3. HOW TO UPDATE GIS DATABASE

3.1 INTRODUCTION

In this chapter, mainly two issues, firstly (i) Energy source selection for each village in Cambodia; modeling, its real implementation and focal points for future updating and secondly (ii) Updating the GIS Database; its importance and fundamental methods has been discussed and presented. The first issue "Village Energy Source Selection" has been discussed in section one while section two has been dedicated to "Updating GIS Database".

Finding suitable and feasible source of energy for a village is an important step to achieve the rural electrification goal. For energy source suitability analysis GIS based approach, using GIS platform, has been selected. In this analysis all villages/settlements inside the country has been included with two main objects:

i) Formulation and calibration of the model

ii) Applying the model to categories the village in most suitable energy source group for its electrification.

While formulating the model, exhaustive approach has been followed to find the suitable, but available as well as viable, renewable energy source for each villages, before turning to conventional energy source for electrification.

An updated and reasonably acceptable quality database is the starting point for any GIS application. For Rural Electrification Master Plan project, a large amount of spatial data as well as attribute data has been accumulated from various sources. As the project has been formulated with long term vision, updating GIS database is the one of most import task to keep it relevant for the project or organization those suppose to use them in time and again. Not updated database keeps little value and even mislead to wrong conclusion with grave consequences in terms of money and time. Realizing the importance of the task, there must be some responsible person who has been assigned for the work. Such person should have administrative access to the computer system of the organization along with some experience in database management. Also, he or she needs some knowledge about the GIS software, preferably ESRI (380 New York Street Redlands, CA 92373-8100, USA) products.

3.2 VILLAGE ENERGY SOURCE SELECTION

This section has been started with preparation of GIS database for energy source selection analysis followed by stepwise energy source selection model implementation. The section has been closed with pointing out some important focal points of data updating that need attention in order to keep the relevancy of the model in future.

3.2.1 GIS Data Preparation

Following Dataset has been prepared and extracted from various sources.

i) Village Point Location Dataset and Village Attribute Data

ii) Political Boundary and Location of its Headquarter (HQ) Dataset

iii) Main Route (Route #1 to #7) Dataset

iv) Exiting Licensee REE Command Area Dataset

v) Land Use/Land Cover Dataset

vi) Potential Hydropower Location Dataset

(1) Village Point Location Dataset

The text X, Y village coordinate in UTM meter and village level socioeconomic survey data of year 2003 has been obtained from Seila, Phnom Penh, Cambodia. Following procedure has been followed to generate Village dataset using these two; (a) location as geographic feature and (b) socioeconomic data as attribute feature; data sets.

i) Generating Village Coverage from text location data

Using X and Y coordinate and the Unique ID, a suitable file had been derived that is ready to be imported into map coverage. The village map coverage had been generated using “GENERATE” command available in ArcGIS 9.0 with Arc/Info, an ESRI software. The coverage was build using “BUILD” command with POINT option. Finally the Map Projection System was defined using “PROJECTDEFINE” command and exported to shape file using “Conversion Tools” available in “Arc Tool”.

ii) Adding Seila, year 2003, attribute data to the village coverage

- The desirable socioeconomic items (for example, family size, population, household TV number, etc) were selected from Seila village socioeconomic survey data in XLS format.
- The Unique Village ID was placed in first Column.
- Each attribute was provided with code (for example, family size with “FAMILY”, number of household TV in rural area as “TV_MUM). In most of the cases the Seila devised codes were used.
- The coded data was saved in dBASE IV (.dbf) file format.
- It was linked with village map coverage using “Joins and Relates” command available in ArcMap and exported to new dataset using “Data” and “Export Data” command line.

iii) Adding NIS, year 1998 attribute data to the village coverage

- The village level lighting energy source data was extracted from NIS census data.
- These attributes were added to the village map dataset with the procedure described earlier.

(2) Political Boundary and Location of its Headquarter (HQ) Dataset

Following political boundary was extracted from MPWT dataset and stored.

i) Provincial Boundary and Provincial HQ location dataset

ii) Commune Boundary and Commune HQ location dataset

(3) Main Route (Route #1 to #7) Dataset

The latest updated national level road feature dataset of year 2005 was obtained from MPWT. This dataset contains all road and trails in the country. The main route map dataset was extracted using following procedure.

- The dataset was opened in ArcMap.
- All Hard Surface and Loose Surface road categories were selected from Attribute Table using logical data query, available in “Attribute Table”, “Option” and “Select by Attribute” command line.
- The selected features were exported to new coverage. By identifying main routes, the not required lines were deleted.
- The routes were provided with unique ID.

(4) Exiting Licensee REE Command Area Dataset

The hard copy map of exiting Licensee REE Command Area was obtained from EDC and digitized. The digitizing work had been contracted out. The digital data has information about the name of owner, location, etc.

(5) Land Use/Land Cover Dataset

The original Land use/Land cover Coverage was extracted from MPWT dataset. There are 40 types of land use/land cover categories available in this dataset from where, following categories were extracted and grouped into two main classless.

i) Grasslands
   - Grassland (undifferentiated)
   - Abandoned field covered by grass
   - Grass Savannah
   - Grass with termites mounds

ii) Shrublands
   - Shrubland (undifferentiated)
   - Abandoned field covered by shrub
   - Flooded shrub

(6) Potential Hydropower Location Dataset

The potential hydropower sites data was colleted and compiled by JICA Study Team. The data has X, Y coordinate in UTM meters along with several valuable parameters. The hydropower potential point map dataset was generated (method described earlier) and the parameters were linked as coded attributes to the dataset.

3.2.2 Model Implementation

The formulated model (given as flow diagram in Part 4-1, Section 2.4, Figure 2.4.2), with set “Criteria” and “Conditions”, was implemented using the data those were extracted and prepared and listed in section 4.2.1. There are two main categories of electrification followed by subcategories, which are listed below.

1) On-grid and
2) Off-grid Electrification
   i) Exiting Licensee REE Diesel Mini-grid
   ii) Exiting Non-Licensee REE Diesel Mini-grid
   iii) Battery lighting
      a. Social electrification by SHS
      b. Remote electrification by Solar BCS
   iv) Mini-grid electrification
      a. Mini-grid by micro hydro
      b. Mini-grid by biomass
         1. Plain region→ Grid extension Or Mini-grid by biomass
         2. Other region→ Mini-grid by biomass
      c. Mini-grid by Diesel
         1. Plain region→ Grid extension Or Mini-grid by diesel
         2. Other region→ Mini-grid by diesel

(1) On-grid and Off-grid Segregation

All 13914 villages were classified into two group using flowing steps.

1) The 40 km buffer zone, around all 24 provincial centers, coverage was generated using "Buffer" command available in "Arc Tool". The point coverage of provincial capital location dataset was used as center of reference point for buffer zone.
2) Two classes of buffer zones were created, namely (a) Plain region and (b) Other region. The "Plain region" includes area inside the buffer zone of 10 provinces (Phnom Penh, Sihanoukville, Svay Rieng, Kep, Kampong Cham, Kandal, Kampong Speu, Prey Veng, Takeo and Kampot) located around lower southeaster flood plain, while rest 14 provincial zone plus all other area out side the buffer zone included in "Other region". The unique ID, for both two regions and 24 buffer zones, was assigned.
3) 1 km buffer zone was generated around the road linear features from the main route #1 to #7 dataset. The line was treated as the center of reference while buffering it with 1 km radius.
4) The villages were "Intersected" in sequence with (a) Provincial buffer zone coverage (b) Licensee REE coverage and (c) 1 km main route buffer zone coverage, using "Identity" command.
5) From the attribute table "using logical data query" the villages intersected with "Phnom Penh EDC command area (from REE coverage)" plus those intersected with both "Provincial buffer zone" and "Main route buffer zone" were selected and assign with "Unique ID" that refer to "On-grid electrification villages", while else "Off-grid electrification villages".

(2) Battery Lighting and Mini-grid Lighting Segregation

Those villages fall under "Off-grid" category, were further placed under "Battery lighting" and "Mini-grid electrification" using following steps.

1) **Exiting Licensee REE Diesel Mini-grid**: villages were "intersected" with licensee REE dataset using "Identity" command. Those villages intersected with REE command area "Except Phnom Penh EDC" were assigned with "Unique ID" that refer to "Exiting Licensee REE Diesel Mini-grid".
2) **Exiting Non-Licensee REE Diesel Mini-grid**: From the village attribute table villages with

equal and over 10 percent electrification (calculated from NIS data: # HH using City Power, Generator and City Power plus Generator), and “Not classified as Exiting Licensee REE Diesel Mini-grid” were selected using “logical data query” and assigned with “Unique ID” that refer to “Exiting Non-Licensee REE Diesel Mini-grid”.

3) **Mini-grid electrification**: Villages “Not classified as Exiting Licensee and Non-Licensee REE Diesel Mini-grid” and having equal to and over 10 percent TV diffusion level (calculated from Seila data: ## HH having TV; both rural and urban areas) were provided with “Unique ID” that represents “Mini-grid electrification”. However, villages satisfy first condition and “NOT” second, but having “Application to PDC” were also added in this category.

4) **Battery lighting**: Villages “Not classified as Exiting Licensee and Non-Licensee REE Diesel Mini-grid” and having less than 10 percent TV diffusion level except those having “Application to PDC” were selected and assigned with “Unique ID” that refer to “Battery lighting”. Further, villages in 6 surveyed provinces having less than 20 percent battery lighting HH and not having “health post” or “school” were categorized in **“Remote electrification by Solar BCS”**, while else **“Social electrification by SHS”** sub categories and provided with “Unique ID”.

(3) Mini-grid Electrification Segregation

Those villages fall under “Off-grid” and “Mini-grid electrification” category were further placed under “Micro Hydro”, “Biomass” and “Diesel” mini-grid electrification group using following steps.

1) **Mini-grid by micro hydro**: Villages those were connected with micro hydro plan. The candidate villages that can be feasibly connected with micro hydro plan was calculated by plotting the villages and potential hydro power sites together with contour lines, river and road network using 1:1000,000 scale map. Calculation was done while observing actual ground access distance, besides other considerations. The listed villages were assigned with “Unique ID” that refer “Mini-grid by micro hydro”.

2) **Mini-grid by biomass:**

Potential land area calculation for producing biomass:

i) The extracted land use/land cover map, which comprises “Grassland” and Shrublands”, were overlayed with “Commune boundary” map (commune boundary map is the smallest administrative boundary dataset available at the moment) using “Union” command that resulted into new coverage.

ii) From the new coverage, total “Grassland” and “Shrublands” area was calculated for each commune using “Frequency” command.

iii) From the Seila data, family size for each commune was calculated.

iv) Using “Area” and “Family Size”, the land available per household (Grassland + Shrublands) was calculated and linked to the “Commune boundary” map dataset.

v) “Village map” dataset was intersected with “Commune boundary” map dataset using “Identity” command.

vi) Finally, the land area availability for villages was obtained.

- **Plain region→ Grid extension Or Mini-grid by biomass**: Village those fall under “Mini-grid electrification” but “Not in Mini-grid by micro hydro” and having equal to and over 0.02 ha/HH land area and came inside the “Plain region”, were categorized in “Plain region→ Grid extension Or Mini-grid by biomass” and provided with “Unique ID”.
- **Other region→ Mini-grid by biomass**: Villages those satisfied all other condition for “Plain region→ Grid extension Or Mini-grid by biomass” category, but came inside “Other region” were placed in “Other region→ Mini-grid by biomass” electrification group and assigned with “Unique ID”.

3) **Mini-grid by Diesel**:

- **Plain region→ Grid extension Or Mini-grid by diesel**: Village those fall under "Mini-grid electrification" but "Not in Mini-grid by micro hydro" and having less than 0.02 ha/HH land area and came inside the "Plain region", were categorized in "Plain region→ Grid extension Or Mini-grid by diesel" and provided with "Unique ID".
- **Other region→ Mini-grid by diesel**: Villages those satisfied all other condition for "Plain region→ Grid extension Or Mini-grid by diesel" category, but came inside "Other region" were placed in "Other region→ Mini-grid by diesel" electrification group and assigned with "Unique ID".

3.2.3 Focal Data Updating Points and Its Sources

Geographical as well as attribute feature data must be updated timely so that the output from the model reflects the changes those occurred in due course of time. From the common sense, it is obvious to notice and overall check the area of datasets those has been listed and used in this model. Some of the main focal points are as listed below

1) Number of village in the kingdom. For updated new villages, Seila, NIS and General Department of Cadastre & Geography (GDCG) should be consulted.
2) Village attribute features:
   i) Village lighting source; currently NIS 1998 census data is being used. Once the new data that reflects the current energy source for village lighting, from any institution, should be used in future.
   ii) Level of TV diffusion: Currently Seila data of year 2003 is being used.
3) Political boundary; updating commune boundary and commune location. Village boundary should be used, once it is available, for extracting the available land for biomass production. Location of provincial capital should be checked and updated, if there is nay change in it. Relevance agencies are GDCG and NIS.
4) Main route; once the new national route appears on the ground with the possibility of grid extension alongside, it should be updated. Relevance agency is MPWT.
5) It is almost sure that number of Licensee REE will grow in future and those new REE should be added in to this database as well. Relevance agency is EDC.
6) The grassland and shrublands has been extracted from currently available land use/land cover map, year 2003. Once the map is updated (consult MPWT and Ministry of Land Management, Urban Planning & Construction), these features should be extracted freshly from new map and replaced.
7) New potential hydropower sites if surveyed in future, it should be updated in this database as well. Relevance agencies are MIME and Ministry of Water Resources and Meteorology.

3.3 UPDATING GIS DATABASE

In this section, some basic requirements of GIS database updating and its method has been presented and discussed briefly. For detail, one has to refer the online help that is available with the software. It should also be noted that some of the command used here originally from Arc/Info, which might not be available in ArcGIS 9.0 with ArcView.

3.3.1 Planning and Design of Database

According to agreement between JICA and MIME, JICA Study Team has been provided with office space at Department of Energy Technique (DET) of MIME. The team has installed one server with Local Area Network (LAN) facility. In order to provide data access to all connected computer (JICA Study Team Member), GIS database has been setup in the server. It has been assumed that similar setup will be available with the DET while handing over the database, else the database also can be copied to the standalone computer while making necessary modification in the address of the files those linked with projects, specifically map composition.

A simple layout of the main and subfolder has been created (Figure 3.3.1). The required and relevant basic information about the data has been given in the ReadMe.Doc files with folder and subfolder. The name of folders itself provides some information, which is the source of type of data in most of the cases. It is desirable to keep the integrity of the name of folders and subfolders as the dataset and coverage has been linked to the projects.

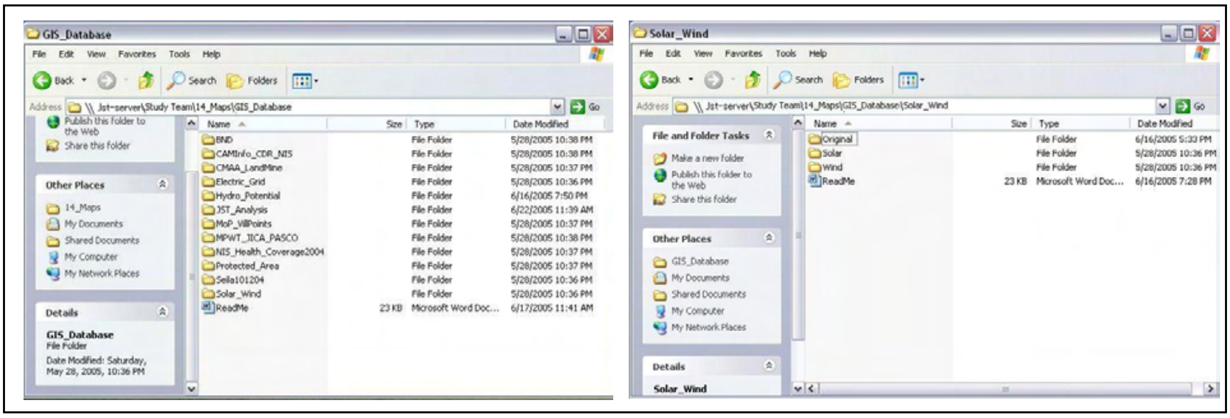

Figure 3.3.1 Layout of GIS Database at JICA Study Team Server

3.3.2 Structure of the Database

This database is well structured, but very simple so that any person who has basic computer knowledge can reach to the desired dataset. Here access to the desired dataset can be reached by clicking the folder and subfolder, while reading the ReadMe.Doc file.

Before updating the database, one need to know its structure, most importantly which data has been kept where. To become familiar with the database, one need to open the folder and read the ReadMe.doc file first. In most of the case it will give following information

1) Source of the data
2) Date of the collection/compilation/creation
3) Name of the folder and brief description of the files, dataset, coverage inside
4) Brief but basic information about the data
5) Brief metadata in some cases

To make things simple and clear, the metadata on the data has been kept separately, with the name MetaData.doc wherever it is necessary and required. However, in some cases, it might not be complete because of such metadata was not available at original source itself. As it is widely know, the metadata is the most important information that must be consulted before updating the database.

3.3.3 GIS Software

There are wide varieties of GIS software, developed by several vendors, available these days, such as ArcMap, MapInfo, GRASS and others. Some are open source while other very profession. For this project ArcMap with ArcView 9.0 developed by ESRI, has been selected. The single and stand-alone desktop licenses also include Spatial Analyst Module. Software has been installed in computer (with Microsoft window operating system) at Department of Energy Technique, MIME. With this ESRI license, much of the GIS work stipulated for this project can be achieved.

3.3.4 Time Frame of Database Upgrading

It is difficult to set the time frame of data updating in real sense. There is no dispute that database should be updated immediately once the original source get any change. However, in many cases it is not feasible to update the data immediately while considering, for example available resources and need. While talking about the time frame of database updating, following category might be considered here.

(1) Long Time

Some of the land feature does not change much and can be used for long time. For example general topography of the country is, more or less, remains unchanged for considerably long time at macro scale. Thus topography map of a country does not require frequent updating. Another example is the national boundary map of a country that might be used for long time.

(2) Less Frequent

Less frequent need of map updating might be, for example, can be defined as five years time frame. Some land feature, for example Land use/Land cover map of a country, keep changing with the time, but such change is not so significant within a year and not economically feasible to update it every year. Depending upon the requirements, importance etc., such map may be updated in every five years. In Cambodia, the political boundary, specifically commune and village is keep changing in current situation. Also, during the field survey it has been found that some new villages are popping up, specifically in remote areas like near Thailand border in Banteay Meanchey province. Such change should be updated as soon as information is made available from concern authority.

