54 | 2.75 | 1.74 | 0.99 | 10.99 | 33.83 | 18.33 |
| 1998 | 27.24 | 9.77 | 2.51 | 5.37 | 30.87 | 7.44 | 3.03 | 2.49 | 1.58 | 1.84 | 2.57 | 1.69 |
| 1999 | 0.70 | 0.57 | 0.63 | 0.83 | 7.85 | 1.27 | 0.66 | 0.63 | 0.60 | 0.62 | 0.62 | 3.80 |
| 2000 | 1.85 | 0.65 | 0.61 | 0.59 | 0.61 | 0.59 | 0.60 | 0.60 | 0.58 | 0.60 | 0.58 | 0.92 |
| 2001 | 2.04 | 1.48 | 0.86 | 14.82 | 13.20 | 1.93 | 2.00 | 3.09 | 1.42 | 1.35 | 8.07 | 4.21 |
| 2002 | 0.84 | 0.56 | 0.59 | 3.73 | 24.19 | 1.61 | 0.97 | 0.76 | 0.60 | 0.60 | 8.11 | 6.26 |
| 2003 | 8.22 | 0.75 | 0.59 | 9.48 | 36.63 | 6.31 | 1.62 | 9.29 | 4.40 | 1.80 | 8.93 | 7.14 |
| 2004 | 2.77 | 1.98 | 0.78 | 5.55 | 13.62 | 1.26 | 0.73 | 0.79 | 0.68 | 0.69 | 9.75 | 5.14 |
| 2005 | 1.55 | 0.57 | 0.59 | 0.61 | 11.80 | 10.72 | 1.59 | 0.83 | 6.57 | 2.44 | 3.17 | 1.07 |
| 2006 | 0.60 | 0.54 | 3.76 | 8.85 | 13.71 | 1.49 | 0.65 | 0.60 | 0.70 | 1.10 | 25.24 | 9.05 |
| 2007 | 10.83 | 1.21 | 0.71 | 2.82 | 7.45 | 13.13 | 2.76 | 7.71 | 5.96 | 2.96 | 5.59 | 1.46 |
| 2008 | 0.81 | 0.58 | 0.59 | 3.77 | 3.71 | 0.99 | 0.62 | 0.58 | 0.75 | 5.85 | 8.23 | 1.36 |
| 2009 | 0.62 | 0.52 | 0.57 | 0.55 | 0.86 | 1.34 | 0.66 | 0.56 | 0.54 | 0.61 | 6.13 | 2.27 |
| 2010 | 9.27 | 1.17 | 11.28 | 12.74 | 14.04 | 2.59 | 0.89 | 3.23 | 9.23 | 5.96 | 11.17 | 2.38 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

Sub-basin: **5BC1** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 6.11 | 16.96 | 1.64 | 2.95 | 38.64 | 17.47 | 5.86 | 15.30 | 13.82 | 2.01 | 2.33 | 7.04 |
| 1992 | 3.01 | 1.52 | 1.59 | 5.02 | 24.30 | 7.15 | 4.96 | 6.83 | 5.98 | 5.85 | 13.00 | 22.69 |
| 1993 | 19.20 | 24.50 | 4.02 | 1.80 | 4.39 | 5.52 | 2.93 | 2.06 | 1.67 | 1.57 | 1.63 | 6.73 |
| 1994 | 2.26 | 1.45 | 1.51 | 1.48 | 50.40 | 10.55 | 4.99 | 4.31 | 2.71 | 1.54 | 23.63 | 10.14 |
| 1995 | 2.53 | 1.50 | 2.33 | 2.61 | 35.57 | 4.70 | 4.39 | 2.32 | 2.09 | 19.55 | 53.39 | 9.97 |
| 1996 | 3.71 | 1.48 | 1.47 | 1.42 | 1.39 | 8.80 | 13.61 | 9.36 | 14.87 | 2.78 | 1.56 | 1.79 |
| 1997 | 1.50 | 1.30 | 1.42 | 25.63 | 49.32 | 4.17 | 7.84 | 5.83 | 2.84 | 19.76 | 82.96 | 65.93 |
| 1998 | 93.42 | 22.10 | 5.15 | 5.97 | 80.82 | 16.67 | 10.25 | 11.60 | 8.56 | 7.69 | 6.09 | 3.80 |
| 1999 | 1.74 | 1.43 | 1.67 | 3.51 | 16.39 | 2.85 | 2.43 | 3.39 | 2.55 | 1.66 | 1.59 | 8.10 |
| 2000 | 5.23 | 1.70 | 1.51 | 1.45 | 1.50 | 1.44 | 1.49 | 1.57 | 1.98 | 1.61 | 1.57 | 1.78 |
| 2001 | 2.67 | 3.60 | 1.82 | 22.78 | 26.36 | 4.54 | 4.37 | 8.91 | 7.96 | 2.20 | 14.20 | 11.91 |
| 2002 | 2.13 | 1.37 | 1.56 | 7.77 | 66.86 | 4.99 | 2.44 | 2.93 | 1.87 | 1.49 | 11.53 | 12.62 |
| 2003 | 18.51 | 1.90 | 1.46 | 24.31 | 111.54 | 14.20 | 3.70 | 23.37 | 13.66 | 2.44 | 16.88 | 19.29 |
| 2004 | 11.69 | 6.53 | 1.93 | 10.86 | 31.81 | 3.26 | 2.15 | 6.47 | 3.40 | 1.77 | 16.21 | 10.94 |
| 2005 | 2.74 | 1.38 | 1.47 | 1.60 | 28.95 | 27.61 | 5.58 | 3.41 | 15.61 | 6.62 | 4.12 | 2.61 |
| 2006 | 1.51 | 1.36 | 6.38 | 16.45 | 23.53 | 3.11 | 2.47 | 3.11 | 4.43 | 2.15 | 53.39 | 28.15 |
| 2007 | 36.18 | 3.00 | 1.63 | 2.75 | 11.92 | 29.26 | 14.61 | 24.95 | 23.19 | 6.59 | 8.27 | 3.06 |
| 2008 | 1.85 | 1.44 | 1.50 | 2.60 | 6.10 | 2.06 | 1.79 | 4.18 | 5.68 | 12.38 | 24.02 | 3.95 |
| 2009 | 1.59 | 1.33 | 1.46 | 1.40 | 1.54 | 2.01 | 1.54 | 1.45 | 1.42 | 1.43 | 12.27 | 7.04 |
| 2010 | 19.57 | 2.72 | 24.30 | 28.43 | 34.78 | 7.45 | 2.31 | 6.75 | 18.38 | 7.33 | 14.52 | 5.62 |

Sub-basin: **5BD** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 1.26 | 17.52 | 1.01 | 2.09 | 1.77 | 3.57 | 3.41 | 15.29 | 13.89 | 1.37 | 1.14 | 1.19 |
| 1992 | 1.01 | 0.89 | 0.97 | 1.95 | 7.15 | 2.17 | 3.54 | 5.07 | 4.28 | 4.03 | 2.95 | 3.03 |
| 1993 | 3.26 | 6.42 | 1.67 | 0.96 | 1.18 | 2.28 | 1.81 | 1.44 | 1.08 | 0.97 | 0.91 | 0.99 |
| 1994 | 0.94 | 0.87 | 0.92 | 0.96 | 8.14 | 3.99 | 3.21 | 3.31 | 1.82 | 1.04 | 1.94 | 2.30 |
| 1995 | 1.02 | 0.83 | 1.07 | 1.01 | 4.06 | 1.63 | 3.21 | 1.60 | 1.51 | 3.95 | 15.82 | 3.26 |
| 1996 | 1.18 | 0.82 | 0.89 | 0.85 | 0.88 | 4.42 | 7.86 | 5.81 | 8.02 | 1.56 | 0.98 | 1.00 |
| 1997 | 0.88 | 0.79 | 0.87 | 8.25 | 16.35 | 1.93 | 4.42 | 3.59 | 1.85 | 1.71 | 15.20 | 24.09 |
| 1998 | 30.97 | 7.05 | 1.82 | 1.22 | 26.76 | 7.63 | 5.37 | 5.48 | 4.17 | 5.31 | 3.02 | 1.61 |
| 1999 | 1.00 | 0.88 | 1.05 | 2.00 | 2.67 | 1.15 | 1.78 | 2.75 | 1.95 | 1.06 | 1.00 | 1.43 |
| 2000 | 1.11 | 0.84 | 0.92 | 0.89 | 0.92 | 0.88 | 0.91 | 1.01 | 1.42 | 1.03 | 1.03 | 1.24 |
| 2001 | 1.39 | 1.07 | 1.00 | 6.88 | 5.90 | 2.63 | 3.28 | 6.13 | 5.79 | 1.45 | 3.92 | 3.43 |
| 2002 | 1.06 | 0.84 | 1.01 | 3.72 | 23.23 | 2.34 | 1.55 | 2.30 | 1.31 | 0.95 | 1.88 | 3.50 |
| 2003 | 6.09 | 0.96 | 0.92 | 6.90 | 41.32 | 4.49 | 2.29 | 12.65 | 6.28 | 1.34 | 1.79 | 3.54 |
| 2004 | 5.93 | 3.02 | 1.09 | 4.69 | 9.39 | 1.65 | 1.41 | 5.10 | 2.21 | 1.11 | 2.67 | 2.15 |
| 2005 | 1.13 | 0.84 | 0.92 | 0.90 | 9.69 | 8.95 | 3.25 | 2.37 | 8.22 | 2.93 | 1.63 | 1.06 |
| 2006 | 0.92 | 0.85 | 2.70 | 3.65 | 3.69 | 1.32 | 1.83 | 2.55 | 3.57 | 1.33 | 12.10 | 10.88 |
| 2007 | 12.62 | 1.41 | 0.99 | 1.14 | 2.29 | 9.70 | 8.63 | 12.68 | 11.86 | 3.03 | 1.91 | 1.10 |
| 2008 | 1.04 | 0.87 | 0.94 | 1.66 | 1.91 | 1.06 | 1.22 | 3.61 | 4.94 | 6.80 | 7.09 | 1.52 |
| 2009 | 0.95 | 0.84 | 0.93 | 0.89 | 0.99 | 1.31 | 0.99 | 0.94 | 0.91 | 0.93 | 3.06 | 1.81 |
| 2010 | 9.01 | 1.69 | 5.39 | 6.25 | 9.59 | 3.49 | 1.42 | 5.78 | 10.94 | 5.22 | 3.59 | 1.34 |

Sub-basin: **5BE** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 11.27 | 17.55 | 0.51 | 3.99 | 61.13 | 10.83 | 1.26 | 12.83 | 11.47 | 5.49 | 21.50 | 28.91 |
| 1992 | 4.25 | 0.70 | 0.47 | 15.94 | 23.28 | 5.67 | 1.07 | 0.76 | 0.65 | 0.68 | 34.11 | 46.71 |
| 1993 | 40.93 | 34.17 | 2.42 | 3.08 | 19.73 | 3.65 | 0.84 | 0.49 | 0.42 | 0.43 | 21.38 | 22.98 |
| 1994 | 2.08 | 0.48 | 0.43 | 5.75 | 40.86 | 5.82 | 1.24 | 0.77 | 0.60 | 4.39 | 66.82 | 22.90 |
| 1995 | 2.22 | 1.15 | 9.52 | 22.10 | 50.87 | 2.30 | 0.95 | 0.52 | 0.47 | 32.58 | 38.24 | 22.93 |
| 1996 | 4.04 | 0.76 | 0.47 | 0.63 | 2.48 | 15.95 | 5.04 | 2.63 | 3.34 | 0.76 | 10.03 | 11.48 |
| 1997 | 0.97 | 0.37 | 0.39 | 33.60 | 33.50 | 1.86 | 2.09 | 1.30 | 0.59 | 40.69 | 90.84 | 57.87 |
| 1998 | 96.15 | 23.49 | 5.08 | 19.08 | 47.65 | 9.81 | 4.88 | 6.15 | 4.55 | 2.04 | 11.90 | 4.59 |
| 1999 | 0.78 | 0.42 | 1.80 | 8.55 | 15.91 | 1.32 | 0.49 | 0.49 | 0.44 | 0.41 | 10.39 | 25.79 |
| 2000 | 6.11 | 1.29 | 0.43 | 1.93 | 1.80 | 0.51 | 0.39 | 0.38 | 0.37 | 0.37 | 8.73 | 14.21 |
| 2001 | 12.87 | 6.57 | 1.09 | 21.93 | 15.68 | 1.33 | 0.71 | 0.87 | 0.65 | 0.42 | 32.18 | 11.81 |
| 2002 | 1.26 | 0.38 | 0.42 | 18.84 | 49.73 | 2.17 | 0.60 | 0.47 | 0.37 | 0.70 | 44.58 | 25.38 |
| 2003 | 10.38 | 0.66 | 0.38 | 35.36 | 52.68 | 6.21 | 0.79 | 2.43 | 2.91 | 12.79 | 41.63 | 22.27 |
| 2004 | 4.84 | 2.66 | 0.70 | 9.13 | 22.13 | 1.21 | 0.53 | 0.90 | 0.58 | 1.46 | 47.30 | 16.35 |
| 2005 | 1.46 | 0.40 | 0.35 | 1.04 | 18.76 | 12.63 | 1.39 | 0.67 | 3.63 | 2.36 | 9.90 | 5.41 |
| 2006 | 0.61 | 0.32 | 6.80 | 22.98 | 21.34 | 1.46 | 0.45 | 0.43 | 0.67 | 5.16 | 59.43 | 32.62 |
| 2007 | 31.15 | 1.70 | 0.48 | 5.91 | 14.62 | 13.03 | 3.36 | 4.33 | 5.84 | 4.97 | 21.48 | 4.84 |
| 2008 | 2.72 | 1.11 | 0.36 | 4.87 | 5.16 | 0.80 | 0.35 | 0.41 | 0.46 | 11.95 | 27.50 | 3.08 |
| 2009 | 0.54 | 0.38 | 0.29 | 0.27 | 2.25 | 1.21 | 0.32 | 0.27 | 0.26 | 5.83 | 28.33 | 13.75 |
| 2010 | 9.30 | 0.71 | 33.91 | 32.94 | 29.44 | 2.81 | 0.63 | 0.61 | 0.71 | 0.69 | 17.64 | 7.17 |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

## 5DA

Sub-basin: **5DA** (Unit: $m^3/s$)

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1991 | 26.28 | 16.41 | 4.26 | 26.79 | 54.01 | 11.13 | 3.15 | 9.08 | 8.54 | 0.56 | 27.46 | 76.29 |
| 1992 | 18.30 | 5.36 | 1.64 | 22.10 | 25.24 | 4.97 | 1.38 | 0.81 | 0.94 | 0.31 | 54.25 | 133.76 |
| 1993 | 105.26 | 88.16 | 9.74 | 16.32 | 37.45 | 4.72 | 1.66 | 0.80 | 0.27 | 0.11 | 40.30 | 56.17 |
| 1994 | 6.13 | 1.79 | 0.66 | 17.23 | 21.83 | 3.51 | 1.45 | 0.89 | 0.71 | 18.61 | 222.32 | 95.48 |
| 1995 | 10.83 | 3.40 | 6.41 | 67.73 | 58.79 | 5.40 | 2.21 | 0.93 | 0.46 | 29.70 | 75.56 | 69.53 |
| 1996 | 16.27 | 3.72 | 1.86 | 2.16 | 0.89 | 2.70 | 2.28 | 1.05 | 2.55 | 0.52 | 22.10 | 19.43 |
| 1997 | 2.50 | 0.75 | 0.25 | 92.34 | 113.16 | 9.36 | 3.81 | 1.66 | 0.90 | 63.80 | 229.43 | 237.59 |
| 1998 | 273.42 | 57.79 | 18.17 | 39.22 | 87.75 | 14.96 | 4.86 | 3.27 | 2.57 | 0.99 | 17.06 | 6.78 |
| 1999 | 1.92 | 0.70 | 10.71 | 14.62 | 14.79 | 2.04 | 0.23 | 0.66 | 0.39 | 0.06 | 33.77 | 75.00 |
| 2000 | 8.44 | 2.43 | 0.96 | 1.00 | 1.01 | 0.39 | 0.06 | 0.00 | 0.28 | 0.06 | 25.92 | 34.03 |
| 2001 | 14.70 | 5.06 | 1.33 | 40.77 | 13.63 | 2.22 | 0.74 | 0.61 | 1.01 | 0.25 | 41.21 | 21.90 |
| 2002 | 5.19 | 1.56 | 11.11 | 78.96 | 105.88 | 8.50 | 2.91 | 0.79 | 0.50 | 3.41 | 74.43 | 61.15 |
| 2003 | 20.47 | 3.15 | 1.01 | 60.29 | 75.80 | 7.90 | 2.64 | 0.00 | 2.69 | 17.83 | 96.65 | 46.90 |
| 2004 | 13.25 | 5.29 | 1.76 | 22.28 | 26.67 | 2.94 | 0.96 | 0.00 | 0.75 | 11.37 | 112.61 | 66.02 |
| 2005 | 7.04 | 2.11 | 0.72 | 0.18 | 11.83 | 9.61 | 1.99 | 0.88 | 0.00 | 0.99 | 19.44 | 6.56 |
| 2006 | 1.47 | 0.52 | 0.27 | 31.06 | 32.32 | 3.58 | 1.13 | 0.00 | 0.84 | 14.00 | 134.53 | 107.42 |
| 2007 | 95.21 | 8.42 | 3.19 | 20.75 | 29.46 | 2.81 | 1.90 | 2.14 | 1.11 | 0.90 | 48.18 | 13.98 |
| 2008 | 20.30 | 3.46 | 1.24 | 21.23 | 6.43 | 1.54 | 0.15 | 0.21 | 0.38 | 0.59 | 25.69 | 3.43 |
| 2009 | 1.14 | 0.96 | 0.58 | 1.31 | 9.63 | 1.74 | 0.56 | 0.10 | 0.00 | 21.92 | 66.84 | 30.60 |
| 2010 | 12.77 | 1.88 | 24.17 | 60.59 | 38.05 | 5.45 | 1.69 | 0.00 | 2.58 | 0.20 | 22.91 | 7.45 |

END

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

# Annex-2

# Regional Area Flood Curve of Major River Basins in NWMP 2030

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

| Catchment Area | Basin Code | River Name | Return Period | Flood Curve |
|---|---|---|---|---|
| Lake Victoria North | LVN-2 | Yala | 10-year | $\log_{10} Q = -1.257 + 0.939 \log_{10} A$ |
| | | | 25-year | $\log_{10} Q = -1.227 + 0.945 \log_{10} A$ |
| | | | 50-year | $\log_{10} Q = -1.212 + 0.951 \log_{10} A$ |
| | | | 100-year | $\log_{10} Q = -1.202 + 0.957 \log_{10} A$ |
| | LVN-3 | Nzoia | 10-year | $\log_{10} Q = -0.866 + 0.776 \log_{10} A$ |
| | | | 25-year | $\log_{10} Q = -0.780 + 0.767 \log_{10} A$ |
| | | | 50-year | $\log_{10} Q = -0.722 + 0.760 \log_{10} A$ |
| | | | 100-year | $\log_{10} Q = -0.669 + 0.752 \log_{10} A$ |
| | LVN-6 | Malikisi | 10-year | $\log_{10} Q = -1.054 + 0.887 \log_{10} A$ |
| | | | 25-year | $\log_{10} Q = -0.974 + 0.883 \log_{10} A$ |
| | | | 50-year | $\log_{10} Q = -0.915 + 0.876 \log_{10} A$ |
| | | | 100-year | $\log_{10} Q = -0.859 + 0.868 \log_{10} A$ |
| | LVN-7 | Malaba | 10-year | $\log_{10} Q = -1.233 + 0.998 \log_{10} A$ |
| | | | 25-year | $\log_{10} Q = -1.178 + 0.997 \log_{10} A$ |
| | | | 50-year | $\log_{10} Q = -1.146 + 0.997 \log_{10} A$ |
| | | | 100-year | $\log_{10} Q = -1.120 + 0.997 \log_{10} A$ |
| Lake Victoria South | LVS-2 | Asure | 10-year | $\log_{10} Q = -1.492 + 1.125 \log_{10} A$ |
| | | | 25-year | $\log_{10} Q = -1.397 + 1.135 \log_{10} A$ |
| | | | 50-year | $\log_{10} Q = -1.341 + 1.142 \log_{10} A$ |
| | | | 100-year | $\log_{10} Q = -1.295 + 1.149 \log_{10} A$ |
| | LVS-5 | Mara | 10-year | $\log_{10} Q = -1.083 + 0.934 \log_{10} A$ |
| | | | 25-year | $\log_{10} Q = -0.959 + 0.915 \log_{10} A$ |
| | | | 50-year | $\log_{10} Q = -0.874 + 0.899 \log_{10} A$ |
| | | | 100-year | $\log_{10} Q = -0.794 + 0.883 \log_{10} A$ |
| | LVS-6 | Migori | 10-year | $\log_{10} Q = -0.954 + 0.879 \log_{10} A$ |
| | | | 25-year | $\log_{10} Q = -0.905 + 0.890 \log_{10} A$ |
| | | | 50-year | $\log_{10} Q = -0.875 + 0.898 \log_{10} A$ |
| | | | 100-year | $\log_{10} Q = -0.850 + 0.906 \log_{10} A$ |
| | LVS-10 | Kabondo Awach | 10-year | $\log_{10} Q = -1.243 + 0.982 \log_{10} A$ |
| | | | 25-year | $\log_{10} Q = -1.184 + 0.982 \log_{10} A$ |
| | | | 50-year | $\log_{10} Q = -1.147 + 0.982 \log_{10} A$ |
| | | | 100-year | $\log_{10} Q = -1.114 + 0.982 \log_{10} A$ |
| | LVS-11 | Sondu | 10-year | $\log_{10} Q = -1.153 + 0.967 \log_{10} A$ |
| | | | 25-year | $\log_{10} Q = -1.108 + 0.967 \log_{10} A$ |
| | | | 50-year | $\log_{10} Q = -1.083 + 0.967 \log_{10} A$ |
| | | | 100-year | $\log_{10} Q = -1.064 + 0.968 \log_{10} A$ |
| | LVS-12 | Nyando | 10-year | $\log_{10} Q = -0.842 + 0.874 \log_{10} A$ |
| | | | 25-year | $\log_{10} Q = -0.782 + 0.872 \log_{10} A$ |
| | | | 50-year | $\log_{10} Q = -0.744 + 0.871 \log_{10} A$ |
| | | | 100-year | $\log_{10} Q = -0.710 + 0.869 \log_{10} A$ |
| | LVS-13 | Oroba | 10-year | $\log_{10} Q = -1.100 + 0.998 \log_{10} A$ |
| | | | 25-year | $\log_{10} Q = -0.975 + 1.021 \log_{10} A$ |
| | | | 50-year | $\log_{10} Q = -0.878 + 1.030 \log_{10} A$ |
| | | | 100-year | $\log_{10} Q = -0.779 + 1.035 \log_{10} A$ |
| | LVS-14 | Kibos | 10-year | $\log_{10} Q = -0.012 + 0.551 \log_{10} A$ |
| | | | 25-year | $\log_{10} Q = +0.061 + 0.555 \log_{10} A$ |
| | | | 50-year | $\log_{10} Q = +0.115 + 0.555 \log_{10} A$ |
| | | | 100-year | $\log_{10} Q = +0.168 + 0.553 \log_{10} A$ |
| | LVS-16 | Awach Seme | 10-year | $\log_{10} Q = -0.012 + 0.551 \log_{10} A$ |
| | | | 25-year | $\log_{10} Q = -0.061 + 0.555 \log_{10} A$ |
| | | | 50-year | $\log_{10} Q = -0.115 + 0.555 \log_{10} A$ |
| | | | 100-year | $\log_{10} Q = -0.168 + 0.553 \log_{10} A$ |

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

| Catchment Area | Basin Code | River Name | Return Period | Flood Curve |
|---|---|---|---|---|
| Rift Valley | RV-2 | Ewaso Ngiro(South) | 10-year | $\log_{10} Q = -1.619 + 1.016 \log_{10} A$ |
| | | | 25-year | $\log_{10} Q = -1.469 + 0.996 \log_{10} A$ |
| | | | 50-year | $\log_{10} Q = -1.374 + 0.983 \log_{10} A$ |
| | | | 100-year | $\log_{10} Q = -1.290 + 0.969 \log_{10} A$ |
| | RV-12 | Kedong | 10-year | $\log_{10} Q = -0.206 + 0.593 \log_{10} A$ |
| | | | 25-year | $\log_{10} Q = -0.234 + 0.636 \log_{10} A$ |
| | | | 50-year | $\log_{10} Q = -0.257 + 0.666 \log_{10} A$ |
| | | | 100-year | $\log_{10} Q = -0.282 + 0.693 \log_{10} A$ |
| | RV-14 | Lake Naivasha | 10-year | $\log_{10} Q = -0.647 + 0.773 \log_{10} A$ |
| | | | 25-year | $\log_{10} Q = -0.585 + 0.781 \log_{10} A$ |
| | | | 50-year | $\log_{10} Q = -0.551 + 0.787 \log_{10} A$ |
| | | | 100-year | $\log_{10} Q = -0.524 + 0.794 \log_{10} A$ |
| | RV-19 | Lake Bogoria | 10-year | $\log_{10} Q = -1.134 + 0.923 \log_{10} A$ |
| | | | 25-year | $\log_{10} Q = -0.937 + 0.873 \log_{10} A$ |
| | | | 50-year | $\log_{10} Q = -0.802 + 0.835 \log_{10} A$ |
| | | | 100-year | $\log_{10} Q = -0.676 + 0.798 \log_{10} A$ |
| | RV-20 | Lake Baringo | 10-year | $\log_{10} Q = -0.832 + 0.783 \log_{10} A$ |
| | | | 25-year | $\log_{10} Q = -0.801 + 0.792 \log_{10} A$ |
| | | | 50-year | $\log_{10} Q = -0.787 + 0.798 \log_{10} A$ |
| | | | 100-year | $\log_{10} Q = -0.776 + 0.803 \log_{10} A$ |
| Athi | TA-1 | Athi | 10-year | $\log_{10} Q = -0.928 + 0.826 \log_{10} A$ |
| | | | 25-year | $\log_{10} Q = -0.902 + 0.895 \log_{10} A$ |
| | | | 50-year | $\log_{10} Q = -0.891 + 0.941 \log_{10} A$ |
| | | | 100-year | $\log_{10} Q = -0.885 + 0.983 \log_{10} A$ |
| Tana | TN-1 | Tana | 10-year | $\log_{10} Q = -0.589 + 0.854 \log_{10} A$ |
| | | | 25-year | $\log_{10} Q = -0.539 + 0.873 \log_{10} A$ |
| | | | 50-year | $\log_{10} Q = -0.513 + 0.887 \log_{10} A$ |
| | | | 100-year | $\log_{10} Q = -0.493 + 0.901 \log_{10} A$ |
| Ewaso Ngiro | EN-1 | Ewaso Ngiro | 10-year | $\log_{10} Q = -1.150 + 0.891 \log_{10} A$ |
| | | | 25-year | $\log_{10} Q = -0.957 + 0.889 \log_{10} A$ |
| | | | 50-year | $\log_{10} Q = -0.835 + 0.888 \log_{10} A$ |
| | | | 100-year | $\log_{10} Q = -0.728 + 0.888 \log_{10} A$ |

END

Source: “National Water Master Plan 2030”, Volume VII Data Book, conducted by JICA in 2013 (arranged by WG)

# Brief Explanation
# of
# Draft Guideline on MHP

By
Working Group on MHP
Under
The Project for Establishment of Rural Electrification Model using Renewable Energy

6th November 2014 - Kivi Milimani Hotel, Nairobi

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# Contents

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# Marks of the Guideline

Many guidelines and manuals on MHP exists in the world.
The marks of this Guideline may be the following two points.
Other parts are similar to other guidelines or manuals.

## Adopting the result of NWMP 2030

Lack of hydrological data is the one of the key challenges for development of MHP.
"NWMP 2030: Natural Water Master Plan 2030" was formulated by 2013. In this master plan study, rainfall-runoff analysis was conducted in national wise, and monthly average naturalized discharge were provided for 204 sub-basins for 20 years period.
The data will be attached in this Guideline. It may contribute preliminary identification & planning.
**However,** measurement of discharge at the candidate site is essential for detailed planning.

## Adopting the Empirical Equations of Japan

In general, there are many alternative approaches, such as location of intake weir, route of power canal and penstock, and location of powerhouse and tailrace, which can be taken in development at a potential site. A comparative study shall be carried out to identify the optimum development plan.
Empirical equations to estimated work quantities were presented in this Guideline for relative evaluation.
Using these equations, comparative study is easily carried out by temporary setting of some major dimensions.

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Brief Explanation <Chapter 1>

# General

**Working Group for MHP**

REA Personnel
  Ms. Judith Kimeu
  Mr. Semekiah Ongong'a
  Mr. Anthony Wanjara
JICA Expert Team
  Mr. Yoshiaki Samejima

## 1.1 Introduction

✓ The Government has given high priority on Rural Electrification.
✓ The total MHP potential in Kenya is estimated to be 3,000 MW.
✓ Development of MHP has been faced with challenges which included:

Insufficient financial resources

Insufficient technical personnel

Lack of hydrological data

✓ Technical cooperation with JICA for Solar PV, Biogas, Wind & MHP. ➡ This guideline was prepared.
✓ Capacity ranges of this Guideline: **10 kW – 1,000 kW**

## 1.2 Necessity of MHP

**Advantages**

✓ Contribute to practical use of natural water resources,
✓ Safest, cleanest, & cheapest power source, and to its contribute to CO2 emission reduction,
✓ Contribute to regional socio – economic activities.

**Disadvantages**

✓ Potential sites depend on topography & hydrology rather than power demand,
✓ Annual energy generations depend on river condition,
✓ Same O&M activities required for any scale in principle.

Development of MHP system shall be studied carefully taking in to consideration the above.

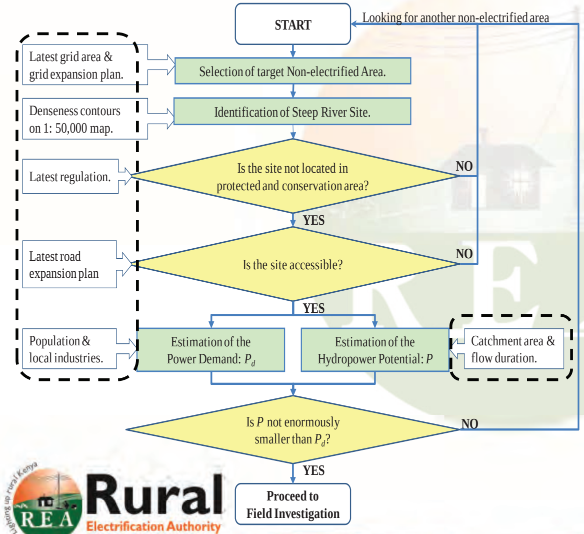
## 1.3 Basic of Hydropower

Power output: $P = 9.8 \times \eta \times Q \times H_e$
Annual energy: $E = \xi \times P \times 24 \times 365 = 8{,}760 \times \xi \times P$
Required generator capacity: $P_d = 0.2N$

Brief Explanation <Chapter 2>

# Identification of the Project

## 2.1 Work Flow of Identification



START

Looking for another non-electrified area

Latest grid area & grid expansion plan.

Selection of target Non-electrified Area.

Denseness contours on 1: 50,000 map.

Identification of Steep River Site.

Latest regulation.

Is the site not located in protected and conservation area?

NO

YES

Latest road expansion plan

Is the site accessible?

NO

YES

Population & local industries.

Estimation of the Power Demand: $P_d$

Estimation of the Hydropower Potential: $P$

Catchment area & flow duration.

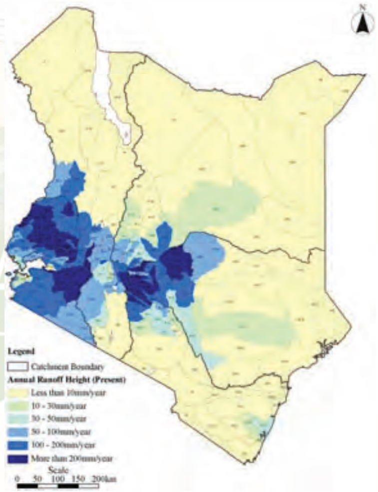
Is $P$ not enormously smaller than $P_d$?

NO

YES

Proceed to Field Investigation

## 2.2 Potential Area of Hydropower



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Brief Explanation <Chapter 2>

# Identification of the Project

## 2.4 Estimation of Hydropower Potential

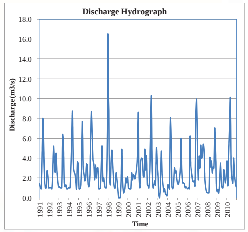
Dependable discharge is estimated as follows:

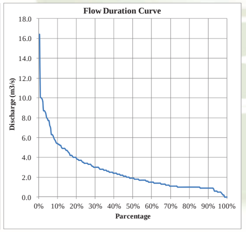
✓ Applying monthly average naturalized discharge by National Water Master Plan 2030,

✓ Estimate the discharge at the candidate site by ratio of catchment area,

✓ Prepare the flow duration curve,

✓ Defined dependable discharge within 90 to 95% of reliable discharge.





Sub-basins (Figure 2.4.3)

Amount of reserve was determined as the 95% value in accordance with WRMA guideline in 2010.

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Brief Explanation <Chapter 2>

# Identification of the Project

## 2.5 Estimation of Power Demand

Generator capacity can be approximated using the following equation based on the following assumptions:

Required Generator Capacity: $P_d$ **= 20% of Community Size** (number of households).

| User | Share per household or Number per village | Assumed Demand | | | |
|---|---|---|---|---|---|
| | | Lighting | TV | Fan/Heater | Total |
| **Domestic** | | | | | |
| Type A | 20% of total households | - | - | - | 0 |
| Type B | 60% of total households | 20 W x 2 | - | - | 40 |
| Type C | 20% of total households | 20 W x 3 | 200 W x 1 | - | 260 |
| Type D | 1 per 100 households | 40 W x 5 | 200 W x 1 | 200 W x 1 | 600 |
| **Public** | | | | | |
| Primary School | 1 per 100 households | 40 W x 15 | 200 W x 1 | 200 W x 1 | 1,000 |
| Community Hall | 1 per 100 households | 40 W x 15 | - | 200 W x 2 | 1,000 |
| Dispensary | 1 per village > 100 households | 40 W x 5 | - | 200 W x 2 | 600 |
| Streetlight | 1 per 4 households | 40 W x 1 | - | - | 40 |
| **Business** | | | | | |
| Battery Carging Station | 1 per 50 households | - | - | - | 1,200 |
| Posho Mill | 1 per 200 households | - | - | - | 5,000 |

## 2.6 Comparison between Power Demand & Hydropower Potential

$P_d < P_{50}$: Proceed to field investigation,

$P_d > P_{50}$: Do not proceed with the candidate site.

---

Brief Explanation <Chapter 3>

# Investigation & Planning

## 3.1 Site Investigation

Identification is depending on some assumption & application of limited data & information.

The assumptions in identification stage shall be reviewed through site investigation.

✓ The following survey points are explained:

- ➢ Power demand forecasting,
- ➢ Future management capability, and
- ➢ Environmental & social impacts.

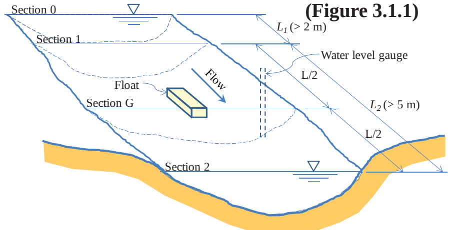
✓ The following measurement methods are explained:

- ➢ Discharge measurement by float,
- ➢ Discharge measurement by current meter,
- ➢ Available head survey method by water hose,
- ➢ Available head survey method by carpenter's level,
- ➢ Available head survey method by pressure gauge,
- ➢ Available head survey method by distance meter.

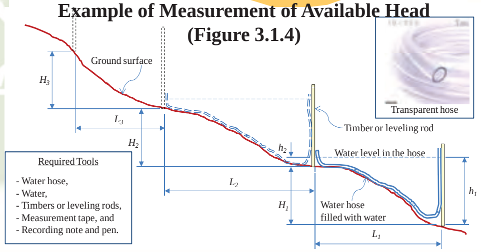
✓ The following **observation points** are explained:

- ➢ Site topography, & site geology.

Example of Measurement of Discharge (Figure 3.1.1)



Example of Measurement of Available Head (Figure 3.1.4)



Required Tools

- Water hose,
- Water,
- Timbers or leveling rods,
- Measurement tape, and
- Recording note and pen.

Brief Explanation <Chapter 3>

# Investigation & Planning

## 3.2 Plan Formulation

✓ The longitudinal profile is created,
✓ Alternative sites of intake weir & powerhouse are defined to obtain <u>high head within a short length</u>.

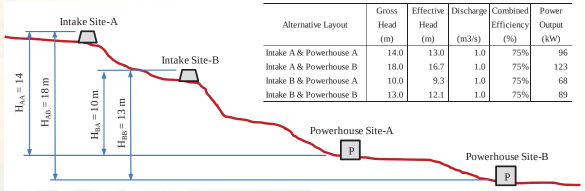
✓ Alternative layouts are prepared by taking the following steps:

1) Define the intake weir site,
2) Define the penstock line,
3) Define the powerhouse site
4) Define the power canal alignment.

✓ The following dimensions are defined for each alternative layout:

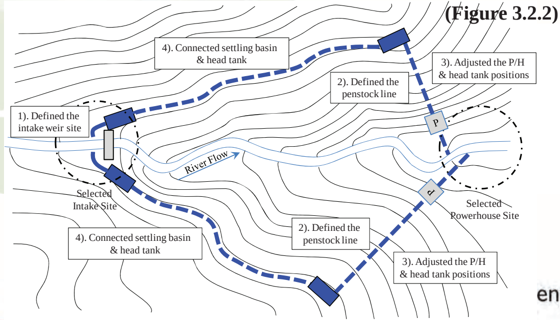
1) Turbine center level,
2) Dimension of power canal,
3) Crest level of intake weir.

**Sample of Alternative Layout (Figure 3.2.1)**



| Alternative Layout | Gross Head (m) | Effective Head (m) | Discharge (m3/s) | Combined Efficiency (%) | Power Output (kW) |
|---|---|---|---|---|---|
| Intake A & Powerhouse A | 14.0 | 13.0 | 1.0 | 75% | 96 |
| Intake A & Powerhouse B | 18.0 | 16.7 | 1.0 | 75% | 123 |
| Intake B & Powerhouse A | 10.0 | 9.3 | 1.0 | 75% | 68 |
| Intake B & Powerhouse B | 13.0 | 12.1 | 1.0 | 75% | 89 |

**Sample Procedure of Preparation of the Alternative Layout (Figure 3.2.2)**



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Brief Explanation <Chapter 3>

# Investigation & Planning

## 3.2 Plan Formulation

✓ The project cost of each alternative is estimated as follows:

**Estimation of Project Cost (Table 3.2.2)**

| Description | Estimation Method |
|---|---|
| I. Preparatory Works | |
| Access road | By (Assumed length) x (Unit price) |
| Land compensation | 5% of Item II + III |
| Temporary facilities | 20% of Item II + III |
| Environmental mitigation | 3% of Item II. |
| II. Civil Works | By (Empirical equations) x (Unit prices) |
| III. Electrical Equipment | By empirical equation |
| IV. Distribution System | By (Assumed length) x (Unit price) |
| **Sub-total 1 (Direct Cost)** | Sum of Item I, II, II, and IV |
| V. Administration and Engineering Cost | 15% of sub-total 1 |
| VI. Physical Contingency | 10% of sub-total 1 |
| **Sub-total 2 (Indirect Cost)** | Sum of Item V and VI |
| **Total** | Sum of Sub-total 1 and Sub-total 2 |

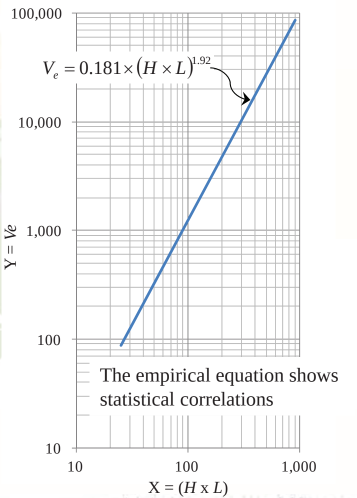
✓ The project benefit of each alternative is estimated as follows:

Benefit = (kW benefit) + (kWh benefit)

✓ The optimum layout is the layout shows higher B/C.

✓ When the optimum layout is selected, it is recommended to commence the <u>application of water use permit</u>.

Example: Excavation volume of weir



The empirical equation shows statistical correlations

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Brief Explanation <Chapter 4>

# Basic Design

## 4.1 Civil Structures

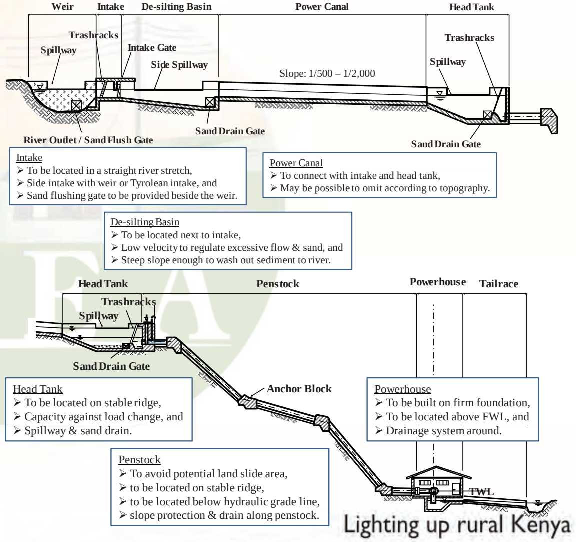
✓ Components of the civil structures are **various** depending on the topographic conditions at candidate site,
✓ Therefore, suitable components & layouts responding to the site condition need to be reflected in the design.

The following points are explained.

✓ Functions and requirements,
✓ Major types for MHP,
✓ Hydraulic design methods, such as:
  - ➢ Overflow discharge from weir,
  - ➢ Required length of de-silting basin,
  - ➢ Uniform flow depth of power canal,
  - ➢ Required volume of head pond,
  - ➢ Inner diameter & thickness of penstock,
  - ➢ Tail water level,
  - ➢ Head loss calculation, etc.

Structural design method are <u>not included</u>.

**Typical Profile of MHP (Figure 4.1.1)**



<u>Intake</u>
- ➢ To be located in a straight river stretch,
- ➢ Side intake with weir or Tyrolean intake, and
- ➢ Sand flushing gate to be provided beside the weir.

<u>Power Canal</u>
- ➢ To connect with intake and head tank,
- ➢ May be possible to omit according to topography.

<u>De-silting Basin</u>
- ➢ To be located next to intake,
- ➢ Low velocity to regulate excessive flow & sand, and
- ➢ Steep slope enough to wash out sediment to river.

<u>Head Tank</u>
- ➢ To be located on stable ridge,
- ➢ Capacity against load change, and
- ➢ Spillway & sand drain.

<u>Powerhouse</u>
- ➢ To be built on firm foundation,
- ➢ To be located above FWL, and
- ➢ Drainage system around.

<u>Penstock</u>
- ➢ To avoid potential land slide area,
- ➢ to be located on stable ridge,
- ➢ to be located below hydraulic grade line,
- ➢ slope protection & drain along penstock.

---

Brief Explanation <Chapter 4>

# Basic Design

## 4.2 Electrical Equipment

✓ Detailed characteristics are variable depending on manufactures,
✓ They are manufacturing by their individual technical know-how,
✓ Package of all electrical equipment exists called as “Water to Wire System”.

➡ The <u>standard types & estimation method</u> of basic technical features are explained.

**<u>Turbine</u>**
✓ Major types for MHP,
✓ Selection diagram,
✓ Specific speed,
✓ Revolving speed,
✓ Turbine efficiency.

**<u>Generator</u>**
✓ Major types for MHP,
✓ Output & rated capacity,
✓ Voltage & current,
✓ Excitation system.

Functions of the follows are explained.

**<u>Other Equipment & Systems</u>**
✓ Inlet valve,
✓ Power transmission,
✓ Governor,
✓ Transformers
✓ Main circuit,
✓ Integrated control panel,
✓ Cooling water supply system,
✓ Water drainage system,
✓ Crane, &
✓ Grounding wire.

## 4.3 Distribution Facilities

The following issuess are explained:

**<u>Distribution Facilities</u>**
✓ Distribution methods,
✓ Distribution line planning,
✓ Electrical design,
✓ Mechanical design,
✓ Overhead distribution line equipment, and
✓ Service drops & watt-hour meter.

Brief Explanation <Chapter 5>

# Economic & Financial Evaluation

## 5.1 Key Comparative Indicators

The following key indicators are explained.

- ✓ Present Value: PV
- ✓ Net Present Value: NPV = (B-C)
- ✓ Benefit-Cost Ratio: B/C
- ✓ Internal Rate of Return: IRR, and
- ✓ Unit Energy Cost: kWh cost.

## 5.3 Economic Evaluation

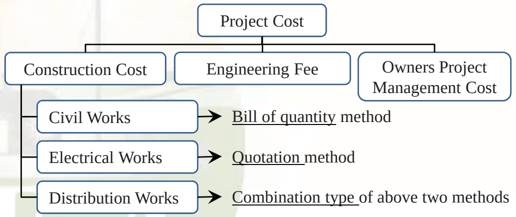
Evaluate the project from perspective of Public Interest and National Economy.

## 5.4 Financial Evaluation

Evaluate the project from perspective of Business Enterprise.

## 5.2 Estimation of Project Cost

**General Components and Estimation Method of MHP Project (Figure 5.2.1)**



| | | Economic Evaluation | Financial Evaluation |
|---|---|---|---|
| **Benefit** | ✓ Grit connection, &<br>✓ Electricity consumption. | Using consumer's Willingness to Pay (WTP). | Using Connection Fee & Electricity Tariff. |
| **Cost** | ✓ Construction cost, | Adjusting for market distortions. | As estimated. |
| | ✓ Installation cost,<br>✓ O&M cost, &<br>✓ Replacement cost. | Assumption & empirical ratio. | Assumption & empirical ratio. |

Same

---

Brief Explanation <Chapter 6>

# Environmental & Social Considerations

## 6.1 Environmental Management System

General environmental management system in Kenya are explained.

## 6.2 EIA Procedures and License System

- ✓ MHP project is subject to the EIA procedures.
- ✓ The following two steps are specified:

| EIA "Project Report" | EIA "Study Report" |
|---|---|
| (45 days in minimum) | (90 days in minimum) |

- ✓ The reports shall be prepared by Registered Lead Expert on EIA/EA.
- ✓ The process and required contents are explained.

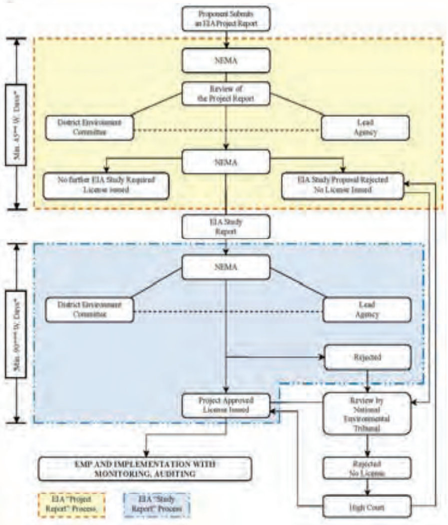
## 6.3 Solid Waste Management

Soiled waste management in compliance with the act & regulations in Kenya are explained.

## 6.4 Individual Subject on MHP Project

- ✓ "Mosquito Emergence Control",
- ✓ "Wastewater Contamination Control", and
- ✓ "Water Quality Control" (at enclosing bunds and weirs).

**Overview of EIA Process (Figure 6.2.1)**



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Explanation <Chapter 7>

# Construction Supervision

## 7.1 Procurement

General procedures of procurement in compliance with the following act & regulations in Kenya are explained:

- ✓ Public procurement and disposal act 2005.
- ✓ Public procurement and disposal regulation 2006.

## 7.2 Construction Supervision

General work items by the Client are explained.

**Details** of inspection items & measurement methods are described in:

7.3 Civil Works
- ✓ Major inspection items, &
- ✓ Procedure of approval & confirmation.

7.4 Electrical Equipment
- ✓ Measurement methods of efficiencies,
- ✓ Major items of shop test & site test.

7.5 Distribution Facilities
- ✓ Major inspection items.

Overall Management ⇒ Internal management & external correspondence.

Schedule Control ⇒ Monitoring & adjustment of official schedule & actual progress.

Quality Control ⇒ Quality control of construction materials, methods, equipment, facilities, etc.

Document Control ⇒ Control & filing of correspondences, minutes of meetings, approved drawings, etc.

Payment Control ⇒ Checking the work performance & quantity calculation sheets, assuming the total budget.

Variation Order ⇒ Confirming the necessity & available of project budget, and issuing the variation order.

Safety & Health Control ⇒ Preparing the emergency communication network, monitoring the project activities, responding in case of emergency..

---

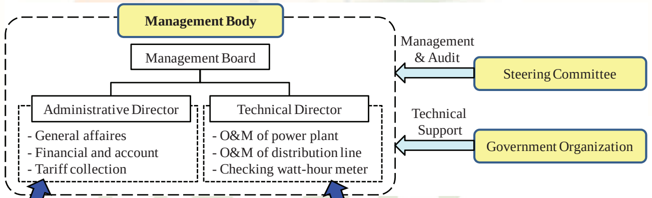
Explanation <Chapter 8>

# Operation & Maintenance

## 8.1 Establishment of Management Body

- ✓ O&M of a MHP station has to be executed by local residence.
- ✓ The management body shall be prepared simultaneously with the construction stage.

**Example of Management Body (Figure 8.1.1)**



## 8.2 Financial Management

⇒ Balance between tariff income & expenditures.

- ✓ How to estimate the required expenditures?
- ✓ How to set the tariff?
- ✓ How to formulate the billing system?
- ✓ How to confirm the financial condition?

## 8.3 Operation & Maintenance

**Administrative Works**

- ✓ General affairs,
- ✓ Med-term planning,
- ✓ Asset management,
- ✓ Complaint and request response,
- ✓ Customer support.

