Table

Table A1.4.1 Water Policy and Irrigation Management of Asian Countries (1/4)

No.	Subjects		Sri Lanka	Japan	Philippines	Thailand	Indonesia	India
A	General Information in 2003	Unit						
1	Population	M	19.2	127.0	81.5	62.0	214.7	1,064.4
2	Land Area	$1,000Km^3$	65	378	298	511	1,812	2,973
3	Agriculture Land (2002)	1,000Ha	1,916	4,762	9,975	19,367	33,700	170,115
	Paddy Harvested	1,000Ha	911	1,665	4,094	11,000	11,477	44,000
	Perennial Crops (2002)	1,000Ha	1,000	272	5,000	3,500	13,200	8,400
	Irrigated Area (2002)	1,000Ha	601	2,607	1,396	4,957	4,815	57,198
4	Gross Domestic Product (GDP)	US$ M	18,237	4,803,200	80,573	142,953	208,312	600,637
5	Agricultural Share in GDP	%	19.0	1.3	19.9	9.8	16.6	22.0
6	Agricultural Labour Force (2002)	%	45	4	34	55	47	59
B	Policy and Legislation on Water							
1	Water Policy		National Water Policy (Draft Level)	National Overall Water Resources Plan (1999. Jun, 2010-2015 target), Water Resources Development Basic Plan, both under the River Law	National Water Vision 2001, (Cabinet Approved)	Water Policy by National Water Resources Committee (year?) or New Water Vision 2001 (Approved by the Cabinet)?	Water Resources Law No.11/1974 and revised WR Law No.7/2004	National Water Policy 1987 & 2002
	Concept		In tradition, water has been considered as social goods and no commercial pricing was adopted. Under the new National Water Policy, it is planned to introduce pricing of water.	Water is public property and not to be used for commercial purposes for private interest. Basin wise planning & implementation.	Water including irrigation is priced by National Water Resources Board, but NIA never paid so far.	Water is public property, but could be commercialised by private sector. (Is it correct?) Basin wise development plan & implementation.	(a) Water is a social good with increasing attention to its economic value; (b) Shift from Water Resources (WR) development to WR management; (c) Decentralisation of WR management; (d) Participatory and integrated basin approach to WR development and management with environmental considerations.	Promotion of conjunctive use of water. Primary benefits (Irrigation & Water Supply) handled by Government, secondary benefits (Hydro power, tourism, aquaculture, etc.) by private sector also.
	Legislation		Water Resources Act to introduce of pricing water (not approved by parliament)	River Law, Water Resources Development Acceleration Law	Presidential Decree 1067	Any law as for water policy other than irrigation related laws?	(a) Water Resources Law No.7/2004; (b) Government Regulation (GR) No.22/1982 (water rights, water	Indian Constitution, 1952 and various Entries, Inter State Water Dispute Act , 1956 (Extended several times),
2	Water Right		not defined	Given to users, traditional water right is given to irrigation. Renewal required.	Defined in relation to costing of water.	All water resources are deemed to be state property.	State is ultimate owner of water rights. Quasi local rights exist in practice. Water rights defined under Water Resources Law No.7/2004	Water right to sgravity and lift from river are recognized indirectly through land rights. Water right of groundwater is not defind. Individual rights for own open well, tube well water owned by farmers.
3	Role of Irrigation in the Policy		Major role, 90% of water resources in use for irrigation, but there are pressures to allocate for other purposes.	As above, water right is given. Share is clearly defined. 65% of water resources in use is for irrigation.	79% of water resources is in use for irrigation.	Major role	Irrigation receives high priority. 80% of water resources utilized are targetted for irrigaiton.	Major role, but there are pressures from other sectors
4	Responsible Ministry		Ministry of Irrigation, Mahaweli & Rajaratha Development, Ministry of Agriculture & Livestock, and Ministry of Housing and Construction	Ministry of Land, Infrastructure & Transport (MLIT)	Department of Public Works, Department of Agriculture	Ministry of Agriculture and Cooperatives, Ministry of Interior (Domestic Water) Ministry of Industries (Hydro Power & Ground Water) Office of Prime Minister (Hydro Power)	(a) Ministry of Public Works; (b) Ministry of Home Affairs; (c) Ministry of Agriculture (farm network); (d) Ministry of Mineral Resources (ground water permits, while MPW is operational)	Ministry of Water Resources, Min. of Agriculture, Environment & Forests, and Min. of Housing & Urban Development (Central Government), Ministry of Irrigation (State Governments)
5	Executing Agency		National Water Resources Council Irrigation Department, Mahaweli Authority of Sri Lanka National Water and Drainage Board,	Water Resources Development Authority (MLIT & Min. of Agri.., Forestry & Fisheries (MAFF)) Department of Water Resources (MLIT), Department of Rural Development (MAFF), Department of Water Supply (Min. of Welfare and Labour (MWL)),	National Water Resources Board Department of Public Works Philippine Electricity Market Corporation, National Irrigation Administration, Local Government Units,	Royal Irrigation Department, Department of Mineral Resources (Ground Water), National Energy Administration and Electricity Generating Authority (Hydro Power)	(a) Water Resources Councils (Central, Provincial, and District); (b) Directorate General of Water Resources, Directorate of Irrigation, (c) Regional/Local Government Irrigation Agencies	Central Water Commission, National Water Resources Council, Central Groundwater Board & National Water Development Authority (Central Government) Irrigation Dep't, Ground Water Boards, Minor Irrigation Dep't. Public Works Dep't. Irrigation Development Co-operation & Water and Land Management Institute (State Government)

Table A 1.4.1 Water Policy and Irrigation Management of Asian Countries (2/4)

No.	Subjects		Sri Lanka	Japan	Philippines	Thailand	Indonesia	India
C	Policy and Legislation on irrigation							
1	Brief History		Irrigation was practised more than 2000 years. There are three significant characteristics in historical irrigations; the 1st is cascade system in one catchments, the 2nd is Yoda Ela (river diversion) constructed and managed by councils under the kings, and the 3rd is O&M by community. Irrigation Department was established in 1900.	Since the 7th century, dams for irrigation had been constructed. Irrigation is a major policy for the statesman. Many river diversions with tunnel was constructed during 17-19 centuries by federal domains and farmer associations. Water Users' Association Rules (1890), Water Users' Association Law (1908) and Land Improvement Law (1949) was enacted after Meiji restoration in 1868 for irrigation.	About 2000 years ago rice terraces were constructed, which were first irrigation farming in the Philippines. The Spaniards introduced new techniques and designs in the construction of irrigation projects. In 1963, National Irrigation Administration (NIA) was created to construct more irrigation systems throughout the country.	A dam was constructed in 13th century during the Sukhothai period. Irrigation was strengthened during the Ayutthaya period in 14-18th centuries. Irrigation development was followed in the Rattanakosin Period from the late 18th century. The Canals Department was established in 1902. The Barrages Department was established in 1924 followed by Royal Irrigation Department in 1927.	Small scale irrigation schemes developed by rural communities before Dutch administration in primarily upland hill and valley areas. Starting during 19th century, modern irrigation systems were developed by the Dutch administration in larger lowland irrigation networks. After independence in 1945, and particularly since late 1960's, irrigation development and rehabilitation promoted, and rice self-sufficiency attained in 1984.	The history of irrigation of India is very old and has been performed 2000 years or more.The large-scale irrigation system began from the 18th century up to the beginning of the 20th century. However, Navigation System was the main purpose those days. It was changed into the practical use to Irrigation System due to the development of land transportation.
2	Policy		Stable supply of foods, Improve efficiency of water use, Participatory O&M of irrigation, Poverty alleviation in rural area,	To increase agricultural production, production efficiency, to expansion of selected option of agriculture, and to improve agriculture through improvement, development and conservation of agricultural lands. To contribute integrated development and conservation of land/water resources in Japan taking harmony with environment into consideration.	Clear delineation of roles of NIA, LGUs (Local Government Units) and IAs (Irrigation Associations), Additional irrigated area development through construction and rehabilitation, and to transfer the O&M of tertiary system to IAs, and to review and recommend reasonable ISFs	Sufficient Water Supply for Agriculture, Development of Water Hazard Prevention System, Encouragement of Efficient People Participation in Tertiary system construction and Water Management, Promotion of better utilisation and conservation of natural resources.	(a) Water defined as social good with increasing emphasis on irrigation economic and cost aspects; (b) From supply driven to demand driven allocation and management; (c) From project driven to integrated dev't and management approach; (d) From top-down to bottom-up methodologies.; (e) Empowerment of WUAs; (f) Participatory water management.	Increase per capita storage; trans-basin diversion, water conservation and rainwater harvest as supplementary measures. National concepts for completing projects; full funding of projects under Acceleted Irrigation Benefit Programme (AIBP). Standing tribunals to address inter-state issues. Water regulators: Ground water ownership status review. Public-private partnership in water sector. System rehabilitation to increases efficiency. Empowered Participatory Irrigation Management (PIM) for collecting and retaining water charges for O&M.
3	Legislation		Irrigation Ordinance	Land Improvement Law (1949)	Agriculture and Fisheries Modernization Act (1997)	People Irrigation Act (1939) State Irrigation Act (1942) Field Dykes and Ditches Act (1962) Ground Water Act (1977) Waterworks and Canal Maintenance Act (1983)	(a) Government Regulation (GR) No.22/1982 (water rights, water licensing, etc.), (b) GR No.23/1982 on Irrigation Management, (c) GR No. 27/1991 on Swamp Management, (d) GR No.35/1991 on River Management, (e) Draft GR on Irrigation (2004) accompanied by 5 draft ministerial regulations (2004).	State Irrigation Acts
4	Ministry & Department In-charge		Ministry of Agriculture, Environment, Irrigation and Mahaweli, Irrigation Department, Mahaweli Authority, Department of Agrarian Dev. Provincial Councils.	MAFF, Dep't of Rural Area Promotion, Prefecture and other local Governments,	Department of Agriculture, National Irrigation Administration, Local Government Units,	Ministry of Agriculture & Cooparatives, Royal Irrigation Department, Department of Mineral Resources (Ground Water),	(a) Ministry of Public Works (Directorate General of Water Resources, Directorate of Irrigation); (b) Ministry of Agriculture; (c) Provincial Governments and District Governments (Irrigation Agencies)	State Irrigation Departments

Table A 1.4.1 Water Policy and Irrigation Management of Asian Countries (3/4)

No.	Subjects		Sri Lanka	Japan	Philippines	Thailand	Indonesia	India
D	Irrigation Management & O&M							
1	Major Issues		Shortage of Government budget for O&M, Dependency of farmers on Government institutions, As a result, facilities are deteriorating.	In relation with WTO in relation to agriculture products, restructure of small farming is inevitable, reducing production costs. Recently Drastic Changes in Agriculture/Farming Structure. Weakened Cooperative Management in Village Community. Tightness of Water Resources. Increasng of Multifunctional Role of Irrigation System.	Active participation of Irrigators Associations (IAs) in rehabilitation and O&M, Irrigation Management Transfer to IAs from NIA,	Improvement of irrigation efficiency and equitable distribution of water through O&M improvement, Focusing environmental aspects, Participation of farmers and WUA on water management,	(a) Irrigation sector shifting from development to management stage. (b) Shortage of current O&M budgets. (d) O&M financing arrangements between central, provincial and district (local) governments. (d) Role of irrigation service charges collected by Water Users' Associations, or WUAs (internal and command-wide uses). (e) Water value not appreciated. In appropriate crops grown, and wastage. (f) Equity among beneficiaries in each scheme (ustream always uses more).	Water scarcity/crisis, competing demands and food security. Problems of drought areas and climate change. Plethora of incomplete irrigation projects and low cropping intensity, irrigation efficiency and tariff. International and inter state conflicts on water sharing. Depleting ground water resources-free/subsidized power for agriculture. Growing problems on urban sanitation, solid waste management and river pollution. Too many Organizations dealing with water
2	Policy & Directions		Participatory Management & no ownership transfer, Joint Operation with Government Institution & FOs on WM, Handing Over on WM on Tertiary Facilities to FOs.	Basically LIDs should be incharge of O&M of Irrigation System, In Large-Scale Irrigation System Joint Management maintained. Technical & Financial Support to LIDs by Govet. for Encourage and Exercise the Capacity of LIDs as a Public Body in Rural Resource Management.	Irrigation Management Transfer to IAs. There are 3 types of transfer to IAs, (1) O&M & WM only, (2) (1) & collection of fee, (3) ownership be transferred. Majority is (1) type, Improve collection of ISFs.	To encourage proper WM & O&M by WUGs for tertiary facilities. RID continues WM & O&M of Main and branch facilities.	To promote co-sharing arrangements between government and WUAs to lower government expenditure and enhance sustainability. WUAs take responsibility for tertiary levels of state irrigation networks and manage community systems. Lower level may request assistance from upper levels.	Comletion of projects under construction, Water rate has been charged in many states. WUAs establishment is pre-requisite for water issue in some projects. Volumetric distribution and group-based allocation were encouraged.
3	Demarcation of Irrigation System		Major & Medium Schemes (above 80Ha, 360nos. 289,000Ha, Central ID) Major & Medium Schemes (above 80Ha, 167nos. 55,000Ha, Provincial ID) Mahaweli Systems (7nos. 97,000Ha) Minor Schemes (18,000nos. 160,000Ha, Dep't of Agrarian Development)	National Projects (≧3,000 (1,000)Ha) Prefectural Projects(≧200Ha) Other Projects (≧20Ha)	National Irrigation Systems (NIS; 679,000Ha) Communal Irrigation Systems (CIS; 486,000Ha) Private Irrigation Systems (PIS; 174,000Ha)	Large and Medium scale RID schemes (3,222,000Ha) Small Scale schemes (1,180,000Ha) Pump Schemes (297,000Ha) Others (149,000Ha) Royal Development Project Schemes (99,000Ha)	Central: (3,000 ha & above) + national strategic and cross country irrigation systems. Province: (1,000 ha - 3,000 ha) + cross district irrigation systems. District: (below 1,000 ha). WUAs/villages: community systems.	Major Irrigation Projects (>10,000Ha) Medium Irrigation Projects (2,000-10,000Ha) Minor Irrigation Project (<2,000Ha)
4	Farmers Organisation		Farmers Organisation (FO) for tertiary facilities,	Land Improvement Districts（LIDs） & LIDs Federation (System Level), Water User's Associations (Village Level under LID)	Irrigators' Association	Water users' group (Tertiary level), Water users' associations or cooperatives (Lateral level)	Water Users Associations (WUAs) Water User Association Federation (WUAFs).	Water Users Association (WUA), Distributory Committee and Project Committee
	Registration		Department of Agrarian Development under AD Act	Local Governments under Land Improvement Law	to register at Securities and Exchange Commission	Data is not available.	District Courts under Government Regulation on Irrigation, No.7/2004	Revenue Department under State Irrigation Acts
	Eligibility of Membership of FO, or IA, or WUA		Owner Farmers, Tenants	Farmers (Owner, Tenant, Owner of Potential Agricultural Lands)	Owner and Tenant Farmers	Owner and Tenant Farmers	Owner and Tenant Farmers	Owner Farmers Only
	Establishment & Decisions		Min. 25 spontaneous members, Decisions on simple majority. No penalty adopted. No compulsory memer ship.	Establishment: Min. 15 farmers. Agreement of 2/3 farmers in beneficial area. All farmers in the area must be the members of LID. Decisions: In case of important subjects decisions are made on 2/3 majority (In practice more than 90%). All members are compelled to follow the decision. If not follow, penalty enforced.	Mandatory membership is proposed. By-law & decision making process are yet to be properly defined.	Spontaneous organisation. By-law & decision making process are yet to be properly defined.	Data is not available.	Min. 12 farmers, Mandatory membership for Major/Medium schemes, mandatory or spontanious membership for minor schemes, decision on simple majority and bind all members. The Andhra Pradesh Farmers Management of Irrigation System Act 1997 was enacted
5	Legislation		Cabinet Paper on Participatory Management of Irrigation Systems (1989), Irrigation Ordinance (1994), Agrarian Development Act (2000),	Land Improvement Law(1949)	Republic Act 7607 (Magna Carta of the Small Farmers, Republic Act 8435 (Agriculture and Fisheries Modernisation Act)	State Irrigation Act	Draft Government Regulation on Irrigation, No.7/2004, accompanied by 5 draft ministerial regulations (2004).	State Irrigation Acts

Table A 1.4.1 Water Policy and Irrigation Management of Asian Countries (4/4)

No.	Subjects		Sri Lanka	Japan	Philippines	Thailand	Indonesia	India
6	Ministry Responsible		Min. of Irrigation, Mahaweli & Rajarata Dev., Min. of Agriculture & Livestock	Min. of Agriculture, Forestry and Ficheries.	National Irrigation Adminiistration (Department of Agriculture)	Ministry of Agriculture and Cooperatives	Ministry of Public Works; Ministry of Home Affairs; Bappenas (National Planning Agency); Ministry of Agriculture	State Irrigation Departments(main) / Ministry of Water Resources
7	Executing Agency		Irrigation Department (Central and Provincial), Irrigation Management Unit, Mahaweli Authority of Air Lanka, Department of Agrarian Development	Dep't. of Rural Area Promotion, Water Resources Development Board (Central), Local Governments	National Irrigation Administration, (Local Government Units)	Royal Irrigation Department and Water Users' Association	Directorate of Irrigation (Central); Provincial & District Governments (via Irrigation Agencies)	Irrigation Dep't, Ground Water Boards, Minor Irrigation Dep't. Public Works Dep't. Irrigation Development Co-operation & Water and Land Management Institute (State Government)
8	Size of FO, IA or WUA,		100-300Ha (every distributary canal)	LIDs:Nos.184 (≧3,000Ha), Nos.479(≧1,000Ha), Nos.3,039(≧100Ha), Nos.3,302(＜100Ha) (every system)	Tertiary canal basis (100-200Ha), and WUA federation on project basis.	30-11,000Ha (every irrigation system)	Variable size and organizational base. Averge 60 ha (for tertiary canal WUAs). Alternative concept: Village based and/or community irrigation systems.	The size of WUAs 2,500-4,000Ha for major & medium schems and each tank & anicut for minor schemes
9	Irrigation Fee		O&M costs for tertiary facilities, Collected by FO & spent by FO.	Ordinary levy for O&M expenses and Special levy for investment project cost, Collected by LIDs.	Full O&M Expenses (NIS level) to be covered.	Irrigation Water Fees from owners of lands as revolving fund for irrigation purposes.	Irrigation Service Fee for (a) internal WUA use or (b) command based use (WUA federations, or WUAFs)	Water rate
	Charges		1 bushel of paddy or Rs.300 (=US$3.0) in cash /acre/crop only for tertiary system O&M.	Ordinary levy for O&M : JYEN.30,000(US$270)/ha. Special levy for Investment Project Costs : JYEN.40,000(US$360)/ha.(Support for project cost payment by Govt. Finance Corporation)	NIS (Gravity) : 2 cavans (50 kg/cavan) for wet season, 3 cavans for dry season & 3rd crop, NIS (Pump) : 3 cavans for wet season. 5 cavans for dry season & 3rd crop, NIS (Reservoir Dam) : 2.5 cavans for wet season, 3.5 cavans for dry season & 3rd crop, Rice Farmers in cash or in kinds but non-rice farmer in cash only. Paady price: PhP9.45/kg, US$1.0=PhP.56	Max. Baht 5.0/Rai/annum (Baht 31.5/Ha/annum, US$0.77/Ha/annum)	US$11-38/ha/annum	In case of Andra Pradesh State, the irrigation fee is Rp 200/- per acre for wet and Rp 100/- per acre for ID Crop respectively Distribution of irrigation fee is determined by the project size. (refer to Table-2 Distibution of irrigation fee) US$1.0=IRs.46.151
	Collections		Not good except Mahaweli Systems (50-70%)	100%	about 50%, not satisfactory level	Data is not available.	Not more than 10% in state systems. Fee collection for system-wide O&M often problematic.	Differed from state to state, In case KC Canal Project, 40-60%.

Data Source:
A: Country Profiles compiled by JICA in 2005, FAO Food and Agriculture Indicators for 2002, other Japanese statistics,
Sri Lanka: Data collection by the study team
Japan: Various statistics of MAFF, Homepage of Land Improvement Association, etc.
Philippines: The Study on the Irrigators Association Strengthening Project in National Irrigation System, July 2003, JICA / Nippon Koei Co., Ltd & Others
Indonesia: Development Policy on Irrigation Management, Sep. 2004, JICA / Nippon Koei Co., Ltd. & Others
Thailand: RID Homepage, and Water Resources Laws in Thailand, Mar. 1999, JICA & JIID, collection by the study team
India: IWMI Research Report 79, Strategic Analysis of Water Institution in India and collection by the study team.

Table A2.5.1 Brief Information of NIRP, MRRP and MUP (1/2)

No.		National Irrigation Rehabilitation Project (NIRP)	Mahaweli Upgrading Project (MUP)	Mahaweli Rehabilitation and Restructuring Project (MRRP)
1.	Period	1992 to 2000	2000 to 2004	1998-2003
2.	Purpose	- Rehabilitation and improvement of 1,000 minor and 60 major/medium irrigation schemes, - Establishment of FOs, - Introduction of improved O&M, and - Training of farmers and staff members of implementation agencies	- Increase of the productivity of the existing irrigation scheme, - Strengthen the capability of of Fos enable them to manage and maintain the system, and - Rectify defects of existing irrigation system	- Institutional transformation of Mahaweli Authority of Sri Lanka into a River Basin Management Agency by restructuring and introducing new tasks, and - Improving the productivity of "Mahaweli System H through rehabilitation, improvement of irrigation facilities and strengthening of O&M
3.	Area	Countrywide including 1,000 minor and 60 major/medium schemes	System C	System H
4.	Cost	US$ 50.34 million (14 % from the Government)	Rs. 3,737 million	US$ 71.13 million
5.	Donor	World Bank / EU	JBIC	World Bank
6.	Achievement	- As of 2000, June, physical rehabilitation of 1,022 minor schemes and 34 major/medium schemes, - Training for major/medium schemes (Unit: man-days 5,544 for staff members, 826 for institutional organizers, 8,900 for farmer leaders and 2,778 for farmers), and - Training for minor schemes (unit: man-day, 3,688 staff members, 7,204 for institutional organizers, 43,524 for farmer leaders and 20,007 for farmers)	- 141 FOs under thecommunity contract concept completed rectification works worth about Rs. 560 million. - Medium & large-scale contractors completed rectification works of main system worth about Rs. 250 million. - Refurbishing of warehouses and improvement of training facilities were also carried out. - Staff training: eleven programs were conducted covering project awareness, community action planning, participatory rural appraisal, maintenance by FOs and so on. - Farmer training: programs covered project awareness, legal aspects of FOs, group credit, financial management, FO office development, construction & contract management, water management and so on.	- As of the end of 2003, 95% of the D- and F-canals and 79% of the main canals were completed. - Cropping intensity has increased to 165% from long-term coverage of 150% (the project target was 200%) - Water use efficiency has been improved. The annual water usage has declined by 45% at the end of the project in comparison to the water duty in 1997. - Water productivity has increased from Rs. 4.05 million/MCM (long-term value) to Rs. 7.53 million/MCM (at the end of the Project). - Private sector development program was not met as anticipated. - With all these activities, farmers household income has not increased as expected. The average income at the end of the project was 5% below the project target.
7.	Farmer Voluntary Contribution	- Major/ medium schemes: 10 % voluntary contribution by 104 DCFOs out of 206 - Minor schemes: 10% of civil rehabilitation cost by 802 out of 1,022 schemes	- Farmers Compulsory Contribution of 10% for rehabilitation activities was fairly successful.	- Farmers compulsory contribution of 10% for rehabilitation activities was fairly successful. The total target of the project was Rs. 230.89 million while the actual contribution was Rs.

Table A 2.5.1 Brief Information of NIRP, MRRP and MUP (2/2)

No.		National Irrigation Rehabilitation Project (NIRP)	Mahaweli Upgrading Project (MUP)	Mahaweli Rehabilitation and Restructuring Project (MRRP)
				140.11 million, about 61% achievement.
8.	Handing over of D&F Canals	- Major/medium schemes: 100 DCFOs out of 206 took over O&M responsibilities - Minor schemes: 788 FOs out of 1,022 took over O&M responsibilities	- Secondary and tertiary system was handed over to FOs. At the end of the Project period, 1,348 FC and 78 DC out of 1,575 and 173 respectively.	- 256 DCFOs covering 31,559 ha have been in operation and out of that 204 have taken over the O&M responsibilities of D&F canals at the end of 2003.
9	Lessons Learnt	- Both software and hardware components must be coordinated well and equally prioritized, - Sufficient lead-time should be allocated for preparation of community and government officers toward participatory approach before physical rehabilitation, - Forming FOs should be started at least one year before actual rehabilitation, - Political commitment is highly required at higher levels for policy changes, - Irrigation policy and institutional reform must be implemented as a national program, not as components built into rehabilitation projects funded by donors, and - Improving agricultural productivity and farmer income must be focused for future program	- Both software and hardware components of irrigation should be equally prioritized. Sufficient lead-time, however, needs to be allocated to orient farmers and strengthen FOs. - Over loading and pressing community organizations to accomplish a task in a given time frame decided by an outsider may result poor quality outcome. - For a successful credit program with remarkable recovery rate, considerable attention should be given to credit management. Credit management should include changing attitudes of borrowers and a systematically planned follow-up program. - Strengthening of FOs is not an activity, it is a process and it will continue even after the project. During the project period FOs mainly involved with restoration works and after that the time should be allocated to institutionalize O&M of the system alone with the self-sustaining agricultural input service. Hence an "Aftercare" phase is necessary to achieve the MUP objectives as specified.	- Improvements of farm to market roads, hamlet roads etc were not addressed successfully by the project although marketing of agricultural product in System H was seriously affected by the deteriorated road condition had in the area. As a result of this the project lost an opportunity to make significant contribution in increasing farmers income. - The rehabilitation was mainly "supply driven" although initial problem identification was in a participatory way. It would have been in a "demand driven" basis allowing farmers to decide their priority from the areas such as agriculture, rehabilitation, marketing, strengthening of Farmers organization etc and prepare work plan accordingly. - The physical rehabilitation was completed during the project period. However, some of the important components such as institutional development, agricultural productivity increase, enterprise development etc began to move at the end of the project. There is no doubt that the Farmers Organizations need further assistance to reach the final goal of the project as stated.

