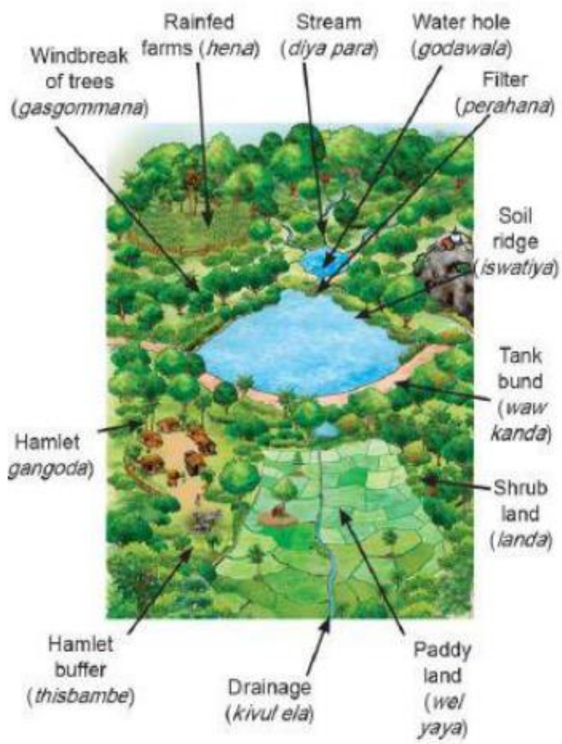
Feasibility Study

Technical Feasibility Report

Strengthening the resilience of smallholder farmers in the Dry Zone to climate variability and extreme events through an integrated approach to water management



Ministry of Mahaweli Development and Environment
Democratic Socialist Republic of Sri Lanka

A report prepared by the Government of Sri Lanka, with technical support from United Nations Development Programme

Forward

Sri Lanka is a country highly vulnerable to climate change. As with many countries around the world, the country has experienced the impact of rising temperatures and erratic rainfall patterns associated with prolonged droughts and floods, respectively. In response to this situation, Sri Lanka has played an active role in climate change adaptation activities, both locally and globally. The Framework Convention on Climate Change was ratified by Sri Lanka in 1993, and action was taken to ratify Kyoto Protocol and establish a Climate Change Secretariat. Other actions include formulation of national policies, strategic plans and strategies including a National Adaptation Plan (NAP) for Climate Change Impacts in 2015. Intended Nationally Determined Contributions (INDCs) of Sri Lanka were developed in 2015. Over the last few years, Sri Lanka has received a limited amount of adaptation finance from existing global vertical funds including the Special Climate Change Fund and Adaptation Fund.

A large proportion of Sri Lankans are dependent on livelihoods connected to agriculture. Substantial investments in irrigation and agriculture, especially in the Dry Zone, have made the country self-sufficient in rice. However, the Dry Zone extending over 60% of the land, is heavily impacted by climate change. The loss of production from climate-related hazards affects mostly farmers with small land holdings, and undermines domestic food security as well as livelihood opportunities. At the national level, both food security of the nation and foreign income from export crops are adversely affected due to the impacts of climate change.

Most smallholder farmers of the Dry Zone cultivate under "Village Irrigation Systems", which consist of small reservoirs and water diversions, each irrigating less than 80 ha of land. These irrigation systems have provided water for domestic purposes, livestock, crops and inland fisheries of rural villages for several generations. They continue to be vital for the life, health and well-being of villagers. Climate change is compounding numerous other constraints affecting the agriculture sector. In particular, services provided by these irrigation systems are adversely affected, and have contributed to deteriorated water quality and quantity issues. With mounting concerns about the impact of climate change on the agriculture sector, the Government of Sri Lanka, under the leadership of the newly elected President, is paying the highest attention to this mounting and worsening crisis in the Dry Zone. Concerns are especially elevated due to the prevailing incidence of Chronic Kidney Disease, for which poor-quality water is cited as a contributing factor, and is increasing at an alarming rate in the Dry Zone. Recent experiences show that current climate forecasting and early warning systems have to be improved, in addition to structural and institutional solutions, to comprehensively address the impacts of the climate change on the agriculture sector.

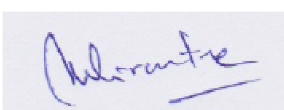
While several projects and programmes aimed at improving the resilience of the vulnerable communities to climate change were implemented in the recent times, many of them had often a sector specific focus which, in hindsight, has limited impacts. In the recent times, the increased realization of the inter-dependence of various issues and sectors such as drinking water, health and agriculture has become more prominent. Against this background, the Ministry of Mahaweli Development and Environment is pleased to present the findings of the feasibility study on

'Strengthening the resilience of smallholder farmers in the Dry Zone to climate variability and extreme events'.

The Ministry of Mahaweli Development and Environment prepared this assessment with inputs from the Ministries of Disaster Management, City Planning and Water Supply, Agriculture and Department of Agrarian Development, National Water Supply and Drainage Board, Department of National Community Water Supply, Department of Meteorology, Disaster Management Centre and several other national institutions. United Nations Development Programme provided the technical support to the Ministry to complete this assessment.

The study examines the observed climate change and projections in Sri Lanka, impacts on agriculture and drinking water supply and their linkages, current state of irrigation, water supply, seasonal forecasting and early warning systems. It further outlines gaps in current approaches to address these critical issues for achieving key Sustainable Development Goals in Sri Lanka, the barriers to fill these gaps, and recommends solutions and measures to remove such barriers in three river basins and seven administrative districts which are found to be most vulnerable. The recommendations formulated by this study will be used to identify and inform concrete activities for implementation to strengthen the resilience and adaptive capacity of the most vulnerable communities in Sri Lanka, with a special focus on women.

We look forward to working together with the concerned national and international institutions, UNDP and the Green Climate Fund to increase the resilience of vulnerable communities in the Dry Zone of Sri Lanka. It is expected that the experiences gained through implementation of these recommendations will result in policy impacts and strategic frameworks that can be replicated in other vulnerable river basins and districts.



Udaya Seneviratne
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Acronyms

ADB	Asian Development Bank
AMS	Agro-Meteorological Stations
ASC	Agrarian Services Centre
CBO	Community Based Organization
CBSL	Central Bank of Sri Lanka
CIAT	International Centre for Tropical Agriculture
CKDu	Chronic Kidney Disease of unknown etiology
CRIP	Climate Resilience Improvement Project
CSA	climate-smart agriculture
CSO	Civil Society Organization
DAD	Department of Agrarian Development
DCS	Department of Census and Statistics
DEWN	Disaster and Emergency Warning Network
DMC	Disaster Management Centre
DoA	Department of Agriculture
DoM	Department of Meteorology
DRM	Disaster Risk Management
DSWRPP	Dam Safety and Water Resources Planning Project
EC	Electrical Conductivity
FIM	First Inter Monsoon

FO	Farmer Organisation
GDP	Gross Domestic Product
GND	Grama-Niladari Division
HSBC	Hong Kong and Shanghai Bank Corporation
ID	Irrigation Department
IDA	International Development Association
IIMI	International Irrigation Management Institute
INDC	Intended Nationally Determined Contribution
IWMI	International Water Management Institute
JBIC	Japan Bank for International Corporation
JICA	Japan International Corporation Agency
LKR	Lankan Rupees
MASL	Mahaweli Authority of Sri Lanka
MCB	Mahaweli Consultancy Bureau
MCP&WS	Ministry of City Planning and Water Supply
MDG	Millennium Development Goals
MDM	Ministry of Disaster Management
mm/year	Millimeters per year
NAP	National Adaptation Plan
NCCAP	National Climate Change Adaptation Plan
NCCAS	National Climate Change Adaptation Strategy
NCDM	National Council for Disaster Management
NCP	North Central Province
NCPCP	NCP Canal Project
NDMCC	National Disaster Management Coordinating Committee
NEIAP	North-East Irrigated Agriculture Project
NEM	North East Monsoon
NGO	Non-Government Organizations
NPD	Department of National Planning
NWSDB	National Water Supply and Drainage Board
O&M	Operation and Maintenance
PDOA	Provincial Department of Agriculture
PEACE	Pro-poor Economic Advancement and Community Enhancement Project
PID	Provincial Irrigation Department
PO	Partner Organization
RO	Reverse Osmosis
Rs	Rupees
RWH	Rainwater harvesting
RWSSD	Rural Water Supply and Sanitation Division
SAPSRI	South Asia Partnership, Sri Lanka

SDI	Spatial Data Infrastructure
SWM	South West Monsoon
SIM	Second Inter Monsoon
SLCDMP	Sri Lanka Comprehensive Disaster Management Program
UN	United Nations
UNDP	United Nations Development Program
VIRP	Village Irrigation Rehabilitation Project
VIS	Village Irrigation System
WFP	World Food Program
WHO	World Health Organization

Executive Summary

Sri Lanka, an island of 65,610 km^2, is located in close proximity to the equator in the Indian Ocean with a population of 20 million. It is a lower middle-income country, just recovering from a civil war that lasted over 30 years. While poverty in the country has decreased, geographically-based inequalities and poverty trends vary widely for many low-income groups. The country is divided into three climatic zones- Wet, Dry and Intermediate Zones. The Dry Zone, spreading over approximately 60% of the country, is heavily rural and dependent on agriculture. Farmers with small land areas (less than 2 ha) dominate Sri Lankan agriculture. They consume a substantial part of the production domestically, and therefore production losses affect both their incomes and food security.

Increasing temperatures and increasing unpredictability of rainfall characterize Sri Lanka's vulnerability to climate change. Observations and predictions indicate a higher number of intense/heavy rainfall incidents, which can lead to flash floods, as well as changes in seasonal timing and periods of rainfall. These phenomena have adverse impacts on the Dry Zone, which has been affected by ethnic conflict and suffers from water-related health problems, exacerbated by increasing temperatures. Agriculture in the dry zone is often reliant on irrigation, provided through village irrigation schemes.

Village irrigation systems (VIS) are those having irrigated command areas of less than 80ha, with the majority of the farmers holding less than 1 ha of land. Generally the VIS with reservoirs have around 25-30 ha as command area. These systems are heavily dependent on local rainfall in the immediate watershed, which is often highly degraded. Water is stored in small reservoirs (known as 'tanks'), which are linked via canals (known as 'anicuts') in systems that are collectively known as 'cascades'. Increasing intensities of rainfall and degraded watersheds contribute to silting up of tanks, decreasing their ability to retain floodwaters, as well as degrading home gardens. In recent years, a large number of village irrigation systems were breached or damaged due to floods, weakening the effectiveness of irrigation infrastructure. Additionally, decreasing capacity of tanks due to siltation, increased temperatures and evaporation, as well as variability in the timing of the monsoon rains, have all contributed to decreasing water availability during dry periods and droughts, times when farmers and populations rely on tanks for irrigation and drinking water supplies. Ethnic conflicts and related security situations have, in the past, resulted in damages and neglect of vital water infrastructure.

Availability of good quality drinking water is heavily impacted by climate change. Many people in the Dry Zone have to travel long distances to obtain their drinking water, and the distance increases during drought periods. Water quality, which is dependent on water volumes in the tanks, deteriorates during dry periods. Heat stress further complicates the situation leading to both greater evaporation and drinking water requirements. Drinking water quality further deteriorates due to excessive use of fertilizer and agrochemicals, which are concentrated in water supplies and paddies during dry periods. **Health problems (including CKDu and other kidney-related afflictions),** as a result poor quality drinking water, have prevented farmers from productively engaging in livelihood activities, substantially increasing family medical expenses, and weakening the rural economy and farmers' ability to withstand losses from livelihood activities.

Inadequate early warnings of extreme weather events, particularly high intensity rainfall, exacerbate damage to rural irrigation infrastructure, through the inability to plan water releases from tanks (increasing the efficient and safe flow of water through the cascade), and mitigating measures related to flood management in the cascades and further downstream (including protecting grain stores, service centres, and diverting floodwaters). **Significantly insufficient access to useable and tailored seasonal climate forecasts, as well as inadequate knowledge about climate resilient crops and weak institutional arrangements to link farmers to markets** further constrain farmers from adopting climate-resilient agricultural practices. This also reduces the ability of farmers and villages to timely prepare water management practices e.g. conserving water ahead of projected drought conditions, or keeping water-levels able to withstand expected higher than normal rainfall seasons.

Based on the lessons learned from past and ongoing efforts it is evident that an integrated approach to address irrigation systems and watersheds, together with interventions to address drinking water, agricultural practices and use of climate information and early warnings is critical. Business as usual or single efforts to address agriculture, water, and water-related risk management in the Dry Zone are not effective long-term.

The policy environment is generally conducive to addressing many of the climate resilience issues faced by Dry Zone farmers. The water sector is in an important position in promoting adaptation to climate change as a cross-cutting sector. It additionally recognizes the need for providing good quality water in adequate quantities, protecting water sources, as well as minimizing climate change impacts on food security, promoting climate smart agriculture and access to improved weather information. In this regard, interventions in these sectors include improvement and upgrading of irrigation systems, watershed protection, introduction of climate smart agricultural (CSA) practices, rural water supply options such as advanced filtering facilities, rainwater harvesting and community water supply schemes, and improving climate/weather and hydrological monitoring and forecasting capabilities.

However, there are gaps in ongoing efforts, which impose constraints to improving climate resilience of smallholder farmers in the Dry Zone. The coverage of drinking water services is comparatively low in rural Dry Zone areas in terms of coverage, as well as duration of supplies. There are many village irrigation systems that need improvement and upgrading (including capacity to deal with anticipated changes in climate). Needs include restoration of the watershed, repairs to irrigation infrastructure and de-silting of reservoirs. While limited weather forecasts and early warning systems are available, they are not in a format to be used effectively by farmers, and dissemination to the grass roots level is poor.

There are several key barriers, which hinder efforts to address these gaps. These include the need for an integrated, river-basin approach to irrigation restoration combining modern and traditional engineering techniques; unavailable information on seeds/planting material for climate resilient crops; farmers without access to climate smart agro-technology including micro irrigation and soil conservation as well as the development of farmer-friendly warnings and advisories which can be used for planning. Financial barriers include inadequate public funds (from tax revenues) to improve rural water infrastructure and unsustainable current investments in the face of recurrent climate-related extreme events. These include financing gaps to improve and upgrade village irrigation systems and provide initial investments in CSA, as well as to provide better drinking water facilities and improve the coverage of weather and hydrological monitoring stations. Institutional barriers include inadequate training and capacity to use the improved technologies for climate resilient agriculture, weather information, provide marketing support for farmers and producer groups and coordination between institutions responsible for managing different aspects of a watershed- village and larger irrigation schemes, drinking water systems and agriculture.

Recent experiences provide several important lessons to be considered when designing solutions to the compromised effectiveness of village irrigation systems due to climate change related extreme weather events and variability. VIS are intricately linked with their associated watersheds, and traditional irrigation management gives due consideration to this. Key lessons from past experiences show that the participation of irrigation beneficiaries in designing, planning and implementation, as well as post-project operation of irrigation and water supply facilities, is essential to ensure the sustainability of the interventions. Prior work and field level consultations also indicates the linkages between irrigation water and drinking water, the success of the community-based model for operation and management of rural drinking water supply systems, the need for better weather and climate information to guide and manage water supplies and crop production, and the need for an integrated approach.

Recommendations for addressing identified gaps and barriers, which are presented in this report, were designed through an extensive assessment of past experiences and consultations with stakeholders, including an assessment of ongoing related projects and efforts. It was found that community participation is required in all key activities, including the design of watershed and irrigation infrastructure. This study recommends building on best practices, such as community participation in all steps in upgrading irrigation systems; promoting an integrated approach to irrigation (e.g. using excavated silt for catchment protection and dam strengthening); improving drinking water; and the use of weather/climate and hydrological information. Improving seed availability and access to markets will be needed to enhance the use of CSA techniques, including training and development of CSA packages and knowledge management through Agricultural Resource Centres (ASCs). The development of home gardens contributes to sustainability and contributes to promoting the role of women as income providers. The report recommends establishing of cascade level committees for water management, which allows for an integrated and holistic management of water. CBOs have roles to play in the provision of drinking water supply through operating community treatment plants, as well as the operations and use of weather/climate/hydrological risk information and monitoring equipment (including both operations and maintenance, and data collection). Technologies to automatically relay information to oversight institutions will be combined with manual observations by communities for redundancy and to promote ownership and participation. Communities and local organizations should be strengthened to perform traditional roles such as managing upgraded VIS, drinking water facilities and capacitated to manage weather and hydrological equipment. Where this is difficult, joint management with local ASCs is recommended to ensure sustainability.

The recommendations are guided by **an integrated approach to enhance the climate resilience of communities**. A holistic approach for the village irrigation systems, watersheds and cascade, including a mix of short- and long-term measures, as well as integrating different agency-led measuring systems, are innovative aspects of this project. This also includes new technologies for climate-smart agriculture, combining short- and long-term solutions for rural water supply, and the use of technologies such as automatic rain gauges and data transmission systems.

The key paradigm shift of these recommendations derives from the approach at the VIS level, and at cascade level to address food security, watershed and water supply management in an integrated manner. This will provide effective solutions to three river basins identified as most vulnerable, and which include districts that are affected by CKDu. Cost effectiveness is ensured by community mobilization for implementation and participatory management, and synergizing with ongoing efforts in the water and agriculture sectors.

The proposed interventions will benefit the inhabitants of the Mi Oya, Malwathu Oya and Yan Oya river basins, mostly located in the Dry Zone of Sri Lanka. These river basins contain a large number of village irrigation systems and cascades. River basin assessments have found these basins as among the most vulnerable to climate change. They contain some of the districts worst affected by CKDu. Their selection was based on hydrological, socio-economic and health considerations. **The key interventions proposed are intrinsically linked within the hydrological confines of the village reservoir and irrigation system and include**: Improvement, upgrading and restoration of the reservoir and immediate watersheds, provision of safe drinking water supply using a combination of advanced filtering facilities, RWH systems and community water supply schemes, and enabling access to weather forecasts and early warnings in a manner to be applied to agricultural and water management planning, through enhancement of the hydrological and meteorological monitoring network. The implementation of the recommendations will enhance resilience against floods and droughts, increase rural incomes and result in better health conditions**.** The key recommendations of this study integrate past best practices and facilitate being used as a model for the interventions to be undertaken in other river basins.

Feasibility Study: Strengthening the resilience of smallholder farmers in the Dry Zone to climate variability and extreme events through an integrated approach to water management

Chapter 1 : Climate Risk Profile of Sri Lanka

1.1 Country Background: Development Context and Challenges

Sri Lanka is an island located at the southern tip of India, between 50 55' and 90 50' North and 790 42' and 810 53' East and in close proximity to the equator. The country spreads over a total area of about 65,610 km^2. According to 2012 estimates, the population of Sri Lanka was 20.36 million[1]. Population increase in the recent years has ranged between 1.7% (1981) and 0.7% (2012)[2] and the population is expected to reach 23 million by 2025. As yet, the population is heavily rural (over 70% live in rural areas and 6% in plantation areas) with little evidence of large-scale urban migration. Sri Lanka is a lower middle-income country and is still recovering from a civil war that lasted over 30 years.

Sri Lanka is a multi-party democracy, with the President of Sri Lanka as the Head of the State. The country gained independence from British in 1948. The most recent elections were held in January 2015 to elect a President and in August 2015 to elect a new Parliament. The new government aims at minimizing environmental and economic shocks by, among others, alleviating poverty especially in rural areas and districts directly impacted by conflict.

Sri Lanka is a lower middle-income country[3], with gross national income (GNI) per capita (PPP) of US$10,370 (World Bank, 2014). With respect to poverty, the national poverty headcount rate declined from 22.7% to 6.7% between 2002 and 2012/3[4]; similarly, extreme poverty fell from 13.2% to 3.2%, using the US$1.25-a-day poverty line, while moderate poverty declined from 56.2% to 32.1% on the $2.50-a-day poverty line.[5] Nevertheless, latest estimates show that in 2013, the poorest 10% received 1.4% of total household income, whereas the wealthiest enjoyed 38.7%, indicating significant income disparities.[6] Almost 80 per cent of poor Sri Lankans live in the rural areas and depend on agriculture for food and income. This persistence of rural poverty, indebtedness and vulnerability (despite many efforts by government to support farmers through input subsidies and marketing interventions), high youth unemployment at 19 per cent, low

[1] Department of Census and Statistics 2013. Census of Population and Housing 2012. DCS
[2] Department of Census and Statistics 2015. Statistical Abstract. DCS
[3] Central Bank of Sri Lanka (2013). 'Annual Report 2013', p 25. Retrieved from: http://www.cbsl.gov.lk/pics_n_docs/10_pub/_docs/efr/annual_report/AR2013/English/5_Chapter_01.pdf [Accessed on 30.11.2015]
[4] Department of Census & Statistics (2014). 'Poverty Headcount Ratio Brief: Decomposition of Consumption Poverty'. Retrieved from: http://www.statistics.gov.lk/poverty/HIES-2012-13-News%20Brief.pdf [Accessed on 30.11.2015]
[5] World Bank Sri Lanka (2015). "Ending Poverty, Promoting Shared Prosperity: A Systematic Country Diagnostic". Retrieved from: http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2015/10/14/090224b08314704b/1_0/Rendered/PDF/Sri0Lanka000En0c0country0diagnostic.pdf. Accessed [17.03.2016].
[6] Household Income & Expenditure Survey 2012/13, Department of Census & Statistics, 2013, p. 18. http://www.statistics.gov.lk/HIES/HIES2012PrelimineryReport.pdf

participation of women in the labour force and large scale migration in search of employment all indicate a high level of unevenness in growth and opportunity across the provinces and districts.

Sri Lanka has been adversely affected by natural hazards and extreme weather patterns in the last decade, projected to worsen with climate change. 2015 witnessed a significantly higher incidence of high rainfall resulting in localised floods, especially in the post-war North[7], affecting roughly 31,500 people, and landslides in 3 districts,[8] affecting 295 people and leading to 7 deaths.[9] In addition, droughts affected 7 out of 25 districts and roughly 258,000 people.[10] The average annual disaster loss in Sri Lanka is estimated to be US$380 million, with floods accounting for an annual expected loss of US$240 million.

Among the poor people, women, women-headed households and children are found to be highly vulnerable. The economically active female population being half that of the economically active male population. The unemployment rate for women was more than twice as much as that of men in 2011. Many women in the labour force are engaged in low paid work, in the plantations and in the garment sector. In addition, twice as many women engage in unpaid family work[11]. This situation has made many women taking up foreign employment, with many of them taking up jobs as housemaids and other manual, unskilled forms. Such migration has made their children vulnerable as well.

1.1.1 Incomes and poverty

Despite being categorized as a middle-income country since early 2000[12], and as a country with high human development[13], the status of Sri Lanka is actually complicated with deep regional disparities in wealth and well-being. The country faced continued challenges in the past 15 years, such as the conflict, which caused some years of negative growth in the early 2000s, and the Indian Ocean tsunami in 2005 which decimated two thirds of Sri Lanka's coastal belt. Contrary to typical expansion in trade and manufacturing, the main foreign income contributor (49% in 2010) is remittances from migrant workers (around half of whom are poor and unskilled domestic women workers employed in middle-eastern countries). Remittance accounts for 8% of GDP and helps face Balance of Payment challenges, especially weak trade balance faced by the Sri Lankan Treasury.[14]

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[7] Disaster Management Centre (2015). Situation Report, November 2015. Use of DesInventar query system, retrieved from: http://www.desinventar.lk:8081/DesInventar/main.jsp?countrycode=sr&continue=y. Accessed [30.11.2015] Also in Sunday Times (29 November 2015), "Climate Change Has Come to Stay…" quoting the Director General of the Department of Meteorology.

[8] Disaster Management Centre (2015). Situation Report, November 2015. Use of DesInventar query system, retrieved from: http://www.desinventar.lk:8081/DesInventar/main.jsp?countrycode=sr&continue=y. Accessed [30.11.2015]

[9] Disaster Management Centre (2015). Situation Report, November 2015. Use of DesInventar query system, retrieved from: http://www.desinventar.lk:8081/DesInventar/main.jsp?countrycode=sr&continue=y. Accessed [30.11.2015]

[10] Disaster Management Centre (2015). Situation Report, November 2015. Use of DesInventar query system, retrieved from: http://www.desinventar.lk:8081/DesInventar/main.jsp?countrycode=sr&continue=y. Accessed [30.11.2015]

[11] Ariyaratne, T., Najab, N., Lokuge, G. and Fernando, P. undated. The vulnerability of women in the economy. http://www.cepa.lk/uploads/4bae1bc28cb6cbe73a08a2bf084b8fa3-120830-ER-The-vulnerability-of-women-in-the-economy---CEPA.pdf

[12] World Bank 2012

[13] UNDP Human Development Report 2015 ranked Sri Lanka number 73 out of 188 countries.

[14] Migration profile Sri Lanka 2013 Ministry of Foreign Employment and Welfare http://www.ips.lk/ips_migration/publication/migration_profile/migration_profile_ips.pdf

Although the percentage of people living below the national poverty line steeply declined from 22.7% in 2006/2007 to 8.9% in 2009/10 to 6.5% in 2012/2013[15], Sri Lanka's growth figures mask high levels of inequality in the distribution of wealth and human development across the population. While the MDG target for poverty reduction was achieved in 2008[16], certain indicators within the poverty targets, for instance, nutrition, lag far behind indicating deeper, unresolved issues in addressing the multi-dimensional nature of poverty. Analysis shows that growth in Sri Lanka has been uneven across regions and across sectors. In the past two decades, the urbanized and more industrialized Western province grew three times faster than any other region. Industrial and services sectors expanded faster than agriculture, which accounts for over 70% of the rural economy and employs the largest number of people. The poverty benchmark itself is now under review by the new government, which at USD 1.25 per day, is vastly inadequate for a lower middle income country.[17] A recent report by World Bank indicated that a USD 2 per day poverty line would see as much as 20% of the population, and the majority of many rural districts living below acceptable poverty limits. This population is extremely susceptible to economic shocks, natural disasters and other environmental shocks.[18] Overall unemployment is low at 4.4% in 2013; however youth unemployment, at 19%[19], remains an issue. Underemployment and "pockets" or groups of unemployment (e.g. districts/demographic/social groups where unemployment is high) are visible across social/demographic groups.

Pockets of poverty and social exclusion are most prevalent in under-developed, rural districts such as Puttlam, Anuradhapura, Kurunegala, Polonnaruwa, Moneragala (see Figure 1) and all of the conflict-affected districts in the Northern and Eastern Provinces of the country where a long deprivation and exclusion from the benefit of a steady economic growth and development resulted in greater social vulnerabilities.[20]

While the impacts of the conflict were experienced throughout the country (eg. Bombing and attacks on public places, economic downturn, social issues with war casualties), certain districts were directly affected by the fighting and resultant large-scale displacement. The five districts of the Northern Province, three districts in the Eastern Province and peripheral districts such as Puttlam, Anuradhapura, Moneragala and Polonnaruwa were directly impacted by the war. Eleven districts were directly affected by the conflict and many of these have populations who are still struggling to resettle and resume a livelihood. This is about 60% of the land area, and around two thirds of the coastline of the country

The end of the war in 2009 has allowed many of these districts to re-enter the economic mainstream. Roads and telecommunication networks were restored and rebuilt within a short period including penetration of the national electricity grid. The donor community and government have launched large-scale resettlement and livelihood programmes. However serious challenges remain in completing resettlement and meaningful resumption of economic activities in this region, complicated by frequent and recurrent climate-induced disasters and extreme weather events in the last five years. All the districts struggling to overcome direct impacts of conflict have

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15 Colombage S. (2015) quoting HIES Data of the Department of Census and Statistics in Poverty Reduction in Sri Lanka: A Statistical Illusion. Daily Mirror January 05, 2015

15. With the caveat that the estate sector is 'on track

16 Estate sector represents workers on Sri Lanka's tea and rubber plantations. Poverty has reduced in the estates from 32% in 2006/07 to 10.9 in 2013. However prevalence of poverty is still higher than the national average.

17 Presentation of the National Budget 2016. Speech in Parliament by the Finance Minister. www.treasury.gov.lk

18 World Bank Country Diagnostics Report Draft December 2015

19 Labour Force Survey Annual Bulletin 2013

20 National Human Development Report on regional disparities of Human Development UNDP 2012

been battered by recurrent cycles of flood and drought in the last 5-6 years, with severe impacts on food security, income, and water for drinking and sanitation of displaced/resettled communities as well as those living in remote border districts.

1.1.2 Conflict and Poverty: the Dry Zone legacy

Sri Lanka is divided into three climatic zones based on rainfall distribution; Dry, Intermediate and Wet (Figure 1 below). Recent studies show that a large number of people in the Dry Zone hover in the margins of poverty[21] and are extremely susceptible to economic and environmental shocks, and to the impacts of long-term conflict. The districts impacted directly by conflict all lie in the Dry Zone of Sri Lanka. Persistence of rural poverty, indebtedness and vulnerability despite heavy investments in rural development over the last decade is a cause of grave concern. Due to the lack of income opportunity and industrial growth in Dry Zone districts, many men joined the armed forces and large numbers lost their lives or were maimed during the war.

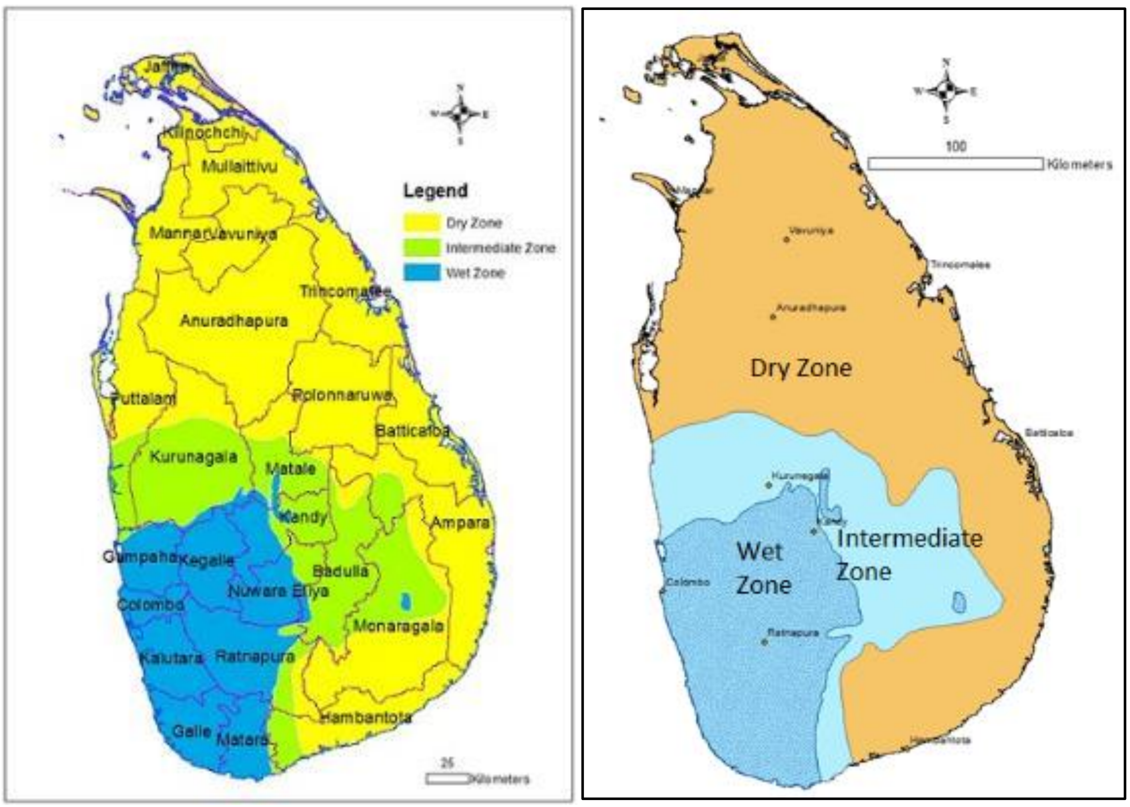

Figure 1: Distribution of administrative districts among the climate zones of Sri Lanka

Poverty in Sri Lanka is highly spatially varied, and many Dry Zone districts display low human development due to years of spatially biased investment[22]. All Dry Zone districts are agricultural and as such, have higher incidence of poverty and under-nutrition. All the dry-zone districts, except

[21] World Bank Systemic Country Diagnostic 2015
[22] National Human Development Report, Sri Lanka 2012

for two, were impacted by the conflict in some way and have large areas, which have not been accessible for development due to the conflict.

District-based development plans for the Northern and Eastern Provinces show that development needs are largely in the sectors of road, water supply and irrigation infrastructure.[23] The National Planning Department, with the District Development Committees have estimated that in the Eastern province, irrigation and drinking water needs account for half the estimated urgent development needs budget of USD 3.5 billion. In the Northern Province irrigation and drinking water supply needs account for a third of the total development budget of USD 2.5 billion.[24]

The war damaged or destroyed 160,000 houses in these districts and many other basic infrastructure such as markets, water supply schemes, roads, schools, hospitals and irrigation infrastructure. Both the Northern Province and the Eastern Province where much of the actual fighting took place are not serviced by large irrigation systems and communities here are highly dependent on small-scale village irrigation systems for food security. 80% of the war-displaced households were involved in farming. As a result of the conflict, they lost agricultural equipment and seeds and some agricultural land is no longer accessible because of landmine threats. Irrigation infrastructure and access roads were seriously damaged due to the protracted conflict and neglected during the displacement.

The conflict also severely damaged water and sanitation infrastructure. Within a year and a half after it ended, an estimated 8,421 dug wells were cleaned and rehabilitated and 121 bore wells have been repaired, drilled or re-drilled by the Government and development partners. However, thousands of wells still need cleaning, upgrading and rehabilitating. Existing schemes providing pipe-borne water are either not functioning or need rehabilitating. Over the same period after the conflict, close to 9,000 toilets were repaired and reconstructed, but several thousand more need to be urgently constructed to avoid water contamination.

In addition to loss of physical assets and livelihood implements, the conflict has also resulted in high levels of social vulnerability. The number of female-headed households and homes with chronic illness and disability are high in Dry Zone districts. Around 22% of all households in Sri Lanka are female-headed, in conflict-affected districts, and districts with high incidence of Chronic Kidney disease, the percentage could be as high as 30%[25]. The Dry Zone has larger number of women headed households and women taking care of disabled due to conflict and chronic diseases (especially the high incidence of chronic kidney failure affecting male farmers in the north and north central regions). Social isolation and poverty are inevitable for this group, many of whom are widowed at a young age mainly due to the conflict.

In addition to this, the female unemployment rate, at 22%, is double that of men in Sri Lanka. Poverty in rural areas has pushed women to take up insecure forms of employment such as migrating to Middle-Eastern countries as unskilled domestic workers, exposing them to various forms of violence and deprivation.[26] Besides garment workers and migrant workers[27], the largest proportion of women in the informal sector is engaged in cultivation.

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[23]Department of National Planning and Office of National Unity and Reconciliation October 2015

[24] Department of National Planning and Office of National Unity and Reconciliation October 2015

[25] Sri Lanka: Strengthening the Resilience of Post Conflict Recovery and Development to Climate Change Risks in Sri Lanka." Www.undp.org. https://info.undp.org/docs/pdc/Documents/LKA/SCCF Approved Prodoc.pdf.

[26] Jayasundere, Ramani et al. *An examination of Sri Lankan policies which apply to migrant workers who fall under the domestic domain and their impact on the right of workers to freely access employment.* UN Resident Coordinator's Office 2014

[27] Women consist 78% of the unskilled labour force leaving the country to work in Middle Eastern states

1.1.3 Temperature, rainfall, seasons and agro-climate zones

Sri Lanka experiences a tropical monsoon climate, primarily determined by its position in the Indian Ocean. Based on the rainfall from 1961-1990, the mean annual rainfall of Sri Lanka is estimated as 1860 mm. Average temperature for the country is 27°C. However, there is a wide variation of minimum and maximum temperatures, ranging across the differing topographic and climatic zones.

On the basis of rainfall distribution, the country is classified into three climatic zones- Wet, Dry and Intermediate Zones (see Figure 1). The Wet Zone receives a mean annual rainfall over 2,500 mm. The Dry Zone receives a mean annual rainfall of less than 1,750 mm and the mean annual rainfall in the Intermediate Zone is between 1,750 to 2,500 mm.

In addition to three main climatic zones described above, the island has 46 different agro-ecological regions differentiated by monthly rainfall expectancy and distribution, soil type, elevation, land use and vegetation. The demarcations of agro-ecological regions are carried out at three levels:

a. Wet, Intermediate and Dry Zones described above (denoted by W,I and D)
b. Low country (below 300 m above sea level), mid country (300-900 m) and up country (above 900 m) denoted by L, M and U
c. Further division according to homogeneous climatic conditions, soils, landforms and land use[28]

Agro-ecological regions are important in the selection of farming systems, crop types, irrigation scheduling, and rainfall-runoff relationships.

The "climatic year" or "hydrological year" of the island begins in March and comprise of four monsoon seasons (see Table 1). These rainfall seasons do not bring homogeneous rainfall regimes over the whole island and this is the reason that the island exhibits such a high agro-ecological diversity, despite its relatively small aerial extent. Two consecutive rainfall seasons make up the two agricultural seasons of Sri Lanka, namely **Yala** and **Maha**.. Generally the Dry Zone, which is also the agricultural heartland of the country, receives the First Inter-Monsoon (FIM), part of Second Inter-Monsoon (SIM) and North-East Monsoon NEM rains. This enables an area-limited cultivation season (Yala) in April-July which is the minor growing season. The major growing season (Maha) spans October to February. Table 1 shows the contribution of seasonal rainfall to the annual rainfall over the island.

Crop types cultivated in the two seasons vary according to the water availability and soil type. Usually in the Maha season, rainfall is sufficient to complete a full cultivation season; in the minor season in April-July tendency is for water scarcity especially towards the end of the season. Usually, when there is sufficient water, the tendency of the farmers is grow rice. However, the government is promoting diversified cropping in Yala or minor season in the soils which suits field crops such as onion or . Success of crop diversification depends on the availability of markets, seeds, and agricultural extension.

[28] Panabokke, 2002. Review of data on soils and geology in the basin area and their relevance to groundwater in the area. In World Water Assessment Programme, Sri Lanka case study, Ruhuna Basins: Workshop Proceedings. Imbulana, K.A.U.S., Droogers, P. and Makin, I. (eds). IWMI, Sri Lanka

Season	Period	Average rainfall(mm)	Percentage of annual total
First inter-monsoon (FIM)	March-April	268	14
South-west Monsoon (SWM)	May-September	556	30
Second Inter-monsoon (SIM)	October-November	558	30
North-east Monsoon (NEM)	December-February	479	26

Table 1: Average annual rainfall (1961-1990) and the contribution of seasonal rainfall to the annual total.

1.1.4 Water resources, agriculture and rural livelihoods

Water Resources: Sri Lanka's rainfall varies from over 5,000 mm in the central mountains to around 900 mm in the extreme north-west and south-east regions. The annual rainfall results in approximately 45 billion m^3 of surface water in the island. 103 distinct river basins are identified with the drainage pattern of surface water. Of these, 20 river basins that are entirely in the south-west quarter of the country, convey about 50% of the surface runoff creating the water-rich Wet Zone. In contrast, Dry Zone has fewer perennial rivers and has overall low annual rainfall and a pronounced seasonal deficit of rain. It is Sri Lanka's agricultural heartland, cultivating most food crops including the staple crop, rice. Over half the populations in Dry Zone districts are employed in agriculture. Districts such as Moneragala (56.9%), Anuradhapura (55%), Polonnaruwa (43%), Mulaitivu (44.6%), Mannar (39.1%), Hambantota (39.3%), Kilinochchi (38.8%) and Kurunegala (35%) record high levels of agricultural employment and many of the 'other' forms of employment available in these districts are agriculture related (fishery, labourers, mill workers, agricultural equipment operators etc). Additional members of the population are employed in other supporting livelihood activities such as agricultural trade, transport, and financial services. As such the rural economy of these districts is heavily dependent on agriculture and related services.

The contribution of agriculture to rural livelihoods and economy in Sri Lanka is significant. Overall, agriculture remains the mainstay of rural economy and the largest rural livelihood base; and is unlikely to change in the short to medium term, as urban rural migration in Sri Lanka remains sluggish.[29] In 2012, this sector employed 2.5 million people or 31% of the total labour force[30]. Farmers having small land holdings dominate Sri Lanka's agriculture outside the plantation sector. As **Error! Reference source not found.**show[31], more than 90% of the farmers have land extents less than 3 ha. Therefore, it is evident that a significant portion of their produce is consumed domestically and output from the farms has a substantial impact of domestic food security. Land fragmentation and poor productivity are concerns in the Dry Zone farming areas where land holding size generally ranges from 0.5 to 2.0 ha.

[29] Department of Census and Statistics 2012; Central Bank Annual Reports of 2013 and 2014
[30] Department of Census and Statistics, 2013. Sri Lanka Labour Force Survey 2012
[31] Department of Census and Statistics 2003. Census of Agriculture 2002, Department of Census and Statistics

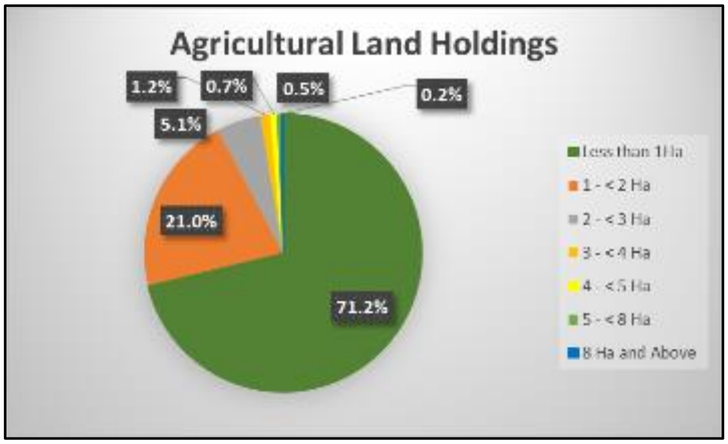

Figure 2: Percentage of agricultural land holdings by size

Increasing agricultural productivity and expanding irrigation has been central to successive governments' rural development and poverty alleviation policies. This continues to be a key priority for the country with the government providing farmers with subsidized fertilizer, extension services and free irrigation water, where possible.

Availability of water, its timeliness and quality- have been key determinants of rural well-being in the past and now. To overcome the water deficit in the Dry Zone, which is the agricultural heartland of the country, many types of diversions and storage systems have been devised from ancient times. These include irrigation reservoirs, canals and diversions from rivers and streams. Dry Zone communities lived and cultivated for many centuries in villages/village clusters organized around stored water in the form of man-made reservoirs. In a few rare locations, settlements were organized around rich sources of ground water, these are few and far between.

As described in Box 2, village reservoirs (small tanks) have traditionally catered for all the water needs of a village community. Experts on Village Irrigation systems emphasize on the multi-functional nature of these systems. Villages in the northern Dry Zone are described as "Tank-Villages" where the reservoir provided water for domestic, agricultural uses as well as provided for fishery and allowed the harvesting of lotus flowers for Buddhist worship. The use of water during normal weather and dry periods are governed by traditional norms. Village Tank is described as the "pivot" on which the life in the Dry Zone revolves even in the modern times[32].

The multi-purpose nature of the services provided by these reservoirs in the Dry Zone have been studied by scholars as well. These services range from economic purposes such as irrigating the command area, social purposes such as domestic use (drinking, bathing and washing)meeting livestock needs, supplementary food (roots and fish), environmental purposes such as cooling a harsh climate, groundwater recharge and cultural needs such as using for festivals. They argue that non-economic uses such as domestic needs and water needs of the livestock are more important than for economic uses. As these systems are mainly managed by the villagers, it is found that they

[32] Dissanayake, J.B. 2000. Water Heritage of Sri Lanka. University of Colombo Sri Lanka.

decide to forego irritated cultivations during seasons of deficit rainfall in favor of social needs[33] respecting the multi-use nature of the village reservoirs.

Groundwater aquifers in the Dry Zone are recharged by seasonal rainfall, and water stored in reservoirs/tanks during the dry period[34]. Villages in the Dry Zone use irrigation reservoirs directly as domestic/drinking water sources. Therefore, the quality and availability of drinking water in Dry Zone villages is heavily dependent on the storage capacity and functionality of reservoir/tank systems.

Drinking water in the Dry Zone is sourced from multiple sources. Generally both surface and ground water is used for drinking water. Most communities have dug wells in their homes but the water availability and quality vary widely. Many large irrigation systems (trans-basin diversion canals and large reservoirs) are used to supply drinking water to towns and villages nearby. Traditionally village reservoirs provided drinking water to the village as well. Literature[35] points out that village reservoirs provided good quality drinking water as they primarily collected rainwater. Dug wells in the Dry Zone are used commonly but can have quality issues relating to hardness, presence of iron and fluoride and now increasingly, the presence of agro-chemical residues in the ground water.

Box 2: Village reservoir and reservoir cascades and their role in rural economy in the Dry Zone

Village reservoirs and associated irrigation systems, for centuries, have been the foundation of rural economies and human wellbeing in the Dry Zone of Sri Lanka. It was the traditional mode of adapting to the water-deficit of the Dry Zone in general[36] and provided multiple benefits (irrigation, domestic water and livestock) and supports aquatic ecosystems and human settlements in a geo-physical environment that would have otherwise been parched and desolate, especially in the dry season. Hence a large number of rainwater storage reservoirs can be observed throughout the Dry Zone, especially dense in districts that experienced low rainfall even during the northeast monsoon. It has been demonstrated that these tanks are not isolated entities but are often found in clusters forming a hydrologically integrated system known as a ‘cascade’. A cascade is defined as a “connected series of tanks organized within micro- (or meso) catchments”. Not all the tanks in the cascades, apparently, were meant for irrigation. Some were used as silt traps, for fishing or for the benefit of domesticated animals and even wild life. In the traditional systems, conservation of the catchment was considered crucial for the sustainability of the village irrigation system- to improve water yield and storage throughout the year. These catchments are local forests and/or multi-use landscapes yielding fruit, fodder, firewood and other benefits to the community, but devoid of annual crops (vegetables etc). In addition, the village reservoirs can act as percolation tanks, recharging aquifers and retarding runoff in areas where water is both precious and scarce[37].A

[33] Panabokke,C.R, Tennakoon, M.U.A, and Ariyabandu, R.de S. Undated..Small Tank Systems in Sri Lanka: Issues and Considerations. thakshana.nsf.ac.lk/slstic/NA-241/NA_241.pdf

[34] Panabokke, C.R. and Perera, A.P.G.R.L. 2005. In Proceedings of the Preparatory Workshop on Sri Lanka National Water Development Report. Wijesekera, S., Imbulana, K.A.U.S. and Neupane B. (eds). MIMRD, WWAP, UNESCO New Delhi and UoM. Sri Lanka

[35] Panabokke C. R et al, Small Tank Systems in Sri Lanka: Issues and Considerations. National Science Foundation 2006

[36] Maddumabandara C. et al, University of Peradeniya 2008

[37] Aheeyar M.M.M Climate change adaptation in water management for food security: Recent developments in Sri Lanka-A review of Existing Knowledge and Information. Sri Lanka Water Partnership 2012

cluster of village irrigation cascades forms a sub-watershed of a major river[38] as is the case of many Dry Zone rivers and as such play a hydrologically important role. The cascade of tanks and associated components (canals, catchment etc) are intrinsically integrated with the natural environment and harbor a number of birds, fish, animals and plant species.

Ancient legislation made it compulsory that farmers maintain these systems and this legacy continues to today, as village irrigation systems are managed locally through Farmer Organisations (FOs).

A summary of water diversion and storage infrastructure in Sri Lanka is provided in Table 2.

Diversion and storage infrastructure	Number of structures
Large scale reservoirs	246
Large scale diversions	122
Village irrigation schemes (reservoirs)	13,100
Village irrigation schemes (diversions and canals)	16,316

Table 2: Water diversions and storage(sources: Meegastenna, pers. Comm. and DAD,2011)

Figure 3 provides a sketch of main infrastructural components of a village irrigation reservoir. They comprise of an earthen bund (dam), a sluiceway constructed with concrete and fitted with a cast iron or wooden gate with a lifting arrangement, a stone-masonry or a concrete spillway.
The spillway is generally uncontrolled overflow type, (i.e. without gates). Although there were bottom-level sluices to remove silt in some older reservoirs, most of them are not absent now or not functioning.

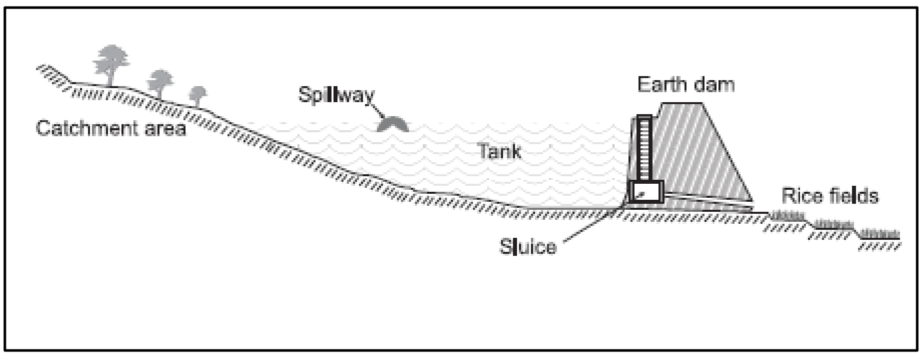

Figure 3: Main infrastructural components of a village irrigation reservoir

Infrastructure for watershed management include the small earthen dikes constructed on the upstream watershed of the reservoir, silt trapping ponds on clearly defined water inflow paths, a tree girdle on the high flood level line, and planting the reservation on the downstream of dam with suitable trees. For details, please see Annex 1. For design specifications of irrigation infrastructure, please see Annex 2.

The major barriers related to irrigation and related rural infrastructure to perform at the desired efficiency, as seen from the survey in 2014 (MCB, 2015) are as follows:

a. Siltation of the reservoir bed and vegetation growth, limiting the storage capacity
b. Dam breaching and subsequent abandonment, resulting fallow agricultural lands

[38] Panabokke, C.R. undated. The small tank cascade systems of the Rajarata: Their setting, distribution patterns nd hydrography. MASL

c. Deficiencies in spillways and dams resulting in deficiencies in flood management
d. Poor condition of the reservoir related infrastructure including sluices and drainage canals

Cropping Patterns and seasonal cultivation calendar of minor or village irrigation systems: Village Irrigation Systems also follow the two main cropping seasons. Generally farmers target to complete the Maha or major growing season (November to February) as this coincides with the rainy season. The seasonal cultivation (kanna) meeting is held to decide water allocation and land preparation dates. Land preparation for the major season begins with the onset of the second inter-monsoon rains in October as by then village reservoirs have dwindled to a minimum (dead storage). Much of the Maha crop is grown with rainfall and it is supplemented by irrigation if a sudden dry spell occurs or if the monsoon dwindled at the tail end. Cropping intensity during the Maha is less than 1, indicating that there is some extent of crop failure even during the major rains season. During the rainy season farmers cultivate rice in irrigated command area and vegetables and other crops in the upland fields, which are totally rain fed or supplemented with ground water irrigation.

The minor cultivation season is the challenging time for VIS. Many VIS have larger spread than depth and evaporation losses are high. The hotter months April-August mean very high evaporation and low storage. This is when the drinking water shortage also occurs, putting pressure on the stored water resources. Many farm fields are left fallow; or farmers decide to divide a small extent of the irrigated command area (30% -50%) among the farmers to make use of the stored water. These decisions are made at the Kanna meeting. However, Yala cultivation is prone to damage and many farmers migrate to urban areas in search of day-labour, leaving women and elderly alone at home to cope with the dry period which brings both food and water shortages for smallholder households.

1.2 Climate Change in Sri Lanka: Risks and Impacts

1.2.1 Sri Lanka in the global context: predictions for Asia and South Asia

Sri Lanka is a tropical island with 1585 km of coastline. As such, the major impacts of climate change are expected to be sea level rise and coastal inundation, increased temperatures and increased frequency of extreme events. Global temperature projections indicate that average annual temperatures could rise by more than 2°C in South Asia by the mid-21st century and exceed 3°C by the late-21st Century under a high-emissions scenario, compared to the average in the 20th century. Under RCP2.6 (a low emissions scenario providing an estimate of the lowest expected changes), average temperatures would rise by less than 2°C in the 21st century in most places. However, at higher latitudes, temperature rise would be up to 3°C[39]. Oceans in subtropical and tropical regions of Asia are expected to warm under all emissions scenarios over the region.

Higher rainfall will be very likely at higher latitudes by the mid-21st century in South Asia under a high-emissions scenario in the late-21st century. Under a low emissions scenario, more rainfall at higher latitudes will be likely by mid-century but changes in rainfall are not likely at low latitudes[40].

[39]Department of Census and Statistics 2012; Central Bank Annual Reports of 2013 and 2014
[40] Climate and Development Knowledge Network (CDKN), 2014. The IPCC's Fifth Assessment Report, What is in it for South Asia? CDKN

The population in coastal areas subjected to floods is predicated to increase from 13 million to 94 million annually, and almost 60%ofthisincreasewilloccur in South Asia including Sri Lanka. In monsoonal Asia, decreasing sediment flux can worsen coastal erosion. Agriculture in tropical areas is one of the worst affected sectors and production is predicted to decrease. Suggested adaptation measures include modifying farming practices to suit a changing climate, improvement of irrigation systems, breeding new climate resistant rice varieties and creating better awareness[41].

Significant increases in the inter-annual and intra-seasonal variability of monsoon rainfall are to be expected in South Asia, according to a study conducted by the World Bank. Using RCP 2.6 and RCP 8.5, under a global mean warming approaching 4°C, an increase in intra-seasonal variability in the Indian summer monsoon precipitation of approximately 10 percent is projected[42]. The fundamental change in behavior of the Indian summer monsoon under global warming is increased uncertainty, associated with an increase in the number of consecutive dry days, leading to droughts aggravated by continued warming. High-risk areas include north-western India, Pakistan and Afghanistan. Over southern India, increasing wetness is projected with broad agreement between climate models[42].

Another study on climate change impacts on South Asia[43] uses a regional climate model (RCM) at a 30-kilometer (km) grid resolution. It analyzes the impacts under A2, A1B, and B1 scenarios from the 2001 Special Report on Emission Scenarios (SRES) of the IPCC, representing high, medium, and low emission futures, with respect to three time periods—2030s, 2050s, and 2080s. The results shown in Figure 4indicate increases of mean monsoon rainfall in the long term in Southern India, the Maldives, and Sri Lanka by the late 21st century, with smaller increases earlier in the century. Whilst, these results may be dependent on the choice of RCM for the modeling, results from General Circulation Models (GCMs) used in the 5th IPCC assessment report also indicate a more likely wetter future under higher emissions scenarios[44]. However, the same report also shows that observed trends (from station records) for the period 1951-2010 show a decreasing amount of total annual rainfall over time, in contrast to the modeled future trends. This suggests caution and that modeled future changes may not be valid for the near future.

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[41] Cruz, R.V., *et a*l, 2007: Asia. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry *et al*, Eds., Cambridge University Press, Cambridge, UK, 469-506.

[42] World Bank. 2013. Turn Down the Heat: Climate Extremes, Regional Impacts, and the Case for Resilience. A report for the World Bank by the Potsdam Institute for Climate Impact Research and Climate Analytics. Washington, DC:World Bank. License: Creative Commons Attribution—Non Commercial–No Derivatives 3.0 Unported license (CC BY-NC-ND 3.0)

[43] Ahmed, M. and S. Suphachalasai.2014. Assessing the costs of climate change and adaptation in South Asia. Asian Development Bank, Mandaluyong City, Philippines

[44]Hijioka, Y., E. Lin, J.J. Pereira, R.T. Corlett, X. Cui, G.E. Insarov, R.D. Lasco, E. Lindgren, and A. Surjan, 2014: Asia. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi,Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1327-1370

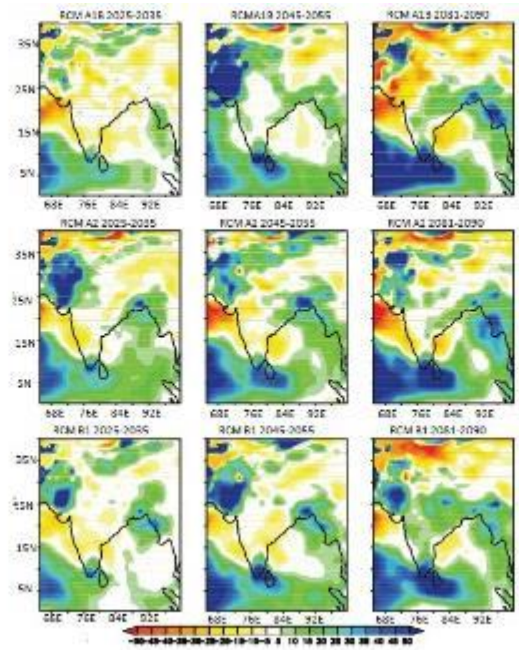

Figure 4: Projected changes in mean monsoon rainfall over South Asia. Source: Ahmed and Suphachalasai.2014

1.2.2 Climate change in Sri Lanka

As an island country with a dense coastal population and agricultural economy heavily reliant on rainfall for its water resources, Sri Lanka is highly vulnerable to the impacts of climate change.[45]

Observed changes in weather/climate: Climate change in Sri Lanka is manifesting through a slow but steadily rising temperature and increasingly erratic rainfall seasons[46]. A number of meteorological studies point to a clear warming trend[47]. An analysis of temperature regimes in the past 50-75 years shows a distinct upward and accelerating trend of both day-time maximum and night time minimum air temperature at most meteorological stations in the country, with night-time minimum temperatures accelerating the fastest.[48]The number of warm days has increased in all districts and cold nights have decreased, resulting in high evaporation losses and physical discomfort especially for those working outdoors for extensive periods, especially in farm fields.[49] Trend analysis of temperature reveals that both daytime maximum and nighttime minimum temperature are significantly increasing at a rate of 0.01 to 0.03 °C per year with a few exceptions.[50]

[45]Fourth Assessment Report of the IPCC. https://www.ipcc.ch/pdf/assessment-report/ar4/.../ar4-wg2-chapter10.pdf and Second National Communication to the UNFCCC, Sri Lanka, Ministry of Environment 2012

[46] Second National Communication to the UNFCCC, Sri Lanka, Ministry of Environment 2012

[47] Sri Lanka's Second National Communication to UNFCCC (2010)

[48] Abeysekara, AB, Punyawardena, BVR. and Premalal, KHMS, 2015. Recent trends of extreme positive rainfall anomalies in the Dry zone of Sri Lanka. Annals of the Sri Lanka Department of Agriculture, 17: 1-4

[49] Abeysekara, AB, Punyawardena, BVR. and Premalal, KHMS, 2015. Recent trends of extreme positive rainfall anomalies in the Dry zone of Sri Lanka. Annals of the Sri Lanka Department of Agriculture, 17: 1-4

[50] Premalal KHMS and Punyawardena BVR 2013. Occurrence of extreme climatic events in Sri Lanka. In: Gunasena HPM, Gunathilake HAJ, Everard JMDT, Ranasinghe CS and Nainanayake AD (eds), Proceedings of the International Conference on Climate Change Impacts and Adaptations for Food and Environment Security. Hotel Renuka, Colombo, Pages 49-57

These findings are consistent with the predicted increases in temperature from climate models which range from 0.46°C per decade for maximum daytime temperature; and around 0.27°C per decade for minimum nighttime temperature.[51]

Although total annual rainfall (compared to the 30 year average 1960-1990) remains steady,[52] changes are observable in the increased variability of monsoon behavior: This pertains to monsoon and inter-monsoon onset time, duration, nature of rainfall and extreme rainfall events during a season. Changes in the distribution of rainfall (quantity and duration) across these four seasons are already observable, with highest variability observed during the FIM and the NEM.[53]Observed changes of several climatic variables are described in Box 1.

Box 1. Observed changes in the climate of Sri Lanka - Some scientific evidence

Temperature: Analysis of past data suggests that atmospheric temperature is gradually rising almost everywhere in the country.[54] Varied rates of increase in temperature have been reported from different locations and in recent years, the warming trend has become faster. Annual mean air temperature anomalies have shown significant increasing trends in all stations during the recent decades. It has been reported that mean daytime maximum and mean nighttime minimum air temperatures also have increased. Increases in nighttime minimum air temperature contribute more to average increases in annual temperature than daytime maximum air temperatures[55].

Precipitation: Unlike in the case of temperature, no clear pattern or trend has been observed in precipitation. Some researchers, comparing the mean annual precipitation of recent and earlier periods, suggest that average rainfall is showing a decreasing trend[56]. However, there is no consensus on this among researchers and opposing trends can be observed at different locations. Heavy rainfall events have become more frequent[57] in the central highlands during the recent period. However, many researchers seem to agree that the variability of rainfall has increased over time, especially in Maha season[58]. Moreover, the number of consecutive dry days has increased and the number of consecutive wet periods has decreased[59]. There are also indications that the spatial distribution of rainfall is changing although a distinct pattern cannot be recognized yet. Studies also suggest that changes in rainfall distribution can lead to the shifting of agro-ecological boundaries[60].

Extreme events: The intensity and frequency of extreme events such as floods and droughts have increased during recent times[61].

Sea level rise: Sea level rise of 1-3 mm/year is observed in the Asian region and is marginally higher than the global average. An accelerated level of sea level rise has been observed during the period of 1993-2001 (3.1mm/year) for the Asian region. However, specific levels of sea level rise in areas around Sri Lanka are yet to be assessed.

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[51] Punyawardena et al, Predicted temperature Change over Sri Lanka by PRECIS RCM for B2 Scenario in combination with ECHAM4 GCM 2010
[52] Punyawardena et al. Vulnerability Analysis of Districts 2012
[53] National Adaptation Action Plan 2010-2016, Climate Change Secretariat and ADB 2010
[54] Chandrapala, L. (1996b) Long term trends of rainfall and temperature in Sri Lanka. In Climate Variability and Agriculture, Abrol, Y. P., S. Gadgil and G. B. Pant. (Eds.) New Delhi, India: Narosa Publishing House. Pp 153-162.
[55]Premalal and Punyawardena 2014 and Basnayake, B.R.S.B. (2007) Climate Change. In The National Atlas of Sri Lanka. Survey Department of Sri Lanka, Colombo, Sri Lanka: 54-55
[56]Premalal and Punyawardena 2014 and Basnayake, B.R.S.B. (2007) Climate Change. In The National Atlas of Sri Lanka. Survey Department of Sri Lanka, Colombo, Sri Lanka: 54-55
[57]Premalal and Punyawardena 2014
[58]Premalal and Punyawardena 2014
[59]Ratnayake, U. and Herath, G. (2005) Changes in Water Cycle: Effect on Natural Disasters and Ecosystems. In S. Wijesekara, K.A.U.S. Imbulana, B. Neupane (Eds.), Proceedings of the Preparatory Workshop on Sri Lanka National Water Development Report, World Water Assessment Programme, Paris, France: 192-205.
[60]Eriyagama, N., V. Smakhtin., L. Chandrapala and K. Fernando (2010) Impacts of climate change on water resources and agriculture in Sri Lanka: a review and preliminary vulnerability mapping. Colombo, Sri Lanka: International Water Management Institute. 51p. (IWMI Research Report 135). [doi:10.5337/2010.211]
[61] Disaster Management Center; Disinventar Database 2014

Source: National Adaptation Plan, Ministry of Environment 2015; Department of Meteorology/Adapted from the National Adaptation Strategy 2011-2016

Projected changes in weather and climate: Figure 5 shows that temperatures are projected to increase in the medium to long term in North and North Central Provinces. A study using HADCM3 found that average annual temperature is predicted to increase by 1.6°C and 1.2°C under the A2 and B2 SRES scenarios respectively. The highest increase was predicted in Anuradhapura in the Dry Zone, which was 2.1°C[62].

Rainfall modeling presents a more complex scenario than projected temperature increases, but generally indicate that the wetter areas will decline and that large areas of the Dry Zone will receive less rainfall in the medium term (2015-2025)[63,64]. Figure 6, based on a single downscaling of one global model, shows that a rainfall reduction in North and North Central Provinces is to be expected, while the rainfall in the already wet western and southern coastal areas is predicted to increase.

A study carried out using HADCM3 showed that SWM rains could increase by 38% (SRES A2 scenario) and 16% (B2 scenario) in the 2050s. The NEM rainfall, which provides the major part of rainfall to Dry Zone, was projected to decrease by 34% and 26% under the same scenarios respectively[65]. Furthermore, a simple daily intensity index, defined as the annual total rainfall divided by the number of wet days, indicated a positive trend in the Dry Zone, though the trends were not statistically significant[66].

[62] De Silva, C.S, 2013

[63] Shantha, W. W. A and J. M. S. B. Jayasundara (2005). Study on changes of rainfall in the Mahaweli upper watershed in Sri Lanka due to climatic changes and develop a correction model for global warming. Paper presented at the International Symposium on the Stabilisation of Greenhouse Gas Concentrations. Hadley Centre, Met Office, Exeter, UK.

[64] Punyawardena, B. V. R., S. Mehmood., A. K. Hettiarachchi., M. Iqbal., S. H. S. A. Silva and A. Goheer (2013) Future climate of Sri Lanka: An approach through dynamic downscaling of ECHAM4 General Circulation Model (GCM).Tropical Agriculturist 161: 35-50

[65] De Silva C.S. 2013. Impact of climate change on water resources and agriculture in Sri Lanka In: Gunasena HPM, Gunathilake HAJ, Everard JMDT, Ranasinghe CS and Nainanayake AD (eds), Proceedings of the International Conference on Climate Change Impacts and Adaptations for Food and Environment Security., Colombo, PP 67-72..