**Technical Works**

| Civil Structures | Electrical Equipment | Distribution Facilities |
|---|---|---|
| ✓ Gate operation, | ✓ External inspection, | ✓ Scheduled outage, |
| ✓ Water drainage operation, | ✓ Internal inspection, | ✓ Fault recovery, |
| ✓ Water filling operation, | ✓ Emergency inspection, | ✓ Regular measurement, |
| ✓ Routine inspection. | ✓ Storing spar parts list. | ✓ Periodic patrol. |

Explanation <Chapter 8>

# Operation & Maintenance

## 8.4 Assistance for Management Body

✓ Local residence might not have any experience or knowledge of electrical utility service.

⇒ Assistance for the organization & development of human resources capacities are **essential**.

✓ The assistance needs before and after the commencement of the power supply service.

### Necessity before the Commencement

- ✓ Number of staff is limited…
- ✓ It is difficult to commit a time for training.
- ✓ Therefore, the training is necessary simultaneous with the construction stage.
- ✓ Assistance program with…

OJT | Lecture | Workshop

### Necessity after the Commencement

- ✓ Initial troubles often occurs within first one year,
- ✓ Some contradictions among the rules are apparent,
- ✓ Operation manner of MHP varies due to rainy seasons & dry seasons & river flow.

Repeat training on Actual situation

### Major Assistance Items

For Representative & Manager
- ✓ Establishment of management body & joint steering committee,
- ✓ Arrangements to obtain business license,
- ✓ Start-up of power generation.

For Administrative Staff
- ✓ Outline & function of power facilities,
- ✓ Lecture on electricity charge system,
- ✓ Development of office management manual,
- ✓ Guidance on work procedure.

For Technical Staff
- ✓ Outline & function of power facilities,
- ✓ Guidance on functions & structures of facilities,
- ✓ Preparation of O&M manual,
- ✓ Guidance on inspection, maintenance & repairing,
- ✓ Guidance on documentation of maintenance.

---

# END

Thank you for your kind attention.

# Simple Pre-Feasibility Study
# on
# Asurur MHP Scheme

**February 2015**

**Ministry of Energy and Petroleum**

# Table of Contents

## List of Tables

## List of Figures

## List of Annexes

Note: All tables, figures, and annexes are prepared by the Working Group otherwise specified.

# List of Terms and Abbreviations

| Abbreviation | Description |
|---|---|
| HPP | Hydro Power Project |
| JICA | Japan International Cooperation Agency |
| JET | JICA Expert Team |
| KMD | Kenya Meteorological Department |
| KSh. | Kenya Shilling |
| MHP | Micro Hydro Power |
| MoE&P | Ministry of Energy and Petroleum |
| NWMP 2030 | National Water Master Plan 2030 |
| PMF | Probable Maximum Flood |
| REA | Rural Electrification Authority |
| SHER | Similar Hydrological Elements Response |
| TV | Television |
| WG | Working Group |
| WRMA | Water Resources Management Authority |

# List of Electrical Terminology

| Unit | Description |
|---|---|
| A (Ampere) | Unit of current |
| V (Volt) | Unit of voltage |
| kV (kilovolt) | 1,000 volts |
| W (Watt) | Unit of electric power |
| kW (kilowatt) | 1,000 watts |
| MW (Megawatt) | 1,000 kW |
| Wh (Watt-hour) | Unit of energy |
| kWh (kilowatt-hour) | 1,000 Wh |
| MWh (Megawatt-hour) | 1,000 kWh |

# CHAPTER 1 GENERAL

## 1.1 Background

Asurur Micro Hydro Power (MHP) scheme was originally planned and proposed by a local self-help group known as “Asurur Multipurpose Water Project” (the Group). The local community formed the self-help group to improve their livelihood, and the Group was subsequently registered on 20th June 2012 in Nandi South District, Nandi County.

Rural Electrification Authority (REA) and JICA Expert Team (JET) identified Asurur MHP scheme during site visits and investigations to identify a MHP pilot project site under the “Project for Establishment of Rural Electrification Model Using Renewable Energy in the Republic of Kenya” (the Project) under implementation by REA, MOE&P and JET in cooperation with Japan International Cooperation Agency (JICA).

Asurur MHP scheme was initially selected as a pilot project in the Project, in July 2012. However, the pilot project was cancelled in November 2012 due to management issues that arose in the Project. As a result, the Project decided to conduct a simple pre-feasibility study of Asurur MHP scheme in October 2013, as one of four technical transfer activities, based on the same initial project budget allocation.

“The simple pre-feasibility study on Asurur MHP scheme” (the Study) was conducted within the Project activities. However, the assignment period and budget for the Study were constrained, and accordingly the contents of the study are not as exhaustive as common pre-feasibility studies due to the limitations.

## 1.2 Outline of the Study

The outline of the Study is summarized below.

(1) Scope of the Study

- ✓ Preliminary evaluation of the hydropower potential of Asurur site, and
- ✓ Preliminary formulation of the development plan for Asurur MHP scheme

(2) Study Period

The study period was between November 2013 and December 2014
The actual working period was limited to four months (131 days) corresponding to the assignment period of the JICA Expert as follows:

| | |
|---|---|
| 1st to 5th November 2013, | 5 days |
| 8th January to 19th February 2014, | 43 days |
| 2nd July to 9th August 2014, and | 39 days |
| 3rd October to 15th November 2014. | 44 days |

(3) Study Team

The Study was conducted by the MHP Working Group (WG) of the Project, comprised of the following members:

| | |
|---|---|
| Ms. Judith Kimeu | Assistant Engineer - Renewable Energy Department, REA |
| Mr. Semekiah Ongong’a | Assistant Engineer - Renewable Energy Department, REA |
| Mr. Anthony Wanjara | Technician - Renewable Energy Department, REA |
| Mr. Yoshiaki Samejima | JICA Expert for Micro Hydropower Generation |

## 1.3 Summary of the Study

### (1) Evaluation of Power Demand

Power demand in the community was unknown, as the community was completely unelectrified. Power demand was therefore forecasted based on the results of interviews and assumptions made by WG as follows:

Peak Power Demand: 190 kWh → Required Generation Output: 250 kW

### (2) Evaluation of Hydropower Potential

Reliable discharge and probable flood discharge were estimated using the following four (4) sets of data: i) WRMA discharge data, ii) KMD rainfall data, iii) Simulated discharge data by NWMP 2030, and iv) observed discharge data by WG.

As a result, the design plant discharges and design flood discharge were defined as follows:

Minimum Design Plant Discharge: 0.1 $m^3/s$ ($Q_{90\%}$ - $Q_{95\%}$)
Maximum Design Plant Discharge: 0.7 $m^3/s$ ($Q_{50\%}$ - $Q_{95\%}$)
Design Flood Discharge: 42.0 $m^3/s$ (50-year probable discharge)

### (3) Plan Formulation

Three (3) alternative sites of intake weir and one (1) site of powerhouse were identified from the topographic map with a scale of 1: 500 of the area surrounding Asurur site. Three (3) alternative layouts, Layout A, Layout B and Layout C, were prepared, and a comparative study of these alternatives carried out as summarized below. As a result, Layout A was selected as the optimum layout.

**Table 1.1.1 Summary of Comparison of Three (3) Alternative Layouts**

| Item | Unit | Layout A | Layout B | Layout C |
|---|---|---|---|---|
| Maximum Plant Discharge | $m^3/s$ | 0.7 | 0.7 | 0.7 |
| Effective Head | m | 31.2 | 25.1 | 16.3 |
| Maximum Output | kW | 154.1 | 124.0 | 80.5 |
| Project Cost | KSh. | 140,511,000 | 134,607,000 | 125,105,000 |
| Annualized Project Cost (C) | KSh./year | 15,456,210 | 14,806,770 | 13,761,550 |
| Annualized Project Benefit (B) | KSh./year | 28,970,442 | 23,311,698 | 15,133,850 |
| B / C | - | 1.87 | 1.57 | 1.10 |
| B – C | KSh./year | 13,514,232 | 8,504,928 | 1,372,300 |
| Generation Cost | KSh./kWh | 15.79 | 18.80 | 26.92 |

## 1.4 Recommendations for Subsequent Stages

The Study results showed that the estimated power generation was smaller than the forecasted power demand. It was therefore recommended that the following issues be considered and implemented in subsequent stages:

1. Monitoring of the water level at the site continuously in order to improve the accuracy of hydrological analysis by accumulating discharge data,
2. Comparison of alternative heights to determine optimum height of intake weir in order to secure minimum power generation to meet power demand,
3. Obtain quotations for electrical equipment from manufacturers in order to increase the accuracy of estimation of project development costs, and
4. Study other power sources such as hybridization with diesel generator or grid connection in order to provide sufficient electricity to meet the forecasted power demand.

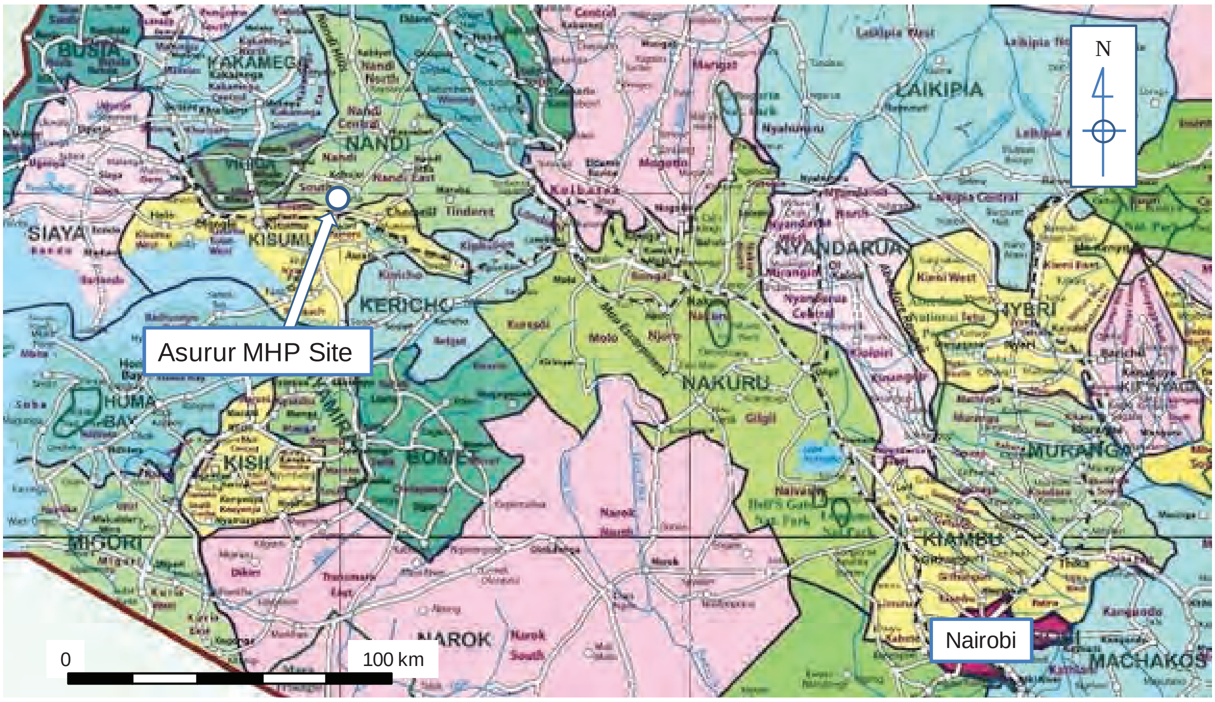
# CHAPTER 2 SOCIAL CONDITION

## 2.1 Location of the Site

The proposed Asurur MHP scheme is located in Nandi county, Aldai constituency, Nandi South district, Aldai division, earlier a part of Rift Valley Province. The project falls within two locations namely Kibwareng and Kapkolei.

The basic concept of Asurur MHP scheme is to develop hydropower potential at Asurur waterfall.

General location of the site, overview of Asurur area and Asurur waterfall are shown below.



Source: "A New County Map in Kenya" published by Tourist Maps Kenya Limited (Presented by WG)

**Figure 2.1.1 General Location of the Proposed Asurur Site**

**Overview of Asurur Area** **Asurur Waterfall**

Taken by JET and WG

**Figure 2.1.2 Photos of the Asurur Area and Asurur Waterfall**

(1) Nandi County

Nandi County was formed in 2013 in accordance with the recentralization. The county's major area is covered by the Nandi Hills. Its capital, Kapsabet, is the largest town in the county.

The county has high agricultural potential and human densities. The county's population is some 750,000 according to a 2009 census. Although there are a number of tribal communities in Nandi, the majority of the people belong to the native tribe called Nandi. The county's major business is agriculture, sports and tourism. The major crops are tea, maize, coffee, and sugarcane.

The household electrification rate of Nandi County was 6.4% while the overall national household electrification rate was 22.7% for household numbers as of 2009 based on the National Census 2011. Nandi County ranked twenty-nine (29) out of forty-seven (47) counties in decreasing order according to electrification rate.

#### (2) Accessibility to the Site

The proposed Asurur site is located between Kapsabet and Kisumu. The site is accessible by car about 1 to 1.5 hours from both town centers.

Asurur Waterfall is 200 m from the Kimaren – Kobujoi Road. There is no access road from the existing culvert bridge on the road to the waterfall, but the site is accessible by foot via left bank of the river. The area is currently under cultivation by the local residences.

#### (3) Electrification Status surrounding the Site

Kibwareng and Kapkolei locations where the load center for the proposed Asurur MHP scheme targeted are not electrified. But, grid is exists approximately 8 km away on the south, 2.5 km on the north and 4 km to the east.

### 2.2 Protection and Conservation Area

One protected area called as "South Nandi Forest Reserve" exists a mid-elevation lying west of Kapsabet town and south of the main Kipsegak – Serem Road, and a part of the catchment area is including in the forest reserve.

The forest reserve was specified in 1936 as a trust forest covering 20,200 ha. At most 13,000 ha is closed-canopy forest, 2,200 ha have been excised for settlement, 1,400 ha planted with exotic tree species, 340 ha planted with tea, and the rest being scrub, grassland or cultivation.

The forest reserve has rich rainfall of 1,600 – 1,900 mm/year in average depending on altitude. Major drains from the forest are Kimondi and Sirua rivers, which merge to form the Yala River flowing into Lake Victoria.

Northern part of some 720 ha of the catchment area of Asurur MHP scheme is situated in the forest reserve area. The area is about 3.3% of the forest reserve. Asurur MHP facilities are located about 5 km south side from boundary of the forest reserve. Therefore, any direct influences by the development are not conceivable. It is preferable for the MHP scheme in terms of watershed protection to maintain river discharge.

### 2.3 Social and Economic Conditions

#### (1) Local Self-help Group: Asurur Multipurpose Water Project

The inhabitants and villages surrounding the proposed Asurur MHP site unite together to organize a self-help group named as "Asurur Multipurpose Water Project (the Group)" for the purpose of improving livelihood and registered to district office. They started it in 2011 and registered after they heard the pilot project to ensure the realization.

It is the most important social factor for the development of Asurur MHP scheme because the Group will operate and maintain the power generation system and manage the power provision service if Asurur MHP scheme had been developed.

### (2) Interview Result to the Asurur Multipurpose Water Project

JET and WG conducted interview survey twice to the Group at the proposed Asurur site. The interview results are summarized in the table below.

**Table 2.3.1 Interview Results to the Asurur Multipurpose Water Project Group**

| Item | Description |
|---|---|
| Member Community | The Group covers at least 10 communities located in two sub-locations in Nandi South district:<br>- Samitui sub-location in Kibwareng location, and<br>- Kimolwo sub-location in Kapkolei location |
| Member Ethnic Group | The Group is composed only by Nandi (a sub ethnic group of Kalenjin). |
| Number of Household | About 440 households |
| Major Occupation | Production of various crops (maize, beans and root crops),<br>Production of milk |
| Average Annual Income | About Ksh 320,000 as of 2011 (Average of the interviewed 7 households) |
| Present Energy Source | 2 of 7 households: Solar panels (for television and radio for one of them and lighting and mobile phone charging for the other), and<br>5 of 7 households: Kerosene lamp and firewood (for lighting). They are spending about 840 KSh./month in average for energy (lighting and phone charging). |
| Expecting Electric Use | The electricity would be used for water pumping in a nearby spring, and industries like milk cooling, coffee processing and juice extraction from passion fruits, battery and phone charging, etc. |
| Expectation for Electrification | They state that the urgent need for this area is electricity. Until now, there is no any clear plan from Government to supply electricity to this area.<br>They wish to raise living standard by selling more agricultural products (kept in the refrigerator) and reduce time wastage when people travel for energy. |

# CHAPTER 3 POWER DEMAND FORECAST

## 3.1 Estimation of Total Power Demand

Power demand in the communities is unknown before electrification. Therefore, power demand was forecasted based on the interview result and the assumptions as explained hereinafter.

(1) Assumption of User

Users in the project area are assumed in three (3) categories as follows:

i) Domestic User

Four (4) types of domestic uses were assumed depending on the difference of household income. Unit power demands were assumed to be lighting, TV and fan or heater. Number of each electric goods is various.

ii) Public User

Primary and secondary schools, dispensaries, trading centers and streetlights were considered as public power users. Unit power demands were also assumed to be lighting, TV and fan or heater except trading centers. Power demand of trading center is variable depending on size and kind of each trading center, so unit demand was assumed as lump sum.

iii) Business User

Posho mill, dairy husbandry and restaurant were considered as business power users. Unit power demands may be variable depending on each owner, so unit demand was assumed as lump sum.

Number of each user was assumed based on the result of interview and assumption by WG as tabulated below.

**Table 3.1.1 Assumed Number of each User**

| User | Number | Remarks |
|---|---:|---|
| **Domestic** | | |
| Type A | 340 | Assumed by WG (20% of total households of 1,700) |
| Type B | 1,000 | Assumed by WG (60% of total households of 1,700) |
| Type C | 340 | Assumed by WG (20% of total households of 1,700) |
| Type D | 20 | Assumed by WG (1 per 100 households) |
| **Public** | | |
| School | 16 | Interview result (11 primary schools and 5 secondary schools) |
| Dispensary | 4 | Assumed by WG (1 per 500 households) |
| Streetlight | 170 | Assumed by WG (1 per 10 households) |
| Trading Center | 10 | Interview result (6 shops per center in estimated average) |
| **Business** | | |
| Posho Mill | 19 | Interview result |
| Dairy Husbandry | 4 | Assumed by WG (1 per 500 households) |
| Restaurant | 4 | Assumed by WG (1 per 500 households) |

(2) Estimation of Power Demand

Based on the above assumptions, the power demand of the project area is calculated to be 305 kW as shown below.

### Table 3.1.2 Assumed Power Demand in Asurur Area

| User | Assumed Unit Demand | | | | Quantity (nos.) | Power Demand |
|---|---|---|---|---|---|---|
| | Lighting | TV | Fan/Heater | Total | | |
| **Domestic User** | | | | | | |
| Type A | - | - | - | 0 W | 340 | 0 W |
| Type B | 40 W<br>(20 W x 2) | - | - | 40 W | 1,000 | 40,000 W |
| Type C | 60 W<br>(20 W x 3) | 200 W<br>(200 W x 1) | - | 260 W | 340 | 88,400 W |
| Type D | 200 W<br>(40 W x 5) | 200 W<br>(200 W x 1) | 200 W<br>(200 W x 1) | 600 W | 20 | 12,000 W |
| **Public User** | | | | | | |
| School | 600 W<br>40 W x 15 | 200 W<br>(200 W x 1) | 200 W<br>(200 W x 1) | 1,000 W | 16 | 16,000 W |
| Dispensary | 200 W<br>(40 W x 5) | - | 400 W<br>(200 W x 2) | 600 W | 4 | 2,400 W |
| Streetlight | 40 W<br>(40 W x 1) | - | - | 40 W | 170 | 6,800 W |
| Trading Center | (L.S.) | | | 2,000 W | 10 | 20,000 W |
| **Business User** | | | | | | |
| Posho Mill | (L.S.) | | | 5,000 W | 19 | 95,000 W |
| Dairy Husbandry | (L.S.) | | | 5,000 W | 4 | 20,000 W |
| Restaurant | (L.S.) | | | 1,000 W | 4 | 4,000 W |
| **Total** | | | | | | 304,600 W<br>= 305 kW |

## 3.2 Estimation of Peak Power Demand

Power demand varies hourly, daily and seasonally depending on each user. It was assumed that power demand of weekday is larger than that of weekend, and power demand of weekday was assumed as follows:

i) Domestic User

Utilizing time was assumed to concentrate in the morning and in the evening.

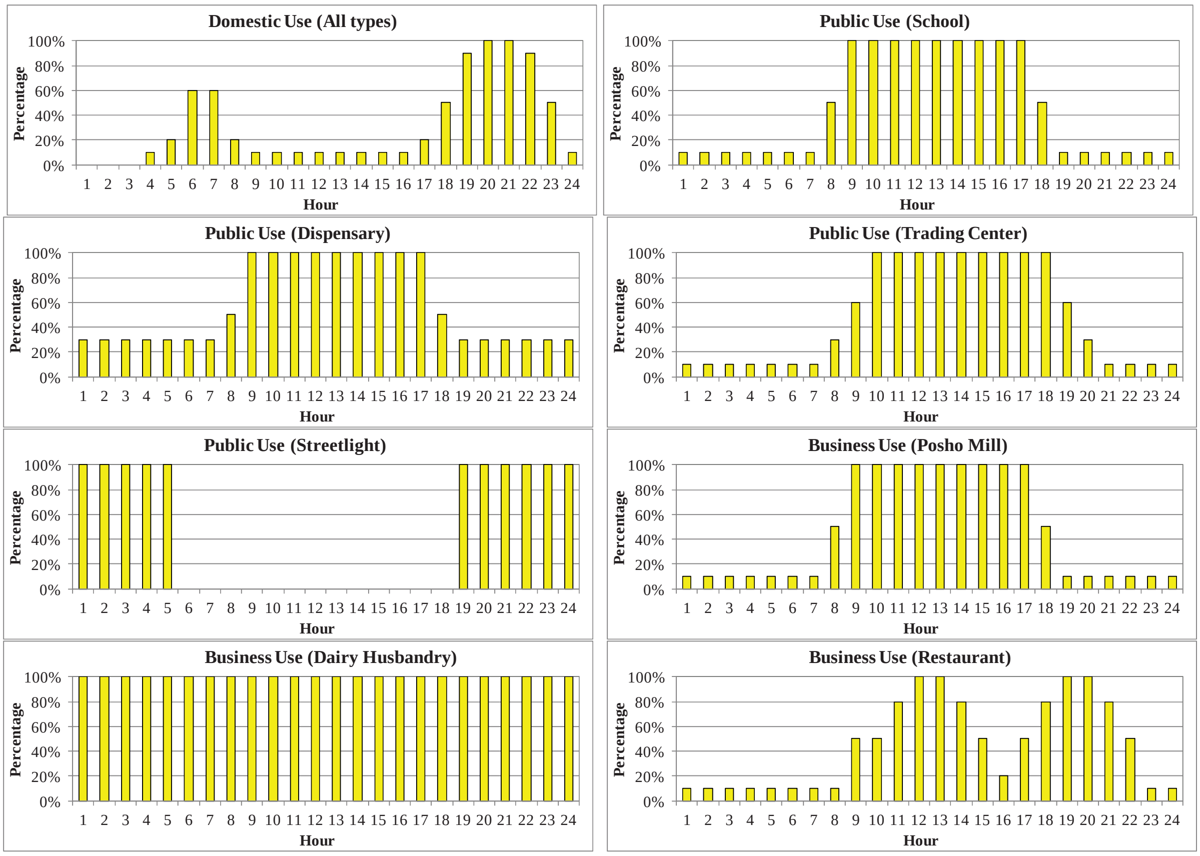
ii) Public User

Utilizing time was assumed from the morning to evening, except streetlight. Utilizing time of streetlight was assumed from the evening to the early morning.

iii) Business User

Utilizing time was assumed from each business such as daytime for posho mill, daytime to nighttime for restaurant, and 24 hours for dairy husbandry (refrigerator).

Assumed ratios of the power demand of each user in each hour are shown in Figure 3.2.1. Daily power demand curve creates by multiple of these ratios and power demand estimated in Section 3.1 as shown in Figure 3.2.2. The peak power demand was calculated to be 189 kWh.


Domestic Use (All types)

Public Use (School)

Public Use (Dispensary)

Public Use (Trading Center)

Public Use (Streetlight)

Business Use (Posho Mill)

Business Use (Dairy Husbandry)

Business Use (Restaurant)

**Figure 3.2.1 Assumed Ratios of Power Demand of Each User**

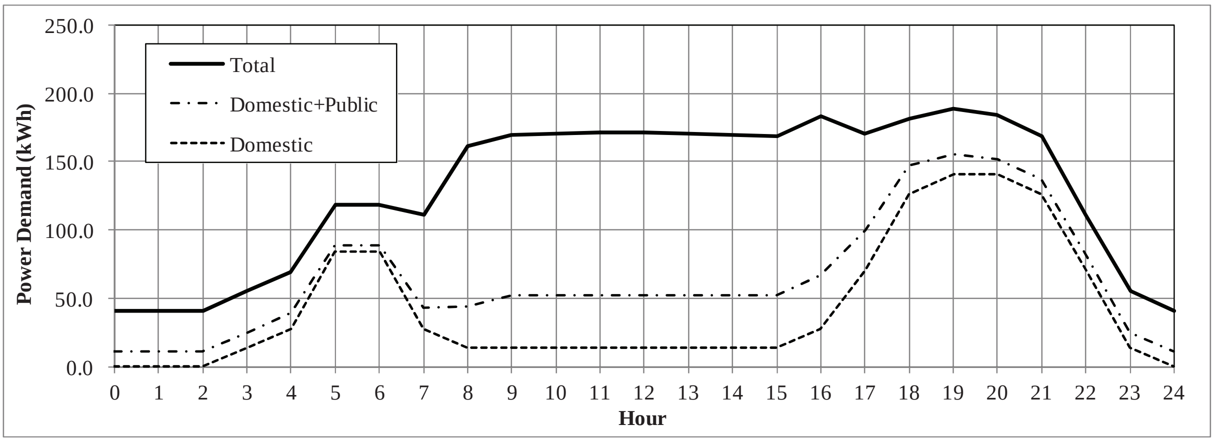


**Figure 3.2.2 Assumed Daily Load Curve for Asurur MHP System**

## 3.3 Estimation of Required Generator Output

The required generator output of Asurur MHP station was estimated to be 250 kW by the following formula:

$$P_r = P_d + w_1 + w_2$$

$$= P_d \times (1 + 0.2 + 0.1) = 1.3P_d$$

= 1.3 x 190 = 247 kW = 250 kW

Where,

$P_r$: required generator output (kW)

$P_d$: power demand (kW)

$w_1$: losses of distribution line, assumed to be 20% of $P_d$

$w_2$: reserved power, assumed to be 10% of $P_d$

# CHAPTER 4 HYDROLOGICAL ANALYSIS

## 4.1 Available Data for the Analysis

The hydrological analysis was carried out using the following three (3) sets of data:

- Collected discharge data from WRMA, and rainfall data from KMD,
- Observed discharge data measured by the Working Group, and
- Simulated discharge data and regional area – flood curve by NWMP 2030.

The location of the planned Asurur site, related gauging stations, and related sub - basin are shown below.

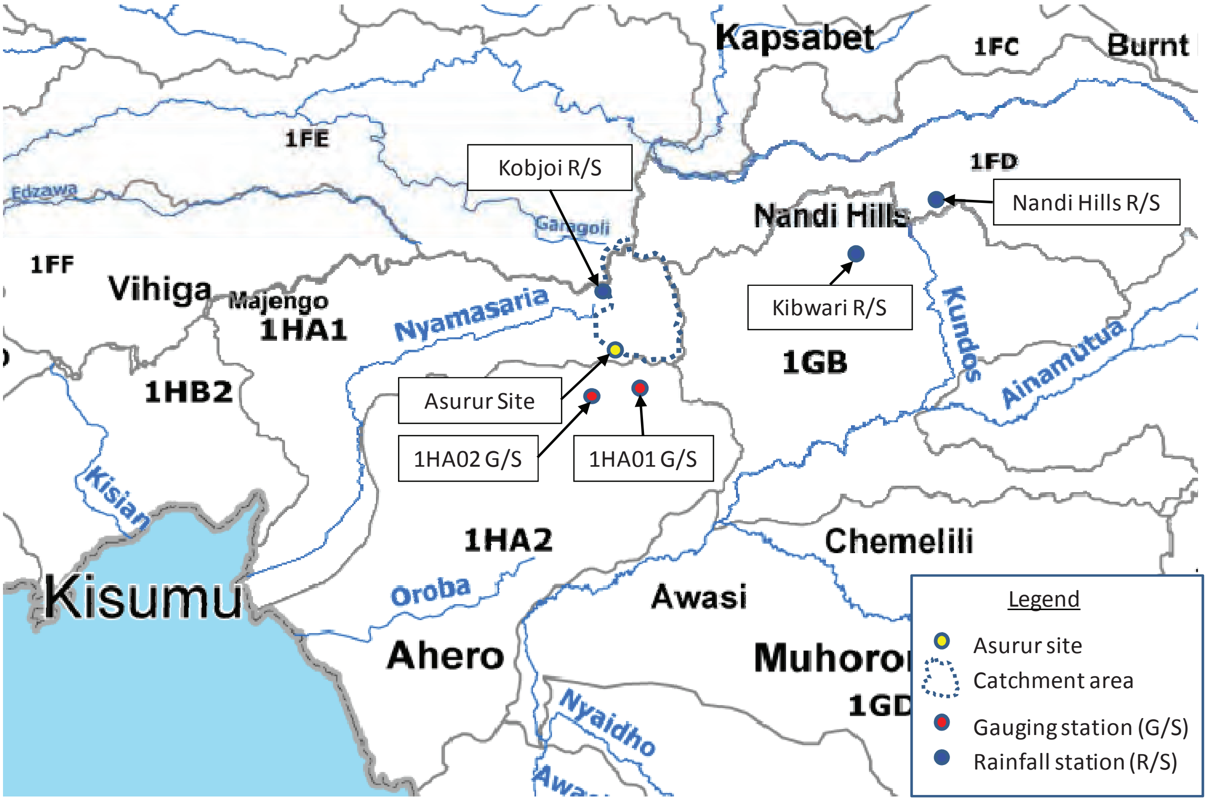


**Figure 4.1.1 Location Map of Data Sources**

According to WRMA classification Oroba River basin is 1HA2 and Kibos River basin is 1HA1, as shown in the location map above. WRMA data therefore shows that Asurur catchment area is situated in Kibos River basin (1HA1). However, it was confirmed from topographic maps with a scale of 1:50,000 that Asurur catchment area is situated in Oroba River basin.

### (1) Collected Data from WRMA and KMD

The collected discharge and rainfall data for the study are listed below.

**Table 4.1.1 Collected Discharge and Rainfall Data around Asurur Site**

| Source | Station ID | Name | Data | Period |
|---|---|---|---|---|
| WRMA | 1HA01 | Great Oroba | Daily discharge | Jan. 1932 – Aug. 1999 |
| WRMA | 1HA02 | Little Oroba | Daily discharge | Aug. 1931 – Dec. 2008 |
| KMD | 8934157 | Kabujoi Forest Station | Monthly rainfall | Jan. 1993 – Dec. 2012 |
| KMD | 8935033 | Nandi Hills – Savani Estate | Monthly rainfall | Jan. 1993 – Dec. 2012 |
| KMD | 8935161 | Kibweri Tea Estate – Nandi Hills | Monthly rainfall | Jan. 1993 – Dec. 2012 |

### (2) Observed Data Measured by the Working Group

River discharge at the planned Asurur site was measured in 2012 and 2014 by WG. The measurement records are attached in Annex-1, and tabulated below.

**Table 4.1.2 Discharge Measurements Recorded at Asurur Site**

| **Measurement Date** | **1st Measurement** ($m^3/s$) | **2nd Measurement** ($m^3/s$) | **Daily Average** ($m^3/s$) | **Monthly Average** ($m^3/s$) |
|---|---|---|---|---|
| 21 Jun. 2012 | 1.64 | - | 1.64 | 1.71 |
| 22 Jun. 2012 | 1.77 | - | 1.77 | |
| 26 Jul. 2012 | 1.97 | - | 1.97 | 1.97 |
| 13 Aug. 2012 | 1.46 | 1.59 | 1.53 | 1.77 |
| 14 Aug. 2012 | 1.45 | 1.54 | 1.50 | |
| 27 Aug. 2012 | 2.11 | 2.46 | 2.29 | |
| 28 Aug. 2012 | 2.10 | 1.87 | 1.99 | |
| 29 Aug. 2012 | 1.57 | 1.46 | 1.52 | |
| 10 Sep. 2012 | 2.26 | 2.13 | 2.20 | 1.79 |
| 11 Sep. 2012 | 1.95 | 2.03 | 1.99 | |
| 12 Sep. 2012 | 2.04 | 1.58 | 1.81 | |
| 23 Sep. 2012 | 1.46 | 1.47 | 1.47 | |
| 24 Sep. 2012 | 1.70 | 1.66 | 1.68 | |
| 25 Sep. 2012 | 1.60 | 1.60 | 1.60 | |
| 31 Jan. 2014 | 1.33 | 1.22 | 1.28 | 1.28 |
| Maximum | - | - | 2.29 | 1.97 |
| Minimum | - | - | 1.28 | 1.28 |

### (3) Simulated Data by NWMP 2030

Hydrological analysis was conducted in “Project on Development of the National Water Master Plan 2030 (NWMP 2030)” by JICA in 2013. The following results of the analysis in NWMP 2030 were adopted for the study.

i) Rainfall - runoff Analysis

Rainfall - runoff analysis was conducted in NWMP 2030 by applying the Similar Hydrological Elements Response model (SHER model) for the entire country. As a result of simulation using SHER model, monthly average naturalized discharge in 204 sub - basins were determined for the period from 1991 to 2010. Naturalized discharge refers to the river runoff that is not affected by any water use in the catchment area.

The monthly average discharge data in sub - basin 1HA1 where the Asurur site is located, were applied.

ii) Flood Analysis

Flood analysis was carried out in NWMP 2030. 18 gauging stations each having over 15 valid years was selected from the collected daily discharge data at 47 gauging stations, for the frequency analysis. A valid year was defined as a year in which the data availability was over 80%. The probable flood discharges of 21 major river basins in Kenya were evaluated based on the simulated river discharge, in the same way as the evaluation based on observed data.

Regional area flood curve in Kibos River where Asurur site is located, were applied.

## 4.2 Estimation of the Reliable Discharge

Reliable discharge at the planned Asurur site was estimated based on the following three (3) sets of data:

i) Estimation by WRMA Daily Discharge Data

Correlation between the collected WRMA daily discharge data at two (2) stations - 1HA01 and 1HA02 - was checked. The correlation was 0.208, and this was slightly positive, and supplementation of missing data was therefore not executed.

Daily discharge data at 1HA01, located downstream of the planned Asurur site, was used for the analysis. Daily discharges at the planned Asurur site were estimated as a ratio of the catchment area.

ii) Estimation by KMD Monthly Rainfall Data

Correlations among the collected KMD monthly rainfall data at three (3) stations were checked. The correlations were 0.658, 0.689 and 0.809, and these were moderately to strongly positive. Supplementation of missing data was therefore executed.

Monthly rainfall data at Kabujoi Forest station, located on the planned Asurur catchment area, was applied in the analysis. Monthly discharges at the planned Asurur site were estimated based on the assumed runoff coefficient.

iii) Estimation by Simulated Monthly Discharge Data by NWMP 2030

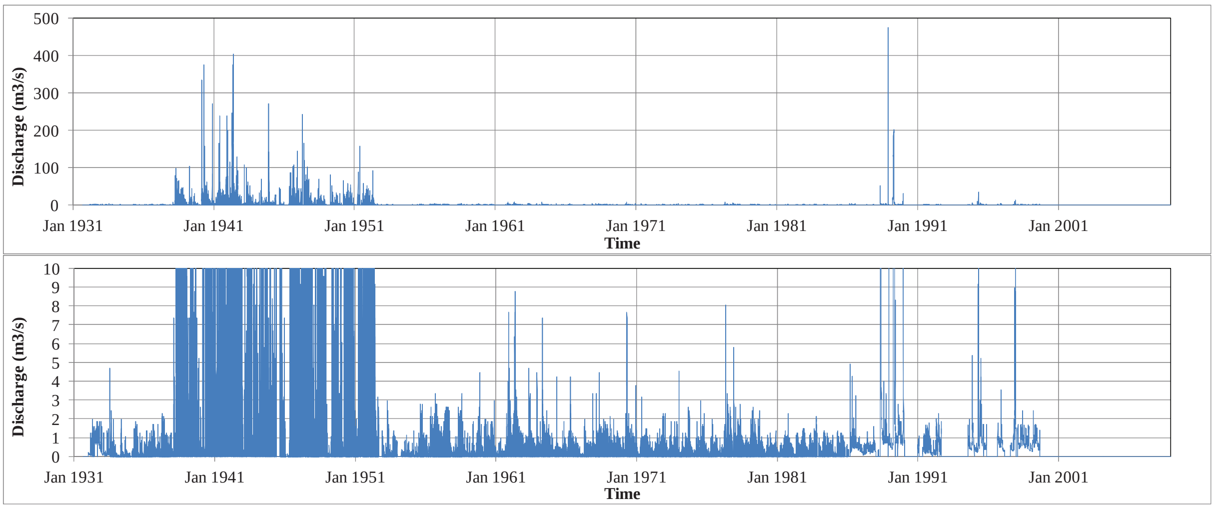
The simulated monthly average discharges in sub - basin 1HA1, which is the location of the planned Asurur catchment area, were converted into the discharges at Asurur site as a ratio of the catchment area.

Discharge hydrograph and flow duration curve were created from the estimated daily or monthly average discharges derived from the three (3) sources of data above, and probability calculated. The results obtained were compared with the observed discharges at the site.

As a result, discharge data estimated by WRMA daily discharge and NWMP 2030 simulated monthly discharge were relatively smaller than the observed discharges. Further, the discharge data estimated by KMD monthly rainfall data was selected for definition of the design discharges.

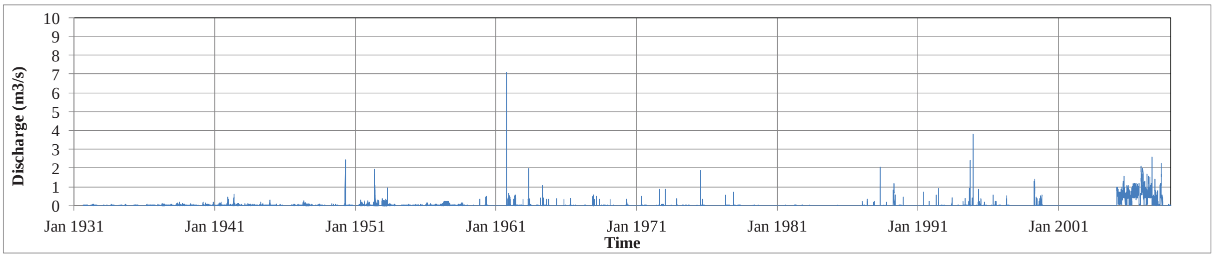
### 4.2.1 Estimation by WRMA Discharge Data

Daily discharge data at two (2) gauging stations, 1HA01 and 1HA02, were arranged in discharge hydrographs as shown below.



Note: Both hydrographs show the same data, with different discharge scales.

**Figure 4.2.1 Discharge Hydrograph at 1HA01**



Source: WRMA daily discharge data (Presentation by WG)

**Figure 4.2.2 Discharge Hydrograph at 1HA02**

Correlation between daily discharge data at 1HA01 and 1HA02 was 0.208. The correlation was slightly positive. Accordingly, it was determined that supplementation of missing data was meaningless.

Discharge data at 1HA01 between 1956 and 1988 (33 years) were adopted to create the flow duration curve, taking the following points into consideration:

- As shown in Figure 4.2.1, some periods have abnormally large values of discharge in comparison to other periods. (Year 1938 to 1952 and 1989), and
- Data for over half of the year were missing in some instances (Year 1934, 1935, 1945 to 1955, 1990, 1993, 1994 and 1996).

Discharges at 1HA01 are converted into discharges at the planned Asurur site as a ratio of the catchment area (0.697 = 37.9 km$^2$ / 54.4 km$^2$), and flow duration curves at Asurur site were estimated using daily discharges and monthly average discharges as shown below.

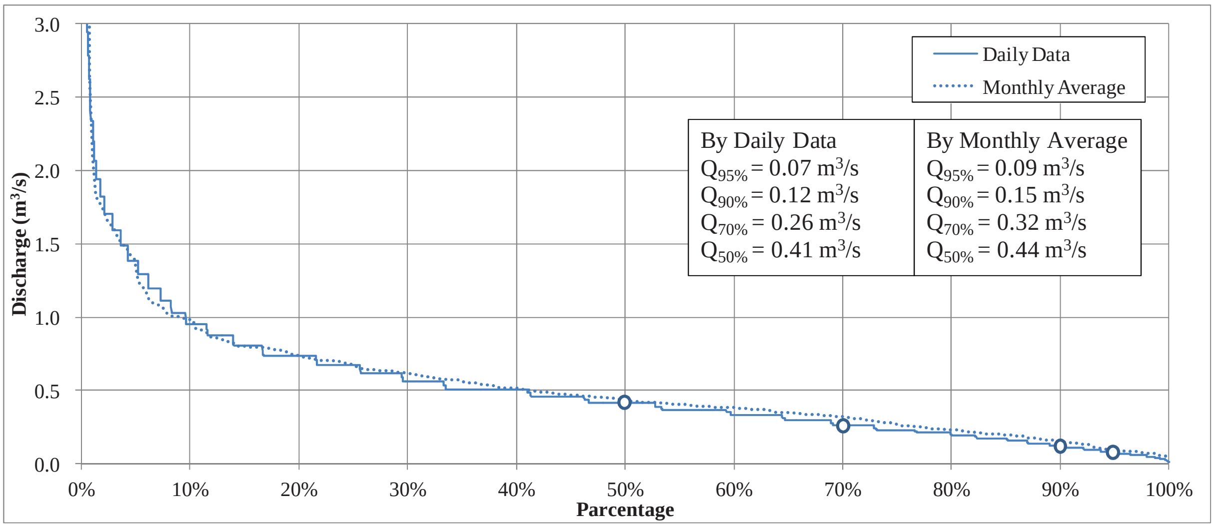


**Figure 4.2.3 Flow Duration Curve at Asurur Site based on WRMA Discharge Data**

### 4.2.2 Estimation by KMD Rainfall Data

Correlations between each monthly rainfall data at three (3) gauging stations are as follows:

Kabujoi Forest & Nandi Hills – Savani estate : 0.658 = moderately positive
Kabujoi Forest & Kibweri tea estate : 0.689 = moderately positive
Nandi Hills – Savani estate & Kibweri tea estate : 0.809 = strongly positive.

Accordingly, missing monthly data at Kabujoi Forest Station were supplemented by others as tabulated below.

## Table 4.2.1 Monthly Rainfall Data for Asurur Catchment Area (Kabujoi)

(Unit: mm)

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1993 | 79.4 | 74.4 | 42.2 | 85.9 | 176.3 | 156.4 | 114.5 | 65.5 | 58.2 | 113.3 | 85.6 | 74.4 | 1,126 |
| 1994 | 15.9 | 76.0 | 207.8 | 273.7 | 227.2 | 126.5 | 140.7 | 89.9 | 200.9 | 90.2 | 243.8 | 19.2 | 1,712 |
| 1995 | 35.4 | ***36.3*** | 122.0 | 310.8 | 172.8 | 137.1 | 75.4 | ***91.6*** | 149.3 | 146.0 | 203.5 | 52.7 | 1,533 |
| 1996 | 82.8 | 87.0 | 136.8 | 247.9 | 241.9 | 181.0 | 163.3 | 230.7 | 173.5 | 139.5 | 210.4 | 29.3 | 1,924 |
| 1997 | 93.0 | 0.0 | 77.8 | 327.7 | 171.4 | 126.2 | 89.0 | 147.1 | 41.9 | 172.6 | 245.3 | 144.7 | 1,637 |
| 1998 | ***147.7*** | ***63.9*** | ***51.9*** | ***96.4*** | ***206.5*** | ***101.8*** | ***98.0*** | ***95.0*** | ***90.4*** | ***111.1*** | ***86.4*** | ***13.5*** | 1,163 |
| 1999 | 70.9 | 14.3 | 310.2 | 175.2 | 227.8 | 94.7 | 168.9 | 173.3 | 174.1 | 78.0 | 79.8 | 85.5 | 1,653 |
| 2000 | 8.5 | 38.0 | 62.5 | 92.9 | 213.4 | 72.3 | 105.9 | 145.5 | 185.9 | 153.8 | 151.0 | 106.0 | 1,336 |
| 2001 | 279.2 | 74.5 | 118.7 | 307.1 | 228.7 | 184.7 | 197.1 | 76.3 | 140.0 | 164.6 | 57.4 | 19.6 | 1,848 |
| 2002 | 117.1 | 16.8 | 233.6 | 311.7 | 149.4 | 121.1 | 94.5 | 147.1 | 87.5 | 124.3 | 188.4 | 331.6 | 1,923 |
| 2003 | 51.3 | 33.7 | 33.7 | 238.2 | 183.4 | 116.6 | 128.9 | 152.0 | 155.4 | 190.1 | 112.6 | 50.1 | 1,446 |
| 2004 | 77.0 | 76.2 | 208.0 | 196.1 | 147.4 | 105.9 | 123.0 | 222.1 | 255.9 | 166.4 | 195.3 | 92.8 | 1,866 |
| 2005 | 120.5 | 44.1 | 148.5 | 105.4 | 368.0 | 111.6 | 209.8 | 2.7 | 163.7 | 117.7 | ***34.7*** | 15.6 | 1,442 |
| 2006 | 54.4 | 59.7 | 153.6 | 290.5 | 178.3 | 180.8 | 215.4 | 127.7 | 197.3 | ***77.7*** | 352.6 | 237.3 | 2,125 |
| 2007 | 63.0 | 160.1 | 85.8 | 173.7 | ***192.2*** | 135.6 | 152.0 | 220.4 | 212.4 | 116.2 | 85.4 | 43.9 | 1,641 |
| 2008 | 58.0 | 52.6 | 203.7 | 259.2 | 159.2 | 134.3 | 132.3 | 221.0 | 228.5 | 199.5 | 128.4 | 27.8 | 1,805 |
| 2009 | 118.0 | 36.7 | 107.2 | 194.5 | 207.2 | 60.6 | 119.1 | 179.8 | 186.2 | 185.9 | 121.5 | 98.8 | 1,616 |
| 2010 | 120.0 | 154.8 | 117.2 | 215.1 | 255.3 | 165.1 | 143.8 | 211.3 | 247.1 | 260.5 | 93.2 | 128.8 | 2,112 |
| Average | 88.4 | 61.1 | 134.5 | 216.8 | 205.9 | 128.5 | 137.3 | 144.4 | 163.8 | 144.9 | 148.6 | 87.3 | 1,661 |

Note: 17 Values with ***Italic Bold*** are supplemented values.

Source: KMD data and supplemented data by WG

Monthly average discharges at the planned Asurur site were estimated based on the supplemented monthly rainfall data at Kabujoi using the following formula:

$$Q_{ave} = \frac{C \times R \times 10^{-3} \times CA \times 10^{6}}{60 \times 60 \times 24 \times D}$$

Where, $Q_{ave}$: monthly average discharge ($m^3/s$)
$C$: runoff ratio ( - ) = 0.50
(hilly area with forest, rocky land)
R: monthly rainfall (mm)
CA: catchment area (km2) = 37.9 ($km^2$)
D: days of each month (31, 30, 29 or 28 days)

The estimated monthly average discharges at the planned Asurur site, and discharge hydrograph and flow duration curve from these discharges were as shown below.