Table A3.1.2 Water Duty and Water Productivity in Nachchaduwa Scheme

Season	Water Issue		Extent		Water Duty		Production			Water Productivity
	Nachchaduwa (Ac.ft.)	Nachchaduwa (MCM)	(Ac)	(Ha)	(ft.)	(mm)	(Busal/Ac)	(Kg/Ac)	(Kg/Ha)	(kg/m3)
1990-Yala	24,059	29.7	6,200	2,573	3.9	1,183	N.A.	-	-	-
1991-Yala	6,820	8.4	800	332	8.5	2,597	N.A.	-	-	-
1992-Yala	9,780	12.1	2,000	830	4.9	1,490	N.A.	-	-	-
1993-Yala	10,997	13.6	4,100	1,701	2.7	817	N.A.	-	-	-
1994 -Yala	24,688	30.5	6,274	2,603	3.9	1,198	N.A.	-	-	-
1995-Yala	33,180	40.9	6,000	2,490	5.5	1,686	N.A.	-	-	-
1996-Yala	8,176	10.1	1,400	581	5.8	1,780	N.A.	-	-	-
1997 -Yala	-	0.0	-	-	-	-	N.A.	-	-	-
1998-yala	20,608	25.4	3,680	1,527	5.6	1,707	**76**	1,703	4,208	0.253
1999-Yala	31,324	38.6	6,154	2,554	5.1	1,551	**83**	1,872	4,626	0.306
2000- Yala	33,416	41.2	6,274	2,603	5.3	1,625	**83**	1,865	4,608	0.291
2001-Yala	12,062	14.9	2,352	976	5.1	1,561	**89**	1,999	4,939	0.323
2002-Yala	8,214	10.1	2,481	1,030	3.3	1,009	**84**	1,893	4,678	0.477
2003-Yala	35,630	43.9	7,000	2,905	5.1	1,551	**77**	1,731	4,277	0.283
2004-Yala	-	-	320	133	-	-	**-**	-	-	-
Total		319.4		22,703		19,755	492		27,336	1.933
Average		**22.8**		**1,622**		**1,411**	**82**		**4,556**	**0.322**
90/91-Maha	24,414	30.1	6,200	2,573	3.9	1,198	N.A.	-	-	-
91/92-Maha	34,732	42.8	6,200	2,573	5.6	1,707	N.A.	-	-	-
92/93-Maha	20,336	25.1	6,200	2,573	3.3	1,000	N.A.	-	-	-
93/94-Maha	17,744	21.9	6,200	2,573	2.9	872	N.A.	-	-	-
94/95-Maha	22,383	27.6	6,274	2,603	3.6	1,085	N.A.	-	-	-
95/96-Maha	13,683	16.9	6,274	2,603	2.2	664	N.A.	-	-	-
96/97 -Maha	23,333	28.8	6,274	2,603	3.7	1,134	N.A.	-	-	-
97/98 -Maha	38,552	47.6	6,274	2,603	6.1	1,871	N.A.	-	-	-
98/99-Maha	20,256	25.0	6,274	2,603	3.3	997	**86**	1,938	4,789	0.499
99/00-Maha	24,334	30.0	6,274	2,603	3.9	1,183	**88**	1,969	4,865	0.422
00/01-Maha	11,830	14.6	6,274	2,603	4.0	1,228	**98**	2,204	5,446	0.971
01/02- Maha	15,590	19.2	6,274	2,603	2.5	756	**97**	2,176	5,377	0.729
02/03-Maha	12,070	14.9	6,274	2,603	1.9	585	**88**	1,977	4,885	0.853
03/04- Maha	34,650	42.7	7,000	2,905	5.0	1,509	**94**	2,112	5,219	0.355
04/05-Maha	21,700	26.8	7,000	2,905	3.1	945	**96**	2,167	5,355	0.580
Total	335,607	414.0	95,266	39,529	54.9	16,734	**646**		35,936	4.409
Average	**22,374**	**27.6**	**6,351**	**2,635**	**3.7**	**1,116**	**92**		**5,134**	**0.630**

Source: Nachchaduwa IE Office

Table A3.1.3 Water Duty and Water Productivity in Thuruwila Scheme

Season	Water Issue		Extent		Water Duty		Production			Water Productivity kg/m^3
	(Ac.ft.)	(MCM)	(Ac.)	(Ha)	(ft.)	(mm)	(Busal/Ac)	(Kg/Ac)	(Kg/Ha)	
1990-Yala	3,720	4.6	465	192.9	8.00	2,438	90	2,025	5,004	0.205
1991-Yala	3,767	4.6	465	192.9	8.10	2,469	90	2,025	5,004	0.205
1992-Yala	3,767	4.6	465	192.9	8.10	2,469	90	2,025	5,004	0.205
1993-Yala	3,813	4.7	465	192.9	8.20	2,499	90	2,025	5,004	0.200
1994 -Yala	3,674	4.5	465	192.9	7.90	2,408	90	2,025	5,004	0.209
1995-Yala	3,627	4.5	465	192.9	7.80	2,377	90	2,025	5,004	0.209
1996-Yala	3,627	4.5	465	192.9	7.80	2,377	90	2,025	5,004	0.209
1997 -Yala	3,581	4.4	465	192.9	7.70	2,347	90	2,025	5,004	0.214
1998-yala	3,534	4.4	465	192.9	7.60	2,316	90	2,025	5,004	0.214
1999-Yala	3,534	4.4	465	192.9	7.60	2,316	90	2,025	5,004	0.214
2000- Yala	3,488	4.3	465	192.9	7.50	2,286	90	2,025	5,004	0.219
2001-Yala	3,348	4.1	465	192.9	7.20	2,195	90	2,025	5,004	0.230
2002-Yala	3,255	4.0	465	192.9	7.00	2,134	90	2,025	5,004	0.235
2003-Yala	3,209	4.0	465	192.9	6.90	2,103	90	2,025	5,004	0.235
2004-Yala	3,255	4.0	465	192.9	7.00	2,134	90	2,025	5,004	0.235
		65.6				34,868				3.238
		4.4		**192.9**		**2,325**			**5,004**	**0.216**
90/91-Maha	3,255	4.0	465	192.9	7.00	2,134	90	2,025	5,004	0.235
91/92-Maha	3,302	4.1	465	192.9	7.10	2,164	90	2,025	5,004	0.230
92/93-Maha	3,348	4.1	465	192.9	7.20	2,195	90	2,025	5,004	0.230
93/94-Maha	3,255	4.0	465	192.9	7.00	2,134	90	2,025	5,004	0.235
94/95-Maha	3,348	4.1	465	192.9	7.20	2,195	90	2,025	5,004	0.230
95/96-Maha	3,302	4.1	465	192.9	7.10	2,164	90	2,025	5,004	0.230
96/97 -Maha	3,488	4.3	465	192.9	7.50	2,286	90	2,025	5,004	0.219
97/98 -Maha	3,209	4.0	465	192.9	6.90	2,103	90	2,025	5,004	0.235
98/99-Maha	3,209	4.0	465	192.9	6.90	2,103	90	2,025	5,004	0.235
99/00-Maha	3,116	3.8	465	192.9	6.70	2,042	90	2,025	5,004	0.248
00/01-Maha	3,023	3.7	465	192.9	6.50	1,981	90	2,025	5,004	0.254
01/02- Maha	3,023	3.7	465	192.9	6.50	1,981	90	2,025	5,004	0.254
02/03-Maha	2,976	3.7	465	192.9	6.40	1,951	90	2,025	5,004	0.254
03/04- Maha	2,790	3.4	465	192.9	6.00	1,829	90	2,025	5,004	0.277
04/05-Maha	2,837	3.5	465	192.9	6.10	1,859	90	2,025	5,004	0.269
Total		58.5				31,121				3.635
Average		**3.9**		**192.9**		**2,075**			**5,004**	**0.242**

*Assumed Average paddy yield for a scheme as 2025 Kg/Ac (90 Busals/Ac)
Source: Nachchaduwa IE Office

Table A3.1.4 Water Duty and Water Productivity in Rajangana Scheme (Including Lift Irrigation)

Season	Water Issue					Extent		Water Duty		Production			Water Productivity kg/m^3
	Angamuwa(Ac.ft.)	Angamuwa(MCM)	Rajangana (Ac.ft.)	Rajangana (MCM)	Total (MCM)	(Ac)	(Ha)	(ft)	(mm)	(Busal/Ac)	(Kg/Ac)	(Kg/Ha)	
1990-Yala	10,456	12.9	85,321	105.2	118.1	14,240	5,909	6.7	2,042	N.A.	-	-	-
1991-Yala	21,603	26.6	109,787	135.4	162.0	14,640	6,075	9.0	2,743	N.A.	-	-	-
1992-Yala	5,278	6.5	124,628	153.7	160.2	14,000	5,809	9.3	2,835	N.A.	-	-	-
1993-Yala	6,704	8.3	87,292	107.7	116.0	13,000	5,394	7.2	2,195	N.A.	-	-	-
1994 -Yala	25,376	31.3	105,433	130.0	161.3	14,632	6,071	8.9	2,713	N.A.	-	-	-
1995-Yala	19,881	24.5	125,347	154.6	179.1	11,600	4,813	12.5	3,810	N.A.	-	-	-
1996-Yala	12,885	15.9	101,488	125.2	141.1	12,142	5,038	9.4	2,865	N.A.	-	-	-
1997 -Yala	6,192	7.6	85,760	105.8	113.4	8,186	3,397	11.2	3,414	N.A.	-	-	-
1998-yala	10,504	13.0	101,956	125.8	138.8	15,700	6,515	7.2	2,195	**80.00**	1,800	4,448	0.209
1999-Yala	14,357	17.7	116,926	144.2	161.9	15,000	6,224	8.8	2,682	**85.40**	1,922	4,749	0.183
2000- Yala	12,671	15.6	111,615	137.7	153.3	13,642	5,661	9.1	2,774	**84.20**	1,895	4,682	0.173
2001-Yala	11,318	14.0	102,801	126.8	140.8	10,200	4,232	11.2	3,414	**92.50**	2,081	5,142	0.155
2002-Yala	Total of both tanks		**90,266**	111.3	111.3	15,572	6,461	3.9	1,177	**89.20**	2,007	4,959	0.288
Total					1,857.3	172,554	71,599	114.4	34,859	**431.3**	9,705	23,980	1.007
Ave					**142.9**	**13,273**	**5,508**	**8.8**	**2,682**	**86.3**	**1,941**	**4,796**	**0.201**
90/91-Maha	33,189	40.9	92,194	113.7	154.6	13,268	5,505	9.5	2,896	N.A.	-	-	-
91/92-Maha	32,529	40.1	101,076	124.7	164.8	14,240	5,909	9.4	2,865	N.A.	-	-	-
92/93-Maha	34,772	42.9	42,167	52.0	94.9	13,268	5,505	5.8	1,768	N.A.	-	-	-
93/94-Maha	490	0.6	79,508	98.1	98.7	5,680	2,357	14.1	4,298	N.A.	-	-	-
94/95-Maha	22,874	28.2	104,102	128.4	156.6	14,079	5,842	9.0	2,743	N.A.	-	-	-
95/96-Maha	40,130	49.5	97,752	120.6	170.1	15,374	6,379	9.0	2,743	N.A.	-	-	-
96/97 -Maha	36,996	45.6	130,254	160.7	206.3	16,000	6,639	10.5	3,200	N.A.	-	-	-
97/98 -Maha	49,842	61.5	77,724	95.9	157.4	13,647	5,663	9.3	2,835	**84.50**	1,901	4,697	0.169
98/99-Maha	35,662	44.0	84,891	104.7	148.7	15,000	6,224	8.0	2,438	**92.10**	2,072	5,120	0.214
99/00-Maha	15,789	19.5	61,215	75.5	95.0	15,000	6,224	5.1	1,554	**87.90**	1,978	4,888	0.320
00/01-Maha	23,411	28.9	88,277	108.9	137.8	13,642	5,661	8.2	2,499	**101.00**	2,273	5,617	0.231
01/02- Maha	Total of both tanks		**112,661**	139.0	139.0	14,025	5,820	5.8	1,765	**96.70**	2,176	5,377	0.225
02/03-Maha	Total of both tanks		**82,439**	101.7	101.7	14,025	5,820	3.7	1,128	**92.00**	2,070	5,115	0.293
					1,825.6	177,248	73,548	107.4	32,732	554.2	12,470	30,814	1.452
					140.4	**13,635**	**5,658**	**8.3**	**2,518**	**92.4**	**2,078**	**5,136**	**0.242**

Source: Rajangana IE Office

Table A3.1.12 Comparison of O&M of Irrigation between Study Area & System C

No.	Items to Compare	Unit	Nachchaduwa	Thuruwila	Rajangana	System C*1
A	**General Information**					
1	Comand Area (Max.)	Ha	2,904	193	6,639	16,500
2	Ave. Havested Area in Yala	Ha	1,617	193	5,508	16,500
3	Ave. Havested Area in Maha	Ha	2,635	193	5,658	16,500
4	Ave Yield in Yala	Kg/Ha	4,556	N.A.	4,796	4,755
	Yield of the latest Yala	Kg/Ha	4,278 (2003)	N.A.	4,959 (2002)	5,200 (2005)
5	Ave Yield in Maha	Kg/Ha	5,133	N.A.	5,135	4,915
	Yield of the latest Maha	Kg/Ha	5,354 (04/05)	N.A.	5,115 (02/03)	5,423 (04/05)
6	No. of FO Members	Nos.	2,448	140	6,340	16,500
7	No. of Farmers (Operators)	Nos.	1,817	250	6,695	16,500
8	Average Area per Operator	Ha	1.60	0.77	0.99	1.0
9	No. of FOs	Nos.	10	1	59	142
10	No. of Farmers per FO	Nos.	245	140	107	116

Note: System C Area is considered for Mahaweli Upgrading Project Area, but not whole System C
Average harvested areas of Rajangana, Nachchaduwa and Thuruwila are 13 years from Yala 90 tc Maha 02/03 and 15 years from Yala 90 to Maha 04/05 respectively.
Average yield of Rajangana and Nachchaduwa 11 seasons from Maha 97/98 to Maha 02/03 and 15 years from Yala 98 to Maha 04/05 except Yala 04 due to no cultivation respectively. Thuruwila has nc
Average yield in System C is from Yala 95 to Maha 2004/05,

Source: Respective IE offices & System C RPM office,

Table A3.1.13 FO Activities & Fees

No.	Items to Compare	Unit	Nachchaduwa	Thuruwila	Rajangana	System C
B	**FO Activities & Fees**					
1	Member, Owner and/or Tenant		Mianly Owner	Mainly Owner	Owner & Tenant	Owner & Tenant
2	Reristration to		ADC	ADC	ADC	RPM office, MASL
3	Who Operates:					
	Main & Branch Canals		ID	ID	ID	RPM
	D- Canals		FO	FO	FO	FO
	F- Canals		FO (FCG)	FO (FCG)	FO (FCG)	FO (FCG)
4	Who Maintains:					
	Main & Branch Canals		ID (FO for Cleaning)	ID (FO for Cleaning)	ID (FO for Cleaning)	RPM (FO for Cleaning)
	D- Canals		ID (Contract) & FO	ID (Contract) & FO	ID (Contract) & FO	FO
	F- Canals		FO	FO	FO	FO (FCG)
4	Collection of Fees					
	Acreage Tax paid to ADC	Rs/Ha/ Annum	15	16	15	Nil
	Ratio of Collection	%	100	100	100	-
	Membership Fee	Entrance Rs.	100	130 (Life Time)	100	100
		%	100	100	100	100
		Annual Rs.	25	0	0	50-150
		%	100	-	-	>80%
	O&M Fee for Jalapalaka & Maintenance	Rs/Ha/ Annum	1,500 (1 bushel /crop/acre)	750 (300 / acre/year)	1,500 (1 bushel /crop/acre)	500-1,000
	Ratio of Collection	%	Very Poor	Poor	80-90 (Gravity)	80-100
5	Chairman of Kanna Meeting		GA	GA	GA	RPM (Addl. GA)

Source: Respective RPM offices and interviews to FO leaders by the Study Team,

Table A3.1.14 Agencies Provided Services in Each Project

No.	Items to Compare	Nachchaduwa	Thuruwila	Rajangana	System C
C	**Agencies to Provide Services**				
1	Institutional Development	IMD (IDO)	ID	IMD (IDO)	RPM (IDO)
2	Agriculture Technology	DA	DA	DA	RPM (Agriculture Officer)
3	Land Subject	DS, ADC, DAD	DS, ADC, DAD	DS, ADC, DAD	RPM (Land Officer)
4	Agricultural Inputs	ADC, Traders	ADC, Traders	Traders, ADC, Cooperatives	RPM (Agriculture Officer)
5	Marketing of Product	Individual, Middleman, Informal Group	Individual, Middlema	Individual, Middleman	FO & Middleman
6	Credit	Death Donation Society, Agrarian Bank, Mudalali, Samurudhi Bank, NGOs	Mudalali, Agrarian Bank, Death Donation Society, Samurudhy Bank, NGOs	Mudalali, Agrarian Bank, Samurudhi Bank, Death Donation Society, NGOs, Micro Credit Organisations	**FO**, Mudalali, RDB, SANASA, BOC, PB, Seylan Bank, Sarvodaya, etc.

Source: Respective RPM offices and interviews to farmers by the Study Team,

Table A3.1.15 Operation and Maintenance Expenses (2005 Budget) for Each Project

No.	Items to Compare	Unit	Nachchaduwa	Thuruwila	Rajangana	System C
D	**Operation and Maintenance Expenses (2005 Budget)**					
1	Operation Budget of ID & MASL	Rs. **(Rs./ha)**	132,320 **(46)**	9,000 **(46)**	281,600 **(42)**	2,533,000 **(153)**
	a ID's Expenses	Rs.	67,100	9,000	84,480	No separate budget for Sub-items.
	b FO Expenses on contracts	Rs.	67,100	0	197,120	
2	Maintenance Budget of ID & MASL	Rs. **(Rs./ha)**	872,200 **(301)**	58,500 **(303)**	1,835,900 **(277)**	4,451,000 **(269)**
	a Headworks	Rs.	174,920	No separate budget for Sub-items.	555,700	No separate budget for Sub-items.
	b Roads	Rs.	87,460			
	c Main & Branch Canal	Rs.	349,840		535,731	
	d Distributory Canal	Rs.	262,380		377,286	FO's Responsibility
	e Field Canal	Rs.	FO's Responsibility	FO's Responsibility	367,180	FCG's Responsibility

Source: Respective IE offices and RPM offices and interviews to FO leaders by the Study Team,

Table A3.1.16 Comparison of Water Duty and Productivity

No.	Items to Compare	Unit	Nachchaduwa	Thuruwila	Rajangana	System C
E	**Water Duty & Productivity**					
1	Warter Duty					
	2000 Yala	mm	1,625	2,286	2,774	2,660
	2001 Yala	mm	1,561	2,194	3,414	2,440
	2002 Yala	mm	1,009	2,133	1,177	2,270
	Ave. Yala	**mm**	**1,398**	**2,204**	**2,455**	**2,457**
	2000/01 Maha	mm	756	1,981	2,499	1,500
	2001/02 Maha	mm	585	1,950	1,765	1,630
	2002/03 Maha	mm	1,509	1,828	1,128	1,440
	Ave Maha		**950**	**1,920**	**1,797**	**1,523**
2	Ave. Yield					
	2000 Yala	kg/Ha	4,607	Assuming 5,003	4,681	4,996
	2001 Yala	kg/Ha	4,940	Assuming 5,003	5,142	4,894
	2002 Yala	kg/Ha	4,678	Assuming 5,003	4,959	4,890
	Ave. Yala	**kg/ha**	**4,742**	**5,003**	**4,927**	**4,927**
	2000/01 Maha	kg/Ha	5,376	Assuming 5,003	5,615	5,151
	2001/02 Maha	kg/Ha	4,884	Assuming 5,003	5,376	4,805
	2002/03 Maha	kg/Ha	5,218	Assuming 5,003	5,114	5,574
	Ave Maha	**kg/ha**	**5,159**	**5,003**	**5,368**	**5,177**
3	Water Productivity of Paddy					
	2000 Yala	kg/M3	0.284	0.219	0.159	0.168
	2001 Yala	kg/M3	0.316	0.228	0.120	0.205
	2002 Yala	kg/M3	0.464	0.235	0.281	0.216
	Ave. Yala	**kg/m^3**	**0.355**	**0.227**	**0.187**	**0.196**
	2000/01 Maha	kg/M3	0.710	0.253	0.285	0.342
	2001/02 Maha	kg/M3	0.833	0.257	0.220	0.316
	2002/03 Maha	kg/M3	0.346	0.274	0.286	0.334
	Ave Maha	**kg/m^3**	**0.630**	**0.261**	**0.264**	**0.331**

Source: Respective IE offices and System C RPM Office,

Table A 3.3.1 Present Situation and Problems for Irrigation Sector (1/5)

Irrigation

Category	Present Situation	Problems Description
1. Function of Main Irrigation Facilities	Common Points	
1.1 Physical condition	• Conveyance efficiency of main canals is low. Downstream block or tract is facing water shortage. • Turnout gates on main canals are highly deteriorated. • Physical rehabilitation and improvement is expected by ID under the PEACE Project.	• Facilities at main level are deteriorated primarily due to low quality of construction and insufficient maintenance by the government. • Rehabilitation and improvement are, therefore, required with capacity development of the government staff concerned.
1.2 Government budget for O&M	• Government budget is supposed to be provided for maintenance of main facilities including tanks, main canals and those related facilities. • The budget provided for abovementioned O&M is, however, reported to be only 20 to 30 % of the actual requirement to maintain existing facilities.	• Government budget allocated for main system O&M is insufficient. • As a result, timely maintenance cannot be carried out, leading to further deterioration.
	Particular Situation in Nachchaduwa Major Scheme.	
1.1 Physical condition	• Rehabilitation was implemented under MIRP (1989). Canals are, however, highly sedimented and weedy which hinder smooth conveyance of irrigation water.	• Quality of the construction was insufficient. Further rehabilitation is required. • Regular O&M of main facilities by the government is insufficient.
1.2 Drainage condition	• The area is inundated at some parts where the siphon from Thruwila scheme is crossing the HL Main Canal.	• Some facilities are inadequately designed.
	Particular Situation in Rajangana Major Scheme	
1.1 Physical condition (canals)	• Rehabilitation was conducted under MIRP (1989). Canals are, however, highly sedimented and weeded which hamper smooth conveyance of irrigation water. • Canal section is significantly collapsed particularly the upstream from ch. 0+20 to 3+00.	• Quality of the construction was insufficient. Further rehabilitation is, therefore, required with adequate supervision by the government. • Drainage problem in the Manel Wewa command area is observed caused by the RB BC 3 canals located at the boundary of Manel Wewa.
1. Physical condition (roads)	• Roads along main canals are deteriorated (LB Main, RB Main, BC2 canals).	• Maintenance works are not sufficiently carried out.
	Particular Situation in Thruwila Medium Scheme	
1.1 Physical condition	• Rehabilitation of main facilities is on-going through the project by Anuradhapura Water Supply Scheme under National Water Supply and Drainage Board. • However, collaterally, water is issued without careful attention to rehabilitation works.	• The work has not been completed yet due to delay. • Some portions, where rehabilitation is incomplete, have been already significantly inundated which affect rehabilitated facilities. • Abovementioned issue is caused by inadequate construction supervision by the government.
2. Function of D- and F-canal level Irrigation Facilities	Common Points	
2.1 Physical condition	• D- and F-canal density of three schemes ranges from 62 m to 67 m per hectare which could be nearly standard value to improve the irrigation canal network at tertiary level.	• Deterioration is widely observed, therefore, canals and structures are required to be rehabilitated and improved.

