Identification of Hydrologically Endowed Small Tanks for Rehabilitation and Agrowell Development Potential in the Cascades of Anuradhapura District, North Central Province, Sri Lanka

MAIN REPORT

Volume I

Study Team

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Abbreviations and Synonyms

ADA	Agricultural Development Authority
ADB	Asian Development Bank
CID	Central Irrigation Department
DAS	Department of Agrarian Services
DS	Divisional Secretariat
FST	Field Study Team
GOSL	Government of Sri Lanka
ha	hectares
IEE	Initial Environmental Evaluation
IFAD	International Fund for Agricultural Development
IIMI	International Irrigation Management Institute
NCP	North Central Province
NGO	Non-governmental Organization
NRMS	Natural Resources Management Study
PID	Provincial Irrigation Department
PPTA	Pre-Project Technical Assistance
SIDA	Swedish Development Agency
VES	Vertical Electrical Soundings
WFP	World Food Program

Summary

1. INTRODUCTION

The International Fund for Agricultural Development (IFAD) and the Government of Sri Lanka (GOSL) have accepted the cascade approach for rehabilitating small tanks under the water resources component of the Participatory Rural Development Project (PRDP) in the Anuradhapura district. The project plans to identify about 350 micro-tanks with command areas of less than 25 ha, 65 minor tanks each with command area ranging between 25 and 80 ha; and 5 medium tanks with command area exceeding 80 ha for rehabilitation.

For selection, these tanks need to satisfy two criteria: i) the selected tanks must have sufficient hydrologic and hydrogeological potential to cater to development needs, and ii) tanks must serve poor farmers. A two-stage approach to the selection of tank cascades and individual tanks was proposed by IFAD. In the first stage, the project would use hydrologic and hydrogeological criteria to select and produce an adequate number of tank cascades and individual tanks for rehabilitation (roughly twice the number of tanks planned for rehabilitation). In the second stage, the project would select the tanks for final implementation using socio-economic criteria. IIMI has undertaken to identify hydrologically endowed cascades and tanks for rehabilitation

IIMI completed the following activities: fine-tuning the cascade selection criteria based on the IIMI-IIE study and the IFAD tank selection criteria; developed a base map of the Anuradhapura district and layout of the cascade systems in the project area; selected cascades in the project area; carried out field studies for developing a data base related to cropping intensity, catchment and tank hydrology, tank capacity and existing condition, water distribution and management, water use - crop production aspects and other socio-economic issues; collection of information regarding hydrologic and groundwater potential; selected target cascades and tanks that have potential for rehabilitation based on hydrologic, agricultural and socio-economic potentials; also delineated potential zones for groundwater exploration and siting of agrowells; and prepared maps indicating the target cascades and target tanks for rehabilitation.

This section provides brief summaries i) of the methodology used in selecting hydrologically endowed cascades and tanks for rehabilitation, ii) the procedure used for delineating agro-well development zones and siting of agrowells, and iii) an implementation strategy for the water resources component of the Participatory Rural Development Project.

2. METHODOLOGY

2.1 Assessment of Tank Cascade Hydrology

First, cascade water surplus (hydrological endowment) is defined as the quantity of water discharged at the base of the cascade annually after satisfying the present water demand for agriculture as a percentage of total water supply available to the cascade. Basically, it represents the difference between water supply available to the cascade and present water use adjusted for the scale of total water use.

Estimation of cascade outflow involves a four step procedure :

a. Use maps to screen the cascades to select a group of cascades for further investigation.

b. Use rapid assessment techniques to collect data on the initially selected cascades. This data can be used for further screening of cascades.

c. For the selected cascades, use participatory appraisal and planning techniques to carry out further investigations and rehabilitation planning with farmers.

d. Use the collected data and a computer simulation model to determine the expected outflow from each cascade.

The key bit of information used to determine water availability in the cascade was data gathered from farmers on spilling from the tanks, including period, frequency, and approximate quantities.

From the prior studies of small tank and tank cascade hydrology, two key criteria were developed to eliminate cascades from further consideration. These criteria are:

- The ratio of cascade area (CAA) to the total tank water surface area in the cascade (WA) should exceed 8.

- The ratio of cascade command area (COA) to total tank water surface area (WA) should be less than 2.

Land use specialists on the IIMI team used these criteria to select 104 out of 239 cascades in Anuradhapura District from the standard government of Sri Lanka 1: 50,000 topographic maps.

The second step is to visit the cascades selected in the initial screening to collect information on water resources, agricultural land (presently cultivated, potential for expansion), cropping pattern, seasonal cropping intensities, population details (number of farmers under each tank), tank management details and groundwater use details. This information is collected by interviewing small groups of knowledgeable farmers in each village using a format. The data collected in each cascade is scored to assess the land, water and labour resources potential in each cascade.

The third step is to conduct multi-level participatory planning sessions with farmers from all villages within each cascade. The output of each effort is a set of six maps defining land and water resources, agricultural systems, and land use, social and management institutions and infrastructure and proposals for improvements and changes in all three of these areas.

The fourth step is to use a computer simulation model to calculate two important parameters:

- The cascade outflow, i.e. the annual runoff volume discharging at the foot of the cascade per unit cascade area (V).

- The effective maha (main) season runoff (Ro) to individual tanks.

In this study, the simulation model was used to evaluate the cascade water surplus of the 96 cascades and to validate farmer proposals for augmenting water supply to particular tanks.

The cascade water surplus (WSc) is the ratio of the outflow per unit area (V) to the mean annual rainfall (R50) That is : WSc = V/R50. For Anuradhapura District, we estimated that if this ratio is greater than 5 percent, the cascade has surplus water. For any cascade where the water surplus is above five percent, tank system rehabilitation planning may consider tank expansion or augmentation from additional sources. In any cascade where the water surplus is less than five percent, no tank expansion or augmentation should be considered.

2.2 Assessment of Tank Rehabilitation Proposals

2.2.1 Planning for Small Tank Rehabilitation

The potential components of small tank rehabilitation are: tank repairs including main canal and distribution system repairs; management improvement; tank water augmentation; tank capacity expansion; and command area expansion.

When planning small tank rehabilitation, three basic aspects are to be considered :

- First, the types of investment that can permitted must be specified.
- Second, the tank must be selected for investment based on relevant criteria
- Third, for any selected tank system the particular works to be carried out must be identified.

2.2.2 Hydrologic Evaluation of Small Tanks

Evaluation of the individual tank involves:

- Evaluating each individual tank in the cascade using water resource, tank storage capacity and agricultural criteria to identify its potential to benefit from repair and improvement.
- Comparing the farmers' repairs and improvement proposals for the cascade and individual tanks with the potential benefit to arrive at a set of repair and improvement recommendations.

The following indicators are used to evaluate the potential of a tank system to benefit from rehabilitation investment.

- Tank water supply adequacy: If the ratio of effective runoff to the tank (RO) to the irrigation water requirement (IWD) is greater than 1, i.e. RO/IWD > 1, the tank has adequate water supply to meet the irrigation requirement; otherwise additional water is needed to meet the irrigation requirement.

- Tank storage capacity: If the ratio of tank storage capacity (C) to irrigation water requirement (IWD) is less than 0.3, i.e C/IWD < 0.3, then the tank capacity has to be increased.

- Cropping Intensity: If the maha cropping intensity (CI maha) is greater than 60%, then it is considered a well performing tank system.

These indicators together with the cascade water surplus indicator lead to the following recommendations:

- Tank repairs are recommended in all hydrological situations.
- Management improvements are recommended if the main season cropping intensity for the tank is low (CImaha < 60%).
- Tank water augmentation is recommended if there is a cascade water surplus (WSc > 5%) and tank water supply is inadequate (RO/IWD < 1.0)
- Tank capacity expansion is recommended if there is a cascade water surplus (WSc > 5%) the tank water supply is adequate (RO/IWD > 1.0), but the tank storage capacity is inadequate (C/IWD < 0.3).
- Both tank augmentation and tank capacity expansion are recommended if there is a cascade water surplus (WSc > 5.0%), tank water supply is inadequate (RO/IWD < 1.0), and tank storage capacity is inadequate (C/IWD < 0.3). In this case, the tank capacity expansion is required to make use of the increased water supply to be provided through tank augmentation. However, if there is no source of water for tank augmentation, then tank expansion is not needed.
- Command area expansion is recommended only when a cascade water surplus exists (WSc>5%), tank water supply is adequate (RO/IWD > 1.0), tank storage is adequate (C/IWD > 0.3), cropping intensity is high (CImaha > 60%) and land for command area expansion is easily available.

The purely hydrological indicators bear only on recommendations for tank system augmentation or expansion. The conditions that support recommendations for augmentation or expansion are expressed in Figure 1. Recommendations for tank repairs are independent of the hydrological evaluation and have to be based on other criteria, such as cost/benefit estimates. Similarly, recommendations for management improvements are based solely on cropping intensity which is used as a measure of system agricultural performance. Additional, non-hydrological criteria are needed for deciding whether and how to invest in any particular tank system.

The two key non-hydrological considerations used to eliminate small tank systems from rehabilitation consideration are:

- Number of beneficiaries from a tank must be at least five for a tank system to be considered for rehabilitation.
- There should have been a time gap of at least 10 years since the last rehabilitation for a tank system to be considered for rehabilitation.

In order to estimate the level of investment in tank repairs, a tank system Physical Status Score (PSS) was developed. If the computed PSS score is greater than 60, then the tank needs heavy investment; if it is between 40 and 60 then the tank needs moderate investment and if it is less than 40, then the tank needs only low investment.

2.3 Groundwater and Agro-wells

The main groundwater bearing formations are the weathered overburden which has an average thickness of around 12 m, and the underlying fractures and fissures of the basement crystalline rocks which are less frequent in this hardrock region. The existing agro-wells can be grouped within four categories as follows:

1. Wells located in the upper part of the cascade catchment
2. Wells located in the middle part of the cascade catchment
3. Wells located in the lower part of the cascade catchment
4. Wells located below the tanks in the command area.

The agro-wells in categories 1 and 2 have a drawdown of around 1.0 m and a recovery time of around 1.5 days; while in categories 3 and 4 have a drawdown of around 0.6 m and recovery time of less than 1.0 day. Agro-well recommendations are therefore made on the basis of 20 percent to the catchment area and 80 percent to the command area.

Out of the total of 50 cascades that were studied in the first round, 39 cascades were considered as suitable for groundwater exploitation, while the remaining 11 cascades had already reached the limit of exploitation and had no further hydrological potential for construction of agrowells.

The areas considered as suitable for agro-well development are shown in the set of maps for the 50 cascades in Volume 3 of the Final Report, together with the number of agro-wells recommended within the catchment area and command area respectively; a total of 3595 agro-wells is considered the total carrying capacity for agro-wells within these 50 cascades. These numbers range from around 165 agro-wells for the larger and better endowed cascades to around 16 agro-wells for the smaller and less well endowed cascades.

When more agrowells are requested over and above the presently existing agro-wells, it is recommended that these be located within the area demarcated in the set of maps provided both in Volume 3 as well as in the new set of maps (15 in number) which show the areas suitable for agro-well development at a scale of 1:50,000. A convenient practical way to use these maps is to cross refer the table provided in annex 6.1 of the main report with the table provided for each cascade in Volume 3, and thus decide on the suitable sites for new locations for extra agro-wells.

On no condition should the recommended number of agro-wells be exceeded which includes the present number of existing agrowells together with the new ones proposed.

The total number of agro-wells for these 50 cascades should not therefore exceed 3600. A demarcation of areas for further number of agro-wells within the additional 46 cascades that are being now investigated could be made at a later period after conducting a minimum set of field studies on similar lines as for the 50 cascades now reported.

3. IMPLEMENTATION STRATEGY

IIMI work has contributed to the identification of 96 cascades comprising 648 micro, minor and medium tanks eligible for small tank rehabilitation. Out of these, the project intends to identify about 350 micro tanks with command area less than 40 ha, 65 minor tanks each with command area ranging between 40 and 80 ha; and 5 medium tanks with command area exceeding 80 ha for rehabilitation. The 96 selected cascades come from 15 divisional secretariat divisions which will be considered as the unit of operation for implementation.

The selected cascades, and the tanks within them together with their particulars have been tabulated as shown in Table 1 and four files have been prepared. The first file is called a master file while the other three are called respectively micro, minor, and medium-tank files. In the master file, for each D.S. Division, the selected cascades are arranged in descending order of water surplus (hydrological endowment). This arrangement makes the first cascade of each D.S. division to be the most hydrologically well endowed cascade in that division, followed by decreasingly well endowed cascades. Also, the tanks within each cascade are arranged in the descending order of water supply adequacy (RO/IWD) with the first tank in the list having the highest RO/IWD in that division followed by tanks with decreasing RO/IWD. In addition, the following information is also provided in the tabular statement.

- Div. No; Cascade No; Priority order
- Name of tank
- Command area of each tank
- No. of farm families
- Year of last rehabilitation
- RO/IWD
- C/IWD
- CI maha
- PSS Score
- Farmers' proposals for rehabilitation
- Recommendations
- Investment level
- Category

The other 3 files contain information pertaining to tanks falling within their limits. i.e., micro-tank files will have information relating to tanks having a command area of 40 ha or less;

similarly minor tank files will have information of tanks falling within 40 to 80 ha and medium tank files with tanks having command area greater than 80 ha.

An important point to be noted in this arrangement is that D.S. Division is taken as a unit of implementation; cascades in each D.S. Division are prioritized and arranged in descending order of their hydrological endowment.

The following procedure is suggested for selecting tanks for rehabilitation implementation under the PRDP. Let us illustrate this procedure with a hypothetical example. Suppose that it is decided to take up 5 micro-tanks, 2 minor tanks and 1 medium for rehabilitation in 1997 in a particular D.S. Division. First take up the micro-tank file; in that file, the cascades are arranged according to their hydrological endowment and the tanks within it are prioritized according to their water supply adequacy (RO/IWD). Let us assume that there are only 4 cascades in that D.S. Division with selected micro-tanks. First select the first prioritized tank in the first cascade; then go to the second cascade, select the first prioritized tank; repeat the procedure till you exhaust the cascades, in this case 4 cascades. Through this procedure you would have selected 4 tanks. For selecting the fifth tank, go back to the first cascade and select the second prioritized tank in that cascade thereby completing the selection of planned number of micro-tanks. In the next year, if you are going to select say 3 micro-tanks, then start with where you have left namely start with the second cascade and select the second prioritized tank, then go to third and fourth cascades to complete the selection of 3 micro tanks. If for some reason, one of the tanks selected in a cascade cannot be taken up for rehabilitation, e.g. because farmers are not willing to participate in the rehabilitation implementation, then pick up the next priority tank from that cascade. The same procedure is applicable for minor and medium tanks also. Each implementing agency will be given a file of tanks for the category they are working with in addition to a master file which contains the overall tank rehabilitation proposals.

Once a tank is selected for rehabilitation by the implementing agency in consultation with community, then the agency concerned prepares a preliminary report about the rehabilitation of that tank based on the IIMI report after visiting the tank and discussing with the farmers.

These preliminary reports prepared for the selected tanks will be submitted to the Water Resources Working Group (Water Resources Committee) for their scrutiny and approval. Once a report is approved by the Water Resources Committee, then the agency undertakes a detailed survey of the selected tanks and prepares detailed quantity and cost estimates. These detailed estimates will again be submitted to the Water Resources Committee which scrutinizes the estimates and passes its recommendation to the Project Director for approval. After the project designs and estimates are approved by the Project Director, the tanks can be taken up for implementation.

Since the implementation will be carried out by three Departments (DAS, DID, CID), it is suggested:

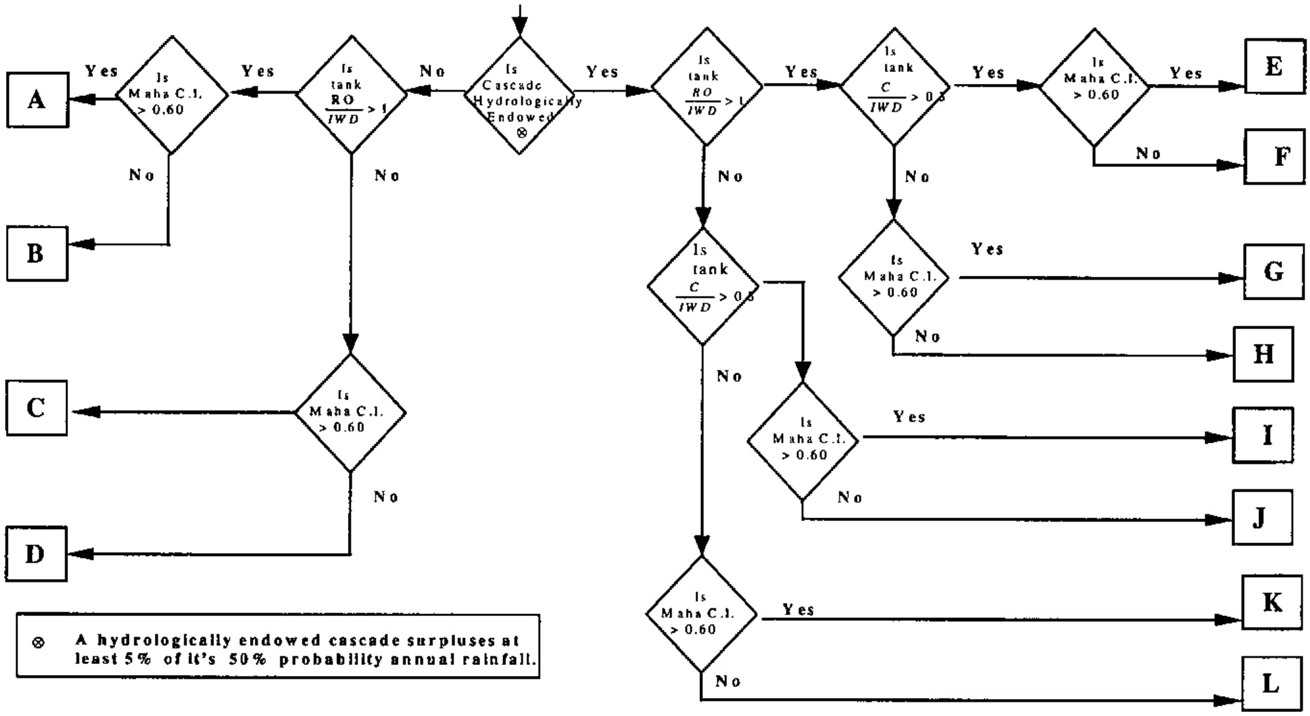
i. Frame a 'common norm' for implementing the project so that uniformity will be maintained among different agencies implementing the project.

ii. As far as possible, it would be better that only a single agency at a time be implementing tank rehabilitation in a cascade; in other words, try to avoid two or more agencies working simultaneously in the same cascade.

iii. It would be ideal to develop a total package of rehabilitation of tanks by different agencies, their time of implementation, and other components of development in a cascade under the PRDP over the project period and make it transparent to the cascade community so that better co-operation can be achieved.

iv. The ultimate objective is to improve the agricultural performance of each and every tank in the cascade as well as to improve upland agriculture to help improve the living standards of rural poor. Unless this development activity is undertaken in a holistic manner, at the cascade level, institutional development at a cascade level would be difficult; that is why a comprehensive development planning for each cascade should be prepared in consultation with the community and made known to all concerned with the development of the cascade.

Figure 1: Flow Chart for Selecting Tanks for Rehabilitation and Modernization



Rehabilitation Improvement Scheme	Description of Activities
A	Tank repairs. Improve WUE*
B	Tank repairs. Management of Institutional Improvements. Improve WUE.
C	Resource augmentation. Tank repairs. Improve WUE.
D	Resource augmentation. Tank repairs. Management of Institutional improvements. Improve WUE.
E	Capacity expansion. Water diversion. Tank repairs. Improve WUE.
F	Management of Institutional Improvements. Tank repairs. Improve WUE.
G	Capacity augmentation. Command area expansion. Water diversion. Tank repairs. Improve WUE.
H	Capacity augmentation. Management of institutional improvements. Tank repairs. Improve WUE.
I	Resource augmentation. Tank repairs. Improve WUE.
J	Resource augmentation. Management of Institutional improvements. Tank repairs. Improve WUE.
K	Resource augmentation. Capacity augmentation. Tank repairs. Improve WUE.
L	Resource augmentation. Capacity augmentation. Management of Institutional Improvements. Tank repairs. Improve WUE.

* Water productivity in many of these small schemes are low. Therefore, improving water use efficiency (WUE) is a common activity for all rehabilitation improvement schemes.

Table 1 : Sample Specimen of Tabulated Particulars

Padawiya DS division - 1

Cascade : Navagaswewa (1)

Endowed cascade *V/R50= 11.61 %*

Div. No.	Cas. No.	Prio. order	Tank	No. of families	Command area (ha)	Previous year of rehabilitation	RO/IWD ratio	C/IWD ratio	Maha CI	PSS score	Farmer's proposal in priority order	Recommendations	Investment level	Category
1	1	1	Pahala Nawagas wewa (3)	15	40.50		1.11	0.19	0.75	72	i. Bund raising and strengthening. ii. Replace step sluices (3). iii. Increase storage capacity. iv. Construction of new channels.	Recommended. Type - G - All tank repairs and improvements. - Capacity augmentation. - Command area expansion. - Water diversion. - Improve water use efficiency.	High investment.	Minor
1	1	2	Ihala Nawagas wewa (1)	24	24.30	1967	0.66	0.34	0.50	54	i. Construction of new channels. ii. Repairs to sluices. iii. Arrest bund leakage. iv. Increase storage capacity.	Recommended. Type - J - All tank repairs and improvements. - Resource augmentation. - Management and institutional improvements. - Improve water use efficiency.	Medium investment.	Micro
1	1	3	Mahasenpura wewa (2)	10	20.00		0.40	0.09	0.00	82	An abandoned tank for a long period. Farmers require a full	Recommended.	High investment.	Micro

Summary of recommended and total tanks is annexed

Summary of Tanks
(Recommended and Total)

No of Divisions	Total No. of Cascades	Total No. of Tanks	Total No. of Cascades Selected	Total No. of Tanks	No. of Tanks Recommended
15	239	1874	96	1123	647

D S Division Number and Name	Selected Cascades Number and Name	Recommended tanks				Total number of tanks			
		No. of micro tanks. (0 - 10 ha.)	No. of micro tanks. (10 - 40 ha.)	No. of minor tanks. (40 - 80 ha.)	No. of medium tanks. (above 80 ha.)	No. of micro tanks. (0 - 10 ha.)	No. of micro tanks. (10 - 40 ha.)	No. of minor tanks. (40 - 80 ha.)	No. of medium tanks. (above 80 ha.)
01 Padawiya	01 Navagaswewa	0	2	1	0	0	2	1	0
Sub total for the division	**Number of cascades - 1**	**0**	**2**	**1**	**0**	**0**	**2**	**1**	**0**
02 Kebithigollewa	08 Kunchchuttuwa	5	4	2	0	9	4	3	0
	09 Meegaha Ulpotha	4	1	2	1	5	2	2	1
	10 Kolibendawewa	1	3	0	1	2	5	3	1
	11 Kiwulekada	2	3	0	1	4	6	0	1
	12 Thammennawa	2	6	0	0	4	7	0	1
	14 Usgollewa	2	2	1	0	3	2	1	0
	15 Eithalwidda wewa	0	4	0	1	2	6	0	1
	17 Sinhala Etaweera wewa	1	1	1	0	1	6	1	0
Sub total for the division	**Number of cascades - 8**	**17**	**24**	**6**	**4**	**30**	**38**	**10**	**5**

D S Division Number and Name	Cascade Number and Name	Recommended tanks				Total number of tanks			
		No. of micro tanks. (0 - 10 ha.)	No. of micro tanks. (10 - 40 ha.)	No. of minor tanks. (40 - 80 ha.)	No. of medium tanks. (above 80 ha.)	No. of micro tanks. (0 - 10 ha.)	No. of micro tanks. (10 - 40 ha.)	No. of minor tanks. (40 - 80 ha.)	No. of medium tanks. (above 80 ha.)
03 Medawachchiya	01 Mekichchawa	5	6	2	0	6	7	2	0
	07 Kiddawarankulama	5	4	3	1	7	9	3	2
	08 Marakkala Hammillewa	3	1	0	0	6	2	2	0
	09 Ethawetuna wewa	0	0	1	0	2	1	1	0
	10 Muruthamaduwa	2	9	2	1	2	12	2	2
	14 Divul wewa	1	1	0	0	1	3	0	0
	16 Medawachchiya	4	7	1	1	10	18	1	2
	22 Angunuchchiya	1	4	4	0	4	7	6	0
	23 Parana Halmillewa	5	7	4	1	7	8	4	1
	24 Kongollewa	3	1	2	0	4	2	3	0
Sub total for the division	**Number of cascades - 10**	**29**	**40**	**19**	**4**	**49**	**69**	**24**	**7**
04 Nuwaragam Palatha (Central)	06 Tammannawa	1	2	3	0	4	4	3	0
	07 Galpottegama	2	2	0	1	5	5	0	1
	14 Mahabulankulama	5	1	0	1	8	2	0	1
	15 Vihara Thirappane	1	3	1	1	1	3	2	1
	16 Vihara Kallanchiya	1	0	1	0	1	1	2	0
	18 Galkadawala	6	2	0	1	16	5	1	1
	22 Bellankadawala	1	4	0	1	4	7	1	1

D S Division Number and Name	Cascade Number and Name	Recommended tanks				Total number of tanks			
		No. of micro tanks. (0 - 10 ha.)	No. of micro tanks. (10 - 40 ha.)	No. of minor tanks. (40 - 80 ha.)	No. of medium tanks. (above 80 ha.)	No. of micro tanks. (0 - 10 ha.)	No. of micro tanks. (10 - 40 ha.)	No. of minor tanks. (40 - 80 ha.)	No. of medium tanks. (above 80 ha.)
Sub total for the division	**Number of cascades - 7**	**17**	**14**	**5**	**5**	**39**	**27**	**9**	**5**
05 Maha Wilachchiya	03 Dunumadalawa	1	0	0	0	2	1	1	0
	04 Nabadagasdigiliya	0	2	0	0	1	4	0	0
	08 Maningamuwa	0	0	0	1	1	1	0	1
	12 Sandamaleliya	3	3	1	0	7	3	2	0
Sub total for the division	**Number of cascades - 4**	**4**	**5**	**1**	**1**	**11**	**9**	**3**	**1**
07 Rajanganaya	01 Thammannawa	0	0	0	0	3	0	0	0
Sub total for the division	**Number of cascades - 1**	**0**	**0**	**0**	**0**	**3**	**0**	**0**	**0**
10 Nuwaragam Palatha (East)	05 Kuda Kalattawa	1	4	0	0	1	5	1	0
Sub total for the division	**Number of cascades - 1**	**1**	**4**	**0**	**0**	**1**	**5**	**1**	**0**
11 Mihintale	01 Ukkulankulama	3	2	1	0	4	2	1	0
	08 Maha Kirindegama	0	2	0	0	1	7	1	0
	10 Katupota	0	2	0	0	6	5	0	0
	11 Mankulama	2	0	0	0	3	4	1	0
	12 Maha Rambewa	1	2	1	0	6	3	3	0
	14 Indigollewa	1	1	0	0	2	1	1	0
	15 Katukeliyawa	0	4	1	0	0	5	1	0
	20 Weruppankulama	1	3	0	1	11	4	0	1

D S Division Number and Name	Cascade Number and Name	Recommended tanks				Total number of tanks			
		No. of micro tanks. (0 - 10 ha.)	No. of micro tanks. (10 - 40 ha.)	No. of minor tanks. (40 - 80 ha.)	No. of medium tanks. (above 80 ha.)	No. of micro tanks. (0 - 10 ha.)	No. of micro tanks. (10 - 40 ha.)	No. of minor tanks. (40 - 80 ha.)	No. of medium tanks. (above 80 ha.)
	21 Seeppukulama	1	0	2	0	1	2	3	0
Sub total for the division	**Number of cascades - 9**	**9**	**16**	**5**	**1**	**34**	**33**	**11**	**1**
12 Rambewa	03 Kadurugasdamana	0	2	1	2	0	3	1	2
	06 Bandara Ikkirigollew	0	0	0	0	2	2	0	0
	07 Rota wewa	0	1	0	0	3	3	0	0
	10 Kapriggama	5	3	1	1	7	7	2	1
	11 Pihimbiyagollewa	2	8	3	1	3	14	3	2
	12 Kokatiyagollewa	2	5	1	1	2	7	1	1
	14 Kendawa	4	2	1	0	4	4	1	0
Sub total for the division	**Number of cascades - 7**	**13**	**21**	**7**	**5**	**21**	**40**	**8**	**6**
13 Kahatagasdigiliya	01 Pethiankada	1	10	1	1	4	19	1	2
	04 Hammillewa	6	10	1	1	7	16	1	1
	05 Moragahawala	1	3	2	0	2	6	5	0
	06 Rampathwila	4	16	2	4	5	18	3	4
	09 Ella wewa	1	3	1	0	2	7	4	1
	10 Gangurawa	7	7	1	0	9	16	4	1
	11 Mahakirimatiyawa	3	9	3	0	4	10	3	0
	16 Pandarellewa	2	8	3	1	6	10	3	1

D S Division Number and Name	Cascade Number and Name	Recommended tanks				Total number of tanks			
		No. of micro tanks. (0 - 10 ha.)	No. of micro tanks. (10 - 40 ha.)	No. of minor tanks. (40 - 80 ha.)	No. of medium tanks. (above 80 ha.)	No. of micro tanks. (0 - 10 ha.)	No. of micro tanks. (10 - 40 ha.)	No. of minor tanks. (40 - 80 ha.)	No. of medium tanks. (above 80 ha.)
	18 Nelugollakada	6	1	1	3	8	1	3	3
	19 Iethalwetuna wewa	1	3	1	1	3	5	1	1
Sub total for the division	**Number of cascades - 10**	**32**	**70**	**16**	**11**	**50**	**108**	**28**	**14**
14 Horowpatana	03 Dutu wewa	0	0	0	1	2	0	1	3
	06 Horowpathana	0	13	1	3	6	18	1	3
	10 Kalpemorakewa	3	4	0	2	3	7	1	2
	11 Morakewa	1	3	1	0	2	7	1	0
	12 Olugaskada	1	4	0	0	6	5	0	1
	14 Puliyankadawala	2	8	3	1	3	10	3	1
	19 Demata wewa	0	3	1	0	6	3	1	0
	21 Diyathitha wewa	1	1	3	0	2	2	4	1
Sub total for the division	**Number of cascades - 8**	**8**	**36**	**9**	**7**	**30**	**52**	**12**	**11**
15 Galenbindunuwewa	01 Veheragala	0	1	0	0	1	2	1	0
	04 Ichchankulama	1	5	0	0	5	6	1	0
	05 Himbutugollewa	6	9	2	1	12	15	2	1
	09 Muwapitiya	0	1	0	0	2	3	0	0
	10 Sivalakulama	6	5	3	0	9	8	4	0
	11 Karuwalagaswewa	2	2	0	0	4	2	0	0