(3) Frequent

Several types of statistical data are recorded on annual basis in many countries and published towards the end of physical year. For example, currently in Cambodia, Seila is collecting socioeconomic village data every year. In this database, year 2003 Seila Village data is being used and year 2004 data will be published soon. Thus, it should be updated on annual basis. Similarly, meteorological agency of a country publishes rain, solar irradiance, wind, etc. data on daily/monthly/yearly basis and need to be updated frequently according to the need of the program/project.

There are two categories of frequent updating data, namely (i) those should be replaced with new data and (ii) just needed to be adding/editing. In first category, data should be totally replaced while in second, portion of it should be added or edited. For example, there are several attributes added to the village dataset extracted from various sources. The villages have been provided with unique Ids that is being followed widely in various institutions. The socioeconomic village data should be replaced with new one from Seila, while other attribute should be edited as it gets updating in original source. Some new attributes might need to be added (for example availability of school/hospital in the village) once it is available.

3.3.5 Feature to be Updated

GIS database primarily comprises two types of features, namely (i) geographic and (ii) attributes. While keeping the geographic feature intact, several attribute features can be added or linked to it in tabular format. Once the geographic features updated, the attributes for the new added/updated features should also be added/updated.

(1) Geographic Features

There ate three types of geographic features in this database, namely (i) point, (ii) line and (iii) polygon. Also, database includes both ArcInfo Coverage as well as shape (SHP) files (ArcView can read and use both of them). Care should be taken while defining the data types (point, line, polygon) during updating and rebuilding the data. If the point data is build or exported as polygon, for example, the related features cannot be used or analyzed further.

(2) Attribute Features

The attributes of the dataset can be found in attribute table attached to every datasets. Most of the dataset has been attached with additional attributes that explain the related information about dataset. There are some default attributes, generated by software, for example area and perimeter incase of polygon type of dataset, attached to the dataset as well. The default attributes get updated automatically once the geographic features are being updated while additional attributes need to be updated by user separately.

The new set of information can be added by defining new attribute column in attribute table. Alternatively, the new information can be kept separately in table and linked to the dataset by defining common Ids. The attribute should be edited either by typing individually or calculating them after selecting desirable group of features.

(3) Metadata

Metadata is “data” about the “data”. A simple example of the metadata is library catalogue containing information (metadata) about publications (data). In GIS, the dataset (Coverage/ shape files) are data while the text explaining about it features (both geographic and attributes) is called metadata. Metadata is an important and integral part of GIS database and, in many cases, the dataset might keep little value without metadata. It is obvious that once any of dataset features get updated, the metadata should also be updated accordingly, else there is no need to update it.

(4) Adding New Dataset

The GIS database is itself being updated once the new dataset is added to it. The selection of additional new dataset depends upon requirements. It is advisable to avoid adding unnecessary dataset as it occupy space and might create confusion during application. Also, several new dataset can be produced by modifying/manipulating the original one. It is good idea to keep the suitable few selected one and deleted other. During the data processing, in many cases, intermediate/temporary dataset has been produced. Such dataset should be deleted once the final goal of analysis has been achieved.

3.3.6 Illustrative Method of Updating Database

In this manual, most demanding data updating methods has been illustrated by using the pictorial approach. As the software is window driven, the command line has been opened step by step and put them here in picture with some explanation.

(1) Geographical Features

Adding new village point:

It is most likely that number of village in Cambodia will be changed; as several exiting villages are not recorded as well as new villages will popup with continuing rehabilitation program. Thus, it is desirable to update village data as much as possible.

Open desirable village dataset and go to “Editor” in main menu and select “Start Editing” (Figure 3.3.2), which resulted in to popup window shown in Figure 3.3.3. Select desirable folder, where the dataset is placed. The list of dataset will be displaced in the lower part of the window. Finally, press “OK” radio button to start editing the dataset. Figure 3.3.4 shows the selection of desirable target dataset and appropriate tools to adding village points.

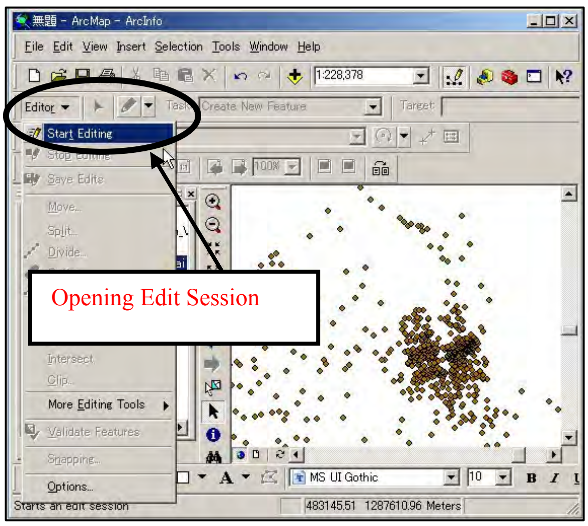

Figure 3.3.2 Starting Edit Session

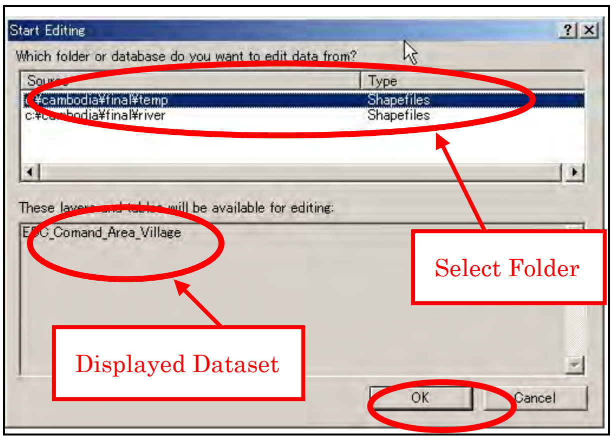

Figure 3.3.3 Selecting Dataset Folder

Obtained the location (X and Y Coordinate of New Village) of new village and move cursor (mouse) at desired (X, Y) location and click it. It will add the new point feature in dataset (Figure 3.3.5). After completion of adding all points, go to “Editor” and select “Stop Editing” followed by pressing “Yes” in the “Save” popup window that followed. The new village will be added and saved in the dataset.

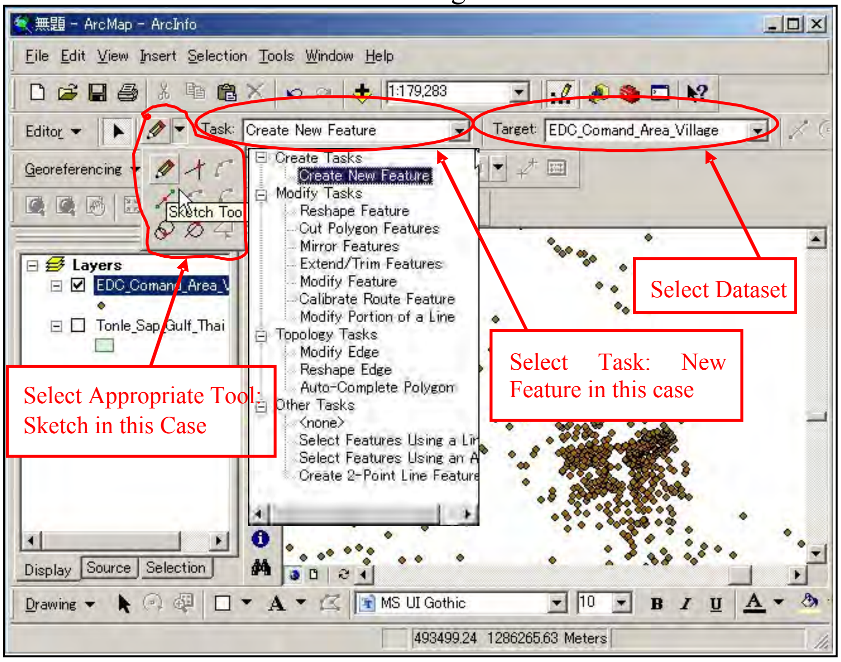

Figure 3.3.4 Selecting Target, Task and Appropriate Editing Tool

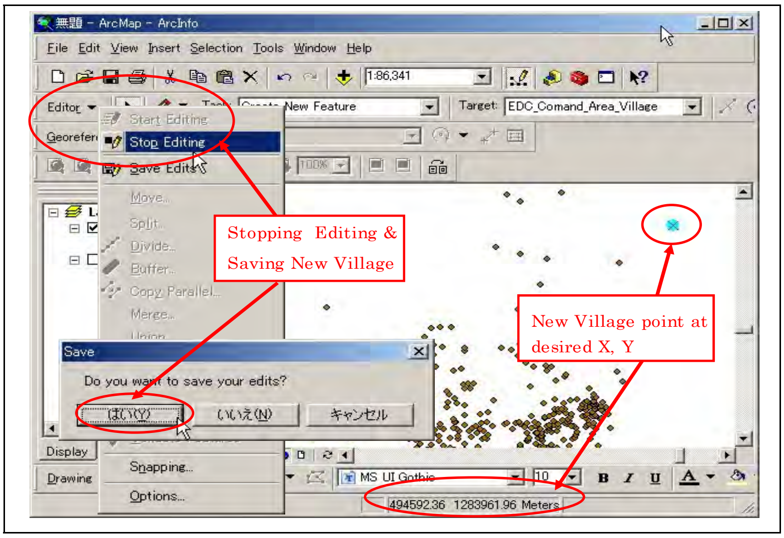

Figure 3.3.5 Adding New Village in the Dataset

Similarly line and polygon dataset can be edited by selecting appropriate tools.

(2) Attribute Features

Attribute feature can be updated/added using data query in the attribute tables. As mentioned earlier, either data can be typed or calculated by selecting items and calculating them in desirable column.

Select desirable dataset in available layers and click “Right Mouse” and select “Open Attribute Table” to open the attribute features attached with this dataset (Figure 3.3.6). The table will appear (Figure 3.3.7), where attribute can be typed directly using “keyboard” or calculated using “data query”.

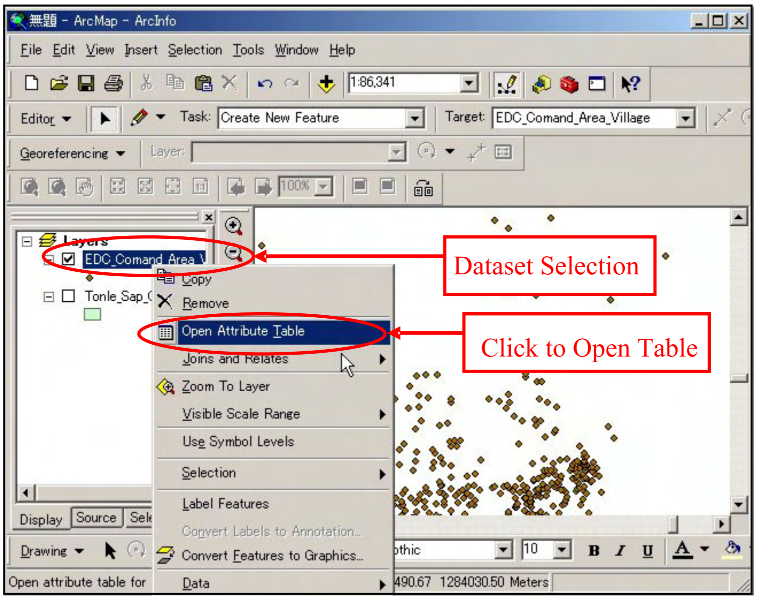

Figure 3.3.6 Opening Attribute Table of Dataset

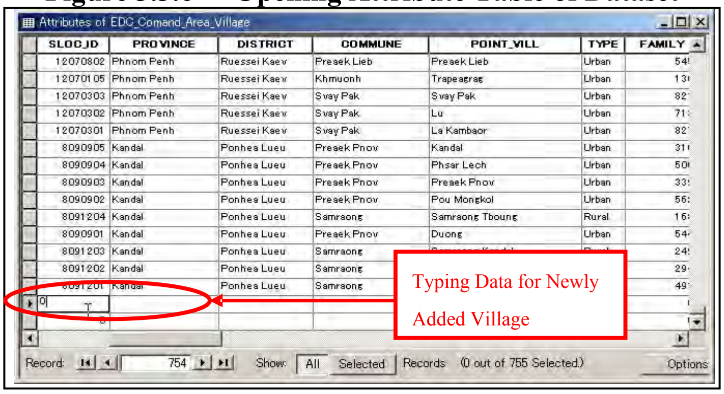

Figure 3.3.7 Attribute Table in Edit Mode

To calculate attribute using data query, first select the desirable number of items (row) either using logical search (Figure 3.3.8) or simply selecting rows while holding and dragging the mouse. For logical selection, go to "option" and select "Select By Attributes", which resulted in to popup window that is being shown on the left side of Figure 3.3.8. Select the desirable item ("FID" in this case) and enter the logical expression to select the desirable items.

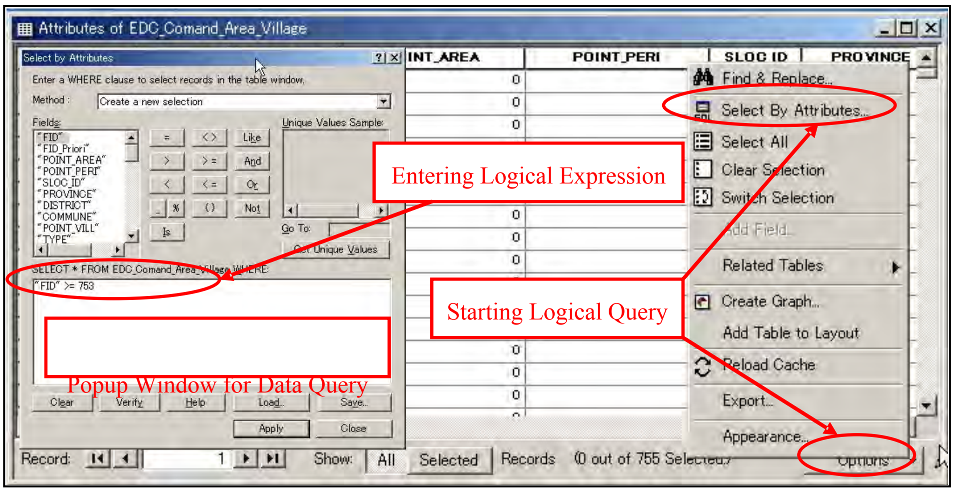

Figure 3.3.8 Selecting Items Using Data Query

Once desirable items (rows) selected, go to the required attribute that need to be calculated by selecting appropriate "Column" as shown in Figure 3.3.9.Click the "Right Mouse" and select "Calculate Values" that resulted into popup window shown in Figure 3.3.10. The left side of the Figure 3.3.10 shows the case of calculating "Character Type" attribute while right side shows the "Numerical Type". The character (or string) should be kept inside "Double Apostrophe".

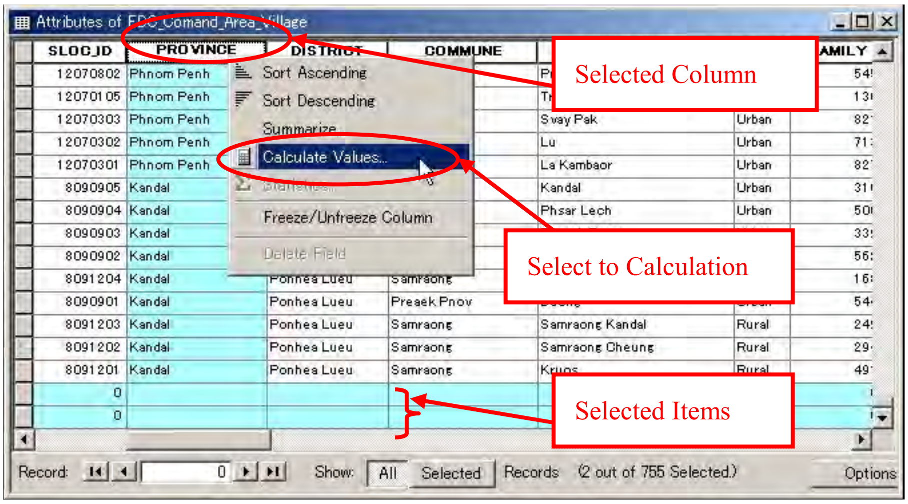

Figure 3.3.9 Selected Column for Calculating Attribute

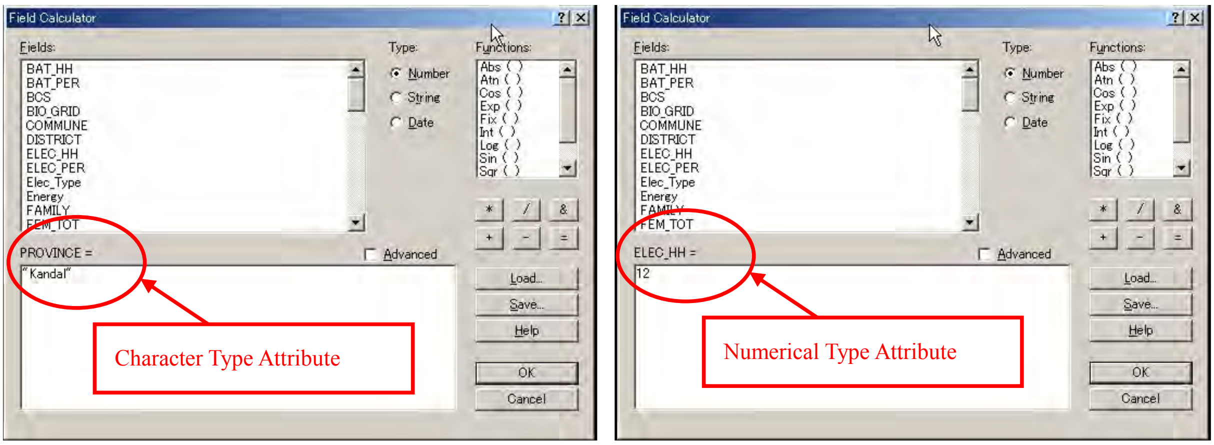

Figure 3.3.10 Calculating Character and Numerical Attributes

(3) Metadata

Metadata can be updated by simply modifying the text (editing, adding) of original metadata. Modified metadata should reflect the last changes those have been made recently.

3.3.7 Map Projection System

Responsible institute for standardization of coordinate system in Cambodia is The General Department of Cadastre & Geography (GDCG), Ministry of Land Management, Urban Planning & Construction (MLMUPC). Recently, the UTM (Universal Transverse Mercator) with Zone 48N, Datum Indian 1960 and Spheroid Everest has been widely used. All the data in this Database are kept with this projection system. While adding new data, attention should be paid to reproject it, if it is not in the above mentioned coordinate system.