Table A 3.3.1 Present Situation and Problems for Irrigation Sector (2/5)

Category	Present Situation	Problems Description
	• Some rehabilitation works at D- and F-canal level were carried out in late 80s to early 90s. • Most of the measuring devices at the head of F-canal have been deteriorated. • Ratio of attendance to Shramadana for system O&M differs among schemes: highest in Nachchaduwa (91%) while 76% in Rajangana and lowest in Thruwila (69%).	
2.2 Handing-over of systems from the Government to FOs (Government Side Issue)	• D-canal was rehabilitated with random rubble masonry in '90s. • Handing over of D- and F-canal level system to FOs is officially declared for Nachchaduwa and Rajangana major scheme, however, ID is still providing O&M expenses. • This situation pinches government budget for O&M of main facilities.	• M&E activities by the government field staff are not sufficiently carried out. • It is resulted from various reasons such as (i) insufficient process of handing-over by the government (lack of awareness and training program to FOs, preparedness of facilities and so forth), (ii) lack of capability and sense of ownership of FOs, which clog up proper O&M of facilities by FOs.
2.3 Government Field Staff (Government Side Issue)	• All the schemes face insufficient number of field staffs (engineering assistant, work supervisor and water issue laborer) in M&E of D- and F-canal level. • Insufficient technical skills of existing government field staff are in serious condition to carry out M&E.	• It is difficult to sufficiently carry and monitoring and evaluation (M&E) in irrigation activities at the D- and F-canal level.
2.4 FOs Capability and Attitude (FOs Side Issue)	• Dependency attitude to the government still remain among FOs. Therefore, D- and F-canal level O&M is not effectively carried out. • Because of the lack of farm turnout, PVC and other temporary means are set by FOs for diverting water from F-canal into the field including illegal tapping. The survey shows that the situation Thruwila medium scheme is worse than in that in Nachchaduwa and Rajangana kajor schemes. Latter two schemes reveals that 84 % and 93 % of all farm turnout respectively is constructed by concrete while only 68 % is in Thruwila. • In some areas, encroachment of canals and reservation are observed. • In Rajangana, O&M fee is collected only from 4% of FOs members while almost zero in Nachchaduwa and Thruwila.	• Handing-over process from the government to FOs is insufficient (lack of awareness and capability for maintenance of D- and F-level facilities in FOs). • Setting of additional make-shift turnout and illegal tapping would be weakening canal section caused by insufficient preparedness of facilities.
Particular Situation in Nachchaduwa Major Scheme.		
2.1 Physical condition	• Facilities rehabilitation at D- and F-canal level was carried out under MIRP (1989). • According to the mapping survey, out of 264 nos. of D- and F-canal related structures, nearly 60 % of D- and F-level structures are in poor condition.	• Although being rehabilitated, quality control was not satisfactory thereby already causing deterioration of facilities. • Further rehabilitation of canals and related structure is required.
2.2 Handing-over from the government to FOs	• Handing-over has been officially declared, however, O&M by FOs are poor.	• The problem is as mentioned in general and common points.

Table A 3.3.1 Present Situation and Problems for Irrigation Sector (3/5)

Category	Present Situation	Problems Description
	Particular Situation in Rajangana Major Scheme	
2.1 Physical condition	• Rehabilitation was carried out under MIRP (1989). • In addition, pilot area tract 2 (D-1) command area was rehabilitated by "the performance evaluation of automatic head and flow control system at D-level" financially assisted by World Bank in early 1990s, therefore, they are comparatively in better condition. • As seen in above-stated pilot areas, some baffle distributor is destroyed and removed by FO members. • Mapping survey shows that out of 260 nos. of structures in D- and F-canal levels, more than 80 % of those in LB tract 2 (pilot area) are in good condition. • Other than the pilot areas, however, most of the turnout gates on D-canals are missing or impossible to be operated.	• Other than the pilot areas, O&M of D- and F-canal level is in poor leading to deterioration of facilities. • Further rehabilitation and improvement is required. • The situations that baffle distributor are forcedly removed shows that insufficient length of time was allocated for an introduction of improved technology.
2.2 Encroachment	• Along the upstream of D-1 (LB tract 2) is highly encroached identified by mapping survey.	• Such encroachment seriously affects security of D- and F-canal level facilities.
	Particular Situation in Thruwila Medium Scheme	
2.1 Physical condition	• Rehabilitation at D- and F-canal level is on going through the project by Anuradhapura Water Supply Scheme under National Water Supply and Drainage Board. • Rehabilitation works are not sufficiently informed to FOs in Thruwila. • In accordance with the mapping survey, out of 257 nos. of D- and F-canal related structures, 70 % of those are in better condition.	• However, the work has not yet completed due to delay due to poor construction management on site and budget allocation from the central level. • Participation of FOs to above-mentioned rehabilitation works is quite limited.
3. Water Management at Main Level	Common Points	
3.1 Water Management Decision-making Process	• Water issue schedule within the system depend upon distribution schedule to each scheme prepared by Mahaweli Water Management Committee (MWMC) before every cropping season. All the schemes are, therefore, defined as supply-oriented system. • Water management schedule in the system is finalized by Pre-Kanna Meeting and Kanna Meeting. The activities are monitored and evaluated by the Project Management Committee (PMC).	• M&E by PMC in water management is limited. • Farmers' participation is limited in water issue decision-making process.
3.2 Gate Operation	• Tank outlet and tunrout gate is operated by WIL (ID Jalapalaka) based on water issue schedule prepared prior to each cropping season. • Although slight revision is observed, gate is generally operated on schedule.	• Since discharge cannot be measured at turnouts, gate is operated generally on-off basis. Irrigation water is not equitably distributed within the system. • Security of D- and F-canals are jeopardized by such excessive discharge.

Table A 3.3.1 Present Situation and Problems for Irrigation Sector (4/5)

Category	Present Situation	Problems Description
	・ Discharge is not measured at the head of D-canal since most of the measuring device is deteriorated. ・ Therefore, excessive discharge is diverted to D-canal according to the water measurement at pilot and control areas in LB tract 2, pilot and control areas.	
	Particular Situation in Nachchduwa Major Scheme	
3.1 Physical condition	・ Main canal is seriously deteriorated which causes high conveyance losses.	・ O&M of main canal by the government is insufficient.
	Particular Situation in Rajangana Major Scheme	
3.1 Physical condition	・ Main canal is seriously deteriorated causing high conveyance losses. ・ Downstream areas particularly in Right Bank Tract 16, 17 and 18.	・ Gate operation and water measurement of main canal by the government is inadequate (on-off basis only without discharge measurement).
	Particular Situation in Thruwila Medium Scheme	
3.1 Physical Condition	・ Main canals are recently rehabilitated with concrete U-flume under Anuradhapura Water Supply Project. Although work is incomplete, efficiency on water management has been much improved. ・ Others are as mentioned in general and common points.	-
4. Water Management at D- and F-canal Level	Common Points	
4.1 Handing-over of Systems to FOs (Government side issue)	・ As for Nachchaduwa and Rajangana scheme, FOs are supposed to take charge of O&M of D- and F-canal level facilities in accordance with the Irrigation Ordinance (1994) and Agrarian Development Act (2000). ・ Prior to handing-over, agreement was concluded among FOs and RDI. Then basic training was provided to FOs at ITI covering the subject of O&M, financial management and so forth. ・ ID is, however, still providing substantial amount of funds for those O&M. ・ Lack of communication among FO members and government field staff exist.	・ Overall, handing-over process from the government to FOs was not so satisfactory (insufficient transitional period of handing-over, training, follow-up and M&E) which could not foster FOs to properly carry out water management at D- and F-canal level. ・ Lack of communication measures to bridge gaps among government field staff and FOs.
4.2 Government Field Staff	・ D- and F-canal water management activities by FOs are not well monitored by the government field staff (EA, WS and WIL).	・ Government field staff taking charge of water management (water issue laborer) is not well trained. ・ Number of government field staff is insufficient.
4.3 FOs' capability and attitude (FOs side issue)	・ FOs' awareness about importance of irrigation water is insufficient. ・ Although rotational irrigation schedule is prepared within D- and F-canal level under the support of EA, it is not actually practiced in Maha season. ・ Due to insufficient knowledge on O&M, sense	・ Related with abovementioned issue (handing-over process), FOs' capability and attitude is not adequately prepared for conducting water management at D- and F-canal level by themselves. ・ Awareness about importance of irrigation water is insufficient among FOs.

Table A 3.3.1 Present Situation and Problems for Irrigation Sector (5/5)

Category	Present Situation	Problems Description
	of ownership among FOs is insufficient. ・ Dependency attitude to the government still remain among FOs for water management. ・ FO Jalapalaka have insufficient water management skill.	
Particular Situation in Nachchduwa Major Scheme		
4.1	・ As mentioned in general and common points.	
Particular Situation in Rajangana Major Scheme		
4.1	・ Nearly double of designed discharge has been diverted from main to D-canals which are identified through water measurement study at the control areas in LB tract 2. ・ This is caused because discharge measurement is not carried out at the head of D-canals.	・ Sustainability of canals and related structures at D- and F-level is not ensured due to such excessive discharge in D-canals. ・ The amount of wastage water through ineffective water management by FOs is not negligible.
Particular Situation in Thruwila Medium Scheme		
4.1	・ Different from Nachchaduwa and Rajangana, continuous irrigation is practiced within D- and F-canal command areas, the works of which are entrusted to FOs. ・ Others are as mentioned in general and common points.	

Table A 4.2.1 Problems and Approach for Irrigation Sector (1/4)

Irrigation

Category	Problem Description	Approach	Target Group
1. Function of Main Irrigation Facilities	Common Points		
1.1 Physical condition	• Deteriorated main level facilities • Poor Maintenance by the government	• Capacity development of government staff through rehabilitation works • Training program for government staff: quality control for rehabilitation and construction works including earth and concrete works, field inspection, document preparation for construction supervision • Two different levels of program are proposed for ID (more technical side) and IMD (basic techniques plus coordination and facilitation skill).	• ID / IMD
1.2 Government budget for O&M	• Budget shortage allocated for main system O&M is insufficient resulting untimely maintenance	• Increasing budget for irrigation should be attended by the government. • Supporting to establish transparent financial management procedure would partly improve situation.	• ID / IMD
	Particular Situation in Nachchaduwa Major Scheme.		
1.1 Physical condition	• As mentioned in C1.1	• As mentioned in C1.1	• ID / IMD
1.2 Drainage condition	• Inadequate design of facilities at siphon crossing HLM canal	• To be redesigned and rehabilitated with capacity development of government staff • Development of design guideline	• ID / IMD
	Particular Situation in Rajangana Major Scheme		
1.1 Physical condition (canals)	• Insufficient quality of the construction • Drainage problem in the Manel Wewa command area	• Training on quality control for rehabilitation and construction works, the contents for which to the government staff is described in C1.1 • To be redesigned and rehabilitated with capacity development of government staff • Development of design guideline	• ID / IMD
1.2 Physical condition (roads)	• Insufficient maintenance works for the road along the main canal	• To be redesigned and rehabilitated with capacity development of government staff • Development of design guideline	• ID / IMD
	Particular Situation in Thruwila Medium Scheme		
1.1 Physical condition	• Delay of rehabilitation works • Insufficient construction supervision	• Development of construction management guideline for re-scheduling and work acceleration • Training on quality control for rehabilitation and construction works as explained in C1.1	• ID

Table A 4.2.1 Problems and Approach for Irrigation Sector (2/4)

Category	Problem Description	Approach	Target Group
2. Function of D- and F-canal level Irrigation Facilities	Common Points		
2.1 Physical condition	• Deteriorated D- and F-canal level facilities • Discharge not measured	• Rehabilitation through community participation approach • Training necessary for government staff and FOs for facilitation and implementation of community participation approach are respectively explained in C2.2 and C2.4 as follows.	• ID / IMD
2.2 Handing-over of systems from the Government to FOs (Government Side Issue)	• Insufficient handing-over process	• Capacity development for government staff to facilitate community participation approach: • Training program for government staff: Participatory planning, communication with farmers, skills on technology transfer, handing-over of O&M responsibilities to farmers	• ID / IMD
2.3 Government Field Staff (Government Side Issue)	• Insufficient M&E by the government field staff for D- and F-canal level activities	• Training of government field staff for M&E of FOs' D- and F-canal level activities	• ID / IMD
2.4 FOs Capability and Attitude (FOs Side Issue)	• Insufficient handing-over process (lack of awareness and capability for maintenance) • Make-shift turnout and illegal tapping	• Additional farm turnout to be planned and rehabilitated through community participation approach • Training program for FOs: participatory planning, transect walk and field investigation, design and cost estimate, contract management for construction works, quality control for earth and concrete works, field inspection, preparation of document for rehabilitation and construction, organization of shramadana for O&M, collection of O&M fee and financial management	• FOs • Community organizations such as school
	Particular Situation in Nachchaduwa Major Scheme.		
2.1 Physical condition	• Deteriorated facilities	• As same as C2.1 • Training contents for government staff and FOs are explained in C2.2 and C2.4	• ID / IMD
2.2 Handing-over from the government to FOs	• Insufficient handing-over process	• As same as C2.1 • Training contents for government staff and FOs are explained in C2.2 and C2.4	• ID / IMD
	Particular Situation in Rajangana Major Scheme		
2.1 Physical condition	• Poor O&M of D- and F- canal level and deterioration • The situations that baffle distributor are forcedly removed shows that insufficient length of	• As same as C2.1 • Training contents for government staff and FOs are explained in C2.2 and C2.4 • Dedicating enough transition period to introduce new technology in order to	• ID / IMD

Table A 4.2.1 Problems and Approach for Irrigation Sector (3/4)

Category	Problem Description	Approach	Target Group
	time was allocated for an introduction of improved technology.	ensure social acceptability through scaling-up approach (workshop, study tour, trial water management practice and so forth)	
2.2 Encroachment	• Encroachment along D-canals	• Legalization • Physical approach (partial canal lining, protection works)	• ID / IMD • FOs
	Particular Situation in Thruwila Medium Scheme		
2.1 Physical condition	• Delay of physical rehabilitation works under Anuradhapura Water Supply Scheme • Insufficient participation of FOs to above-mentioned rehabilitation works	• Development of construction management guideline for re-scheduling and work acceleration • Socialization among stakeholders: awareness workshop and O&M planning	• ID
3. Water Distribution at Main Level	Common Points		
3.1 Water Management Decision-making Process	• Limited M&E by PMC in water management • Limited farmers participation in water management decision-making process	• PMC activities improvement for M&E in water management	• ID / IMD and other related agencies • FOs
3.2 Gate Operation	• Not equitable water distribution within the system • Excessive discharge to D-canals	• Capacity development of government field staff related with 3.3 • Training program for government staff: Awareness program, communication skill with farmers, technology transfer skills to FOs, water requirement estimation, water issue schedule preparation, gate operation for tanks and turnout to D-canals, discharge measurement and monitoring skill • Rehabilitation of measuring device • Two different levels of program are proposed for ID (more-technical side) and IMD (basic techniques, and coordination and facilitation skill).	• ID /IMD
	Particular Situation in Nachchduwa Major Scheme		
3.1 Physical condition	• Insufficient maintenance of main canal by the government.	• Capacity development on water management for government staff as mentioned in C3.1 • Rehabilitation of main facilities (as explained in C1.1)	• ID
	Particular Situation in Rajangana Major Scheme		
3.1 Physical condition	• Insufficient maintenance of main canal by the government	• As mentioned in C3.1	• ID
	Particular Situation in Thruwila Medium Scheme		
3.1 Physical	• As mentioned in C3.1	• As mentioned in C3.1	• ID

Table A 4.2.1 Problems and Approach for Irrigation Sector (4/4)

Category Condition	Problem Description	Approach	Target Group
4. Water Distribution at D- and F-canal Level	Common Points		
4.1 Handing-over of Systems to FOs (Government side issue)	• Insufficient handing-over process (training, follow-up and M&E)	• Capacity development for the government staff on the facilitation of community participatory water management • Training program for government staff: Awareness program, communication skill with farmers, technology transfer skills to FOs, water requirement estimation, water issue schedule preparation, discharge measurement and monitoring skill at D- and F-canal level	• ID / IMD
4.2 Government Field Staff (Government side issue)	• Not well trained government field staff taking charge of water management • Insufficient number of government field staff	• As explained in C4.1 • Development of monitoring and evaluation guideline to effectively conduct D- and F-level M&E • Increasing the number of field staff should be attended by the government.	• ID /IMD
4.3 FOs' capability and attitude (FOs side issue)	• Unprepared FOs' capability and attitude for conducting water management at D- and F-canal level by themselves.	• Capacity development for FOs' participatory water management: awareness and training • Training program for FOs: awareness program, communication with government staff, communication among farmers, communication with other FOs, preparation of water distribution schedule, skill of gate operation on D-canals, dispute settlement over water use	• FOs • Community organizations such as school
	Particular Situation in Nachchduwa Major Scheme		
4.1	• As mentioned in C4.1 to 4.3	• Capacity development for government staff and FOs as respectively mentioned in C4.1 to 4.3	• ID / IMD • FOs
	Particular Situation in Rajangana Major Scheme		
4.1	• Sustainability of canals and related structures at D- and F-level is not ensured due to excessive discharge. • Wastage water through ineffective water management is not negligible.	• Establishment of proper water measurement mechanism at the head of D-canals through training of both government and FO Jalapalaka: joint monitoring • Training program for government staff and FOs as mentioned in C4.1 and C4.3	• FOs
	Particular Situation in Thruwila Medium Scheme		
4.1	• As mentioned in C4.1 to 4.3	• As mentioned in C4.1 to 4.3	• FOs

Table A 4.2.2 Contents of Training Courses (Irrigation Sector) (1/2)

Title	Program Contents	Target Group
Function of Main Level Facilities Improvement		
Irrigation Rehabilitation	- Situation analysis and its constraints identification regarding function of main facilities - Rehabilitation planning ・ Deterioration assessment method ・ Rehabilitation plan and design ・ Cost estimate - Construction supervision ・ Quality control ・ Progress control ・ Security control ・ Document control ・ Financial management for construction works - Maintenance planning ・ Maintenance plan (structures, frequency, organization and maintenance responsibility) ・ Maintenance cost estimate ・ Budgeting procedure	Government officials
Financial Management Improvement		
Financial management for Irrigation	- Awareness program - Responsibility on financial management - Review of existing financial management system - Identification of current financial management system and its improvement planning - Book keeping - Effective auditing system (frequency, responsibility, internal and external monitoring and evaluation)	Government officials
Community Participatory Approach Rehabilitation	**(D- and F-canal Level)**	
Community Participatory Approach Facilitation in Irrigation Rehabilitation	- Community participatory planning facilitation - Communication skill with farmers - Technology transfer skill - Follow-up programming	Government officials
Community Participatory Approach in Irrigation Rehabilitation	- Awareness program - Community participatory planning - Transect walk and field investigation - Rehabilitation design and cost estimate - Contract management - Farmers' contribution to rehabilitation works - Quality control for rehabilitation works (such as earth and concrete works) - Document preparation for rehabilitation works - Field inspection	FOs

Table A 4.2.2 Contents of Training Courses (Irrigation Sector) (2/2)

Title	Program Contents	Target Group
	- Maintenance planning and its responsibility - Maintenance cost preparation	
Water Management Improvement	**(Overall)**	
Organizational Management for PMC	- Awareness program - Function of PMC - Review of current activities and its constraints - Selection of agenda - Monitoring and evaluation method for irrigation activities on both main, and D- and F-level. - Responsibility sharing	Government officials and FOs
Water Management Improvement	**(Main Level)**	
Water Management on Main Level Facilities	- Awareness program - Review of current water management practice and identify its constraints - Water management responsibility and organization - Water requirement estimation - Water issue scheduling - Gate operation for tanks and turnout on main canal - Discharge measurement and monitoring skill	Government officials
Community Participatory Water Management	**(D- and F-canal Level)**	
Community Participatory Water Management Facilitation	- Awareness program - Technology transfer skill to FOs - Water requirement estimation - Water issue schedule preparation (continuous and/or rotational irrigation scheduling) - Discharge measurement and monitoring skill at D- and F-canal level	Government officials
Community Participatory Water Management (FOs)	- Awareness program - Communication skill with government staff - Communication among farmers - Dispute settlement over water use - Preparation of water management schedule - Skill of gate operation on D-canal	FOs

Figure

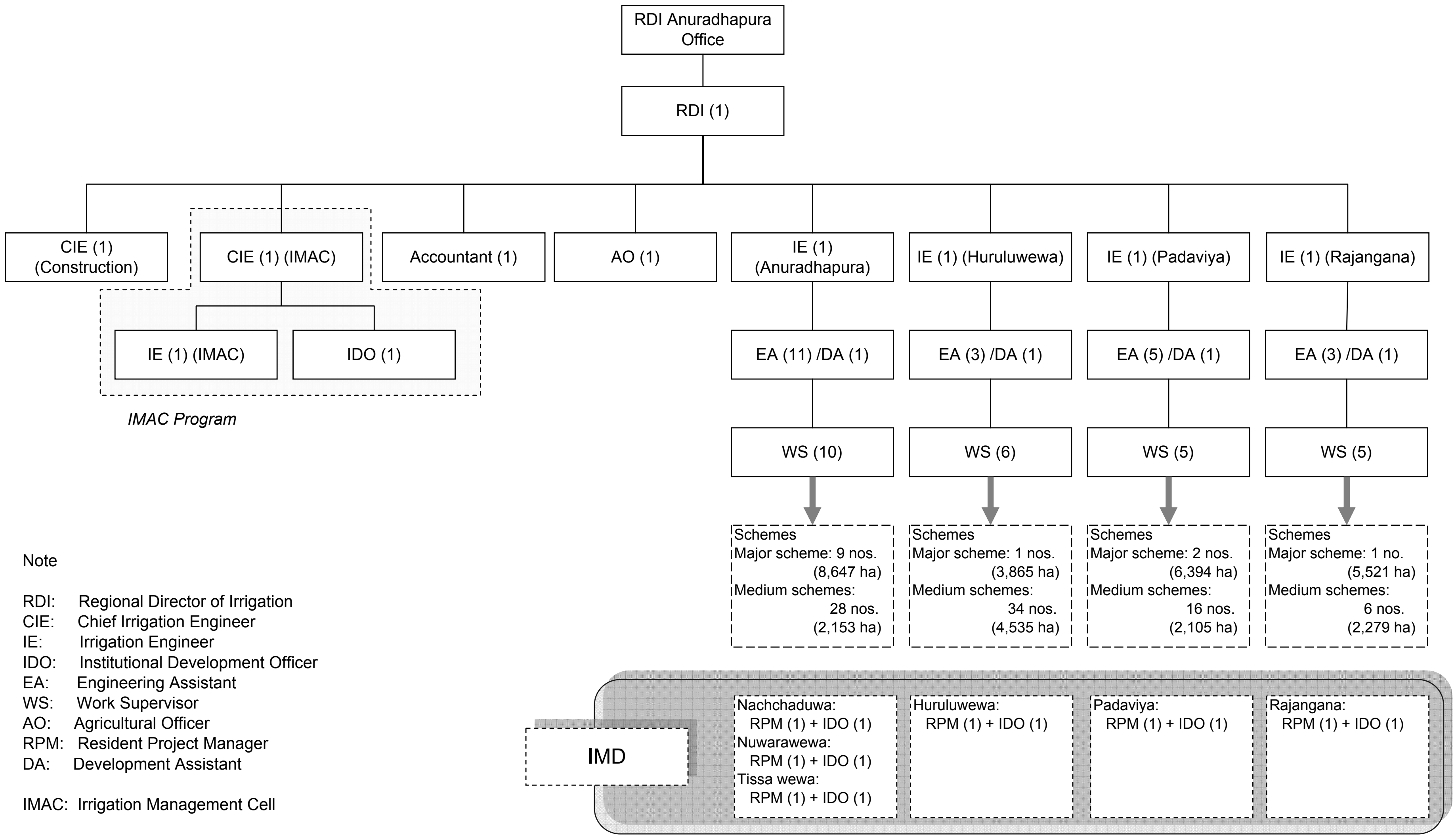
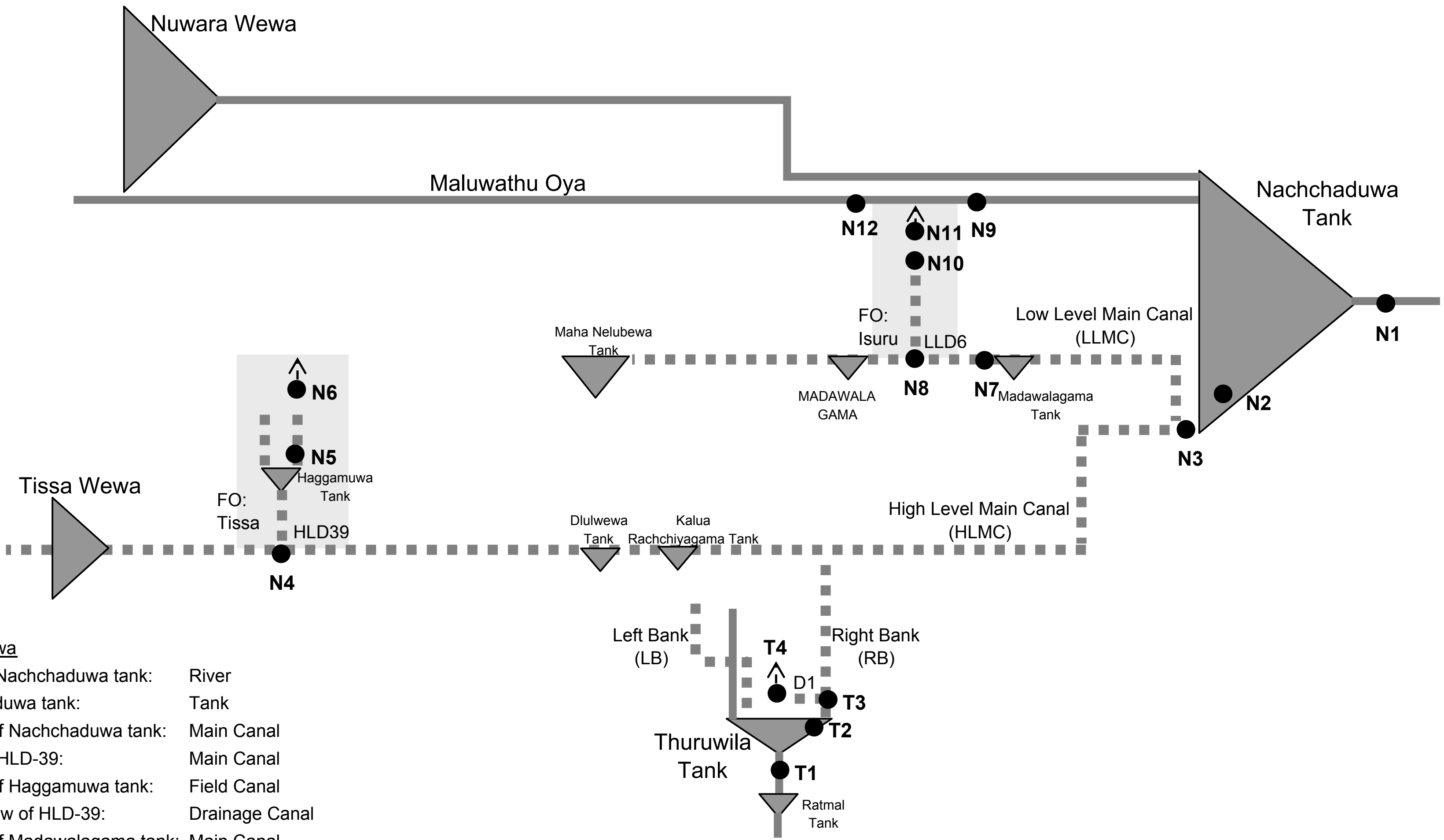