D S Division Number and Name	Cascade Number and Name	Recommended tanks				Total number of tanks			
		No. of micro tanks. (0 - 10 ha.)	No. of micro tanks. (10 - 40 ha.)	No. of minor tanks. (40 - 80 ha.)	No. of medium tanks. (above 80 ha.)	No. of micro tanks. (0 - 10 ha.)	No. of micro tanks. (10 - 40 ha.)	No. of minor tanks. (40 - 80 ha.)	No. of medium tanks. (above 80 ha.)
	13 Thammennawa	1	1	2	0	2	1	2	0
	14 Kawarak Kulama	0	0	0	0	0	0	1	0
	17 Divulwewa	5	4	0	1	9	4	0	1
Sub total for the division	**Number of cascades - 9**	**21**	**28**	**7**	**2**	**44**	**41**	**11**	**2**
16 Thirappane	04 Maha Kanamulla	6	11	7	0	7	13	8	0
	05 Thirappane	2	4	0	0	4	6	0	0
	06 Ulagalla	2	5	3	2	7	8	5	2
	08 Pahala Ambatale	2	2	0	0	3	4	1	1
	10 Kattamurijjana	0	3	0	0	0	5	1	0
	11 Meewellawa	1	2	1	0	2	2	1	0
	13 Kadurugaspitiya	1	1	1	0	4	2	1	0
	14 Konwewa	0	1	1	0	2	1	1	0
	15 Pairamaduwa	1	0	2	0	1	0	2	0
	16 Wannankulama	1	0	0	0	5	1	0	1
	17 Muriyakadawala	1	1	0	0	2	2	0	2
Sub total for the division	**Number of cascades - 11**	**17**	**30**	**15**	**2**	**37**	**44**	**20**	**6**
17 Palugas wewa	01 Mahadivulwewa	2	2	1	0	4	2	1	0
	06 Demunnewa	1	4	2	1	2	7	3	2

D S Division Number and Name	Cascade Number and Name	Recommended tanks				Total number of tanks			
		No. of micro tanks. (0 - 10 ha.)	No. of micro tanks. (10 - 40 ha.)	No. of minor tanks. (40 - 80 ha.)	No. of medium tanks. (above 80 ha.)	No. of micro tanks. (0 - 10 ha.)	No. of micro tanks. (10 - 40 ha.)	No. of minor tanks. (40 - 80 ha.)	No. of medium tanks. (above 80 ha.)
	08 Palugaswewa	1	0	1	1	8	2	1	1
	10 Weragala	1	4	0	0	2	6	0	0
	11 Mahameegas wewa	1	1	0	0	1	1	0	0
	14 Maharambewa	1	1	0	0	1	3	0	0
Sub total for the division	**Number of cascades - 7**	**7**	**12**	**4**	**2**	**18**	**21**	**5**	**3**
21 Palagala	02 Hammillewa	2	8	0	0	3	9	0	0
	03 Meegaswewa	2	8	4	0	8	17	8	0
	04 Mee wewa	1	6	0	0	3	10	2	0
	05 Andiyagala	0	0	0	0	1	2	0	0
Sub total for the division	**Number of cascades - 1**	**5**	**22**	**4**	**0**	**15**	**38**	**10**	**0**
GRAND TOTAL : **Number of divisions - 15**	**Number of cascades - 96**	**180**	**324**	**99**	**44**	**382**	**527**	**153**	**61**

Chapter 1

INTRODUCTION

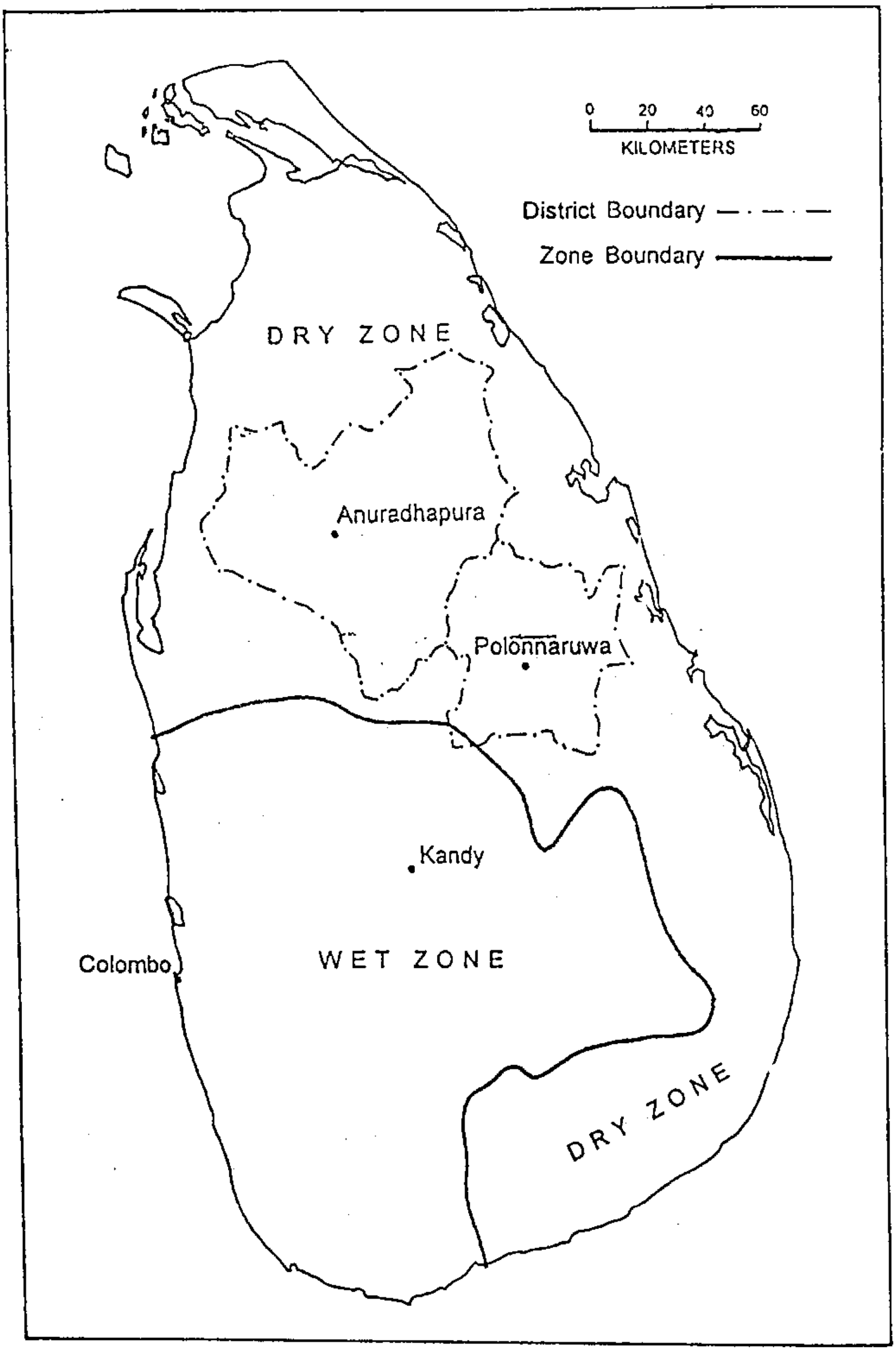
1.1 Tank Cascades and Water Resources Development in Sri Lanka

Because of the importance of irrigated agriculture, improving irrigation facilities has long been a popular means of rural development. In the dry zone, there have been numerous small tank rehabilitation projects and efforts. These projects have been strongly criticized for having poor benefit-cost ratios (Dayaratne, 1991). The major problem has been poor supply of water to tanks. Without additional water, tank rehabilitation has often failed to increase cropped area or cropping intensity. The major reason for this failure has been due to inadequate understanding of tank hydrology and the variability of tank water supplies in the dry zone. A detailed account of the experiences and lessons learnt from previous tank rehabilitation projects are found in Sakthivadivel et al, (1996).

The North Central Province (NCP) [Figure 1.1] lies wholly within the dry zone. Sri Lanka is implementing two coordinated projects in the NCP at present: NCP Area Development Project, funded primarily by the Asian Development Bank (ADB), and Participatory Rural Development Project (PRDP), funded primarily by the International Fund for Agricultural Development (IFAD). Both projects include water resources development components focussed mainly on the repair and rehabilitation of small and medium tanks. ADB and IFAD requested the International Irrigation Management Institute (IIMI) to define a strategy for the land and water development component of the project to improve the prospects of good results from tank rehabilitation.

Rather than focussing development efforts on individual small tanks, IIMI chose to focus on tank cascades. A tank cascade is a chain of tanks located one above another within a meso-catchment (Sakthivadivel et al, 1996). Several meso-catchments make up a sub-watershed, and several sub-watersheds make up the main watershed. The Anuradhapura District is made up of 310 cascades or meso-catchments distributed over 36 sub-watersheds of 5 main river basins or watersheds of the district. Tank cascades are characteristic of the dry zone. Except for some special cascades, the small tanks located in cascades are heavily dependent on water flows coming from within the cascade catchment area. Drainage from one tank forms the inflow to the next lower tank; that is the tanks in a cascade are hydrologically interconnected. The lowest tank in the cascade (defined by its position immediately above the river that defines the watershed) often receives water from many tanks above it.

Figure 1.1. *Sri Lanka: The climatic zones and the two administrative districts of the North Central Province (NCP).*



Because of the hydrological interconnections, augmentation of water supply in one tank can affect other tanks and other water users in the following ways:

* Increasing the capacities of tanks located in the upper sections of the cascade may reduce the inflows to the lower tanks (for an extreme case see Kariyawasam et al, 1984);

* Increasing the capacity of a tank may lead to inundation of lands in the command area of the tank immediately upstream in the cascade;

* Tank hydrology has a strong influence on groundwater; dug-wells constructed below tanks have consistently more groundwater, even in the driest part of the year, than do other tanks. Change in water availability in tanks can thus affect the availability of groundwater for irrigation and other purposes.

Because of the linkages between upstream and downstream tanks and between surface and groundwater resources, development plans should focus on tank cascades rather than on individual tanks.

Moreover, individual tanks within a cascade have come into existence at different periods of time; apparently, hydrological adequacy of these tanks has not played a major role in siting these tanks. This has borne out of the inter-relationships existing among catchment area, tank capacity and command area of the tank. While some tanks within a cascade have sufficient capacity and catchment area to have enough water potential, others do not have that potential. This inequitable potential and capacity to capture adequate water has resulted in a persistent demand from the farming community requesting for supplementary water supplies through inter-connected water conveyance canals from another tank, or a diversion from run-of-the-river system or from drainage channels. Therefore, assessing the water potential of a cascade and planning for the optimal use of water within a cascade assumes a greater significance in the context of tank rehabilitation programme especially when water supply is becoming scarce.

1.2 Previous Studies on Tank Cascades

1.2.1 The Thirappane Cascade Study

The first water balance study to be conducted on a whole cascade was by Itakura (1993) in the Thirappane cascade located between Anuradhapura and Maha Illupallama. Results of his studies conducted over four seasons have been reported in Itakura and Abernethy (1993) and Itakura (1994).

The Thirappane cascade is made up of four minor tanks along the main valley and two minor tanks on a side valley. In a water balance study conducted over 2 maha seasons and 2 yala seasons, measurements were made on rainfall, water issues from small tanks, drainage flows from the command area, water level in the tanks and evaporation. It has been observed that for two

successive maha seasons, the average runoff percentage was 30 and 12 percent, respectively and for the two successive yala seasons it was 10 and 4.5 percent, respectively.

For the first time, a measure of drainage return flows from the upstream to downstream tanks was obtained for a total cascade. The proportion of drainage return flows averaged approximately 23 percent of the tank located midway along the main valley, and 29 percent for the tank located at the lowest end of the main valley. For the tank located at the lower end of the side valley it averaged 12 percent. The above values were for the maha season, while the return flow values for the yala seasons were zero.

1.2.2 Guidance Package Study for Water Development Component of Small Tank Cascade Systems

The government of Sri Lanka together with the International Fund for Agricultural Development (IFAD) and the Swedish Development Agency (SIDA) prepared a Participatory Rural Development Project for the North Central province of Sri Lanka. As part of the preparatory process, IFAD carried out an Initial Environmental Evaluation (IEE) to provide a preliminary assessment and guidelines for assessing the Water Development Component of the project by entrusting a consultancy contract to IIMI to carry out a study. The study report is found in Sakthivadivel et al (1994).

The study is based on the analysis of information and data available with relevant agencies and from research report, staff appraisal reports and post-project evaluation reports of irrigation rehabilitation programmes pertaining to the Anuradhapura District in the North Central Province (NCP). In addition, data was collected through field survey and discussions with stakeholders, agency officials and other interested parties. Also, for selected sub-watersheds, rapid appraisal of land and water resources of minor tanks, mapping the catchment and command areas, and looking at the ratio of catchment, tank waterspread and the command as a unit of the cascade for surface and groundwater potential was carried out.

The preliminary assessment involved:

* Characterization of watersheds and selection of five typical sub-watersheds;

* Mapping of tank cascade system on sub-watershed basis and assessment of catchment land use pattern, drainage density, etc;

* Collection and analysis of data for selected tanks including: size distribution; catchment area; tank storage capacity; waterspread area; command area; groundwater potential; present groundwater extraction and tank inflow; and spatial and temporal characteristics of rainfall in the NCP.

* Estimation of the present and proposed use of tank water and groundwater for irrigation and other purposes; and

* A water balance study for the cascade as well as for individual tanks within the cascade.

This study outlined a new approach stressing the need for the catchment, tank, highlands, command and drainage area of a tank being considered the mosaics of a geographically and socially integrated, micro-watershed unit for integrated rural development planning and implementation under which tank rehabilitation may be considered and implemented for proper management of land and water resources within that watershed unit in order to improve the income and well-being of the people.

In addition, this study suggested:

* guidelines, including indicators and criteria, for characterizing tank cascades and evaluating their potential;

* guidelines, including indicators and criteria for selection of tanks for rehabilitation.

* criteria for agrowell development both in upland and lowland areas.

* a model for simulating tank cascades and individual tanks for various rehabilitation scenarios; and

* an implementation strategy for the water resources development component.

1.2.3 Natural Resources Management Study of the NCP

The Asian Development Bank (ADB) has provided to the GOSL a Pre-Project Technical Assistance (PPTA) to assist the government in preparing a comprehensive development programme for the Area Development Project of the NCP. In this connection, the GOSL and the ADB invited IIMI to conduct a Natural Resources Management Study (NRMS) of the North Central Province. The study included among other things an assessment of Land and Water Potential of the NCP. A detailed output of the study is found in Sakthivadivel et al (1996).

The study noted that water is the limiting resource in many parts of the NCP and the land is also becoming a limiting resource due to increasing population pressure and environmental degradation. Hence, all facets of an area development project designed for the NCP should be based on land and water resources development as well as related agro-based rural industry and support services. The study suggested an innovative approach to development which will look at the resource potential at the cascade, subwatershed and watershed levels and identify ways and means of optimizing the production level with protection of resource base.

The proposed strategy includes selection of sub-watersheds and cascades for project intervention based on hydrological endowment and assessment of the land and water resource base including its present extent/quantities, quality status, and potential for future use. This study conducted a

basinwise assessment of natural resources of the NCP as the basis for delineating hydrologically endowed sub-basins and cascades. The study suggests the possibility of transferring surplus water within and among the cascades. The study also suggests that with detailed data collection, the effects and impacts of such water transfers on the medium and major tanks downstream and outside the cascades have to be studied in detail with a hydrological simulation model.

The study proposes a new approach for land and water resources management. In the proposed approach, farmer beneficiaries will be consulted through participatory appraisal and mapping techniques for selected cascades to capture their experiences, needs and suggestions to develop indicative plans for water resources development and management at cascade level. The study suggests validating and improving such indicative development plans through appropriate hydrological, technical and economic feasibility studies for cascades before implementation.

1.2.4 Nature of Small Tank Cascade Systems and a Framework for Rehabilitation of Tanks within Them

Based on the studies reported under items 1.2.1, 1.2.2 and 1.2.3, IIMI brought out a country paper (IIMI Country Paper, Sri Lanka No.13) on the above subject. The summary and conclusions arrived at in that study are presented below since this formed the basis for refinement of criteria used in this report.

Small tank cascades totaling 310, covering the Anuradhapura District in the North Central Province of Sri Lanka were identified and demarcated on colored 1 inch to 1 mile topographic sheets.

The procedure adopted at present for small tank rehabilitation under cascades is the same as that developed by the Irrigation Department a few decades ago. A more rational approach that takes into consideration a proper diagnosis of both technical and institutional problems is therefore required. The approach suggested in this study considers tank rehabilitation in the broader context of land and water resources management of the total area within a given meso-catchment or watershed unit. This approach stresses the need for the catchment, tank highlands and the command as well as the drainage area of a tank, all to be considered a mosaic unit for integrated development. A framework for small tank selection for rehabilitation has been proposed and an explanatory text for each of the sequential steps shown in this framework has been provided. This analysis is mainly based on the hypothesis that a high hydrological potential of a tank cascade is prerequisite for individual tank improvement within that cascade.

The criteria for selecting tanks for rehabilitation are based on three key indicators: (a) Maha Cropping Intensity (CI); (b) Ratio of Tank Catchment Area (CAA) to Water spread Area (WA); and (c) Ratio of Command Area (COA) to Water spread Area (WA).

The proposed method has been tested for its cost-effective rehabilitation in ten of the tanks that underwent rehabilitation in the recent past according to the presently adopted procedure. We believe that this procedure will result in cost-saving as well as in improving the performance of rehabilitated tanks. The proposed method was also tested in 15 cascades and a typical water

resources development plan for a cascade proposed and developed by the farmers through consensus building using participatory appraisal and mapping is presented.

1.3 Participatory Rural Development Project

1.3.1 *Description of the Project*

The North Central Province Participatory Rural Development Project (NCP-PRDP) was formulated in 1994 and approved for implementation in 1995 after IFAD/SIDA joint appraisal. The loan became effective from 9 January 1996.

The project adopts a participatory approach which seeks to give the project beneficiaries a key role in the selection design and implementation of the project activities and to direct the benefits of the project towards specific target groups making up the poorest segments of the population.

The present PRDP area comprises 15 DS divisions in the district which do not fall completely or largely under the Mahaweli project. It covers 5403km^2 (51% of the NCP) and comprises 476 Grama Niladari divisions and 1303 villages.

The project seeks to address the following problems in the project area:

* low productivity of agriculture, lack of economic diversification resulting in low income and low living standards;

* lack of alternative sources of income for poor and disadvantaged families especially those with little or no land;

* deficiencies in human resources development which hold back improvements in production and which inhibit the acquisition of skills for the promotion of rural development;

* threats to environmental sustainability due to wide scale clearing and poor husbandry practices; and

* lack of organization among small producers and hence the weaknesses in accessing facilities.

1.4 Project Strategy

Since the large number of people in the project area being rural and involved directly or indirectly in agriculture or related works, the first focus of the project has been on productive resource management and protecting the environment base. Under this, water and crop management within a framework of village economy assumes greater significance. Tank rehabilitation and upland farming has become the number one investment priority for the project. The project will invest in

the improvement of irrigation performance, sustainable upland cropping practices and crop yields and at the same time exercise through participatory action, control over exploitation of groundwater and environmental degradation.

The project would build on the social mobilization and crop, livestock and water resources development initiatives already started as part of the on-going SIDA assisted Integrated Rural Development Project (IRDP), the World Food Program (WFP) poverty alleviation project and NGO initiatives. The project's approach would be based on a proven process of social mobilization linked to the determination of investment priorities at the village level by the members of the IFAD target group.

Anuradhapura District has around 310 small tank cascades of different form, size, shape, hydrologic and hydrogeologic endowment with about 2650 big and small tanks and about 5000 agrowells. Some of these tanks are hydrologically well endowed while others are unsuited for extensive development because of unfavorable conditions, hydrological and hydrogeological.

The project intends to rehabilitate about 350 micro-tanks with command areas of less than 25 ha, 65 minor tanks each with command areas ranging between 25 and 80 ha, and 5 medium tanks with command area exceeding 80 ha. These tanks would be rehabilitated in conjunction with development of about 600 agrowells.

Selection of these tanks, to be done prior to implementation, would need to satisfy two criteria: first, the selected tanks must have sufficient hydrologic and hydrogeologic potential to cater to the development needs; second, development of these tanks must be targeted to focus on the poor to bring them above the poverty line.

A two-stage approach to the selection of tank cascades and individual tanks is proposed. In the first stage, the project would use hydrologic and hydrologeologic criteria to select and provide an adequate number of tank cascades and individual tanks for rehabilitation (roughly twice the number of tanks planned for rehabilitation); in the second stage, using the IFAD tank selection criteria, the project would select the appropriate number of tanks for final implementation.

IIMI has undertaken the first stage study to identify hydrologically and hydrogeologically potential cascade and, then to select and prioritize sufficient number of tanks within these cascades with economic potential for rehabilitation and a potential for agrowell development. The proposed study would integrate agrowell development with surface water use; at the same time, it would recognize that there is a critical upper limit (density) of agrowells to balance the use of both surface and groundwater supplies which are limited in quantity and highly variable over space and time.

IIMI, in this study has refined its cascade and tank selection criteria and based on these refined criteria, identified roughly twice the number of tanks planned for rehabilitation. This constitutes the first stage of selection. From among these tanks, the project authorities would select requisite number of tanks satisfying the IFAD criteria which will be the second stage of selection.

1.5 Scope of the Study

The activities of the present study conducted by IIMI are:

* Fine tune the cascade selection criteria based on the IIMI-IEE study and the IFAD tank selection criteria:

    a. average cropping intensity for the last five maha seasons; the cropping intensity is defined as the area irrigated during the maha season divided by the total command area;

    b. hydrologic potential for increasing cropping intensity and/or command area; the hydrologic potential is defined as a ratio of the catchment area to the tank ponded area; and

    c. tank storage capacity for increasing cropping intensity and/or command area: the tank storage capacity is defined as a ratio of the tank ponded area to the command area.

* Develop a base map for the Anuradhapura District and layout of the cascade systems in the project area.

* Collect information from the line departments (Central Irrigation Department (CID), Provincial Irrigation Department (PID), Department of Agrarian Services (DAS)) of the tanks selected for rehabilitation during 1996, especially by the DAS under the WFP.

* Make a tentative selection of around 150 cascades in the project area and to initiate field studies for the collection of data related to cropping intensity, catchment and tank hydrology, tank capacity and existing condition, water distribution and management, water use-crop production aspects and other socio-economic issues; information regarding hydrogeologic and groundwater potential would also be collected.

* Code the cascades and tanks and develop a database.

* Characterize and classify cascades and tanks which have potential for rehabilitation and groundwater exploitation.

* Select target cascades and tanks which have potential for rehabilitation based on hydrologic, agricultural and socio-economic potentials; also identify the locations for groundwater exploitation and siting of agrowells.

* Provide information to the line departments for the potential cascades and tanks which need rehabilitation (100 micro, 10 minor, 2 medium) within 45 days of the start of the study. Also provide information to ADA for potential locations of 50 agro-wells.

* Prepare maps indicating the target cascades and target tanks for rehabilitation and locations for siting of agrowells;

* Prepare a progress report at the end of the field work;

* Prepare a draft report including the guidelines for the use of the maps and to carry out the second stage study to adjust the IFAD tank selection criteria.

* Present the draft report to the line departments at a workshop and modify the report based on the suggestions made by the line departments.

* Submit a final report which would include the selection of 10 medium tanks, 100 minor tanks, and 500 micro tanks; and

* Present the final report with tanks database to IFAD within six months from the date of the award of the consultancy. The report and database would include identified potential cascades and tanks with description of the three selection indices, recommended level of rehabilitation, etc. along with the relevant annexures.

1.6 Team Composition and Responsibilities

The study was carried out by a team of IIMI international scientists along with nationally recruited staff in consultation with the implementing agencies closely associated with land and water resources development in the NCP, i.e., CID, PID, DAS, and the Field Crops Research and Development Institute, Maha Illuppallama. Although IIMI planned to involve one technical person from each line department as part of the team so that after completion of the study these staff members would own the study and would be capable of completing the second stage of identification and the implementation of the rehabilitation programme, this arrangement could not be effective due to reasons beyond IIMI's control.

IIMI fielded the following team members whose respective responsibilities are given in **Annexure 1.1**: A Water Resources Specialist (Team Leader); a Natural Resources/Soil Scientist Specialist; a Land Use Planner; a Water Resources Engineer; a Hydro-geologist; and a Social Scientist. Also one representative from each of the following implementing agencies, nominated by the respective agency heads, formed part of the Study Committee which guided and oversaw the study: Irrigation Departments (CID, PID); Department of Agriculture, Provincial Council, Department of Agrarian Services, and Agriculture Development Authority. The Ministry of Planning was also represented in the committee. The committee met once a month to review the progress of work and to provide course correction during the implementation of the study.

1.7 Organization of the Report

Chapter 2 presents the preliminary screening and selection procedure adopted for cascade identification. This chapter provides a brief account of the number of cascades considered for preliminary screening, the procedure adopted and the number of cascades selected. It also develops a base map for the Anuradhapura District and layout of the cascade systems in the project area.

Chapter 3 describes the field studies carried out for cascade identification. It describes the methodology adopted, process followed and outcome of the field studies. During the field study information relating to cropping intensity, catchment and tank hydrology, tank capacity and existing condition, water distribution and management, water-use crop production aspects and other socio-economic issues were collected; information regarding existing agrowells (functioning and non-functioning), potential for agrowell development were also collected.

Chapter 4 presents the procedure adopted in updating and refining cascade selection based on field studies. Based on the field-studies, the cascade maps were also updated.

Chapter 5 provides the methodology adopted for selecting tanks for rehabilitation; a description of simulation model, simulation model results and the use of simulation model for selecting hydrologically endowed cascades and within those cascades, selection of tanks for rehabilitation. This chapter provides a detailed recommendation for components of tank rehabilitation for each tank based on its hydrologic potential and compares these components with farmers requirements.

Chapter 6 provide a description of how potential for agrowell development of a cascade is determined. It includes collection of data from the ADA and through field survey; marking all existing wells in the cascade maps; preparation of hydrògeological maps for each of the selected cascades; identification of potential areas for agro-well development through resistivity surveys; and preparation of maps showing potential sites for agro-well development.

Chapter 7 presents conclusions and recommendations; these include significant outputs arising out of this study; major recommendations; process to be adopted in implementing the recommendations and further recommended studies for data collection, monitoring and evaluation.

Chapter 2

PRELIMINARY SCREENING AND SELECTION PROCEDURE ADOPTED FOR CASCADE IDENTIFICATION

2.1 Introduction

As stated in Section 1.2.4, a total of 310 small tank cascades were earlier identified and demarcated on the colored 1 inch to 1 mile topographic sheets of the Survey Department during the course of the previous studies that were reported in the 1994 IFAD study and in the 1995 NCP/ADB study.

While the foregoing studies were carried out directly on the topo sheets, further refinements on present land use patterns within the cascades and individual tank catchment boundaries had to be properly demarcated, and the individual areas accurately computed on the 1:50,000 scale ABMP maps. These refinements were very essential for the present phase of this study.

More detailed use was made of both the 1:50,000 scale ABMP maps of the Survey Department and the air-photo coverage of the Medawachchiya and Anuradhapura topo sheets in order to assess more accurately the values of the different variables that were needed for subsequent tank selection for rehabilitation.

The screening and selection procedures adopted in this study for selection of cascades involved several sequential steps which concluded with an objective ranking of the suitability of the several cascades which occur within a Divisional Secretariat region.

It could thus be seen that a more detailed and intensive study of the cascade components had to be conducted in this study as compared with the two earlier studies.

2.2 Team Composition

The senior Natural Resources/Soil Specialist was responsible for framing the study strategy and methodology; and he was assisted full-time by two highly experienced Land Use Planners who have had over 25 years experience in land use and soil survey with the Land Use Division of the Irrigation Department, especially in the dry zone regions of the country.

The photogrammetric facility available with the National Building Research Organization (NBRO) office under a UNDP supported project was availed of in transferring information from the stereo air-photo interpretation to the 1:50,000 scale base maps.

2.3 Methodology Adopted

The first stage in the study was to accurately transfer the administration boundaries of the individual 21 Divisional Secretariat (DS) of the district on to a set of 1 inch to 1 mile topo sheets. For purposes of this study, however, only 15 out of 21 DS divisions were taken up for the complete study.

The second stage was transferring all the previously demarcated 310 individual cascade boundaries on to a fresh set of 1 inch to 1 mile topo sheet using a simple light table. The DS division boundaries were also demarcated on this set.

The third stage was eliminating all cascades that fall outside the 15 DS divisions that were taken up in this study. At this stage, a total of 237 out of the 310 cascades of the Anuradhapura District were identified for further study, all of which fall within the present 15 DS division.

The sequential steps involved in finally selecting a total of 96 cascades from the 239 cascades falling within the 15 DS divisions is next described.

***Step 1*:**

For illustrative purposes let us start with the Kebithigollewa DS division which has a total of 23 cascades within it (see **Table 2.1**).

The boundaries of each of these 23 cascades were transferred from the 1 inch to 1 mile topo sheet on to the 1:50,000 scale ABMP map of the Survey Department. This transfer was done visually using the light table and matching the prominent map details such as roads, streams, tank bunds and rock outcrops, etc.

By a rapid photo interpretation of stereo-pairs of 1;20,000 scale air-photo (1982 flights) a quick check was made of the base detail of the 1:50,000 ABMP maps, and corrections made wherever necessary including cascade boundary demarcations.

For each of the 23 cascades the following measurements were made by making use of the dotted grid method overlain on the base map for each cascade.

i. Total area of each cascade.

ii. Number of tanks within the cascade (both present and abandoned).

iii. Total surface water spread area of all tanks within the cascade.

iv. Total paddy area within cascade.