### Table 4.2.2 Estimated Monthly Average Discharge at Asurur Site based on KMD Rainfall Data

(Unit: $m^3/s$)

| Year | Jan. | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1993 | 0.56 | 0.53 | 0.30 | 0.61 | 1.25 | 1.11 | 0.81 | 0.46 | 0.41 | 0.80 | 0.61 | 0.53 | 0.66 |
| 1994 | 0.11 | 0.54 | 1.47 | 1.94 | 1.61 | 0.90 | 1.00 | 0.64 | 1.42 | 0.64 | 1.72 | 0.14 | 1.01 |
| 1995 | 0.25 | 0.26 | 0.86 | 2.20 | 1.22 | 0.97 | 0.53 | 0.65 | 1.06 | 1.03 | 1.44 | 0.37 | 0.90 |
| 1996 | 0.59 | 0.62 | 0.97 | 1.75 | 1.71 | 1.28 | 1.16 | 1.63 | 1.23 | 0.99 | 1.49 | 0.21 | 1.13 |
| 1997 | 0.66 | 0.00 | 0.55 | 2.32 | 1.21 | 0.89 | 0.63 | 1.04 | 0.30 | 1.22 | 1.74 | 1.02 | 0.96 |
| 1998 | 1.04 | 0.45 | 0.37 | 0.68 | 1.46 | 0.72 | 0.69 | 0.67 | 0.64 | 0.79 | 0.61 | 0.10 | 0.69 |
| 1999 | 0.50 | 0.10 | 2.19 | 1.24 | 1.61 | 0.67 | 1.19 | 1.23 | 1.23 | 0.55 | 0.56 | 0.60 | 0.97 |
| 2000 | 0.06 | 0.27 | 0.44 | 0.66 | 1.51 | 0.51 | 0.75 | 1.03 | 1.32 | 1.09 | 1.07 | 0.75 | 0.79 |
| 2001 | 1.98 | 0.53 | 0.84 | 2.17 | 1.62 | 1.31 | 1.39 | 0.54 | 0.99 | 1.16 | 0.41 | 0.14 | 1.09 |
| 2002 | 0.83 | 0.12 | 1.65 | 2.21 | 1.06 | 0.86 | 0.67 | 1.04 | 0.62 | 0.88 | 1.33 | 2.35 | 1.13 |
| 2003 | 0.36 | 0.24 | 0.24 | 1.69 | 1.30 | 0.82 | 0.91 | 1.08 | 1.10 | 1.34 | 0.80 | 0.35 | 0.85 |
| 2004 | 0.54 | 0.54 | 1.47 | 1.39 | 1.04 | 0.75 | 0.87 | 1.57 | 1.81 | 1.18 | 1.38 | 0.66 | 1.10 |
| 2005 | 0.85 | 0.31 | 1.05 | 0.75 | 2.60 | 0.79 | 1.48 | 0.02 | 1.16 | 0.83 | 0.25 | 0.11 | 0.85 |
| 2006 | 0.38 | 0.42 | 1.09 | 2.06 | 1.26 | 1.28 | 1.52 | 0.90 | 1.40 | 0.55 | 2.49 | 1.68 | 1.25 |
| 2007 | 0.45 | 1.13 | 0.61 | 1.23 | 1.36 | 0.96 | 1.08 | 1.56 | 1.50 | 0.82 | 0.60 | 0.31 | 0.97 |
| 2008 | 0.41 | 0.37 | 1.44 | 1.83 | 1.13 | 0.95 | 0.94 | 1.56 | 1.62 | 1.41 | 0.91 | 0.20 | 1.06 |
| 2009 | 0.83 | 0.26 | 0.76 | 1.38 | 1.47 | 0.43 | 0.84 | 1.27 | 1.32 | 1.32 | 0.86 | 0.70 | 0.95 |
| 2010 | 0.85 | 1.10 | 0.83 | 1.52 | 1.81 | 1.17 | 1.02 | 1.49 | 1.75 | 1.84 | 0.66 | 0.91 | 1.25 |
| Average | 0.63 | 0.43 | 0.95 | 1.53 | 1.46 | 0.91 | 0.97 | 1.02 | 1.16 | 1.02 | 1.05 | 0.62 | 0.98 |

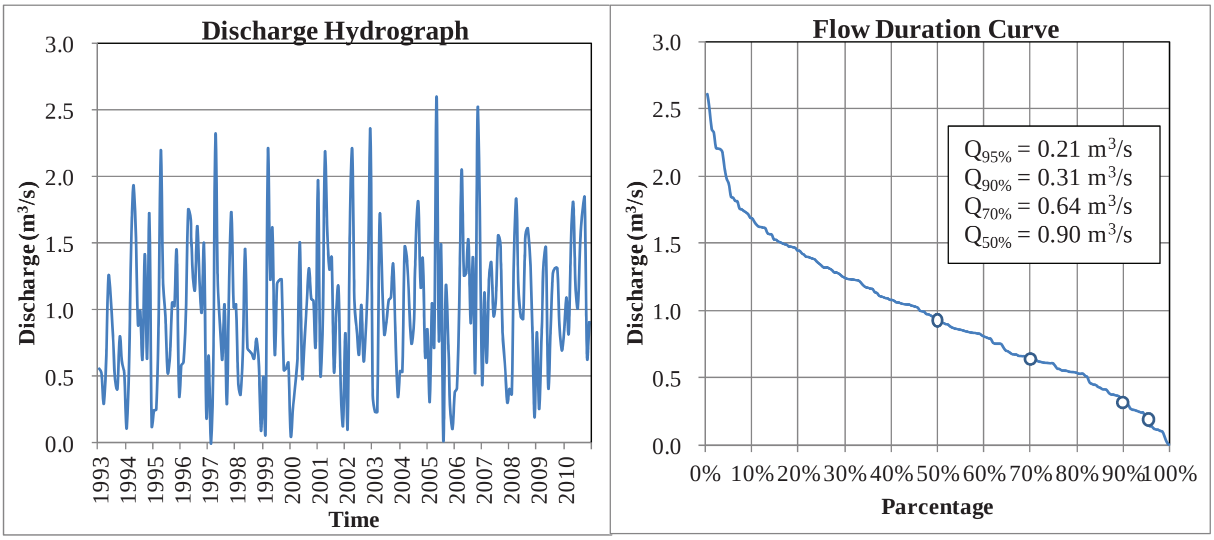


Figure 4.2.4 Flow Duration Curve at Asurur Site based on KMD Data

### 4.2.3 Estimation by Simulated Monthly Discharge Data in NWMP 2030

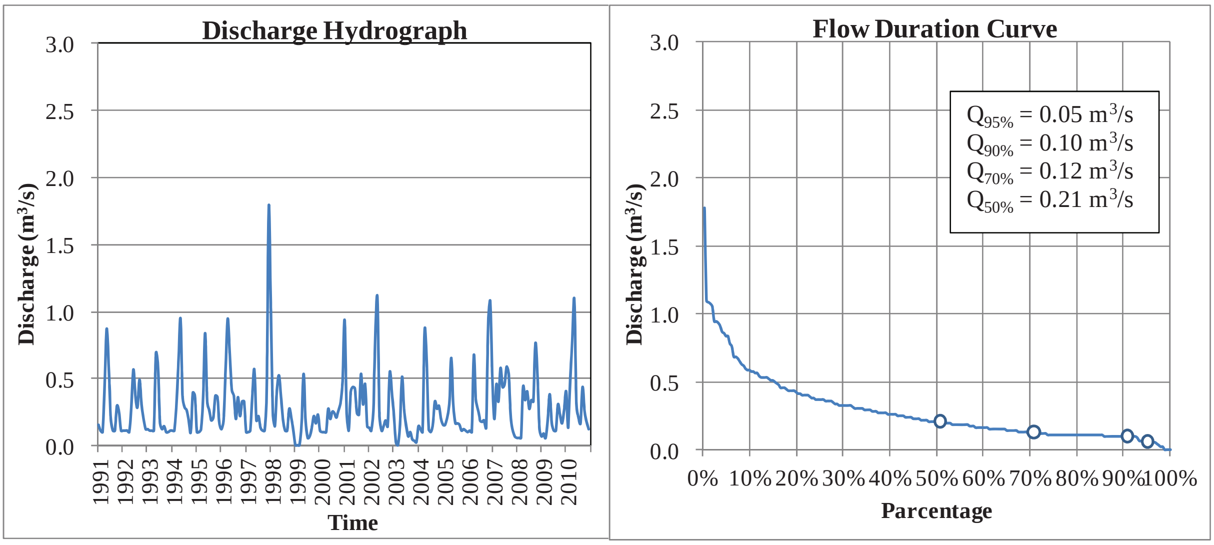
Simulated monthly discharges in sub - basin 1HA1 were converted into discharge at the planned Asurur site as a ratio of catchment area ($0.109 = 37.9\ km^2 / 348.8\ km^2$) as tabulated below. Flow duration curves at Asurur site were also estimated using these discharge data as shown below.

**Table 4.2.3 Estimated Monthly Average Discharge at Asurur Site based on NWMP 2030 Data**

(Unit: $m^3/s$)

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1991 | 0.15 | 0.11 | 0.10 | 0.45 | 0.87 | 0.59 | 0.20 | 0.11 | 0.11 | 0.29 | 0.25 | 0.11 | 0.28 |
| 1992 | 0.11 | 0.11 | 0.11 | 0.10 | 0.28 | 0.56 | 0.37 | 0.28 | 0.49 | 0.30 | 0.20 | 0.12 | 0.25 |
| 1993 | 0.12 | 0.11 | 0.11 | 0.11 | 0.68 | 0.60 | 0.16 | 0.12 | 0.14 | 0.10 | 0.10 | 0.11 | 0.20 |
| 1994 | 0.11 | 0.11 | 0.30 | 0.62 | 0.95 | 0.36 | 0.28 | 0.26 | 0.18 | 0.10 | 0.39 | 0.37 | 0.34 |
| 1995 | 0.10 | 0.10 | 0.12 | 0.35 | 0.84 | 0.33 | 0.26 | 0.18 | 0.21 | 0.37 | 0.36 | 0.15 | 0.28 |
| 1996 | 0.12 | 0.18 | 0.58 | 0.95 | 0.68 | 0.41 | 0.37 | 0.20 | 0.36 | 0.22 | 0.33 | 0.33 | 0.39 |
| 1997 | 0.10 | 0.10 | 0.11 | 0.37 | 0.56 | 0.18 | 0.22 | 0.13 | 0.11 | 0.11 | 0.38 | 1.78 | 0.35 |
| 1998 | 1.05 | 0.24 | 0.14 | 0.41 | 0.52 | 0.36 | 0.18 | 0.11 | 0.11 | 0.27 | 0.21 | 0.11 | 0.31 |
| 1999 | 0.00 | 0.00 | 0.00 | 0.15 | 0.53 | 0.17 | 0.05 | 0.07 | 0.13 | 0.22 | 0.16 | 0.23 | 0.14 |
| 2000 | 0.11 | 0.10 | 0.10 | 0.10 | 0.27 | 0.20 | 0.25 | 0.24 | 0.21 | 0.26 | 0.32 | 0.48 | 0.22 |
| 2001 | 0.93 | 0.24 | 0.11 | 0.40 | 0.43 | 0.42 | 0.24 | 0.23 | 0.53 | 0.30 | 0.46 | 0.14 | 0.37 |
| 2002 | 0.13 | 0.11 | 0.25 | 0.84 | 1.10 | 0.22 | 0.11 | 0.14 | 0.18 | 0.14 | 0.54 | 0.40 | 0.35 |
| 2003 | 0.23 | 0.02 | 0.00 | 0.15 | 0.51 | 0.26 | 0.15 | 0.07 | 0.10 | 0.04 | 0.03 | 0.02 | 0.13 |
| 2004 | 0.14 | 0.12 | 0.10 | 0.86 | 0.63 | 0.12 | 0.10 | 0.15 | 0.33 | 0.27 | 0.29 | 0.20 | 0.28 |
| 2005 | 0.15 | 0.15 | 0.21 | 0.29 | 0.65 | 0.29 | 0.16 | 0.16 | 0.15 | 0.11 | 0.12 | 0.11 | 0.21 |
| 2006 | 0.10 | 0.11 | 0.10 | 0.67 | 0.33 | 0.27 | 0.18 | 0.17 | 0.18 | 0.13 | 0.91 | 1.08 | 0.35 |
| 2007 | 0.51 | 0.20 | 0.46 | 0.33 | 0.58 | 0.43 | 0.46 | 0.59 | 0.53 | 0.21 | 0.11 | 0.07 | 0.37 |
| 2008 | 0.05 | 0.05 | 0.05 | 0.43 | 0.34 | 0.40 | 0.27 | 0.34 | 0.33 | 0.76 | 0.53 | 0.12 | 0.31 |
| 2009 | 0.07 | 0.09 | 0.05 | 0.18 | 0.38 | 0.16 | 0.11 | 0.11 | 0.30 | 0.23 | 0.16 | 0.26 | 0.18 |
| 2010 | 0.40 | 0.13 | 0.50 | 0.78 | 1.09 | 0.30 | 0.21 | 0.16 | 0.43 | 0.25 | 0.17 | 0.12 | 0.38 |
| Average | 0.23 | 0.12 | 0.17 | 0.43 | 0.61 | 0.33 | 0.22 | 0.19 | 0.26 | 0.23 | 0.30 | 0.31 | 0.28 |

Source: NWMP 2030 by JICA (Presented by WG)

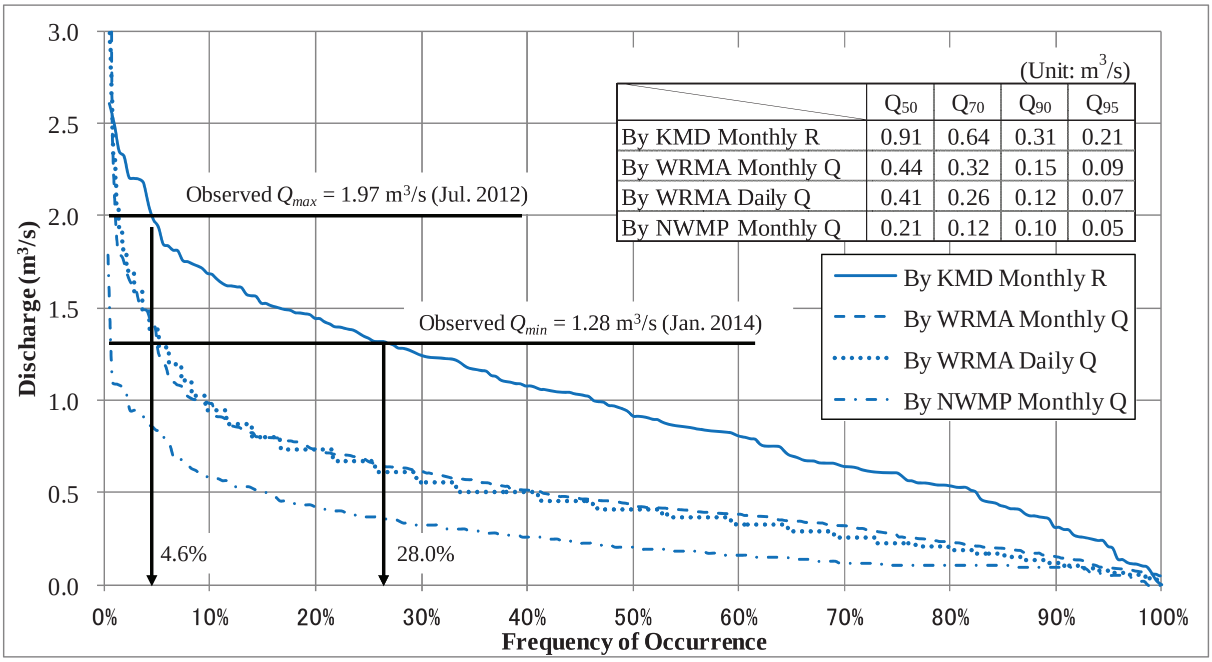


Source: NWMP 2030 by JICA (Presented by WG)

**Figure 4.2.5 Flow Duration Curve at Asurur Site based on NWMP 2030 Data**

### 4.2.4 Comparison among Estimated Flow Duration Curves

Estimated flow duration curves and observed maximum and minimum discharges were compared as shown below. The range of observed discharges showed relatively low probability in the flow duration curves.



(Unit: $m^3/s$)

| | $Q_{50}$ | $Q_{70}$ | $Q_{90}$ | $Q_{95}$ |
|---|---|---|---|---|
| By KMD Monthly R | 0.91 | 0.64 | 0.31 | 0.21 |
| By WRMA Monthly Q | 0.44 | 0.32 | 0.15 | 0.09 |
| By WRMA Daily Q | 0.41 | 0.26 | 0.12 | 0.07 |
| By NWMP Monthly Q | 0.21 | 0.12 | 0.10 | 0.05 |

**Figure 4.2.6 Comparison between Observed Discharge and Flow Duration Curves**

### (1) Comparison between Observed Discharge and Estimated Discharge based on KMD Rainfall Data

From all the collected data, only rainfall data at Kabujoi Forest Station was available on measurement months. Monthly average discharge on measurement months at the planned Asurur site were estimated from the available KMD monthly rainfall data in 2012, in the same manner as that described in Section 4.2.2. The results obtained were as tabulated below.

**Table 4.2.4 Observed and Estimated Monthly Discharge at Asurur Site**

| Month/Year | Jun. 2012 | Jul. 2012 | Aug. 2012 | Sep. 2012 | Jan. 2014 |
|---|---|---|---|---|---|
| Monthly average of observed Q ($m^3/s$) | 1.71 | 1.97 | 1.77 | 1.79 | 1.28 |
| KMD monthly rainfall data (mm/month) | 144.5 | N.A. | 158.5 | 206.1 | N.A. |
| Estimated monthly average Q ($m^3/s$) | 1.02 | - | 1.12 | 1.46 | - |

As seen in the above table, the observed discharge values were larger than the estimated monthly average discharges.

Average annual rainfall at Kabujoi for 18 years (1993 to 2010) was calculated at 1,661 mm/year. The annual rainfall at Kabujoi in 2012 was not available due to missing data in July and December, but it was assumed to be 1,360 mm/year based on the monthly average rainfall in July and December for 18 years (1993 to 2010). Therefore, annual rainfall in 2012 was lower than the average. However, the observed discharges showed higher values than the estimated monthly average discharges.

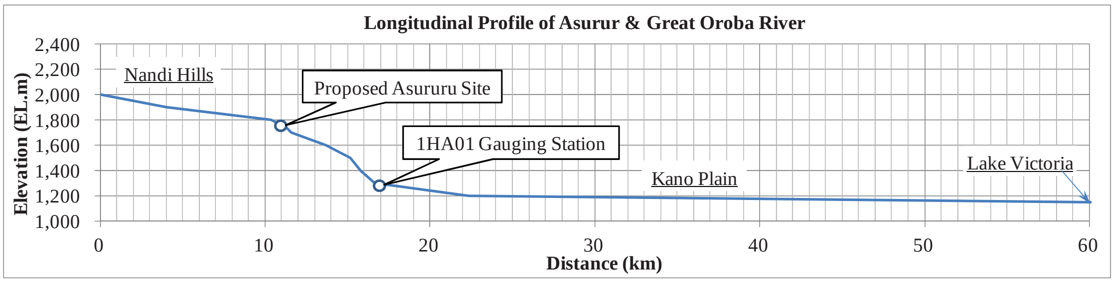
Accordingly, it is conceivable that the estimated flow duration curves using the three (3) different methods are underestimations.

### (2) Consideration of the Difference between Observed Discharge and Flow Duration Curves

The following possibilities are conceivable as the reason why the flow duration curves showed low discharges.

#### i) WRMA discharge data at 1HA01

Asurur River is a tributary of the Great Oroba River. The planned Asurur site is located at the shoulder of Nandi Hills, while 1HA01 gauging station is located at the foot of Kano Plains as shown below. Accordingly, it is conceivable that infiltration is occurring near 1HA01 gauging station, located at the river plain.



Source: Prepared by WG from a topographic map with a scale of 1:50,000

**Figure 4.2.7 Location of Asurur MHP Site on Longitudinal Profile of Great Oroba River**

ii) NWMP 2030 simulated Discharge Data in Sub - basin 1HA1

The rainfall - runoff analysis was conducted nationally. The planned Asurur catchment area occupies 10% of the sub - basin 1HA1. Accordingly, local characteristics of the Asurur catchment area could not be expressed adequately.

iii) Overestimation of Discharge Measurement at Asurur Site

Discharge measurement has some observation error, and it is conceivable that the observed discharge is overestimated.

Taking into consideration the above and observed results at the site, the flow duration curve prepared using KMD monthly rainfall data was applied for the planning of Asurur MHP.

## 4.3 Estimation of the Flood Discharge

Probable flood discharge at the planned Asurur site was studied based on three (3) sets of data as summarized below.

i) Estimation by Annual Maximum Discharge in WRMA Daily Discharge Data

Maximum daily discharge for each year from 1956 to 1988 at the 1HA01 station of WRMA was extracted for the estimation. However, these annual maximum discharges showed relatively small values compared with the observed discharge at the planned Asurur site. Accordingly, it was determined that flood discharge data was not indicated in the daily discharge data, and it was not adopted for the probable flood estimation.

ii) Estimation by Rational Formula

The rational formula is commonly applied for the estimation of flood discharge at catchment areas of less than 200 km$^2$. The formula is used to estimate the peak flood discharge from runoff coefficient, average rainfall intensity in flood duration, and catchment area. The runoff coefficient was defined by land use condition in the catchment area, and the average rainfall intensity was estimated from KMD monthly rainfall data and characteristics in the catchment area.

iii) Estimation by Regional Area Flood Curve by NWMP 2030

Regional area – flood curves are given by logarithmic functions for each major sub – basin, in the same way as the results of flood analysis in NWMP 2030. According to WRMA’s classification, the planned Asurur catchment area is located in Kibos River basin, and flood discharges were estimated by the regional area flood curve for Kibos River basin.

The probable flood discharges estimated using the first two (2) methods were compared with those of other hydropower projects in Eastern Kenya by Creager’s coefficient (“C” value). As a result, “C” values of the flood discharge estimated by the regional area – flood curve were relatively smaller than the range of “C” values of other projects. The flood discharge estimated by rational formula was therefore selected for definition of the design discharges.

### 4.3.1 Estimation by WRMA Daily Discharge Data

Annual maximum daily discharge from daily discharge data at 1HA01 during 1956 to 1988 were extracted and converted into discharge at the planned Asurur site as a ratio of the catchment area ($0.697 = 37.9\ \text{km}^2 / 54.4\ \text{km}^2$), and these were compared with the average observed discharge of 1.70 $\text{m}^3$/s at the site as tabulated below.

**Table 4.3.1 Annual Maximum Discharges at Asurur Site**

| **No.** | **Date** | $Q_a$ ($\text{m}^3$/s) | $Q_b$ ($\text{m}^3$/s) | $Q_b/Q_m$ ( - ) | **No.** | **Date** | $Q_a$ ($\text{m}^3$/s) | $Q_b$ ($\text{m}^3$/s) | $Q_b/Q_m$ ( - ) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 06 Sep. 1956 | 3.35 | 2.33 | 1.4 | 18 | 16 Jan. 1973 | 2.28 | 1.59 | 0.9 |
| 2 | 27 Jun. 1957 | 2.61 | 1.82 | 1.1 | 19 | 02 Jan. 1974 | 4.53 | 3.15 | 1.9 |
| 3 | 27 Jul. 1958 | 3.35 | 2.33 | 1.4 | 20 | 25 Jul. 1975 | 2.96 | 2.06 | 1.2 |
| 4 | 03 Nov. 1959 | 4.45 | 3.10 | 1.8 | 21 | 22 May 1976 | 1.99 | 1.38 | 0.8 |
| 5 | 17 Nov. 1959 | 2.96 | 2.06 | 1.2 | 22 | 06 May 1977 | 8.04 | 5.60 | 3.3 |
| 6 | 27 Nov. 1961 | 7.68 | 5.35 | 3.2 | 23 | 08 May 1978 | 2.78 | 1.94 | 1.1 |
| 7 | 19 May 1962 | 8.78 | 6.11 | 3.6 | 24 | 12 Apr. 1979 | 2.61 | 1.82 | 1.1 |
| 8 | 09 May 1963 | 4.70 | 3.27 | 1.9 | 25 | 22 Nov. 1980 | 1.36 | 0.95 | 0.6 |
| 9 | 24 Apr. 1964 | 7.34 | 5.11 | 3.0 | 26 | 12 Oct. 1981 | 2.28 | 1.59 | 0.9 |
| 10 | 03 May 1965 | 4.22 | 2.94 | 1.7 | 27 | 29 Nov. 1982 | 1.47 | 1.03 | 0.6 |
| 11 | 25 Apr. 1966 | 4.22 | 2.94 | 1.7 | 28 | 11 Oct. 1983 | 2.13 | 1.49 | 0.9 |
| 12 | 27 Nov. 1967 | 3.35 | 2.33 | 1.4 | 29 | 09 May 1984 | 1.36 | 0.95 | 0.6 |
| 13 | 29 Apr. 1968 | 4.45 | 3.01 | 1.8 | 30 | 16 Apr. 1985 | 1.36 | 0.95 | 0.6 |
| 14 | 10 Feb. 1969 | 2.13 | 1.49 | 0.9 | 31 | 07 Mar. 1986 | 4.92 | 3.42 | 2.0 |
| 15 | 24 Apr. 1970 | 7.68 | 5.35 | 3.2 | 32 | 09 Nov. 1987 | 1.60 | 1.11 | 0.7 |
| 16 | 18 May 1971 | 3.15 | 2.20 | 1.3 | 33 | 04 Dec. 1988 | 474.60 | 330.65 | 194.5 |
| 17 | 20 Nov. 1972 | 2.28 | 1.59 | 0.9 | - | - | - | - | - |

Note: $Q_a$ means discharge data at 1HA01, $Q_b$ means converted discharge at Asurur ($Q_b = 0.697\ Q_a$), and $Q_m$ means average observed discharge at Asurur ($Q_m = 1.70\ \text{m}^3/\text{s}$).

Prepared by WG based on WRMA daily discharge data at 1HA01

As seen in the table, annual maximum discharges were distributed within the range of 0.6 to 3.6 times of the average observed discharge of 1.70 $\text{m}^3$/s, except for the year 1988. Further, 11 of the 33 values of annual maximum discharges were smaller than the average observed discharge.

Accordingly, it was determined that the daily discharge data at 1HA01 was not indicated discharge during flood, and was therefore not applicable for the estimation of probable flood discharge.

### 4.3.2 Estimation by Rational Formula

Regional formula is commonly applied for the estimation of flood discharge at catchment areas of less than 200 $\text{km}^2$. The formula is as follows:

$$Q_P = \frac{1}{3.6} \times f \times R_T \times A \qquad \text{[Rational Formula (Lloyd Davies, 1906)]}$$

Where, $Q_P$: peak discharge ($\text{m}^3$/s)

$f$: runoff coefficient ( - )

= 0.60 (Intermediate value of undulating land and forest)

$R_T$: average rainfall intensity in flood duration (mm/hr)

$A$: catchment area ($\text{km}^2$) = 37.9 ($\text{km}^2$)

$$\therefore\ Q_P = \frac{1}{3.6} \times 0.6 \times R_T \times 37.9$$

Average rainfall intensity in flood duration ($R_T$) is estimated based on the monthly rainfall and topographic characteristics in the basin as explained below.

(1) Estimation of Average Rainfall Intensity ($R_T$)

The average rainfall intensity ($R_T$) is estimated using the following formula:

$$R_T = \frac{R_{24}}{24} \times \left( \frac{24}{T} \right)^{2/3}$$ [Mononobe Formula]

$$R_T = R_{24} \times \left( \frac{347.1}{t^{1.35} + 1{,}502} \right)$$ [Ito Formula]

Where $R_T$: average rainfall intensity (mm/hr)
$R_{24}$: probable daily rainfall (mm/day)
$T$: time to concentration of runoff (hr)
$t$: time to concentration of runoff (min)

i) Estimation of Probable Daily Rainfall ($R_{24}$)

Probable daily rainfall is assumed to be 10% of monthly rainfall, where daily rainfall data is not available. Maximum monthly rainfall in each year at Kabujoi Forest station was extracted from KMD monthly rainfall data, and daily maximum rainfall was assumed as listed below.

**Table 4.3.2 Assumed Annual Maximum Daily Rainfall of Asurur Basin**

| **Year** | **1993** | **1994** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **2001** |
|---|---|---|---|---|---|---|---|---|---|
| Maximum monthly rainfall (mm) | 176.3 | 273.7 | 310.8 | 247.9 | 327.7 | 206.5 | 310.2 | 213.4 | 307.1 |
| Assumed daily rainfall (mm) | 17.6 | 27.4 | 31.1 | 24.8 | 32.8 | 20.6 | 31.0 | 21.3 | 30.7 |
| **Year** | **2002** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** |
| Maximum monthly rainfall (mm) | 331.6 | 238.2 | 255.9 | 368.0 | 352.6 | 220.4 | 259.2 | 207.2 | 260.5 |
| Assumed daily rainfall (mm) | 33.2 | 23.8 | 25.6 | 36.8 | 35.3 | 22.0 | 25.9 | 20.7 | 26.0 |

Prepared by WG based on KMD monthly rainfall data

Probability of daily rainfall was calculated based on the 18 values above. The log Pearson type III was used as the probability distribution function, as recommended by the Engineering Manual (EM1110-2-1417: Flood-runoff Analysis) of the US Army Corps of Engineers. The results of the probable rainfall depth and frequency (return period) are as shown below.

**Table 4.3.3 Probable Daily Rainfall of Asurur Basin**

| Return Period | (Year) | 200 | 100 | 50 | 20 | 10 | 5 |
|---|---|---|---|---|---|---|---|
| Excess Probability | (%) | 0.5 | 1.0 | 2.0 | 5.0 | 10.0 | 20.0 |
| Probable Rainfall ($R_{24}$) | (mm/day) | 47.1 | 44.4 | 41.7 | 38.0 | 35.1 | 31.9 |

ii) Estimation of Flood Concentration Time

Flood concentration time is generally estimated in two steps, i.e., overland inflow time from the basin to river and river flow time to the site. These values are determined as follows:

<u>Overland Inflow Time</u>

$$T_{OF} = \left( \frac{2}{3} \times 3.28 \times l \times \frac{N}{\sqrt{S}} \right)^{0.467}$$ [Kerby Formula]

Where, $T_{OF}$: overland inflow time (min)
$l$: length between basin crest and top of river (m)
$N$: retardance coefficient ( - ) = 0.60 (Forest area with deciduous trees)
$S$: slope of the extreme edge elevation at the most upstream reach ( - )

River Flow Time

$$T_{RF} = \frac{L}{W}, \ W = 20 \times \left(\frac{h}{L}\right)^{0.6}$$ [Rziha Formula] ($L$ > 1/20)

Where, $T_{RF}$: river flow time (s)

$L$: horizontal length of river channel from top of river to site (m)

$W$: flood velocity (m/s)

$h$: height difference from top of river to site (m)

(2) Basin Characteristics

The topographic characteristics of the planned Asurur catchment area were assumed from a topographic map with scale of 1:50,000 as follows:

| | |
|---|---|
| Catchment area: | A = 37.9 (km$^2$) |
| Length between basin crest and top of river: | $l$ = 860 (m) |
| Slope of the extreme edge elevation at top of river: | $S$ = (2,060 – 2,000)/860 = 0.070 ( - ) |
| Length of river reach: | $L$ = 11,270 (m) = 11.3 (km) |
| Height difference from top of basin to site: | $h$ = 2,060 – 1,740 = 320 (m) |
| Slope of river reach: | $I = L/H$ = 1/35.2 = 0.028 ( - ) |

(3) Estimation of Peak Flood Discharge

Peak flood discharges are calculated by the above formula and basin characteristics as explained below.

i) Estimation of Flood Concentration Time ($T = T_{OF} + T_{RF}$)

Overland inflow Time ($T_{OF}$)

$$T_{OF} = \left(\frac{2}{3} \times 3.28 \times l \times \frac{N}{\sqrt{S}}\right)^{0.467} = \left(\frac{2}{3} \times 3.28 \times 860 \times \frac{0.6}{\sqrt{0.070}}\right)^{0.467}$$

= 49.6 (min) = 0.8 (hr)

River Flow Time ($T_{RF}$)

$$W = 20 \times \left(\frac{h}{L}\right)^{0.6} = 20 \times \left(\frac{320}{11,270}\right)^{0.6} = 2.36 = 2.4 \text{ (m/s)}$$

$$T_{RF} = \frac{L}{W} = \frac{11,270}{2.4} = 4,696 \text{ (s)} = 78.3 \text{ (min)} = 1.3 \text{ (hr)}$$

Flood Concentration Time ($T$)

$T = T_{OF} + T_{RF} = 0.8 + 1.3 = \underline{2.1 \text{ (hr)}}$

$t = t_{OF} + t_{RF} = 49.6 + 78.3 = \underline{128 \text{ (min)}}$

ii) Estimation of average rainfall intensity ($R_T$)

The average rainfall intensity was calculated using the two (2) formulae and the results were as shown below.

**Table 4.3.4 Estimated Average Rainfall Intensity at Asurur Site**

| Return Period | (Year) | 200 | 100 | 50 | 20 | 10 | 5 |
|---|---|---|---|---|---|---|---|
| Excess Probability | (%) | 0.5 | 1.0 | 2.0 | 5.0 | 10.0 | 20.0 |
| $R_{24}$ | (mm/day) | 47.1 | 44.4 | 41.7 | 38.0 | 35.1 | 31.9 |
| $T$ | (hr) | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 |
| **$R_{T1}$ (Mononobe)** | **(mm/hr)** | **9.7** | **9.1** | **8.5** | **7.8** | **7.2** | **6.5** |
| $T$ | (min) | 128 | 128 | 128 | 128 | 128 | 128 |
| **$R_{T2}$ (Ito)** | **(mm/hr)** | **7.4** | **7.0** | **6.6** | **6.0** | **5.5** | **5.0** |

Note: $R_{T1}$ is average rainfall intensity by Mononobe Formula and $R_{T2}$ is average rainfall intensity by Ito Formula.

iii) Estimation of peak flood discharge ($Q_P$)

Peak flood discharges for each return period were calculated as summarized below.

**Table 4.3.5 Estimated Peak Flood Discharge at Asurur Site**

| Return Period | (Year) | 200 | 100 | 50 | 20 | 10 | 5 |
|---|---|---|---|---|---|---|---|
| Excess Probability | (%) | 0.5 | 1.0 | 2.0 | 5.0 | 10.0 | 20.0 |
| $R_{T1}$ (Mononobe) | (mm/hr) | 9.7 | 9.1 | 8.5 | 7.8 | 7.2 | 6.5 |
| **$Q_p$** | **($m^3$/s)** | **61.0** | **57.5** | **54.0** | **49.2** | **45.4** | **41.3** |
| $R_{T2}$ (Ito) | (mm/hr) | 7.4 | 7.0 | 6.6 | 6.0 | 5.5 | 5.0 |
| **$Q_p$** | **($m^3$/s)** | **46.9** | **44.2** | **41.5** | **37.9** | **35.0** | **31.8** |

### 4.3.3 Estimation by Regional Area Flood Curve in NWMP 2030

The probable flood discharge at the planned Asurur site was calculated by using the regional area – flood curve at Kibos River, which was presented in NWMP 2030, as shown below.

**Table 4.3.6 Flood Discharge by Regional Area Flood Curve presented in NWMP 2030**

| Return Period | Regional Area Flood Curve | $log_{10}A$ | $log_{10}Q$ | $Q$ |
|---|---|---|---|---|
| 10-year | $log_{10}Q$ = -0,012 +0.551 $log_{10}A$ | 1.579 | 0.857 | 7.2 $m^3$/s |
| 25-year | $log_{10}Q$ = +0.061 +0.551 $log_{10}A$ | 1.579 | 0.937 | 8.7 $m^3$/s |
| 50-year | $log_{10}Q$ = +0.115 +0.551 $log_{10}A$ | 1.579 | 0.991 | 9.8 $m^3$/s |
| 100-year | $log_{10}Q$ = +0.168 +0.551 $log_{10}A$ | 1.579 | 1.040 | 11.0 $m^3$/s |

Note: "A" means catchment area of 37.9 $km^2$.

Source: Regional Area Flood Curve: Final Report of NWMP 2030, Sector Report B, Table 6.3.2 LVS-14 Kibos, by JICA (Presented by WG)

### 4.3.4 Confirmation by Creager Envelope Curve

The adequacy of estimated flood discharges is checked by the Creager envelope curve. The Creager envelope curve is an empirical formula which indicates the relation between catchment area and estimated or recorded flood peak discharge, in the form of specific discharge.

The Creager envelope curve is given by the following formula:

$$Q_P = 0.503 \times C \times \left(\frac{A}{2.59}\right)^{a-1}$$

$$a = 0.894 \times \left(\frac{A}{2.59}\right)^{-0.048}$$

Where, $Q_P$: Specific peak discharge ($m^3/s/km^2$)
$C$: Creager's coefficient ( - )
$A$: catchment area ($km^2$)

The Creager coefficient "C" indicates regional characteristics of catchment area. It therefore varies depending on the location of the basin in question. However, its values become similar for nearby basins. The "C" value shall therefore be estimated based on the available flood records and/or design flood discharges in existing projects to obtain the appropriate value near the basin in question.

The flood peak specific discharges and the "C" values of hydropower projects in Western Kenya, and 100 - year probable flood peak discharges estimated using two (2) different methods for Asurur site were compared as shown below.

**Table 4.3.7 Creager's Coefficient for Hydropower Projects in Western Kenya**

| Project Name | County | A ($km^2$) | $Q_d$ ($m^3/s$) | $Q_p$ ($m^3/s/km^2$) | C ( - ) | Remarks |
|---|---|---|---|---|---|---|
| Asurur MHP | Nandi | 37.9 | 61 | 1.609 | 5.7 | 100 - year flood |
| | | | 47 | 1.237 | 4.4 | 100 - year flood |
| | | | 11 | 0.290 | 1.0 | 100 - year flood |
| *Proposed MHP* | | | | | | |
| Greater Orobo | Nandi | 50 | 121 | 2.407 | 9.3 | Flood during construction |
| Kiptiget - Itare Conf. | Bomet | 186 | 42 | 0.227 | 1.4 | Flood during construction |
| Ainamoi – Kitio | Kericho | 333 | 75 | 0.227 | 1.9 | Flood during construction |
| Chemosit - Kabianga | Bomet | 1,370 | 310 | 0.227 | 3.8 | Flood during construction |
| Wei Wei - Sighor | Nakuru | 203 | 35 | 0.172 | 1.1 | Flood during construction |
| Embobut - Tot | Elegeyo Marakwet | 34 | 496 | 14.714 | 50.1 | Flood during construction |
| *Large Scale HPP* | | | | | | |
| Sondu/ Miriu | Kisumu | 3,345 | 1,046 | 0.313 | 8.6 | PMF |
| | | | 749 | 0.224 | 6.1 | 1000 - year flood |
| Magwagwa | Nyamira | 3,160 | 1,920 | 0.608 | 16.1 | PMF |
| | | | 1,634 | 0.517 | 13.7 | 1000 - year flood |

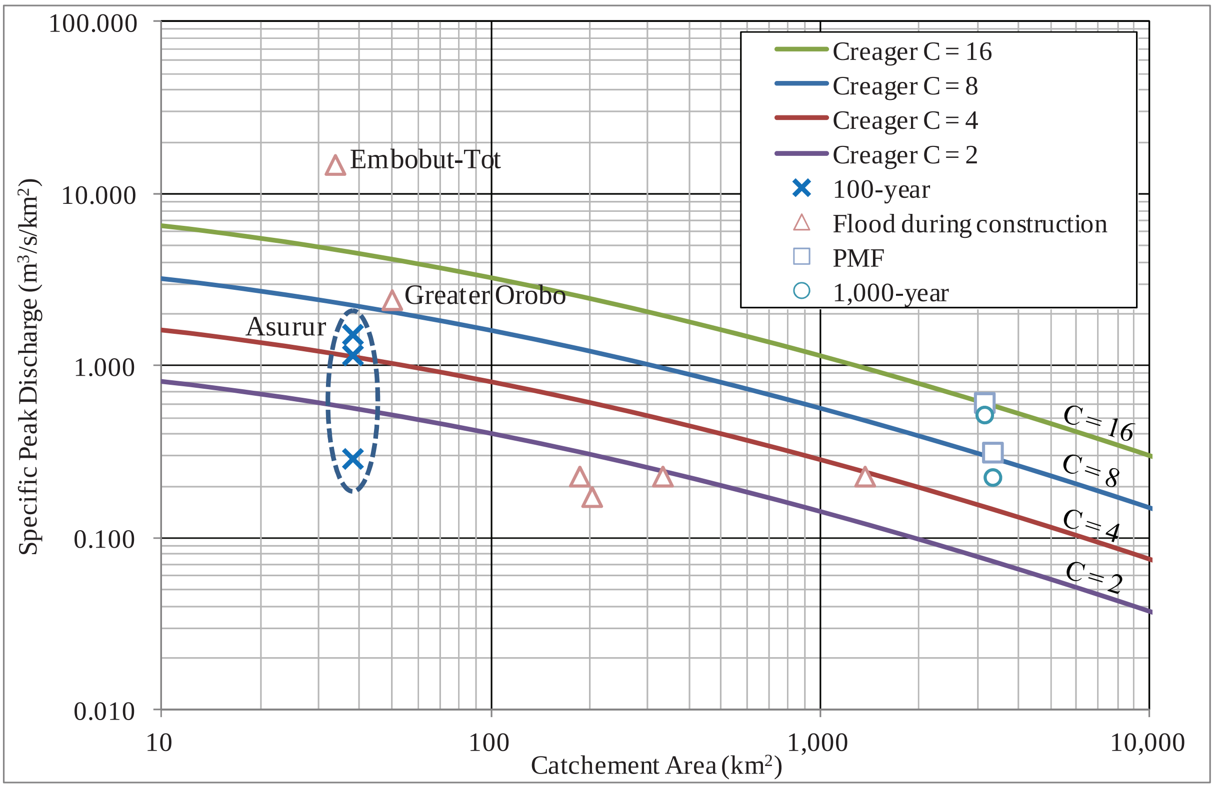


**Figure 4.3.1 Creager's Coefficient for Hydropower Projects in Western Kenya**

The following issues were confirmed as a result of the comparison:

- ✓ Design flood discharges of probable maximum flood (PMF) and 1,000 - year probable flood for Sondu/Miriu HPP and Magwagwa HPP were defined based on international standards of hydrological analysis, and were regarded as rough indicative values,
- ✓ Design flood discharges of MHP projects were defined as flood during construction, and it were conceivably 5 - year to 10 - year probable floods. However, the “C” values seemed relatively large, especially for Embobut -Tot and Greater Orobo which were abnormally large,
- ✓ The “C” values of assumed 100 - year probable flood by Rational Formula for Asurur MHP were smaller than “C” values of PMF and 1,000 - year probable flood. However, they were larger than “C” values of flood during construction. The “C” values therefore seemed reasonable, and
- ✓ The “C” values of assumed 100 - year probable flood from NWMP 2030 regional area – flood curve for Asurur MHP were the smallest among all “C” values, and this seems unreasonable.

Taking the above conditions into consideration, flood discharges estimated by Rational Formula and average rainfall intensity estimated by Ito Formula were adopted for the design discharge of Asurur MHP.

## 4.4 Design Discharge

Design plant discharges of Asurur MHP were defined in this stage based on the flow duration curve prepared by KMD monthly rainfall data as explained below. The design plant discharge shall be confirmed or reviewed in future based on further observation results of discharge at the site.

### 4.4.1 Design Plant Discharge

The design plant discharges are defined as follows:

Minimum design plant discharge ($Q_{pmin}$):

$$Q_{p\min} = Q_{90\%} - Q_{95\%} - Q_{eu} = 0.31 – 0.21 – 0.00 = 0.1 \text{ m}^3/\text{s}$$

Maximum design plant discharge ($Q_{pmax}$):

$$Q_{p\max} = Q_{50\%} - Q_{95\%} - Q_{eu} = 0.91 – 0.21 – 0.00 = 0.7 \text{ m}^3/\text{s}$$

Where, $Q_{90\%}$: 90% reliable discharge at the site = 0.31 ($m^3/s$)
$Q_{95\%}$: 95% reliable discharge at the site = 0.21 ($m^3/s$)
$Q_{50\%}$: 50% reliable discharge at the site = 0.91 ($m^3/s$)
$Q_{eu}$: existing water use at upstream of the site = 0.00 ($m^3/s$)

The amount of reserve, consisting of ecological and basic human needs, was set at 95% of the value of naturalized daily flow for each river, in accordance with “Guidelines for Water Allocation (WRMA, 2010)”. Therefore, the minimum discharge was determined to be 90% reliable discharge minus 95% reliable discharge.

The maximum design plant discharge is generally determined as 50 to 70% of reliability in the flow duration curve. Its value depends on the required power output and available head, with maximum plant discharge of 0.7 $m^3/s$.

### 4.4.2 Plant Factor

The plant factor is calculated to be 72.5% as shown below.

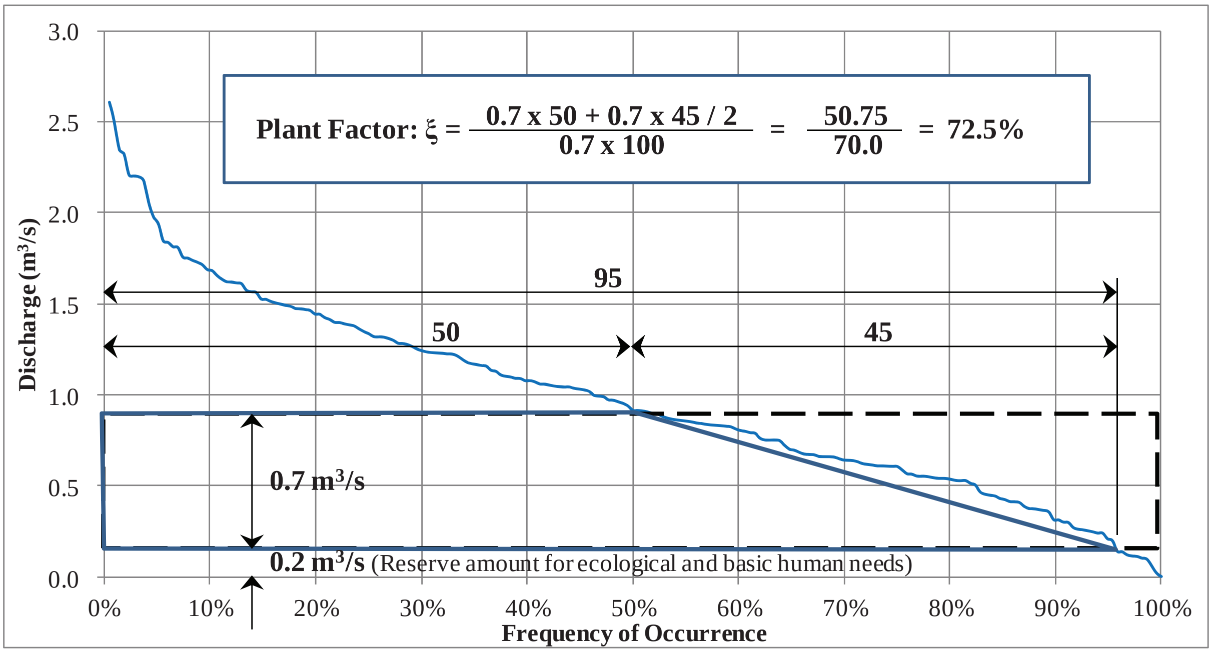


**Figure 4.4.1 Plant Factor of Asurur MHP**

### 4.4.3 Design Flood Discharge

Design flood discharge is defined as 50 - year probable flood taking into consideration the project scale and project life.

$Q_f$ = 41.5 = 42.0 $m^3$/s (50 - year probable flood) Refer to Table 4.3.5.

# CHAPTER 5 PLAN FORMULATION

## 5.1 Preparation of Alternative Layouts

This chapter describes the preparation of alternative layouts, comparison of the alternatives and selection of the optimum layout.

A topographic map with a scale of 1: 500, which was prepared during the preparation stage of the pilot project in 2012, was used to carry out the comparative study.

At first, possible positions of intake weir and powerhouse were determined based on the longitudinal profile of Asurur River, and three (3) intake sites and one (1) powerhouse site were identified. Then, three (3) alterative layouts, Layout A, Layout B and Layout C, were prepared for comparison.

For each of the three (3) alternative layouts, development cost (C) was estimated using empirical equations and benefit (B) was estimated based on the different available heads and the same discharge estimated in Chapter 4. Then, alternative layouts were compared in terms of ratio of cost and benefit, as well as generation power against estimated power demand in Chapter 3.

As a result of comparative study, Layout A was selected as the optimum layout.

### 5.1.1 Position of Intake Weir and Powerhouse

Alternative positions of intake weir and powerhouse were studied by creating the longitudinal profile of Asurur site from the topographic map as shown below.

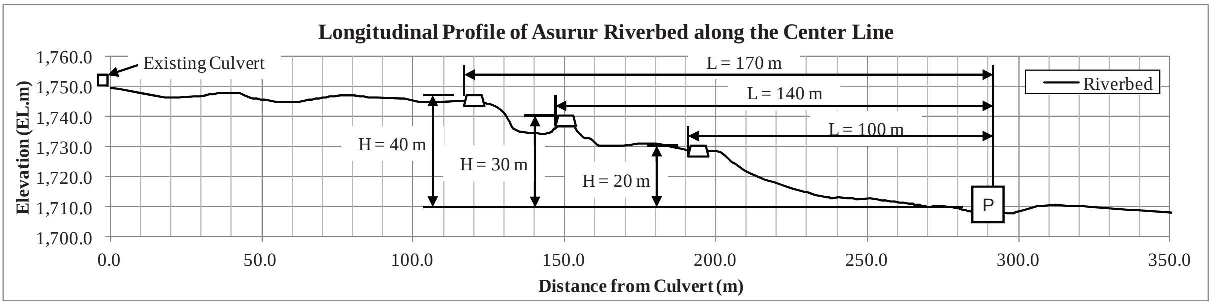


**Figure 5.1.1 Alternative Head of Asurur Site**

As a result, the alternative positions were considered as follows:

- ✓ Intake weir: A gentle slope is maintained downstream for 120 m from the existing culvert under the road. Then, the river gradient is rapid from there to Asurur waterfall. Three (3) alternative sites of intake weir were therefore possible along the rapids section, and
- ✓ Powerhouse: The river gradient downstream of Asurur waterfall is a gentle slope. Therefore, there are no alternatives for powerhouse site.

### 5.1.2 Alternative Layouts for Comparison

Taking into consideration the alternative sites of intake weir, and topographic conditions along Asurur River from intake weir sites and powerhouse site, three (3) alternative layouts were prepared as shown below.

It is noted that an alternative layout on the left bank was not prepared because the waterway distance on the left bank was clearly longer than on the right bank due to topographic conditions.

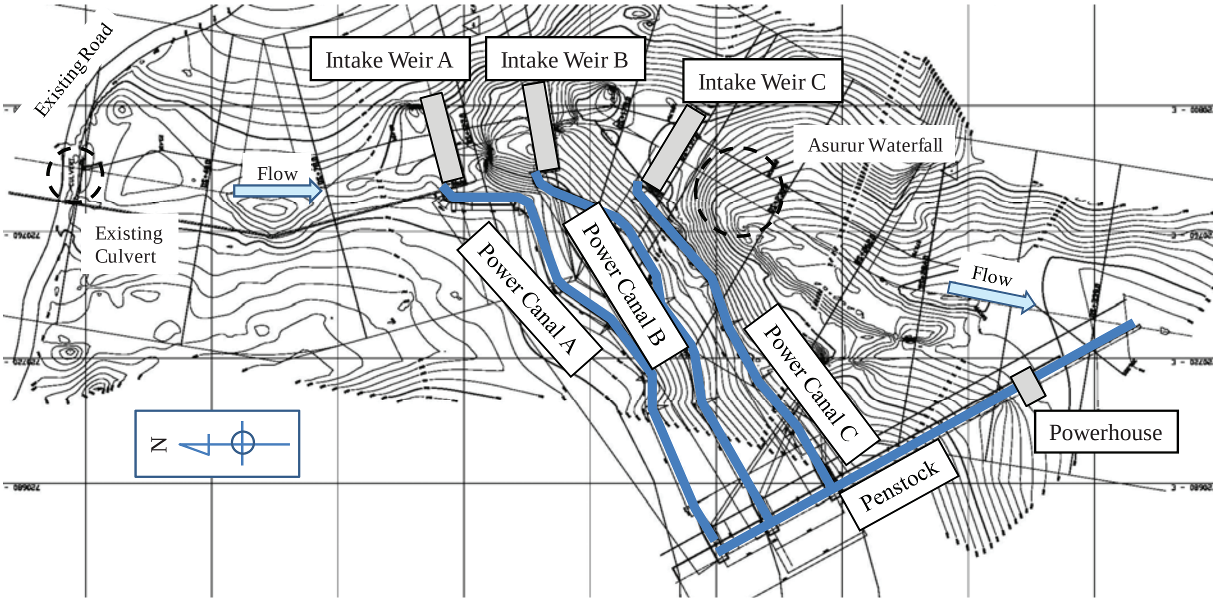


**Figure 5.1.2 Alternative Layouts for Comparison**

### 5.1.3 Temporary Setting of Major Dimensions

The following major dimensions were temporarily set in order to define the major dimensions of each alternative layout.