Figure A 3.1.2 Organizational Structure of RDI Anuradhapura Office



Nachchaduwa

1. Inflow of Nachchaduwa tank: River
2. Nachchaduwa tank: Tank
3. Outflow of Nachchaduwa tank: Main Canal
4. Intake of HLD-39: Main Canal
5. Outflow of Haggamuwa tank: Field Canal
6. Return flow of HLD-39: Drainage Canal
7. Outflow of Madawalagama tank: Main Canal
8. Intake of LLD-6: Main Canal
9. Drainage river: Maluwatu oya
10. End point of LLD-6: Distributory Canal
11. Return flow of LLD-6: Drainage Canal
12. Return flow to the river: River

Thuruwila

1. Inflow of Thuruwila tank: River
2. Thuruwila tank: Tank
3. Intake of RB D-1: Main Canal
4. Return flow of D-1: Drainage Canal

● N1 Sampling Point in Nachchaduwa Irrigation Scheme
● T1 Sampling Point in Thruwila Irrigation Scheme

Figure A 3.1.4 Sampling Sites of Water Quality Survey in Nachchaduwa & Thuruwila Irrigation Schemes (Irrigation Water)

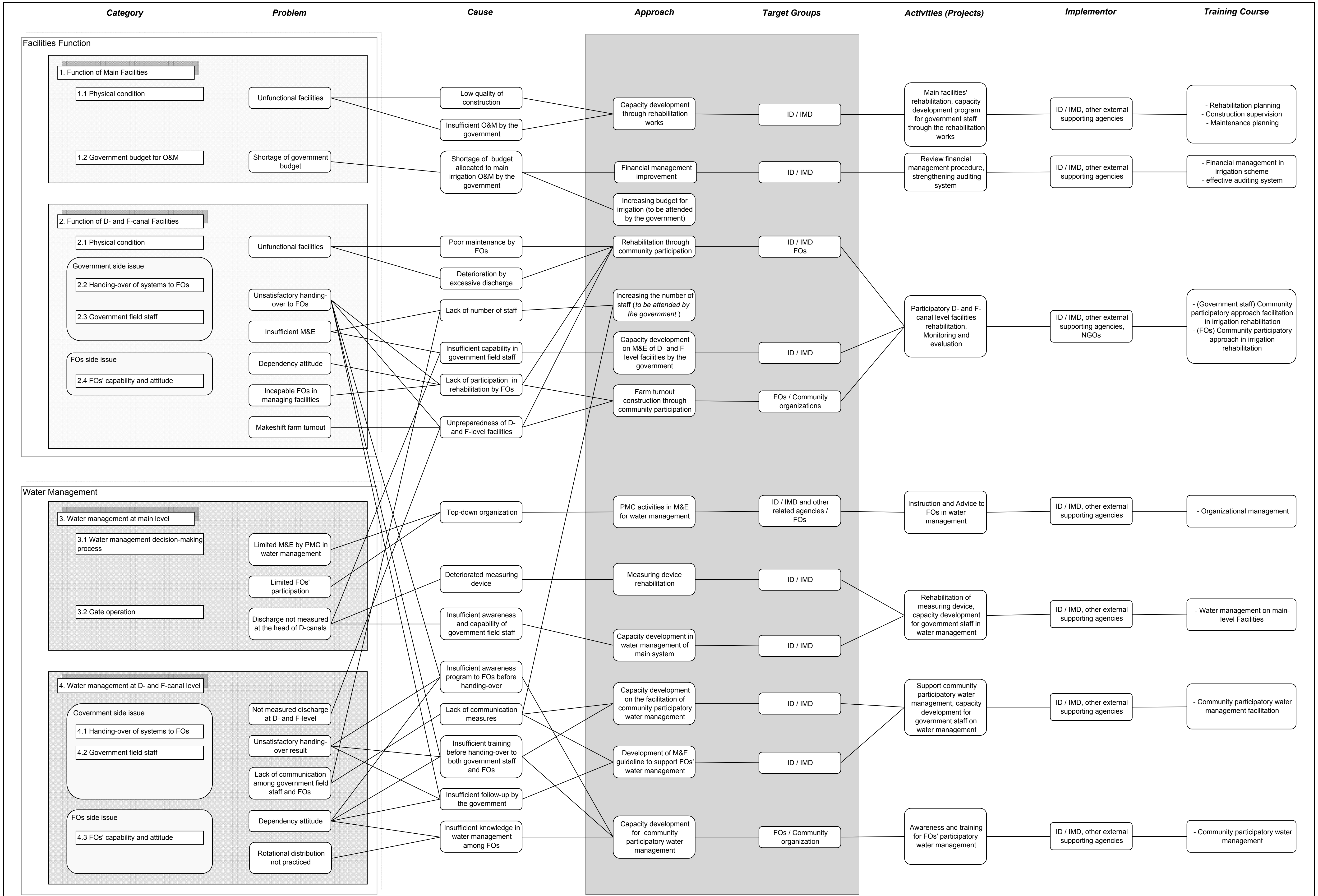


Figure A 4.2.1 Capacity Development Approach for Irrigation Sector

Attachment

Attachment A1

Performance Evaluation of Long-crested Weir and Baffle Distributor

CHAPTER 1 INTRODUCTION

1.1 Background

In view of maximizing the performance of irrigation project, proper planning and design of tertiary system is essential as well as the operational capacity of the users. In the study area, there was a pilot programme which was conducted under Major Irrigation Rehabilitation Project (MIRP, 1989) and performance of the newly introduced devices: neyrpic automatic water level control gates, long-crested weir, and baffle distributor, was studied. The programme, taken over by ITI, continued over four consecutive seasons: 1992 Yala, 1992/93 Maha, 1993 Yala, and 1993/94 Maha. It aimed at introducing new devices for irrigation management in selected schemes, and thereafter to extend it to a wider section of the nationwide irrigation systems. Comparison of pilot area and control area revealed that performance of that modern system was effective and equity in water distribution was attained in the pilot area. Following the programme, this study analyzes the current performance and propose future improvement process.

1.2 Objective

Objective of this analysis is to:

- reconfirm and verify an effectiveness of long-crested weir and baffle distributor in improving equity and efficiency in water use
- propose further modification and future improvement process, and
- propose an approach of improving water distribution within D-canal command areas.

1.3 Methodology

1.3.1 Distribution Facilities

Distribution system under D-canal level consists of: head gate of D-canals, check structures on the D-canals, turnout of F-canals, and F-canals. In the pilot area, neyrpic automatic water level control gate is located just after the steel slide gate at the head of D-1 canal. It maintains the downstream water level and enables to convey the constant volume in combination with the baffle distributor. At the head of each F-canal, baffle distributor is installed just upstream of long-crested weir on the parent D-canal and distribute the constant water to F-canal. On the other hand, devices in the control area are conventional and commonly used i.e. steel slide gates at the head of both D- and F-canals. Distribution facilities in the pilot and control area are presented as follows:

Table 1 Devices in the Pilot and Control Areas

	Pilot Area - Modern System -	Control Area - Conventional System -
Head of D-canal	 Steel slide gate with Neyrtec Automatic Head Control Gate	 Steel slide gate
Check Structure	 Long-crested weir (duckbill or diagonal weir)	Cross Regulator or Weir (There is no structure in the study area)
Turnout	 Baffle Distributor	 Steel slide gate with measuring weir

Source: JICA Study Team

Feature of the devices installed in the pilot area are as follows:

(1) Neyrpic Automatic Head Control Gate

(Above) Neyrpic Automatic Head Control Gate (downstream view)
(Below) –do- with baffle distributor

Neyrpic automatic head control gates designed for sluices and canal reaches are radial gates operated by floats filled to the gate the operational principles of orifice type downstream control gates designed for sluices is shown in fig.

These gates which maintain the downstream water level at constant, consists of a float fitted to the gate at downstream of the gate hinge line. Initially the movable counter weight is adjusted so that the neutral equilibrium is attained when the downstream water level is at the hinge line elevation.

The hydraulic thrust on the gate leaf passage through the hinge and has no effect on the equilibrium. The torques due to the weight and that due the buoyancy is balanced by addition of ballasts and the position of the gate will be governed by the head loss required to pass the desired discharge.

Therefore if the irrigation demand drops the water level, downstream of the gate rises and lower the gate and vise-versa.

(2) Long-crested Weir

The pilot area of Rajangana LB tract 2 adopted duckbill weir and diagonal weir. In general, the concept of long-crested weir is to ensure longer length of weir than is possible with typical weirs installed across the canal with the crest perpendicular to the centerline of the canal. Such additional length enables design flow discharge to pass with smaller variable of heads, meaning that even large changes in discharges over the crested weir will result in smaller changes in head thereby changing smaller in flow into F-canals. In general, constant flow rates are comparatively user-friendly requiring less workforce in irrigation water management, therefore, long-crested weir can contribute to reducing difficulties in water management. In addition, if adopting conventional system, upstream area are often provided with excessive water due to difficulty in managing large variation of head as well as misuse of turnout, however, the system of long-crested weir can be helpful for water to be allocated among command areas equally in accordance with water management schedule.

(Above) Duckbill weir in the upstream of FC-9.
(Below) Diagonal weir in the upstream of FC-12

(3) Baffle Distributor

Baffle distributor control discharge by opening specified number and combination of different width of baffle gate so that the required discharge is released through the opening of the gate. This system is not related to the downstream discharge conditions to maintain the flow nearly constant. They are easily understood by gate operators as well as water users', if appropriately introduced. The flow rate is easily known by observing how many gates are open. Therefore, from technical point of view, combination of long-crested weir with baffle distributor enhance diverting constant discharge from D-canal to F-canal as scheduled.

Gate of 10L is open at the turn-out of FC-8.

Baffle distributors control discharge by opening specified number and combination of different width of baffle gates so that the required discharge is released through the opening of the gates. The flow rate is easily known by observing how many gates are open.

1.3.2 Study Area

The pilot area is located in the LB Tract 2 of Rajangana, having D-1 canal with 11 turnouts serving 115.8ha. The control area, covered by similar D-canal with conventional devices, is on D-2 canal with 22 turnouts serving 172.9ha (see the table below). Irrigation diagram of each area are shown in Figure 1, and each structure is presented in Table 3.

Table 2 Features of Pilot and Control Area

	Extent (ha)	D-canal	D-canal Length (km)	No. of turnout
Pilot Area	115.8	D-1	1.06	11 (8)
Control Area	172.9	D-2	2.42	22 (15)

*( ): Number of turnout directly connected to the D-canal

Source: Irrigation Engineers' Office, Rajangana

Figure 1 Irrigation Diagram of the Pilot and Control Area

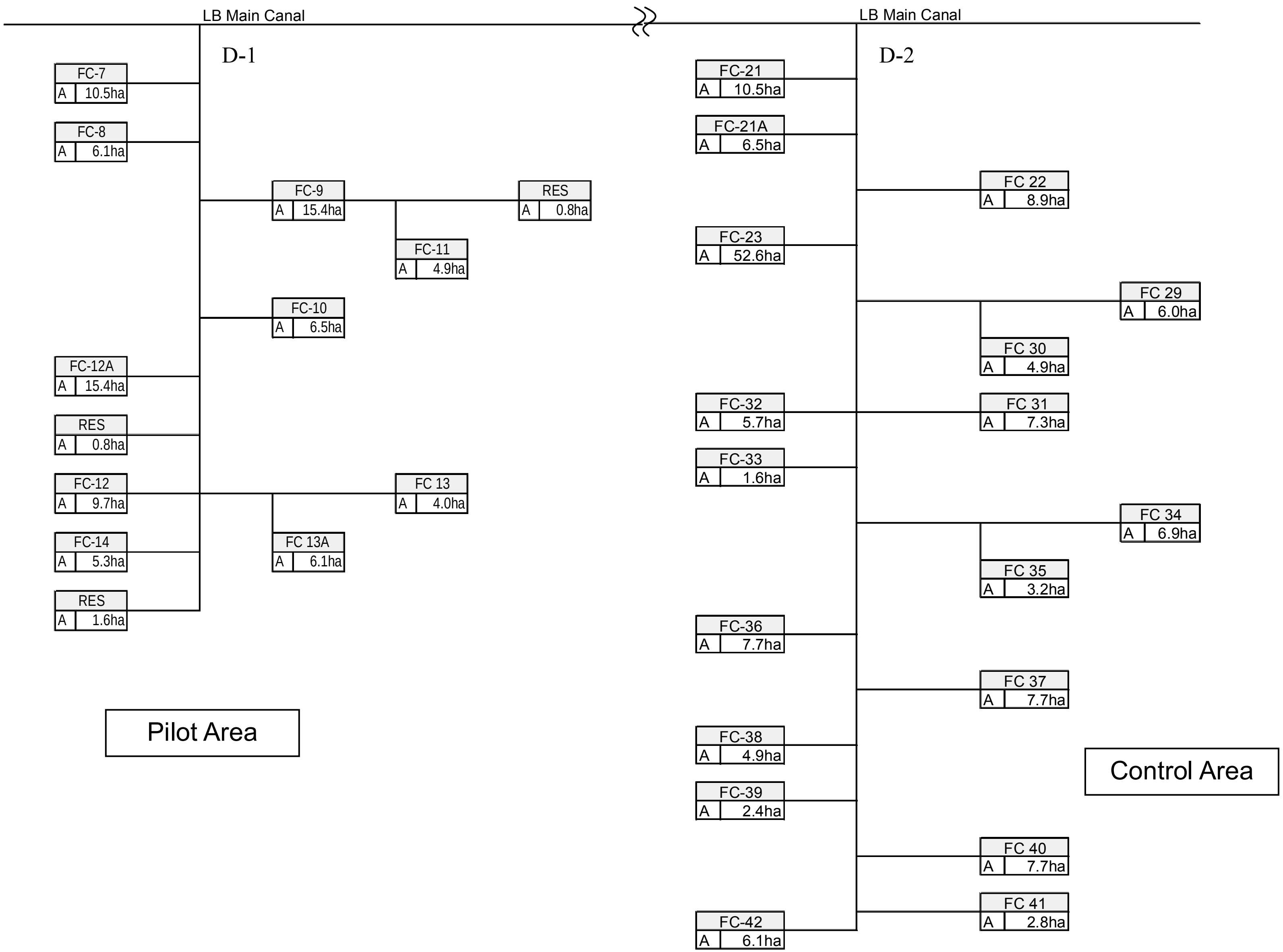


Table 3 Rajangana LB Tract 2 Structures -Pilot Area-

Canal: D-1
Structures

Serial No.	Name	Accumulated Distance	Photo	Present Condition: Gate (number)	Present Condition: Weir	Present Condition: Water Measurement
P1-1	BP of D-1 Nerpic Gate	Ch. 0+0		NA	NA	NA
P1-2	BP of D-1 Baffle Gate	Ch. 0+0		6	NA	NA
P1-3	BP of D-1 Staff Gauge	Ch. 0+0		NA	NA	Yes
2-1	FC-7 Baffle Distributor			3	NA	Yes
2-2	FC-8 Baffle Distributor			3	NA	Yes
2-3	Check Structure Duckbill Weir			NA	NA	NA

Table 3 Rajangana LB Tract 2 Structures -Pilot Area-

Canal: D-1
Structures

Serial No.	Name	Accumulated Distance	Photo	Present Condition		
				Gate (number)	Weir	Water Measurement
3-1	FC-9 Baffle Distributor			4	NA	Yes
3-2	FC-10 Baffle Distributor			3	NA	Yes
3-3	FC-12A Baffle Distributor			3	NA	Yes
3-4	Duckbill Weir Check structure			NA	-	NA
4-1	FC-12 Baffle Distributor			3	NA	Yes
4-2	Check Structure Diagonal Weir			NA	-	NA

Table 3 Rajangana LB Tract 2 Structures -Pilot Area-

Canal: D-1
Structures

Serial No.	Name	Accumulated Distance	Photo	Present Condition		
				Gate (number)	Weir	Water Measurement
5-1	FC-13 Baffle Distributor			3	NA	Yes
5-2	FC-13A Baffle Distributor			3	NA	Yes
5-3	FC-14 Baffle Distributor			3	NA	Yes

Table 3 Rajangana LB Tract 2 Structures -Control Area-

Canal: D-2
Structure

Serial No.	Name	Accumulated Distance	Photo		Present Condition		
					Gate	Weir	Water Measurement
C-1	BP of D-2 Concrete Weir (Measuring Device)	Ch. 0+0			NA	Yes	Yes
C-2	BP of D-2 Staff Gauge	Ch. 0+0			NA	NA	Yes
C-3	FC-21				Yes	No	No
C-4	FC-21A				Yes	Yes	Yes
C-5	FC-22				Yes	No	No
C-6	FC-23				Yes	Yes	Yes
C-7	FC-29				No	Yes	Yes

Table 3 Rajangana LB Tract 2 Structures -Control Area-

Canal: D-2
Structure

Serial No.	Name	Accumulated Distance	Photo		Present Condition		
C-8	FC-30				Yes	No	No
C-9	FC-31				No	Yes	Yes
C-10	FC-32				No	Yes	Yes
C-11	FC-34				Yes	No	No
C-12	FC-36				Yes	No	No
C-13	FC-37				Yes	No	No
C-14	FC-38				Yes	No	No

Table 3 Rajangana LB Tract 2 Structures -Control Area-

Canal: D-2
Structure

Serial No.	Name	Accumulated Distance	Photo		Present Condition		
C-15	FC-39				Yes	No	No
C-16	FC-40				Yes	No	No
C-17	FC-41				No	No	No
C-18	FC-42				No	No	No

1.3.3 Measurement Method and Observation Period

Site observation was done in the following manner (See Table 4):

(1) Measurement Method

<u>Pilot Area</u>

(a) D-canal: H-Q curve was prepared using current meter before the commencement of the measurement (Form O-1 and O-2). Water level was measured by reading staff gauge at beginning point (BP) of D-1 canal and estimate the discharge using the prepared H-Q curve (see Figure 2 and 3). Data record form is shown in Form A_Pilot Area.
(b) F-canal: Baffle setting at each turnout was monitored (Form B_Pilot Area).

<u>Control Area</u>

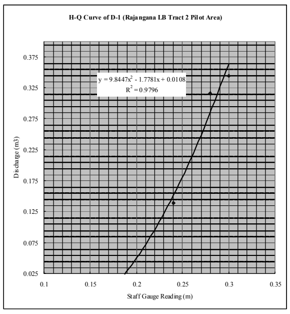
(a) D-canal: H-Q curve was prepared and water level was measured at beginning point (BP) of D-2 canal (Form A_Control Area).
(b) F-canal: Among the existing measuring devices at each turnout, the ones with little damage on the weirs were selected and the measuring gauges were repainted (FC21A, FC23, FC29, FC31, FC32, FC34). In addition to them, temporal measuring weir were installed at FC38 and FC40. Water level at those turnouts was monitored using Form B_Control Area.

Table 4 Measurement Method

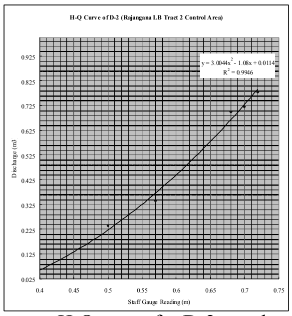
<table>
<tr><th></th><th>Pilot Area</th><th>Control Area</th></tr>
<tr><td>D-canal</td><td colspan="2">

<u>Preparation of H-Q curve</u>

- Measure the discharge with current meter in several flow conditions
- Plot the water level and measured discharge
- Draw the H-Q curve



H-Q curve for D-1 canal



H-Q curve for D-2 canal

↓

<u>Reading staff gauge</u>

- Measure the water level reading the staff gauge and read the discharge from the H-Q curve.