In some cases, data is projected with a projection system, but the projection definition is not present in the coverage. Once the projection system is know, it can be defined for that particular coverage. Also, before reprojecting the coverage from one projection to another projection system, the projection definition must be defined prior to reprojecting it.

(1) Method of Defining the Map Projection

Go to the "ArcToolbox" and select "Database Management Tools" and proceed to "Projections and Transformation" and select "Define Projection" (Figure 3.3.11). The popup window (Figure 3.3.12) will appear.

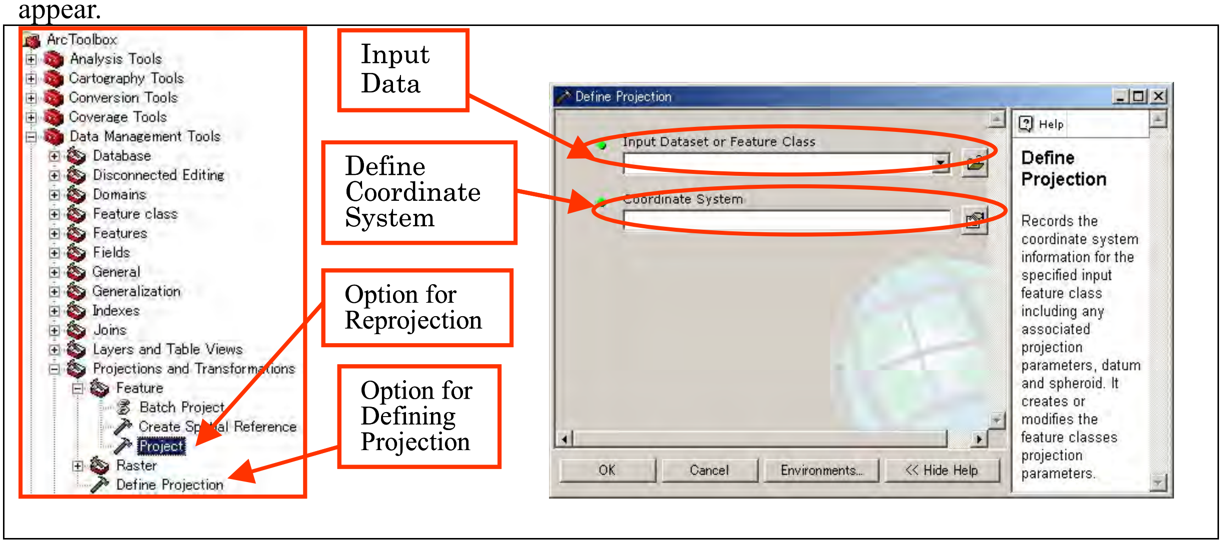

Figure 3.3.11 ArctToolbox Popup Window after Selecting ArcTool from Main Menu

Figure 3.3.12 Popup Window for Defining Dataset Projection

Select input dataset where projection needed to be defined followed by clicking radio button beside "Coordinate System" selection space, which resulted into popup window as shown in Figure 3.3.14. The radio buttons, "Select", "Import" and "New" can be used for selecting the predefined projection system, importing the projection system from other dataset and defining new coordinate system respectively.

(2) Method of Reprojecting the Map

Go to the "ArcToolbox" and select "Database Management Tools" and proceed to "Projections and Transformation" and select "Project" (Figure 3.3.11). The popup window (Figure 3.3.13) will appear.

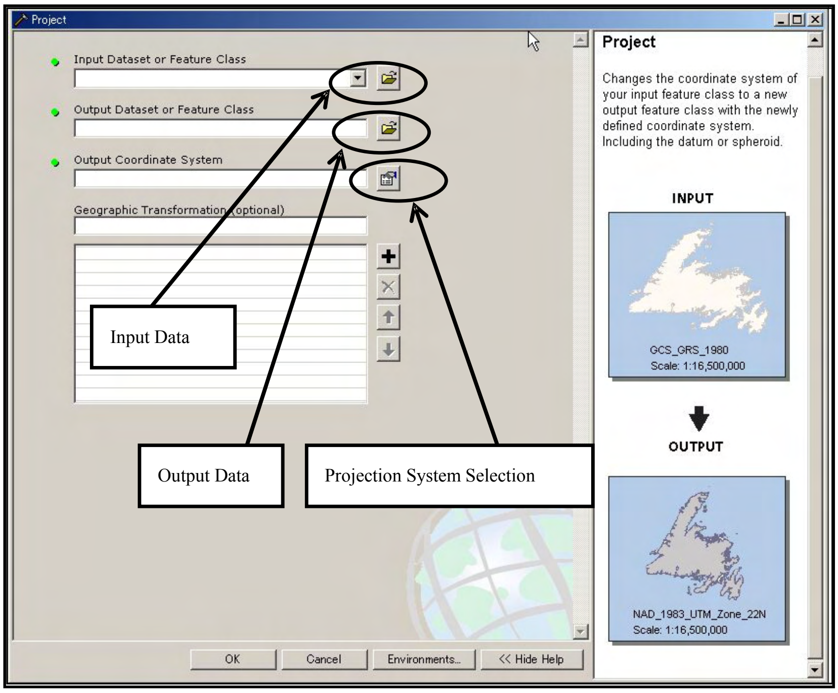

Figure 3.3.13 Map Reprojection Main Window

Select input dataset (need to be reprojected) and output dataset (new dataset with new desirable projection system). The output coordinate system can be defined by clicking radio button beside "Output Coordinate System" selection space, which resulted into popup window as shown in Figure 3.3.14. The radio buttons, "Select", "Import" and "New" can be used for selecting the predefined projection system, importing the projection system from other dataset and defining new coordinate system respectively. After inputting necessary information, press "OK".

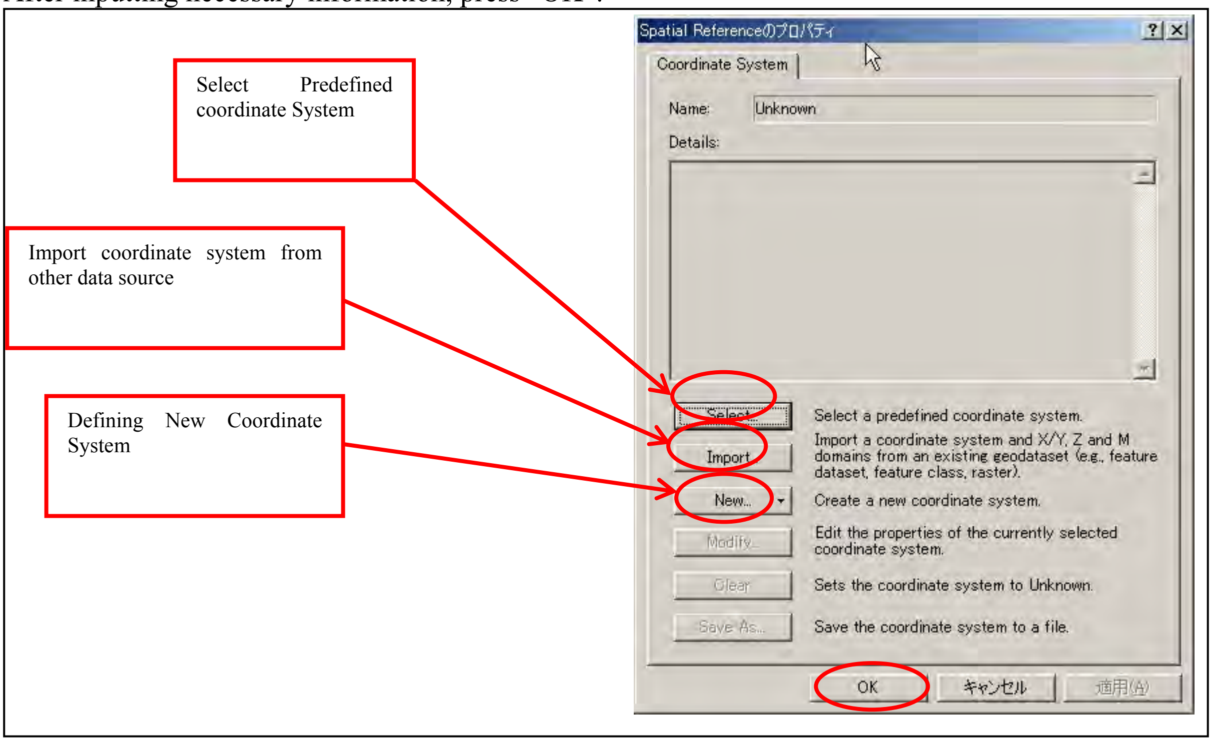

Figure 3.3.14 Options for Selecting New Coordinate System

The following map projection system has been used in this database.

Map Projection

(i) Projection Type: UTM (Universal Transverse Mercator)

(ii) Zone: 48 N

(iii) Datum: Indian 1960 (ING_B)

(iv) Spheroid: Everest

(v) False Easting: 500000.0000

(vi) False Northing: 0.00000000

(vii) Central Meridian: 105.0000

(viii) Scale Factor: 0.999000

(ix) Latitude of Origin: 0.00000

3.3.8 Data Sharing and Copyright

These days most of the institutions have policy of sharing information with various degrees, ranging from very open (sharing all whatever it has) to very limited, depending upon the nature of the organization. In this database, most of the data has been collected from different institution in Cambodia while JICA Study Team has created some primary digital data as well. Furthermore, some new data has been extracted from original sources. Such extraction, for example, came from logical data analysis using formulated model, simple overlaying, rearranging attribute data, reclassification, updating geographical and attribute feature, data merging from various sources, new map composition, so on and so forth.

For collected original data, copyright remains with source institution, while for JICA Study Team input and output data, through various analyses, copyright remains jointly with JICA and MIME. It is well know that one need to respect the copyright norms while sharing the information in any case and situation, which also apply for this database.

3.3.9 Some Important Dataset that Need Urgent/Timely Attention for Updating

As mentioned earlier, all the datasets stored here should be updated timely. However, some of the important datasets, those need urgent attention, have been listed below.

1) Boundary: Political Boundary Map of the Cambodia

- International: Authorized Updated Map is not available. Currently the provincial boundary map has been used, also as International Boundary map. The boundary of the provinces, those share the boundary with surrounding country, are considered as unofficial international boundary of Cambodia.
- Commune: While using NIS (National Institute of Statistics) and Seila data village attributes, many discrepancies have been encountered in
  - i) Name of the Commune and
  - ii) There are several cases where listed Village in attribute data for Commune and its actual location on the ground not matching.It should be updated by consulting with concerned parties in future. Recently the updated and authorized nomenclature has been posted by NIS, which can be found at "http://www.nis.gov.kh/areaname/area_name.htm".
- Village: Boundary map for village is not available, only point location (possible the village

center) was made available from Seila, Cambodia on 10 December 2004. This location is not official, but most updated one with 13910 Village. The official village location is being released from GDCG, MLMUPC, but all villages have not been registered yet.

2) Exiting Village Electrification Level

3) Natural Landscape Features

Reserved Area, Land Use and River Network are the natural as well as manmade boundaries and subject to be changed by time. In most of the cases, these maps are updated on regular basis while fixing the time interval of such update. The updated data should be obtained from relevance agency for replacement in the GIS Database.

4) Suspected Landmines Sites

5) REE and Grid Extension Lines

6) Village Attribute dataset features

3.4 CONCLUSION

Using most updated and available dataset, the energy source selection for village electrification has been achieved. All 13914 listed villages in this database were grouped one or other type of energy source. Such grouping is based on available and feasible source of energy for particular village in question. Furthermore, detailed account of methodology and calculation procedure has been presented along with requirements of data updating to keep the model relevant in due course of time.

Updating database should keeps higher place in the prioritized work list of an organization. Regular updating not only provides relevant and meaningful data analysis result, but also save time, money and effort that might be placed at wrong place in wrong way otherwise. Furthermore, regular updating enhance the understanding about data and make it easier compared to updating data on irregular basis.

The issue of data updating time frame, varies from one type of data to another. Some data like contour lines of natural land feature needs less frequent updating while other should be update very frequently for example village electrification level. Also, care should be taken about the type of data and level of updating. Some data might be replaced with new one, while other needs minor editing. Lastly, metadata should also be updated immediately once the dataset is updated, replaced or newly added.

4. PUBLIC RELATIONS

A key element of the success for promotion and diffuse of RET-based RE development is to keep the relevant stakeholders, including developers (REEs and CBOs) informed timely and properly. Thus, the development and implementation of relevant PR activities, namely, awareness raising & communication activities related to the policy objectives should be undertaken at national and local levels.

MIME/DIME and REF and/or a new independent institution (say the renewable energy center) to be established by MIME will make public awareness campaigns and train prospective REEs and CBOs who invest in the rural electrification projects. Concrete PR activities include the following:

- To distribute and diffuse " the Visual Guide" produced by the JICA Study Team to all communes and representatives of REEs, CBOs and NGOs
- To hold seminar/workshops for REEs/CBOs/NGOs
- To publish the contents of the seminar/workshops in the form of lecture notes at the website
- To publish Renewable Energy News as periodicals/circulars
- To establish the Renewable Energy Technology (RET) consultation Room in MIME's Technical Energy Dept.
- To install a website on RETs and disseminate information on them
- To establish the REC's branch office in each DIME office for responding to local needs and requests
- To conduct applied research and organized dissemination of new RETs for Cambodia (setting up a new organization like "Biomass Center" as the needs be)
- To implement pilot projects using RETs and disseminate the lessons and experiences
- To prepare technical standards and safety codes on RET-based rural electrification projects and make the relevant parties aware of them

Volume 3 Manuals

Part 1	Manual for Updating Master Plan
Part 2	Manual for Preparation of Electrification Plan

THE MASTER PLAN STUDY
ON
RURAL ELECTRIFICATION BY RENEWABLE ENERGY
IN THE KINGDOM OF CAMBODIA

FINAL REPORT
VOLUME 3 : MANUALS

Table of Contents

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HOW TO USE THE MANUAL

Who are the Manual for?

The Manual for Preparation of Electrification Plan aims at serving people living in non-electrified villages and wishing electrification, NGO, staff of DIME and Development Committees at Communes and Provinces. The Manual will also be helpful for such service providers as REE, suppliers of equipment and materials, EdC, REF, and REC.

What is the purpose of the Manual?

The Manual provides basic information and procedures for conceptual planning of village electrification and application to REC for financial supports. The Manual aims at providing information to clarify most of the questions listed below that villagers and REE may have in planning rural electrification:

1) What is the Government policy to achieve national electrification?
2) What is power grid?
3) When is the national grid expected to come to my village?
4) What are the on-grid area and off-grid areas?
5) What kind of options are available for the villagers living in the off-grid areas to achieve electrification?
6) What is renewable energy?
7) What is potential power by renewable energy?
8) What level of electrification can be achieved by renewable energy?
9) What is the renewable energy most suitable for the village?
10) How to estimate the potential of renewable energy?
11) How to plan village electrification?
12) What are the expected level of construction costs and tariff?
13) What kind of supports are available and who can support?
14) What are the required preparatory works and procedures up to application for financial support?
15) What is the next step?

Are there any other references?

The Manual constitutes Part 2 of the Master Plan for Rural Electrification by Renewable Energy. Part 1 presents another Manual for Updating Master Plan.

Part 2 Manual for Preparation of Electrification Plan

1. INTRODUCTION

1.1 STRATEGY FOR RURAL ELECTRIFICATION

1.1.1 Policy Targets of Rural Electrification (RE)

- To achieve 100% level of village electrification including battery lighting by 2020
- To achieve 70% level of household electrification by grid quality electricity by 2030

1.1.2 Staged RE

Table 1.1.1 Strategy of Three Staged RE

RE Stage	Media	Source of Energy	Use of Electricity	Power Consumption Level per Household	Tariff Level in $/kWh	
					in 2005	Target of MP
1	Battery	Solar power (PV panels at BCS or public facilities)	- Home lighting, optionally TV - Health post, night school, community hall	- 10 W - 40 W with TV - 3.3 kWh per month	1.02 including battery cost 0.38 per charging	0.56 including battery cost 0.10 per charging
2	Mini-grids	Biomass gasification power, Micro hydro	- Home lighting, TV, other light load appliances - Streetlights, public facilities, commercial - Handicraft industry, BCS, water pumps, etc.	- 100 W on average - (30-200 W) - 5-15 kWh per month	0.30-0.91	0.35
3	National grid	Diesel, Imported power, Hydro, etc.	- any kind of domestic uses - industry, commerce, etc.	- as much power as needed - 50 kWh per month in 2004	0.09-0.15	0.10

It is the target of the Master Plan to bring down the present high tariff to the following:

1) Battery lighting: charging fee of 70 Ah battery at $0.10 (Riel 400) per charging and $0.56/kWh including battery costs in those new solar BCS that will be implemented with 100% subsidy and operated by villagers (Village Organization, VO).

2) Mini-grids: $0.40/kWh (Riel 1,600) that will be implemented by community based organization (CEC) under the proposed subsidy system of the Master Plan 2005 and villagers' contribution in labor force and operated managed by CEC. In the case of implementation and O&M by experienced REE, higher efficiency could be achieved. However, the REE mode will require the following additional cost elements compared with the CEC mode:

- Labor costs are to be included in the tariff to recover the capital costs.
- Less subsidy is available compared with the CEC mode because of a greater scale in the REE mode in general;
- Profits in an order of 10% is required.

The tariff of mini-grids will further be brought down to the level of the national grid upon connection to the national grid (the grid connection).

3) National grid: $0.10/kWh (Riel 400). Bulk imports of low cost electric energy will be started from Thailand (upon completion of 115 kV transmission lines by ASK from Thai border to Siem Reap and Battambang in 2007) as well as from Vietnam (upon completion of WB-ADB financed 220 kV transmission lines from Vietnam –Takeo – Phnom Penh in 2008). In addition, a trunk 220 kV transmission links around the Tonle Sap would be implemented from 2007 to distribute these low cost imported energy to major provincial capitals. Upon commissioning of these transmission projects, the unit generation costs of EdC will significantly be brought down, to facilitate lowering of the power tariff.

1.1.3 Ownership of RE Systems

1) The National Grid owned by EdC
2) Mini-grids owned by licensed REE or CEC
3) Mini-grids owned by non-registered REE (to get license from EAC by 2007)
4) Public solar BCS under *Remote Electrification*, including PV systems for public facilities under *Social Electrification*
5) Diesel or solar BCS owned by REE or CEC
6) Private SHS on individual basis or on rental basis from REE
7) Self-supply by private generator set (these do not need license from EAC)
8) DIME owns some provincial grids as of 2005 but these will gradually be transferred to EdC. DIME will focus on such functions as policy making, dissemination and monitoring of policy measures, window for the people to apply to REF and get information and supports for village electrification, monitoring of implementation and management of RE schemes by REE and CEC.