Step 2:

Adopting the accepted criteria that the ratio of total catchment area of the cascade to the total water spread area should exceed a value of 8; and that the ratio of paddy area to tank area should as far as possible be less than 2, a process of elimination of those cascades that do not satisfy these criteria was made. A certain degree of flexibility is permitted in respect of the second ratio in instances where there are only very few cascades within the DS division that attain this ratio.

By this process of elimination, a total of between 1 to 12 cascades within each DS division was initially selected. From the Kebithigollewa DS division a preliminary selection of 8 cascades out of the 23 was made in this manner. These 8 cascades were further examined in more detail using the 1:25,000 scale air-photos for confirming the ground land use information.

Table 2.1 shows the DS division, the total number of cascades present within the division, the total number of cascades selected in the preliminary screening of this Step 2, and the final number selected.

> *Note:* It should be clearly borne in mind at this stage of selection of 1 to 11 cascades within each DS division, that there could be some very good tanks that would qualify for rehabilitation that could exist within the non-selected cascades. But since the focus of selection has been the cascade at this stage, such good tanks could get picked up at a future stage in the envisaged seven year project life. Furthermore, the IFAD Terms of Reference clearly warrants the selection of 96 individual cascades from the present 239 at this stage of the study.

Step 3:

Each of these 1-11 cascades selected from within each DS division were next enlarged by the photo-copier on to a scale of 1:25,000 or double the scale of 1:50,000. This 1:25,000 scale enlargement was updated to show all essential field details in order to enable the Field Study Team (FST) to collect the relevant information that is outlined in Step 1 of Section 3.3.1 Basic Data Collection. The existing and abandoned tanks within each cascades were numbered, and the drainage network within the cascade was also clearly demarcated in order to understand the nature of the tank cascade sequence in the field. The road network was shown in red, the tank water spread area in blue, and the command area in green color on this set of 1:25,000 scale field maps.

Table 2.1
Number of Cascades Present in Each D.S. Division, Initially Selected and Finally Selected.

No.	Name of Divisional Secretariats (D.S.)	Total No. of Cascades Present within the D.S.	No. of Cascades Initially Selected	No. of Cascades Finally Selected
1	Padaviya	01	01	01
2	Kebithigollewa	23	08	08
3	Medawachchiya	24	12	10
4	Nuwaragam Palatha (Central)	24	07	07
5	Maha Wilachchiya	14	04	04
7	Rajanganaya	01	01	01
10	Nuwaragam Palatha (East)	05	01	01
11	Mihintale	23	09	09
12	Rambewa	15	09	07
13	Kahatagasdigiliya	19	11	10
14	Horowpotana	31	10	08
15	Galenbidunuwewa	18	09	09
16	Thirappane	19	11	11
17	Palugaswewa	15	07	06
21	Palagala	07	04	04
	TOTAL	**239**	**104**	**96**

A corresponding set of updated maps on the original 1 inch topo sheets was also provided for the FST in order to orient themselves and get their proper locations while conducting the field investigation.

A separate set of 1:50,000 scale updated maps of 50 selected cascades was prepared and provided to the hydrogeologist and his team to conduct their field investigations.

Step 4:

The FST conducted their field investigation according to the procedures outlined in Chapter 3 of this report. Based on their field studies they updated the ground information, especially changes that have taken place since 1982 after the last air-photography. This map provided by the FST on a scale of 1;25,000 could be taken as the master copy which accurately delineates the tank location, water spread area, command area and other important land features such as roads, forests, etc.

The final selection of the requisite number of cascades from each DS division was made by the FST during this phase of their field investigations. For example, out of the ten cascades that were initially selected for the Horowpathana DS division based on the preliminary studies, the FST selected eight cascades based on their Participatory Rural Appraisal as shown in **Table 2.1**.

2.4 Outcome

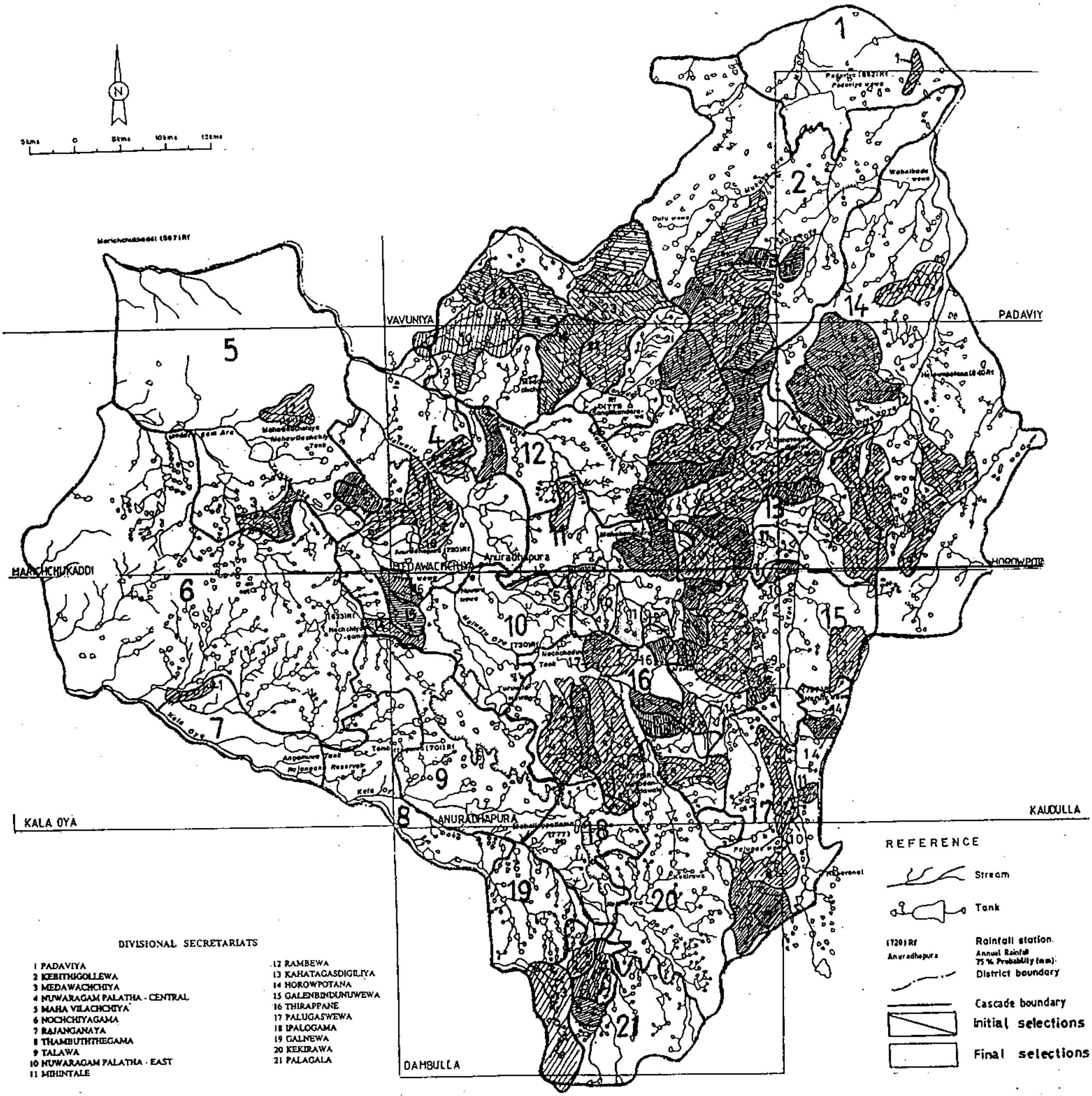
Out of a total of 104 cascades that were initially identified in the preliminary studies conducted in Step 2, the FST had to select a total of 96 cascades based on their field studies. The location and distribution of the finally selected 96 cascades are shown in **Figure 2.1** in map form.

Table 2.1 shows the number of cascades that were initially selected in respect of each DS division, as well as the final number selected for each DS division by the FST.

The results of the FST studies were finally depicted on a map of scale 1:25,000. This map was finally checked against the available base maps and air-photos (where available) for accuracy of the information depicted on them, especially the drainage sequence and network of all the tanks located within each cascade.

This final 1;25,000 scale map was considered to be accurate in respect of the essential ground details such as location of existing and abandoned tanks, water spread area, command area drainage network, etc.

Figure 2.1. Location and distribution of finally selected 94 cascades



Chapter 3

FIELD STUDIES CARRIED OUT FOR CASCADE IDENTIFICATION

3.1 Introduction

The field study conducted had the following two-fold objectives:

a. To select 96 out of 104 pre-selected cascades based on field studies conducted on all 104 cascades.

b. To develop proposals for cascades and tanks rehabilitation in 96 selected cascades based on farmer's indigenous knowledge and wisdom, and by also using technical judgement of the technical personnel (socio-technical process for irrigation rehabilitation).

3.2 Methodology Adopted for Field Studies

Several sequential steps were followed to achieve the two-fold objectives mentioned under Item 3.1.

Step 1. Basic field data collection for selecting 96 hydrologically well endowed cascades.

Step 2. Selection of 96 out of 104 cascades using several indicators developed based on field data collected.

Step 3. Conducting participatory rural appraisals to capture farmer needs and their proposals for cascade and tank rehabilitation.

Step 4. Visits to tanks by Technical Officers (TOs) to evaluate the technical feasibility of the farmer proposals.

In the above four-step process of the methodology described above, two main concepts were applied as follows:

a. Socio-technical approach for irrigation rehabilitation using multi-disciplinary group for field studies, i.e., social science and engineering.

b. Institutionalization of the approach by getting different personnel of the implementing agencies involved in critical activities of the field study.

3.2.1 *Field Study Team*

A Research Associate with rural development management background was responsible for the field study. Four Field Assistants with social-science background were involved in data collection and participatory rural appraisals. The Study Team also comprised of two TOs with extensive experience in irrigation development.

The Field Study Team received guidance from the IIMI Study Team, namely Senior Irrigation Specialist, Senior Social Scientist, Agronomist and a Water Resource Engineer. In addition, the Study Reference Group which met monthly also provided useful directions for the field studies.

3.3 Application of the Methodology and the Process Followed

The four-step methodology and the steps taken for institutionalization are discussed in this section in a sequential manner.

3.3.1 Step 1: *Basic Data Collection for Selecting 96 Cascades*

The main objective of the activities carried out in this step was collection of data to analyze the degree of resource endowment or potential of 96 cascades out of the 104 cascades for improvement.

To achieve this objective basic data was collected from individual tanks of all 104 cascades.

The nature of data collected and the purpose in relation to objectives are shown in the following table 3.1.

In addition to the above data and information, specific data was collected on the existing physical condition of the tank and canal system. Physical condition of tank bund, tank bed, sluices, spill, canal system and some other environmental factors were considered. (see **Annexure 3.1** for the format used for data collection on this aspect).

All data mentioned above was collected from 2-3 farmers of each tank of the cascade; where Farmer Organizations (FOs) have been established, FO Leaders were consulted when collecting data and where there were no FOs, 2-3 knowledgeable farmers including velvidanes were consulted. In many cases small group discussions were held with 3 or more farmers who participated voluntarily.

Table 3.1 : Nature of Data Collection and the Purpose in Relation to Objectives

Nature of Data	Purpose
* Beneficiaries: - Number of families in each village of the cascade. - Number of farmers in each village of the cascade. - Number of farmers within each tank of the cascade.	* To identify the number of potential beneficiaries.
* Existing Water Resources: - Number of tanks in each village of the cascade. - Number of agro-wells in each village of the cascade. - Number of agro-wells inside and outside of command area of the tanks within a cascade.	* To prepare inventory of tanks and agro-wells in each cascade.
* Agricultural Land: - Size of command under each tank including puranawela and akkarawela. - Extent of land that can be undertaken for further cultivation if water resource of the particular tank is enhanced.	* To obtain inventory of existing and potential agricultural land within each cascade.
* Cropping Intensity: - Area cultivated during each maha and yala seasons (situation for the past 10 years).	* To assess the agricultural performance in tank command of each cascade. And also to assess the water resource potential of each tank in the cascade.
* Area Cultivated: - Area cultivated under each agro-well during yala and maha seasons.	* To assess management performance of agro-wells.
* Cropping Pattern: - Crops cultivated during maha and yala seasons (general situation for the past 10 years).	* To assess the performance of crop diversification during the maha and yala seasons.
* Crop Yield: - Maha and yala crop yield under each tank (general situation for the past 10 years)	* To assess yield performance during different seasons and also analyze the causes for changes.
* Spilling Data: - Number of tanks that spill annually for a considerable period in each cascade (general performance for the past 10 years). - Number of tanks that spill occasionally in each cascade (general pattern). - Number of tanks that have not spilled (general pattern).	* To assess the water resource potential of each tank of the cascade.
* Management of Tank System: - Availability of Farmer Organization (FO). - Any other existing arrangement of water management (through velvidane or somebody else).	* Assessment of existing community management system.

3.3.2 Step 2: *Selection of 96 Cascades*

The main objective of the activities carried out in this step was to identify 96 resource potential cascades out of the 104 cascades studied.

The following criteria were considered in identification of resource potential cascades.

* Potential beneficiary families.
* Average landholding size (family unit).
* Cropping intensity.
* Yield.
* Magnitude (quantitywise) of excess water that can be captured.
* Conditions of the physical features of the tanks in the cascade.
* Possibility of conjunctive water resource use (agro-wells).
* Potential new area for development.

The above-mentioned criteria were developed based on field data collected mentioned above. These criteria and some special factors[1] observed by the Field Study Team (FST) were converted into measurable indicators through scoring index shown in **Annexure 3.2**.

It should be noted that to have a reliable assessment idea of cascade potential for water resource improvement, the different scoring index shown in **Annexure 3.2** should be considered as a whole. Consideration of individual scoring index does not give the correct meaning, besides, it might also project a wrong picture.

The objective of this scoring index was to assess the degree of land and water resource potentials in each cascade. The following assumptions were considered in selecting cascades that were better endowed with water resources.

* Higher the number of beneficiaries, more the justification for development.

* Higher the average size of family landholdings, better the potential for development.

* Lower the cropping intensity during maha, higher the potential for development.

* Lower the yield due to water factors, higher the potential for justification of water resource development.

* Higher the number of tanks spilling annually in the cascade, more the potential for water resources development.

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[1] Special factors observed include potential for tapping additional water flows into the cascade and also possibility of inter-tank transfer of water.

* Higher the length of spilling period, more the potential for water resources development.

* More the number of tail-end tanks of cascade spilling annually, higher the potential for water resource development.

* Higher the number of tanks with dilapidated features, more the potential for justification for improvement.

* Higher the number of agro-wells with adequate and good quality of water, more the potential for water resource development.

* Larger the area existing for development, more the justification of investment in water resource development.

* Higher the number of significant additional water sources observed, more the potential for water resource development.

The assessment of 96 cascades using the developed scoring index is shown in **Annexure 3.3**.

3.3.3 Step 3: *Participatory Rural Appraisals*

The objectives of the Participatory Rural Appraisals (PRA) is to capture farmers' wisdom and knowledge for developing rehabilitation proposals for cascades and tanks. To achieve this objective PRA sessions were held in 96 cascades finally selected for improvement.

a. Geographic Representation of the PRA Sessions

PRA sessions were organized to represent the entire geographical area of the cascade. This was done with the assumption that farmers of different tanks when taken as a group would have more knowledge about the cascade than farmers in an individual tank. In the cascade where the geographical area is relatively small one PRA session was held. In some cascades this was not possible because of the large geographical area, and in such cases two PRA sessions were held and later proposals of the two PRA sessions were compared and contrasted for deciding as one unit of intervention.

b. Community Representation at PRA Sessions

Formally, at least 2-3 farmers from each tank got involved in PRA sessions. These farmers represented the following categories of the community.

* If the particular tank had a FO, then the Chairman, the Secretary and the Treasurer were invited. At least two persons from each tank represented the PRA sessions.

* If the particular tank had no FO, then the session was represented by a velvidane and two other knowledgeable farmers.

We did not invite more than 40 farmers from the cascade because we would not be able to manage at the PRA sessions. In general, more farmers participated than anticipated. (This cannot be avoided mainly because of the farmers' interests in getting their water resources improved).

c. Nature of PRA Sessions

PRA sessions were organized as "Participatory Resources Management Audits." Farmers were not mere data and information providers but they also actively participated in analyzing the present performance of land and water resources in their tank areas. The analyses include preparation of proposals for land and water resource improvement through cascade and tank rehabilitation.

d. Activities at PRA Sessions

A guideline was used to discuss significant activities in a systematic manner. The following activities took place at the PRA session.

i. *Identification of Hydrology of the Cascade.* Cascade maps drawn at the scale of 1:50,000 was used to first explain to the farmer groups about significant features of the cascade. Significant features includes nature of inflows to each tank (inflows from own catchment plus inflows from upper tanks), nature of the catchment and its potential yield.

ii. *Devising Development Proposals.* This is the major activity undertaken and the following issues were discussed in detail.

  * For each tank elicit a history of government or NGO interventions for repairs or rehabilitation. Situation within the last 10 years was considered. Information on problems during previous rehabilitation programs, if any was also obtained.

  * Proposals for augmentation or inter-tank connections in the cascade for its water resources improvements.

  * Proposals for improving each tank of the cascade.

  The following specific issues related to the above activities were stressed at PRA sessions:

  * In some cascades tank repairs become effective only if augmentation or inter-tank connection proposals are implemented.

* Prioritization of farmers' proposals due to limited funds available for rehabilitation work.

* Benefits that can be achieved if farmer proposals are implemented. Possible benefits were assessed in terms of potential for increasing cropping intensity.

* Possible impacts of the proposed development on water availability for the downstream of the cascade.

iii. *Agrowells.* Although the agro-well development study was conducted as a separate component, potential for groundwater extraction was discussed at the PRA session. The following specific points were discussed with the farmers

* Identify potential areas for agro-well development; i.e., the areas where good quality and sufficient water exists in abundance for irrigation.

* Performance of existing agro-wells including those within the tank command and outside the tank command.

iv. *Existing Management System at Cascade Level.* This was not given priority at the PRA session but the following basic issues were discussed.

* Availability of community organizations at cascade level and individual tank level.

* Who are those responsible for the operation and maintenance of tanks in the cascade?

* Any other problems related to management performance of tanks including major reasons for low cropping intensity, if any.

v. *Possible Implementation Arrangement of the Proposed Rehabilitation Work.* The availability of labor for the rehabilitation construction work at the PRA sessions was discussed with farmer leaders who represented their tanks. The possible arrangement for implementing proposals that are common to the cascade was also discussed in detail with the farmers.

It must be mentioned that Social Mobilizers (SMs) of PRDP attended PRAs in many cascades. This was quite useful since they may have in the future to assist the farmers in actually carrying out rehabilitation implementation activities. The participation of the Agrarian Service was limited to several cascades. This was mainly due to the tight time schedule of the field study and also due to some other factors beyond the control of IIMI Study Team.

3.3.4 Step 4: *Visit to Tanks by Technical Officers*

The main objective of the visits to tank was to verify the technical feasibility of the various proposals formulated at the PRA sessions on cascade and tank rehabilitation. The TOs were accompanied by farmer leaders of the particular tank who also attended the PRA sessions. Therefore, the proposals made at the PRA could be field verified. The following activities were carried out by TOs during visits to tanks:

* Observations of the farmer proposals relating to cascade and tank rehabilitation.

* Convince farmer leaders, if their proposals were not technically and practically feasible.

3.3.5 *Awareness Program*

Although it was not in the original study design, the IIMI Study Team conducted an awareness session in each of the DS Divisions coming under the project intervention area.

The objective of the awareness program was to explain the methodology of the cascade identification study to the relevant officials at DS level who would be responsible for implementation of the water resource improvement activities.

The Assistant Director, Planning attached to each DS Division co-ordinated the awareness program under the guidance of the staff attached to the PRDP office.

The SMs appointed in each DS Divisions were called for the program but in those divisions where no SM had been appointed, discussions were held with Divisional Secretaries and Assistant Directors of Planning.

The following aspects were taken up for discussion at the awareness sessions:

a. The basic problems observed in previous small tank rehabilitation programs implemented in NCP.

b. Need to have an alternative approach for land and water resources development in the NCP with emphasis on the significance of cascade-based rehabilitation strategies.

c. Systematic process followed in potential cascades and tanks identification for rehabilitation.

d. Application of PRA methods in developing proposals for cascade and tank rehabilitation.

e. The role to be played by agency officials in implementation of cascade-based rehabilitation strategies.

f. The specific roles that should be played by SM during design, construction and post-construction period.

3.4 Outputs Achieved

The specific outputs achieved under each step of the methodological process are discussed in this section.

3.4.1 *Outputs Achieved under Step 1*

The main output achieved is a database including data on the following aspects.

a. *Hydrological data.* This included inflow and outflow pattern of the cascades, names of the tanks in each cascade which have excess water during the maha season, the existing physical condition of each tank of the cascades and, finally inventory of agro-wells in each cascade.

b. *Agricultural Data.* Cropping intensity of each tank in the cascades, reasons for low cropping intensity, average yield for the past ten years and reasons for variations, etc.

c. *Socio-economic.* Less attention was paid on this aspect and basic data was collected on a number of families in the villages, landholding and non-landholding families, and beneficiary families under the command area of each tank.

Note: The abovementioned data was collected from 96 cascades. Virtually no data is presently available on cascades in the NCP. Therefore, this data set is useful not only for the on-going IFAD-PRDP project but also for future development programs. It must also be mentioned that a vast geographical area was covered by the IIMI study. This is roughly 25 percent of the total cascades in the NCP. (See **Annexure 3.3** for the names of the 96 cascades).

3.4.2 *Outputs Achieved under Step 2*

The main outputs of this step are development of methods for identifying land and water resources potentials in a cascade and selection of 50 cascades for rehabilitation. (See **Annexure 3.3** for the names of the 96 cascades).

3.4.3 *Outputs Achieved under Step 3*

The main output of this step is developing proposals for cascade/tank rehabilitation. The nature of specific rehabilitation proposals for 96 cascades are presented in Volume II of this study. annexures.

The following specific outputs were achieved during the PRA sessions.

a. Refinement of cascade maps including the tanks and other key features that are not shown in the presently available topo sheet and ABMP maps of the Survey Department.

b. Developing cascade maps depicting the rehabilitation proposals.

c. Testing methods of PRA for land and water resource development planning that could be used in future.

3.4.4 *Specific Recommendations for Implementors of the Rehabilitation Proposals*

a. The cascade-based rehabilitation approach has not yet been implemented under any previous project. Therefore it is necessary to select 2 to 3 cascades which represent different modes of rehabilitation proposals for application of cascade approach. IIMI may be able to monitor the rehabilitation process closely to validate the assumptions made by the study.

b. The knowledge and skills of project implementors, specially the officials of DAS, DS office and the SM must be enhanced on the proposed strategies of rehabilitation.

c. Community organization process must commence prior to construction work. This has to be done by SMs.

d. The SMs must be provided with the list of proposals for rehabilitation of their cascades. This would provide them the basis to conduct detail beneficiary consultation process.

Physical Status of Tanks

Name of Cascade :

Annex 3.1

Name of TA :

	Tank Name														
Tank Bund															
Water spread area Approx. (acres)															
breached															
badly deteriorated															
moderately deteriorated															
fairly good															
good															
Approximate length (m)															
height (m)															
Tank Bed															
Heavily silted up															
Moderately silted up															
Depth of silting															
Effective FSD (m)															
Sluices															
No of sluices															
Type/size															
(Indicate RB/LB)															
not working															
dilapidated															
Good															
Spill															
Type/length (m)															
Free board (m)															
Non existing															
Damaged															
Good															
Canal System															
Canal length (m)															
LB															
RB															
Heavily dilapidated															
Moderately dilapidated															
Good															
Environmental Factors															
Inflow streams blocked															
heavily															
moderately															
not much															
Drains grown with weeds															
heavily															
moderately															
not much															
Lands affected by salinity															
Tank foreshore area extent (acres)															
Tank command area extent (acres)															

Annexure 3.2

Scoring Index Selected for Assessing Land and Water Resources Potential of Cascades

Criteria	Indicator	Score
(1) Potential beneficiary families	* Less than 500 families * More than 500 families	0 1
(2) Average land holding size of a family	* Less than .5 acres * Between 1-2 acres * More than 2.5 acres	0 1 2
(3) Cropping intensity	(Only maha season considered) * 100% * 100% - 75% * 75% - 50% * Less than 50%	0 1 2 3
(4) Yield	* Low due to unsuitable soil, weather, and other conditions. * Low due to low level of input application. * Yield low due to insufficient water.	0 1 2
(5) Magnitude of excess water	* More than 50% of tanks do not spill. * More than 50% of tanks spills occasionally. * More than 50% of tanks spills annually. * More than 50% of tanks spills for less than 7 days continuously per season. * More than 50% tanks spills between 7-15 days per season. * More than 50% of tanks spills for more than 15 days per season.	0 1 2 0 1 2
	* Last two tanks does not spill. * Last two tanks spills. * More than two tanks in the tail-end of the cascade spill.	0 1 2
Physical condition	* In more than 50% of tanks all components of the headwork are in good condition. * In more than 50% of tanks, some components are dilapidated.	0 1

Criteria	Indicator	Score
conjunctive water resource use	* More than 50% of existing agro-wells has insufficient water.	0
	* More than 50% of existing agro-wells has unsuitable water (quality).	0
	* More than 50% of existing agro-wells has sufficient and good quality water.	1
Potential new land for development	* No significant area available for new development. Less than 50 acres).	0
	* Moderately significant area available for new development (between 50-250 acres).	1
	* Significant area available for new development (more than 250 acres).	2
Special factors	* No special factors observed.	0
	* Observed moderately significant factors.	1
	* Observed significant factors.	2

Note: To have a comprehensive idea of tank potential, the different scoring indicators should be considered collectively. Consideration of individual scoring index does not give the correct meaning, besides, it might also project a wrong picture.

Annexure 3.3

Assessment of 104* Cascades Using the Developed Scoring Index

AGA Division	Cascades Initially Selected	Scores	Cascades Selected for Development
1. Galenbindunuwewa	1. Sivalakulama 2. Ichchankulama 3. Divulwewa 4. Karuwalagaswewa 5. Himbatugollawa 6. Tammannawa 7. Veheragala 8. Muwapitiya 9. Kawarakkulama	13 12 11 11 10 09 09 08 07	1. Sivalakulama 2. Ichchankulama 3. Diwulwewa 4. Karuwalagaswewa 5. Himbatugollawa 6. Tammannawa
2. Padawiya	1. Navagaswewa	-	1. Nawagaswewa
3. Kebetigollawa	1. Kunchuttuwa 2. Kolibendawa 3. Usgollawa 4. Tammannawa 5. Migaha Upotha 6. Kiwulekada	15 14 12 10 09 08	1. Kunchuttuwa 2. Kolibendawa 3. Usgollawa 4. Tammannawa
4. MEdawachchiya	1. Parana Halmillawa 2. Mekichchawa 3. Muratamadu 4. Divulwewa 5. Etawatunawewa	15 13 11 10 91/2 09	1. Parana Halmillawa 2. Kongollawa 3. Mekichchcawa 4. Muratamadu
5. Nuwara Palata Central	1. Galkadawala 2. Galpottegama 3. Tammannawewa 4. Bellanakadawala 5. Vihara Kallanchiya	12 11 11 10 10	1. Galkadawala 2. Galpottegama 3. Tammannawewa 4. Bellankadawala
6. Maha Willachchiya	1. Sandamal Eliya 2. Dunumadalawa 3. Maningamuwa 4. Nabadadigiliya	12 10 09 08	1. Sandamal Eliya 2. Dunumadalawa
7. Rajanganaya	1. Ihala Tammannawa	-	1. Ihala Tammannawa
8. Nuwaragam Palata	1. Kuda Kalattawa	-	1. Kuda Kalattawa
9. Mihintale	1. Maha Rambewa 2. Mankulama 3. Katupota 4. Maradankalla 5. Rambewa 6. Katukeliyawa 7. Werappankulama	13 13 11 11 10 10 08	1. Maha Rambewa 2. Mankulama 3. Katupota 4. Maradankalla 5. Rambewa
10. Rambewa	1. Pihimbiyagollawa 2. Kendawa 3. Kappirigama 4. Bandara Ikkirigollawa 5. Rotawewa	14 12 11 08 07	1. Pihimbiyagollawa 2. Kendawa 3. Kappirigama
11. Kahatagasdigiliya	1. Pandarellawa 2. Rampathwala 3. Maha Kirimatiyawa 4. Nelugollakada 5. Gangurewa 6. Halmillawa 7. Moragahawela 8. Kumbukwewa 9. Ellewewa	14 14 13 13 13 13 10 10 06	1. Pandarellawa 2. Rampatwilla 3. Maha Kirimatiyawa 4. Nelugollakada 5. Gangurewa 6. Halmillawa

12. Palugaswewa	1. Palugaswewa 2. Weragala 3. Mahadivulwewa 4. Maha Rambewa 5. Maha Meegaswewa	14 12 09 07 08	1. Palugaswewa 2. Weragala 3. Mahadivulwewa
13. Palagala	1. Meegaswewa 2. Halmillawa 3. Meewewa 4. Kahalla 5. Andiyagala	14 13 12 09 08	1. Meegaswewa 2. Halmillawa
14. Thirapanne	1. Ulagala 2. Pahala Ambatale 3. Maha Kanumulla 4. Wannamkulama 5. Thirappane 6. Muriyakadawala	14 12 11 09 08 07	1. Ulagalla 2. Pahala Ambatale 3. Maha Kanumulla 4. Wannamkulama
15. Horowpatana	1. Puliyankadawala 2. Dematawewa 3. Diyatittawewa 4. Dutuwewa 5. Olugaskada 6. Morakewa	15 15 14 14 10 09	1. Puliyankadawala 2. Dematawewa 3. Diyatittawewa 4. Dutuwewa

* Scoring procedure was adopted only for 75 cascades. For other cascades, area ratio criteria were used in identifying cascades.

Chapter 4

UPDATING AND REFINEMENT OF CASCADE SELECTION BASED ON FIELD STUDIES

4.1 Methodology

The 1:25,000 scale map on which all essential field details were depicted was matched against the field map prepared for each cascade by the FST. This field map showed the locations of all the tanks situated within the cascade as well as the numbers allocated to them by the FST. It also showed the correct location of the existing agro-wells both in the command and upland area as well as the proposed agro-wells according to farmer understandings. It also showed in figures the extent of the command area under each tank.

A composite map was then prepared showing all essential features that would be required in order to compute the hydrological endowment and potential of all tanks within the cascade as well as the total cascade.