(1) Center Level of Turbine

Turbine center level had to be set to avoid inundation during flooding. The design flood discharge was defined to be 42.0 $m^3/s$ (50-year probable flood) as explained in Chapter 4.

Water levels against several discharges along Asurur River were calculated by non-uniform analysis. Thirteen (13) cross sections were prepared from the topographic map as attached in Annex-2, and roughness coefficients defined through some trial calculations as follows:

| | |
|---|---|
| River channel: | 0.060 |
| Left and right bank: | 0.080 |

The analysis was carried out using free software (HEC-RAS), yielding the calculated water levels summarized in the table below.

**Table 5.1.1 Result of Water Level Calculation against Design Flood Discharge**

| Section | Positin | Discharge ($m^3/s$) | Riverbed Level (EL.m) | Water Level (EL.m) | Critical WL (EL.m) | Energy Line (EL.m) | Energy Slope (m/m) | Flow Velocity (m/s) | Flow Area ($m^2$) | Flow Width (m) | Froude Number ( - ) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CH+340 | Culvert | 42.00 | 1,747.80 | 1,749.76 | | 1,749.96 | 0.01 | 2.31 | 26.32 | 38.08 | 0.65 |
| CH+300 | | 42.00 | 1,747.80 | 1,749.41 | | 1,749.53 | 0.01 | 1.56 | 27.73 | 28.37 | 0.46 |
| CH+262.0 | | 42.00 | 1,747.00 | 1,748.48 | 1,748.48 | 1,748.98 | 0.03 | 3.16 | 13.96 | 15.67 | 0.96 |
| CH+222.0 | Intake A | 42.00 | 1,744.60 | 1,745.71 | 1,745.71 | 1,746.08 | 0.03 | 2.91 | 17.47 | 23.88 | 0.94 |
| CH+213.0 | | 42.00 | 1,742.60 | 1,743.99 | 1,743.99 | 1,744.48 | 0.04 | 3.10 | 13.56 | 14.09 | 1.01 |
| CH+189.0 | Intake B | 42.00 | 1,736.00 | 1,737.90 | 1,737.90 | 1,738.31 | 0.02 | 3.16 | 18.19 | 22.32 | 0.82 |
| CH+165.0 | | 42.00 | 1,730.10 | 1,731.64 | 1,731.64 | 1,732.01 | 0.02 | 2.96 | 18.36 | 24.33 | 0.84 |
| CH+143.0 | Intake C | 42.00 | 1,728.40 | 1,729.80 | 1,729.80 | 1,730.23 | 0.03 | 3.06 | 16.11 | 20.63 | 0.92 |
| CH+110.0 | | 42.00 | 1,714.40 | 1,716.26 | 1,716.26 | 1,716.84 | 0.03 | 3.36 | 12.65 | 11.96 | 0.99 |
| CH+78.0 | | 42.00 | 1,710.40 | 1,712.67 | 1,712.67 | 1,713.29 | 0.04 | 3.48 | 12.06 | 9.95 | 1.01 |
| CH+56.0 | | 42.00 | 1,708.20 | 1,711.78 | | 1,711.89 | 0.00 | 1.50 | 27.95 | 15.36 | 0.36 |
| CH+28.0 | Powerhouse | 42.00 | 1,710.50 | 1,711.30 | 1,711.30 | 1,711.61 | 0.04 | 2.45 | 17.82 | 32.07 | 0.97 |
| CH+1.0 | Tailrace | 42.00 | 1,708.40 | 1,709.52 | 1,709.52 | 1,709.81 | 0.03 | 2.52 | 20.19 | 42.15 | 0.90 |

Water level against the design flood discharge surrounding powerhouse and tailrace was calculated as EL. 1,709.5 m to EL. 1,711.3 m.

Accordingly, the center level of turbine was defined as follows, taking into consideration margin of freeboard and thickness of floor concrete of powerhouse:

Center level of turbine: EL. 1,712.5 m

### (2) Dimensions of Power Canal

Dimensions of the power canal were determined as the economical section against the design maximum discharge. The economical section is that which circumscribes the semicircle of radius equal to the water depth.

Dimensions of the power canal were calculated using Manning's formula:

$$Q = \frac{A}{n} \times R^{2/3} \times I^{1/2}$$

Where,
$Q$: discharge (m$^3$/s)
$A$: flow area (m$^2$)
$n$: roughness coefficient = 0.015 ( - )
$R$: hydraulic radius = A/S (m)
$S$: wetted perimeter (m)
$I$: gradient of water surface = 0.001 (1/1,000)

Free board of the power canal was calculated using the following formula:

$$F_{br} = 0.05 \times h_d + h_v + h_c$$
$$h_v = \alpha \times V^2 / 2g$$
$$h_c = b \times V^2 / (R \times g)$$

Where,
$F_{br}$: required free board (m)
$h_d$: design flow depth (m)
$h_v$: flow velocity head (m)
$h_c$: water rising due to curve (m)
$\alpha$: flow coefficient = 1.1 ( - )
$g$: gravity acceleration = 9.8 (m/s$^2$)
$b$: bottom width (m)
$R$: curve radius of canal = 5.0 (m)

Flow depths and required free board against given bottom widths of 10 cm interval were calculated as tabulated below.

**Table 5.1.2 Trial Calculation of Flow Conditions for Power Canal**

| Bottom Width b (m) | Flow Depth h (m) | b/h ( - ) | Flow Area A (m$^2$) | Hydraulic Radius R (m) | Discharge Q (m$^3$/s) | Velocity V (m/s) | Velocity Head hv (m) | Margin for Curve hc (m) | Free Board Fbr (m) |
|---|---|---|---|---|---|---|---|---|---|
| 0.50 | 1.82 | 0.27 | 0.91 | 0.22 | 0.70 | 0.77 | 0.03 | 0.012 | 0.14 |
| 0.60 | 1.40 | 0.43 | 0.84 | 0.25 | 0.70 | 0.83 | 0.04 | 0.014 | 0.12 |
| 0.70 | 1.14 | 0.61 | 0.80 | 0.27 | 0.70 | 0.88 | 0.04 | 0.016 | 0.12 |
| 0.80 | 0.96 | 0.83 | 0.77 | 0.28 | 0.70 | 0.91 | 0.05 | 0.017 | 0.11 |
| 0.90 | 0.84 | 1.07 | 0.76 | 0.29 | 0.70 | 0.93 | 0.05 | 0.018 | 0.11 |
| 1.00 | 0.74 | 1.35 | 0.74 | 0.30 | 0.70 | 0.94 | 0.05 | 0.018 | 0.10 |
| 1.10 | 0.67 | 1.64 | 0.74 | 0.30 | 0.70 | 0.95 | 0.05 | 0.018 | 0.10 |
| 1.20 | 0.61 | 1.97 | 0.73 | 0.30 | 0.70 | 0.95 | 0.05 | 0.018 | 0.10 |
| 1.30 | 0.57 | 2.30 | 0.73 | 0.30 | 0.70 | 0.95 | 0.05 | 0.018 | 0.10 |
| 1.40 | 0.53 | 2.64 | 0.74 | 0.30 | 0.70 | 0.95 | 0.05 | 0.018 | 0.10 |

Economical bottom width against the design maximum discharge was seen to be 0.9 m. However, the following dimensions were adopted taking the required free board against flow velocity into consideration:

| | |
|---|---|
| Inner width of power canal: | 1.0 m |
| Inner depth of power canal: | 1.0 m |

### (3) Crest Level of Intake Weir

Crest level of intake weir was defined as follows, and the intake water level defined as the crest level.

$CL = EL_{RB} + h_{sf} + h_0$ Where,

$CL$: crest level of intake weir (EL.m)
$EL_{RB}$: original riverbed level (EL.m)
$h_{sf}$: depth for sand deposit and flushing = 0.75 (m)
$h_0$: design water depth of power canal = 0.74 (m)

**Table 5.1.3 Calculation of Intake Water Level**

| Alternative | $EL_{RB}$ | $h_{sf}$ | $H_0$ | CL |
|---|---|---|---|---|
| Layout A | 1,744.5 | 0.75 | 0.74 | 1,746.0 |
| Layout B | 1,737.0 | 0.75 | 0.74 | 1,739.5 |
| Layout C | 1,728.5 | 0.75 | 0.74 | 1,730.0 |

### 5.1.4 Major Dimensions of Alternative Layouts

Based on the above calculations and the topographic map, major dimensions of the three (3) alternative layouts were set as listed below.

**Table 5.1.4 Major Dimensions of Alternative Layouts**

| Item | Unit | Layout A | Layout B | Layout C |
|---|---|---|---|---|
| 1. Overall Plan | | | | |
| - Design maximum discharge | ($m^3$/s) | 0.7 | 0.7 | 0.7 |
| - Intake water level | (EL. m) | 1,746.0 | 1,739.5 | 1,730.0 |
| - Turbine center level | (EL. m) | 1,712.5 | 1,712.5 | 1,712.5 |
| - Gross head | (m) | 33.5 | 27.0 | 17.5 |
| - Effective head | (m) | 31.2 | 25.1 | 16.3 |
| - Number of turbines | (nos.) | 2 | 2 | 2 |
| - Combined efficiency | (%) | 72.0 | 72.0 | 72.0 |
| - Maximum output | (kW) | 154.1 | 124.0 | 80.5 |
| 2. Intake Weir | | | | |
| - Design discharge of flush gate | ($m^3$/s) | 31.8 | 31.8 | 31.8 |
| - Height | (m) | 2.0 | 2.0 | 2.0 |
| - Crest length | (m) | 25.0 | 27.0 | 29.0 |
| 3. Intake and De-Silting Basin | | | | |
| - Radius of inlet | (m) | 0.7 | 0.7 | 0.7 |
| - Height of inlet | (m) | 0.5 | 0.5 | 0.5 |
| - Radius of drainage gate | (m) | 0.3 | 0.3 | 0.3 |
| 4. Power Canal | | | | |
| - Inner width | (m) | 1.0 | 1.0 | 1.0 |
| - Inner height | (m) | 1.0 | 1.0 | 1.0 |
| - Concrete thickness | (m) | 0.2 | 0.2 | 0.2 |
| - Length | (m) | 120.0 | 105.0 | 80.0 |
| 5. Spillway Canal | | | | |
| - Inner radius | (m) | 0.2 | 0.2 | 0.2 |
| - Length | (m) | 70.0 | 55.0 | 40.0 |
| 6. Penstock | | | | |
| - Inner diameter | (m) | 0.6 | 0.6 | 0.6 |
| - Length | (m) | 110.0 | 90.0 | 65.0 |
| 7. Tailrace | | | | |
| - Radius | (m) | 0.7 | 0.7 | 0.7 |

## 5.2 Estimation of Project Cost

Project cost was estimated based on empirical methods and equations compiled in the following references:

- ✓ "Guide Manual for Development Aid Programs and Studies of Hydro Electric Power Development" published by New Energy Foundation, under Ministry of Economy, Trading and Industry of Japan, in December 1996.
- ✓ "Handbook for Estimation of Hydropower Project Costs" published by Agency for Natural Resources, under Ministry of Economy, Trading and Industry of Japan, in March 2013.

These references describe in an understandable manner, the studies involved from the initial planning stage, to the feasibility study stage of development projects. It is intended for hydropower engineers and is based on the rich experience in MHP accumulated in Japan.

Estimation of MHP project cost hereinafter is for comparative study only. Further detailed estimation is therefore required in the next stages.

Project cost is estimated using the following components and empirical methods.

**Table 5.2.1 Estimation of Project Cost**

| Description | Estimation Method |
|---|---|
| I. Preparatory Works | Access road: assumed length (km) multiple unit prices.<br>Land compensation: 5% of Item II + Item III.<br>Temporary facilities: 20% of Item II + Item III.<br>Environmental mitigation: 3% of Item II. |
| II. Civil Works | Estimate work quantity of major works of each structure using empirical equations, and the work quantities using multiple unit prices. |
| III. Electro-mechanical Equipment | Estimate using empirical equation. |
| IV. Distribution System | Assumed length (km) multiple unit prices. |
| **Sub-total 1 (Direct Cost)** | Sum of Item I, II, III, and IV. |
| V. Administration and Engineering Cost | 15% of sub-total 1 (Direct cost) |
| VI. Physical Contingency | 10% of sub-total 1 (Direct cost) |
| **Sub-total 2 (Indirect Cost)** | Sum of Item V and VI. |
| **Total** | Sum of Sub-total 1 and Sub-total 2 (direct cost and indirect cost). |

Source: "Guide Manual for Development Aid Programes and Studies of Hydro Electric Power Development" and "Handbook for Estimation of Hydropower Project Costs" (arranged by WG).

### 5.2.1 Civil Works

(1) Estimation of Major Work Quantities

Major work quantities of each alternative layout are estimated as explained hereinafter based on the empirical equations in the references mentioned above.

i) Intake Weir

Intake weir considered is a concrete gravity type.

The following empirical equations are applied. Height of intake weir and design discharge for sand flushing gate are the same for the three (3) alternative layouts, but crest length of the weir is different for each layout. Therefore, different work quantities are applied for each layout.

**Table 5.2.2 Empirical Equations of Intake Weir**

| Description | Empirical Equation | Remarks |
|---|---|---|
| a. Excavation ($m^3$) | $V_e = 0.181 \times (H \times L)^{1.92}$ | H: height of weir (m)<br>L: crest length of weir (m)<br>Q: design discharge of gate ($m^3/s$) |
| b. Concrete ($m^3$) | $V_c = 11.9 \times (H^2 \times L)^{0.701}$ | |
| c. Re-bar (ton) | $W_r = 0.00893 \times V_c^{1.04}$ | |
| d. Sand flush gate (ton) | $W_g = 0.145 \times Q^{0.692}$ | |
| e. Others (L.S.) | 30% of sum of the above costs | Grouting, river diversion, etc. |

ii) Intake Structure

Intake structure considered is a non-pressure type.

The following empirical equations are applied. Design maximum discharge and inner radius of inlet are the same for the three (3) alternative layouts. Therefore, same work quantities are applied for the three (3) layouts.

**Table 5.2.3 Empirical Equations of Intake Structure**

| Description | Empirical Equation | Remarks |
|---|---|---|
| a. Excavation ($m^3$) | $V_e = 637 \times (R \times Q)^{0.580}$ | R: inner radius of inlet (m)<br>Q: design plant discharge ($m^3/s$) |
| b. Concrete ($m^3$) | $V_c = 43.6 \times (R \times Q)^{1.01}$ | |
| c. Re-bar (ton) | $W_r = 0.0345 \times V_c^{1.05}$ | |
| d. Intake gate (ton) | $W_g = 2.67 \times (R \times Q)^{0.470}$ | |
| e. Intake screen (ton) | $W_s = 1.04 \times (R \times Q)^{0.534}$ | |
| f. Others (L.S.) | 25% of sum of the above costs | River diversion, dust collector, etc. |

iii) De-silting Basin

De-silting basin considered is a surface type without slab.

The following empirical equations are applied. Design maximum discharge is the same for the three (3) alternative layouts. Therefore, same work quantities are applied for the three (3) layouts.

**Table 5.2.4 Empirical Equations of De-silting Basin**

| Description | Empirical Equation | Remarks |
|---|---|---|
| a. Excavation ($m^3$) | $V_e = 515 \times Q^{1.07}$ | Q: design plant discharge ($m^3/s$) |
| b. Concrete ($m^3$) | $V_c = 188 \times Q^{1.04}$ (without slab) | |
| c. Re-bar (ton) | $W_r = 0.150 \times V_c^{0.808}$ | |
| d. Drainage gate (ton) | $W_g = 0.910 \times Q^{0.613}$ | |
| e. Drainage screen (ton) | $W_g = 0.696 \times Q^{1.27}$ | |
| f. Others (L.S.) | 20% of sum of the above costs | Slope protection, dust collector, etc. |

iv) Power Canal

Power canal considered is an open concrete type.

The following empirical equations are applied. Inner width, inner height and thickness of concrete as well as design maximum discharge are the same for the three (3) alternative layouts, but length is different for each layout. Therefore, different work quantities are applied for the three (3) layouts.

**Table 5.2.5 Empirical Equations of Power Canal**

| Description | Empirical Equation | Remarks |
|---|---|---|
| a. Excavation ($m^3$) | $V_c = 1.66 \times \{(B \times H)^{1/2}\}^{2.40} \times L$ | B: inner width of canal (m)<br>H: inner height of canal (m)<br>L: Length of canal (m)<br>t: thickness of concrete (m) |
| b. Concrete ($m^3$) | $V_e = \{H \times t \times 2 + (B + 2t) \times t\} \times L$ | |
| c. Re-bar (ton) | $W_r = 0.0592 \times V_c^{0.896}$ | |
| d. Others (L.S.) | 30% of sum of the above costs | Slope protection, fence, etc. |

v) Head Tank

Head tank considered is a surface type without slab.

The following empirical equations are applied. Design maximum discharge is the same for the three (3) alternative layouts. Therefore, same work quantities are applied for the three (3) layouts.

### Table 5.2.6 Empirical Equations of Head Tank

| Description | Empirical Equation | Remarks |
|---|---|---|
| a. Excavation ($m^3$) | $V_e = 398 \times Q^{1.07}$ | Q: design plant discharge ($m^3/s$) |
| b. Concrete ($m^3$) | $V_c = 66.0 \times Q^{1.14}$ | |
| c. Re-bar (ton) | $W_r = 0.0724 \times V_c$ | |
| d. Others (L.S.) | 40% of sum of the above costs | Slope protection, gate, screen, etc. |

vi) Spillway Canal

Spillway canal considered is an open concrete type.

The following empirical equations are applied. Inner radius and design maximum discharge are the same for the three (3) alternative layouts, but length is different for each layout. Therefore, different work quantities are applied for the three (3) layouts.

### Table 5.2.7 Empirical Equations of Spillway Canal

| Description | Empirical Equation | Remarks |
|---|---|---|
| a. Excavation ($m^3$) | $V_e = 17.4 \times R^{1.01} \times L$ | R: inner radius of spillway (m) |
| b. Concrete ($m^3$) | $V_c = 3.38 \times R^{1.31} \times L$ | L: length of spillway |
| c. Re-bar (ton) | $W_r = 0.0358 \times V_c$ | |
| d. Others (L.S.) | 30% of sum of the above costs | Slope protection, fence, etc. |

vii) Penstock

Penstock considered is an open type with single lane.

The following empirical equations are applied. Inner diameter and design maximum discharge are the same for the three (3) alternative layouts, but length and effective head are different for each layout. Therefore, different work quantities are applied for the three (3) layouts.

### Table 5.2.8 Empirical Equations of Penstock

| Description | Empirical Equation | Remarks |
|---|---|---|
| a. Excavation ($m^3$) | $V_e = 12.2 \times D^{1.26} \times L$ | D: inner diameter of penstock (m) |
| b. Concrete ($m^3$) | $V_c = 2.92 \times D^{1.26} \times L$ | L: length of penstock (m) |
| c. Re-bar (ton) | $W_r = 0.0178 \times V_c$ | $H_e$: effective head (m) |
| d. Steel penstock (ton) | $W_p = 0.0003 \times H_e + 0.04$ | Q: design plant discharge ($m^3/s$) |
| e. Others (L.S.) | 20% of sum of the above costs | Grouting, slope protection, etc. |

viii) Powerhouse

Powerhouse considered is a surface type.

The following empirical equations are applied. Design discharge and number of turbines are the same for the three (3) alternative layouts, but effective head is different for each layout. Therefore, different work quantities are applied for each layout.

### Table 5.2.9 Empirical Equations of Powerhouse

| Description | Empirical Equation | Remarks |
|---|---|---|
| a. Excavation ($m^3$) | $V_e = 11.4 \times (Q \times H_e^{2/3} \times n^{1/2})^{0.952}$ | Q: design plant discharge ($m^3/s$) |
| b. Concrete ($m^3$) | $V_c = 6.79 \times (Q \times H_e^{2/3} \times n^{1/2})^{0.824}$ | $H_e$: effective head (m) |
| c. Re-bar (ton) | $W_r = 0.0326 \times V_c^{1.04}$ | n: number of turbine (nos.) |
| d. Others (L.S.) | 50% of sum of the above costs | Building works, drainage, etc. |

ix) Tailrace

Tailrace considered is a non-pressure type without tailrace gate.

The following empirical equations are applied. Design discharge is the same for the three (3) alternative layouts. Therefore, same work quantities are applied for the three (3) layouts.

### Table 5.2.10 Empirical Equations of Tailrace

| Description | Empirical Equation | Remarks |
|---|---|---|
| a. Excavation ($m^3$) | $V_e = 164 \times (R \times Q)^{0.532}$ | R: radius of tailrace (m)<br>Q: design plant discharge ($m^3/s$) |
| b. Concrete ($m^3$) | $V_c = 36.4 \times (R \times Q)^{0.353}$ | |
| c. Re-bar (ton) | $W_r = 0.113 \times V_c^{0.823}$ | |
| d. Others (L.S.) | 25% of sum of the above cost. | River diversion, slope protection, etc. |

x) Miscellaneous

5% of the sum of the amounts in items 1) to 9) is budgeted for miscellaneous works.

(2) Applied Unit Prices

The following unit prices are applied for the estimation.

### Table 5.2.11 Applied Unit Prices for the Estimation

| Work Item | Unit | Unit Price | Source |
|---|---|---|---|
| 1. Access Road | KSh./km | 2,000,000 | Assumed by REA |
| 2. Excavation | KSh./$m^3$ | 1,075 | Current Construction Costs Handbook 2012/13 (Published by Cost Planning Unit of the Quantities and Contracts Department, Ministry of Public Works) |
| 3. Concrete | KSh./$m^3$ | 13,400 | |
| 4. Re-bar | KSh./ton | 140,000 | |
| 5. Metal works (Gate) | KSh./ton | 696,000 | Assumed by WG (8,000 USD/ton) |
| 6. Metal works (Screen) | KSh./ton | 435,000 | Assumed by WG (5,000 USD/ton) |
| 7. Metal works (Steel Penstock) | KSh./ton | 348,000 | Assumed by WG (4,000 USD/ton) |
| 8. Distribution Line | KSh./km | 2,500,000 | Assumed by REA |

Notes: 1. Unit price of excavation is assumed to be the average of common excavation and rock excavation: (350 + 1,800) / 2 = 1,075 KSh./$m^3$
2. Applied exchange rate: 1 USD = 87 KSh.

(3) Direct Cost of Civil Works

Direct cost of civil works for each alternative layout is calculated as the work quantities estimated by empirical equations multiplied by the unit prices as shown in the following Table 5.2.12, 5.2.13, and 5.2.14, respectively.

## Table 5.2.12 Direct Cost of Civil Works of Layout A

| Description | Unit | Unit Price | | Quantity | Amount | |
|---|---|---|---|---|---|---|
| | | KSh. | USD | | KSh. | USD |
| **1 Intake Weir** | | | | | **7,772,900** | **89,344** |
| a. Excavation | $m^3$ | 1,075 | (12) | 331 | 355,900 | 4,091 |
| b. Concrete | $m^3$ | 13,400 | (154) | 301 | 4,033,400 | 46,361 |
| c. Re-bar | ton | 140,000 | (1,609) | 3.4 | 476,000 | 5,471 |
| d. sand flush gate | ton | (696,000) | 8,000 | 1.6 | 1,113,600 | 12,800 |
| e. Others | L.S. | | | | 1,794,000 | 20,621 |
| **2 Intake Structure** | | | | | **3,268,500** | **37,569** |
| a. Excavation | $m^3$ | 1,075 | (12) | 422 | 453,700 | 5,215 |
| b. Concrete | $m^3$ | 13,400 | (154) | 22 | 294,800 | 3,389 |
| c. Re-bar | ton | 140,000 | (1,609) | 0.9 | 126,000 | 1,448 |
| d. Intake gate | ton | (696,000) | 8,000 | 2.0 | 1,392,000 | 16,000 |
| e. Intake screen | ton | (435,000) | 5,000 | 0.8 | 348,000 | 4,000 |
| f. Others | L.S. | | | | 654,000 | 7,517 |
| **3 Settling Basin** | | | | | **4,724,700** | **54,307** |
| a. Excavation | $m^3$ | 1,075 | (12) | 352 | 378,400 | 4,349 |
| b. Concrete | $m^3$ | 13,400 | (154) | 130 | 1,742,000 | 20,023 |
| c. Re-bar | ton | 140,000 | (1,609) | 7.7 | 1,078,000 | 12,391 |
| d. Drainage gate | ton | (696,000) | 8,000 | 0.8 | 556,800 | 6,400 |
| e. Drainage screen | ton | (435,000) | 5,000 | 0.5 | 217,500 | 2,500 |
| f. Others | L.S. | | | | 752,000 | 8,644 |
| **4 Power Canal** | | | | | **2,272,800** | **26,124** |
| a. Excavation | $m^3$ | 1,075 | (12) | 200 | 215,000 | 2,471 |
| b. Concrete | $m^3$ | 13,400 | (154) | 82 | 1,098,800 | 12,630 |
| c. Re-bar | ton | 140,000 | (1,609) | 3.1 | 434,000 | 4,989 |
| d. Others | L.S. | | | | 525,000 | 6,034 |
| **5 Head Tank** | | | | | **1,862,000** | **21,402** |
| a. Excavation | $m^3$ | 1,075 | (12) | 272 | 292,400 | 3,361 |
| b. Concrete | $m^3$ | 13,400 | (154) | 44 | 589,600 | 6,777 |
| c. Re-bar | ton | 140,000 | (1,609) | 3.2 | 448,000 | 5,149 |
| d. Others | L.S. | | | | 532,000 | 6,115 |
| **6 Spillway channel** | | | | | **519,350** | **5,970** |
| a. Excavation | $m^3$ | 1,075 | (12) | 18 | 19,350 | 222 |
| b. Concrete | $m^3$ | 13,400 | (154) | 20 | 268,000 | 3,080 |
| c. Re-bar | ton | 140,000 | (1,609) | 0.8 | 112,000 | 1,287 |
| d. Others | L.S. | | | | 120,000 | 1,379 |
| **7 Penstock** | | | | | **7,532,350** | **86,579** |
| a. Excavation | $m^3$ | 1,075 | (12) | 706 | 758,950 | 8,724 |
| b. Concrete | $m^3$ | 13,400 | (154) | 169 | 2,264,600 | 26,030 |
| c. Re-bar | ton | 140,000 | (1,609) | 3.1 | 434,000 | 4,989 |
| d. Steel Penstock | t | (348,000) | 4,000 | 5.5 | 1,914,000 | 22,000 |
| e. Inlet gate | ton | (696,000) | 8,000 | 1.3 | 904,800 | 10,400 |
| f. Others | L.S. | | | | 1,256,000 | 14,437 |
| **8 Powerhouse** | | | | | **1,445,575** | **16,616** |
| a. Excavation | $m^3$ | 1,075 | (12) | 101 | 108,575 | 1,248 |
| b. Concrete | $m^3$ | 13,400 | (154) | 45 | 603,000 | 6,931 |
| c. Re-bar | ton | 140,000 | (1,609) | 1.8 | 252,000 | 2,897 |
| d. Others | L.S. | | | | 482,000 | 5,540 |
| **9 Tailrace** | | | | | **971,075** | **11,162** |
| a. Excavation | $m^3$ | 1,075 | (12) | 113 | 121,475 | 1,396 |
| b. Concrete | $m^3$ | 13,400 | (154) | 29 | 388,600 | 4,467 |
| c. Re-bar | ton | 140,000 | (1,609) | 1.9 | 266,000 | 3,057 |
| d. Others | L.S. | | | | 195,000 | 2,241 |
| **10 Miscellaneous** | L.S. | | | | **1,519,000** | **17,460** |
| **Total** | | | | (Roundup) | **31,888,250**<br>**31,889,000** | **366,532**<br>**366,540** |

## Table 5.2.13 Direct Cost of Civil Works of Layout B

| Description | Unit | Unit Price | | Quantity | Amount | |
|---|---|---|---|---|---|---|
| | | KSh. | USD | | KSh. | USD |
| **1 Intake Weir** | | | | | **8,162,200** | **93,818** |
| a. Excavation | $m^3$ | 1,075 | (12) | 384 | 412,800 | 4,745 |
| b. Concrete | $m^3$ | 13,400 | (154) | 317 | 4,247,800 | 48,825 |
| c. Re-bar | ton | 140,000 | (1,609) | 3.6 | 504,000 | 5,793 |
| d. sand flush gate | ton | (696,000) | 8,000 | 1.6 | 1,113,600 | 12,800 |
| e. Others | L.S. | | | | 1,884,000 | 21,655 |
| **2 Intake Structure** | | | | | **3,268,500** | **37,569** |
| a. Excavation | $m^3$ | 1,075 | (12) | 422 | 453,700 | 5,215 |
| b. Concrete | $m^3$ | 13,400 | (154) | 22 | 294,800 | 3,389 |
| c. Re-bar | ton | 140,000 | (1,609) | 0.9 | 126,000 | 1,448 |
| d. Intake gate | ton | (696,000) | 8,000 | 2.0 | 1,392,000 | 16,000 |
| e. Intake screen | ton | (435,000) | 5,000 | 0.8 | 348,000 | 4,000 |
| f. Others | L.S. | | | | 654,000 | 7,517 |
| **3 Settling Basin** | | | | | **4,724,700** | **54,307** |
| a. Excavation | $m^3$ | 1,075 | (12) | 352 | 378,400 | 4,349 |
| b. Concrete | $m^3$ | 13,400 | (154) | 130 | 1,742,000 | 20,023 |
| c. Re-bar | ton | 140,000 | (1,609) | 7.7 | 1,078,000 | 12,391 |
| d. Drainage gate | ton | (696,000) | 8,000 | 0.8 | 556,800 | 6,400 |
| e. Drainage screen | ton | (435,000) | 5,000 | 0.5 | 217,500 | 2,500 |
| f. Others | L.S. | | | | 752,000 | 8,644 |
| **4 Power Canal** | | | | | **2,008,925** | **23,091** |
| a. Excavation | $m^3$ | 1,075 | (12) | 175 | 188,125 | 2,162 |
| b. Concrete | $m^3$ | 13,400 | (154) | 72 | 964,800 | 11,090 |
| c. Re-bar | ton | 140,000 | (1,609) | 2.8 | 392,000 | 4,506 |
| d. Others | L.S. | | | | 464,000 | 5,333 |
| **5 Head Tank** | | | | | **1,862,000** | **21,402** |
| a. Excavation | $m^3$ | 1,075 | (12) | 272 | 292,400 | 3,361 |
| b. Concrete | $m^3$ | 13,400 | (154) | 44 | 589,600 | 6,777 |
| c. Re-bar | ton | 140,000 | (1,609) | 3.2 | 448,000 | 5,149 |
| d. Others | L.S. | | | | 532,000 | 6,115 |
| **6 Spillway channel** | | | | | **409,525** | **4,707** |
| a. Excavation | $m^3$ | 1,075 | (12) | 15 | 16,125 | 185 |
| b. Concrete | $m^3$ | 13,400 | (154) | 16 | 214,400 | 2,464 |
| c. Re-bar | ton | 140,000 | (1,609) | 0.6 | 84,000 | 966 |
| d. Others | L.S. | | | | 95,000 | 1,092 |
| **7 Penstock** | | | | | **6,281,075** | **72,196** |
| a. Excavation | $m^3$ | 1,075 | (12) | 577 | 620,275 | 7,130 |
| b. Concrete | $m^3$ | 13,400 | (154) | 139 | 1,862,600 | 21,409 |
| c. Re-bar | ton | 140,000 | (1,609) | 2.5 | 350,000 | 4,023 |
| d. Steel Penstock | t | (348,000) | 4,000 | 4.3 | 1,496,400 | 17,200 |
| e. Inlet gate | ton | (696,000) | 8,000 | 1.3 | 904,800 | 10,400 |
| f. Others | L.S. | | | | 1,047,000 | 12,034 |
| **8 Powerhouse** | | | | | **1,282,600** | **14,743** |
| a. Excavation | $m^3$ | 1,075 | (12) | 88 | 94,600 | 1,087 |
| b. Concrete | $m^3$ | 13,400 | (154) | 40 | 536,000 | 6,161 |
| c. Re-bar | ton | 140,000 | (1,609) | 1.6 | 224,000 | 2,575 |
| d. Others | L.S. | | | | 428,000 | 4,920 |
| **9 Tailrace** | | | | | **971,075** | **11,162** |
| a. Excavation | $m^3$ | 1,075 | (12) | 113 | 121,475 | 1,396 |
| b. Concrete | $m^3$ | 13,400 | (154) | 29 | 388,600 | 4,467 |
| c. Re-bar | ton | 140,000 | (1,609) | 1.9 | 266,000 | 3,057 |
| d. Others | L.S. | | | | 195,000 | 2,241 |
| **10 Miscellaneous** | L.S. | | | | **1,449,000** | **16,655** |
| **Total** | | | | | **30,419,600** | **349,651** |
| | | | | (Roundup) | **30,420,000** | **349,655** |

## Table 5.2.14 Direct Cost of Civil Works of Layout C

| Description | Unit | Unit Price | | Quantity | Amount | |
|---|---|---|---|---|---|---|
| | | KSh. | USD | | KSh. | USD |
| **1 Intake Weir** | | | | | **8,574,300** | **98,555** |
| a. Excavation | $m^3$ | 1,075 | (12) | 441 | 474,100 | 5,449 |
| b. Concrete | $m^3$ | 13,400 | (154) | 334 | 4,475,600 | 51,444 |
| c. Re-bar | ton | 140,000 | (1,609) | 3.8 | 532,000 | 6,115 |
| d. sand flush gate | ton | (696,000) | 8,000 | 1.6 | 1,113,600 | 12,800 |
| e. Others | L.S. | | | | 1,979,000 | 22,747 |
| **2 Intake Structure** | | | | | **3,268,500** | **37,569** |
| a. Excavation | $m^3$ | 1,075 | (12) | 422 | 453,700 | 5,215 |
| b. Concrete | $m^3$ | 13,400 | (154) | 22 | 294,800 | 3,389 |
| c. Re-bar | ton | 140,000 | (1,609) | 0.9 | 126,000 | 1,448 |
| d. Intake gate | ton | (696,000) | 8,000 | 2.0 | 1,392,000 | 16,000 |
| e. Intake screen | ton | (435,000) | 5,000 | 0.8 | 348,000 | 4,000 |
| f. Others | L.S. | | | | 654,000 | 7,517 |
| **3 Settling Basin** | | | | | **4,724,700** | **54,307** |
| a. Excavation | $m^3$ | 1,075 | (12) | 352 | 378,400 | 4,349 |
| b. Concrete | $m^3$ | 13,400 | (154) | 130 | 1,742,000 | 20,023 |
| c. Re-bar | ton | 140,000 | (1,609) | 7.7 | 1,078,000 | 12,391 |
| d. Drainage gate | ton | (696,000) | 8,000 | 0.8 | 556,800 | 6,400 |
| e. Drainage screen | ton | (435,000) | 5,000 | 0.5 | 217,500 | 2,500 |
| f. Others | L.S. | | | | 752,000 | 8,644 |
| **4 Power Canal** | | | | | **1,544,975** | **17,758** |
| a. Excavation | $m^3$ | 1,075 | (12) | 133 | 142,975 | 1,643 |
| b. Concrete | $m^3$ | 13,400 | (154) | 55 | 737,000 | 8,471 |
| c. Re-bar | ton | 140,000 | (1,609) | 2.2 | 308,000 | 3,540 |
| d. Others | L.S. | | | | 357,000 | 4,103 |
| **5 Head Tank** | | | | | **1,862,000** | **21,402** |
| a. Excavation | $m^3$ | 1,075 | (12) | 272 | 292,400 | 3,361 |
| b. Concrete | $m^3$ | 13,400 | (154) | 44 | 589,600 | 6,777 |
| c. Re-bar | ton | 140,000 | (1,609) | 3.2 | 448,000 | 5,149 |
| d. Others | L.S. | | | | 532,000 | 6,115 |
| **6 Spillway channel** | | | | | **315,625** | **3,628** |
| a. Excavation | $m^3$ | 1,075 | (12) | 11 | 11,825 | 136 |
| b. Concrete | $m^3$ | 13,400 | (154) | 12 | 160,800 | 1,848 |
| c. Re-bar | ton | 140,000 | (1,609) | 0.5 | 70,000 | 805 |
| d. Others | L.S. | | | | 73,000 | 839 |
| **7 Penstock** | | | | | **4,787,075** | **55,024** |
| a. Excavation | $m^3$ | 1,075 | (12) | 417 | 448,275 | 5,153 |
| b. Concrete | $m^3$ | 13,400 | (154) | 100 | 1,340,000 | 15,402 |
| c. Re-bar | ton | 140,000 | (1,609) | 1.8 | 252,000 | 2,897 |
| d. Steel Penstock | t | (348,000) | 4,000 | 3.0 | 1,044,000 | 12,000 |
| e. Inlet gate | ton | (696,000) | 8,000 | 1.3 | 904,800 | 10,400 |
| f. Others | L.S. | | | | 798,000 | 9,172 |
| **8 Powerhouse** | | | | | **1,003,825** | **11,538** |
| a. Excavation | $m^3$ | 1,075 | (12) | 67 | 72,025 | 828 |
| b. Concrete | $m^3$ | 13,400 | (154) | 32 | 428,800 | 4,929 |
| c. Re-bar | ton | 140,000 | (1,609) | 1.2 | 168,000 | 1,931 |
| d. Others | L.S. | | | | 335,000 | 3,851 |
| **9 Tailrace** | | | | | **971,075** | **11,162** |
| a. Excavation | $m^3$ | 1,075 | (12) | 113 | 121,475 | 1,396 |
| b. Concrete | $m^3$ | 13,400 | (154) | 29 | 388,600 | 4,467 |
| c. Re-bar | ton | 140,000 | (1,609) | 1.9 | 266,000 | 3,057 |
| d. Others | L.S. | | | | 195,000 | 2,241 |
| **10 Miscellaneous** | L.S. | | | | **1,353,000** | **15,552** |
| **Total** | | | | | **28,405,075** | **326,495** |
| | | | | (Roundup) | **28,406,000** | **326,506** |

### 5.2.2 Electrical Equipment

Electrical equipment is defined as all equipment for MHP including inlet valve, turbine, generator, transformers, and all attachments of these equipments. The direct cost of electro-mechanical equipment is given by the following empirical equation in the references:

$$C_E = 7.09 \times \left( P_{\max} \Big/ \sqrt{H_e} \right)^{0.774} \times F$$

$$F = 1{,}000{,}000 \times 0.3/80 = 3{,}750$$

Where,

$C_E$: direct cost of electrical equipment (USD)
$P_{max}$: maximum output (kW)
$H_e$: effective head (m)
$F$: conversion factor from Japanese Yen to US Dollar (USD)

The existing small hydropower projects in Kenya procured electrical equipment from Europe and/or India. The direct cost of equipment from Europe and India is approximately 30% of the direct cost should equipment be procured from Japan, based on interview results and the experience of JICA expert.

Additionally, the original empirical equation in the references gives direct cost of equipment in million Japanese Yen. It is therefore necessary to convert the direct cost into USD by dividing it by the current exchange rate for the JPY. The exchange rate was 1 USD = 80 JPY in 2013 when the empirical equation was created.

**Table 5.2.15 Direct Costs of Electrical Equipment**

| Alternative | $P_{max}$ (kW) | $H_e$ (m) | $C_E$ (USD) | $C_E$ (KSh.) | kW/USD |
|---|---|---|---|---|---|
| Layout A | 154.1 | 31.2 | 346,580 | 30,153,000 | 2,249 |
| Layout B | 124.0 | 25.1 | 318,650 | 27,723,000 | 2,570 |
| Layout C | 80.5 | 16.3 | 269,560 | 23,452,000 | 3,349 |

Note: 1 USD = 87 KSh

### 5.2.3 Distribution System

Direct cost of distribution system is estimated to be the same for each alternative layout as follows:

| | |
|---|---|
| Estimated total length of distribution line: | 10 km |
| Estimated unit price per km: | 2,500,000 KSh./km |
| Direct cost of distribution system: | 25,000,000 KSh. |

### 5.2.4 Preparatory Works

The preparatory works considered are as explained below.

i) Access Road

Construction cost of access road is estimated to be the same for each alternative layout as follows:

| | |
|---|---|
| Estimated total length of access road: | 6 km |
| Estimated unit price per km: | 2,000,000 KSh./km |
| Direct cost of access road: | 12,000,000 KSh. |

ii) Land Compensation

Land compensation cost is not considered as land for the MHP project was already earmarked by the Asurur Multiple Water Project Group.

iii) Temporary Facilities

Cost of temporary facilities is estimated by empirical ratio of direct cost of civil works and electrical equipment as follows:

Cost of temporary facilities = 20% of Direct cost of civil works and electrical equipment

iv) Environmental Mitigation Measures

Cost of environmental mitigation measures during the construction is estimated by empirical ratio of direct cost of civil works as follows:

Cost of environmental mitigation measures = 3% of Direct cost of civil works

The cost of preparatory works of each alternative layout was calculated as follows:

**Table 5.2.16 Cost of Preparatory Works**

(Unit: KSh.)

| Description | Layout A | Layout B | Layout C | Reference |
|---|---|---|---|---|
| II. Direct cost of Civil Works | 31,889,000 | 30,420,000 | 28,406,000 | T 5.2.12 - 14 |
| III. Direct Cost of Electrical Equipment | 30,153,000 | 27,723,000 | 23,452,000 | T 5.2.15 |
| **Sub-total** (II + III) | **62,042,000** | **58,143,000** | **51,858,000** | |
| 1. Access Road | 12,000,000 | 12,000,000 | 12,000,000 | |
| 2. Land Compensation | 0 | 0 | 0 | |
| 3. Temporary Facilities | 12,409,000 | 11,629,000 | 10,372,000 | (II+III) x 20% |
| 4. Environmental Mitigation Measures | 957,000 | 913,000 | 853,000 | (II) x 3% |
| **Total of Preparatory Works** | **25,366,000** | **24,542,000** | **23,225,000** | |

### 5.2.5 Project Cost of each Alternative Layout

Project cost of each alternative layout is estimated as shown in the following tables.

**Table 5.2.17 Estimation of Project Costs**

(Unit: KSh.)

| Description | Layout A | Layout B | Layout C | Reference |
|---|---|---|---|---|
| I. Preparatory Works | 25,366,000 | 24,542,000 | 23,225,000 | T 5.2.16 |
| II. Civil Works | 31,889,000 | 30,420,000 | 28,406,000 | T 5.2.12 – 14 |
| III. Electro-mechanical Equipment | 30,153,000 | 27,723,000 | 23,452,000 | T 5.2.15 |
| IV. Distribution System | 25,000,000 | 25,000,000 | 25,000,000 | |
| **Sub-total 1 (Direct Cost)** | **112,408,000** | **107,685,000** | **100,083,000** | |
| V. Administration and Engineering Cost | 16,862,000 | 16,153,000 | 15,013,000 | Direct x 15% |
| VI. Physical Contingency | 11,241,000 | 10,769,000 | 10,009,000 | Direct x 10% |
| **Sub-total 2 (Indirect Cost)** | **28,103,000** | **26,922,000** | **25,022,000** | |
| **Total** | **140,511,000** | **134,607,000** | **125,105,000** | |

### 5.3 Selection of Optimum Development Layout

Alternative plans are compared in terms of economic feasibility by the following two indexes.

i) Benefit-Cost Method

$B/C \geq 1$ , or $B-C \geq 0$:

MHP is economically better than the thermal power alternative

$B/C < 1$ , or $B-C < 0$:

MHP is economically less attractive than the thermal power alternative.

Where an alternative plan shows higher B/C value than others, the alternative plan is judged to be more economically attractive than the others.

ii) Generation Cost Method

$$C_G = Ch / E \times \alpha$$

Where,

$C_G$: generation cost (KSh./kWh)

$C_h$: construction cost (KSh.)

$E$: annual energy generation (kWh)

$\alpha$: annual cost factor = 0.10 to 0.12 ( - )

Where an alternative layout shows cheaper generation cost value ($C_G$) than others, the alternative layout is judged to be more economically attractive than the others.

Benefit ($B$), cost ($C$) and generation cost ($C_G$) of each alternative layout were obtained as explained hereinafter.

### 5.3.1 Estimation of Project Benefit

Benefit of Asurur MHP scheme is estimated to be the cost of an alternative thermal power plant that supplies electricity equivalent to Asurur MHP. A diesel thermal plant is a possible alternative thermal power installation.

The annualized benefit (B) consists of kW benefit and kWh benefits as given by the following formula:

Annualized Benefit (B)

$$B = B_1 + B_2$$

Where,
$B_1$: kW benefit (KSh.)
$B_2$: kWh benefit (KSh.)

(1) Estimation of kW Benefit

The kW benefit ($B_1$) is the product of effective output, output by the minimum design discharge, and kW value as given by the following formula:

$$B_1 = P_h \times b_1$$

$$P_h = 9.8 \times Q_{\min} \times H_e \times \eta$$

$$b_1 = Ct \times \alpha \times \beta$$

= 30,000 x 0.15 x 1.1
= 4,950

Where,
$P_h$: effective output (kW)
$B_1$: kW value (KSh./kW)
$Q_{min}$: minimum plant discharge = 0.1 ($m^3$/s)
$H_e$: effective head (m)
$\eta$: combined efficiency = 72%
$b_1$: kW value ( - )
$C_t$: unit construction cost of alternative thermal power 30,000 (KSh./kW)
$\alpha$: annual cost factor of alternative thermal power = 15%
$\beta$: kW adjustment factor = 1.1 ( - ) This is the adjustment factor of reliability between hydropower and thermal power (ratio of station use, forced outage and scheduled outage).

The effective output and kW benefit of each alternative layout were calculated as follows:

**Table 5.3.1 Effective Output and kW Benefit**

| Alternative | $Q_{min}$ ($m^3$/s) | $H_e$ (m) | $\eta$ (%) | $P_h$ (kW) | $b_1$ (KSh./kW) | $B_1$ (KSh.) |
|---|---|---|---|---|---|---|
| Layout A | 0.1 | 31.2 | 72.0 | 22.0 | 4,950 | 108,900 |
| Layout B | 0.1 | 25.1 | 72.0 | 17.7 | 4,950 | 87,615 |
| Layout C | 0.1 | 16.3 | 72.0 | 11.5 | 4,950 | 56,925 |

(2) Estimation of kWh Benefit

The kWh benefit ($B_1$) is the product of annual energy generation and kWh value as given by the following formula:

$$B_2 = E \times b_2$$

$$E = 8{,}760 \times \xi \times P$$

$$b_2 = R_h \times P_f = \frac{860}{T_e} \times P_f$$

= 860 / 0.35 x 0.012 = 24.49

Where,
$E$: annual energy generation (kWh)
$b_2$: kWh value (KSh./kWh)
$\xi$: plant factor = 72.5%
$P$: maximum output (kW)
$R_h$: heat consumption rate (kcal/kWh)
$P_f$: unit price of fuel (KSh./kcal) = 110 (KSh./$l$) / 9,126 (kcal/$l$) = 0.012 (KSh./kcal)
$T_e$: thermal efficiency = 35%

The annual energy generation and kWh benefit of each alternative layout were calculated as follows:

**Table 5.3.2 Annual Energy Generation and kWh Benefit**

| Alternative | $\xi$ (%) | $P$ (kW) | $E$ (kWh) | $b_2$ (KSh./kWh) | $B_2$ (KSh.) |
|---|---|---|---|---|---|
| Layout A | 72.5 | 154.1 | 978,689 | 24.49 | 28,861,542 |
| Layout B | 72.5 | 124.0 | 787,524 | 24.49 | 23,224,083 |
| Layout C | 72.5 | 80.5 | 511,256 | 24.49 | 15,076,925 |

(3) Annualized Benefit

The annualized benefit of each alternative layout was the sum of kW benefit and kWh benefit as shown in the table below.

**Table 5.3.3 Estimated Annualized Benefit**

(Unit: KSh./year)

| Item | Layout A | Layout B | Layout C | Reference |
|---|---|---|---|---|
| kW Benefit ($B_1$) | 108,900 | 87,615 | 56,925 | T 5.3.1 |
| kWh Benefit ($B_2$) | 28,861,542 | 23,224,083 | 15,076,925 | T 5.3.2 |
| Benefit ($B = B_1+B_2$) | 28,970,442 | 23,311,698 | 15,133,850 | |

### 5.3.2 Annualized Project Cost

Annualized project cost is calculated as follows:

Annualized Cost (C)

$$C = Ch \times \alpha$$

$$\alpha = RCF + OM = \frac{i \times (1+i)^n}{(1+i)^n - 1} + OM$$

= 0.11

Where,

$Ch$: project cost

$RCF$: capital recovery factor

$i$: interest rate = 10 %

$n$: service line (year) = 50 years

$OM$: ratio of operation and maintenance cost = 1%

**Table 5.3.4 Estimated Annualized Cost**

| Item | Layout A | Layout B | Layout C | Reference |
|---|---|---|---|---|
| Project Cost ($C_h$) | 140,511,000 | 134,607,000 | 125,105,000 | T 5.2.17 |
| Annual Cost Factor ($\alpha$) | 11.0% | 11.0% | 11.0% | |
| Annualized Cost (C) | 15,456,210 | 14,806,770 | 13,761,550 | |

### 5.3.3 Evaluation by Benefit – Cost Method

Benefit (B), cost (C) and their corresponding ratios are summarized in the table below. As seen the table, Layout A and Layout B show B / C values higher than 1.0. Asurur MHP is therefore economically better than the diesel power alternative, and Layout A is the most feasible alternative in economic terms.