[66] Premalal and Punyawardena, 2014

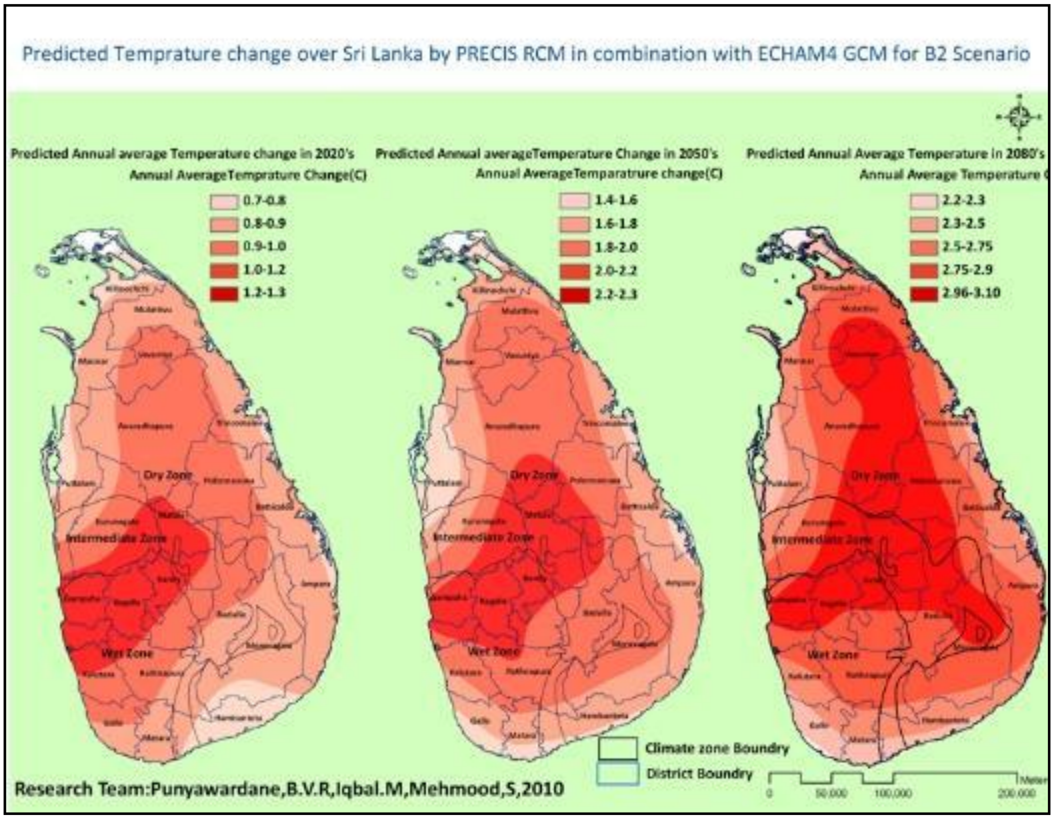


Figure 5:Predicted temperature change over Sri Lanka

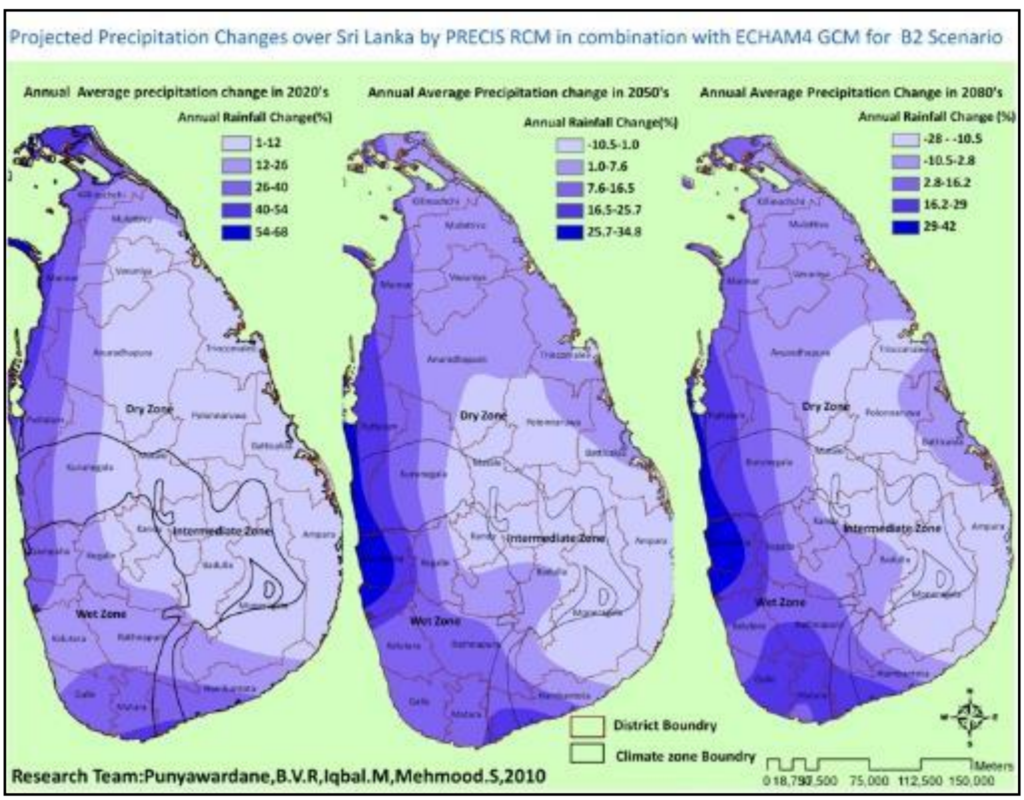


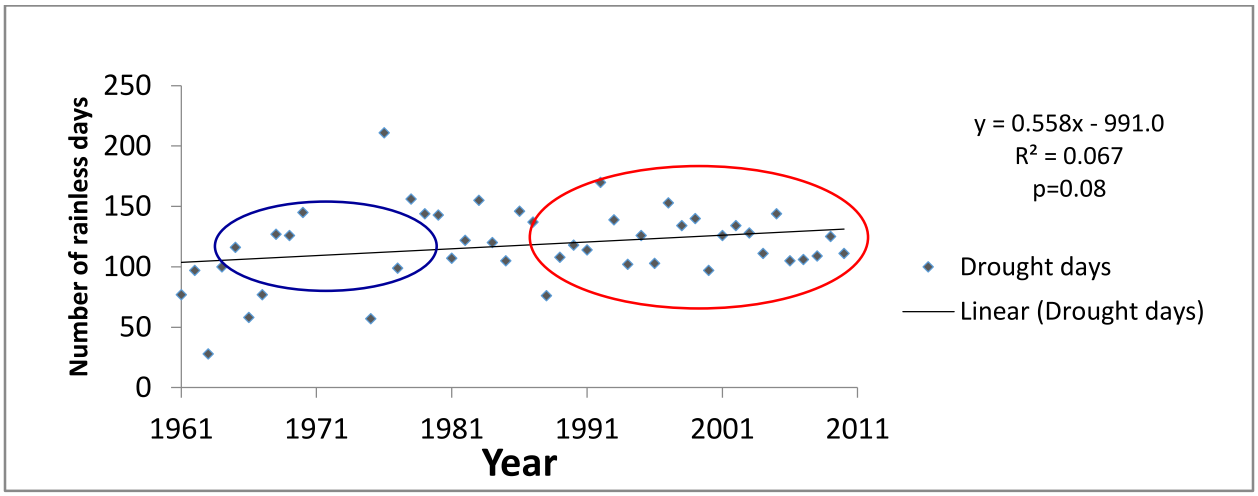
Figure 6:Predicted precipitation changes over Sri Lanka

1.2.3 Climatic hazards and extreme events

Sri Lanka is affected by a number of climatic hazards and extreme events, and these are projected to worsen with climate change. Being an island country with a mountainous central-region, Sri Lanka has historically been affected by flood, drought, landslides, coastal storms and erosion, cyclones and storm surges. Climate-induced changes in rainfall are clearly manifested in a higher number of intense/ heavy rainfall incidents leading to flash floods downstream and higher temperatures increasing the risk of drought during the dry season.

During 2010 - 2015, Sri Lanka suffered from a cycle of hydro-meteorological disasters that impacted mainly the war-affected Dry Zone districts (see Table 4). Droughts and flood incidents in quick succession, within a few months of each other, alternated within the same districts, affecting the same vulnerable communities and eroding their capacity to cope. The drought of 2012 has been the worst in past 20 years in the Central Highlands, and one of the worst crop years for the country[67]. However by January 2013 floods were affecting 10 districts, many of which were earlier in the clutches of drought. In 2014 drought affected over 1.8 million people in 16 districts including Mannar, Vavuniya, Mulaitivu, Trincomalee, Batticaloa, Puttlam, Kurunegala, Anuradhapura and Polonnaruwa.[68]World Food Programme (WFP) assessments showed that in April 2014 over 750,000 people were in a situation of food insecurity, a condition that was worsened by low rainfall until October 2014. Heavy floods in 21 districts in November 2014-January 2015 subsequently impacted the same districts affecting 1.1 million people[69] destroying crops, homes, livestock and other assets

A recent analysis[70] clearly shows an increased frequency of extreme rainfall events in the country, especially the Dry Zone. Another study on extreme rainfall events in the Dry Zone[71]shows that both longer dry periods and high intensity rainfall events have considerably increased over the past two decades. The study looked at rainfall data from a series of Dry Zone locations from the north, north central and southern provinces to conclude that the number of rainless days in the Dry Zone has increased significantly showing more frequent drought episodes (see Figure 7).



[67] Central Bank of Sri Lanka. Annual Report 2012

[68] UNOCHA Drought Update. August 2014/

[69] Disaster Management Centre Database 2013

[70] Premalal KHMS and Punyawardena BVR 2013. Occurrence of extreme climatic events in Sri Lanka. In: Gunasena HPM, Gunathilake HAJ, Everard JMDT, Ranasinghe CS and Nainanayake AD (eds), Proceedings of the International Conference on Climate Change Impacts and Adaptations for Food and Environment Security. Hotel Renuka, Colombo, Pages 49-57.

[71] Abeysekara, AB, Punyawardena, BVR. and Premalal, KHMS, 2015. Recent trends of extreme positive rainfall anomalies in the Dry zone of Sri Lanka. Annals of the Sri Lanka Department of Agriculture, 17: 1-4

Figure 7: Total number of rainless days per year in the Dry Zone (Premalal and Punyawardena 2014)

	> 100 mm	> 150 mm	> 200 mm
1985-94	24	9	2
1995-04	31	15	8
2005-14	32	13	6

Table 3: Occurrence of Heavy rainfall events (weekly cumulative) in a decade during Maha season in one agro-met station in the Dry Zone (Anuradhapura District)

Meanwhile the incidence of heavy and very heavy rainfall events have also increased throughout the Dry Zone. As Table 3 demonstrates, the occurrence of intense rainfall events of more than 200mm in a week has increased from an average of 2 in 1985-1995 to 6 during the period 2005-2014. Analysis of very heavy rainfall events during Maha or the major growing season in several different agro-ecological regions of the Dry Zone has shown significant increases during the North East Monsoon (NEM)[72] denoting high variability of monsoon rainfall during the crucial cultivation season. Figure 8 demonstrates this increase in three agro-ecological zones from North Central, Eastern and Southern provinces respectively. It is also observed in these studies that inter-annual rainfall variability is higher in the Dry Zone than the intermediate and Wet Zone.

Drought in Sri Lanka is hydrological in nature and agricultural in impact- as it relates to soil moisture deficiency and anomalous rainfall behavior disrupting the cropping seasons. Changes in rainfall and temperature during the past decades directly impact on exacerbating drought in Sri Lanka. Both the first inter-monsoon (FIM) and the north-east monsoon (NEM) periods show a decrease in total seasonal rainfall. In addition to this the number of rain days has reduced[73] with observed increases in the intensity of rainfall. Climate models also suggest that this trend may continue and that the NEM season will yield less rainfall in the future. Some models predict that the North-East monsoon rains will decrease by 34%, directly affecting the Dry Zone water availability.[74] As explained above, significant increases in the incidence of high rainfall events, coupled with longer dry spells have become the new normal for the Dry Zone, making it hard for farmers to plan their agricultural activities around established patterns of rainfall.

Traditionally, the Dry Zone is considered drought-prone, and the Wet Zone as flood-prone. Accordingly, communities and associated institutions had some degree of built-in resilience to floods in the Wet Zone, such as anticipation of floods in monsoon periods, higher concentrations of rain gauges and stream gauges and flood management procedures. However, recent experiences show that the Dry Zone is inadequately prepared for climate change induced flash floods, which have been occurring with higher frequency and magnitude. Similarly, Dry Zone farmers have traditionally coped with drought and water deficiencies by building storage reservoirs to cultivate

[72]Abeysekara, AB, Punyawardena, BVR. and Premalal, KHMS, 2015. Recent trends of extreme positive rainfall anomalies in the Dry zone of Sri Lanka. Annals of the Sri Lanka Department of Agriculture, 17: 1-4

[73] Premalal and Punyawardena 2014

[74]De Silva, C. S. (2006b) Impacts of climate change on water resources in Sri Lanka. Paper presented at the 32nd WEDC International Conference, November 13-17, 2006, Colombo, Sri Lanka.

the dry season and ensure sufficient ground water recharge. Farmers had coping mechanisms to cope with regular dry periods and the occasional longer drought. However, the frequency and intensity of drought (and flood) occurring now has robbed farmers of the capacity to cope, as extreme events closely follow one another, allowing little respite for farmers to regain their assets and crops.

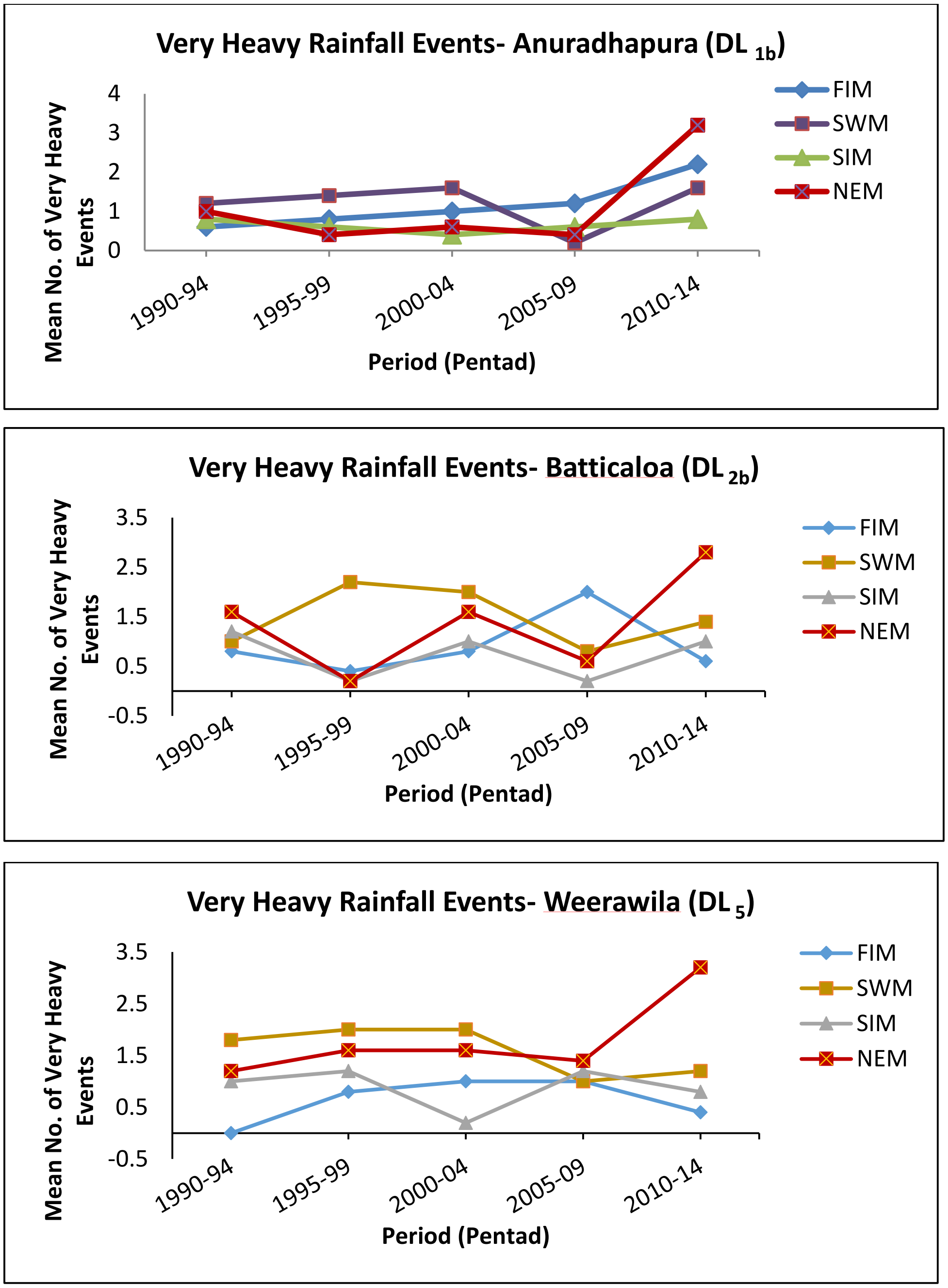


Figure 8: Change in the pattern of very heavy rainfall events over time in three Dry Zone rainfall stations

1.3 Vulnerabilities and Exposure to Climate Change in the Dry Zone: Key Impacts to lives and livelihoods

1.3.1 Climate change impacts on water for agriculture and drinking

Climate change has heavily impacted upon the wellbeing and livelihoods in the Dry Zone. Increased and prolonged droughts have resulted in crop losses, drastically reducing the cultivated area in the dry season. Increased intensity of rainfall and flash flooding damage crops and spoil harvests. Heavy rainfall, combined with the gradual clearing of immediate upstream watersheds, results in high sediment runoff to the reservoirs. Siltation compromises the water retention capacity of village reservoirs and carry-over storage from the wet to dry season. This is compounded by the decreasing reliability of seasonal rains and inadequate advance knowledge about seasonal weather pattern.

The increased frequency and intensity of floods takes a heavy toll on the village irrigation systems. When reservoirs are damaged beyond locally reparable limits, villagers have to wait for several cultivation seasons for state assistance to come in. In the meantime, they are deprived of the means of supporting their needs for food, income and drinking water. The availability of drinking water is significantly reduced due to falling water storage capacity, and consequently affects the quality of drinking water during dry periods. In many conflict affected districts village tanks and their associated infrastructure had been periodically abandoned due to displacement. Efforts at restoring these local irrigation schemes have been hampered by intense floods in 2011, 2013, 2014 and 2015. In locations where these reservoirs have been abandoned, disused or damaged, the community resorts to dug wells for drinking water. Ground water quality in the Dry Zone is questionable, and is believed to be heavily polluted by agro-chemical use. Many Dry Zone districts have serious chronic health issues related to water, especially Chronic Kidney Disease.

While the decision-making by the community with regard to allocation of water is often democratic and scientific (with due regard to higher weightage for domestic needs), they have depended on their traditional wisdom to forecast dry periods and make water allocation decisions. However, erratic rainfall and decreased predictability in rainfall seasons have hampered the decision making of farmers. When the command area is cultivated anticipating normal rainfall, the tendency of the farmers is to save the crop and their investments; but in the process the availability of drinking water suffers during unexpected dry spells. Therefore, often the families have to depend on external help (such as water bowsers provided by the government) or unsafe sources.

Thus, smallholder farmers living in Dry Zone river basins associated with small-tank cascade systems face three clear inter-connected threats to food security, health and decent livelihood. These are;

1) Decreasing production in farm fields due to water shortages resulting from decreased storage capacity, high levels of evaporation in the village reservoirs, and erratic rainfall
2) Decreased availability of year-round safe drinking water due to longer droughts, declining water quality and lack of adequate water storage, worsened by inadequate knowledge regarding seasonal weather patterns. This has resulted in increased exposure to water-related health issues among smallholder farmers.
3) Increased crop losses and damage to livelihood assets including livestock due to very heavy rainfall events, flash floods and longer periods of drought damaging village irrigation infrastructure.

Whilst the impacts of climate change on life and livelihoods of the Dry Zone are clearly inter-connected, they are analysed frequently in a sectoral manner and the following sections describe these sectoral impacts.

1.3.2 Impacts on agriculture, life and livelihoods

Predicted impacts on Agriculture: Climate change predictions show a negative impact on agriculture, especially in the Dry Zone. This is due to the soil-moisture deficit that is predicted to be severe due to decreases in rainfall and increases in temperature. The areas of highest soil moisture deficit would be Jaffna, Mannar, Vavuniya, Trincomalee and Anuradhapura Districts, which will result in an increase of irrigation requirements for rice by 23% (A2 scenario) to 13% (B2 scenario), with similar increases predicted for field crops[75]. Another study predicts rice yields will decrease by about 20% in the next 20-30 years, along with expected increases of pest and weed problems[76]. As such, climate change will have significant impacts on agriculture and food production, especially given that 80% of rice production is obtained from irrigated lands, and such lands are located mainly in the Dry Zone.

Vulnerability of small holder farmers to impacts of climate change: The Dry Zone farmer faces a number of challenges such as reduced land productivity and size, increasing cost of labour and inputs, quality of seeds, low yields and access to timely irrigation. As discussed earlier, the seasonal rainfall patterns around which Dry Zone agriculture practices were built have been disrupted in the last few decades, severely testing the coping capacity of farmers.

A number of studies confirm that smallholder farmers cultivating under village irrigation systems (small reservoirs and anicuts) are poorer and more vulnerable than their Dry Zone counterparts who have access to major irrigation[77,78]. Farmers in village irrigation systems are generally poorer[79] with very little market access[80], poor basic infrastructure such as roads, drinking water and communication and are also disadvantaged due to other social and health issues such as conflict and chronic disease. Such farmers are much more vulnerable to impacts of changes in weather than farmers cultivating under larger irrigation systems[81]. Many of these farmers grow their own requirement of the staple rice and other food crops. A delayed monsoon or heavy rainfall during the sowing or harvesting period can damage an entire cropping season. For farmers who cultivate under village irrigation systems, the crop from the *Maha* Season (NEM) is often their main source of income and household food. Remoteness and disconnect with the larger irrigation and agricultural institutional infrastructure has compounded facets of vulnerability among farmers in village irrigation systems. As productivity and crop yields decline with low water availability

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[75] De Silva, C.S. et al 2007. Predicting the impacts of climate change—A case study of paddy irrigation water requirements in Sri Lanka. Agricultural water management 93 (2007) 19–29

[76] Weerakoon, W.M.W. 2013. Impact of climate change on food security in Sri Lanka. In: Gunasena HPM, Gunathilake HAJ, Everard JMDT, Ranasinghe CS and Nainanayake AD (eds), Proceedings of the International Conference on Climate Change Impacts and Adaptations for Food and Environment Security. Hotel Renuka, Colombo, PP 73-86.

[77] Minor schemes generally irrigate less than 80ha. Anything larger is considered a medium or major irrigation system. Major schemes, according to Irrigation Department, irrigates over 400ha.

[78] Aheeyar M.M.M Climate change adaptation in water management for food security: Recent developments in Sri Lanka-A review of Existing Knowledge and Information. Sri Lanka Water Partnership 2012

[79] IWMI 2010 and Sri Lanka Water Partnership 2012

[80] http://www.ifad.org/evaluation/public_html/eksyst/doc/impact/2013/srilanka/dzlspp_impact.pdf

[81] Aheeyar M.M.M Climate change adaptation in water management for food security: Recent developments in Sri Lanka-A review of Existing Knowledge and Information. Sri Lanka Water Partnership 2012

and unseasonal rains, farmers are dragged deeper in to poverty and face food deficits, which have to be met by buying food for consumption, increasing debt among smallholder farmers.

1.3.3 Increased crop losses and damages to livelihood assets

Changes in weather patterns, attributable to climate change, have caused the rapid destruction and deterioration of village irrigation reservoirs and systems in the past decade. High intensity rainfall and associated soil erosion has caused rapid and unprecedented levels of siltation in village reservoirs reducing storage capacity. Due to siltation, the water spread of a village tank increases leading to higher evaporation during dry periods. Evaporation losses are much more evident in small tank systems than in medium or large reservoirs.

Figure 9 shows that farmers under village irrigation are indeed much more exposed to climate change related changes in rainfall distribution than their counterparts cultivating under major irrigation schemes. As is evident in a normal rainfall year (2013) these farmers can complete one full cropping season, which is the Maha. Almost 40% of farmers fail to cultivate the minor season, Yala. In a drought year in comparison (2014), more than half the farmers fail to cultivate either season, with the greatest deficit being in Yala season.

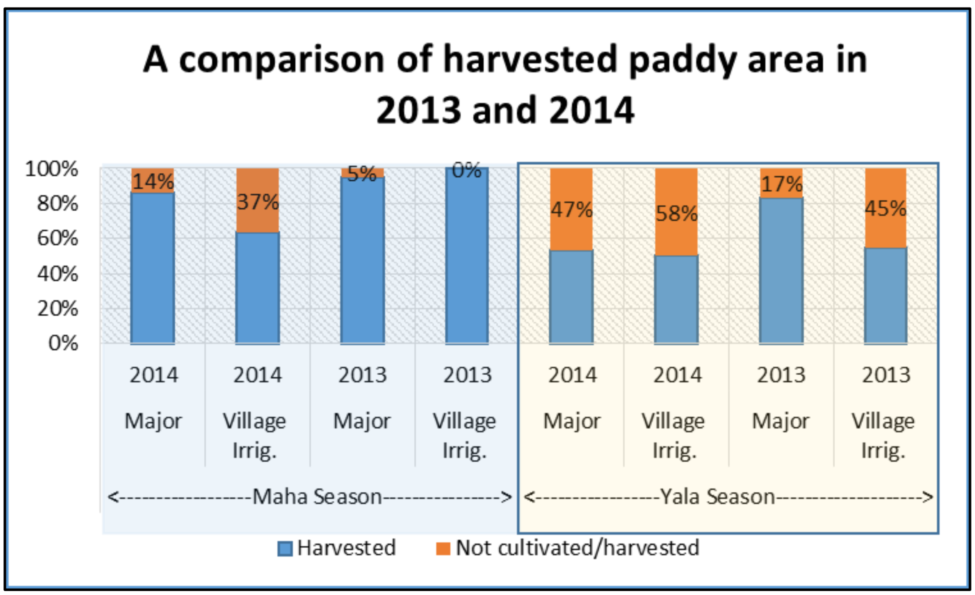

Figure 9:Impact of droughts on different types of irrigation systems. **Source: Department of Census and Statistics, Paddy Statistics, 2013 and 2014**

Village irrigation systems were built in a way that they mitigated localized floods, by capturing run-off in the catchment of a basin. However, recent flash floods associated with very high rainfall events have destroyed irrigation infrastructure such as bunds, sluices, canals and spillways etc. In the past five years due to the extreme weather cycle described above, around 1,950 village irrigation reservoirs and diversions have been breached due to floods (Table 4).Climate change-related extreme events are threatening the sustainability of small village irrigation systems across the country, but most severely in certain identified river basins. Department of Agrarian

Development (DAD), through an analysis of the hydrological and physical parameters of different basins, and the exposure to climate related rainfall variability that influence floods and droughts, is in the process of ranking the vulnerability of river basins that have large presence of village reservoirs and irrigation systems. Several such river basins that are impacted by and are increasingly vulnerable to climate related water-deficits and extreme rainfall events have been identified. They include; Mi Oya, Deduru Oya, in the north western region of the country; Malwathu Oya and Yan Oya in the northern region; and Kumbukkan Oya and Menik Ganga in the south-eastern region. These rivers originate from already rain-deficit areas on the 'fringes' of the Dry Zone, and are now impacted by the changed pattern of rainfall in both the Dry and Intermediate Zones[82].

Year	**2012**		**2014**		
District	**Damaged Reservoirs & diversions**	**Area affected**	**Damaged reservoirs**	**Damaged Diversions**	**Area affected ha**
Anuradhapura	113	10,595	253	2	28,018
Polonnaruwa	67	2,262	23	-	25,101
Kurunegala	84	2,328	22	-	9,286
Hambantota	123	1,135	-	-	
Ampara	25	1,014	-	-	
Trincomalee	34	2,644	43	9	20,793
Batticaloa	16	607	33	1	40,121
Mannar	46	758	-	-	
Matale	136	1,136	21	8	486
Puttalam	85	3,628	18	8	5,037
Badulla	5		3	162	1,369
Gampaha	0		-	21	0
Moneragala	105	1,271	17	1	729
Vavuniya	78	2,927	30	4	1,893
Kandy	0	0	8	82	2,022
Kilinochchi	0	0	4	-	
Mulaitivu	29	1,113	26	-	2,455
Nuwaraeliya	36	679	9	4	
Matara	0	0	8	49	433
Kegalla	0	0	-	98	
Total	**982**	**32,096**	**518**	**449**	**137,741**

Table 4: Village Irrigation Systems damaged in 2012 and 2014 floods by district. Source: Department of Agrarian Development

[82] Punywardena and Premalal 2014

The impact of damaged irrigation reservoirs if often under-estimated, and usually the damage is assessed with reference to the physical damage to the infrastructure. However, due to the multi-functionality of village irrigation systems, the village community is deprived of water for domestic purposes and livestock, fish production and other related livelihood activities. Although sufficient research and documentation have not been carried out in this subject, the anecdotal evidence collected after the 2014 floods showed that families were made destitute after a dam breach. They had no plans for the survival till the dam breach is repaired and filled with the next rains. Some resorted to selling of cattle and the males found ad-hoc employment outside the village. For domestic water, they had to depend on the depleting well water and government-supported water bowsers, or private vendors.

Small village irrigation systems, including small tanks/reservoirs and small tank cascades have been a neglected area of Sri Lanka's development investments in the past 30 years. At different times, the government supported new settlements in the Dry Zone, however without adequately supporting the traditional cultivation systems under which many poor farmers eke out subsistence agricultural livings. Years of neglect by policy makers and planners, have been compounded by reforms in state institutions and local organisations mandated to upkeep these structures.

1.3.4 Drinking water and health: implications for climate resilience

In Sri Lanka only 35% of people have access to pipe-borne drinking water from a purified 'safe' source. Others depend on deep/shallow wells with hand pumps, protected springs, protected dug wells, and protected rainwater catchments systems. In rural Dry Zone, especially in agricultural areas, drinking water is mainly from dug wells or from village reservoirs. The access is comparatively low in the Dry Zone and especially in the north and the east. These deficiencies in the Dry Zone relate to sufficiency and the location of water sources for domestic purposes[83], as shown in Table 5.

The Dry Zone has a number of drinking water sources including perennial rivers, transbasin canals, large irrigation systems, ground water, minor tanks and rainwater harvesting systems at household level. All of these are threatened by climate change to some degree. The most threatened, however, are village reservoirs, seasonal rivers and associated ground water wells. Drinking water systems are highly susceptible to climate change impacts, especially changes in rainfall pattern (causing flood or drought) and high evaporation. High temperatures and longer dry periods impact on water availability. As storage capacity declines, water quality issues become more pronounced- with both surface and ground water quality deteriorating rapidly during dry periods. While this is a normal phenomenon in regular years during the dry months (July-September); predictability of this seasonal change (and required water management measures associated with these changes) is becoming increasingly difficult and communities in the Dry Zone are experiencing water quality issues throughout the year[84]and generally people have to travel longer distances to get drinkable water[85]. Flash floods caused by heavy rainfall damage water supply infrastructure (intakes, pumps, storage tanks and pipelines) at community level and many villagers are not able to repair or upgrade them. Floods also carry sediments which lead to siltation and turbidity in water sources,

[83] Department of Census and Statistics, 2015. Household Income and Expenditure Survey 2012/13. www.statistics.gov.lk

[84] Field Consultations in Puttlam, Anuradhapura and Kurunegala Districts with Farmer Organisations working in small village irrigation systems. November-December 2015

[85] Field Consultations in Puttlam, Anuradhapura and Kurunegala Districts with Farmer Organisations working in small village irrigation systems. November-December 2015

especially in small reservoirs. More importantly, high intensity rains and heavy runoff prevent effective seepage and recharge of ground water aquifers. While sources deplete, communities extract more and more ground water to overcome deficits in water availability in village reservoirs, streams and seasonal rivers. Additionally, poor quality ground water in the Dry Zone is due to several factors such as agro-chemical and pesticide over-use[86] (nitrates, phosphates and heavy metals) and presence of iron and fluorides[87]. Over extraction, and contracting of aquifers due to non-replenishment has led to a concentration of pollutants in ground water in the Dry Zone, leading to health issues such as Chronic Kidney Disease.

District	**Percent population having**			
	insufficient water for drinking	**insufficient water for bathing**	**Water Source outside premises**	**A distance to water source > 200 m**
Hambantota	6.3	10.6	15.4	4.6
Jaffna	2.0	1.7	49.6	14.4
Mannar	9.9	17.1	53.0	9.4
Vavuniya	7.7	28.7	54.0	13.2
Mullativu	0.6	2.7	37.4	4.8
Kilinochchi	23.1	23.3	32.4	9.6
Batticaloa	4.4	6.9	25.5	6.6
Ampara	9.2	13.6	22.7	5.3
Trincomalee	10.9	10.6	35.5	4.5
Puttlam	11.6	19.7	26.9	11.1
Anuradhapura	8.4	12.2	36.9	16.3
Polonnaruwa	17.1	25.1	29.8	10.0
Moneragala	20.5	39.6	27.1	6.7
Sri Lanka	**7.2**	**11.3**	**20.1**	**4.1**

Table 5: Access to water for domestic purposes in the Dry Zone districts

Water pollution, health and rural economy: One of the biggest water-related health issues in the Dry Zone is the high incidence and geographical spread of Chronic Kidney Disease of unknown etiology (CKDu), which affects the resilience to climate change impacts. While studies[88] point to heavy metal contaminants found in ground water as a source of the disease, exact cause has not been identified, and can be partly attributable to heat stress related dehydration and decreasing quality/availability of ground water. The disease has affected 81 divisions in 11 Dry Zone districts with the number of patients being highest in Polonnaruwa and Anuradhapura districts, in the North-Central Province. The problem is now clearly spreading both north and southwards (see

[86] Silva, E.I.L, 1996. Water quality in Sri Lanka. A review of 12 water bodies

[87] Dharmawardana, M.W.C.,. Amarasiri S.L., Dharmawardene, N. and Panabokke, C.R. 2014. Chronic Kidney Disease of Unknown aetiology and ground-water ionicity; study based on Sri Lanka. preprint of Environmental Geochemistry and Health: Volume 37, Issue 2 (2015), Page 221-231

[88] WHO 2013

Figure 10), with new patients being identified in several divisions during the last three years.[89] CKDu largely affects male farmers between the ages of 35-50 and the death rate is highest among this age group. The disease has also left women widowed and young children orphaned in farming villages in the North-Central Province.

While the root cause for CKDu has not been identified yet, correlation between the disease and unsafe agricultural practices have been established. It is noted that most of the paddy farmers in North Central, North Western and Eastern Sri Lanka are heavily exposed to pesticides and fertilizers, while agrochemicals are being freely and irrationally used. A study conducted by university academics and medical professinals in Padawiya and Mahawilachchiya (in the NCP), where CKDu patients were present, found that Arsenic content in drinking water was between 20-200 µg/l, which is much higher than the permissible limits. It is also noted that Arsenic content in rice in the affected areas were higher than those in unaffected areas, and the content has been rising in the recent years. Pesticides are considered as a source of Arsenic[90]. Another study found that while Cd (for which fertilizer is a source) levels in water in affected areas were within the permissible levels, it was higher than the allowable limits in vegetables and freshwater fish in the same areas[91]. Among the control measures recommended by the WHO for CKDu include regulating fertilizers and agrochemicals and providing safe drinking water to the CKDu-affected areas[92].

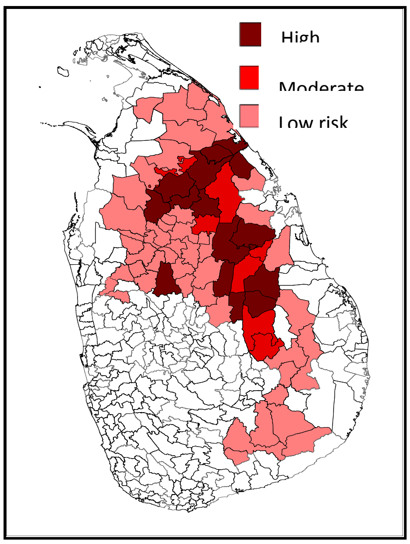

Figure 10 - CKD/CKDu Effected Divisional Secretariat Areas

<u>Climate and chronic disease:</u> It is noted that health impacts from elevated air temperature have been observed in many studies, and respiratory, cardiovascular, and kidney disease have all been

[89] Provincial Renal Disease Prevention and Research Unit - North Central Province 2015

[90] De Silva, N. et al, undated. Chronic Kidney Disease of unknown etiology (CKDu) and Arsenic poisoning due to Illegal pesticides. http://dspace.costi.gov.lk:8080/xmlui/bitstream/handle/ 123456789/148/ Arsenic_and_CKDu.pdf? sequence=1

[91] Jayatilke, N., Mendis, S., Maheepala, P. and Mehta, F.R. 2013. Chronic kidney disease of uncertain aetiology: prevalence and causative factors in a developing country. BMC NephrologyBMC series. http:// bmcnephrol.biomedcentral.com /articles/10.1186/1471-2369-14-180

[92] Ranasinghe, H. R. A. L. N., Lokuge, L. D. M. N., Edirisinghe, J. C. and L. Bandara, L. 2015. Water Treatment, Preventive Measures and the Chronic Kidney Disease in the Farming Community in Sri Lanka. The Journal of Agricultural Sciences. Vol. 10, No. 2, May 2015. pp 98 - 108

linked to global warming. The body's natural methods of cooling include convection, conduction, and evaporation of sweat. Only evaporation will lower body temperature when air temperature is higher than 35°C (which is common in tropical countries), and it is less effective when humidity is high. Evaporation leads to loss of body water and electrolytes, especially sodium and chloride, which are responsible for maintenance of overall fluid balance. Depletion of water and sodium results in loss of extracellular fluid volume, which can place acute or chronic stress on kidney function and ultimately lead to kidney disease.

Kidney disease is usually divided into 2 forms: acute kidney failure (sudden loss of kidney function) and chronic kidney failure (slow, gradual loss of kidney function). Acute kidney failure can result from severe dehydration. Slow loss of kidney function is exacerbated by diabetes, hypertension, and blockage from kidney stones. Kidney stones are more common with chronic dehydration. Heat waves and related dehydration are associated with both acute renal failure and chronic renal disease.

From 1951 to 2003, the mean maximum daily temperature in Thailand increased by 0.56°C, and the mean minimum temperature increased even more, by 1.44°C. A study conducted in Thailand found a corresponding increase in Chronic Kidney Disease in the country from 2001-2007 and an increase in renal deaths and high incidence of kidney stones in manual workers. This study could not directly establish that kidney disease resulted from heat stress. However, the study found that the risk of kidney disease increased with increasing dose of prolonged heat stress exposure in men and that the risk was higher among those aged 35 years or older and those with physical jobs. Older men in physical jobs had a 5.3-times increase in the risk of incident kidney disease[93].

In Central America, case reports and government statistics document high mortality due to chronic kidney disease (CKD), particularly among younger men and in certain regions of the Pacific coast. Northwestern Nicaragua has a high prevalence of CKD of unknown cause among young adult men. A study conducted through interviews with medical professionals in this region indicated a relationship CKD with both heat stress and medication patterns. All interviewees regarded occupational and environmental exposure to sun and heat, and dehydration as critical factors associated with the occurrence of CKD. Health professionals indicated that reluctance among workers to hydrate might be influenced by perceptions of water contamination. The study highlighted several potential contributors to CKD in Nicaragua including heat stress and use of potential nephrotoxic medications, supporting the plausibility of a multi-factorial cause of CKD[94].

Adequate research has not been conducted in Sri Lanka on the linkages of climatic parameters and CKDu. However, increasing temperatures in the Dry Zone, prevalence among agricultural workers exposed to heat stress and anecdotal evidence on low water intake due to fears of contamination points to possible correlations between climate change and the spread of the disease.

Box 3. Chronic Kidney Disease:

[93] Tawatsupa, B. Lynette L-Y Lim, Kjellstrom, T., Seubsman, S. , Sleigh, A and the Thai Cohort Study Team. 2012. Association Between Occupational Heat Stress and Kidney Disease Among 37 816 Workers in the Thai Cohort Study (TCS). J Epidemiol. 2012; 22(3): 251–260. Published online 2012 May 5. http://www.ncbi.nlm.nih.gov /pmc/articles/ PMC3798627/

[94] Ramirez-Rubio,O., Brooks, D.R., Amador, J.J., Kaufman, J.S.,Weiner, D.E., and Scammell, M.K.. 2013. Chronic kidney disease in Nicaragua: a qualitative analysis of semi-structured interviews with physicians and pharmacists. BMC Public Health201313:350. http://bmcpublichealth.biomedcentral.com/articles/ 10.1186/1471-2458-13-350

A high prevalence of chronic kidney disease of unknown etiology has been reported among agricultural communities, mainly male farm workers, in Central America, Egypt, India and Sri Lanka. Possible associations are reported as agricultural work, agrochemical exposure, dehydration, hypertension, homemade alcohol use and family history of chronic kidney disease. In Sri Lanka, this was first detected in the 1990s in the North Central Province. However, since the seriously affected populations lived in rural areas with limited economic resources and often little access to health services, it may be that CKDu was present well before detected. Medical tests revealed that the patients' urine contained high levels of arsenic and cadmium, both of which, plus lead, were found in agrochemicals sampled. It was hypothesized that the population could be exposed to these contaminants through food and drinking water, and that water hardness could play a role[95]. Another study analysed the collected data and concluded that the main reasons are the high ionicity of NCP ground waters in certain areas together with dehydration/insufficient intake of potable water under hot sunny stressful work conditions, routine alcohol consumption habits of the farming community in place of potable water during long working hours in the sun, and changes in weather patterns especially higher day time temperature with erratic precipitation due to climate changes[96]. Please refer to the **Special Note on Climatic and Non-Climatic Drivers of Chronic Kidney Disease of Unknown Aetiology (CKDU),** in the Annex 3 of Technical Feasibility Report for further details.

Gender aspects of health and climate: Human health is a major factor that determines a household's ability to cope with impacts of climate change. In the Dry Zone both war-related disability/maiming and CKDu related deaths are prevalent among young males. This results in a considerable loss of productivity in the farms due to the loss of labor, and the loss of income to the farmer families. In addition, the treatment of kidney disease is expensive, despite the government setting up/upgrading health facilities to treat the disease. Poor health of male family members affects household incomes and food security substantially. Additional medical expenses and care imposes an extra burden on the spouse. Women carry a major responsibility in providing water for household drinking and sanitation. Many women in the Dry Zone are forced to bear the burden of being the main income earner as well. Climate change impacts on this scenario are twofold; reducing the ability of farm families to eke out a regular income and sufficient food for the household and drought and flood impacting further on household water availability for drinking and sanitation, aggravating the vulnerabilities caused by death/disability of male family members.

[95] Almaguer, M. Herrera, R., Orantes, C.M. 2014. Chronic Kidney Disease of Unknown Etiology in Agricultural Communities. MEDICC Review, April 2014, Vol 16, No 2. http://www.ncbi.nlm.nih.gov/pubmed/24878644

[96] Gunatilake, S.K., Samaratunga, S.S. and RubasingheR.T., 2014. Chronic Kidney Disease (CKD) in Sri Lanka - Current Research Evidence Justification: A Review. Sabaragamuwa University Journal 2014, V. 13 NO. 2 pp 31-58

1.4 Vulnerability ranking and Mapping

1.4.1 Vulnerability ranking based on socio-economic and meteorological parameters

A spatial analysis of vulnerability to Climate Change conducted by the Natural Resources Management Centre, Department of Agriculture in 2013 showed that Sri Lanka's northern, north western and north central provinces are in general vulnerable to climate change, given a number of meteorological, socio-economic factors and land use patterns. The rankings of administrative districts are shown in Figure 11and the parameters used for the ranking are presented in Table 6. This vulnerability analysis clearly shows that Dry Zone districts with higher numbers of smallholder farmers cultivating under village irrigation systems are more vulnerable than districts where farmers have access to year-round irrigation and better access to services. Small-scale farming systems, both rain-fed and minor tank irrigated are particularly vulnerable to climate change. As most of the farming community is not in control of sufficient land to produce a marketable surplus, climate effects further reduce agricultural production. All these districts are agricultural, and have a high portion of farmers cultivating under rain-fed conditions in village tanks or minor irrigation schemes.

The analysis measured exposure by observed changes in temperature, warm days and cold nights as well as disaster incidence (loss and damage reports/number of disasters reported). The study clearly delineated districts with smallholder farmers, rain-fed cultivation and presence of village irrigation systems as particularly sensitive to the observable impacts of climate change in Sri Lanka. Therefore, districts that had higher percentages of populations cultivating under village irrigation systems and rain-fed systems were ranked higher in the sensitivity index. The analysis of vulnerability included aspects such as connectivity (roads, banks, telecommunication), education level, prevalence of chronic diseases and income inequality.

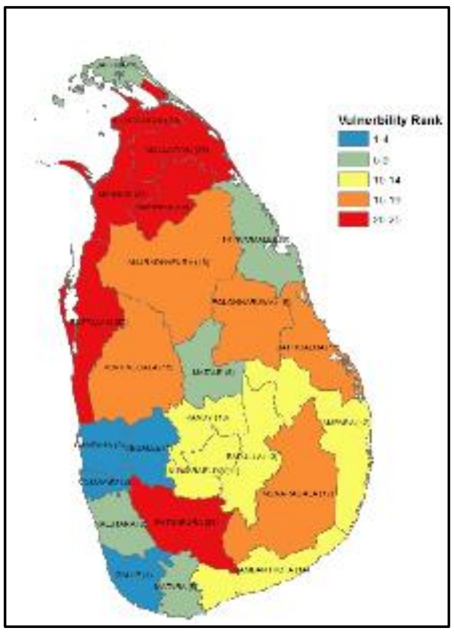

Figure 11: Administrative districts of Sri Lanka with their climate change vulnerability rank

Exposure	Sensitivity	Adaptive capacity to climate change impact
Minimum temperature	Rice cultivation under minor irrigation Yala season	Secondary education
Maximum temperature	Rice cultivation under minor irrigation Maha season	Road density
Flood	Rain fed upland cultivation	Life expectancy at birth
Drought	Population density	Banking density index
Land slides	Agriculture based household	Lands under home gardens
	Agriculture labor	GINI coefficient of income receivers
	Rural population	Chronic disease
	Coastal length	
	Land degradation	
	Access to drinking water	

Table 6: Variables used to evaluate the vulnerability to climate change

An earlier vulnerability analysis conducted in 2008-2009 for the development of the National Climate Change Adaptation Strategy (NCCAS 2010-2016) by ADB also looked at drought impacts on agriculture and drinking water. This analysis excluded the Northern Province for lack of data at that time. However, the analysis showed that both irrigation/agriculture and drinking water is highly susceptible to the impacts of flood and drought in Sri Lanka. Drinking water related vulnerabilities were higher, and chronic diseases were more prevalent in Divisions where people depended mostly on ground water sources for drinking. In the vulnerable Divisions less than 20% of people accessed water through a regular pipe-born supply scheme. The rest depended on dug wells, bore holes, tanks, rivers and canals. Less than 30% had a water source (well or pipe) within their own premises and had to travel some distance to access potable water.

1.4.2 Potential to cope with climate change impacts and ranking based on hydrology and related physical parameters

The Department of Agrarian Development (DAD) is currently developing a ranking system for village reservoir cascades in Dry Zone river basins to determine their exposure to risks posed by climate change, based on several parameters including hydrology, climate, agro-ecological zones, land use, and terrain. According to their analysis, it was found that Mi-Oya river Basin has the highest vulnerability rank with respect to climate change. By applying this ranking system, DAD will be able to identify cascades with greater/less potential to cope with climate change and those that will be prioritized for improvement and upgrading[97].

The parameters considered for assessing the potential for coping with climate change impacts are,

a. Agro-ecology of the region,
b. Ratios between water surface area of the reservoir, watershed or catchment area, irrigation command area, area of the cascade, area of the river basin
c. Number of functioning reservoirs in the cascade
d. Percentage of paddy land in the irrigated by the cascades
e. Forest cover in the watershed
f. Rock-knob plain rock outcrops and erosion remnants
g. Land slope or potential for erosion in the watershed

1.5 Suggested geographies and sectors for intervention for climate change adaptation in the Dry Zone of Sri Lanka

Smallholder farmers living in Dry Zone vulnerable river basins face three clear threats to food security, health and decent livelihood. These are:

1) Decreasing yields in farm fields due to decreased storage capacity and high levels of evaporation in the village reservoirs
2) Increased crop losses and damage to livelihood assets including livestock due to very heavy rainfall events, flash floods and longer periods of drought damaging village irrigation infrastructure

[97] Witharana, D.D.P, 2015. Ranking of Village Tank Cascades (Ellangawa) on potential coping capacity for climate change resilience in the dry zone of Sri Lanka. A paper presented at the INWEPF Symposium, 2015

3) Decreased availability of year-round safe drinking water due to longer droughts, declining water quality and a lack of adequate water storage. This has resulted in increased exposure to water-related health issues among smallholder farmers.

Water is clearly the priority sector impacted by climate change in the Dry Zone. It is proposed that suggested rural development interventions should build on and complement existing efforts to address the government's objectives in rural development, especially in provision of irrigation and drinking water for community well-being and food and livelihood security. The adaptation interventions in this project should target public goods that can have sustainable and long term impact – such as irrigation, agriculture water supply and early warning and water-related information systems, where the additional investment required to build resilience to climate change is prohibitive for a government that is constrained by heavy debt and an unfavorable balance of payments and there is no short or medium term prospect of private sector investment in such public goods for the very poor.

The following chapters provide an analysis of the policies and institutional framework, lessons and best practices derived from past and on-going activities in these sub-sectors of water management and discuss gaps and barriers that hinder the wider adoption of these best practices; in view of designing an integrated package of climate resilient options for small holders farmers in these vulnerable river basins of the Dry Zone.

Chapter 2 : Policy and Institutional Frameworks related to climate-resilient development

2.1 National Development Policies and Strategies

With the change of Government in 2015, the Ministry of Finance and Ministry of National Policies and Economic Affairs is reviewing and revising the national development policies and strategies for Sri Lanka. Effective rural development, job creation to overcome youth un-and-under employment is priorities for the new government. The government, in view of the tight fiscal environment and unfavorable balance of payments, resolves to moderate public expenditure and attract more investment from private sector both domestic and international. The Ministries of Finance and National Policies are responsible for developing and executing the government's public finance policy, economic policy and long term planning. In addition, Department of National Planning (NPD) and the Ministry of Mahaweli Development and Environment, Ministry of Irrigation and Water Management (MIWM) Ministry of Agriculture (MA), Ministry of City Planning and Water Supply and Ministry of Disaster Management (MDM) contribute to the policies and investment strategies for rural development, agriculture, irrigation, disaster risk reduction, and water supply –which are the sectors directly related to this project.

The budget speech for 2016[98] delivered in November 2015, emphasized that agriculture is the prime enterprise of the nation. It also notes that the farmers are a most vulnerable segment of the society, battered by the changing weather patterns and inability to get a reasonable price for their produce. The policies promote crop diversification, stronger role for the private sector to provide good quality seed etc., tax concessions for agriculture machinery, equipment and drip irrigation systems, and providing storage facilities for farm products. The budget speech of 2016 also notes that overuse of fertilizer have led to water and soil contamination resulting in health hazards.

The Government has increased its investments to improve the quality of healthcare delivery in rural areas facing chronic diseases, especially screening and haemodialysis facilities in high risk areas for CKD. The government has taken steps to prohibit the importation of three agrochemicals suspected to contribute towards the prevalence of the Chronic Kidney Disease of Uncertain aetiology (CKDu)[99]. This is parallel to investments by national and provincial governments in overcoming drinking water shortages and quality-related issues for communities in the Dry Zone.

2.1.1 National Climate Change Policy

The National Climate Change Policy of Sri Lanka, developed in 2010, promotes climate change adaptation and mitigation within the framework of sustainable development. More specifically, the Climate Change Policy recognizes the need to assess climate change vulnerability in the national development agenda, develop an information dissemination strategy to enhance adaptive capacities at all planning levels, and adopt multiple approaches to enhance knowledge and skills

[98] www.treasury.gov.lk
[99]De Silva, Amarasiri. "Sri Lanka: Stop Hoodwinking The Public Over Kidney Disease." Www.colombotelegraph.com. https://www.colombotelegraph.com/index.php/sri-lanka-stop-hoodwinking-the-public-over-kidney-disease/.

of different stakeholders to address current and emerging issues on climate change. The policy has the following key objectives:

- Sensitize and make communities aware periodically of the country's vulnerability to climate change.
- Take adaptive measures to avoid/minimize adverse impacts of climate change to the people, their livelihoods and ecosystems.
- Mitigate greenhouse gas emissions in the path of sustainable development.
- Promote sustainable consumption and production.
- Enhance knowledge on the multifaceted issues related to climate change in the society and build their capacity to make prudent choices in decision making.
- Develop the country's capacity to address the impacts of climate change effectively and efficiently.
- Mainstream and integrate climate change issues in the national development process.

Sri Lanka's National Climate change policy recommends taking timely action to address the adverse impacts on crop and animal production and fisheries sectors due to climate change and to minimize the impacts on food production and to ensure food security. It further recommends encouraging climate resilient-environmental friendly and appropriate innovative technologies, while recognizing and promoting the utilization of appropriate traditional knowledge and practices in food production. With regard to water resources, the policy recommends to promote integrated watershed and water resources management and efficient water use through technologies and behaviors adaptive to changing weather patterns and trends.

2.1.2 National Climate Change Adaptation Plan

National Climate Change Adaptation Plan (NCCAP 2011-2016) recommends the following adaptation options for water and agriculture sectors:

- Improvement of farm water management
- Promotion of resource-efficient farming systems
- Improvement of watershed management
- Promote efficient practices of water management
- Improvement of climate information management and communication systems
- Improvement of disaster risk preparedness and management

Priority actions listed in the NCCAP include:

1. Develop and promote water efficient farming methods
2. Adjust cropping calendars according to climate forecasts
3. Develop and implement watershed management plans for critical watershed areas
4. Increase the efficiency of use and reduce losses of irrigation water

2.1.3 The Intended Nationally Determined Contribution of Sri Lanka

The Intended Nationally Determined Contribution (INDC) of Sri Lanka notes that the country intends to contribute to the global adaptation goal by enhancing resilience in key vulnerable sectors. These vulnerable sectors, and adaptation options therein have been identified and developed based on the National Climate Change Adaptation Strategy (NCCAS 2010) and the National Adaptation Plan (NAP 2015). The broader adaptation targets are:

- Mainstreaming climate change adaptation into national planning and development
- Enabling climate resilient and healthy human settlements
- Minimizing climate change impacts on food security
- Improving climate resilience of key economic drives
- Safeguarding natural resources and biodiversity from climate change impacts

INDC for Sri Lanka notes that the water sector is the most crucial sector where immediate adaptation measures are required that cuts across all the other sectors including health, food security and renewable energy generation. INDC adaptation targets include the minimizing climate change impacts on food security.

2.1.4 Disaster Management Policy

The Draft Disaster Management Policy of Sri Lanka (2013)[100] has the objective of achieving sustainable and resilient disaster management through:

- Appropriate institutional, legal and implementation mechanisms;
- Informed, scientific, multi-hazard risk reduction approaches mainstreamed in development and reconstruction based on national priorities.
- Participatory, multi-agency, multi-stakeholder engagement in line with national and international standards for effective disaster relief and response

The implementation of these policy principles were facilitated by several strategic plans including "Road Map Towards a Safer Sri Lanka 2005-2015[101] which focuses on preparedness and response to disasters, awareness and creation of the legal and institutional structures, contributing to an enabling environment for risk reduction. The expected outcomes of the Sri Lanka Comprehensive Disaster Management Programme[102] (SLCDMP 2014-2018) currently being implemented by the Ministry of Disaster Management, include:

- National and sub national level agencies are capable of assessing disaster risk and make decisions for short, medium and long term disaster management
- Key development sectors are able to incorporate Disaster Risk Management (DRM) in their respective development initiatives/ processes/ activities at different administrative levels
- Communities, Local Governments and sub national agencies have necessary capacities and mechanisms to respond to and recover from disasters.
- A system in place for obtaining advises and continuous monitoring, learning and adapting to facilitate the ongoing planning and implementation process.

[100] Ministry of Disaster Management, 2013. National Policy on Disaster Management
[101] Source http://www.dmc.gov.lk/Publications/Road_Map_Volume_2.pdf
[102] Ministry of Disaster Management, 2014. Sri Lanka Comprehensive Disaster Management Programme 2014-2018

2.1.5 Agriculture Policy

National Agriculture Policy of Sri Lanka[103] aims at meeting the basic needs of the farming community in terms of food and nutrition security and enhance employment opportunities and incomes, through technically feasible, social acceptable economically viable and environment friendly agricultural production technologies, marketing and related strategies. The policies promote production and utilization of organic fertilizers and gradually reduce the use of chemical fertilizers. It also supports reducing the use of synthetic pesticides through the promotion of bio – pesticides and integrated pest management.

The agricultural policy reference to fertilizers and pesticides is important in the light of several studies on the health impacts of heavy use of fertilizer and pesticides, which show that heavy metals from various forms of fertilizers and agrochemicals are entering the human body through the food chain[104]. Research findings based on postmortem tests have found deposits of arsenic in diseased kidneys of CKD patients. Even small amounts of arsenic can harm human health, and WHO has recommended urgent action to improve the safe use and quality control of agrochemical use[105].

2.1.6 National Watershed Management Policy

The National Watershed Management Policy of 2004 notes that watersheds of the country are being degrades at a rapid pace. It recognizes that there are deficiencies in the implementation of relevant acts and regulations addressing various sectoral aspects of watershed management, and therefore it is essential that community has a role in the process. The policy recommends promoting and strengthening communities or stakeholders to manage their respective watersheds, and to create awareness and consciousness among them for sustainable watershed management through participation and partnership.

2.1.7 National Policy on Rural Water Supply and Sanitation sector

This policy was formulated in 2001 and acknowledges the importance of health and well-being of the people for social and economic development. It defines the respective roles of the stakeholders in rural water supply and sanitation. Accordingly, the role of the government, Provincial Council and the Local Government Authorities should regulate and facilitate in the implementation of the sector activities while the CBOs, private sector and NGOs should be the providers of services. Local Authorities also may provide services when required. The policy recommends that users be encouraged to share the capital investment, own and manage the facilities and assets, and they should bear the full responsibility of sustainably operating and maintaining such facilities. Furthermore, women should play a central role in decision making process of the sector, and private sector participation in the provision, operation and maintenance of facilities and services are recommended to be encouraged. The need for all sector activities to be in harmony with the environment is emphasized as well. The policy stipulates the minimum requirement of water for

[103] http://www.agrimin.gov.lk/web/images/docs/1252389643AgPolicy4.pdf

[104] Jayasumana, C. et al, 2015. Phosphate fertilizer is a main source of arsenic in areas affected with chronic kidney disease of unknown etiology in Sri Lanka. http://link.springer.com/article/10.1186/s40064-015-0868-z/fulltext.html

[105] Bandarage, A. 2013. Political Economy of Epidemic Kidney Disease in Sri Lanka. http://sgo.sagepub.com/content/3/4/2158244013511827, Published 25 November 2013

direct consumption, preparation of food and personnel hygiene, maximum haul distance to the dwelling, adequacy, quality requirements and sources considered as safe.

2.1.8 National Rainwater Harvesting Policy

In 2005, the government of Sri Lanka realizing the importance of rainwater harvesting as a solution to overcome the water scarcity in the country, accepted a "National Policy on Rainwater Harvesting and Strategies" which was presented to the Parliament.[106]The Rain Water Harvesting Secretariat of the Ministry of Urban Development and Water Supply and the National Water Supply and Drainage Board jointly with the Lanka Rain Water Harvesting Forum officially implemented this policy on the 27th of September 2005.[107] The main objective of the National Rain Water Harvesting Policy is to ensure that the urban and rural residential areas adopt and apply rainwater harvesting broadly, by the control of water near its source.[108] This results in minimizing the use of treated water for secondary purposes, providing water for domestic use with adequate treatment, reduction of flooding, improving soil conservation and groundwater recharge, agricultural benefits and reduced energy consumption.

This policy document states the legislative changes needed in the Urban Development Authority (UDA) and Road Development Authority (RDA) by-laws on drainage and National Water Supply and Drainage Board (NWSDB) by-laws to incorporate rainwater harvesting as a source of domestic water. Regulations were gazetted on the 17th of April 2009, which make rainwater harvesting mandatory in certain categories of new buildings in areas under municipal and urban council jurisdiction.[109] Rainwater is one of the purest sources of water available, as it does not come into contact with many of the pollutants often discharged into local surface waters. It comes free and can be used to supply both potable (drinkable) water and non-potable water.

2.2 Institutional framework

A large number of institutions provide different services in the water, agriculture, and disaster management areas,[110] including water resources planning and management, groundwater management, agricultural extension, research, provision of agriculture-related services, drinking water supply and the management of watersheds. Considering the vulnerabilities highlighted in Chapter 1, the following discussion focuses on the institutions, non-governmental organizations (NGO) and the private sector who have the major responsibilities in providing services to the village irrigation systems, providing drinking water, flood and drought management, early warning and weather forecasting, which are substantially related to mitigating observed climate change impacts in the Dry Zone of Sri Lanka.

However, it needs to be stated at the outset that Sri Lanka's institutional framework for service provision is complicated by multiple, and at times, overlapping levels of government. There is a Central Government with National Ministries who administer the policies mentioned earlier. These

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106 "National Rain Water Harvesting Policy and Strategies." www.lankarainwater.org. http://lankarainwater.org/wp/?page_id=70.
107 "National Rain Water Policy and Strategies." www.lankarainwater.org. https://drive.google.com/file/d/0B8hkh22KemLudWhhMjdfWTRvLWs/view.
108 "National Rain Water Harvesting Policy and Strategies." www.lankarainwater.org. http://lankarainwater.org/wp/?page_id=70.
109 Ariyananda, Tanuja. "Domestic Rainwater Harvesting as a Water Supply Option in Sri Lanka." www.nepjol.info. 2010. http://www.nepjol.info/index.php/HN/article/viewFile/4189/3563.

110

Ministries and their allied agencies work in the field through their own decentralized arms that align with District and Divisional Secretariats. However through the 13th Amendment to the Constitution in 1987, Provincial Councils were created with elected Chief Ministers who run their own Cabinet of Ministers. Some technical subjects (such as agriculture and irrigation) are devolved to these Provincial Councils to a greater extent and others (disaster risk reduction, agrarian development and water supply). Below is a brief overview of national, provincial and local level institutions and non-governmental parties that are important for the proposed project.

2.2.1 Institutions at National level

2.2.1.1 Department of Agrarian Development

The Department of Agrarian Services was established under the Paddy Lands Act of 1958, and was made the Department of Agrarian Development (DAD) by the related Act of 2000. Its functions include matters relating to tenancy of paddy lands, agrarian development councils, land banks, agrarian tribunals, and management of irrigation water under village irrigation systems. Water Management Division of the DAD maintains a detailed database on village irrigation systems and conducts related research. The department maintains a database of village irrigation systems including hydrological data, extent cultivated, farmer families. The databases include data on rainfall in different watersheds as well. The Department's other divisions include; agricultural land development, institutional development, legal, water resources management and other administration-related divisions.

The DAD is present in all 25 Districts. To perform the assigned functions, it operates 559 divisional offices. It employs about 12,500 field level animators, who operate at the village level, and provide and coordinate services and inputs to the farmers. This work is coordinated at Agrarian Services Centers (ASC), which service a cluster of villages. Depending on the size and population of the district and agriculture activities, the number of ASCs could vary. In the Dry Zone Districts, the number varies from 8 (Vavuniya) to Kurunegala (55). The intention of the ASC is to provide various services needed to the farmer such as advice on agriculture, fertilizer etc under one roof. Both DAD and Department of Agriculture/Provincial Department of Agriculture field officers visit or maintain offices in the ASC. The DAD deals with approximately 14,000 Farmer Organizations (FOs), and handles the registration of FOs under the DAD Act.

Agrarian Services Centers

Under the Agricultural Productivity Law that was enacted in 1972 Agrarian Service Centers were set up island wide. The DAD employs about 12,500 field level animators, who operate at the village level to provide services and inputs to the farmers. This work is coordinated at the Agrarian Services Centre (ASC). Depending on the size and population of the district and agriculture activities, the number of ASCs could vary. In the Dry Zone Districts, the number varies from 08 (Vavuniya) to Kurunegala (55) depending on the number of densities of smallholder farmers under village irrigation systems.

The intention of the ASC is to provide various services needed by the farmer such as advice on agriculture, fertilizer etc. under one roof. The tasks of the Agrarian Services Officers include strengthening farms, managing agricultural lands, re-cultivating abandoned paddy lands, repairing small irrigation channels, improving the economy of the farming community, fertilizer supplies coordination and other objectives relevant to the Agrarian Services Act activated under Agrarian Service Centers.

Staffing: The ASCs are organized on a district basis under an Assistant Commissioner. Agrarian Development Officers of the DAD operate from the ASC and manage the Center. Agriculture Instructors of the DoA maintain an office at agrarian service centers in inter-provincial agriculture extension service areas. They provide information on new technologies, training field visit & advisory service, field problem solving assisting in input supplies and marketing, coordination with other relevant stakeholders. The centers could also host Divisional officers (DO), Livestock Development officers/veterinary officers (Department of Livestock) and coconut cultivation officers (Coconut Cultivation Board) Extension Officer of the Department of Export Agriculture.

The ASC receives funds from the DAD Head Office for general maintenance of the building and for the core DAD staff. Salaries of other organizations are paid by the respective organizations. Additional income is generated by a commission/ percentage of the Acreage Tax collected from the farmers, and the profit made from the sale of fertilizer and other agricultural inputs.

2.2.1.2 Department of Agriculture (DoA)

This Department is responsible for the development of food and cash crops (other than tea, rubber, coconut, sugar and spice crops- which are treated as plantation crops). In addition to its mandate of ensuring food security and modern agriculture, the DoA is responsible for drought management (as it affects production of crops) and implementing the Soil Conservation Act. The Department is also responsible for agricultural extension and this function is carried out with the Provincial Councils. It provides advice and recommendations on crop suitability, climate-smart agriculture, and conducts research on new technologies and crop varieties.
The DoA functions nation-wide. A Deputy Director manages the district level functions of agriculture extension. There are Segment Assistant Directors liaising with ASCs for agricultural extension works. Agricultural Instructors (AI) of the DoA operate in liaison with the enumerators of the DAD under the supervision of Segment Assistant Director. The DoA manages several seed farms as well and provides certified seeds, which however, meets only a fraction of farmers' seed requirement. After the establishment of Provincial Councils (1988), DoA functions are mainly focused on inter-provincial irrigation schemes (those which are connected to inter-provincial rivers). Extension for other irrigation schemes is provided by the Provincial DoA (PDoA). However, all PDoAs use the technical instructions and research findings of the DoA as well.

2.2.1.3 Irrigation Department

Irrigation Department (ID) was established in 1900 and in the early periods handled almost all the water- related functions. Subsequently, groundwater related functions and land reclamation functions were handed over to different institutions. Currently the Department handles the operation and maintenance of all the inter-provincial major irrigation schemes (including the schemes designated as medium by the Department), water resources planning and management and protection of land from flooding, water-logging and sanitation[111].

Hydrology Division of the Irrigation Department is responsible for the Management of Hydro-meteorological Information System of the country. About 24 major rivers which convey about

[111] Imbulana, K.A.U.S., Wijesekara, N.T.S. Neupane B.R., Aheeyar, M.M.M. and Nanayakkara V.K. (eds.), 2010. Sri Lanka Water Development Report. MAD&AS, UN-WWAP, UNESCO, HARTI and University of Moratuwa, Sri Lanka, Paris and New Delhi

80% of total river flows are considered highly important in hydrological point of view, and the system focused on those rivers, and comprises of 33 principal stations, 33 peripheral stations, 18 rainfall stations and 4 Weather Stations. Most of these stations are manually operated except for few rainfall recorders and data loggers installed recently.This system was expanded and modernized under the Dam Safety and Water Resources Planning (DSWRP) Project funded by the World Bank, and several new gauging stations established. Processing and flood modelling are yet to commence.

The Water Management Division of the ID is responsible for implementing cultivation calendars and patterns, catchment protection and water shed management related to major irrigation systems, scheduling irrigation and rotational issues, monitoring water deliveries, and coordinating with the Mahaweli Water Panel, which makes decisions regarding the distribution of water among the irrigation systems benefitted by Mahaweli Development Project. For regional irrigation management, the ID divides the country in to 14 regions, managed by a senior engineer. Depending on the density of irrigation, these regions may cover one or more districts.