To this end, the catchment or watershed boundary of each individual tank within a cascade was demarcated by an interpretation of the relevant topographic features. Where air-photo coverage was available as in the Medawachchiya topo sheet area, a cross check was made with this method of demarcation against that obtained by air-photo interpretation. Since a good match was obtained by both methods, the more rapid one of straight interpretation of the topographic features was adopted. This catchment boundary of each individual tank is hereafter referred to as the micro-catchment boundary in contrast to the meso-catchment boundary which refers to the catchment boundary of the whole cascade. This demarcation of the micro-catchment boundaries for all tanks within a cascade proved to be a very tedious and time consuming endeavor which had, in any case, to be accomplished. Equally tedious was the computation of the area of the micro-catchment for each tank, which again was measured by the dotted grid overlay method.

The tank waterspread areas was also measured by this method and a comparison was made with the measured value of the micro-catchment area. This comparison together with the value for the command area as provided by the FST in respect of each individual tank within the cascade, served as a very effective cross check of the respective component parameters that contribute towards the tanks hydrology.

This measurement of tank area, micro-catchment area (both gross and net), and command area was carried out for a total of more than 1000 individual tanks that were located across the 96 selected cascades.

Measurement of Co-ordinate values of all 648 selected individual tanks of the selected 96 cascades were made using the 1:63,360 topographical sheets of the Survey Department. These values are given according to two methods, i.e.:

(1) measuring the x and y distances of the tanks (in cms), and

(2) measuring the longitude and latitude values of the tank, given in the topo sheets.

Method I

Each topo sheet was divided into 4 quadrants and for each quadrant an identification symbol was given, e.g., Medawachchiya topo sheets quadrant Nos. C24, C25, F4 and F5. The distances are measured in x and y directions in each quadrant for the particular tank.

D.S. 12 Rambewa

Cascade No.11 Pihimbiyagollewa

Tank No.5 Kongaswewa

C-25, 22.7 cms x 2.2 cms

Method II

The longitude and latitude values are usually indicated on the edges of the topo sheets. These values are measured for each tank falling within the cascade.

Tank No.5 Kongaswewa

C-25, 80° 38' 58" x 8° 29' 33"

Alongside this study, the location of agro-wells as depicted in the 1:50,000 scale maps by the hydro-geological study group was compared with the location shown in the 1:25,000 scale field map. Doubtful locations were eliminated and an authentic location map was developed for the benefit of the hydro-geological study team.

4.2 Output

A set of 96 cascade maps at a scale of 1:25,000 showing all essential field features, tank location, water spread area and micro-catchment boundaries of all tanks within a cascade have been produced.

Data on the micro-catchment area, water spread area and command area in respect of 648 individual tanks has been provided. These are available in a set of standard tables.

The co-ordinate values of each of the 648 individual tanks has been compiled in a set of tables and bound in a volume (see **Volume IV**). This would enable easy identification of each tank by field officials. The foregoing data set provides an all inclusive set of essential information in respect of all tanks situated within the 96 cascades.

Chapter 5

SELECTION OF TANKS FOR REHABILITATION

5.1 Introduction

5.1.1 *Background*

One of the key tasks of this study is to: a) refine the methodology and criteria developed for the selection of small tanks for rehabilitation under the previous IFAD study, and b) apply the improved methodology and criteria for selecting tanks for rehabilitation under the Participatory Rural Development Project (PRDP). A refined methodology has become necessary in view of the fact that the previous tank selection criteria was developed with limited data. It was based on the hydrological parameters of individual tanks and did not evaluate the hydrological endowment of the entire cascade in adequate coverage. The previous tank selection criteria has been elaborated in the **Section B, Annexure 5** of the Staff Appraisal Report of the PRDP. In the present study, substantial effort was made to improve the tank selection methodology and criteria based on a large sample size (96 cascades) and apply the criteria for the selection of tanks for rehabilitation under the PRDP. This chapter describes the process, methodology, criteria and application of the criteria for selection of tanks.

5.1.2 *Team Composition*

The sub-team that focused on the selection of tanks for rehabilitation included; Senior Irrigation Specialist, Water Resources Engineer, two System Analysts and a field-team headed by a technical assistant to collect field data. The Senior Irrigation Specialist and Water Resources Engineer developed the tank selection methodology and criteria described in this chapter. Substantial inputs have been provided by the study consultation group at monthly meetings and subsequent workshop organized to discuss on the draft selection criteria.

The criteria prescribed in the chapter is the final version agreed between the IIMI consultants and the Study Consultative Committee. The simulation model "ROSES" was developed exclusively for this study by a local consultant. Two system analysts employed to run the "ROSES" were responsible for: entering the input data to the computer; constructing the cascade network diagrams; simulating the hydrology of the cascade; computing the water balance of tanks within each cascade; evaluating the indicators required to apply the tank selection criteria, and providing computer outputs of cascade water balance sheets, tank evaluation parameters and cascade network diagrams. Those tasks were completed by them for nearly 650 tanks in 96 selected cascades.

5.2 Small Tank Rehabilitation

Because of the importance of irrigation in Sri Lanka, improving irrigation facilities has long been a popular means of rural development. In the Dry Zone, there have been numerous small tank rehabilitation projects and efforts including special donor funded projects, components of integrated rural development projects, and efforts by several non-government organizations.

Local histories show that individual tanks within a cascade have come into existence at different times (cf Brow 1978). Apparently, water supply adequacy has not played a major role in siting of the tanks. Thus whereas some tanks have sufficient storage capacity and catchment area to supply adequate water, others do not have enough catchment potential or tank capacity to satisfy the requirements of the designed command area. In many cases, the inability to capture adequate water has resulted in a persistent demand from the farming community for augmentation of water supply through increasing tank capacities or taking water from other tanks, diversions from streams, or drainage channels. In addition, increasing population is leading to increasing demands for irrigation and domestic water in the Dry Zone.

Not surprisingly, therefore, small tank rehabilitation and improvement projects generally aim to do two things:

- Repair the distribution network to let the farmers improve the efficiency of water distribution and expand the irrigated area.
- Augment water availability by raising and/or extending the tank bund or through other means.

If the hydrology of one or more tanks is altered by increasing storage capacity, expanding irrigated command area, or by diverting water elsewhere from the cascade, the cascade hydrology is changed. If the cascade has more water than is demanded, the effect of altering the tank hydrology may not have significant downstream impact; but if water is limited in relation to total demand, there may be serious implications in terms of water availability to downstream users. In the worst case, improving an upstream tank takes away water from a downstream tank (for an extreme case see Kariyawasam et al 1984). Improvements to one tank can also affect other water users by inundating lands in the command area of the tank immediately upstream. Also, because tank hydrology has a strong influence on groundwater; wells below tanks have consistently more groundwater, even in the driest parts of the year, than do other tanks. Changes in water availability in tanks thus can affect the availability of groundwater for irrigation and other purposes.

Thus planning the rehabilitation or improvements of any tank system calls for assessing and understanding the entire hydrology of the cascade before any intervention to any tank in the cascade is contemplated, especially when water is becoming scarce. Unfortunately, in Sri Lanka, except for a few cascades, there is virtually no data on cascade hydrology. There has been no government or other attempt to systematically collect hydrological data on small scale irrigation systems, including the tank cascades.

The numerous small tank rehabilitation projects carried out in Sri Lanka's Dry Zone have been strongly criticized for having poor benefit-cost ratios (Abeyratne 1990; Dayaratne 1991; Dayaratne & Moragoda 1991; Dayaratne & Wickramasinghe 1990; Ekanayake et al 1990).

The major problem has been poor supply of water to the tanks. Without additional water, tank rehabilitation has often failed to increase cropped area or cropping intensity. In large part, this failure has been due to poor understanding of and lack of data on tank hydrology and the variability of water supplies in the Dry Zone. To improve the planning of tank rehabilitation projects, the key need is to obtain data on the amount of water available for use in the cascade - its cascade water surplus.

A review of procedures adopted in the past small tank rehabilitation in Sri Lanka reveals that tanks are restored and improved without adequate attention to the overall hydrology of the cascade. Adoption of a cascade-based holistic approach to water management and small tank rehabilitation has been difficult due to:

- Lack of a data on and a clear understanding of the hydrology and the physical characteristics of tank cascades.
- Absence of field-tested methodologies, tools and criteria for evaluating the water surplus of cascades.
- Failure to link planning of rehabilitation interventions with cascade water surplus and with suitable management institutions.

The present tank rehabilitation planning process adopted by local irrigation agencies does not include a proper assessment of surface and groundwater potential, recharge and the possibility for harnessing groundwater to complement rainfall and tank water to increase overall cropping intensity.

5.2.1 IIMI Studies Leading to the Present Methodology

The methodology described here was developed specifically for small tank rehabilitation project planning in the Anuradhapura District of the North Central Province in Sri Lanka. The methodology was developed through participation in three efforts:

- Initial Environmental Evaluation Study conducted by IIMI for the International Fund for Agricultural Development (IIMI 1994),
- Natural Resources Management of North Central Province of Sri Lanka undertaken by IIMI for the Asian Development Bank (IIMI 1996a)
- Identification of Small Tanks in Cascades undertaken by IIMI for the International Fund for Agricultural Development (IIMI 1996b).

These efforts are part of two interlinked projects, one funded primarily by the International Fund for Agricultural Development and the other funded primarily by the Asian Development Bank.

These projects are designed to help develop the natural resources of the North Central Province in a sustainable way.
To illustrate the methodology, data from the third effort listed above is used. This work was carried out in 1996 and 1997 was limited to Anuradhapura District, one of the two districts in the North Central Province. The primary data used for this study came from field work carried out by IIMI. Secondary data was obtained from the Department of Agrarian Services and the Central Irrigation Department of the Government of Sri Lanka, and from the North Central Provincial Irrigation Department.

Anuradhapura District is situated entirely in the Dry Zone and is characterized by the existence of a large number of small tank cascades. Although the mean annual rainfall is around 1,500 mm, because of high variation, the 75 percent probability value of the annual rainfall provides a more realistic figure of dependable rainfall. This value is approximately 800 mm. The Maha season, the main rainfall season has a 75 percent probable rainfall of about 650 mm. The weaker rainy season, Yala, has a 75 percent probable rainfall of 150 mm. During the period late May to September, the district experiences a four-to-five month dry season with strong desiccating winds. Evaporation rates during this period are around 7.0 mm per day and the total annual evaporation is approximately 1,800 mm. Thus the average annual evaporation exceeds the average annual rainfall implying water stress during certain periods of the year. The area is undulating with many upthrusting rocks. Soils are relatively shallow and groundwater is not extensively available in this hard rock region.

Given the seasonal and yearly variability of rainfall and the relative scarcity of groundwater, small tanks are very important for agriculture in Anuradhapura District. There are 315 tank cascades wholly or partially within the district; these include over 4000 small tanks. A whole pattern of agriculture and living centered on these small tanks has developed (Abeyratne 1956, Leach 1961, Brow 1978). Indeed, the village tank, along with the Buddhist temple and the village itself, has come to symbolize the ancient rural roots of Sri Lanka (Spencer 1990).

5.3 ASSESSMENT OF TANK CASCADE HYDROLOGY

5.3.1 Alternative Methods

We define cascade water surplus as the quantity of water discharged at the base of the cascade annually after satisfying the present water demand for agriculture as a percentage of total water supply available to the cascade. Basically, it represents the difference between water supply available to the cascade and present water use adjusted for the scale of total water use.

In cascades, water related activities initiated at one point will have an impact at a point lower down the system. If the cascade water surplus can be estimated accurately, water use planning within the cascade can be done without causing unnecessary conflicts. In a cascade with little cascade water surplus, rehabilitation measures such as storage capacity expansion or diversion of water from one tank to another will entail reduction of supply to tanks further down the cascade. In such cases, capacity expansion or water diversion from one tank to another will simply shift

water use from one point in the cascade to another. On the other hand, if there is a significant cascade water surplus, there will be potential to increase water use at specific points within the cascade without affecting downstream users.

As pointed out in Section 5.2, the initial task is to determine the overall water availability within the cascade by estimating the cascade water surplus. The primary problem is estimation of actual outflow from the cascade. We have identified three methods by which cascade outflow can be estimated. In descending order to preference these are:

- Actual measurement over a number of years.
- Data collection from farmers and observation using rapid assessment methods and calculation of outflow from a computer simulation model.
- Estimation of cascade outflow by use of empirical relations between some simple measurements and outflow.

If measurements of cascade outflow were available this would have been the best way. Unfortunately, measurements of flow between the tanks and from the cascade exist for almost none of the cascades in Sri Lanka's Dry Zone. Also, very little data on the physical and hydrologic characteristics of tanks and their interactions within the cascade exists. Since we did not have adequate flow measurements, we devised the other two approaches mentioned above.

5.3.2 Estimating Cascade Outflow with a Simulation Model

Our preferred method to estimate cascade outflow involves a four step procedure:

1. Use maps to screen the cascades to select a group of cascades for further investigation.

2. Use rapid assessment techniques to collect data on the initially selected cascades. This data can be used for further screening of cascades.

3. For the selected cascades, use participatory appraisal and planning techniques to carry out further investigations and rehabilitation planning with farmers.

4. Use the collected data and a computer simulation model to determine the expected outflow from each cascade.

The key bit of information used to determine water availability in the cascade was data gathered from farmers on spilling from the tanks, including period, frequency, and approximate quantities.

This procedure has the advantage of devising initial rehabilitation plans as well as determining the key data needed to evaluate cascade water surplus.

Initial Cascade Screening The first step is to make key measurements of the cascades from maps. Topographic maps are used to identify the cascades. Then for each cascade, the total surface area is measured, the total tank surface area is measured, and the total command area is measured.

From the prior studies of small tank and tank cascade hydrology, we developed two key criteria to eliminate cascades from further consideration. These criteria are:

- The ratio of cascade area (CAA) to the total tank water surface area in the cascade (WA) should exceed 8,
- The ratio of cascade command area (COA) to tank water surface area (WA) should be less than 2.

These are generalizations from criteria developed for individual tanks (IIMI 1994, Sakthivadivel et al 1996) with the substitution of mean annual rainfall for mean Maha season rainfall. The derivations of these criteria for tanks are given in Annex A. These indicators are further discussed in Section 5.3.3.

In our 1996 and 1997 effort, land use specialists on the IIMI team used these criteria to select 104 out of the 315[2] cascades in Anuradhapura District from their measurements from the standard Government of Sri Lanka 1:50,000 topographic maps.

Cascade Data Collection The second step is to visit the cascades selected in the initial screening and use rapid assessment methods to collect information on water resources, agricultural land (presently cultivated, potential for expansion), cropping pattern, seasonal cropping intensities, population details (number of farmers under each tank), tank details (number of tanks in a village, spilling details, physical condition, year of last rehabilitation), tank management details (responsibility for tank management), and groundwater use details (numbers of wells, water quality).

In the 1996 and 1997 study (IIMI 1996b), this information was collected by interviewing small groups of knowledgeable farmers in each village. A format was used to speed and focus data collection efforts. Almost all tanks were visited to confirm the interview data.

Once the data is collected, each cascade is scored to assess the land, water, and labor resources potential in each cascade. We used the scoring system shown in Table 5.1. The individual items in this table correspond to key dimensions of evaluation as follows:

- the greater the number of beneficiaries, the better use of investment funds,
- the greater the landholdings, the more each beneficiary can benefit
- if yields are low due to insufficient water, the greater the potential yield improvements from tank system improvements
- if the tanks spill the greater the cascade water surplus of the cascade
- if the tank systems are in poor physical condition, the more they will benefit from rehabilitation

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[2] Certain portions of Anuradhapura District were excluded from consideration; the selection was done from approximately 239 cascades.

- having groundwater implies that better water supplies may help the groundwater or vice versa
- the greater the potential to irrigate new land, the greater the potential to benefit from investment.

No one item in this scoring system is definitive; the scoring index must be considered as a whole. The higher the score, the better is the cascade's potential for development.

In our 1996 and 1997 effort, we used this data to select 96 cascades, a number which had been based on the number of tanks to be identified for rehabilitation efforts under the PRDP of Anuradhapura.

Table 5.1. **Scoring for Assessing Land and Water Resources Potential of a Cascade**

Criteria	Indicator	Score
Potential beneficiary families	* Less than 500 families * More than 500 families	0 1
Average family land holding	* Less than 0.5 acres. * Between 1-2 acres. * More than 2.5 acres.	0 1 2
Maha season cropping intensity	* 100% * 100% - 75% * 75% - 50% * Less than 50%	0 1 2 3
Yields	* Low due to soil, weather or other conditions. * Low due to low level of input application. * Yield low due to insufficient water.	0 1 2
Frequency of tank spilling	* More than 50% of tanks do not spill. * More than 50% of tanks spill occasionally. * More than 50% of tanks spill annually.	0 1 2
Duration of spills	* More than 50% of tanks spill less than 7 days in a row per season. * More than 50% of tanks spill between 7-15 days per season. * More than 50% of tanks spill for more than 15 days per season.	0 1 2
Spills at the bottom of the cascade	* Last two tanks do not spill. * Last two tanks spill. * More than 2 tanks in the tail-end of the cascade spill.	0 1 2
Physical condition	* In more than 50% of tanks, the headworks are in good condition. * In more than 50% of tanks, some headworks components need repair.	0 1
Conjunctive water use	* More than 50% of existing agrowells have insufficient water. * More than 50% of existing agrowells have unsuitable water quality. * More than 50% of existing agrowells have sufficient good quality water.	0 0 1
Potential new land for development	* Less than 50 acres of additional land can be irrigated. * Between 50 and 250 acres of additional land can be irrigated. * More than 250 acres of additional land can be irrigated.	0 1 2
Special factors	* None.	0

	* Moderately significant factors. * Significant factors.	1 2

Multi-level Participatory Planning The third step is to conduct participatory planning sessions with farmers from all villages within each cascade. We call the technique used multi-level participatory planning because it involves having farmers in each village to propose work needed on their tank systems, and then getting representatives from all the villages together to analyze the cascade hydrology and agricultural systems as the basis for defining development plans for the cascade. Participatory mapping was the main technique used for data analysis and planning. For a detailed description of the technique see Jinapala et al (1996).

Participatory planning was essential for two reasons:

- First, both we and the farmers needed better data on hydrology and agriculture than exists in official records. Farmers have the necessary knowledge from their experience with their own systems. However, farmers generally know the situations only for their own tanks, not for the cascades as a whole. Getting them together allowed them to share data and build a comprehensive picture of water resources and water use within each cascade.

- Second, we found that because most farmers did not think beyond their own tanks, they were not aware of possibilities of augmenting tank water supplies from other sources nor were they aware that augmenting water supplies might affect downstream farmers. Multi-village participatory planning allowed them to consider the development of water resources in the cascade as a whole so as to make the best use of the potential water supply and to avoid conflicts that might arise from improvements made without considering effects on downstream users.

The output of each effort was a set of six maps defining land and water resources, agricultural systems and land use, social and management institutions and infrastructure, and proposals for improvements and changes in all three of these areas.

Estimating Runoffs The fourth step is to use a computer simulation model to calculate two important parameters:

- The cascade outflow, ie the runoff volume discharging at the foot of the cascade per unit area (V),
- The effective Maha (main) season runoff (R_o) to individual tanks.

This last, R_o, is the sum of rainfall runoff, direct rainfall on the tank water surface, surplus water from the upstream tank, irrigation drainage water from the immediate upstream command area, minus tank evaporation and seepage and percolation losses.

The computer model used to simulate cascade daily hydrological behavior is the Reservoir Operation Simulation Extended System (ROSES). This model specifically developed for this study, but other models can be used as well. ROSES uses the widely accepted node-link method for water resource simulation. The model integrates modules for individual tank level, cascade

level, and sub-basin level. At the first level, the model simulates the water balance on an individual small tank. At the next level, the model aggregates the hydrological behavior of all the tanks in a cascade for a given set of supply and demand conditions. The model provides graphical and tabular outputs of the results of calculations of the temporal pattern of storage volume, spilling, and water levels for every tank in the cascade as well as runoff at any point along the natural stream or river system. The model also has the ability to integrate the behavior of all the cascades within an entire river basin or sub-basin.

The input variables for the simulation and the sources we used are:

- mean annual rainfall (government data)
- cascade area (measured from maps)
- command areas of cascade tanks (measured from maps)
- present main (Maha) season cropping intensity (from field data collection)
- crop evapotranspiration values (from published data and use of CROPWAT program)
- drainage return flow coefficients (from Itakura 1994)
- catchment runoff-rainfall relationships (from Ponrajah 1982)
- water application, conveyance and distribution efficiencies (averages from the Irrigation Department)
- seepage and percolation losses (averages from the Irrigation Department).

An additional item needed for this model is a representative depth-area-volume relationship for the small tanks. We used the formula:

$$C = 0.4 \times A_t \times d$$

where C is the storage capacity of the tank, A_t is the surface area at full supply level, and d is the depth from full supply level to the sill of the tank sluice (effective tank depth). This relationship is an empirical one based on a study of 14 representative tanks carried out as part of this exercise (IIMI 1994).

Key outputs from the model are the inflows, water releases, and expected spilling from each tank. During field data collection we collected partially quantified estimates for these variables, particularly for tank spilling. We used this data from farmers to check the model's output to ensure that no major mistakes were made.

In our 1996 and 1997 work, we used the model to evaluate the cascade water surplus of the 96 cascades and to validate farmer proposals for augmenting water supply to particular tanks.

5.3.3 Estimating Cascade Outflow from Area Measurements

In our first study (IIMI 1994) we argued that potential water availability for a tank could be evaluated using two easily determined ratios for each tank:

- The ratio of tank catchment area (A_{tca}) to tank water spread area (A_{tws}) represents the hydrological potential of the tank. We showed (see Annex A) that, in most cases, if this ratio is greater than 7.5, then the tank has sufficient water to improve its cropping intensity.

- The ratio of tank command area (A_{tco}) to tank water spread area (A_{tws}) describes the adequacy of the tank storage capacity to serve the command. We showed (see Annex A) that, for tanks of average depth, this ratio should be less than 2 in order to serve the command well.

We generalized these relations to the whole cascade to provide the criteria for initial screening of the cascades from map data (see Section 5.3.2).

Following our 1996 and 1997 study of 96 cascades and more than 1000 tanks, we analyzed the data to validate the idea that the simulated outflows from tanks and cascades were related to easily measurable parameters such as cascade area, tank catchment area, tank water surface area, command area, etc. The following relationships were the ones we found:

- The effective runoff for an individual tank (R_o) is related to its catchment area (A_{tca}) with the regression equation:

  $$R_o = 0.2738A_{tca} - 1.4861 \quad (r^2 = 0.73, \text{area in hectares, volume in hectare-meters})$$

  The relationship is plotted in Figure 5.1.

- Tank system irrigation water demand (IWD) is related to the tank command area (A_{tco}) by the regression equation:

  $$IWD = 5.7947 + 0.7078A_{tco} \quad (r^2 = 0.42, \text{area in hectares, volume in hectare-meters})$$

  The relationship is plotted in Figure 5.2.

- The ratio of tank storage capacity (C) to tank irrigation water demand (IWD) is related to effective tank depth (d) and the ratio of tank water surface area (A_{tws}) to tank command area (A_{tca}) with the regression equation:

  $$C/IWD = 0.1571y^2 + 0.1703y + 0.3218 \quad \text{where} \quad y = 1.22(A_{tws}/A_{tco}) + 0.62d - 1.52$$
  $$(r^2 = 0.85, \text{depth in meters})$$

  The relationship is plotted in Figure 5.3.

- The cascade outflow (R_c) is related to the cascade area (CAA), total tank water surface area in the cascade (WA), and the total command area in the cascade (COA) with the regression equation:

$$\log R_c = 1.4582 + 0.0003(CAA - WA - COA)$$
$$(r^2 = 0.44, \text{area in hectares, volume in hectare-meters})$$

The relationship is plotted in Figure 5.4.

This analysis indicates that the cascade outflow is directly related to cascade area, command area and tank water surface area of the cascade and indirectly to tank storage capacities and irrigation water demand. This analysis gives a quantitative expression to the fact that features of individual tank systems affect the cascade outflow. Incidentally, this analysis validates our use of the simple area ratios for initial screening of the cascades.

The last relation gives a direct way to estimate the cascade outflow from simple area measurements for the cascade.

5.3.4 Evaluating Cascade Water Surplus

In order to make use of the cascade outflow for rehabilitation planning, it is necessary to determine its significance. Specifically, in an average or above average rainfall year, there should be some volume of cascade outflow. Outflow is required to protect the environment; this requirement is related to the area of the cascade and the rainfall received by the cascade. Outflow in specific quantities may also be required by users downstream. Thus, when evaluating outflow, the concern is whether the outflow is sufficiently high so that some portion of it can be productively distributed among some or all of the tanks in the cascade.

To evaluate the cascade water surplus, we first define cascade outflow per unit area (V) as the cascade outflow (R_c) divided by the cascade's total area (CAA). That is:

$$V = R_c / CAA$$

Then we define the cascade water surplus (WS_c) as the ratio of the outflow per unit area (V) to the mean annual rainfall (R_{50}). That is:

$$WS_c = V / R_{50}$$

For Anuradhapura District in Sri Lanka, we estimated that if this ratio is greater than five per cent ($WS_c > 0.05$), the cascade has surplus water. We arrived at the five percent figure from the following reasoning:

- The annual rainfall averages 1500 mm in Anuradhapura District but varies from 1200 mm to about 1600 mm from place to place.
- The total crop water requirement for rice in this area is about 650 mm and about 450 mm normally seeps into the groundwater. If the sum of these two values (1100 mm) is subtracted from the minimum annual rainfall (1200 mm), the remainder is 100 mm. This

would be the expected runoff in a fully developed cascade in the minimum rainfall situation.

- Five percent of the rainfall would be 60-80 mm which is close to the 100 mm figure mentioned above.

Five percent is an approximate figure that should be refined from field measurements.

In our 1996 and 1997 study, we did not consider uses of water downstream from the cascade itself. In Anuradhapura District and in other parts of Sri Lanka, the bottom of the tank cascade is defined by the last tank system before water flows into a major river. The water in the major rivers is also used, notably for large-scale irrigation systems. It would be good to take the requirements of these irrigation systems into account also. Indeed, it has been documented that development of small tank systems has significantly reduced the inflow into one larger system in Anuradhapura District (Kariyawasam et al 1984).

Basically then, for any cascade where the cascade water surplus is above the criterion - here five percent - tank system rehabilitation planning may consider tank expansion or augmentation from additional sources. In any cascade where the water surplus is less than the criterion, no tank expansion or augmentation can be considered.

5.4 ASSESSMENT OF TANK REHABILITATION PROPOSALS

5.4.1 Planning of Small Tank Rehabilitation

Basic Planning Decisions When planning small tank rehabilitation, there are three basic considerations:

- First, the types of investment that can be permitted must be specified.
- Second, since development funds are limited, the tank must be selected for investment based on relevant criteria.
- Third, for any selected candidate the particular works to be carried out must be identified.

The procedure suggested in Section 5.3.2 for determining the cascade water surplus includes holding participatory planning sessions with farmers. One output of this process is a set of proposals for rehabilitation works, including both proposals for individual tank systems, and proposals to augment tank systems. Planning then consists largely of deciding which proposals to accept.

The alternative, and the more common, planning process, involves experts visiting each candidate tank system and working out the rehabilitation proposals themselves, sometimes in consultation with farmers. In the situation of little detailed knowledge of the tank cascades, the participatory planning approach described in Section 5.3.2 has four major advantages over planning by experts (cf Jinapala et al 1996):

- Having the farmers make their own plans gives them ownership of the plans and makes their cooperation more likely and more effective. Since small tank rehabilitation projects generally require farmer input in the form of labor or cash, such cooperation is essential.

- Proposals for tank augmentation or capacity expansion can have effects on the tank systems downstream in the cascade. When the farmers of the cascade are involved in planning, they can anticipate these effects based on their combined knowledge of cascade hydrology. They often can come to preliminary solutions to the potential conflicts through negotiations among the farmers from different villages. These negotiations were quite common in our participatory planning sessions.

- As part of participatory planning, farmers can be asked to prioritize the proposed interventions. If resources are not sufficient for all of the proposed investments, selecting investments using the farmers' priorities is likely to be more politically acceptable than selecting through other means. We found farmers were quite willing and capable of using their detailed local knowledge to prioritize the proposed interventions.

- Finally, since participation of the farmers is essential to gather the data needed for each cascade, involving farmers in participatory planning is very efficient.

These then provide the proposals to be evaluated against the criteria as discussed below. Once those are defined, planning consists of selection of tank systems for rehabilitation and, for each selected tank system, determination of the improvement proposals to implement.

Potential Components of Small Tank Rehabilitation Numerous components can be considered when planning small tank rehabilitation in Sri Lanka. We will classify these into the following classes:

- *Tank repairs*: This category includes repairs to the tank bund (including repairing a breached bund), repairs to the tank sluice and spill, repairs to the main canal(s), secondary canals, and tertiary canals and their control structures, and repairs to drains.

- *Management improvements*: This category includes upgrading of information sources and management skills of the farmers who manage the system; it may include installing measurement devices, training of managers, creating management organizations, devising new rules, etc. It also includes training farmers in more efficient application of water to crops and in other means of improving water use efficiency.

- *Tank augmentation*: This category includes works intended to increase the water supply to the tank, such as a diversion canal from a stream not intercepted by the tank or a canal taking water from the spill of an upstream tank whose water would not normally flow to the tank under rehabilitation.

- *Tank capacity expansion*: This category includes increasing the capacity of tank, generally by raising and lengthening the tank bund. Note that tank desiltation would fall

into this category but, in Sri Lanka, it has long been against government policy to fund tank desiltation even though farmers often request it.

- *Command area expansion*: This category includes expanding the command area, where possible, to take advantage of excess water.

At the level we are considering here, the primary question is which categories of works should be considered. More planning is needed to define all of the details of a category of investment for any one tank system.

5.4.2 Hydrologic Evaluation of Individual Tanks

Basic Procedure Evaluation of the individual tanks involves:

- Evaluating each individual tank in the cascade using water resource, tank storage capacity and agricultural criteria to identify its potential to benefit from repair and improvement.
- Comparing the farmers' repairs and improvement proposals for the cascade and individual tanks with the potential for benefiting to arrive at a set of repair and improvement recommendations.