</td></tr>
<tr><td>F-canal</td><td>

- Read the baffle setting

Confirm each baffle is open or closed

</td><td>

- Read the measuring gauge and calculate the discharge volume

Read measuring gauge

Measure using temporal measuring weir

</td></tr>
</table>

Figure 2 H-Q Curve of D-1 (Rajangana LB Tract 2 Pilot Area)

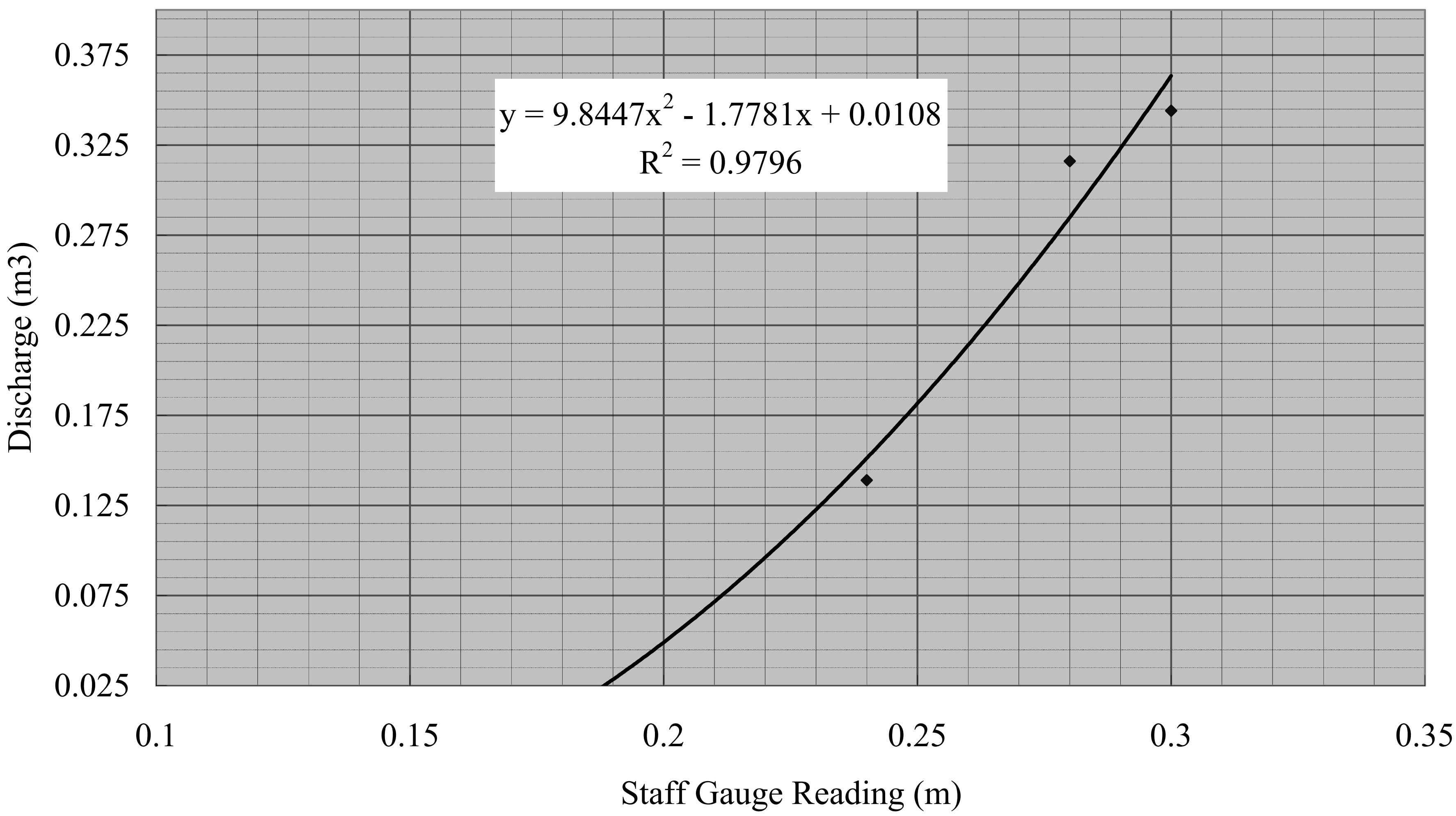
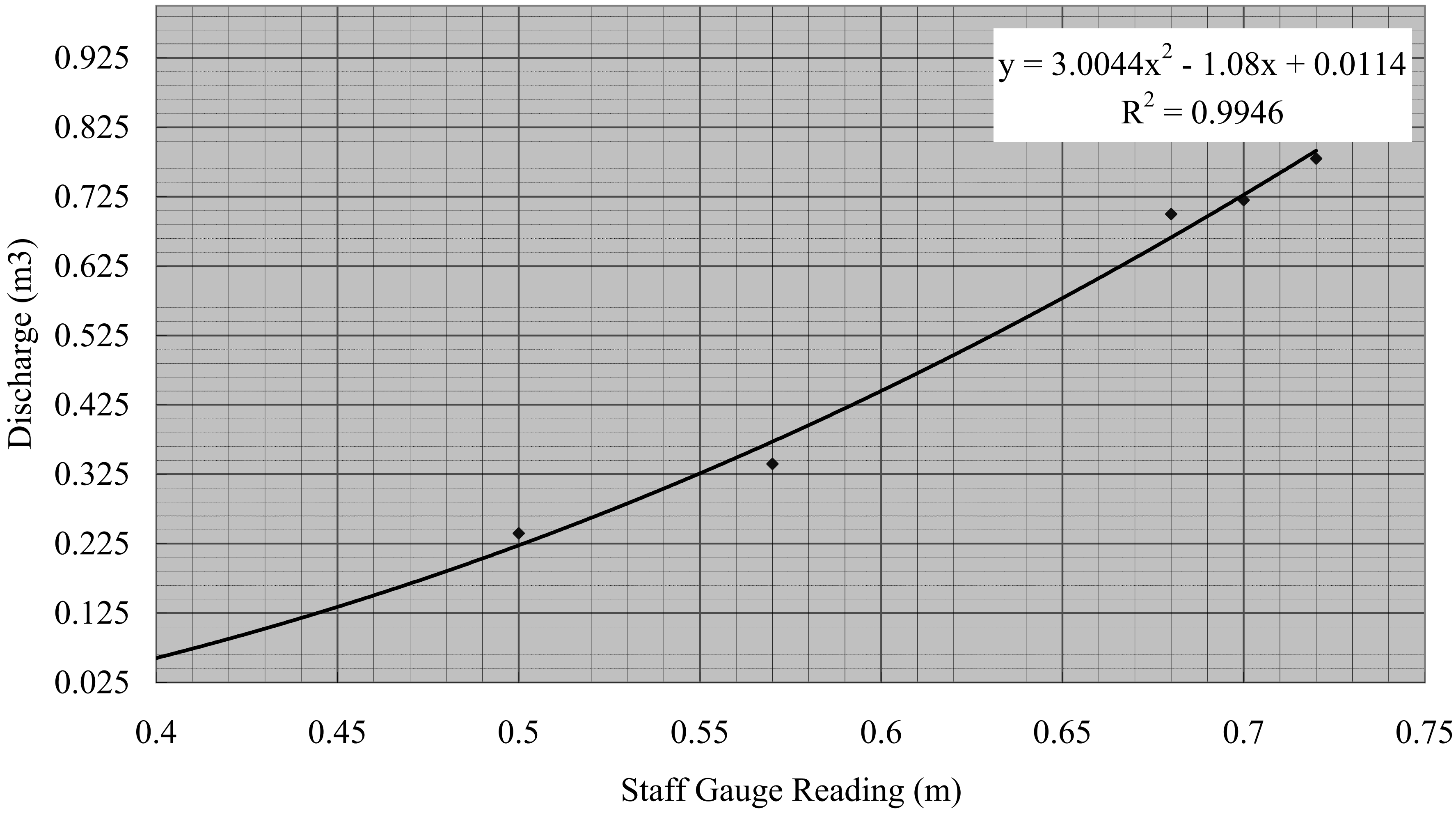


Figure 3 H-Q Curve of D-2 (Rajangana LB Tract 2 Control Area)



Form-O1 Discharge Measurement and Calculation

Date:

Canal:

Measurement Point										
Water depth (m)										
Vertical point from water surface										
Staff Gauge Reading at BP										
Measurement 1										
Dial number (1, 5, 10, 20, 50 or 100) =(a1)										
Number of Buzzer (=b1)										
Time (sec) (=c1)										
velocity (m/sec) (=v1=0.086 x N (a1 x b1)/c1) +0.019)										
Measurement 2										
Dial number (1, 5, 10, 20, 50 or 100) =(a2)										
Number of Buzzer (=b2)										
Time (sec) (=c2)										
Velocity (m/sec) (=v2=0.086 x N (a2 x b2)/c2) +0.019)										
Average velocity (m/sec) (=1=(v1+v2)/2)										
Canal base width (m) (=b)										
Water surface width (m) (=B)										
Area of Cross-section (m2) (=2=((b+B)xD)/2)										
Discharge (m3/sec) (=3=1x2)										

Current meter: Sanei-3,No. 6137
velocity = 0.086 N + 0.019
N = (dial number) x (number of buzzer) / (time)
(Applicable range: 0.120 m/sec - 1.997 m/sec)

Name of person in charge:

Signature:

Form-O2 Plotting Sheet for H-Q Curve Preparation

Discharge (Q m3)

Water Level at BP of Canal (H m)

Daily Discharge to D-Canal

Scheme:	Rajangana
Tract:	LB Tract 2
Canal:	D-1 Pilot Area

Date	Time	H (cm)	Remarks

Name of person in charge:

Signature:

Note:

1 Readings are to be taken at beginning point (BP) of D-canal once a day at 9:30 in th

2 In the remarks column, any occurances such as gate closure, deviation from issue sch misappropriation attempts are recorded.

Daily Discharge to F-Canal

Scheme:	Rajangana
Tract:	LB Tract 2
Canal:	D-1 Pilot Area
Date:	

FC No.	Time	Baffle Setting	Water Level	Duckbill / Diagonal Weir Spilling Over	Remarks
FC_7		20 / 10 / 5	Yes / No	Yes / No	
FC_8		20 / 10 / 5	Yes / No	Yes / No	
FC_9		30 / 20 / 10 / 5	Yes / No	Yes / No	
FC_10		20 / 10 / 5	Yes / No	Yes / No	
FC_12A		20 / 10 / 5	Yes / No	Yes / No	
FC_12		20 / 10 / 5	Yes / No	Yes / No	
FC_13		20 / 10 / 5	Yes / No	NA	
FC_13A		20 / 10 / 5	Yes / No	NA	
FC_14		20 / 10 / 5	Yes / No	NA	

Name of person in charge:

Signature:

Note:
1 Readings are to be taken once a day in the morning between 9:30 and 10:30.
2 Water level is judged by checking the level at the horizontal bar attached on the buffle gate (see right). If the water level is almost same as that of bar, mark "yes". If the level is lower, mark "no".
3 If the water is spilling over appurtenant duckbill or diagonal weir, select "yes."
4 In the remarks column, any occurances such as gate closure, deviation from issue schedule, misappropriation attempts are recorded.

2. Water level measurement bar
- How to check water level

Daily Discharge to D-Canal

Scheme: Rajangana

Tract: LB Tract 2

Canal: D-2 Control Area

Date	Time	H1 (cm)	H2 (cm)	Remarks

Name of person in charge:

Signature:

Note:

1 Readings are to be taken at beginning point (BP) of D-canal once a day at 9:30 in the morning.
2 H1 is measured at the concrete weir (overflow depth) while H2 is at the staff gauge.
3 In the remarks column, any occurances such as gate closure, deviation from issue schedule, misappropriation attempts are recorded.

FORM-B_Control Area

Daily Discharge to F-Canal

Scheme:	Rajangana
Tract:	LB Tract 2
Canal:	D-2 Control Area
Date:	

FC No.	Time	Gate	Water Level (cm)	Remarks
FC_21		Open / Close	Not measurable	
FC_21A		Open / Close		
FC_22		Open / Close	Not measurable	
FC_23		Open / Close		
FC_29		Open / Close		
FC_30		Open / Close	Not measurable	
FC_31		Open / Close		
FC_32		Open / Close		
FC_34		Open / Close	Not measurable	
FC_36		Open / Close	Not measurable	
FC_37		Open / Close	Not measurable	
FC_38		Open / Close		to be measured using Portable Weir No.2
FC_39		Open / Close	Not measurable	
FC_40		Open / Close		to be measured using Portable Weir No.1
FC_41		Open / Close	Not measurable	
FC_42		Open / Close	Not measurable	

Name of person in charge:

Signature:

Note:

1. Readings are to be taken once a day in the morning between 9:30 and 10:30.
2. Water level is measured by staff gauge attached on the beginning point of each FC.
3. Under the remarks column, any occurances such as gate closure, deviation from issue schedule, misappropriation attempts are recorded.

(2) Observation Period and Frequency

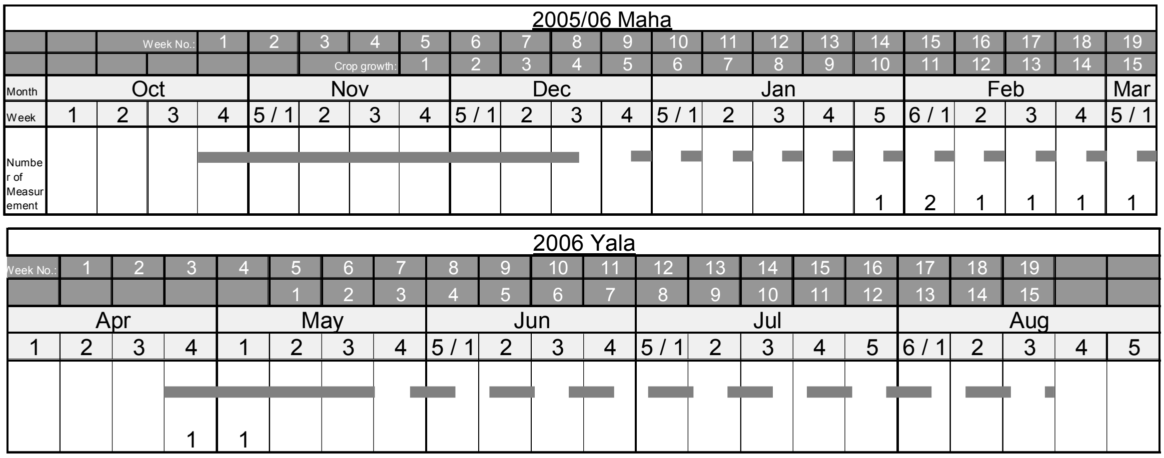
The measurement was conducted during (i) the latter part of 2005/06 Maha, from 27th January to 5th March in 2006, and (ii) the beginning of 2006 Yala, from 20th April to 10th May. Basically, it was carried out every Friday from the following viewpoints:

(a) In Rajangana, rotational irrigation starts after the land preparation period. In the rotation schedule, delivery date to D-1 and D-2 is scheduled from Friday to Sunday during the measurement period. No rotational practice is found below D-canal level.

(b) Head gate of D-canal is controlled by on/off operation. Once the gate is open, almost no adjustment is done before closing the gate. The water volume is mainly controlled by the duration.

In order to monitor the actual supply period in each rotational period, Form C (Pilot Area/Control Area) was prepared and filled by field officers.

Figure 4 Observation Period and Frequency



(3) Site Observation and Interview

In addition to the measurement, condition of each facility was confirmed through site inspection and current operation practice was surveyed through interview to FO jalaparakas.

FORM-C_Pilot Area

Water Issue Schedule (Plan/Actual)

Scheme:	Rajangana
Tract:	LB Tract 2
Canal:	D-1 Pilot Area
Season:	Yala 06

No.	1st date of issue						Last date of issue					
	Plan			Actual			Plan			Actual		
	Date		Time	Date		Time	Date		Time	Date		Time
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												

Name of person in charge:

Signature:

Note:

1 Before starting the measurment, write down the schedule decided in Kanna meeting ("Plan"). Fill in the "Actual" schedule after starting each rotation.

FORM-C_Control Area

Water Issue Schedule (Plan/Schedule)

Scheme:	Rajangana
Tract:	LB Tract 2
Canal:	D-2 Control Area
Season:	Yala 06

No.	1st date of issue				Last date of issue			
	Plan		Actual		Plan		Actual	
	Date	Time	Date	Time	Date	Time	Date	Time
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								

Name of person in charge:

Signature:

Note:

1 Before starting the measurment, write down the schedule decided in Kanna meeting ("Plan"). Fill in the "Actual" schedule after starting each rotation.

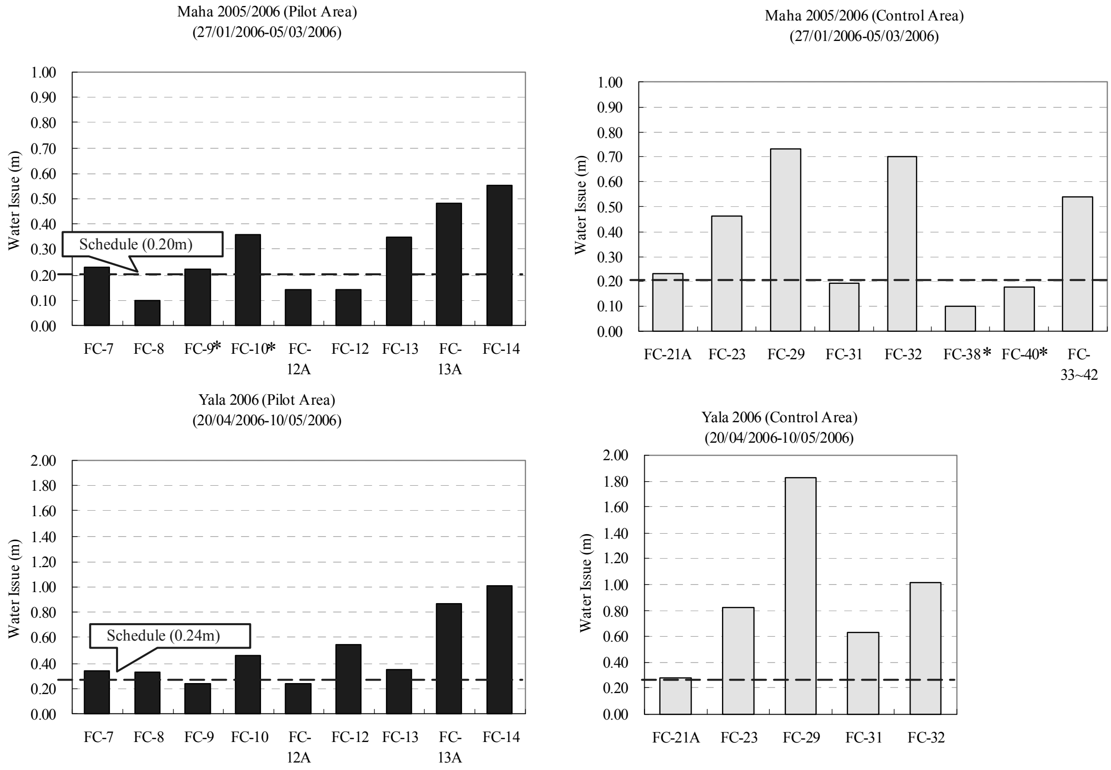
CHAPTER 2 RESULTS

2.1 Result of Water Measurement

2.1.1 Equity in Water Distribution

Total water issue during the measurement period was calculated and compared with the scheduled duty[1] (see Table 5 and the figure below).

Figure 5 Total Water Issue



(Source: JICA Study Team)

*Scheduled water for FC-38 is 0.10 m, while the one for FC-40 is 0.17 in Maha season. No reliable data was available in Yala season.

**According to the "Inception Report, Performance Evaluation of Down Stream Control Systems" by ITI Galgamuwa, FC-9 and FC-12A have other supply resources.

In general, enough water was supplied both in the pilot and control area and no significant difference was observed between the upstream and downstream area. However, inequality of discharge was observed in both areas, while more variation was observed in the control area[2]. It would be cause by several reasons such as: (i) unworkable gate conditions, (ii) difference in crop growth stage in each field, however, utilization of long-crested weir and baffle distributor would have contributed in equality in water distribution.

[1] As there was no description about the scheduled duty of D-and F-canals, it was calculated based on crop water requirement estimation, using water issue schedule prepared in Rajangana IE's office and "Design of Irrigation Headworksfor Small Catchment" by A.J.Ponnaraja.

[2] Deviation between the actual discharge (Qa) and the schedule (Qs) is measured by mean square prediction error (e) of which theory was proposed in by Theil (1966), and adapted by Sampath (1989) and Seckler et al. (1988).

$$e2 = 1/n \ \Sigma (Qa - Qs)$$

In the above equation, "e" is 0.173 in the pilot area and 0.293 in control area in Maha season, while 0.359 in the pilot area and 0.848 in control area in Yala season, which means that there is much deviation in control area in both Maha and Yala season.

Table 5 Discharge at the Head of F-canals (Maha 2005/2006)

Pilot Area

Week Date			January 5th 27/01/2006		January 5th 30/01/2006		February 1st 03/02/2006		February 2nd 10/02/2006		February 3rd 17/02/2006		February 4th 24/02/2006		March 1st 03/03/2006		Total			Schedule
			Q (lit/s)	D (day)	Q (lit/s)	D (day)	Q (lit/s)	D (day)	Q (lit/s)	d (day)	Q (lit/s)	D(day)	Q (lit/s)	D (day)	Q (lit/s)	D (day)	Q (MCM)	D (day)	Q (m)	Qs(m)
D-1		115.8ha	323	1.7	285	1.7	248	2.4	248	2.4	248	3.0	72	2.0	0	0.0	0.269	13.2	0.23	0.22
FC-7	15/10/5	10.5ha	30	1.7	15	1.7	30	2.4	30	2.4	20	3.0	0	2.0	0	0.0	0.024	13.2	0.23	0.20
FC-8	15/10/5	6.1ha	10	1.7	10	1.7	10	2.4	5	2.4	0	3.0	0	2.0	0	0.0	0.006	13.2	0.10	0.20
FC-9	30/15/10/5	15.4ha	30	1.7	30	1.7	30	2.4	30	2.4	30	3.0	30	2.0	0	0.0	0.034	13.2	0.22	0.20
FC-10	15/10/5*	6.5ha	30	1.7	30	1.7	30	2.4	30	2.4	5	3.0	5	2.0	0	0.0	0.023	13.2	0.36	0.20
FC-12A	15/10/5	15.4ha	25	1.7	25	1.7	25	2.4	25	2.4	10	3.0	10	2.0	0	0.0	0.022	13.2	0.14	0.20
FC-12	15*/10*/5	9.7ha	25	1.7	25	1.7	0	2.4	0	2.4	25	3.0	0	2.0	0	0.0	0.014	13.2	0.14	0.20
FC-13	15/10/5	4.1ha	15	1.7	0	1.7	15	2.4	25	2.4	15	3.0	0	2.0	0	0.0	0.014	13.2	0.35	0.20
FC-13A	15*/10*/5*	6.1ha	30	1.7	30	1.7	30	2.4	30	2.4	30	3.0	0	2.0	0	0.0	0.029	13.2	0.48	0.20
FC-14	15*/10*/5*	5.3ha	30	1.7	30	1.7	30	2.4	30	2.4	30	3.0	0	2.0	0	0.0	0.029	13.2	0.55	0.20

*Gate is broken

Control Area

Week Date		January 5th 27/01/2006		January 5th 30/01/2006		February 1st 03/02/2006		February 2nd 10/02/2006		February 3rd 17/02/2006		February 4th 24/02/2006		March 1st 03/03/2006		Total			Schedule
		Q (lit/s)	D (day)	Q (lit/s)	D (day)	Q (lit/s)	D (day)	Q (lit/s)	D (day)	Q (lit/s)	D (day)	Q (lit/s)	D (day)	Q (lit/s)	D (day)	Q (MCM)	D (day)	Q(m)	Qs(m)
D-2	172.9ha	1.891	1.7	1.876	1.7	1.881	2.4	1.876	2.4	1.879	3.0	1.894	2.0	0	0.0	0.002	13.2	0.00	0.22
FC-33~42	65.6ha	1.99	1.7	1.99	1.7	1.99	2.4	1.99	2.4	1.99	3.0	1.99	2.0	1.99	0.0	0.002	13.2	0.00	0.20
FC-21A	6.5ha	0.32	1.7	0.32	1.7	0.32	2.4	0.32	2.4	0.32	3.0	0.32	2.0	0.32	0.0	0	13.2	0.00	0.20
FC-23	52.6ha	0.91	1.7	0.91	1.7	0.91	2.4	0.91	2.4	0.91	3.0	0.91	2.0	0.91	0.0	0.001	13.2	0.00	0.20
FC-29	10.9ha	0	1.7	0	1.7	0	2.4	0	2.4	0.2	3.0	0.2	2.0	0.2	0.0	0	13.2	0.00	0.20
FC-31	7.3ha	0	1.7	0	1.7	0.29	2.4	0.29	2.4	0.29	3.0	0.29	2.0	0.29	0.0	0	13.2	0.00	0.20
FC-32	5.7ha	0	1.7	0	1.7	0	2.4	0	2.4	0	3.0	0	2.0	0	0.0	0	13.2	0.00	0.20
FC-38	4.9ha							20	2.4	0	3.0	0	2.0	0	0.0	0.004	7.4	0.08	0.10
FC-40	7.7ha					0	2.4	0	2.4	0	3.0	0	2.0	0	0.0	0	9.8	0.00	0.17

Table 5 Discharge at the Head of F-canals (Yala 2006)

Pilot Area

Week Date			April 4th 28/04/2006		May 1st 05/05/2006		Total			Schedule
			Q (lit/s)	D (day)	Q (lit/s)	D (day)	Q (MCM)	D (day)	Q (m)	Qs(m)
D-1		115.8ha	-*	8.00	-	12.4	-	20.4	-	0.27
FC-7	15/10/5	10.5ha	5	8.00	30	12.4	0.036	20.4	0.34	0.24
FC-8	15/10/5	6.1ha	5	8.00	15	12.4	0.02	20.4	0.33	0.24
FC-9	30/15/10/5	15.4ha	15	8.00	25	12.4	0.037	20.4	0.24	0.24
FC-10	15/10/5*	6.5ha	20	8.00	15	12.4	0.03	20.4	0.46	0.24
FC-12A	15/10/5	15.4ha	30	8.00	15	12.4	0.037	20.4	0.24	0.24
FC-12	15*/10*/5	9.7ha	30	8.00	30	12.4	0.053	20.4	0.55	0.24
FC-13	15/10/5	4.1ha	5	8.00	10	12.4	0.014	20.4	0.35	0.24
FC-13A	15*/10*/5*	6.1ha	30	8.00	30	12.4	0.053	20.4	0.87	0.24
FC-14	15*/10*/5*	5.3ha	30	8.00	30	12.4	0.053	20.4	1.01	0.24

*Not reliable data was avairable.

Control Area

Week Date		April 4th 28/04/2006		May 1st 05/05/2006		Total			Schedule
		Q (lit/s)	D (day)	Q (lit/s)	D (day)	Q (MCM)	D (day)	Q(m)	Qs(m)
D-2	172.9ha	1.909	8.0	1.879	12.4	0.003	20.4	0.00	0.27
FC-21A	6.5ha	0.32	8.0	0.32	12.4	0.001	20.4	0.02	0.24
FC-23	52.6ha	0.91	8.0	0.91	12.4	0.002	20.4	0.00	0.24
FC-29	10.9ha	0.2	8.0	0.2	12.4	0	20.4	0.00	0.24
FC-31	7.3ha	0.29	8.0	0.29	12.4	0.001	20.4	0.01	0.24
FC-32	5.7ha	0	8.0	0	12.4	0	20.4	0.00	0.24

2.1.2 Water Use Efficiency

Total discharge to D-canals during the measuring period is 0.20m in the pilot area and 0.40m in the control area in Maha season. Compared with the scheduled discharge, it is clearly mentioned that much more water was diverted to D-canal in the control area. Actual and scheduled discharge of each D-canal is shown in the table below.

Table 6 Irrigation Duty (m)

	Pilot Area	Control Area	Schedule
Irrigation Duty (Maha 2005/2006)	0.20m (87%)	0.40m (182%)	0.22m (100%)
Irrigation Duty (Yala 2006)	--* (--)	0.62m (223%)	0.27m (100%)

(Source: JICA Study Team)
*Reliable data was not available.