1.1.4 Financial Support System

The REF will provide the following subsidy options depending on the electrification types, type of energies (renewable or not), types of entities (REE or CEC)

Option 1: equity (30%) and loan (70%) applied to EdC grid extension

Option 2: subsidy (25%), equity (25%) and soft loan (50%) applied to REE grid extension, REE-owned diesel-based mini grid systems and diesel-based BCS systems (This scheme is the current REF facility)

Option 3: subsidy (30%), equity (20%) and soft loan (50%) applied to CEC-owned diesel-based mini grid systems

Option 4: subsidy (40%), equity (20%) and soft loan (40%) applied to REE-owned renewable-based mini grid systems and REE-owned solar BCS/SHS systems

Option 5: subsidy (50%), equity (10%) and soft loan (40%) applied to CEC-owned renewable-based mini grid systems and CEC-owned solar BCS/SHS systems

Option 6: government grant (100%) for public-owned solar BCS/PV systems

For details of the financing support scheme please contact the REF Secretariat Office to be set up in September 2005.

The financial support shall be applicable only for capital costs, not applicable for operation and maintenance costs. The O&M costs shall be recovered by tariff revenue in principle. This is vital for maintaining operational and financial sustainability of running the electricity supply business.

1.1.5 Planning Strategy of Mini-Grids by Biomass Gasification Power

Principle of fuel supply by growing fuel trees under contract between REE/CEC and farmers. It should be avoided to buy fuel trees in the market since it may increase such pressure to forest as illegal cutting.

Only when there are agricultural wastes including forest wastes in sufficient amount without conflict with existing users, these can be planned as fuel sources. It should be kept in mind that transportation of the wastes from distant places should not be planned since it will be quite expensive and affect the sustainability of such scheme. The wastes include rice husks, rubber trees, peanut shells, coconut shells, corncobs, casaba stalk, and so forth.

A mini-grid scheme should preferably have a scale of greater than 200 households. The greater household number the lower generation costs and electricity tariff. Therefore, if there are villages adjacent within 1-2 km, it is recommendable that such villages be integrated into one scheme as far as good solidarity and cooperation among the villages are secured.

1.1.6 Why Mini-Grids in the Off-Grid Area?

Mini-grids and BCS are the two tools recommended for promoting quick electrification in the off-grid area instead of simply waiting for the grid extension.

For example, if a village with 200 households is located 3 km off a 22 kV distribution lines of EdC, cost of a 22 kV distribution line of 3 km long may be cheaper than the generation cost of mini-grid (costs of LV distribution lines within the village is common between the mini-grid and grid extension). If it is farther than 3 km, the mini-grid option will be cheaper.

If grid extension is expected within a 10 year period for example, with the mini-grid option you can enjoy life with electricity also during such 10 years. Extra costs you need for such earlier electrification are as listed below:

1) cost of generating equipment (on an average about one half of the total costs of a mini-grid);
2) Operation and maintenance costs of the mini-grids;
3) an interest on the cost of LV distribution lines during the 10 years (The same cost of LV distribution lines will be required also in the grid extension but after 10 years).

In addition to early realization and benefit by electrification with the mini-grid option, it could be possible to sell extra electricity to EdC after the grid connection. Such selling requires quality generating equipment, extra fuel wood, and a new institution to facilitate such energy trade between EdC and REE/CEC. (At present under the provisions of the Electricity Law, the energy trade is possible by negotiation and agreement between EdC and REE/CEC.) Upon realization of the energy trade, the energy cost of mini-grid could be brought down from $0.35/kWh to below $0.10/kWh. It means that the mini-grids with quality equipment should not be replaced by the grid extension but the mini-grid can continue operation also after the grid connection with improved financial viability. The Manual is to provide concept of such institutional system and to recommend that REE and CEC make use of the system for early electrification of villages in the off-grid area.

1.1.7 Planning Strategy of Mini-Grids by Micro Hydro

1) Potential sites of micro hydro greater than 10 kW in the dry season output have been identified on 1:100,000 maps. Before attempting to plan mini-grid by micro hydro, these data annexed to this manual should be checked.

2) Micro hydro potential totally depends on the head (height difference between water intake and power station site) and the dry season river flow. It is the first step of planning micro hydro to measure the head and flow.

1.1.8 Planning Strategy of Solar BCS and PV Systems for Public Facilities

1) Solar system can technically be introduced anywhere in Cambodia.

2) However, these are still expensive for villagers to introduce at their own costs. A grant support (90% subsidy for capital costs) is needed for implementation of *Remote Electrification and Social Electrification*. The key for electrification by the solar power is in the villagers' strong will and motivation for electrification, that is, commitment to undertaking the operation and management of such facilities after implementation.

1.1.9 Business Strategy of Mini-Grids by Biomass Gasification Power

<u>Implement with the proposed subsidy</u>

This is to back up such weak point common to all the mini-grids, that is, low load factor at around 10% (that is, power generation and distribution facilities can be used only during evening hours and are idling for most of the time (90%) without earning money) will inevitably and significantly raise the unit generation cost.

<u>Specification of distribution facilities</u>

The distribution facilities should meet the EAC specifications with options for rural mini-grids of REE and CEC as may be guided and approved by EAC to facilitate the grid connection in the near future. The generating equipment should preferably be designed to facilitate parallel operation with the national grid when the grid connection is realized. Ability of continuous operation (for 24 hour) is desirable for improving the plant factor upon the grid connection in particular.

Installation of BCS

Attach BCS to every mini-grid to service villages nearby as well as to improve the plant factor and lower the unit generation cost. Promote daytime demand other than BCS such as commercial, water pumping, handicraft industry, agro-industry, and so forth.

Selling excess energy

Sell excess energy to EdC upon the grid connection. This would substantially improve the plant factor to 50% (12 hour/day) or even more. However, the selling price cannot exceed the marginal costs of EdC for generation, which was about $0.15/kWh in 2004.

CDM

Apply for small scale CDM to get additional finance to improve the revenue and expenditure balance.

1.2 WHAT OPTIONS ARE AVAILABLE FOR ELECTRIFICATION?

1.2.1 Types of Electrification Available in the Off-grid Areas

The types of electrification to be applied to the off-grid area will be as follows:

1) Mini-grid by biomass gasification power
2) Mini-grid by micro hydro
3) Mini-grid by diesel generator (DG)
4) Diesel BCS
5) Individual SHS
6) ***Remote Electrification*** by solar BCS for battery lighting
7) ***Social Electrification*** by PV systems for public facilities for battery lighting

1.2.2 Institutional Options for Implementation and Management

Main entities doing electrification business in the off-grid rural areas will be REEs and CECs

1) REEs are local and rural business people or private organizations.
2) CECs are village organizations (cooperative or association) established by electricity users.
3) Besides REE and CEC, other entities like Edc, National Solar Dealer and rural electricity utilities will be involved in rural electricity business. These service providers will be intervened and facilitated by various organizations as shown below:

Table 1.2.1 Implementation Responsibility of Stakeholders

Business Model	Ownership	Operation	Training and Facilitation	Approval	Licensing and Regulation
EdC	EdC	EdC or REE	-	MIME/REF	EAC
REE	REE	REE	EdC or NGO	MIME/REF	EAC
CEC	CEC	CEC	NGO	MIME or MRD	EAC
National Solar Dealer	MIME	CEC or REE	MIME or NGO	-	-
REU	Local Gov't or Municipality	Own force or REE	EdC	MIME	EAC

Source: JICA Study Team

1.2.3 Supporting Facilities Available for Implementation

The investors have access to various support facilities as shown below:

1) Grant assistance from REF, donors and NGOs. (see (4) of 1.1 above)
2) Loan facilities from financial institutions (contact REF for details)
3) Technical assistance from REF
4) Technical training provided at EdC's training center in Phnom Penh
5) Financial and technical assistance from NGOs and Bilateral Agencies (see Chapter 10 of this manual)

1.3 CONTENTS OF MANUAL

The manual includes the following:

- Procedure from developing electrification concept of villages of interest up to applying to REC for financing
- Village survey required for planning and application to REC
- Selection criteria of energy sources
- Planning method of micro hydro
- Planning method of biomass gasification power
- Planning method of distribution lines
- Planning method of ***Remote Electrification*** by solar BCS and ***Social Electrification*** by PV systems
- Way for application to REC for financial support
- Supports available for further planning and implementation

1.4 PROMOTION OF RURAL ELECTRIFICATION

The electricity services in rural areas tend to be more expensive, yet equally important for the inhabitants. In order to balance out the disadvantage in rural areas, people's participation will be crucial factor. The efficient management largely depends on the cooperative efforts of beneficiaries.

Based on the field surveys and lessons learned from existing rural electrification projects, the following three key issues should be considered in order to promote rural electrification for sustainable manner.

1) To provide **equal opportunities** even to those poorer population in marginal areas.
2) To assess **capacity and constraints** of their own community by participatory approach
3) To encourage **participation and contribution** among the beneficiaries

Above key aspects are concerned stakeholders promote the electrification project and assess the target areas from the view points of socio-economic indicators. The detail will be shown below.

1.4.1 Equal Opportunities by Means of Public Relation

Electricity is one of the basic infrastructures that everyone requires. The government has responsibility for providing electricity even in rural areas; yet, the benefit-received principle is necessary in order to expand electricity service in rural areas more sustainable way. In order to provide the equal opportunities to every household, the MIME in collaboration with DIME, and provincial authority will distribute the leaflet to non-electrified communes. It helps people to understand the scheme and institution necessary for electrification projects of various energy type and modes of service, namely either by mini-grid system or by battery charging system..

1.4.2 Capacity and Constraints

Not only the technical feasibility but also current capacities and constrains communes face for forming a preparation committee needs to be clarified. Even though there were several NGOs or government supported activities exist, few communes have experiences of operation and maintenance activities. Potential beneficiaries, therefore, need to assess the capacities for setting up the RE system within their areas with guidance of external facilitators, such as NGOs and provincial departments.

At the outset of the RE projects, communes / villages utilize the meeting of planning their development plan or hold a workshop and/or meeting discussing their development agenda and future plan based on the assessment of their social and natural environment. The potential of communes should be discussed by themselves and the positive impacts and negative impacts by electrification, and constraints for materializing RE projects should be identified through participatory discussion.

Regarding the identification of impact by Rural Electrification Project, the commune might need the detailed information from the DIME and/or NGOs. Ideally, the DIME/NGOs will play a facilitating role for workshops and will answer the questions raised by inhabitants. After the workshop, commune members should discuss further in order to select the schemes and institutional set-up applicable for themselves. The selection of schemes depends on the commune members. DIME and/or NGOs should facilitate the consensus-making process and the decision-making process.

1.4.3 Participation and Contribution

In case REE implement the RE project; commune / village members need to sign the agreement one by one, based on the standard form prepared by REE. While profits will be enjoyed by REEs, all the technical / managerial problems have to be solved by REEs. In case there is no REE to have incentives to invest electricity services, those who are eager to have electricity attempt to establish a CEC for electrification. Comparing the REEs, management of the CEC is technically more complex and requires training for various stakeholders. Besides, the CECs are always in short of financial resources. Therefore, finding an appropriate investor to be REE is also good alternative for community to run electrification projects, while CEC can play a certain role, for example, customer relations. No matter what form of operation commune choose such as by CEC or by REE, or by combination of the two, stakeholders have to acknowledge the significance of participation and contribution from the commune / village members. The REF and officials in charge of Rural Electrification Project have to explain the system in detail to communes / villages well from the beginning in order to avoid the high expectation or dependency to the external organizations. The socioeconomic survey by form of household survey and participatory assessment in order to disseminate information and to confirm sound demand, are vital exercise for preparation.

Then, CECs have to have their agreement concerning the operation and the management of electricity services. The MIME /DIME have to provide guidance to prepare a standard agreement. The contents will include as follows.

- To clarify the roles and responsibility by respective stakeholders
- To demarcate the duty and task in practice by respective stakeholders
- To identify the rules of financial arrangement and profit sharing
- To verify the tariff
- To stipulate the penalty and incentive of payment

2. SELECTION OF ENERGY SOURCES

2.1 CRITERIA FOR SELECTION OF ENERGY SOURCES

2.1.1 Energy Selection Criteria, 2005

Energy Selection Criteria, 2005 is given in Figure 2.1.1, for selection of source of energy by REE or CEC for planning electrification of certain villages. The selection procedure is explained below:

1) The first three criteria are to exclude those villages situated in the On-Grid Area shown in Figure 2.3.1 of Part 4-1.

2) The next criterion is to exclude those villages supplied by existing or planned mini-grids by diesel. Here, the planned mini-grids mean those offer proposed by REE to villages and basic agreement for implementation has been reached.

3) The next is to identify the maturity of the villages to proceed to RE Stage 2 (mini-grids) in view of the diffusion level of battery lighting. The high diffusion level means a high demand to mini-grids and high affordability. A diffusion level of battery at 50% is considered as the level to start consideration of introducing RE Stage 2 by mini-grids.

To take up those villages that have high ATP although the battery diffusion level is below 50%, the next test on ATP is made.

4) Among those villages passed tests 3) and 4) above, if there are micro hydro potential identified and development plan proposed by the JICA Study Team or newly proposed by REE or CEC, those villages should be planned as mini-grid by micro hydro. Of the rest, if there are grassland (4 sub-groups of grassland (undifferentiated), abandoned field covered by grass, grass Savannah, and grass with termite mounds except for grasslands of marsh and swamp) and shrublands (shrubland (undifferentiated), abandoned field covered by shrub, flooded shrub) of more than 0.02 ha per household, then the village should be planned as mini-grid by biomass gasification power. The rest is judged not to have sufficient land for growing fuel trees and should be planned as mini-grids by diesel power.

Of the mini-grids either by biomass gasification power or by diesel power, another test should be made to judge if these are situated inside “the Plain Area”, which are defined as the areas within PAGE but of only the following 10 provinces:

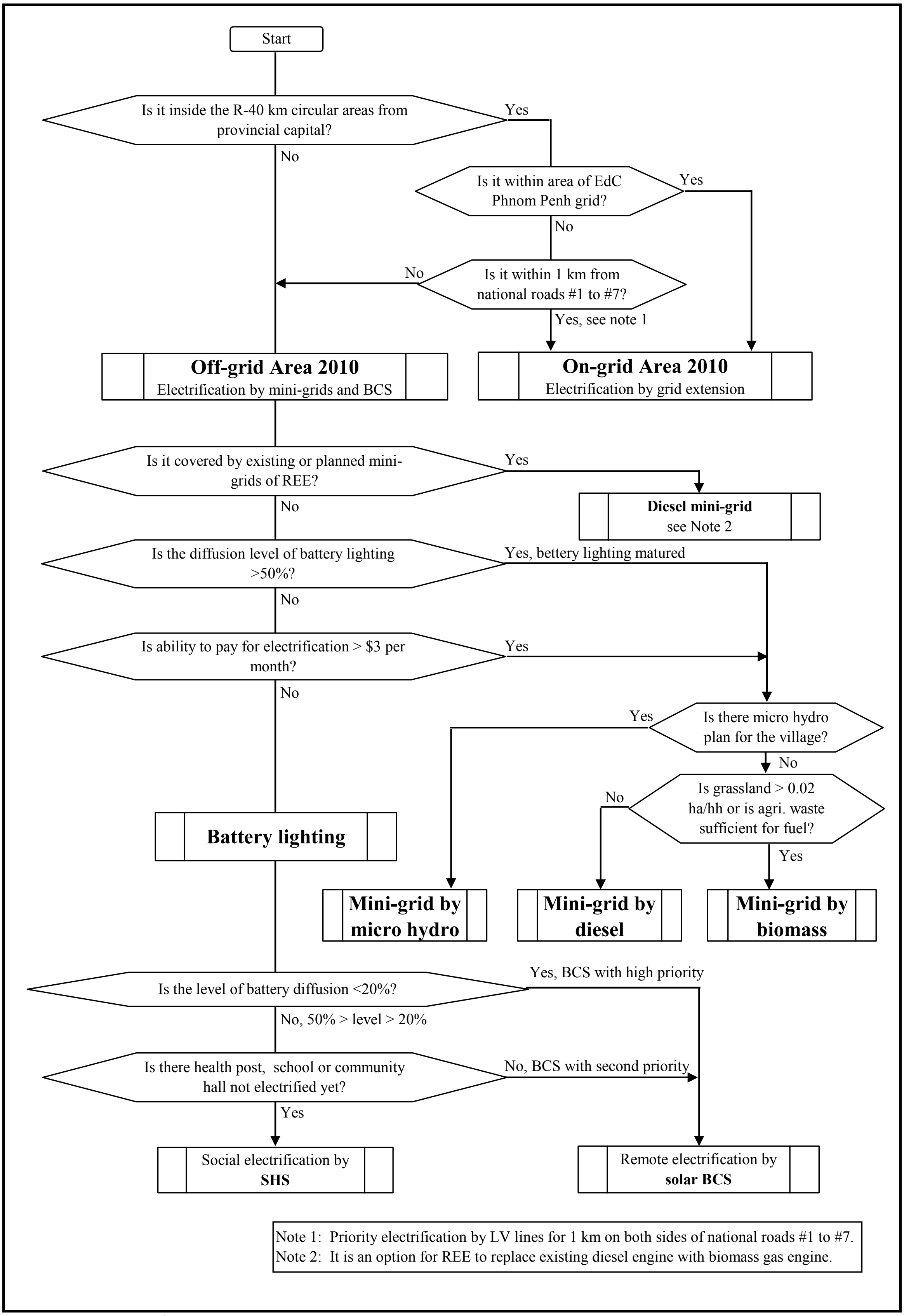
1) Phnom Penh
2) Kandal
3) Kampong Cham

4) Kampong Speu
5) Prey Veng
6) Svay Rieng
7) Takeo
8) Kampot
9) Kep
10) Sihanoukville

The area is shown by thick circles in Figure 2.3.1 of Part 1. The mini-grids in the Plain Area have a higher probability of grid extension than those outside because of their dense distribution of villages and proximity to the national grid. Accordingly, the mini-grids falling in the Plain Area should first consult EdC for the latest plan of grid extension. If it is electrified by the grid extension in several years, it is recommended that such villages wait for the grid extension since it can realize electrification at a low tariff.