Indicators for Evaluating Individual Tanks The following indicators are used to evaluate the potential of a tank system to benefit from rehabilitation investment:

- *Tank Water Supply Adequacy* A cascade may be hydrologically well endowed, but a tank within it may not be. Water supply adequacy of a tank measures the extent to which the effective runoff (R_o) to the tank is adequate to meet the irrigation requirement (IWD) in the main (Maha) season. Water supply adequacy is evaluated using the ratio of these two values (R_o/IWD). If $R_o/IWD > 1$, the tank has adequate water supply to meet the irrigation requirement; otherwise additional water is needed to meet the irrigation requirement.

- *Tank Storage Capacity* The storage capacity (C) of a tank measures the extent to which the tank is capable of storing the runoff water and releasing it to meet the irrigation requirement (IWD). This measure is evaluated using the ratio of these two quantities (C/IWD). If $C/IWD > 0.3$ then the tank has the capacity to hold at least 30 percent of irrigation requirement. The value of 0.3 is arrived at based on the farmers' perception that a tank should have storage capacity to hold at least 5 weeks of irrigation requirement before starting any irrigation operation.

- *Cropping Intensity* Agricultural performance of a tank is a measure of the extent to which the command area of a tank is cultivated with irrigation water successfully in Maha seasons. It is evaluated using the average main season (Maha) cropping intensity (CI_{maha}) for the past few consecutive seasons. In our 1996 and 1997 study, information on average Maha cropping intensity for the last few consecutive Maha seasons for each

individual tank was collected from the farmers. Based on the variability of rainfall and findings in our study, we concluded that a well performing cascade or tank in Anuradhapura District would have a Maha season cropping intensity of 60% or more.

These indicators, together with the cascade water surplus indicator are used to define the rehabilitation components recommended.

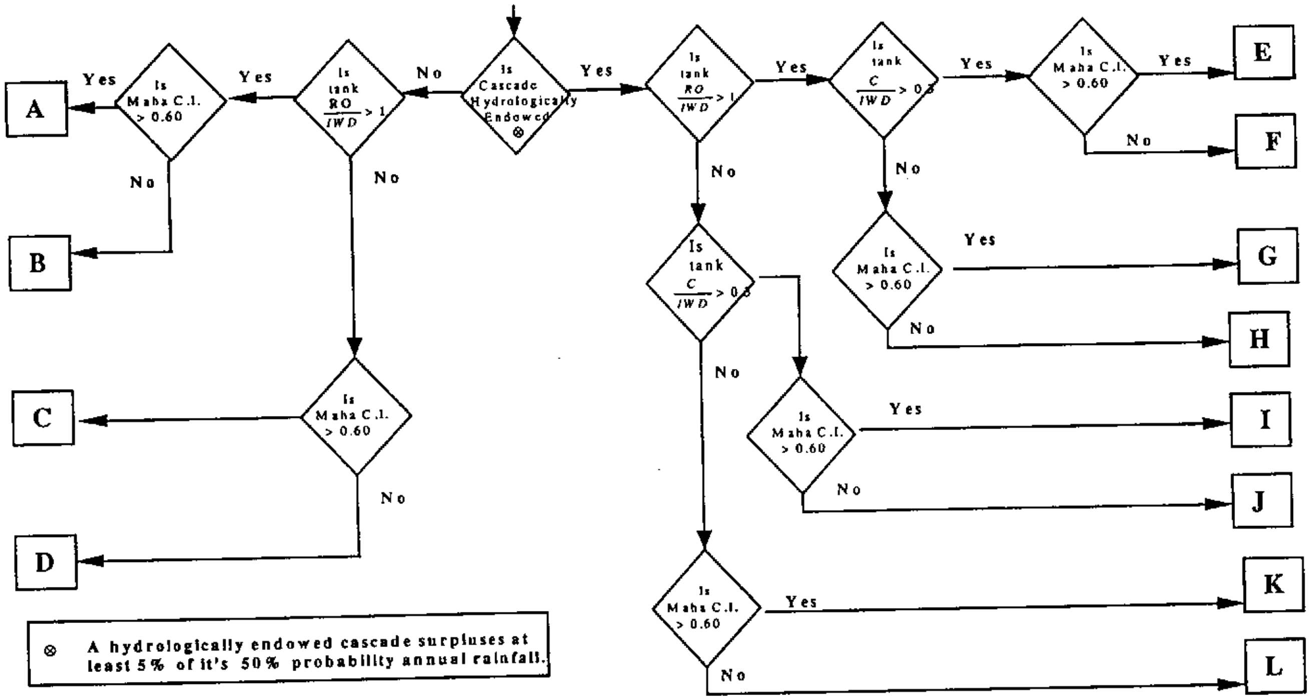
Recommending Tank Rehabilitation Components The indicators lead to the following recommendations:

- Tank repairs are recommended in all hydrological situations
- Management improvements are recommended if the main season cropping intensity for the tank is low ($CI_{maha} < 60\%$).
- Tank augmentation is recommended if there is a cascade water surplus ($WS_c > 5\%$) and tank water supply is inadequate ($R_o/IWD < 1.0$).
- Tank capacity expansion is recommended if there is a cascade water surplus ($WS_c > 5\%$), the tank water supply is adequate ($R_o/IWD > 1.0$), but the tank storage capacity is inadequate ($C/IWD < 0.3$).
- Both tank augmentation and tank capacity expansion are recommended if there is a cascade water surplus ($WS_c > 5\%$), tank water supply is inadequate ($R_o/IWD < 1.0$), and tank storage capacity is inadequate ($C/IWD < 0.3$). In this case, the tank capacity expansion is required to make use of the increased water supply to be provided through tank augmentation. However, if there is no source of water for tank augmentation, then tank expansion is not needed.
- Command area expansion is recommended only when a cascade water surplus exists ($WS_c > 5\%$), tank water supply is adequate ($R_o/IWD > 1.0$), tank storage is adequate ($C/IWD > 0.3$), cropping intensity is high ($CI_{maha} > 60\%$), and land for command area expansion is easily available.

The purely hydrological indicators bear only on recommendations for tank system augmentation or expansion. The conditions that support recommendations for augmentation or expansion are expressed in Table 5.2. Recommendations for tank repairs are independent of the hydrological evaluation and have to be based on other criteria, such as cost/benefit estimates. Similarly, recommendations for management improvements are based solely on cropping intensity which is used as a measure of system agricultural performance.

These criteria alone do not provide a full basis for deciding whether and how to invest in any particular tank system. Additional, non-hydrological, criteria are needed.

Table 5.2 – Guidelines for Selecting Tanks for Rehabilitation and Specific Types of Interventions



Rehabilitation Improvement Scheme	Description of Activities
A	Tank repairs. Improve WUE*
B	Tank repairs. Management of Institutional Improvements. Improve WUE.
C	Resource augmentation. Tank repairs. Improve WUE.
D	Resource augmentation. Tank repairs. Management of Institutional improvements. Improve WUE.
E	Capacity expansion. Water diversion. Tank repairs. Improve WUE.
F	Management of Institutional Improvements. Tank repairs. Improve WUE.
G	Capacity augmentation. Command area expansion. Water diversion. Tank repairs. Improve WUE.
H	Capacity augmentation. Management of institutional improvements. Tank repairs. Improve WUE.
I	Resource augmentation. Tank repairs. Improve WUE.
J	Resource augmentation. Management of Institutional improvements. Tank repairs. Improve WUE.
K	Resource augmentation. Capacity augmentation. Tank repairs. Improve WUE.
L	Resource augmentation. Capacity augmentation. Management of Institutional Improvements. Tank repairs. Improve WUE.

* Water productivity in many of these small schemes are low. Therefore, improving water use efficiency (WUE) is a common activity for all rehabilitation improvement schemes.

Confirming the Data The basic data on which these hydrologic evaluations are based comes from not well quantified farmers' recollections rather than from detailed measurements. For this reason, wherever the data and the rules recommend proposals for tank augmentation, tank expansion, or command area expansion, it is critical that the basic data be checked. In our experience, the farmers not only accept the necessity for such checking but they welcome it.

5.4.3 Evaluation of Tank Rehabilitation Proposals against Non-Hydrological Criteria

While the hydrologic evaluation provides guidelines on what kinds of rehabilitation should be proposed to avoid problems of conflicts over water, it does not provide sufficient guidance to actually select which tank systems will be rehabilitated and how much will be invested in each. Additional criteria are required. For a government sponsored rehabilitation project, these will necessarily be politically acceptable social and economic criteria.

It is not our intention to recommend any particular criteria. To illustrate criteria that might be used, we will describe those being used for the selection of tank systems for rehabilitation in Anuradhapura District under the project that IIMI assisted.

Criteria for Selection of Tank Systems for Rehabilitation In Anuradhapura District, the various project authorities have adopted two key criteria that can be used to eliminate small tank systems from consideration:

- *Number of Beneficiaries* This refers to the number of farm families to be benefited by repairs and improvement; for the Anuradhapura District project, it was decided that there must be at least five beneficiaries for a tank system to be considered for rehabilitation.

- *Rehabilitation History* Because small tank rehabilitation has been a popular development strategy, many small tank systems have already had some form of rehabilitation. For the Anuradhapura District project, it was decided that there should have been at least 10 years since the last rehabilitation for a tank system to be considered for rehabilitation.

As we will see in Section 5.5, these two criteria eliminate many tanks from consideration. Further elimination may have to be made using other criteria, particularly those that allow explicit or implicit comparison of costs and benefits of each investment.

Evaluation of Investment in Tank System Repairs Under the criteria given so far, tank system repairs are recommended for all tanks selected for rehabilitation. Because funds are limited, a means of estimating level of investment in tank repairs is useful for planning purposes.

For this purpose, we developed the tank system physical status score (PSS) to give an approximate idea of the level of investment needed for each tank system. The PSS scoring system is shown in Table 5.3. In this scoring system, the more important items (tank bunds, tank sluices, tank spills, and the canal systems) have been given double the weight of the other items.

The higher the score the more the repairs needed; a tank system in the worst possible condition would receive a score of 100.

Table 5.3: **Physical Status Scoring for Individual Tanks**

Item*	Condition	Score
Tank Bund	Breached	20
	Badly dilapidated	16
	Moderately dilapidated	12
	Fairly good	8
	Good	4
	No problems	0
Tank Bed	Heavily silted	10
	Moderately silted	6
	Unsilted	0
Tank Sluice(s)	Not working and need replacement	20
	Dilapidated and needing major repair	12
	Good/minor repairs	4
	No problems	0
Tank Spill	Non-existent	20
	Needs replacement/needs major repairs	12
	Good/minor repairs	4
	No problems	0
Canal System	Heavily dilapidated	20
	Moderately dilapidated	12
	Minor repairs	4
	No problems	0
Inflow Streams	Heavily clogged	10
	Moderately clogged	6
	Not much clogging	2
	No clogging	0

* The more important items - tank bunds, tank sluices, tank spills, and the canal systems have been given double the weight of the other items.

For simple estimation, we proposed that if the computed PSS is greater than 60, then the tank needs heavy capital investment; if it is between 40 and 60, then the tank needs moderate investment and if it is less than 40, then the tank needs only low investment. Per hectare cash costs can then be assigned to these classes for preliminary costing. The costs then form another basis for selecting tank systems for rehabilitation.

5.5 Makichchawa Cascade: An Example

In this section, we analyze Makichchawa Cascade to illustrate the use of the methodology. Makichchawa Cascade is one of the 96 cascades in Anuradhapura District studied in 1996 and 1997. The cascade particulars are given in Annex B. Proposals and recommendations for the tanks in the cascade are summarized in Table 5.4. An explanation for these recommendations is given below.

Evaluation of Cascade Water Surplus As shown in Annex B, the cascade water surplus (WS_c) for Makichchawa Cascade is 8.12 %, well above the standard of five percent required for a cascade to be classed as having a significant water surplus. Therefore, tank augmentation, tank capacity expansion, and command area expansion can be considered, including repairs to breached tanks.

Eligibility for Tank Rehabilitation and Repair Table 5.4 gives the numbers of farmers and the years of the most recent rehabilitation for each tank in Makichchawa Cascade.

Examination of this list shows that all of the tanks, except Tank 7 (Kuda Divulgaskada Tank), have more than 5 farmers, hence all except Tank 7 are eligible on the grounds of sufficient beneficiaries. Tank 7 is a special case and is discussed separately below.

However, three of the tanks - Tank 3 (Etambaskada Tank), Tank 10 (Makichchawa Tank), and Tank 14 (Kongollewa Kuda Tank) - have had rehabilitations within the last 10 years. Tank 10 was undergoing rehabilitation at the time of fieldwork. These three tanks are, therefore, not eligible for rehabilitation.

Evaluation of Rehabilitation Proposals for Tank 4 Table 5.4 shows the farmers' proposals, the hydrologic evaluation indicators, the Maha season cropping intensity (CI_m), and the Physical Status Score (PSS) for each tank. The hydrologic evaluation indicators are the two ratios:

- R_o/IWD (ratio of runoff to tank irrigation requirement)
- C/IWD (ratio of tank storage capacity to tank irrigation requirement).

To see how these are used, let us take the example of Tank 4 (Maha Meegaskada Tank).

- Tank 4 does not receive adequate water. To receive adequate water, R_o/IWD should be at least 1.0. This ratio for Tank 4 ratio is only 0.54, well under 1.0. Therefore, augmentation from another source should be considered. Farmers proposed augmentation by diverting a stream called Ulpath Ela to the tank. This proposal is thus recommended.

- Tank 4 also has less than adequate tank capacity since the C/IWD ratio is 0.26. For adequate tank capacity, the C/IWD ratio should be at least 0.3. This tank thus should be considered for tank capacity expansion. The farmers proposed extending the Tank 4

bund to the end of the bund of nearby Tank 5, combining the two tanks and effectively increasing the capacity of the two tanks. This proposal is thus also recommended.

- Maha cropping intensity over 0.60 is considered high. The Maha cropping intensity for Tank 4 is 0.76. Therefore, management improvements are not recommended.

- Tank repairs are recommended for all eligible tanks. Therefore the farmers' proposals to repair the bund and provide a spill on the right bank are also recommended. Since the PSS score is 82, tank repairs will require a high level of investment.

These recommendations are clearly shown in Table 5.4.

Evaluation of Rehabilitation Proposals for Tank 9 Tank (Puhudivula Tank) offers a contrasting example.

- The R_o/IWD ratio for Tank 9 is 0.99; this is close enough to 1.0 that we will take it as 1.0. Hence augmentation is not needed for this tank. The farmers did not propose augmentation.

- The C/IWD ratio for Tank 9 is 0.65, well above 0.3. This tank therefore has adequate capacity and capacity is not warranted. The farmers, however, proposed raising the tank bund to increase the capacity. This proposal is not recommended.

- The Maha cropping intensity is 1.0 therefore there is no need for management improvements.

- Tank repairs are recommended. For Tank 9, farmers proposed repairing the bund, repairing the sluice gate, providing a spill, and providing a channel system. The PSS score of 66 indicates that the required investment level for these repairs is high.

Therefore, for Tank 9 only tank repairs are recommended.

Nonfunctioning Tanks Four of the tanks in the cascade (Tanks 1, 2, 11, and 12) are breached so that they will not hold water. Another (Tank 8) has severe leaks in the bund so it will also not hold water. Because this is an surplus water cascade, restoration of all of these can be recommended. For three of these (Tanks 8, 11, and 12) the storage capacity will not be adequate, once the capacity has been restored. Therefore we recommend consideration of capacity increases as well for these tanks. For one of these (Tank 8), the tank also does not receive adequate water, hence augmentation of water supply, as proposed by the farmers, is recommended.

Command Area Increase Recommendations If the tank has adequate water and adequate storage capacity and has a high cropping intensity, the procedure recommends consideration of command area enlargement if suitable land is available. This is the case for three of the tanks (Tanks 5, 6, and 13).

Tank 7 (Kuda Divulgaskada Tank) This is an unusual tank and offers an unusual case. At the moment, this tank is not used for irrigation. In the Dry Zone of Sri Lanka, almost all agricultural land is owned by the government. Legally, it can be farmed only with a government permit. No permits have been issued for land under Tank 7 hence this tank is not legally used for irrigation.

Farmers under nearby Tank 6 (Maha Divulgaskada Tank) proposed using the water stored in Tank 7 by building a canal to convey that water to Tank 6. Tank 6, however, has adequate water by the standards used here (R_0/IWD = 1.53). Therefore, we do not recommend construction of this canal. However, Tank 6 is one of the tanks eligible for command area increase. It is possible therefore that further investigation would show that farmers could use the water by enlarging the command under Tank 6.

Need for Further Checks The procedure described earlier permits a systematic and rational approach for selecting tank rehabilitation activities. The procedure takes into account cascade water limitations, individual tank characteristics, social and economic criteria, and farmers' requests. This is a far more systematic approach than has been used before in planning small tank rehabilitation in Sri Lanka.

However, it is essential that further assessments of the tank and cascade hydrology be made to determine the effects of the recommended activities. This should be done before construction begins.

Table 5.4: **Evaluation of Tank Rehabilitation Proposals for Makichchawa Cascade**

Tank No	Tank Name	Evaluation Indicators						Farmer Proposals in Priority Order	Recommendations	Investment Level
		No of Fmr's	Rehab Year	R_0/IWD	C/IWD	CL_{maha}	PSS Score			
1	Thimbiri	20	-	4.98	0.43*	-	70	Breached tank 1. Restore tank bund 2. Provide spill 3. Provide channel system	1. Capacity restoration by bund repair 2. Tank repairs	High
2	Dutu	8	-	6.45	0.60*	-	66	Breached tank 1. Restore tank bund 2. Provide spill & sluice	1. Capacity restoration by bund repair 2. Tank repairs	High
3	Etambagaskada	105	1992	6.1	0.95	0.75	66	1. Repair bund 2. Repair leaks in sluices 3. Repair canal system	Not eligible	-
4	Maha Meegaskada	65	-	0.54	0.26	0.76	82	1. Divert local stream into tank 2. Repair bund, fill scours & depressions. 3. Provide a spill on the RB 4. Connect to Kuda Meegaskada by extending bund	1. Tank augmentation 2. Tank repairs 3. Combine tanks (capacity increase)	High
5	Kuda Meegaskada	65	-	3.05	0.39	0.77	72	1. Repair bund; fill breach, scours & depressions 2. Replace step sluice with control gated sluice 3. Provide sluice 4. Provide channel system	1. Tank repairs 2. Plan work with plans for Maha Meegaskada 3. Consider command area increase	High
6	Maha Divulgaskada	65	1976	1.53	0.44	0.67	46	1. Repair LB sluice leaks & bent spindle 2. Repair RB sluice leaks 3. Repair spill damage & leaks; provide gates & locks 4. Provide channel system	1. Tank repairs 2. Consider command area increase	Medium
7	Kuda Divulgaskada***	-	-	-	-	-	52	Not used for irrigation (see text) 1. Construct canal to Maha Divulgaskada	See text.	See text.
8	Palugolla	35	1976	0.76	0.18*	-	62	Severe leaks in bund 1. Divert drainage from local hill into tank 2. Repair bund leaks; fill scours & depressions 3. Replace LB step sluice 4. Provide channel system	1. Capacity restoration by bund repair 2. Tank augmentation 3. Tank repairs 4. Consider capacity increase	High

Table 5.4: **Evaluation of Tank Rehabilitation Proposals for Makichchawa Cascade** (continued)

Tank No	Tank Name	Evaluation Indicators						Farmer Proposals in Priority Order	Recommendations	Investment Level
		No of Fmr's	Rehab Year	R_0/IWD	C/IWD	CI_{maha}	PSS Score			
9	Puhudivula	45	1978	0.99	0.65	1.0	66	1. Raise bund; fill scours & depressions 2. Repair sluice gate leak 3. Provide spill 4. Provide channel system	1. Tank repairs	High
10	Makichchawa	89	1996	23.21	2.41	0.81	24	None: prresently under rehabilitation	Not eligible	-
11	Muda	15	-	0.59	0.14*	**	66	Breached tank 1. Restore tank bund 2. Provide spill 3. Replace step sluice with gated sluice	1. Capacity restoration by bund repair 2. Tank repairs 3. Consider capacity increase	High
12	Vedikkarayaga	12	1965	1.03	0.27*	**	46	Breached tank 1. Restore tank bund 2. Provide sluice 3. Provide spill	1. Capacity restoration by bund repair 2. Tank repairs 3. Consider capacity increase	Medium
13	Kadawatha	8	1965	1.73	0.46	1.0	86	1. Repair bund; fill breaches, depressions & scours 2. Replace step sluice with control gated sluice	1. Tank repairs 2. Consider command area increase	High
14	Kongollewa Kuda	5	1995	0.74	0.32	0.33	54	1. Provide spill	Not eligible	-
15	Ratmalwetiya	15	-	1.78	0.21	0.58	82	1. Repair bund; fill breaches, depressions & scours 2. Replace step sluice with control gated sluice	1. Tank repairs 2. Management improvements 3. Consider capacity increase	High

* These tanks have no effective capacity; the numbers represent what the tank capacity would be if the tanks functioned.

** Farmers use the command area for rainfed cultivation during Maha.

*** See discussion of this tank in the text.

5.6 Outcome

The key outcome of this component is as follows:

i. Development of a hydrological simulation model for analyzing the overall hydrology of any given cascade using a set of input parameters.

ii. As a result of application of the above model combined with field data the study has produced.

    a. Compilation of catchment areas, command areas, water spread areas, cropping intensity, previous year of rehabilitation, number of families benefitted, farmers proposal and priorities for rehabilitation in respect of all tanks in 96 cascades studied.

    b. Detailed annual and seasonal water balances for about 648 small tanks in 96 tank cascades.

    c. Annual water balance of 95 tank cascades.

    d. Computation of the tank cascade water surplus and evaluation indicators for 96 cascades and 648 tanks in it.

iii. Based on the analysis of more than 1000 tanks in 96 cascades, selection of 648 tanks for funding for rehabilitation under PRDP of the NCP.

iv. Preparaiton of 96 individual cascade reports giving details such as the number of tanks (working and non-working), number of agrowells (commands and highlands), catchment areas, total cascade area, total tank area, total irrigated commmand areas, overall cropping intensity, and computed cascade evaluation indicators.

v. Ninety six separate cascade maps of one each for each cascade studied; showing details such as: location of the tanks, catchment areas, command areas water spread area, cropping intensity, number of families in respect of each tank in the cascade.

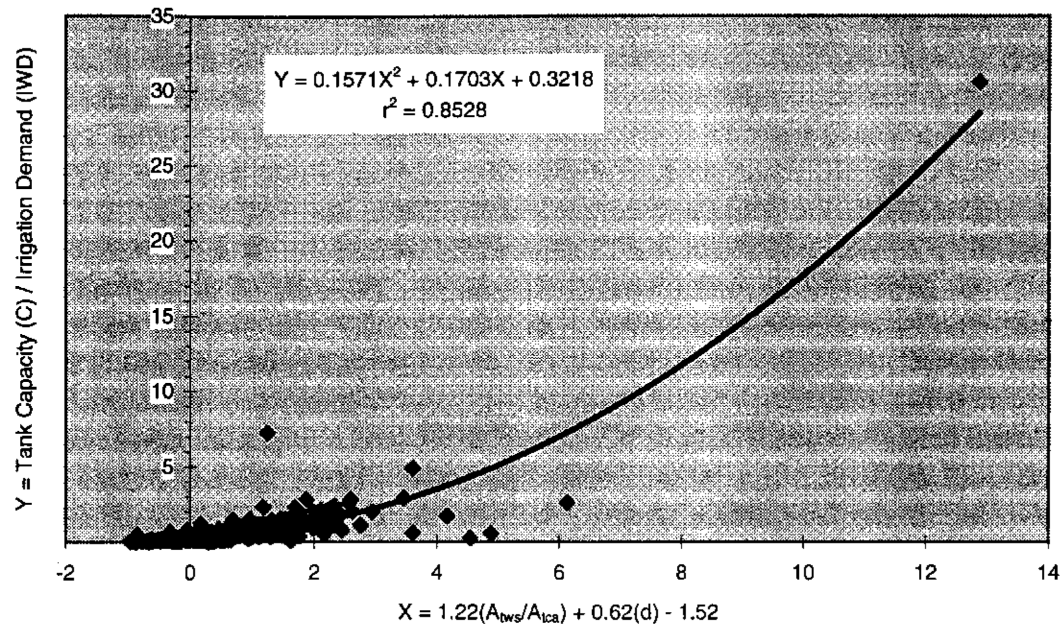


Figure 5.1 Tank Capacity/Irrigation Demand vs Tank Physical Features

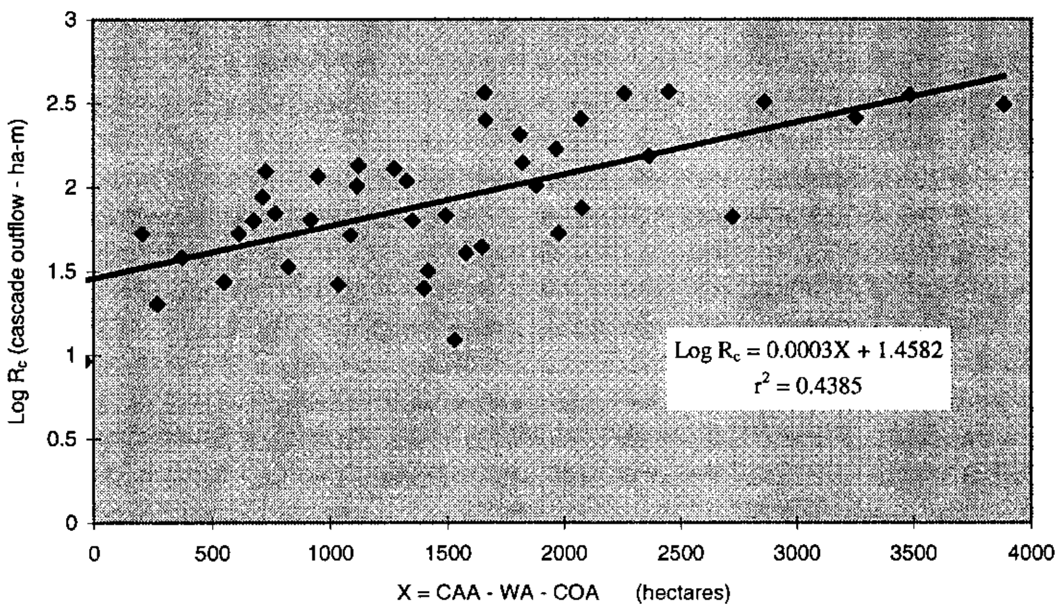


Figure 5.2 Cascade Outflow vs Cascade Physical Features

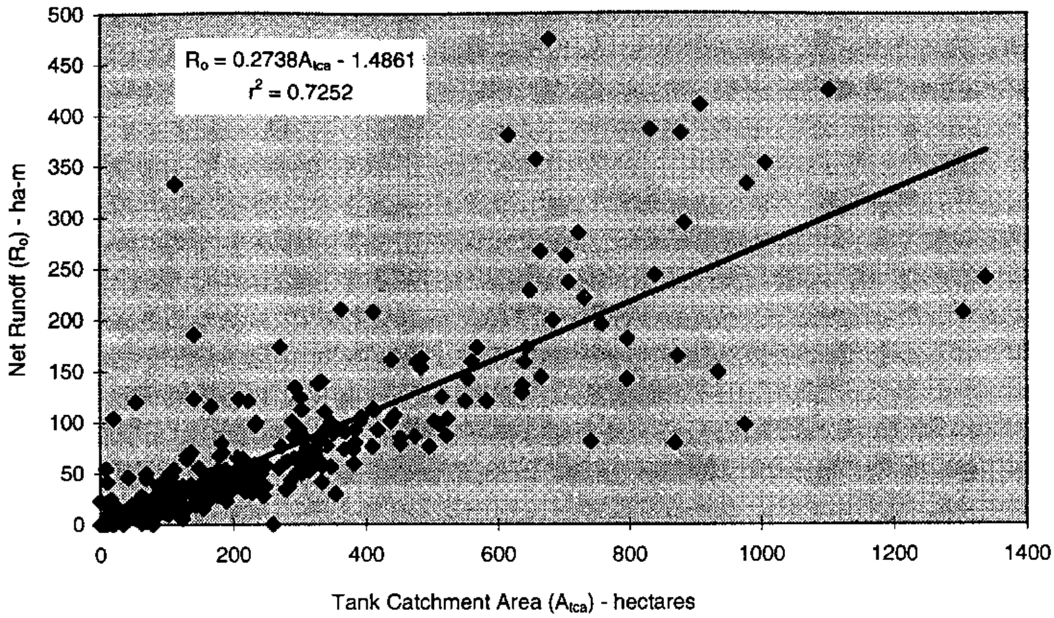


Figure 5.3 Net Runoff vs Tank Catchment Area

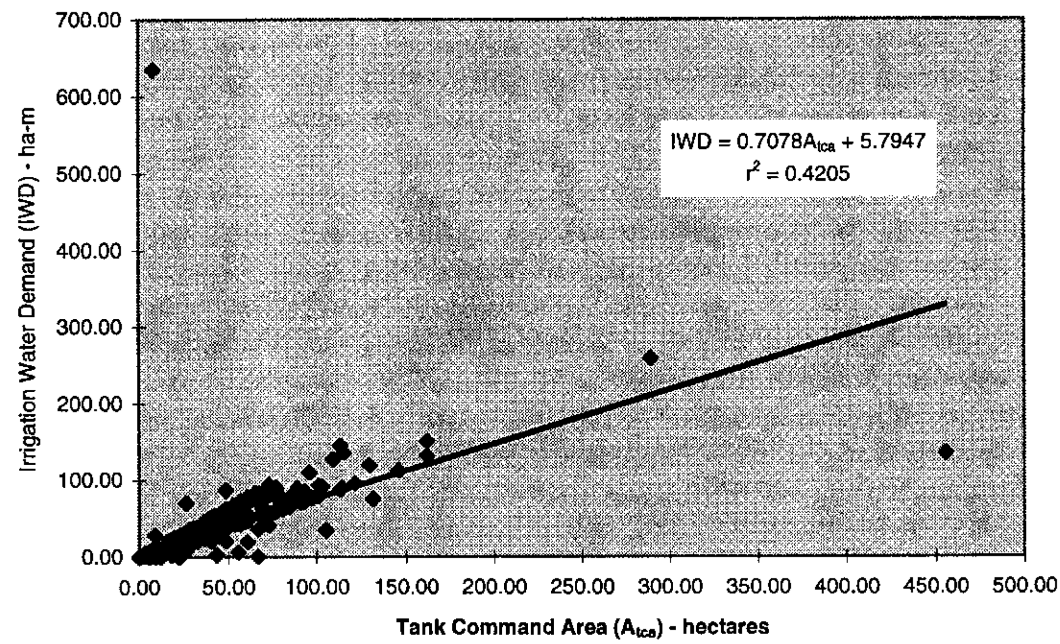


Figure 5.4 Irrigation Water Demand Vs Tank Command Area

Annex A

DERIVATION OF LIMITING VALUES FOR TANK HYDROLOGICAL INDICATORS

The following basic assumptions are made in deriving limiting values for the tank indicators:

a. Maha rainfall contribution to runoff should be equal to or greater than 1.5 times the Maha irrigation water requirements.

b. A maximum of 1.5 tank fillings is required for the Maha crop to mature.

c. The rainfall runoff coefficient is 0.30.

d. The mean Maha rainfall which varies between 600 mm to 900 mm in the North Central Province will be used for runoff computations.

e. The irrigation water requirement at the tank outlet is taken as 3 acre-feet/acre (0.90 ha-m/ha).

f. Tank storage capacity (C) is computed using the equation C = 0.4 x A_{tws} x d where A_{tws} is the tank waterspread area and d is the effective tank depth at sluice head (depth from full supply level to the sill level).