**Table 5.3.5 Benefit and Cost of each Alternative**

(Unit: KSh./year)

| Item | Layout A | Layout B | Layout C | Reference |
|---|---|---|---|---|
| Annualized Project Benefit (B) | 28,970,442 | 23,311,698 | 15,133,850 | T 5.3.3 |
| Annualized Project Cost (C) | 15,456,210 | 14,806,770 | 13,761,550 | T 5.3.4 |
| B / C | 1.87 | 1.57 | 1.10 | |
| B – C | 13,514,232 | 8,504,928 | 1,372,300 | |

### 5.3.4 Evaluation by Generation Cost Method

The generation cost ($C_G$) of each alternative is shown below. As seen in the table, Layout A has the cheapest generation cost value ($C_G$), and is therefore more economically attractive than the others.

**Table 5.3.6 Generation Cost of each Alternative**

(Unit: KSh./year)

| Item | Layout A | Layout B | Layout C | Reference |
|---|---|---|---|---|
| Project Cost (*Ch*) | 140,511,000 | 134,607,000 | 125,105,000 | T 5.2.17 |
| Annual Energy Generation (*E*) | 978,689 | 787,524 | 511,256 | T 5.3.2 |
| Annual Cost Factor ($\alpha$) | 11.0% | 11.0% | 11.0% | T 5.3.4 |
| Generation Cost ($C_G = Ch / E \times \alpha$) | 15.79 | 18.80 | 26.92 | |

### 5.3.5 Selection of Optimum Layout

Layout A shows better indicative values through both benefit – cost method and generation cost method. Accordingly, it is judged that Layout A is the most optimum layout amongst the three (3) alternative layouts.

Preliminary drawings of Layout A are included in Annex-3.

# CHAPTER 6 RECOMMENDATIONS FOR THE NEXT STAGE

The study was conducted within a context of limited time, data and information. Despite this, it was clearly determined that the selected Layout A is a relatively advantageous development plan. However, the estimated power generation was smaller than the forecasted power demand.

It is recommended that the following issues are considered in the next stage.

### (1) Continuous Observation of Water Level

As seen in the hydrological analysis in Chapter 4, there is a discrepancy between the results of analyzed discharges based on the existing data and the observed discharges. It is likely that actual river discharge is larger than the defined design plant discharges.

Therefore, it is recommended to record water level at the site on daily basis in normal conditions and hourly basis during flood conditions. Water level at the site is valuable information for the estimation of flow duration. It is further recommended to review hydrological analysis using the actual water level records in order to increase the accuracy of dependable discharge at the site.

### (2) Study on Height of the Intake Weir

The comparative study was carried out based on fixed condition of intake weir at minimum height. It is possible to secure some storage capacity for several hours by increasing the height at which the intake weir is set. In this case, natural environmental impacts due to enlargement of pondage area will increase but power generation appropriately corresponding to power demand will become possible.

Therefore, it is recommended to study the optimum height of the intake weir in terms of power generation, construction cost and environmental impacts.

### (3) Obtain Quotation for Electrical Equipment

Cost of electrical equipment was estimated as a lump sum using empirical equation. It is necessary to obtain price quotations for electrical equipment in order to increase the accuracy of estimation of development cost.

### (4) Study on Other Power Sources

In case Asurur MHP does not generate adequate electricity to meet forecasted power demand, other power sources shall be studied. Two (2) alternatives; i) hybrid generation of MHP and diesel generator, and ii) grid connection if the area is located near the existing grid, are possible.

It is recommended to carry out a comparative study on the optimum power development plan to satisfy the current forecasted power demand as well as potential future power demand.

# Annex 1

# Discharge Observation Sheets at Asurur Site

## List of Observation Sheet

## Observation Sheet on 21 June 2012

***JICA Expert Team*** (Field Notebook of Discharge Observation)

FIELD WORKS

| No. of measure-ment | Distance from bank (m) | Depth of Water. (m)<br>First (one way) | Second (return) | Average | Velocity Mesurement (Flow speed)<br>Depth of observation(m) | Count of current meter | | Time in seconds<br>1st | 2nd | Average |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0.00 | 0.00 | 0.000 | | | | | | |
| 2 | 1 | 0.34 | 0.33 | 0.335 | 0.201 | 140 | =(10 x 14) | 31.90 | | 31.900 |
| | | | | | 0.201 | 150 | =(10 x 15) | 32.90 | | 32.900 |
| 3 | 2 | 0.47 | 0.46 | 0.465 | | | | | | |
| 4 | 3 | 0.45 | 0.44 | 0.445 | 0.267 | 70 | =(10 x 7) | 34.30 | | 34.300 |
| | | | | | 0.267 | 100 | =(10 x 10) | 35.10 | | 35.100 |
| 5 | 4 | 0.45 | 0.43 | 0.440 | | | | | | |
| 6 | 5 | 0.34 | 0.33 | 0.335 | 0.201 | 100 | =(10 x 10) | 30.90 | | 30.900 |
| | | | | | 0.201 | 130 | =(10 x 13) | 32.10 | | 32.100 |
| 7 | 6 | 0.29 | 0.28 | 0.285 | | | | | | |
| 8 | 7 | 0.25 | 0.25 | 0.250 | 0.150 | 100 | =(10 x 10) | 31.30 | | 31.300 |
| | | | | | 0.150 | 110 | =(10 x 11) | 31.70 | | 31.700 |
| 9 | 8 | 0.33 | 0.33 | 0.330 | | | | | | |
| 10 | 9 | 0.17 | 0.17 | 0.170 | 0.102 | 100 | =(10 x 10) | 40.40 | | 40.400 |
| | | | | | 0.102 | 90 | =(10 x 9) | 33.10 | | 33.100 |
| 11 | 9.3 | 0.00 | 0.00 | 0.000 | | | | | | |
| 12 | | | | | | | | | | |
| 13 | | | | | | | | | | |
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HOME WORKS

| Velocity<br>Mesu. Veloc. at point(m/s) | Mean meas. Veloc.in vert(m/s) |
|---|---|
| | |
| 0.721 | 0.735 |
| 0.749 | |
| | |
| 0.341 | 0.407 |
| 0.472 | |
| | |
| 0.534 | 0.600 |
| 0.666 | |
| | |
| 0.528 | 0.550 |
| 0.572 | |
| | |
| 0.411 | 0.431 |
| 0.450 | |
| | |

| Area of cross section<br>Average depth(m) | Width of section(m) | Area of Section($m^2$) |
|---|---|---|
| 0.17 | 1.00 | 0.17 |
| 0.40 | 1.00 | 0.40 |
| 0.46 | 1.00 | 0.46 |
| 0.44 | 1.00 | 0.44 |
| 0.39 | 1.00 | 0.39 |
| 0.31 | 1.00 | 0.31 |
| 0.27 | 1.00 | 0.27 |
| 0.29 | 1.00 | 0.29 |
| 0.25 | 1.00 | 0.25 |
| 0.09 | 0.30 | 0.03 |

| Total Area($m^2$) | Disch-arge ($m^3$/s) |
|---|---|
| 0.57 | 0.42 |
| 0.90 | 0.37 |
| 0.70 | 0.42 |
| 0.56 | 0.31 |
| 0.28 | 0.12 |

| | | | |
|---|---|---|---|
| Station No. | | ***Downstream of the culvert*** | |
| Observation Date | | Yr: 2012 Mon: 6 | Date: 21 |
| Observer Name | Mesure | ***Ezekiel, Reuben*** | |
| | Wrote | ***Ueda*** | |
| Weather | Weather | :clear, :fine, :cloudy :rain | |
| | Wind blows | from Down/s, Up/s, Left, Right | |
| | Wind power | 0:None, 1:light, 2:windy, 3:strong, 4:very strong | |
| Mesurement Time (Hour, min) | Start | | |
| | End | | |
| | Average | | |
| Water Level at gauging station (m) | | Initial Point | No.1 Point |
| | Start | | |
| | End | | |
| | Average | | |
| Current meter | Type of current meter | Digital | |
| | Table/formula | V = 0.162 * N + 0.010 | |
| | Useing method | lods・wire・weight | |
| | | by boat / bridge / walk | |
| Calculator | Calculator | | |
| | Checker | | |
| Result | Total Discharge ($m^3$/s) | **1.64** | |
| | Total area cross section($m^2$) | **3.01** | |
| | Average Velocity（m/s） | **0.54** | |

Notes

| | |
|---|---|
| Catchment Area ($km^2$)= | **35.0** |
| Discharge ($m^3$/s)= | **1.64** |
| Specific Discharge ($m^3$/s*100$km^2$)= | **4.69** |

Remark:

# Observation Sheet on 22 June 2012

***JICA Expert Team*** (Field Notebook of Discharge Observation)

| FIELD WORKS | | | | | | | | | | | HOME WORKS | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of measure-ment | Distance from bank (m) | Depth of Water. (m) | | | Velocity Mesurement (Flow speed) | | | | | | Velocity | | Area of cross section | | | | Disch-arge (m$^3$/s) |
| | | First (one way) | Second (return) | Average | Depth of observation(m) | Count of current meter | | Time in seconds | | | Mesu. Veloc. at point(m/s) | Mean meas. Veloc.in vert(m/s) | Average depth(m) | Width of section(m) | Area of Section(m$^2$) | Total Area(m$^2$) | |
| | | | | | | | | 1st | 2nd | Average | | | | | | | |
| 1 | 0 | 0.00 | 0.00 | 0.000 | | | | | | | | | 0.32 | 1.00 | 0.32 | | |
| 2 | 1 | 0.64 | 0.64 | 0.640 | 0.384 | 50 | =(10 x 5) | 34.50 | | 34.500 | 0.245 | 0.245 | 0.56 | 1.00 | 0.56 | 0.88 | 0.22 |
| 3 | 2 | 0.49 | 0.48 | 0.485 | | | | | | | | | 0.52 | 1.00 | 0.52 | | |
| 4 | 3 | 0.55 | 0.56 | 0.555 | 0.333 | 50 | =(10 x 5) | 32.30 | | 32.300 | 0.261 | 0.261 | 0.51 | 1.00 | 0.51 | 1.03 | 0.27 |
| 5 | 4 | 0.48 | 0.45 | 0.465 | | | | | | | | | 0.48 | 1.00 | 0.48 | | |
| 6 | 5 | 0.48 | 0.49 | 0.485 | 0.291 | 180 | =(10 x 18) | 30.80 | | 30.800 | 0.957 | 0.957 | 0.46 | 1.00 | 0.46 | 0.94 | 0.90 |
| 7 | 6 | 0.44 | 0.44 | 0.440 | | | | | | | | | 0.45 | 1.00 | 0.45 | | |
| 8 | 7 | 0.46 | 0.45 | 0.455 | 0.273 | 90 | =(10 x 9) | 31.00 | | 31.000 | 0.480 | 0.480 | 0.35 | 1.00 | 0.35 | 0.80 | 0.38 |
| 9 | 8 | 0.27 | 0.22 | 0.245 | | | | | | | | | 0.12 | 0.60 | 0.07 | | |
| 10 | 8.6 | 0.00 | 0.00 | 0.000 | 0.000 | 0 | =(10 x 0) | 0.00 | | 0.000 | 0.000 | 0.000 | | | | 0.07 | 0.00 |
| 11 | | | | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | | | | |

| | | | |
|---|---|---|---|
| Station No. | | ***Downstream of the fall*** | |
| Observation Date | | Yr: 2012 Mon: 6 Date: 22 | |
| Observer Name | Mesure | ***Ezekiel, Reuben*** | |
| | Wrote | ***Ueda*** | |
| Weather | Weather | :clear, :fine, :cloudy :rain | |
| | Wind blows | from Down/s, Up/s, Left, Right | |
| | Wind power | 0:None, 1:light, 2:windy, 3:strong, 4:very strong | |
| Mesurement Time (Hour, min) | Start | | |
| | End | | |
| | Average | | |
| Water Level at gauging station (m) | | Initial Point | No.1 Point |
| | Start | | |
| | End | | |
| | Average | | |
| Current meter | Type of current meter | Digital | |
| | Table/formula | V = 0.162 * N + 0.010 | |
| | Useing method | lods・wire・weight | |
| | | by boat / bridge / walk | |
| Calculator | Calculator | | |
| | Checker | | |
| Result | Total Discharge (m$^3$/s) | **1.77** | |
| | Total area cross section(m$^2$) | **3.72** | |
| | Average Velocity(m/s) | **0.48** | |

Notes

| | |
|---|---|
| Catchment Area (km$^2$)= | 35.0 |
| Discharge (m$^3$/s)= | **1.77** |
| Specific Discharge (m$^3$/s*100km$^2$)= | **5.06** |

Remark:

# Observation Sheet on 26 July 2012

***JICA Expert Team*** (Field Notebook of Discharge Observation)

| FIELD WORKS | | | | | | | | | | | HOME WORKS | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of measure-ment | Distance from bank (m) | Depth of Water. (m) | | | Velocity Mesurement (Flow speed) | | | | | | Velocity | | Area of cross section | | | | Disch-arge ($m^3/s$) |
| | | First (one way) | Second (return) | Average | Depth of observation(m) | Count of current meter | | Time in seconds 1st | 2nd | Average | Mesu. Veloc. at point(m/s) | Mean meas. Veloc.in vert(m/s) | Average depth(m) | Width of section(m) | Area of Section($m^2$) | Total Area($m^2$) | |
| 1 | 0 | 0.00 | 0.00 | 0.000 | | | | | | | | | 0.16 | 1.00 | 0.16 | | |
| 2 | 1 | 0.33 | 0.32 | 0.325 | 0.195 | 160 | =(10 x 16) | 32.10 | 32.10 | 32.100 | 0.817 | 0.817 | 0.37 | 1.00 | 0.37 | 0.53 | 0.43 |
| 3 | 2 | 0.42 | 0.42 | 0.420 | | | | | | | | | 0.46 | 1.00 | 0.46 | | |
| 4 | 3 | 0.50 | 0.49 | 0.495 | 0.297 | 160 | =(10 x 16) | 32.00 | 32.80 | 32.400 | 0.810 | 0.810 | 0.44 | 1.00 | 0.44 | 0.90 | 0.73 |
| 5 | 4 | 0.39 | 0.38 | 0.385 | | | | | | | | | 0.31 | 1.00 | 0.31 | | |
| 6 | 5 | 0.23 | 0.22 | 0.225 | 0.135 | 130 | =(10 x 13) | 31.40 | 31.90 | 31.650 | 0.675 | 0.675 | 0.25 | 1.00 | 0.25 | 0.56 | 0.38 |
| 7 | 6 | 0.27 | 0.29 | 0.280 | | | | | | | | | 0.25 | 1.00 | 0.25 | | |
| 8 | 7 | 0.21 | 0.22 | 0.215 | 0.129 | 150 | =(10 x 15) | 31.50 | 27.60 | 29.550 | 0.832 | 0.832 | 0.27 | 1.00 | 0.27 | 0.52 | 0.43 |
| 9 | 8 | 0.33 | 0.33 | 0.330 | | | | | | | | | 0.17 | 1.10 | 0.19 | | |
| 10 | 9.1 | 0.00 | 0.00 | 0.000 | 0.000 | 0 | =(10 x 0) | 0.00 | 0.00 | 0.000 | 0.000 | 0.000 | | | | 0.19 | 0.00 |
| 11 | | | | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | | | | |

| | | | |
|---|---|---|---|
| Station No. | | ***Downstream of the culvert*** | |
| Observation Date | | Yr: 2012 Mon: 7 | Date: 26 |
| Observer Name | Mesure | ***Ezekiel*** | |
| | Wrote | ***Ueda*** | |
| Weather | Weather | :clear, :fine, :cloudy :rain | |
| | Wind blows | from Down/s, Up/s, Left, Right | |
| | Wind power | 0:None, 1:light, 2:windy, 3:strong, 4:very strong | |
| Mesurement Time (Hour, min) | Start | | |
| | End | | |
| | Average | | |
| Water Level at gauging station (m) | | Initial Point | No.1 Point |
| | Start | | |
| | End | | |
| | Average | | |
| Current meter | Type of current meter | Digital | |
| | Table/formula | V = 0.162 * N + 0.010 | |
| | Useing method | lods・wire・weight | |
| | | by boat / bridge / walk | |
| Calculator | Calculator | | |
| | Checker | | |
| Result | Total Discharge ($m^3/s$) | **1.97** | |
| | Total area cross section($m^2$) | **2.70** | |
| | Average Velocity(m/s) | **0.73** | |

Notes

| | |
|---|---|
| Catchment Area ($km^2$)= | **35.0** |
| Discharge ($m^3/s$)= | **1.97** |
| Specific Discharge ($m^3/s*100km^2$)= | **5.63** |

Remark:

# Observation Sheets on 13 August 2012

***JICA Expert Team*** (Field Notebook of Discharge Observation)

| FIELD WORKS | | | | | | | | | | | HOME WORKS | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of measure-ment | Distance from bank (m) | Depth of Water. (m) | | | Velocity Mesurement (Flow speed) | | | | | | Velocity | | Area of cross section | | | | Disch-arge $(m^3/s)$ |
| | | First (one way) | Second (return) | Average | Depth of observation(m) | Count of current meter | | Time in seconds | | | Mesu. Veloc. at point(m/s) | Mean meas. Veloc.in vert(m/s) | Average depth(m) | Width of section(m) | Area of Section$(m^2)$ | Total Area$(m^2)$ | |
| | | | | | | | | 1st | 2nd | Average | | | | | | | |
| 1 | 0 | 0.00 | 0.00 | 0.000 | | | | | | | | | 0.16 | 1.00 | 0.16 | | |
| 2 | 1 | 0.32 | 0.32 | 0.320 | 0.192 | 140 | =(10 x 14) | 42.26 | | 42.260 | 0.547 | 0.541 | | | | 0.51 | 0.28 |
| | | | | | 0.192 | 150 | =(10 x 15) | 46.37 | | 46.370 | 0.534 | | 0.35 | 1.00 | 0.35 | | |
| 3 | 2 | 0.38 | 0.39 | 0.385 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.41 | 1.00 | 0.41 | | |
| 4 | 3 | 0.42 | 0.44 | 0.430 | 0.258 | 80 | =(10 x 8) | 14.79 | | 14.790 | 0.886 | 0.883 | | | | 0.79 | 0.70 |
| | | | | | 0.258 | 100 | =(10 x 10) | 18.63 | | 18.630 | 0.880 | | 0.38 | 1.00 | 0.38 | | |
| 5 | 4 | 0.34 | 0.33 | 0.335 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.30 | 1.00 | 0.30 | | |
| 6 | 5 | 0.26 | 0.27 | 0.265 | 0.159 | 100 | =(10 x 10) | 35.03 | | 35.030 | 0.472 | 0.458 | | | | 0.55 | 0.25 |
| | | | | | 0.159 | 130 | =(10 x 13) | 48.47 | | 48.470 | 0.444 | | 0.25 | 1.00 | 0.25 | | |
| 7 | 6 | 0.24 | 0.24 | 0.240 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.24 | 1.00 | 0.24 | | |
| 8 | 7 | 0.23 | 0.24 | 0.235 | 0.141 | 110 | =(10 x 11) | 42.67 | | 42.670 | 0.428 | 0.410 | | | | 0.44 | 0.18 |
| | | | | | 0.141 | 100 | =(10 x 10) | 42.40 | | 42.400 | 0.392 | | 0.20 | 1.00 | 0.20 | | |
| 9 | 8 | 0.17 | 0.17 | 0.170 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.09 | 1.00 | 0.09 | | |
| 10 | 9 | 0.00 | 0.00 | 0.000 | 0.000 | 100 | =(10 x 10) | 32.97 | | 32.970 | 0.501 | 0.504 | | | | 0.09 | 0.05 |
| | | | | | 0.000 | 90 | =(10 x 9) | 29.42 | | 29.420 | 0.506 | | | | | | |
| 11 | | | | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | | | | | |
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| 19 | | | | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | | | | |

| | | | | |
|---|---|---|---|---|
| Station No. | | *Downstream of the culvert* | | |
| Observation Date | | Yr: 2012 | Mon: 8 | Date: 13 |
| Observer Name | Mesure | ***Ezekiel, Reuben*** | | |
| | Wrote | ***Ezekiel*** | | |
| Weather | Weather | :clear, :fine, :cloudy :rain | | |
| | Wind blows | from Down/s, Up/s, Left, Right | | |
| | Wind power | 0:None, 1:light, 2:windy, 3:strong, 4:very strong | | |
| Mesurement Time (Hour, min) | Start | **10:30 AM** | | |
| | End | **12:00 PM** | | |
| | Average | **11:15 AM** | | |
| Water Level at gauging station (m) | | Initial Point | No.1 Point | |
| | Start | | | |
| | End | | | |
| | Average | | | |
| Current meter | Type of current meter | Digital | | |
| | Table/formula | V = 0.162 * N + 0.010 | | |
| | Useing method | lods・wire・weight | | |
| | | by boat / bridge / walk | | |
| Calculator | Calculator | | | |
| | Checker | | | |
| Result | Total Discharge $(m^3/s)$ | **1.46** | | |
| | Total area cross section$(m^2)$ | **2.38** | | |
| | Average Velocity（m/s） | **0.61** | | |

Notes

| | |
|---|---|
| Catchment Area $(km^2)$= | **35.0** |
| Discharge $(m^3/s)$= | **1.46** |
| Specific Discharge $(m^3/s*100km^2)$= | **4.17** |

Remark:

***JICA Expert Team*** (Field Notebook of Discharge Observation)

| FIELD WORKS | | | | | | | | | | | HOME WORKS | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of measurement | Distance from bank (m) | Depth of Water. (m) | | | Velocity Mesurement (Flow speed) | | | | | | Velocity | | Area of cross section | | | | Discharge ($m^3/s$) |
| | | First (one way) | Second (return) | Average | Depth of observation(m) | Count of current meter | | Time in seconds | | | Mesu. Veloc. at point(m/s) | Mean meas. Veloc.in vert(m/s) | Average depth(m) | Width of section(m) | Area of Section($m^2$) | Total Area($m^2$) | |
| | | | | | | | | 1st | 2nd | Average | | | | | | | |
| 1 | 0 | 0.00 | 0.00 | 0.000 | | | | | | | | | 0.16 | 1.00 | 0.16 | | |
| 2 | 1 | 0.32 | 0.31 | 0.315 | 0.189 | 130 | =(10 x 13) | 45.62 | | 45.620 | 0.472 | 0.475 | | | | 0.52 | 0.25 |
| | | | | | 0.189 | 140 | =(10 x 14) | 48.44 | | 48.440 | 0.478 | | 0.36 | 1.00 | 0.36 | | |
| 3 | 2 | 0.38 | 0.42 | 0.400 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.42 | 1.00 | 0.42 | | |
| 4 | 3 | 0.43 | 0.45 | 0.440 | 0.264 | 90 | =(10 x 9) | 15.13 | | 15.130 | 0.974 | 0.967 | | | | 0.79 | 0.76 |
| | | | | | 0.264 | 100 | =(10 x 10) | 17.05 | | 17.050 | 0.960 | | 0.37 | 1.00 | 0.37 | | |
| 5 | 4 | 0.27 | 0.32 | 0.295 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.27 | 1.00 | 0.27 | | |
| 6 | 5 | 0.26 | 0.23 | 0.245 | 0.147 | 100 | =(10 x 10) | 26.74 | | 26.740 | 0.616 | 0.613 | | | | 0.51 | 0.31 |
| | | | | | 0.147 | 130 | =(10 x 13) | 35.13 | | 35.130 | 0.609 | | 0.24 | 1.00 | 0.24 | | |
| 7 | 6 | 0.22 | 0.24 | 0.230 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.22 | 1.00 | 0.22 | | |
| 8 | 7 | 0.22 | 0.20 | 0.210 | 0.126 | 110 | =(10 x 11) | 47.28 | | 47.280 | 0.387 | 0.386 | | | | 0.46 | 0.18 |
| | | | | | 0.126 | 120 | =(10 x 12) | 51.86 | | 51.860 | 0.385 | | 0.24 | 1.00 | 0.24 | | |
| 9 | 8 | 0.28 | 0.25 | 0.265 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.13 | 1.00 | 0.13 | | |
| 10 | 9 | 0.00 | 0.00 | 0.000 | 0.000 | 110 | =(10 x 11) | 28.58 | | 28.580 | 0.634 | 0.655 | | | | 0.13 | 0.09 |
| | | | | | 0.000 | 90 | =(10 x 9) | 21.90 | | 21.900 | 0.676 | | | | | | |
| 11 | | | | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | | | | | |
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| 19 | | | | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | | | | |

| | | | |
|---|---|---|---|
| Station No. | | ***Downstream of the culvert*** | |
| Observation Date | | Yr: 2012 Mon: 8 | Date: 13 |
| Observer Name | Mesure | ***Ezekiel, Reuben*** | |
| | Wrote | ***Ezekiel*** | |
| Weather | Weather | :clear, :fine, :cloudy :rain | |
| | Wind blows | from Down/s, Up/s, Left, Right | |
| | Wind power | 0:None, 1:light, 2:windy, 3:strong, 4:very strong | |
| Mesurement Time (Hour, min) | Start | **2:30 PM** | |
| | End | **4:30PM** | |
| | Average | **3:30PM** | |
| Water Level at gauging station (m) | | Initial Point | No.1 Point |
| | Start | | |
| | End | | |
| | Average | | |
| Current meter | Type of current meter | Digital | |
| | Table/formula | V = 0.162 * N + 0.010 | |
| | Useing method | lods・wire・weight | |
| | | by boat / bridge / walk | |
| Calculator | Calculator | | |
| | Checker | | |
| Result | Total Discharge ($m^3/s$) | **1.59** | |
| | Total area cross section($m^2$) | **2.41** | |
| | Average Velocity(m/s) | **0.66** | |

Notes

Catchment Area ($km^2$)= **35.0**
Discharge ($m^3/s$)= **1.59**
Specific Discharge ($m^3/s*100km^2$)= **4.54**

Remark:

# Observation Sheets on 14 August 2012

***JICA Expert Team*** (Field Notebook of Discharge Observation)

| FIELD WORKS | | | | | | | | | | | HOME WORKS | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of measure-ment | Distance from bank (m) | Depth of Water. (m) | | | Velocity Mesurement (Flow speed) | | | | | | Velocity | | Area of cross section | | | | Disch-arge (m³/s) |
| | | First (one way) | Second (return) | Average | Depth of observation(m) | Count of current meter | | Time in seconds | | | Mesu. Veloc. at point(m/s) | Mean meas. Veloc.in vert(m/s) | Average depth(m) | Width of section(m) | Area of Section(m²) | Total Area(m²) | |
| | | | | | | | | 1st | 2nd | Average | | | | | | | |
| 1 | 0 | 0.00 | 0.00 | 0.000 | | | | | | | | | 0.16 | 1.00 | 0.16 | | |
| 2 | 1 | 0.32 | 0.33 | 0.325 | 0.195 | 130 | =(10 x 13) | 38.96 | | 38.960 | 0.551 | 0.537 | | | | 0.52 | 0.28 |
| | | | | | 0.195 | 140 | =(10 x 14) | 44.17 | | 44.170 | 0.523 | | 0.36 | 1.00 | 0.36 | | |
| 3 | 2 | 0.38 | 0.39 | 0.385 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.42 | 1.00 | 0.42 | | |
| 4 | 3 | 0.45 | 0.44 | 0.445 | 0.267 | 100 | =(10 x 10) | 26.03 | | 26.030 | 0.632 | 0.618 | | | | 0.81 | 0.50 |
| | | | | | 0.267 | 100 | =(10 x 10) | 27.34 | | 27.340 | 0.603 | | 0.39 | 1.00 | 0.39 | | |
| 5 | 4 | 0.32 | 0.33 | 0.325 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.30 | 1.00 | 0.30 | | |
| 6 | 5 | 0.26 | 0.27 | 0.265 | 0.159 | 100 | =(10 x 10) | 24.49 | | 24.490 | 0.671 | 0.684 | | | | 0.55 | 0.38 |
| | | | | | 0.159 | 130 | =(10 x 13) | 30.70 | | 30.700 | 0.696 | | 0.25 | 1.00 | 0.25 | | |
| 7 | 6 | 0.23 | 0.23 | 0.230 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.22 | 1.00 | 0.22 | | |
| 8 | 7 | 0.20 | 0.23 | 0.215 | 0.129 | 110 | =(10 x 11) | 35.47 | | 35.470 | 0.512 | 0.507 | | | | 0.46 | 0.23 |
| | | | | | 0.129 | 120 | =(10 x 12) | 39.56 | | 39.560 | 0.501 | | 0.24 | 1.00 | 0.24 | | |
| 9 | 8 | 0.25 | 0.27 | 0.260 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.13 | 1.00 | 0.13 | | |
| 10 | 9 | 0.00 | 0.00 | 0.000 | 0.000 | 100 | =(10 x 10) | 35.95 | | 35.950 | 0.461 | 0.460 | | | | 0.13 | 0.06 |
| | | | | | 0.000 | 90 | =(10 x 9) | 32.53 | | 32.530 | 0.458 | | | | | | |
| 11 | | | | | | | | | | | | | | | | | |
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|---|---|---|---|---|---|
| Station No. | | ***Downstream of the culvert*** | | | |
| Observation Date | | Yr: 2012 | Mon: 8 | Date: 14 | |
| Observer Name | Mesure | ***Ezekiel, Reuben*** | | | |
| | Wrote | ***Ezekiel*** | | | |
| Weather | Weather | :clear, :fine, :cloudy :rain | | | |
| | Wind blows | from Down/s, Up/s, Left, Right | | | |
| | Wind power | 0:None, 1:light, 2:windy, 3:strong, 4:very strong | | | |
| Mesurement Time (Hour, min) | Start | **10:30 AM** | | | |
| | End | **12:00 PM** | | | |
| | Average | **11:15 AM** | | | |
| Water Level at gauging station (m) | | Initial Point | No.1 Point | | |
| | Start | | | | |
| | End | | | | |
| | Average | | | | |
| Current meter | Type of current meter | Digital | | | |
| | Table/formula | V = 0.162 * N + 0.010 | | | |
| | Useing method | lods・wire・weight | | | |
| | | by boat / bridge / walk | | | |
| Calculator | Calculator | | | | |
| | Checker | | | | |
| Result | Total Discharge (m³/s) | **1.45** | | | |
| | Total area cross section(m²) | **2.47** | | | |
| | Average Velocity(m/s) | **0.59** | | | |

Notes

| | |
|---|---|
| Catchment Area (km²)= | 35.0 |
| Discharge (m³/s)= | **1.45** |
| Specific Discharge (m³/s*100km²)= | **4.14** |

Remark:

***JICA Expert Team*** (Field Notebook of Discharge Observation)

| FIELD WORKS | | | | | | | | | | | HOME WORKS | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of measure-ment | Distance from bank (m) | Depth of Water. (m) | | | Velocity Mesurement (Flow speed) | | | | | | Velocity | | Area of cross section | | | | Disch-arge (m$^3$/s) |
| | | First (one way) | Second (return) | Average | Depth of observation(m) | Count of current meter | | Time in seconds | | | Mesu. Veloc. at point(m/s) | Mean meas. Veloc.in vert(m/s) | Average depth(m) | Width of section(m) | Area of Section(m$^2$) | Total Area(m$^2$) | |
| | | | | | | | | 1st | 2nd | Average | | | | | | | |
| 1 | 0 | 0.00 | 0.00 | 0.000 | | | | | | | | | 0.17 | 1.00 | 0.17 | | |
| 2 | 1 | 0.32 | 0.34 | 0.330 | 0.198 | 130 | =(10 x 13) | 45.01 | | 45.010 | 0.478 | 0.482 | | | | 0.53 | 0.26 |
| | | | | | 0.198 | 100 | =(10 x 10) | 34.13 | | 34.130 | 0.485 | | 0.36 | 1.00 | 0.36 | | |
| 3 | 2 | 0.38 | 0.40 | 0.390 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.41 | 1.00 | 0.41 | | |
| 4 | 3 | 0.40 | 0.44 | 0.420 | 0.252 | 100 | =(10 x 10) | 19.51 | | 19.510 | 0.840 | 0.830 | | | | 0.80 | 0.66 |
| | | | | | 0.252 | 120 | =(10 x 12) | 24.02 | | 24.020 | 0.819 | | 0.39 | 1.00 | 0.39 | | |
| 5 | 4 | 0.38 | 0.34 | 0.360 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.30 | 1.00 | 0.30 | | |
| 6 | 5 | 0.23 | 0.25 | 0.240 | 0.144 | 100 | =(10 x 10) | 22.77 | | 22.770 | 0.721 | 0.718 | | | | 0.53 | 0.38 |
| | | | | | 0.144 | 130 | =(10 x 13) | 29.92 | | 29.920 | 0.714 | | 0.23 | 1.00 | 0.23 | | |
| 7 | 6 | 0.21 | 0.23 | 0.220 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.22 | 1.00 | 0.22 | | |
| 8 | 7 | 0.21 | 0.22 | 0.215 | 0.129 | 90 | =(10 x 9) | 36.09 | | 36.090 | 0.414 | 0.392 | | | | 0.46 | 0.18 |
| | | | | | 0.129 | 100 | =(10 x 10) | 45.02 | | 45.020 | 0.370 | | 0.24 | 1.00 | 0.24 | | |
| 9 | 8 | 0.25 | 0.28 | 0.265 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.13 | 1.00 | 0.13 | | |
| 10 | 9 | 0.00 | 0.00 | 0.000 | 0.000 | 100 | =(10 x 10) | 33.95 | | 33.950 | 0.487 | 0.484 | | | | 0.13 | 0.06 |
| | | | | | 0.000 | 100 | =(10 x 10) | 34.44 | | 34.440 | 0.480 | | | | | | |
| 11 | | | | | | | | | | | | | | | | | |
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|---|---|---|---|
| Station No. | | ***Downstream of the culvert*** | |
| Observation Date | | Yr: 2012 Mon: 8 | Date: 14 |
| Observer Name | Mesure | ***Ezekiel, Reuben*** | |
| | Wrote | ***Ezekiel*** | |
| Weather | Weather | :clear, :fine, :cloudy :rain | |
| | Wind blows | from Down/s, Up/s, Left, Right | |
| | Wind power | 0:None, 1:light, 2:windy, 3:strong, 4:very strong | |
| Mesurement Time (Hour, min) | Start | **2:30 PM** | |
| | End | **4:30PM** | |
| | Average | **3:30PM** | |
| Water Level at gauging station (m) | | Initial Point | No.1 Point |
| | Start | | |
| | End | | |
| | Average | | |
| Current meter | Type of current meter | Digital | |
| | Table/formula | V = 0.162 * N + 0.010 | |
| | Useing method | lods・wire・weight | |
| | | by boat / bridge / walk | |
| Calculator | Calculator | | |
| | Checker | | |
| Result | Total Discharge (m$^3$/s) | **1.54** | |
| | Total area cross section(m$^2$) | **2.45** | |
| | Average Velocity（m/s） | **0.63** | |

Notes

Catchment Area (km$^2$)= **35.0**

Discharge (m$^3$/s)= **1.54**

Specific Discharge (m$^3$/s*100km$^2$)= **4.40**

Remark:

## Observation Sheets on 27 August 2012

***JICA Expert Team*** (Field Notebook of Discharge Observation)

FIELD WORKS

| No. of measure-ment | Distance from bank (m) | Depth of Water. (m) First (one way) | Second (return) | Average | Velocity Mesurement (Flow speed) Depth of observation(m) | Count of current meter | | Time in seconds 1st | 2nd | Average |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0.00 | 0.00 | 0.000 | | | | | | |
| 2 | 1 | 0.42 | 0.43 | 0.425 | 0.255 | 90 | =(10 x 9) | 20.70 | | 20.700 |
| | | | | | 0.255 | 110 | =(10 x 11) | 25.95 | | 25.950 |
| 3 | 2 | 0.53 | 0.54 | 0.535 | | | | | | |
| 4 | 3 | 0.50 | 0.51 | 0.505 | 0.303 | 110 | =(10 x 11) | 20.13 | | 20.130 |
| | | | | | 0.303 | 130 | =(10 x 13) | 25.15 | | 25.150 |
| 5 | 4 | 0.41 | 0.43 | 0.420 | | | | | | |
| 6 | 5 | 0.33 | 0.35 | 0.340 | 0.204 | 100 | =(10 x 10) | 39.80 | | 39.800 |
| | | | | | 0.204 | 120 | =(10 x 12) | 44.11 | | 44.110 |
| 7 | 6 | 0.32 | 0.30 | 0.310 | | | | | | |
| 8 | 7 | 0.34 | 0.33 | 0.335 | 0.201 | 110 | =(10 x 11) | 35.48 | | 35.480 |
| | | | | | 0.201 | 90 | =(10 x 9) | 31.40 | | 31.400 |
| 9 | 8 | 0.43 | 0.44 | 0.435 | | | | | | |
| 10 | 9 | 0.00 | 0.00 | 0.000 | 0.000 | 100 | =(10 x 10) | 34.60 | | 34.600 |
| | | | | | 0.000 | 90 | =(10 x 9) | 30.77 | | 30.770 |
| 11 | | | | | | | | | | |
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HOME WORKS

| Velocity Mesu. Veloc. at point(m/s) | Mean meas. Veloc.in vert(m/s) | Area of cross section Average depth(m) | Width of section(m) | Area of Section($m^2$) | Total Area($m^2$) | Disch-arge ($m^3$/s) |
|---|---|---|---|---|---|---|
| | | 0.21 | 1.00 | 0.21 | | |
| 0.714 | 0.706 | | | | 0.69 | 0.49 |
| 0.697 | | 0.48 | 1.00 | 0.48 | | |
| | | | | | | |
| | | 0.52 | 1.00 | 0.52 | | |
| 0.895 | 0.871 | | | | 0.98 | 0.85 |
| 0.847 | | 0.46 | 1.00 | 0.46 | | |
| | | | | | | |
| | | 0.38 | 1.00 | 0.38 | | |
| 0.417 | 0.434 | | | | 0.71 | 0.31 |
| 0.451 | | 0.33 | 1.00 | 0.33 | | |
| | | | | | | |
| | | 0.32 | 1.00 | 0.32 | | |
| 0.512 | 0.493 | | | | 0.71 | 0.35 |
| 0.474 | | 0.39 | 1.00 | 0.39 | | |
| | | | | | | |
| | | 0.22 | 1.00 | 0.22 | | |
| 0.478 | 0.481 | | | | 0.22 | 0.11 |
| 0.484 | | | | | | |

| | | | |
|---|---|---|---|
| Station No. | | ***Downstream of the culvert*** | |
| Observation Date | | Yr: 2012 Mon: 8 | Date: 27 |
| Observer Name | Mesure | ***Ezekiel, Reuben*** | |
| | Wrote | ***Ezekiel*** | |
| Weather | Weather | :clear, :fine, :cloudy :rain | |
| | Wind blows | from Down/s, Up/s, Left, Right | |
| | Wind power | 0:None, 1:light, 2:windy, 3:strong, 4:very strong | |
| Mesurement Time (Hour, min) | Start | **10:30 AM** | |
| | End | **12:00PM** | |
| | Average | **11:15Am** | |
| Water Level at gauging station (m) | | Initial Point | No.1 Point |
| | Start | | |
| | End | | |
| | Average | | |
| Current meter | Type of current meter | Digital | |
| | Table/formula | V = 0.162 * N + 0.010 | |
| | Useing method | lods・wire・weight | |
| | | by boat / bridge / walk | |
| Calculator | Calculator | | |
| | Checker | | |
| Result | Total Discharge ($m^3$/s) | **2.11** | |
| | Total area cross section($m^2$) | **3.31** | |
| | Average Velocity（m/s） | **0.64** | |

Notes

| | |
|---|---|
| Catchment Area ($km^2$)= | **35.0** |
| Discharge ($m^3$/s)= | **2.11** |
| Specific Discharge ($m^3$/s*100$km^2$)= | **6.03** |

Remark:

**THERE WAS HEAVY RAIN THE PREVIOUS NIGHT**

***JICA Expert Team*** (Field Notebook of Discharge Observation)

FIELD WORKS

| No. of measure-ment | Distance from bank (m) | Depth of Water. (m) | | | Velocity Mesurement (Flow speed) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | First (one way) | Second (return) | Average | Depth of observation(m) | Count of current meter | | Time in seconds | | |
| | | | | | | | | 1st | 2nd | Average |
| 1 | 0 | 0.00 | 0.00 | 0.000 | | | | | | |
| 2 | 1 | 0.42 | 0.42 | 0.420 | 0.252 | 100 | =(10 x 10) | 17.61 | | 17.610 |
| | | | | | 0.252 | 110 | =(10 x 11) | 20.12 | | 20.120 |
| 3 | 2 | 0.48 | 0.49 | 0.485 | | | | | | |
| 4 | 3 | 0.50 | 0.51 | 0.505 | 0.303 | 90 | =(10 x 9) | 15.10 | | 15.100 |
| | | | | | 0.303 | 120 | =(10 x 12) | 20.99 | | 20.990 |
| 5 | 4 | 0.42 | 0.44 | 0.430 | | | | | | |
| 6 | 5 | 0.34 | 0.35 | 0.345 | 0.207 | 100 | =(10 x 10) | 36.79 | | 36.790 |
| | | | | | 0.207 | 120 | =(10 x 12) | 38.08 | | 38.080 |
| 7 | 6 | 0.34 | 0.37 | 0.355 | | | | | | |
| 8 | 7 | 0.31 | 0.32 | 0.315 | 0.189 | 90 | =(10 x 9) | 22.60 | | 22.600 |
| | | | | | 0.189 | 110 | =(10 x 11) | 27.49 | | 27.490 |
| 9 | 8 | 0.40 | 0.41 | 0.405 | | | | | | |
| 10 | 9 | 0.00 | 0.00 | 0.000 | 0.000 | 90 | =(10 x 9) | 28.43 | | 28.430 |
| | | | | | 0.000 | 100 | =(10 x 10) | 29.77 | | 29.770 |
| 11 | | | | | | | | | | |
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HOME WORKS

| Velocity | | Area of cross section | | | | Disch-arge |
|---|---|---|---|---|---|---|
| Mesu. Veloc. at point(m/s) | Mean meas. Veloc.in vert(m/s) | Average depth(m) | Width of section(m) | Area of Section($m^2$) | Total Area($m^2$) | ($m^3/s$) |
| | | 0.21 | 1.00 | 0.21 | | |
| 0.930 | 0.913 | | | | 0.66 | 0.60 |
| 0.896 | | 0.45 | 1.00 | 0.45 | | |
| | | | | | | |
| | | 0.50 | 1.00 | 0.50 | | |
| 0.976 | 0.956 | | | | 0.97 | 0.93 |
| 0.936 | | 0.47 | 1.00 | 0.47 | | |
| | | | | | | |
| | | 0.39 | 1.00 | 0.39 | | |
| 0.450 | 0.486 | | | | 0.74 | 0.36 |
| 0.521 | | 0.35 | 1.00 | 0.35 | | |
| | | | | | | |
| | | 0.34 | 1.00 | 0.34 | | |
| 0.655 | 0.657 | | | | 0.70 | 0.46 |
| 0.658 | | 0.36 | 1.00 | 0.36 | | |
| | | | | | | |
| | | 0.20 | 1.00 | 0.20 | | |
| 0.523 | 0.539 | | | | 0.20 | 0.11 |
| 0.554 | | | | | | |

| | | | |
|---|---|---|---|
| Station No. | | ***Downstream of the culvert*** | |
| Observation Date | | Yr: 2012 Mon: 8 | Date: 27 |
| Observer Name | Mesure | ***Ezekiel, Reuben*** | |
| | Wrote | ***Ezekiel*** | |
| Weather | Weather | :clear, :fine, :cloudy :rain | |
| | Wind blows | from Down/s, Up/s, Left, Right | |
| | Wind power | 0:None, 1:light, 2:windy, 3:strong, 4:very strong | |
| Mesurement Time (Hour, min) | Start | **2:30 PM** | |
| | End | **4:30PM** | |
| | Average | **3:30PM** | |
| Water Level at gauging station (m) | | Initial Point | No.1 Point |
| | Start | | |
| | End | | |
| | Average | | |
| Current meter | Type of current meter | Digital | |
| | Table/formula | V = 0.162 * N + 0.010 | |
| | Useing method | lods・wire・weight | |
| | | by boat / bridge / walk | |
| Calculator | Calculator | | |
| | Checker | | |
| Result | Total Discharge ($m^3/s$) | **2.46** | |
| | Total area cross section($m^2$) | **3.27** | |
| | Average Velocity（m/s） | **0.75** | |

Notes

Catchment Area ($km^2$)= **35.0**
Discharge ($m^3/s$)= **2.46**
Specific Discharge ($m^3/s$*$100km^2$)= **7.03**

Remark:

**There was rain the previous night**

# Observation Sheets on 28 August 2012

***JICA Expert Team*** (Field Notebook of Discharge Observation)

FIELD WORKS

| No. of measure-ment | Distance from bank (m) | Depth of Water. (m) | | | Velocity Mesurement (Flow speed) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | First (one way) | Second (return) | Average | Depth of observation(m) | Count of current meter | | Time in seconds | | |
| | | | | | | | | 1st | 2nd | Average |
| 1 | 0 | 0.00 | 0.00 | 0.000 | | | | | | |
| 2 | 1 | 0.35 | 0.37 | 0.360 | 0.216 | 100 | =(10 x 10) | 21.72 | | 21.720 |
| | | | | | 0.216 | 110 | =(10 x 11) | 23.60 | | 23.600 |
| 3 | 2 | 0.43 | 0.44 | 0.435 | | | | | | |
| 4 | 3 | 0.45 | 0.48 | 0.465 | 0.279 | 100 | =(10 x 10) | 19.95 | | 19.950 |
| | | | | | 0.279 | 110 | =(10 x 11) | 21.92 | | 21.920 |
| 5 | 4 | 0.39 | 0.40 | 0.395 | | | | | | |
| 6 | 5 | 0.33 | 0.36 | 0.345 | 0.207 | 100 | =(10 x 10) | 28.02 | | 28.020 |
| | | | | | 0.207 | 120 | =(10 x 12) | 34.32 | | 34.320 |
| 7 | 6 | 0.30 | 0.33 | 0.315 | | | | | | |
| 8 | 7 | 0.23 | 0.25 | 0.240 | 0.144 | 90 | =(10 x 9) | 20.54 | | 20.540 |
| | | | | | 0.144 | 110 | =(10 x 11) | 24.54 | | 24.540 |
| 9 | 8 | 0.33 | 0.31 | 0.320 | | | | | | |
| 10 | 9 | 0.00 | 0.00 | 0.000 | 0.000 | 100 | =(10 x 10) | 21.34 | | 21.340 |
| | | | | | 0.000 | 90 | =(10 x 9) | 20.56 | | 20.560 |
| 11 | | | | | | | | | | |
| 12 | | | | | | | | | | |
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HOME WORKS

| Velocity | | Area of cross section | | | | Disch-arge |
|---|---|---|---|---|---|---|
| Mesu. Veloc. at point(m/s) | Mean meas. Veloc.in vert(m/s) | Average depth(m) | Width of section(m | Area of Section($m^2$) | Total Area($m^2$) | ($m^3$/s) |
| | | 0.18 | 1.00 | 0.18 | | |
| 0.756 | 0.761 | | | | 0.58 | 0.44 |
| 0.765 | | 0.40 | 1.00 | 0.40 | | |
| | | | | | | |
| | | 0.45 | 1.00 | 0.45 | | |
| 0.822 | 0.823 | | | | 0.88 | 0.72 |
| 0.823 | | 0.43 | 1.00 | 0.43 | | |
| | | | | | | |
| | | 0.37 | 1.00 | 0.37 | | |
| 0.588 | 0.582 | | | | 0.70 | 0.41 |
| 0.576 | | 0.33 | 1.00 | 0.33 | | |
| | | | | | | |
| | | 0.28 | 1.00 | 0.28 | | |
| 0.720 | 0.728 | | | | 0.56 | 0.41 |
| 0.736 | | 0.28 | 1.00 | 0.28 | | |
| | | | | | | |
| | | 0.16 | 1.00 | 0.16 | | |
| 0.769 | 0.744 | | | | 0.16 | 0.12 |
| 0.719 | | | | | | |

| | | | | |
|---|---|---|---|---|
| Station No. | | ***Downstream of the culvert*** | | |
| Observation Date | | Yr: 2012 | Mon: 8 | Date: 28 |
| Observer Name | Mesure | ***Ezekiel, Reuben*** | | |
| | Wrote | ***Ezekiel*** | | |
| Weather | Weather | :clear, :fine, :cloudy :rain | | |
| | Wind blows | from Down/s, Up/s, Left, Right | | |
| | Wind power | 0:None, 1:light, 2:windy, 3:strong, 4:very strong | | |
| Mesurement Time (Hour, min) | Start | **10:30 AM** | | |
| | End | **12:00PM** | | |
| | Average | **11:15Am** | | |
| Water Level at gauging station (m) | | Initial Point | No.1 Point | |
| | Start | | | |
| | End | | | |
| | Average | | | |
| Current meter | Type of current meter | Digital | | |
| | Table/formula | V = 0.162 * N + 0.010 | | |
| | Useing method | lods・wire・weight | | |
| | | by boat / bridge / walk | | |
| Calculator | Calculator | | | |
| | Checker | | | |
| Result | Total Discharge ($m^3$/s) | **2.10** | | |
| | Total area cross section($m^2$) | **2.88** | | |
| | Average Velocity（m/s） | **0.73** | | |

Notes

Catchment Area ($km^2$)= 35.0
Discharge ($m^3$/s)= **2.10**
Specific Discharge ($m^3$/s*100$km^2$)= **6.00**

Remark:

**THERE WAS RAIN THE PREVIOUS NIGHT**

***JICA Expert Team*** (Field Notebook of Discharge Observation)

| FIELD WORKS | | | | | | | | | | | HOME WORKS | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of measure-ment | Distance from bank (m) | Depth of Water. (m) | | | Velocity Mesurement (Flow speed) | | | | | | Velocity | | Area of cross section | | | | Disch-arge (m³/s) |
| | | First (one way) | Second (return) | Average | Depth of observation(m) | Count of current meter | | Time in seconds | | | Mesu. Veloc. at point(m/s) | Mean meas. Veloc.in vert(m/s) | Average depth(m) | Width of section(m) | Area of Section($m^2$) | Total Area($m^2$) | |
| | | | | | | | | 1st | 2nd | Average | | | | | | | |
| 1 | 0 | 0.00 | 0.00 | 0.000 | | | | | | | | | 0.17 | 1.00 | 0.17 | | |
| 2 | 1 | 0.33 | 0.35 | 0.340 | 0.204 | 100 | =(10 x 10) | 21.30 | | 21.300 | 0.771 | 0.772 | | | | 0.54 | 0.42 |
| | | | | | 0.204 | 110 | =(10 x 11) | 23.38 | | 23.380 | 0.772 | | 0.37 | 1.00 | 0.37 | | |
| 3 | 2 | 0.40 | 0.41 | 0.405 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.43 | 1.00 | 0.43 | | |
| 4 | 3 | 0.44 | 0.47 | 0.455 | 0.273 | 90 | =(10 x 9) | 19.15 | | 19.150 | 0.771 | 0.775 | | | | 0.85 | 0.66 |
| | | | | | 0.273 | 120 | =(10 x 12) | 25.29 | | 25.290 | 0.779 | | 0.42 | 1.00 | 0.42 | | |
| 5 | 4 | 0.38 | 0.37 | 0.375 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.34 | 1.00 | 0.34 | | |
| 6 | 5 | 0.29 | 0.30 | 0.295 | 0.177 | 100 | =(10 x 10) | 27.01 | | 27.010 | 0.610 | 0.612 | | | | 0.64 | 0.39 |
| | | | | | 0.177 | 120 | =(10 x 12) | 32.18 | | 32.180 | 0.614 | | 0.30 | 1.00 | 0.30 | | |
| 7 | 6 | 0.29 | 0.30 | 0.295 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.28 | 1.00 | 0.28 | | |
| 8 | 7 | 0.26 | 0.27 | 0.265 | 0.159 | 90 | =(10 x 9) | 27.70 | | 27.700 | 0.536 | 0.520 | | | | 0.58 | 0.30 |
| | | | | | 0.159 | 110 | =(10 x 11) | 36.16 | | 36.160 | 0.503 | | 0.30 | 1.00 | 0.30 | | |
| 9 | 8 | 0.31 | 0.35 | 0.330 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.17 | 1.00 | 0.17 | | |
| 10 | 9 | 0.00 | 0.00 | 0.000 | 0.000 | 90 | =(10 x 9) | 26.54 | | 26.540 | 0.559 | 0.578 | | | | 0.17 | 0.10 |
| | | | | | 0.000 | 100 | =(10 x 10) | 27.61 | | 27.610 | 0.597 | | | | | | |
| 11 | | | | | | | | | | | | | | | | | |
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| | | | |
|---|---|---|---|
| Station No. | | ***Downstream of the culvert*** | |
| Observation Date | | Yr: 2012 | Mon: 8 Date: 28 |
| Observer Name | Mesure | ***Ezekiel, Reuben*** | |
| | Wrote | ***Ezekiel*** | |
| Weather | Weather | :clear, :fine, :cloudy :rain | |
| | Wind blows | from Down/s, Up/s, Left, Right | |
| | Wind power | 0:None, 1:light, 2:windy, 3:strong, 4:very strong | |
| Mesurement Time (Hour, min) | Start | **2:30 PM** | |
| | End | **4:30PM** | |
| | Average | **3:30PM** | |
| Water Level at gauging station (m) | | Initial Point | No.1 Point |
| | Start | | |
| | End | | |
| | Average | | |
| Current meter | Type of current meter | Digital | |
| | Table/formula | V = 0.162 * N + 0.010 | |
| | Useing method | lods・wire・weight | |
| | | by boat / bridge / walk | |
| Calculator | Calculator | | |
| | Checker | | |
| Result | Total Discharge ($m^3/s$) | **1.87** | |
| | Total area cross section($m^2$) | **2.78** | |
| | Average Velocity（m/s） | **0.67** | |

Notes

Catchment Area ($km^2$)= **35.0**

Discharge ($m^3/s$)= **1.87**

Specific Discharge ($m^3/s*100km^2$)= **5.34**

Remark:

**THERE WAS HEAVY RAIN THE PREVIOUS NIGHT**

## Observation Sheets on 29 August 2012

***JICA Expert Team*** (Field Notebook of Discharge Observation)

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FIELD WORKS | | | | | | | | | | | HOME WORKS | | | | | | |
| No. of measure-ment | Distance from bank (m) | Depth of Water. (m) | | | Velocity Mesurement (Flow speed) | | | | | | Velocity | | Area of cross section | | | | Disch-arge ($m^3$/s) |
| | | First (one way) | Second (return) | Average | Depth of observation(m) | Count of current meter | | Time in seconds | | | Mesu. Veloc. at point(m/s) | Mean meas. Veloc.in vert(m/s) | Average depth(m) | Width of section(m | Area of Section($m^2$) | Total Area($m^2$) | |
| | | | | | | | | 1st | 2nd | Average | | | | | | | |
| 1 | 0 | 0.00 | 0.00 | 0.000 | | | | | | | | | 0.17 | 1.00 | 0.17 | | |
| 2 | 1 | 0.33 | 0.35 | 0.340 | 0.204 | 100 | =(10 x 10) | 25.98 | | 25.980 | 0.634 | 0.624 | | | | 0.54 | 0.34 |
| | | | | | 0.204 | 110 | =(10 x 11) | 29.55 | | 29.550 | 0.613 | | 0.37 | 1.00 | 0.37 | | |
| 3 | 2 | 0.40 | 0.41 | 0.405 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.41 | 1.00 | 0.41 | | |
| 4 | 3 | 0.39 | 0.43 | 0.410 | 0.246 | 90 | =(10 x 9) | 18.49 | | 18.490 | 0.799 | 0.798 | | | | 0.81 | 0.65 |
| | | | | | 0.246 | 120 | =(10 x 12) | 24.71 | | 24.710 | 0.797 | | 0.40 | 1.00 | 0.40 | | |
| 5 | 4 | 0.37 | 0.40 | 0.385 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.33 | 1.00 | 0.33 | | |
| 6 | 5 | 0.26 | 0.29 | 0.275 | 0.165 | 100 | =(10 x 10) | 26.64 | | 26.640 | 0.618 | 0.622 | | | | 0.60 | 0.37 |
| | | | | | 0.165 | 120 | =(10 x 12) | 31.61 | | 31.610 | 0.625 | | 0.27 | 1.00 | 0.27 | | |
| 7 | 6 | 0.26 | 0.28 | 0.270 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.24 | 1.00 | 0.24 | | |
| 8 | 7 | 0.20 | 0.23 | 0.215 | 0.129 | 90 | =(10 x 9) | 47.39 | | 47.390 | 0.318 | 0.311 | | | | 0.49 | 0.15 |
| | | | | | 0.129 | 100 | =(10 x 10) | 55.32 | | 55.320 | 0.303 | | 0.25 | 1.00 | 0.25 | | |
| 9 | 8 | 0.27 | 0.30 | 0.285 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.14 | 1.00 | 0.14 | | |
| 10 | 9 | 0.00 | 0.00 | 0.000 | 0.000 | 100 | =(10 x 10) | 39.77 | | 39.770 | 0.417 | 0.402 | | | | 0.14 | 0.06 |
| | | | | | 0.000 | 90 | =(10 x 9) | 38.64 | | 38.640 | 0.387 | | | | | | |
| 11 | | | | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | | | | |
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| 19 | | | | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | | | | |

| | | | |
|---|---|---|---|
| Station No. | | ***Downstream of the culvert*** | |
| Observation Date | | Yr: 2012 | Mon: 8 Date: 29 |
| Observer Name | Mesure | ***Ezekiel, Reuben*** | |
| | Wrote | ***Ezekiel*** | |
| Weather | Weather | :clear, :fine, :cloudy :rain | |
| | Wind blows | from Down/s, Up/s, Left, Right | |
| | Wind power | 0:None, 1:light, 2:windy, 3:strong, 4:very strong | |
| Mesurement Time (Hour, min) | Start | **10:30 AM** | |
| | End | **12:00PM** | |
| | Average | **11:15Am** | |
| Water Level at gauging station (m) | | Initial Point | No.1 Point |
| | Start | | |
| | End | | |
| | Average | | |
| Current meter | Type of current meter | Digital | |
| | Table/formula | V = 0.162 * N + 0.010 | |
| | Useing method | lods・wire・weight | |
| | | by boat / bridge / walk | |
| Calculator | Calculator | | |
| | Checker | | |
| Result | Total Discharge ($m^3$/s) | **1.57** | |
| | Total area cross section($m^2$) | **2.58** | |
| | Average Velocity（m/s） | **0.61** | |

Notes

| | |
|---|---|
| Catchment Area ($km^2$)= | **35.0** |
| Discharge ($m^3$/s)= | **1.57** |
| Specific Discharge ($m^3$/s*100$km^2$)= | **4.49** |

Remark:

**There was no rain realised**

***JICA Expert Team*** (Field Notebook of Discharge Observation)

FIELD WORKS

| No. of measure-ment | Distance from bank (m) | Depth of Water. (m) First (one way) | Second (return) | Average | Velocity Mesurement (Flow speed) Depth of observation(m) | Count of current meter | | Time in seconds 1st | 2nd | Average |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0.00 | 0.00 | 0.000 | | | | | | |
| 2 | 1 | 0.33 | 0.34 | 0.335 | 0.201 | 100 | =(10 x 10) | 23.97 | | 23.970 |
| | | | | | 0.201 | 110 | =(10 x 11) | 26.34 | | 26.340 |
| 3 | 2 | 0.39 | 0.40 | 0.395 | | | | | | |
| 4 | 3 | 0.39 | 0.42 | 0.405 | 0.243 | 90 | =(10 x 9) | 21.17 | | 21.170 |
| | | | | | 0.243 | 100 | =(10 x 10) | 23.34 | | 23.340 |
| 5 | 4 | 0.33 | 0.34 | 0.335 | | | | | | |
| 6 | 5 | 0.27 | 0.30 | 0.285 | 0.171 | 100 | =(10 x 10) | 31.62 | | 31.620 |
| | | | | | 0.171 | 110 | =(10 x 11) | 35.34 | | 35.340 |
| 7 | 6 | 0.26 | 0.27 | 0.265 | | | | | | |
| 8 | 7 | 0.26 | 0.29 | 0.275 | 0.165 | 90 | =(10 x 9) | 50.05 | | 50.050 |
| | | | | | 0.165 | 110 | =(10 x 11) | 52.69 | | 52.690 |
| 9 | 8 | 0.30 | 0.28 | 0.290 | | | | | | |
| 10 | 9 | 0.00 | 0.00 | 0.000 | 0.000 | 90 | =(10 x 9) | 38.59 | | 38.590 |
| | | | | | 0.000 | 100 | =(10 x 10) | 37.79 | | 37.790 |
| 11 | | | | | | | | | | |
| 12 | | | | | | | | | | |
| 13 | | | | | | | | | | |
| 14 | | | | | | | | | | |
| 15 | | | | | | | | | | |
| 16 | | | | | | | | | | |
| 17 | | | | | | | | | | |
| 18 | | | | | | | | | | |
| 19 | | | | | | | | | | |
| 20 | | | | | | | | | | |

HOME WORKS

| Velocity Mesu. Veloc. at point(m/s) | Mean meas. Veloc.in vert(m/s) |
|---|---|
| | |
| 0.686 | 0.687 |
| 0.687 | |
| | |
| 0.699 | 0.702 |
| 0.704 | |
| | |
| 0.522 | 0.518 |
| 0.514 | |
| | |
| 0.301 | 0.325 |
| 0.348 | |
| | |
| 0.388 | 0.414 |
| 0.439 | |

| Area of cross section Average depth(m) | Width of section(m) | Area of Section($m^2$) | Total Area($m^2$) | Disch-arge ($m^3/s$) |
|---|---|---|---|---|
| 0.17 | 1.00 | 0.17 | 0.54 | 0.37 |
| 0.37 | 1.00 | 0.37 | | |
| 0.40 | 1.00 | 0.40 | 0.77 | 0.54 |
| 0.37 | 1.00 | 0.37 | | |
| 0.31 | 1.00 | 0.31 | 0.59 | 0.31 |
| 0.28 | 1.00 | 0.28 | | |
| 0.27 | 1.00 | 0.27 | 0.55 | 0.18 |
| 0.28 | 1.00 | 0.28 | | |
| 0.15 | 1.00 | 0.15 | 0.15 | 0.06 |

| | | | | |
|---|---|---|---|---|
| Station No. | | ***Downstream of the culvert*** | | |
| Observation Date | | Yr: 2012 | Mon: 8 | Date: 29 |
| Observer Name | Mesure | ***Ezekiel, Reuben*** | | |
| | Wrote | ***Ezekiel*** | | |
| Weather | Weather | :clear, :fine, :cloudy :rain | | |
| | Wind blows | from Down/s, Up/s, Left, Right | | |
| | Wind power | 0:None, 1:light, 2:windy, 3:strong, 4:very strong | | |
| Mesurement Time (Hour, min) | Start | **2:30 PM** | | |
| | End | **4:30PM** | | |
| | Average | **3:30PM** | | |
| Water Level at gauging station (m) | | Initial Point | No.1 Point | |
| | Start | | | |
| | End | | | |
| | Average | | | |
| Current meter | Type of current meter | Digital | | |
| | Table/formula | V = 0.162 * N + 0.010 | | |
| | Useing method | lods・wire・weight | | |
| | | by boat / bridge / walk | | |
| Calculator | Calculator | | | |
| | Checker | | | |
| Result | Total Discharge ($m^3/s$) | **1.46** | | |
| | Total area cross section($m^2$) | **2.60** | | |
| | Average Velocity(m/s) | **0.56** | | |

Notes

| | |
|---|---|
| Catchment Area ($km^2$)= | 35.0 |
| Discharge ($m^3/s$)= | **1.46** |
| Specific Discharge ($m^3/s*100km^2$)= | **4.17** |

Remark:

**There was no rain realized**

## Observation Sheets on 10 September 2012

***JICA Expert Team*** (Field Notebook of Discharge Observation)

FIELD WORKS

| No. of measure-ment | Distance from bank (m) | Depth of Water. (m) First (one way) | Depth of Water. (m) Second (return) | Depth of Water. (m) Average | Velocity Mesurement (Flow speed) Depth of observation(m) | Count of current meter | | Time in seconds 1st | Time in seconds 2nd | Time in seconds Average |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0.00 | 0.00 | 0.000 | | | | | | |
| 2 | 1 | 0.40 | 0.40 | 0.400 | 0.240 | 100 | =(10 x 10) | 18.93 | | 18.930 |
| | | | | | 0.240 | 120 | =(10 x 12) | 22.88 | | 22.880 |
| 3 | 2 | 0.44 | 0.48 | 0.460 | | | | | | |
| 4 | 3 | 0.48 | 0.50 | 0.490 | 0.294 | 90 | =(10 x 9) | 20.36 | | 20.360 |
| | | | | | 0.294 | 100 | =(10 x 10) | 21.50 | | 21.500 |
| 5 | 4 | 0.40 | 0.43 | 0.415 | | | | | | |
| 6 | 5 | 0.37 | 0.38 | 0.375 | 0.225 | 90 | =(10 x 9) | 27.11 | | 27.110 |
| | | | | | 0.225 | 100 | =(10 x 10) | 30.36 | | 30.360 |
| 7 | 6 | 0.33 | 0.34 | 0.335 | | | | | | |
| 8 | 7 | 0.34 | 0.37 | 0.355 | 0.213 | 90 | =(10 x 9) | 18.83 | | 18.830 |
| | | | | | 0.213 | 110 | =(10 x 11) | 24.37 | | 24.370 |
| 9 | 8 | 0.35 | 0.35 | 0.350 | | | | | | |
| 10 | 9 | 0.00 | 0.00 | 0.000 | 0.000 | 100 | =(10 x 10) | 34.22 | | 34.220 |
| | | | | | 0.000 | 110 | =(10 x 11) | 35.77 | | 35.770 |
| 11 | | | | | | | | | | |
| 12 | | | | | | | | | | |
| 13 | | | | | | | | | | |
| 14 | | | | | | | | | | |
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| 18 | | | | | | | | | | |
| 19 | | | | | | | | | | |
| 20 | | | | | | | | | | |

HOME WORKS

| Velocity Mesu. Veloc. at point(m/s) | Velocity Mean meas. Veloc.in vert(m/s) | Area of cross section Average depth(m) | Area of cross section Width of section(m) | Area of cross section Area of Section($m^2$) | Area of cross section Total Area($m^2$) | Disch-arge ($m^3$/s) |
|---|---|---|---|---|---|---|
| | | 0.20 | 1.00 | 0.20 | | |
| 0.866<br>0.860 | 0.863 | 0.43 | 1.00 | 0.43 | 0.63 | 0.54 |
| | | 0.48 | 1.00 | 0.48 | | |
| 0.726<br>0.763 | 0.745 | 0.45 | 1.00 | 0.45 | 0.93 | 0.69 |
| | | 0.40 | 1.00 | 0.40 | | |
| 0.548<br>0.544 | 0.546 | 0.36 | 1.00 | 0.36 | 0.76 | 0.41 |
| | | 0.35 | 1.00 | 0.35 | | |
| 0.784<br>0.741 | 0.763 | 0.35 | 1.00 | 0.35 | 0.70 | 0.53 |
| | | 0.18 | 1.00 | 0.18 | | |
| 0.483<br>0.508 | 0.496 | | | | 0.18 | 0.09 |

| | | | | | |
|---|---|---|---|---|---|
| Station No. | | ***Downstream of the culvert*** | | | |
| Observation Date | | Yr: 2012 | Mon: 9 | | Date: 10 |
| Observer Name | Mesure | ***Ezekiel, Reuben*** | | | |
| | Wrote | ***Ezekiel*** | | | |
| Weather | Weather | :clear, :fine, :cloudy :rain | | | |
| | Wind blows | from Down/s, Up/s, Left, Right | | | |
| | Wind power | 0:None, 1:light, 2:windy, 3:strong, 4:very strong | | | |
| Mesurement Time (Hour, min) | Start | **10:30 AM** | | | |
| | End | **12:00PM** | | | |
| | Average | **11:15Am** | | | |
| Water Level at gauging station (m) | | Initial Point | | No.1 Point | |
| | Start | | | | |
| | End | | | | |
| | Average | | | | |
| Current meter | Type of current meter | Digital | | | |
| | Table/formula | V = 0.162 * N + 0.010 | | | |
| | Useing method | lods・wire・weight | | | |
| | | by boat / bridge / walk | | | |
| Calculator | Calculator | | | | |
| | Checker | | | | |
| Result | Total Discharge ($m^3$/s) | **2.26** | | | |
| | Total area cross section($m^2$) | **3.20** | | | |
| | Average Velocity(m/s) | **0.71** | | | |

Notes

Catchment Area ($km^2$)= **35.0**

Discharge ($m^3$/s)= **2.26**

Specific Discharge ($m^3$/s*100$km^2$)= **6.46**

Remark:

**THERE WAS HEAVY RAIN THE PREVIOUS NIGHT-9TH 09-2012**

***JICA Expert Team*** (Field Notebook of Discharge Observation)

| FIELD WORKS | | | | | | | | | | | HOME WORKS | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of measure-ment | Distance from bank (m) | Depth of Water. (m) | | | Velocity Mesurement (Flow speed) | | | | | | Velocity | | Area of cross section | | | | Disch-arge (m$^3$/s) |
| | | First (one way) | Second (return) | Average | Depth of observation(m) | Count of current meter | | Time in seconds 1st | 2nd | Average | Mesu. Veloc. at point(m/s) | Mean meas. Veloc.in vert(m/s) | Average depth(m) | Width of section(m) | Area of Section(m$^2$) | Total Area(m$^2$) | |
| 1 | 0 | 0.00 | 0.00 | 0.000 | | | | | | | | | 0.20 | 1.00 | 0.20 | | |
| 2 | 1 | 0.40 | 0.41 | 0.405 | 0.243 | 100 | =(10 x 10) | 19.52 | | 19.520 | 0.840 | 0.850 | | | | 0.63 | 0.54 |
| | | | | | 0.243 | 110 | =(10 x 11) | 20.99 | | 20.990 | 0.859 | | 0.43 | 1.00 | 0.43 | | |
| 3 | 2 | 0.42 | 0.47 | 0.445 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.47 | 1.00 | 0.47 | | |
| 4 | 3 | 0.50 | 0.50 | 0.500 | 0.300 | 100 | =(10 x 10) | 21.32 | | 21.320 | 0.770 | 0.767 | | | | 0.95 | 0.73 |
| | | | | | 0.300 | 120 | =(10 x 12) | 25.83 | | 25.830 | 0.763 | | 0.48 | 1.00 | 0.48 | | |
| 5 | 4 | 0.44 | 0.46 | 0.450 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.43 | 1.00 | 0.43 | | |
| 6 | 5 | 0.40 | 0.41 | 0.405 | 0.243 | 90 | =(10 x 9) | 29.93 | | 29.930 | 0.497 | 0.498 | | | | 0.81 | 0.40 |
| | | | | | 0.243 | 100 | =(10 x 10) | 33.12 | | 33.120 | 0.499 | | 0.38 | 1.00 | 0.38 | | |
| 7 | 6 | 0.36 | 0.36 | 0.360 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.36 | 1.00 | 0.36 | | |
| 8 | 7 | 0.35 | 0.36 | 0.355 | 0.213 | 80 | =(10 x 8) | 24.02 | | 24.020 | 0.550 | 0.527 | | | | 0.72 | 0.38 |
| | | | | | 0.213 | 100 | =(10 x 10) | 32.79 | | 32.790 | 0.504 | | 0.36 | 1.00 | 0.36 | | |
| 9 | 8 | 0.35 | 0.37 | 0.360 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.18 | 1.00 | 0.18 | | |
| 10 | 9 | 0.00 | 0.00 | 0.000 | 0.000 | 100 | =(10 x 10) | 38.76 | | 38.760 | 0.428 | 0.440 | | | | 0.18 | 0.08 |
| | | | | | 0.000 | 110 | =(10 x 11) | 40.44 | | 40.440 | 0.451 | | | | | | |
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|---|---|---|---|
| Station No. | | ***Downstream of the culvert*** | |
| Observation Date | | Yr: 2012 Mon: 9 Date: 10 | |
| Observer Name | Mesure | ***Ezekiel, Reuben*** | |
| | Wrote | ***Ezekiel*** | |
| Weather | Weather | :clear, :fine, :cloudy :rain | |
| | Wind blows | from Down/s, Up/s, Left, Right | |
| | Wind power | 0:None, 1:light, 2:windy, 3:strong, 4:very strong | |
| Mesurement Time (Hour, min) | Start | **2:30 PM** | |
| | End | **4:30PM** | |
| | Average | **3:30PM** | |
| Water Level at gauging station (m) | | Initial Point | No.1 Point |
| | Start | | |
| | End | | |
| | Average | | |
| Current meter | Type of current meter | Digital | |
| | Table/formula | V = 0.162 * N + 0.010 | |
| | Useing method | lods・wire・weight | |
| | | by boat / bridge / walk | |
| Calculator | Calculator | | |
| | Checker | | |
| Result | Total Discharge (m$^3$/s) | **2.13** | |
| | Total area cross section(m$^2$) | **3.29** | |
| | Average Velocity(m/s) | **0.65** | |

Notes

| | |
|---|---|
| Catchment Area (km$^2$)= | 35.0 |
| Discharge (m$^3$/s)= | 2.13 |
| Specific Discharge (m$^3$/s*100km$^2$)= | 6.09 |

Remark:

**There was rain the previous night OF 9TH sep 2012**

# Observation Sheets on 11 September 2012

***JICA Expert Team*** (Field Notebook of Discharge Observation)

FIELD WORKS

| No. of measure-ment | Distance from bank (m) | Depth of Water. (m) | | | Velocity Mesurement (Flow speed) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | First (one way) | Second (return) | Average | Depth of observation(m) | Count of current meter | | Time in seconds 1st | 2nd | Average |
| 1 | 0 | 0.00 | 0.00 | 0.000 | | | | | | |
| 2 | 1 | 0.39 | 0.40 | 0.395 | 0.237 | 100 | =(10 x 10) | 19.93 | | 19.930 |
| | | | | | 0.237 | 120 | =(10 x 12) | 23.36 | | 23.360 |
| 3 | 2 | 0.42 | 0.44 | 0.430 | | | | | | |
| 4 | 3 | 0.47 | 0.48 | 0.475 | 0.285 | 100 | =(10 x 10) | 26.64 | | 26.640 |
| | | | | | 0.285 | 120 | =(10 x 12) | 32.63 | | 32.630 |
| 5 | 4 | 0.40 | 0.45 | 0.425 | | | | | | |
| 6 | 5 | 0.36 | 0.37 | 0.365 | 0.219 | 90 | =(10 x 9) | 27.36 | | 27.360 |
| | | | | | 0.219 | 110 | =(10 x 11) | 32.38 | | 32.380 |
| 7 | 6 | 0.32 | 0.34 | 0.330 | | | | | | |
| 8 | 7 | 0.34 | 0.33 | 0.335 | 0.201 | 90 | =(10 x 9) | 28.09 | | 28.090 |
| | | | | | 0.201 | 100 | =(10 x 10) | 28.50 | | 28.500 |
| 9 | 8 | 0.33 | 0.34 | 0.335 | | | | | | |
| 10 | 9 | 0.00 | 0.00 | 0.000 | 0.000 | 100 | =(10 x 10) | 26.06 | | 26.060 |
| | | | | | 0.000 | 120 | =(10 x 12) | 30.46 | | 30.460 |
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HOME WORKS

| Velocity | | Area of cross section | | | | Disch-arge |
|---|---|---|---|---|---|---|
| Mesu. Veloc. at point(m/s) | Mean meas. Veloc.in vert(m/s) | Average depth(m) | Width of section(m) | Area of Section($m^2$) | Total Area($m^2$) | ($m^3/s$) |
| | | 0.20 | 1.00 | 0.20 | | |
| 0.823 | 0.833 | | | | 0.61 | 0.51 |
| 0.842 | | 0.41 | 1.00 | 0.41 | | |
| | | | | | | |
| | | 0.45 | 1.00 | 0.45 | | |
| 0.618 | 0.612 | | | | 0.90 | 0.55 |
| 0.606 | | 0.45 | 1.00 | 0.45 | | |
| | | | | | | |
| | | 0.40 | 1.00 | 0.40 | | |
| 0.543 | 0.552 | | | | 0.75 | 0.41 |
| 0.560 | | 0.35 | 1.00 | 0.35 | | |
| | | | | | | |
| | | 0.33 | 1.00 | 0.33 | | |
| 0.529 | 0.554 | | | | 0.67 | 0.37 |
| 0.578 | | 0.34 | 1.00 | 0.34 | | |
| | | | | | | |
| | | 0.17 | 1.00 | 0.17 | | |
| 0.632 | 0.640 | | | | 0.17 | 0.11 |
| 0.648 | | | | | | |

| | | | |
|---|---|---|---|
| Station No. | | ***Downstream of the culvert*** | |
| Observation Date | | Yr: 2012 Mon: 9 | Date: 11 |
| Observer Name | Mesure | ***Ezekiel, Reuben*** | |
| | Wrote | ***Ezekiel*** | |
| Weather | Weather | :clear, :fine, :cloudy :rain | |
| | Wind blows | from Down/s, Up/s, Left, Right | |
| | Wind power | 0:None, 1:light, 2:windy, 3:strong, 4:very strong | |
| Mesurement Time (Hour, min) | Start | **10:30 AM** | |
| | End | **12:00PM** | |
| | Average | **11:15Am** | |
| Water Level at gauging station (m) | | Initial Point | No.1 Point |
| | Start | | |
| | End | | |
| | Average | | |
| Current meter | Type of current meter | Digital | |
| | Table/formula | V = 0.162 * N + 0.010 | |
| | Useing method | lods・wire・weight | |
| | | by boat / bridge / walk | |
| Calculator | Calculator | | |
| | Checker | | |
| Result | Total Discharge ($m^3/s$) | **1.95** | |
| | Total area cross section($m^2$) | **3.10** | |
| | Average Velocity(m/s) | **0.63** | |

Notes

| | |
|---|---|
| Catchment Area ($km^2$)= | **35.0** |
| Discharge ($m^3/s$)= | **1.95** |
| Specific Discharge ($m^3/s*100km^2$)= | **5.57** |

Remark:

**THERE WAS HEAVY RAIN THE PREVIOUS NIGHT-10TH 09-2012**

***JICA Expert Team*** (Field Notebook of Discharge Observation)

| FIELD WORKS | | | | | | | | | | | HOME WORKS | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of measure-ment | Distance from bank (m) | Depth of Water. (m) | | | Velocity Mesurement (Flow speed) | | | | | | Velocity | | Area of cross section | | | | Disch-arge (m$^3$/s) |
| | | First (one way) | Second (return) | Average | Depth of observation(m) | Count of current meter | | Time in seconds 1st | 2nd | Average | Mesu. Veloc. at point(m/s) | Mean meas. Veloc.in vert(m/s) | Average depth(m) | Width of section(m) | Area of Section(m$^2$) | Total Area(m$^2$) | |
| 1 | 0 | 0.00 | 0.00 | 0.000 | | | | | | | | | 0.18 | 1.00 | 0.18 | | |
| 2 | 1 | 0.36 | 0.37 | 0.365 | 0.219 | 100 | =(10 x 10) | 16.27 | | 16.270 | 1.006 | 1.002 | | | | 0.56 | 0.56 |
| | | | | | 0.219 | 120 | =(10 x 12) | 19.68 | | 19.680 | 0.998 | | 0.38 | 1.00 | 0.38 | | |
| 3 | 2 | 0.40 | 0.40 | 0.400 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.44 | 1.00 | 0.44 | | |
| 4 | 3 | 0.48 | 0.47 | 0.475 | 0.285 | 90 | =(10 x 9) | 18.61 | | 18.610 | 0.793 | 0.778 | | | | 0.88 | 0.68 |
| | | | | | 0.285 | 100 | =(10 x 10) | 21.53 | | 21.530 | 0.762 | | 0.44 | 1.00 | 0.44 | | |
| 5 | 4 | 0.40 | 0.40 | 0.400 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.38 | 1.00 | 0.38 | | |
| 6 | 5 | 0.35 | 0.36 | 0.355 | 0.213 | 90 | =(10 x 9) | 26.41 | | 26.410 | 0.562 | 0.546 | | | | 0.71 | 0.39 |
| | | | | | 0.213 | 110 | =(10 x 11) | 34.31 | | 34.310 | 0.529 | | 0.33 | 1.00 | 0.33 | | |
| 7 | 6 | 0.30 | 0.31 | 0.305 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.32 | 1.00 | 0.32 | | |
| 8 | 7 | 0.32 | 0.34 | 0.330 | 0.198 | 90 | =(10 x 9) | 31.49 | | 31.490 | 0.473 | 0.487 | | | | 0.66 | 0.32 |
| | | | | | 0.198 | 100 | =(10 x 10) | 33.00 | | 33.000 | 0.501 | | 0.34 | 1.00 | 0.34 | | |
| 9 | 8 | 0.35 | 0.34 | 0.345 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.17 | 1.00 | 0.17 | | |
| 10 | 9 | 0.00 | 0.00 | 0.000 | 0.000 | 90 | =(10 x 9) | 32.05 | | 32.050 | 0.465 | 0.474 | | | | 0.17 | 0.08 |
| | | | | | 0.000 | 100 | =(10 x 10) | 34.27 | | 34.270 | 0.483 | | | | | | |
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|---|---|---|---|
| Station No. | | ***Downstream of the culvert*** | |
| Observation Date | | Yr: 2012 Mon: 9 Date: 11 | |
| Observer Name | Mesure | ***Ezekiel, Reuben*** | |
| | Wrote | ***Ezekiel*** | |
| Weather | Weather | :clear, :fine, :cloudy :rain | |
| | Wind blows | from Down/s, Up/s, Left, Right | |
| | Wind power | 0:None, 1:light, 2:windy, 3:strong, 4:very strong | |
| Mesurement Time (Hour, min) | Start | **2:30 PM** | |
| | End | **4:30PM** | |
| | Average | **3:30PM** | |
| Water Level at gauging station (m) | | Initial Point | No.1 Point |
| | Start | | |
| | End | | |
| | Average | | |
| Current meter | Type of current meter | Digital | |
| | Table/formula | V = 0.162 * N + 0.010 | |
| | Useing method | lods · wire · weight | |
| | | by boat / bridge / walk | |
| Calculator | Calculator | | |
| | Checker | | |
| Result | Total Discharge (m$^3$/s) | **2.03** | |
| | Total area cross section(m$^2$) | **2.98** | |
| | Average Velocity（m/s） | **0.68** | |

Notes

Catchment Area (km$^2$)= **35.0**
Discharge (m$^3$/s)= **2.03**
Specific Discharge (m$^3$/s*100km$^2$)= **5.80**

Remark:

**There was rain the previous night**

## Observation Sheets on 12 September 2012

***JICA Expert Team*** (Field Notebook of Discharge Observation)

| FIELD WORKS | | | | | | | | | | | HOME WORKS | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of measure-ment | Distance from bank (m) | Depth of Water. (m) | | | Velocity Mesurement (Flow speed) | | | | | | Velocity | | Area of cross section | | | | Disch-arge ($m^3$/s) |
| | | First (one way) | Second (return) | Average | Depth of observation(m) | Count of current meter | | Time in seconds | | | Mesu. Veloc. at point(m/s) | Mean meas. Veloc.in vert(m/s) | Average depth(m) | Width of section(m) | Area of Section($m^2$) | Total Area($m^2$) | |
| | | | | | | | | 1st | 2nd | Average | | | | | | | |
| 1 | 0 | 0.00 | 0.00 | 0.000 | | | | | | | | | 0.19 | 1.00 | 0.19 | | |
| 2 | 1 | 0.35 | 0.39 | 0.370 | 0.222 | 100 | =(10 x 10) | 20.36 | | 20.360 | 0.806 | 0.779 | | | | 0.58 | 0.45 |
| | | | | | 0.222 | 120 | =(10 x 12) | 26.23 | | 26.230 | 0.751 | | 0.39 | 1.00 | 0.39 | | |
| 3 | 2 | 0.40 | 0.41 | 0.405 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.44 | 1.00 | 0.44 | | |
| 4 | 3 | 0.46 | 0.47 | 0.465 | 0.279 | 100 | =(10 x 10) | 23.11 | | 23.110 | 0.711 | 0.716 | | | | 0.88 | 0.63 |
| | | | | | 0.279 | 110 | =(10 x 11) | 25.10 | | 25.100 | 0.720 | | 0.44 | 1.00 | 0.44 | | |
| 5 | 4 | 0.40 | 0.42 | 0.410 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.36 | 1.00 | 0.36 | | |
| 6 | 5 | 0.30 | 0.32 | 0.310 | 0.186 | 90 | =(10 x 9) | 22.58 | | 22.580 | 0.656 | 0.659 | | | | 0.67 | 0.44 |
| | | | | | 0.186 | 100 | =(10 x 10) | 24.90 | | 24.900 | 0.661 | | 0.31 | 1.00 | 0.31 | | |
| 7 | 6 | 0.30 | 0.32 | 0.310 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.33 | 1.00 | 0.33 | | |
| 8 | 7 | 0.33 | 0.35 | 0.340 | 0.204 | 80 | =(10 x 8) | 25.09 | | 25.090 | 0.527 | 0.552 | | | | 0.67 | 0.37 |
| | | | | | 0.204 | 110 | =(10 x 11) | 31.48 | | 31.480 | 0.576 | | 0.34 | 1.00 | 0.34 | | |
| 9 | 8 | 0.33 | 0.36 | 0.345 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.17 | 1.00 | 0.17 | | |
| 10 | 9 | 0.00 | 0.00 | 0.000 | 0.000 | 90 | =(10 x 9) | 15.21 | | 15.210 | 0.969 | 0.891 | | | | 0.17 | 0.15 |
| | | | | | 0.000 | 100 | =(10 x 10) | 20.18 | | 20.180 | 0.813 | | | | | | |
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|---|---|---|---|---|
| Station No. | | ***Downstream of the culvert*** | | |
| Observation Date | | Yr: 2012 | Mon: 9 | Date: 12 |
| Observer Name | Mesure | ***Ezekiel, Reuben*** | | |
| | Wrote | ***Ezekiel*** | | |
| Weather | Weather | :clear, :fine, :cloudy :rain | | |
| | Wind blows | from Down/s, Up/s, Left, Right | | |
| | Wind power | 0:None, 1:light, 2:windy, 3:strong, 4:very strong | | |
| Mesurement Time (Hour, min) | Start | **10:30 AM** | | |
| | End | **12:00PM** | | |
| | Average | **11:15Am** | | |
| Water Level at gauging station (m) | | Initial Point | No.1 Point | |
| | Start | | | |
| | End | | | |
| | Average | | | |
| Current meter | Type of current meter | Digital | | |
| | Table/formula | V = 0.162 * N + 0.010 | | |
| | Useing method | lods・wire・weight<br>by boat / bridge / walk | | |
| Calculator | Calculator | | | |
| | Checker | | | |
| Result | Total Discharge ($m^3$/s) | **2.04** | | |
| | Total area cross section($m^2$) | **2.97** | | |
| | Average Velocity(m/s) | **0.69** | | |

Notes

| | |
|---|---|
| Catchment Area ($km^2$)= | **35.0** |
| Discharge ($m^3$/s)= | **2.04** |
| Specific Discharge ($m^3$/s*100$km^2$)= | **5.83** |

Remark:

**THERE WAS HEAVY RAIN THE PREVIOUS NIGHT-11TH 09-2012**

***JICA Expert Team*** (Field Notebook of Discharge Observation)

| FIELD WORKS | | | | | | | | | | | HOME WORKS | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of measure-ment | Distance from bank (m) | Depth of Water. (m) | | | Velocity Mesurement (Flow speed) | | | | | | Velocity | | Area of cross section | | | | Disch-arge ($m^3/s$) |
| | | First (one way) | Second (return) | Average | Depth of observation(m) | Count of current meter | | Time in seconds | | | Mesu. Veloc. at point(m/s) | Mean meas. Veloc.in vert(m/s) | Average depth(m) | Width of section(m) | Area of Section($m^2$) | Total Area($m^2$) | |
| | | | | | | | | 1st | 2nd | Average | | | | | | | |
| 1 | 0 | 0.00 | 0.00 | 0.000 | | | | | | | | | 0.18 | 1.00 | 0.18 | 0.58 | 0.33 |
| 2 | 1 | 0.35 | 0.36 | 0.355 | 0.213 | 100 | =(10 x 10) | 27.44 | | 27.440 | 0.600 | 0.575 | | | | | |
| | | | | | 0.213 | 110 | =(10 x 11) | 33.02 | | 33.020 | 0.550 | | 0.40 | 1.00 | 0.40 | | |
| 3 | 2 | 0.43 | 0.44 | 0.435 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.45 | 1.00 | 0.45 | 0.88 | 0.55 |
| 4 | 3 | 0.45 | 0.46 | 0.455 | 0.273 | 100 | =(10 x 10) | 26.27 | | 26.270 | 0.627 | 0.627 | | | | | |
| | | | | | 0.273 | 110 | =(10 x 11) | 28.93 | | 28.930 | 0.626 | | 0.43 | 1.00 | 0.43 | | |
| 5 | 4 | 0.40 | 0.41 | 0.405 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.38 | 1.00 | 0.38 | 0.70 | 0.27 |
| 6 | 5 | 0.34 | 0.35 | 0.345 | 0.207 | 90 | =(10 x 9) | 37.32 | | 37.320 | 0.401 | 0.386 | | | | | |
| | | | | | 0.207 | 100 | =(10 x 10) | 44.91 | | 44.910 | 0.371 | | 0.32 | 1.00 | 0.32 | | |
| 7 | 6 | 0.30 | 0.30 | 0.300 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.31 | 1.00 | 0.31 | 0.64 | 0.35 |
| 8 | 7 | 0.32 | 0.33 | 0.325 | 0.195 | 80 | =(10 x 8) | 24.36 | | 24.360 | 0.542 | 0.542 | | | | | |
| | | | | | 0.195 | 110 | =(10 x 11) | 33.49 | | 33.490 | 0.542 | | 0.33 | 1.00 | 0.33 | | |
| 9 | 8 | 0.31 | 0.35 | 0.330 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.17 | 1.00 | 0.17 | 0.17 | 0.08 |
| 10 | 9 | 0.00 | 0.00 | 0.000 | 0.000 | 90 | =(10 x 9) | 29.55 | | 29.550 | 0.503 | 0.489 | | | | | |
| | | | | | 0.000 | 100 | =(10 x 10) | 34.90 | | 34.900 | 0.474 | | | | | | |
| 11 | | | | | | | | | | | | | | | | | |
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|---|---|---|---|---|
| Station No. | | ***Downstream of the culvert*** | | |
| Observation Date | | Yr: 2012 | Mon: 9 | Date: 12 |
| Observer Name | Mesure | ***Ezekiel, Reuben*** | | |
| | Wrote | ***Ezekiel*** | | |
| Weather | Weather | :clear, :fine, :cloudy :rain | | |
| | Wind blows | from Down/s, Up/s, Left, Right | | |
| | Wind power | 0:None, 1:light, 2:windy, 3:strong, 4:very strong | | |
| Mesurement Time (Hour, min) | Start | **2:30 PM** | | |
| | End | **4:30PM** | | |
| | Average | **3:30PM** | | |
| Water Level at gauging station (m) | | Initial Point | No.1 Point | |
| | Start | | | |
| | End | | | |
| | Average | | | |
| Current meter | Type of current meter | Digital | | |
| | Table/formula | V = 0.162 * N + 0.010 | | |
| | Useing method | lods · wire · weight | | |
| | | by boat / bridge / walk | | |
| Calculator | Calculator | | | |
| | Checker | | | |
| Result | Total Discharge ($m^3/s$) | **1.58** | | |
| | Total area cross section($m^2$) | **2.97** | | |
| | Average Velocity(m/s) | **0.53** | | |

Notes

Catchment Area ($km^2$)= **35.0**
Discharge ($m^3/s$)= **1.58**
Specific Discharge ($m^3/s*100km^2$)= **4.51**

Remark:

**There was rain the previous night**

## Observation Sheets on 23 September 2012

***JICA Expert Team*** (Field Notebook of Discharge Observation)

FIELD WORKS

| No. of measure-ment | Distance from bank (m) | Depth of Water. (m) First (one way) | Second (return) | Average | Velocity Mesurement (Flow speed) Depth of observation(m) | Count of current meter | | Time in seconds 1st | 2nd | Average |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0.00 | 0.00 | 0.000 | | | | | | |
| 2 | 1 | 0.32 | 0.33 | 0.325 | 0.195 | 100 | =(10 x 10) | 20.55 | | 20.550 |
| | | | | | 0.195 | 110 | =(10 x 11) | 22.48 | | 22.480 |
| 3 | 2 | 0.37 | 0.38 | 0.375 | | | | | | |
| 4 | 3 | 0.41 | 0.43 | 0.420 | 0.252 | 90 | =(10 x 9) | 25.19 | | 25.190 |
| | | | | | 0.252 | 100 | =(10 x 10) | 26.17 | | 26.170 |
| 5 | 4 | 0.36 | 0.40 | 0.380 | | | | | | |
| 6 | 5 | 0.32 | 0.35 | 0.335 | 0.201 | 100 | =(10 x 10) | 33.59 | | 33.590 |
| | | | | | 0.201 | 110 | =(10 x 11) | 36.17 | | 36.170 |
| 7 | 6 | 0.23 | 0.24 | 0.235 | | | | | | |
| 8 | 7 | 0.25 | 0.27 | 0.260 | 0.156 | 100 | =(10 x 10) | 43.77 | | 43.770 |
| | | | | | 0.156 | 110 | =(10 x 11) | 52.00 | | 52.000 |
| 9 | 8 | 0.27 | 0.29 | 0.280 | | | | | | |
| 10 | 9 | 0.00 | 0.00 | 0.000 | 0.000 | 90 | =(10 x 9) | 42.79 | | 42.790 |
| | | | | | 0.000 | 100 | =(10 x 10) | 46.30 | | 46.300 |
| 11 | | | | | | | | | | |
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HOME WORKS

| Velocity Mesu. Veloc. at point(m/s) | Mean meas. Veloc.in vert(m/s) | Area of cross section Total Area($m^2$) | Disch-arge ($m^3$/s) |
|---|---|---|---|
| 0.798 | 0.801 | 0.51 | 0.41 |
| 0.803 | | | |
| 0.589 | 0.609 | 0.80 | 0.49 |
| 0.629 | | | |
| 0.492 | 0.498 | 0.65 | 0.32 |
| 0.503 | | | |
| 0.380 | 0.367 | 0.52 | 0.19 |
| 0.353 | | | |
| 0.351 | 0.356 | 0.14 | 0.05 |
| 0.360 | | | |

| Average depth(m) | Width of section(m | Area of Section($m^2$) |
|---|---|---|
| 0.16 | 1.00 | 0.16 |
| 0.35 | 1.00 | 0.35 |
| 0.40 | 1.00 | 0.40 |
| 0.40 | 1.00 | 0.40 |
| 0.36 | 1.00 | 0.36 |
| 0.29 | 1.00 | 0.29 |
| 0.25 | 1.00 | 0.25 |
| 0.27 | 1.00 | 0.27 |
| 0.14 | 1.00 | 0.14 |

| | | | |
|---|---|---|---|
| Station No. | | ***Downstream of the culvert*** | |
| Observation Date | | Yr: 2012 Mon: 9 | Date: 23 |
| Observer Name | Mesure | ***Ezekiel, Reuben*** | |
| | Wrote | ***Ezekiel*** | |
| Weather | Weather | :clear, :fine, :cloudy :rain | |
| | Wind blows | from Down/s, Up/s, Left, Right | |
| | Wind power | 0:None, 1:light, 2:windy, 3:strong, 4:very strong | |
| Mesurement Time (Hour, min) | Start | **10:30 AM** | |
| | End | **12:00PM** | |
| | Average | **11:15Am** | |
| Water Level at gauging station (m) | | Initial Point | No.1 Point |
| | Start | | |
| | End | | |
| | Average | | |
| Current meter | Type of current meter | Digital | |
| | Table/formula | V = 0.162 * N + 0.010 | |
| | Useing method | lods・wire・weight | |
| | | by boat / bridge / walk | |
| Calculator | Calculator | | |
| | Checker | | |
| Result | Total Discharge ($m^3$/s) | **1.46** | |
| | Total area cross section($m^2$) | **2.62** | |
| | Average Velocity（m/s） | **0.56** | |

Notes

| | |
|---|---|
| Catchment Area ($km^2$)= | **35.0** |
| Discharge ($m^3$/s)= | **1.46** |
| Specific Discharge ($m^3$/s*100$km^2$)= | **4.17** |

Remark:

***JICA Expert Team*** (Field Notebook of Discharge Observation)

FIELD WORKS

| No. of measure-ment | Distance from bank (m) | Depth of Water. (m) |  |  | Velocity Mesurement (Flow speed) |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  |  | First (one way) | Second (return) | Average | Depth of observation(m) | Count of current meter |  | Time in seconds |  |  |
|  |  |  |  |  |  |  |  | 1st | 2nd | Average |
| 1 | 0 | 0.00 | 0.00 | 0.000 |  |  |  |  |  |  |
| 2 | 1 | 0.34 | 0.37 | 0.355 | 0.213 | 100 | =(10 x 10) | 31.72 |  | 31.720 |
|  |  |  |  |  | 0.213 | 110 | =(10 x 11) | 36.92 |  | 36.920 |
| 3 | 2 | 0.35 | 0.37 | 0.360 |  |  |  |  |  |  |
| 4 | 3 | 0.38 | 0.40 | 0.390 | 0.234 | 100 | =(10 x 10) | 26.30 |  | 26.300 |
|  |  |  |  |  | 0.234 | 110 | =(10 x 11) | 30.44 |  | 30.440 |
| 5 | 4 | 0.37 | 0.39 | 0.380 |  |  |  |  |  |  |
| 6 | 5 | 0.30 | 0.32 | 0.310 | 0.186 | 90 | =(10 x 9) | 25.55 |  | 25.550 |
|  |  |  |  |  | 0.186 | 120 | =(10 x 12) | 33.84 |  | 33.840 |
| 7 | 6 | 0.25 | 0.25 | 0.250 |  |  |  |  |  |  |
| 8 | 7 | 0.25 | 0.27 | 0.260 | 0.156 | 100 | =(10 x 10) | 31.55 |  | 31.550 |
|  |  |  |  |  | 0.156 | 110 | =(10 x 11) | 35.02 |  | 35.020 |
| 9 | 8 | 0.23 | 0.25 | 0.240 |  |  |  |  |  |  |
| 10 | 9 | 0.00 | 0.00 | 0.000 | 0.000 | 100 | =(10 x 10) | 21.10 |  | 21.100 |
|  |  |  |  |  | 0.000 | 110 | =(10 x 11) | 23.00 |  | 23.000 |
| 11 |  |  |  |  |  |  |  |  |  |  |
| 12 |  |  |  |  |  |  |  |  |  |  |
| 13 |  |  |  |  |  |  |  |  |  |  |
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| 20 |  |  |  |  |  |  |  |  |  |  |