However, if an REE or CEC do wish to electrify certain villages by mini-grids of biomass power without waiting for the grid extension, it is possible and economically feasible if well planned taking the following into consideration:

(1) Tariff until the grid connection will be around $0.35/kWh, which should be explained and agreed with the villagers. It can be lowered to that of EdC only after the grid connection.
(2) REE/CEC should negotiate with EdC for rates and terms for selling extra energy to EdC upon the grid connection.
(3) The generating equipment should be able to be operated in parallel with EdC grid. It should be able to be operated for 24 hours or more than 12 hours everyday as may be required by EdC.
(4) Supply of fuel trees should be sufficient for long operation hours above.



Source: JICA Study Team

Figure 2.1.1 Flowchart for Selection of Energy Source by REE or CEC

(5) Those villages that did not pass ATP test in item 4) above are candidates for battery lighting by solar power. The villages with battery diffusion level below 20% is candidates for BCS with high priority and those between 20% and 50% with second priority. The villages having non-electrified public facilities such as health post/center, night school, commune hall are candidates for *Social Electrification* by PV systems.

Thus all the villages are grouped into the following six groups:

1) On-Grid
2) Grid extension
3) Mini-grids by diesel, probably combined with diesel BCS
4) Mini-grids by micro hydro
5) Mini-grids by biomass gasification power
6) Solar BCS including PV system for public facilities

The mini-grids by biomass gasification or diesel power will be further sub-grouped into:

1) Grid extension or mini-grids in the Plain Area;
2) Mini-grids outside the Plain Area

(6) However, it is the option for villagers who may choose from among the following other than the four derived from the flowchart above:

1) To receive electricity from existing or new diesel mini-grids, if offered by REE and if initial connection fee and tariff are affordable (if the tariff is too high, examine the possibility of mini-grids by biomass under village management);
2) To own and operate private diesel generator set if demand exceeds 200 W per household and it is affordable;
3) To install and operate pico hydro (of smaller than 1 kW in net output) if potential exists nearby;

2.1.2 Check if there is any new version of the *Energy Selection Criteria*

The Energy Selection Criteria may be modified upon review and updating of the Master Plan, which will be made in accordance with Part 1 Manual for Updating Master Plan. Therefore, it is advisable for REE and CEC to ask DIME, after year 2008, for the latest version of Part 2 Manual for Preparation of Electrification Plan.

2.2 CHECK POTENTIAL AND VILLAGE SITUATION

Before selection of the energy source, the following commune / village situation and potential energy sources should be checked:

- ■ Is there EdC grid or mini-grid of REE nearby your village? Yes No
- ■ Is there grid extension plan to your village? Yes No

  Figure 2.2.1 shows Potential Area of Grid Expansion and On-Grid Area expected for implementation by 2010.

- Is there any offer from REE for new mini-grid? Yes No
- Is there any hydro potential nearby your village? Yes No
- Potential micro hydro sites are presented in Chapter 4.
- Is there any biomass waste in or nearby your village? Yes No
- Potential biomass wastes are presented in Chapter 5.
- Is there land for farming fuel trees? Yes No
- When there is no biomass waste sufficient for biomass power, a land (grassland, shrubland, fallow land also possible) of 2 ha is needed to electrify 100 households, 4 ha for 200 households, and so on.
- Is the diffusion level of battery lighting in your village higher than 50%? Yes No

  A high diffusion level of battery lighting shows the village has been matured to introduce RE by mini-grids and has a certain affordability for paying electricity tariff in an order of $3-5 per month. Upon introduction of mini-grid, you will no longer need money for buying battery.
- Is there any public facilities that need electrification? Yes No

  A high priority is given to electrification of such public facilities as health post, night school, community hall in order to achieve the 100% level of village electrification by 2020.

2.3 SELECT ENERGY SOURCE SUITABLE FOR YOUR VILLAGE

For each village, source of renewable energy for electrification shall first be selected in accordance with a flowchart given in Figure 2.1.1. In the figure diesel mini-grids are also shown as a possible option for such villages where no micro hydro potential exists and no sufficient land is available for growing fuel tress.

The procedure for selection of the energy source is explained below:

(1) Is it inside PAGE?

You (people who wish to electrify their own village and REE who wish to provide electricity to certain villages) can check if your village is inside PAGE in Figure 2.3.1. If you have difficulty in identifying the location of your village in the figure, you can simply measure on a Cambodia map the distance from your village to the provincial capital along a shortest road. If this distance is longer than 40 km, it means that your village would be difficult to have grid electrification. Go to next paragraph (2).

If your village is inside PAGE, your options for electrification are:

1) **To wait for grid extension**: If your village is located along the national roads #1 to #7 within 1 km distance on both sides of the road, your village will be electrified by grid extension with priority.

   If your village is located within district towns in the "**Plain Area**" (the southern part of PAGE which is encircled by thick arcs in Figure 2.3.1) or within PAGE around the Tonle Sap (along the national roads #5 and #6), your village would be electrified by grid extension also with priority, subject to grid extension planning by EdC.

   If your village is located close to the national road #2 within "Plain Area", again possibility of grid electrification is high.

   If your village is located in one of the three areas above, you had better ask EdC or DIME for the latest plan of grid extension for your region. It is your option either to wait for the grid extension or to implement village electrification by a mini-grid preceding the grid extension. The two options may be featured as briefed below:

Grid extension: Your particular effort is not required. The grid extension will be implemented by EdC accompanied with sub-grids of REE. The tariff upon grid electrification will be low being comparable to that of the EdC grid since the EdC grid will have the low cost energy from Vietnam, Thai, and Lao upon completion of the committed transmission line projects. These projects will be commissioned in 2007/08. In general, it may be prudent to wait for the grid extension if your village is grid electrified within five years. If the grid electrification of your village is in a distant future, say only after 10 years, and if you do wish to have grid quality electricity by your own effort, you have another option of implementing mini-grid.

Mini-grid: A firm will for electrification as the community is essential to achieve electrification by mini-grids. The mini-grid can be implemented either by REE (private energy service company) or CEC (village organization). The tariff will be in an order of $0.35/kWh. The greatest advantage of mini-grid is in achievement of electrification in advance of the grid extension. If there is significant daytime demand on electricity, the tariff can be lowered depending on the amount of daytime demand. Upon the grid connection in the future, there is an option to sell extra energy to EdC. The selling price may be equal to a buying rate from EdC (wholesale price, expected to be around $0.10/kWh or lower after 2008). Alternatively, you can buy electricity from EdC either directly or through REE upon the grid connection, and the tariff can be lowered to the level of EdC.

2) If your village does not corresponds to the conditions above, go to next paragraph (2).

(2) **Off-grid area**: Is battery diffusion level higher than 50%? Or is ability to pay greater than $3 per month per household?

If your village has a battery diffusion level higher than 50% or if most of the households can pay $3 per month, it is a time for your village to examine a plan to electrify your village with mini-grids. Go to next paragraph (3).

Your practical option available is **solar power** for charging batteries for home lighting. If many households (say more than 10%) of your village can buy battery for own home lighting and pay battery charging fee at around $0.30 per charging, you can select **solar BCS** to be installed in your village. If your village has no BCS at all, such BCS can be installed with almost 100% subsidy and rent to your village free of charge on condition that your village can provide land for BCS, build a station house, and undertake required management and maintenance of the BCS at your costs.

If most of the villagers cannot afford to buy battery, you can choose **PV system for public facilities**. The PV system will be installed to such public facilities as health post/center, night school, or community hall mainly for lighting purpose. You can have a community meeting in the evening time at such community hall. As option to such PV system, a small BCS can be added if there are some villagers who can afford to buy batteries.

(3) Mini-grids:

If there is a mini-hydro plan nearby your village which have been identified and proposed in the Master Plan 2005 (refer to Chapter 5 hereof), it is advised that your village examine a plan of electrification with **min-grid by micro hydro**.

If your village has a land sufficient to grow fuel trees, your option is **mini-grid by biomass gasification power**. The minimum land required is 0.02 ha per household or 2 ha per 100 households. The land can be grassland, shrubland, fallow land, and so forth.

If your village has a community forest wider than 0.2 ha per household or 20 ha per 100 households, your option may be **min-grid by biomass gasification power**. However, you had better consult forestry experts for the potential of forest wastes available as fuel for biomass power.

If your village has abundant agricultural wastes such as rice husks, peanut shells, corncobs, coconut shells, casaba stems, rubber trees, and so forth, your option could be also **biomass gasification power**. The required amount of such wastes is roughly 240 kg per household per annum. A village of 200 households require some 50 dry tones a year. With the fuel amount, you can use electricity up to 10 kWh per household per month, which is a standard level of consumption in existing diesel mini-grids in 2004 (it is about 50 kWh in Phnom Penh in 2004). For more detail of the biomass gasification power, refer to Chapter 4 hereof.

If your village does not correspond any of the above, your only option is **mini-grid by diesel power**. Diesel generator is featured by low capital costs but high fuel price. If the demand is very low (say, lower than 5 kWh per household per month on an average of your village) and if there is no specific difficulty in fuel transportation, this can be an economic option.

3. CONSIDERATION OF SOCIO-ECONOMIC FACTORS

3.1 PURPOSE OF CONSIDERATION OF SOCIO ECONOMIC FACTORS

Once energy source is confirmed, overall design of the project including assessing demand of electricity, establishing the framework of sustainable operation and maintenance needs to be determined. In order to incorporate socioeconomic factors into rural electrification projects, socioeconomic assessment activities, namely baseline data gathering and participatory planning by focus group discussions, workshop by beneficiary- representatives shall be conducted. Both qualitative and quantitative outputs obtained through socioeconomic assessment will improve potential project designs and assess the potential impacts.

The key features needs to be assessed are following elements:

- Willingness and affordability to pay based on the current economic features and energy usage.
- Strategy for achieving sustainable operation based on analysis of institutional set up, socio-cultural context.
- Identification of adequate and practical monitoring and evaluation procedures and indicators.

3.2 IDENTIFICATION OF SOCIO-ECONOMIC FACTORS

3.2.1 Current socioeconomic data available

The National Institute of Statistics under the MOP, provides various socioeconomic data starting from the census 1998 and CAMBODIA SOCIO-ECONOMICS SURVEY (CSES) periodically (latest one is conducted in 2003-04). This is the formal national data available in the NIS (http://www.nis.gov.kh/). Yet, these data does not contain the latest population or household numbers which are the key factor for designing the demand scale. Therefore, annually updated commune database (CDS) in the Seila Program Website (www.seila.gov.kh) can be useful to obtain updated information.

Once the designated target areas are identified, provincial authorities or commune / village chief needs to provide update demographic data referring their registration book.

3.2.2 Commune Development Planning Process

Even though communes acknowledge the appropriate energy sources and prioritize the electricity project under the development planning process, there is little information available for preparing an electrification project. The special guidance will be required from DIME / NGOs / consultants in terms of technical and management issues.

From the preparation stage, it is recommended to form a committee under the Commune Council to prepare an electrification plan so that discussion will continue and ownership will be nurtured. The meetings of a committee consisting of potential users initially identify the following information.

Topics	Discussion points and identification of training needs
Requirement for operating the electricity facility	・Operation needs especially financial matters, keeping of records, manpower requirements (Training needs and similar experiences gained from the other project) ・Maintenance/technical requirements ・Relation of watershed, forestry resources to an electric facility
Role of consumers, local officials, and CEC:	・Availability to pay for initial connection fees and monthly fees, and how to deal with late-paying or non paying clients ・Structure of CEC that will manage: membership, roles and responsibilities ・Maintenance issues: when, who and knowledge requirements and financial requirements
Needs of public utilities and industry	・Identification of the needs of public facilities such as health posts and schools, and clarify the financing methods. ・Identification how electricity can be maximized especially for productive activities such as water pumping and agriculture processing activities, etc.

These will be identified by the general meeting or some participatory exercise such as SWOT (Strength, Weakness, Opportunity and Threat) analysis and the Mapping to identify social and natural resources, etc. In order to promote participation from various groups, the meeting and planning exercises are recommended to hold convenient time for villagers. The Commune Development Planning scheduled regularly by the local authorities will be a good opportunity to consolidate the project plan.

3.2.3 Assessment of electrification demand

Current situation of energy use and income level to finance future electricity service is key features needs to be identified by the commune members. The baseline information can be obtained by a household survey. The outputs shall be analyzed by the stakeholders. If the target areas are not large, complete survey can be ideal. If there is limited time and fund, a sample survey will be more appropriate by using a list of residents.

In order to obtain the amount willingness to pay for electricity service, enumerators need to interview potential customers step by step so that interviewees can comprehend their financial level.

Major survey items will be as follows.

1) Basic information (ethnic component, family component, occupation, property of land/house)
2) Data of expenditure by items and if possible of incomes
3) Current condition of energy consumption (kinds, costs, uses, electric appliances in use)
4) Demand of electricity service (supply hours, expectation for uses of electricity after electrification)
5) Willingness to pay for electricity service (considering current expenditure of energy and

future convenience)

More specifically, the item 3) the monthly expenditure on candles, kerosene, for lighting, car batteries and generators for electric appliance will be questioned as summarized as follows.

Candles		Kerosene		Car battery		Private diesel generator	
Cost of a candle		Number of kerosene lamps owned		Numbers and types of baterries owned		Type of generator owned	
Monthly consumption		Cost of kerosene per liter		Charing prices of nearest BCS		Cost of diesel per liter	
Monthly expenses for candles	Riel	Monthly consumption	liter	Recharging times per month		Monthly consumption	liter
		Monthly expenses	Riel	Monthly expenses for recharging	Riel	Monthly expenses for diesel	Riel
		Cost of kerosene lamp	Riel	Cost of car batteries obtained by types	Riel	Cost of a generator	Riel
Estimated total expenses of the lighting and energy sources per month					**Riel**		

The item 4) The demand of household level can be obtained by following sheets.

	Wattage	Using hours / day	Daily Electricity Consumptior	Monthly Electricity Consumption
Lighting	____ W	____ hours	____ Wh	____ Wh
Other Appliances want to use				
TV	____ W	____ hours	____ Wh	____ Wh
Radio	____ W	____ hours	____ Wh	____ Wh
Fan	____ W	____ hours	____ Wh	____ Wh
---	____ W	____ hours	____ Wh	____ Wh
Total amount consumer needs to pay (multiplied by 30 days)				____ kWh

The item 5) Willingness to pay for the connection fee and monthly tariff shall be questioned after interviewees comprehend the cost and benefit of electricity and their financial capacity more clearly. The amount payable has to be underpinned by their financial capacity, naming income source and credit and loan availability. Indicative tariff for electricity will be helpful to understand their consumption and payment scale. The outputs of the demand survey should be integrated with technical advice from external experts.

3.2.4 How to utilize the survey result into the design of the project

The amount of demand of electricity and ability to pay by potential customers will be a baseline for designing the business plan. After compiling the data and result of workshops, several features can be reflected to the project design. The following are examples of

Example 1: The benefits of electricity such as less expensive, more reliable, easy to read and work at night are widely acknowledged, but not among the poorest.

Action: Disseminate more information on advantage of electricity to villagers including poorest groups.

Example 2: Concerns were expressed over the initial connection fees as few villagers have saving habits.

Action: Discuss among beneficiaries how to finance initial fees. Selling livestock or divided payments system, utilizing credit and saving association will be potential solutions. Seek advice on NGOs and local authorities that are familiar to the financial matters.

Example 3: Great interest in electrification of health centers, yet there is no fund from the government.

Action: Estimate the amount required for electricity services to the public centers and clarify how to shoulder such expenses by the community.

3.3 BUSINESS PLAN INCORPORATING SOCIOECONOMIC FACTORS

After analyzing the result of household survey and participatory assessment, CEC has to prepare a business plan which would be agreed by beneficiaries and stakeholders (DIME, local government authorities) in detail, goals of projects, organizations, rules and so on. The DIME and RE have to be functioning as consultants who facilitate the consensus-making and formulation of organization.

3.3.1 Indicative business plan

In order to implement the RE project, the business plan needs to be properly prepared for sound operation and maintenance. The formulating the business plan would require external supports. Indicative business plan will require following contents.

1) Business description: energy sources, profile of management
2) Business location: geographic boundaries of business.
3) Customer characteristics (market analysis) and electricity demand
4) Technical design, construction plan
5) Operating and organization plan:
 -Identification of ownership, key personnel for manager, accountant, and technical operators.
 -Description of tariff, operation hours, bill-collection system.
7) Financial analysis (capital / operation costs, expected revenues)

Based on the business plan, the rule of CEC will be formulated together with an agreement with potential customers. Following are major items needs to be specified in the agreements.

- Organization (role and responsibility)
- Working regulations (Operation and Maintenance)
- Price list / tariff
- Safety and security issues
- Penalty for nonpayment or delayed payment

More detail will be written in Chapter 8 Organization for Implementation and Management.

3.3.2 Applying the external financial support

CEC will prepare the proposal of business plan of RE project to the MIME and REF, and commune fund for technical training by receiving technical advice from DIME, local government authority, and NGOs. The evaluation of the proposals will be done by committee of REF and contracts will be exchanged among the concerned actors. The budget will be allocated according to the schedule. The system of apply is mentioned in Chapter 10 hereof.

3.4 SUPPORT SYSTEM FOR THE CEC

Training needs are identified by the communities together with external supporters. The indicative training subjects will be summarized as follows.

<table>
<tr><th>Training subjects</th><th>Training providers</th><th>Participants</th></tr>
<tr><td>Establishment of CEC</td><td>Provincial authorities such as District Facilitation Team
REF / MIME/ DIME including assigned consultants and NGOs</td><td rowspan="5">Commune Council
CEC including a manager, plant operators, accountants.
Representative of potential customers, including existing and potential commercial electricity users</td></tr>
<tr><td>Management schemes such as customer relations and connection procedures</td><td>REF / MIME/ DIME including assigned consultants and NGOs</td></tr>
<tr><td>Tariff setting and collection
Meter reading and billing</td><td>REF / MIME/ DIME including assigned consultants and NGOs</td></tr>
<tr><td>Financial management, accounting and its transparency</td><td>REF / MIME/ DIME including assigned consultants and NGOs, possibly advisor from local financial institutions</td></tr>
<tr><td>Productive use campaign</td><td>REF / MIME/ DIME including assigned consultants and NGOs, possibly advisor from local financial institutions, business advisors.</td></tr>
</table>

The training subjects and providers needs to be tailored for the needs of specific communes.

Since the capacity of DIME varies, necessary technical training also needs for DIME staff. The detailed support system of REF and DIME, including technical assistance and consultation services, is mentioned in Chapter 10 hereof.