Based on the above assumptions, the following limiting values can be derived:

1. Ratio of the tank catchment area (A_{tca}) to the tank command area (A_{tco}).

Assumption a implies that

$$\frac{\text{tank runoff volume}}{\text{tank irrigation water requirement}} > 1.5$$

From assumptions c and d, tank runoff volume is A_{tca} x 0.3 x R_{50} where A_{tca} is the tank catchment area and R_{m50} is the mean (50% probable) Maha rainfall. Also, from assumption e, the tank irrigation water requirement is A_{tco} x 0.9 meters where A_{tco} is the command area.

Substituting in the above equation gives:

$$\frac{A_{tca} \times 0.3 \times R_{m50}}{A_{tco} \times 0.9} > 1.5$$

Simplifying:

$$\frac{A_{tca}}{A_{tco}} > \frac{4.5}{R_{m50}}$$

The limiting values depend upon the expected Maha rainfall expressed in meters as follows:

$$\frac{A_{tca}}{A_{tco}} > 5 \text{ when } R_{m50} = 0.9 \text{ m (900 mm)}$$

$$\frac{A_{tca}}{A_{tco}} > 7.5 \text{ when } R_{m50} = 0.6 \text{ m (600 mm)}$$

2. Ratio of tank command area (A_{tco}) to tank waterspread area (A_{tws}):

From assumption b above, we have that

$$\frac{\text{tank irrigation water requirement}}{\text{tank storage capacity}} < 1.5$$

From assumption e, the tank irrigation water requirement is A_{tco} x 0.9 meters. From assumption f, the tank storage capacity is 0.4 x A_{tws} x d where A_{tws} is the tank water spread area (in hectares) and d is the effective depth of the tank at the sluice (in meters).

Substituting in the above equation gives:

$$\frac{A_{tco} \times 0.9}{A_{tws} \times 0.4 \times d} < 1.5$$

Simplifying:

$$\frac{A_{tco}}{A_{tws}} < \frac{2d}{3}$$

This can be interpreted as follows:

$$\frac{A_{tco}}{A_{tws}} < 1 \text{ where } d = 5 \text{ ft (1.5 m) or less}$$

$$\frac{A_{tco}}{A_{tws}} < 2 \text{ where } d = 5 \text{ to } 10 \text{ ft (1.5 to 3.0 m)}$$

$$\frac{A_{tco}}{A_{tws}} > 2 \text{ where } d > 10 \text{ ft } (3.0 \text{ m})$$

3. Ratio of tank catchment area (A_{tca}) to the tank water spread area (A_{tws}).

First, note that

$$\frac{A_{tca}}{A_{tws}} = \frac{A_{tca}}{A_{tco}} \times \frac{A_{tco}}{A_{tws}}$$

Substituting from the above two calculations:

$$\frac{A_{tca}}{A_{tws}} \geq \frac{4.5}{R_{m50}} \times \frac{2d}{3}$$

simplifying

$$\frac{A_{tca}}{A_{tws}} \geq \frac{3d}{R_{m50}}$$

Then consider three cases:

(a) When d < 5 ft (1.5 m) and the mean Maha rainfall varies between 900 mm and 600 mm, then

$$\frac{A_{tca}}{A_{tws}} < 7.5$$

(b) When d varies between 5 and 10 ft (1.5 to 3.0m) and the mean Maha rainfall varies between 900 mm and 600 mm, then

$$7.5 < \frac{A_{tca}}{A_{tws}} < 10$$

(c) When d > 10 ft (3.0 m) and the mean Maha rainfall varies between 900 mm and 600 mm, then

$$\frac{A_{tca}}{A_{tws}} > 10$$

Annex B

MAKICHCHAWA CASCADE

1. Location

1.1	Cascade Name	:	Makichchawa
1.2	River Basin	:	Malwatu Oya
1.3	Divisional Secretary Division	:	Medawachchiya

2. General Information

2.1	Cascade Area	:	2816.2 ha
2.2	Number of Tanks	:	15
	Working	:	9
	Non Working	:	6
2.3	Agricultural Wells	:	11

A diagram showing the relationships of the tanks in the cascade is given at the end of the Annex.

3. Cascade Hydrological Characteristics

Total cascade area (CAA)	:	2816.2 ha
Total cascade water spread area (WA)	:	170.4 ha
Total cascade command area (COA)	:	294.6 ha
Mean tank depth (d)	:	1.93 m
Mean annual rainfall (R_{50})	:	1587 mm (Station - Mahailluppallama)
Cascade Maha cropping intensity (CI_c)	:	0.79
Net annual runoff from the cascade (R_c)	:	363.0 ha-m

4. Computation of Screening Indicators

Ratio of cascade area to cascade water spread area:

$$CAA/WA = 2816.2 \text{ ha} / 170.4 \text{ ha} = 16.52 > 8$$

Ratio of cascade command area to cascade water spread area:

$$COA/WA = 294.6 \text{ ha} / 170.4 \text{ ha} = 1.73 < 2$$

The cascade satisfies the two criteria for selection in the preliminary screening round.

5. Computation of Cascade Water Surplus

Cascade outflow per unit area: $V = R_c/CAA = 363.0$ ha-m / 2816.2 ha = 0.1289 m

Cascade water surplus: $WS_c = V/R_{50} = 0.1289$ m / 1.587 m = 0.0812 = 8.12 % > 5 %

Since the water surplus is greater than 5%, Makichchawa is a water surplus cascade.

6. Tank Features

Table B1: **Basic Tank Features** (areas in hectares, depth in meters)

Tank No	Tank Name	Command Area	Catchment Area	Water Spread Area	Depth
1	Thimbiri	12.1	328.6	8.5	1.8
2	Dutu	9.7	235.1	11.3	1.0
3	Etambagaskada	48.6	498.2	37.6	2.4
4	Maha Meegaskada	34.4	62.7	8.1	2.1
5	Kuda Meegaskada	18.2	204.8	6.5	2.1
6	Maha Divulgaskada	72.8	178.5	22.7	2.7
7	Kuda Divulgaskada	-	119.8	1.8	1.5
8	Palugolla	12.1	31.9	2.4	1.8
9	Puhudivula	26.7	75.3	15.8	2.1
10	Makichchawa	22.3	534.2	43.3	2.4
11	Nuga	8.1	16.2	1.8	1.2
12	Vedikkarayage	8.1	19.0	2.0	2.1
13	Kadawatha	4.9	38.8	3.4	2.1
14	Kongollewa Kuda	6.1	19.4	2.8	1.8
15	Ratmalwetiya	10.5	38.4	2.4	1.8

7. Tank Water Balances for Maha Season

Table B2: **Tank Water Balances for Maha Seasons**

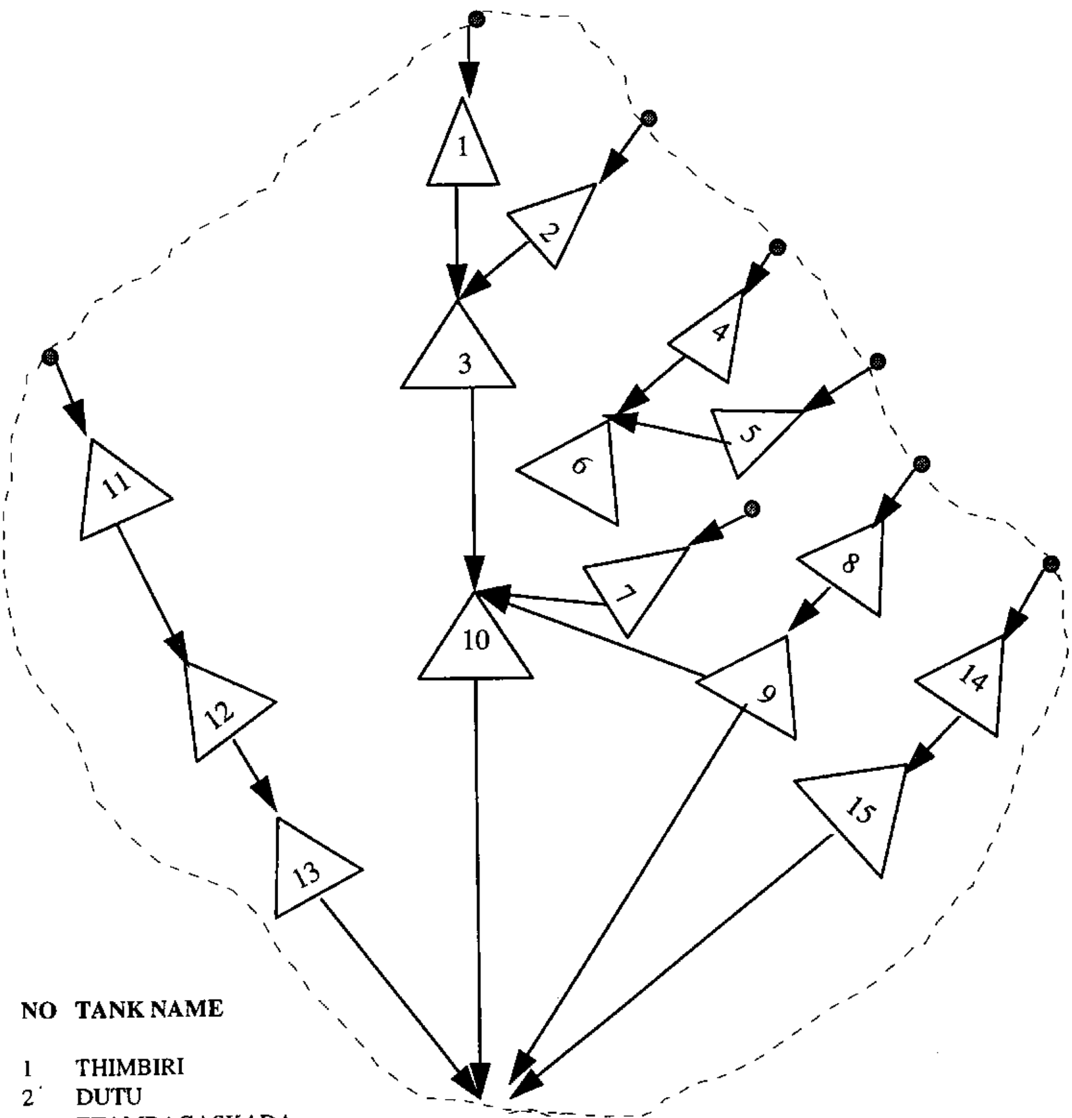
Tank No	Tank Name	Begin Storage	Inflows: Catchment	Inflows: Direct Rainfall	Inflows: Drainage	Inflows: Tank Spills	Outflows: Spillage	Outflows: Irrigation	Outflows: Losses	End Storage
1	Thimbiri	0	78.26	9.33	0.00	0.00	55.21	14.19	16.83	1.37
2	Dutu	0	56.00	12.35	0.00	0.00	38.18	7.51	19.91	2.75
3	Etambagaskada	0	174.26	38.71	4.34	93.39	172.13	37.53	78.44	22.60
4	Maha Meegaskada	0	14.94	1.89	0.00	0.00	0.00	13.99	2.43	0.40
5	Kuda Meegaskada	0	48.78	6.75	0.00	0.00	25.53	14.07	12.66	3.28
6	Maha Divulgaskada	0	69.37	17.14	5.61	25.53	25.77	55.46	31.70	4.74
7	Kuda Divulgaskada	0	28.52	2.07	0.00	0.00	25.66	0.00	3.87	1.08
8	Palugolla	0	7.61	1.29	0.00	0.00	0.52	6.43	1.73	0.21
9	Puhudivula	0	22.06	6.66	1.29	0.52	0.00	19.81	10.15	0.57
10	Makichchawa	0	209.05	46.33	18.60	223.55	349.94	17.21	97.95	32.46
11	Nuga	0	3.85	0.77	0.00	0.00	0.10	3.52	0.91	0.09
12	Vedikkarayage	0	6.24	1.25	0.70	0.10	0.77	5.48	1.87	0.18
13	Kadawatha	0	11.26	2.93	1.09	0.77	3.64	6.26	5.24	0.89
14	Kongollewa Kuda	0	4.62	0.00	0.00	0.00	2.82	1.80	0.00	0.00
15	Ratmalwetiya	0	11.28	0.00	0.36	2.82	10.65	3.80	0.00	0.00

8. Calculation of Tank Evaluation Indicators

Table B3: **Tank Evaluation Indicators (Maha Season)** (volumes in hectare-meters)

Tank No	Tank Name	Irrigation Need (IWD)	Catchment Runoff (R_0)	Tank Capacity (C)	R_0/IWD	C/IWD
1	Thimbiri	14.19	70.76	6.13	4.98	0.35
2	Dutu	7.51	48.45	4.52	6.45	0.86
3	Etambagaskada	37.53	232.26	36.09	6.19	0.16
4	Maha Meegaskada	26.58	14.40	6.81	0.54	0.02
5	Kuda Meegaskada	14.07	42.87	5.46	3.05	0.22
6	Maha Divulgaskada	56.29	85.94	24.53	1.53	0.03
7	Kuda Divulgaskada	0	26.72	1.08	-	-
8	Palugolla	9.38	7.17	1.73	0.76	0.08
9	Puhudivula	20.64	20.38	13.28	0.99	0.05
10	Makichchawa	17.22	399.58	41.56	23.21	1.35
11	Nuga	6.26	3.70	0.87	0.59	0.09
12	Vedikkarayage	6.26	6.42	1.68	1.03	0.16
13	Kadawatha	6.26	10.81	2.86	1.73	0.28
14	Kongollewa Kuda	6.26	4.62	2.02	0.74	0.12
15	Ratmalwetiya	8.13	14.46	1.73	1.78	0.22

SCHEMATIC DIAGRAM OF MAKICHCHAWA CASCADE



NO TANK NAME

1 THIMBIRI
2 DUTU
3 ETAMBAGASKADA
4 MAHA MEEGASKADA
5 KUDA MEEGASKADA
6 MAHA DIVULGASKADA
7 KUDA DIVULGASKADA
8 PALUGOLLA
9 PUHUDIVULA
10 MAKICHCHAWA
11 NUGA
12 VEDIKKARAYAGE
13 KADAWATHA
14 KONGOLLEWA KUDA
15 RATMALWETIYA

Chapter 6

POTENTIAL FOR AGROWELL DEVELOPMENT

6.1 General Background

Groundwater Occurrences in General

Groundwater occurrence in the study area can be divided into three main categories:

i. Groundwater in the soil overburden.
ii. Groundwater in the weathered rock.
iii. Groundwater in deep fractures.

The shallow wells in the NCP are fed by the water migrating through the soil cover. Most of the farmers are not bothered to go beyond the soil overburden into the better yielding fractured weathered rock. Only at few places the investigators have come across deep wells where water present in the fracture zones have been tapped. At some places, the saprock has been found to be clogged by calcareous precipitation which has a bearing on the transmisivity of the aquifer.

Geology

Undifferentiated meta-sediments, mostly dominated by Charnokitic Gneiss, Garnetiferous Biotite Gneiss and intermingling Quartzite bands were found to be the main rock type within the Anuradhapura District. The high siliceous (quartzitic) nature of the soils of elevated areas can be attributed to the weathered gneiss which is rich in quartz and feldspar. Similarly the presence of clayey sediments in lowlying areas and paddy fields is a result of feldspar weathering. Exfoliation weathering is common in rock outcrops resulting in the accumulation of thin colluvial scree, while elsewhere in-situ chemical weathering is dominant. The regional strike of rocks in the study area is approximately N.S.

6.2 Methodology

This study has been conducted in two phases, namely:

<u>Phase I</u>

1. Plotting available data on 1:50,000 "*Cascade Maps*".

2. Demarcating potential areas for shallow groundwater extraction in each cascade on the basis of geomorphological characteristics.

<u>Phase II</u>

1. Field checking of well data plotted on 1:50,000 topographic maps.

2. Field checking of potential areas identified during the Phase I by visiting the area with the PRA Team. During these meetings the hydrogeologists were able to collect first hand information on existing agro-wells and their performance.

3. Confirmation of groundwater potential in predicted areas (where dugwellls are not available) by means of electrical resistivity and light drilling surveys.

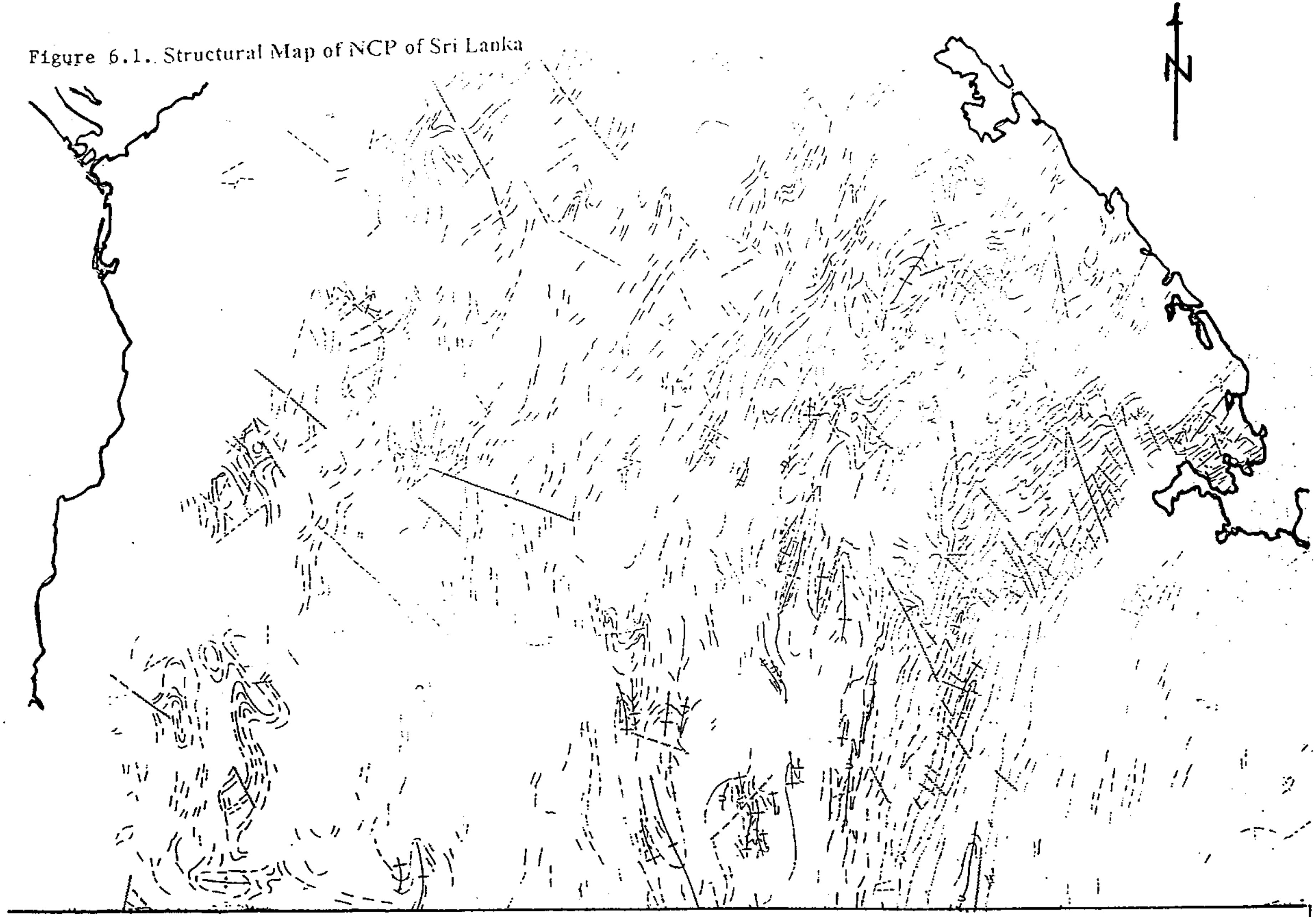
Figure 6.1 a structural map of the NCP, shows the predicted hydrogeological characteristics (mainly fracture zones and strike valleys-Phase I). These areas have been extended after considering other lithological characteristics to show potential areas for digging agrowells. These areas were visited by the team of hydrogeologists (Phase II) to check the applicability of the technique and found very successful agrowells within the predicted zones. (*Volume IV, page 1 through page 21) further show areas confirmed by resistivity surveys and light drilling. These maps also indicate areas rejected after field visits and in some instances after Resistivity Surveys.

Interpretation of Topographical Maps

The fracture zones and the lithological strike lines were first drawn on cascade maps in order to demarcate potential areas for agricultural wells. The alluvium deposited in marginal areas of the tanks can also be considered as potential zones though the transmisivity in such sediments is not considered significant. However, in the process of identifying potential areas for agro-wells, fracture zones, strike valleys and alluvium filled areas have been seriously considered.

In the NCP cascades it was noted that the rock at the soil-rock interface is very highly weathered and also that the lower level of this weathered zone is highly fractured. The transmisivity in the fractured (weathered) rock is very high and makes a pathway for the groundwater flow through the cascades. In almost all the cascades visited, the predictions were found to be accurate. In only few instances, farmer selected locations were not recommended as the on-site light drilling was not able to prove the presence of water.

Figure 6.1. Structural Map of NCP of Sri Lanka



Resistivity Survey

Since 1978, deep well drilling for rural water supplies has expanded to an unprecedented level, drilling more than 3,000 wells in many parts of the island. Currently the success rate in tapping deep fracture zones with flowing water is about 95 percent. This rate was achieved by employing geophysical techniques in addition to conventional geological and structural interpretation of topographical maps and aerial photographs, in groundwater exploration.

In the present study, geophysical surveys have been employed to verify the results of geomorphological and topographical interpretations, specially when the presence of water is not indicated on the ground or in domestic wells and when the farmers insist on the availability of water.

Geophysical surveys have been conducted during visits at locations where farmers have requested for new agro-wells and when there are no previously constructed dugwells around. Two teams of hydrologists were employed and the Vertical Electrical Soundings (VES) were conducted at selected locations with two site specific arrays. The Resistivity data obtained from the soundings were analyzed using RESLXS, a special software developed by the ITC of Netherlands for similar groundwater studies.

6.3 Hydrogeology of a Tank Environment

Based on the agro-well position, in relation to the tank, the agro-wells can be classified in to four types (**Figure 6.2**):

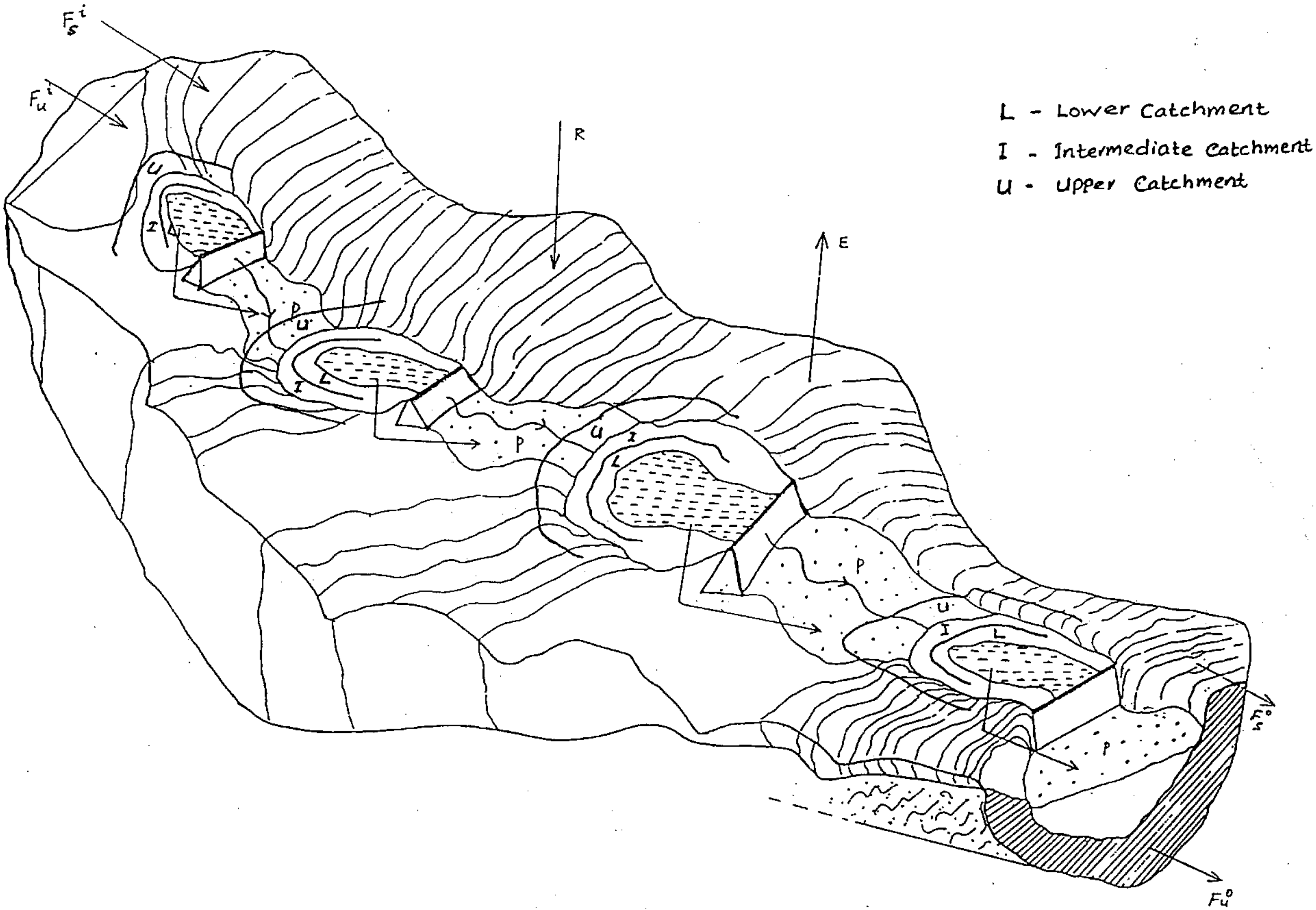
i. Wells located in the upper part of the catchment.
ii. Wells located in the middle part of the catchment.
iii. Wells located in the lower part of the catchment.
iv. Wells located below the tank bund or in the command area.

The performance of agrowells in the above four categories also seem to vary within each category due to variations in the rock type.

Occurrence and Distribution of Groundwater within a Cascade in the NCP

The main water bearing formations in the area are the weathered overburden and the crystalline bed rock. The alluvial deposits along streams and few springs present in south-west part of the area also play a vital role in water supply. The thickness of the overburden ranges from 0 to 20m with an average thickness of about 12m. The depth to the groundwater table varies between 1m to 10m with an average seasonal fluctuation of 4m.

Figure 6.2. Cascade Environment with Generalized Hydrological Components



In the study area most of the agrowells are distributed around tanks. The number of agrowells dug in the upper catchment area is much less than that in the middle and lower catchment areas. Most of these agrowells have not been sited using scientific means of groundwater exploration. However, some areas have been already identified as groundwater potential areas by the indigenous knowledge of villagers. The number of agrowells is rapidly increasing in such areas.

Design of Agrowells in the NCP

Most of the agrowells dug in the visited cascades have a common design recommended by the Agricultural Development Authority (ADA). In general they have 6m depth and 5m to 7m diameter. Most of the agrowells are lined with brick or rock material. Some agrowells have a parapet wall. The height of the parapet wall varies from 0.2m to 1.2m. Most of the agrowells are dug in the overburden and only a few wells are found to penetrate into fractured hard rock.

6.4 Performance of Agrowells in Cascades under Investigation

After thorough analysis of information gathered during field visits, it was found that performance of all the agrowells in a given cascade is not uniform. Some wells provide a high amount of water with a rapid recovery. Some do not perform well due to poor recovery rate. Large diameter of all these wells, however, facilitate a good storage.

The agrowells observed under the second phase of the IFAD project were categorized into four groups as indicated above, based on their geographical location in each catchment.

i. *Wells in Upper Catchment Area*

About 20 percent of the agrowells are located in the upper catchment area. Most of these wells have penetrated through the soil overburden and gone in to the fractured (partially weathered) rock (see **Table 6.1**).

During pumping, agrowells show varied drawdown and recovery rates owing to their varying overburden conditions. Except in agrowells on biotite gneiss, the other agro-wells have shown a decrease in recovery rate since their construction. During pumping of the agrowells, water levels in nearby wells also drops at varying degrees depending on the geological structure which governs the flow of groundwater.

Table 6.1. Performance of Agrowells in the Upper Part of the Catchment

Rock Type	No. of Wells*	Average Depth (m)	Water Level (m)		Drawdown	Recovery Time (days)
			Rainy	Dry		
Charnockite	6	8.0	G.L.	3.0	0.7	1
Biotite	6	7.0	G.L.	5.0	0.5	1
Granulite	8	7.5	G.L.	6.5	1.0	2
Quartzite	3	7.0	G.L.	7.0	1.0	2

* Number of wells selected for rock type/recovery analysis
** Recovery time 100%
Note: G.L. = Ground level

ii. ***Wells in the Middle Intermediate Reaches of the Catchment Area***

About 37 percent of the agrowells studied under the present study are located in the middle part of the catchment. They can be again grouped according to rock type on which they are located. There are nineteen agrowells located on charnockite and seventeen on biotite gneiss (**Table 6.2**).