2.2.1.4 National Water Supply and Drainage Board

Created in 1974, the Board is mandated to supply drinking water and provide sewerage services. It has functions under regulation, planning, designing, implementing and operation of water supply systems. The Board monitors water quality that is relevant to the sources of water supply schemes operated by them. Currently the Board has main offices in each province and is presently operating 324 Water Supply Schemes which cover 34% of the total population with pipe borne water supply. 10.5% of the population is served with pipe borne water supply by some Local Authorities, NGO's and Community Based Organizations. 13% of the population is served with hand pump tube wells[112].

2.2.1.5 Department of National Community Water Supply

This Department was established in 2013 to provide guidance to and strengthen CBOs that manage community water supply systems, and thereby improve the living standards of rural communities. The Department provides technical advice, arranges for financial support and conducts capacity development activities. The Department facilitates the implementation of National Policy on Rural Water Supply and Sanitation sector through participatory development strategies involving Community Development Officers and CBOs at the village level. The National Water Supply and Drainage Board support these CBOs to resolve technical issues of the Water Supply schemes.

2.2.1.6 Department of Meteorology

The Department provides services pertaining to meteorology, hydrometeorology, agricultural meteorology, and climatology to government agencies, private sector and the general public. It also provides seasonal, monthly and daily weather forecasts and maintains a weather and climate information database. However, many of these services require further investment to enable them

[112] http://www.waterboard.lk/web/index.php?option=com_content&view=article&id=8&Itemid=104&lang=en

to provide effective information for support decisions in water and agricultural management (see Annex 6).

Department of Meteorology (DoM) is currently providing the basic Hydro-meteorological services needed by various development sectors and government ministries and for disaster risk reduction activities in the country. To provide the above services and climate analyses DoM maintains a meteorological network, which consists of 22 conventional (synoptic) weather stations, 37 Automatic Weather Stations, 20 telemeter Rainfall stations, four upper air observation centers and 42 agro-meteorological stations. In addition, DoM has more than 400 rain gauges in a network which observe rainfall at 24 hour intervals. Most of the agro-met network is maintained collaboratively with the DoA, DAD and other institutions, and the network was started in 1976 with the Department under the supervision of the United Nations. This division of data and infrastructure between departments complicates the effective use of the full network by any one party as it relies on the smooth sharing of data and information between institutions.

The DoM is under a Director General and consists of 5 major divisions. Main divisions in the headquarters include observation network and instruments, data processing and archival, forecasting and decision support (including the National Meteorological and Early Warning Center) and administration and finance.

2.2.1.7 Disaster Management Centre

The Disaster Management Centre (DMC) has the responsibility of implementing provisions of the Disaster Management Act. The DMC operates through four Divisions dealing with Mitigation Research and Development, Preparedness Planning, Emergency Operations and Education and Public Awareness. The DMC coordinates with the technical agencies responsible for forecasting different hazards. The Emergency Operations Centre operates 24 hours per day throughout and coordinates all information regarding disasters including receiving, analyzing and displaying the information. The District Disaster Management Units are guided by the Emergency Operations Centre to disseminate disaster information to district, village and community levels and also collect information on loss and damage post-disaster.

Framework for an effective Early Warning System

The EW Coordination Framework is illustrated in Figure 12. Dissemination of warning from national level to the grassroots level are divided into four layers, namely, National, District, Divisional and GN Level. The Emergency Operation Center (EOC) of the DMC receives the EW message from International and Regional Technical Agencies. A national level EW message is disseminated to the emergency response committees and their responsibility is to pass the messages to their own organizations. District level EW is disseminated through District Disaster Management Centre Units (DDMCU) to the District Secretariat and stakeholder agencies and also to the political authority. Divisional level EW messages are disseminated to the divisional secretariat from DDMCUs. Divisional secretariat then disseminate messages to political authority, S & R teams, Police and district stakeholders. At the same time that the EW is disseminated to the local authorities they will pass the message to the vulnerable community.

According to the EW framework, when there is an impending disaster, the technical agency responsible for the given hazard determines the scale of the disaster and the decision is conveyed to the Ministry of Disaster Management and the Emergency Operation Centre of the Disaster Management Centre. The technical agency may receive hazard alerts from its own in-country monitoring facilities/ mechanisms or from regional and international EW agencies. The vulnerable community itself can also be a source of information to the technical agency regarding an impending disaster. The technical agency or the first respondent is different for different hazards.

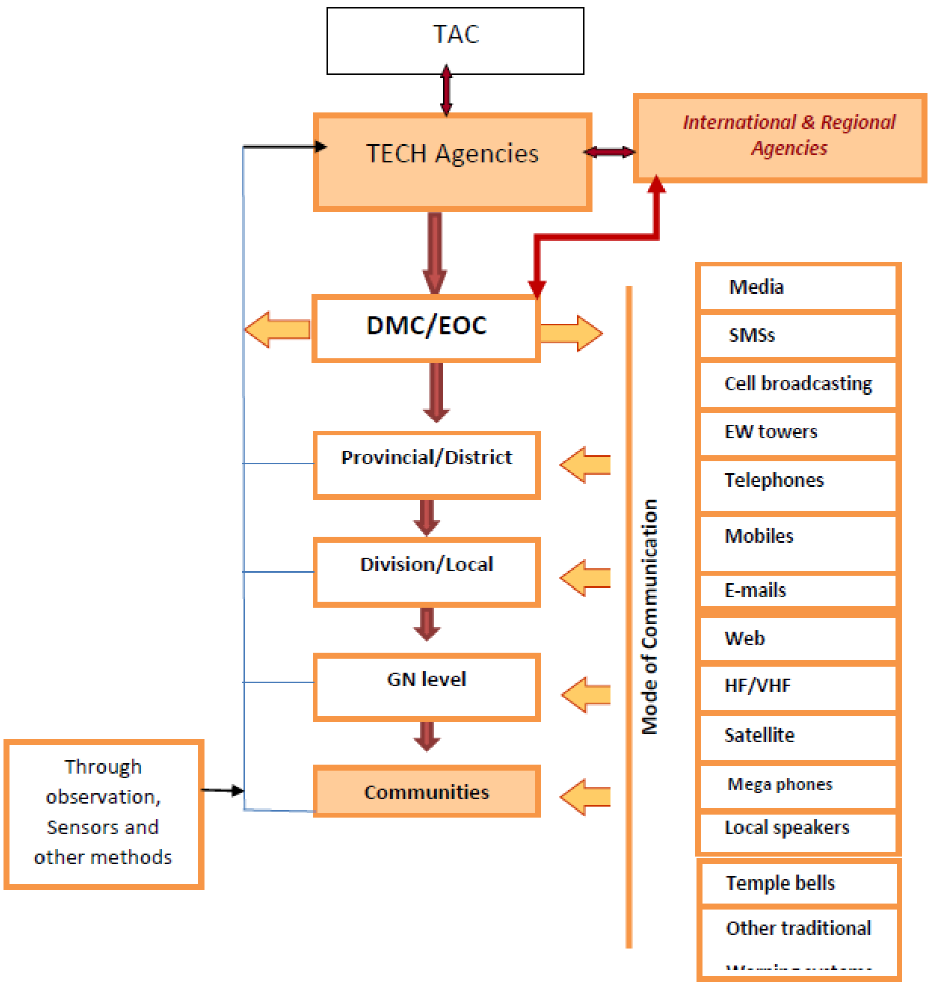
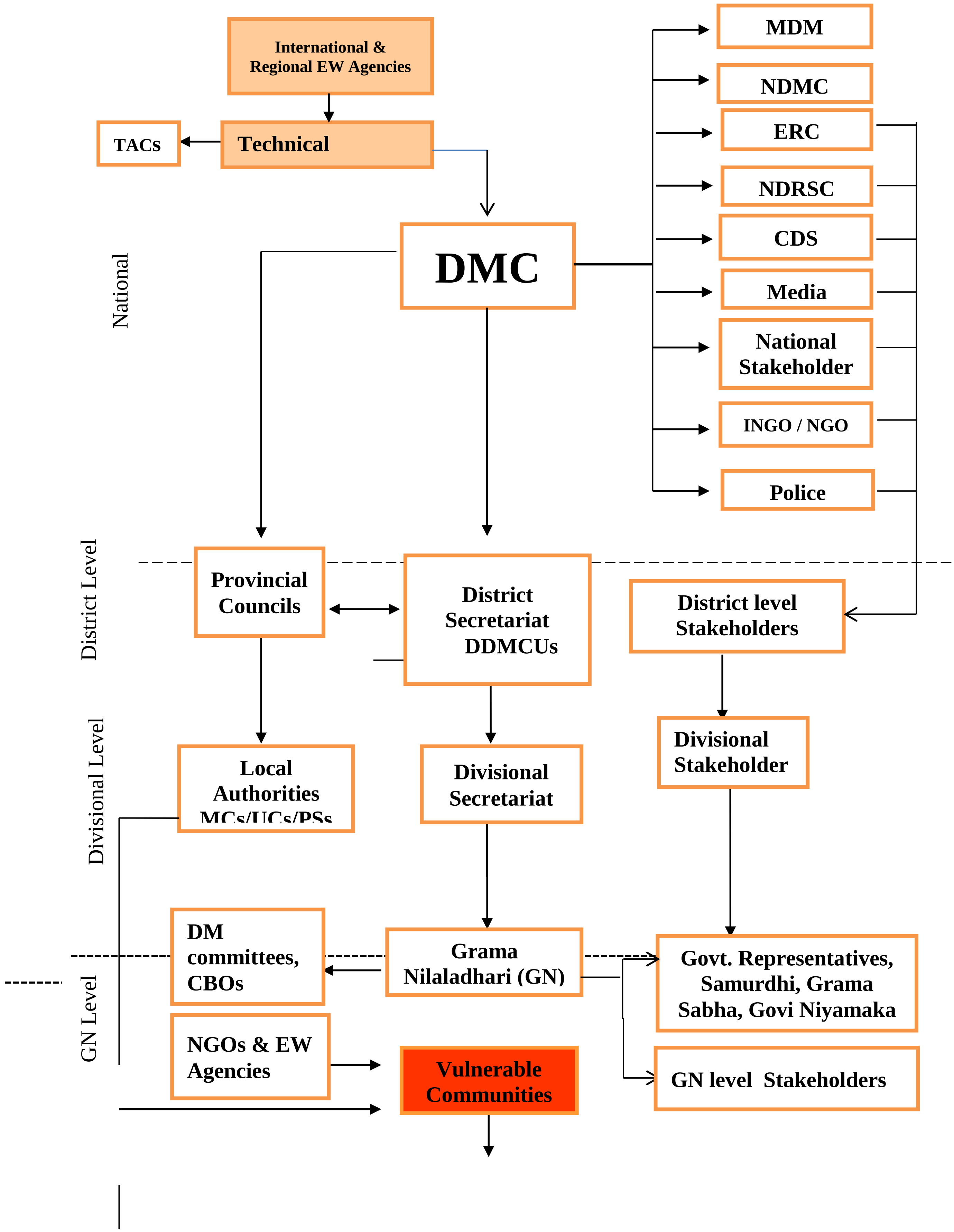


Figure 12: Method of Receiving Information and Dissemination

Figure 13 shows the early warning coordination framework, including the relevant agencies and their roles. In particular it shows how technical agencies at the national level communicate data and information to government and non-government agencies, including police media and NGOs. Key agencies at the district level include provincial councils and district level disaster management units, who then pass information and warnings to the ground-level disaster management committees and communities.



International & Regional EW Agencies
TACs
Technical
DMC
MDM
NDMC
ERC
NDRSC
CDS
Media
National Stakeholder
INGO / NGO
Police
National
District Level
Provincial Councils
District Secretariat DDMCUs
District level Stakeholders
Divisional Level
Local Authorities MCs/UCs/PSs
Divisional Secretariat
Divisional Stakeholder
DM committees, CBOs
Grama Nilaladhari (GN)
Govt. Representatives, Samurdhi, Grama Sabha, Govi Niyamaka
GN Level
NGOs & EW Agencies
Vulnerable Communities
GN level Stakeholders

Figure 13: Early Warning Coordination framework

Role of the Media in the Early Warning Dissemination: Media can play a significant role in creating awareness about disasters among common masses and thus reduce disaster risks. Media plays a prominent role in Sri Lanka, covering the entire island easily through television and FM radios with more than 50 channels. National and local media channels have the capability to complement standard EWS. Their business is communication: getting the word out to the largest possible group of listeners or readers. The media also have the responsibility to relay accurate and timely information to those in need.

Role of Military and Police for Early Warning dissemination: DMC has direct coordination with military and police to disseminate the early warning messages to vulnerable communities. Military and Police posts are located in many areas in the entire country. Military and Police have their own communication systems which can access vulnerable communities and they can direct these communities to safe locations at ground level.

2.2.2 Institutions at provincial level

Provincial Councils: The 13th Amendment to the Constitution of Sri Lanka handed over several rural development functions to the Provincial Councils. They include agriculture and irrigation (except in inter-provincial irrigation schemes), rehabilitation and maintenance of minor (village) irrigation schemes, health, land including land use, land improvement and land settlement, and protection of the environment within the limits set by the Parliament. The legislation desired by Provincial Council becomes valid law only after the endorsement by the President, the Parliament and other Provincial Councils. Irrigation and agriculture services, which are within the authority of the Provincial Councils are provided by the Provincial Department of Irrigation (PID) and Provincial Department of Agriculture (PDOA), respectively.

2.2.3 Community-based organizations

The role of Community Based Organizations (CBOs) in rural development in Sri Lanka has significantly increased during the last few decades. The process of the establishment of CBOs was strengthened through the participatory development approaches adopted by the government and Nongovernmental institutions[113], and the promotion of the same by donor agencies. The CBOs charge a fee for their services and employ staff from the profit they make.

The Government promoted the establishment of Farmer Organisations since 1980s. In major irrigation systems, the Farmer Organisations have a hierarchical arrangement, with the lowest level being the field channel groups (field channel serve 10-20 ha generally). In the village irrigation systems, the Farmer Organisation (FO) is established generally at the village level, where the members are socially connected. The FO may cover one or more village irrigation facilities such as reservoirs and diversions, within the village. Regardless whether the FO is established for a major irrigation system or village irrigation system, they are registered under the DAD, which

[113] De. Silva, P.K.W. 2003. CBO Federation for the sustainability of rural water supply. Towards the Millennium Development Goals. WEDC International Conference Abuja, Nigeria, 2003

provides the FO with legal status. The Farmer Organisations collect a fee for routine maintenance of their irrigation systems. The amount depends on the consensus among the members. This amount is not sufficient for emergency repairs such as flood damages.

Both the CBOs in water supply and irrigation sub sectors have a democratic procedure for the election of office bearers and accounting system for their funds, which are disclosed at their annual general meeting. Several of them operate a bank account. The capacities of FOs are not homogeneous however and many operate without rulebooks, procedures and registration.

2.2.4 Non-governmental organizations

2.2.4.1 Agriculture and irrigation

Many NGOs actively participate in rural development and especially agriculture, water supply and irrigation. Some NGOs operate at the national level and some other at local level. The activities performed by the NGOs include; pre-production planning, post-harvest technologies and marketing of crops, micro finance programmes, crop insurance, village irrigation system improvement and upgrading. During the conflict and post-conflicts periods, NGOs contributed heavily to essential development activities in affected areas where government agencies could not reach. Such NGOs/ INGOs include IUCN, Practical Action, and CARE international, SANASA, Sarvodaya, Sevalanka, LIRNEasia and several other local level organizations.

2.2.4.2 Rural water supply

In this sector, the NGOs provide services for the establishment and management of community water supply schemes, provision of advanced filtering plants and RWH units, public wells, tube wells, water purification and cleaning of water sources, providing latrines and sanitation facilities. Among the many active NGOs in this field include Lanka Rainwater Harvesting Forum, World Vision and Sarvodaya.

2.2.4.3 Weather forecasting, early warning and disaster management

The major contributions from NGOs are in community level preparedness, mobilizing community networks for response and relief provision after disaster. Sri Lanka Red Cross Society, International Red Cross Organisations, OXFAM and Practical Action, have been especially active in supporting community preparedness and disaster mitigation activities in the field. IWMI and several other international NGOs are testing out early warning, seasonal forecasting and loss and damage assessment systems using innovative information gathering technologies. Specific projects undertaken by NGOs and INGOSs are described in Chapter 3.

2.2.5 The private sector

2.2.5.1 Agriculture and irrigation

Agriculture policy of Sri Lanka encourages private sector investments particularly in areas of seed and planting material production, agricultural research and development, human resources development, post-harvest management, marketing, export promotion and agricultural entrepreneurship[114]. The Ministry of Agriculture promotes joint ventures with the state and private sector for local seed and planting materials production to meet food requirement. Encouragement is provided to the farmers to convert into commercial agriculture. Other avenues for private sector participation include farm mechanization, modern technology and value addition in the cultivation of supplementary food crops, vegetable and fruit[115].

Accordingly, a large number of private sector organizations are engaged in seed production, fertilizer, pesticides, marketing, transport, agriculture machinery, credit, insurance and agriculture extension to a limited degree. They also engage in the supply of micro-irrigation units. Some private sector establishments have an island-wide coverage. The Hayleys Agriculture Holdings Ltd, for example, is a large national-level company that offers a wide array of agro inputs and reaches farmers throughout the country. In several village reservoir upgrading and improvement projects, Farmer Organisations or local CBOs become local level private sector as they bid for and undertake rehabilitation projects as contractors.

The recent national budget addressed the issue of financing for farmers by requiring local banks to dedicate a percentage (20%) of their lending portfolio to agriculture. Small farmers usually do not access large private sector banks but instead depend on the Farmers Bank at the Agrarian Services Centres (ASCs) or Cooperative Banks in the villages to finance the cultivation season, often repaying these debts after harvest.

2.2.5.2 Rural water supply

The National Rural Water Supply Sector Policy promotes the participation of private sector subject to the regulations imposed and standards set by the Government, Provincial Council and the Local Authorities. The following activities are encouraged: i) assess the needs, demand and the aspirations of the community for water supply and sanitation facilities and services. (ii) assess the technical feasibility, economic viability of different options for providing water supply and sanitation facilities. (iii) arrange funding. (iv) ensure participation of the user community and other partners at all stages of the process. (v) plan, design, implement and manage the assets and facilities with the Community. (vi) manage the facilities and services to the satisfaction of the user community[116].

Accordingly, a large number of private sector organizations provide services for rural water supply sector. Their services include contracting RWH and sanitation activities, provision of spare parts for water supply schemes and direct supply of water treatment plants in rural areas. Many of the CBOs who manage community water supply schemes function as profit-making enterprises, and therefore could be considered private sector as well. Large private sector companies such as Brandix PLC conducts CSR projects around water management focused on providing drinking water to their employees or Dry Zone communities living around their garment production factories.

[114]http://www.agrimin.gov.lk/web/images/docs/1277294350enationalagriculturalpolicy.pdf
[115] http://www.agrimin.gov.lk/web/index.php/en/division-2/development
[116] Ministry of Urban Development, 2001. National Rural Water Supply Sector Policy. Construction & Public Utilities, Rural Water Supply & Sanitation Division 9th Floor “Sethsiripaya” Battaramulla

2.2.5.3 Seasonal forecasting and early warning

Apart from DoM, several private sector organizations provide weather information, by linking with global data. The information is available over the Internet including from www.Vivalanka.com[117], digathanews.com[118] and the weekly reports by the *Foundation for Environment, Climate and Technology (a local NGO)*, which provides monitored and predicted climate for Sri Lanka. The latter is provided on an experimental basis and there is, however, little information regarding quality assurance. DoM through it's position as the nationally mandated institution dealing with climate and weather data has the opportunity to provide a denser network of observations with a transparent data processing mechanism to build trust with users.

Tea estates in the central mountainous region of Sri Lanka monitored rainfall for a considerable time, and some of those rain gauges are a part of the rain gauge network of DoM. Such data are usually transmitted to the DoM on monthly basis. In addition, there are rain gauges maintained by schools and other organizations on voluntary basis, which as yet do not make any significant input to the DoM network.

2.2.6 2.2.6 Institutional framework for decision making in agriculture

Monsoon forum: This is a follow up of the South Asian Climate Outlook Forum (SACOF) sponsored by the WMO and several other international organizations. Sri Lanka Monsoon Forum is chaired by Director General of the DoM and held prior to the cultivation seasons, with the attendance of institutions relevant to agriculture, water supply and disaster management. The forecasts given by SACOF at the national level is scaled down to district level and provided to the institutions, at this meeting. In addition, the actual situation of the previous season is compared with the forecasts issued for that season, by the participating institutions.

Seasonal cultivation meeting (*Kanna* meeting): This meeting has a legal basis provided by the Agrarian Development Act of 2000 enabling local level decision-making on seasonal cropping and water management. It is a meeting of the farmers and farm land owners prior to the beginning of either season (Yala or Maha) cultivation, which is attended by the relevant officers of the government including officers from Agrarian Department and Agriculture Inspectors. A Kanna meeting is held for every irrigation system and village tank. The meeting is convened by powers assigned to the Commissioner General of Agrarian Development. At this meeting, the decisions taken include; cultivation extent and crops, cultivation calendar, irrigation rotation schedule, maintenance schedule, assignment of maintenance responsibilities depending on the extent of land ownership, appointment of a farmer representative to implement the decisions. The maintenance activities to be carried out by the farmers include clearing of the reservoir bund, canal system and their minor repairs.

Chapter 3 : Past and ongoing efforts to improve resilience of the agricultural-based livelihoods and communities in Dry Zone

[117] http://www.vivalanka.com/newspage/1385298ai-local-weather-forecast

[118] http://digathanews.com/weather-forecast-for-next-36-hours/

3.1 The Context

Increased variability of rainfall and the rapid increase in incidence of droughts and floods adversely impact irrigation services and drinking water, thus affecting livelihoods, health and food security of rural farming communities in the Dry Zone. This in turn, reduces their resilience against observed and anticipated climate change impacts. A rural community's ability to cope with current and future climate change would require timely information and capacity to respond to this information in a practical manner.

Past and on-going efforts to improve resilience of Dry Zone communities have had a heavy focus on water and agriculture. As mentioned earlier in Chapter 1, the Dry Zone was heavily impacted by the ethnic conflict, and this made regular maintenance of irrigation and water supply facilities quite challenging. Neglect, damage and abandonment of village irrigation and water supply systems is common in the conflict-affected districts, and this is a huge impediment for communities now resettling in these areas. Well-functioning and upgraded irrigation systems are required to ensure the timeliness, reliability and adequacy of irrigation and domestic water services.

These requirements are acknowledged by the current national policy framework of Sri Lanka as explained in Chapter 2, and many institutions have the mandate to carry out the necessary interventions at national, provincial and local levels. A number of government and donor-funded initiatives have focused on the water, irrigation and agriculture sectors as they form the backbone of the rural economy of Sri Lanka. These range from large trans-basin diversions creating multi-purpose reservoirs (hydropower, irrigation, drinking water and recreation) to interventions focused on improving village irrigation systems.

The 30,000 village irrigation systems (VIS) in the country (village reservoirs, diversions and anicuts) provide a huge potential to intervene at village level and address rural poverty and vulnerability where it is most prevalent (in areas where agriculture is primarily rain-fed or irrigated by VIS). Taken as a sub-basin or cascade system, the VIS also provide the opportunity to intervene at an eco-system or landscape level- looking at the different inter-connected sub-components of rural resilience at the heart of which is the village water storage/irrigation supply system.

However the majority of rural development programmes described below have considered the village 'tank' or reservoir as the main point of intervention and prioritized irrigation against drinking water supply and other multiple uses. This has gradually eroded the ability of Farmer Organisations (FOs) to consider the VIS as an integrated system lending itself to holistic rural development as was traditionally practiced; and is now increasingly important for improved rural resilience. There have been a number of pilot initiatives to manage drought in agricultural systems as a disaster management effort, incorporating resilient crop types (both newly developed and traditional) with efforts at improving seasonal forecasting and its use. However these have been experimental and rarely replicated in a systematic manner.

Table 7 below summarises some of the more important rural development initiatives in the past two decades, including projects that are on-going, in order to distil the important lessons, analyses the gaps in coverage and approach; and determine the barriers that need to be addressed in order to build greater resilience to climate change for small holder farmers in the Dry Zone of Sri Lanka.

Project/programme	Period of implementation	Main interventions and location
Village Irrigation Rehabilitation Project (VIRP) and National Irrigation Rehabilitation Project (NIRP)	Mid-1980s to 2000	Rehabilitated around 2100 village irrigation schemes island-wide focusing on infrastructure, mainly deepening the storage tank and rehabilitating conveyance channels.
Pro-poor Economic Advancement and Community Empowerment (PEACE) Project	2006 – 2011	rehabilitation of 80 minor irrigation schemes, in addition to major and medium schemes in the Anuradhapura, Kurunegala, Matale and Puttalam Districts
North-East Irrigated Agriculture Project (NIEAP)	2000 - 2005	400 irrigation systems in the Northern and Eastern provinces
Dry Zone Agricultural Development Project (DZADP) of CARE International	2002 - 2005	Rehabilitated 42 minor tanks; 20 in Puttlam, 18 in Moneragala and four in Mannar district. including the surrounding watersheds and cascade connections
Cascade based small tanks rehabilitation project in the Anuradhapura district	2004-2010	Conducted in five small tank cascades in Mahawilachchiya, Nuwaragam Palatha Central, and Medawachchiya Divisional Secretariat (DS) Division
IUCN/HSBC project: Restoring Traditional Cascading Tank Systems for Enhanced Rural Livelihoods and Environmental Services in Sri Lanka	Ongoing	Restore village irrigation eco system and Partial de-silting
Tank-based Biodiversity Improvement and Protection Project	On-going	In Alisthana village reservoir in the Tirappane cascade located in Anuradhapura District
Strengthening the Resilience of Post Conflict Recovery and Development to Climate Change Risks in Sri Lanka	On-going	In 12 districts in the Dry Zone (Mulaitivu, Vavuniya, Ratnapura, Puttlam, Mannar, Kilinochchi, Kurunegala, Moneragala, Anuradhapura, Polonnaruwa, Batticaloa, Hambantota)
Re-genesis: A new beginning - Rehabilitation of Irrigation Infrastructure & Initialising Market Development	2011- 2012	Benefitted 883 recently re-settled and re-located families in the Kilinochchi District
The Third Water Supply and Sanitation Project		In 6 districts the project provided water supply connections to about 293,359 households,
The second Community Water Supply and Sanitation Project (CWSSP) World Bank	2001 - 2009	In Kandy, Matale, Nuwara Eliya, Kurunegala, Ampara and Trincomalee districts the project provided 92,000 new piped water supply connections 384,100 people with access to improved water sources
The Eastern Province Water Supply Development Project (EPWSDP)	2010 - 2014	In Trincomalee, Batticaloa and Ampara Districts in the Eastern Province

Dam Safety and Water Resources Planning project		Hydro-meteorological information system : Dam safety improvement component
Multi Hazard Early Warning System for coastal areas of Sri Lanka (2015-2025)		Upgrading and strengthening the existing EW system and capacity building - to upgrade 77 early warning towers, strengthening the existing system
Climate Resilience Improvement Project (CRIP) of the World Bank	Initiated in 2014currently in the mobilization stage	Mahaweli, Maha Oya, Deduru Oya, Kelani Ganga, Attanagalu Oya, Kala Oya, Gin Ganga, Nilwala Ganga, Gal Oya and Malwathu Oya river basins. A comprehensive study including detailed flood and drought analysis, forecasting and Comprehensive river basin investment plans
North Central Canal Project (NCPCP) supported by ADB	2016-2025	Aims to augment about 1,100 village irrigation reservoirs with trans-basin diversion from Sri Lanka's longest river, the Mahaweli which has a rich Wet Zone catchment.
International Water Management Institute (IWMI) and Sri Lanka Rainwater Harvesting Forum	experimental stage	Low-cost mobile weather stations - to help monitoring of the weather and assist rural communities to better prepare for floods and landslides
National Building Research Organisation's landslide early warning project using automated rain-gauges and community managed rain gauges supported by UNDP and World Bank	2012-on going	Tested out different models of real-time rainfall measurements and communication to trigger early warning for landslide risk prone communities (identified through a risk mapping supported by UNDP). Community managed rainfall measurement units have also been installed to warn remote and isolated mountainous villages of possible threats. These are measured and managed by villagers.

Table 7: Summary of the past and ongoing efforts for resilience in Dry Zone rural communities

In addition to these projects there is regular government (central and provincial) investment in urgent repairs to irrigation, subsidies for agriculture, expansion of pipe borne water supply and strengthening national meteorological capacity for improved disaster warning.

3.2 An overview of past and on-going projects aimed at improving rural wellbeing and livelihoods

While the above mentioned projects, and many other smaller and limited initiatives focus on upgrading rural economy, incomes, safety, health and well-being in general, the projects can be clearly classified in to three sectors of intervention- irrigation provision and climate smart, ecologically sound agriculture, drinking and domestic water supply and disaster risk reduction through improved early warning communication.

3.2.1 Efforts for the improvement and upgrading of irrigation with special emphasis on VIS

The **Village Irrigation Rehabilitation Project (VIRP**) and its successor **National Irrigation Rehabilitation Project (NIRP)** were funded by the World Bank and had a national focus, selecting village irrigation systems in dry and Intermediate Zones for improvements. These projects rehabilitated over 2000VIS but work was often hampered by the adverse security situation linked to the conflict throughout its implementation. Despite this, the NIRP's final report notes that physical work targets and training targets were fully met and the handing over of rehabilitated village irrigation systems to FOs was satisfactory[119].

Since then, a large number of projects focusing on specific geographic areas were implemented in the country. They include Pro-poor Economic Advancement and Community Enhancement (PEACE) Project funded by JBIC/JICA, World Food Programme (WFP) funded small tank rehabilitation projects carried out from 1994 onwards, Small Tank Rehabilitation Project of the Freedom from Hunger Campaign (FFHC), Dry Zone Agricultural Development Project (DZADP) of Care International, Small tank Cascade Development Programme by Kala Oya Basin Management Organization of the MASL, several Integrated Rural Development Projects focusing on livestock, land and irrigation, and myriad small scale projects.

The PEACE Project (2006-2011) focused on uplifting living conditions of rural farmers through the development and upgrading of irrigation infrastructure and intervened in 80 minor irrigation schemes, in addition to major and medium schemes in the Anuradhapura, Kurunegala, Matale and Puttalam Districts. Beneficiary farmers solely executed all the major activities of the project such as problem identification, planning, implementation and operation. The project had a strong focus on building capacity of FOs to plan and undertake the necessary rehabilitation work, in addition to managing finances.

The World Bank funded NIEAP focused on irrigation and water supply and other rural infrastructure covering 400 irrigation systems in the conflict-affected Northern and Eastern provinces between 2000-2005. The project was evaluated as satisfactory and the importance of community mobilization was highlighted[120].

Care International's **Dry Zone Agricultural Development Project (DZADP)** aimed to improve living standards of rural farmers through an approach that increased productivity (and incomes) in command and catchment areas of small reservoirs. The project rehabilitated a total of 42 minor tanks; 20 in Puttlam, 18 in Moneragala and four in Mannar district. The salient features of the tank rehabilitation project included expanding the focus of interventions beyond the tanks to the surrounding watersheds and cascade connections[55].

By the mid-to-late 2000s, the 'cascade' approach had come in to the mainstream and experts widely agreed that interventions in village irrigation systems, especially repairs to small tanks and reservoirs should consider the surrounding sub-watershed ecosystem. A number of pilot projects were thus trialed by government and non-government partners on this 'cascade' wide approach. Some of these projects are still on-going.

Plan Sri Lanka implemented the **Cascade based small tanks rehabilitation project in the Anuradhapura district** in 2004-2010. The project was conducted in five small tank cascades in Mahawilachchiya, Nuwaragam Palatha Central, and Medawachchiya Divisional Secretariat (DS) Divisions. Participatory Rural Appraisal (PRA) was conducted at the beginning of project implementation to identify the existing problems in the village in general and the irrigation system in particular. The construction contracts were given to local FOs. The project had a component for watershed management and provided training and awareness on watershed management, home garden development and land improvement at the community and school levels.

[119] DHV Consultants BV, TYPSA and EML, 2000. Final Report. National Irrigation Rehabilitation Project. Sri Lanka

[120] World Bank, 2005. Project completion report. North-east irrigated agriculture project. World Bank

Following this, the Hong Kong and Shanghai Banking Corporation Limited (HSBC) in partnered with the International Union for Conservation of Nature (IUCN), to implement a project titled "**Restoring Traditional Cascading Tank Systems for Enhanced Rural Livelihoods and Environmental Services in Sri Lanka**" to restore a cascade village irrigation system in the North Central Province of Sri Lanka[121].The project will restore the Kapirikgama cascade, covering 21 village irrigation systems spread over 2,391 ha, and develop a sustainable management mechanism with the full participation of local communities and regulatory bodies. All the activities have been carried out with active contribution of small farmers cultivating under the village irrigation systems. The project is ongoing, but community mobilization, improvements to irrigation infrastructure and watershed restoration activities have been successfully implemented in several of the village irrigation systems.

A GEF-funded Small Grant Project is also demonstrating the rehabilitation of the ecosystem around VIS to prove the close inter-connectedness of the different components of the system. Implemented by South Asia Partnership (SAPSRI) this project is also in the Anuradhapura District. Activities include restoration of immediate upper watershed and downstream watershed, establishing natural silt traps, improvement of home gardens (soil conservation measures, especially), inland fisheries, bee keeping, and market facilities for farm produce including active involvement of the community in all the activities. An external review found successful community engagement and mobilization in upstream catchment protection. The project has planted 8,000 trees in an upstream tree belt.

The Special Climate Change Fund (SCCF) funded project on *Strengthening the Resilience of Post Conflict Recovery and Development to Climate Change Risks in Sri Lanka* includes measures to improve climate resilience include enhanced water storage and rational use, conservation of soil, coastal ecosystems for improved agricultural production, improved crop choice and built infrastructure such as roads, irrigation systems and water supply which incorporate climate risk reduction. There are three main components of this project. The first is the development of climate risk profiles for each district detailing geographical and spatial exposure to climate impacts using the disaster hazard maps and profiles. The second component includes building the technical capacity of public officials to identify and integrate climate risk considerations in designing, approving and implementing development projects. The third component provides adaptation actions in selected villages including soil conservation measures, water conservation at household and community level, promoting climate sensitive cropping/farming practice. The actual ground level work will be sub-contracted to community-based organisations such as Farmer Organisations (FO), Welfare Societies and other CBOs that will be established through project, and approved by the Ministry of Finance[122]. This project's investment in developing climate risk profiles for divisions and districts will provide tools for and train local officials and sectoral agencies to evaluate climate risks and mitigation options.

SCCF resources are currently used to test methods to prioritize of village tank cascades as an adaptation measure for climate change (developed by the Department of Agrarian Development and described in Chapter 1) in Maha-Nanneriya cascade of the Mi Oya basin[123] covering one cascade and 30 small reservoirs in Kurunegala District. The parameters considered in prioritization are catchment slope, and the type of soil and land use including the presence of Rock Knob Plains.

[121] www.about.hsbc.lk/~/media/sri-lanka/en/news-and-media/

[122] UNDP, 2013. Project Document.Strengthening the Resilience of Post Conflict Recovery and Development to Climate Change Risks in Sri Lanka

[123] UNDP/DAD 2015. Prioritization of Village Tank Cascades as an adaptation measure for the Climate Change Project, unpublished report

The DAD-UNDP-SCCF project has applied this methodology to rank cascades within the Mi Oya river basin, considering its potential coping capacity against climate change. The Project has also incorporated some design innovations to enhance climate resilience. Accordingly, a bottom level sluice (mud sluice) and the vegetative interceptor to draw out salinity and minerals from irrigation water has been incorporated to the designs. The mud sluice is manually operated to let out the silt-containing bottom water layer just before the monsoon rains begin, in order to prevent long-term silt deposits. In addition, the water releases will be measured with a Broad Crested Weir (BCW) Flume.

Lately, the emphases on environmental and disaster management aspects have gained prominence due to the increasing and visibly intensified cycle of flood and drought. Accordingly, the NCP Canal Project (NCPCP) currently in design by the MMDE aims to augment around 1,100 village irrigation reservoirs through a trans-basin diversion (Sri Lanka's longest river, Mahaweli which is already heavily diverted to support irrigation in the north-central province is not currently extended towards the northern province). In the process, the project would undertake the restoration of some abandoned reservoirs, regardless of their hydrological richness. This project proposes two main canals for augmentation of village irrigation systems; the NW (North Western) Canal benefiting large areas of Kurunegala, Puttlam, Anuradhapura, Vavuniya and Mannar Districts covering river basins of Mi Oya and Hakwatuna Oya, Malwathu Oya, Pali Aru Parangi Aru, Kanakarayan Aru, Ma Oya and Yan Oya. Out of these river basins, Mi Oya, Malwathu Oya and Yan Oya are the most climatically threatened river basins, in terms of river basin area and the number of village irrigation systems under threat. The vulnerabilities of these river basins have already been described in Chapter 1.

3.2.1.1 Research activities related to irrigation development in village systems

The International Water Management Institute (IWMI) has published several research studies on selection of VIS for rehabilitation. IWMI and other experts carried out studies on water management in village irrigation schemes. In 1994, IWMI developed a guidance package for water management and development in small tank cascade systems. These and other studies[124] focused on the hydrology of cascade systems and recommend a methodology for selection of irrigation systems based on the assumption that impact of rehabilitation effort is significant if the reservoir is hydrologically well endowed.

The DAD's Water Management Division as mentioned in Chapter 1, has developed a methodology to rank river basins and village irrigation cascades within a river basin, considering the potential coping capacity against climate change. According to a related vulnerability assessment study, it is revealed that Mi-Oya River Basin located in both Kurunegala and Puttlam districts has the highest vulnerability rank under climate changes scenario. Ranking of other river basins is being conducted. Ranking of cascades within Mi Oya basin has been completed[125].DAD, has also produced a comprehensive database including the hydrological features. These guidelines serve as a base for designing interventions in village irrigation improvement and upgrading.

[124] "Identification of Hydrologically Endowed Small Tanks for Rehabilitation and Agrowell Development in the Cascades of Anuradhapura District, North Central Province Sri Lanka" by IWMI and a study by Sakthivadivel *et al* (1996) titled "Nature of Small Tank Cascade Systems and a Framework for Rehabilitation of Tanks within Them"

[125] Withrana, DDP. 2015. Ranking of Village Tank Cascades (Ellangawa) on potential coping capacity for Climate Change Resilience in the dry zone of Sri Lanka. A Paper Presented to INWEPF Symposium, Sri Lanka.

3.2.2 Climate resilient Ecological Agriculture

The Department of Agriculture provides a set of recommendations to select crops based on the agro-ecological regions of Sri Lanka[126]. It provides the advice to select crops based on agro-climatology at different Agrarian Service Centres (of the DAD) and Grama Niladari Divisions. The DoA implements"crop germplasm collection" to allow farmers access new modified climate resilient crops and "systematic crop comparison programmes" that target farmers in different agro-ecological regions. Other activities include the research and development of ultra-short term rice varieties with lower irrigation water demand. Several universities are conducting field studies with the DoA on traditional rice varieties that can cope with longer dry days and more regular floods. The HSBC-IUCN project tested a few new traditional varieties of rice such as Pokkali, Nonabokra, Muppangam etc. which are tolerable to a salinity level (EC) up to 5 milli-mhos/cm[127].

The DoA has listed a set of climate-smart agricultural (CSA) practices, as well. These practices are based on successful interventions carried out in other countries, and they have been tried out in Sri Lanka in recent times. The practices with high adoption rates include: planting with onset of rains (for maize), land preparation for rice utilizing rainfall in Yala, agro-forestry and crop diversification (in home gardens), short and ultra-short duration varieties (in rice cultivation)[128]. Practices that address water salinization and soil degradation and erosion are critical for ensuring the productivity and sustainability of important food and export crops. Reducing synthetic fertilizer and pesticide use through mulching, thatching, and agroforestry systems, among others, promotes good water and soil quality. Integrated pest management, mechanized planting in paddy fields, types of climate resilient paddy varieties are recommended by the DoA (see Annex X).

Land productivity and resilience has been also achieved through the adoption of perennial cropping systems and short-duration and agro-ecologically adapted plant varieties. On the mitigation side, emissions reduction and carbon sequestration result from CSA practices such as crop–animal integration, manure production, and reduced use of chemical inputs. Awareness programmes on organic fertilizer production and use are held at the Regional Agricultural Research and Development Centre at Makandura, which is the training centre of the Organic Fertilizer Programme. A study shows that the number of farmers in Sri Lanka engaged in organic agriculture rose from 0.65% of total cultivated land in 2006 to 1.08% of total cultivated lands in 2008[129]. However, adoption levels of some of these efforts are generally low, especially among small-scale farmers. It is noted that adoption of organic practices are constrained by inadequate markets[62] and high labour input required. The advisories of DoA include cultivation practices for uplands and home gardens and suitable crops for such lands (see Annex X). The crop recommendations for paddy lands, uplands and home gardens are being updated by the DoA.

Successful adoption of ecological agriculture, tested out in a GEF-SGP Project in flood-prone Ratnapura district[130] showed high success. Before the project, 180 farmers used heavy chemical fertilizers for paddy cultivation, which reduced to 20 after the project interventions which included

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[126]http://nrmc.lk/crop_suitability/

[127] Dharmasena, P.B. 2014. Traditional Rice Farming. Back to Practice. Technical Note No. 2. IUCN-HSBC

[128] World Bank; CIAT. 2015

[129] Aheeyar, M.M.M. (2013). Alternative Approaches to Small Tank/Cascade Rehabilitation: Socio-economic and Institutional Perspective, HARTI Research Report No: 162, Hector Kobbekaduwa Agrarian Research and Training
Institute, Colombo, Sri Lanka.

[130]Community-Based Adaptation to Floods in the Elapatha DS Division of Ratnapura District implemented by Sabaragamu Janatha Padanama

soil testing, advice on suitable rice varieties and cropping patterns, mechanical and other pest control, mulching and using hay back in the fields etc. Home gardens using organic farming increased. Some home gardens are generating as much as 30% of monthly income of some families[131].

The DAD has established local level soil testing units and maintains a "soil health-card system" to overcome depletion of soil quality and overuse of agro-chemical inputs. This is important to rationalize and organize farming-including crop selection and input selection- based on the soil quality and needs instead of ad hoc interventions.

Micro-irrigation techniques have been used in Sri Lanka for several decades. A memorandum was submitted to the Cabinet of Ministers if Sri Lanka in 2000 to obtain approval for providing subsidies micro-irrigation systems, in order to increase water use efficiency and productivity. A survey conducted in 2004 found that land productivity and farmers income has been increased, especially in the Dry Zone, due to application of micro-irrigation systems. Among the farmers satisfied with micro irrigation systems, the majority were resourceful and innovative farmers with access to markets. Education level and training positively influenced the adoption[132]. DoA provides island-wide agricultural extension services on water management including micro-irrigation, through training programmes and demonstrations, cost estimates and plans and information on market etc. Demonstrations are provided on low-cost, bucket type drip irrigation systems.

Considering the initial capital investment is a constraint for the adoption of micro-irrigation systems, affordable micro-irrigation technologies have been promoted in countries such as India. A typical family drip system consists of a water delivery tanks, simple control head, water distribution pipelines and irrigation dripper lines. A study conducted in India found that women benefit from smaller kits, which are predominantly used in home gardens[133].

While technical recommendations on suitable crop types based on various agro-ecological conditions are useful, cultivation of such crops by the farmers depends on the seed availability and marketing facilities for the particular crop. The Practical Action implemented a project titled "**Re-genesis: A new beginning - Rehabilitation of Irrigation Infrastructure & Initialising Market Development""** in the Northern Province from 2011-2012, with funds from the Office of U.S. Foreign Disaster Assistance (OFDA). It benefitted 883 recently re-settled and re-located families in the Kilinochchi District. The project created linkages with wholesale buyers for a Participatory Market System Development Program. In addition, the Market Mapping exercises carried out by the project provided the necessary marketing information to farmers, and Market Forums were strengthened to facilitate necessary support for farmers.

Improving market-relation information transfer has been successfully implemented in countries such as India. **e-Choupal is an initiative of the Indian Tobacco Company (ITC**), a conglomerate in India, to link directly with rural farmers via the Internet for procurement of agricultural and aquaculture products such as soybeans, wheat, coffee, and prawns. The programme installs computers with Internet access in rural areas of India to offer farmers up-to-date marketing and agricultural information. The farmers can directly negotiate the sale of their produce with ITC Limited. Each ITC Limited kiosk having Internet access is run by a trained

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[131] UNDP – GEF SGP, 2015. Coping with Climate Change and Variability: Lessons from Sri Lankan Communities

[132] Ekanayake, E.M.T, Gunaratne, L.H.P. and Gunawardena, E.R.N. undated. Technical and socio-economic assessment of micro irrigation systems in the small scale farming sector in Sri Lanka. Postgraduate Institute of Agriculture. University of Peradeniya.

[133] Intermediate Technology Consultants, HR Wallingford, EDA Rural Systems, Birsa Agricultural University, ITDG and Ian Hancok, 2003. Low cots micro irrigation systems for the poor. Final report

farmer, who earns a service fee for the e-transactions. There are 6,500 e-Choupals in operation in 40,000 villages in 10 states, affecting around 4 million farmers[134].

Mobile phone operators and manufacturers are increasingly promoting agricultural data dissemination world-wide. Nokia Life Tools on low-cost phones are being piloted to deliver context-tailored extension services in China, India, and Indonesia. In Macedonia, SMS is used to advice farmers on timely application of pesticide, reducing its use by 30%, with beneficial impact on incomes and environment. In Pune, India, an Internet-based discussion portal that provides an open forum where users (farmers, experts) have created more than 90 % of the content. In Indonesia, Ghana, Uganda, and Malaysia, mobile apps are also deployed to build communities of practice among farmers, and obtain market information and agricultural expertise. In Africa, SMS via mobile is used to provide extension services for animal husbandry (iCow in Kenya). In Bhutan, mobile phones, combined with milk processing units, helped induce production and increased income of milk producers by 40% within a year. In Gujarat, India, networked and computerized milk collection centers ensured quality standards, fair prices, faster processing, and immediate payment to farmers. In Sri Lanka and India, satellite technology and mobile are used to forecast fishing grounds-- increasing yield and incomes by as much as 100%, and also in Trinidad and Tobago 95% of those in the fishing industry use cell phone for market information.

In Sri Lanka, the government with private sector and non-governmental organization support has tested out mobile phone (telephone) based initiatives for information and consumer services, including agricultural advice. There is a toll free hotline number for agrarian advisory service by Ministry of Agriculture; a number for free information by the Government Information Centre, and an SMS based Agricultural Commodity Price Dissemination Service. Dialog Trade net, a service delivered by Dialog Axiata PLC (a private sector Telecommunicators operator) and Farmer Intelligence Service (an NGO) offer market price information. Most private initiatives often source their base information from government research agencies (state or national level) and may not be exactly in the form required by farmers for their decision-making. The Sri Lankan Government Information Center connects the caller to an information service provider. This particular service is based on dialogue and accessible to fixed-line and mobile telephones, but similar directory services are also offered over the Internet. LIRNEasia's research illustrates the use of SMS in assisting farmers to search for market and trading partners and to provide market prices thereby improving their ability to scout for better prices and markets. An example of this is the Dialog Tradenet initiative in Sri Lanka that has been providing farmers with market price information via SMS since 2009.

Agro-meteorological Advisory Service provided by India Meteorological Department aims at applying meteorological information to improve agricultural production. Information support system include; provision of weather, climate, crop/soil and pest disease data for on-farm strategic and tactical decisions, translate weather and climate information into farm advisories using research knowledge, introduction of technologies such as crop-simulation model based decision support system to adapt agricultural systems to changing weather and climate variability, develop effective mechanism for effective dissemination of agro-met advisories to farmers. The weather advisories are generated using a Multi-model ensemble technique using forecast products available from several countries. Regional meteorological centers add value to these products

[134]https://en.wikipedia.org/wiki/E-Choupal

using computer models and bias-correction methods. The performance evaluation of forecasts carried out by different states show variation among states but is reasonably good for rainfall range of 10-65 mm. The dissemination to farmers is through mass media. Although farmer's response to this system is to be assessed, AMS has developed a mechanism to assess users' needs[135].

3.2.3 Rural water supply

ADB has funded several major water and sanitation projects in the last two decades: First, second and third Water Supply and Sanitation Projects, Secondary Towns and Rural Community Based Water Supply and Sanitation Project, Dry Zone Urban Water Supply and Sanitation Project, Jaffna-Kilinochchi Rural Community Based Water Supply and Sanitation Project[136]. **The Third Water Supply and Sanitation Project**'s main purpose was to provide sustainable WASH facilities to 1 million people through policy reforms and project investments at the rural and urban levels in 6 districts. The project at the completion provided water supply connections to about 293,359 households, which was more than the target of 180,000 households during appraisal. In the recent times, IDA (the World Bank) has funded four projects in the water and sanitation sector including one project in the rural water supply sub-sector. **The second Community Water Supply and Sanitation Project (CWSSP)** is important as it was implemented through community-based organisations (CBOs). The project provided 92,000 new piped water supply connections (57% of the target), 384,100 people with access to improved water sources (53%) and 922 improved community water points (82% of the target).Shortfalls in achieving set project targets are attributed to reallocation of funds for tsunami emergency operations, inadequate coordination among stakeholders especially in the north and east, security problems in the field and re-allocation of funds to respond to urgent needs of the 2004 Indian Ocean Tsunami[137].

The spread of CKD and the resultant mortality, morbidity and health expenditure has elicited additional response from the government. The National Water Supply and Drainage Board and National Community Water Trust developed a strategy and work plan, which include short term, medium term and long term plans to provide safe drinking water to CKDu affected areas, many of which overlap with project intervention areas. The parliamentary subcommittee has endorsed these work plans for CKDu. The short term programme cover the districts of Anuradhapura, Polonnaruwa, Badulla, Mannar, Ampara, Trincomale, Kurunegala and Matale to provide immediate relief and safe water to 163 villages[138]. Under the short-term measures, the following strategies are adopted to control this disease.

a. Establish **Reverse Osmosis** (RO) plants to purify groundwater from wells or boreholes. These small treatment units are operated by CBOs. Continuous technical support of the NWSDB is provided for operational and maintenance purposes.

   Currently established RO Plants are summarized as follows:

Province	**NCP**	**Uva**	**Central**	**North**

[135] Sing, K.K, undated. Weather forecasting and Agromet Advisory Services in India. New Delhi. http://www.iasri.res.in/ebook/TEFCPI_sampling/weatherforecastingndagrometadvisoryservicesinindia.pdf
[136] ADB, 2015. Sri Lanka's Water Supply and Sanitation Sector: Achievements and a Way Forward. Asian Development Bank. Metro Manila, Philippines
[137] World Bank, 2011. Implementation completion and results report, Second Community Water Supply and Sanitation Report. Sri Lanka Country Management Unit. World Bank
[138] Ministry of City Planning and Water Supply. Official documents. 2015

Large RO plants (10 m3/day)	61	2	1	2
Other	2	0		
School RO Units	150	9		4

Table 8: Installed RO plants by Mid-2015

The NWSDB has estimated the requirement of advanced filtering facilities including RO plants for the future as well. These are presented in the gaps and needs section in the following chapter.

b. Bring treated water from existing water supply schemes through truck or bowser to the community.
c. Service extensions from existing piped water supply schemes to selected areas.
d. Rainwater harvesting in areas where bowser supply is uneconomical[139].

Rainwater harvesting (RWH): RWH is recognized and promoted by the National Rainwater Policy of 2005. Lanka Rainwater Harvesting Forum and several other organizations implement and provide guidance in design and installation of RWH systems in collaboration with government and non-government institutions including UNHABITAT. NWSDB also implements projects to establish RWH systems. It is estimated that there are about 42,000 domestic rainwater units in Sri Lanka.

Study conducted in Hambantota district (Southern Dry Zone) found 83%-90% of the households in the surveyed areas use collected roof-water for drinking and cooking purposes. A study conducted in 10 District Secretariat divisions in Anuradhapura district reports that more than 85% households use stored rainwater for drinking where such units are installed and in use. For 71% of these households it is the most crucial water source during the dry season. Analysis of water quality of the rain water systems during this study has revealed that chemical and physical quality of the stored rainwater meet the Sri Lanka standard (SLS) of potable water quality. Although some users have abandoned RWH systems, high percentages of use were reported from Kurunegala and Anuradhapura districts. One of the main reasons for promotion of the rainwater option is CKD in these districts. Estimated average maintenance cost of a RWH system in the Dry Zone was LKR 933 in 2011. Average time saved per day in the Dry Zone was 4hrs and it was 6 hrs per day for a woman in Anuradhapura. Average economic return of saved time varied from LKR.50/day but it was as high as LKR 195/day in Anuradhapura and 200/day in Puttalam[140].

3.2.4 Interventions in disaster risk management

Implementation of interventions outlined in the “Road Map Towards a Safer Sri Lanka” during the past nine years (2005-2013) has resulted in significant improvements in the disaster management capacity of the country in terms of preparedness, response, awareness and creation of the legal and institutional structures, together with the fostering of an enabling environment for

[139] Abegunasekara and Wickramasinghe, undated
[140] Ariyananda, T. and Aheeyar, M.M. 2011. Effectiveness of Rain Water Harvesting (RWH) Systems as a Domestic Water Supply Option, A Report Submitted to Water Supply & Sanitation Collaborative Council (WSSCC) Through
WSSCC National Coordinator, Sri Lanka. Lanka Rainwater Harvesting Forum

risk reduction. The Roadmap also focused on community-based disaster risk management resulting in establishment of village level committees, participatory village development planning, rehabilitation of minor infrastructure for drainage or erosion/landslide control etc. The DMC has developed hazard profiles at district level and disaster resilient building guidelines. These actions were supported by Sri Lanka Red Cross, OXFAM, Practical Action, UNDP, UNHABITAT and others organizations[141].The contributions by NGOs are separately discussed later in this Chapter. In the study of hazard profiles, it is noted that flood occurrence is generally increasing, possibly due to the impacts of the climate change. **The Sri Lanka Comprehensive Disaster Management Programme (SLCDMP)** acknowledges that climate change has increased flood incidence and likelihood. While there is a notable reduction in loss of life due to improved warning and response capacity at districts, SLCDMP noted that crop and asset losses are still high downstream of irrigation systems in the Dry Zone, mainly due to lack of timely early warnings and a coherent method of delivery to downstream communities.[142]

UNDP has submitted a project proposal to the **ESCAP Trust Fund for Tsunami, Disaster and Climate Preparedness in Indian Ocean and Southeast Asian countries** titled "**Multi Hazard Early Warning System for coastal areas of Sri Lanka (2015-2025)**" targeting Sri Lanka's coastal population of an estimated 1 million. The proposed early warning system will serve 14 coastal districts of the island with more than a third of the total population of Sri Lanka. The project strategy involves two components: upgrading and strengthening the existing EW system and capacity building. Under the first component, the project proposes to upgrade 77 early warning towers, strengthening the existing system by complementing it with the Disaster and Emergency Warning Network (DEWN) terminals and EW system through landlines and expanding the warning system to cover floods in the coastal areas. In addition to the above, the proposed project will also explore the next stage of early warning and assessing the survivability and availability of the local telecom system in support of emergency communications. The project proposes to complement the existing communication system of the towers with a more robust DEWN system localy manufactured and tested in coastal areas. The proposed DEWN system uses widely available mobile communications technologies such as Short Messages Service (SMS) for early warning and cell broadcast (CB) and its purpose is to provide a cost effective but reliable mass alert system. The project will develop skills among stakeholder agencies and awareness among communities on responding to the alerts.

The skills on climate risk assessment and economic valuation have been developed among technical staff of ministries of Agriculture, Fisheries, Irrigation, Livestock and Economic Development through several disaster management capacity enhancement programs implemented by the **Training, Education and Public Awareness Division of the DMC**. These new skills enable responsible agencies at all levels of decision-making and planning to design locally appropriate climate risk reduction measures easily implemented through regular development programmes. Such programmes are generally a part of the DMC's annual programme, and are implemented with government funds.

International Water Management Institute (IWMI) and Sri Lanka Rainwater Harvesting Forum promote low-cost mobile weather stations, designed to monitor weather patterns and assist rural communities to better prepare for floods and landslides. This effort is at experimental stage. In addition, IWMI provides guidance on online HTTP Information Server and SMS Alerts System

[141] Ministry of Disaster Management, 2014. Sri Lanka Comprehensive Disaster Management Programme - 2014-2018.

[142]

for the mobile weather stations through GSM Wireless Communication. The purpose of the system is to alert the key personals about the rainfall readings above threshold values and update an information server with set intervals[143].

There are several NGOs active in the field of early warning and[144] disaster management. **Sarvodaya Community Disaster Risk Management Center** develops medium and long-term preparedness plans for villages in risk-prone districts. The organization creates volunteer groups to identify and rank probable hazards in the area. NGOs such as Sarvodaya, Oxfam and Red Cross have conducted community-based risk management trainings for community volunteers and for local officers. Sarvodaya officers establish committees that network with government disaster management officers and other regional disaster management centers. They contribute to identifying hazards, designing evacuation routes and small-scale village alert systems. The Sri Lanka Red Cross Society (SLRCS)'s disaster management programme has two thematic areas; institutional preparedness for disaster management and Community preparedness for disaster risk reduction. The components under these thematic areas institutional preparedness for response targeting local officials and divisional and district DM committees, on approach for community based disaster risk management, recovery activities including livelihood development including development of skilled human resources[145].

EW systems used by DMC

The DEWN Device: The DEWN device (was developed by the Dialog Axiata (Pvt.) Ltd. in colloboration with the University of Moratuwa Mobile Communications Research Laboratory and Disaster Management Centre as a public priviate partnership intiative. These devices have been distributed to few selected communities to serve as an additional means to alert the public equipped with GSM functionality and an FM radio receiver the devices meet the following requirements:

- Alarm triggered by reception of either SMS or Cell Broadcast from a recognized source
- Alarm siren and flashing light display
- Compact size, portable and low power consumption
- Powered from mains power supply but with battery back up
- Capable of multilingual support with a user friendly GUI and colour touch screen
- GSM call-back facility to receive further advice from a hotline
- Message acknowledgement
- Remote and local testing function

[143] http://www.iwmi.cgiar.org/tools/mobile-weather-stations/online-http-information-server-and-sms-alerts-system-for-mobile-weather-station.pdf

[144] Oxfam Humanitarian Field Studies Disaster Management Policy & Practice: Lessons for Government, Civil Society, & the Private Sector in Sri Lanka October 2006

[145] www.**redcross**.lk

The device is placed in selected locations such as police stations, religious places, schools and community centres. The excisting 77 multi-hazard early warning towers will be connected through DEWN system along the coastal belt of Sri Lanka.

Figure 14: The DEWN Device. *Source: University of Moratuwa.* DEWN devices are activated by the reception of an SMS or a Cell Broadcast message.

Short Message Service (SMS): SMS is one of the most commonly used services in any mobile operator's portfolio. Given the structural constrains of the network and the channels that SMS uses on the air interface, SMS is prone to congestion, although much less so than a voice call. In the lead up to a disaster, mobile networks may experience technical challenges and so early warning service design should consider the attributes of the network and its management to avoid adding additional pressure onto the network. The SMS message is sent directly to the handset number and messages received on the handset are independent of its location. As a mass-alerting tool, this means SMS may not be as location friendly. Reliability of reachining the vulnerable gropus on time is one of the drawbacks of SMS option. However, for a more focused alert , SMS could be considered. Whilst there are currently 5000 district-level officers and communities who receive warnings the service is open to the general public through Dialog mobile company by dialling #117#.

Cell Broadcast: Cell Broadcast is an under-utilised signaling channel on the air interface between the handset and the transceiver and in basic terms allows the network to function as a traditional radio, so every handset in the area can pick up that broadcast message. Cell Broadcast has the unique feature of not being subjected to or contributing to network congestion. Since it uses a signaling channel it is not affected by traffic channel availability and it does not carry voice traffic.

DEWN alerts are issued through a secure computer application where the text, geographical area and recipients (individuals or groups) can be selected for the message which is automatically drafted in the three main languages of Sinhala, Tamil and English. The interface between this application and the telecom network entities SMS Centre (SMSC) and Cell Broadcast Control (CBC) is done via a message broker. The messaging system supports the internationally accepted Common Alerting Protocol with the ability to easily in tegrate other generic alerting mechanisms.

3.2.5 Weather, climate and hydrological forecasts and early warning

Department of Meteorology (DoM), DoA, ID, MASL and DAD maintain a network of hydrological and meteorological data collection system and relevant databases. These databases are maintained independently and there is no central information repository. Some data, including the previous day's rainfall, seasonal and daily weather forecasts, as well as water levels in major reservoirs can be accessed by the Internet (www.meteo.gov.lk), though not always reliably. Other more detailed information and long term data have to be obtained on request, and require a processing fee.

DoM is the main provider of weather and climate forecasts and early warnings for different stakeholders and general public. Current hazard warning systems include warning by loud speakers, announcements over radio and television and warning sirens (especially in the case of tsunami warning). Initiatives have been taken to make use of the mobile phone network, but such coverage is not wide spread.

In addition, DoM provides early warnings for different hazards like lightning, cyclone, strong winds, heavy rainfall etc. Through its website, DOM provides the following forecasts related to rainfall:

a. Rainfall forecast for each rainfall season for each District with probabilities;

b. Rainfall forecast for each month for each District with probabilities;

c. Consensus seasonal weather outlook for three months with maps; and

d. 14-day daily precipitation

e. Weekly Agro met Bulletin providing past week's rainfall and temperature data and rainfall predictions for the future week

Extracts and examples from these forecasts are presented in Annex 5.

Based on the weather forecasts issued by the DoM, the Natural Resources Management Centre of the DoA issues a tri-monthly (quarterly) rainfall advisory for each agro-ecological region. The advisory contains predicted rainfall values, their comparison with average or "normal" rainfall conditions, and recommendations regarding cultivations. These advisories do not generally contain advice on the type of crops.

DoM maintains 23 main weather stations[146] scattered throughout the Island, manned by trained meteorological observers. There are 37 Automatic Weather Stations (AWS), and the data from each are used for forecasting purposes. The Figure 15 shows the location of AWS, which are mostly found in the central and southern regions. Out of those, 20 are synoptic stations. Agro-meteorological stations are further maintained in different parts of the island in collaboration with government institutions engaged in the agriculture sector.

The network of rain gauge stations comprises of 487 rain gauge stations, out of which, data are regularly received from 410 stations. Daily rainfall data from 215 stations out of these 410 are obtained on daily basis to be used for weather forecasting purposes. These stations are maintained in collaboration with government and non-governmental institutions and voluntary observers.

The network of agro-meteorology stations makes surface meteorological observations, soil temperature at different depths, minimum observed temperature and evaporation rates. The observations are made at these stations twice a day at 08.30 am and 05.30 pm. The data are transmitted to the institutions, which maintain them as well as to the DoM to prepare weekly Agro-met bulletins.

[146] http://www.meteo.gov.lk/images/Weather_summary/WXSYNSep.pdf

Upper atmospheric observations are made in Colombo, and they are made three times a week at 0600 hours UTC using radar and radiosonde equipment up to a height of approximately 20 km from the surface. Radar wind observations were done at Colombo to determine the wind speed and direction at different heights in the lower atmosphere. Radiosonde Observations performed at Colombo at 1200 hours UTC for the determinations of pressure, temperature and humidity at different heights in the lower atmosphere thrice a week. In addition to radiosonde observations, upper atmospheric wind information is calculated utilizing the Pilot Balloon observations. Pilot balloon observations were performed at Hambantota, Mannar and Polonnaruwa throughout the year at 0000, 0600, 1200 UTC to determine the lower atmospheric level wind velocity[147].

Figure 15: Location of Automatic Weather Stations maintained by DoM(Source: DoM and S. Premalal,pers. Comm)

Data processing and dissemination: The data received from weather stations and rain gauge network is examined and quality controlled. Computer Division archives all the data. The DoM

[147] DoM, Annual administration report for the year 2012.

uses manual methods for quality controlling the data. The data received at the DoM head office are plotted to identify outliers. The 22 main weather stations of the DoM record wind, temperature (including maximum and minimum), rainfall and evaporation. Using these data from the main stations, barographs, thermographs, pluviographs and hygrographs are plotted. The plots from observed data are compared with these plots from main stations and corrections are made.

Monthly and annual climatological means are calculated for various parameters. Meteorological data received from its own field offices and other sources such as government offices and private sector are processed in the DoM head office in Colombo.

In addition to the local observational data, globally observed data is also used for the weather forecasting purposes after analyzing it. In addition, the observational data and the satellite radiance data are utilized to prepare the numerical weather forecast guidance using the Weather Research and Forecasting model (WRF). At present, DoM is capable of downscaling global available Gridded Binary (GRIB) data (50x50 km) for a finer grid (5x5 km). The model provides forecast guidance for 7 days.The DoM runs the WRF model with data assimilation of observed and radiance data. For GRIB data downscaling, the data from National Oceanic and Atmospheric Administration (NOAA) and National Centers for Environmental Prediction (NCEP) are used as boundary conditions.

Early warnings on severe weather events are disseminated to the district administration and the local DMC office by telephone, email and fax and uploaded to the Internet as well. There is no arrangement to directly disseminate the information to Farmer Organisations, although warnings are available on the Internet and announced over the radio and television. Flood warnings are generally related to main rivers. Irrigation Department also issues flood warnings, based on their stream gauge reading in major rivers and water levels at major reservoirs. Flood warnings are issued prior to spill gate opening of reservoirs however do not adequately reach the targeted downstream populations due to lack of coordination among different government agencies and lack of effective communication system to enable mass dissemination of the warning.

Under the **Sri Lanka Comprehensive Disaster Management Programme** (SLCDMP) implemented by the Ministry of Disaster Management, the seasonal forecasting capacity of the DoM is to be improved within a timeframe of 2014-18 by fostering cooperation with regional centers for early warnings, training and instrumentation. The DoM is in the process of preparing training needs for such seasonal forecasting capacity.

The World Bank's **Dam Safety and Water Resources Planning project** also has a component to enhance the institutional capacity and physical and analytical infrastructure for monitoring hydro-meteorological data, detecting and forecasting water-related hazards, and improving water resources planning and management based on such data. The subcomponents include: establishment and upgrading of 122Hydro-meteorological stations (see Figure 16), establishment of a database at the Irrigation Department (ID), improvement of the analytical capacity of the ID, flood protection procedures, tools and training for analysis of flood inflows to major reservoirs, and establishment of a groundwater monitoring system. The Project has a dam safety improvement component mainly benefiting the large reservoirs, but the hydro-meteorological information system (HMIS) will improve the water related disaster management capacity at river basin level. The establishment of hydrometric stations is mostly completed and currently installed stations can be categorized as follows:

Type of measurement	Number of stations
Discharge, water level and precipitation (QLP)	56
Precipitation only (P)	13
Precipitation and weather (PE)	1
Water level, precipitation and weather (LPE)	12
Discharge, water level, precipitation and weather (QLPE)	5
Water level and precipitation (LP)	22
Discharge and water level (QL)	13

Table 9: HMIS and type of measurement

Some of these stations are in the three basins suggested to be targeted from the vulnerability analysis in section 1.5, however the ID has identified areas which need additional stations. Processing of data and flood modelling has not been started yet. It is planned to use AQUARIUS model to process the data and MIKE11 model to forecast floods. These models have been selected on the basis of the experience of the ID and after a technical evaluation.