4. PLANNING MINI-GRID BY BIOMASS POWER

Biomass power is electricity generated by fuel woods and agricultural residues such as rice husks, peanuts shells, corncobs and coconut shells. We can use the biomass as fuel like diesel oil to generate electricity. The technology appropriate for village electrification is gasification system. Biomass is burnt with limited air to produce combustible gas called producer gas. The producer gas called can run engine to generate electricity. You can grow your own energy trees or collect agricultural residues instead of buying diesel oil to generate electricity.

4.1 CHECK OF POTENTIAL

4.1.1 Energy Tree Farming

Your village is selected as an appropriate biomass electrification village because there are more than 0.02 ha of grassland and/or shrubland per household to plant sufficient energy trees for electrifying all the households in village. Energy tree farming or energy tree plantation at a large scale is a principal issue to be tackled with for securing the primary fuel supply. The energy tree farming has the following advantages:

- Woody biomass is the best fuel for gasification power generation.
- Stable fuel wood supply is guaranteed and long-term supply plan can be established.
- Farmers can get additional income from growing energy trees.
- Expenditures spent on buying fuel trees from contracted farmers will remain within the commune or region to stimulate the local economy rather than paying to foreign countries for buying diesel oil.
- Planting trees of appropriate species with appropriate management has positive impact of both local and national or even global environment.

(1) What tree should we plant?

Multi purpose legume trees such as *Leucaena leucocephala* and *Gliricidia sepium* are appropriate species for small scale energy tree farming. These species can fix nitrogen and grow very fast even on degraded soils. Their foliage can be used as nutritious livestock feed or as green manure. They resprout vigorously after cutting. People can start harvesting branches as early as one year after planting and continue harvesting every four to six months for many years as fuel woods for biomass power plant. These trees can be planted in any wasteland, fallow garden, mixed with fruit trees or other crops or as living fence. Farmers can get extra income from selling fuel woods to the power plant. *Leucaena* has been tested around Battambang area and showed good growth. This species is poorly adapted to acid soils or waterlogged soils therefore might not be suitable for some areas in Cambodia. *Gliricidia* can grow in wider range of soil type but the foliage is less preferable as livestock feed. Contact local Department of Agriculture station for advice. SME Cambodia (NGO) has wide experience and information about *Leucaena*.

(2) How much area do we need?

The 1 ha land will provide fuel of 10 ton/yr which can generate 6,700 kWh/yr at 1.5 kg/kWh. In most of the existing mini-grids, unit household consumption is around 10 kWh per month. This means 1 ha of tree farming can generate power for 56 households. Project of 200 consumers requires about 3.6 ha of tree farming area. You can also find required land area for tree planting according to your project size in Table 4.3.2.

4.1.2 Energy Tree Plantation / Energy Reserve

In the case of large scale power plant (> 100 kW, > 1000 HH), energy tree plantation or energy reserve which can provide about half of fuel woods should be established by the project in addition to tree farming by individual farmers. Roughly tree plantation at 0.1 ha/kW or 10 kW/ha (i.e. 10 ha plantation for 100 kW power plant) has to be established as back up fuel source for stable fuel supply. Fast growing tropical plantation species such as *Eucalyptus* spp., *Acacia* spp. and *Pinus* spp. would be suitable for energy tree plantation.

Reserve fuel trees planted by individual CEC members are also recommended. Study team conducted a biomass survey for *Eucalyptus camaldulensis* plantation in Mear Nork, Kampong Chhnang Province. *Eucalyptus camaldulensis* is one of the most common tree species planted for both industrial scale plantations and village scale reforestations. Study team harvested 10 trees with dbh (diameter at breast height) ranged 4.4 – 20.2 cm to measure biomass and found that dbh was a strong predictor of the biomass. The relationship between dbh and biomass is shown in Figure 4.1.1. The woody biomass is calculated from dbh (cm) with the following formula.

Woody biomass (> 2 cm diameter) with bark = 0.0616 x dbh (cm) ^ $^{2.5266}$ (R^2 = 0.99)

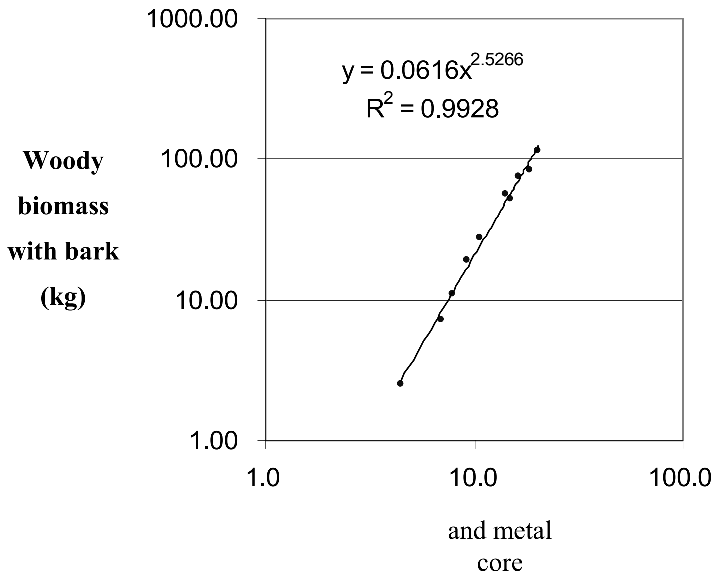


Figure 4.1.1. Relation ship between dbh and woody biomass of *Eucalyptus camaldulensis* in Mear Nork Plantation, Kampong Chhnang Province.

Table 4.1.1. Woody biomass of different dbh size of *Eucalyptus camaldulensis* in Mear Nork Plantation, Kampong Chhnang Province.

dbh (cm)	Woody biomass (kg)
5	4
10	21
15	58
20	119
25	210
30	332

In the case of that average monthly electricity consumption per household is 10 kWh, required fuel wood per household in a year is 180 kg. It would be sufficient if each household maintain enough wood for two years of requirement as standing trees. Table 4.1.1. shows woody biomass of trees of different dbh sizes calculated from the above formula. A tree with dbh 25 cm supplies sufficient fuel wood for generating electricity for a household for a whole year. Each CEC can make rules regarding to reserve energy trees according to the information provided above.

Seek further information and assistance at Forest Administration of RGC.

4.1.3 Agricultural Residues

Villages where excess agricultural residues are available, they should be fully utilized. Rice husks, peanut shells, corncobs, cassava stems are suitable for gasification. If you have other kind of solid agricultural residues, please contact DIME or MIME office for potentials. Even there is enough agricultural residues for village electrification, each village should have tree plantation energy reserve of 0.05 ha/kW (1 ha in the case of 20 kW mini-grid) which can produce ¼ of necessary woody biomass for power plant as a back up fuel source.

4.1.4 Forest Management Residues

Woody biomass from natural forest should not be used for biomass power generation. Only the case there is large amount of excess forest management residues such as thinned undesirable trees to improve forest quality available, they maybe used as fuel. Such villages should discuss the matter with their community forest organizer (Forest Administration, Ministry of Environment or NGOs). Even the case where so much forest management residues are available, at least half of fuel (0.1 ha/kW or 10 ha in the case of 100 kW mini-grid) should be supplied by planted trees to avoid over harvesting pressure to natural forest as well as for stable fuel supply.

4.2 CONCEPTUAL PLANNING OF FUEL SUPPLY

4.2.1 Size of Electrification Project

It is important to estimate the maximum number of households to be supplied from mini-grid when your village gets electrified. Your tariff will be cheaper when more households connected. If only less than 100 households are willing to be connected, your project hardly be finacially viable and is considered less priority (difficult to obtain subsidies). Preferably more than 200 households should be involved in electrification project. If there are less than one hundred households in your village but there are other villages within 1 km road distance, try to organize multi-village electrification project. It is impossible to electrify villages more than 1 km away because extending the distribution line costs at about $14,000 per km. Even if your village is isolated from other villages and has less than 100 households, biomass electrification is still possible if there is strong demand for electrification. There is a sample of 70 household scheme in Battambang. Please bring your idea to MIME or DIME office and discuss the possibility.

4.2.2 Assess the Village Power Demand

Assess the electricity demand of your village in accordance with the procedure and forms presented in Chapter 3 hereof. The minimum demand may be around 30 W per household if people need only lighting. The average in rural area of Cambodia is in an order of 100 W. It would increase towards 200 W in those villages nearby big towns and having battery powered TV etc. already in most of the households. In addition to the household demand, streetlight demand should be considered.

If the demand is underestimated, it will cause power failure (black out) and load shedding (power supply every other day changing supply area within the village) will inevitably be forced to users. If the demand is overestimated, it will require over-investment and generation capacity installed will partially be idling. The tariff will become unnecessarily high.

It is important to understand that the mini-grid is for RE Stage 2 to providing electricity for lighting, TV and some light loading appliances. Heavy loading electric appliances such as electric iron, cooking heater, and so forth should not be used in the mini-grid.

The key to achieve low power tariff is to have daytime demand such as power supply to BCS, rice-mills, water pumps, cottage industry including pre-processing of agricultural products, and commercial uses.

4.2.3 How Much Biomass Fuel Do We Need?

Rough estimation of required amount of biomass fuel (wood and rice husk) and land for energy tree planting is shown in Table 4.2.1. If your electrification project involves 200 households connection, you will need 36 ton of dry wood per year which requires about 4 ha of energy tree planting. This estimate is based on the annual productivity assumption of 10 t/ha/yr. It should be noted that you could harvest much less than this at first year then more in later years if trees were properly managed. In the case of rice husks, 200 households project requires 48 t/yr. We do not have estimation for fuel requirement for other agricultural residues such as peanuts shells and corncobs at this stage but it will be available in the revised version of the manual. The estimation for rice husk can be used for other agricultural residues as well for the time being. The estimation based on 10 kWh/HH/month which is the average monthly power consumption per household in rural villages where majority households normally use one or two fluorescent light and a TV. In the case of villages that have daytime electricity demand would require much more biomass fuel and will bring down the power tariff significantly. Discuss the matter with DIME. Secure at least 50% more fuel than required amount.

4.2.4 Planning Mini-Grid by Biomass Gasification Power

This sub-section presents some planning details of biomass gasification power. You may skip this sub-section.

(1) Fuel supply by tree farming

Determine the installed capacity of gas engine set by:

P_i = 1.30 x P_d including distribution losses and reserved capacity at 30% on top of the forecast demand

where, P_i : installed capacity of engine generator on continuous output basis (kW)

P_d : total power demand of the villages to be supplied under the scheme (kW)

The allowance of 30% above is required to have additional capacity for station use like tree cutter and lighting, streetlights, losses in distribution lines, and to cope with sudden but short time load rise without causing voltage drop or blackout. P_d may be planned as 100 W times number of households to be supplied. However, if most of the villagers use TV and other light load appliances in addition to lighting, the unit demand of 100 W may not be sufficient. It should be estimated in accordance with the procedure given in Sub-section 4.2.2.

The annual requirement of fuel tree can be estimated by:

$$F_t = (P_i\, t_o\ n_d) / F_c$$

where, F_t : required fuel tree (ton/year)

t_o : operation hour per day (hr)

n_d : operation days per year (365 days)

F_c : unit fuel consumption (kg/kWh)

The requirement of fuel tree above includes fuel allowances at 30% (10% for station use, streetlights, and distribution losses, 20% for over loading and handling losses of fuel trees).

The required land area for tree farming can be estimated by:

$$A_t = F_t / w_t$$

where, A_t : required land area of tree farming, (ha)

w_t : unit yield of tree farming, (ton/ha/year)

For example, assuming a village size of 200 households, the village power demand, required generator capacity, and land area for fuel supply are calculated below for reference:

$\boldsymbol{P_d}$ **=** 100 W x 200 households

= 20 kW

P_i = 1.30 x 20 kW

= 26 kW

F_t = (26 kW x 2.7 hr x 365 days) / 1.5 kg/kWh

= 94,900 kWh / 1.5 kg/kWh

= 25,600 kg/yr

= about 26 ton/yr

A_t = 26 ton / 10 ton/ha

= 4 ha

(2) Fuel supply required by type of material

The unit weight of biomass required for producing electricity of 1 kWh by biomass gasification power is listed in Table 4.3.2 by type of biomass (to be elaborated based on ongoing field survey and laboratory analyses):

4.3 PRELIMINARY COST ESTIMATE

4.3.1 Biomass Gasification Power Generation Facilities

Table 4.3.1 gives you rough idea of cost of biomass gasification power generation system. It does not include costs of distribution lines. This is just an example and actual prices vary in a wide rage (quality one costs even 10 times that of required specifications) from manufacturer to manufacturer and by specifications. There are also unclear factors on prices such as taxation and transportation. Collect information from DIME and providers listed in REFERENCE section of this manual.

4.3.2 Fuel costs

Prices of fuel wood or residues can be determined by each project. For woody biomass, \$20/t dry wood is a good indicative price. Tree growers can earn \$200/ha annually and fuel cost for unit power generation is about \$0.03/kWh. This is lower than diesel fuel cost of \$0.23/kWh. In the case of agricultural residues, fuel cost would be even cheaper. However, if you have to transport them over certain distance, it could be costly. In principle, biomass power plant shall be located beside fuel sources and beside village and fuel transportation over long distance should not be attempted.

4.3.3 Operation and Maintenance Costs

The following persons will be needed for operation and maintenance of mini-grids at the minimum:

1) One operation chief (mechanics/electrician)
2) One operator (fuel supply)
3) One accountant/tariff collector

The minimum labor costs are in an order of \$100 per month and \$1,200 per year. It will increase in a big grid but not in proportion to the scale. In general the larger grid can have the lower labor cost per kWh supplied.

In addition some consumables, spare parts, and maintenance expenses are required. An annual OM cost gasifiers and engine-generator is estimated as 3% and 5% of the initial costs of generating equipment respectively.

4.3.4 Depreciation Cost for Future Replacement

The power tariff collected from the users is required to cover the following expenditures:

1) Monthly expenditures;
2) Repayment of loan provided by REF/CFR;
3) Depreciation cost of some equipment for future replacement.

In the case of mini-grid by biomass gasification power, the following equipment needs deposit for future replacement depending on the lifetime:

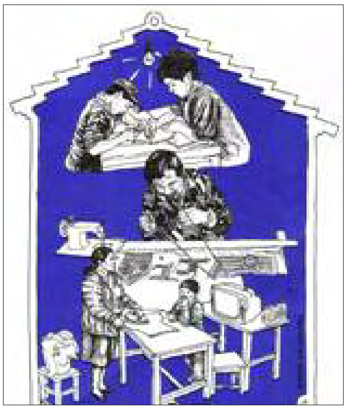
The lifetime depends on the quality, operating hours and maintenance. In general, gasifiers and engine generator is considered to be last about 10 years. You will need to set aside 10% of equipment installation cost for future replacement. The mini-grids can last for 30 years if it is properly designed in accordance with the standards of EAC. Long lifetime product is expensive in general. Unit price of gasifier engine generator set varies from $500/kW to over $5,000 /kW. In the Master Plan it was assumed at $1,300/kW. A high quality set can generate power for 24 hours. However, mini-grid does not require such 24 hour operation. It is advisable that some forced outage of the power station be accepted for achieving a lower cost.

For details on biomass gasification power generation, please refer to Appendix-C of Volume 5 Appendixes to Sector Study.

5. PLANNING OF MINI-GRID BY MICRO HYDRO

5.1 FIELD SURVEYS

5.1.1 Work Flow from Planning to Operation



For planning of micro hydro power (hereinafter, called "MHP"), it is important to check the potentials of hydropower or power demand of the target area at preliminary stage. If difficult to conduct checking of these potentials, contact Department of Industry, Mines and Energy (DIME) nearby for help consultation. The MHP scheme may be implemented following the procedure illustrated in Figure 5.1.1.

As the first step towards realization of the MHP Scheme, organization of the preparatory Group is essential. The main tasks of the Group are:

- To contact DIME office for institutional and technical supports;
- To contact and invite Expert/NGO for their site inspection, potential assessment, basic planning, and cost estimate (The cost of such Expert should be borne by the preparatory Group but could be treated as part of equity in future when the MHP scheme is implemented with support from REE.)
- To organize and establish community electricity company (CEC) based on the plan.

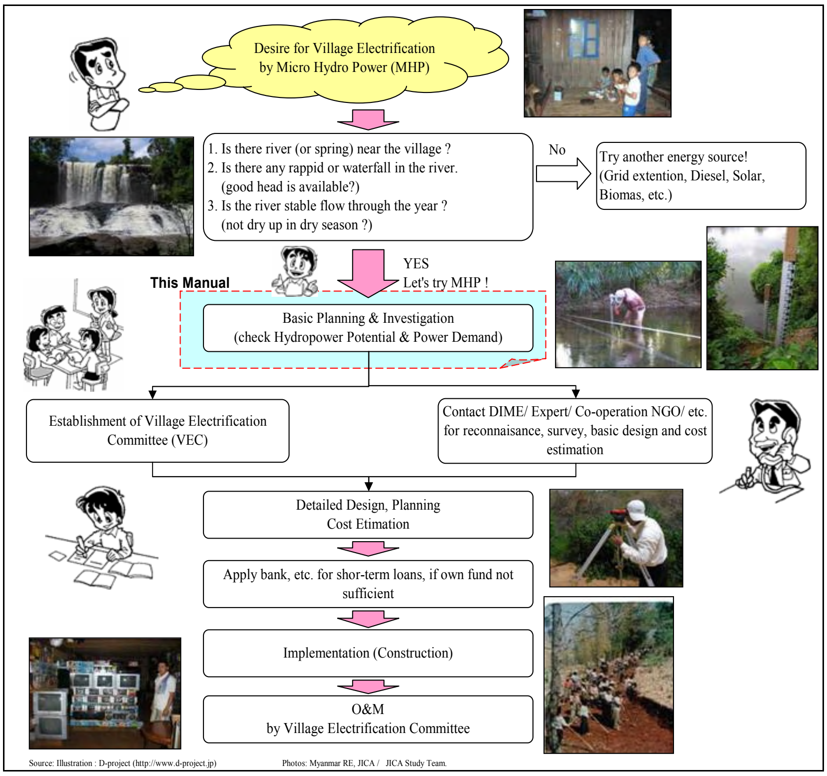
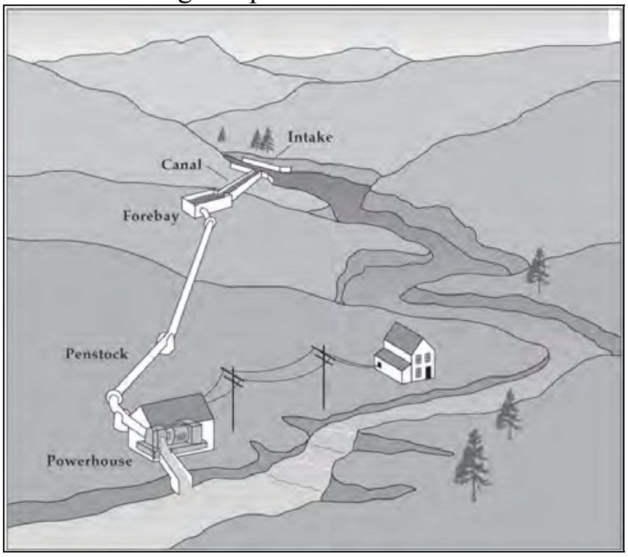


Figure 5.1.1 Procedure for Micro Hydro Power Scheme Implementation

5.1.2 Features of Micro Hydro

As illustrated below, typical MHP Scheme consists of the following components:

- Intake Weir: to secure necessary water level to guide water to Power Canal. This may be omitted depending on the site conditions;
- Intake Gate: to take necessary water and block flood water and flowing debris;
- Power Canal: to carry water to Head Tank;
- Head Tank (Forebay) : to change the flow condition from free flow in Power Canal to pressure flow in Penstock;
- Penstock: to convey the pressured flow to Turbine;
- Powerhouse: to accommodate Turbine and Generator;
- Tailrace: to return the flow back to the river.