Table 6.2. Performance of Agrowells in the Middle Part of the Catchment

Rock Type	No. of Wells*	Average Depth (m)	Water Level (m)		Drawdown	Recovery Time (days)
			Rainy	Dry		
Biotite-Gneiss	17	8.0	G.L.	4.0	0.8	2
Charnockite	19	7.5	G.L.	4.0	1.2	1

* Number of wells selected for rock type/recovery analysis
** Recovery time 100%
Note: G.L. = Ground level

In the middle catchment area, water level of all the agrowells come up to ground level during the rainy season and go to 4m below during the dry season. During pumping the agrowells on charnockite rocks have shown high drawdown (1.2/h) and wells on biotite gneiss rocks have shown low drawdowns (0.8m/h). However, the farmers say 100 percent recovery in wells on biotite gneiss takes about two days (one-day in wells on charnockite rock). The above two statements are, however, contradictory to each other where the recovery in biotite gneiss based wells should be faster than that on charnockite rock. Agrowells that are very close to tanks or irrigation channels have very fast recovery rates and low drawdown.

Most of the agrowells have shown decrease in recovery rates and discharge since their construction. The agrowells very close to tanks or irrigation channels, however have not shown such decrease.

The lowering of recovery can be attributed to clogging in the aquifer surrounding the well, where the clay and other colloidal substances in suspension can slowly build-up at points of extraction, (i.e., agrowells).

iii. *Wells in the Lower Reaches of the Catchment*

About 20 percent of the agrowells visited by the team to evaluate their performance, were situated in the lower reaches of the catchment area, eight on biotite gneiss and 12 on charnockite rock (**Table 6.3**).

Table 6.3. Performance of Agrowells in the Lower Part of the Catchment

Rock Type	No. of Wells*	Average Depth (m)	Water Level (m)		Drawdown	Recovery Time (days)
			Rainy	Dry		
Biotite-Gneiss	8	8.5	G.L.	3.0	0.7	1
Charnockite	12	7.5	G.L.	4.0	0.7	1

* Number of wells selected for rock type/recovery analysis
** Recovery time 100%
Note: G.L. = Ground level

In the lower catchment area, the water level of all agrowells come up to ground level during the rainy season. During the dry season it lowers down to about 3m (average) below ground level. In wells on biotite gneiss it is 3m and on charnockite rocks it is 4m. The water level of agrowells close to tanks or irrigation channels go 1.53m below the surface during the dry season. Overburden characteristics, however, do not vary from charnockite based soil profiles to biotite gneiss based soil profiles. All agrowells on biotite gneiss and six on charnockite have gone to hard rock. When the wells of same depth, and diameter are compared for their recovery, the wells penetrating thicker overburden have shown better discharges than the wells with shallow overburden.

However, these wells have shown high drawdown and slow recovery during the dry season. Some wells close to irrigation channels recover within 6 hours. In this part of catchment (lower reaches) lining depth of the well affects the drawdown and recovery.

iv. *Wells Located below the Tanks*

About 27 percent of the visited wells are located below the tanks. The farmers, however, use both rain and tank water during the rainy season. When the tank distributes water for cultivation, agrowells are least utilized in the command areas. During the yala season when supplementary irrigation is required the farmers utilize agrowells to alleviate the water deficit for the crops. The wells dug below the tank bund have shown stabilized water table or a water table with small fluctuations (0.5m-1.2m). The water level of wells close to tanks are controlled by the water level of the tank or by the "hanging water table" (Senaratne 1996).

6.5 Allocation of Agrowells

Well Allocation Procedure

A certain number of wells have been allocated to each cascade based on different cascade environments as mentioned above. This procedure is based on several assumptions.

Assumptions

1. The underground flow is always towards the lowest area in the cascade (i.e., recommended area).

2. The recharge in the catchment area is restricted by rainfall amount, while the recharge in tank waterspread and the low-lying paddy area is restricted by underground weathered formation.

3. The recharge per average agrowell is estimated based on the following:

   * depth to water table is approx. 12 ft.
   * diameter of an agrowell is approx. 20 ft.
   * maximum depth of an agrowell is approx. 20 ft.
   * volume of water in an agrowell during dry season is pr^2

4. A 50 percent of water volume (of underground flow) is extractable keeping the environmental impacts to the minimum.

The agrowell recommendations were further distributed among tank environments based on the size of each tank in the cascade. (20 percent of agrowells to the catchment and 80 percent to the command area of the tank).

Detailed well recommendations covering a total of 50 cascades distributed across the 15 DS divisions are given in **Table 6.4.**

The recommended number of wells together with the possible number of wells for each of the 50 cascades is also included in the tables of Volume IV.

A separate set of maps of scale 1:50,000 also provides the essential information on the potential areas within each cascade suitable for agrowell location. These are shown in a separate volume.

6.6 Recommendations

The well recommendation for each cascade and for each tank environment was based on a numerical calculation with hydrological parameters. The number of wells allowed for each cascade were distributed among each tank based on the size of the tank.

The number of wells allocated for each tank was distributed to the catchment and command on 20%-80%. This was based on the current practice of the local farmers.

A total number of 3,295 agrowells can be supported by the local hydrological budget. However, some cascade (04) have already reached or exceeded their hydrological limits, where no more agrowell should be constructed.

3598 for 50 cascades

3500 x 7

24500

100 - 7000

200 - 14,000

300 - 21,000

DETAILED WELL RECOMMENDATION

NORTH CENTRAL PROVINCE OF SRI LANKA

Pages 1/8

D.S. DIVISION	CASCADES NAME	CASCADES RECOM. WELLS	CASCADES POSSIBLE WELLS 50%		NAME OF TANK	TANK AREA ha.	WELL RECOMENDATIONS TANK	WELL RECOMENDATIONS Catchment 20%	WELL RECOMENDATIONS Command 80%
01. PADAWIYA	01. NAWAGASWEWA	64	32	1	Ihala Nawagaswewa	12.50	13	3	10
				2	Mahasenpura	4.00	4	1	3
				3	Pahala Nawagaswewa	14.20	15	3	12
						30.70	32	7	25
02. KABITHIGOLLEWA	08. KUNCHUTTUWA	231	116	1	Meda wewa	7.28	8	2	6
				2	Kuda wewa	3.24	4	1	3
				3	Pincha wewa	3.24	4	1	3
				4	Kudagama	2.02	2	0	2
				5	Kolibendewa	10.12	11	2	9
				6	Minipitiya	1.21	1	0	1
				7	Galapita	2.43	3	1	2
				8	Kunchuttuwa	39.54	43	9	34
				9	Nikatuwa	1.62	2	0	2
				10	Viharagama	4.86	5	1	4
				11	Viharahalmillewa	13.76	15	3	12
				12	Dambulu wewa	2.02	2	0	2
				13	Kudahalmillawetiya	3.24	4	1	3
				14	Maha Halmille Wetiya	3.24	4	1	3
				15	Kudakadigalla	4.05	5	1	4
				16	Mahakadigalla	3.24	4	1	3
						105.11	117	24	93
	10. KOLIBENDAWEWA	130	65	1	Ralapanawa	15.38	6	1	5
				2	Damunugollewa	4.86	2	0	2
				3	Kirimetiyawa	18.62	7	1	6
				4	Kuda Udangewa wewa	1.62	1	0	1
				5	Udangawa wewa	10.52	4	1	3
				6	Kolibendewa	28.33	11	2	9
				7	Kohombagas wewa	7.69	3	1	2
				8	Tikiri Siyambalawa	5.67	2	0	2
				9	Lolugas wewa	11.33	4	1	3
				10	Timbiri wewa	12.95	5	1	4
				11	Hendagama	48.56	19	4	15
						165.53	64	12	52
	12. THAMMANNEWA	140	70	1	Meegahawewa	2.60	2	0	2
				2	Appuwewa	8.10	5	1	4
				3	Kuda Appuwewa	1.80	1	0	1
				4	Tikiri Hendewa	8.90	6	1	5
				5	Tikiri Hendewa Kuda	3.60	2	0	2
				6	Makanduragolle		0	0	0
				7	Nike wewa	7.90	5	1	4
				8	Kuda Nike wewa	4.00	3	1	2
				9	Watte wewa	30.40	20	4	16
				10	Kuda Watte wewa	23.90	16	3	13
				11	Ihala Thammannewa	4.90	3	1	2
				12	Pahala Thammenewa	9.70	6	1	5
						105.80	69	13	56
	14. USGOLLEWA	331	166	1	Siyambala wewa	6.88	20	4	16
				2	Ihala usgollewa	7.69	23	5	18
				3	Pahalausgollewa	25.89	76	15	61
				4	Pankotuwa	3.24	10	2	8
				5	Veheragala	1.62	5	1	4
				6	Palupuliyankulama	11.33	33	7	26
						56.65	167	34	133
03. MEDAWACHCHIYA	01. MAKICHCHAWA	39	20	1	Timbiriwewa	8.50	1	0	1
				2	Dutuwewa	11.30	1	0	1
				3	Etambagaswewa	37.60	3	1	2
				4	Mahameegaskaada	8.10	1	0	1
				5	Kudmeegaskada	6.50	1	0	1
				6	Mahadivulgaskada	22.70	2	0	2
				7	Kudadivulgaskada	1.60	0	0	0
				8	Palugollewa	2.40	0	0	0
				9	Puhuduwula	15.80	1	0	1
				10	Makichchawa	43.30	4	1	3
				11	Nugawewa	1.80	0	0	0
				12	Wedikkarayagewewa	2.00	0	0	0
				13	Kadawatha	3.40	0	0	0
				14	Kongollewa kudawewa	2.80	0	0	0
				15	Rathmalwetiya	2.40	0	0	0
				16	Aluth halmillewa	55.00	5	1	4
						226.40	19	3	16

Table 6.4 Recommended well distribution among different tank environments

DETAILED WELL RECOMMENDATION

NORTH CENTRAL PROVINCE OF SRI LANKA

D.S. DIVISION	CASCADES NAME	RECOM. WELLS	POSSIBLE WELLS 50%		NAME OF TANK	TANK AREA ha.	WELL RECOMENDATIONS TANK	Catchment 20%	Command 80%
03. MEDAWACHCHIYA	10. MARUTHAMADU	NOT RECOMMENDED FOR MORE WELLS							
Contd.,	23. PARANAHALMILLEWA	NOT RECOMMENDED FOR MORE WELLS							
	24. KONGOLLEWA	234	117	1	Malwila	1.00	1	0	1
				2	Diwulwewa	2.80	2	0	2
				3	Galegama	23.90	20	4	16
				4	Panwewa	1.40	1	0	1
				5	Kongollewa	23.10	20	4	16
				6	Lolugaskada	.16.60	14	3	11
				7	Kongollewa kudawewa	2.80	2	0	2
				8	Rathmalwetiya	2.60	2	0	2
				9	Aluthhalmillewa	53.80	46	9	37
				10	Kuda Indigollewa	1.40	1	0	1
				11	Indigollewa	8.10	7	1	6
						137.60	**116**	**21**	**95**
04. NUWARAGAMPALATHA CENTRAL	06. TAMMANNEWA	180	90	1	Ihala Diganagama	17.80	11	2	9
				2	Pahala Diganagama	22.70	13	3	10
				3	Ihala Madurupitiya	16.20	10	2	8
				4	Madurupitiya	8.90	5	1	4
				5	Elayapattuwa	62.70	37	7	30
				6	Weliwewa	2.60	2	0	2
				7	Midellawewa	3.40	2	0	2
				8	Ihala Tammanna Kulama	3.20	2	0	2
				9	Tammanne Kulama	5.70	3	1	2
				10	Pahala wewa	5.30	3	1	2
				11	Kudamenikkadullewewa	4.50	3	1	2
						153.00	**91**	**18**	**73**
	07. GALPOTTEGAMA	211	106	1	Ralapanawa	6.90	6	1	5
				2	Katukeliyawa	8.10	7	1	6
				3	Kurrukkankulama	23.10	20	4	16
				4	Ihala Palugaswewa	7.70	7	1	6
				5	Pahala Palugaswewa	7.10	6	1	5
				6	Hinguraggama	10.10	9	2	7
				7	Rambawela Amuna	1.80	2	0	2
				8	Gale wewa	2.60	2	0	2
				9	Walaththewa	4.70	4	1	3
				10	Galpoththegama	42.10	37	7	30
				11	Gurudiyawewa	5.30	5	1	4
						119.60	**106**	**19**	**86**
	18. GALKADAWALA	245	123	1	Ihala Halmillewa	2.00	2	0	2
				2	Pahala Halmillewa	4.50	4	1	3
				3	Kerambage	13.80	12	2	10
				4	Ihala kuda wewa	3.20	3	1	2
				5	Pahala Kuda wewa	1.60	1	0	1
				6	Paresangale wewa	8.90	8	2	6
				7	Meda wewa	5.70	5	1	4
				8	Ihal Indukketiyawa	4.50	4	1	3
				9	Galkadawala	76.10	66	13	53
				10	Panekkewa	1.40	1	0	1
				11	Kadugama	0.80	1	0	1
				12	Ihala Halmille Kulama	1.00	1	0	1
				13	Nindagama	1.80	2	0	2
				14	Pahala Halmillewa	3.60	3	1	2
				15	Wane wewa	2.40	2	0	2
				16	Ihala Demata wewa	0.90	1	0	1
				17	Pahala Demata wewa	1.20	1	0	1
				18	Ihala Thalakola wewa	1.00	1	0	1
				19	Thalakola wewa	4.00	4	1	3
				20	Ihala Lolugas wewa	0.80	1	0	1
				21	Lolugas wewa	2.00	2	0	2
				22	Heenuk wewa	0.80	1	0	1
						142.00	**126**	**23**	**103**

Table 6.4 Recommended well distribution among different tank environments

DETAILED WELL RECOMMENDATION

NORTH CENTRAL PROVINCE OF SRI LANKA

D.S. DIVISION	CASCADES NAME	RECOM. WELLS	POSSIBLE WELLS 50%		NAME OF TANK	TANK AREA ha.	WELL RECOMENDATIONS TANK	Catchment 20%	Command 80%
04. NUWARAGAMPALATHA CENTRAL Contd.,	22. BELLANKADAWALA	199	100	1	Ihalakudawewa	9.88	3	1	2
				2	Kudagama	11.12	3	1	2
				3	Tammannewa	36.06	9	2	7
				4	Galkulama	9.88	3	1	2
				5	Gambirigswewa	93.86	24	5	19
				6	Bandiyawewa	5.93	2	0	2
				7	Kudagambirigaswewa	7.90	2	0	2
				8	Kudabellankadawala	9.88	3	1	2
				9	Bellankadawala	89.91	23	5	18
				10	Siyambalawa	27.91	7	1	6
				11	Kuda Tammannewa	16.06	4	1	3
				12	Kadahathgama	21.98	6	1	5
				13	Diwulwewa	51.87	13	3	10
						392.24	**102**	**22**	**80**
05. MAHA WILACHCHIYA	03. DUNUMADALEWA	216	108	1	Siwalapitiya	39.66	50	10	40
				2	Palugama	6.48	8	2	6
				3	Ihalawewa	7.28	9	2	7
				4	Kadurupitiya	31.97	40	8	32
						85.39	**107**	**22**	**85**
	12. SANDAMAL ELIYA	NOT RECOMMENDED FOR MORE WELLS							
07. RAJANGANA	01 IHALA THAMMENNAWA	215	108	1	Viharagodellewewa	7.30	34	7	27
				2	Puhudiwulwewa	5.30	25	5	20
				3	IhalaTammannewa	10.50	49	10	39
						23.10	**108**	**22**	**86**
10. NUWARAGAMPALATHA EAST	05. KUDAKALATHTHEWA	163	82	1	Kudasattambikulama	2.20	3	1	2
				2	Sattambikulama	2.00	3	1	2
				3	Teriyankulama	16.20	21	4	17
				4	Palugaswewa	4.00	5	1	4
				5	Nelunkanniya	20.20	26	5	21
				6	Halmillewa	2.20	3	1	2
				7	Kudakalaththewa	16.20	21	4	17
						63.00	**82**	**17**	**65**
11. MIHINTALE	01, UKKULANKULAMA	203	102	1	Pudukkulama	10.10	15	3	12
				2	Konwewa	6.50	10	2	8
				3	Tammannewa	3.60	6	1	5
				4	Ukkulankulama	21.40	33	7	26
				5	Siyambalawewa	2.00	3	1	2
				6	Kudagamawewa	2.80	4	1	3
				7	Sangilikulama	20.20	31	6	25
						66.60	**102**	**21**	**81**
	08. MAHAKIRINDEGAMA	181	91	1	Wellamorana	13.00	9	2	7
				2	Ethapitiyawa	4.90	3	1	2
				3	Katukeliyawa	17.80	12	2	10
				4	Kudakirindegama	10.50	7	1	6
				5	Elappankulama	8.90	6	1	5
				6	Siyambalagaswewa	6.10	4	1	3
				7	Katupotha	39.10	26	5	21
				8	Humbasbendawewa	7.30	5	1	4
				9	Mahakirindegama	30.80	20	4	16
						138.40	**92**	**18**	**74**
	10. KATUPOTHA	331	166	1	Ihala Kidapolagama	4.50	6	1	5
				2	Pahala Kidapolagama	6.90	10	2	8
				3	Galatabendawewa	2.60	4	1	3
				4	Mugappalliya	5.30	8	2	6
				5	Ginigalwewa	2.60	4	1	3
				6	Maradankalla	31.60	45	9	36
				7	Elapathwewa	2.80	4	1	3
				8	Mannakkulama	11.30	16	3	13
				9	Kadirikkulama	42.10	60	12	48
				10	Gal Kulama	2.80	4	1	3
				11	Punchi Kulama	3.60	5	1	4
						116.10	**166**	**34**	**132**

Table 6.4 Recommended well distribution among different tank environments

DETAILED WELL RECOMMENDATION

NORTH CENTRAL PROVINCE OF SRI LANKA

D.S. DIVISION	CASCADES NAME	RECOM. WELLS	POSSIBLE WELLS 50%		NAME OF TANK	TANK AREA ha.	WELL RECOMENDATIONS TANK	Catchment 20%	Command 80%
11. MIHINTALE Contd.,	11. MANKULAMA	140	70	1	Kahapathwilagama	14.60	9	2	7
				2	Kahapathwila pahala	5.30	3	1	2
				3	Kudanochchikulama	6.50	4	1	3
				4	Mankulama	15.80	10	2	8
				5	Kapapuwewa	14.60	9	2	7
				6	Pallankulama	8.90	5	1	4
				7	Mudirippuwewa	16.20	10	2	8
				8	Mahanochchikulama	26.30	16	3	13
				9	Sooppugala	6.50	4	1	3
						114.70	**70**	**15**	**55**
	12. MAHARAMBEWA	230	115	1	Wewahenawewa	1.42	1	0	1
				2	Elapathwewa	1.32	1	0	1
				3	Dematawewa	13.35	11	2	9
				4	Katukeliyawa	14.54	12	2	10
				5	Karuwalagaswewa	2.43	2	0	2
				6	Ihalahinguruwewa	12.55	11	2	9
				7	Kirimetiyawa	2.43	2	0	2
				8	Maharambewa	16.99	14	3	11
				9	Nikawewa	4.45	4	1	3
				10	Kittambugama	21.85	18	4	14
				11	Bogahawewa	2.02	2	0	2
				12	Kaletirappane	42.89	36	7	29
						136.24	**114**	**21**	**93**
12. RAMBEWA	10. KAPIRIKGAMA	204	102	1	Mailagammana wewa	7.30	3	1	2
				2	Palugonamariawa	6.50	3	1	2
				3	Kona Kumbuk wewa	19.40	8	2	6
				4	Puliyankulama	2.40	1	0	1
				5	Maha Kadiyawa	4.90	2	0	2
				6	Kuda Kadiyawa	2.40	1	0	1
				7	Peenagama	21.90	9	2	7
				8	Kuda Peenagama	4.90	2	0	2
				9	Aluketiwala	10.50	4	1	3
				10	Aluth wewa	19.40	8	2	6
				11	Kohombagaswewa	6.50	3	1	2
				12	Galkadawala	24.30	9	2	7
				13	Karuwalagas wewa	3.20	1	0	1
				14	Messalewa	21.00	8	2	6
				15	Kapiriggama	92.30	36	7	29
				16	Penikewewa	12.90	5	1	4
				17	Andarawewa	4.00	2	0	0
						263.80	**105**	**22**	**81**
	11. PIHIMBIYAGOLLEWA	NOT RECOMMENDED FOR MORE WELLS							
	14. KENDAWA	207	104	1	Weddewawewa	5.67	5	1	4
				2	Kendewa	31.56	29	6	23
				3	Kendewa kudawewa	6.07	6	1	5
				4	Diwulgahawewa	2.43	2	0	2
				5	Poradutugama	4.05	4	1	3
				6	Kudawewa	2.43	2	0	2
				7	Ehetuwegama	8.90	8	2	6
				8	Siyambalagaswewa	48.56	45	9	36
				9	Aluthwewa	3.04	3	1	2
						112.71	**104**	**21**	**83**

Table 6.4 Recommended well distribution among different tank environments

DETAILED WELL RECOMMENDATION

NORTH CENTRAL PROVINCE OF SRI LANKA

D.S. DIVISION	CASCADES: NAME	CASCADES: RECOM. WELLS	CASCADES: POSSIBLE WELLS 50%		NAME OF TANK	TANK AREA ha.	WELL RECOMENDATIONS: TANK	Catchment 20%	Command 80%
13. KAHATAGASDIGILIYA	04. HAMILLEWA	35	18	1	Mahakulumwakkada	16.99	1	0	1
				2	Ihalakanhindigama	8.70	1	0	1
				3	Pahalakanhindigama	12.55	1	0	1
				4	Konwewa	1.42	0	0	0
				5	Panbattiya	5.87	0	0	0
				6	Ambagahawewa	7.69	0	0	0
				7	Nikawewa	4.45	0	0	0
				8	Kaluwaragaswewa	1.42	0	0	0
				9	Madayakade	2.23	0	0	0
				10	Amunuwettiya	9.51	1	0	1
				11	Rambewewa	3.64	0	0	0
				12	Thalgahapothana	23.27	1	0	1
				13	Ulpathwewa	3.03	0	0	0
				14	Kuda Galkandegama	7.65	0	0	0
				15	Galkandegama	4.05	0	0	0
				16	Ihalahalmillewa	13.35	1	0	1
				17	Weliwewa	5.06	0	0	0
				18	Aluthwewa	3.84	0	0	0
				19	Dachchihalmillewa	27.11	2	0	2
				20	Pahalawewa	3.04	0	0	0
				21	Mahahamillewa	67.58	4	1	3
				22	Kudahettiwewa	5.67	0	0	0
				23	Hettiyawa	8.49	1	0	1
				24	Kirihapuwewa	2.43	0	0	0
				25	Wirangollewa	10.52	1	0	1
				26	Weliwewa	2.43	0	0	0
				27	Diyamillagaswewa	38.44	2	0	2
				28	Welanawewa	8.90	1	0	1
						309.33	17	1	16
	06. RANPATHWILA	NOT RECOMMENDED FOR MORE WELLS							
	10. GANGUREWA	NOT RECOMMENDED FOR MORE WELLS							
	11. MAHAKIRIMETIYAWA	78	39	1	Nikawewa	16.62	5	1	4
				2	Meegaswewa	6.07	2	0	2
				3	Nikakatuwewa	2.43	1	0	1
				4	Palugahagodawala	1.42	0	0	0
				5	Dahanekawewa	31.97	9	2	7
				6	Katorewa	3.24	1	0	1
				7	Dikwewa	2.83	1	0	1
				8	Wessiyaddewawewa	7.69	2	0	2
				9	Mukariyawa	21.85	6	1	5
				10	Kirimetikonwewa	9.31	3	1	2
				11	Rambewala	0.61	0	0	0
				12	Timbiriwewa	1.21	0	0	0
				13	Mahaweligollewa	4.45	1	0	1
				14	Kudaweligollewa	3.24	1	0	1
				15	Puliyankulama	1.21	0	0	0
				16	Mahakirimetiyawa	26.71	7	1	6
				17	Kiralegala Tottame	1.21	0	0	0
						144.07	39	6	33
	16. PANDARELLEWA	75	38	1	Kirimetiyawa	9.31	1	0	1
				2	Tharanagollewa	5.67	1	0	1
				3	Timbiriwewa	14.16	2	0	2
				4	Kumbukwewa	28.33	4	1	3
				5	Kayangollewa	0.91	0	0	0
				6	Talakoa wewa	8.90	1	0	1
				7	Pandithayawewa	4.76	1	0	1
				8	Palugaswewa	2.83	0	0	0
				9	Miminnawala	27.11	4	1	3
				10	Ambagahawewa	15.38	2	0	2
				11	Kurinnamkulama	5.67	1	0	1
				12	Aluthwewa	18.21	3	1	2
				13	Ihalagama	6.47	1	0	1
				14	Madurugoda	2.83	0	0	0
				15	Panwella	45.32	7	1	6
				16	Pandarellewakuda	2.02	0	0	0
				17	Pandarellewa	44.92	7	1	6
				18	Viharawewa	2.02	0	0	0
				19	Rathmalgaha	6.07	1	0	1
				20	KudaRathamagaha	1.21	0	0	0
						252.10	36	5	31

Table 6.4 Recommended well distribution among different tank environments

DETAILED WELL RECOMMENDATION

NORTH CENTRAL PROVINCE OF SRI LANKA

D.S. DIVISION	CASCADES NAME	CASCADES RECOM. WELLS	CASCADES POSSIBLE WELLS 50%		NAME OF TANK	TANK AREA ha.	WELL RECOMENDATIONS TANK	Catchment 20%	Command 80%
13. KAHATAGASDIGILIYA Contd.	18. NELLUGOLLEKADA	144	72	1	Kurunduwewa	5.90	2	0	2
				2	Kurundugaswewa	9.30	3	1	2
				3	Weddewewa	1.60	1	0	1
				4	Ihalagama	5.30	2	0	2
				5	Kumbukgollewa	30.20	10	2	8
				6	Kodinnewa	12.10	4	1	3
				7	Digatipotana	27.90	9	2	7
				8	Nelugollakada	36.40	12	2	10
				9	Eswahawedunwewa	6.10	2	0	2
				10	Moragoda	9.30	3	1	2
				11	Wahagapuwewa	54.20	18	4	14
				12	Kudawewa	5.70	2	0	2
				13	Kendagaswewa	3.60	1	0	1
				14	Galgewewa	3.60	1	0	1
				15	Kayangollewa	5.90	2	0	2
						217.10	**72**	**13**	**59**
14. HOROWPATHANA	03. DUTUWEWA	233	117	1	Kirikongollewa	3.20	2	0	2
				2	Atuannawa	10.50	7	1	6
				3	Ambagaswewa	61.50	40	8	32
				4	Dikwewa	7.30	5	1	4
				5	Dutuwewa	79.30	51	10	41
				6	Palugaswewa	19.40	13	3	10
						181.20	**118**	**23**	**95**
	14. PULIYANKADAWALA	141	71	1	Siyambelawa	7.90	1	0	1
				2	Ulpath wewa	29.89	5	1	4
				3	Kongasyaya	3.95	1	0	1
				4	Kimbulpitiyawa	69.90	11	2	9
				5	Wassallagama	9.88	2	0	2
				6	Palugas wewa	5.93	1	0	1
				7	Timbiri wewa	4.94	1	0	1
				8	Welan wewa	5.93	1	0	1
				9	Ramba wewa	11.12	2	0	2
				10	Muwapenna wewa	17.04	3	1	2
				11	Aluthgama	2.96	1	0	1
				12	Mekonda	100.04	16	3	13
				13	Kanhindewa	76.08	12	2	10
				14	Puliyankada Ramba	7.90	1	0	1
				15	Puliyankadawla	54.09	9	2	7
				16	Galhiriyawa	6.92	1	0	1
				17	Kendabe wewa	33.10	5	1	4
						447.67	**73**	**12**	**61**
	19. DEMETAWEWA	76	38	1	Nitulgollewa	24.95	3	1	2
				2	Bellankadawala	27.91	3	1	2
				3	Marandamadua	41.99	5	1	4
				4	Ihala Halmillegala	28.90	4	1	3
				5	Pahala Halmillegala	23.96	3	1	2
				6	Ihala Demata wewa	12.10	2	0	2
				7	Demata wewa	58.05	7	1	6
				8	Panuwannagama	25.94	3	1	2
				9	Ihala Hapitiyagama	17.04	2	0	2
				10	Pahala Hapitiyagama	49.89	6	1	5
						310.73	**38**	**8**	**30**
	21. DIYATITHTHAWEWA	182	91	1	Talapth Kulama	57.06	15	3	12
				2	Diyatiththwewa	30.88	8	2	6
				3	Amunuwetiya	9.88	3	1	2
				4	Angunachchiya	91.88	24	5	19
				5	Katupothana	30.88	8	2	6
				6	Pandithayagame	9.88	3	1	2
				7	Bandara Kumbukwewa	41.00	11	2	9
				8	Welahiddakudawewa	11.12	3	1	2
				9	Walahiddawewa	66.94	17	3	14
						349.52	**92**	**20**	**72**