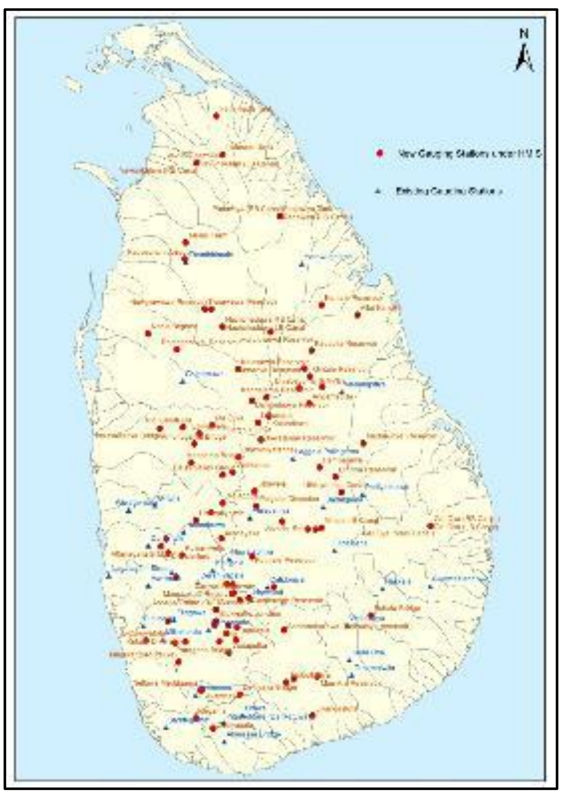

Figure 16:Location of the hydrometric stations under the DSWRPP(Source: ID and J. Meegastenne, pers. comm)

The Sri Lanka Comprehensive Disaster Management Programme (SLCDMP) identified the need to address the early warning and flood management in some key river basins. The World Bank funded **Climate Resilience Improvement Project (CRIP)** was initiated in 2014 in response**.** This project provides a critical first investment drive under the government's plans to manage disaster risks and provide a longer-term investment plan to build disaster resilience. Accordingly, a comprehensive study in ten selected river basins, including detailed flood and drought analysis, forecasting and formulating possible adaptation interventions will be prepared[148]. The river basins are: Mahaweli Ganga, Maha Oya, Deduru Oya, Kelani Ganga, Attanagalu Oya, Kala Oya, Gin Ganga, Nilwala Ganga, Gal Oya and Malwathu Oya. The proposed interventions include comprehensive river basin investment plans. Investments to be financed include: i) acquisition of a digital elevation model; ii) flood and drought vulnerability and risk modeling; and, iii) identification of basin investment programs. Flood risk mitigation will focus primarily on rehabilitating infrastructure damaged by floods in 2011-2014 or those particularly at risk to future floods. Investments will not involve construction of new infrastructure, but instead critical reinforcement to existing structures to withstand future floods. All rehabilitation works under this component are on canals and bunds downstream of dams. The Project is currently in the mobilization stage.Complementary to this; Irrigation Department (ID) has proposed river basin based disaster management plans and interventions in Kalu Ganga, Walawe Ganga, Kirindi Oya, Mundeni Aru, Yan Oya and Mi Oya basins. The proposed interventions are similar to the CRIP, but include the preparation of structural development proposals and implementing them.

In India a study by researchers from the International Maize and Wheat Improvement Center (CIMMYT) in 2011 found a number of crucial gaps and limitations in current advisory services being delivered by mobile phone to farmers in the Indo-Gangetic Plain. They found that farmers are keen to get very specific information, such as how to manage pest attacks or specific crop varieties that are more climate-resilient, rather than general advisories on the weather or pesticide use. It was also found that, without the support of additional institutions, such as markets, credit institutions, warehouses and storage facilities, messages on their own do not bring about much change. Following up from this study results, Consultative Group on International Agriculture Research (CGIAR)'s program on Climate Change, Agriculture and Food Security (CCAFS) and CIMMYT are implementing a pilot project aimed at improving delivery of climate-related information to farmers in Karnal in Haryana and Vaishali in Bihar. This project is sending voice and text (SMS) messages in Hindi to farmers' mobile phones. These are aimed at encouraging farmers to adopt technologies that can mitigate climate risks. Messages include weather forecasts and recommended actions that farmers should take, and information about pests and remedies, seed varieties and climate-smart technologies such as conservation agriculture. Additional messages provide up-to-date- market information and contact details for seed providers such as the Haryana State Cooperative Supply and Marketing Federation Limited. This project was started in August 2013, and currently reaches out to 1200 men and women farmers in eight villages and will run for eight months at a pilot level. Based on farmer interviews, it is found that the early results are promising[149].

3.3 Best Practices and Lessons learnt from implemented and on-going projects

[148] World Bank, 2014. Project Appraisal Document for Climate Resilience Improvement Project. World Bank
[149] https://ccafs.cgiar.org/blog/project-tests-new-ways-deliver-climate-related-messages-farmers-cell-phones#.VlGU4aShf4g

Many of the best practices and lessons learnt from past and present projects are presented in Table 10 below.

Best Practices/ Lessons Learnt	Applicable to which sectors/ intervention area of project	Tried through which projects
Village Irrigation Systems especially village reservoirs/tanks provide a strong, cost-effective and tested basis for intervention and investment in rural development and rural resilience building in Dry Zone districts, and especially in vulnerable river basins.	Irrigation improvement, ecologically sound agriculture, domestic water supply, drought forecasting and preparedness	VIRP, NIRP, PEACE, DZADP, IUCN/HSBC project, NEIAP, Tank-based Biodiversity Improvement and Protection Project, Strengthening the Resilience of Post Conflict Recovery and Development to Climate Change Risks in Sri Lanka (UNDP-SCCF), proposed NCPCP
Cascade-wide/ sub-basin approach to village irrigation rehabilitation. Considering the wider village irrigation eco-system that includes: reservoir bed, reservoir bund (dam) and appurtenances, upstream reservation, mechanism to trap sediment including small ponds and water holes, upstream earth ridges to retard sediment inflow, downstream reservation, command area drainage, and downstream sanitary cordon.	Irrigation improvement, ecologically sound agriculture, domestic water supply	IUCN/HSBC project, UNDP-SCCF project, Cascade based small tanks rehabilitation project in the Anuradhapura district (PLAN SL), DZADP, AF Project, GEF SGP Climate Adaptation Pilot Projects and proposed NCPCP
Partial-desilting of the tank or reservoir to avoid heavy costs of desilting/dredging the tank sediment. A sedimentation study used by the project indicated that the about half the amount of sediment deposited in village reservoirs is found within one third of the reservoir bed area closer to dam. Such partial de-silting by removing the silt in this area close to the dam would increase the Capacity/Water spread area ratio and add additional storage especially during drought periods.	Irrigation improvement and domestic water supply	IUCN/HSBC project, UNDP-SCCF Project, proposed NCPCP
Ensuring higher water yields and preventing siltation of reservoirs by tree planting, reforesting and promoting agro-forestry home gardens in local watersheds and catchments.	Irrigation improvement, ecologically sound agriculture, domestic water supply	IUCN/HSBC project, Tank-based Biodiversity Improvement and Protection Project, proposed NCPCP, GEF SGP and Adaptation Fund (AF) Project
Home garden investments and improvements for dry period food/fodder and income and to productively utilize rural labor. Soil conservation measures in the upstream home gardens to prevent sediment run-off to the water storage reservoirs.	Ecologically sound agriculture and irrigation water availability	Tank-based Biodiversity Improvement and Protection Project, IUCN/HSBC project, proposed NCPCP, UNDP SCCF Project

Establishment of a cascade management committee comprising farmers, FOs, officers from relevant government organizations and religious leaders to oversee the function of cascade systems as an integrated unit.	Irrigation management and domestic water supply, forecasting and flood early warning.	Cascade based small tanks rehabilitation project in the Anuradhapura district (PLAN SL), proposed in the NCPCP project
Mobilisation and capacity building for FOs to function as effective CBOs with a bank account for maintenance of the VIS, Water Supply Systems with savings from the rehabilitation contract. FOs collect from village irrigation services and re-invest money from the maintenance fund to purchase equipment such as ‘bush cutter’ machines which help to keep the channels and bund free of overgrowth.	Irrigation management and domestic water supply, forecasting and flood early warning.	PEACE Project
A large number of guidelines for design or village irrigation systems and O&M Manuals were prepared by the NIRP. The IUCN/HSBC Project produced a set of technical notes for several subjects including catchment conservation, restoration of the watershed. The CWSSP Project developed guidelines for maintaining community water supply schemes through local committees.	Irrigation management and rehabilitation	NIRP, IUCN/HSBC Project, CWSSP
Using Agrarian Service Centers as the primary node of communication between technical agencies such as Irrigation, Meteorology, Water Board, Agriculture Research and the Farmer Organisations	Irrigation management and domestic water supply, forecasting and flood early warning.	
Risk profiles show the exact details (locations, densities etc) of the populations at risk to a particular disaster and can be used to ensure that the early warning messages reach these people on time for effective disaster risk management. A risk profile is currently being developed for Badulla district and a risk profile has done to some extent for Walawe downstream at pilot scale. A risk profile for the entire country is yet to be developed. The DMC and SLCDMP are working on the methodology.	Flood early warning and drought mitigation through irrigation water management.	Activities under SLCDMP
The successful community based management of rural water and	Irrigation management and	Second Community Water Supply and Sanitation Project (CWSSP), The Eastern

sanitation schemes is recognized as best practice and replication of the model is part of the current policy of rural water services. These systems are operated and maintained by village-level CBOs. However, there are concerns about the sustainability of the model because it relies completely on the community volunteers to hold the offices and there is a risk of exclusion of the poorest, who are unable to pay the fees to access the services.	domestic water supply	Province Water Supply Development Project (EPWSDP), Third Water Supply and Sanitation Project (WSSP)
As such, there is a need to mobilize and train the Communities need to be sensitized by providing them opportunities to participate in decision making at all stages in project implementation. Such sensitization leads to create a sense of ownership of the facilities among users. Provisions should be made to obtain the services of knowledgeable, skilled and committed grassroots-level Change Agents (Social Mobilizers) for this task, without depending on local government officials for social mobilization. Often other priorities of the officials and local politics were constraints to achieve full social mobilization. This is especially true of CBOs to actively participate in source protection and management of local water sources.	Irrigation management and domestic water supply	Second Community Water Supply and Sanitation Project (CWSSP), The Eastern Province Water Supply Development Project (EPWSDP), Third Water Supply and Sanitation Project (WSSP)
Government or NGOs with some amount of beneficiary contribution- usually provide RWH units either in form of labour or cash. There are programmes to train the families to construct, use and maintain the RWH systems and ground water recharge. The sustainability of the projects is ensured by the availability of skilled personnel from the community to maintain these units and provision of technical services such as periodical water quality testing.	Domestic water supply	Community Water Supply and Sanitation Project, Rainwater Harvesting in a Water Scarce Small Village in Northern Sri Lanka by UN HABITAT
In some community water supply and sanitation projects water treatment options were introduced where necessary, considering the source water quality issues, capital investment and O&M flexibility. Such treatment was mainly to	Domestic water supply	EPWSDP, 3rd CWSSP

eradicate possible bacteriological contamination in the water supply. The design provided for 5% contribution from the community for civil works, in the form of labor or cash and taking over the operation and maintenance.		
Community mobilization and training to respond to disasters at village level has meant the establishment of village or divisional-level disaster response committees and trained volunteers. These networks are sometime non-operational due to the informal and volunteering nature of these committees.	Irrigation management and domestic water supply, forecasting and flood early warning.	
River basin approach to disaster risk management and water resources management is currently being piloted in several projects. Flood modeling at basin level is considered important to provide floods management and effective early warning services to downstream communities. CRIP project and the Irrigation Department plans to invest in flood modelling in at least nine river basins in the next three years.	Drought forecasting and flood early warning.	Climate Resilience Improvement Project (CRIP)
Modern communication methods including SMS/texts and News Alerts and free call-in services to connect farmers to information centres on climate smart agriculture, marketing information and early warning for climatic hazards have been successfully tested and applied in many countries, including in limited scope, in Sri Lanka.	Irrigation management, climate smart agriculture, drought forecasting and flood early warning.	DoA: A call centre solution known as Agriculture Advisory Service, to assist farmers in solving their various problems such as agriculture related technical matters, inputs and marketing problems., was introduced by the DoA in 2006.The objectives were to give quick advice to farmers over the phone on their queries, to refer experts or relevant literature and give advice within 72 hours for complicated problem, and to maintain a digital database on the queries for further action and report generation. (http://www.doa.gov.lk/index.php/1920-hotline). Dialog TradeNet: Dialog Telekom's TradeNet platform provides on-line agri-produce price information from three Dedicated Economic Centres at Dambulla, Meegoda and Narahenpita. It is planned to add more sites in the future. Dialog Tradenet is a repository for national-level market information built on a suite of digital technologies. TradeNet encompasses the collation, comparison, qualification and subsequent dissemination of trade enablement information to large numbers of stakeholders minimising information arbitrage. The service is immediately available

		to Dialog's 6 million-plus subscriber base from across all nine provinces of Sri Lanka. Information on the TradeNet platform is disseminated via multiple digital communication technologies such as SMS, Unstructured Supplementary Service Data (USSD) via mobile phones, web and Interactive Voice Response (IVR). http://www.mimobimedia.com/about/media/86-dialog-tradenet-revolutionizing-the-agri-market-access-in-sri-lanka

Table 10: Summary of best practices and lessons learnt from past and on-going projects

3.3.1 Return to investment and cost effectiveness

A study conducted in Kurunegala District in Sri Lanka by the UNDP describes the cost-benefit relationships in investing in rehabilitating irrigation systems and accompanied disaster reduction measures. There are 5,400 village Irrigation systems in this district with 141,000 farmer families dependent on them for seasonal agriculture. Of these, 1,090 are operating at sub optimal capacity due to unattended maintenance after floods in 2010-2012 and 2014. The cropping intensity of the paddy lands under damaged irrigation systems is less than 1, which means that farmers do not completely cultivate even one full season of the year. The annual opportunity cost of the neglect of these damaged minor tanks is calculated as LKR 897,950,785 (i.e. the marginal annual income increase if the tanks are rehabilitated). But the repair cost of the damaged tanks is estimated to be LKR 1,090,444,500[150]. Therefore the rehabilitation cost can be recovered within first 2 years from the marginal income increase for farmers cultivating these tanks, assuming cropping intensity increases to over 1.5 (at least one season fully and one season partly cultivated). The increase of extent of cultivation, land productivity and total crop production is found to be the main direct impacts of the rehabilitation of small irrigation systems. A survey found that the minor season cultivation was made possible to some extent in all surveyed schemes after rehabilitation[151].

According to a survey conducted to evaluate the performance of **Third Water Supply and Sanitation Project**, 87% of respondents reported that their incomes had increased during the project period, partly as a result of improved water supply services. This can be due to time saved in fetching water and reallocation of time for income generating activities, better water availability for home gardens etc. According to the evaluation report prepared by the ADB, 82% of women found it easier to collect water after the project, and 57% of women increased their monthly incomes because they were able to use time saved from collecting water to pursue income-generating activities.[152]

Under the same project, a community contribution of 20% of the cost of common facilities and 50% for individual facilities was required to qualify for project assistance. In urban water supply schemes, this contribution could be either in cash or labor, usually trench excavation and pipe laying for small diameter pipes in water supply, and 50% of costs of household sanitation facilities.

[150] Department of Agrarian Development 2014
[151] Aheeyar, 2013
[152] ADB, 2011. Validation Report Sri Lanka Third Water Supply and Sanitation Sector Project. Independent Evaluation Department. ADB

Experience from implementation showed that both cash and labor contributions exceeded the amount required by the project[153].

3.3.2 The importance of a participatory approach

A major lesson learnt from the past projects is that farmer/beneficiary participation in planning, design and implementation of such projects is very important to ensure the sustainability and cost effectiveness. World Bank (1991)[154] notes that, in the case of irrigation schemes that did not meet the project completion and sustainability requirements under Village Irrigation Rehabilitation Project, farmer interest was not properly ascertained and therefore works did not meet farmer requirements.

As learnt from subsequent projects for rehabilitation of village irrigation systems, ensuring the community participation in all phases of the project makes the project outputs sustainable. While voluntary work is useful for some components, a practical method to include the community in the project was to provide a payment for their work. Examples are those implemented by the Practical Action in the North, where the "cash for work" principle ensured the benefits were transferred to the farmer families during the project implementation period[155]. This also ensures that contractors use locally available labour and provide villagers with additional income during the dry season, when cultivation ceases and villagers are often looking for alternate employment such as wage labour in nearby towns. The infrastructure improvement strategy had been to focus on essential rehabilitation needs of main irrigation infrastructure such as reservoir bunds, sluices, spillways etc.

In the rural water supply and sanitation sector, the lessons that highlight the importance of community participation in all the stages of project implementation include:(i) demand-driven and community-based development require a flexible design to accommodate community preferences, (ii) enhancing community ownership requires that beneficiaries contribute cash and labor and communities have more responsibility for O&M, and (iii) handover of water supply to local communities requires continued support during transition and follow-up periods. In addition, it was found that substantial community awareness campaigns and community organization work are necessary to foster community interest, participation, and commitment. It takes considerable time to promote and build up community engagement, but such engagement can ensure the success, viability, and sustainability[78].

A survey on the impacts of third Water Supply and Sanitation Project[156] showed that women have assumed positions of responsibility as caretakers and CBO executive committee members. The incidence of water-borne diseases among beneficiaries decreased from 17% to less than 1%. The project promoted strong community participation in environmental initiatives, which reduced pollution of water sources and enhanced water quality. It strengthened the capacity of NWSDB, CBOs, and other partner organizations, including local authorities. The rural water units

[153] Ministry of Water Supply and Drainage, National Water Supply and Drainage Board (NWSDB). 2008.
Third Water Supply and Sanitation Sector Project, Sri Lanka Loan no. 1575 Sri (SF) Component A: Provision of Water Supply and Sanitation in Six Districts. Project Completion Report.

[154] World Bank, 1991. National Irrigation Rehabilitation Project. Staff Appraisal Report. Agriculture Operations Division. Asia Region

[155] Final programme performance report to OFDA: 16th August 2011 to 16th November 2012 Practical action grant no. Aid-ofda-g-12-00134 SRI LANKA

[156],ADB, 2011. Validation Report Sri Lanka Third Water Supply and Sanitation Sector Project. Independent Evaluation Department. ADB

established under the project are an important step toward improving service delivery at the local level.

3.3.3 The importance of an integrated river-basin approach that considers the multiple uses of water in VIS and risks to such multiple users

As has been done in many previous projects, components of water resources management in a sub-basin should not be considered in isolation of each other. Likewise the sub-components of the village irrigation system- such as the reservoir, canals and catchment- should not be considered in isolation[157]. It can be seen that investments made in expensive items such as de-silting will be effective in the long run, only if the watersheds are well maintained. Second, in many Dry Zone river basins, a large number of village irrigation systems are arranged in a hydrological cascade, and improvement and upgrading should evaluate a whole cascade[158] the micro-watershed, the sub-river basin and then the entire river basin in designing improvement, upgrading and modernizing irrigation systems. The importance of considering the entire river basin was noted in the final report on the NIRP[159], and the importance of this approach in flood risk mitigation was highlighted during 2011 floods[160]. Some lessons in summary are;

a. Village irrigation improvement and upgrading should be planned through a participatory watershed development approach, which involve all stakeholders including local officials and farmers.
b. This approach should provide guidance to designing irrigation infrastructure, rehabilitation plan (hardware components) including restoration of associated catchment and downstream reservation, community institutional strengthening plan, ecological agriculture (in irrigation command areas and home gardens) and other livelihood development plans, drinking water development plans and weather forecasting/early warning system development
c. A cascade of village irrigation systems consists of several individual reservoir based ecosystems and it should be considered in a holistic manner in the development strategies. Consideration given to cascade as a development unit is important to accommodate flood management and agriculture development activities
d. As traditional, clearly defined ecosystems do not exist in pristine form, and some stakeholders do not respect their boundaries, restoration of ecosystems through direct government intervention could create conflicts. Therefore social mobilisation should be an important part to bring all stakeholders to same table and to want to restore ecosystem collectively in their own individual long-term interest.
e. Not all farmer organisations (FO) or other village institutions are equally strong to mobilise the community. Strengthening village institutions including FO is essential for successful implementation of the proposed interventions.
f. Any new interventions in village irrigation systems may need to start with a strong capacity building of local government officials and Partner Organizations (local Civil Society Organizations who can help the government) in social mobilisation including exposure visits to current pilot projects.

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[157] Please refer to Appendix 1 for the salient features and components of village irrigation systems
[158] Aheeyar, M.M.M. 2013
[159] DHV Consultants et al, 2000. Final Report. National Irrigation Rehabilitation Project
[160] Jayawaardena, 2011

3.3.4 Climate smart agriculture to improve production and reduce threats to the VIS/ local water sources

Department of Agriculture has developed some technical recommendations for ecological and climate resilient agricultural practices. Much experience can be derived from ongoing projects and their technical notes. There are guidelines for the use of traditional varieties from the projects in projects implemented by IUCN/HSBC and SAPSRI (Kapiriggama and Tirappane cascade). These also show that closer interaction with the Farmer Organisations by the project implementation team can make such tools adoptable.

In addition, the seed availability and marketing facilities for the particular crop play an important role in adoption of such technologies by the farmers. Creating market linkages, market mapping and market forums have provided the required support to the farmers, as in the case of Practical Action-implemented project in Mullaitivu and Kilinochchi Districts[161]. This project benefited 28,169 fisher and farmer family members with strengthened access to new markets and business services. These models should be up-scaled.

The traditional systems and norms to share water and land during drought periods and sharing of water for multiple uses such as domestic needs, washing and bathing, agriculture, livestock and inland fisheries also need to be incorporated into the new project designs. Crop diversification and micro irrigation have been identified as climate-smart strategies for agriculture. Micro irrigation makes it possible to grow high value crops without the risk of failure even during periods of law rainfall or low storage in village irrigation reservoirs. Among many success stories, chilli cultivation in the Mahaweli system H area (northern Dry Zone), onion production in Dambulla (dry and Intermediate Zones) and banana production in Udawalawe irrigation scheme (southern Dry Zone) have been highlighted[162].

3.3.5 Forecasting climate extreme events and timely communication to at-risk communities

Investing in risk reduction is costly and a challenge for cash-strapped national treasuries with so many competing development priorities. However, given the impact on infrastructure and the heavy cost to livelihoods, risk reduction measures can often be justified with very short payback periods. The following lessons were learned from literature surveys and stakeholder consultations:

- The lesson that can be learnt from the current use of weather forecasts issued by the DoM by ID and MASL is that the dissemination of forecasted seasonal weather information to irrigation system level is technically feasible, though technical capacity enhancement of the officials of both the government and FOs is urgently needed. The accuracy of the forecasts has to be improved to ensure acceptance and timely action at village level.
- The experiences from India suggest that climate relate information should come with a ready-to-apply set of solutions including what crops to cultivate and access to markets.

[161] Final programme performance report to OFDA: 16th August 2011 to 16th November 2012 Practical action grant no. Aid-ofda-g-12-00134 sri LANKA

[162] http://www.fao.org/docrep/003/X6906E/x6906e0b.htm

- Accordingly, the interventions should be carried out in a participatory mode, to enable addressing the community needs and NGOs, private sector and the communities have a role to play in weather information provision and data sharing
- Timely and unrestricted sharing of information and meteorological data between the many different agencies and private sector that collect such information is essential to ensure optimum results from the investments in this field

Chapter 4 : Current needs, gaps and barriers; constraints to improve the resilience of vulnerable communities

4.1 Gaps in service and coverage of past and on-going projects

A number of gaps exist in current levels and coverage of water for agriculture and domestic use, as well as weather and climate information to rural farmers and organisations. These gaps exacerbate the implications of climate risks described in 1.2 and 1.3, and often serve to increase the vulnerability of farming communities living in remote, rural districts.

Despite years of intervention in village irrigation systems and rural drinking water supply, there are large gaps in coverage. Less than 15% of the total VIS have been targeted by previous donor projects, and of these, many tanks were rehabilitated to their 'previous' condition but without adequate safeguards against the increasing frequency of floods and siltation. As a result, despite many years of government and donor investment, the VIS are extremely susceptible to climate change related weather aberrations as seen in Table 4 above. After flood damage (in 2011 and 2013) the government and sometimes, NGOS or Private Sector, support the most essential repairs but these have no design considerations for greater resilience against increased intensity of rainfall or high evaporation rates, making the entire system and farmer livelihoods more exposed and vulnerable to climate change impacts. The gaps identified below, stemming from an analysis of the baseline investments and lessons learnt, are crucial to strengthen the resilience of rural infrastructure and in turn, livelihoods of small-holder farmers.

4.1.1 Comprehensive river basin / landscape approaches

Many of the large rural development projects focused on expanding services to key districts/ demographies but did not plan comprehensively based on a river basin approach. This is due to the traditional administration through District Secretariats making it the more viable level at which to intervene locally. However as Sri Lanka's water resources are mainly distributed along well-defined river basins with distinct geo-physical and agro-ecological characteristics, rural development plans that do not take a comprehensive river basin approach would be less sustainable and more exposed to climate change impacts on water resources.[163] The proposed NCP Canal Project plans to divert water from Sri Lanka's longest river to augment several village irrigation cascade systems is planned to commence in early 2016. Feasibility studies have shown that the project's intervention will cover parts of three climatically vulnerable (drought and flood prone) river basins. However, as shown by Figure 17, the NCP Canal Project benefits only the sections of these three river basins, which lie in close proximity to the conveyance canal.

[163] Sector Vulnerability Profile: Water. National Climate Change Adaptation Strategy for Sri Lanka (2011-2016) ADB and Ministry of Environment 2010

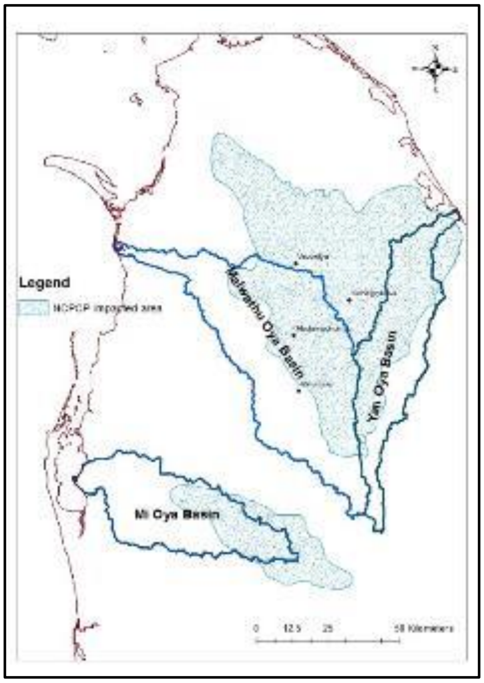


Figure 17: Spatial coverage of three river basins by the NCPCP

Accordingly, the NCP Canal Project (NCPCP) will impact 531 out of 1,731 irrigation systems (31%) in the Malwathu Oya basin, 236 out of 746 (32%) in the Yan Oya basin and 192 out of 1,561 (12%) in the Mi Oya basin. These irrigation systems are chosen on the basis of the accessibility to the water distribution network of the NCP Canal, not through hydrological assessment or vulnerability ranking based on a review of the entire basin.

Most of the interventions in village irrigation system upgrading are focused on the storage tank and allied infrastructure and do not consider the linkage between reservoir and watershed and the entire eco-system of natural and man-made elements that make the VIS a holistic integrated unit. Apart from the village irrigation system and its command area, the immediate and upper watershed areas are most important. This includes home gardens around the VIS, which also contribute to domestic food security, farmer family incomes. Furthermore, silt has to be removed periodically, at least once a year, to maintain the reservoir capacity. Although this has been the traditional practice, it is not been carried out uniformly across all the village irrigation systems. Additionally, the bottom level sluices or “mud sluices” are not functioning well or are totally absent in many village irrigation reservoirs.

4.1.2 Gaps in coverage of safe drinking water facilities

Safe drinking water in the Dry Zone remain one of the most pressing development needs, again despite years of investment in different modalities of drinking water supply to remote rural communities. As Table 5 indicates, the major problems are insufficiency for drinking and bathing, not having a water supply source within the premises and the need to travel long distances to access water. In 13 Dry Zone districts the percentage of people who have to travel more than 200 m to access safe drinking water range from 4.5 around 16.3%, compared to the national average of 4.1%. These problems become more severe during a drought, and people have to travel longer distances or opt for poor quality water. The definition of safe drinking water does not adequately cover the quality aspects and its variation with wet and dry conditions. There are many water supply schemes, including NWSDB schemes[53], which are unable to provide a 24-hour continuous water supply. Furthermore, protected dug wells comprise 53% of the drinking water source in rural areas. The current concerns about CKDu necessitate the provision of treated and quality-tested water to the households in the affected areas. The development of water supply systems are designed and delivered separately from irrigation interventions, although most often, they use the same local source of ground or surface water. Roof rainwater harvesting was promoted heavily but went in to a period of disuse as households faced longer dry periods or when other forms of drinking water became more accessible or affordable.

Many domestic water supply schemes fail due to issues with water-sources, either contamination or drying up of the source. Seasonally the Dry Zone faces high levels of water insecurity, aggravated now due to longer dry periods and the high intensity rainfall that prevents effective percolation and recharge of ground water sources. The World Bank's CWSS Project installed a large number of community water supply schemes however at times, sources dried up or quality issues forced the closure of schemes.

The choice of method for purifying water sources that have been contaminated depends on the nature of the contamination (including the particulate size of the contaminant matter). Table 1 shows the different advanced filtering options for different types of contaminants. Figure 18 further indicates the associated particle sizes of each contaminant and process.

Filtration process	Micro Filtration	Ultrafiltration	Nano Filtration	Reverse Osmosis
Target cotaminants	Particulate material like algae, Giardia, Crypto, bacteria and clays	All substances removed by micro filters plus humic acids and some viruses	All substances removed by micro filters and ultra filters plus dissolved metals and salts	All substances removed by micro filter, ultra filters nano filters plus smaller dissolved metals and salts.

Table 11: Comparison and selection of Membrane Filtration Method

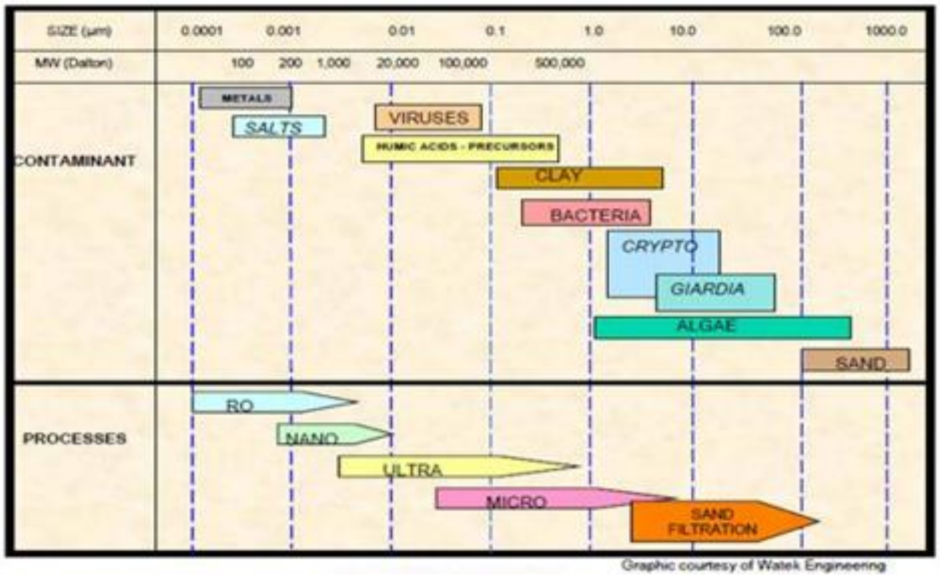


Figure 18: Particle sizes of different contaminants and required processes needed to remove contaminants from drinking water supplies.

The poor quality of water sources, and the threats imposed by CKD has pushed the government to opt for membrane treatment (RO or other advanced filtering methods) as a viable solution for the short term, until sustainable solutions could be devised for all non-serviced areas in the Dry Zone[164]. Considering the threats imposed by CKDu, the Ministry of City Planning and Water Supply has prepared a short-term strategy to address the coverage gaps in the vulnerable areas, for 2016, as follows:

Type of solution	Requirement (units)
RO Plants (10 m^3/day)	63
School RO plants	74
Hospital RO plants	18
Bowsers	6
Pipe line extension	300 km + new works

Table 12: Requirement of the facilities of MCP&WS for 2016

These RO or advanced filtration units are planned to be installed in Matale, Mannar, Vavuniya, Trincomalee, Kurunegala, Puttalam, Anuradhapura and Polonnaruwa Districts. The membrane filtration process removes toxic chemicals and heavy metals by straining the water through the tiny pores of a membrane. In Sri Lanka, large scale RO plants that can produce 10 m^3/day and

[164] Abegunaseka, A and Wickremasinghe, T. Undated. Short term measures to control Chronic Kidney Disease of Unknown Aetilogy. Ministry of Water Supply and Drainage

small plants which can produce about 5 m^3/day are being used. The smaller plant is generally provided to hospitals and schools.

The current requirement of water supply facilities has been estimated by the Ministry of City Planning and Water Supply in eight selected Districts (Table 13), which record the incidence of CKDu. The districts are Anuradhapura, Polonnaruwa, Vavuniya, Puttalam, Trincomalee, Mannar, Kurunegala and Matale. The requirements are as follows:

Item	**Cost per one plant/tank/ scheme LKR**	**No of plants/tanks**	**Total Estimated Cost LKR Million**
Community water supply projects (Simple treatment)	20 million	25 projects	500
Pipe Line Extension		100 km	450
Medium scale water supply project in 8 districts	80 million	8	640
Rain water Harvesting tanks	75000	1800	135
RO Plants			
Large - 10 m^3	2.5Mn	75	175
School – 5 m^3	0.5Mn	40	20
Hospital – 5m^3	0.5Mn	15	7.5
Total			**1927.5**

Table 13: Water supply facilities required in selected districts affected by CKDu. The technical details of these facilities are provided in Annex 3.

4.1.3 Gaps in forecasting and weather and hydrological observations

In order to develop short to medium term forecasting capacity, the Meteorological Department has pointed a number of gaps in coverage of Automatic Weather Stations (AWS) linked to the existing telecommunication system. These gaps are especially visible in the northern, north central and northwestern areas of the country (please see Figure 19) where drought and flash floods are increasingly common. To predict floods with accuracy, water level measurement and monitoring is required. Of the 103 river basins, many Dry Zone river basins do not have sufficient stream gauges. Furthermore, most of the village irrigation reservoirs do not have water level measuring gauges or rainfall measuring facilities. Many village irrigation systems do not have arrangements to monitor reservoir water level and facilities or knowledge to link its change to a rainfall value. Additionally these measurements are not transmitted to a central server or used for monitoring and water management purposes i.e. planning and scheduling water releases etc. In addition, the DSWRPP provided the 122 hydro-meteorological stations, 17 of which include weather stations. Figure 19 indicates the location of these stations (denoted as HMIS+ weather). It can be seen that the coverage is low in the Dry Zone river basins. Furthermore, during the floods of 2011 and 2013, ID found that previously planned water level measuring stations under HMIS component of the DSWRPP in major reservoirs and rivers are not adequate. Similarly, as HMIS are located on the major stream of a river basin and major reservoirs, it was found that village irrigation systems are left out, though they could make a contribution to flood early warning.

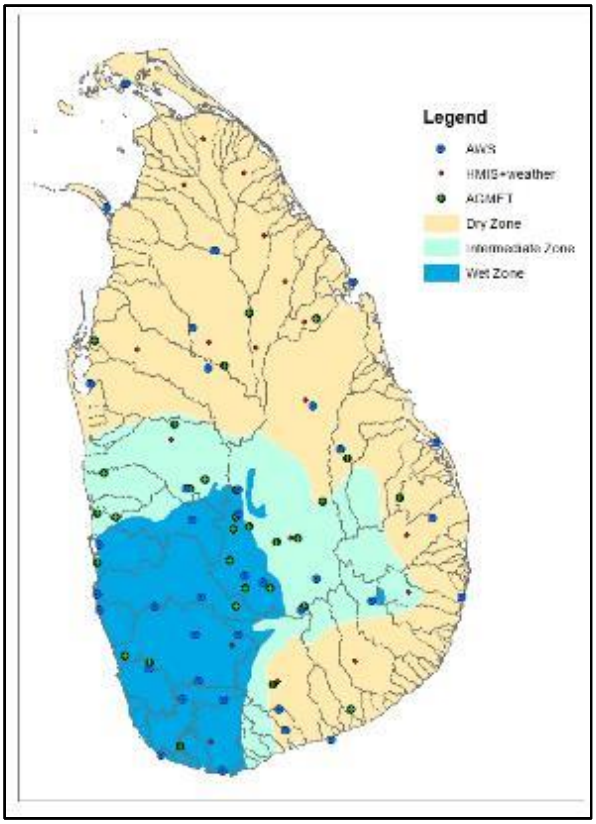


Figure 19: Location of weather stations in Sri Lanka.

(Note: HMIS – Hydro meteorological information system source: www.meteo.gov.lk and ID)

There are 42 agro-meteorological stations maintained by various government institutions including DoA and DAD. Their coverage is insufficient to capture the variations in different agro-ecological regions[165] and the non-uniformity of coverage and lesser density of stations in the Northern and North Central Provinces shown by Figure 19. Due to relatively low maintenance and replacement cost, there is the potential to share the management of any new stations with communities, as well as involve them directly in the use of data for management planning.

While it is generally agreed by the DoM, DAD and ID (Irrigation Department) that coverage by AMS, automatic rainfall stations and HMIS stations is not adequate, the required number has to be assessed through an analysis of the respective river basins, considering the relative importance in terms of irrigation, drinking water, and disaster management, with due consideration to agro-ecological regions. This is now at a very early stage, but some initial assessments have been carried out under the World Bank's CRIP and in Mi Oya and Yan Oya by ID.

With regard to agro-meteorological stations (AMS), the available stations do not adequately cover the river basins in the Northern and North Central Provinces. The DAD specifies that AMS should cover the major agro-ecological zones, to use such data for agricultural planning. The DoM and DAD estimate that addition of two to three stations, which measure rainfall, temperature, wind

[165] Source: Discussions with DAD and DoM

velocity, relative humidity and evaporation for the river basins in the Dry Zone are required. In combination with these stations, automatic rainfall stations are needed. Additional automatic rainfall stations requirement is approximately 3 stations for a river basin, based on the main agro-ecological regions in the basin.

4.1.4 Infrastructure design gaps that intensify vulnerability

Despite the important role of village irrigation systems in providing food security, the capacity to adapt to climate change is constrained by several factors. First, water storage capacity of approximately 13,100 village irrigation reservoirs is substantially reduced. As many of these reservoirs are not connected to perennial streams and diversions from the Wet Zone, their capacity to adapt to droughts is dependent on how much rainwater that can be retained during the wet season. In addition, their flood management capacity is poor, resulting in frequent dam breaches.

Though the hydrological design of village irrigation cascade systems facilitate optimizing water use, the same design intensifies the vulnerability of these reservoirs to floods, unless tank bunds and spillways are strengthened and water retention capacity is improved by at least partial de-silting. As such, investing in rehabilitating juts a part of the infrastructure is counter-productive and could actually expose the system to greater threats.

Local watersheds of village reservoirs are deteriorated due to removal of tree cover and cultivation in the watershed. With the absence of any structural measures such as dikes to retard the flood inflow, the high intensity rains, as mentioned before, result in further degradation of the watershed and siltation of reservoir bed.

While local soil laboratories and “soil health card system” can improve the understanding of soil conditions that affect water quality, the number and distribution of laboratories are inadequate to provide satisfactory service to farmers. Accordingly, DAD has estimated that main laboratories at district level and improvements to existing ASC level mini-laboratories are required.

4.1.5 Technology gaps for irrigation, water purification, climate smart agriculture and early warning for extreme climatic events

As described in Chapter 3, there had been many interventions by government and NGOs to rehabilitate village irrigation systems. Most projects such as VIRP, NEIAP and NIRP focused on rehabilitating irrigation infrastructure Projects such as IUCN/HSBC and SAPSRI have provided the farmers with guidance to restore and manage local watersheds as well. However, there is a clear need for incorporating the effects of climate change and learn from isolated and undocumented design changes such as those carried out in the Giant’s Tank rehabilitation works in the Mannar District.

Climate resilient crops and ecological agricultural practices have been tried out in a number of previous and on-going projects (see Table 10). Livestock are increasingly included to improve food and nutrition security, and may contribute to increasing biodiversity[166]. However, low level of adoption by the farmers indicates inadequate technology transfer to the farmer level, among others. While it is found that excessive application of fertilizer and agro-chemicals result in health

[166] World Bank, CIAT, 2015

hazards, required scientific information and technology awareness for adopting alternatives is inadequate. This is especially noticeable with micro irrigation, especially drip irrigation, which has been proved effective in increasing water use efficiency and thereby improving the resilience to climate change impacts. The adoption of such technologies by the farmers, and the sustainability of their practice is low. A major reason for this is that the technology of micro irrigation is often available with the manufacturers and service providers only, and therefore, the farmers have to depend on them for O&M and replacement of parts.

The technology for operation and maintenance are largely in the hands of the institutions and the private sector that provide such services. As the advanced filtering methods including RO plants use comparatively new technology, there is a need to transfer the knowledge of operation and maintenance as well as the system design information to especially the educated youth. The beneficiaries have to depend on the state and other institutions to measure water quality, and therefore, pollution of the sources and its seasonal variations remain undetected, at times.

The main challenge posed by climate change on agriculture relates to increasing rainfall variability and seasonal uncertainty. Lack of climate forecasting models and dissemination methods to farmer community hinders the local level crop planning decisions. The Dry Zone farmers in general and the farmers of village irrigation systems in particular, have inadequate access to weather information, both seasonal forecasts of droughts and early warnings about floods. However, there is no such mechanism in place for village irrigation systems to disseminate the weather and climate related information to the farmer community. Even when early warning is received by the farmers, they lack of the capacity to respond to such warnings by adapting their agricultural and local water management activities. This lack of capacity affects agricultural productivity, sustenance of livestock as well as drinking water supplies, through inability to allocate sufficient water for domestic purposes at the beginning of a cultivation season. Even in the case of major irrigation systems, there is a need to improve the quality of weather forecasting, with additional observation stations and efficient dissemination methods in place. A large number of major irrigation reservoirs are sources of drinking water as well, and climate forecasting helps water allocation decisions in such systems too.

In addition to reliable weather data, information on vulnerable areas is required to respond to floods. Under the CRIP discussed in Chapter 3, flood risk modelling and mapping will be conducted in several river basins including in Kala Oya and Malwathu Oyain the Dry Zone. Irrigation Department has identified six other river basins for similar interventions including Yan Oya and Mi Oya, but they are not covered by the current funding arrangements. Accordingly, several technological gaps with regard to flood modelling exist in some river basins. As shown in Figure 20, there are gaps in flood modelling as many river basins are not covered by CRIP, but needs flood modelling due to increased intensity of rainfall.

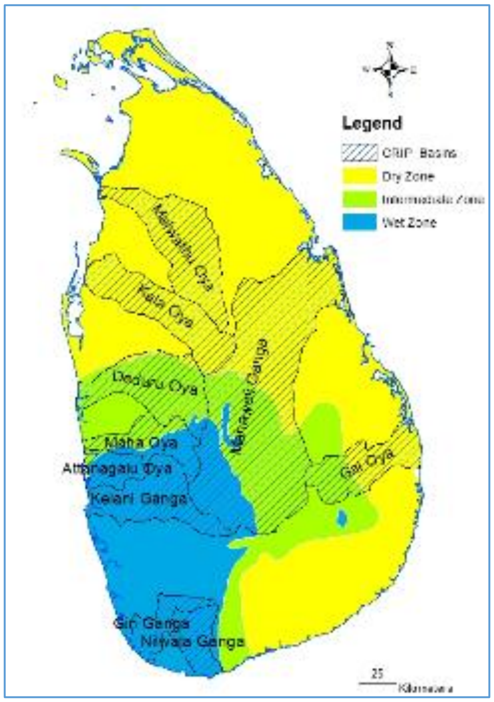


Figure 20: River basins to be included for flood modelling under CRIP

4.1.6 Gaps in Institutional service provision coverage/capacity

Farmer Organisations (FO) generally manages village irrigation systems, and they are registered under the DAD, with a legal basis for various functions including fee collection from members. While the FOs can make a valuable contribution to planning, improving, upgrading and maintenance of irrigation systems, previous experiences in PEACE and DZLiSP discussed in section 3.2 has highlighted the need for training on construction management and financial management at the initial stage of the rehabilitation. The need for watershed management, soil conservation and home gardening has also been highlighted[167].

As hydrology connects several irrigation systems in a cascade (see Annex1), there is a need to manage the cascade holistically to address water management, flood mitigation and agricultural management activities. This need has been recognized by the project implemented by Plan Sri Lanka, and in the proposed NCP Canal Project. This is especially important for multiple-use reservoirs serving irrigation, water supply and other local needs.

While there are technological packages for ecological and climate resilient agriculture, their adoption is low among the farmer community, despite livelihood losses and health risks caused by crop failures and water pollution. The relevant information to create awareness has to come from several organizations and at present, the coordination for such information dissemination is weak. In addition, the institutional responsibilities in the management of the upstream watersheds of village irrigation systems are not clearly defined. At present, no government institution is taking a

[167] Aheeyar, 2013

clear responsibility for the management of these watersheds. As a result, they remain exploited and degraded.

While there is a marked improvement in climate forecasting and early warning of climate-induced disasters in terms of technical capacity and instrumentation, there is a clear gap in terms of dissemination the required information to the grass-root level, in a form of communication the communities can respond to. Effective participation of the farmer community in flood and drought management at the cascade level is important in the face of the frequency of such events. In a flood and drought event, water allocation decisions among users of the reservoir, and among reservoirs in the same cascade is useful to mitigate the adverse impacts, but such practices are not in place. Most of the decisions taken by the farmers and local level authorities are based on limited knowledge of potential precipitation levels, capacities of the irrigation networks and the availability of water for agricultural activities

4.1.7 Sectoral nature of planning and executing service delivery to local communities

Many large rural development projects focus on expanding services through key line ministries and department, preventing a comprehensive local solution to water management. This is due to the sectoral nature of development planning and execution, which is further complicated by multiple actors at local level. However as Sri Lanka's water resources are mainly distributed along well-defined river basins with distinct geo-physical and agro-ecological characteristics, rural development plans that do not take a comprehensive river basin approach are often less sustainable and more exposed to climate change impacts on water resources.[168] Many projects described in Chapter 3 do not lend themselves to integrated solutions for irrigation, agriculture and drinking water. At times, competing demands for water and conflicting interests of the different agencies make integrated planning a challenge.

Rural development planning and budgeting is done on a sectoral basis that also filters down to local level CBOs. Often Farmer Organisations are associated with irrigation maintenance and rehabilitation, while different CBOs are established to manage drinking water projects including RO systems (such as the CWSSP and other national Water Board initiatives). Agriculture related initiatives including value addition and new technologies are delivered to the village through several community organisations, including women's organisations, with the same community members often present in different organisations.

4.1.8 Coordination between of sectors when implementing water resources development programmes in the field

District and divisional development committee meetings are often presented as the best mode of coordination between these different initiatives in the field. However these meetings generally only provide the space to share information but are not tailored for/conductive to inter-sectoral planning. The lack of technical guidelines or procedures to implement a river basin approach to water resources development and management make it difficult to resolve the issue of such inter-sectoral coordination.

[168] Sector Vulnerability Profile: Water. National Climate Change Adaptation Strategy for Sri Lanka (2011-2016) ADB and Ministry of Environment 2010

Most of the development planning and coordination occurs at the level of D.S. Divisions, where the Divisional Secretary has the overall mandate to coordinate and ensure harmonized approach to local development planning and implementation. However, rural development interventions have a large number of actors, and the multiple layers of governance as described earlier in Chapter 2 complicate their coordination. Most of the development plans and financing for them is provided through the central sectoral Ministries and there is often extremely limited information sharing and coordination at the local level by the different sectoral agencies. Some Ministries/ Departments plan and budget for activities at a scale larger than a Division (the Irrigation Department, the Mahaweli Authority and DAD work along geographies, which may encompass many D.S. Divisions), or at site level (National Water Supply and Drainage Board will oversee only water intakes and supply schemes). This leads to disjointed planning and implementation of activities – and with extremely limited or no considerations for issues that cut across jurisdictions. Provincial level institutions for agriculture, irrigation, health and rural development further complicate the picture.

There are weaknesses and overlaps in the role of government institutions, and this is more evident in the case of village irrigation systems. The current institutional arrangement of the government and local government institutions is not strong enough to mobilize the farmers to adopt sustainable agricultural and watershed management practices, as shown by the project implemented by Plan Sri Lanka[169] and EPWSDP (see Table 7). In addition, the irrigation systems in a cascade are often managed by several organizations such as the DAD, PID and ID, resulting in overlaps of functions. The absence of a mechanism to coordinate is a constraint to operate and manage the cascade and its water resource as a planning unit.

4.1.9 Fractured responsibilities of service agencies where overlaps and gaps in jurisdiction challenge a landscape approach

Due to the number of national, provincial and local institutions engaged in delivering services, there are a number of overlaps and also gaps in coverage/jurisdiction. For example, both Agrarian Services Department and Provincial Agriculture Department is responsible for agricultural production. Different national institutions that have offices at the Divisional Secretariat handle Plantation and spice crops. Disaster risk reduction is the overseen by a Divisional Disaster Officer, but drought management is generally the responsibility of Department of Agriculture and flood management is an assigned responsibility of the Irrigation Department. Drought management also needs to integrate drinking water shortages and needs and water sharing protocols in surface water bodies during drought. Segments of a sub-basin (such as the local watersheds) and aspects such as quality of drinking water become orphaned in terms of responsibility. These necessary aspects of an integrated approach are not managed or maintained by any of the multitude of national and provincial agencies

4.1.10 Knowledge and technology gaps to adapt traditional practices to modern challenges

Climate resilient crops and ecological agricultural practices have been tried out in a number of previous and on-going projects (see Table 7). Livestock are increasingly included to improve food

[169] Aheeyar, 2013

and nutrition security, and may contribute to increasing biodiversity[170]. However, a low level of adoption by the farmers indicates inadequate technology transfer and knowledge to the farmer level. While it is found that excessive application of fertilizer and agro-chemicals result in health hazards, required scientific information and technology awareness for adopting alternatives is inadequate. This is especially noticeable with micro irrigation, especially drip irrigation, which has been proved effective in increasing water use efficiency and thereby improving the resilience to climate change impacts. The adoption of such technologies by the farmers, and the sustainability of their practice is low. A major reason for this is that the technology of micro irrigation is often available with the manufacturers and service providers only, and therefore, the farmers have to depend on them for O&M and replacement of parts.

Dry Zone farmers in general and the farmers of village irrigation systems in particular, have inadequate access to weather information, both seasonal forecasts of droughts and early warnings about floods. However, there is no such mechanism in place at the local level to disseminate the weather and climate related information to the farmer community. Even when farmers receive early warnings, they lack the ability to correctly interpret the warnings or the capacity to respond to such warnings by adapting their agricultural and local water management activities. Even in the case of major irrigation systems, there is a need to improve the quality of weather forecasting, including the content, accuracy and presentation of information. This requires additional meteorological and hydrological observing stations (see Figure 15 and Figure 16), the ability to translate the raw data into useful and actionable information, as well as ensure that efficient and timely dissemination methods are in place to reach farmers and water managers.

This gap was evident during 2011 floods that affected a large number of village irrigation systems. In the aftermath of floods in the Dry Zone of Sri Lanka in January 2011, the International Centre for Water Hazard and Risk Management (ICHARM) under the auspices of UNESCO, fielded a mission to study the causes of floods. The mission found that the flooding was mainly due to the release of excess water in irrigation tanks (reservoirs) through the spillways. It was noted that reservoir operating rules, and better communication between upstream and downstream users, could have minimized the damage. At the beginning of the spell of rainfall prior to the floods, most of the irrigation tanks (reservoirs) were full, and there was the option to gradually release water in the tanks to avoid massive releases later on (which caused the floods downstream). However, the mission noted that this option could have been feasible only if there is a reliable rainfall forecasting system[171]. At the river basin level, the problem is aggravated by non-availability of flood and water resource modeling and inadequate coordination of gate openings due to divided management responsibilities among institutions and FOs.

4.1.11 Financing to overcome and repair repeated damage to village infrastructure from cycles of disasters

The Government of Sri Lanka, despite its commitment to uplifting the rural economy and overcoming key vulnerabilities, is hard pressed to keep re-investing in repairing damages to rural infrastructure from repeated cycles of disaster. As explained in sections 1.2 and 1.3 cycles of flood, intense rainfall and periods of deep drought have intensified causing damage to irrigation, water supply, roads and other rural infrastructure. The Climate Resilience Improvement Project of the

[170] World Bank, CIAT, 2015

[171] Jayawardena, A. W. 2011. Report on the UNESCO-ICHARM mission to Sri Lanka. Public Works Research Institute Tsukuba, Japan

World Bank is spending USD 80 million on repairing damages to major/large irrigation schemes that are managed by the Irrigation Department. The project and other government investments, however, cannot meet the demand for repairs and upgrading of village irrigation systems to withstand repeated climate impacts. Village systems are generally repaired and maintained by the community through FOs, however the cycle of disasters has been so intense and with short turn-around time lately, that such traditional community-based systems of upkeep are no longer able to cope.

4.2 Technical, financial and institutional barriers to addressing identified gaps and needs

Strengthening the resilience of smallholder farmers through upgraded village irrigation and drinking water systems in the Dry Zone using an integrated landscape approach is constrained by a number of barriers.

There is a lack of a strong institutional framework that allows sharing information and coordination to enable climate-smart adaptation of existing solutions, including combining traditional local knowledge with scientific information, for carrying out risk assessments at the local level and communicating risk reduction options to farmer communities, as well as for communicating early warnings that will minimise residual risk and the loss of lives and assets. Sri Lanka's dual governance system creates a plethora of central/local government institutions at the local level that take ownership of different geographies and of different responsibilities for water management, which can create competing mandates and significant inefficiencies.

The preceding chapters provided information which shows that Dry Zone communities are small land holders, who are heavily dependent on the village irrigation systems for their agriculture-based livelihoods and domestic water needs. Current development trends and plans do not indicate siting of industries or large-scale urbanization in these areas limiting the options of Dry Zone villagers to engage in other avenues of income/livelihood. In these villages the main non=agricultural avenues of employment are 1) migrating to cities in search of work during the dry season 2) joining the armed forces (this too is limited now that the war has ceased) and 3) migrating to the Middle Eastern countries in search of unskilled/semi-skilled jobs. Very few people (1-2% are engaged in government jobs such as teaching, village administrator, development officer etc. As such, the rural community in the Dry Zone will continue be dependent on agriculture as their main livelihood option and on irrigation reservoirs to meet their water needs in the foreseeable future.. This dependency will be more pronounced in village irrigation, where local rainfall is the main water source. Accordingly, the analysis of barriers will focus on irrigation in general and village irrigation systems in particular.

Limited financial capacity of government agencies to invest in upgrading village infrastructure especially irrigation and drinking water systems to withstand climate impacts
Traditionally, small farmers have managed their village irrigation systems, building on local knowledge and generally using their own resources, and communities have operated and managed community water supply schemes. But years of neglect of the irrigation systems, and the cumulative deterioration resulting from increasing climate events, have reduced productivity and impoverished small farmers, so that farmer organisations no longer have the capacity to manage

water for agriculture and domestic consumption with their own resources. The pressures of eking out a living, lack of social and political capital and voice, plus the marginalisation in national investment strategies that favour major irrigated systems have limited farmer organisations' ability to mobilise resources. The Government too has been constrained by a number of factors to invest in these small village irrigation schemes. The security situation in the war affected areas, including the border areas in the north and east and competing post-war reconstruction pressures have diverted government resources to meet other infrastructure needs. An unsustainably accumulated public debt has created a situation of insufficient government revenues to meet recurrent expenditure including expenditure related to development projects that have already been started. The current water crisis also warrants extensive investments in long term solutions such as rainwater harvesting, advanced filtering methods and short term capital-intensive schemes such as RO filtration options, the financial costs of which are outside the financial capability of individual farmer households or of communities and the demand for which, being widespread in the Dry Zone, extends the capacity of government.

Government institutions are also constrained by funding to reach the more vulnerable areas where many of these cascade systems exist, for providing extension services to agriculture and irrigation, or for establishing local seasonal forecasting services that are responsive to local conditions. Existing Agrarian Service Centres are underfunded and do not have the capacity to respond to the multiple needs of smallholder farmers. A cash-strapped national treasury with competing development priorities is unlikely to invest in disaster risk reduction, even though better risk management is likely to reduce the recurring costs of flood, damage and repairs to rural infrastructure and relief payments to disaster-affected households. Furthermore, the remoteness and disconnect to the national road network in many districts makes village irrigation systems an unlikely target for private sector investment, domestic or foreign.

Farmer Organisations collect a moderate amount of money for O&M of the irrigation facilities, but the collected fees are not sufficient to meet the maintenance needs, worsened by recent flood damage, conflict related abandonment and siltation of irrigation systems. Farmers' are also constrained by their inability to make initial financial investment to obtain seeds, planting material, organic farming tool kits and micro-irrigation kits required for climate smart agriculture. The experiences from Sri Lanka and India related to micro irrigation systems show that initial external investment is vital to popularize such new technologies. Financial constraints also prevent FOs adopting a more rational scientific approach to agriculture such as soil testing at local level. The government is cash strapped to support establishment of new laboratory facilities for the major districts such as Anuradhapura and Kurunegala and to improve the existing mini laboratories with better equipment.

In the field of rural water supply, many community organizations have demonstrated their ability to operate and maintain such systems. However, they lack the financial capacity to install or establish water supply and simple treatment facilities, as well as advanced filtering plants and RWH units. The records available at community-based organizations show that community water supply schemes are capable of operating at a profit and manage their maintenance affairs, when the initial capital investment is provided. While social and attitudinal barriers to use rainwater for drinking and other domestic uses are diminishing, the affordability of rainwater harvesting systems, especially the investment in a tank and possibly upgrading a roof, is preventing some households from adopting them.

Because Government institutions are constrained by the lack of funds to map the inundation and vulnerable areas, local organisations have limited information to respond to flood warnings. Carrying out surveys and ground level verification of output from models developed for flood mapping is a crucial need but requires significant financing. Financial support is also needed to establish additional AMS, rain gauges, water level recorders at strategic locations and community managed reservoir water level and manually operated rain gauges. Many technical agencies including the Department of Agriculture, the Department of Agrarian Development, and the Meteorological Department etc. have limitations in accessing technology that can improve their service delivery to the local level. While the DoM currently develops seasonal and other weather forecasts, the accuracy and the reliability of these measurements needs to be further improved with better spatial coverage. DoM and DAD have identified that additional weather stations are needed to improve the accuracy of these forecasts at the district, cascade and river basin level. Inadequacy of automated rainfall stations at identified strategic locations in the river basin is a constraint for early warning system. It is estimated that in large Dry Zone river basins, the requirement of automatic rainfall stations range from 3 to 4 per basin. In the case of flood warning, the absence of automated water level sensors at vulnerable locations in the river basin hinders the early warning capability and the recommendation by the DAD is that there should be two such sensors for each watershed. Community- managed manually operated water level gauges are required at each village irrigation reservoir and manual rain gauges are needed in relation to village irrigation systems or villages. Wherever an automatic gauge is used a manual gauge should be installed to provide for equipment failure (as a backup) and to enable local level engagement directly with measurements without relying on more sophisticated ways of receiving data.

Limited technical guidance and procedures for to apply a river basin approach for integrated water management

Despite scientific studies and general expert agreement that a river basin or hydrological landscape approach is required to tackle impacts of flood and drought in Sri Lanka, there is no clear technical or institutional guidance on this. This has complicated the field application of integrates sub-basin level interventions, especially rehabilitation of cascades for multiple uses.

There is an urgent need to improve awareness and understanding among government personnel working at national and community level to appreciate the inter-linkages at landscape level between different sectors engaged in water management. Often social protection/safety nets or expensive technical solutions are proposed in place of sustainable and affordable interventions for poverty reduction and short term concerns tend to take precedence over long term solutions. Insufficient collaboration exacerbates the lack of institutional capacity to generate adaptive solutions, to co-create knowledge with farmers and communities and to learn from others. The importance of understanding the work of non-governmental organisations who have implemented integrated and coordinated approaches to addressing rural poverty needs to be underscored.

Weak institutional coordination to implement a river basin approach in village irrigation cascade systems

There are institutional and coordination challenges for different agencies to work together to create climate smart, integrated, locally relevant solutions. Agriculture and water infrastructure management are both national responsibilities and devolved subjects under Sri Lanka's 13th Constitutional Amendment. As a result, a multiplicity of national and provincial government institutions work with farmers at the local level. Ensuring that the project initiatives to strengthen the resilience of small farmers to climate change related impacts are supported and sustained, the officers of national government agencies like the Department of Agrarian Development, the Ministry of Agriculture, the Irrigation Department, the National Water Supply and Drainage Board, need to work with each other at the national and local levels, alongside officers of the local Provincial Council institutions such as the Provincial Departments of Agriculture, and also relevant NGOs and the private sector.

There is an urgent need to improve awareness and understanding among government personnel working at national and community level to appreciate the inter-linkages between climate change/disaster risk, poverty reduction, environment management /development. Often social protection/safety nets or expensive technical solutions are proposed in place of sustainable and affordable interventions for poverty reduction and short term concerns tend to take precedence over long term solutions. Insufficient collaboration exacerbates the lack of institutional capacity to generate adaptive solutions, to co-create knowledge with farmers and communities and to learn from others. The importance of understanding the work of non-governmental organisations who have implemented integrated and coordinated approaches to addressing rural poverty needs to be underscored.

The Agrarian Service Centres that serve a cluster of villages can be a focal point for facilitating such coordination at local level, though currently their capacity to do so is limited.While the ASCs were designed to provide various services required by the farmers in a coordinated manner, the weaknesses in the ASCs –such as lack of trained advisors, lack of funding, lack of modern equipment such as computers and software such as GIS -prevent such services being provided in an efficient manner. With impacts of climate change increasingly evident, the weakness of ASCs is being highlighted as unable to deliver a coherent and practical package of solutions to farmers.

Limited knowledge and technical guidance on climate resilient practices, especially for infrastructure development, in irrigation, agriculture and drinking water supply

The absence of technical guidelines, which consider the irrigation systems, watersheds and the cascade in an integrated manner, remains an obstacle to sustainably improve and upgrade these systems. There are important lessons learnt from recent interventions such as selection on a hydrological basis, watershed management, and irrigation infrastructure improvement with a view to mitigate flood and drought (see Table 7). However, these lessons are often not integrated in project planning and day to day operations. A complete package of technology for the upgrading, improvement (to deal with climate change), operation and maintenance of VIS is not currently available through the government institutions.

With regard to climate smart and ecological agriculture, the DoA has developed a set of instructions on crop types, which are suitable for different ecological zones and climatic conditions. There are tool kits designed for organic farming as well. However, inadequate technical documentation which packages such instructions tailor-made to suit the particular agro-ecological zone of a village reservoir system is a constraint to adopt such solutions at the farm level. Extension officers do not effectively pass on these recommendations to farmers, with clear instructions on practical applications of the recommendations.

There is limited knowledge in the community on short- and long-term solutions to water pollution. Field observations and community consultations showed that over exploitation of the existing sources is depleting the sustainability of the quality and quantity of water available at source in areas such as Puttalam, which needs to be addressed immediately. While there are plans by the NWSDB to extend current pipe-borne coverage to more households, either through main grid or community water supply schemes, the quality of local sources remain a major challenge. CBO and NWSDB records of water quality confirm the quality challenge and the community is quite aware of this situation.

While the existing CBOs managing rural water supply schemes are generally functioning well, inadequate technical knowledge of water source protection as well as the ability to operate and maintain new innovations such as advanced filtering plants prevents these facilities being used in a sustainable way. Questions about appropriate waste disposal and long term commitment of private sector suppliers to provide maintenance and waste disposal remain moot.

Limited knowledge and awareness of climate-change risks, impacts, and adaptation solutions:
Generally there is awareness that recent changes in weather patterns and increase in extreme climatic events may be partly attributable to climate change. However there is limited availability of information as well as lack of knowledge sharing mechanisms to develop, disseminate, and adopt climate-friendly practices. This is true for village irrigation management, agricultural planning as well as for urgent responsive action to extreme weather events. There is limited infrastructure and technology to develop and disseminate climate-sensitive technologies and information.

There is no institutional knowledge management framework that facilitates knowledge generation and sharing on innovative and adaptive measures to improve local water management, climate resilient crops, water quality improvement, seasonal weather forecasting and early warning. Farmers and farmer communities have a very limited awareness of these adaptive solutions. At the same time the traditional knowledge on which communities depended for agricultural planning and water management is fast becoming inadequate in the context of climate change. The potential for scaling-up of good practices has not been addressed and an integrated approach, which incorporates multiple approaches to improving water management and supply, is yet to be mainstreamed.

Adoption of integrated solutions to sustainably improve and upgrade the irrigation systems, watersheds and the cascade are constrained by the lack of technical guidelines as mentioned before. There is no local or provincial knowledge management mechanism that extracts lessons learned from recent interventions to integrate in to a complete package of technology for the restoration, improvement, modernization, operation and maintenance for farmers. The DOA has initiated the development of climate-resilient cultivation packages, but their dissemination is constrained by the limited capacity of agricultural extension services to work with farmers to adapt these 'packages' to deliver practical and sustainable solutions. Adoption of solution packages such as climate resilient crops, agro-ecological zone based crop recommendations by the farmers is weak, also due to inadequate linkages with markets for different crops. This is the result of lack of communication linkages between markets such as village fair, supermarket chains including Keells and Cargills Food City and Dedicated Economic Centres managed by the Government and FOs/ASCs.

Access to improved weather forecasting and early warning is vital to improve the community resilience to climate change. To be relevant and useful at the community level, weather and seasonal forecasts need to be processed using local level information and additional coverage by meteorological stations. Field level officers need to have the technology knowledge so that they understand the uncertainties and vagaries of forecast information. They should also be able to transform this knowledge into a form and language that can be understood by farmers. Currently Farmers' Organisations do not have access to real-time rainfall and water level information at critical locations and are therefore unable to respond to the recent increases in the occurrence of extreme weather events.

In the past, farmers have employed different traditional methods to measure water levels or for forecasting weather patterns. The applicability of these methods in the context of climate change are now questionable, but inadequate and inaccessible information on rainfall and water levels constrain farmers efficient water management and response to extreme events. Such information barriers constrain the farmer organisations from making optimum allocations among domestic water needs and agricultural needs.