Source: "Small Hydropower Systems", U.S. DOE, NREL

Figure 5.1.2 Layout of Typical MHP

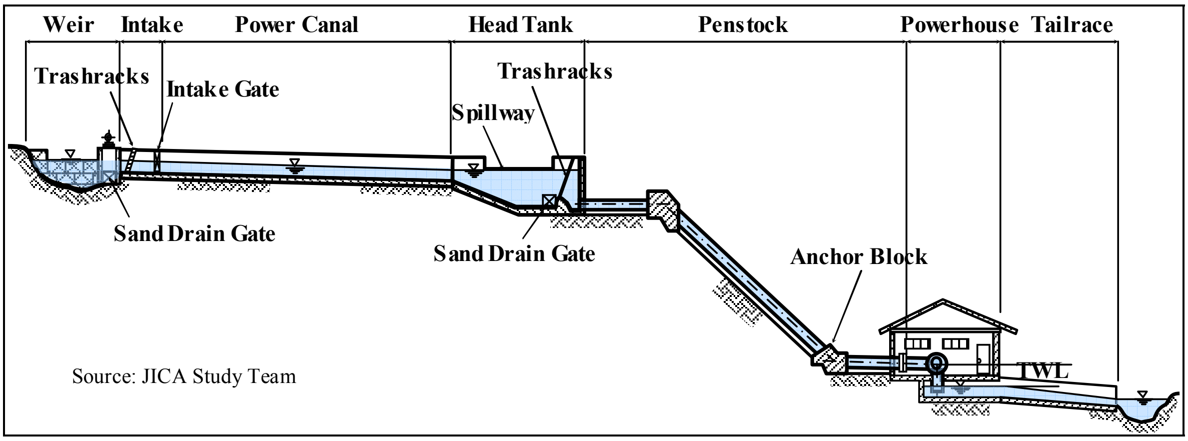


Figure 5.1.3 General Profile of Waterway

The water taken at the Intake will be guided to a Power Canal, which has a gentle slope to minimize the loss of head. The water will then rush down in Penstock which is usually placed on a steep slope to shorten the expensive Penstock length.

It is important to select the site where topography is suitable for such layout. In the case of micro hydro power, the detailed topography cannot be read and identified on a topographic map at a scale of 1/50,000 or 1/100,000. Accordingly, site reconnaissance and topographic survey on site are essential and should be performed repeatedly to well confirm the head in particular.

5.1.3 Potential Sites in Cambodia

According to the isohyetal map of annual rainfall in Cambodia (Figure 5.1.4), the potential site for the micro hydro power (MHP) will be located in the southwestern coastal area and eastern part of Cambodia, depending on the topography and rainfall. However, the monthly rainfall distribution pattern shows a distinct rainy season from May to November with a peak in August/September.

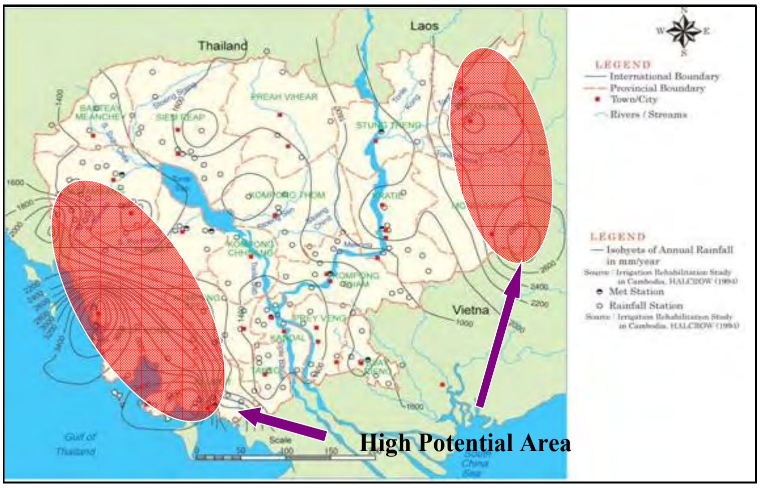
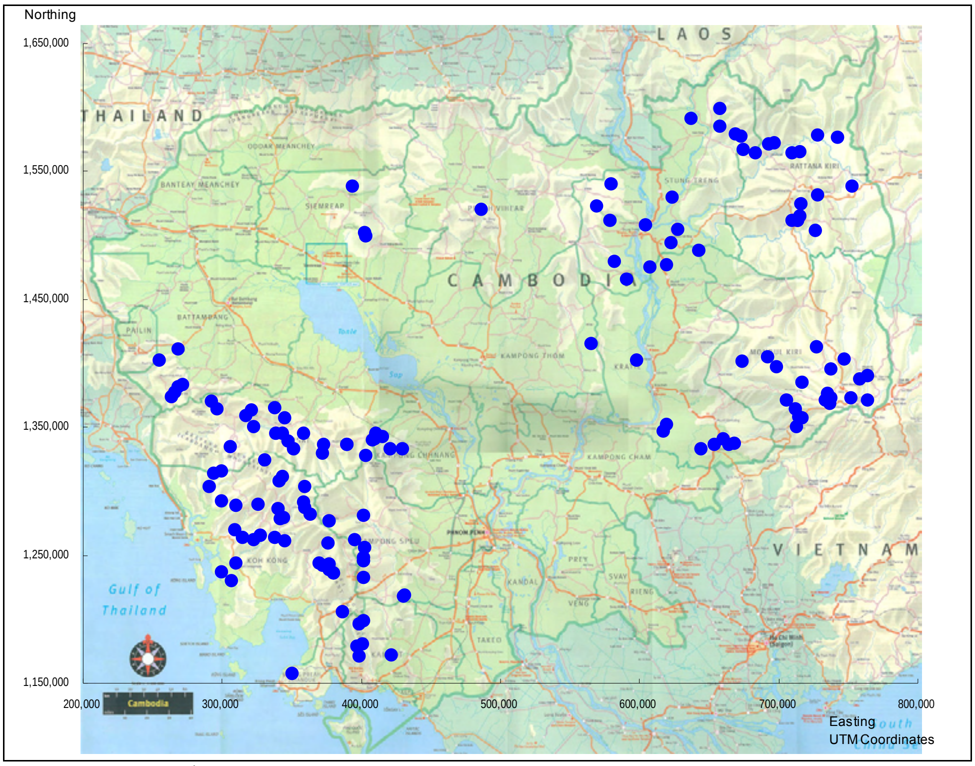


Figure 5.1.4 Isohyetal Map of Mean Annual Rainfall

Approximately 85~90% of the annual rainfall are observed during the rainy period. The period from December to April is the dry season, January being the driest month. It has been found through the first field reconnaissance made in December 2004 that most of the small rivers have very low flows in the dry season as a result of the hydrologic features unique to Cambodia.

Accordingly the Study Team checked potential sites on 1:50,000 and 1:100,000 maps seeking those sites that have significant flows in the dry season (refer to Figure 5.1.5 for the location). The results of map study for micro hydro power are attached in Table 5.1.4, Part 1.

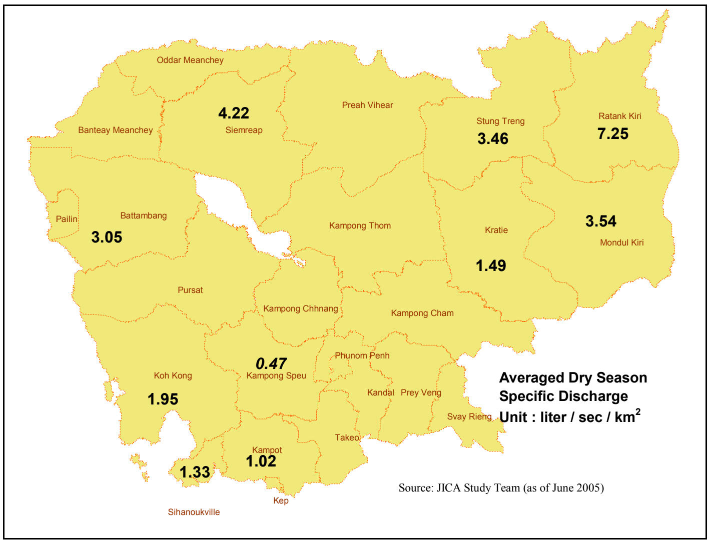


Source: JICA Study Team

Figure 5.1.5 Location Map of MHP Sites Identified through Map Study

5.1.4 Map of Specific Dry Season Discharge at Small Rivers in Cambodia

Discharge observation in dry season at the proposed site is important for the planning of MHP. However, for the preliminary stage, the provincial-wise spatial map of averaged dry season specific flows of small rivers (Figure 5.1.6), which is provided based on available existing discharge observation records as well as those measured by the Study Team, is useful for the reference.



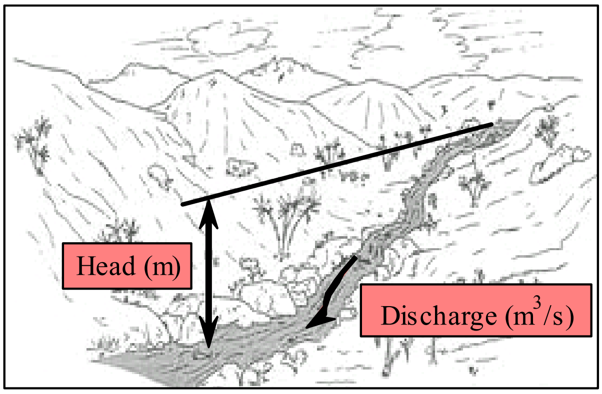
Please Note that these figures are not to guarantee minimum dry season discharge for the provinces. Figures are retrieved from reports or by actual measurement for promising sites, just for reference.

Figure 5.1.6 Mean Specific Dry Season Flow by Province

5.1.5 Survey of Head

The detailed planning and design are to be made based on a topographic map with a scale of 1/500 or more, but in the preliminary planning stage, much quicker and less costly methods can be used for measurement of the head.

The gross head is defined as the difference in the river water levels at the intake site and at outfall site where the turbine discharge will be released to the river. The head can be measured by simple and less-costly methods as described below:



Source: Micro-hydropower Sourcebook, NRECA

Figure 5.1.7 Head and Discharge

(1) Water Hose Method (for Gentle Slope)

A water tube/hose filled with water is placed as shown in Figure 5.1.8. The hose may preferably be transparent so that the water level inside the hose is visible. Both the ends of the hose shall be kept nearly at the same level by fixing to a rod/stand bar. Measure the height from the water level to the ground at both the ends. Measure the distance between the two ends if the slope is required.

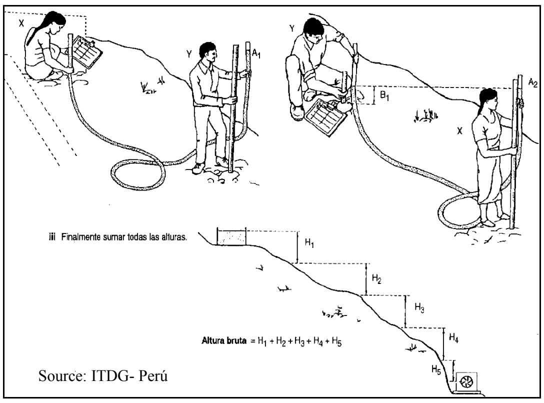
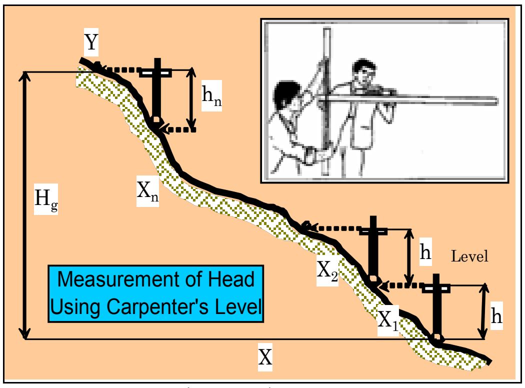


Figure 5.1.8 Leveling with Water Hose

(2) Carpenter's Level Method (for Steep Slope)

The method on the gentle slope could be applied also on the steep slope by repeating the procedure. In that case, two sets of movable stand should be provided to fix the two pipe ends. The second option is to measure the height difference using a carpenter's level and timber of 2" x 1" x 6 feet long. Height difference hi shall be measured progressively to arrive at destination. The gross head can be obtained by summing up h_i for i = 1 to n-step. ($H_g = h_1 + h_2 + h_3 + \sim + h_n$)



Source: JICA Study Team/ ITDG- Perú

Figure 5.1.9 Leveling Survey using Carpenter's Level

(3) Angle and Distance Method

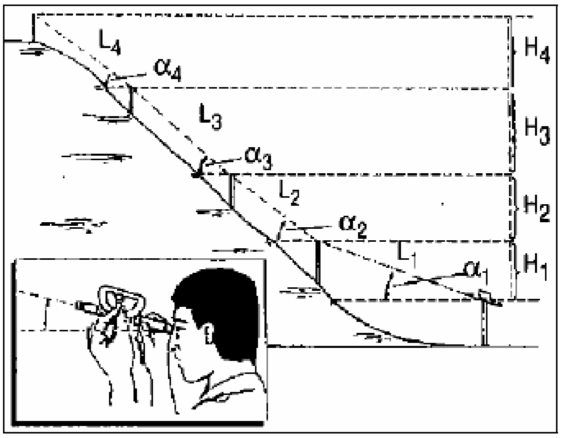
This option is to use a combination of a pocket distance meter (or measuring tape) and a hand level with Protractor (or clinometer or pocket compass, etc.). An inclined length is measured by the distance meter (or measuring tape) while the horizontal angle α is measured by the hand level. The H can be give by the following equation:

$$H = L * \sin \alpha$$

where, H: height difference (m)

L: distance (m)

α : horizontal angle (degree)



Source: ITDG- Perú

Figure 5.1.10 Leveling Survey using Distance Meter & Hand Level with Protractor

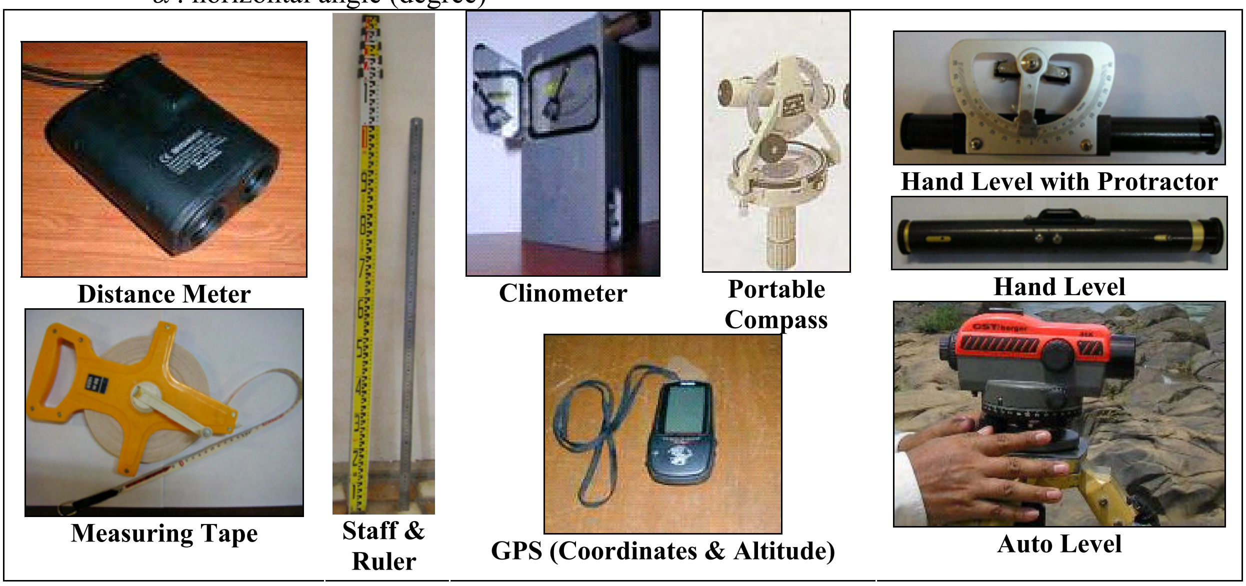
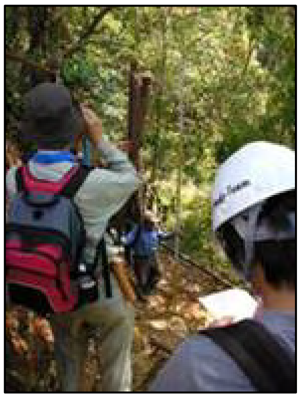


Figure 5.1.11 Tools for Measurement of Head

(4) Leveling Survey Methods by using Hand-Level (or Auto-Level)

This method is most applied widely and recommended method for aculeate survey of head. The procedure of this method is follows:



a) A **staff-man** setup a staff (or long measuring ruler/rod) vertically at the point "***A***". (see Figure 5.1.12)

b) **Observer** stands with the hand-level (or setup Auto-Level) at around the middle point between points "***A***" and "***B***". If the distance between ***A*** and ***B*** is too long the accuracy will be decreased. Check affords an unobstructed view.

c) The **observer** sets the hand-level horizontally by check a bubble of hand-level, and leads the height of the staff-"***A***" (a_1). This height is called "*Back-Sight* (B.S.)". **DO NOT MOVE!** The **Observer SHOULD KEEP his position** until finish to lead of height of next point "***B***".

d) The **staff-man** shifts to point "***B***" and sets the staff (or long ruler) vertically.

e) The **observer** turn and train to point-***B*** (but **DO NOT MOVE** at this point). Set the hand-level horizontally and lead the height of the staff-"***B***" (b_1). This height is called "*Fore-Sight* (F.S.)".

f) The **observer** shifts to next observation point at around the middle point between ***B*** and ***C***. Set the hand-level (or Auto-Level) and lead back-sight (BS) height of point ***B***. (a_2). The **Staff-man SHOULD KEEP his position** at the point-***B*** until finish to lead of height for point "***B***" by observer.

g) The staff-man shifts to point "***C***" and sets the staff (or long ruler) vertically.

h) Repeat the above procedure until arriving at the desired place.

i) The total head from point-***A*** to ***D*** is able to calculate by using following sample table (Table 5.1.1).