2.2 Factors to Affect the Water Distribution & Water Efficiency

In section 2.1, variations were observed in the process of investigating water distribution and low water use efficiency was found in the control area. Variations in water distribution were caused by (i) unworkable gate conditions, and (ii) difference in crop growth stage in each field, while low water use efficiency was caused mainly by (i) insufficient canal maintenance, and (ii) water wastage in the downstream. Those factors are described as follows:

2.2.1 Inequality in Discharge

(1) Damage in turnouts and related structures

Damages in the turnouts directly affect the intake and damages in the regulator make it difficult to divert water. In both areas, gates were missing and measuring weirs were damaged in several turnouts. For example, the turnouts for FC-29 and FC-32 in the control area were provided with relatively large scale off-take and damage in the gate caused too much diversion. On the other hand, some baffles in the downstream of the pilot area were damaged due to less understanding of farmers. Condition of the turnouts is presented in Table 3 and summarized as follows.

Table 7 Condition of the Turnouts in Pilot Area and Control Area

Area	FC	Condition		
		Gate	Measuring Weir	Specific Condition
Pilot Area	FC-7			
	FC-8			
	FC-9			
	FC-10	X		One baffle is damaged.
	FC-12A			
	FC-12	X		Two baffles are damaged. The regulator, diagonal weir, is damaged

Area	FC	Condition		
		Gate	Measuring Weir	Specific Condition
	FC-13			
	FC-13A	X		All three baffles are damaged.
	FC-14	X		All three baffles are damaged
Control Area	FC-21		X	
	FC-21A			
	FC-22		X	
	FC-23			
	FC-29	X		Spindle is missing.
	FC-30	X		
	FC-31	X		
	FC-32	X		
	FC-34		X	
	FC-36		X	
	FC-37		X	
	FC-38		X	
	FC-39		X	
	FC-40		X	
	FC-41	X	X	Gate is missing.
	FC-42	X	X	Gate is damaged.

Source: JICA Study Team

(2) Difference in Crop Growth Stage

Since the measurement was carried out in the final stage of Maha season and initial stage of Yala season, water delivery was largely influenced by crop growth stage. For instance, it is clearly observed that farmers did not need water in FC-8, FC-38 and FC-40 of Yala season. Therefore, data collection consecutive to the whole season is prerequisite.

2.2.2 Low Water Use Efficiency

(1) Condition of Canals

Canal length and the condition are directly connected to canal conveyance losses. Comparing D-1 and D-2 canals, length of D-2 canal is more than twice the one of D-1 canal. Meanwhile, siltation was found in D-2 canal especially in the downstream. According to FO jalaparakas, maintenance work (shramadana) is done twice in a season with participation rate 75% in the pilot area, while it is once in a season with 50% participation in the control area. Those situations resulted in low water use efficiency in the control area.

(2) Wastage Water in the Control Area

In Figure 7, water issue to FC 33-42 is quite large and it means that wastage water was observed in the control area. In the control area, there was no check structure to keep the water level, therefore, the certain amount of water has to be discharged to divert water to F-canals.

2.3 Other Findings

2.3.1 Social Acceptability of New Technology

Interview to jalaparaka of the pilot area revealed that damages of the gates in the downstream area occurred just one year after the installation. One of the reasons is that downstream area is operated mostly by tenant farmers and they needed to obtain water immediately. Another reason is that their understanding for the new devices was not enough and that they might have recognized that devices as obstructs. It implies that it is necessary to take measures to enhance the understanding of water users in introducing new technology.

2.4 Conclusions and Recommendations

Results of water measurement and related surveys revealed that new devices are advantageous in equity in water distribution and water use efficiency. However, there are still some uncertainties in extending them to new areas. Those should be overcome by adoptive approach composed of consecutive four stages: experimental, pilot, demonstration, application, and replication phases (see Figure 6).

Experimental phase is to understand problems and find more useful ways of coping with basic social needs. The analytical process written here is situated in this phase. In the process, a problem was identified, that is, some baffles had been removed because of lack of understanding by some farmers. It should be overcome in the next phase.

A pilot phase will come in the next step. One of the important points is to overcome the problems observed in the experimental site. Some approach should be taken to enhance the understanding of farmers on new devices. In addition, devices damaged due to daily operation shall be rehabilitated in that experimental site. At the same time, that approach should be adapted to some areas, for example, one block in RB tract 4 and another block in RB tract 8. After those installations, joint monitoring will be done by FOs and government officers.

When the monitoring period is over, a demonstration phase will start. Surrounding blocks will be the target area. It will not only show the advantage of new devices but also encourage the farmers the awareness of water management. Those processes in D- and F-canal level will contribute to the improvement of water management in surround area.

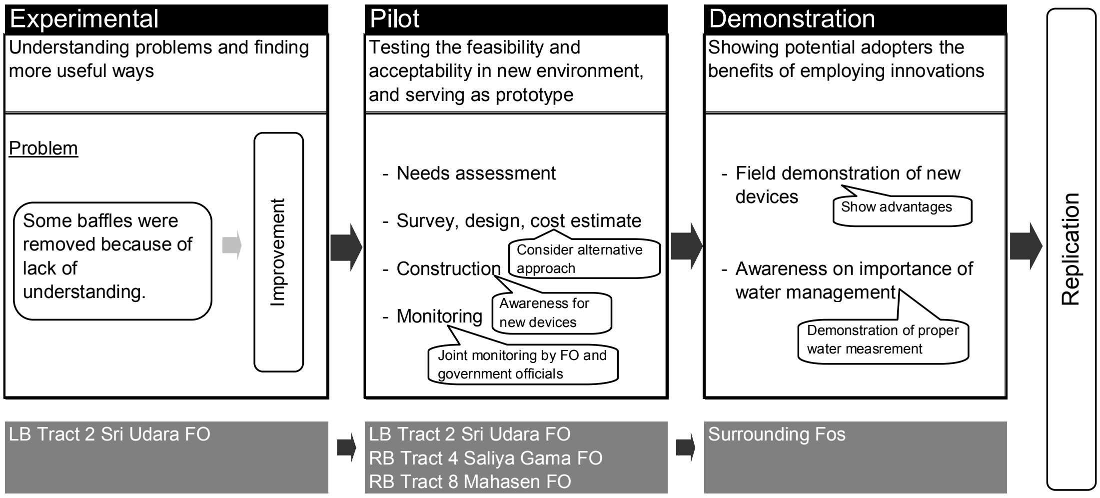


Figure 6 Application Process of New Devices

Attachment A2

Water Quality Analysis

CHAPTER 1 INTRODUCTION

1.1 Objectives

Water quality survey is conducted to clarify the present condition of the water quality in the Study areas, Nachchaduwa, Thuruwila, and Rajangana Irrigation Schemes. It was analyzed from the viewpoints of irrigation and drinking use, and impact of farming practices to the source river was examined. Some approach to improve the present condition is presented after the discussion.

1.2 Recent Studies

There is an on-going study which has been done with the same purposes in Rajangana Irrigation Scheme. The survey was conducted in the last *yala* season, from June to September in 2005 and has been continued until this *maha* season. Sampling points were selected from the surface water considering irrigation use; source river, convey canals and return flow, and seasonal changes were monitored during the cultivation period. Parameter covers major ions, total phosphorus (TP), Nitrate-N (NO3-N), Ammonia-N (NH4-N), dissolved silica (DSi), Total Suspended Solids (TSS), BOD5, and COD. The result in the last *yala* season said that deterioration of source water was not highly significant within the Rajangana Irrigation Scheme though some features, such as nutrient concentration, high values of COD and DSi, were observed.

1.3 Survey Method

1) Sampling Site and Frequency

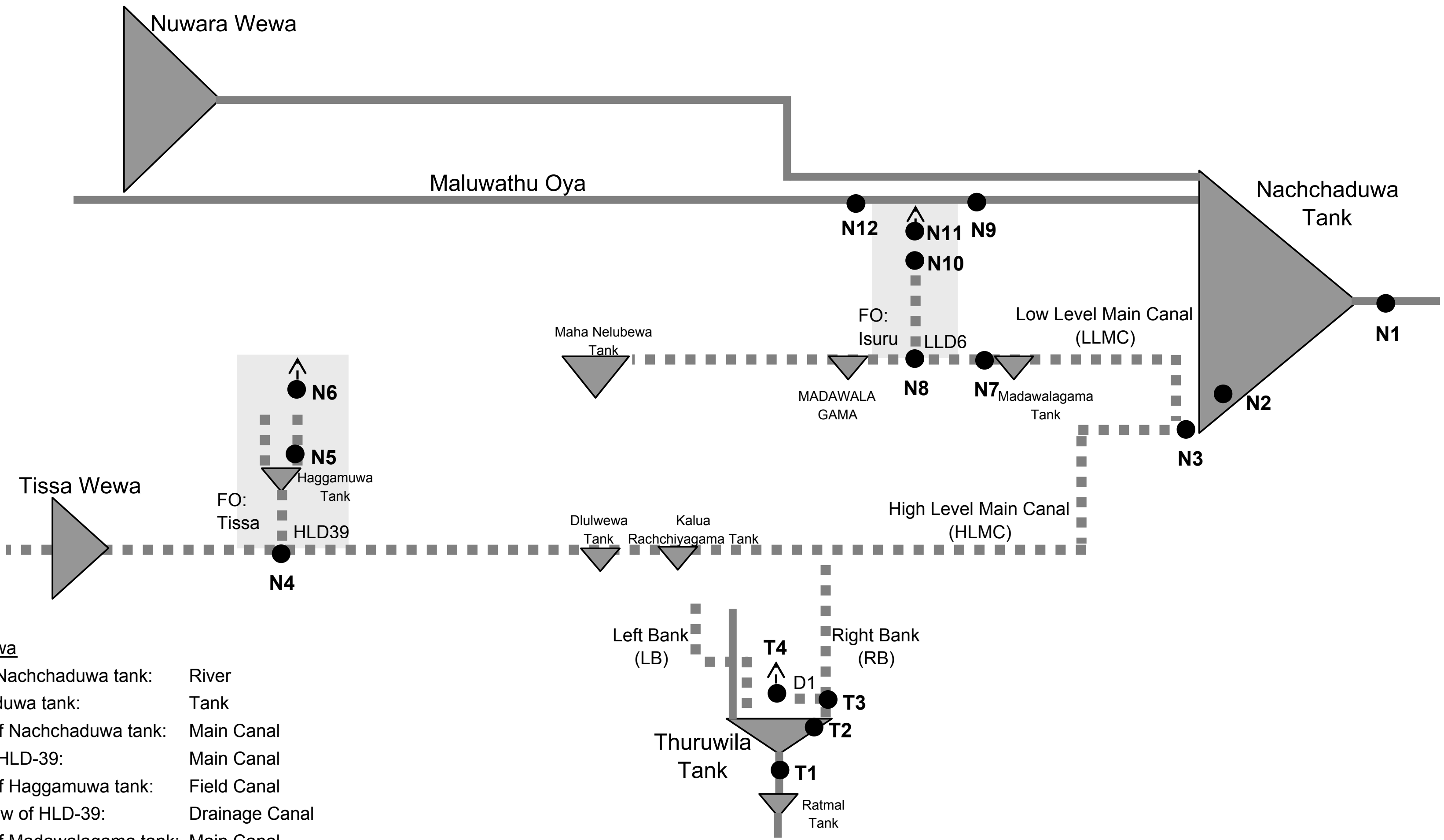
Samples are taken from the river, canals and existing wells. Number of the sampling sites is 16 for irrigation water and 12 for drinking water as shown in the table below. Those sampling locations are depicted in Figure1 and exact coordinates are presented in Table 2.

Table 1 Number of Sampling Sites

Scheme	Irrigation Water	Drinking Water
Rajangana*	0	6
Nachchduwa	12	4
Thuruwila	4	2
Total	16	12

*As irrigation water in Rajangana is covered by the on-going survey mentioned above, survey was done only for the drinking water.
Source: Prepared by the JICA Study Team

The survey is conducted once a month from December 2005 to February 2006, three times in entire period.



Nachchaduwa

1. Inflow of Nachchaduwa tank:	River
2. Nachchaduwa tank:	Tank
3. Outflow of Nachchaduwa tank:	Main Canal
4. Intake of HLD-39:	Main Canal
5. Outflow of Haggamuwa tank:	Field Canal
6. Return flow of HLD-39:	Drainage Canal
7. Outflow of Madawalagama tank:	Main Canal
8. Intake of LLD-6:	Main Canal
9. Drainage river:	Maluwatu oya
10. End point of LLD-6:	Distributory Canal
11. Return flow of LLD-6:	Drainage Canal
12. Return flow to the river:	River

Thuruwila

1. Inflow of Thuruwila tank:	River
2. Thuruwila tank:	Tank
3. Intake of RB D-1:	Main Canal
4. Return flow of D-1:	Drainage Canal

● N1 Sampling Point in Nachchaduwa Irrigation Scheme
● T1 Sampling Point in Thruwila Irrigation Scheme

Figure 1 Sampling Sites of Water Quality Survey in Nachchaduwa & Thuruwila Irrigation Schemes (Irrigation Water)

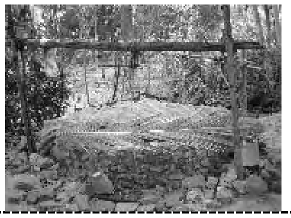
Table 2 Sampling Sites of Water Quality Survey (1/2)
Irrigation Water

No.	Coordinates	Name	Category	Photo
N1	E0177011 N0335753	Inflow of Nachchaduwa tank	River	
N2	E0166450 N0338409	Nachchaduwa tank:	Tank	
N3	E0166328 N 0338408	Outflow of Nachchaduwa tank	Canal	
N4	E0155402 N0345597	Intake of HLD-39	Canal	
N5	E0155745 N0345316	Outflow of Haggamuwa tank	Canal	
N6	E0156184 N0345187	Return flow of HLD-39	Drainage Canal	
N7	E0162921 N0339146	Outflow of Madawalagama tank	Canal	
N8	E0162915 N0339153	Intake of LLD-6	Canal	

No.	Coordinates	Name	Category	Photo
N9	E0162804 N0340227	Drainage river	River	
N10	E0162631 N0340271	End point of LLD-6	Canal	
N11	E0162585 N0340210	Return flow of LLD-6	Drainage Canal	
N12	E0161038 N0341112	Return flow to the river	River	
T1	E0162752 N0332551	Inflow of Thuruwila tank	River	
T2	E0162582 N0335486	Thuruwila tank	Tank	
T3	E0162343 N0335634	Intake of RB D-1	Canal	
T4	E0161381 N0335865	Return flow of D-1	Drainage Canal	

Table 2 Sampling Sites of Water Quality Survey (2/2)
Drinking Water

No.	Cooridates	Name	Photo
ND1	E0162349 N0340055	LLMC Isuru (LLD6) upstream	
ND2	E0162869 N0339160	LLMC Isuru (LLD6) downstream	
ND3	E0155615 N0345603	HLMC Tissa (HLD39) upstream	
ND4	E0156171 N0345291	HLMC Tissa (HLD39) downstream	
TD1	E0162341 N0335625	Thuruwila village (D1) upstream	
TD2	E0161663 N0336081	Thuruwila village (D1) downstream	

No.	Cooridates	Name	Photo
RD1	E0133185 N0329877	RB Tract No.4 Saliya Gama upstream	
RD2	E0133038 N0329533	RB Tract No.4 Saliya Gama downstream	
RD3	E0133288 N0331916	RB Tract No.8 Mahase upstream	
RD4	E0132999 N0332181	RB Tract No.8 Mahase downstream	
RD5	E0134432 N0327038	LB Tract No.2 Sri Udara upstream	
RD6	E0133912 N0326466	LB Tract No.2 Sri Udara downstream	

2) Parameters and Analysis Method

Before the commencement of the survey, parameters were selected in consideration of Sri Lankan water quality standards. The parameters and analysis method are presented in the table below:

Table 3 Parameters and Analysis Method

Parameter	Abbreviation	Unit	Irrigation	Drinking	Method
01. Temperature	Temp.	$^{\circ}C$	+	+	Thermometer
02. Dissolved Oxygen	DO	mg l^{-1}	+		DO meter (see Table 4)
03. Electric Conductivity	EC	µS cm^{-1}	+	+	EC meter (see Table 4)
04. Total Suspended Solids	TSS	mg l^{-1}		+	Gravimetric
05.Turbidity	Turb.	NTU		+	Turbidity Meter
06. pH	pH		+	+	pH meter (see Table 4)
07. Alkalinity	Alk.	mg l^{-1}	+	+	APHA (see Table 4)
08. Sodium	Na	mg l	+	+	AAS
09. Calcium	Ca	mg l	+	+	AAS
10. Magnesium	Mg	mg l	+	+	AAS
11. Potassium	K	mg l	+	+	AAS
12. Chloride	Cl	mg l	+	+	APHA
13. Sulphate	SO_4^{2-}	mg l	+	+	APHA
14. Hardness	Hd	mg l		+	APHA
15. Total Dissolved Salts	TDS	mg l	+	+	Calculation
16. Ammonia N	NH_3-N	µg l^{-1}	+	+	APHA
17. Nitrite as N	NO_2-N	µg l^{-1}	+	+	APHA
18. Nitrate as N	NO_3-N	µg l^{-1}	+	+	APHA
19. Fluoride	F	µg l^{-1}		+	Electrometric
20. Total Iron	Fe	µg l^{-1}	+	+	AAS
21. Total Phosphorous	TP	µg l^{-1}	+	+	APHA
22. Diss. Phosphorous	DP	µg l^{-1}	+	+	APHA
23. Biological Oxygen Demand	BOD_5	mg l^{-1}	+	+	APHA
24. Chemical Oxygen Demand	COD	mg l^{-1}	+	+	APHA
25. Copper	Cu	µg l^{-1}	+	+	AAS
26. Manganese	Mn	µg l^{-1}		+	AAS
27. Zinc	Zn	µg l^{-1}	+	+	AAS
28. Boron	B	µg l^{-1}	+		AAS
29. Sodium Absorption Ratio	SAR	meq l^{-1}	+		Calculation

Source: Prepared by the JICA Study Team

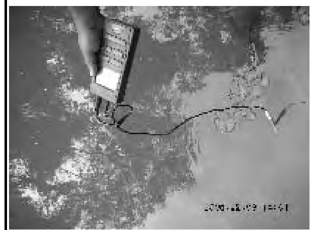
Temperature, dissolved oxygen (DO), electrical conductivity (EC), pH, and alkalinity were determined in the field. Water samples were transported to the Institute of Fundamental Studies (IFS), Kandy in coolers for laboratory analysis of other water quality parameters. Atomic Absorption Spectrometer under flame mode (AAS) was utilized for detection of cations, boron, total ion and trace metals, whereas other parameters were analyzed based on the method prescribed by the American Public Health Association (APHA)[1].

Same sampling methods are depicted in Table 4.

[1] APHA. 1998. Standard Methods for Estimation of Water and Waste Water, 20th Edition, American Public Health Association, Washintong, D.C., USA.

Table 4 Sampling Method of Water Quality Survey

Serial No.	Photo	Title	Explanation
Sampl ing		Sampling of water (Irrigation water)	Water samples were collected to the unused (brand new) mineral water bottles using a clean plastic bucket
Sampl ing		Sampling of water (Drinking water)	Water samples were drawn from dug wells in sample FO villages.
Sampl ing		On site filtering of water	Water samples were filtered through membrane filter papers using a suction filter apparatus
Analy sis: 1		Measuring of Dissolved Oxygen	Dissolved Oxygen was measured using a Oxygen meter.

Serial No.	Photo	Title	Explanation
Analy sis: 2		Measuring of Electric Conductivity	Electric Conductivity was measured using Orian conductivity meter.
Analy sis: 3		Measuring of pH	pH measurements were obtained using a pH meter.
Analy sis: 4		Acid titration for bicarbonate Alkalinity	Bicarbonate Alkalinity was determined by acidimetric titration with a methyl orange indicator (end point detected at pH=4.5).
Trans portati on		Storage method	Storage of Samples during trasportation for other analysis.

3) Water Quality Standards

Concerning the standards, WHO guidelines[2] (Attachment 3) are normally utilized for drinking water in Sri Lanka, while there is no particular one for irrigation water. Therefore, parameter and value was quoted from "The Water Encyclopedia, Second Edition[3] (Attachment 1)" and values for some parameters were complemented by "Japanese Water Quality Standard for Paddy Field[4] (Attachment 2)".

In addition, there is a guideline which determines the water quality of particular river basins, recently prepared and still draft, namely, "Draft Sri Lanka Standard; Guidelines for the Surface and Ground Water Quality for Designated Uses of River Basins in Sri Lanka, Part I: Kala Oya Basin[5] (Attachment 4)". It was referred to analyze the parameters which are not shown in the other standards.

[2] WHO. 1989. Guidelines for Drinking Water Quality. Vol 1. Recommendations. WHO, Geneva, Switzerland.

[3] Van der Leeden, F. Troise, F.L. & Todd, D.K. 1990. Geraghty & Miller Ground Water Series: The Water Encyclopedia (Second Edition), Lewis Publishers. NY, USA.

[4] Ministry of Agriculture, Forestry and Fisheries (MAFF), Research Committee on environmental pollution. 1970. Japanese Water Quality Standard for Paddy Field, MAFF, Tokyo, Japan.

[5] Draft Sri Lanka Standard. 2006. Guidelines for the surface and ground water quality for designated uses of river basins in Sri Lanka Part 1 : Kala Oya Basin , Sri Lanka Standard Institute. Colombo, Sri Lanka.

CHAPTER 2 RESULTS AND DISCUSSION

2.1 Result of the Analysis in the Study Area

2.1.1 Irrigation Water

FAO irrigation and drainage papers No.29[6] indicates that the potential problems caused by irrigation water quality are salinity, infiltration rate, specific ion toxicity, and miscellaneous effect including nitrogen. Salinity condition affecting crop water availability is interpreted as electric conductivity (EC) and total dissolved salts (TDS), while water infiltration rate to the soil is assessed by sodium absorption ratio (SAR) and EC. As for ion toxicity problem[7], primary concerns are chloride, sodium and boron.

Nitrogen concentration[8] is usually reported by total amount of nitrogen, that is, NO3-N, NO2-N, NH3-N and organic-N. As organic-N was not analyzed in this survey, discussion was made based on NO3-N and NH3-N. Analysis was done also for phosphorus which is an important indicator of eutrophication, although there are no set guidelines with respect to irrigation water.

Analysis was done comparing the surveyed data and the value stipulated by the standards, with some detailed discussion given especially for nitrogen and phosphorus.

1) Nachchaduwa Irrigation Scheme

<u>Salinity and water infiltration rate (EC, TDS, and SAR)</u>

EC of average three months in Nachchaduwa ranged from 260 to 674 μS cm-1 (see Table 5), whereas it was 250-705 in December, 273-730 μS cm-1 in January and 304-609 μS cm-1 in February 2006, respectively (see Attachment 5). This range is common for the dry zone surface water during *Maha* season and indicates low salinity condition. This value also resulted in low SAR. In other term of salinity problem, TDS of average three months ranged from 180 mg l-1 to 524 mg l-1 and below 1,000 mg l-1 in entire period. All three parameter were below the recommended maximum levels and, thus, there was no salinity and water infiltration problem in the irrigation water.

<u>Toxicity (Cl, SAR, and B)</u>

Chloride ion ranged from 14 mg l-1 to 85 mg l-1 in average three months (see Table 5). It did not exceed recommended levels during the entire period. Amount of sodium ion is evaluated by SAR and it did not show high concentration. Concentration of boron was also less than the detection limit, that means well below the recommended level. It is said that irrigation water in Nachchaduwa is free from toxicity problem.

[6] FAO..1985. Water quality for agriculture, Irrigation and drainage papers No.29 Rev.1 FAO, Rome, Italy.
[7] Toxicity problems occur if certain constituents in the water taken up by the plant and accumulate to concentrations high enough to cause crop damage or reduced yields.
[8] High nitrogen concentration causes excessive vegetable growth, lodging, and delayed crop maturity.

Table 5 Salinity, Infiltration and Toxicity Condition in Nachchaduwa

		Temp. (C^o)	pH -	EC (μS cm^{-1})	TDS (mg l^{-1})	SAR (meq l^{-1})	Cl (mg l^{-1})	B (μg l^{-1})
Suitable range for irrigation		-	6.5-8.4	<750	<2,000	<3.00	<250	<1.0
N1	River (inflow)	26.0	7.49	538	297	1.85	34	<1.0
N2	Tank	28.1	8.02	288	180	1.09	17	<1.0
N3	Canal	28.0	7.76	274	199	1.07	35	<1.0
N4	Canal	27.6	7.49	340	208	1.11	32	<1.0
N5	Canal	27.3	7.50	405	256	1.42	14	<1.0
N6	Drainage	27.2	7.40	473	328	1.61	25	<1.0
N7	Canal	28.3	7.64	306	223	1.04	65	<1.0
N8	Canal	28.0	7.59	295	251	1.02	74	<1.0
N9	River	27.7	7.48	674	524	1.67	71	<1.0
N10	Canal	28.9	7.62	260	250	1.04	85	<1.0
N11	Drainage	28.3	7.52	424	361	1.14	67	<1.0
N12	River	26.8	7.41	537	429	1.53	69	<1.0

Note: Standard value was taken from the Water Encyclopedia (second edition) (Attachment 1

Source: Prepared by the JICA Study Team

Eutrophication (Nitrogen and Phosphorous)

Table 6 Nitrogen and Phosphorus in Nachchaduwa

		NO_3-N (μg l^{-1})	NO_2-N (μg l^{-1})	NH_3-N (μg l^{-1})	TP (μg l^{-1})
Suitable range for irrigation		-*	-*	-*	<100**
N1	River (inflow)	368	28	65	75
N2	Tank	71	19	157	30
N3	Canal	51	22	130	25
N4	Canal	56	26	572	43
N5	Canal	67	44	127	55
N6	Drainage	233	97	674	60
N7	Canal	95	23	111	46
N8	Canal	95	33	129	39
N9	River	386	74	100	75
N10	Canal	74	30	138	37
N11	Drainage	120	44	257	97
N12	River	530	81	121	95

Note: *According to the Japanese water quality standard for paddy field, less than 1.0ppm equal to 1,000μg l-1 is the value of total nitrogen which is composed of NO3-N, NO2-N, NH3-N, and organic-N.
**Value of the Japanese water quality standard for domestic water, Category V (not applicable for irrigation water)

Source: Prepared by the JICA Study Team

Nitrogen and phosphorus in average three months are shown in Table 6. The concentration of NO3-N ranged from 51 μg l-1 to 530 μg l-1in average three months while it was 50-768 μg l-1 in December, 48-466 μg l-1 in January and 47-367 μg l-1 in February (see Attachment 5). Although ranges are wide, the concentrations of NO3-N are not extremely high as water draining an irrigation watershed.