While these technologies could enhance the accuracy of forecasting, the field officers and FO and CBO officers need the necessary skills and computer software packages, which can be used to store, process and translate the data to local level warnings. Perhaps more importantly the skills required to understand a risk management approach in which weather, climate and hydrological information are one source of information, are lacking and there is a clear need for training on how to correctly interpret and use this information.

Limited community capacities to design integrated solutions sustainably manage rural infrastructure and resolve user conflicts over water management

As stated before, the lack of technology dissemination and financing remain a constraint for community based organisations in general and farmer organisations especially to adopt climate resilient practices and upgrade the local irrigation and water supply infrastructure. However, beyond these barriers there is also a gradual decline of FO functionality in terms of human resources and social organization. Confined to up-keeping VIS, many of which are already in differing states of deterioration, the FOs are not considered dynamic rural development organisations, nor do they attract young men and women to participate. Women's participation in traditional FOs is generally low, while in many villages, especially in the conflict affected Northern Province, women form their own organisations call WRDS (Women's Rural Development Societies). The potential for FOs to become dynamic local service providers meeting irrigation and drinking water needs of communities, while employing younger people with entrepreneurial skills exists but is not exploited. FOs could also be the conduit for technical information, disaster early warning and adaptation measures for drought forecasts to be communicated to the farmer community in the village or sub-basin.

FOs are currently established for irrigation systems which cover less than 80 ha, and as such it is difficult to influence the markets as a production unit. On the other hand, in the case of droughts and floods, the cascades of reservoirs have a better capacity to absorb the impacts, if well managed. Furthermore, the FOs are generally confined to the reservoir, appurtenances and the canal system and therefore, the institutional arrangement for the management of the watershed is not clearly defined. There is an institutional gap with regard to mobilizing the FOs to include the watershed in their maintenance program and to arrange the links with markets. FOs manage their water allocations within the individual irrigation systems, and their performance is generally acceptable.

From the lessons learned and described in Chapter 3, it is clear that provision of drinking water alone could become a viable, profitable enterprise at the local level. FOs lack organizational capacity, guidance, access to technologies and training on integrated planning to design and implement climate smart solutions to local agricultural and drinking water issues.

Chapter 5 : Recommendations for project interventions, given current efforts, gaps and barriers

The recommendations outlined in this Technical Feasibility are aimed at increasing the resilience or adaptive capacity of small-holder farmers in the Dry Zone of Sri Lanka to climate variability and extreme events. Therefore, they aim at increasing the ability of the farmers to cope with climatic challenges, as well as adaptive response to extreme climatic events.

The preceding chapters explained the importance of strengthened village irrigation reservoirs and their upgraded watersheds to cope with climatic challenges. Upgraded watersheds increase groundwater recharge and minimize reservoir storage loss, while increased storage and improved irrigation infrastructure better absorb the impacts of floods, maintain a carry-over storage to the dry periods and increase agricultural productivity, and thereby farmer incomes through efficient water distribution. Upgraded storage in reservoirs also increases the availability of drinking water (quantity), which has to be of sufficient quality. Availability of safe drinking water in adequate quantities reduces the risk of health hazards and saves time spent on fetching water. Thus, additional health related expenditure is saved. In addition, in a drought or post-drought situation where agricultural livelihoods are adversely affected, families would use the time saved in fetching water in other income generating activities. Accordingly, our recommendations build on the intricate nexus between village irrigation systems, domestic food security, farmer incomes and safe and adequate drinking water availability, and the role of this nexus in improving resilience to climate change. The recognition that sectoral approaches to drinking water and irrigated agriculture are inefficient in providing comprehensive climate resilience, highlighted in the previous chapters, influences the adoption of this approach.

In the previous sections, the policy and institutional framework governing water resources management, current efforts to improve rural economy and resilience, the gaps in the coverage and effectiveness of these efforts, and technological, financial and institutional barriers to bridge these gaps were discussed. This section proposes an approach and recommends certain key interventions, building on best practices and lessons discussed earlier.

5.1 Overall approach recommended to address the barriers

Stakeholder discussions pointed to the importance of adopting a river basin approach to enhance resilience to climate change impacts. Available literature (discussed earlier) also demonstrates that river basin-based management of water resources has been discussed substantially during the past decades. However, comprehensive river basin management plans giving due consideration to multiple water uses, disaster risk management and socio-economic aspects, were not undertaken until a few years ago. Under the DSWRPP (described in Chapter 3) two comprehensive river basin management plans were prepared for the Mahaweli Basin and Mundeni Aru Basins (in the Eastern Province). Following on DSWRPP, the World Bank funded CRIP (see Chapter 3) plans to develop basin management plans for 10 other rivers and ID has proposed similar interventions in six more river basins. As such, there is increased acceptance of the basin approach and acknowledgement of the hydrological nature of drought in Sri Lanka.

Several conceptual approaches to river basin-based water management have been presented by recent research work and these are summarized in Annex 1.

The approach adopted here aims to develop solutions at local level to multiple and sometimes-conflicting water uses. As discussed under lessons learnt, the lack of such an integrated approach especially between irrigation, agriculture and drinking water development plans has led to issues of sustainability as these are closely inter-linked in Dry Zone agricultural eco-systems. The idea is to promote a sub-watershed or sub-basin level water resources management plan (considering that village irrigation cascades are micro watersheds in a river basin) that incorporates the needs of multiple users. Establishment of cascade level Farmer Organisations (FOs) that enable multi-stakeholder planning can promote conflict resolution and the development of water-sharing protocols with community and user inputs. While different stakeholders linked to sectoral government agencies or different CBOs will carry out different activities under this sub-watershed plan, the integrated plan should be monitored by a common panel with representation from government and community users/beneficiaries.

For many centuries village irrigation systems provided communities with a means of coping with seasonal variability. Improving their functionality - by restoring traditional features but with modern risk reduction elements - is strongly recommended as a means of adaptation to climate change impacts. For example, community based adaptation projects implemented by the GEF Small Grants Programme in Sri Lanka (2010-2014) restored a number of village irrigation systems including five village reservoirs. It has been demonstrated through these projects that business-as-usual restoration of village irrigation systems, i.e focusing on the core infrastructure of the system, does not improve resilience to heightened cycles of flood and drought. Recognising the close inter-connectedness of different components of the village irrigation system, especially the catchment tree belt, home gardens, silt traps, water management techniques, water for drinking and appreciation of the multiple uses of the system, is essential to restore these systems to meet climate challenges. This was demonstrated in the GEF SGP Climate Adaptation project in Alistana, Anuradhapura. In addition to re-instating many traditional aspects of village irrigation systems, resilience to flood and drought requires cost-effective design changes and enhancements to the system (including village tanks) to reduce flood damages and improve dry-season storage.

A holistic approach to village irrigation rehabilitation that can contribute to long-term resilience against climate variability would also consider the entire 'cascade' or sub-basin within which is it based as a planning unit. This is because rehabilitating single units of VIS would be counter-productive unless upstream and downstream components of this inter-connected unit are considered, as was demonstrated in the projects by Plan International and HSBC-IUCN. Such an approach would also ensure the long-term availability of drinking water in surface and ground sources, and enable local planning for drinking water needs that do not conflict with irrigation and other multiple uses.

Without modern inputs into water management planning, including agronomic practices that are tailored to withstand both longer dry periods and more intense rainfall, Dry Zone farming under VIS will not be viable even when infrastructure is upgraded. Additionally, the liberal and irrational use of fertilisers and pesticides, which have contributed to pollution of drinking sources, needs to be curtailed without compromising on yields. This requires investment in climate-smart and ecologically sustainable agricultural practices. For this and better management of water supplies and the cascade responses to floods and high rainfall, improved forecasting of the seasons and timely warning of floods is essential. This aspect of rural resilience should be tackled with more frequent and practically applicable information flow from technical agencies to farmers on weather and seasonal climate predictions. .

Women are affected more severely by climate change and associated natural disasters, such as floods, droughts, cyclones and storms, compared to men. Men and women are bound by distinct traditional, socio-economic roles and responsibilities that give rise to differences in vulnerability and ability to cope with climate change impacts. In Sri Lanka, the participation of women in community work is very high, with women to men ratio of 80:20. However, it is noted that not many women take part in the decision-making process. A rapid appraisal of the various community organizations in Sri Lanka's rural areas found that men play a major role in Farmer Organisations. It is very hard to find a FO led by a woman, although some women (rarely) bear important committee roles such as Treasurer or Secretary. However, the community-based model promoted by the Government for drinking water supply schemes is increasingly women-led. There are a number of women-managed water supply and treatment plants, including sophisticated Reverse Osmosis Plants supplying water to rural consumers. They are also active in the management of community water supply schemes as office bearers. Women's participation in water sector programmes and enterprises is very important because their incomes are more readily related to family well-being, compared to those of men. There is the potential to increase their participation, given comparatively non-restrictive social norms and the low disparity of literacy levels between men and women.

5.2 Proposed targeting criteria and geographies for intervention

Considering the lessons learnt from the NIRP[172], hydrologic linkages among village irrigation systems, and currently ongoing climate-resilient interventions such as CRIP, it is recommended

[172] DHV Consultants et al, 2000. Final Report. National Irrigation Rehabilitation Project

that the selection of village irrigation systems for improvement and upgrading be based on a river basin approach. The following criteria are recommended in the selection of river basins:

a. Inclusion of districts of high and medium vulnerability to climate change;
b. Inclusion of areas with high and moderate CKDu risk;
c. Inclusion of river basins with high presence of village irrigation and cascade systems.

This approach will enable socio-economic, health and hydrological factors to be considered in the design. Out of the Dry Zone river basins Mi Oya is considered as the most vulnerable river basin by studies using hydrological criteria[173]. Malwathu Oya is one of the two river basins mostly in the Dry Zone, selected for the World Bank funded Climate resilient Improvement Project (CRIP), which is to be studied for interventions to improve climate resilience and disaster management. Mi Oya and Yan Oya are selected for studies similar to those planned under CRIP, by the ID, and funding sources are being sought. Therefore the importance in improving the climate resilience and water related disaster management efforts in these three river basins is accepted and corresponding investment programs are to be developed in the future.

Considering the vulnerabilities described in sections 1.2, 1.3, 1.4 and the suggested key considerations in section 1.5, including the Agrarian Department's classification of river basins according to drought exposure and climate change risk, three river basins were identified for possible intervention: Malwathu Oya, Mi Oya, and Yan Oya (see Figure 21 for location of these basins in relation to the district vulnerability ranking shown in Figure 11 and the incidence of CKDu shown in Figure 10). These river basins span the northwestern, north-central and Northern provinces where vulnerability is intensified due the presence of large numbers of poor, smallholder farmers, chronic disease and the impacts of conflict over the past three decades.
These river basins have been experiencing elevated levels of extreme climatic events in the past ten years, especially intensified flood and drought. They also have a large number of village irrigation systems, especially cascade systems at the sub-basin level, providing an ideal platform on which to implement integrated solutions for water management in the Dry Zone that have been tried and tested through a number of previous projects, described in Chapter 3.

[173] Witharana, D.D.P., 2015. Ranking of Village Tank Cascades (Ellangawa) on potential coping capacity for climate change resilience in the Dry Zone of Sri Lanka. A paper presented at the INWEPF Symposium, 2015

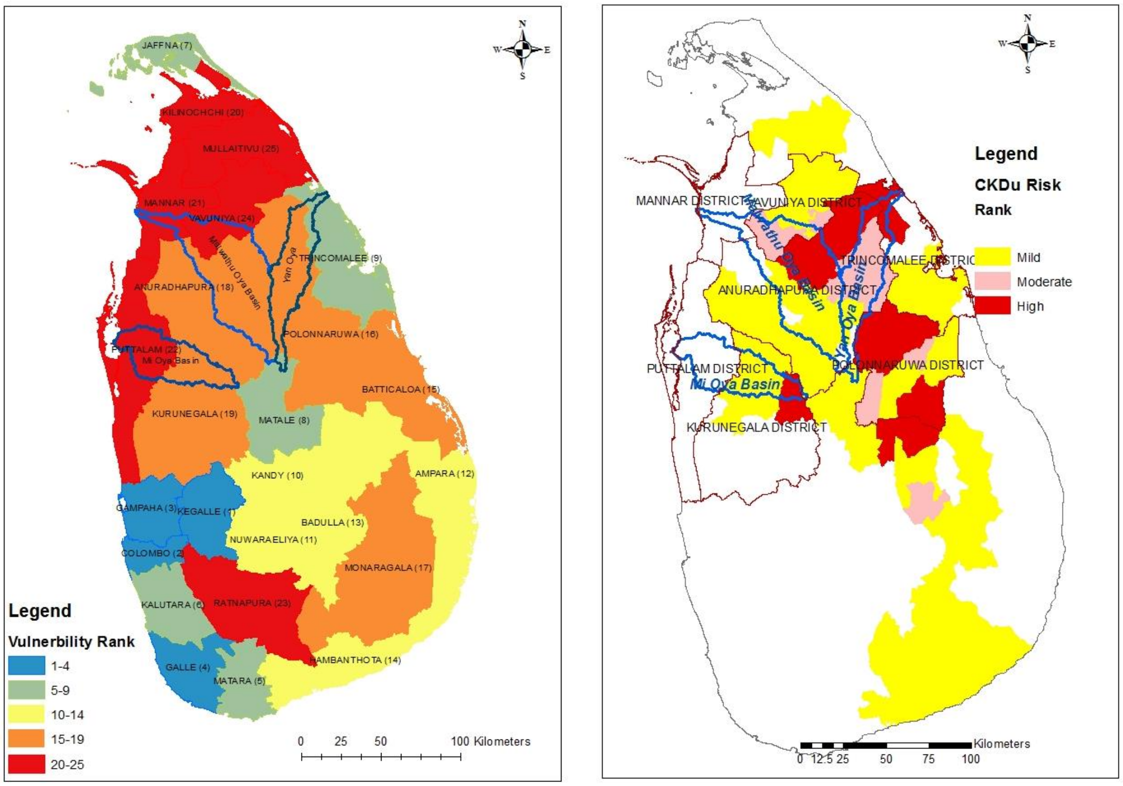


Figure 21: Climate vulnerability (left) and CKDu incidence (right) in relation to the target river basins

The three river basins include areas of high CKDu incidence and 1,731, 1,242, 746 village irrigation systems in Malwathu Oya, Mi Oya and Yan Oya respectively. They are the largest river basins to be benefitted by the proposed NCPCP. Part of the irrigation systems in these three river basins are to be improved by the NCPCP, and the return flows from directly benefited schemes are expected to expand the positive impacts to downstream parts of the basins. Therefore, the selection of these three river basins will enable an integrated set of interventions to improve the climate change resilience in priority areas, within the framework of a comprehensive river basin based climate resilience plan to be prepared in the future.

It is further recommended that the project makes interventions in three inter-connected subject areas; i) improvement and upgrading of village irrigation systems together with climate resilient agricultural practices; ii) provision of good quality water for drinking; and iii) improved access to useful and interpretable climate and weather information. Details of existing village irrigation systems found in these river basins are shown in Table 14.

Watershed Name	**Area Km ^{2}**	**No. of Village Irrigation Reservoirs**			
		Located in a Cascade	**Isolated**	**Total**	**Planned to be augmented by the NCP Canal Project**
Malwathu Oya	3183	1491 (86%)	240	1731	531 (31%)
Mi Oya	1561	1146 (92%)	96	1242	192 (12%)
Yan Oya	1529	618 (83%)	128	746	236 (32%)

Table 14:Village irrigation statistics in the selected river basins

Poor quality drinking water and associated health problems are difficult to address with a purely river basin approach. This is because the relationship of CKDu and water quality issues to river basin borders is not clear, and likely contributing causes, such as the presence of fluorides and contaminated groundwater aquifers, cut across river basin boundaries. As such, this study recommends that interventions to provide good quality drinking water be undertaken in seven districts; Kurunegala, Puttalam, Anuradhapura, Mannar, Trincomalee, Vavuniya and Polonnaruwa (Figure 21), all of which are connected to the recommended river basins. Out of these districts, Puttalam and Kurunegala straddle Dry and Intermediate Zones, while the other districts are in the Dry Zone. Figure 22 shows how the proposed district-river basin combined approach contributes to synergize the recommended interventions with the planned and ongoing interventions of CRIP and NCPCP.

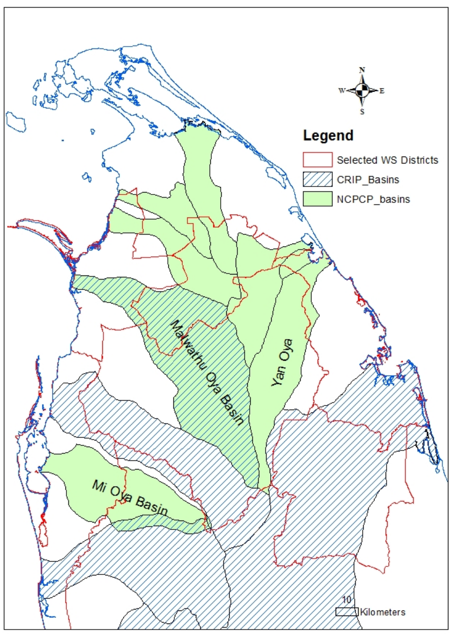


Figure 22: Spatial coverage by ongoing climate resilience projects and their relation to CKDu areas

Beneficiaries: Irrigation infrastructure development will directly benefit 16,800 farmer families or 67,000 persons. Provision of safe drinking water will further benefit 165,000 persons. The early warning and seasonal forecasting information component will benefit the entire agricultural community of approximately 1,000,000 in the three river basins and indirectly benefit the entire river basin population of 2.6 million through the reduction of water related disasters and impacts.

5.2.2 Community profiles

Poverty: Poverty statistics of the study were obtained from the survey data of 2012-13 published by the Department of Census and Statistics[174]. According to these statistics, average Head Count Index (HCI), which measures the percentage of population below the poverty line) was 6.7 for the country. The highest poverty levels were found in Moneragala (20.8), Mannar (20.1), and Mullaitivu (28.8). For this study, the DS Division level statistics were overlaid on the cascades in three selected river basins and Figure 23 shows the distribution of poverty, in relation to cascades. In the major part of the river basins, HCI was ranging from 4.0 to 12.0 and high poverty areas were HCI values from 8.0 to 12.0. HCI values between 12.0 and 20.0 were scarce, except in cascades in the Mannar district, where outliers with HCI values above 20.0 exist.

<u>Flood and drought affected areas:</u> The number of affected people obtained from the DMC was used to analyse flood-affected areas. The data indicate that coastal areas of Mannar, Puttalam and Trincomalee districts are highly vulnerable to floods. However, the middle reaches of Yan Oya basin is also subject to moderate levels of flooding and this was substantiated during the stakeholder meetings. Stakeholder meetings indicated that individual Tanks in some cascades are subjected to flood damage, though inundations of areas downstream of the cascade were also experienced. In the case of droughts, stakeholder discussions showed that generally the whole Dry Zone is affected in an event. Therefore, categorization of cascades using drought impacts was difficult.

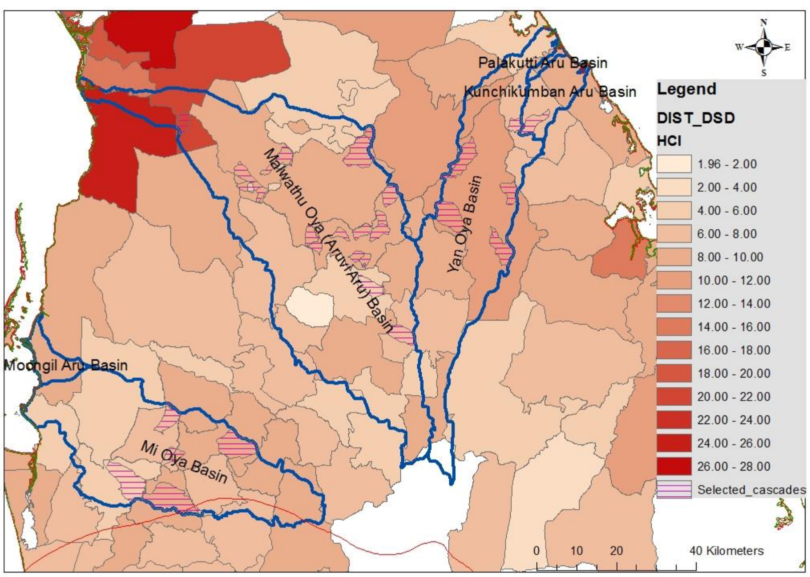


Figure 23. Poverty ranking of the recommended river basins and cascades

[174] DCS, 2015. The spatial distribution of poverty in Sri Lanka. DCS. http://www.statistics.gov.lk/poverty/SpatialDistributionOfPoverty2012_13.pdf

5.3 Climate-smart investments to improve resilience and upgrade lives and livelihood of small holders farmers in targeted areas

Taking in to consideration the lessons and best practices of past and on-going projects in water resources management; and in order to address the barriers listed out in the previous chapter this Study recommends the following interventions and activities that are cost-effective methods of improving resilience among small holder farmers in the Dry Zone. The interventions are classified in to four major areas or sub-sectors for ease of implementation through government and non-government partners. However, it must be stated at the outset that these should be seen as components of an integrated sub-basin/watershed level water resource management plan. Each cascade will have its own hydrological character and unique water use pattern and natural ecosystem. Therefore the recommended activities will need to be tailored to each cascade carefully considering anthropogenic and environmental needs, plus climate change related risks.

5.3.1 Improving and upgrading of village irrigation systems

Based on the gaps and needs identified in Chapter 4, this study recommends a suite of best practices and tested solutions for improving and upgrading village irrigation systems and modernization where necessary, together with watershed restoration, using an approach that would enable participation of both men and women farmers in all steps of implementation and sustained community ownership after the project lifetime. Government organizations currently involved in the management of these irrigation systems have demonstrated their ability to implement the physical work related to the irrigation infrastructure with FOs, as witnessed in projects such as NIRP and PEACE. In the case of watershed restoration and improvement, employing a non-governmental Partner Organization who has demonstrated capacity in this field is recommended engage and mobilize the farmers. The solutions are built on the lessons learnt from the analysis of previous efforts, outlined in Chapter 3.

Cascade systems targeted by the project

A number of cascades have been preselected through a methodology developed in consultation with DAD officials in the districts, and the technical working group (TWG) convened for project development. The below criteria was generally adopted to pre-select these cascades and target the most vulnerable and climate-sensitive geographies and communities in the river basins. The selection shall be finalized during implementation in consultation with the District or Divisional Agricultural Committees, which comprise local government officials and farmer organization representatives.[175] .

Selection of village irrigation systems for the interventions and targeting the vulnerable groups: The following considerations should be made:

- Based on the prioritization criteria currently being developed by the DAD, it is expected that about 30-40% of the irrigation systems will have a high potential to improve resilience if rehabilitated with the suite of interventions described below and also elaborated in Annex 2

[175] During district consultations for cascade selection, it was clear that final selection should be subjected to further local review including the need to reconcile with DAD's ongoing and planned upgrading activities with government investment.

- There had been recent projects such as PEACE project discussed in Chapter 3, and government investments in urgent rehabilitation, which have benefitted several village irrigation systems. If entire cascades were benefitted from such interventions they may be assigned a low priority, as many of the basic rehabilitation needs have been addressed
- Table 14 shows that about 10-15% of the village irrigation systems are located outside cascades, and isolated systems can be assigned a low priority unless vulnerability aspects like exposure to flood deem these areas deserving of intervention
- Priority should be given to cascade systems connected to drinking water supply schemes and having strategic importance in terms of flood management
- Livelihoods in the Dry Zone are linked to the village irrigation systems, and poorly functioning irrigation systems contribute to loss of livelihoods and poverty. Therefore, poverty can be considered as a criteria for interventions leading to improved livelihoods through better functioning irrigation systems
- As noted in Table 14, from 12% to 32% of the village irrigation systems in the selected river basins are planned to benefit from NCPCP. Such cascades will have an augmented water supply from the NCPCP (which is funded by the ADB) when it is completed around 2020-25. However, as the rehabilitation works of these cascades are still being planned at the conceptual stage, being benefitted from the NCPCP may not be considered as criterion to strictly exclude from the interventions

As such, it is estimated that 10-12% of village irrigation systems should be prioritised for improvements and upgrades.

Accordingly, consultations with the relevant institutions including DAD District Offices were carried out to get their inputs for cascade selection. During the discussions, most of the preferences provided by field officers were based on individual village irrigation systems. These preferences were combined with poverty (HCI) flood affected areas, and the incidence of CKDu. In addition, the DAD has developed a ranking system based on the coping capacity for Mi Oya Basin, and these criteria were also used for Mi Oya. In the other areas, DL1b agro-ecological region, which is considered as having a high coping capacity, was also considered in prioritization. The details of the recommended cascades in this manner are given in the Annex 2, and Figure 23 shows their locations. The number of village irrigation systems in the selected cascades works out to be about 325 village irrigation systems.

Thus, 325 village irrigation systems located in cascades are proposed for such interventions. The main components of an irrigation system to be improved and upgraded include the following:

i. Upstream watershed and immediate downstream of the reservoir
    a. reservoir bed,
    b. upstream reservation,
    c. upstream mechanism to trap sediment including small ponds and water holes,
    d. upstream earth ridges to retard sediment inflow,
    e. downstream reservation/interceptor to trap alkaline water seeping through the dam,
    f. command area drainage canal

    See Annex 1 for details of tree types etc.

ii. Reservoir bund (dam) and appurtenances

a. Dam consisting of an earthen bund with 1 vertical to 1.5 -2.0 (depending on the dam height and soil parameters) horizontal side slopes and top surface serving as a gravel road
b. Sluice with a gate with lifting arrangement, barrel and downstream well
c. Spillway made of concrete or stone masonry with the approach canal and the tail canal
d. Other structures such as lower level sluice or mud sluice, bathing steps

See Annex 2 for technical and construction specifications.

Based on the recent surveys conducted by the NCPCP and ongoing projects such as SCCF, SAPSRI and IUCN/HSBC, and gaps and needs identified in Chapter 4, this study recommends the following improvement and upgrading activities:

a. An awareness programme for FOs and field officers regarding their role in the recommended interventions and rapid appraisal of improvement and upgrading needs will be carried out prior to any physical improvements
b. Community mobilization through a non-governmental partner organization in consultation with relevant government organizations. This may be carried out during the project initiation
c. Mapping and demarcation of catchment, reservation, high flood level and downstream command area by Department of Agrarian Development (DAD) technical staff and Farmer Organisations.
d. Restoring and renovating the upstream watershed and downstream reservation by provision of dikes and silt traps and by growing recommended trees (see Annex 1 for details)
e. Strengthening the reservoir bunds (dams) by filling up eroded sections, bringing the slopes to technically acceptable gradients
f. Partial de-silting of the tank nearest to the bund to increase the storage depth and reduce evaporation losses by increased spread
g. Improving and upgrading the structural components of the reservoir including the spillways, sluices and bathing steps (see Annex 2 for technical details). In addition, the sluiceways should be incorporated with a suitable measuring device such as broad-crested weir flume. A bottom level sluice ("mud sluice") should be incorporated to the designs to facilitate periodical removal of accumulated silt.
h. The FOs should maintain the improved and upgraded irrigation systems, and responsibilities to manage the local watershed and irrigation infrastructure should be assigned to FOs. The government agencies responsible for these systems should continue to provide technical advice and training to the FOs and to attend to critical repairs to structures damaged by extreme events as well as structural improvements beyond the capacity of FOs

<u>O&M of improved and upgraded irrigation schemes</u>: While some FOs already operates a maintenance fund, it is required to create such funds where they do not exist, and provide advice to manage the existing funds better. The FOs are recommended to be actively involved in the improvement and upgrading activities and they may be contracted to carry out the work. A part of the incomes from such activities should be deposited in the maintenance fund

Improving the capacity of FOs to manage irrigation systems, through training in operation and maintenance, technology transfer to use weather, financial management, aggregating FOs and forming cascade level farmer committees, and market links are recommended to remove the institutional barriers to sustain the interventions in the long term. The targeted participants should include field officers of relevant government organizations, local farmer organisations and women's groups, while encouraging youth leadership, entrepreneurship and marketing training to ensure long-term sustainability. The FO is recommended to undertake O&M of the irrigation systems after improvement and modernization. To perform this function effectively, O&M procedures may be introduced to the FOs and required training should be provided. In addition, the FOs should be provided with O&M equipment such as bush cutters. The cost of O&M is calculated on the basis of LKR 120,000 per year for an average irrigation reservoir based scheme having about 16 ha of irrigated land. For a diversion (Anicut) scheme the corresponding value is LKR 70,000 for an average of 12 ha. However, being traditionally farmer-managed schemes, this requirement is partly met by the inputs from farmer communities in routine maintenance and operation. In addition, external support should be provided to the FOs to enhance their financial viability. Such support should be provided as O&M equipment and seed money to strengthen the maintenance fund.

Based on the lessons learnt from the projects implemented by Plan Sri Lanka, it is recommended that Cascade level farmer committees be formed comprising the officials of existing FOs. Water management at the cascade level and agricultural planning are recommended to be carried out by the cascade level committee. Active contribution by the government institutions such as the DAD, PID, PDoA and ID is recommended, such as technical overseeing and attending to structural failures beyond the capacity of FOs.

Where the village irrigation reservoir is used as a source for drinking water, the FO should function as the CBO to manage the drinking water supply facility, as well, in order to manage conflicts. FOs should be guided to establish a separate tariff structure for water supply facility, and they may set up a sub-committee to manage drinking water supplies.

Development of farmer institutions and cascade level water management committees to enhance the climate resilience: This includes capacity improvements of FOs mentioned above. However, those interventions alone will not be sufficient to address the issues of climate resilience. There is a need to manage water distribution among individual village irrigation systems within a cascade for multiple uses with fairness and equity as well as to optimally utilize the stored water. In addition, individual systems, commanding about 16 ha on the average, would not be able to influence the markets. Accordingly, this feasibility study recommends the formation of Cascade Farmer Organisations, to undertake cascade level water resources planning and agricultural planning. Similar interventions have been carried out in the projects described in Chapter 3. The cascade level farmer organisations could provide inputs to river basin management plans, which are envisaged to be developed under currently planned projects of the Irrigation Department. The cascade farmer committee should be guided by a cascade development and water management plan.

5.3.2 Climate resilient agricultural practices and market alternatives

The recommendations for climate resilient agriculture are based on the climate smart agricultural practices discussed in the Section 3.2.2 and lessons learnt discussed in section 3.3.4. Accordingly, **climate-resilient agricultural practices** and crops developed by the DoA (and field trialed/tested) with high potential for quick uptake **by farmers will be promoted through project**

interventions throughout the 70 ASCs. Together with the seasonal climate predictions and improved marketing options for the recommended crops, the climate resilient agriculture package will provide more food, income and improve ability of farmers to cope with seasonal variability and improve rational use of water (please see Annex 3 for greater details). The project will also promote the cultivation of traditional types of rice, which are drought tolerant, and high in micronutrients and with proven medicinal benefits[176] and locally adapted varieties of vegetables and other field crops.

This intervention should cover both the irrigated command area and the home gardens. This package of agricultural practices should be disseminated to the field level staff (such as Agriculture Instructors and Agrarian Research Assistants in the field) on a regular basis through in-service training programmes. At the seasonal cultivation meeting, where the farmers make decisions regarding cultivation and crops, these recommendations may be disseminated as well, and they shall be made available at ASCs for further reference. The practices having high adoption rates include: planting with onset of rains (for maize), agro-forestry and crop diversification (in home gardens), as well as short- and ultra-short duration varieties (in rice cultivation). Cultivating the minor season with low water requiring crops such as onion, soybean, black gram, chillie and watermelon instead of high-water demanding rice is one of the key recommendations of the DOA. Third season cultivation (between Yala and Maha- generally around July-September) with the seepage and ground moisture is possible in village irrigation systems that have managed to conserve their storage. Generally mung bean (green gram) is recommended – and this can be field sown and harvested easily off the paddy fields. The nitrogen fixing nature of the mung bean, will further enhance fertility of the soil for the major rice cultivation season in Maha.

Another strong recommendation of the DOA and DAD is to introduce soil-testing based inputs (fertilizer, primarily) so that over-use and misuse of chemical inputs could be minimized. The DAD recommends a soil health card system for every farm field. It is recommended that the soil health card system be adopted at least for every command area in the downstream of the VIS and for every upland farm field in the upstream catchment area. The soil health card gives every farmer an indication of the status of his soil, inputs required –chemical and organic). This measure and the strict adoption of integrated pest management (IPM) instead of purely chemical weed and pest control will ensure minimal leaching of harmful agro chemicals into surface and ground water tables. With time this will restore the quality of surface and ground water, which is today compromised by continuous inflow of agro-chemicals due to irrational overuse.

The lessons learnt discussed in Section 3.3.5 highlighted that it is required to **improve the capacity of the DoA, DAD, PDoA and DoM to provide tailored weather/climate information to farmers** that can be easily adopted, and the capacity of farmers to receive and adopt such practices. Such information would comprise seasonal and weather forecasts, recommended crops based on such forecasts, information regarding seed availability, markets etc. Assistance of a partner organization to mobilize farmers to create awareness and facilitate links with markets is also recommended. The farmers of irrigation systems selected for improvement and upgrading should be trained with, the tools such as O&M procedures and CSA (climate smart agriculture) practices developed under the project.

[176] Many traditional rice varieties have been proven to have properties that have positive impacts on non-communicable diseases like diabetes, hyper tension, blood cholesterol, and even kidney disease.

Considering that ecological agriculture positively influences water quality, these practices are recommended to be expanded to the districts identified for safe drinking water provision, targeting the village irrigation systems that are identified as sources of drinking water.

The following activities and technologies are recommended:

a. Identify the roles of the private sector (including local farmer groups, women-led producer groups) to provide good quality seed, climate resilient plant and seed varieties. Marketing options such as buy-back guarantees and community capacity building should precede the interventions.

b. Based on the experiences from IUCN/HSBC project and SAPSRI Project (Chapter 3), the other recommended practices include using short-term and climate resilient traditional rice varieties; landscaping for erosion control, crop diversification and composting in home gardens; and use of organic fertilizers, and those which have been identified as having a potential for scaling up (crop diversification and crop establishment techniques such as dry sowing in paddy fields, and micro irrigation) with due regard to the agro-ecological regions (please refer Annex 3 for more details)

c. The set of instruction packages tailored for each seasons will be disseminated by the field level officers of the DoA and DAD located in Agrarian Service Centers (ASC) to the farmers via FOs

d. It is noted that the DoA does not have the capacity to provide the full requirement of good quality seed to the farmers. To reduce the dependency of the farmers on the DoA, it is recommended that local seed farms catering for seed paddy and field crops be established at the community level with the involvement of the private sector

e. To make the optimum use of water, it is recommended that improved water management at the farm level be practiced. Such practices include improved paddy field bunds, maintaining an optimum water level in the paddies and maintaining farm ditches. A package of practices should be prepared using the experiences of the DAD and ID

f. In parallel with the improvement of water management in the farm, water management in the home gardens should be improved. In the case of micro-irrigation, low cost technologies that can be maintained with local expertise are promoted for adoption. Such technologies have been practiced in India and demonstrated in Sri Lanka.

g. Micro sprinklers/drip systems are to be introduced as demonstrations as one for each selected village irrigation system. These systems will be designed after the selection of suitable farmers based on their soil parameters and water quality. Private sector participation and collaboration to introduce low-cost micro-irrigation options, especially catering to women and disabled farmers, should be prioritised and promoted given the high levels of social vulnerabilities in these areas.

h. Considering that markets positively influence the adoption and cultivation of climate resilient crops, the project should promote value addition at local levels to overcome market-exploitation. As such value chain surveys and strong networks with local and regional private sector is encouraged. The intervention should focus on strengthening existing women and youth led producer groups and connecting them to markets for value-added, fair-traded agriculture produce. The markets include local markets (village fair or "Pola"), supermarket chains and dedicated economic centres. In the vicinity of the focus area two such dedicated economic centres exist in Dambulla and Thambuttegama. Market information transfer through mobile applications and linking farmers directly to markets (as is happening in many major irrigated areas) should be promoted for small holder farmer organisations working in VIS. Market linkages could be forged with long term buy back agreements with exporters of exotic fruit and specialty rice.

i. In Chapter 4, weak capacity of the ASCs to deliver the services required by the farmers was highlighted. As the recommended interventions call upon ASCs to deliver additional services such as CSA, the ASCs have to be strengthened. Accordingly, the ASCs should be provided with equipment such as computers, and they should function as coordinating forum to package CSA, weather forecasts and market access information. This would enable some of institutional coverage weaknesses and overlaps discussed in Chapter 4 to be compensated
j. Considering the barriers identified with regard to improving awareness on the soil and water quality status to the communities, soil and water quality testing facilities at district/province level should be strengthened through PDOA or DAD offices. Improvements to existing mini laboratories have to be carried out with repairs and equipment. At least two main laboratories are needed in the largest districts in the focus area; Anuradhapura and Kurunegala. Mini laboratories already functioning in the ASCs need to be selected after a field survey for further improvement.
k. Capacity building of local level field officers and FOs to produce expert advice and to receive and adopt them, respectively. FO should have good access to the ASC to obtain information regarding CSA and other services such as seeds, fertilizer etc.
l. Use of a non-governmental partner organization to mobilize the farmers in the above activities

<u>Targeting vulnerable groups:</u> The above mentioned agriculture package should be promoted to all farmers in the three river basins and the basin districts, through the ASCs and AIs in these areas. However in order to address specific climate and non-climate drivers of vulnerability, it is recommended that women farmers, farm households suffering from chronic diseases and disabled farmers become the primary targets for benefitting through demonstrations and field trials promoted by the intervention. The actual field testing of the recommendations should target the cascades selected for upgrading first. Subsequently, the interventions shall be expanded to the whole basin through ASCs including the cascades or village irrigation systems selected as sources of drinking water using simple treatment should be selected for the interventions.

5.4 Providing increased access to and quality of drinking water in selected vulnerable areas

5.4.1 Removing the barriers to increased access and improved quality

In Chapter 1, it was clearly identified that water quality and quantity issues in the Dry Zone are aggravated by climate change, and health issues largely attributed to water quality and quantity would deplete the climate resilience of Dry Zone farmers. Considering the lessons learnt, such as the contribution of community engagement to the success and acceptability of the interventions and gender inclusiveness outlined section 5.1, this study recommends that the interventions should be made through a multi-pronged partnership approach that seeks to replenish sources, build storage, purify contaminated water and address root causes of water quality issues. A number of baseline investments by community, provincial and national governments have been made to increase drinking water supply coverage in rural areas. However the water is generally of poor quality in varying degrees and when extracted from a well associated with the VIS has issues of turbidity and coliforms as well. Many villagers extract water from wells in a central location in the village or their own homestead but again water quality is questionable, and deteriorates rapidly during the dry season. Increasingly rural villagers in the Dry Zone travel long distances to find a 'good' source of water or pay Rs. 2-3 a litre of water sold in towns and mobile vendors (trucks/bowsers) without any guarantee of quality or safety of it.

Accordingly, financial support is needed to increase the community's access to safe and reliable drinking water. Support should be provided to establish purification plants (treatment such as filtration, chlorination, UV etc) between intakes and supply systems where such systems exist but are in disuse due to water quality. Community based simple water treatment plants using water from the VIS reservoir and RWH systems for domestic use should be promoted through the project.

The Ministry for City Planning and Water Supply (MCP&WS) and the National Water Supply and Drainage Board (NWSDB) recommends advanced filtration plants including RO systems, for areas that have known spread of kidney disease.

The location of infrastructure and the number of facilities should be based on the requirement and locations identified by the MCP&WS, but option is to be kept open to increase the coverage of Community based water supply schemes and RWH systems, depending on the demand that could change in response to health issues. Accordingly, this intervention should synergize with the efforts to improve watersheds of village irrigation systems and popularize ecological agriculture, in selected cascades.

Accordingly, this study recommends the following:

a. Spatial coverage by the community water supply interventions to be limited to the seven districts of Anuradhapura, Polonnaruwa, Kurunegala, Puttalam, Mannar, Vavuniya and Trincomalee. **The facilities are to be located in vulnerable villages identified by the MCP&WS while the selected cascades or their Divisional Secretary Divisions should be used as a criterion to locate the facilities, as well.**

b. A combination of short term and long term measures are implemented to address the water supply issues. The **temporary or short term measures** should include provision of advanced filtration systems to strain out heavy metal contaminants, for areas identified as having high CKDu risk including identified schools and hospitals in the seven districts. At present, such advanced filtration methods are proposed by the government for these areas. The district-wise distribution of government-proposed RO plants is provided in Table 13 and the specifications are provided in Annex 4. There is a possibility of introducing other advanced filtering methods in such locations when the water quality studies are conducted. The communities should manage these schemes with technical advice from the DNCWS and NWSDB. It is further recommended that the government enters into an agreement with the suppliers of the filtration units that the used filters and any toxic material are disposed without any damage to the environment, and the government may be requested to implement a monitoring mechanism

c. **As a permanent solution to the drinking water issues including water quality problems and accessibility problems**, it is recommended that small-scale community managed water supply schemes with simple treatment are provided in the seven districts. The requirement identified by the MCP&WS was described in section 4.1.2. Furthermore, these small scale schemes should be planned in excess of currently identified demand, to cater for future increase of demand for community managed water supply schemes. In this regard, it is noted that there is a requirement of seven medium scale water supply schemes by the MCP&WS, which are not community managed. As the community managed systems have shown good performance, there is a possibility of expanding the number of community-managed systems, in place of the proposed medium schemes. **Accordingly 35 small-scale community water supply schemes are recommended to be installed, based on the villages subjected to water quality issues and water availability constraints, identified by the MCP&WS**. As it is practiced now, these schemes will be managed by the communities with technical advice from the DNCWS and NWSDB (see Annex 4)

d. Current practice is to sell water produced by community water supply schemes with simple treatment and advanced filtering facilities, including RO plants, at a profit to the consumers by the CBO. The selling price is determined by the CBO and different rates apply to the members and non-members. The profit made from the sales are used to employ the labour required for operation, buy spare parts and carry out other maintenance activities including saving for future needs. The maintenance of RWH units are undertaken by the households. The same methods of management should be adopted for the proposed water supply facilities

e. The RWH units are completely community managed and are not affected by the condition of the source area. Studies described in Chapter 3 shows that water quality in RWH systems are within the Sri Lanka Standards for drinking water. The field observations during the feasibility study showed that the social acceptance of RWH solution is improving. The studies conducted and described in section 3.2.3 and lessons learnt discussed in 3.3 shows that return to investment in the maintenance of RWH systems is very high. As such, it is recommended that RWH units in the seven districts are planned in excess of currently identified requirements, and plan for extra units in the seven districts. **These units should preferably be located in high CKDu areas, in the areas, which are not covered by NWSDB's water supply schemes, and those who undergo water shortages during the dry periods**. The total population in the seven districts is 4.3 million persons. Local masons should be trained to build ferro-cement RWH units. Prior to the installation of RWH systems, the willingness to use rainwater and assurance for maintenance will be obtained. Arranging the households to bear the cost of gutter system and the labor for installation of the RWH unit is needed to ensure the commitment of the beneficiaries and their ability to maintain them after the project

f. **Institutional barriers to sustain the interventions may be removed through training** on financial management, source area protection and drinking water quality monitoring. When the source area is an irrigation reservoir, the activities may be combined with watershed protection and ecological agricultural practices planned under the village irrigation system improvements. Training programs shall be designed in collaboration with the government sector, NGOs and private sector whom have successfully implemented the above mentioned activities. In the case of RO Plants and other advanced filtering options, the private sector should be promoted to provide services such as training of the CBOs to manage toxic material and carry out simple maintenance, and such training should be included as a package to the delivery of the plant

5.4.2 Technical details

A typical RO plant would comprise of

a. Water source (usually a well)
b. Pump house with pump, suction and delivery pipes
c. 5-10 m3 capacity tank to collect pumped water
d. RO Plant with feed pump, permeate pump and permeate collection tank
e. 10 -40 m3 capacity tank for purified water storage

A small-scale water supply scheme would comprise of:

a. Pump house with pumps, pressure switch and pressure gauge
b. Up flow roughening filter for surface water treatment
c. Storage tank (usually overhead)
d. Pipelines

A rainwater harvesting system would comprise of

a. 5000-8000 l storage tank made of ferro-cement or plastic
b. Roof gutter system with an arrangement to remove first flush
c. Sand and pebble filter

For further details, please see Annex 4.

5.4.3 Selection of the water source and treatment method

Source selection

Generally, groundwater sources are considered as the first option. The groundwater source could be a dug well for reaching ground water at medium depth, but tube wells are more suitable for drawing water from deeper water-bearing ground strata. Dug wells often are within the local construction capabilities.

If ground water is not available, the costs of digging a well or drilling a tube well would too high, or if a high level of contamination is suspected, it will be necessary to consider surface water from other sources.

Where the rainfall pattern permits rainwater harvesting, when the community is scattered, topography and other physical parameters do not permit laying pipelines, rainwater harvesting may be considered as a better option. Other factors to be considered are the constraints to travel to a community water source such as being women-headed households, having disabled members and young children. Willingness to use and ability to do the minimum maintenance should be a positive factor as well, and in such cases, the households may be supported on a priority basis.

The basic water quality requirements that need to be considered when selecting a source includes the following:

a. Free from disease causing (Pathogenic) organisms
b. Fairly clear (low turbidity, little colour)
c. Containing no compounds that cause an offensive taste or smell
d. Containing no compounds that have an adverse effect acute or in the long term, on human health

e. Not of causing corrosion or encrustation of the water supply system, nor staining clothes[177]

Water quality parameters in terms of the highest desirable level and the maximum permissible level are provided by the NWSDB. They include criteria for bacteriological quality, chemical compounds and toxic substances such as heavy metals.

Treatment of water: There are some common elements in the treatment process such as screening of water by passing the water through closely spaced bars, gratings or perforated plates, for the removal of floating and other large material. Specific criteria for groundwater and surface water are discussed below:

Groundwater treatment: If the water is depleted in oxygen (Anaerobic) in an aquifer containing organic matter, a spray aerator is required to increase the oxygen content in water and to remove dissolved CO_2. In addition ground water may contain Iron and Manganese. They can be oxidized to form precipitates to be collected in filters. If the water contains Iron and Manganese it is possible to have spray aerator followed with a rapid filter. However for rural water supply schemes, use of rapid filters is rare, because of its complex design & construction, and back washing process. Sometimes it may be possible to use an elevated service reservoir for back washing filter.

Ground water is generally free from turbidity and pathogenic organisms. When it originates from a clean sand aquifer, other hazardous or objectionable substances are likely to be absent. In such a situation, direct use as drinking water may be permitted without any treatment.

Rapid filtration is also used for the removal of iron and manganese from groundwater.

Surface Water Treatment: Water in surface sources originates partly from ground water outflows and partly from rainwater converted to runoff. Ground water could bring dissolved solids into the surface water, and surface runoff contributes to turbidity and organic matter, as well as pathogenic organisms. In the surface water bodies, the dissolved mineral particles will remain unchanged but the organic impurities are degraded through chemical and microbial processes. Sedimentation in impounded or slow flowing surface water results in removal of suspended solids. Generally, clear surface water may require no treatment to make it suitable for drinking water. However taking into account the incidental contamination, chlorination should be provided whenever feasible.

Surface water of low turbidity may be purified by slow sand filtration as a single treatment process, or rapid sand filtration followed by Chlorination. Slow sand filters have the advantage since the local workmen can build them with locally available materials and without much expert supervision. The main purpose of slow sand filtration is the removal of pathogenic organisms from the raw water, in particular the bacteria and viruses responsible for water-related diseases. Slow sand filters are also very effective in removing suspended matter from the raw water. However, the clogging of the filter bed may be too rapid necessitating frequent cleanings.

The removal of impurities from the raw water is brought about by a combination of different processes such as sedimentation, adsorption, straining, and bio-chemical and microbial actions. If water contains large quantities of sediment or mud, chemical pre-treatments by coagulation-flocculation or precipitation prior to sedimentation or filtration is implemented.

Surface water with medium turbidity should initially lowered to a desired value by using a rapid sand filter. Water treated from the rapid filter is allowed to pass through sand filters, where turbidity can be reached to the desired standards. The destruction of pathogens also takes place

[177] NWSDB, 2008. Design of Rural Water Supply Schemes for Engineering Assistants.

while water passing through sand filters. If water contains algae, the recommended method is using an activated carbon filter.

Roughening filter: Some time a more limited treatment than rapid filtration using a sand beds, can be adequate for treating the raw water. This can be obtained by using gravel or plant fibers as filter material.

Disinfection: Processes such as storage and filtration reduces the bacterial content of water to varying degrees. However these processes cannot assure that the water they produce is bacteriologically safe. In cases where no other methods of treatment are available, disinfections may be resorted to as a single treatment against bacterial contamination of drinking water. Disinfection by chlorination in rural water supply schemes is generally by chlorine compounds. Chlorinated lime or bleaching powder is a readily available. Pot chlorination can be used to open dug-well chlorination.

Rainwater: Currently, rainwater is considered free from impurities if the roof catchment is well managed. The authorities including Lanka Rainwater Harvesting Forum have prepared guidelines for such management. If there is a concern about the quality, it is recommended that periodic quality monitoring is carried out and the treatment could include boiling and chlorination[178].

Source area and treatment method selection is further explained by Figure 24 below

[178] Ariyananda T., Wickramasuriya S. S., and Wijeyesekera D. S.2010. Rain Water Harvesting for Water Efficiency and Management. In Proceedings of the International Conference on Sustainable Built Environment (ICSBE-2010) Kandy, 13-14 December 2010

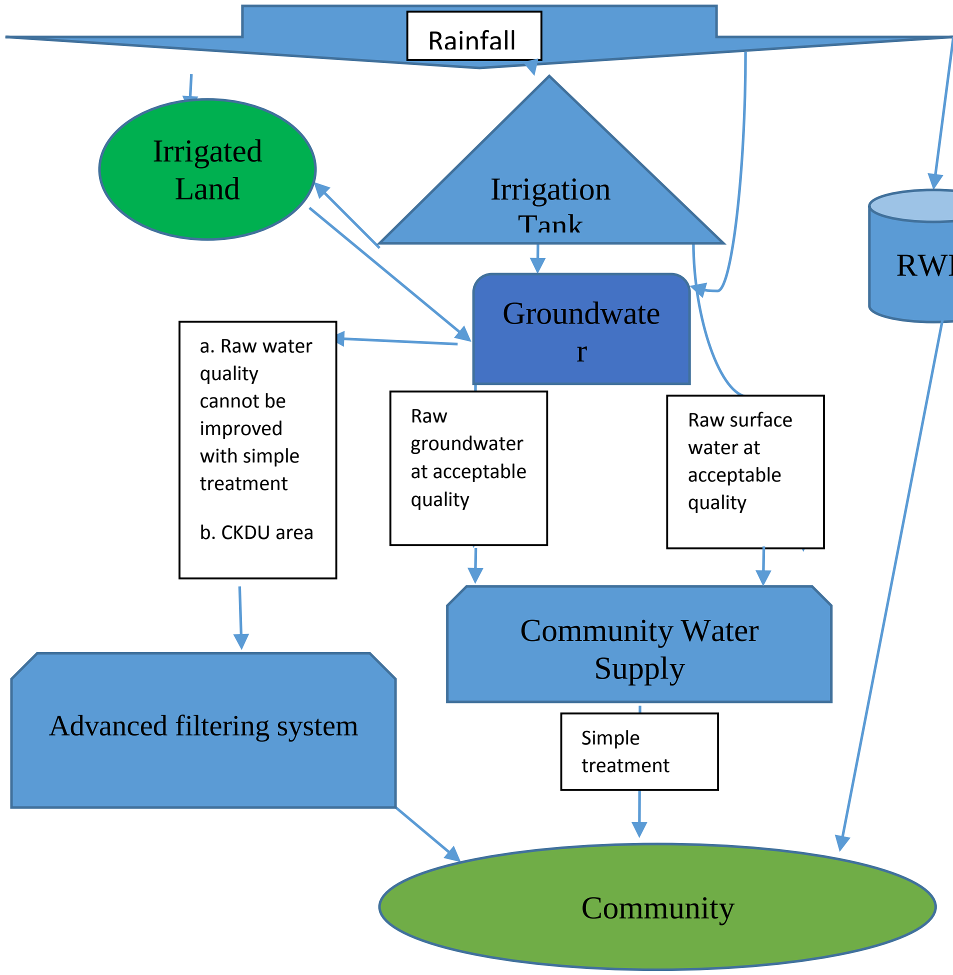


Figure 24. Water sources, treatment and distribution

5.4.4 Maintenance of the water supply schemes

It is recommended that all three types of water supply solutions (RO, RWH and small scale water supply schemes) are managed by the CBOs. The government organizations such as DNCWS and NWSDB should provide technical advice and supervision. The maintenance cost of community based small-scale water supply scheme is LKR 400 per household served per year for gravity schemes and 600 LKR for pumping schemes (2010 prices)[179]. For advanced filtering facilities including RO plants, which are comparatively a new introduction, the annual O&M costs may be calculated as 5% of the capital cost[180]. In the case of RWH units, the maintenance cost is estimated as LKR 933 per year in 2011[181]

[179] World Bank, 2011. Implementation Completion And Results Report (Ida-H0350), Second Community Water Supply And Sanitation Project June 29, 2011

[180] MCP&WS, pers. Comm. 2015.

[181] Ariyananda, T. and Aheeyar, M.M. 2011. Effectiveness of Rain Water Harvesting (RWH) Systems as a Domestic Water Supply Option, A Report Submitted to Water Supply & Sanitation Collaborative Council (WSSCC) Through WSSCC National Coordinator, Sri Lanka. Lanka Rainwater Harvesting Forum

Targeting the most vulnerable: The project's interventions are focused on community level water supply schemes, which are generally managed by women. The project will work towards increased collaboration between the women led water supply CBO and the Farmer Organisation at village level.

Therefore the institutional strengthening part of the intervention should be focused towards building the capacity of women-led CBOs and their coordination with irrigation water management structures at divisional, ASC and village level. Enabling young women to take on the technical and financial roles of water supply infrastructure management has proven to be successful in earlier implemented community water supply programmes and this model can also provide viable employment (through fee collection for decentralized O&M) for a few women in every village.

Rainwater harvesting structures will be provided to village households that are located far from the supply system therefore physical access to the water supply is difficult, HH that are women-headed, have chronic illness and therefore with a heavy care burden, or have disabled or elderly-headed (as is common in conflict resettled areas). This will ensure equitable access to water for the most vulnerable households in these villages.

5.5 Improving the quality of weather and seasonal forecasting, early warning systems and dissemination and communication of information

This study identified key barriers in the field of early warning and weather forecasting that results in inadequate access to seasonal weather forecasting and early warning of extreme weather events, in section 4.1.3. They include inadequacies in weather monitoring network, water measurement network and inadequate coordination among the sector institutions (DoA, DoM, ID, DAD, PID, PDoA, DMC etc) that prevents a comprehensive and farmer-friendly set of instructions being delivered. A lack of access to this information results in losses and impacts on key livelihood assets, which otherwise might be avoided. It is recommended that proposed interventions should include improvements in the generation, coding, modelling, dissemination and providing access to weather/climate related knowledge such as advice on future seasonal conditions (for agricultural planning) and early warning of storms and flooding (for managing water resources e.g. planning tank releases and potential preparedness activities ahead of floods). However, the quality of weather forecasts will need to be improved, both in terms of accuracy and information content (including quantitative precipitation estimates, likelihood of rainfall etc) to ensure confidence of the stakeholders to adopt them, as well as improve their utility. While the installation of Automatic Weather Stations will improve the spatial coverage of observations and are essential for improving the accuracy of satellite-based monitoring and weather/seasonal forecasts, they are expensive to manage, and the arrangements to manage them after the project need to be carefully considered. Accordingly, this study recommends that the following suite of interventions are implemented, with due attention to share data and information between the different institutions collecting, managing and using the different data sources. The proposals correspond to technological, infrastructural and financial barriers identified in Section 4.2.

5.5.1 Agro-meteorological stations

This study recommends providing **agro-meteorological stations (AMS)** at local level, to be jointly managed by the DAD, and FOs, while the DoM will provide technical supervision. The AMS are recommended to be located in Yan Oya (2-3), Malwathu Oya (2-3) and Mi Oya (2-3). This recommendation is based on the number of agro-ecological zones in these river basins and current AMS coverage. The exact location will have to be refined based on the presence of well-functioning FOs and suitable locations, such as Agrarian Service Centres (ASC). ASCs are the preferred locations for housing these AMS. These stations will measure temperature, wind velocity, relative humidity, evaporation and rainfall. The data will be used by institutions (DAD, DoM, DoA, PID, PDOA and ID) to improve seasonal planning. These data should be transmitted to the DoM daily, in order that weather and seasonal monitoring capabilities are improved, helping to quickly identify fast onset problems such as those associated with flooding. For each automatic gauge, a manual equivalent will be used and maintained by the local FO in order to ensure that the data is used and interest from local communities is maintained, as well as providing redundancy in the event of equipment failure.

A typical AMS will consist of:

a. Ordinary mercury thermometer on plastic scale
b. Maximum mercury thermometers in wooden mount
c. Minimum alcohol thermometers in wooden mount
d. Cup counter anemometer
e. Rain gauge (splayed base type)
f. Measuring cylinders
g. Evaporation pan with hook gauge and still well

For manual measurements, computer programs developed to run on mobile devices (e.g. an app) should enable recording and sharing of data that can be also sent to a cloud-based server for sharing.

Please see Annex 5 for details.

5.5.2 Automatic rainfall stations

To increase coverage of rainfall, which is heterogeneous across the basins, three to four (total of 10) **automatic rainfall stations** for each river basin, spread throughout the agro-ecological zones, is recommended. These should be distributed as 4 for Malwathu Oya and 3 each for Mi Oya and Yan Oya. Figure 15 shows the current distribution of automatic stations across the country and the relatively sparse coverage over the three river basins in the dry zone. These recommended additional stations would provide data to the DoM, local Disaster Management Centre, and other institutions managing water and FOs, via the mobile telecommunication network. They should complement the coverage by agro-meteorological stations when possible. The weather data will be used to facilitate contingency plans during an agricultural season (i.e. the changes in water management in response to rainfall, advice for water conservation), early warning (using automatic rainfall stations) and to improve the quality of seasonal and other weather forecasting in the long-term, with a higher density of data to smooth spatial variations in monitoring and prediction activities. It will be necessary to upgrade some of the current observing equipment as well. Each automatic rainfall station should be coupled with a manually operated rain gauge operated by a

FO. As appropriate the automatic rain gauge may be cited at public building premises (such as a school, ASC) with permission for access provided to the FO and other relevant government institutions.

5.5.3 Automated water level sensors at sub-watershed level

It is recommended that automatic water level sensors are established at selected critical locations in river basins. These are in addition to the water level monitoring in the major reservoirs by the ID. The automatic water level sensors are required at two per each sub-watershed (monitoring upper and lower parts of the sub-watershed catchment), and accordingly, it is recommended that eight sensors for Mi Oya, 14 sensors for Yan Oya, and 28 sensors for Malwathu Oya are established.

The instruments should contain a radar sensor, which measures the water level, and a data logger, which stores and transmits data. The data logger should have the facility to integrate with a GPRS transmitter, so that with a SIM it can send data to central data servers/cloud-based storages maintained at the DAD, ID and DMC. DMC/ID will inform the local Disaster Management Centre for local flood warnings, ASCs for sending information and advice regarding the operation of village irrigation systems, and local ID offices for gate operations and warnings in major irrigation systems and at the river basin level flood warnings, to facilitate emergency responses. The local Disaster Management Centre is responsible for disseminating the disaster information to the community.

Please see Annex 5 for details.

5.5.4 Water level and rainfall monitoring at village irrigation system:

Some FOs already have water level gauges in their reservoirs. It is recommended that each irrigation reservoir selected for improvement be provided with a **manually read water level gauge** (where they do not exist) and a simple rainfall gauge, to be managed by the FO or a CBO. This intervention is meant to enhance the capacity of the FO to relate flood events to measured rainfall and to set up their own simple operational rules. The surveys conducted for the NCPCP noted that some FOs record water level, and similar observations were made by the SAPSRI Project in the Alistana Tank (See Chapter 3).

5.5.5 Stream Gauging coupled with Rain gauges

ID operates stream gauges in selected rivers, and has assessed the adequacy of this equipment. Their network was considerably strengthened with the **HMIS facilities** provided by the **DSWRPP**. However, based on the experiences of the floods in 2011 and 2013, ID has estimated that six automatic (6) stream and rain gauges for Yan Oya and three (2) similar facilities for Malwathu Oya are required in addition. **It is recommended that additional gauges, with due consideration to identified needs and strategic relevance to flood forecasting are established in the selected river basins**. They should measure water level and discharge, as required by the ID for river basin level early warning. The instruments should contain a radar level sensor, which measures the water level and discharge, and a data logger, which stores and transmits data. The data logger should have the facility to integrate with a GPRS transmitter, so that with a SIM it can send data to a central data servers/cloud-based storages maintained at the ID and DMC. The stream gauges should be coupled with automated rain gauges to relate rainfall to the stream flow measurements.

5.5.6 Flood inundation area mapping

It is recommended that **the ID carries out flood inundation area mapping in the river basins**. This will facilitate identifying vulnerable communities and physical assets at risk, and thereby improve the early warning capability. The mapping should be carried out in Mi Oya and Yan Oya basins, as Malwathu Oya is included in the CRIP for similar interventions. Mapping will be carried out with GPS instruments (to identify past flood levels), available satellite images and tied to past disasters to estimate expected losses from different levels of flood. These flood risk maps should be made available to any central data server used by the project, and via GIS-type tools be combined with the climate/hydrological monitoring data, as well as weather and seasonal forecasts, in order to identify assets and livelihoods at risk. This will facilitate the development of tailored forecasts for floods and enable warnings to be more targeted to community and farmer needs.

5.5.7 Dissemination and the use of the data

It is recommended that **an agreement is reached among the institutions that generate weather information, and those who use them, to readily share the data**. Manually collected data shall be uploaded to existing websites and a central server on a daily basis. Automated data shall be transmitted to the respective institutions as described above, helping to issue warnings to farmers and the public, which will be the responsibility of the local DMC and DAD.

The government is promoting data sharing and it is understood that a data sharing policy is being prepared[182]. Therefore, the data sharing mechanism may be developed in reference to this policy. In the meantime, some institutions share their knowledge product such as training manuals and research outputs over the Internet. It is recommended that institutions such as DAD, DoM, DMC, ID, PID and PDoA who will generate or will have access to the data generated in response to the recommended interventions, shall store them in a data and information base in their respective institutions, and make them readily available. A central data and information base should be developed in response to the forthcoming policy changes.

The sharing of data will maximize the benefits of the proposed interventions. This is because certain functions related to early warning and weather forecasting are carried out by different agencies. Seasonal and other forecasts are the responsibility of the DoM. Early warning and especially the dissemination to communities is conducted by the DMC, and ID has the responsibility of flood warning. These institutions have different skills and capabilities, such as scientific knowledge about climate, reach to communities and capacity for hydraulic and hydrological engineering. Therefore, the collected data should be accessible to each entity. Sharing of data over the Internet allows a wider audience to use the data for seasonal and shorter duration forecasting and modeling. However, early warnings where timing is critical often require direct transmission of data to the concerned institutions such as DMC, DAD, PID and ID through the mobile telecommunication network.

[182]https://www.gov.lk/elaws/wordpress/wp.../Data-Sharing-Policy-v3.pdf

The AMS information collected by the DAD needs to be disseminated to the DOM and offices which operate monitor and warn against flooding conditions (such as ID) and the local offices of the relevant government organizations including the DMC and FOs using the Internet. Data from automatic rain gauges maintained by the DoM, water level sensors at sub-watershed level maintained by the DAD and HMIS stations maintained by the ID need to be communicated directly to institutions through the mobile phone network, in addition to the Internet. Data from manually operated rain gauges and water level gauges maintained by the FOs should be displayed for public information at ASCs, at most on a weekly basis and preferably collected more frequently. Information and advisories relevant to emergency situations (DoM, ID) and contingency plans (by the DAD) will need to be disseminated to the FOs through the ASC and made available to the public via the Internet as well.

It is recommended that institutions such as DAD, PID, DoA, PDOA and ID will jointly develop mechanisms to transform seasonal and real-time information in a form that can be used by the farmers for their operations, contingency plans, disaster mitigation, and seasonal plans. The seasonal forecasts need to be translated to agricultural advisories by the respective government organizations including the DAD, DoA, PID, PDoA, and ID. This study recommends that a methodology for this is developed jointly by the respective organizations, learning from the successful innovations in the region and outside. This aspect is recommended to be included under a capacity building component, and funds should be allocated accordingly.

5.5.8 Maintenance and quality management

The DAD, with the participation of FOs, should carry out the maintenance of new agro-meteorological stations. This arrangement has to be outlined in consultation with the concerned parties. DoM should provide technical advice regarding maintenance, operation, and replacement. The collaborating institutions (DAD in this case) and FOs will take over the maintenance by the end of the project period and the DoM will continue to provide technical assistance. Necessary training for these activities shall be provided to the institutions. The quality of data will be managed by the respective institutions who will manage the stations, with guidance provided by the DoM.

5.5.9 Capacity building

Based on the lessons learned, discussed in Section 3.3, capacity development of field level officials and FO officials is required. As the AGMET stations are to be managed by the DAD with the participation of FOs, sufficient capacity should be built in the DAD and **among FO officials**. Accordingly, DoM scientists and the officers of the DMC should be involved in these training activities. The topics covered should be; instrument use, routine maintenance of instruments, interpretation of seasonal, weekly and daily forecasts by the DoM, and response to disasters. In the case of response to disasters, the DMC has sufficient skills and has prepared preparedness planning modules, which should be applied in the focus areas. In collaboration with the irrigation managers (DAD, PID and ID officials) and FO officials, suitable breaching sections in the dam to cater for excessive floods and possible inundation areas along the spill tail canal path and downstream of the breaching section should be identified, as part of the capacity building. Such inundation areas should be selected in a manner to result in the minimum damage to assets and livelihoods.

5.6 Targeting women and gender-focused interventions

Farmer Organization Decision Making: Commonly women are part of the Farmer Organisation in a village but are not generally part of the decision-making committee. There are instances when FOs have women as Secretaries or Treasurers (almost never as President). In some villages women have organized themselves in to producer groups found in Kurunegala and Puttlam districts or Women's Rural Development Society's (WRDS), which are common in war-affected districts in Mannar and Vavuniya. Youth or young farmers are also generally absent from the FO decision-making tier. Sometimes the absence of such broad-based village community representation skews water allocation towards traditional forms of water-intense cultivation which is neither resilience nor market oriented, at the expense of other multiple uses in the system.

The project recommends that in order to address specific vulnerabilities faced by women during drought and flood in small holder farming communities that the project focus on strengthening and democratizing decision in FOs especially in regard to water allocation among multiple uses such as drinking, personal hygiene and bathing, household need for cooking and washing, livestock and fishery. This means encouraging greater women's involvement in the FO or stronger links between the FO and women's organisations in the village.

Women Producer Groups adopting climate smart and ecologically safe agriculture: Ecological and climate smart agriculture options promoted by this intervention target both men and women. However women will be specifically and purposefully targeted to engage in producing seeds for drought tolerant varieties of recommended and locally adapted crops (DOA recommended), water saving cultivation methods and value addition technologies for these recommended varieties. The project's recommended demonstrations in low-input farming, micro irrigation, upland soil conservation and agro-produce value addition (such as peanut hulling/ cashew processing/ milling) should be targeted towards reducing the vulnerabilities of households that are characterized by women-headed, disability-affected, conflict re-resettled or ones with chronic illness such as kidney disease. This will not only create and improve income opportunities and savings for women farmers, but also save their time and energy in farming.