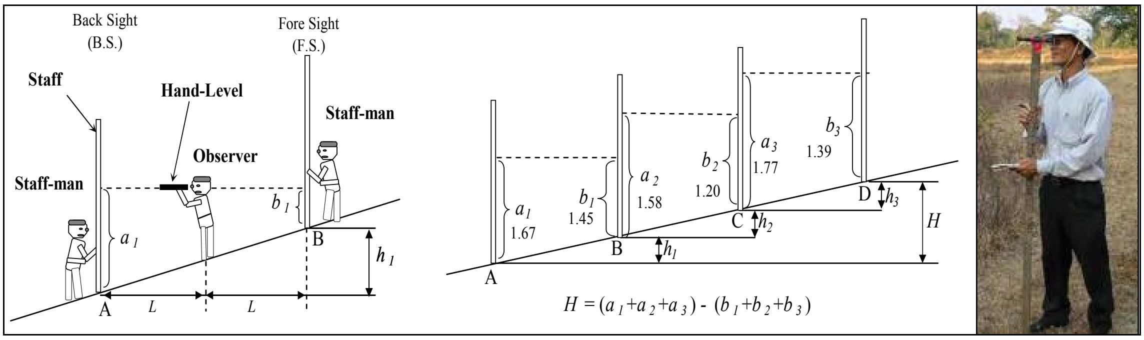


Figure 5.1.12 Leveling Survey by Using Head-Level

Table 5.1.1 Sample of Leveling Survey Results

Point No.	Distance (m)	B.S. (m)	F.S. (m)	h (m)	Notes
A		1.67			B.M.1 (TWL)
B		1.58	1.45	0.22	
C		1.77	1.20	0.38	
D			1.39	0.38	B.M.1 (IWL)
Total		5.02	4.04	0.98	
Head =5.02 - 4.04 = **0.98 m**					

Source: JICA Study Team

5.1.6 River Flow Measurement

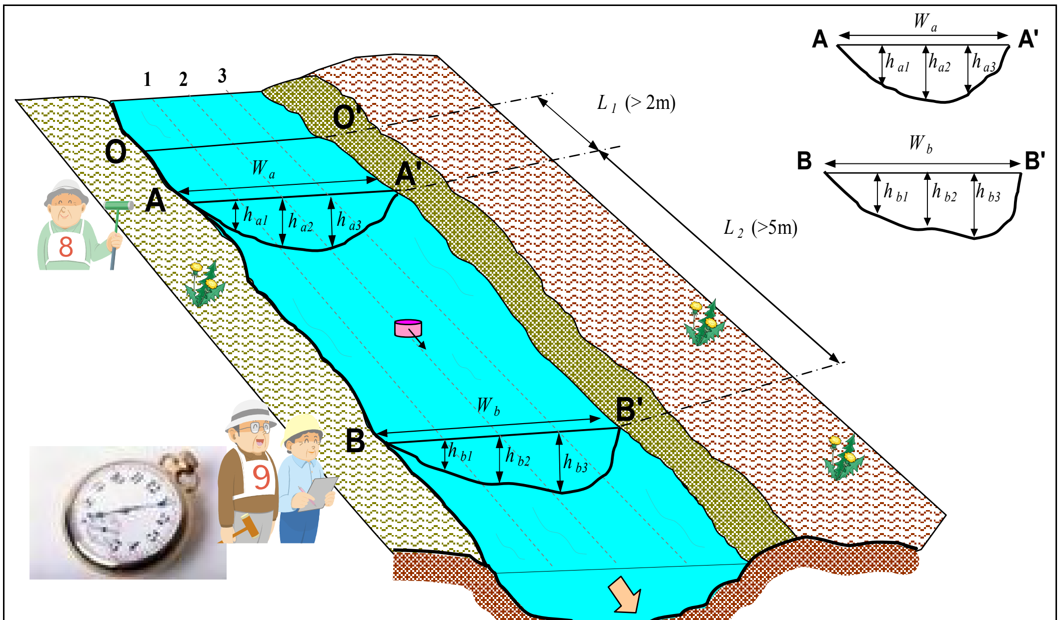
In order to supply the required electric power constantly throughout the year, it is essential that the minimum river discharge in the dry season meets the requirements. In this context, it is important to measure the river discharge in the dry season, in the months of March, April, May and June in particular.

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

The following methods are available to measure the river discharge:

(1) Float Method

This is the fastest method to measure velocities in a stream without any special equipment. However, the accuracy cannot be expected where the stream is irregular, wide, and shallow.



Source: JICA Study Team
Clip illustration : Microsft-Word, ClipArt
Reference: Hiromichi Chiya, Mincro Hydro Power Guidebook, Power Company, 1992.

Figure 5.1.13 Discharge Measurement by Float

Discharge measurement by float shall be carried out as follows:

a) To select measuring site (from **Section A-A’** to **Section B-B’**) for float method where is recommended at following condition:

- straight line and smooth flow
- almost same river width between W_a and W_b
- almost same depth between **Section A-A’** (h_{a2}) and **Section B-B’** (h_{b2})
- uniform slope of river bed

- no obstacle between **Section O-O'** to **Section B-B'**

b) To select point "**O**" for dropping a float for the measurement (see Figure 5.1.13) approximately 1~2m upstream from **Section A-A'**;

c) To determine point **B**, L_2 m downstream of point **A** (for small stream, L=3~5m);

d) Divide the river width into n uniform strips for each Section and measure water depth at center of each strip for the **Sections A-A'** and **Section B-B'**. (n = 3 ~ 10).

e) To obtain the average section area "**AREA**" among the **Sections A-A'** and **Section B-B'** by the following equations:

$$AREA = \frac{\mathrm{AREA_a} + \mathrm{AREA_{lb}}}{2}$$

$$AREA_a = \frac{\mathrm{W_a}\ (\mathrm{d_{a1}} + \ldots\ldots + \mathrm{d_{an}})}{\mathrm{n}} \quad , \quad AREA_b = \frac{\mathrm{W_b}\ (\mathrm{d_{b1}} + \ldots\ldots + \mathrm{d}_{bn})}{\mathrm{n}}$$

f) Drop a float (wooden-tips etc.) at **Section O-O'** and measure by stopwatch the time when the float passes the **Section A-A'** till the **Section B-B'**;

g) Repeat same procedure f) at left, center and right parts of river cross section;

h) To calculate the average flow velocity by the following equation:

$$V_i = \frac{L}{\mathrm{t_i}}$$

where, V_i: flow velocity at i-th measurement, (m/s)

L: distance between points **A** and **B**, (m)

t_i: arrival time of float from points **A** to **B**, (second)

The velocity V_i shall be measured for more than 2 times and their average shall be treated as the average flow velocity of one discharge measurement.

i) The river discharge can be obtained by the following equation:

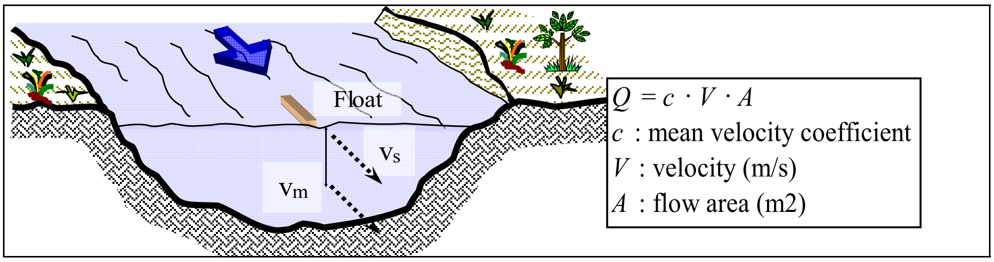
$$Q = c\ V A$$

where, Q: river discharge, (m^3/s)

V: average flow discharge (m/s)

c: mean velocity coefficient to surface velocity

(c = 0.85 for concrete channel, 0.80 for smooth flow, 0.65 for shallow flow)



Source: JICA Study Team

Figure 5.1.14 Mean Velocity Coefficient to Surface Velocity for Float Measurement

(2) Current Meter Method

This is the most common method to measure velocities where the stream is not irregular and turbulent. A location for the measurement should be selected in a straight stretch of the river. If there is a water level gauging station near the proposed MHP site, the discharge measurement should be conducted at the selected one section near the staff gauge. Depth and flow area measurement shall be carried out. Velocity measurement can be made by one point method at 0.6 d (60% of the depth from the water surface), if the water depth at the measurement point is less than 75cm as illustrated in Figure 5.1.15.

It is essential to check if the current meter has been calibrated prior to the measurement. As a general rule, the current meter should be calibrated once a year in order to obtain reliable velocity. Old current meter without calibration shall not be used. In such case, float measurements would give more dependable results.

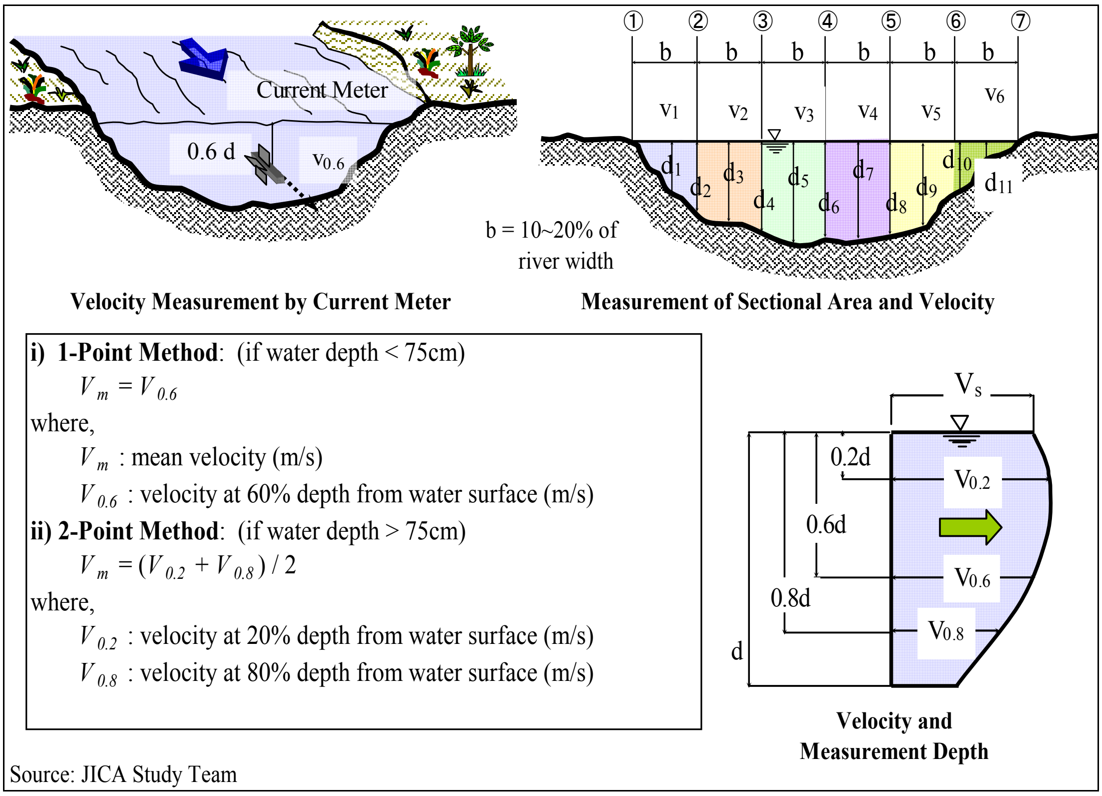


Figure 5.1.15 Discharge Measurement by Current Meter Method

If the river width is wide, the velocity measurement shall be made at center of each strip (refer to Figure 5.1.15 for strip). In this case, the discharge can be calculated by the following equation:

$$Q = Q_i + \dots\dots + Q_n$$

$$Q_i = \frac{W}{n} \times d_i \times v_i$$

where,
- Q : discharge (m^3/s)
- Q_i : discharge in the i-th strip (m^3/s)
- W : river width (m)
- n : number of strips ($n = 5 \sim 10$)
- d_i : depth at center of i-th strip (m)
- V_i : flow velocity at a depth of 0.6 x d_i on the center of i-th strip (m/s)

(3) Weir Method

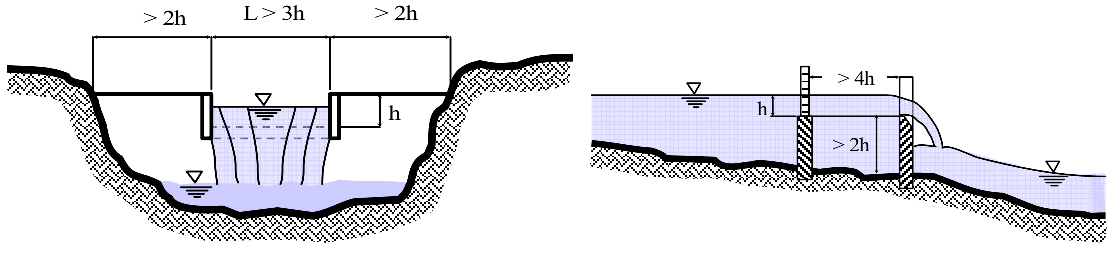
This method requires construction of a weir across the stream to measure discharge directly in the stream. The discharge of flow is given by the following formula:

$$Q = 1.84 \times (L - 0.2 \cdot h) \times h^{1.5}$$

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

L : length of weir (m)

h : overflow depth (m)

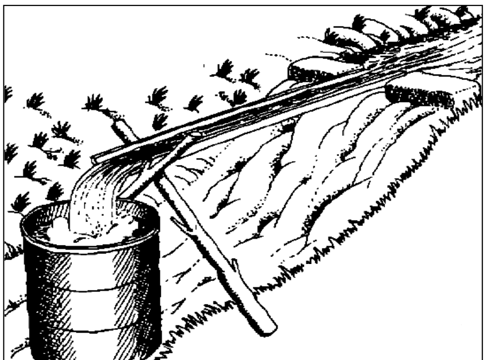


Source: JICA Study Team

Figure 5.1.16 Discharge Measurement by Weir

(4) Bucket Method

This method simply involved recording the amount of time requirement for the discharge in the stream to fill a bucket, oil drum, or other suitably shaped and sized container. For this method, one must be able to divert the entire stream discharge into the container. To apply this method, first measure the volume of the container "*Vc*" by making a few length measurements and using the appropriate volume formula or by counting the number of known volumes (from bottle, graduated cylinder, or tin can) required to fill it. Then record the time "*t*" required for the stream to fill the container. The discharge in the stream is then, $Q = Vc / t$ (m^3/s).



Source: ITDG- Perú

Figure 5.1.17 Discharge Measurement by Bucket

A form for discharge measurement (for current meter method) is shown below:

Table 5.1.2 Form of Filed Note for Discharge Measurement (Current Meter Method)

JICA Study Team Form 2-4-2 (Field Notebook of Discharge Observation)

River Name : , Site: , [Province:]

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 (on way)	Second (return)	Average	Depth of observation(m)	Count of current meter	Time in seconds 1st	2th	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)	
0 (Left)																
1						100 (=10*10)										
2																
3																
4																
5																
6																
7																
8																
9																
10																
11																
12																
13																
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16																
17																
18																
19																
20																
21																
22																

Station No.			
Observation Date		Year: Mon: Date:	
Observer Name	Mesure		
	Wrote		
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	Sanei type 3 current meter	
	Table/formula	V = 0.163 * N + 0.007	
	Useing method	lods · wire · weight	
		by boat / bridge / walk	
Calculator	Calculator	***Hirata***	
	Checker	***Hirata***	
Result	**Obs. Discharge (m^3/s)**		
	Total area cross section (m^2)		
	Average Velocity (m/s)		
	Catchment Area (km^2)		
	Specific Q ($m^3/s/km^2$)		

Measurement Site :
around 10m u/s from Meritec proposed Intake site.

Site Coordinate (GPS) (GPS Datum: **Indian-Thai**)
No.061 E Elevation (m) : by GPS m
N (accuracy by Alt. m

Gross Head m (Source: JICA Study Team, Obs.)
Design Q m3/s
Estimated P **kW (η =)**

Notes)

*weather: ○=0.clear weather ◑=1.fair, ◎=3.cloudy, ●=4.rain

Table 5.1.3 Form of Filed Note for Discharge Measurement (Float Method)

Form 3-14

JICA Study Team

Type	Station Code

Discharge Calculation (FLOAT TYPE)

(Year:)

Basin		River Name		Station Name	
Times of Observation	No. Times			No. of Year	

Obs. date		Obs. time			Weather	Wind blows	Wind power
	Year:		Start	:			
	Month:		End	:			
	Date:		Ave.	:			

W. Level(Base) (m)	Total Discharge (m^3/s)	No. of Vert. (point)	Width of w.surface (m)	Total Area (m^2)	Slope of w.surface	Ave. Veroc. (m)	Distance of stream (m)

Water Level	W.Level (Base) (m)	W.Level (No.1) (m)	W.Level (No.2) (m)	W.Level Staff (m)	Gap of Level (m)	Distance (m)	Slope of w.surface
Start	.	.	.	.	.	.	.
End	.	.	.	.	.	.	.
Ave.	.	.	.	.	.	.	.

No. of sect.	Type of float: Type	sink	Float throwing time (hour, min)	Float go down time (second)	Float go down velocity (m/sec)	coeff-icient	Corrected velocity (m/sec)	Area section(before and after flood): No.1 Sect. (m^2)	No.2 Sect. (m^2)	Average (m^2)	Section Discharge (m^3/s)
		.	.	.	.	.	.	.	.	.	.
		.	.	.	.	.	.	.	.	.	.
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		.	.	.	.	.	.	.	.	.	.
										Total=	

NOTES