HOME WORKS

| Velocity |  | Area of cross section |  |  |  | Disch-arge |
|---|---|---|---|---|---|---|
| Mesu. Veloc. at point(m/s) | Mean meas. Veloc.in vert(m/s) | Average depth(m) | Width of section(m) | Area of Section($m^2$) | Total Area($m^2$) | ($m^3$/s) |
|  |  | 0.18 | 1.00 | 0.18 |  |  |
| 0.521 | 0.507 |  |  |  | 0.54 | 0.27 |
| 0.493 |  | 0.36 | 1.00 | 0.36 |  |  |
|  |  |  |  |  |  |  |
|  |  | 0.38 | 1.00 | 0.38 |  |  |
| 0.626 | 0.611 |  |  |  | 0.77 | 0.47 |
| 0.595 |  | 0.39 | 1.00 | 0.39 |  |  |
|  |  |  |  |  |  |  |
|  |  | 0.35 | 1.00 | 0.35 |  |  |
| 0.581 | 0.583 |  |  |  | 0.63 | 0.37 |
| 0.584 |  | 0.28 | 1.00 | 0.28 |  |  |
|  |  |  |  |  |  |  |
|  |  | 0.26 | 1.00 | 0.26 |  |  |
| 0.523 | 0.521 |  |  |  | 0.51 | 0.27 |
| 0.519 |  | 0.25 | 1.00 | 0.25 |  |  |
|  |  |  |  |  |  |  |
|  |  | 0.12 | 1.00 | 0.12 |  |  |
| 0.778 | 0.782 |  |  |  | 0.12 | 0.09 |
| 0.785 |  |  |  |  |  |  |

|  |  |  |  |  |
|---|---|---|---|---|
| Station No. |  | ***Downstream of the culvert*** |  |  |
| Observation Date |  | Yr: 2012 | Mon: 9 | Date: 23 |
| Observer Name | Mesure | ***Ezekiel, Reuben*** |  |  |
|  | Wrote | ***Ezekiel*** |  |  |
| Weather | Weather | :clear, :fine, :cloudy :rain |  |  |
|  | Wind blows | from Down/s, Up/s, Left, Right |  |  |
|  | Wind power | 0:None, 1:light, 2:windy, 3:strong, 4:very strong |  |  |
| Mesurement Time (Hour, min) | Start | **2:30 PM** |  |  |
|  | End | **4:30PM** |  |  |
|  | Average | **3:30PM** |  |  |
| Water Level at gauging station (m) |  | Initial Point | No.1 Point |  |
|  | Start |  |  |  |
|  | End |  |  |  |
|  | Average |  |  |  |
| Current meter | Type of current meter | Digital |  |  |
|  | Table/formula | V = 0.162 * N + 0.010 |  |  |
|  | Useing method | lods · wire · weight |  |  |
|  |  | by boat / bridge / walk |  |  |
| Calculator | Calculator |  |  |  |
|  | Checker |  |  |  |
| Result | Total Discharge ($m^3$/s) | **1.47** |  |  |
|  | Total area cross section($m^2$) | **2.57** |  |  |
|  | Average Velocity(m/s) | **0.57** |  |  |

Notes

| | |
|---|---|
| Catchment Area ($km^2$)= | **35.0** |
| Discharge ($m^3$/s)= | **1.47** |
| Specific Discharge ($m^3$/s*100$km^2$)= | **4.20** |

Remark:

**There was rain the previous night**

# Observation Sheets on 24 September 2012

***JICA Expert Team*** (Field Notebook of Discharge Observation)

| FIELD WORKS | | | | | | | | | | | HOME WORKS | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of measure-ment | Distance from bank (m) | Depth of Water. (m) | | | Velocity Mesurement (Flow speed) | | | | | | Velocity | | Area of cross section | | | | Disch-arge (m³/s) |
| | | First (one way) | Second (return) | Average | Depth of observation(m) | Count of current meter | | Time in seconds | | | Mesu. Veloc. at point(m/s) | Mean meas. Veloc.in vert(m/s) | Average depth(m) | Width of section(m | Area of Section(m²) | Total Area(m²) | |
| | | | | | | | | 1st | 2nd | Average | | | | | | | |
| 1 | 0 | 0.00 | 0.00 | 0.000 | | | | | | | | | 0.17 | 1.00 | 0.17 | | |
| 2 | 1 | 0.34 | 0.34 | 0.340 | 0.204 | 100 | =(10 x 10) | 23.59 | | 23.590 | 0.697 | 0.654 | | | | 0.54 | 0.35 |
| | | | | | 0.204 | 100 | =(10 x 10) | 26.99 | | 26.990 | 0.610 | | 0.37 | 1.00 | 0.37 | | |
| 3 | 2 | 0.38 | 0.40 | 0.390 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.40 | 1.00 | 0.40 | | |
| 4 | 3 | 0.38 | 0.42 | 0.400 | 0.240 | 90 | =(10 x 9) | 19.48 | | 19.480 | 0.758 | 0.748 | | | | 0.80 | 0.60 |
| | | | | | 0.240 | 130 | =(10 x 13) | 28.94 | | 28.940 | 0.738 | | 0.40 | 1.00 | 0.40 | | |
| 5 | 4 | 0.38 | 0.40 | 0.390 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.35 | 1.00 | 0.35 | | |
| 6 | 5 | 0.29 | 0.33 | 0.310 | 0.186 | 100 | =(10 x 10) | 28.39 | | 28.390 | 0.581 | 0.587 | | | | 0.63 | 0.37 |
| | | | | | 0.186 | 120 | =(10 x 12) | 33.34 | | 33.340 | 0.593 | | 0.28 | 1.00 | 0.28 | | |
| 7 | 6 | 0.24 | 0.27 | 0.255 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.25 | 1.00 | 0.25 | | |
| 8 | 7 | 0.23 | 0.27 | 0.250 | 0.150 | 100 | =(10 x 10) | 28.90 | | 28.900 | 0.571 | 0.557 | | | | 0.52 | 0.29 |
| | | | | | 0.150 | 110 | =(10 x 11) | 33.48 | | 33.480 | 0.542 | | 0.27 | 1.00 | 0.27 | | |
| 9 | 8 | 0.29 | 0.30 | 0.295 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | 0.15 | 1.00 | 0.15 | | |
| 10 | 9 | 0.00 | 0.00 | 0.000 | 0.000 | 100 | =(10 x 10) | 26.83 | | 26.830 | 0.614 | 0.610 | | | | 0.15 | 0.09 |
| | | | | | 0.000 | 120 | =(10 x 12) | 32.63 | | 32.630 | 0.606 | | | | | | |
| 11 | | | | | | | | | | | | | | | | | |
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|---|---|---|---|---|
| Station No. | | *Downstream of the culvert* | | |
| Observation Date | | Yr: 2012 | Mon: 9 | Date: 24 |
| Observer Name | Mesure | ***Ezekiel, Reuben*** | | |
| | Wrote | ***Ezekiel*** | | |
| Weather | Weather | :clear, :fine, :cloudy :rain | | |
| | Wind blows | from Down/s, Up/s, Left, Right | | |
| | Wind power | 0:None, 1:light, 2:windy, 3:strong, 4:very strong | | |
| Mesurement Time (Hour, min) | Start | **10:30 AM** | | |
| | End | **12:00PM** | | |
| | Average | **11:15Am** | | |
| Water Level at gauging station (m) | | Initial Point | No.1 Point | |
| | Start | | | |
| | End | | | |
| | Average | | | |
| Current meter | Type of current meter | Digital | | |
| | Table/formula | V = 0.162 * N + 0.010 | | |
| | Useing method | lods・wire・weight | | |
| | | by boat / bridge / walk | | |
| Calculator | Calculator | | | |
| | Checker | | | |
| Result | Total Discharge ($m^3/s$) | **1.70** | | |
| | Total area cross section($m^2$) | **2.64** | | |
| | Average Velocity(m/s) | **0.64** | | |

Notes

Catchment Area ($km^2$)= **35.0**

Discharge ($m^3/s$)= **1.70**

Specific Discharge ($m^3/s*100km^2$)= **4.86**

Remark:

**THERE WAS HEAVY RAIN THE PREVIOUS NIGHT-23$^{RD}$- 09-2012**

**JICA Expert Team** (Field Notebook of Discharge Observation)

| FIELD WORKS | | | | | | | | | | | HOME WORKS | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of measure-ment | Distance from bank (m) | Depth of Water. (m) | | | Velocity Mesurement (Flow speed) | | | | | | Velocity | | Area of cross section | Disch-arge |
| | | First (one way) | Second (return) | Average | Depth of observation(m) | Count of current meter | | Time in seconds | | | Mesu. Veloc. at point(m/s) | Mean meas. Veloc.in vert(m/s) | Total Area(m$^2$) | (m$^3$/s) |
| | | | | | | | | 1st | 2nd | Average | | | | |
| 1 | 0 | 0.00 | 0.00 | 0.000 | | | | | | | | | | |
| 2 | 1 | 0.32 | 0.34 | 0.330 | 0.198 | 100 | =(10 x 10) | 22.51 | | 22.510 | 0.730 | 0.731 | 0.53 | 0.39 |
| | | | | | 0.198 | 110 | =(10 x 11) | 24.72 | | 24.720 | 0.731 | | | |
| 3 | 2 | 0.39 | 0.39 | 0.390 | | | | | | | | | | |
| 4 | 3 | 0.41 | 0.45 | 0.430 | 0.258 | 90 | =(10 x 9) | 21.24 | | 21.240 | 0.696 | 0.716 | 0.80 | 0.57 |
| | | | | | 0.258 | 120 | =(10 x 12) | 26.82 | | 26.820 | 0.735 | | | |
| 5 | 4 | 0.34 | 0.36 | 0.350 | | | | | | | | | | |
| 6 | 5 | 0.28 | 0.30 | 0.290 | 0.174 | 100 | =(10 x 10) | 28.43 | | 28.430 | 0.580 | 0.589 | 0.59 | 0.35 |
| | | | | | 0.174 | 120 | =(10 x 12) | 33.04 | | 33.040 | 0.598 | | | |
| 7 | 6 | 0.24 | 0.26 | 0.250 | | | | | | | | | | |
| 8 | 7 | 0.26 | 0.28 | 0.270 | 0.162 | 100 | =(10 x 10) | 32.41 | | 32.410 | 0.510 | 0.496 | 0.54 | 0.27 |
| | | | | | 0.162 | 120 | =(10 x 12) | 41.16 | | 41.160 | 0.482 | | | |
| 9 | 8 | 0.26 | 0.31 | 0.285 | | | | | | | | | | |
| 10 | 9 | 0.00 | 0.00 | 0.000 | 0.000 | 90 | =(10 x 9) | 25.27 | | 25.270 | 0.587 | 0.594 | 0.14 | 0.08 |
| | | | | | 0.000 | 100 | =(10 x 10) | 27.39 | | 27.390 | 0.601 | | | |
| 11 | | | | | | | | | | | | | | |
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| Area of cross section | | |
|---|---|---|
| Average depth(m) | Width of section(m) | Area of Section(m$^2$) |
| 0.17 | 1.00 | 0.17 |
| 0.36 | 1.00 | 0.36 |
| 0.41 | 1.00 | 0.41 |
| 0.39 | 1.00 | 0.39 |
| 0.32 | 1.00 | 0.32 |
| 0.27 | 1.00 | 0.27 |
| 0.26 | 1.00 | 0.26 |
| 0.28 | 1.00 | 0.28 |
| 0.14 | 1.00 | 0.14 |
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|---|---|---|---|---|
| Station No. | | ***Downstream of the culvert*** | | |
| Observation Date | | Yr: 2012 | Mon: 9 | Date: 24 |
| Observer Name | Mesure | ***Ezekiel, Reuben*** | | |
| | Wrote | ***Ezekiel*** | | |
| Weather | Weather | :clear, :fine, :cloudy :rain | | |
| | Wind blows | from Down/s, Up/s, Left, Right | | |
| | Wind power | 0:None, 1:light, 2:windy, 3:strong, 4:very strong | | |
| Mesurement Time (Hour, min) | Start | **2:30 PM** | | |
| | End | **4:30PM** | | |
| | Average | **3:30PM** | | |
| Water Level at gauging station (m) | | Initial Point | No.1 Point | |
| | Start | | | |
| | End | | | |
| | Average | | | |
| Current meter | Type of current meter | Digital | | |
| | Table/formula | V = 0.162 * N + 0.010 | | |
| | Useing method | lods・wire・weight | | |
| | | by boat / bridge / walk | | |
| Calculator | Calculator | | | |
| | Checker | | | |
| Result | Total Discharge (m$^3$/s) | **1.66** | | |
| | Total area cross section(m$^2$) | **2.60** | | |
| | Average Velocity (m/s) | **0.64** | | |

Notes

| | |
|---|---|
| Catchment Area (km$^2$)= | **35.0** |
| Discharge (m$^3$/s)= | **1.66** |
| Specific Discharge (m$^3$/s*100km$^2$)= | **4.74** |

Remark:

**There was rain the previous night 23$^{RD}$-09-2012**

# Observation Sheets on 25 September 2012

***JICA Expert Team*** (Field Notebook of Discharge Observation)

| FIELD WORKS | | | | | | | | | | | HOME WORKS | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of measure-ment | Distance from bank (m) | Depth of Water. (m) | | | Velocity Mesurement (Flow speed) | | | | | | Velocity | |
| | | First (one way) | Second (return) | Average | Depth of observation(m) | Count of current meter | | Time in seconds | | | Mesu. Veloc. at point(m/s) | Mean meas. Veloc.in vert(m/s) |
| | | | | | | | | 1st | 2nd | Average | | |
| 1 | 0 | 0.00 | 0.00 | 0.000 | | | | | | | | |
| 2 | 1 | 0.35 | 0.35 | 0.350 | 0.210 | 100 | =(10 x 10) | 26.10 | | 26.100 | 0.631 | 0.619 |
| | | | | | 0.210 | 110 | =(10 x 11) | 29.90 | | 29.900 | 0.606 | |
| 3 | 2 | 0.40 | 0.42 | 0.410 | | | | | | | | |
| 4 | 3 | 0.42 | 0.43 | 0.425 | 0.255 | 100 | =(10 x 10) | 26.62 | | 26.620 | 0.619 | 0.626 |
| | | | | | 0.255 | 120 | =(10 x 12) | 31.25 | | 31.250 | 0.632 | |
| 5 | 4 | 0.38 | 0.40 | 0.390 | | | | | | | | |
| 6 | 5 | 0.32 | 0.36 | 0.340 | 0.204 | 100 | =(10 x 10) | 24.98 | | 24.980 | 0.659 | 0.662 |
| | | | | | 0.204 | 120 | =(10 x 12) | 29.68 | | 29.680 | 0.665 | |
| 7 | 6 | 0.25 | 0.27 | 0.260 | | | | | | | | |
| 8 | 7 | 0.25 | 0.27 | 0.260 | 0.156 | 90 | =(10 x 9) | 36.78 | | 36.780 | 0.406 | 0.394 |
| | | | | | 0.156 | 100 | =(10 x 10) | 43.65 | | 43.650 | 0.381 | |
| 9 | 8 | 0.27 | 0.29 | 0.280 | | | | | | | | |
| 10 | 9 | 0.00 | 0.00 | 0.000 | 0.000 | 100 | =(10 x 10) | 28.80 | | 28.800 | 0.573 | 0.579 |
| | | | | | 0.000 | 110 | =(10 x 11) | 31.03 | | 31.030 | 0.584 | |
| 11 | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | |

| Area of cross section | | | | Disch-arge |
|---|---|---|---|---|
| Average depth(m) | Width of section(m) | Area of Section($m^2$) | Total Area($m^2$) | ($m^3$/s) |
| 0.18 | 1.00 | 0.18 | 0.56 | 0.35 |
| 0.38 | 1.00 | 0.38 | | |
| 0.42 | 1.00 | 0.42 | 0.83 | 0.52 |
| 0.41 | 1.00 | 0.41 | | |
| 0.37 | 1.00 | 0.37 | 0.67 | 0.44 |
| 0.30 | 1.00 | 0.30 | | |
| 0.26 | 1.00 | 0.26 | 0.53 | 0.21 |
| 0.27 | 1.00 | 0.27 | | |
| 0.14 | 1.00 | 0.14 | 0.14 | 0.08 |

| | | | | |
|---|---|---|---|---|
| Station No. | | ***Downstream of the culvert*** | | |
| Observation Date | | Yr: 2012 | Mon: 9 | Date: 25 |
| Observer Name | Mesure | ***Ezekiel, Reuben*** | | |
| | Wrote | ***Ezekiel*** | | |
| Weather | Weather | :clear, :fine, :cloudy :rain | | |
| | Wind blows | from Down/s, Up/s, Left, Right | | |
| | Wind power | 0:None, 1:light, 2:windy, 3:strong, 4:very strong | | |
| Mesurement Time (Hour, min) | Start | **10:30 AM** | | |
| | End | **12:00PM** | | |
| | Average | **11:15Am** | | |
| Water Level at gauging station (m) | | Initial Point | No.1 Point | |
| | Start | | | |
| | End | | | |
| | Average | | | |
| Current meter | Type of current meter | Digital | | |
| | Table/formula | V = 0.162 * N + 0.010 | | |
| | Useing method | lods・wire・weight | | |
| | | by boat / bridge / walk | | |
| Calculator | Calculator | | | |
| | Checker | | | |
| Result | Total Discharge ($m^3$/s) | **1.60** | | |
| | Total area cross section($m^2$) | **2.73** | | |
| | Average Velocity（m/s） | **0.59** | | |

Notes

Catchment Area ($km^2$)= **35.0**

Discharge ($m^3$/s)= **1.60**

Specific Discharge ($m^3$/s*100$km^2$)= **4.57**

Remark:

**THERE WAS RAIN THE PREVIOUS NIGHT-24TH 09-2012**

***JICA Expert Team*** (Field Notebook of Discharge Observation)

FIELD WORKS

| No. of measure-ment | Distance from bank (m) | Depth of Water. (m) | | | Velocity Mesurement (Flow speed) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | First (one way) | Second (return) | Average | Depth of observation(m) | Count of current meter | | Time in seconds | | |
| | | | | | | | | 1st | 2nd | Average |
| 1 | 0 | 0.00 | 0.00 | 0.000 | | | | | | |
| 2 | 1 | 0.35 | 0.35 | 0.350 | 0.210 | 100 | =(10 x 10) | 33.47 | | 33.470 |
| | | | | | 0.210 | 110 | =(10 x 11) | 35.85 | | 35.850 |
| 3 | 2 | 0.42 | 0.43 | 0.425 | | | | | | |
| 4 | 3 | 0.43 | 0.44 | 0.435 | 0.261 | 90 | =(10 x 9) | 22.74 | | 22.740 |
| | | | | | 0.261 | 100 | =(10 x 10) | 25.16 | | 25.160 |
| 5 | 4 | 0.40 | 0.40 | 0.400 | | | | | | |
| 6 | 5 | 0.32 | 0.31 | 0.315 | 0.189 | 100 | =(10 x 10) | 24.61 | | 24.610 |
| | | | | | 0.189 | 120 | =(10 x 12) | 29.46 | | 29.460 |
| 7 | 6 | 0.27 | 0.29 | 0.280 | | | | | | |
| 8 | 7 | 0.25 | 0.26 | 0.255 | 0.153 | 90 | =(10 x 9) | 34.99 | | 34.990 |
| | | | | | 0.153 | 100 | =(10 x 10) | 37.73 | | 37.730 |
| 9 | 8 | 0.29 | 0.29 | 0.290 | | | | | | |
| 10 | 9 | 0.00 | 0.00 | 0.000 | 0.000 | 100 | =(10 x 10) | 26.45 | | 26.450 |
| | | | | | 0.000 | 110 | =(10 x 11) | 29.91 | | 29.910 |
| 11 | | | | | | | | | | |
| 12 | | | | | | | | | | |
| 13 | | | | | | | | | | |
| 14 | | | | | | | | | | |
| 15 | | | | | | | | | | |
| 16 | | | | | | | | | | |
| 17 | | | | | | | | | | |
| 18 | | | | | | | | | | |
| 19 | | | | | | | | | | |
| 20 | | | | | | | | | | |

HOME WORKS

| Velocity | | Total Area(m$^2$) | Disch-arge (m$^3$/s) |
|---|---|---|---|
| Mesu. Veloc. at point(m/s) | Mean meas. Veloc.in vert(m/s) | | |
| | | | |
| 0.494<br>0.507 | 0.501 | 0.57 | 0.29 |
| | | | |
| 0.651<br>0.654 | 0.653 | 0.85 | 0.55 |
| | | | |
| 0.668<br>0.670 | 0.669 | 0.66 | 0.44 |
| | | | |
| 0.427<br>0.439 | 0.433 | 0.54 | 0.23 |
| | | | |
| 0.622<br>0.606 | 0.614 | 0.15 | 0.09 |

| Area of cross section | | |
|---|---|---|
| Average depth(m) | Width of section(m) | Area of Section(m$^2$) |
| 0.18 | 1.00 | 0.18 |
| 0.39 | 1.00 | 0.39 |
| 0.43 | 1.00 | 0.43 |
| 0.42 | 1.00 | 0.42 |
| 0.36 | 1.00 | 0.36 |
| 0.30 | 1.00 | 0.30 |
| 0.27 | 1.00 | 0.27 |
| 0.27 | 1.00 | 0.27 |
| 0.15 | 1.00 | 0.15 |

| | | | |
|---|---|---|---|
| Station No. | | ***Downstream of the culvert*** | |
| Observation Date | | Yr: 2012 Mon: 9 Date: 25 | |
| Observer Name | Mesure | ***Ezekiel, Reuben*** | |
| | Wrote | ***Ezekiel*** | |
| Weather | Weather | :clear, :fine, :cloudy :rain | |
| | Wind blows | from Down/s, Up/s, Left, Right | |
| | Wind power | 0:None, 1:light, 2:windy, 3:strong, 4:very strong | |
| Mesurement Time (Hour, min) | Start | **2:30 PM** | |
| | End | **4:30PM** | |
| | Average | **3:30PM** | |
| Water Level at gauging station (m) | | Initial Point | No.1 Point |
| | Start | | |
| | End | | |
| | Average | | |
| Current meter | Type of current meter | Digital | |
| | Table/formula | V = 0.162 * N + 0.010 | |
| | Useing method | lods・wire・weight | |
| | | by boat / bridge / walk | |
| Calculator | Calculator | | |
| | Checker | | |
| Result | Total Discharge (m$^3$/s) | **1.60** | |
| | Total area cross section(m$^2$) | **2.77** | |
| | Average Velocity（m/s） | **0.58** | |

Notes

Catchment Area (km$^2$)= **35.0**

Discharge (m$^3$/s)= **1.60**

Specific Discharge (m$^3$/s*100km$^2$)= **4.57**

Remark:

**There was rain the previous night**

## Observation Sheets on 30 January 2014

(Field Notebook of Discharge Observation)

FIELD WORKS

| No. of measure-ment | Distance from bank (m) | Depth of Water. (m) First (one way) | Depth of Water. (m) Second (return) | Depth of Water. (m) Average | Velocity Mesurement (Flow speed) Depth of observation(m) | Count of current meter | | Time in seconds 1st | Time in seconds 2nd | Time in seconds Average |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0.00 | 0.00 | 0.000 | | | | | | |
| 2 | 1 | 0.22 | 0.22 | 0.220 | 0.090 | 20 | =(10 x 2) | 42.50 | | 42.500 |
| | | | | | 0.120 | 30 | =(10 x 3) | 52.70 | | 52.700 |
| 3 | 2.5 | 0.22 | 0.23 | 0.225 | 0.135 | 30 | =(10 x 3) | 44.10 | | 44.100 |
| | | | | | 0.135 | 40 | =(10 x 4) | 55.40 | | 55.400 |
| 4 | 3.5 | 0.17 | 0.17 | 0.170 | 0.102 | 40 | =(10 x 4) | 41.80 | | 41.800 |
| | | | | | 0.102 | 30 | =(10 x 3) | 55.90 | | 55.900 |
| 5 | 4.5 | 0.31 | 0.27 | 0.290 | 0.174 | 30 | =(10 x 3) | 58.80 | | 58.800 |
| | | | | | 0.174 | 30 | =(10 x 3) | 53.00 | | 53.000 |
| 6 | 5.5 | 0.31 | 0.28 | 0.295 | 0.177 | 30 | =(10 x 3) | 49.90 | | 49.900 |
| | | | | | 0.177 | 30 | =(10 x 3) | 47.90 | | 47.900 |
| 7 | 6.5 | 0.30 | 0.30 | 0.300 | 0.180 | 70 | =(10 x 7) | 45.60 | | 45.600 |
| | | | | | 0.180 | 70 | =(10 x 7) | 47.90 | | 47.900 |
| 8 | 7.95 | 0.24 | 0.24 | 0.240 | 0.144 | 60 | =(10 x 6) | 47.00 | | 47.000 |
| | | | | | 0.144 | 50 | =(10 x 5) | 49.60 | | 49.600 |

HOME WORKS

| Velocity Mesu. Veloc. at point(m/s) | Velocity Mean meas. Veloc.in vert(m/s) | Area of cross section Average depth(m) | Area of cross section Width of section(m) | Area of cross section Area of Section($m^2$) | Area of cross section Total Area($m^2$) | Disch-arge ($m^3/s$) |
|---|---|---|---|---|---|---|
| | | 0.11 | 1.00 | 0.11 | | |
| 0.086 | 0.094 | | | | 0.11 | 0.01 |
| 0.102 | | | | | | |
| | | 0.23 | 2.50 | 0.58 | | |
| 0.120 | 0.124 | | | | 0.58 | 0.07 |
| 0.127 | | | | | | |
| | | 0.17 | 3.50 | 0.60 | | |
| 0.165 | 0.131 | | | | 0.60 | 0.08 |
| 0.097 | | | | | | |
| | | 0.29 | 4.50 | 1.31 | | |
| 0.093 | 0.098 | | | | 1.31 | 0.13 |
| 0.102 | | | | | | |
| | | 0.30 | 5.50 | 1.65 | | |
| 0.107 | 0.109 | | | | 1.65 | 0.18 |
| 0.111 | | | | | | |
| | | 0.30 | 6.50 | 1.95 | | |
| 0.259 | 0.253 | | | | 1.95 | 0.49 |
| 0.247 | | | | | | |
| | | 0.24 | 7.95 | 1.91 | | |
| 0.217 | 0.195 | | | | 1.91 | 0.37 |
| 0.173 | | | | | | |

| | | | | |
|---|---|---|---|---|
| Station No. | | ***Downstream of the culvert*** | | |
| Observation Date | | Yr: 2014 | Mon: 1 | Date: 30 |
| Observer Name | Mesure | ***ekiel, Reub*** | ***Judith/Samejimah*** | |
| | Wrote | ***Ezekiel*** | ***Judith*** | |
| Weather | Weather | :clear, :fine, :cloudy :rain | | |
| | Wind blows | from Down/s, Up/s, Left, Right | | |
| | Wind power | 0:None, 1:light, 2:windy, 3:strong, 4:very strong | | |
| Mesurement Time (Hour, min) | Start | **10:30 AM** | | |
| | End | **11:20 AM** | | |
| | Average | **10:55 AM** | | |
| Water Level at gauging station (m) | | Initial Point | No.1 Point | |
| | Start | | | |
| | End | | | |
| | Average | | | |
| Current meter | Type of current meter | Digital | | |
| | Table/formula | V = 0.162 * N + 0.010 | | |
| | Useing method | lods・wire・weight | | |
| | | by boat / bridge / walk | | |
| Calculator | Calculator | | | |
| | Checker | | | |
| Result | Total Discharge ($m^3/s$) | **1.33** | | |
| | Total area cross section($m^2$) | **8.11** | | |
| | Average Velocity(m/s) | **0.16** | | |

Notes

| | |
|---|---|
| Catchment Area ($km^2$)= | **35.0** |
| Discharge ($m^3/s$)= | **1.33** |
| Specific Discharge ($m^3/s*100km^2$)= | **3.80** |

Remark:

(Field Notebook of Discharge Observation)

| FIELD WORKS | | | | | | | | | | | HOME WORKS | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of measure-ment | Distance from bank (m) | Depth of Water. (m) | | | Velocity Mesurement (Flow speed) | | | | | | Velocity | | Area of cross section | | | | Disch-arge (m$^3$/s) |
| | | First (one way) | Second (return) | Average | Depth of observation(m) | Count of current meter | | Time in seconds | | | Mesu. Veloc. at point(m/s) | Mean meas. Veloc.in vert(m/s) | Average depth(m) | Width of section(m) | Area of Section(m$^2$) | Total Area(m$^2$) | |
| | | | | | | | | 1st | 2nd | Average | | | | | | | |
| 1 | 0 | 0.00 | 0.00 | 0.000 | | | | | | | | | 0.11 | 7.95 | 0.87 | | |
| 2 | 7.95 | 0.21 | 0.24 | 0.225 | 0.090 | 50 | =(10 x 5) | 47.80 | | 47.800 | 0.179 | 0.194 | | | | 0.87 | 0.17 |
| | | | | | 0.120 | 60 | =(10 x 6) | 49.20 | | 49.200 | 0.208 | | | | | | |
| | | | | | | | | | | | | | 0.32 | 6.50 | 2.08 | | |
| 3 | 6.5 | 0.28 | 0.36 | 0.320 | 0.192 | 60 | =(10 x 6) | 54.60 | | 54.600 | 0.188 | 0.217 | | | | 2.08 | 0.45 |
| | | | | | 0.192 | 70 | =(10 x 7) | 48.00 | | 48.000 | 0.246 | | | | | | |
| | | | | | | | | | | | | | 0.27 | 5.50 | 1.49 | | |
| 4 | 5.5 | 0.33 | 0.20 | 0.265 | 0.159 | 50 | =(10 x 5) | 58.40 | | 58.400 | 0.149 | 0.181 | | | | 1.49 | 0.27 |
| | | | | | 0.159 | 60 | =(10 x 6) | 47.80 | | 47.800 | 0.213 | | | | | | |
| | | | | | | | | | | | | | 0.31 | 4.50 | 1.40 | | |
| 5 | 4.5 | 0.32 | 0.30 | 0.310 | 0.186 | 20 | =(10 x 2) | 48.30 | | 48.300 | 0.077 | 0.121 | | | | 1.40 | 0.17 |
| | | | | | 0.186 | 50 | =(10 x 5) | 52.20 | | 52.200 | 0.165 | | | | | | |
| | | | | | | | | | | | | | 0.17 | 3.50 | 0.60 | | |
| 6 | 3.5 | 0.16 | 0.18 | 0.170 | 0.102 | 30 | =(10 x 3) | 65.40 | | 65.400 | 0.084 | 0.137 | | | | 0.60 | 0.08 |
| | | | | | 0.102 | 50 | =(10 x 5) | 45.10 | | 45.100 | 0.190 | | | | | | |
| | | | | | | | | | | | | | 0.23 | 2.50 | 0.58 | | |
| 7 | 2.5 | 0.22 | 0.23 | 0.225 | 0.135 | 20 | =(10 x 2) | 48.70 | | 48.700 | 0.077 | 0.098 | | | | 0.58 | 0.06 |
| | | | | | 0.135 | 30 | =(10 x 3) | 45.10 | | 45.100 | 0.118 | | | | | | |
| | | | | | | | | | | | | | 0.20 | 1.00 | 0.20 | | |
| 8 | 1 | 0.19 | 0.21 | 0.200 | 0.120 | 20 | =(10 x 2) | 41.20 | | 41.200 | 0.089 | 0.113 | | | | 0.20 | 0.02 |
| | | | | | 0.120 | 40 | =(10 x 4) | 51.00 | | 51.000 | 0.137 | | | | | | |

| | | | |
|---|---|---|---|
| Station No. | | *Downstream of the culvert* | |
| Observation Date | | Yr: 2014 Mon: 1 | Date: 30 |
| Observer Name | Mesure | ***ekiel, Reub*** | ***Judith/Samejimah*** |
| | Wrote | ***Ezekiel*** | ***Judith*** |
| Weather | Weather | :clear, :fine, :cloudy :rain | |
| | Wind blows | from Down/s, Up/s, Left, Right | |
| | Wind power | 0:None, 1:light, 2:windy, 3:strong, 4:very strong | |
| Mesurement Time (Hour, min) | Start | **11:30 AM** | |
| | End | **12:20 PM** | |
| | Average | **11:55 AM** | |
| Water Level at gauging station (m) | | Initial Point | No.1 Point |
| | Start | | |
| | End | | |
| | Average | | |
| Current meter | Type of current meter | Digital | |
| | Table/formula | V = 0.162 * N + 0.010 | |
| | Useing method | lods・wire・weight | |
| | | by boat / bridge / walk | |
| Calculator | Calculator | | |
| | Checker | | |
| Result | Total Discharge (m$^3$/s) | **1.22** | |
| | Total area cross section(m$^2$) | **7.22** | |
| | Average Velocity(m/s) | **0.17** | |

Notes

| | |
|---|---|
| Catchment Area (km$^2$)= | **35.0** |
| Discharge (m$^3$/s)= | **1.22** |
| Specific Discharge (m$^3$/s*100km$^2$)= | **3.49** |

Remark:

# Annex 2

# Cross Section Data for Water Level Calculation

List of Data

# Cross Section Data 1

| **CH+1.0** | | | **CH+28.0** | | | **CH+56.0** | | | **CH+78.0** | | | **CH+110.0** | | | **CH+143.0** | | | **CH+165.0** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Height (EL.m) | Distance (m) | | Height (EL.m) | Distance (m) | | Height (EL.m) | Distance (m) | | Height (EL.m) | Distance (m) | | Height (EL.m) | Distance (m) | | Height (EL.m) | Distance (m) | | Height (EL.m) | Distance (m) |
| L | | 50.0 | L | | 50.0 | L | | 50.0 | L | | 50.0 | L | | 50.0 | L | | 50.0 | L | | 50.0 |
| | 1,710.2 | 46.2 | | 1,717.6 | 47.3 | | 1,725.0 | 49.5 | | 1,729.0 | 48.5 | | 1,738.0 | 49.3 | | 1,744.0 | 49.4 | | 1,744.0 | 48.8 |
| | 1,710.2 | 44.6 | | 1,717.4 | 43.2 | | 1,724.8 | 48.0 | | 1,728.0 | 46.2 | | 1,737.0 | 46.6 | | 1,743.0 | 45.5 | | 1,743.0 | 43.4 |
| | 1,710.2 | 41.4 | | 1,717.4 | 36.7 | | 1,724.0 | 46.9 | | 1,727.0 | 44.0 | | 1,736.0 | 43.7 | | 1,742.0 | 41.8 | | 1,742.0 | 38.5 |
| | 1,710.0 | 38.5 | | 1,717.6 | 35.0 | | 1,723.0 | 45.0 | | 1,726.8 | 43.6 | | 1,735.0 | 40.6 | | 1,741.0 | 38.2 | | 1,741.0 | 33.7 |
| | 1,709.8 | 35.2 | | 1,717.8 | 34.1 | | 1,722.0 | 42.6 | | 1,726.6 | 42.9 | | 1,734.0 | 37.1 | | 1,740.0 | 34.7 | | 1,740.0 | 29.6 |
| | 1,709.6 | 31.6 | | 1,718.0 | 33.5 | | 1,721.0 | 40.2 | | 1,726.6 | 41.1 | | 1,733.8 | 36.4 | | 1,739.0 | 31.3 | | 1,739.0 | 27.3 |
| | 1,709.4 | 17.7 | | 1,718.2 | 32.9 | | 1,720.0 | 37.8 | | 1,726.8 | 40.2 | | 1,733.6 | 36.0 | | 1,738.0 | 28.8 | | 1,738.0 | 25.0 |
| | 1,709.2 | 10.5 | | 1,718.4 | 32.5 | | 1,719.0 | 35.4 | | 1,727.0 | 39.6 | | 1,733.0 | 35.6 | | 1,737.0 | 27.1 | | 1,737.0 | 22.7 |
| | 1,709.0 | 3.8 | | 1,719.0 | 31.7 | | 1,718.0 | 32.9 | | 1,727.2 | 38.6 | | 1,732.0 | 35.0 | | 1,736.0 | 25.2 | | 1,736.0 | 20.4 |
| C | 1,708.9 | 0.0 | | 1,719.2 | 31.5 | | 1,717.0 | 30.3 | | 1,727.4 | 38.0 | | 1,731.8 | 34.9 | | 1,735.0 | 23.3 | | 1,735.0 | 18.1 |
| | 1,708.8 | -2.7 | | 1,719.2 | 31.2 | | 1,716.0 | 27.3 | | 1,727.6 | 37.6 | | 1,731.6 | 34.7 | | 1,734.0 | 21.4 | | 1,734.0 | 15.8 |
| | 1,708.6 | -8.5 | | 1,719.0 | 31.0 | | 1,715.0 | 24.4 | | 1,728.0 | 37.2 | | 1,731.4 | 34.4 | | 1,733.0 | 19.4 | | 1,733.0 | 13.5 |
| | 1,708.4 | -12.8 | | 1,718.0 | 30.2 | | 1,714.0 | 21.3 | | 1,728.6 | 36.5 | | 1,731.0 | 33.7 | | 1,732.0 | 17.5 | | 1,732.0 | 11.2 |
| | 1,708.6 | -13.9 | | 1,717.0 | 29.5 | | 1,713.4 | 19.1 | | 1,728.6 | 36.5 | | 1,730.0 | 32.0 | | 1,731.0 | 15.2 | | 1,731.0 | 8.6 |
| | 1,708.8 | -14.6 | | 1,716.0 | 29.0 | | 1,713.0 | 18.4 | | 1,728.0 | 35.7 | | 1,729.0 | 30.3 | | 1,730.8 | 14.6 | | 1,730.4 | 6.9 |
| | 1,709.0 | -15.1 | | 1,715.0 | 28.6 | | 1,712.0 | 16.3 | | 1,727.8 | 34.5 | | 1,728.0 | 28.8 | | 1,730.6 | 14.0 | | 1,730.2 | 5.7 |
| | 1,710.0 | -17.6 | | 1,714.4 | 28.3 | | 1,712.0 | 16.2 | | 1,727.0 | 32.9 | | 1,727.0 | 27.3 | | 1,730.4 | 12.8 | | 1,730.1 | 2.9 |
| | 1,711.0 | -20.0 | | 1,714.0 | 27.7 | | 1,713.0 | 15.7 | | 1,726.0 | 31.6 | | 1,726.0 | 25.9 | | 1,730.4 | 12.2 | | 1,730.2 | 1.9 |
| | 1,712.0 | -22.2 | | 1,713.6 | 27.1 | | 1,714.0 | 15.3 | | 1,725.0 | 30.5 | | 1,725.0 | 24.7 | | 1,730.6 | 11.3 | | 1,730.4 | 0.7 |
| | 1,713.0 | -23.9 | | 1,713.4 | 26.6 | | 1,715.0 | 15.0 | | 1,724.0 | 29.7 | | 1,724.0 | 23.4 | | 1,730.6 | 10.3 | | 1,730.6 | 0.3 |
| | 1,714.0 | -25.6 | | 1,713.2 | 25.7 | | 1,716.0 | 14.6 | | 1,723.0 | 29.0 | | 1,723.6 | 22.9 | | 1,730.4 | 9.5 | | 1,730.8 | 0.0 |
| | 1,715.0 | -27.3 | | 1,713.0 | 24.8 | | 1,716.2 | 13.9 | | 1,722.0 | 28.4 | | 1,723.4 | 22.5 | | 1,730.2 | 8.9 | | 1,731.0 | -0.6 |
| | 1,716.0 | -28.9 | | 1,712.0 | 20.6 | | 1,716.4 | 13.2 | | 1,721.0 | 27.7 | | 1,723.0 | 21.4 | | 1,730.0 | 8.1 | | 1,731.2 | -1.5 |
| | 1,717.0 | -30.6 | | 1,711.8 | 19.4 | | 1,716.4 | 12.9 | | 1,720.8 | 27.5 | | 1,722.0 | 19.4 | | 1,729.0 | 2.6 | | 1,731.2 | -4.4 |
| | 1,718.0 | -32.3 | | 1,711.6 | 17.9 | | 1,716.2 | 12.6 | | 1,720.4 | 26.8 | | 1,721.0 | 17.7 | C | 1,728.5 | 0.0 | | 1,731.1 | -8.5 |
| | 1,719.0 | -34.1 | | 1,711.4 | 15.9 | | 1,716.0 | 12.3 | | 1,720.2 | 26.3 | | 1,720.0 | 16.1 | | 1,728.4 | -1.2 | | 1,731.2 | -13.1 |
| | 1,720.0 | -35.9 | | 1,711.2 | 13.5 | | 1,715.0 | 10.6 | | 1,720.0 | 25.6 | | 1,719.0 | 14.6 | | 1,728.6 | -3.8 | | 1,731.4 | -13.6 |
| R | | -50.0 | | 1,711.0 | 10.7 | | 1,714.0 | 9.1 | | 1,719.4 | 22.8 | | 1,718.0 | 13.0 | | 1,728.8 | -6.1 | | 1,732.0 | -14.8 |
| | | | | 1,710.8 | 7.3 | | 1,713.0 | 7.7 | | 1,719.0 | 21.2 | | 1,717.0 | 12.0 | | 1,729.0 | -8.4 | | 1,733.0 | -16.6 |
| | | | | 1,710.6 | 3.1 | | 1,712.0 | 6.3 | | 1,718.8 | 20.2 | | 1,716.8 | 11.9 | | 1,730.0 | -15.0 | | 1,734.0 | -18.5 |
| | | | C | 1,710.5 | 0.0 | | 1,711.0 | 5.0 | | 1,718.4 | 19.0 | | 1,716.6 | 11.1 | | 1,731.0 | -17.5 | | 1,735.0 | -20.4 |
| | | | | 1,710.5 | -4.3 | | 1,710.0 | 3.6 | | 1,718.0 | 18.5 | | 1,716.6 | 10.7 | | 1,732.0 | -20.3 | | 1,736.0 | -22.4 |
| | | | | 1,710.6 | -10.8 | | 1,709.0 | 2.3 | | 1,717.0 | 17.4 | | 1,717.0 | 10.1 | | 1,733.0 | -22.6 | | 1,737.0 | -24.3 |
| | | | | 1,710.8 | -13.3 | | 1,708.2 | 0.9 | | 1,716.0 | 16.3 | | 1,717.2 | 9.7 | | 1,734.0 | -24.8 | | 1,738.0 | -26.2 |
| | | | | 1,711.0 | -15.1 | | 1,708.2 | 0.7 | | 1,715.0 | 15.3 | | 1,717.2 | 8.7 | | 1,735.0 | -26.9 | | 1,739.0 | -28.0 |
| | | | | 1,711.2 | -16.6 | C | 1,708.5 | 0.0 | | 1,714.0 | 14.3 | | 1,717.0 | 7.9 | | 1,736.0 | -28.9 | | 1,740.0 | -29.8 |
| | | | | 1,711.4 | -18.0 | | 1,709.0 | -1.5 | | 1,713.4 | 13.7 | | 1,716.8 | 7.4 | | 1,737.0 | -30.8 | | 1,741.0 | -31.5 |
| | | | | 1,711.6 | -18.9 | | 1,710.0 | -4.2 | | 1,713.2 | 13.3 | | 1,716.0 | 5.9 | | 1,738.0 | -33.0 | | 1,742.0 | -33.2 |
| | | | | 1,711.8 | -19.6 | | 1,711.0 | -7.1 | | 1,713.0 | 12.7 | | 1,715.0 | 4.4 | | 1,738.6 | -34.6 | | 1,742.4 | -33.9 |
| | | | | 1,712.0 | -20.2 | | 1,712.0 | -10.0 | | 1,713.0 | 11.9 | | 1,714.8 | 4.1 | | 1,738.8 | -35.6 | | 1,742.6 | -34.5 |
| | | | | 1,713.0 | -22.7 | | 1,713.0 | -13.0 | | 1,714.0 | 8.2 | | 1,714.4 | 3.0 | | 1,739.0 | -37.2 | | 1,742.8 | -35.3 |
| | | | | 1,714.0 | -25.0 | | 1,714.0 | -16.0 | | 1,714.2 | 7.4 | | 1,714.6 | 0.9 | | 1,740.0 | -42.4 | | 1,742.0 | -36.1 |
| | | | | 1,715.0 | -27.1 | | 1,714.4 | -17.3 | | 1,714.2 | 6.5 | C | 1,714.8 | 0.0 | | 1,741.0 | -46.7 | | 1,741.8 | -36.2 |
| | | | | 1,716.0 | -29.2 | | 1,714.6 | -18.0 | | 1,714.0 | 6.0 | | 1,715.0 | -0.8 | | 1,741.8 | -49.7 | | 1,741.6 | -36.5 |
| | | | | 1,717.0 | -31.3 | | 1,714.8 | -18.9 | | 1,713.0 | 3.7 | | 1,716.0 | -4.6 | R | 0.0 | -50.0 | | 1,741.4 | -36.9 |
| | | | | 1,718.0 | -33.2 | | 1,715.0 | -20.5 | | 1,712.0 | 1.6 | | 1,717.0 | -8.3 | | | | | 1,741.6 | -38.0 |
| | | | | 1,719.0 | -35.1 | | 1,714.4 | -22.1 | C | 1,711.2 | 0.0 | | 1,718.0 | -12.2 | | | | | 1,741.8 | -38.6 |
| | | | | 1,720.0 | -36.9 | | 1,715.0 | -23.4 | | 1,711.0 | -0.4 | | 1,719.0 | -16.6 | | | | | 1,742.0 | -39.1 |
| | | | | 1,721.0 | -38.6 | | 1,716.0 | -25.2 | | 1,710.4 | -1.7 | | 1,719.2 | -17.6 | | | | | 1,743.0 | -41.3 |
| | | | | 1,721.2 | -39.9 | | 1,717.0 | -27.0 | | 1,710.4 | -2.2 | | 1,719.4 | -18.7 | | | | | 1,744.0 | -43.3 |
| | | | R | | -50.0 | | 1,718.0 | -28.9 | | 1,711.0 | -3.6 | | 1,719.6 | -19.9 | | | | | 1,745.0 | -45.2 |
| | | | | | | | 1,719.0 | -30.8 | | 1,712.0 | -5.6 | | 1,719.8 | -21.3 | | | | | 1,746.0 | -47.1 |
| | | | | | | | 1,720.0 | -32.8 | | 1,713.0 | -7.6 | | 1,720.0 | -23.3 | | | | | 1,747.0 | -49.1 |
| | | | | | | | 1,721.0 | -34.8 | | 1,714.0 | -9.5 | | 1,721.0 | -25.1 | | | | R | 0.0 | -50.0 |
| | | | | | | | 1,722.0 | -37.0 | | 1,715.0 | -11.5 | | 1,722.0 | -26.6 | | | | | | |
| | | | | | | | 1,723.0 | -39.6 | | 1,716.0 | -13.3 | | 1,723.0 | -28.2 | | | | | | |
| | | | | | | | 1,724.0 | -41.5 | | 1,717.0 | -15.2 | | 1,724.0 | -29.9 | | | | | | |
| | | | | | | | 1,725.0 | -43.6 | | 1,718.0 | -17.0 | | 1,725.0 | -31.6 | | | | | | |
| | | | | | | | 1,725.2 | -44.4 | | 1,719.0 | -18.9 | | 1,726.0 | -33.5 | | | | | | |
| | | | | | | | 1,725.4 | -45.2 | | 1,720.0 | -21.0 | | 1,727.0 | -35.5 | | | | | | |
| | | | | | | | 1,725.6 | -46.2 | | 1,720.6 | -22.2 | | 1,728.0 | -37.7 | | | | | | |
| | | | | | | | 1,725.8 | -47.4 | | 1,720.8 | -22.6 | | 1,729.0 | -40.4 | | | | | | |
| | | | | | | | 1,726.0 | -49.0 | | 1,721.0 | -23.7 | | 1,730.0 | -42.6 | | | | | | |
| | | | | | | R | | -50.0 | | 1,721.2 | -25.0 | | 1,731.0 | -44.8 | | | | | | |
| | | | | | | | | | | 1,721.4 | -26.3 | | 1,732.0 | -46.9 | | | | | | |
| | | | | | | | | | | 1,721.6 | -27.8 | | 1,733.0 | -49.1 | | | | | | |
| | | | | | | | | | | 1,721.8 | -29.1 | R | 0.0 | -50.0 | | | | | | |
| | | | | | | | | | | 1,722.0 | -30.2 | | | | | | | | | |
| | | | | | | | | | | 1,722.4 | -31.3 | | | | | | | | | |
| | | | | | | | | | | 1,722.6 | -31.7 | | | | | | | | | |
| | | | | | | | | | | 1,723.0 | -32.3 | | | | | | | | | |
| | | | | | | | | | | 1,723.2 | -32.5 | | | | | | | | | |
| | | | | | | | | | | 1,723.4 | -32.8 | | | | | | | | | |
| | | | | | | | | | | 1,723.6 | -33.3 | | | | | | | | | |
| | | | | | | | | | | 1,723.8 | -33.7 | | | | | | | | | |
| | | | | | | | | | | 1,724.0 | -34.6 | | | | | | | | | |
| | | | | | | | | | | 1,724.2 | -35.4 | | | | | | | | | |
| | | | | | | | | | | 1,725.0 | -36.2 | | | | | | | | | |
| | | | | | | | | | | 1,725.8 | -37.1 | | | | | | | | | |
| | | | | | | | | | | 1,726.0 | -37.3 | | | | | | | | | |
| | | | | | | | | | | 1,727.0 | -38.0 | | | | | | | | | |
| | | | | | | | | | | 1,727.2 | -38.1 | | | | | | | | | |
| | | | | | | | | | | 1,727.4 | -38.3 | | | | | | | | | |
| | | | | | | | | | | 1,727.8 | -38.7 | | | | | | | | | |
| | | | | | | | | | | 1,728.0 | -40.1 | | | | | | | | | |
| | | | | | | | | | | 1,728.2 | -41.4 | | | | | | | | | |
| | | | | | | | | | | 1,728.4 | -42.8 | | | | | | | | | |
| | | | | | | | | | | 1,728.6 | -44.8 | | | | | | | | | |
| | | | | | | | | | | 1,728.6 | -47.0 | | | | | | | | | |
| | | | | | | | | | | 1,728.4 | -49.5 | | | | | | | | | |
| | | | | | | | | | R | | -50.0 | | | | | | | | | |