Linking women to markets: Rural water supply schemes and Agro-Production Groups both provide entry points for women to develop their entrepreneurship skills and the intervention should invest in developing such skills and developing the social networks that could be exploited for women to engage with external markets. The project should use existing government financing aimed at improving capacities and skills of women to manage accounts, organizational structures, savings and credit societies and technical skills for the operation and maintenance of equipment/technologies involved.

The intervention should identify local and national private sector and non-governmental organisations or large cooperatives who would be strong partners in supporting women producer groups with skills, technologies and markets. It is recommended that the project invest in value chain analysis for climate resilient crops, especially crops recommended by DOA, and strengthen partnerships with private sector buyers for these products (especially seasonal vegetables and fruits which cannot be stored) and with local banks that can support women's producer groups and women's water supply CBOs to develop in to strong rural enterprises.

5.7 Summary of recommended interventions

A summary of recommended interventions, as discussed in the previous sections of this chapter, is provided in Table 15 below.

Intervention **Geographical location**	**Village irrigation systems (VIS) improvement and upgrading**	**CSA and Eco. Agr.**	**Capacity Building in VIS improvement upgrading, maintenance and CSA and Eco Agr.**	**Advanced filtering plants** **10 m3**	**Advanced filtering plants** **5 m3**	**Small scale CWSS**	**RWH units**	**Capacity building for improved management of CWSS and advanced filtering schemes**	**AMS**	**Automatic rainfall stations**	**Manual RF and WL gauges**	**HMIS stations**	**Capacity Building in EWS and seasonal forecasting**
Malwathu Oya Basin	Total 325	Total 325 schemes	8,000 farmers 2000 field level officials						2	4	Total 325	3	650 FO officials 100 govt. officials
Mi Oya basin									1	3		-	
Yan Oya Basin									2	3		5	
Kurunegala				4	-	35 projects	625	1000 CBO officials or members 200 field officials					
Puttalam				6	2		500						
Anuradhapura				30	28		1,250						
Polonnaruwa				10	18		375						
Mannar				4	2		375						
Vavuniya				8	3		375						
Trincomalee				8	2		500						

Table 15: Summary of recommended interventions in different districts and basins

5.8 Approach to the maintenance of infrastructure and equipment

The maintenance of proposed improved infrastructure and equipment would require mobilization of different resources. Farmers traditionally manage village irrigation systems, and the proposed training programmes should improve the capacity of FOs to function more efficiently. Supported by enhanced incomes from agriculture, it is envisaged that FO contribution would improve. The government will periodically support large-scale repairs to structures, as at present. However, there should be external support to capacity enhancement of the FOs.

The CBOs will eventually take over the maintenance of community water supply facilities. However, some initial support in terms of spare parts and replacement will be needed till the capacity of CBOs is improved. DNCWS will continue to provide technical advice and support school and hospital with advanced filtration facilities.

Equipment proposed for improving EWS and seasonal forecasting will be maintained by the government institutions responsible for operating the equipment, whereas VIS-based equipment will be maintained by the FOs. Initial support in the form of spare parts and training for maintenance shall be provided by the GCF.

In summary, the approach to maintenance of the propose infrastructure and equipment are as follows:

- Initial external support is provided to maintain the facilities. In the case of VIS, this support includes formation of cascade farmer committees, development of technical guidelines for water management, SOPs, maintenance manuals, training for preparing an annual maintenance plan, enhancing the financial management capacity, providing support to enhance their financial capacity including provision of O&M equipment and seed money.
- In the case of CBOs managing community water supply schemes (including advanced filtering facilities), external support should be provided to maintain the facilities until the CBO capacity is strengthened, to provide an initial stock of spare parts for all the CWSS including RWH units, training in financial management and routine maintenance of CBOs, providing cascade level source protection plans, and training of skilled labour for RWH units.
- In the case of weather and hydrological measurement equipment, the external support will comprise of an initial stock of spare parts, maintenance of the equipment for a limited period after the warranty periods, training of government officials to maintain the equipment, as well as phasing in/out government/GCF support.
- After the capacities of FOs, CBOs and government officials are built to maintain the infrastructure and equipment, the external support should be gradually withdrawn within the lifetime of the project.
- In the case of infrastructure managed by the FOs and CBOs, the government should continue to provide technical support and periodic upgrading and training to ensure an acceptable standard of maintenance

5.9 Innovativeness and Effectiveness of the proposed interventions

5.9.1 Innovativeness

In designing the proposed interventions, lessons learnt from previous interventions of similar nature were utilized as applicable. Many of these have been successfully piloted in previous projects and found to be technically effective. However, the lessons learnt were used in an innovative manner to design the solutions:

Holistic approach: The recommendations are guided by an integrated approach to enhance climate resilience of the communities. In the proposed process, integration is effected at different levels. First, at sector level, the village irrigation systems, watersheds and cascade systems are to be improved and upgraded in a manner that the interactions among these components are taken into account. In the Rural Water Supply sector, the recommendations include a mix of short-term measures and a set of long term measures to address the issues. In the weather forecasting and early warning sector, the recommended approach integrates different measuring systems such as those employed by the DoM, DAD, DoA and ID to serve common purposes of monitoring and using seasonal forecasting and early warning for preparing agricultural planning, water management at the tank level and flood warning at the basin scale.

In addition, the recommended approach integrates the sector-wise interventions to a common purpose; improving the climate resilience of the communities in the Dry Zone. The literature provides evidence for the inter-connectivity of the status of village irrigation systems, safe drinking water availability and better access to weather information as tools to enhance the resilience of the communities to climate change impacts. In this regard, the recommendations consider the climate change impacts on village irrigation systems and drinking water, the linkage among village irrigation systems, drinking water supply and weather information and climate resilience, and propose a package of interventions to address the issues.

O&M approaches: While the capacity building of FOs for O&M was identified as necessary from the lessons learnt, the recommended interventions combines O&M capacity of irrigation systems (dams, structures and canals) with on farm water management and watershed management. By including home gardens and drinking water source protection under the FO agenda, the solutions provide better opportunities women's participation in the FO activities. The FOs are also recommended to be actively involved in the improvement and upgrading activities and they may be contracted to carry out the work. A part of the incomes from such activities should be deposited in the maintenance funds for VIS.

Packaging agricultural solutions: Apart from integrating across sectors, the recommendations provide innovative solutions within the sectors. While several technical documentation on ecological and climate-smart agriculture are available as literature, their adaptation has been low. As such, the interventions provide an innovative package of solutions, which will combine seasonal weather forecasts, climate smart agricultural practices, suitability with respect to agro-ecological regions, and access to markets.

Rural water supply: In the Rural Water Supply sector, an innovative approach to address the issues is adopted through the integration of short term as well as long term solutions. While the short-term solutions address the immediate water quality issues, the sustainability of long-term solutions such as small-scale water supply schemes is ensured by the recommendations for ecological agriculture and source area protection.

New technology: The interventions incorporate technologies such as automatic rain gauges and data transmission systems. With regard to weather forecasting and early warning, the recommendations combine a set of solutions, which are implemented locally, as well as solutions that require more technological input and therefore needing government input. Accordingly generated information and data, such as reservoir water levels and local rainfalls, will be used locally without having to wait for central/national agencies to transmit the data back to them. New observational records will enhance knowledge about weather pattern changes over the long-term, help ground-truth other sources of satellite-based data, and can contribute to better weather and seasonal forecasting. The data generated by the AMS and automatic rain gauges will be transformed to information that can be used at the local level i.e. tailored to local applications for agriculture and water management. In addition, automatic water level sensors at strategic locations have not been employed to cover an entire river basin in the previous interventions, and the additional sensors proposed here will significantly enhance the early warning capability within the river basin.

5.9.2 Effectiveness

Alternative solutions: An alternative solution to the loss of productivity in village irrigation systems is to divert the agricultural population to other forms of production such as industries. However, the government policies in the past 60-70 years are aimed at improving the agricultural productivity in this region. Sri Lanka made a huge investment in 1980s in the Accelerated Mahaweli Development Programme. However, due to several reasons including security issues, the planned benefits did not materialize in the North Central and Northern Provinces. The Mahaweli Water Security Investment Program, which is the first phase of NCP Canal Project described in Chapter 3, will envisage an investment of about US$ 675 million by both the ADB and the Sri Lanka Government. This project will eventually divert about 1000 million m^3 of water to the Dry Zone and would particularly benefit the three river basins targeted by this proposal. The NCPCP will be implemented till about 2030 and therefore would underline the government policies for agricultural development in the Dry Zone in the foreseeable future. Therefore, investments in strengthening the village irrigation systems and improved agricultural practices will eventually complement the government investments, and any investments in alternative sectors are unlikely to be that effective.

In the case of drinking water, this study has considered all the possible alternatives including RWH, small-scale water supply schemes with simple treatment and advanced filtering methods for complicated water pollution cases. The option that has not been considered is large-scale water supply schemes. Considering the extraction capacity of the water resources and scattered nature of the population compared to town centres, the study proposes an optimum mix of above mentioned solutions excluding large and medium scale water supply schemes.

The study noted that weather forecasting and early warning systems have to be improved to ensure the safety of the infrastructure and availability of water for both domestic purposes and livelihoods. One solution to this is a fully automated system of weather and hydrological information, which can be centrally operated. However, the country’s ability to maintain such a sophisticated system is not clearly established at present. On the other hand, the recommended solutions should be in line with the community ownership concept applied to village irrigation systems and water supply schemes. Therefore, the proposed solutions include a mix of automated weather and hydrological measurements that are necessary for effective early warning, and manual systems for local level planning and long-term weather forecasting. This recommendation is made with the agreement of the concerned national institutions.

Complimentary nature of the recommended solutions: Figure 22 shows that while the recommendations are focused at three major intervention areas, they have the ability to synergize with ongoing and planned interventions. The ongoing interventions include the climate resilient river basin planning under CRIP, which can incorporate the recommended interventions in this proposal into a comprehensive river basin plan. Planned interventions include the NCPCP, which will augment the water resources in the river basins. With better water availability, the cropping intensities can increase in the basins. Better village irrigation infrastructure, safe drinking water availability, effective seasonal forecasting and early warning systems ensure the effectiveness of all the interventions to make the community resilient against the impacts of climate change.

Use of proven best practices: The design incorporates optimum participation of the communities in planning, designing and implementation of the interventions. Previous surveys found that village irrigation systems have some characteristics different from each other, and accordingly their problems and solutions could differ slightly. For example, it is found that some reservoirs have relatively unmolested upper catchments, while in some others the catchments are substantially deteriorated. Hydrological connectivity among reservoirs in some cascades are linear while some others have radial connections. The participation of farmers in planning and designs will enable the most effective solution to differing problems. Undertaking water resource modeling and designing cascade level water management models will help understand the impact of rainfall and help plan mitigating measures during both floods and droughts.

Similarly, in the water supply sector, the involvement of CBOs in the management of water supply facilties is recognised as a best practice (see section 3.3).

Cost effectiveness: The community participation in implementation and operation stages will ensure their cost-effectiveness and maximum output to the labor input. Voluntary labor is anticipated for such activities as catchment protection, based on previous experiences such as the Project carried out by SAPSRI in Alistane Tank[183] (Section 3.2.1). It is also designed to re-use excavated silt for catchment protection and dam strengthening, which will bring down the cost of materials. Some of the currently ongoing and planned water resources development projects such as NCPCP envisage augmentation of village reservoirs, as well. The interventions recommended by this study will synergize with such interventions as water augmentation, increase the productivity in the farms, and thereby improve the cost effectiveness.

In the RWS sector, the recommended water supply facilities are to be managed by the community. This aspect will reduce the operation and maintenance costs of the government in the long term. The experiences from and lessons learnt from second and third Community Water Supply and Sanitation Project (Section 3.3) shows that CBOs performance in maintenance of water supply

[183] Koliba, C. 2015. Community-Based Adaptation to Climate Change in the Dry and Intermediate Zones of Sri Lanka: Rapid Project Assessment. University of Vermont

schemes is satisfactory, thus reducing the overhead cost if the system was maintained by the government.

Similarly, the community contribution to the management of hydro-meteorological stations can make the maintenance cost-effective because this will reduce the inputs (travel, salaries and accommodation) from the government. The recommendations include the provision of manually operated rainfall gauges managed by the community. The data collected by the communities (see section 5.9) will be made available to the researchers and organizations such as DoM, which will enhance the current weather information database, and the resolution of forecasting, without the government having to spend on operation of rainfall and water level gauges.

5.10 Sustainability of the proposed interventions

5.10.1 Sustainability of the interventions for improvement and upgrading of village irrigation systems

Infrastructure: It is found that FOs are managing water-related data, collecting maintenance fees and engaging in commercial enterprises in a limited manner, which will be strengthened with the proposed interventions. Several interventions such as home gardens and rainwater harvesting systems do not require external institutional support to sustain. They only require the necessary intermittent technical advice to provide an uninterrupted service. The development of home gardens contributes to the sustainability in several ways. Women traditionally manage the home gardens and the time saved in fetching water due to recommended interventions can be used for better home garden management. It also provides insurance for food security during a drought event.

While de-silting of the reservoir bed is one of the major requests by the farmers, the degraded watershed results in the siltation of the reservoir. This is prevented by managing immediate watershed and the irrigation system including the reservoir and dams etc as a single unit. Therefore, the recommended approach helps in sustaining positive impacts of de-silting the reservoir bed for a longer time without being silted up again. Development of early warning capability at the local level mitigates the flood damages to infrastructure, which has become a frequent occurrence in the recent times. Accordingly, the risk of dam failure during floods is reduced. At a higher level, the improvement of cascade to enhance the resilience to climate change contributes to better flood management at the river basin level, and thereby mitigates the flood damage. Institutional arrangements: The recommendations incorporate interventions that are found to be sustainable in other projects. The market-farmer links established under the project will be continued after the project without external intervention. FOs will be directly linked to the DoM weather forecasting system, and the linkages will be strengthened during the project, as well.

Post-project operation and maintenance and capacity building: The recommendations would lead to FOs taking over the O&M of the systems after the improvements. The training provided during the implementation, documentation of O&M best practices and periodic training after the project will enhance their capacity. It is noted that FOs already maintain an O&M fund. Their capacity for maintenance will be enhanced by the strengthening of their O&M fund by the income generated from engaging in infrastructure upgrading activities, as well as using GCF resources to buy spare parts towards the end of the project. Implementation of such recommendations will enhance the sustainability of the interventions.

The study noted that security situation prevailed in this area contributed to the deterioration of irrigation systems. However, these non-climatic factors do not exist now and the current situation will enable better investment by the government and communities in maintenance and private sector investment in marketing, inputs supply and purchasing of farm products. Better incomes received from the farm are expected to influence farmers' investment in operation and maintenance of irrigation facilities.

5.10.2 Safe drinking water supply

The water supply projects, which have a community based management aspect, operate with a profit, and the proportion of failure is small. In RO plants, while the production cost was bout 40-50 cents per liter, water was sold to the consumers at a minimum of 1.00 LKR/ liter. In the case of community water supply schemes, the failure rate was less than 10%. The proposed solutions to provide safe drinking water such as small-scale water supply schemes will be mainly managed by the community, with some state inputs.

The interventions such as the RO plants are identified as per the requirements of the state institutions, and their input in maintenance is ensured. As RO plants are considered as a short-term solution, a long-term commitment for maintenance is not envisaged from the government. However, the currently operating RO plants are functioning at a profit, and therefore, routine maintenance by the CBOs is ensured.

The community at a very low cost is maintaining currently installed RWH units. Such practices will be introduced to the recommended activities as well.

In this regard, the National Rural Water Supply Sector Policy stipulates that government and the provincial authorities are responsible for the sector development particularly in technical expertise to sector partners, training and capacity building. As such, post-project capacity building of the CBOs is ensured by the sector policy.

A factor contributing to sustainability is the sense of ownership. The project design ensures that a major part of infrastructure introduced by the project is owned and operated by the beneficiaries. A community contribution is envisaged for most of the project activities, such as providing for the gutter system in RWH, community labour for community water supply schemes, which will infuse a sense of ownership as well.

5.10.3 Access to weather information

The recommendations under this component include AMS, rain gauges, hydrological stream flow gauges, water level gauges, flood monitoring and modeling, water resource modeling, seasonal forecasting techniques, and the currently installed stations are managed in collaboration with government institutions in the agriculture sector. The same method will be applied to manage the proposed AMS, but a community contribution to their management is added. The FOs at some locations currently monitor reservoir water levels. The recommendations include interventions to improve the capacity of FOs to mitigate floods and to include such data in agricultural planning. As explained suggested previously DoM officials who are skilled and knowledgeable about instrument operation and maintenance should conduct the training, ensuring the equipment will be managed in a sustainable manner after the project. Additionally the government has committed funds for spare parts and routine maintenance, which will be phased in as the GCF contribution to these items is phased out (see Annex 7). Additional funds from GCF are provided for extra spare parts during the last 3 years of the project in order to help the government in the case of equipment failure, as well as hedge against the risk that suppliers will not be able to provide such parts during the post-project period. This approach is considered a pragmatic approach to easing the burden and helping to prepare the government for the extra O&M required for equipment installed through the project.

5.11 Knowledge management and learning

The recommended interventions are expected to generate a substantial amount of knowledge for future river basin management and development activities. This expectation is based on its novel approach of integration among irrigation, agriculture, drinking water, and weather and seasonal early warning information within a river basin context. While the importance and relevance of river basin approach had been discussed during the last decade, there is inadequate policy support for such approaches in the development activities. However, the emergence of projects such as CRIP indicates that the country gradually turning towards river basin based sustainable development. Therefore, the management of the knowledge gained during the implementation of the recommendations will be useful in planning future development activities, river basin management plans, and especially in formulating sustainable development policies.

The recommendations described in the preceding sections will lead to documentation of operation and maintenance procedures in village irrigation systems and climate smart ecological agriculture practices. The implementation of recommendations will lead to the design and conducting training and awareness programmes in on-farm water management, low-cost micro irrigation, watershed management and financial management in FOs. Training manuals for field level officials on climate smart agriculture will be prepared as well.

In the RWS sector, the recommendations will lead to the documentation of O&M practices for community managed water supply schemes, with special reference to water quality and source area management. Documentation for training for the management of community funds including planning and budgeting, expenditure management are recommended to be included.

In the weather forecasting and early warning field, the community as well as the field level officials would gain knowledge about monitoring of weather parameters, function and maintenance of equipment and awareness will be created about their relevance to the climate change. It is recommended that such lessons be adequately recorded for future use and replication in other river basins.

It is further recommended that performance monitoring of irrigation and water supply schemes are built into the training programmes and orientation towards performance-based management is introduced during the interventions. These lessons are to be documented and be made available for replication.

Databases and knowledge products: The evaluation reports, training manuals, O&M procedures and operating manuals for equipment are the products resulting from the interventions. Such products should be stored in the databases maintained by each institution such as DAD, ID, PID, PDOA, DOM and DMC. The knowledge products should be made available to the public over the Internet. Printed copies should be shared among the relevant organizations and in the libraries with public access. Weather and water related data generated, shall be made available over the Internet, and archived data in the databases maintained by the institutions shall be made accessible on request.

Chapter 6 : Summary and Conclusions

Increasing temperatures and increasing unpredictability of rainfall characterize Sri Lanka's vulnerability to climate change. Farmers under village irrigation systems are less resilient to the impacts of climate change, because of the limited water retaining capacity of village reservoirs, weak water infrastructure, and declining productivity of home gardens. Dry Zone farmers in general are less resilient due to poor quality drinking water and inadequate access to weather and climate information, in a form they could use in their agricultural decision making processes.

Recent experiences provide several important lessons to be considered when designing solutions to existing problems. Village irrigation systems are intricately linked with the associated ecosystem, and traditional irrigation management gives due consideration to this fact. Participation of the beneficiaries in designing, planning and implementation, as well as post-project operation of irrigation and water supply facilities, is essential to ensure the sustainability of the interventions.

The proposed project is designed based on three strongly linked components managed largely at community level with strong support from grassroots level officials/extension services and national government support when technically required. This approach will improve the cost-effectiveness and long-term sustainability of the proposed components. The components are; improving, upgrading and restoration of small reservoirs and the associated ecosystem of village irrigation systems; provision of safe drinking water supply to a targeted population; and enabling access to weather forecasts and early warnings in a manner to be applied to agricultural planning and water management. These components have been experimented with, in recent and past projects aiming at rural development, and found to be implementable. This proposed project would integrate such best practices and facilitate being used as a model for the interventions to be undertaken in other river basins.

Annex 1. A note on Village Irrigation Systems with technical details

Introduction

Village irrigation systems comprising small scale reservoirs (locally termed “Tanks”), diversions across small, non-perennial streams and their watersheds are mainly located in the dry zone of Sri Lanka. There are a few irrigation systems, mainly diversions located in the intermediate and wet zones as well. It is estimated that there are 13,141 reservoirs 13,849 diversions and 2467 canals support the livelihoods of 644,502 farmer families and provide water to 768,652 ha of agricultural land. Accordingly, the land area owned by these farmers is about 1.2 ha. Although a detailed study of the capacities of these reservoirs has not been conducted, an approximate assessment made for the NCP Canal Project in selected river basins shows that the capacity of a reservoir is about 0.20 million m3.

An examination of the natural drainage patterns in relation to the location of the individual tanks reveals a hydrological connection among these reservoirs (Madduma Bandara, 1985, and Panabokke et al, 2002[184]). It is believed that the small tank systems were initiated and constructed by the small village communities by a communal effort throughout this period of approximately fifteen centuries.

It is observed that these reservoirs served multiple purposes other than irrigated paddy including augmentation of the groundwater table in order to prevent the depletion of the domestic well water supply during the protracted dry seasons, as silt trapping tanks during the rainy season, provision of water for livestock. There was a forest tank in the jungle above the village, to provide water to wild animals and, thereby preventing wild animals coming the village. Another type was the mountain tanks, which were built to provide water for slash-and burn agriculture in the more hilly areas (Maddumabandara, undated).

Main components

The main components of a village irrigation system can be described in the following manner:

reservoir bed,
reservoir bund (dam) and appurtenances,
upstream reservation,
upstream mechanism to trap sediment including small ponds and water holes,
upstream earth ridges to retard sediment inflow,
downstream reservation/interceptor to trap alkaline water seeping through the dam,
command area drainage canal,[185][186] [187]

[184] Panabokke, C. R. ; R. Sakthivadivel; A. D. Weerasinghe. 2002. Evolution, present status and issues concerning small tank systems in Sri Lanka. Colombo, Sri Lanka: International Water Management Institute.
[185] Geekiyanage, N., and Pushpakumara, D.K.N.G., 2013. Ecology of ancient Tank Cascade Systems in island Sri Lanka. Journal of Marine and Island Cultures (2013)2, 93–101 www.sciencedirect.com
[186] Dharmasena, P.B. 2014. Tank ecosystem development. Technical Note 5. IUCN Cascade Development Project. Sri Lanka
[187] SAPSRI (South Asia Partnership, Sri Lanka), 2015. Annual Report 2014-2015. Sri Lanka

The village itself consisted of the shrub forest, hamlets (containing home gardens) and the paddy fields in the irrigation commanded. Some authors consider these aspects as components of the village irrigation system.

Dharmasena (2014) provides a pictorial presentation of these components, as shown by the figure below:

Figure 25: A pictorial representation of a village irrigation system[188]

Traditionally, certain types of trees have been grown on the upstream tree belt and the downstream interceptor of saline water. The perennial tree species like Mee (Maduka longiflia) and Kumbuk (Terminalia arjuna) were provided by Plan Sri Lanka to plant in in the upstream. Trees found in the upstream tree belt include kumbuk, nabada, maila, damba etc. and climbers such as kaila, elipaththa, katukeliya, kalawel, bokalawel[189]. In addition to these tree species, other salt absorbing plant species were also introduced to Interceptor in the downstream, to restrict the free flow of salt water to downstream fields. 46 plant and tree types found in the interceptor are listed by Dharmasena, (2014) including Kumbuk (Terminalia arjuna), Karanda (Pongamia pinnata), Bakmee (Nauclea orientails), Patabeli (Hibiscus tfliaceus), Kayarn (Memecylon capitellatum), Aththora (Atylosia trinervia), Thunhiriya (Cyperus pangoreil), Hana (Unum usitatissimum), Vetakeya (Pandanus kaida) and We-wel (Calamus spp.).

[188] Source: Dharmasena, 2014

[189] Dharmasena, P.B., 2014. Technical Note no5 prepared for the IUCN/HSBC project

Hydrology: Scientific studies have shown that most of these reservoirs are hydrologically connected forming a cascade of reservoirs. 'A 'cascade' is a connected series of tanks organized within a micro-(or meso-) catment of the dry zone landscape, storing, conveying and utilizing water from an ephemeral rivulet'(Madduma Bandara 1985). These hydraulic connections can vary from linear connections to fan-like or radial connections.

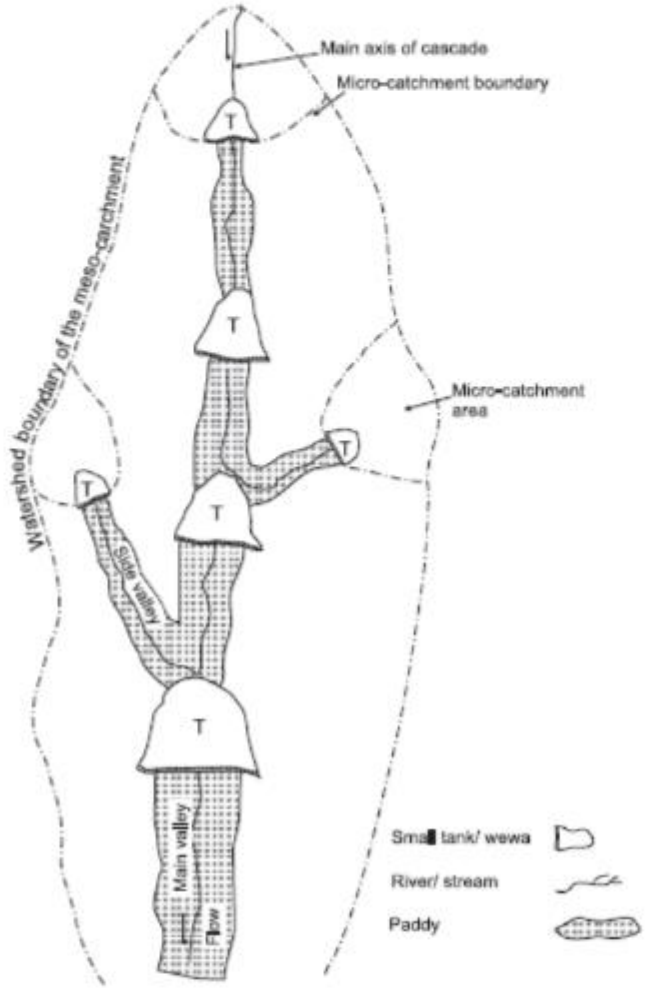


Figure 26: A schematic representation of a cascade[190]

[190] Source: Panabokke et al, 2002

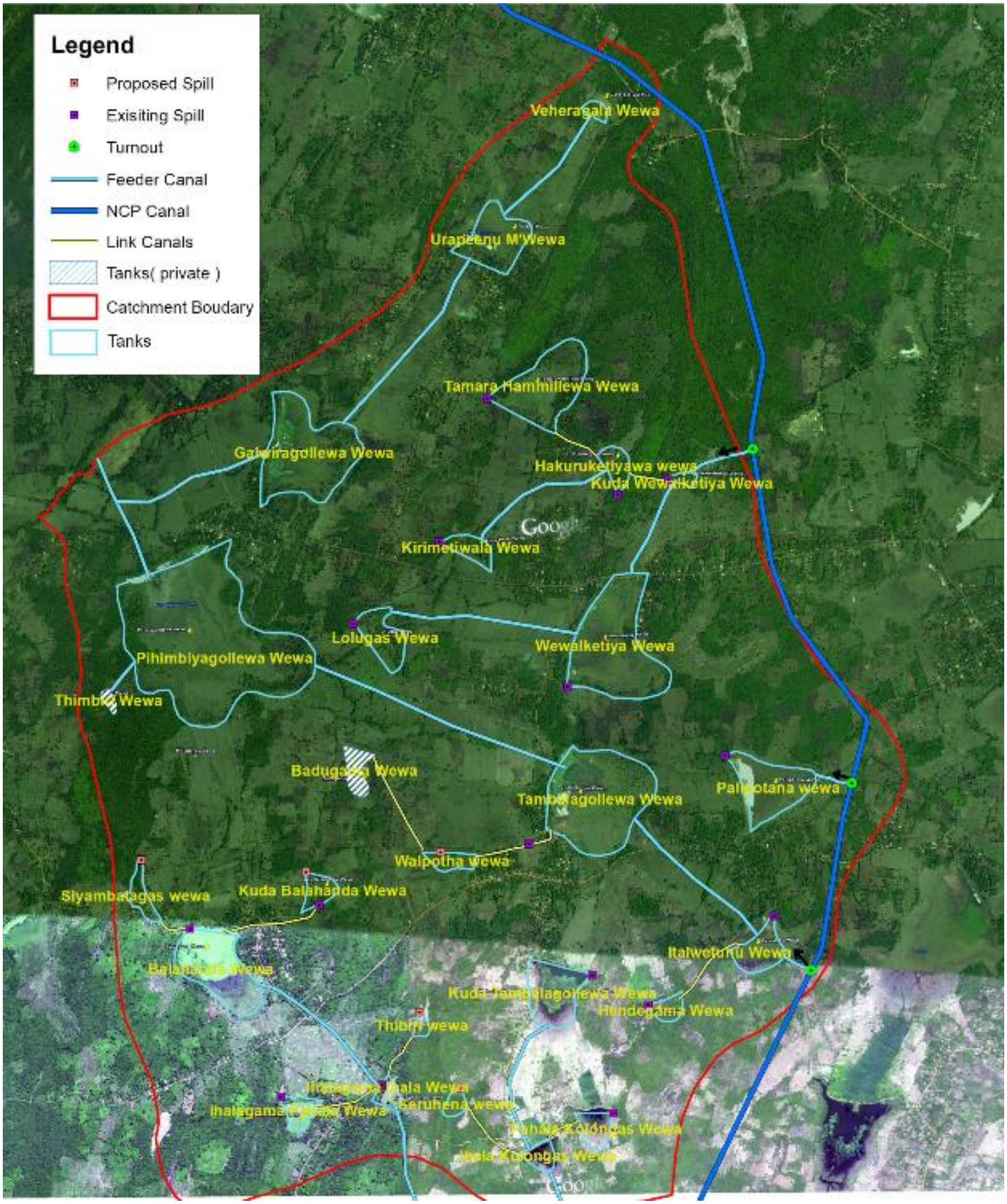

Legend
Proposed Spill
Exisiting Spill
Turnout
Feeder Canal
NCP Canal
Link Canals
Tanks(private)
Catchment Boudary
Tanks
Urapeenu M'Wewa
Tamara Hammillewa Wewa
Galwiragollewa Wewa
Hakuruketiyawa wewa
Kirimetiwala Wewa
Lolugas Wewa
Wewalketiya Wewa
Pihimbiyagollewa Wewa
Tambalagollewa Wewa
Walpotha wewa
Kuda Balahanda Wewa
Hendegama Wewa

Figure 27: An aerial view of Pihimbiyagollewa cascade with links between reservoirs identified: Source Feasibility studies of NCP Canal [191]

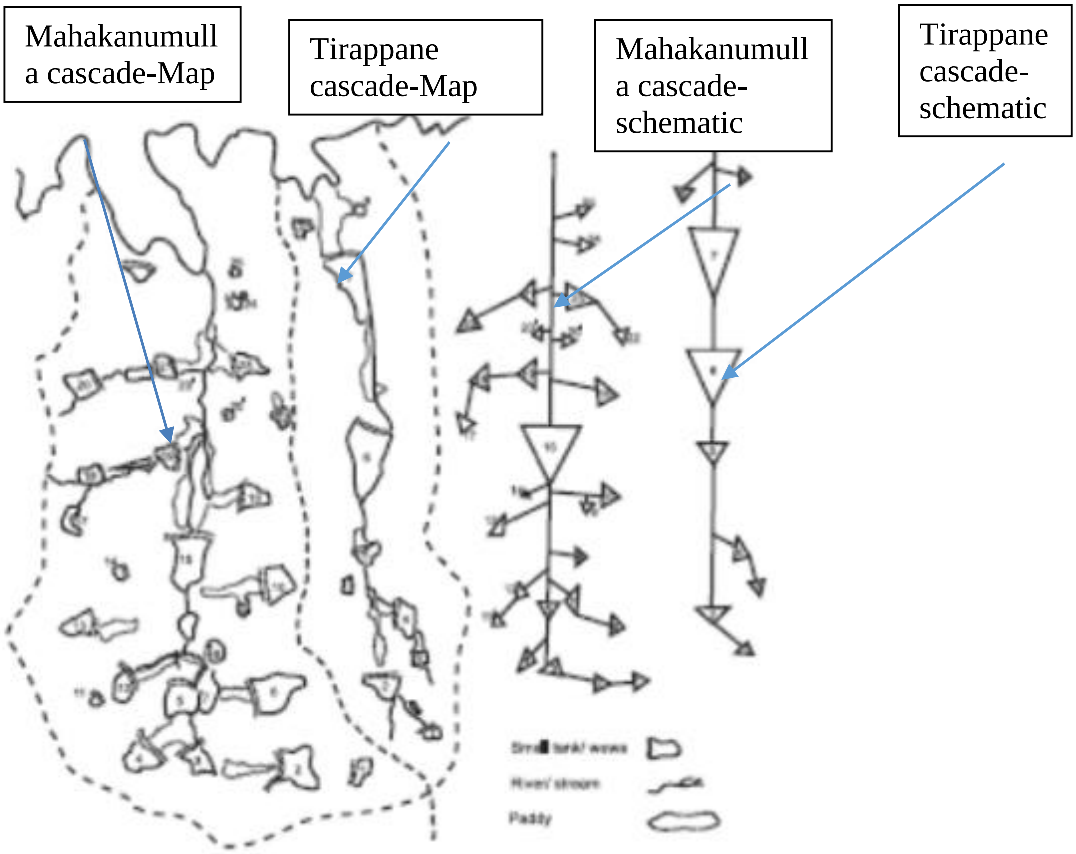


Figure 28: Different types of hydrological connections in cascades[192]

<u>Management of Village Irrigation Systems</u>

Irrigation systems that command less than 80 ha of agricultural areas are classified as village irrigation or minor irrigation systems. Village irrigation systems were traditionally managed by the farmers, from the ancient times. However, abolition of the traditional system of management during the colonial times (prior to 1948) and subsequent changes to socio-economic environment and land use have made the management of these systems to be improved. In the recent times, Farmer Organizations have been set up on the village/or Tank basis and legal recognition for these organizations are provided through their registration under the Agrarian Services Act. Managerial support is provided by the Department of Agrarian Development and the Provincial Irrigation Department, and this sharing of responsibility slightly differ among the provinces. In addition, in a cascade there could be larger reservoirs which command more than 80 ha, and such irrigation systems come under the purview of the Irrigation Department. Several other institutions such as Department of Agriculture, Provincial Department of Agriculture and various other

[191] Source: Mahaweli Consultancy Bureau, 2015. Draft Feasibility Report of the NCP Canal Design. MCB
[192] Source: Panabokke et al, 2002

governmental and non-governmental organizations provides technical and other inputs to the farmers.

Cultivation decisions are taken at the seasonal cultivation meeting attended by all the farmers, farmer organization leaders (usually comprising the President, Secretary and Treasurer and other office bearers) a senior officer representing provincial/district administration and other government officers who provide inputs to agriculture. The decisions taken at this meeting are legal but the enforcement of them depends on the social cohesion in the village. On the other hand, although cascade hydrology is important from a water management and disaster management point of view, there is hardly any management arrangement at the cascade level. In addition, the FO based management does not generally extend to the watersheds or the home gardens.

Distribution of village irrigation systems

Main River Basin	Extent km2	No. of Sub-water sheds	No. of cascades	No. of Village Tanks	Village Tanks/ km2
Walawe Ganga	2538	15	49	750	0.30
Malala Oya	477	2	18	325	0.68
Kirindi Oya	1176	5	32	334	0.28
Manik Ganga	1278	9	36	376	0.29
Kubukkan Oya	1211	6	9	93	0.08
Karanda Oya	435	3	12	80	0.18
Pankulam Aru	495	3	12	150	0.30
Yan Oya	1525	7	70	746	0.49
Ma Oya	1063	7	45	328	0.31
Per Aru	479	3	17	154	0.32
Kanakarayan Aru	905	3	23	200	0.22
Pali Aru	474	3	18	124	0.26
Paranki Aru	875	4	36	386	0.44
Malwatu Oya	3183	14	189	1731	0.54
Modaragam Aru	1142	3	45	449	0.39
Kala Oya	2847	14	91	1015	0.36
Mi Oya	1561	4	64	1242	0.80
Deduru Oya	2689	12	164	2408	0.90
Karambalan Oya	799	4	24	419	0.52
Rathabalan Oya	260	0	24	209	0.80

Table 16: Main river basins containing village irrigation schemes and cascades. Source: Witharana, 2015 [193]

193 Witharana, D.D.P., 2015. Ranking of Village Tank Cascades (Ellangawa) on potential coping capacity for Climate Change Resilience in the dry zone of Sri Lanka. A paper submitted at the INWEPF Symposium, 2015

Use of water resources in the village tank cascade sysytem

Source- IUCN (2015), Tank ecosystem restoratio

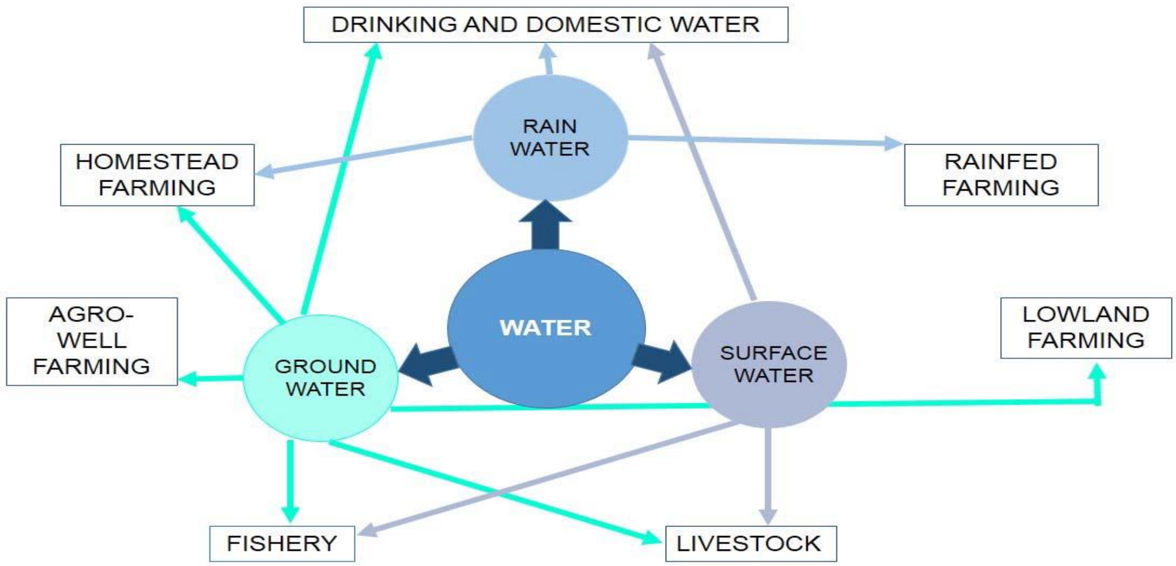


Figure 29. Use of water resources in VIS

Range of rehabilitation activities to be carried out in upgrading and improving VIS

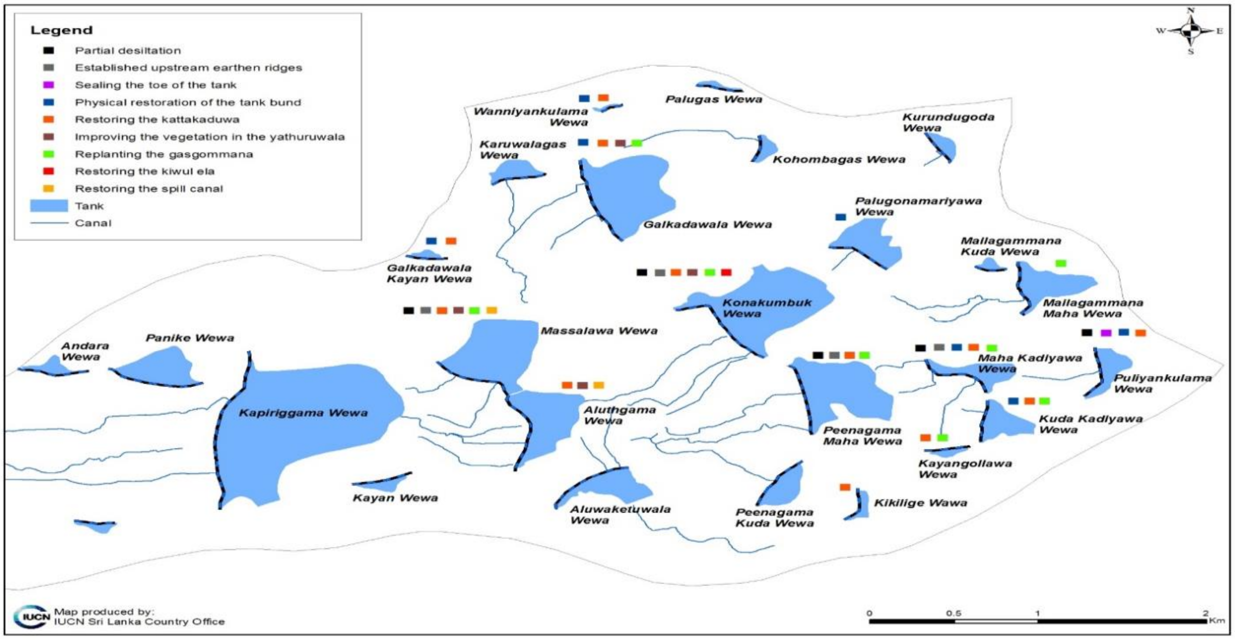


Figure 30. Range of rehabilitation interventions carried out in Kapiriggama cascade

The Figure 30 shows the range of rehabilitation activities carried out by the IUCN in Kapiriggama Cascade, which is representative of the interventions in an upgrading and improvement programme in a cascade of VIS in the Dry Zone.

Annex 2: VILLAGE IRRIGATION SYSTEMS: SELECTION CRITERIA, DESIGN AND CONSTRUTION SPECIFICATIONS

Prioritisation of Cascades

Nine parameters with both negative and positive functions were used to rank the village tank cascades after normalizing figures. Statistical analysis, GIS applications and field verifications are required to attain the final task. Updating existing database, and incorporating new climate change related parameters in to the analyzing process will improve the reliability and accuracy of the results.

"Nature of small tank cascade systems and framework to rehabilitation of tanks with in them" (Sakthivadivel et al, 1996) discussed the hydrology of small tank cascade and selection criteria for tanks in the same and weighted cropping intensity was used as the main indicator to assess the hydrological endowment of VTC. Fallowing criteria were proposed to select the tanks for rehabilitation.

- Maha cropping intensity.
- Ratio of tank gross catchment area to water spread area.
- Ratio between command area to water spread area.

"Rehabilitation planning for small tank in cascades" (Sakthivadivel , et al - 1997) discussed the screening indicators and water surplus indicators of cascades.

Screening Indicators

Cascade Area: Cascade water spread area

Cascade command area : Cascade water spread Area

Cascade Water Surplus

$$\text{Cascade outflow per unit area} = \frac{\text{Net Annual Runoff (Yield)}}{\text{Total Cascade Area}}$$

$$\text{Cascade water surplus} = \frac{\text{Cascade outflow per unit area}}{\text{Mean Annual Rain-fall}}$$

This study was more concerned about the cascade water balance and identify water surplus cascade.

Comprehensive detail study done by "Guideline package for Water Development Component of Small Tank Cascade System" (Shakthivadivel, et al ,1994) was more focus about the guideline for, Characterizing a Tank cascade systems.

Surface water estimation.

Simulation modeling for water balance of Tank Cascade.

Ground water estimation and agro well development.

Fallowing research studies carried out under VTC systems also important to understand the behavior of VTC systems in the dry zone of Sri Lanka.

Thirappane Tank cascade study by J.Itakawa in 1990 (Water balance Model)

Thirappane Tank cascade study by Y.Shinogi in 1995 (Optimization Model)

Eco system management study at Kappirikgama cascade by IUCN - 2013

Climate change adaptation study done at Mahananneriya in Mi-oya basin by MDM & UNDP (2014)

As a summery, it is understood that all of these studies were carried out to identify individual tanks for rehabilitation and it has no direct relationship with climate change, but, some of the parameters developed under those studies seen valid even today to measure the hydrological endowment of VTC ageist climate change.

Following Parameters were identified and data collection was done for all 64 Cascades in Mi-Oya basin.

Agro –Ecological Region

DL- 1b AE –region was identified as the best out of all four other regions in the Basin, as positive coping capacity and area percentage of each cascade covered by .DL-1b region was taken in to consideration.

Water body area over Cascade area (WSA/CAS.A)

This Parameter is conceded as a one with Positive copying Capacity under hydrology and area computation was done for GIS vector layers generated from 1:50,000 ABMP Maps. This was cross checked with DAD attribute data bases as a validate measure.

Command Area /Water shed Area (Com. A/WSA)

This is to asset the hydrological endowment of the VTC and also considered as positive a function, when compared to coping capacity against climate change. Those Figures were extract and validated as same as (b) above.

Cascade Area / River Basin Area/RBA)

This is also a positive function to means coping capacity through the hydrological endowment of the VTC , measured as same as (b) above.

Number of working Tanks (W.T.No)

Not only the water body area but also its distribution is also important to access the coping capacity of VTC. This figure was extracted from Google earthy Map and validated by the DAD data base and incorporated as a positive parameter.

Paddy land area Percentage (PL %)

Paddy land area percentage in the entire VTC is also an important positive parameter to assess the coping capacity of the VTC and figures were extracted from 1:50,000. GIS digital layer and validated through DAD databases.

Same as paddy ,forest cover (f%) in the watershed is also behave as a positives function to measure coping capacity of VTC and incorporated as a positive function in this exercise , and measured from 1:50000 land use digital cover.

(b) Rock plain percentage (R P%)

Rock knob plains, rock outcrops and erosional remnants came under the category of rocky surfaces in land use and percentage of land use covers were computed from 1:50,000 scale land use and soil GIS layers. This is considered an a negative parameter that trigger high surface runoff (flood) and reduce water yield from the catchment.

(c) Land slope (L S%)

Land slop above 4% gradient in the catchment generates high Floods and area percentage covered in the VTC with 4% or more land stops was considered as a parameter with negative function. For this computation, 5m elevation contours were generated from Google earth map by using a special software called "power civil" from Bentleys software company in USA.

Statistical Analysis

The statistical analysis for the ranking exercise was done in two stages.

For all 64 cascades, located in Mi –Oya .basin.

For 21 cascades that are having more than 10 village tanks out of same list of VTC.

The following Table shows the range of values for all nine parameters

Table 17: Value Range for nine Parameters.

Serial No	Parameter	64 Cascades			21 Cascades		
		Min	Max	(Max-Min)	Min	Max	(Max - Min)
1	AER	0	100	100	0	100	100
2	WSA/CAS.A	0.	.07	.07	0.001	0.05	0.049
3	COM.A/WSA	.01	6.76	6.75	0.01	5.23	4.95
4	CAS.A/RBA	.001	.05	.040	.001	.05	.049
5	WT NO	1	114	113	11	114	101
6	PL%	0	60.25	60.25	0.07	30.92	30.85
7	F%	0	38	38	0.07	34.18	34.11
8	RP%	0	66.65	66.65	0	30.92	30.92
9	LS %	0	66.65	66.65	0.16	52.11	51.95

The above sharp variation of ranges show that normalization is required to asses the weightage of functions, assuming that all parameters are equally important.

Following normalization equations were used and re-tabulated the valves that vary from 0 to 1, after normalization.

Equation for positive functions

$$X_{nom} = \frac{X_{act} - X_{min}}{X_{max} - X_{min}}$$

Equation for negative functions

$$X_{nom} = \frac{X_{max} - X_{act}}{X_{max} - X_{min}}$$

or

$$X_{nom} = 1 - \frac{X_{act} - X_{min}}{X_{max} - X_{min}}$$

Where

X nom - Normalized value.

X act - Actual value computed.

X max - Maximum value computed in the data set under each parameter.

X min - Minimum value computed in the data set under each parameter.

Normalized score for each cascade wring nine parameters considered was done using two method.

First method (Summation of all normalized score)

$$\sum_1 S_{nom} = [AER_{nom} + (WSA/ CAS. A)_{nom} + (COM.A / WAS)_{nom} + [CAS.A/RBA)_{nom} + (WT.NO)_{nom} + (RL\%)_{nom} + [F\%)_{nom} + RP\%_{nom} + LS\%_{nom}]$$

and arrange the data set in descending order to get the highest normalized score at the top and then ranking was done accordingly. (Annexure –ix an x)

Second Method (Summation of class value)

Arrange score data set in descending order and divided under in to five equal classes, under each parameter.

Ex :- class width = $\underline{(RER_{max} - R_{min})}$

and assign a class value (from1 to 5) for all the data falls within the class. Finally all class values are sum- up to get the final score of each VTC system. The disadvantage of this method is that two VICs can appear with the same rank which is not realistic.

The idea of second method is to introduce group theory and avoid small changes between the data set while doing ranking.

Data set was tabulated and ranked under both methods and ranking of VTC system in Mi – Oya basin was done, for all 64 VICs and also listed 21 sample cascade s with more than ten village tanks, as criteria for the selection of VTC for development under climate change.

Recommending cascades for the current proposal

The criteria used for recommending VIS cascades for this proposal is as follows:

- Hydrology-referenced coping capacity based ranking system developed by the DAD (available for Mi Oya only)
- Poverty measured by the Head Count Index
- Located in the flood affected DSD Divisions
- Incidence of CKDU
- Recommendations by the District Offices
- Views expressed and clarifications made by the DAD Head Office regarding cascade names etc
- Considering river basin level impacts, preference was given to cascades with more than five village irrigation systems

The major constraints and difficulties involved in the exercise were as follows:

- Some of the cascade names used in the GIS database are not used in the field. Some of the Tank names used in the GIS based topographical are not used in the field either. Therefore, the cascades recommended by the field offices were identified by the coordinates, where ever possible
- There are a large number of abandoned Tanks especially in war-affected Vavuniya and Trincomalee Districts. Therefore, the exact number of Tanks that could be improved have to be verified by further field inspection

Considering the above, a set of second priority cascades were identified from each District. The total number of Village Irrigation systems identified in this manner are approximately 325. They are distributed as 147 in Malwathu Oya, 100 in Mi Oya and 84 in Yan Oya. The following list is to be finalised after consultations with National level, District, Divisional officials and FOs.

Malwathu Oya

Anuradhapura District

Cascade	DAD high potential/coping capacity ranking	CKDu	Poverty/ HCI	Recommended by District	No. of Tanks	Priority	ASC
Kokatiyagolla	Not available	High	11.37		8	1	Kallanchiya
Gekarawa Wewa		High	8.56		5	1	Kallanchiya
Kongollawewa		High	8.56		7	1	Kallanchiya
Ratmalgaha Wewa		High	8.56		5	1	Rambewa
Siyambalagaswewa		High	8.56		11	1	Kallanchiya
Thalgaha wewa		High	8.56		6	1	Kallanchiya
Kirimetiyawa		High	8.55		7	1	Kallanchiya
Abagaswewa		High	8.30		7	1	Rambewa
Aluth Halmillewa		High	8.30		21	1	Ethakada, Kebithigollewa
Palugaswewa (Weruppankulam)		Low-Med	8.97	Yes	15	1	Mihintale
Sivalakulam		Low	7.40	Yes	16	1	Siwalakulam
Kapiriggama (under IUCN Project)		High				2	Rambewa
Kudagama Wewa (Medawachchiya)		High	8.11		20	2	Medawchchiya
Priority 1 total					107		

2. **Vavuniya District**

Cascade	DAD high potential/coping capacity ranking	CKDu	Poverty/ HCI	Recommended by District	No. of Tanks	Priority	ASC
Kappachchikulam		Medium-low	9.45	Yes	5	1	Cheddikulam
Thudduvakai Kulam		Medium	9.4	Yes	7	1	Cheddikulam
Mathavaitha Kulam		Medium	7.2	Yes	11	1	Cheddikulam
Periyanochchikulam		Medium	7.2	Yes	6	1	Cheddikulam
Ulukkulam		Medium	7.2	Yes	5	1	Cheddikulam
Kalayanoruwa		Med-low	6.9	Yes	27	2	
Pettiveli Kulam		Med-low	6.6	Yes	5	2	
Suduventapulavu		Med-low	6.6	Yes	4	2	
Karuweppan Kulam		Low-Med	6.3	Yes	11	2	
Nedunkarachchane		Medium	9.4	Yes	4	2	
Koolankulam		Medium	9.4	Yes	2	2	
Total (Priority 1)					36		

3. **Mannar District**

Cascade	DAD high potential/coping capacity ranking	CKDu	Poverty/HCI	Recommended by District	No. of Tanks	Priority	ASC
Sinnakkunchukkulam		No risk	22	yes	4	1	Palampiddi
Uvayadi Kulam		No risk	22		5	2	

Total Malwathu Oya Basin **= 147**

Mi Oya Basin

Kurunegala District

Cascade	DAD high potential/ coping capacity ranking	CKDu	Poverty/HCI	Recommended by District*	No. of Tanks	Priority	ASC
Mottapetthawa	2	Low	8.37		42	1	Galgamuwa
Kadawala	7	Low-no-risk	7.10		13	1	Mahananneriya, Nawagattegama, Inginimitiya

Sub cascade in Nabadewa	14	Low	8.74		10	2	Kotawehera, Mahagirilla
Uriyawa (sub cascades in Kurunegala District)	3	Low-No risk	5.73			2	
Total						55	

Puttalam District

Cascade	DAD high potential/coping capacity ranking	CKDu	Poverty/HCI	Recommended by District	No. of Tanks**	Priority	ASC
Uriyawa	3	Low risk	5.7	yes	31	1	Anamaduwa
Medde Rambewa (Moragahawewa)	13	Low	6.32	Yes	14	1	Nawagattegama
Maha Karambewa (Relapanawa)	No rank			Yes	9	2	
Acharigama (Kirimetiyawa)	No rank			yes	10	2	

Total Puttalam District = 45
Total Mi Oya Basin = 100
Yan Oya Basin
Anuradhapura District

Cascade	DAD high potential/ coping capacity ranking	CKDu	Poverty/HCI	Recommended by District	No. of Tanks	Priority	ASC
Hammillawa	Not available	High-Med	10.1	Yes	8	1	Horowpotana, Kapugollewa
Bandara Kubuk Wewa		Medium risk	10.0	Yes	17	1	Parangiyawadiya
Pemorakewa		Medium	9.5	Yes	29	1	Horowpotana
Kadadeke Kandura		High	9.35		16	2	
Keulkadawewa		Medium	8.5	Yes	15	2	
Ella Wewa		Med-low	7.81	Yes	3	2	
Total (priority 1)					54		

Polonnaruwa District

Cascade	DAD high potential/ coping capacity ranking	CKDu	Poverty/HCI	Recommended by District*	No. of Tanks	Priority
Keulekada						2 (included under Anuradhapura)
Diulwewa		High	4.26		9	2

Trincomalee

Cascade	DAD high potential/ coping capacity ranking	CKDu	Poverty /HCI	Recommended by District*	No. of Tanks	Priority	ASC
Ratmale		Med-low	9.98		7	1	Horowpotana, Morawewa
Medawachchiya Ela		High-Med	8.32		11	1	Gomarankadawala
Galkeppu Wewa		High-Med	6.1		8	1	Gomarankadawala
Kandamalawa		Medium	6.1		15	2	
Dutu Wewa		Medium	6.1		7	2	
Mahalandawa					12	2	
Kibulpitiyawa		Medium	6.1		6	2	
Totall (Priority 1)					26		

*Cascade recommendations not received

Total Yan Oya = 80

Total number of village irrigation systems = 324-328

DESIGN AND CONSTRUCTION: SITE INVESTIGATIONS[194]

6.1.1 General

In addition to the data and information collected for the Preliminary Investigation Report further site investigations are required for the design purposes. The site investigations include:

- Topographical site surveys for dam or diversion weir and sites for spillways, sluices etc
- Sub soil investigations including collection of soil samples and laboratory testing
- Geological explorations including drilling and core sampling
- Prospecting for materials (sand, earth, metal and gravel etc.)

6.1.2 Topographical Site Surveys

The following surveys will be required:

- Reservoir bed
- Dam axis
- Spill and sluice sites
- Borrow Areas

6.1.3 Sub Soil Information and Data to be Determined

The designer needs the following sub-soil and geo-technical information in order to provide appropriate designs for headworks. Some of these involve probing foundation conditions and others refer to prospecting for materials.

Sub-soil Data

- Soil horizons of top soil mantle (depth, classification and characteristics)
- Depth of hard pan below surface
- Bearing capacity of soil at each horizon
- Soil strength parameters (cohesion and angle of internal friction) at each horizon
- Soil permeability
- Soil plasticity

Geo-technical data

- Stratigraphy
- Structural (folds, faults etc.)data
- Weathering rock

[194] Note: The information for Design and Construction Specifications have been obtained from Mahaweli Consultancy Bureau, 2015. Consultancy Services for Detailed Designs of Upper Elahera Canal, Kaluganga-Moragahakanda Link Canal and Manakkattiya-Eruwewa-Mahakanadarawa Irrigation System, Volume II, Part 5., Appendix B. Speciment Bid Document of UEC/ICB-1, and several other project documents

SURVEY STANDARDS - (Specifications)

6.1.4 General

It is necessary to submit Documents and Sketches in standard format for Bench Marks & Temporary Bench Marks, including coordinates.

All horizontal reference points shall be tied to National Grid Coordinates, All levels shall be with respect to mean sea level (m MSL).

Soft copies of all surveys such as site surveys should be submitted in AutoCAD 2007 format or later version, and in MS Excel.

Tank Bund Surveys

Traverse survey, longitudinal sections (LSS) and cross sections (CSS) for the tank bund:

Traverse survey along the Centre Line of the bund.

Longitudinal sections at 100 m intervals along the centre line of the tank bund and at significant changes of spot heights within the intervals and at all structures, breaches etc.

Cross sections at 100 m intervals along the centre line of the bund and at significant changes of spot heights within the intervals. The length of the cross section shall be the bund base width + 10m on both upstream and downstream normal to the centre line. The spot heights at the cross section shall be at 10m intervals and at changes of slopes within the interval.

Details to be covered:

Rock outcrops, roads, foot paths, outlets and structures, boundaries of private lands and buildings etc.

Bench Marks:

At 1 km intervals and at the LB and RB ends of the bund

6.1.5 Detailed Site Surveys at specified locations of interest

Grids and Spot Height:

Squares of 40m sides with grids at 5m intervals along and perpendicular to the base line and covering the area specified. Spot Levels at grids and at changes of ground slope within the grids. The survey shall be carried out with the Grid Lines at 5 m.

Extra Details to be covered: (If any)

Rock outcrops, Streams / drainage lines, roads, foot paths, culverts / bridges, boundaries of private lands and buildings etc.

6.1.6 Accuracy of Surveys

Survey shall be done by “Total Station” or better Instrument. Levelling shall be done by “Dumpy Level” or better Instrument

6.1.7 Drawings

Site Surveys in Natural Scale of 1:1000. L. SS in 1:100 Vertical & 1:1000 Horizontal and C. SS in Natural Scale of 1:100. Drawing setup is to be adjusted to include at least 6 CSS in A3 size paper.

The drawing shall show in plan all features surveyed and levelled, give values of spot levels taken at specified intervals and additional spot levels taken for definition of other features. The drawing shall show in plan all features surveyed and levelled, give values of spot levels taken at Grid Points and other additional spot levels taken for definition of other features. And Contours be drawn for 500mm intervals.

Hard copies to be produced in A3 size and soft copies shall be to AUTOCAD 2007 or later version.

All measurements given shall be in metric units.

All printed copies shall be produced in A3 size and soft copies shall be in AutoCAD 2007 format or later.

(Based on the specifications made by North Central Province Canal Project for the University of Ruhuna Survey Camp)

HYDROLOGICAL AND STRUCTURAL DESIGN STANDARDS

6.1.8 Hydrological Design Standards

Computation of flood hydrograph is an important feature for hydrologic design of spill. The flood hydrograph at a point of interest can be obtained by actual observed stream flow measurements. But for minor irrigation tanks such observed data are not available and hence flood studies are performed using synthetic hydrographs. For simplicity a hydrograph is assumed using Uniform Intensity Storms with the peak flow derived from using Rational Formula as given below.

Q = C I A

Where Q = peak run-off for any particular return period

C = Run-off coefficient

I = Rainfall intensity in inches per hour

A = Catchment area in acres

Run-off coefficient

Run-off coefficient basically depends on the catchment slope. The catchment slope is taken as the difference in level between the highest point in the longest water course and the point of interest divided by the length of the longest watercourse.

Catchment slope %	Run-off coefficient
0 to < 2	0.3
2 to < 4	0.4
4	0.5

Rainfall Intensity

The rainfall intensity is the total rainfall divided by the duration of the storm. But the actual intensity may vary widely during the duration of the storm.

From the studies of observed rainfall data over long periods, the Irrigation Department has developed Depth – Duration – Frequency cures and Intensity – Duration – Frequency curves for 6 Hydrological Zones in Sri Lanka. These curves are available in the Irrigation Department Technical Guidelines.

6.1.9 Structural Design Standards

Design criteria and standards for canal design

Trapezoidal shaped canal section is suitable for unlined earth canal. The canal discharge to be computed based on the water requirement of the crop.

In smaller canals the effect of friction of canal parameters causes more pronounced drag on the water stream. Thus to maintain the same velocity of the flow, the bed slope of the canal is to be kept at a higher value of 0.0004.

The Manning's formula as given below is used to determine the velocity of the flow.

$$V = \frac{1}{n} R^{2/3} S^{1/2} \quad \text{(in Metric Units)}$$

where V is the velocity of flow in m/s, R is the hydraulic radius (R = A/P, A= Area of the canal and P= perimeter of canal at full supply level) and "n" is the Manning's rough coefficient.

Manning's Roughness Coefficient varies according to the material type of the canal.

Material	'n' valve
Earth canals in good order	0.025
Rocky banks and bed	0.040
Concrete lined canals	0.015
Masonry	0.018

Design of canal structures - Spills

Spillways are provided in the reservoirs to send excess water which may flow during rainy seasons. In minor irrigation tanks, the most common type of spill way is the solid overflow spillways. These spillways are made of concrete or masonry.

The cross section profile of a solid overflow spill usually has a vertical face in the upstream and slope or an ogee shape profile at the downstream.

The length of the spillway is computed using the weir formula given below.

$$Q = C_d * L * H_e^{3/2}$$

Where Q = flood discharge

Cd = Coefficient of discharge over the weir crest

L = Length of the spill way

H_e = Head over the crest

Aprons and cutoff walls are to be incorporated to the spill structure to minimize the seepage through the spillway and to prevent scouring at upstream and downstream edges.

Design of Sluice Structure

The essential components of a sluice are:

- Intake tower, control gate and lifting arrangement
- Access foot bridge for gate operations
- Sluice barrel
- Downstream outlet structure including stilling basin

In many of the village tanks the intake towers are cylindrical towers constructed of hume pipes. A foot bridge to provide access to the tower and operating platform and a gauge post to register reservoir stage or water levels are features that are incorporated with the intake tower.

The sluice gates are made of cast iron or timber. The gate should be capable of issuing full design discharge when fully open and with water in the tank at minimum operating level.

The downstream section of sluice consists of a head wall and wing walls are designed as standard retaining walls. A stilling basin with a depressed bed is required to dissipate the high kinetic energy of the water coming from the sluice barrel.

SPECIFICATIONS FOR CIVIL WORKS

6.1.10 General

Survey Works prior to civil works

The Contractor shall furnish all materials, labour and equipment including stakes, templates, patterns, platforms and special labour that may be required by the Contractor in setting out any part of the Works. The Contractor shall render all services for, setting out and measurements as required for the performance of the Works.

Based on the drawings and on the instructions given by the Engineer the Contractor shall execute all surveying and mapping required for the setting out and for construction works. The production of drawings and maps, wherever required, shall be deemed to be part of the Works.

All survey works performed by the Contractor shall be subject to approval by the Engineer.

The Contractor shall be responsible for the maintenance and protection of datum points, benchmarks and reference monuments during construction, and shall regularly perform full check surveys to confirm that they have not been affected by construction activities or in any other way disturbed or damaged.

Prior to completion of a partial survey task or upon completion of setting out the Contractor shall inform the Engineer accordingly so that the Engineer shall have the opportunity to carry out the necessary checks and inspections. This shall be particularly applicable for structures which will be covered up and/or are of a permanent nature. Notwithstanding the above the Engineer shall have the right to check at his discretion performance, accuracy, stations, etc., and all survey results, measurements and calculations as well as conformity with plans and drawings related to the survey work. The Contractor shall without delay provide to the Engineer any assistance and auxiliary services required to permit him to carry out control surveys and measurements.

The Contractor shall survey all excavated and final surfaces as required by the Engineer for the purpose of recording as-constructed details and for the measurement of quantities:

(i) on completion of excavation and prior to commencement of placing embankment, backfill, concrete or other work;

(ii) on placing intermediate horizons of different fill types for measurement purposes;

(iii) on completion of placing embankment, backfill, concrete or other work.

The Contractor shall give the Engineer not less than 24 hours notice of his intention to set out, survey or give levels for any part of the Works in order that arrangements can be made for checking the accuracy of the setting out, survey or levels. In order that the Engineer can expedite such checking the Contractor shall as soon as practical supply the Engineer with records in an approved form relating to all reference pegs and benchmarks in connection to the set out, survey or levels for any part of the Works which are required to be checked.

The Contractor shall perform all setting out and check surveying of the Works in accordance with methods of working approved by the Engineer before work commences. The methods and programme of checking shall be such as to ensure the construction of every part of the Works to the correct line and level. The Engineer may at any time request the Contractor to submit proof that his own setting out has been satisfactorily checked, and the Contractor shall comply immediately with any such request.

The number of points required for setting out as well as the spacing between these points shall be determined by the Contractor together with the Engineer in accordance with the type of the work. In addition to any coordinated points and datum levels which the Contractor establishes for his own use, the Engineer may require that certain or all of the given points and datum levels be clearly marked during construction in such a way that the marks can be retained after completion of the construction. Where this is not possible for any reason, the Contractor shall inform the Engineer in writing and an alternative position shall be agreed with the Engineer and confirmed in writing.

The Engineer will carry out regular check surveys during the course of construction and the Contractor shall cooperate with and provide all assistance as required by the Engineer.