As for the NH3-N, the concentration was irregular compared with the one of NO3-N. Extremely high concentrations were found at two occasions. It was 1239 μg l-1 for N6 (Return-flow of HLD-37, Main Canal) in December and 1462 μg l-1 for N4 (Intake of HLD-37, Main Canal) in January. It may be attributed either to addition of urea or stagnant nature.

Total of NO3-N, NO2-N, and NH3-N did not exceed 1,000 μg l-1, which can imply that amount of nitrogen is within the permissible level.

Concentration of total phosphorous (TP) ranged from 25 to 97 μ g l-1 in average three months and it was more or less similar during the investigation period. Irrespective of the sampling site, a majority of sites had more than 60 μ g l-1but less than 100 μ g l-1 which is not unusual for tropical surface water draining agriculture fields.

(i) NO3-N Concentration Process

Relatively high concentrations of NO3-N were observed in the inflow to the tank, the drainage river and the return-flow. Figure 2 shows the difference in nitrogen concentration in the tank inflow, tank and canal. Tank inflow is highly concentrated while other two are not concentrated

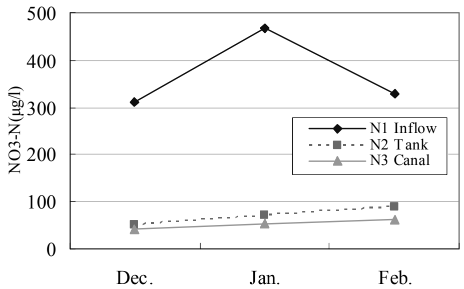


Figure 2 NO3-N at Inflow, Tank, and Canal

much. It is said that highly concentrated water flowing into the tank become less concentrated due to denitrification and sedimentation while stagnant in the tank.

Figures 3 and 4 show the difference of NO3-N in the irrigation supply canal and drainage canals. Although there are variations among the fields, drainage water is highly concentrated. It is mainly due to fertilizer application. It also implies that the field in the downstream of paddy-to-paddy irrigation has a risk to receive excessive nitrogen.

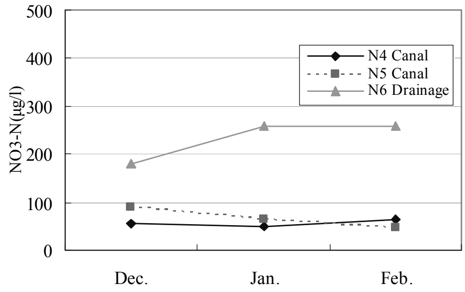


Figure 3 NO3-N in Canals and Drainage Canals (1)

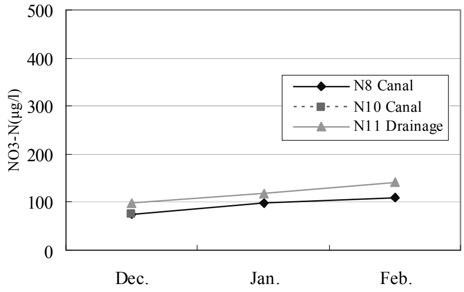


Figure 4 NO3-N in Canals and Drainage Canals (2)

Figure 5 presents the elevation of nitrogen in the river (N1, N9 and N12) and values of the return-flow (N11). In January, difference between N9 and N12 is quite large, however, drainage water (N11) is not so significantly concentrated. The difference can not be explained only by the impact of drainage water.

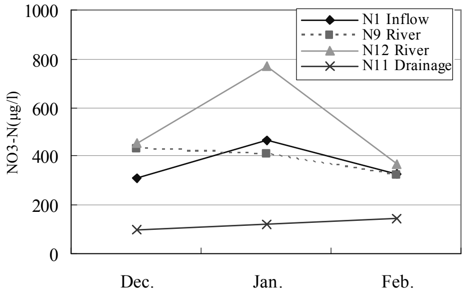


Figure 5 NO3-N in the Source River

It concluded that there is a nutrient enrichment during the irrigation and that some fields in the downstream of paddy-to-paddy irrigation have a risk to be affected by nitrogen concentration. It is also said that the impact to the source river is not so highly significant.

<u>(i) TP Concentration Process</u>

Same analysis was done for TP (see Figures 6 to 9). A similar trend was observed in TP, however, there were some features which imply the impact of the return-flow (Figure 9). Figure 6 shows that water flowing into the tank comes to be less concentrated due to sedimentation process, and it becomes enriched in the distribution to the canals and the fields (Figure 7 and 8). Then, when it drains to the river, it gives some load to the river (Figure 8).

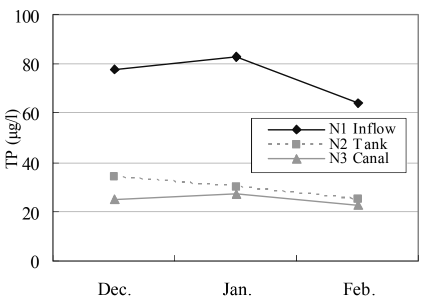


Figure 6 TP at Inflow, Tank, and Canal

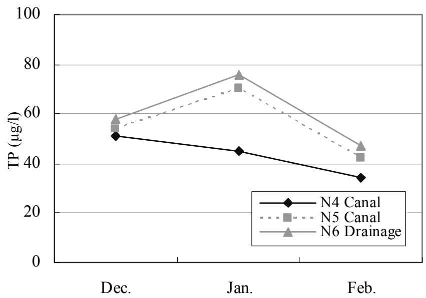


Figure 7 TP at Canals and Drainage Canals (1)

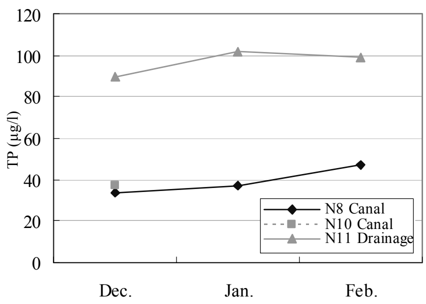


Figure 8 TP at Canals and Drainage Canals (2)

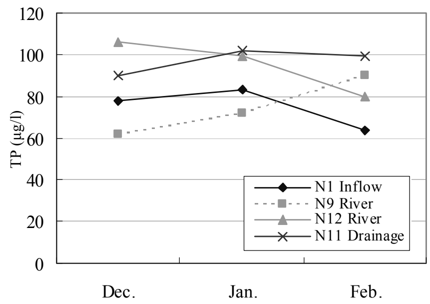


Figure 9 TP in the Source River

Other Contamination Indicators (BOD5, COD, DO, and TSS)

BOD5, COD, DO, and TSS of average three months are presented in Table 7.

Table 7 BOD5, COD, DO and TSS in Nachchaduwa

		BOD_5 (mg l^{-1})	COD (mg l^{-1})	DO (mg l^{-1})	**TSS** (mg l^{-1})
Suitable range for irrigation		<6.00*	<30.0*	>5.00**	<100**
N1	River	2.44	44.2	5.76	51.7
N2	Tank	1.38	39.9	6.93	6.0
N3	Canal	1.75	35.7	6.97	6.3
N4	Canal	2.64	34.8	5.46	19.0
N5	Canal	1.64	75.0	4.22	14.0
N6	Drainage	3.83	63.1	2.86	23.7
N7	Canal	1.70	49.4	6.30	7.3
N8	Canal	1.87	64.1	6.35	9.3
N9	River	1.11	60.1	3.66	15.7
N10	Canal	1.22	29.4	6.28	9.0
N11	Drainage	1.39	61.4	4.47	17.7
N12	River	1.09	58.1	4.74	23.3

Note: *The draft Sri Lanka standard; guidelines for the surface and ground water quality for designated uses of river basins in Sri Lanka Part 1: Kala Oya Basin

**The Japanese water quality standard for paddy field

Source: Prepared by the JICA Study Team

BOD5 ranged from 1.09 to 3.83mg l^{-1} and the highest value was 5.34mg l^{-1} determined for N6 (Return-flow of HLD-37, Main Canal) in December (see Attachment 5). Relatively low values of BOD5 in irrigation water may be attributed to non-contamination with organic waste. However, the high concentration of BOD5 at certain sampling sites may be related to stagnant nature.

COD ranged from 29.4 to 75.0mg l^{-1} in average three months and the highest value was 81.0mg l^{-1} determined for N5 (Outflow of Haggamuwa Tank, Field Canal) in February. COD values were higher than the recommended level (30.0 mg l-1) for Sri Lankan surface water. High values of COD in the entire system of Nachchaduwa cannot be explained for the time being; perhaps more inert organic compounds added to the system after dry-off period may be resulted in increased COD.

Dissolved oxygen (DO) concentration of irrigation water ranged from 2.86 to 6.97µg l^{-1} in average three months and the lowest value was 2.30µg l^{-1} determined for N6 (Return-flow of HLD-37, Main Canal) in December. Those low oxygen concentrations are primary due to stagnant nature of canal water. The Japanese water quality standards determine above 5.00µg $l^{-1}$of DO as recommended levels, and most of the canals are above.

Total suspended solids (TSS) during the period under investigations ranged from 6.0 to 51.7mg l^{-1} in average three months and the highest value was 54g l^{-1} determined for N1, Nachchaduwa tank in January. Japanese water quality standards determine less than 100mg $l^{-1}$of TSS value as recommended level, and all the sites were far below the recommended level.

2) Thuruwila Irrigation Scheme

Being located close to Nachchaduwa irrigation scheme within the same agro-ecological zone, Thuruwila irrigation scheme also experiences the same weather conditions. In addition, it is noted that Thuruwila Tank releases water for drinking water supply for the Anuradhapura new town.

<u>Salinity and water infiltration rate (EC, TDS, and SAR)</u>

Electrical conductivity (EC) of Thuruwila irrigation scheme ranged from 332 to 508 µS cm-1 in average three months and highest value was 531µS cm-1 in T4 (return-flow of D-1, drainage canal). Electrical conductivity was little higher in the return-flow compared to other sites. This range was less narrow than Nachchaduwa irrigation scheme since Thuruwila tank receives transfer water on a regular basis. Further, low range of conductivity is a good indication of low salinity and resulting low sodium absorption ratio (SAR) as shown for Nachchaduwa.

Total dissolved salts (TDS) or in other terms salinity of Thuruwila irrigation system also did not exceed 1000 mg l-1 during this survey and the maximum value was less than that found for Nachchaduwa.

EC, TDS and SAR in Thuruwila is presented in Table 8.

<u>Toxicity (Cl, SAR, and B)</u>

Chloride ion ranged from 17 mg l-1 to 47 mg l-1 in average three months and highest value was 50 mg l-1 in T4. Relatively high value was observed in return flow but the maximum value was less than that of Nachchaduwa. Both SAR and boron was less than recommended level and no toxicity problem was observed in Thuruwila.

Cl and B in Thuruwila is presented in Table 8.

Table 8 Salinity, Infiltration and Toxicity Condition in Thuruwila

		Temp. (C^{o})	pH -	EC ($\mu S\ cm^{-1}$)	TDS ($mg\ l^{-1}$)	SAR ($meq\ l^{-1}$)	Cl ($mg\ l^{-1}$)	B ($\mu g\ l^{-1}$)
Suitable range for irrigation		-	6.5-8.4	<750	<2,000	<3.00	<250	<1.0
T1	Inflow	27.6	7.57	347	381	1.55	30	<1.0
T2	Tank	26.4	7.62	332	294	1.55	17	<1.0
T3	Canal	27.7	7.62	336	266	1.10	27	<1.0
T4	Drainage	29.8	7.59	508	530	1.67	46	<1.0

Note: Standard value was taken from the Water Encyclopedia (second edition) (Attachment 1

Source: Prepared by the JICA Study Team

<u>Eutrophication (Nitrogen and Phosphorous)</u>

The concentration of NO3-N ranged from 91 µg l-1 to 274 µg l-1in average three months while it was 86-342 µg l-1 in December, 66-267 µg l-1 in January and 121-221 µg l-1 in February. Relatively high concentrations of NO3-N were observed in the return-flow (T4) compared to other sites, while inflow water was not contaminated significantly.

In terms of NH3-N, very irregular with respect to site and time and relatively high concentrations were found in December (732 µg l-1) and January (824 µg l-1) for the return-flow (T4). It may be attributed to fertilizer use or stagnant feature.

Concentration of total phosphorous ranged from 30 to 94 μg l-1 in average three months which is very similar to Nachchaduwa. Relatively low concentrations of total phosphorus were found in the inflow to the tank (T1) and in the tank (T2). Return flow was not significantly concentrated in case of Thruwila. Irrespective of sampling site, a majority of sites have less than 100 μg l-1 of TP, which means eutrophication is not severe problem in Thuruwila.

Nitrogen and phosphorus concentration is shown in Table 9.

Table 9 Nitrogen and Phosphorus in Thuruwila

		NO_3-N ($\mu g\ l^{-1}$)	NO_2-N ($\mu g\ l^{-1}$)	NH_3-N ($\mu g\ l^{-1}$)	TP ($\mu g\ l^{-1}$)
Suitable range for irrigation		-*	-*	-*	<100**
T1	Inflow	163	22	384	30
T2	Tank	91	22	125	48
T3	Canal	153	27	99	94
T4	Drainage	274	59	619	62

Note: *According to the Japanese water quality standard for paddy field, less than 1.0ppm equal to 1,000μg l-1 is the value of total nitrogen which is composed of NO3-N, NO2-N, NH3-N, and organic-N.
**Value of the Japanese water quality standard for domestic water, Category V (not applicable for irrigation water)

Source: Prepared by the JICA Study Team

<u>Other Contamination Indicators (BOD5, COD, DO, and TSS)</u>

BOD5 ranged from 2.13 to 3.70μg l^{-1} in average three months and the highest value was 4.13μg l^{-1} determined for T4 in December. Relatively low values of BOD5 in irrigation water may be attributed to non-contamination with organic waste.

Relatively high values were found in COD, ranging from 44.2 to 85.0μg l^{-1} in average three months, and exceeded the permissible value (30.0 mg l-1) for surface water (Attachment 4). High values of COD in the entire system cannot be explained for the time being as pointed out earlier.

Dissolved oxygen concentration of irrigation water ranged from 4.82 to 5.22 mg l-1 in average three months, and the least concentration was found for the return-flow. It should be noted that even the Thuruwila tank was not saturated with oxygen during sampling.

As for the TSS value, it was highest in the return-flow water in December (46 mg l-1) but far less than recommended levels.

Table 10 BOD5, COD, DO and TSS in Thuruwila

		BOD_5 ($mg\ l^{-1}$)	COD ($mg\ l^{-1}$)	DO ($mg\ l^{-1}$)	**TSS** ($mg\ l^{-1}$)
Suitable range for irrigation		<6.00*	<30.0*	>5.00**	<100**
T1	Inflow	2.13	85.0	5.14	9.7
T2	Tank	3.08	63.8	4.89	7.3
T3	Canal	2.54	73.0	5.22	6.7
T4	Drainage	3.70	44.2	4.82	33.3

Note: *The draft Sri Lanka standard; guidelines for the surface and ground water quality for designated uses of river basins in Sri Lanka Part 1: Kala Oya Basin
**The Japanese water quality standard for paddy field

Source: Prepared by the JICA Study Team

2.1.2 Drinking Water

Several water quality parameters of water samples collected from dug wells located

Nachchaduwa, Thuruwila and Rajangana are given in Table 11. Only the important parameters relevant to drinking water quality are highlighted and discussed under this section.

Table 11 Parameters for Drinking Water

		Temp. C°	pH -	EC µS cm-1	Turb. NTU	Hd mg l-1	TDS mg l-1	Na mg l-1	SO42- mg l-1	Cl mg l-1	F µg l-1	TP µg l-1	NO3-N µg l-1	NO2-N µg l-1	NH3-N µg l-1	BOD5 mg l-1	COD mg l-1
Suitable range for drinking wate		-	6.5-	<1,000	5	<500	<1200	<200	<500	<250	<1.5	-	-	<10	-	-	-
ND1		25.9	7.80	858	6	129	503	25.66	26	91	943	38	332	27	28	1.18	84.1
ND2		27.0	7.18	568	2	106	392	25.27	10	88	267	41	93	16	11	0.77	82.8
ND3		27.3	7.35	450	1	112	391	29.78	8	38	453	78	372	19	19	0.78	54.1
ND4		26.8	7.04	1052	2	155	561	42.73	23	107	447	66	411	25	11	1.05	51.6
TD1		26.5	7.20	1197	4	362	837	89.27	14	78	1010	52	197	16	42	1.30	69.9
TD2		27.2	7.25	1017	7	297	844	89.78	10	66	953	43	612	34	59	0.71	75.5
RD1		25.9	7.28	651	5	199	517	50.29	14	48	900	94	138	24	20	1.83	45.5
RD2		26.2	7.28	857	4	256	726	71.95	23	53	847	86	140	12	24	0.43	44.2
RD3		27.1	7.30	432	1	144	418	37.57	9	78	683	90	134	9	27	13.91	56.7
RD4		27.5	7.40	418	3	149	400	32.34	7	58	657	114	193	13	60	0.28	62.7
RD5		27.1	7.29	653	2	210	614	60.91	18	77	217	70	270	19	22	1.02	57.0
RD6		26.5	7.34	672	3	221	661	53.48	19	88	387	30	109	14	47	0.59	56.9

Note: Standard value was taken from WHO guidelines for drinking water

Source: Prepared by the JICA Study Team

<u>Physicochemical parameters (pH, EC, Turbidity, and TDS)</u>

- pH of drinking water collected from all dug wells fall well within the permissible range for drinking purpose
- Conductivity of water collected from several well has exceeded the upper limit of the recommended value of 1000 µS cm-1 (Table 11) according to Sri Lankan guidelines (Attachment 4). It was consistent for three wells (ND4, TD1 and TD2) throughout three sampling periods.
- Most of the well water was turbid to a certain extent and contained a fair amount of total suspended solids ranging from 0.5 to 8.0 mg l-1 (Table 11). This is not unusual in the case of shallow dug wells which are receiving seepage water resulting from surface run-off. Turbidity was more than 5 NTU (WHO recommended guideline) during six occasions and it was high in TD2 during the period under investigation.
- Hardness and total dissolved solids (TDS) did not exceed the permissible levels for drinking water quality (Table11).

<u>Major ions (SO42-, Ca, Mg, F, Cl)</u>

- Sodium ion concentration had not exceeded the stipulated guideline value of 200 mg l-1 by WHO for drinking water (Table 11) and the highest value of 94.9 mg l-1 was found for TD2 in February. Further, sodium ion concentration in two dug wells located Thuruwila was higher than that of the well water collected from Nachchaduwa and Rajangana (Table 11)
- Relatively high concentrations of calcium and magnesium ions were found in the well water analyzed from Thuruwila and Rajangana compared to Nachchaduwa (Attachment 5). The highest concentration of calcium ion of 114.9 mg l-1 was found for the dug well (RD2) located in the Track 2 of the left bank of the Rajangana.
- Sulphate and chloride ion concentrations in all drinking water wells were well below the stipulated guidelines (Table 11)
- Fluoride ion, one of the important water quality parameters with respect to drinking water and an endemic feature of the North Central Province of Sri Lanka, ranged from 0.23 mg l-1 to 0.96 mg l-1 in December and it was 0.23 -0.99 mg l-1 and 0.19 – 1.10 mg

l-1 in January and February respectively. However, the maximum value did not exceed the upper limit (1.50 mg l-1) of the stipulated guideline by WHO.

Nitrogen and phosphorus

- Concentration of total phosphorous ranged from 26 to 104 μg l-1 in twelve drinking water wells during the period under investigation (Table 11). No guidelines have been set for both dissolved and total phosphorous in drinking water by WHO (Attachment 3).
- The concentration of NO2-N ranged from 72 μg l-1 to 696 μg l-1 from December to February which is well below the proposed guideline for drinking water (10 mg l-1) by WHO (Table 11).
- The concentrations NO3-N and NH3-N were very irregular with respect to site and time and relatively low concentrations were found in all dug wells but these parameters are also not important with respect to drinking water quality.

BOD5 and COD

- BOD5 ranged from 0.05 to 2.28 mg l-1 in 12 dug wells but it was less than 1.00 mg l-1 in 25 occasions (70 %). Although BOD5 is not a standard quality parameter of drinking water, it indicates occurrence of microbial organisms in water. Therefore it is necessary to examine this water for total and faecal coliform bacteria.
- COD ranged from 41.3 to 91.5 mg l-1 in twelve dug wells during the period of three months and the values were above the permissible value (30.0 mg l-1) for surface water (Attachment 4). No guideline value of COD has been stipulated for drinking water by WHO.

Trace elements

- Concentrations of total iron and four trace metals (Cu, Zn, Mn and B) were less than the detection limits, which means below the recommended level.

2.2 Conclusion and Recommendation

2.2.1 General Features of the Water Quality in the Study Area

Based on the discussions presented in the past section, the features of each three scheme are summarized as follows.

(1) Irrigation Water

Nachchaduwa Irrigation Scheme

- Irrigation water did not suffer from salinity problem and toxic concentration, though there were some salinity concentrations in the return-flow and drainage river.
- Concentration of nitrogen and phosphorus was observed in the return flow and drainage river. Some fields in the downstream in paddy-to-paddy irrigation have a risk to be affected by nitrogen concentration, although impact to the source river is not highly significant. On the other hand, extremely high NH3-N concentrations were observed at some occasions, which imply that farmers discharged water soon after the

fertilizer application.

- High values of COD were observed in the entire system and some sites are above the recommended level for Sri Lankan surface water.

Thruwila Irrigation Scheme

- Basically same trend as Nachchaduwa was observed in terms of salinity, toxicity, and eutrification, although condition of inflow water was slightly better in terms of salinity. High values of COD were also observed in the entire system.
- There were some differences in phosphorus distribution. Return flow was not significantly concentrated in Thuruwila.

(2) Drinking Water

- Most of the parameters analyzed for drinking water wells located in the three irrigation systems (i.e., Nachchaduwa, Thuruwila and Rajangana) fall well within the permissible levels for designated use. The well water was less hard, non-saline and non-contaminated with concerned toxic metals or other non-hygienic chemicals such as fluoride.
- There were signs of contamination with either coliform or other bacteria since BOD5 was positive and substantial in some wells.
- The presence of fluoride ion is an endemic feature of North Central Province of Sri Lanka, however, the concentration was relatively low since the source of the well water were seepage from surface runoff rather than ground water from aquifers.

2.2.2 Approach for Improvement of the Water Quality in the Study Areas

The result indicates that the water quality in the study areas is in suitable range for the designated use, irrigation and drinking, however, some nutrient enrichment were observed in all three schemes. To avoid further concentration, the following approaches can be proposed:

1) Proper input of fertilizer

The survey result said that there was a possibility of exceeded fertilizer usage in the Study area. Excessive fertilizer does not contribute to increase in crop production but it causes high production cost and bad taste (in case of paddy). Guidance should be given to the farmers to explain proper amount of fertilizer. It should be also noted that irrigation water in the downstream in paddy-to-paddy irrigation contains fertilizer residue from upstream field and does not need same amount as the upstream field.

2) Suitable Water Management to Avoid Effluent of Fertilizer

Extremely high NH3-N concentrations observed at some occasions imply that farmers discharge water unconsciously after the fertilizer application. Proper water management at field level is prerequisite as well as maintenance of downstream water quality.

Attachment 1 Irrigation Water Quality Standards

Parameter	No problem	Increasing Problem	Severe Problem	Sri Lankan Range
EC (mS cm^{-1})	<0.75	0.75 – 3.00	>3.00	0.05 – 0.56
TDS (g l^{-1})	<2.0	2.0-3.0	>3.0	0.5-1.5
SAR (meq l^{-1})	<3.00	3.00 – 9.00	>9.00	0.20 – 2.50
Chloride (mg l^{-1})	<250	250-500	>500	20-50
Boron (mg l^{-1})	< 1.00	1.00 – 2.00	>2.00	
pH	6.50-8.40	8.40 – 9.00	>9.00	6.50 – 8.50

Source : van der Leeden, F. Troise, F.L. & Todd, D.K. (1990). Geraghty & Miller Ground Water Series: The Water Encyclopedia (Second Edition), Lewis Publishers, 808 p.