Table 6.4 Recommended well distribution among different tank environments

DETAILED WELL RECOMMENDATION

NORTH CENTRAL PROVINCE OF SRI LANKA

D.S. DIVISION	CASCADES NAME	RECOM. WELLS	POSSIBLE WELLS 50%		NAME OF TANK	TANK AREA ha.	WELL RECOMENDATIONS TANK	Catchment 20%	Command 80%
15. GALENBINDUNU WEWA	04. ICHCHANKULAMA	291	146	1	Ihala Kainattama	25.89	34	7	27
				2	Tenkuttiyawewa	5.26	7	1	6
				3	Ketakelewa	1.42	2	0	2
				4	Kudawewa	2.02	3	1	2
				5	Mawathawewa	3.24	4	1	3
				6	Pahala Kainattame	32.40	43	9	34
				7	Kudawewa	1.32	2	0	2
				8	Amunewewa	2.43	3	1	2
				9	Palugaswewa	0.91	1	0	1
				10	Karakolawewa	14.57	19	4	15
				11	Ichchankulama	19.42	26	5	21
				12	Pahala Kudawewa	1.62	2	0	2
						110.60	146	28	117
	05. HIMBUTUGOLLEWA	NOT RECOMMENDED FOR MORE WELLS							
	10. SIVALAKULAMA	119	60	1	Batalawewa	6.07	2	0	2
				2	Ihalaaliyawetunuwewa	9.71	3	1	2
				3	Pahalaaliyawetunu	7.28	2	0	2
				4	Palugollewa	25.01	7	1	6
				5	Weragala	1.62	0	0	0
				6	Aluthwewa	2.83	1	0	1
				7	Muriyakadawala	32.37	8	2	6
				8	Ihala Punchikulama	4.85	1	0	1
				9	Sembige wewa	3.24	1	0	1
				10	Rambewewa	4.86	1	0	1
				11	Wembuwewa	15.78	4	1	3
				12	Kudawembukulam	2.43	1	0	1
				13	Mahagalkulam	1.62	0	0	0
				14	Thamarakulama	36.42	9	2	7
				15	Aruccuwewa	5.67	2	0	2
				16	Kuratiyawewa	1.21	0	0	0
				17	Aralu	18.62	5	1	4
				18	Sivalakulama	32.37	8	2	6
				19	Ihalagalwaduwagama	0.41	0	0	0
				20	Pahalagalwaduwagama	12.94	3	1	2
				21	Pussellagama	4.45	1	0	1
						229.76	59	11	48
	11. KARUWALAGASWEWA	302	151	1	Indiwewa	2.93	15	3	12
				2	Ihalakaluwaragaswewa	6.47	32	6	26
				3	Pahalakaluwaragas	3.24	16	3	13
				4	Rambawala	3.24	16	3	13
				5	Ihalagalkulama	2.83	14	3	11
				6	Karambegama	11.44	57	11	46
	13. THAMMENNAWA	NOT RECOMMENDED FOR MORE WELLS				30.15	150	29	121
	17. DIWULWEWA	134	67	1	Kawarakkulama	2.02	1	0	1
				2	Pansalwewa	1.42	1	0	1
				3	Dambaulpatha	2.33	1	0	1
				4	Nelunwewa	7.28	3	1	2
				5	Kumbukwewa	2.23	1	0	1
				6	Belikuluma	5.26	2	0	2
				7	Grandiulpotha	3.64	1	0	1
				8	Kurinnankulama	3.87	1	0	1
				9	Tammannawaulpatha	3.44	1	0	1
				10	Ihalanithulgollewa	2.23	1	0	1
				11	Pahalanithulgollewa	7.69	3	1	2
				12	Diwulwewa	151.75	52	10	42
				13	Samagiwewa	1.52	1	0	1
				14	Meegaswewa	1.92	1	0	1
						196.60	70	12	58
16. THIRAPPANE	04. MAHAKANAMULLA	NOT RECOMMENDED FOR MORE WELLS							
	06. ULAGALLA	NOT RECOMMENDED FOR MORE WELLS							

Table 6.4 Recommended well distribution among different tank environments

DETAILED WELL RECOMMENDATION

NORTH CENTRAL PROVINCE OF SRI LANKA

D.S. DIVISION	CASCADES: NAME	CASCADES: RECOM. WELLS	CASCADES: POSSIBLE WELLS 50%		NAME OF TANK	TANK AREA ha.	WELL RECOMMENDATIONS: TANK	WELL RECOMMENDATIONS: Catchment 20%	WELL RECOMMENDATIONS: Command 80%
16. THIRAPPANE Contd.,	08. PAHALA AMBATALE	193	97	1	Madugahawewa	16.06	11	2	9
				2	Siyambalawewa	3.95	3	1	2
				3	Timbiriwewa	2.96	2	0	2
				4	Alagollewa	24.95	17	3	14
				5	Pandithwewa	15.07	10	2	8
				6	Ihala Ambatale	18.03	12	2	10
				7	Pahala Ambatale	50.88	34	7	27
				8	Kudawewa	7.90	5	1	4
				9	Wirandagollewa	4.94	3	1	2
						144.74	**97**	**19**	**78**
	16. WANNANKULAMA	226	113	1	Ihalasiyambalawa	8.40	8	2	6
				2	Siyambalawa	27.91	28	6	22
				3	Uttimaduwa	21.80	22	4	18
				4	Berandiyagama	2.96	3	1	2
				5	Konwewa	18.03	18	4	14
				6	Wannankulama	31.86	32	6	26
				7	Nikaawewa	3.46	3	1	2
						114.42	**114**	**24**	**90**
17. PALUGASWEWA	01. MAHADIWULWEWA	147	74	1	Kumbukkadawala	2.80	2	0	2
				2	Ulpothwewa	2.40	2	0	2
				3	Pangurugaaswewa	4.90	3	1	2
				4	Maha Divwulwewa	78.90	48	10	38
				5	Indigas wewa	4.90	3	1	2
				6	Konwewa	19.60	12	2	10
				7	Kudakonwewa	6.50	4	1	3
						120.00	**74**	**15**	**59**
	08. PALUGASWEWA	228	114	1	Palugaswewa	24.70	8	2	6
				2	Elapathwewa	9.70	3	1	2
				3	Yakhandagaswewa	11.70	4	1	3
				4	Maha Borupanwila	10.90	4	1	3
				5	Diyamalan wewa	6.10	2	0	2
				6	Borupanwilawewa	6.70	2	0	2
				7	Kudalugaswewa	5.30	2	0	2
				8	Udakadawalawewa	45.70	15	3	12
				9	Kapugama	3.20	1	0	1
				10	Dumbullagala	2.40	1	0	1
				11	Thalakolawewa	2.80	1	0	1
				12	Horiwilawewa	218.50	72	14	58
						347.70	**115**	**22**	**93**
	10. WERAGALA	225	113	1	Weragala	23.96	21	4	17
				2	Rota wewa	20.01	17	3	14
				3	Indipitiya	6.92	6	1	5
				4	Haba Diwul wewa	41.00	35	7	28
				5	Gambirigas wewa	6.92	6	1	5
				6	Ihala wewa	7.90	7	1	6
				7	Eppawala wewa	16.06	14	3	11
				8	Milla Ulpothawewa	8.89	8	2	6
						131.66	**114**	**22**	**92**
21. PALAGALA	02. HAMMILLEWA	219	110	1	Wadugewewa	1.82	3	1	2
				2	Aliyamalgala	2.83	5	1	4
				3	Siyambalawewa	3.24	6	1	5
				4	Wedinigama	2.83	5	1	4
				5	Halmillewa	11.33	20	4	16
				6	Ihalabamunugama	8.90	16	3	13
				7	Karawilagala	13.76	25	5	20
				8	Galketiyagama	6.47	12	2	10
				9	Pahalabamunugama	2.43	4	1	3
				10	Kudahettiyagama	1.62	3	1	2
				11	Mirihanpitiya	3.64	7	1	6
				12	Mahahettigama	2.43	4	1	3
						61.30	**110**	**22**	**88**
	03. MEEGASWEWA	NOT RECOMMENDED FOR MORE WELLS							

Table 6.4 Recommended well distribution among different tank environments

Where still more agrowells can be allowed, the following procedure is recommended to locate them for sustainable utilization of groundwater.

1. Select only areas well within the recommended areas (see maps).

2. Do not allow to exceed the recommended number of agrowells for each catchment and command for each tank.

3. Advice farmers to adjust themselves (i.e., pumping of water) for the recovery characteristics of their wells in order to maintain a balance.

4. Educate the farmers to utilize the maximum benefit of the sap rock (fractured rock) where water flow is more than in the clayey soil. To penetrate the sap rock a depth of 12-20 ft has to be excavated (in few instances 25-30 ft).

Chapter 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 Significant Output

Out of the total of 310 cascades present in the Anuradhapura District, 239 are found to occur within the 15 Divisional Secretarial divisions that were considered in this study.

The total area of each cascade, the number of tanks occurring within each cascade and the water spread area of all the tanks as well as the total command area under each tank were computed in order to characterize each cascade. By adopting well tested selection criteria a total of 96 promising cascades were initially selected from this 239. This phase was a desk study which made use of the field correlations that were established in the earlier IFAD and ADB studies.

These initially selected 96 cascades were then subjected to an intensive four step field study by an interdisciplinary Field Study Team (FST) which received guidance from a senior irrigation specialist, a soil-environment specialist and a water resource engineer as well as relevant directions from the study advisory group. The four step process followed in this field study is as follows:

Step 1. Basic data collection of 96 cascades.

Step 2. Selection of 96 cascades out of the preliminary 104.

Step 3. Participatory Rural Appraisal (PRA) in each of the 96 cascades in order to explore farmer knowledge and wisdom for framing rehabilitation projects.

Step 4. Visits to tanks by Technical Officers in order to verify the technical feasibility of the proposals suggested at the PRA sessions.

The database on 96 out of the 310 cascades of the district provided very valuable information in respect of hydrological characteristics, agricultural data on cropping intensity of the individual cascades as well as basic socio-economic data on families and landholding patterns. It also provided a very good testing ground for the PRA methodology that could be used in future for land and water resources development planning.

Further intensive studies on the 96 selected cascades have resulted in the production of a set of 96 cascade maps at a scale of 1:25,000 which shows the essential information in respect of more than 1000 individual tanks that are situated within these 96 cascades.

The next important phase of this study was that of selection of tanks within a cascade for purposes of rehabilitation. A set of concepts, criteria, indicators, variables and guidelines were developed for purposes of selection of tanks. A four step process as shown below was employed in the methodology used.

Step 1. Categorize the cascade in terms of its hydrological endowment. (Water surplusness)

Step 2. Evaluate each individual tank in the cascade to identify the potential of those tanks that would benefit from repair and improvement, using both resource and tank capacity criteria.

Step 3. Compare the farmers' repair and improvement proposals for the cascade and individual tanks with the potential for benefitting through the guidelines developed to select a tank for rehabilitation and to arrive at a set of repair and improvement proposals.

Step 4. Determine the level of investment recommended for each tank repairs and improvements proposal.

The variables used, factors and indices/indicators, criteria and guidelines and evaluation of variables for each step has been further explained and elaborated in Chapter 5. Prioritizing the type of rehabilitation component based on hydrological adequacy of tank and tank selection has been given special emphasis in the foregoing steps.

The most significant output from this component of the study has been the development of a hydrological simulation model for analyzing the overall hydrology of any given cascade by making use of a set of input parameters. By application of this model it has been possible to produce a detailed annual and seasonal water balance of more than 1000 tanks located within 96 cascades. Based on the subsequent analysis it has been possible to give priority to 647 tanks for funding for rehabilitation under the Participatory Rural Development Project (PRDP) of the North Central Province (NCP).

For the first time a systematic hydrologeological study was conducted on the cascade systems of the Anuradhapura District. This study was able to shed light on the real potential of shallow groundwater which could be used from agro-wells. It was possible to delineate the areas of potential groundwater within a cascade and also the density of agro-wells that could be safely permitted within the hydrological boundaries of a cascade. This could be considered a long overdue study in view of the indiscriminate expansion of agro-well development that has taken place over the last fifteen years. We now have an objective basis for both location and distribution of agro-wells within the cascade.

7.2 Desilting of Tanks

For virtually every tank, farmers requested desilting. Desilting of tanks however, is controversial. The Irrigation Department firmly believes that it is a waste of development funds, i.e. that the benefits are not worth the costs. For this reason, it has been forbidden in the National Irrigation Rehabilitation Project.

There is a clear difference of opinion between these irrigation professionals and the farmers. Note that the farmers do not back their opinion by carrying out their own desilting work.

There is a clear need to explore this issue. Two methods should be tried. First, a careful economic study of the costs and benefits of tank desilting should be carried out. Second, tank desilting could be negotiated with farmers to see whether they are willing to make significant investments in it. That is, the project might cover only half the cost by providing equipment or food.

7.3 Cascade Planning and Institutional Development

The data developed in this study provides the basis for integrated cascade water resources development. Integrated cascade water resources development should provide the maximum benefits possible. Ideally, cascade water resources development should also be integrated with other development efforts supported by the PRDP, particularly with agricultural and infrastructural development efforts. Doing so, however, will require an **integrated cascade development planning effort.**

An integrated cascade planning effort should include two aspects. First the implementors responsible for each component should sit together, review the information on each cascade to see what efforts are possible.

More importantly, serious effort should be made to bring the stakeholders of each cascade into the planning effort. This will require:

* Publizing the help available through the PRDP.

* Meeting with the beneficiaries preferably through PRA type joint planning sessions, to discuss the best use of project resources in their cascade.

* Organizing the necessary supravillage institutions to deal with cascade level and other supravillage activities.

The last mentioned work can be carried out by the social mobilizers. However, definition of the needs must be carried out jointly with the beneficiaries.

One immediate need in most cascades will be for development of an institutions - probably an intervillage council - to deal with cascade level water management issues. Another need, this time at village level in most places, is devising rules and enforcement mechanisms to control ground water use.

Realizing the full benefits of cascade level work requires further institutional development among the beneficiaries as well as integrated cascade level project planning and implementation.

7.4 Major Recommendations

Arising from the findings of this study, the following ten recommendations are proposed:

01. Steps should be taken to have the data base on the 96 cascades that were comprehensively studied and submitted to the PRDP office, made available in a durable readily accessible form for use over the next seven year period.

02. Although **Figure 2.1** shown in Chapter 2 shows that the finally selected 96 cascades are uniformly distributed across the fifteen DS divisions, there could be certain other compelling considerations that would necessitate a further examination of the remaining (240 - 96 = 144) cascades in a less stringent manner. It would, therefore, be prudent to expand the present data base to cover these remaining 144 cascades with a view to being able to respond quickly to any legitimate requests that arise from the people inhabiting such cascade areas in the future.

03. The knowledge and understandings of the project implementors, especially those officials of the Department of Agrarian Services (DAS), DS office and the social mobilizers (SM) should be improved in regard to the proposed strategies for rehabilitation. Short training classes would help to achieve this objective.

04. The SMs should be provided with a list of proposals that have been suggested for the rehabilitation of the cascades since this would provide them the basis for conducting the detailed beneficiary consultation process. Also, the SMs should take steps to carry out the community organization process prior to the commencement of the construction work.

05. Since the cascade-based rehabilitation approach has up to now not been implemented under any of the previous projects in the NCP, it would be appropriate to select about three individual cascades for integrated cascade planning and detailed monitoring of the process in order to further refine and improve the proposed methodology. IIMI could provide a selective and meaningful input to this monitoring study.

06. Since the methodology that has been outlined for the final step of selection of tanks within a cascade is rather involved and somewhat specialized in nature than the preceding steps, some institutional mechanism should be devised for a gradual take over of some of the more readily implementable steps of this process by the technical staff of the PRDP office. This would help to end reliance on IIMI resources in conducting the future studies on tanks within a cascade. It would also be logical in future for IIMI only to help the PRDP office to build up its own skills. IIMI could, maintain a continuing relationship with the staff of the PRDP office throughout the period of project implementation. In the final analysis, the technical staff of the PRDP office should build up their own self-reliance in a manner that there would be no undue dependance on IIMI services, except in a few selected specialized areas.

07. It is extremely important to ensure that future agro-well development be completely guided by the proposals set out in the Chapter 6 on potential for groundwater development. Since in some cascades the present dugwell development is almost exceeding the available groundwater potential, extreme caution should be exercised in any further expansion.

It should also be very useful to explore the reasons for the very low density of existing agrowells within some cascades and the constraints that exist for further development.

08. There will be a need for development of institutions suitable for integrated water resources management within the cascades. The institutions needed will include those for regulation of groundwater use and those for cascade level water management. Special attention must be given to this institutional development by the project.

09. At the provincial level the following recommendations are proposed:

* The maps and rehabilitation proposals developed for the 96 cascades to be kept at the Divisional Secretaries offices, (i.e., the DAS and the ID). These maps and proposals will be useful for future planning.

* The set of maps prepared for groundwater development for the first 50 cascades should also be kept at the DAS office so that they could monitor the agrowell development program under the PRDP. The recommendations relating to the 50 cascades may be useful for future groundwater development projects.

* It is recommended to conduct similar groundwater studies in the rest of the cascades in NCP. Although this may not be possible under the PRDP due to financial constraints, priority should be given to such a study in the future projects.

* The provincial level authority may seek legal provisions to implement groundwater development proposals made by the IIMI study.

10. At the PRDP level the following recommendations are proposed:

    * The PRDP office may arrange a series of awareness program at DS level to enhance the understanding of field level implementors about the significance of cascade based rehabilitation program.

    * The capacity of social mobilizers should be improved to educate the community to understand the validity of cascade based rehabilitation and thereby increase their active participation in rehabilitation activities and to carry out cascade level institutional development.

    * PRDP under its institutional strengthening program should attempt to explore the possibilities of federating farmers at cascade level for water management and for other development purposes.

11. Among the hydrological studies it is recommended that:

    * Since this study focussed on only 96 cascades, similar data sheets should be prepared covering rest of the cascades present in the NCP. Such information would be desirable for planning programs in the future.

    * The hydrological simulation model be further improved and field tested and calibrated using field measured input data. A field research study designed to collect and compare the field collected data with the simulated data by the model would be desirable for this task. One or two cascades may be selected for this purpose.

    * Criteria and norms for evaluating tanks and cascades presented in this study are applicable only to the specific study setting, i.e., the Anuradhapura district of the North Central Province. Similar norms and guidelines should be developed for the other parts of the country, e.g., the Kurunegala dry zone, following the approach presented here.

7.5 Further Studies Recommended

1 Rather than attempting further refinements to the proposed methodology for both cascade selection and individual tank selection for rehabilitation, it would be more in place to streamline the present process by retaining the main essentials and eliminating the marginal components. This would require a special short term study of three months duration carried out collaboratively between IIMI staff and PRDP staff.

2 As previously indicated a detailed study and monitoring of the rehabilitation process in three selected cascades would help to both refine the present process and also cull out those non-essentials with a view to making the whole process more functional and practical.

3 The issue of the economic advantages that would result from the desiltation of tanks was keenly debated at the final workshop held on 24 August. Since no clear finality could be reached on this issue, it is recommended that this be taken up as a special study during the oncoming implementation phase of the project, and a resolution of this important issue be made within the first two years of implementation, so that the final outcome of this study could be incorporated in the subsequent rehabilitation strategies.

4 The main focus of future studies should be on the on-going implementation process, because it is here that the critical problems and issues are likely to arise. These could not have been predicted or anticipated at this stage, and sufficient leeway should be made in order to explore and address such unpredictable and unforeseen concerns. Since it is not possible at this stage to identify or predict what these would be, it would, in the long term be extremely useful to make some provision for socio-technical investigations to be conducted in a collaborative manner between the IIMI and the PRDP staff over the initial six months of the project implementation phase.

Annex 7.1

Minutes of the Workshop held on 4th January 1997

Introduction

The IIMI study team after meeting with IFAD mission in 18 October, 1996, had undertaken several measurers to complete the cascade identification study with close association of line agencies. The measurers included, i) meeting with study reference group which consists of heads of relevant line agencies ii) interaction with field staff working in each divisional secretariat divisions, iii) frequent informal interactions with officers of RPDP office and iv) finally conducting a workshop with the participation of representatives from relevant line agencies. A workshop (cited under item iv) was held at Mahailluppallama on 4 January 1997. More than 30 participants from line agencies including farmer representatives attended the workshop (Annex). The whole proceedings were conducted in Sinhala language. This annex provides the jist of discussion took place in that workshop. Apart from the above measurers, IIMI study team sociologist presented the results of cascade identification study at a training workshop organized by the Department of Agrarian Services (DAS) in Anuradhapura. Most of the field staff of DAS attended this workshop.

Objective of the Workshop

The main objective was to provide to the line agency personnel better understanding on how to use data, information and findings of IIMI-cascade study for implementation activities. In addition to this main objective, the workshop would provide opportunity to understand from three implementation agencies about constraints and problems to be faced by them in implementing the cascade approach suggested by the IIMI study. The workshop would provide opportunities not only to implementing agencies but also to three farmer representatives to express their views on participatory irrigation rehabilitation activities.

To achieve the objectives mentioned above, representatives from Central Irrigation Department (CID), Provincial Irrigation Department (PID), Department of Agrarian Services (DAS) and farmer representatives were invited. Technical staff who are directly involved in irrigation rehabilitation implementation activities both from the implementing agencies and the PRDP office were specially invited to attend the workshop and present their views.

Activities Carried out at the Workshop

i. IIMI - Study team presented the cascade study results including data and information gathered; procedures adopted; findings and implementation strategy.

ii. CID, PID and DAS presented their experience including their views on proposed approaches and strategies for small tank system improvement.

iii. Farmers expressed their views.

iv. In addition to the above, representatives from Sri Lanka Freedom from Hunger Campaign Board and Agriculture Development Authority attended the workshop and expressed their thinking on suggested methodologies.

Summary of presentation by IIMI Group

Mr. C. Jayawardena, Project Director (PD) introduced the PRDP concepts to the participants with special reference to water resource improvement component of the project. He also explained the significance of the study as far as NCP is concerned. Since a number of participants of the workshop were not regular attendants of the various collaborative activities organized previously under the study, IIMI explained the methodology including the step wise process they followed for the study. IIMI-study team spent considerable time in explaining how to use data, information and findings of IIMI study for planning and implementation of cascade based small tank rehabilitation activities.

Dr. C.R. Panabokke member of IIMI-study team explained the criteria followed for selecting 104 out of 239 cascades for field studies. Cascade area over tank water spread area was one of the criteria used for measuring water resources richness in a particular cascade. Dr. Dharmasena from Mahailuppallama Research Station questioned the validity of this criterion mainly due to heavy siltation of the water spread area of the small tanks. IIMI study team replied that siltation is a common phenomenon in most of the tanks studied which may affect the storage volume but not significantly the surface area of the tank at the full supply level. Many participants questioned about the spatial distribution of cascades selected in the NCP. Dr. Panabokke using the map of NCP showed the distribution of 104 selected cascades in NCP and pointed out that they are more or less spread over 15 DS divisions depending on the richness of the water resources potential in each DS division.

Farmers as well as some agency officials questioned about not selecting some DS divisions coming under the Mahaweli scheme. The PD of PRDP said that areas located within the Mahaweli system H command were not selected under this scheme but NCP - ADB project would consider these areas for its implementation.

IIMI - field study team then explained the nature of field data collected and the analysis done to select initially 50 cascades out of 75. Out of 880 tanks studied under 50 cascades 452 recommended for improvement. The nature of improvements suggested would be varied from tank to tank. It may be relating to hardware or soft ware. IIMI-study team mentioned that they

have rejected working tanks under operating condition only on two basic criteria i.e. Number of beneficiary families and the period of previous rehabilitation.

At this stage of the discussion, PD-PRDP intervened and mentioned that some tanks may be rejected on socio-economic reasons such as unwillingness of the farmers for active participation in rehabilitation. PRDP office is now conducting a socio-economic survey in the 452 tanks selected by the IIMI study. IIMI-field study team showed all the data collected and the indicators used for measuring the resource endowment and potential for improvement. Specially the significance of cropping intensity as an indicator was repeatedly highlighted by giving examples from the field. Some participants including representatives of DAS and farmers mentioned that land fragmentation is one non-water factor influencing for low cropping intensity.

IIMI-presentation highlighted the significance of cascade simulation under the study. The hydrology of cascade is important when rehabilitation of tanks is considered. The IIMI-field study team gave practical field examples from certain cascades they have studied as to how water in the tanks being distributed among themselves within the cascade now and how water can be allocated using simulation results. The problems in water distribution among tanks within cascades can also be solved by selecting the relevant rehabilitation components for a particular cascade. Also, problems created by previous tank rehabilitation projects in certain cascades were highlighted.

Further IIMI explained that they have categorized cascades into two types: resource endowed and resource poor. The nature of rehabilitation proposed was based on water resource endowment. A hydrologically well endowed tanks is one which surplusses at least 5% of its average rainfall at the foot of the cascade. Otherwise it is not. Water resource endowment of individual tanks within a cascade was also analyzed through simulation model and categorized tanks accordingly for selecting the nature of rehabilitation needed.

The final IIMI presentation suggested an implementation process of the cascade based rehabilitation activities. Dr. Panabokke then explained the agro-well component of the IIMI study and attempted to provide understanding on how to use information in the report for implementing the agro-well component of the PRDP.

Summary Notes on the Discussion

Three discussion groups were set-up. These groups represented three irrigation agencies i.e. CID, PID and DAS. Farmers, representatives from Agriculture Development Authority and the representatives from Sri Lanka Freedom from Hunger Campaign Board were given opportunities to express their views on the study.

Each group was requested to concentrate on the following four questions:

1. List out the comments, ideas and views of the line agency officers on the implementation mechanisms suggested by IIMI-study team.

2. The nature of problems and constraints that may be encountered by line agency staff in implementing the cascade based rehabilitation approach.

3. What additional data and information required by line agencies from IIMI?

4. What are your observations, conclusions and recommendations on IIMI's study?

Presentation by CID

The CID presentation was made by Mr. Piyadasa, Deputy Director, Anuradhapura range. First he mentioned that the data and information collected by IIMI under this study would be quite useful and line agencies must be thankful to IIMI. He further mentioned that IIMI presentations have provided better understanding on the methodology and results of the study.

Deputy Director requested IIMI to provide all the data and information collected on the cascades which were not included in the report. He said that these information would be useful to line agencies for their future activities. DD pointed out that irrigation department also considered catchement and command areas when tank rehabilitation's are planned. The methodology developed by IIMI is a further improvement of such methods according to the DD. However, IIMI-concepts on cascade improvements should be validated through field monitoring studies. Cascade based rehabilitation approach is known to PRDP but other agencies who are also involved in small tank rehabilitation will not consider cascade based rehabilitation strategies. Therefore, DD proposed that there must be a National Level Committee for water resources improvements and such committee should decide the policies on rehabilitation of small tanks in cascades.

Problems that Might be Encountered by Irrigation Agencies in Implementing Cascade Based rehabilitation Approach

* When majority of tanks in one cascade are being rehabilitated, there will be problems to obtain active support from farmers from other cascades because some farmers are benefited more than others.

* When different agencies work in the same cascade there can be problems due to various issues such as wages paid to laborers, quality of the work, procedure of implementation etc.

* The ID uses 75% rainfall probability in rehabilitation planning where as IIMI used 50% rainfall probability for assessing hydrological endowment. This should be validated. Software package used for simulation of the cascade hydrology should be made available to the CID in Anuradhapura.

Presentation by PID

The following points were made by the representative of PID

* The PID may not be in a position to go into participatory way of rehabilitation due to resource limitations.

* The PID mentioned that it could undertake required feasibility studies but estimates prepared for such studies should not be revised once they are approved. (This was a request of PID).

* During implementation, rehabilitation should be started simultaneously in all the tanks selected in a cascade. This step would help to solve the problems that might occur due to lack of vehicles for transportation.

* PID also requested the basic data collected by IIMI in 104 cascades in NCP and also computer software package which can be used for cascade hydrology simulation.

* The IIMI-study is based on majority of data collected from farmers and therefore the assumptions must be validated through a monitoring study.

* Finally the PID engineer appreciated the efforts made by IIMI to complete a large study within a short period of time.

Presentation by DAS

The following points were made by DAS.

* The methodology developed by IIMI would be useful for water resources improvement in North Central Province.

* IIMI should provide a complete data set to the line agencies on the cascades they have studied (including both selected and not selected cascades).

* The impact of cascade improvement on the main rivers and major irrigation system should be further studied by IIMI.

* DAS questions were related to using 50% rainfall probability for computing hydrological endowment and use of old government maps for planning.

* DAS may find it difficult to use coordinates mentioned on metric because DAS uses FST system (Feet's, yards etc.).

* DAS suggested that PRDP should focus attention to improve aspects in a village other than small tank under the project.

* Even under this project DAS may have problems in selecting potential tanks due to external interference's such as politics.

* Getting active farmer participation would be a problem when rehabilitation activities are started in several tank on the same cascade simultaneously.

* All the line agency officials who are involved in PRDP activities should be given basic information on the project activities.

* It is a problem that IOs worked for WFO program for nearly 3 years are now withdrawn.

* There are differences between PRDP and WFO criteria for tank selection for rehabilitation.

* The relevant data on rehabilitated tanks must be kept, and managed by an organization.

* DAS also needs the software package that IIMI used for simulating the cascade hydrology.

* DAS pointed out that Department of Agriculture should get involved in the small tank rehabilitation program because improving cropping intensity should be the ultimate objective of rehabilitation program.

* Finally DAS mentioned that this type of studies are important and they can be further improved by testing the assumptions made.

Presentation by the Farmers

The Following points were made by the farmers

1. The information collected from farmers should be validated under real field conditions.

2. Some farmers have developed the tank beds for cultivation and this should be carefully studied.

3. Farmers expressed that 10% contribution is a problem. (This was explained by PD-PRDP to the farmers and convinced that it is an essential requirement under the project).

4. Priority of rehabilitation work should be given to farmer organizations, but farmer organizations work must be monitored.

Presentation by Agriculture Development Authority (ADA)

The following points were raised by the Deputy Director (ADA - Anuradhapura).

* The ADA has so far (since 1987) constructed 15,000 agro-wells in NCP.

* The agriculture development using agro-wells is becoming significant. Therefore the study conducted by IIMI has much practical use.

* The study was completed within a short period and therefore IIMI could not go into details.

* IIMI study has not focused on the following areas.

  - Chemical content of water
  - Ground water levels
  - Environmental factors in detail
  - Economic profitability of agro-wells

* National policy decision relating to agro-well program is required.

Presentation by Freedom from Hunger Campaign Board

Freedom from Hunger Campaign (FFHC) although it is a government statutory board under the Ministry of Agriculture, functions as an NGO. The representative from FFHC highlighted the following facts.

* If certain tanks in a given cascade are not undertaken for improvement what incentives offered to the farmers in those tanks? Are there serious limitations to the provisions for tank improvement.

* Are there programs to create awareness among farmers in a continuous manner.

* What about monitoring of the whole program, who does it? Are sufficient funds allocated for that?

* What is the mechanism established for post-rehabilitation phase.

* Finally FFHC representative mentioned that this is one of the most useful study conducted in the field of small tank system and therefore line agencies should try to use it and such further studies which contribute for development should be encouraged.

Cascade Identification Study Workshop - Mahailluppallama

Attendance

Name	Designation	Organization
S.M.D.B. Samarakoon	A.D. Planning	PRDP
R.H.W.A. Kumarasiri	Assistant Director	PRDP - Anuradhapura
D.R. Seneviratne	A.D. (P)	Medawachchiya D.S.
W. Leelasena de Silva	A.D. (P)	PRDP
P.B. Dayaratne	A.D. (P)	PRDP
S.U. Gunasekera	Project Engineer	PRDP
M.N.J. Weerasinghe	A.D. Planning	Padugaswewa
H. Thilakaratne	A.D. (P)	Kahatagasdigiliya
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		Secretariat
J.M. Samarakoon Banda	RA-IIMI SCOR	IIMI
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