No Payment will be made for the survey works, setting out and for payment works referred in this Section and are deemed to be included or spread over the various rates or lump sum prices of construction/erection works in the Bill of Quantities.

Diversions and Dewatering

The Contractor shall have the general responsibility for planning, designing, constructing and maintaining all necessary diversion works including diversion culverts, cofferdams, canals, drains and sumps and any other temporary diversion and protective works and shall provide, install, maintain and operate all necessary pumping and other equipment for dewatering the various parts of the Works in order to keep the excavations, foundations and other parts of the works de-watered as required for constructing each part of the Works. After having served their purpose, all cofferdams and other temporary protective works shall be removed or levelled or removed so as not to interfere in any way with the operation or usefulness of the Works and in a manner satisfactory to the Engineer. Surplus material shall be transported to approve spoil areas.

Materials from Borrow Areas and Quarries

The Contractor shall be fully responsible for the provision of the fill material, coarse and fine aggregates, rock, granular and cohesive materials for embankment fill, structures, concrete works and any other purposes as specified and required for the Works in accordance with the Contract.

The Contractor shall obtain material which is required in addition to that obtained from the excavation for the Permanent Works, from approved quarries and borrow pits as approved by the Engineer. The Contractor shall investigate and develop such borrow areas or quarries as he may require to meet his requirements under the Contract. Such development of borrow areas or quarries shall include, where applicable, confirming that any permissions and licenses which may be required under Sri Lankan regulations have been obtained, and the construction, operation and maintenance of the required access roads and haulage arrangements, removal and stockpiling of overburden material.

In the case of standard labelled stock products of standard manufacture which have a record of satisfactory performance in similar work over a period of not less than two years, the Engineer may accept a notarised statement from the manufacturer certifying that the product conforms to the applicable Specifications.

Quality Assurance and Quality Control

The Contractor shall submit his detailed Quality Assurance & Quality Control procedures to the Engineer for approval not later than 28 days after the Commencement Date. The Engineer will either approve the quality procedures or require reasonable amendments to be made, and the Contractor shall introduce and implement all such amendments within 14 days and re-submit the documents to the Engineer for approval.

The Contractor shall prepare a set of co-ordinated quality procedures designed to ensure that materials and workmanship by himself will meet the specified requirements for quality, and these procedures shall comply with the quality systems which the Contractor proposes and the Engineer approves for application on the Contract.

The Contractor shall develop Quality Assurance Program (QAP) defining quality control activities such as testing, inspection and procedures for scheduling and managing submittals and reporting in accordance with the Contract.

The Contractor shall perform sufficient inspections and tests of all items of work to ensure compliance with the Contract. This includes, but is not limited to, all the inspection and tests specified in the Contract. While carrying out his own quality control as specified, the Contractor shall provide the Engineer with all facilities for inspecting the work, witnessing required tests and analysing test results.

The QAP shall include a description of how materials suppliers will be controlled to ensure that only materials complying with quality standards are produced and delivered to site, and methods for identifying and removing from the site any non-conforming materials.

The quality assurance system instituted by the Contractor is a requirement under the Contract and no payment will be made to the Contractor for this work.

Construction Programme

Within 01 month of the award of Contract, the Contractor shall submit a construction program to the Engineer for approval. The program shall show the following minimum details

- The duration, sequence and logic links between major activities and any other activities or group of activities which comprise the Works.
- The planned dates for start and completion of the Works and each Section of the Works;
- Information on shutdown periods, vacation days and other non-working time periods;
- The estimated value of work to be done each month;
- Reasons for any changes to timing, work order, method, or resources from the program submitted at the time of tender, or if submitting an updated construction program, reasons for such changes from the previously submitted program.

The construction program submitted in accordance with the provisions of this clause shall in the opinion of the Engineer be reasonable in all respects.

Temporary Works

The Contractor shall execute, erect, maintain and remove upon completion of the Works all Temporary Works. On completion of the Works, all Temporary Works constructed by the Contractor or handed-over to the Contractor by the Engineer, unless otherwise specified or instructed by the Engineer, shall be removed from the Site, as approved by the Engineer. The Contractor shall make safe all areas affected by Temporary Works and reinstate natural drainage.

6.1.11 Site Clearance and Stripping Vegetation

Removal of Trees, Shrubs and Other Vegetation

Prior to any excavation works, the surface of the ground at the site of any structure or over any other designated area within the limits of the Site as defined on the Drawings or as directed by the Engineer shall be cleared of all trees, shrubs and other vegetation. The clearing shall be limited only to the extent required to carry out the Works. Trees and shrubs outside the clearance area shall not be cut down without the prior written consent of the Engineer.

In the event that there exists a clearly defined layer of topsoil, which is capable of being reused for grassing etc., the Contractor shall take every precaution to minimize the loss of such topsoil when clearing the Site.

Disposal of Material

Combustible material arising from clearance shall not be burnt on Site without the written consent of the Engineer. Non-combustible material and material which the Engineer does not permit to be burnt on Site shall be disposed of as spoil.

All removable items which are to be preserved in accordance with the Drawings, the Specification or the instructions of the Engineer shall be stored on Site in a place of safety and in a manner appropriate to their nature. All such items shall remain the property of the Employer.

5.2.3 Stripping of Surface Soil Layer

In the event that, in areas of the ground surface which are to be directly affected by excavation, earthworks or structure foundations, there exists a clearly defined layer of topsoil which is capable of being reused for grassing etc., this topsoil is to be stripped and stored in stockpiles for subsequent re-use in the Permanent Works. Such stockpiled topsoil shall be used in covering fill embankments or any other required areas, and the Contractor shall ensure that sufficient material for this purpose is preserved.

The depth of stripping is expected generally to be up to 200 mm, although in places greater or lesser depths of stripping may be necessary or appropriate, and the final depth will depend on the extent of vegetation or other contamination and shall be subject to the agreement of the Engineer.

For measurement and payment purposes the Contractor shall carry out a survey of both the original ground surface as well as the approved surface of the in-situ soil following the stripping of either an identified topsoil layer or else a surface layer containing vegetation or other contaminating matter.

6.1.12 Excavation

Before any excavation or earthworks is commenced, the site of the excavation or earthworks shall be surveyed by the Contractor for measurement purposes. This survey shall be carried out when the vegetation has been removed and the surface layer of soil has been stripped, if appropriate the surveyed levels shall be used as the initial levels for the measurement of excavation. Excavated surfaces which will remain permanently exposed on completion of the Permanent Works shall be cleared of all loose material, pieces of rock, debris, rubbish and the like and left neat and tidy.

The Contractor shall separate excavated material dependent upon whether it is to be reused in the Permanent Works or whether it is to be disposed to spoil. All excavated material which is designated for reuse in the Permanent Works shall be stacked close to the excavation, separately according to its intended use. Particular care shall be taken to avoid erosion of any stacked material.

All excavated material which will not be reused in the Permanent Works shall be disposed of in accordance with the requirements or as agreed by the Engineer as spoil areas.

6.1.13 Filling

General

Fill shall be any suitable material, either from excavations for the Works or from borrow areas which can be compacted to the required degree of compaction. Irrespective of any other requirements, material for any type of backfill shall not contain boulders or stones having a height when placed of more than two thirds of the compacted thickness of the layer being placed, nor shall it contain lumps of more than this height which are too hard to be broken down during compaction.

Fill material which is too wet for compaction or which in any other way fails to comply with the Specification shall be disposed of to spoil.

Selected material for incorporation into the Works as fill shall be free from soluble and water sensitive particles and organic matter and shall comply with the gradation and other requirements set out for each specific type of suitable embankment fill material or backfill material.

Borrow Areas and Quarries

The Contractor shall be fully responsible for the provision of the fill materials as specified and required for the Works in accordance with the Contract, as well as for the selection of all borrow areas and quarries which may be necessary to satisfy that requirement. The location and extent of the selected borrow areas and quarries for the provision of selected fill material in accordance with the requirements of this Section shall be subject to the approval of the Engineer. The Contractor may develop and/or use any borrow areas and quarries subject to the prior approval of the Engineer, develop and/or use other borrow areas and quarries or other sources of excavation materials to meet the requirement of this Specification.

The cost of all requirements and work specified herein for borrow areas and quarries is deemed to be included in the rates and prices in the Bill of Quantities.

Placing and Compaction of Fill Material

The Contractor shall not commence or perform any fill work using equipment or working methods which deviates in any way from the equipment and methods of execution which have already been approved in writing by the Engineer.

All vegetation, topsoil and any other unsuitable overburden shall be removed from areas on which fill is to be placed.

When fill is placed on ground or against existing fill with a slope exceeding 10° from the horizontal, the slopes shall be benched unless the Engineer agrees that benching is not required.

If filled areas contain material which is susceptible to deterioration due to the excessive absorption or loss of water, it may be necessary to protect such areas by covering with further Permanent Works construction or else with a temporary layer of fill of sufficient thickness to prevent penetration of water into or loss from the permanent fill. Alternatively a suitable impermeable membrane may be used to protect the permanent fill.

Where fill is to be placed in trenches, pits and other places the sides of which are supported, those supports which are to be removed shall as far as practicable be withdrawn ahead of the layer of fill to be compacted and all voids left by the supports shall be filled with fully compacted material.

Where the slope of the natural ground exceeds 10° from the horizontal, or if a lesser slope is deemed unsuitable to take a fill layer, benching shall be provided. The dimensions of the benches shall be sufficient to permit the operation of placing and compaction equipment thereon with an initial bench at the toe of the fill, with gabion or other protective devices accommodated where directed or specified. Each bench shall be cut as the fill is compacted and brought up.

All benching shall be made in accordance with the Drawings or as instructed by and to the approval of the Engineer.

Fill shall be placed in uniform layers across the full width and length of the area to be filled so that the area is built up evenly and shall be compacted as soon as practicable after deposition. The width of an embankment layer shall not be extended by means of the deposition of loose materials from the top of the embankment. Materials of differing characteristics shall not be mixed in any one layer and each layer shall be free from lenses and pockets of such material.

Fill shall be placed so that the surface is sufficiently even, and the surface shall be graded generally level before compaction operations commence while still having sufficient camber to shed surface water and to avoid ponding.

The surface on which fill is to be placed shall be scarified if it is too smooth for proper bonding with the layer of fill to be placed.

The moisture content of embankment fill material shall be adjusted by suitable conditioning to be within a range of the optimum moisture content required by this Specification or determined by the Engineer, depending on the characteristics of the material.

Compaction equipment shall be capable of achieving the required compaction without having any detrimental effects on the fill material. The equipment shall be carefully controlled to ensure that all areas are uniformly compacted for their full width and depth.

Backfilling:

Unless otherwise shown on the Drawings or specified or instructed by the Engineer, excavations which are to be backfilled shall be filled with suitable material obtained from the excavations or from approved borrow areas.

When placing fill as backfill the Contractor shall make due allowance for settlement and shall ensure that the final lines and levels are as shown on the Drawings. Suitable measures shall be taken to minimize erosion of the refilled excavations during wet weather, including sufficient specific measures to shed runoff water to the downslope side of trenches and avoid the formation of waterways along or parallel to the trenches.

Suitable fill shall be compacted to a dry density not less than 95% maximum dry density "modified Proctor", or else as indicated on the Drawings or directed by the Engineer, expressed as a fraction of the maximum dry density and measured by field density tests.

If fill has a moisture content too low to permit the specified dry density to be achieved, the Contractor shall incorporate sufficient water by a method acceptable to the Engineer to permit compliance with the Specification. Such operations shall be included for in the Contractor's rates.

If fill becomes sufficiently wet to cause serious rutting by construction traffic or heaving under compaction plant and to an extent that the required dry density cannot be obtained, placing and compaction shall forthwith cease and shall not be resumed until the Contractor has taken whatever action may be necessary to restore the fill to a proper condition for compaction.

6.1.14 Reinforcements

The Contractor shall furnish and install all reinforcement required for execution of the Works where shown on the Drawings or directed.

All non-prestressing reinforcement shall be high yield deformed bars type II as per BS 4449 or BS 4461 with specified characteristic strength of 460N/mm^2 or plain round hot-rolled mild-steel bars as per BS 4449 with specified characteristic strength of 250 N/mm^2. The BRC fabric reinforcement shall be as per BS 4483 with the wires complying with BS 4482.

Test certificates shall be submitted to the Employer for all reinforcement and reinforcing fabric furnished by the Contractor to be used in the Works and such submission will be prior to using the material in the Works.

The Contractor shall prepare and submit to the Engineer for approval a complete reinforcement bar list including bar bending details in an approved form. All reinforcing bars shown on the drawings shall be identified on the bar lists.

The Contractor shall be responsible for the accuracy of the cutting, bending and placing of the reinforcement. Before the reinforcement is placed, the surfaces of the bars or fabric and the surfaces of any metal bar supports shall be cleaned of heavy rust, loose mill scale, dirt, grease and other objectionable foreign substances. Heavy flaky rust, which can be removed by firm rubbing with hessian or equivalent treatment is considered objectionable. After being placed, the reinforcing bars or fabric shall be maintained in a clean condition until they are completely embedded in the concrete.

Reinforcing bars or fabric shall be accurately placed and secured in position so that there will be a clear distance of at least 25mm between the bars or fabric and any adjacent metalwork and so that the bars and fabric will not be displaced during the placing of concrete, and the Contractor shall ensure that there is no disturbance of the reinforcing bars or fabric in concrete that has already been placed.

Where protruding bars are exposed to the elements for an indefinite period, the bars shall be adequately protected against corrosion and damage and shall be properly cleaned before being permanently encased in concrete.

When it is necessary to bend protruding steel reinforcement aside temporarily, the radius of the bend shall not be less than four times the bar diameter for plain bars or six times the bar diameter for high yield deformed bars. Such bends shall be carefully straightened before concrete placing continues, without leaving residual kinks or damaging the concrete around them.

Unless otherwise detailed on the Drawings, the minimum cover to reinforcement shall be the greater of 50mm, or the normal maximum size of the aggregate plus 5mm.

Splicing of reinforcement shall be done by overlapping the bars or mesh for a distance not less than that shown in the drawings with the bars in contact, or by welding in such a manner as to maintain the full strength of the bars.

Where it is necessary to splice reinforcement, the splices shall be made by lapping, by welding or by mechanical means in accordance with AS 3600 and the detailed provisions of this Clause.

Reinforcing bars which are spliced by welding or by mechanical means shall be tested by the Contractor to verify that the splice has sufficient strength to develop a tensile stress appropriate to the type and grade of steel in the smaller bar at the splice of 0.95 times the specified ultimate strength.

Welding of cold worked deformed reinforcing bars will be permitted only for a particular case or application for which no alternative splicing is practicable and subject to satisfactory testing in accordance with this Clause

Before being permitted to use mechanical couplings on the Works, the Contractor shall prepare four test specimens for each size of coupling using the same materials and processes as will be used for the actual reinforcement. The length of each test bar shall be not less than 450 mm before connection. The connected bars shall be tested by the Contractor in accordance with Subclause a. of this Clause. If all test specimens meet the strength requirements, the coupling will be approved for the Work.

The Contractor shall test two specimens, representing every 100 splices made using welding or mechanical coupling.

6.1.15 Concrete Works

Materials for Concrete

Cement

Cement for concrete and mortar shall be Ordinary Portland Cement (OPC) and shall conform to BS 12. For surfaces exposed to public view, where colour of the finished concrete is important, all cement shall be of the same type and colour and origin from the same plant.

Cement that has not been used within 3 months from the date of initial sampling shall not be used in the Works unless it has been shown to conform to the specified requirements.

Aggregates

Fine and coarse aggregates shall conform to BS 882 and to the requirements of this Specification.

The term "fine aggregate" is used to designate aggregate in which the maximum size is 5 mm. Fine aggregate for concrete and mortar shall be furnished by the Contractor and shall be natural sand, a manufactured sand, a blend of natural sands or a blend of natural and manufactured sands.

The term "coarse aggregate" is used to designate aggregate in which the minimum nominal size is 5 mm and which is reasonably well graded from 5 mm to the largest size required in the work in which the material is being used. Coarse aggregate for concrete shall be furnished by the Contractor and shall consist of natural gravel, a mixture of natural and crushed oversize gravel or manufactured aggregate.

At least 60 days before placing any concrete the Contractor shall submit to the Engineer test results from representative samples of the proposed aggregates.

Grading of Fine Aggregate

The fine aggregate as batched shall be well graded and when tested shall conform to the limits specified as given below.

Sieve Size (mm)	Percentage of total mass passing sieve
4.75	95-100
2.46	80-100
1.18	50-85
0.60	25-60
0.30	10-30
0.15	2-10
0.075	0-3

The grading of the fine aggregate shall be so controlled that at any time the fineness moduli of at least 9 out of 10 consecutive test samples of finished fine aggregate will not vary more than 0.20 from the average fineness modulus of the 10 test samples.

Where fine aggregates from different sources are being used at the one batching plant at the same time, they shall be so blended to ensure uniform grading and colour in successive batches.

Grading of Coarse Aggregate

The coarse aggregate as batched shall be separated into nominal sizes and shall be well graded such that when tested by the sieves designated in the following table the minimum amounts of intermediate sizes shall comply with the requirements set out in.

Designation of size (mm)	Nominal size range (mm)	Minimum percentage retained on sieve indicated
9.5	4.75 to 9.5	Not applicable
20	9.5 to 20	25 on 16.0 mm

40	20 to 40	25 on 31.5 mm

Other Properties of Aggregates

Property	Fine Aggregate	Coarse Aggregate
Minimum specific gravity	2.56	2.56
Aggregate strength (on fraction greater than 9.5 mm)		
Minimum wet strength	N/A	80 kN
Maximum wet/dry strength variation	N/A	35%
Maximum weighted loss of a portion retained on an 0.300 mm sieve when subject to 5 cycles of sodium sulphate test	8% by mass	10% by mass
Maximum sum of flakiness and elongation indices	N/A	60%
Minimum fineness modulus	2.10	N/A
Maximum fineness modulus*		
Natural sand	3.10	N/A
manufactured sand	2.80	N/A
* For a mixture of natural sand and manufactured fine aggregate the maximum fineness modulus shall have a value between 3.10 and 2.80 in proportion to the constituent materials.		

Water

Water used in concrete and mortar, for washing aggregate and for curing concrete shall not contain more than 2000 ppm of suspended colloidal solids. The water shall not be aggressive and shall have a chloride content less than 50 mg/l and sulphate content less than 100 mg/l. Water having a temperature above 25^{o} C shall not be used in concrete.

Concrete Mix Design

The Contractor shall be responsible for the design of concrete mixes and for ensuring that all concrete placed in the Works meets the requirements of the Specification. The Contractor shall prepare, in the Engineer's presence, trial mixes of the proposed mix designs and carry out tests to verify their compliance with the Specification.

The class of concrete and maximum water cement ratio shall be as specified in the table given below. To achieve adequate workability a water reducing agent and/or plasticiser may need to be used. For all structures the use of a plasticiser shall be subject to the approval of the Engineer.

Concrete class refers to a 28 day strength as defined in BS 1881 Part 116 (on cube sample)

Class of Concrete	Characteristic Strength (Mpa)	Minimum Cement Content per Unit Volume of Concrete - (kg/m^3)	Max. w/c ratio
M 25 Mass concrete	25	275	0.5
Blinding	15	-	0.55
S30 structural concrete	30	340	0.5
S40 structural concrete	40	360	0.5

At least 60 days prior to commencement of any concreting of Permanent Works, the Contractor shall start the testing of materials, propose the composition of concrete mixes and prepare trial mixes of each of the proposed concrete classes. The Contractor shall prepare the trial mixes using the cement, water, aggregates manufactured by the crushing and screening plants for the main works and admixtures intended for the work and which conform to the requirements specified herein.

Initially not less than 4 concrete cubes shall be prepared in accordance with ACI-211.1 for each class of concrete. Compressive strength of concrete shall be tested at 7 days (1 cube), and 28 days (3 cubes).

Based on the findings from the initial testing series, additional tests shall be carried out to fine tune the required cement content to fulfil the requirements of ACI-211.1 and BS 1881 standards for each concrete class. This shall include not less than 12 concrete cubes for M25, S30 and S40, testing the compressive strength at 3 days (2 cubes), 7 days (2 cubes), 28 days (3 cubes), 90 days (3 cubes), and 180 days (2 cubes). This shall also include at least 3 tests per concrete mix for drying shrinkage

Mixing

The concrete ingredients shall be mixed thoroughly in approved stationary mixers which are so designed as to ensure uniform distribution of all of the component materials throughout the mass at the end of the mixing period.

The Engineer reserves the right to vary the mixing time or to limit the batch size when the charging and mixing operations fail to produce a batch of concrete that conforms with the foregoing requirements with respect to adequacy of mixing. The concrete of a given composition, as discharged from the mixer, shall be uniform in composition and consistency within batches and from batch to batch.

Water shall be added before, during and following the mixer-charging operations. Excessive over-mixing, requiring addition of water to preserve the required concrete consistency, will not be permitted.

Preparation for Placing

Concrete shall not be placed in water unless the method of depositing the concrete has been approved. All surfaces of forms and embedded materials that have become encrusted with dried mortar or grout from concrete previously placed, shall be cleaned of before the surrounding or adjacent concrete is placed.

Immediately before placing concrete, all surfaces of foundations upon or against which the concrete is to be placed shall be free from standing water, mud, debris, oil, objectionable coatings and loose semi-detached or unsound fragments. Where necessary surfaces of foundations shall be cleaned with air-water jets.

The surfaces of absorptive foundations against which concrete is to be placed, shall be moistened thoroughly so that moisture will not be drawn from the freshly placed concrete. Where directed and approved, a water barrier such as 0.25mm thick polyethylene sheet shall be used to cover absorbent foundations.

Cleaning Previously Placed Concrete Surfaces

The surfaces of construction joints shall be clean and damp when covered with fresh concrete or mortar. Cleaning shall consist of the removal of all laitance, loose or defective concrete, coatings, sand, curing compound if used, and other foreign material to the satisfaction of the Engineer.

The surfaces of block outs against which concrete is to be placed shall be roughened by scrabbling.

Preparation of Existing Concrete Surfaces

Where new concrete is to be placed on or adjacent to existing concrete structures, the existing concrete surface shall be prepared as follows:

- The existing concrete shall be broken out to at least the lines shown on the drawings, further demolition may be required to obtain a surface free from damage or weak materials. The Contractor shall take care not to damage the concrete beyond the lines shown on the drawings and specialised equipment such as concrete saws shall be used to minimise such damage.
- Areas where a feather edge would occur shall be broken out such that a minimum thickness of 70mm of new concrete can be placed and vibrated to the design lines. Alternatively, an approved cement grout having a minimum compressive strength of 40MPa and using approved epoxy resin bonding agents may be used to build up feather edges.
- Where walls and slabs are to be extended with continuous reinforcement, the existing concrete shall be broken out to expose a length of existing reinforcement providing 1.3 times the required lap length as shown in the Drawings.
- The concrete surface shall be cleaned with high pressure air and water with sufficient pressure to remove spalled or weak concrete, organic material, contaminants, material within cracks and voids etc. such that the exposed surfaces is clean, sound concrete with some coarse aggregate exposed.
- The exposed concrete surfaces shall be subject to approval by the Engineer and this shall constitute a hold point.

Placing Concrete

The Contractor shall place all concrete in structures in accordance with this Specification or as approved by the Engineer. The Contractor shall inform the Engineer when concrete will be placed and concrete shall only be placed in the presence of the Engineer, unless otherwise approved.

Appropriate measures shall be taken with respect to transporting and placing the concrete to control the temperature of concrete. Pipe lines for conveying concrete shall be shaded and insulated or painted white; the elapsed time from mixing to placing shall be minimised. Concrete shall be placed promptly when delivered and finishing operations shall not be delayed; concrete surfaces shall be protected from wind and sun during placing, finishing or curing operations.

Whenever practicable, concrete shall be deposited directly in its final position and shall not be dropped, chuted or caused to flow in a manner to permit or cause segregation. Methods and equipment employed in depositing concrete in forms shall not result in clusters or groups of coarse aggregate being separated from the mass. The Contractor shall provide chutes and baffles to confine and control the falling concrete. The movement of concrete within the forms by use of vibrators will not be permitted.

In the event of continuous placing being interrupted for any reason, the Contractor shall thoroughly consolidate the concrete at such joints to a reasonably uniform and stable slope while the concrete is plastic and any concrete which is unconsolidated and no longer plastic shall be removed by the Contractor at his own expense. The concrete at the surface of such cold joints shall be cleaned and damped when covered with fresh concrete.

Except as intercepted by joints and for concrete in tunnel linings, all formed concrete shall be placed in continuous approximately horizontal layers, the depths of which generally shall not exceed 500mm. The Engineer may direct thinner layers where concrete in 500mm layers cannot be placed in accordance with the requirements of this Specification.

In placing unformed concrete on slopes so steep as to make internal vibration of the concrete impracticable, the concrete shall be placed ahead of an unvibrated slip-form screed extending approximately 800mm back from its leading edge. Concrete ahead of the slip-form screed shall be consolidated by internal vibrators so as to ensure complete filling under the slip-form screed.

Placing Mass Concrete

In placing mass concrete, the Contractor shall maintain the exposed area of fresh concrete at the practical minimum, by first building up the concrete in successive approximately horizontal layers to the full width of the block and to full height of the lift over a restricted area at one end of the block and then continuing to the opposite end in similar progressive stages to the full area of the block.

The lift heights and the period between successive lifts shall be controlled to prevent the maximum temperature exceeding the limits specified.

Unless otherwise shown on the Drawings or approved, the times between successive lifts and maximum permissible lift heights shall be as set out in the following **Error! Reference source ot found.**

Table 18: Maximum Lift Height and Time between Lifts

Location	Maximum Lift Height (m)	Minimum Time Between Lifts (hours)
Mass concrete in massive structures	2.25	72
Walls and piers less than 5m thick	2.50	72

Clusters of large aggregate shall be scattered before new concrete is placed over them. Each deposit of concrete shall be vibrated completely before another deposit of concrete is placed over it.

Mass concrete shall not be placed during rains sufficiently heavy or prolonged to wash mortar from coarse aggregate on the forward slopes of the placement.

Once placement of mass concrete has commenced in a block, placement shall not be interrupted by diverting the placing equipment to other uses.

Compaction of Concrete

Concrete shall be consolidated to the maximum practicable density in such a manner that it is free from pockets of coarse aggregate and fits snugly against all surfaces of forms and embedded materials.

Whenever practicable concrete shall be consolidated by immersion type vibrators operated in accordance with the manufacturer’s recommendations. Form vibrators shall be used whenever internal vibration is not possible or would be inadequate. Where the use of mechanical vibration is not possible or would be inadequate concrete shall be consolidated thoroughly by hand.

In consolidating each layer of concrete, the immersion type vibrator shall be operated in a near vertical position and the vibrating head shall be allowed to penetrate and re-vibrate the concrete in the upper portion of the underlying layer. In the area where newly placed concrete in each layer joins previously placed concrete in the same layer, more than usual vibration shall be performed, the vibrator penetrating deeply at close intervals over the areas of contact of these layers. Layers of concrete shall not be placed until layers previously placed have been vibrated thoroughly as specified. Contact of the vibrating head with surfaces of the forms shall be avoided. Direct vibration of the reinforcement will not be permitted.

Curing

All concrete shall be cured in accordance with this Clause using water, except that, for certain surfaces, membrane curing may be approved. Membrane curing will not be approved for surfaces exposed to public view or surfaces which are to be subsequently coated.

At least 14 days before placing concrete in any structure to be water cured, the Contractor shall submit to the Engineer details of the equipment and methods he proposes to use for water curing. After the initial placement of concrete in any structure, subsequent placements will not be permitted until equipment for curing has been satisfactorily installed and is operating on all previous placements in the structure.

Concrete cured with water shall be kept continuously wet for at least seven (7) days immediately following placement of the concrete, or until covered with fresh concrete. Water used for curing shall meet the requirements of this Specification for water used in concrete, but with the additional requirement that the water shall not contain any chemicals or other substances that will cause staining of concrete surfaces.

Membrane Curing

At least 28 days before using curing compound, the Contractor shall submit to the Engineer details of the proposed compound. Such details shall be accompanied by test certificates to show that the compound will give satisfactory results for the proposed application.

Membrane curing, if approved, shall be by application of a type of curing compound which forms a water retaining membrane on the surface of the concrete. Curing compound shall be applied to the concrete surfaces in accordance with the manufacturer's instructions and shall comply with the stipulations of ASTM C309.

When curing compound is to be used on unformed concrete surfaces, application of the compound shall commence immediately after the finishing operations are completed.

When curing compound is to be used on formed concrete surfaces, the surface shall be moistened with a light spray of water immediately after the forms are removed, and shall be kept wet until the surface will not absorb more moisture. As soon as the surface film of moisture disappears but while the surface still has a damp appearance, the curing compound shall be applied.

Traffic and other operations by the Contractor shall be such as to avoid damage to coatings of curing compound for a period of not less than 28 days after application of the curing compound. Where it is impossible because of construction operations to avoid traffic over surfaces coated with curing compound, the membrane shall be protected by a covering of sand not less than 25mm in thickness or by other effective means. The protective covering shall not be placed until the sealing membrane is completely dry. The Contractor shall remove all sand covering after completion of the curing period. Any sealing membrane that is damaged or that peels from concrete surfaces within 28 days after application shall be repaired without delay.

Curing compound shall be delivered to the Site in suitably labelled containers to enable identification of the batch number and date of manufacture.

6.1.16 Form Work

General

Forms shall be used to confine the concrete and shape it to the required lines. Forms shall be designed and constructed by the Contractor in accordance with BS 5975 and shall have sufficient strength to withstand the pressure resulting from placement and vibration of the concrete, and shall be maintained rigidly in position.

Forms shall be sufficiently tight to prevent loss of mortar from the concrete.

Moulding strips shall be placed in the corners of forms so as to produce bevelled edges on permanently exposed concrete surfaces. Interior angles on such surfaces and edges at formed joints will not required bevelling unless the requirement for bevelling is shown on the Drawings.

The Contractor shall be fully responsible for the safety of structures from which he removes formwork.

Form-ties

Embedded ties for holding forms shall remain embedded not less than two diameters or twice the minimum dimension of the tie or 10 mm, whichever is the greater, in from the formed faces of the concrete.

Architectural Requirements

For concrete surface for which F4 finish is specified, bevelled corners and horizontal and vertical grooves and construction joints shall be constructed as shown on the Drawings or directed and shall be straight and true to level and plumb.

Forms for F4 finish surfaces in one plane shall be continuous in a vertical direction so that horizontal form joints occur at approved locations, and generally at 2 m minimum centres coinciding with horizontal construction joints, and at the same horizontal level as form joints on adjacent planes

Form lining shall be continuous for the full height of the form.

Vertical joints in form lining shall be equally spaced along the length of the form for exposed concrete surfaces. The spacing shall be identical in succeeding wall placements.

All edges of lining shall be straight and true to level and plumb. Form ties shall have a regular set-out in relation to the whole form and to each piece of form lining.

Treatment of Forms

Before concrete is placed the surfaces of the forms shall be coated with a napthalinic form oil that will effectively prevent sticking and will not stain the concrete surface. The Contractor shall submit to the Engineer details of the proposed form oil for approval at least 28 days before its use is required.

When concrete is placed, the surfaces of the forms shall be free from encrustations of mortar, grout, or other foreign material.

Removal of Forms

Excepts as provided in BS 8110 Part 1, or as directed or approved, forms shall be removed carefully as soon as the concrete has hardened sufficiently to prevent damage in order to facilitate satisfactory progress with the specified curing and enable the earliest practicable repair of imperfections in the surface of the concrete.

Concrete shall be cured immediately the forms have been removed. Curing shall be only temporarily stopped in the actual locations where repairs are being carried out.

Forms on upper sloping faces of concrete shall be removed as soon as the concrete has attained sufficient stiffness to prevent sagging. Any needed repairs or treatment required on such sloping surfaces shall be performed at once.

In order to avoid excessive stresses in the concrete that might result from swelling of the forms, timber forms for wall openings shall be loosened as soon as this can be accomplished without damage to the concrete. Forms for the openings shall be constructed so as to facilitate such loosening.

Subject to approval, forms on concrete surfaces close to excavated rock surfaces may be left in place, provided that the distance between the concrete surface and the rock is less than 500mm and that the forms are not exposed to view after the completion of the Works.

6.1.17 Joints in Concrete

The location of all construction joints in concrete work shall be subject to the approval of the Engineer and wherever possible such locations shall be determined before the commencement of the concreting. Locations of contraction joints shall be as shown on the drawings or as directed by the Engineer.

Wherever practicable, joints shall be either vertical or horizontal; vertical joints shall be formed against a stop board; horizontal joints shall be level and, wherever possible, so arranged that the joint lines coincide with architectural features of the finished work. Battens may be nailed to formwork to ensure a horizontal line and if desired, may be used to form a grooved joint.

Construction joints are defined as the contact between newly placed concrete and concrete surfaces, upon or against which concrete is to be placed and to which the new concrete is to adhere, that have become so rigid that the new concrete cannot be incorporated integrally by vibration with that previously placed. To ensure high quality of bond and water tightness in a horizontal construction join, the slump shall be the least in the concrete, and especially that in the upper portion of the lift, that will permit proper working and compaction.

Approval by Engineer of construction joints introduced, otherwise than as required by the Engineer, shall be subject to the provision of water-stops as specified, if so required by the Engineer.

6.1.18 Rubble Masonry Works

Materials for Rubble Masonry

Stones for all masonry work shall be obtained from quarries approved by the Engineer and shall be the best quality obtainable. Stones shall be free from imperfections such as cracks, sand holes, veins and laminations. Stones shall be clear grained, dense, heavy, durable and hard. Granite, basalt, quartzite and limestone are suitable for masonry works.

Stones for rubble masonry shall be flat bottomed and not less than 150mm deep in any part and 225mm wide. The average thickness of individual stones may vary between 150mm to 225mm. The percentage of smaller stones shall not be more than 25%.

Mortar

Unless otherwise specified by the Engineer, the mix proportions for the mortar shall consist of 1 part of cement to 5 parts of sand by volume. The mortar shall have a dry consistency.

Rubble Masonry Construction

All stones used in rubble masonry shall be cleaned and wetted before use to ensure bonding to the mortar. Every stone shall be set flush in mortar, leaving no dry work or hollow spaces. The stones shall be laid on their flat face, using the larger stones for the foundation courses. Smaller stones not exceeding 25% of the larger stones shall be carefully selected to roughly fit the spaces between the larger ones. Chips shall be wedged into the spaces between the different sizes of stones, where necessary, to prevent thick beds of mortar. The vertical joints between stones in successive courses shall be staggered as much as possible to avoid continuous joints.

If plastering of the masonry is required, the joints shall be raked to a depth of 25mm as the work proceeds, to form keys for the plaster.

Where plastering is not required the masonry shall be provided with struck-off joints. Selected stones with straight edges shall be used to ensure close fitting joints of uniform width not exceeding 1mm. Immediately after the stones are set in position, the joints shall be neatly struck off with a trowel edge to form “V” grooves 15mm deep. The ‘bushings’ of the stones shall not project more than 25mm from the plane of the joints. Rubble masonry shall be cured with water for a period of at least three days commencing from the time final setting of cement.

Rubble Pitching

Rubble pitching construction for protection of earth slopes of canals and ramps of causeways from erosion shall consist of quarried rock bonded together with cement-sand mortar of specified mix proportion, constructed as lining of specified minimum thickness shown on the drawings or as directed by the Engineer.

The surfaces of the earthwork to be protected with rubble pitching shall be first finished to the prescribed slopes, any weathering, runnels etc. being backfilled with approved material similar to the in-place soils. The surfaces so prepared shall be moistened with water, if required and tamped or rolled to the satisfaction of the Engineer.

The stones shall be laid and hammered down on the prepared surfaces of the earthwork, approximately plane but not smooth. The stones shall be hand-packed in such a manner that joints between stones can be completely filled cement-sand mortar. Stones with overhanging joints shall not be allowed. The rubble pitching shall be finished to the prescribed slopes, the permissible tolerance being 25mm in a length of 3m. The finished surfaces of the pitching shall be planes without depressions.

The rubble pitching shall be cured with water for a period of at least three days commencing from the time of the final setting of cement.

6.1.19 Gravelling

Quarry gravel shall consists of rounded or water-worn pebbles of irregular shape and size occurring in natural deposit mixed with clay acting as binding material. The fines should be sufficient to fill the voids in the gravel and the sand content shall not exceed 15% by weigth. The sand content in the fines shall at least twice as much as the clay content. The maximum size of gravel shall be limited to 20mm. Gravel shall be obtained from quarries approved by the Engineer.

The gravel shall be spread in uniform layers or compacted embankment to the full width and thickness specified and the spreading shall progress along the length of the embankment/canal bund. After spreading, the material shall be raked to ensure as uniform a mixture as possible of all sizes of particles and compacted with a smooth roller to the required thickness. Watering may be required for proper mixing and compaction.

6.1.20 Fixing Dowels

Dowels shall consist of steel bars and shall be of the size, length and shape shown on the drawings or as directed. Dowels shall be fixed in the locations and to depths in holes in concrete as shown in the drawings or as directed.

Holes shall be drilled to receive dowels. The diameter of the hole shall be between 1.2 to 1.5 times the diameter of the dowel bar. After drilling, the holes shall be washed and cleaned immediately prior to filling with grout. The cleaned holes shall be completely filled with either cement-water grout or cement-sand mortar mixed to the consistency and proportions specified or as directed. The dowel bars shall be thoroughly cleaned and forced into place in the grout before the initial set of the grout and the dowel bars shall be vibrated or rapped until the entire surface of the embedded portions of the dowel bars are in intimate contact with the grout. Special care shall be taken to ensure against displacement of the dowel bars until the initial set of the grout.

SAMPLE TYPE PLANS FOR VILLAGE IRRIGATION TANKS

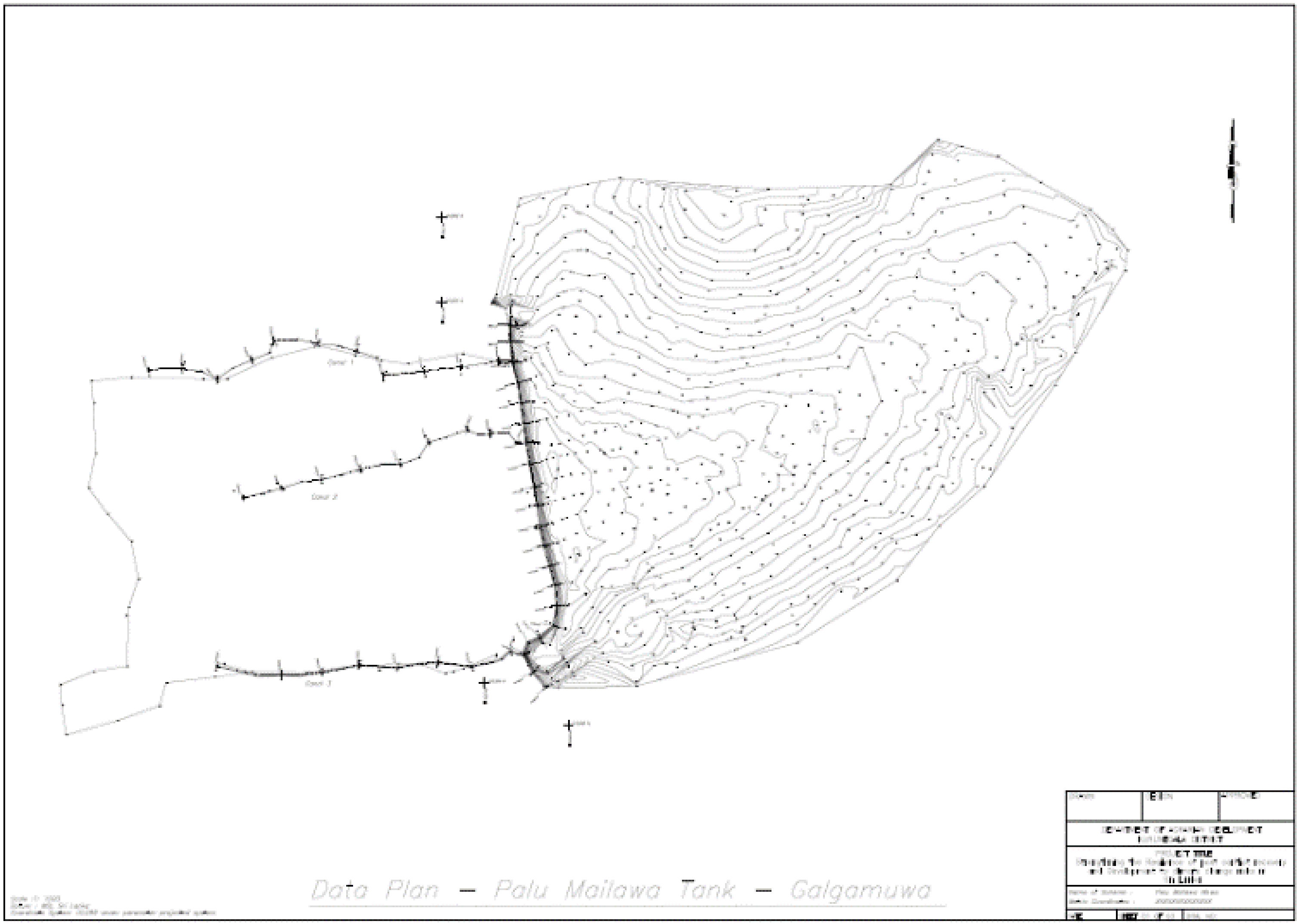


Figure 31: Scheme Map of a Minor Tank

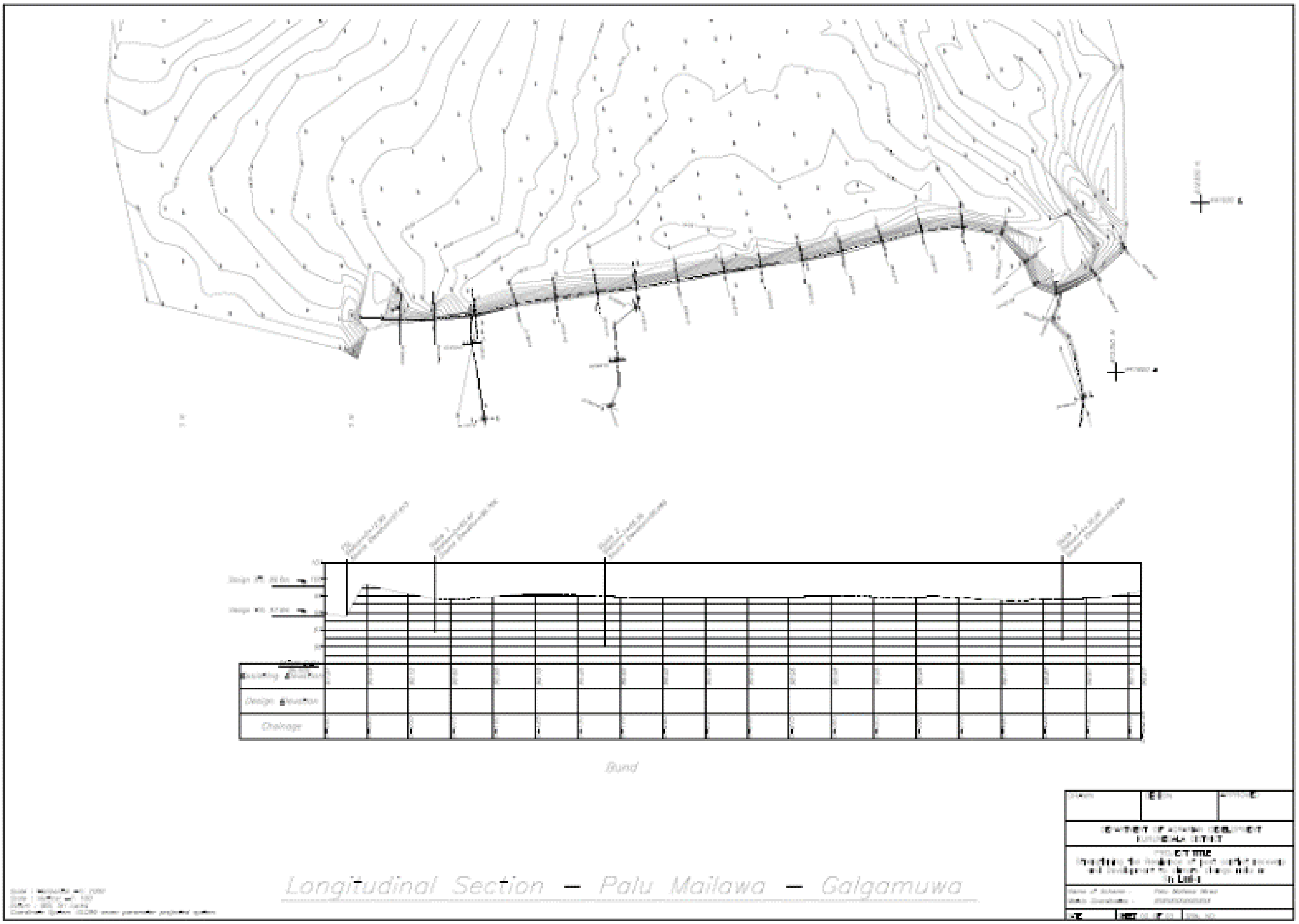

Design Elevation
Chainage
Bund
Longitudinal Section – Palu Mailawa – Galgamuwa

Figure 32: Longitudinal Section of Tank Bund

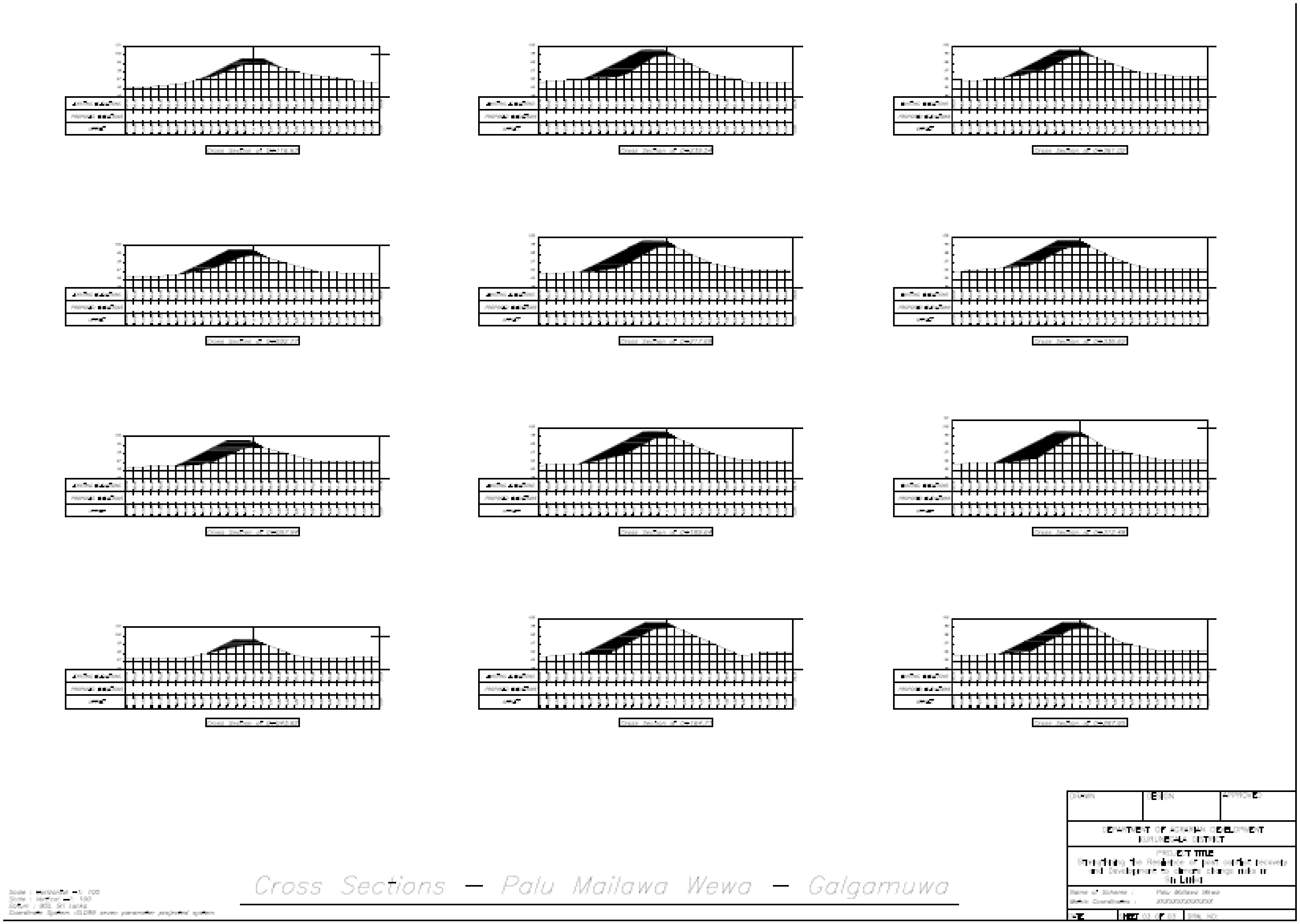


Figure 33: Cross Sections of a Tank Bund

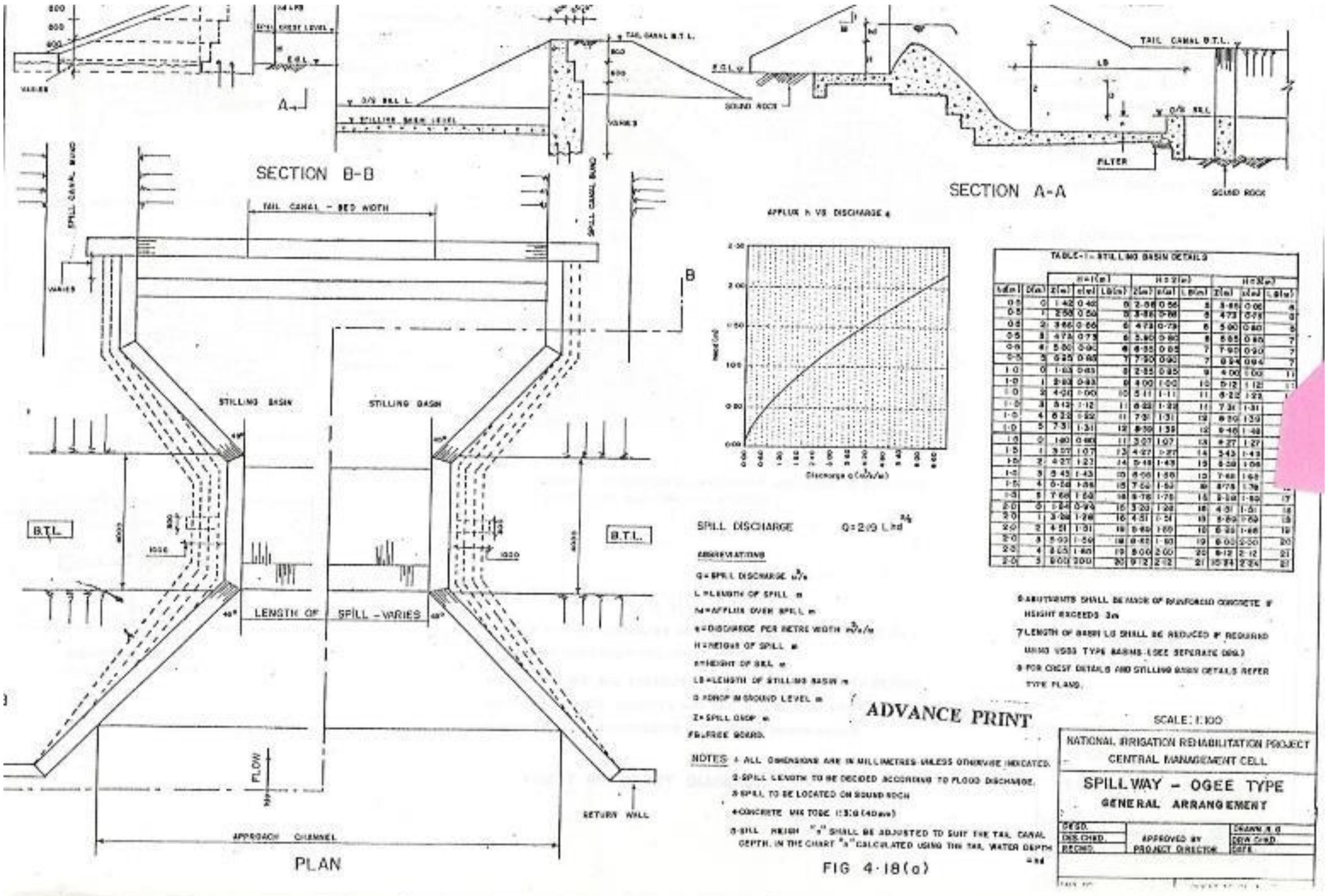


Figure 34: Ogee Type Spillway

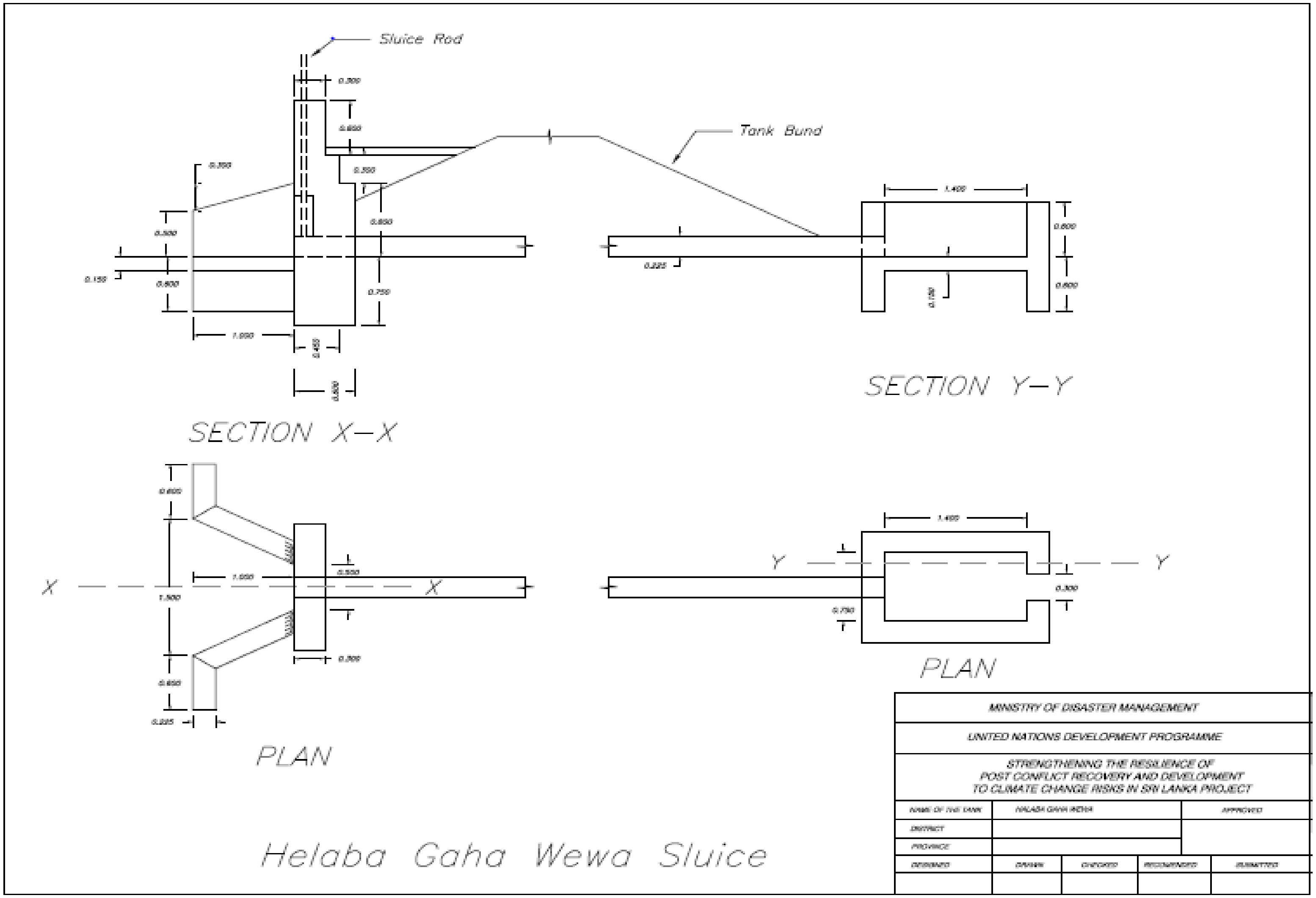

Sluice Rod
Tank Bund
SECTION X–X
SECTION Y–Y
PLAN
PLAN
Helaba Gaha Wewa Sluice
MINISTRY OF DISASTER MANAGEMENT
UNITED NATIONS DEVELOPMENT PROGRAMME
STRENGTHENING THE RESILIENCE OF
POST CONFLICT RECOVERY AND DEVELOPMENT
TO CLIMATE CHANGE RISKS IN SRI LANKA PROJECT
NAME OF THE TANK
DISTRICT
PROVINCE
APPROVED

Figure 35: Sluice Structure

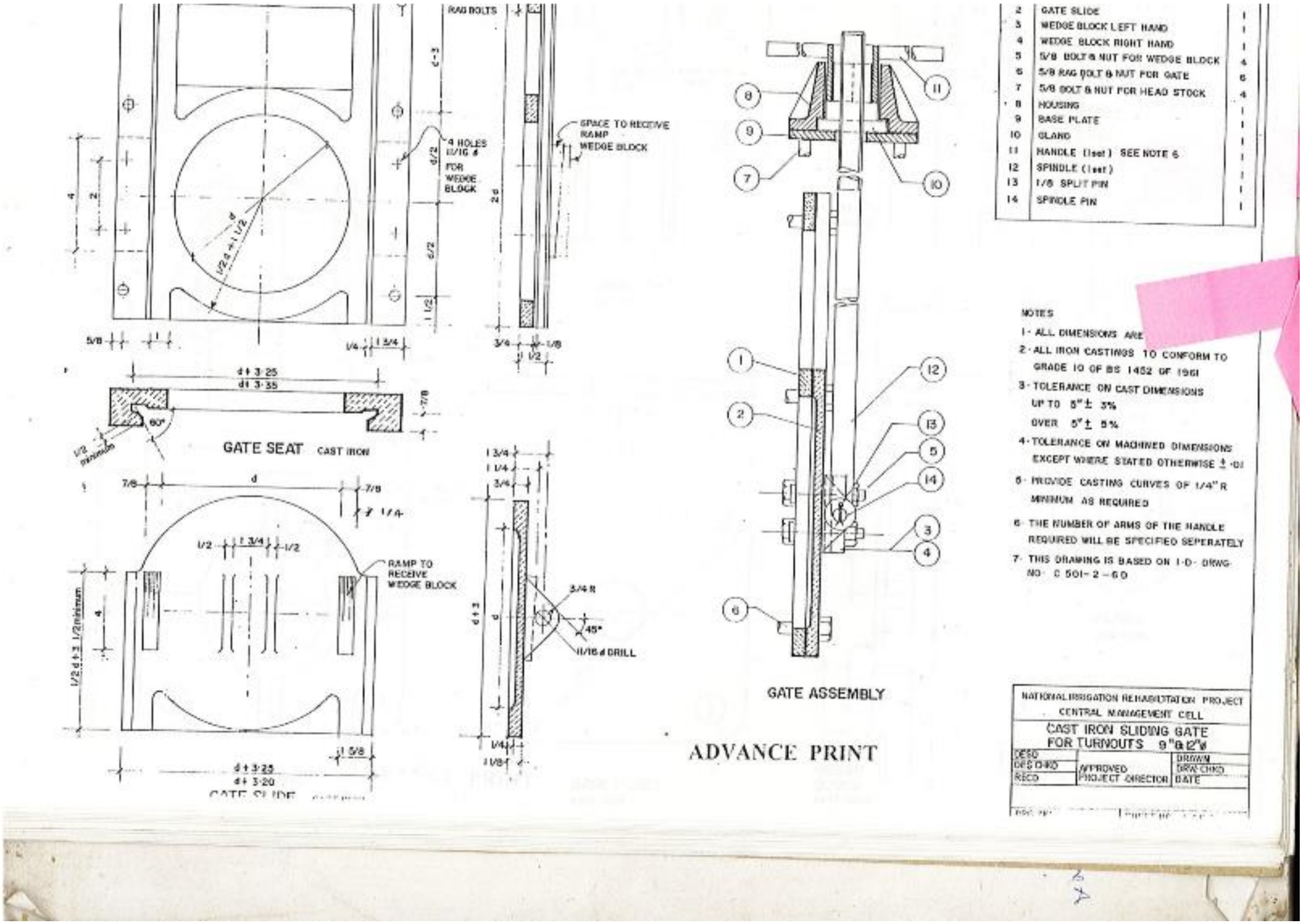


Figure 36: Cast Iron Sliding Gate for Turnout Structure

Low-cost drip irrigation systems

6.1.21 General

Most of the components in a typical low-cost micro irrigation system are manufactured from poly vinyl chloride (PVC) and various types of polyethylene and polypropylene. The manufacturing technology is based on a simple extrusion or injection molding process. Because of this, manufacturers of plastic pipes can easily adapt the technology to the needs of the smallholders and enable them to cultivate high-value cash crops with small amounts of water to increase their income.

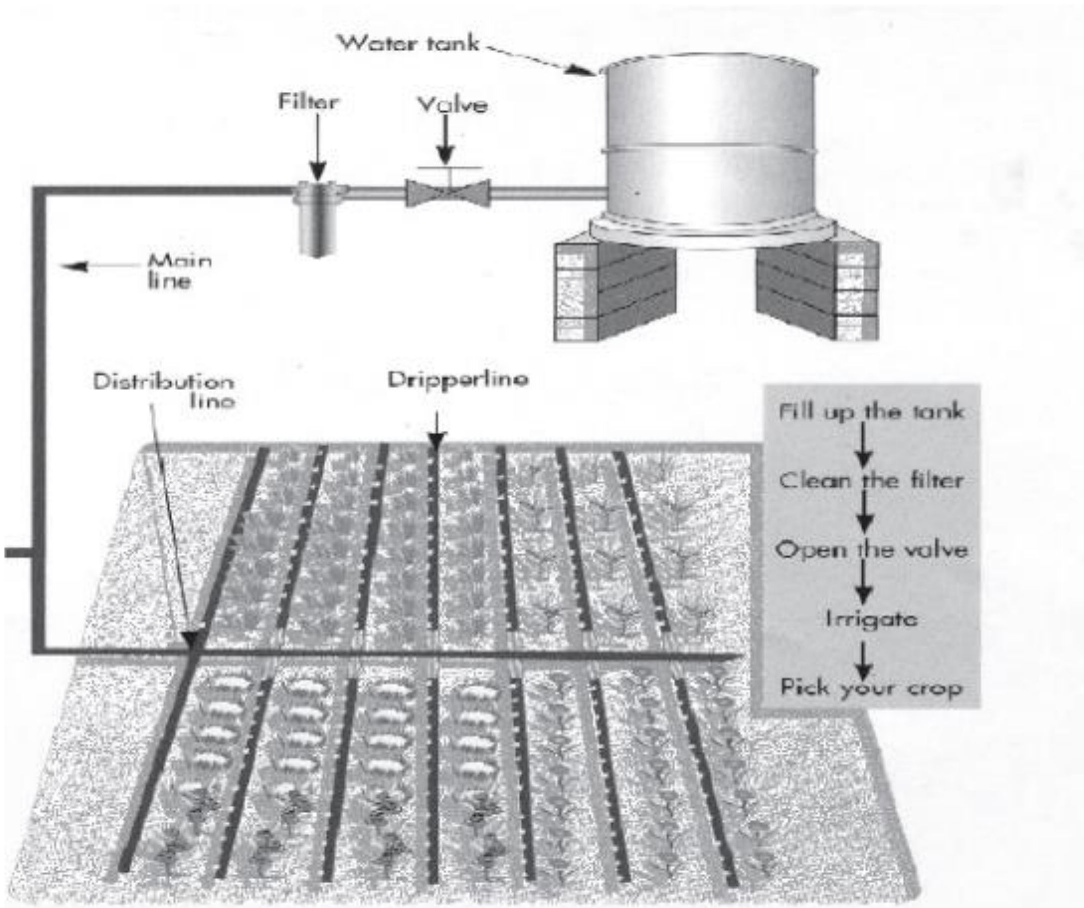


Figure 37: Layout of a low cost drip irrigation system[195]

The following specifications are based on the Technical Manual for IDEal Micro Irrigation Systems developed by [1] International Development Enterprises and CGIAR Challenge Program on Water and Food

[195] Source: FAO, ftp://ftp.fao.org/docrep/fao/010/a1336e/a1336e15a.pdf

6.1.22 BASIC COMPONENTS OF IDEAl Drip SYSTEM

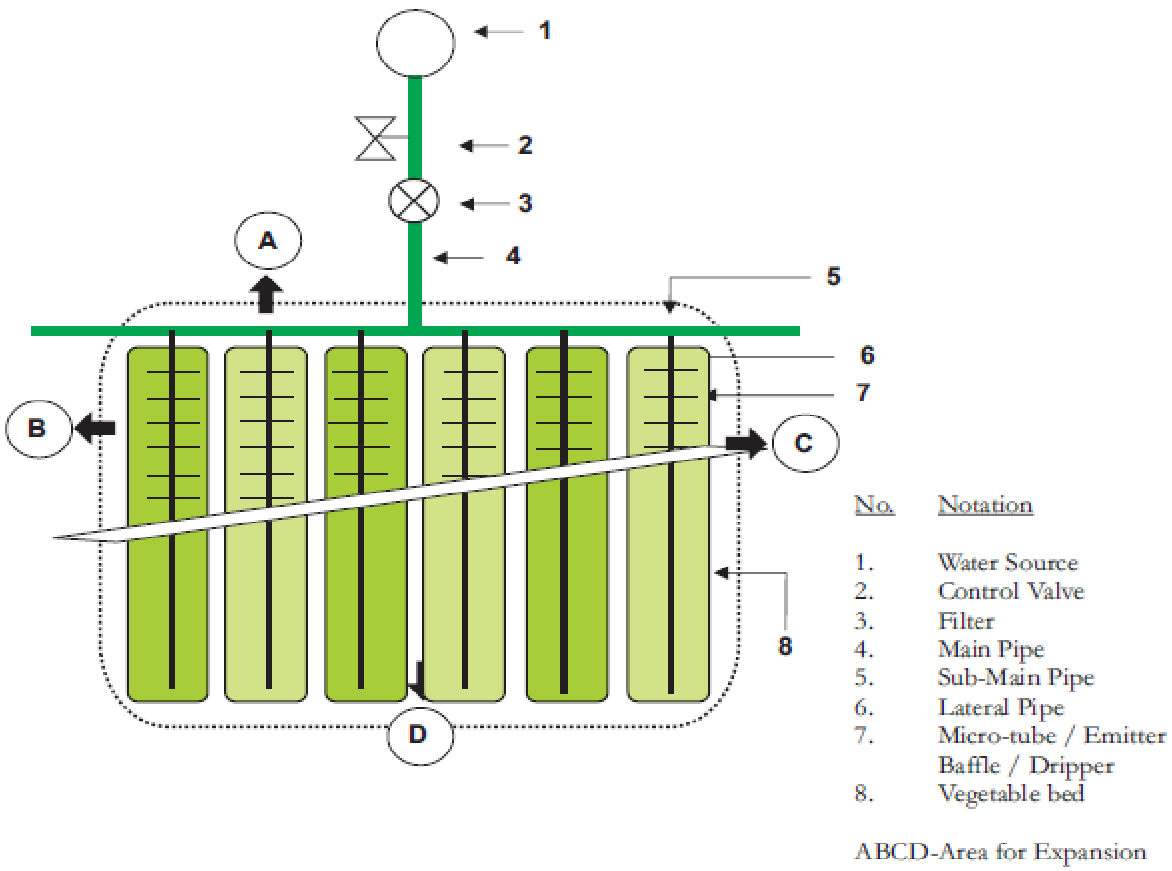


Figure 38: Basic components of an IDEal drip irrigation system[196]

[196] International Development Enterprises and CGIAR Challenge Program on Water and Food, undated Technical manual for IDEal micro irrigation systems, IDE

Figure 39: Main components of a low cost drip irrigation system[197]

1. Water Source:

The IDEal Drip System is a low-pressure system that uses gravity to increase water pressure. The water source can be an overhead tank placed at a minimum of one meter above ground level for smaller systems up to 400 m2 area. For larger systems, the height of the tank should be increased. If the height of the tank is not increased, the system can be connected to a pump that lifts water from sources such as a well, farm pond, storage tank, or a stream / canal. A manually operated pressure pump also can be used to lift water from a shallow water table (up to 7 meters) and used for the system.