# Cross Section Data 2

| **CH+189.0** | | |
|---|---|---|
| | Height (EL.m) | Distance (m) |
| L | | 50.0 |
| | 1,744.0 | 47.9 |
| | 1,743.8 | 45.9 |
| | 1,743.6 | 44.0 |
| | 1,743.4 | 41.4 |
| | 1,743.2 | 38.9 |
| | 1,743.0 | 36.0 |
| | 1,742.8 | 32.4 |
| | 1,742.6 | 28.1 |
| | 1,742.4 | 24.8 |
| | 1,742.2 | 23.8 |
| | 1,742.0 | 23.0 |
| | 1,741.0 | 20.1 |
| | 1,740.0 | 17.7 |
| | 1,739.0 | 15.4 |
| | 1,738.0 | 13.0 |
| | 1,737.0 | 10.2 |
| | 1,736.8 | 9.5 |
| | 1,736.6 | 8.7 |
| | 1,736.4 | 7.2 |
| | 1,736.2 | 6.1 |
| | 1,736.0 | 5.2 |
| | 1,736.0 | 3.8 |
| | 1,737.0 | 3.4 |
| | 1,738.0 | 3.0 |
| | 1,739.0 | 2.6 |
| | 1,739.6 | 2.3 |
| | 1,739.6 | 2.2 |
| | 1,739.4 | 0.9 |
| | 1,739.2 | 0.6 |
| | 1,739.0 | 0.4 |
| | 1,738.7 | 0.0 |
| | 1,738.2 | -0.6 |
| | 1,738.0 | -1.0 |
| | 1,737.6 | -2.2 |
| | 1,737.4 | -3.6 |
| | 1,737.4 | -8.3 |
| | 1,737.0 | -11.4 |
| | 1,737.4 | -12.1 |
| | 1,737.2 | -12.8 |
| | 1,737.2 | -13.0 |
| | 1,738.0 | -14.1 |
| | 1,739.0 | -15.5 |
| | 1,740.0 | -16.9 |
| | 1,741.0 | -18.3 |
| | 1,742.0 | -19.7 |
| | 1,743.0 | -21.1 |
| | 1,744.0 | -22.5 |
| | 1,745.0 | -23.9 |
| | 1,746.0 | -25.3 |
| | 1,747.0 | -26.7 |
| | 1,748.0 | -28.0 |
| | 1,749.0 | -30.3 |
| | 1,750.0 | -34.5 |
| | 1,751.0 | -38.3 |
| | 1,752.0 | -42.3 |
| | 1,753.0 | -45.6 |
| | 1,753.8 | -48.5 |
| R | 0.0 | -50.0 |

| **CH+213.0** | | |
|---|---|---|
| | Height (EL.m) | Distance (m) |
| L | | 50.0 |
| | 1,749.4 | 47.6 |
| | 1,749.2 | 41.7 |
| | 1,749.2 | 36.5 |
| | 1,749.4 | 33.8 |
| | 1,749.6 | 32.4 |
| | 1,749.6 | 30.1 |
| | 1,749.4 | 28.0 |
| | 1,749.2 | 26.2 |
| | 1,749.0 | 24.4 |
| | 1,748.2 | 17.9 |
| | 1,748.0 | 17.2 |
| | 1,747.0 | 13.5 |
| | 1,746.8 | 12.9 |
| | 1,746.6 | 12.0 |
| | 1,746.6 | 9.9 |
| | 1,747.0 | 8.9 |
| | 1,747.2 | 7.9 |
| | 1,747.4 | 6.8 |
| | 1,747.4 | 6.5 |
| | 1,747.2 | 5.8 |
| | 1,747.0 | 5.3 |
| | 1,746.0 | 4.3 |
| | 1,745.0 | 3.0 |
| | 1,744.0 | 1.5 |
| | 1,743.4 | 0.0 |
| | 1,743.0 | -1.3 |
| | 1,742.8 | -2.2 |
| | 1,742.6 | -3.9 |
| | 1,742.6 | -6.5 |
| | 1,742.8 | -8.9 |
| | 1,743.0 | -9.9 |
| | 1,743.2 | -10.5 |
| | 1,743.8 | -11.6 |
| | 1,744.0 | -12.7 |
| | 1,744.2 | -13.5 |
| | 1,745.0 | -15.5 |
| | 1,746.0 | -17.9 |
| | 1,747.0 | -20.1 |
| | 1,748.0 | -22.2 |
| | 1,749.0 | -24.5 |
| | 1,750.0 | -28.1 |
| | 1,751.0 | -31.4 |
| | 1,752.0 | -34.4 |
| | 1,753.0 | -38.2 |
| | 1,754.0 | -42.0 |
| | 1,755.0 | -46.5 |
| | 1,755.6 | -49.5 |
| R | 0.0 | -50.0 |

| **CH+222.0** | | |
|---|---|---|
| | Height (EL.m) | Distance (m) |
| L | | 50.0 |
| | 1,751.0 | 48.3 |
| | 1,750.0 | 29.2 |
| | 1,749.0 | 21.9 |
| | 1,748.0 | 16.4 |
| | 1,747.0 | 13.3 |
| | 1,746.0 | 10.4 |
| | 1,745.8 | 9.8 |
| | 1,745.6 | 9.2 |
| | 1,745.4 | 8.6 |
| | 1,745.2 | 8.0 |
| | 1,745.2 | 6.0 |
| | 1,745.2 | 1.3 |
| | 1,745.1 | 0.0 |
| | 1,745.0 | -1.2 |
| | 1,744.8 | -3.6 |
| | 1,744.6 | -8.0 |
| | 1,744.6 | -10.2 |
| | 1,744.8 | -12.9 |
| | 1,745.0 | -13.2 |
| | 1,746.0 | -14.8 |
| | 1,747.0 | -16.8 |
| | 1,748.0 | -18.8 |
| | 1,749.0 | -20.8 |
| | 1,750.0 | -24.0 |
| | 1,751.0 | -27.8 |
| | 1,752.0 | -31.3 |
| | 1,753.0 | -34.8 |
| | 1,754.0 | -39.1 |
| | 1,755.0 | -43.7 |
| | 1,756.0 | -49.9 |
| R | 0.0 | -50.0 |

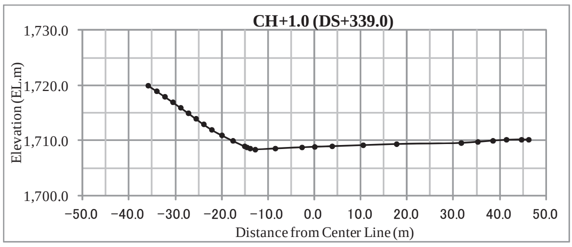
| **CH+300.0** | | |
|---|---|---|
| | Height (EL.m) | Distance (m) |
| L | | 50.0 |
| | 1,755.2 | 49.9 |
| | 1,755.0 | 49.3 |
| | 1,754.2 | 46.2 |
| | 1,754.0 | 31.7 |
| | 1,753.0 | 29.0 |
| | 1,752.0 | 24.3 |
| | 1,751.0 | 18.3 |
| | 1,750.0 | 13.5 |
| | 1,749.0 | 8.2 |
| | 1,748.0 | 1.9 |
| | 1,747.8 | 0.3 |
| | 1,747.8 | 0.0 |
| | 1,747.8 | -2.1 |
| | 1,747.8 | -4.8 |
| | 1,748.0 | -6.8 |
| | 1,749.0 | -14.8 |
| | 1,749.6 | -19.5 |
| | 1,749.8 | -20.7 |
| | 1,750.0 | -21.5 |
| | 1,751.0 | -25.3 |
| | 1,752.0 | -28.6 |
| | 1,753.0 | -31.8 |
| | 1,754.0 | -34.7 |
| | 1,754.2 | -35.4 |
| | 1,754.4 | -36.6 |
| | 1,754.6 | -39.2 |
| | 1,754.8 | -41.2 |
| | 1,755.0 | -42.8 |
| | 1,756.0 | -49.7 |
| R | 0.0 | -50.0 |

| **CH+262.0** | | |
|---|---|---|
| | Height (EL.m) | Distance (m) |
| L | | 50.0 |
| | 1,755.6 | 48.7 |
| | 1,755.4 | 47.2 |
| | 1,755.2 | 45.3 |
| | 1,755.0 | 41.4 |
| | 1,754.0 | 33.3 |
| | 1,753.0 | 26.8 |
| | 1,752.0 | 21.1 |
| | 1,751.0 | 16.6 |
| | 1,750.0 | 12.8 |
| | 1,749.0 | 9.3 |
| | 1,748.0 | 6.4 |
| | 1,747.0 | 3.3 |
| | 1,747.0 | 0.7 |
| | 1,747.1 | 0.0 |
| | 1,748.0 | -5.5 |
| | 1,749.0 | -10.4 |
| | 1,750.0 | -14.8 |
| | 1,751.0 | -19.5 |
| | 1,752.0 | -24.1 |
| | 1,753.0 | -28.5 |
| | 1,754.0 | -33.1 |
| | 1,755.0 | -38.6 |
| | 1,756.0 | -45.4 |
| | 1,756.6 | -49.3 |
| R | 0.0 | -50.0 |

| **CH+340.0** | | |
|---|---|---|
| | Height (EL.m) | Distance (m) |
| L | | 50.0 |
| | 1,754.0 | 49.4 |
| | 1,753.0 | 43.5 |
| | 1,752.8 | 41.7 |
| | 1,752.6 | 36.7 |
| | 1,752.4 | 35.6 |
| | 1,752.2 | 34.6 |
| | 1,752.0 | 33.2 |
| | 1,751.0 | 26.1 |
| | 1,750.8 | 25.0 |
| | 1,750.4 | 23.9 |
| | 1,750.4 | 23.0 |
| | 1,750.6 | 22.4 |
| | 1,750.6 | 21.8 |
| | 1,750.0 | 20.9 |
| | 1,749.4 | 19.6 |
| | 1,749.2 | 19.1 |
| | 1,749.0 | 18.1 |
| | 1,748.8 | 16.6 |
| | 1,748.6 | 14.8 |
| | 1,748.4 | 12.7 |
| | 1,748.2 | 11.4 |
| | 1,748.0 | 10.4 |
| | 1,747.8 | 9.8 |
| | 1,747.8 | 9.7 |
| | 1,748.0 | 9.5 |
| | 1,749.0 | 8.2 |
| | 1,749.2 | 7.6 |
| | 1,749.4 | 7.2 |
| | 1,749.6 | 6.7 |
| | 1,749.6 | 6.5 |
| | 1,749.5 | 0.0 |
| | 1,749.4 | -5.5 |
| | 1,749.2 | -6.7 |
| | 1,749.0 | -7.9 |
| | 1,748.8 | -9.3 |
| | 1,748.7 | -11.6 |
| | 1,748.8 | -14.3 |
| | 1,749.0 | -15.0 |
| | 1,749.4 | -15.7 |
| | 1,749.6 | -16.7 |
| | 1,749.8 | -18.0 |
| | 1,750.0 | -18.6 |
| | 1,750.5 | -20.6 |
| | 1,751.0 | -31.6 |
| R | 0.0 | -50.0 |

| **Longitudinal Profile** | | |
|---|---|---|
| Chanage | Height (EL.m) | Distance (m) |
| CH+340 | 1,749.5 | 0.0 |
| (Culvert) | 1,749.0 | 2.9 |
| | 1,748.0 | 8.5 |
| | 1,747.0 | 14.2 |
| | 1,746.4 | 17.9 |
| | 1,746.2 | 19.1 |
| | 1,746.4 | 22.8 |
| | 1,746.6 | 27.5 |
| | 1,746.8 | 29.8 |
| | 1,747.0 | 31.4 |
| | 1,747.2 | 32.5 |
| | 1,747.4 | 33.9 |
| | 1,747.6 | 35.5 |
| | 1,747.8 | 37.9 |
| | 1,747.8 | 39.6 |
| CH+300 | 1,747.8 | 40.0 |
| | 1,747.8 | 41.9 |
| | 1,747.6 | 42.9 |
| | 1,747.4 | 43.6 |
| | 1,747.0 | 44.4 |
| | 1,746.2 | 46.2 |
| | 1,746.0 | 47.1 |
| | 1,745.8 | 48.5 |
| | 1,745.6 | 49.7 |
| | 1,745.6 | 49.9 |
| | 1,745.4 | 51.2 |
| | 1,745.2 | 52.7 |
| | 1,745.0 | 54.4 |
| | 1,744.8 | 57.9 |
| | 1,744.8 | 58.9 |
| | 1,745.0 | 62.5 |
| | 1,745.2 | 64.2 |
| | 1,745.4 | 65.5 |
| | 1,745.6 | 66.7 |
| | 1,745.8 | 67.8 |
| | 1,746.0 | 68.9 |
| | 1,746.2 | 70.1 |
| | 1,746.4 | 71.3 |
| | 1,746.6 | 72.5 |
| | 1,746.8 | 74.0 |
| | 1,747.0 | 76.1 |
| CH+262 | 1,747.1 | 78.0 |
| | 1,747.0 | 80.3 |
| | 1,746.8 | 82.2 |
| | 1,746.6 | 83.7 |
| | 1,746.4 | 85.3 |
| | 1,746.2 | 88.2 |
| | 1,746.0 | 95.9 |
| | 1,745.8 | 97.3 |
| | 1,745.0 | 101.9 |
| | 1,744.8 | 103.6 |
| | 1,744.8 | 107.5 |
| | 1,745.0 | 111.2 |
| | 1,745.1 | 115.8 |
| | 1,745.1 | 117.8 |
| CH+222 | 1,745.1 | 118.0 |
| (Intake A) | 1,745.0 | 119.5 |
| | 1,744.8 | 121.4 |
| | 1,744.6 | 122.8 |
| | 1,744.4 | 123.8 |
| | 1,744.2 | 124.6 |
| | 1,744.0 | 125.3 |
| CH+213 | 1,743.4 | 127.0 |
| | 1,743.0 | 127.7 |
| | 1,742.0 | 129.1 |
| | 1,741.0 | 130.1 |
| | 1,740.0 | 130.8 |
| | 1,739.0 | 131.4 |
| | 1,738.0 | 132.0 |
| | 1,737.0 | 132.5 |
| | 1,736.0 | 133.2 |
| | 1,735.2 | 134.5 |
| | 1,735.0 | 135.3 |
| | 1,734.8 | 136.1 |
| | 1,734.6 | 138.0 |
| | 1,734.4 | 140.5 |
| | 1,734.2 | 142.5 |
| | 1,734.2 | 143.6 |
| | 1,734.4 | 144.4 |
| | 1,734.6 | 145.0 |
| | 1,734.8 | 145.5 |
| | 1,735.0 | 145.8 |
| | 1,735.8 | 146.7 |
| | 1,736.0 | 147.0 |
| | 1,737.0 | 147.8 |
| | 1,737.8 | 148.5 |
| | 1,738.0 | 148.8 |
| | 1,738.2 | 149.2 |
| | 1,738.4 | 149.5 |
| | 1,738.6 | 149.7 |
| | 1,738.8 | 150.2 |
| | 1,738.8 | 150.3 |
| CH+189 | 1,738.7 | 151.0 |
| CH+189 | 1,738.7 | 151.0 |
| (Intake B) | 1,738.6 | 151.6 |
| | 1,738.4 | 151.9 |
| | 1,738.0 | 152.2 |
| | 1,737.0 | 153.1 |
| | 1,736.0 | 153.7 |
| | 1,735.0 | 154.4 |
| | 1,734.0 | 155.2 |
| | 1,733.0 | 156.2 |
| | 1,732.8 | 156.7 |
| | 1,732.6 | 158.1 |
| | 1,732.0 | 159.3 |
| | 1,731.0 | 160.4 |
| | 1,730.6 | 160.8 |
| | 1,730.4 | 161.6 |
| | 1,730.4 | 164.6 |
| | 1,730.4 | 166.1 |
| | 1,730.2 | 168.4 |
| | 1,730.4 | 169.4 |
| | 1,730.6 | 172.1 |
| | 1,730.8 | 174.2 |
| CH+165 | 1,730.8 | 175.0 |
| (Intake C) | 1,730.8 | 178.6 |
| | 1,730.8 | 180.3 |
| | 1,730.6 | 182.5 |
| | 1,730.0 | 185.3 |
| | 1,729.6 | 186.9 |
| | 1,729.0 | 189.1 |
| | 1,728.8 | 190.3 |
| | 1,728.6 | 192.1 |
| CH+143 | 1,728.5 | 197.0 |
| | 1,728.4 | 200.3 |
| | 1,728.0 | 201.5 |
| | 1,727.0 | 202.9 |
| | 1,726.0 | 204.1 |
| | 1,725.0 | 205.3 |
| | 1,724.0 | 206.5 |
| | 1,723.0 | 207.8 |
| | 1,722.0 | 209.4 |
| | 1,721.0 | 211.5 |
| | 1,720.0 | 213.9 |
| | 1,719.0 | 216.5 |
| | 1,718.0 | 219.3 |
| | 1,717.0 | 222.3 |
| | 1,716.0 | 225.4 |
| | 1,715.0 | 229.2 |
| CH+110 | 1,714.8 | 230.0 |
| | 1,714.0 | 233.0 |
| | 1,713.4 | 234.9 |
| | 1,713.2 | 236.5 |
| | 1,713.0 | 237.4 |
| | 1,712.8 | 237.9 |
| | 1,712.8 | 238.7 |
| | 1,713.0 | 240.4 |
| | 1,713.0 | 240.7 |
| | 1,712.8 | 243.6 |
| | 1,712.6 | 245.1 |
| | 1,712.5 | 246.8 |
| | 1,712.6 | 250.9 |
| | 1,712.4 | 253.6 |
| | 1,712.2 | 255.0 |
| | 1,712.0 | 256.3 |
| | 1,711.8 | 257.6 |
| | 1,711.6 | 259.1 |
| | 1,711.4 | 260.5 |
| CH+78 | 1,711.2 | 262.0 |
| | 1,711.0 | 263.8 |
| | 1,710.9 | 265.1 |
| | 1,710.8 | 265.7 |
| | 1,710.6 | 267.2 |
| | 1,710.4 | 268.1 |
| | 1,710.2 | 269.2 |
| | 1,710.0 | 269.7 |
| | 1,710.0 | 270.9 |
| | 1,710.2 | 272.3 |
| | 1,710.2 | 274.5 |
| | 1,710.0 | 276.7 |
| | 1,709.8 | 278.0 |
| | 1,709.6 | 279.1 |
| | 1,709.4 | 280.0 |
| | 1,709.2 | 280.9 |
| | 1,709.0 | 281.7 |
| | 1,708.8 | 282.5 |
| | 1,708.6 | 283.4 |
| | 1,708.5 | 283.8 |
| CH+56 | 1,708.5 | 284.0 |
| CH+56 | 1,708.5 | 284.0 |
| | 1,708.2 | 285.4 |
| | 1,708.0 | 287.4 |
| | 1,708.1 | 290.2 |
| | 1,708.0 | 293.7 |
| | 1,707.8 | 296.5 |
| | 1,707.6 | 297.8 |
| | 1,707.6 | 298.0 |
| | 1,707.8 | 298.6 |
| | 1,708.0 | 299.1 |
| | 1,709.0 | 301.8 |
| | 1,710.0 | 305.1 |
| | 1,710.2 | 306.2 |
| | 1,710.4 | 308.2 |
| CH+28 | 1,710.5 | 312.0 |
| (P/H) | 1,710.4 | 316.1 |
| | 1,710.2 | 320.3 |
| | 1,710.0 | 323.7 |
| | 1,709.0 | 337.6 |
| CH+1 | 1,708.9 | 339.0 |
| (Tailrace) | 1,708.0 | 349.3 |

# Cross Section Figures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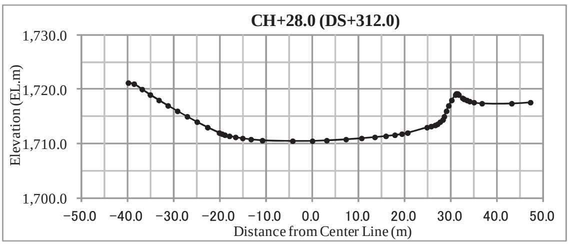
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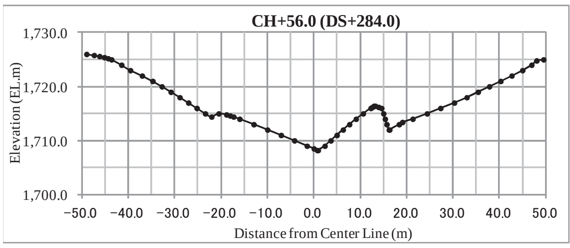
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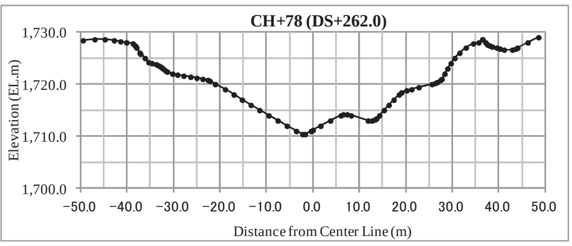
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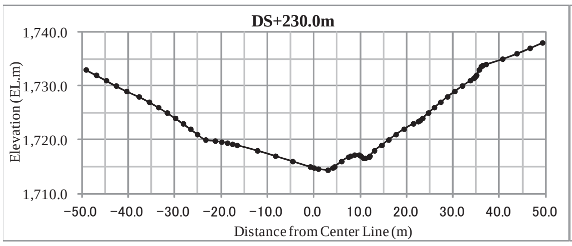
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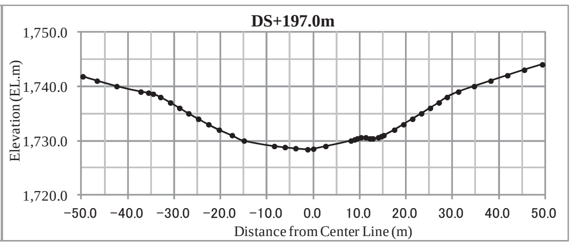
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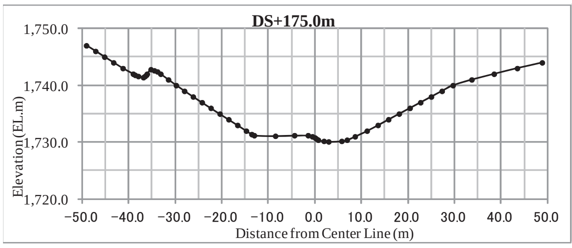
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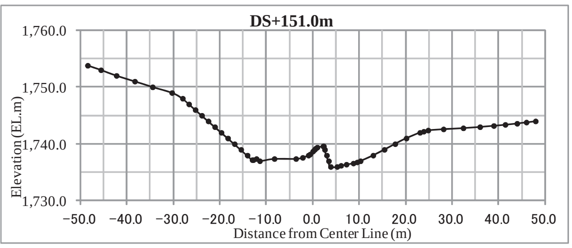
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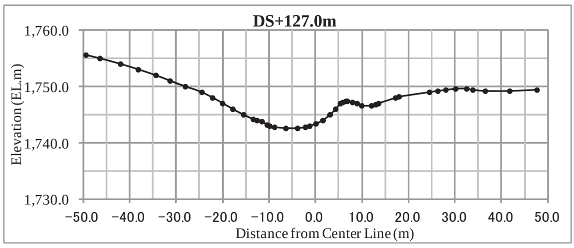
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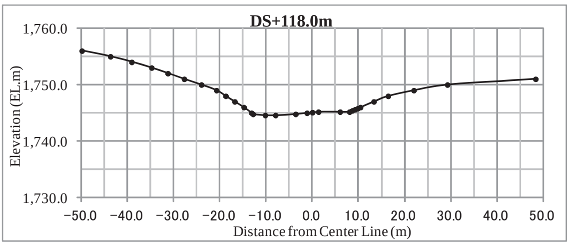
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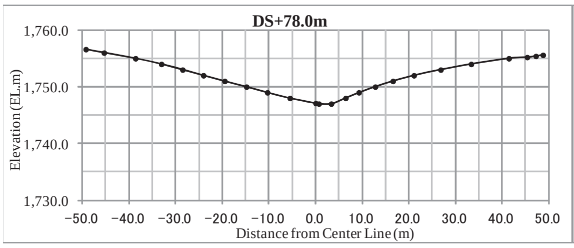
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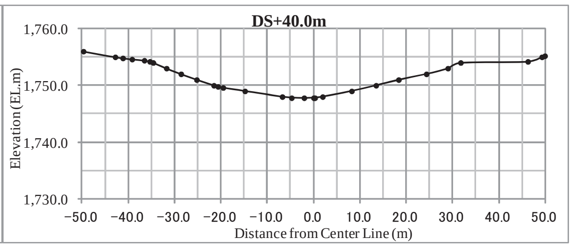
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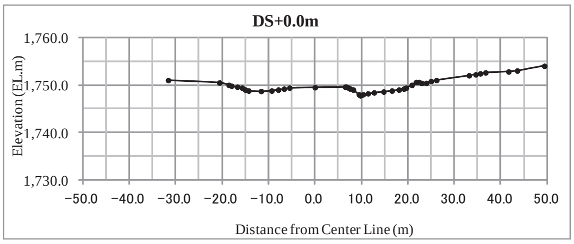
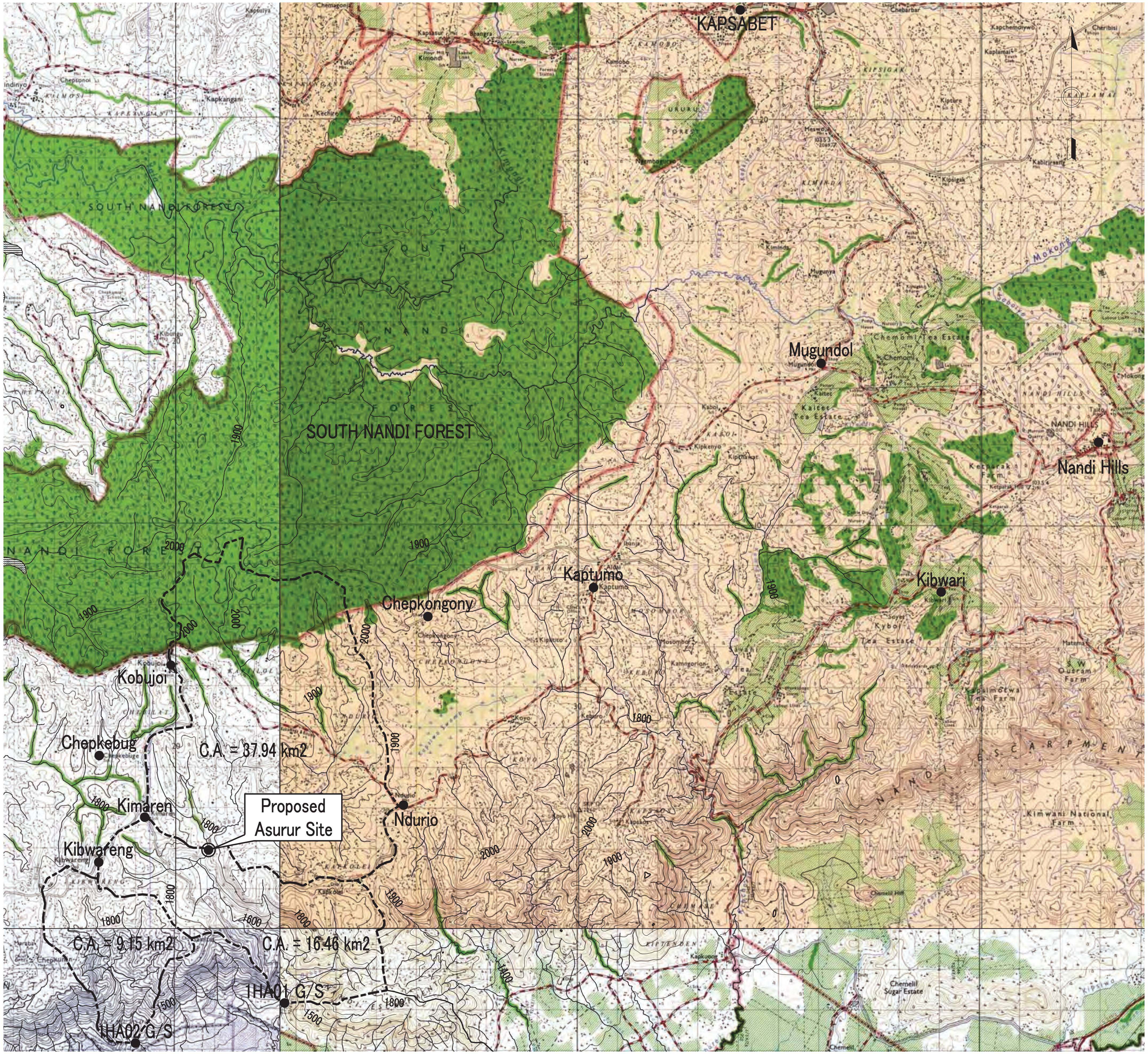

DS+0.0m

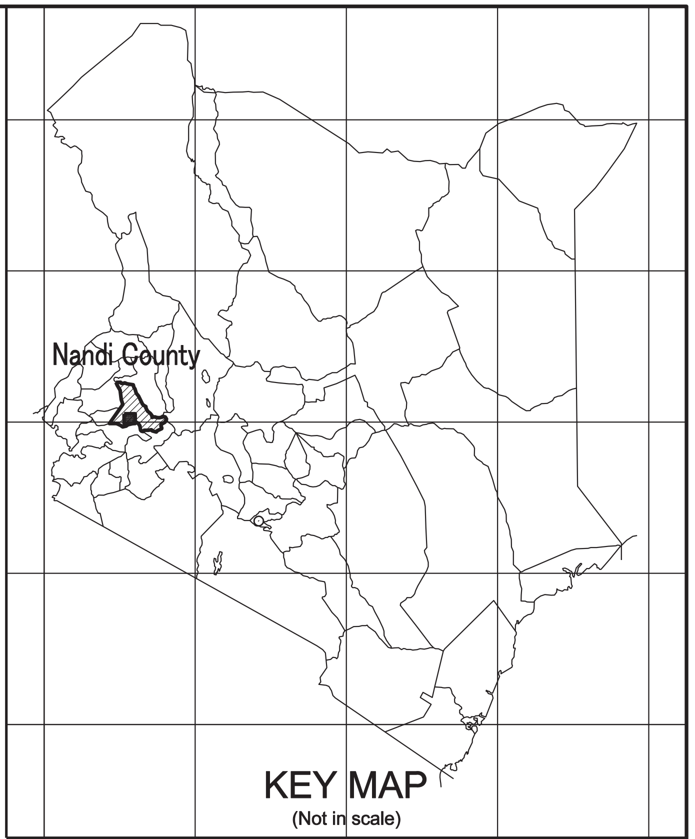
# Annex 3

# Preliminary Drawings of Asurur MHP

## List of Drawings

| | |
|---|---|
| ASR – 01 | Location Map |
| ASR – 02 | General Layout and Intake Weir |
| ASR – 03 | Waterway and Powerhouse |





KEY MAP
(Not in scale)

## Notes

Topographic data are using electric files of the topographic maps with scale of 1:50,000 which were purchased from the Land Survey Department under the Ministry of Land, Housing and Urban Development.
The sheet numbers are; 102-4/4, 103/3, 116/2, & 117/1.

## Legend

◉ Proposed Asurur Site
● Town, Gauging Station (G/S)
◌ Catchment Boundary

SCALE A 0 1,000 2,000 5,000 METRES

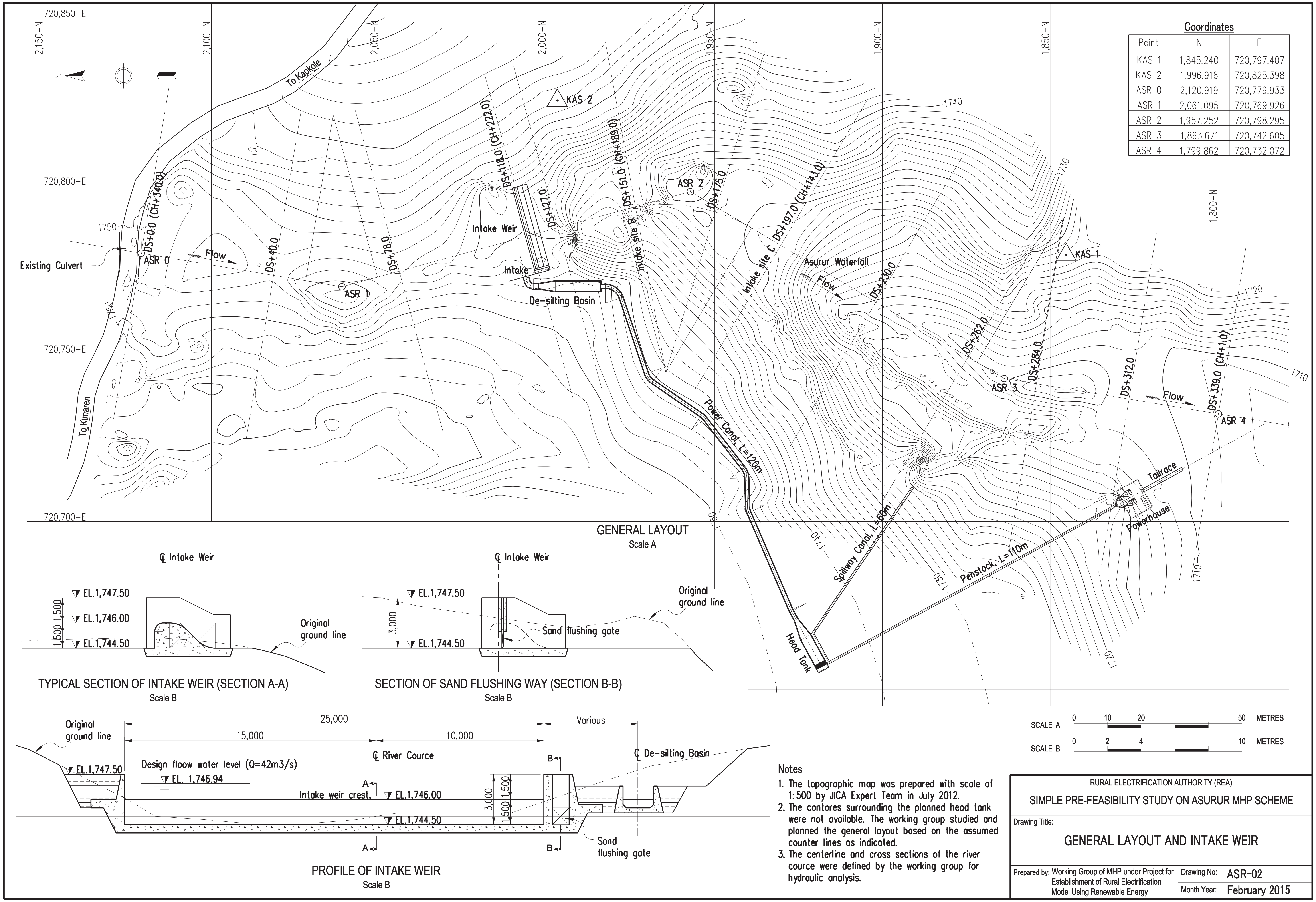
RURAL ELECTRIFICATION AUTHORITY (REA)

SIMPLE PRE-FEASIBILITY STUDY ON ASURUR MHP SCHEME

Drawing Title:

LOCATION MAP

| | | | |
|---|---|---|---|
| Prepared by: | Working Group of MHP under Project for Establishment of Rural Electrification Model Using Renewable Energy | Drawing No: | ASR-01 |
| | | Month Year: | February 2015 |



GENERAL LAYOUT
Scale A

TYPICAL SECTION OF INTAKE WEIR (SECTION A-A)
Scale B

SECTION OF SAND FLUSHING WAY (SECTION B-B)
Scale B

PROFILE OF INTAKE WEIR
Scale B

**Coordinates**

| Point | N | E |
|---|---|---|
| KAS 1 | 1,845.240 | 720,797.407 |
| KAS 2 | 1,996.916 | 720,825.398 |
| ASR 0 | 2,120.919 | 720,779.933 |
| ASR 1 | 2,061.095 | 720,769.926 |
| ASR 2 | 1,957.252 | 720,798.295 |
| ASR 3 | 1,863.671 | 720,742.605 |
| ASR 4 | 1,799.862 | 720,732.072 |

SCALE A 0 10 20 50 METRES

SCALE B 0 2 4 10 METRES

**Notes**

1. The topographic map was prepared with scale of 1:500 by JICA Expert Team in July 2012.
2. The contores surrounding the planned head tank were not available. The working group studied and planned the general layout based on the assumed counter lines as indicated.
3. The centerline and cross sections of the river cource were defined by the working group for hydraulic analysis.

RURAL ELECTRIFICATION AUTHORITY (REA)

SIMPLE PRE-FEASIBILITY STUDY ON ASURUR MHP SCHEME

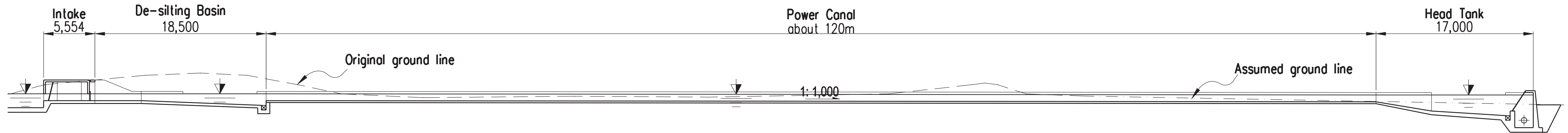
Drawing Title:

GENERAL LAYOUT AND INTAKE WEIR

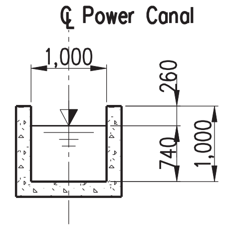
Prepared by: Working Group of MHP under Project for Establishment of Rural Electrification Model Using Renewable Energy

Drawing No: ASR-02

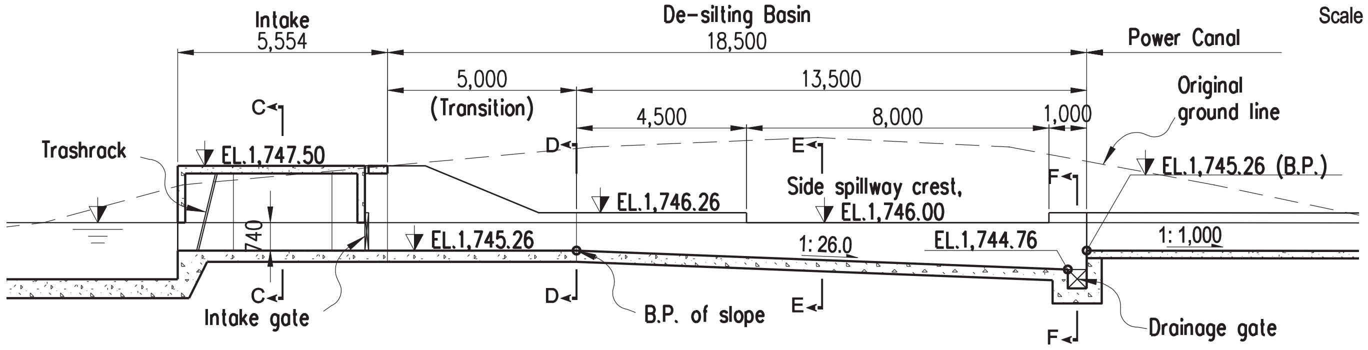
Month Year: February 2015



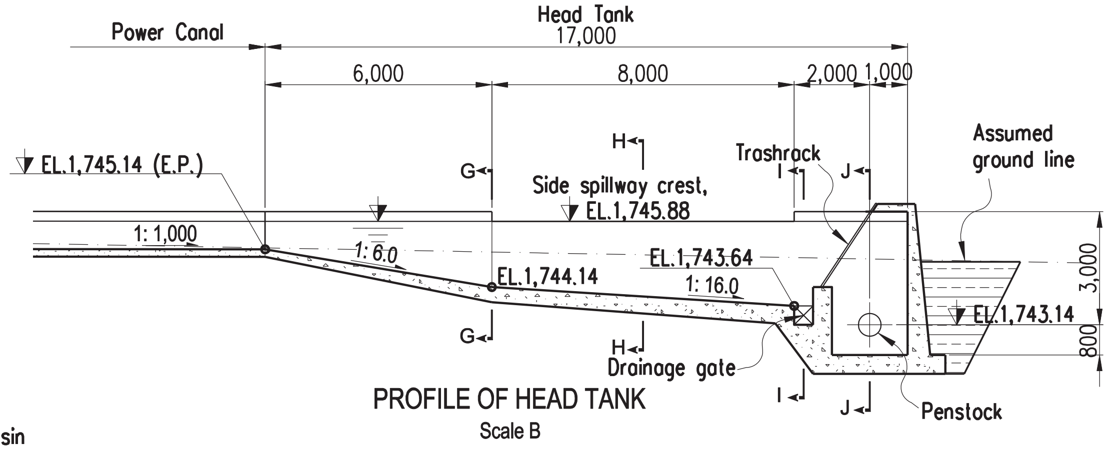
## PROFILE OF WATERWAY
Scale A



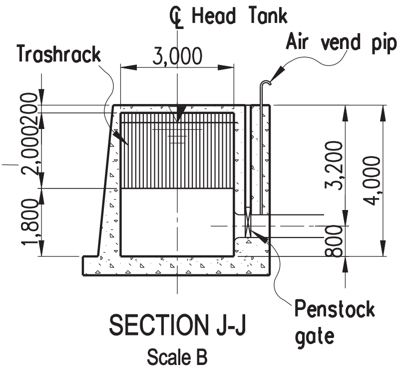
## TYPICAL SECTION OF POWER CANAL
Scale C



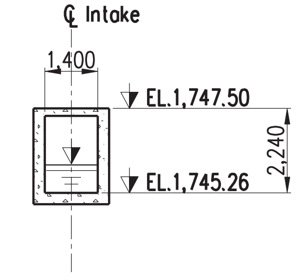
## PROFILE OF INTAKE & DE-SILTING BASIN
Scale B



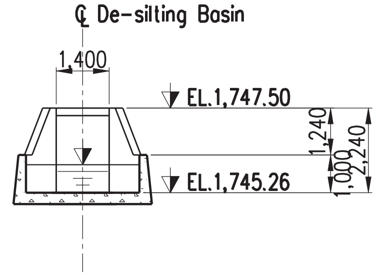
## PROFILE OF HEAD TANK
Scale B



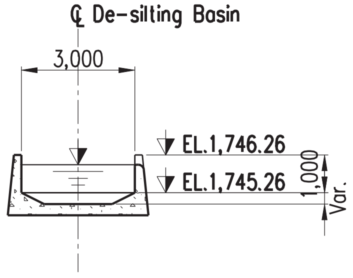
## SECTION J-J
Scale B



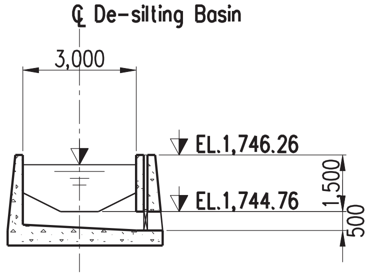
## SECTION C-C
Scale B



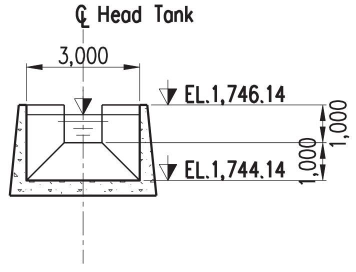
## SECTION D-D
Scale B



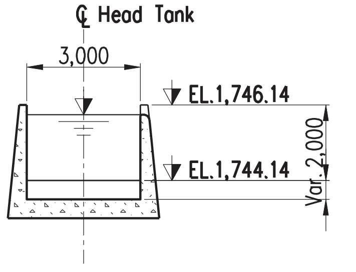
## SECTION E-E
Scale B



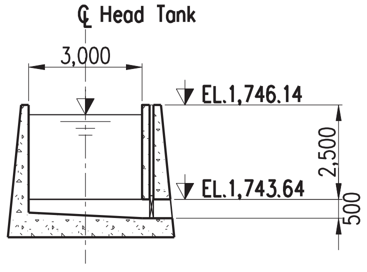
## SECTION F-F
Scale B



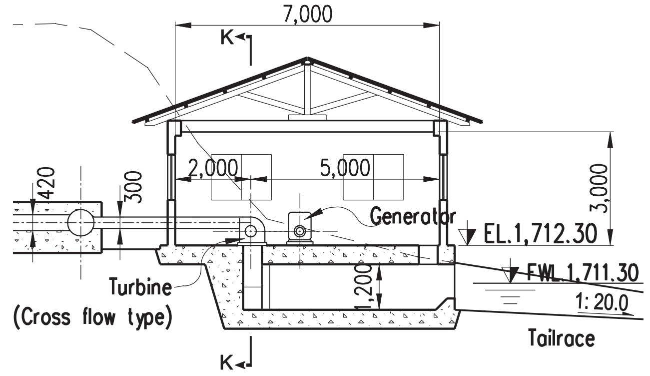
## SECTION G-G
Scale B



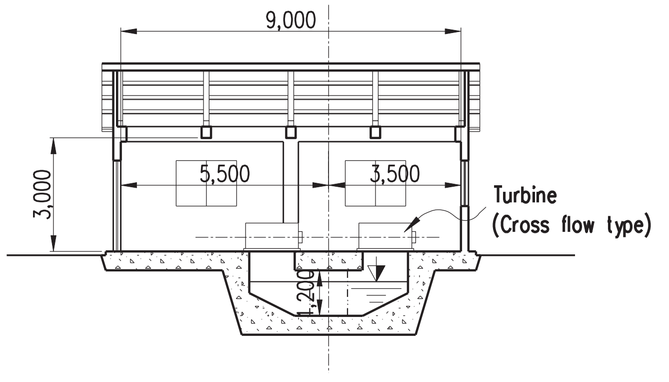
## SECTION H-H
Scale B



## SECTION I-I
Scale B



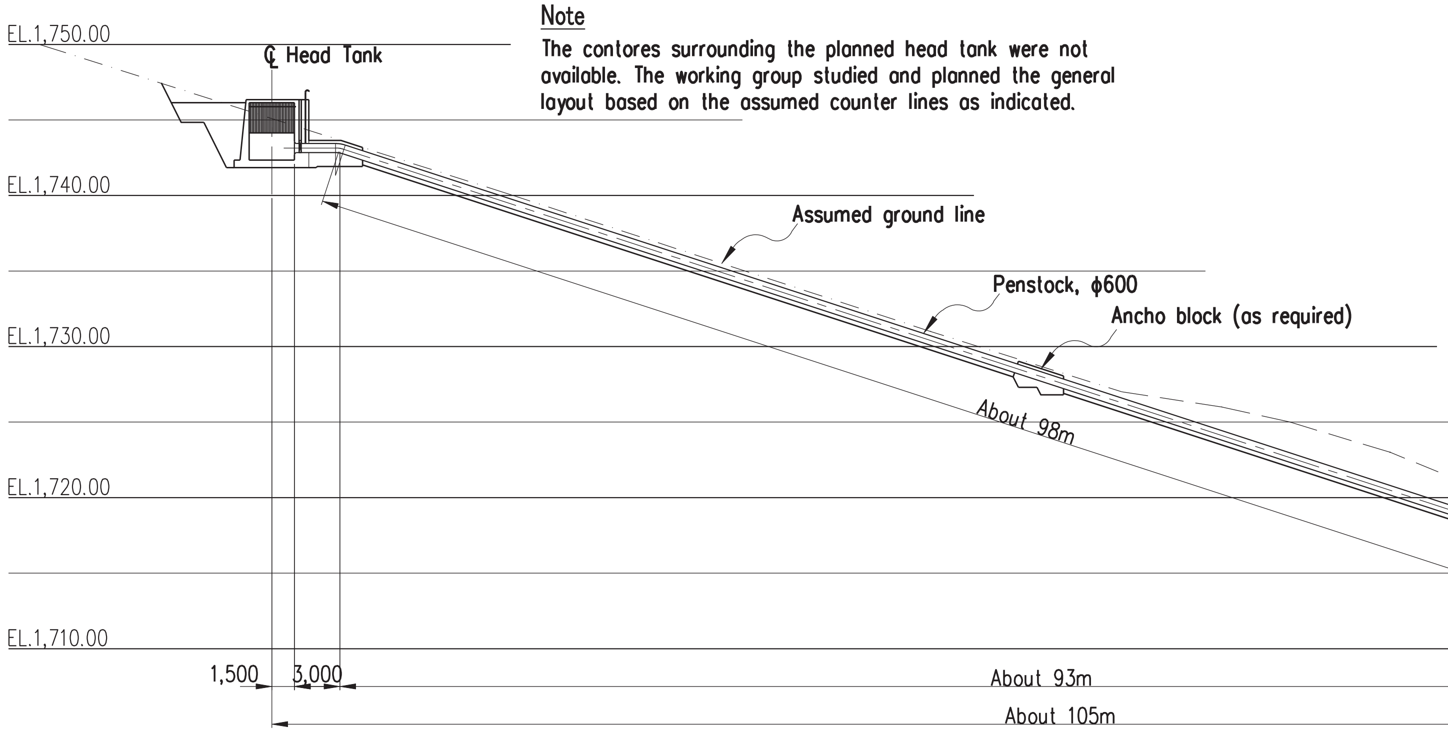
## PROFILE OF POWERHOUSE
Scale B



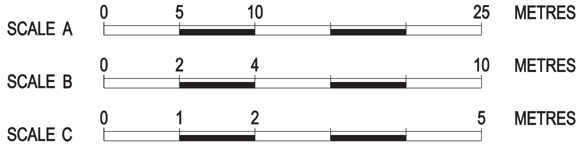
## LONGITUDINAL SECTION OF POWERHOUSE (SECTION K=K)
Scale B

**Note**

The contores surrounding the planned head tank were not available. The working group studied and planned the general layout based on the assumed counter lines as indicated.



## PROFILE OF PENSTOCK
Scale A



RURAL ELECTRIFICATION AUTHORITY (REA)

SIMPLE PRE-FEASIBILITY STUDY ON ASURUR MHP SCHEME

Drawing Title:

WATERWAY AND POWERHOUSE

Prepared by: Working Group of MHP under Project for Establishment of Rural Electrification Model Using Renewable Energy

Drawing No: ASR–03

Month Year: February 2015