Attachment 2 Japanese Water Quality Standard for Paddy Field

Parameter	No problem
pH	6.0-7.5
COD (mg l^{-1})	<=6
SS (mg l^{-1})	<=100
DO (mg l^{-1})	>=5
T-N (mg l^{-1})	<=1
EC (mS cm^{-1})	<=0.3
As (mg l^{-1})	<=0.05
Zn (mg l^{-1})	<=0.5
Cu (mg l^{-1})	<=0.02

Source : Ministry of Agriculture, Forestry and Fisheries (MAFF), Research Committee on environmental pollution. 1970. Japanese Water Quality Standard for Paddy Field, MAFF, Tokyo, Japan.

Attachment 3 WHO guidelines for drinking water

Parameter	Unit	Guideline	Remarks
Colour	TCU	15	Aesthetic quality
Turbidity	NTU	5	Aesthetic quality
pH		6.5-8.5	
Sodium	mg l-1	200	
Chloride	mg l-1	250	
Sulphate	mg l-1	500	
Hardness as $CaCO_3$	mg l-1	500	Aesthetic quality
Total Dissolved Salts	mg l-1	1200	
Nitrite	mg l^{-1}	10	
Nitrate as N	mg l^{-1}	50	
Fluoride	mg l^{-1}	1.5	
Total Iron	mg l^{-1}	0.3	
Mercury	mg l^{-1}	0.001	
Cadmium	mg l^{-1}	0.005	
Lead	mg l^{-11}	0.05	
Copper	mg l^{-1}	1.0	

Parameter	Unit	Guideline	Remarks
Chromium	mg l^{-1}	0.05	
Manganese	mg l^{-1}	0.05	
Zinc	mg l^{-1}	5.0	
Boron	mg l^{-1}	5.0	
Total coliform	N/100ml	0	
Faecal coliform	N/100ml	0	

Source: WHO. 1989. Guidelines for Drinking Water Quality. Vol 1. Recommendations. WHO, Geneva, Switzerland.

Attachment 4 Draft Sri Lanka Standard; Guidelines for the surface and ground water quality for designated uses of river basins in Sri Lanka

Parameter	Abbr.	Unit	Requirement	Method
01. Temperature	Temp.	$^{\circ}$C	23-33	Thermister
02. Diss. Oxygen	DO	mg l^{-1}	-	DO meter
03. Conductivity	EC	µS cm^{-1}	500-1000	EC meter
04. Total Suspended Solids	TSS	mg l-1		Gravimetric
05.Turbidity	Turb.	NTU	100	Turb. meter
06. pH	pH			pH meter
07. Alkalinity	Alk	mg l-1	400	APHA
08. Sodium	Na	mg l-1	200	AAS
09. Calcium	Ca	mg l-1	100	AAS
10. Magnesium	Mg	mg l-1	60	AAS
11. Potassium	K	mg l-1	12	AAS
12. Chloride	Cl	mg l-1	100	APHA
13. Sulphate	SO_4^{2-}	mg l-1	100	APHA
14. Hardness	Hd	mg l-1		APHA
15. Total Dissolved Salts	TDS	mg l-1		Calculation
16. Ammonia NH_4^+	NH_3-N	µg l^{-1}		APHA
17. Nitrite as NO_2^-	NO_2-N	µg l^{-1}		APHA
18. Nitrate as NO_3^-	NO_3-N	µg l^{-1}	50	APHA
19. Fluoride	F	mg l^{-1}	1.5	Colorimetric
20. Total Iron	Fe	mg l^{-1}	3	ASS
21. Total Phosphorous as PO_4^{-3}	TP	µg l^{-1}	1500	APHA
22. Diss. Phosphorous as PO_4^{-3}	DP	µg l^{-1}		APHA
23. Biological Oxygen Demand	BOD_5	µg l^{-1}	6	APHA
24. Chemical Oxygen Demand	COD	µg l^{-1}	30	APHA
25. Copper	Cu	mg l^{-1}	0.05	AAS
26. Manganese	Mn	µg l^{-1}		AAS
27. Zinc	Zn	mg l^{-1}	2	AAS
28. Boron	B	mg l^{-1}	2	AAS
29. Sodium Absorption Ratio	SAR	meq l^{-1}		Calculation

Source: Draft Sri Lanka Standard (2006) Guidelines for the surface and ground water quality for designated uses of river basins in Sri Lanka Part 1 : Kala Oya Basin , Sri Lanka Standard Institute.

Attachment 5. Results sheets

Attachment 5.1 Temperature, pH and alkalinity of 28 sampling sites

	Temp.			pH			Alkalinity		
Site	Dec-05	Jan-06	Feb-06	Dec-05	Jan-06	Feb-06	Dec-05	Jan-06	Feb-06
ND1	27.1	25.8	25.2	7.68	7.06	7.72	193	101	177
ND2	27.8	29.2	27.3	8.61	7.27	8.17	99	112	110
ND3	28.1	28.6	27.2	7.65	7.47	8.17	99	115	110
ND4	27.1	29.1	26.7	7.16	7.42	7.89	148	81	98
ND5	27.2	27.7	27.1	7.34	7.31	7.85	176	176	140
ND6	26.3	29.1	26.3	7.16	7.26	7.77	160	207	256
ND7	28	28.2	28.6	7.44	7.52	7.95	105	129	73
ND8	28	27.9	28	7.45	7.47	7.84	108	126	125
ND9	29.4	27.3	26.4	7.32	7.3	7.81	403	317	262
ND10	28.9			7.62			116		
ND11	30.9	27.4	26.7	7.51	7.36	7.7	161	271	214
ND12	26.1	28.2	26.1	7.42	7.11	7.71	234	295	229
TW1	29.8	26.7	26.2	7.49	7.36	7.85	196	172	198
TW2	28	24.5	26.8	7.53	7.35	7.98	157	168	180
TW3	28.6	27.6	26.8	7.58	7.36	7.93	166	170	113
TW4	31.3	30.7	27.3	7.44	7.36	7.96	248	373	256
NDW1	26.5	25.7	25.5	7.7	7.59	8.1	362	235	357
NDW2	27.2	26.9	26.9	7.08	7.04	7.41	232	237	229
NDW3	26.9	29.2	25.7	7.29	7.15	7.6	220	395	220
NDW4	27.1	27	26.4	6.91	6.89	7.32	381	242	391
TWW1	26.6	26.7	26.2	7.17	6.94	7.5	557	551	519
TWW2	27.9	27.2	26.4	7.26	6.92	7.56	550	662	537
RT2W1	26.9	25.2	25.6	7.03	7.12	7.7	327	319	354
RT2W2	26.6	25.9	26	7.13	7.06	7.64	472	539	458
RT4W1	27	27.3	26.9	7.17	7.09	7.65	258	243	235
RT4W2	27.7	27.9	26.8	7.32	7.2	7.67	267	249	226
RT8W1	26.9	26.7	27.6	7.21	7.03	7.62	367	384	381
RT8W2	26.7	26.1	26.8	7.2	7.23	7.6	411	380	476

Attachment 5.2 Conductivity, dissolved oxygen and percentage saturation of 28 sampling sites

	Conductivity			Diss. Oxygen			Diss. Oxygen %		
Site	Dec-05	Jan-06	Feb-06	Dec-05	Jan-06	Feb-06	Dec-05	Jan-06	Feb-06
N1	705	418	492	4.85	6.13	6.3	65.4	80.9	78
N2	288	273	304	6.3	7.78	6.7	81.6	103.1	88
N3	234	280	308	6.16	7.66	7.1	79.2	95.3	89.4
N4	374	281	365	3.5	6.87	6	44.3	90.7	74
N5	406	393	416	3.58	4.47	4.6	45.2	55.7	58
N6	506	410	503	2.3	2.88	3.4	28.3	36.4	41
N7	271	315	331	6.25	7.55	5.1	79.9	89.3	66
N8	250	312	322	6.91	6.95	5.2	70.2	80.6	64
N9	684	730	609	3.36	3.62	4	43.7	45.6	50
N10	260			6.28			81.8		
N11	306	514	452	5.82	3.88	3.7	78.8	49.7	46
N12	552	535	524	3.84	5.18	5.21	48	65.2	62.4
T1	377	286	378	5.27	5.46	4.7	70.3	66	58
T2	322	332	342	5.34	4.53	4.8	69.4	58.2	61
T3	322	335	351	5.2	5.47	5	67.7	70.3	65
T4	531	497	495	3.91	5.25	5.3	51.2	71.3	66
ND1	845	869	861	5.22	6.96	7.5	64.3	86.9	94
ND2	588	561	554	3.47	5.76	4	43.6	68.6	51
ND3	444	457	449	4.13	4.49	4.5	51.8	54.1	55

	Conductivity			Diss. Oxygen			Diss. Oxygen %		
Site	Dec-05	Jan-06	Feb-06	Dec-05	Jan-06	Feb-06	Dec-05	Jan-06	Feb-06
ND4	1064	1024	1068	1.99	4.24	3.7	25.3	54.1	45
TD1	1187	1273	1132	2.71	2.64	3.1	34.1	32.6	39
TD2	1010	1212	830	3.3	2.71	2.9	40.2	26.8	35
RD1	556	496	900	4.35	4.14	5.4	53.1	51.1	65
RD2	799	964	809	1.78	2.15	1.4	21.3	26.3	30
RD3	457	459	381	2.87	3.52	3.9	35.5	43	48
RD4	428	433	393	2.27	2.47	2.8	28.9	32.2	35
RD5	673	608	677	2.49	5.06	3.8	30.5	63.4	46
RD6	712	674	631	3.48	3.52	4.9	44	45.2	62

Attachment 5.3 Total suspended solids (TSS), turbidity, hardness and total dissolved salts (TDS) of 28 sampling sites

	TSS			**Turbidity**			**Hardness**			**TDS**		
Site	Dec-05	Jan-06	Feb-06	Dec-05	Jan-06	Feb-06	Dec-05	Jan-06	Feb-06	Dec-05	Jan-06	Feb-06
N1	53	54	48	45	43	37	190	95	151	350	214	328
N2	03	8	7	4	2	4	80	72	102	159	180	201
N3	04	6	9	5	8	11	78	78	104	180	212	206
N4	23	14	20	31	21	29	95	90	133	250	169	204
N5	11	18	13	23	17	15	114	91	144	266	258	245
N6	23	26	22	33	27	29	137	111	169	283	311	390
N7	4	9	9	8	11	13	77	88	109	225	239	206
N8	6	9	13	9	12	14	75	92	106	241	257	255
N9	17	13	17	24	19	21	204	197	215	594	511	468
N10	9			20			75			250		
N11	15	12	26	27	24	23	85	149	179	267	434	381
N12	24	26	20	36	34	32	152	180	191	424	460	402
T1	12	4	13	24	6	16	268	264	398	386	337	420
T2	4	7	11	7	9	14	149	145	211	275	280	326
T3	2	9	9	3	13	11	132	142	198	275	273	249
T4	46	23	31	72	32	41	281	243	503	464	564	563
ND1	2	8	3	3	12	4	122	111	153	532	383	593
ND2	1	0.1	3	2	0.5	4	87	113	117	377	398	402
ND3	1	0.5	0.5	2	1	1	92	112	131	330	496	347
ND4	1.5	2.0	3.5	2	2	3	136	145	185	605	441	638
TD1	0.5	4.5	2.5	1	6	4	294	331	461	832	823	855
TD2	6	6	4.5	7	8	6	229	285	377	781	911	840
RD1	2	7.5	3.5	3	9	4	159	186	253	496	480	575
RD2	4	1.5	4.5	5	2	6	178	210	379	681	754	743
RD3	0.5	1	0.5	1	2	1	144	141	146	438	406	411
RD4	1.5	2.5	3	2	3	4	143	159	144	407	400	392
RD5	0.5	2	1	1	3	2	179	166	286	580	600	661
RD6	2.5	2	1	4	4	2	190	179	293	640	598	746

Attachment 5.4 Calcium, magnesium, sodium and potassium ions concentrations of 28 sampling sites

	Ca			Mg			Na			K		
Site	Dec-05	Jan-06	Feb-06	Dec-05	Jan-06	Feb-06	Dec-05	Jan-06	Feb-06	Dec-05	Jan-06	Feb-06
N1	31.46	16.10	30.57	27.24	13.41	18.26	61.84	39.72	52.11	2.22	3.00	3.20
N2	12.81	12.03	20.35	11.69	10.34	12.44	17.72	22.08	29.47	2.08	2.30	3.17
N3	12.85	11.83	20.31	11.16	11.99	13.14	16.92	24.00	28.48	2.59	2.23	2.89
N4	12.84	14.38	26.88	15.41	13.36	16.11	29.92	19.08	29.97	1.98	2.11	2.93

N5	18.70	13.81	28.54	16.35	13.93	17.76	36.64	32.80	35.77	1.95	1.93	2.62
N6	23.15	17.54	29.55	19.28	16.43	23.28	48.88	31.80	51.25	2.10	1.27	1.55
N7	13.60	13.59	19.20	10.61	13.34	14.87	19.12	21.44	28.62	1.70	2.24	2.61
N8	12.98	13.81	17.94	10.58	14.12	15.04	18.80	21.64	27.18	1.39	2.31	2.43
N9	34.80	28.18	36.45	28.56	30.89	30.16	56.20	55.76	52.83	1.40	1.06	1.58
N10	13.88			10.01			20.76			1.14		
N11	13.77	17.77	30.37	12.34	25.50	25.22	23.56	32.60	35.64	1.20	1.36	2.39
N12	26.76	25.48	30.55	20.87	28.46	28.04	44.56	49.12	45.40	1.42	1.71	1.75
T1	42.75	38.26	75.14	39.22	40.94	51.12	66.24	54.68	65.43	1.58	0.10	2.16
T2	40.90	27.49	53.79	11.56	18.75	18.68	45.72	41.80	50.85	1.28	1.89	1.53
T3	32.91	25.85	46.11	12.28	18.90	20.27	31.96	28.08	34.65	0.84	0.37	1.20
T4	68.39	45.42	140.74	27.00	31.56	36.87	72.24	60.21	75.03	1.99	0.71	2.33
ND1	21.75	14.56	28.90	16.51	18.23	19.81	25.28	19.44	32.26	2.32	1.17	2.46
ND2	16.46	14.39	20.79	11.20	18.82	16.01	26.00	25.52	24.30	2.70	3.42	3.21
ND3	17.63	14.58	23.77	11.86	18.43	17.46	29.60	25.80	33.93	2.69	3.64	3.46
ND4	23.23	22.42	35.51	18.96	21.67	23.49	46.80	35.64	45.76	3.00	3.07	2.51
TD1	41.29	44.53	97.01	46.57	53.55	53.30	94.96	82.31	90.54	0.28	0.85	1.31
TD2	32.14	46.31	94.21	36.35	41.30	34.62	91.04	83.33	94.97	0.13	0.84	0.38
RD1	35.29	43.00	67.29	17.41	19.27	20.79	50.84	40.72	59.31	3.30	3.95	4.67
RD2	32.26	44.33	114.95	23.78	24.30	22.44	82.16	63.24	70.45	0.27	1.24	0.66
RD3	27.97	31.14	35.44	18.14	15.56	14.02	39.04	32.32	41.35	1.60	0.97	0.52
RD4	32.00	43.00	41.16	15.40	12.59	10.17	32.32	28.56	36.13	6.32	2.56	1.63
RD5	48.50	46.00	95.88	14.15	12.56	11.35	58.32	55.72	68.68	0.60	7.63	6.13
RD6	43.98	45.31	91.96	19.58	16.20	15.51	52.12	49.16	59.17	1.46	0.84	0.15

Attachment 5.5 Sulphate, chloride and fluoride ion concentrations of 28 sampling sites

	Sulfate			Chloride			Fluoride		
Site	Dec-05	Jan-06	Feb-06	Dec-05	Jan-06	Feb-06	Dec-05	Jan-06	Feb-06
N1	8	7	6	27	34	41	410	330	350
N2	3	5	3	12	17	22	310	240	260
N3	3	5	4	34	42	28	330	290	290
N4	4	5	6	38	34	24	240	270	330
N5	5	6	5	12	14	15	410	340	360
N6	5	8	5	24	29	23	580	580	550
N7	4	5	4	72	59	63	390	340	330
N8	5	7	4	85	73	64	270	290	310
N9	5	6	6	64	72	78	720	690	660
N10	4			85			710		
N11	4	5	4	51	81	70	590	590	580
N12	4	6	6	92	54	61	810	760	740
T1	3	2	4	37	28	24	540	520	500
T2	4	3	3	15	19	18	510	490	470
T3	4	4	4	27	25	30	590	550	520
T4	5	3	4	41	50	48	810	790	750
ND1	19	15	43	84	80	110	910	920	1000
ND2	7	11	13	81	88	96	290	260	250
ND3	7	5	11	41	34	38	450	440	470
ND4	23	18	28	110	98	112	420	470	450
TD1	11	12	20	81	79	74	940	990	1100
TD2	10	7	12	62	70	67	910	960	990
RD1	11	10	21	51	44	48	960	900	840
RD2	25	22	23	46	59	54	870	840	830
RD3	9	4	13	84	79	72	720	680	650
RD4	7	6	9	47	59	68	640	670	660
RD5	15	18	20	76	76	78	230	230	190
RD6	16	18	22	96	88	81	350	410	400

Attachment 5.6. Total phosphorous, nitrate-N, nitrite-N and ammonia-N of 28 sampling sites

	Total phosphorous			Diss. phosphorous			Nitrate-N			Nitrite-N		
Site	Dec-05	Jan-06	Feb-06	Dec-05	Jan-06	Feb-06	Dec-05	Jan-06	Feb-06	Dec-05	Jan-06	Feb-06
N1	78	83	64	19	25	9	310	466	327	27	38	18
N2	34	30	25	10	12	12	50	72	90	15	23	19
N3	25	27	23	8	9	13	41	52	61	13	30	23
N4	51	45	34	13	14	15	55	48	65	17	38	22
N5	54	70	42	14	16	13	90	63	47	76	33	23
N6	58	76	47	23	21	11	181	258	260	133	129	29
N7	47	54	38	20	18	14	78	106	102	31	19	18
N8	34	37	47	19	13	15	74	99	111	22	58	18
N9	62	72	90	11	14	27	431	409	319	101	107	15
N10	37			14			74			30		
N11	90	102	99	13	17	18	99	118	142	55	32	44
N12	106	99	80	22	30	26	456	768	367	146	68	28
T1	31	27	33	8	10	9	155	173	162	25	28	13
T2	49	59	37	14	13	14	86	66	121	19	26	22
T3	98	113	72	25	28	12	108	129	221	20	39	22
T4	65	73	49	15	18	12	342	267	212	87	62	27
ND1	34	30	51	11	12	8	324	329	344	27	29	26
ND2	47	43	34	13	14	14	72	90	118	9	19	21
ND3	74	94	66	21	27	19	351	472	293	14	20	22
ND4	58	76	64	7	10	16	490	341	403	22	31	21
TD1	57	63	37	5	8	16	143	174	273	13	23	11
TD2	47	55	27	17	18	5	668	696	473	39	52	11
RD1	95	104	84	21	28	17	142	123	149	26	33	14
RD2	87	89	81	31	26	20	145	98	177	11	10	14
RD3	98	103	69	28	32	19	99	104	199	10	11	7
RD4	103	127	111	13	17	14	267	146	165	12	15	12
RD5	70	74	66	16	18	15	195	267	347	21	23	14
RD6	29	36	26	15	9	7	90	103	133	11	14	16

Attachment 5.7. BOD5, COD, SAR and Manganese ion concentration of 28 sampling sites

	BOD5			COD			SAR			B		
Site	Dec-05	Jan-06	Feb-06	Dec-05	Jan-06	Feb-06	Dec-05	Jan-06	Feb-06	Dec-05	Jan-06	Feb-06
N1	1.20	3.00	3.12	32.6	41.0	59	1.95	1.77	1.84	>1.0	>1.0	>1.0
N2	0.72	1.64	1.78	53.8	17.0	49	0.86	1.13	1.27	>1.0	>1.0	>1.0
N3	0.96	2.70	1.59	28.5	36.5	42	0.83	1.18	1.21	>1.0	>1.0	>1.0
N4	1.60	3.14	3.19	25.0	31.4	48	1.33	0.87	1.13	>1.0	>1.0	>1.0
N5	0.97	2.36	1.58	67.8	76.2	81	1.49	1.49	1.29	>1.0	>1.0	>1.0
N6	5.34	4.32	1.82	66.9	70.4	52	1.82	1.31	1.71	>1.0	>1.0	>1.0
N7	1.27	1.71	2.11	32.6	46.7	69	0.94	0.99	1.19	>1.0	>1.0	>1.0
N8	1.49	1.92	2.19	50.6	64.6	77	0.94	0.98	1.14	>1.0	>1.0	>1.0
N9	1.04	1.21	1.07	61.8	66.6	52	1.71	1.73	1.57	>1.0	>1.0	>1.0
N10	1.22			29.4			1.04			>1.0	>1.0	>1.0
N11	1.53	0.93	1.71	34.6	80.6	69	1.11	1.16	1.16	>1.0	>1.0	>1.0
N12	0.87	1.64	0.76	46.7	64.6	63	1.57	1.59	1.43	>1.0	>1.0	>1.0
T1	1.94	3.49	0.95	69.1	88.9	97	1.76	1.46	1.43	>1.0	>1.0	>1.0
T2	3.29	3.20	2.74	48.3	60.2	83	1.63	1.51	1.52	>1.0	>1.0	>1.0
T3	2.40	2.19	3.03	69.1	89.0	61	1.21	1.02	1.07	>1.0	>1.0	>1.0
T4	4.13	3.89	3.07	39.7	36.8	56	1.87	1.68	1.45	>1.0	>1.0	>1.0
ND1	1.77	0.93	0.83	81.0	82.3	89	0.99	0.80	1.13	>1.0	>1.0	>1.0

	BOD5			COD			SAR			B		
Site	Dec-05	Jan-06	Feb-06	Dec-05	Jan-06	Feb-06	Dec-05	Jan-06	Feb-06	Dec-05	Jan-06	Feb-06
ND2	1.33	0.89	0.09	85.8	91.5	71	1.21	1.04	0.97	>1.0	>1.0	>1.0
ND3	1.02	0.93	0.40	43.8	50.6	68	1.34	1.06	1.29	>1.0	>1.0	>1.0
ND4	0.92	1.23	0.99	47.4	47.4	60	1.75	1.29	1.46	>1.0	>1.0	>1.0
TD1	1.34	2.38	0.17	68.2	65.5	76	2.41	1.97	1.83	>1.0	>1.0	>1.0
TD2	0.82	0.69	0.62	75.5	73.0	78	2.61	2.14	2.13	>1.0	>1.0	>1.0
RD1	1.24	2.02	2.22	41.3	40.3	55	1.75	1.30	1.62	>1.0	>1.0	>1.0
RD2	0.62	0.55	0.11	43.5	37.1	52	2.68	1.89	1.57	>1.0	>1.0	>1.0
RD3	0.38	0.34	041	55.7	54.3	60	1.41	1.18	1.49	>1.0	>1.0	>1.0
RD4	0.49	0.19	0.16	59.5	55.5	73	1.17	0.98	1.31	>1.0	>1.0	>1.0
RD5	1.21	1.80	0.04	51.2	53.8	66	1.89	1.88	1.77	>1.0	>1.0	>1.0
RD6	0.91	0.80	0.05	55.0	47.7	68	1.64	1.59	1.50	>1.0	>1.0	>1.0

Attachment 5.8. Total iron, copper, zinc and manganese ion concentrations of 28 sampling sites

	Fe			Cu			Zn			Mn		
Site	Dec-05	Jan-06	Feb-06	Dec-05	Jan-06	Feb-06	Dec-05	Jan-06	Feb-06	Dec-05	Jan-06	Feb-06
N1	>0.05	>0.05	>0.05	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0
N2	>0.05	>0.05	>0.05	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0
N3	>0.05	>0.05	>0.05	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0
N4	>0.05	>0.05	>0.05	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0
N5	>0.05	>0.05	>0.05	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0
N6	>0.05	>0.05	>0.05	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0
N7	>0.05	>0.05	>0.05	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0
N8	>0.05	>0.05	>0.05	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0
N9	>0.05	>0.05	>0.05	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0
N10	>0.05	>0.05	>0.05	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0
N11	>0.05	>0.05	>0.05	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0
N12	>0.05	>0.05	>0.05	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0
T1	>0.05	>0.05	>0.05	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0
T2	>0.05	>0.05	>0.05	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0
T3	>0.05	>0.05	>0.05	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0
T4	>0.05	>0.05	>0.05	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0
ND1	>0.05	>0.05	>0.05	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0
ND2	>0.05	>0.05	>0.05	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0
ND3	>0.05	>0.05	>0.05	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0
ND4	>0.05	>0.05	>0.05	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0
TD1	>0.05	>0.05	>0.05	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0
TD2	>0.05	>0.05	>0.05	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0
RD1	>0.05	>0.05	>0.05	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0
RD2	>0.05	>0.05	>0.05	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0
RD3	>0.05	>0.05	>0.05	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0
RD4	>0.05	>0.05	>0.05	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0
RD5	>0.05	>0.05	>0.05	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0
RD6	>0.05	>0.05	>0.05	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0	>1.0