2. Control Valve:

A valve made of plastic or metal to regulate required pressure and flow of water into the system. There are valves of various sizes depending on the flow rate of water in the system.

3. Filter:

The filter ensures that clean water enters the system. There are different types of filters - screen, media and disc. Different sizes of filters are available depending on the flow rate of water in the system.

4. Mainline:

Pipe made of poly vinyl chloride (PVC) or polyethylene (PE) to convey water from the source to the submain line. PE pipe material is normally made from high-density polyethylene (HDPE),

[197] International Development Enterprises and CGIAR Challenge Program on Water and Food, undated Technical manual for IDEal micro irrigation systems, IDE

low-density polyethylene (LDPE) and linear low-density polyethylene (LLDPE). The size of pipe depends on the flow rate of water in the system.

5. Sub-main:

Sub-main lines are made of PVC / HDPE / LDPE / LLDPE pipe to supply water to the lateral pipes. Lateral pipes are connected to the sub-main pipe at regular intervals. The size of pipe depends on the flow rate of water in the system.

6. Lateral:

Pipes made of LLDPE or LDPE placed along the rows of the crop on which emitters are connected to provide water to the plants directly. The lateral pipe size is from 12 mm to 16 mm in most IDEal Drip Systems.

7. Emitters:

Different types of emitters used in IDEal Drip Irrigation Systems are described below:

i) **Micro-tube:** Straight or curled LLDPE tube with an inner diameter ranging from 1 to 1.2 mm. The discharge from the micro-tube is directly proportional to the operating pressure and inversely proportional to its length. The operating pressure that is required can be as low as 1-5 meters.

ii) **Drip Tape / Built-in Dripper:** It has built-in drippers / outlets on the lateral line which give a continuous wetting strip. It is mainly used for row crops. The operating pressure required is from 1-5 meters.

8. Fittings & Accessories:

Various fittings required in IDS are described below.

Tee Connector: Tee Connector: Tee connectors of various sizes are required in IDEal Drip Systems to connect a branch to the main pipe, the main pipe to sub-main pipes, the lateral pipes to sub-main pipes, etc. The tee connectors can be either the equal tee or reducing tee type including 12mm x 12mm, 16mm x 12mm, 16mm x 16mm, 25mm x 12mm, and 32mm x 12 mm.

Straight Connector: The straight connector is also called a joiner and is required to connect pipes. It can be either the equal joiner or reducing joiner including 12mm x 12mm, 12mm x 16mm, 25mm x 32mm, 32mm x 40 mm.

Take-Off Tee: It is used to connect the lateral pipes to the sub-main pipe in larger systems. It is fixed in the wall of sub-main pipe with the help of a rubber washer called a gromate. It is available for different sizes of lateral pipes including 12mm and 16mm.

Metal Punch: It is used along with the wooden guide to punch a hole on the top of the sub-main pipe in order to connect the take-off tee to the sub-main pipe.

6.1.23 Design of the Micro Irrigation System

Water requirement can be calculated as follows:

WR (Liters per day) = ET x Kc x Cp x Area,

Where,

- ET is evapo-transpiration (mm per day)
- Kc is crop factor
- Cp is canopy factor/ crop factor

- Area in m2

If specific crop factor values are not available, then it can be assumed as one

The canopy factor (crop factor) is the percentage of area covered by plant canopy (foliage). It varies according to the growth stage of the plant. The area for orchards is the multiplication of the distance from plant to plant (m) and distance from row to row (m). For row plantation, the unit area can be taken to calculate water requirement.

$$\text{Irrigation time (hrs / day)} = \frac{\text{Water requirement (liters per day)}}{\text{Application rate (liters per hour)}}$$

6.1.24 Selection of Emitter

An emitter should match particular field conditions including type of crop, spacing of the plants, terrain, water requirement, water quality, operating time, pressure head, etc. Some of the criteria that can be applied to the selection of dripper are given below:

- Reliability against clogging and malfunctioning
- Emission uniformity
- Simple to install and maintain
- Pressure compensation in case of undulated terrain
- Percentage area wetted
- Flow rate
- Operating pressure

Annex 3: Climate change resilient Agriculture practices for small holder farmers in the Dry Zone

Problem description:

In the dry and intermediate zones of Sri Lanka farm fields without access to large-scale, trans-basin irrigation demonstrate low cropping intensities. This means that land productivity is low and the ability to crop two seasons fully is almost non-existent for farmers cultivating under minor tanks and village irrigation systems. In some village irrigation systems in the Northern Province, where conflict related neglect of irrigation systems is common, cropping intensities could be below 1 indicating that farmers are unable to fully complete a single season. The main reason for the low cropping intensities relate to both climatic and non-climatic reasons.

-Water yield in the minor cropping season or Yala is very low, thereby compromising farmer's ability to crop the full extent or use high yielding rice cultivars that require longer time in-field.

-The lack of diversification of crops and the preference for rice over more commercially viable and in-demand crops that require less irrigation.

Climate change related intensification of dry periods and extreme rainfall events exacerbate the conditions of low productivity under minor irrigated areas and rainfed agriculture. This severely threatens food security of such farmer families who cultivate their own crops.

Recommendations to reduce the risk of seasonal crop damage due to climatic stresses (longer dry periods and intense rainfall):

For farmers cultivating under minor irrigation systems:

By restoring the functionality of tank cascade systems, including local catchmentsand increasing storage of water will improve chances of completing the major season fully. However to make considerable change in cropping intensity and to alter seasonal cultivation practices and preferences; and to manage the increasing variability of rainfall, it is essential that a suite of modern, improved and time-tested technologies are implemented at farm field level. Some of these are described below;

Maha (major) Season:

- Land preparation to commence with the first inter-monsoon rains without irrigation allowing greater storage in the village reservoirs
- Mechanised planting to prevent weeds. Soil testing should rationalise fertiliser addition to fields
- Cultivation of rice under entirely rainfed conditions during a season with well-paced, normal rainfall.
- Any shortfall of rain during the seed maturing period must be supplemented with irrigation from the tank storage.
- Integrated pest management systems are recommended with selective and controlled use of chemical pesticides
- Short-duration rice cultivars are recommended (BG 250, BG 251, BG 310, AT 307, AT 306, AT 308)

Yala (minor) season:

- Rice is only recommended for downstream tanks with assured inflow where catchment to command area ratio is over 10

- The Agriculture Department recommends village irrigation systems to totally deviate from rice cultivation for Yala (given that the Maha/major season has been successful for rice cultivation)
- Other field crops such as onion, soy bean, chillies, black gram, water melon etc with a good market demand and seed availability should be cultivated with longer irrigation intervals taking advantage of water stored during the Maha and the low Yala rains
- Opting for crops with low water requirement and shorter in-field duration will enable farmers to cultivate the second season fully. Giving up rice during the second season will reduce irrigation demand by 30-50%; allowing reservoir storage to be safely used for multiple purposes such as bathing, fishery and importantly, drinking water.
- Diversifying in to market oriented crops will supplement household income
- If stored water and field moisture is available during the driest months of July-September; farmers can opt for a third season. Mung bean is highly recommended crop for a third season. DOA recommends MI-5, MI-6 and Arii varieties of mung bean which have drought escape capacity being short in-field duration. The crop can be used for household food or for sale in the market, as mung bean is also in high demand. It is nitrogen fixing and thus will improve soil fertility for the Maha rice crop which will follow.

Rain-fed uplands

Uplands are cultivated during the Maha or major season, and farmers often engage in both paddy and vegetables in rain-fed lands. Some key agronomic practices are recommended to sustain rain-fed farming given the climate-related rainfall variability and seasonal changes experienced.

-Land/soil conservation methods such as dykes, bunds, live fences (using nitrogen fixing gliricidiasepium) and stone walls in sloping lands to prevent top soil loss and erosion from uplands during high rainfall events

-mulches or artificial soil covers to prevent soil moisture loss during longer dry periods

-short duration crops/ or crops with high drought tolerance such as ground nut (peanut), chillie and sesame

-Small water retention ponds in the uplands to meet crop water requirement and recharging ground water

- Low cost, micro-irrigation systems such as drum-kit drip systems, open ended drip pipes, sprinklers for effective cultivation of perennials in uplands (fruits, coconut, pepper etc)

Home gardens and other agricultural lands

Home gardens (between 1-0.25 acre) are sources food and income for rural households. Cultivated home gardens in the catchment erode with high intense rainfall and contribute to sedimentation of the village reservoir.

-Land/soil conservation methods such as bunds, live fences (using nitrogen fixing gliricidia sepium or other multi-purpose species that could be used for fuelwood and medicines) and stone walls in sloping lands to prevent top soil loss and erosion from uplands during high rainfall events

-Fruit cultivation (guava, cashew, papaya, lemon, mango and pomegranate) is encouraged in home gardens as fruits with high nutritional value and market demand. Organic cultivation is highly recommended for home gardens and supported through government agri-extension programmes.

- Low cost, micro-irrigation systems such as drum-kit drip systems, open ended drip pipes, sprinklers for effective cultivation of perennials in uplands (fruits, coconut, pepper etc)Traditional methods such as pot irrigation works well in home gardens retaining moisture to the root-system during dry seasons. Supplementary irrigation and availability of water can support off—season crop cultivation which can result in higher incomes for farm families.

--Mulches or compost to enrich and deepen top soil layer and prevent soil moisture loss during longer dry periods

-Small water retention ponds in the uplands to meet crop water requirement and recharging ground water, if possible

Crop recommendations

The DOA is revising its crop recommendations in view of climate change impacts on agricultural yields in the past few years; plus considering national food requirement and export potential of certain crops. The revision is based on data gathered through an AI (agriculture instructor) level questionnaire in 2014.

These crop recommendations are already available and could be field tested through the project in selected Dry Zone locations under minor irrigation depending on agro-ecological appropriateness.

Agriculture value addition

Using women-led producer groups in villages, DOA proposes to establish small-scale value addition, processing units for chillie, ground nut, cashew and coconut which will enhance incomes and give farmers a better return on their labour. Drying and processing will increase storage potential eliminating the need to under-sell to middle-men during the peak of harvest.

Farmer outreach and feedback mechanism

DOA issues advisories every season (Yala and Maha) translating the Meteorological Department's forecast in to agricultural advisory. This message is relayed to provincial departments of agriculture and should eventually reach the AI's who have direct contact with farmer groups and who- being based within the ASC- is in touch with the DAD's field staff and water allocation mechanism.

Annex 4: RURAL WATER SUPPLY SCHEMES

General

Minimum requirement	The minimum requirement of water for direct consumption, preparation of food and personnel hygiene is considered to be 40 liters per person per day.
Haulage Distance	The maximum haul of water to the dwelling of any user should not exceed 200m. In steep terrain this should be reduced with consideration to the effort for hauling water.
Adequacy of the Source	The minimum daily rate of extraction of water should not be less than 10 liters per minute per capita at the source. This supply should be available for 90% of the time.
Equity	A supply system should provide water security to all members of the community. The operation and maintenance of the facilities should be effective and ensure that the total interruptions per year do not exceed 10 days.
Quality	- The quality of water supplied, as a basic service should conform to the currently accepted minimum standards with respect to health related microbiological and chemical contaminants.
Flexibility to Upgrade	The basic facilities provided should be sufficiently flexible to enable upgrading if and when desired by the users. The users should bear the entire cost of additional facilities for improved services over and above the basic facilities provided
Safe Water Supply Systems	Following systems will be the accepted methods of providing safe drinking water, however, under epidemic or other risk situations special treatment may be required: a) Piped Water Supply Systems with Adequate Treatment b) Deep/Shallow Wells with Hand Pumps c) Protected Springs d) Protected Dug Wells e) Protected Rainwater Catchments Systems

Water quality standards: The following may apply**:**

Sri Lanka Standard (SLS) Specification for Potable Water, Physical and Chemical Requirements (SLS 614-1983), and

SLS 722 (1985) **:** Tolerance limits for inland surface waters used as raw water for public water supply

Domestic Rainwater Harvesting Systems

Domestic RWH is a simple mechanism to collect and store rainwater mainly for drinking and cooking. It may be a household based or community based. The system uses a collection surface such as a roof, gutters to guide the rainwater, and a container to store the water.

6.1.25 Components of a domestic RWH system

Domestic RWH systems vary in complexity. Some of the traditional Sri Lankan systems are no more than a pot situated under a piece of cloth or a plastic sheet tied to four poles. The cloth captures the water and diverts it through a hole in its centre into the pot. In contrast, some of the sophisticated systems manufactured in Germany incorporate clever computer management systems, submersible pumps, and links to grey water and domestic plumbing system mains. Somewhere between these two extremes, we find the typical DRWH system in use in developing countries. Such a system will usually comprise a collection surface (a clean roof or ground area), a storage tank, and guttering to transport the water from the roof to the storage tank. Other peripheral equipment is sometimes incorporated, for example: first-flush systems to divert the dirty water which contains roof debris after prolonged dry periods; iltration equipment and settling chambers to remove debris and contaminants before water enters the storage tank or cistern; hand pumps for water extraction; water level indicators, etc.

6.1.26 Typical domestic RWH systems

A typical domestic RWH consists of a collection surface, gutters and a storage container. In addition, there are options for diverting first-flush water and filtration. For domestic rainwater harvesting the most common surface for collection is the roof of the dwelling.

Collection Surface

The style, construction and material of the roof affect its suitability as a collection surface for water. Typical materials for roofing include corrugated iron sheet (also known as tin roof), asbestos sheet; tiles (a wide variety is found), slate, and thatch (from a variety of organic materials). Most thatch are suitable for collection of rainwater, but only certain types of grasses e.g. coconut and anahaw palm (Gould and Nissen Peterson, 1999), thatched tightly, provide a surface adequate for high quality water collection. The rapid move towards the use of corrugated iron sheets in many developing countries favours the promotion of RWH.

Guttering

Guttering is used to transport rainwater from the roof to the storage vessel. Guttering comes in a wide variety of shapes and forms, ranging from the factory made PVC type to home-made guttering using bamboo or folded metal sheet (Figure 1). Guttering is usually fixed to the building just below the roof and catches the water as it falls from the roof.

Storage tanks and cisterns

The water storage tank usually represents the biggest capital investment element of a domestic RWH system. It therefore requires careful design to provide optimal storage capacity while keeping the cost as low as possible. The catchment area is usually the existing rooftop or occasionally a cleaned area of ground, as seen in the courtyard collection systems in China. The guttering for the system can often be obtained relatively cheaply, or can be manufactured locally

There are an almost unlimited number of options for storing water. Common vessels used for very small-scale water storage in developing countries include plastic bowls and buckets, jerrycans, clay or ceramic jars, cement jars, old oil drums, empty food containers, etc. For storing larger quantities of water, the system will require a tank or a cistern.

The storage tank can be classified as an above-ground storage vessel and the cistern as a below-ground storage vessel. These can vary in size from a cubic metre or so (1000 litres) up to hundreds of cubic metres for large projects. The typical maximum size for a domestic system is 20 or 30 cubic metres.

The choice of system will depend on a number of technical and economic considerations listed below.

Space availability

Options available locally

Local traditions for water storage

Cost of purchasing new tank

Cost of materials and labour for construction

Materials and skills available locally

Ground conditions

Use of RWH – whether the system will provide total or partial water supply

One of the main choices will be whether to use a tank or a cistern. Both tanks and cisterns have their advantages and disadvantages.

6.1.27 First-flush systems

Debris, dirt, dust and droppings will collect on the roof of a building or other collection area. When the first rains arrive, this unwanted matter will be washed into the tank. This will cause contamination of the water and the quality will be reduced. Many RWH systems therefore incorporate a system for diverting this 'first flush' water so that it does not enter the storage tank.

The simpler ideas are based on a manually operated arrangement whereby the inlet pipe is moved away from the tank inlet, and then replaced again once the initial first flush has been diverted. This method has obvious drawbacks because there has to be a person present who will remember to move the pipe.

Other systems use tipping gutters to achieve the same purpose. The most common system uses a bucket which accepts the first flush and the weight of this water off-balances a tipping gutter which then diverts the water back into the tank.

The bucket then empties slowly through a small-bore pipe and automatically resets. The process will repeat itself from time to time if the rain continues to fall, which can be a problem where water is really at a premium. In this case a tap can be fitted to the bucket and will be operated manually. The quantity of water that is flushed is dependent on the force required to lift the guttering. This can be adjusted to suit the needs of the user.

Another system relies on a floating ball that forms a seal once sufficient water has been diverted. The seal is made as the ball rises into the apex of an inverted cone. The ball seals the top of the 'waste' water chamber and the diverted water is slowly released, as with the bucket system above, through a small bore pipe. Again, the alternative is to use a tap. In some systems (notably one factory manufactured system from Australia) the top receiving chamber is designed such that a vortex is formed and any particles in the water are drawn down into the base of the vortex while only clean water passes into the storage tank. The 'waste' water can be used for irrigating garden plants or other suitable application. The debris has to be removed from the lower chamber occasionally.

Although the more sophisticated methods provide a much more elegant means of rejecting the first flush water, practitioners often recommend that very simple, easily maintained systems be used, as these are more likely to be repaired if failure occurs.

6.1.28 Filtration systems and settling tanks

Again, there are a wide variety of systems available for treating water before, during, and after storage. The level of sophistication also varies from extremely high-tech to very rudimentary. A German company, WISY, have developed an ingenious filter which fits into a vertical downpipe and acts as both filter and first-flush system. The filter (Figure 8) cleverly takes in water through a very fine (~0.20mm) mesh while allowing silt and debris to continue down the pipe. The efficiency of the filter is over 90%. This filter is commonly used in European systems.

The simple trash rack has been used in some systems but this type of filter has a number of associated problems: firstly it only removes large debris; and secondly the rack can become clogged easily and requires regular cleaning.

The sand-charcoal-stone filter is often used for filtering rainwater entering a tank. This type of filter is only suitable, however, where the inflow is slow to moderate, and will soon overflow if the inflow exceeds the rate at which the water can percolate through the sand. Settling tanks and partitions can be used to remove silt and other suspended solids from the water. These are usually effective, but add significant additional cost if elaborate techniques are used. Many systems found in the field rely simply on a piece of cloth or fine mosquito mesh to act as the filter (and to prevent mosquitoes entering the tank).

Post storage filtration include such systems as the upflow sand filter or the twin compartment candle filters commonly found in developing countries. Many other systems exist and can be found in the appropriate water literature.

6.1.29 Sizing the system

Usually, the main calculation carried out by the designer when planning a domestic RWH system will be to size the water tank correctly to give adequate storage capacity. The storage requirement will be determined by a number of interrelated factors. They include:

- local rainfall data and weather patterns
- size of roof (or other) collection area
- runoff coefficient (this varies between 0.5 and 0.9 depending on roof material and slope)
- user numbers and consumption rates

The style of rainwater harvesting i.e. whether the system will provide total or partial supply will also play a part in determining the system components and their size.

There are a number of different methods used for sizing the tank. These methods vary in complexity and sophistication. Some are readily carried out by relatively inexperienced, first-time practitioners while others require computer software and trained engineers who understand how to use the software. The choice of method used to design system components will depend largely on the following factors:

- the size and sophistication of the system and its components
- the availability of the tools required for using a particular method (e.g. computers)
- the skill and education levels of the practitioner / designer

6.1.30 Rainwater quality and health

There are two main issues when looking at the quality and health aspects of DRWH:

Firstly, there is the issue of bacteriological water quality. Rainwater can become contaminated by faeces entering the tank from the catchment area. It is advised that the catchment surface always be kept clean. Rainwater tanks should be designed to protect the water from contamination by leaves, dust, insects, vermin, and other industrial or agricultural pollutants. Tanks should be sited away from trees, with good-fitting lids and kept in good condition. Incoming water should be filtered or screened, or allowed to settle to take out foreign matter. Water which is relatively clean on entry to the tank will usually improve in quality if allowed to sit for some time inside the tank. Bacteria entering the tank will die off rapidly if the water is clean. Algae will grow inside a tank if sufficient sunlight is available for photosynthesis. Keeping a tank dark and sited in a shady spot will prevent algae growth and also keep the water cool. The area surrounding a RWH should be kept in good sanitary condition, fenced off to prevent animals fouling the area or children playing around the tank. Any pools of water gathering around the tank should be drained.

Secondly, there is a need to prevent insect vectors from breeding inside the tank. In areas where malaria is present, mosquito breeding in the storage tank can cause a major problem. All tanks should be sealed to prevent insects from entering. Mosquito proof screens should be fitted to all openings. Some practitioners recommend the use of 1 to 2 teaspoons of household kerosene in a tank of water which provides a film to prevent mosquitoes.

Run off Rainwater Harvesting

In this method of collecting rainwater for irrigation, water flowing along the ground during the rains will be collected to a tank below the surface of the ground. The tank is constructed using bricks, which are coated with cement. During storage, it is important to incorporate efficient and effective water conservation methods – by reducing evaporation and also by adopting efficient irrigation techniques. It is a very 'easy to adopt' technology proven with many communities in the country that if used properly can be very profitable.

Step-by-step procedure of run off rainwater harvesting

Selecting a location for the construction of a rainwater harvesting tank

• Observe the direction of the surface flow of rainwater in the land.

• Even though some believe that such tanks should be constructed in the lowest lying area of the land, this is not essentially so. Due to the seasonal patterns of rainfall and the high intensity of rains received in Sri Lanka, it is possible to fill a 12,000 litre capacity tank without much difficulty.

• The tank may be subjected to cracks due to the root zone activities (i.e. ramification), therefore, it is advisable not to construct the tank in close proximity to large trees.

• The tank should be close to the area of cultivation to ensure ease of irrigation.

• The tank should not be in close proximity to the house or to paths /roadways as it is possible for children and even negligent adults to fall in. As an additional security measure, construct a fence around the tank.

• The opening of the tank should be to the direction of the flow of rainfall. It is not advisable to obstruct patterns of natural flow of water as there is a possibility of mud and other waste getting into the tank. (The mud filters function only when the water flows directly through them).

Things to bear in mind

• If a very strong current of water is flowing it could place the tank in jeopardy.

• If by construction of the tank, the natural water flow is obstructed, soil erosion can occur and crops can consequently be destroyed.

Constructing the rainwater harvesting tank

• Clear the selected land thoroughly. Flattening the land is important for ease of taking measurements.

• It is advisable to construct a circular tank as it will withstand greater pressures.

• Determine the quantity of water required for irrigation purposes.

In such instances, the following factors should be considered;

The rainfall pattern of the area. (If the area experiences regular rainfall throughout the year, a small tank of 4000-5000 litres would suffice, whereas in particularly dry areas which experience dry spells for about 6 months of the year, it would be beneficial to store as much water as possible.)

The extent of land, which is proposed to be cultivated

The amount of investment that can be made.

The tank should not be more than 1.75 m in depth in order to withstand the pressure of the water. Low depth makes cleaning and use of the tank easier.

The chart given below can be used as a guide to determine the radius of the tank.

Capacity of the Tank - Litres	Radius of Tank - meters
5000	1.0
6000	1.125
7000	1.2
8000	1.275
9000	1.35
10000	1.425
11000	1.5

Table 19: Capacity according to the radius of the tank

• Take a length of rope as long as the radius and tie it to a wedge. Plant the wedge at the place you want to be the centre of the tank and draw a circle.

• Now dig-out the soil within this circle.

• The tank should have a slope of about one foot from the periphery to the middle of the tank.

• After the soil has been removed, a 10 cm slab of concrete has to be laid at the bottom of the tank. The ratio of sand, cement and metal stone in the concrete mixture should be 1: 2: 4

• After the slab of concrete is hardened and has completely dried, construct the walls one foot in height from the inlet with a width of one brick. It is important to use bricks with dimensions of: 5cm x 10cm x 23cm for this purpose. The cement mixture should have a ratio of cement to sand of 4:1.

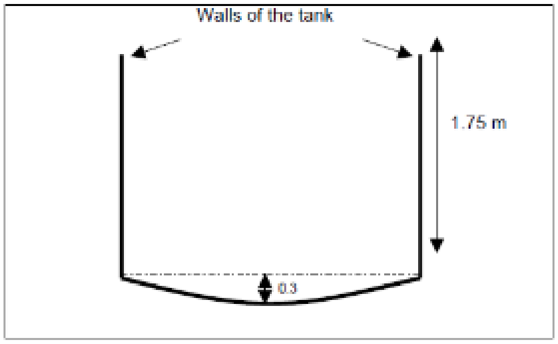


Figure 40: Cross section of a tank

• As the water inlet is connected to the tank at the ground level, the water inlet wall should not be rised above surface level.

• The mud filters are attached to the water inlet. Hence the door has to be sturdy. As depicted in the picture below, a concrete slab measuring in metres 0.75m X 1m (height and length) should be laid near the door.

• When constructing the water inlet, it is necessary to face it in the direction of the natural water-flow of the garden. As the mud filters should be placed around this door, a drain should be constructed close to the inlet of 0.5 meters (near the door) and 1 metre width. The total length of this drain should be 1 metre.

Mud filters

• Various waste items are present in flowing water. Mud, sand and gravel deposits in the tank will lessen the quantity of water that can be stored in the tank. Therefore mud- filters are used as a simple method of reducing the flow of waste items into the tank.

• Construct 2 brick bunds in the shape of a 'V' on either side of the drain, which is constructed near the inlet. Two other small bunds of about one brick (10 cm) high should be constructed across the 'V' shaped bunds. They should be placed in 45 cm and 85 cm from the inlet.

• From these 2 small bunds, the one closer to the tank should be a 0.75 cm lower than the inlet bund. The external bund should be constructed 0.75 cm lower than the internal bund.

By construction of bunds with a gradual rise towards the tank, it is possible to retain waste items, that flow in with the rainwater, in silting chambers located within the bunds

• In the opposite direction of the inlet-door, a 22 cm spill space (outlet) should be constructed in order to facilitate the flow of excess water. It is important to make this a 1.25 cm higher than the inlet-door. inlet bund internal bund external bund

• Now plaster the tank completely with cement. In this case you should plaster the outside of the tank about 15 cm above the ground level.

• You would have observed an empty space of several inches, which has been left around the tank during the construction, to facilitate the process of construction.

This empty space should be filled tightly with sand. Sand is used for the filling of this space as it can be packed tightly and is not easily subjected to decomposition. In the instance of repairs being needed for the tank, this sand layer will allow access to the tank.

• If maintained properly, it will be possible to use the rainwater-harvesting tank with ease, for about 15 years.

Best practices of operation and maintenance

• When the water in the tank becomes empty remove all soil deposits and other waste products from the bottom of the tank and clean it well.

• A small thatched hut and fence should be constructed around the tank to reduce the evaporation of water and for the security of children & domestic pets.

• Do not let water-plants grow in the tank as these will increase water loss through evapotranspiration.

• Still waters are breeding grounds for mosquitoes, therefore fish which prey on mosquito larvae eg. ‘ *Korali’- Oreochromis mossambicus* should be introduced into the tank.

How to use water efficiently for irrigation

Pitcher irrigation is an efficient method of low cost irrigation. It can be adopted in any location.

In the pitcher irrigation, unglazed clay pots are used to distribute water by seepage action through the wall of the pot. This saves over 90% of water over traditional surface irrigation systems and produces higher plants yield than any other traditional or improved irrigation practice. Around 6 - 10 litre pots are sufficient to grow most of the crops. The number of pitchers needed varies with the crop density and the type of crop.

It is important to cover the pots to minimize evaporate ion losses. Deep percolation losses are also minimized under this method. When planting on a slope place pitchers by the side of the plants, rather than above or below the plants, to minimise wastage.

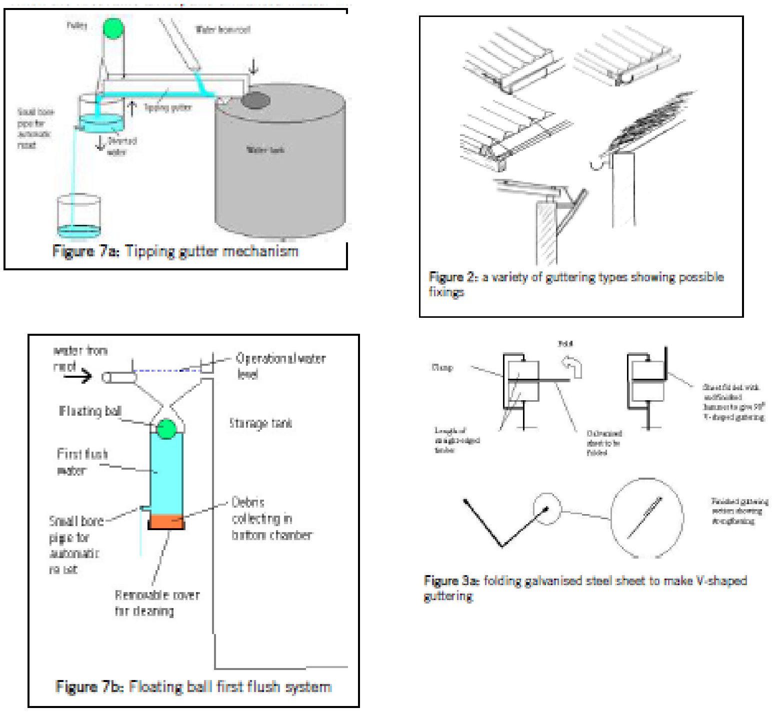
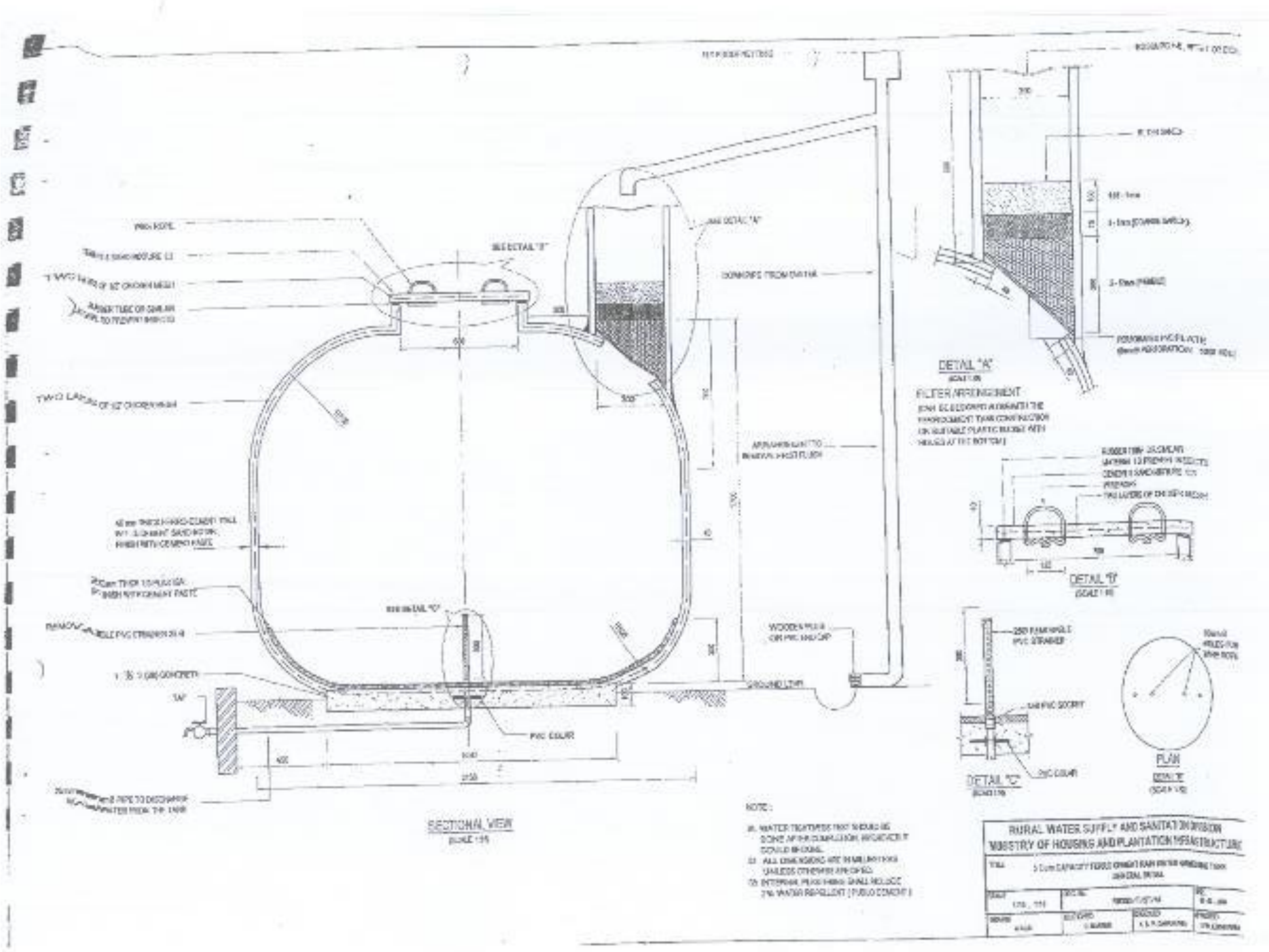
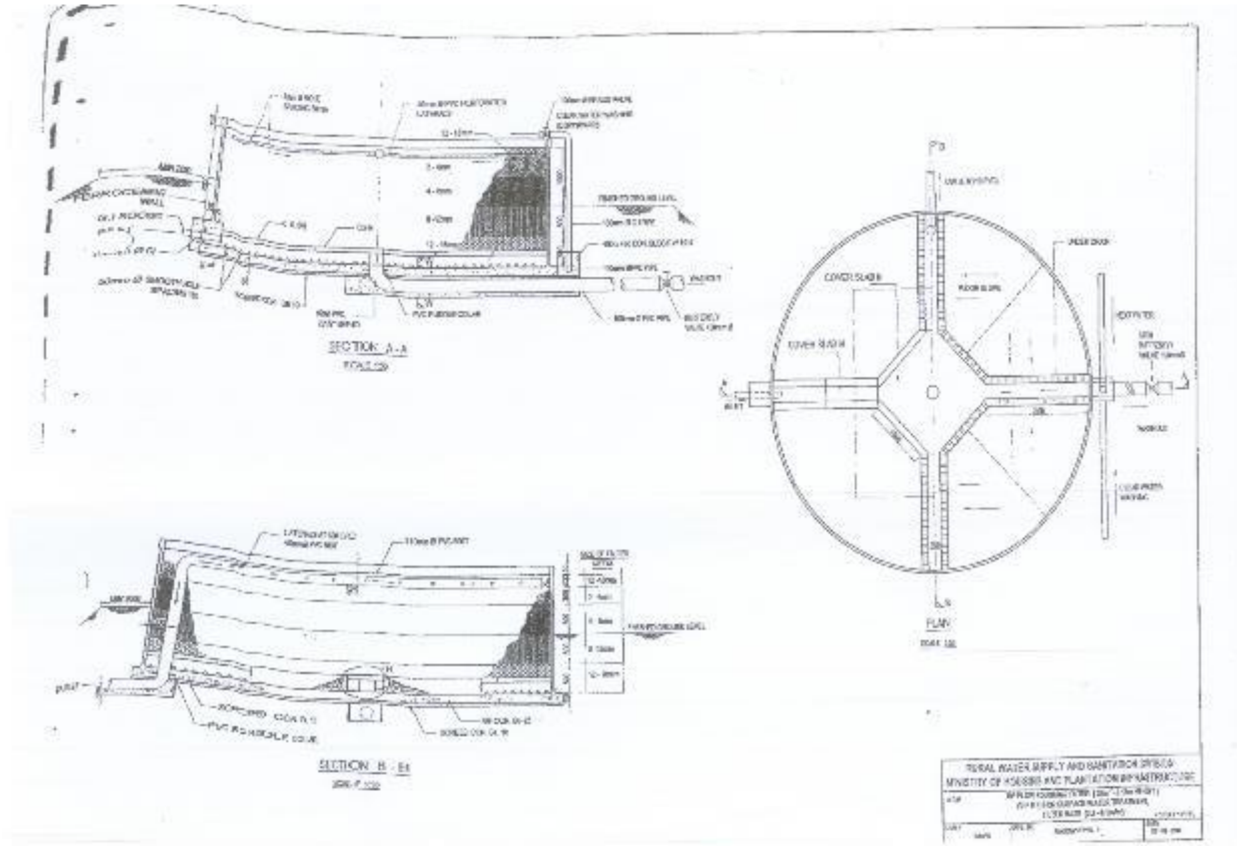
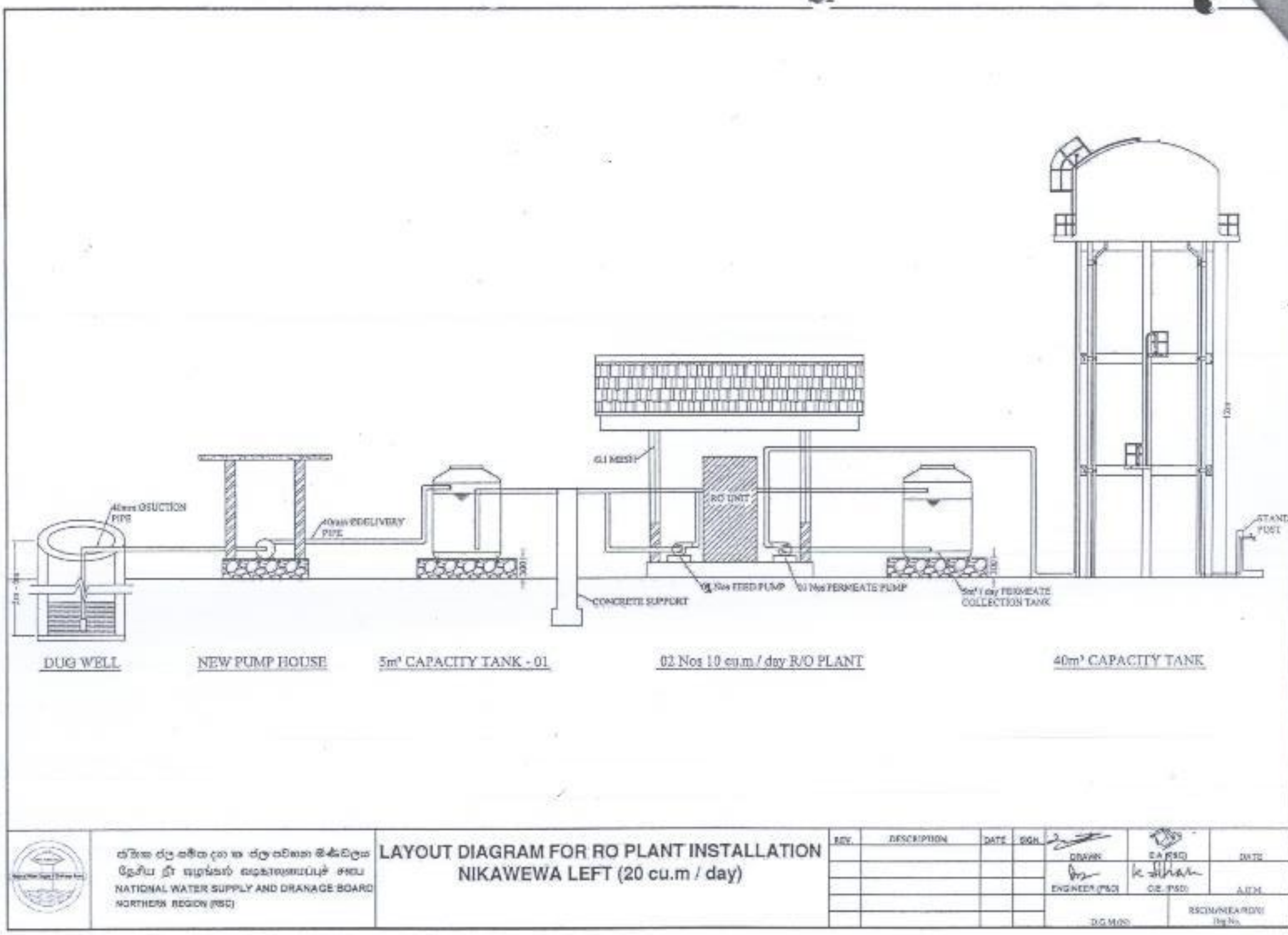


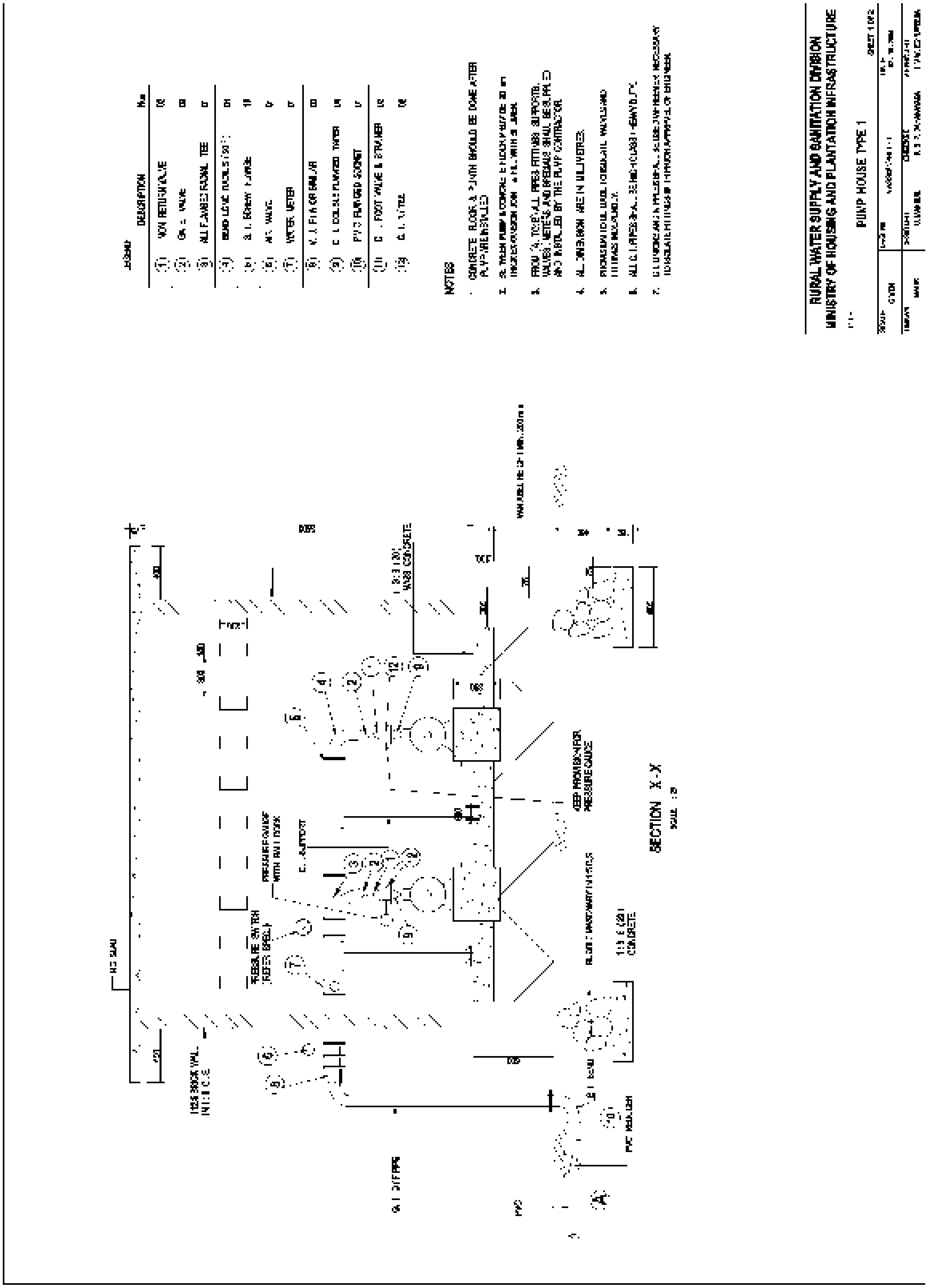
Figure 41: Roof top rainwater harvesting

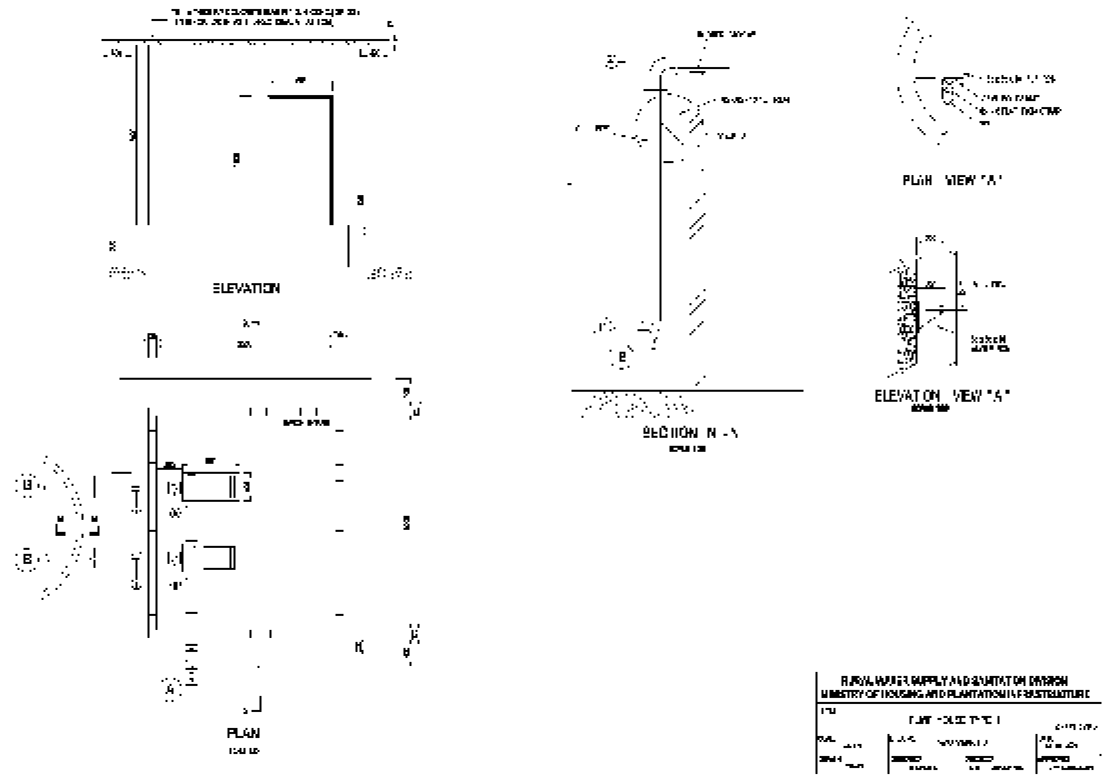
Drawings of typical village rainwater harvesting systems

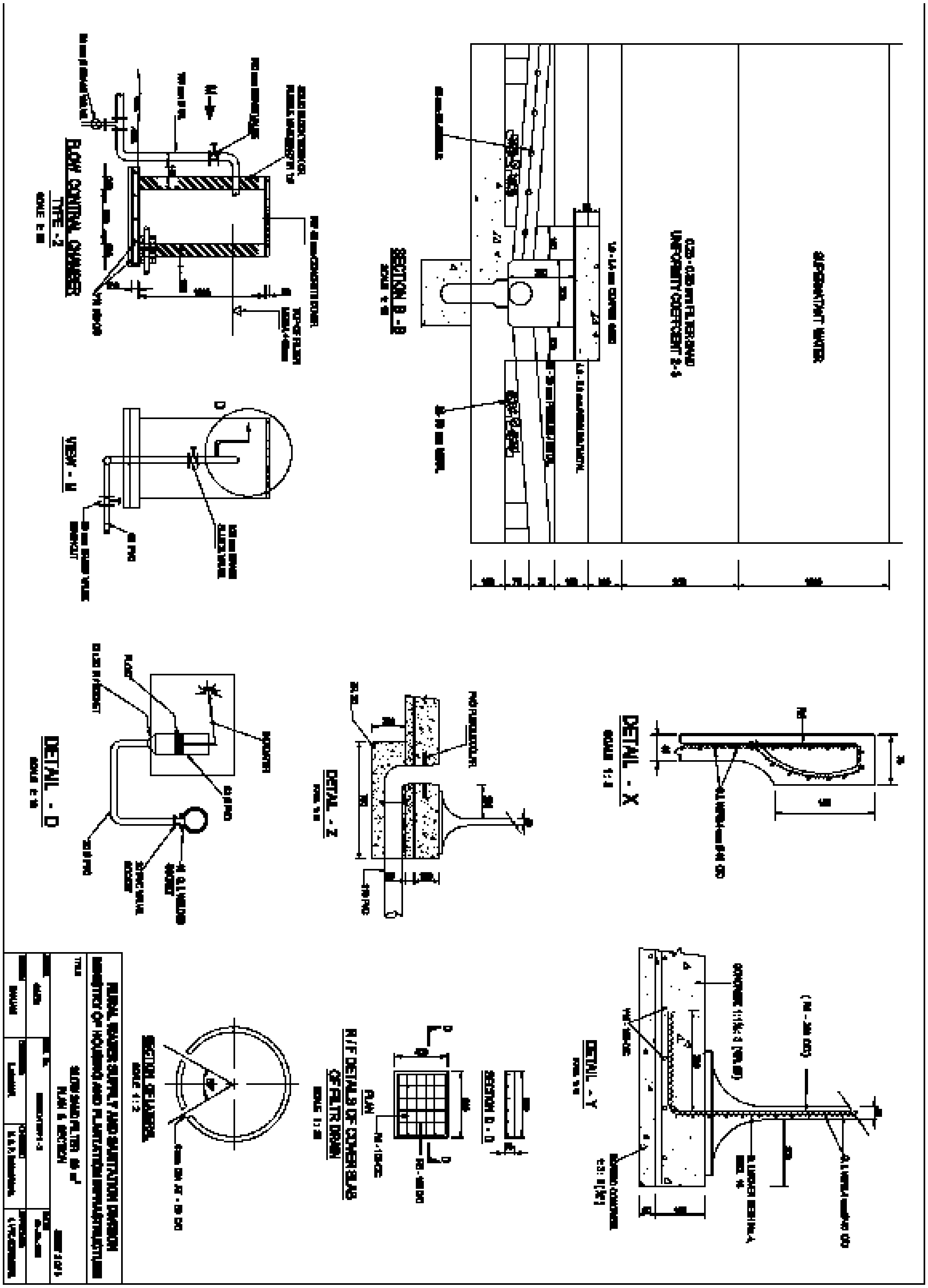

DETAIL "A"
FILTER ARRANGEMENT
DETAIL "B"
DETAIL "C"
PLAN
SECTIONAL VIEW
GROUND LINE
PVC COLLAR
TAP
NOTE:
RURAL WATER SUPPLY AND SANITATION DIVISION

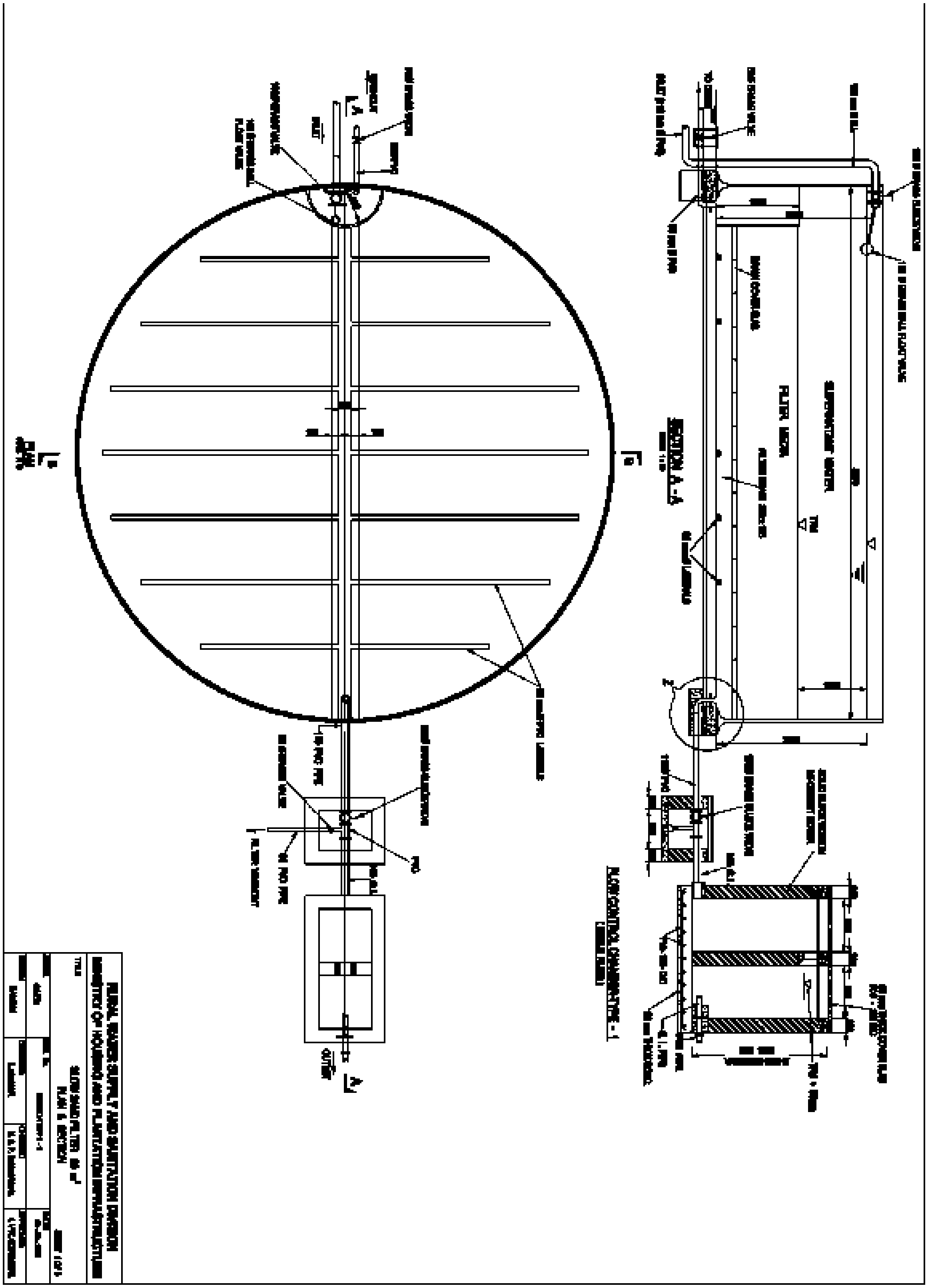

SECTION A-A
SECTION B-B
PLAN

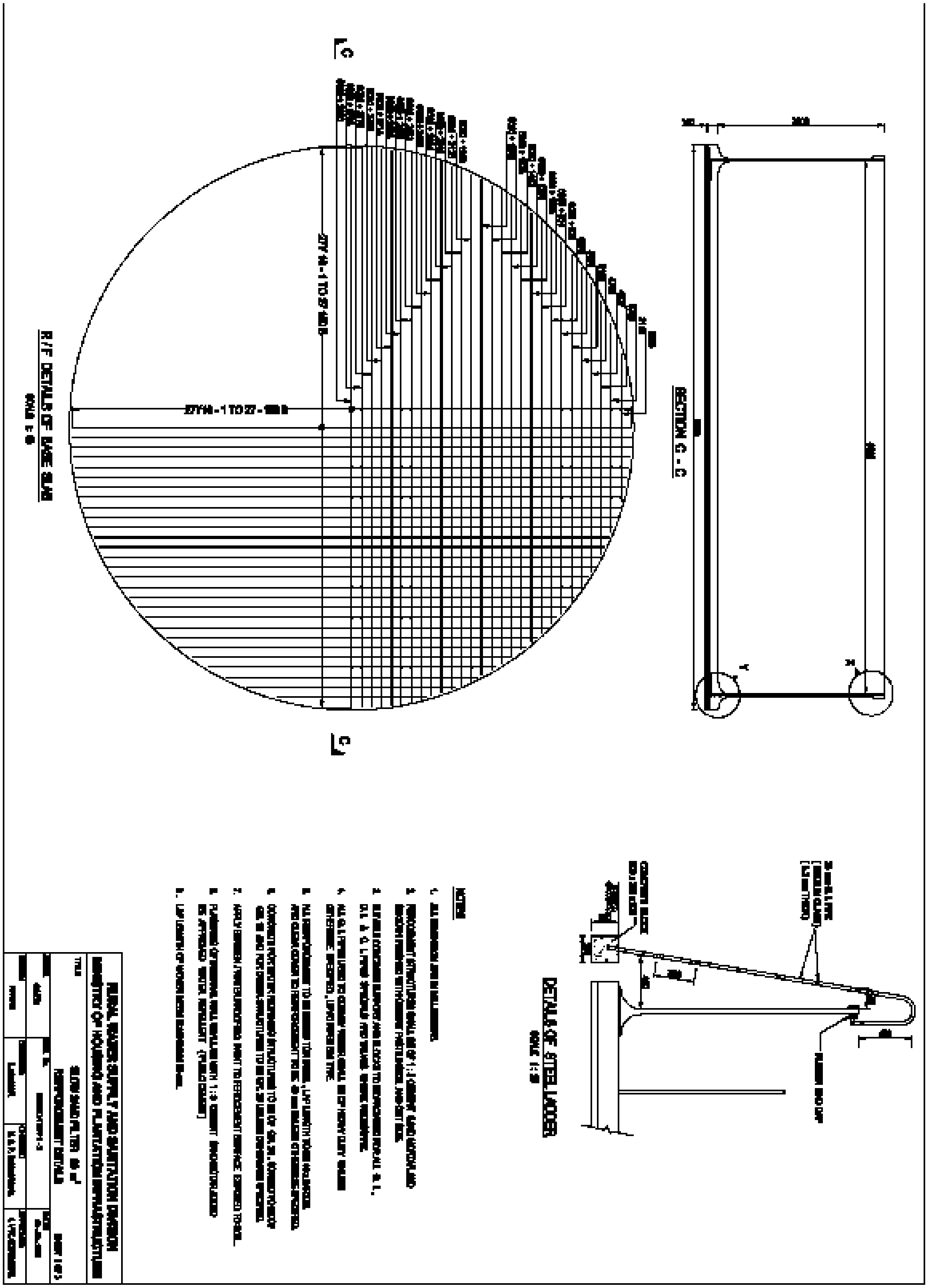

40mm Ø SUCTION PIPE
40mm Ø DELIVERY PIPE
G.I MESH
RO UNIT
CONCRETE SUPPORT
02 Nos FEED PUMP
01 Nos PERMEATE PUMP
5m³ / day PERMEATE COLLECTION TANK
STAND POST
DUG WELL
NEW PUMP HOUSE
5m³ CAPACITY TANK - 01
02 Nos 10 cu.m / day R/O PLANT
40m³ CAPACITY TANK
NATIONAL WATER SUPPLY AND DRANAGE BOARD
NORTHERN REGION (RSC)
LAYOUT DIAGRAM FOR RO PLANT INSTALLATION
NIKAWEWA LEFT (20 cu.m / day)
REV.
DESCRIPTION
DATE
SIGN
DRAWN
EA (RSC)
DATE
ENGINEER (RSC)
CE (RSC)


LEGEND
DESCRIPTION
NON RETURN VALVE
AIR VALVE
WATER METER
NOTES
CONCRETE FLOOR & PLINTH SHOULD BE DONE AFTER PUMP ARE INSTALLED
ALL DIMENSION ARE IN MILLIMETRES
SECTION X - X
PRESSURE SWITCH (REFER SPEC.)
PRESSURE GAUGE WITH BALL COCK
KEEP PROVISION FOR PRESSURE GAUGE
1:2:4 (20) CONCRETE
PVC REDUCER
RURAL WATER SUPPLY AND SANITATION DIVISION
MINISTRY OF HOUSING AND PLANTATION INFRASTRUCTURE
PUMP HOUSE TYPE 1


ELEVATION
PLAN
SECTION
PLAN VIEW "A"
ELEVATION VIEW "A"
RURAL WATER SUPPLY AND SANITATION DIVISION
MINISTRY OF HOUSING AND PLANTATION INFRASTRUCTURE


FLOW CONTROL CHAMBER
TYPE - 2
VIEW - M
SECTION B - B
SUPERNATANT WATER
DETAIL - D
DETAIL - Z
DETAIL - X
DETAIL - Y
SECTION OF LATERAL
R/F DETAILS OF COVER SLAB OF FILTER DRAIN
PLAN
SECTION D - D
RURAL WATER SUPPLY AND SANITATION DIVISION
MINISTRY OF HOUSING AND PLANTATION INFRASTRUCTURE
PLAN & SECTION




R/F DETAILS OF BASE SLAB
SECTION C - C
DETAILS OF STEEL LADDER
NOTES

Special Note: Climatic and Non-Climatic Drivers of Chronic Kidney Disease of Unknown Aetiology (CKDU)

CKDU has emerged in many South American, Eastern European and South Asian countries with over 50,000 patients estimated to have late stage kidney disease.[198] CKDU is a degenerative, progressive condition marked by the gradual loss of kidney function. When the kidney is unable to serve the human body as a filter when once damaged, the body is unable to remove toxic waste and excess liquid thereby purifying the blood. Classified by five stages, stage one and two result in reversible kidney damage while stage three and beyond lead to permanent kidney damage.

In Dry Zone Sri Lanka, CKDU has emerged a major health issue in the past ten years. The WHO Sri Lanka, progress report (2012) states that the underlying cause of kidney disease is closely linked to drinking water, and could be associated with the agrochemicals widely used in farming, the report goes on to say that the nephrotoxic agrochemicals and cadmium may have a direct toxic effect on the kidney, while arsenic, lead, genetic factors, and others (calcium and magnesium) can have interactive effects which can indirectly damage the kidney[199]. In support of this, several other studies highlight that a high concentration of heavy metals such as Cadmium, Lead and Arsenic in the soil were found in the affected areas; Secondly, drinking water has not reached the accepted level of purity in many dry zone agricultural areas.[200] Excessive use of chemical fertilizer, weedicides and pesticides have led to soil contamination which has thus attributed to air pollution and impurity of drinking water.

It is reported that the highest prevalence of CKDU occurs in the largest rice farming areas in Sri Lanka, and that approximately 99 % of CKDU patients are farmers.[201] It was also reported that source of drinking water of CKDU patients are obtained from dug wells (92 %) and tube wells (08 %). Age of majority of the CKDU patients are between 30 – 40 years and they are heavily exposed to agrochemicals as very little attention is given to hazardous effects on human health. Further, high incidence of CKDU in Sri Lanka is shown to correlate with the presence of irrigation works and rivers that bring-in nonpoint source fertilizer runoff from intensive agriculture regions using excessive amounts of cheap synthetic fertilizers. Increased iconicity of drinking waters due to fertilizer runoff into river systems, frequent redox processes in hard rock regolith aquifers in tank cascades releasing more ions into these waters due to erratic weather patterns have jointly caused the CKDU.[202] For example, the WHO report boldly states that heavy metals, in particular, Cadmium (Cd) is the main cause for CKDU in Sri Lanka.[203]

Non climatic drivers of the disease could also be attributed to general poverty, lack of water purification systems, natural soil conditions in this region and food/water consumption habits of the population. A recent WHO investigation states that the social dimension of CKDU, and its impact on poverty stricken dry zone farming communities in Sri Lanka has not received the attention that it deserves. The illness has a direct impact on patients' daily life including livelihood activities, domestic tasks, consumption patterns and their participation in social activities at community level.[204]

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[198] The Island (2014). http://www.island.lk/index.php?page_cat=article-details&page=article-details&code_title=104924

[199] Dr Shanthi Mendis (2012). Progress Report 13 Feb 2012 Chronic Kidney Disease of Uncertain Aetiology (CKDU) Sri Lanka. http://dh-web.org/place.names/posts/WHO-on-CKDU.pdf

[200] Ibid.

[201] Priyani A. Paranagama (2013), http://nas-srilanka.org/wp-content/uploads/2013/01/Paranagama-edited.pdf

[202] Ravi Ladduwahetty (2014), http://villagerinsrilanka.blogspot.com/2014/10/more-on-ckdu-story-worth-updating-our.html

[203] Dr. Parakrama Waidyanatha (2015), http://www.island.lk/index.php?page_cat=article-details&page=article-details&code_title=133014

[204] Ranjit Mullriyawa (2013). Chronic Kidney Disease of Uncertain Origin in the Dry Zone (CKDu). http://www.island.lk/index.php?page_cat=article-details&page=article-details&code_title=85230

Kidney patients profiled by the Ministry of Health and other research studies indicate that male farm workers between the ages of 35-50 are most likely to fall prey to the disease. Subsequent sociological and behavioral analysis showed many practices that could increase disease prevalence in males such as applying pesticides without protective gear, drinking water directly from irrigation channels or drinking less water, and working long hours in the open sun, and increasingly raised temperatures.[205]

Climatic drivers: Many other countries are studying health impacts from elevated air temperature and respiratory, cardiovascular and kidney disease have all been linked to global warming. Only evaporation will lower body temperature when air temperature is higher than 35°C (which is common in tropical countries), and it is less effective when humidity is high.[206] Moreover, occupational heat stress was found to be associated with worse mental health and psychological distress. Heat stress is the buildup in the body of heat generated by the muscles during work and of heat coming warm and hot environments. When the body becomes over-heated, less blood goes to the active muscles, the brain and other internal organs. Workers get weaker, become tired sooner, and may be less alert, less able to use good judgment, and less able to do their jobs well.

In Central America, case reports and government statistics document high mortality due to CKDU, particularly among younger men and in certain regions of the Pacific coast. Northwestern Nicaragua has a high prevalence of CKDU among young adult men. According to a new study by Richard J. Johnson, MD, of the University of Colorado Anschutz Medical Campus, stated that the reason for the mysterious kidney disease that has killed over 20,000 people since 2002 in Central America, most of them sugar cane workers, may be caused by chronic, severe dehydration linked to global climate change.[207] He also stated that this could be the first epidemic directly caused by global warming. His research team studied sugar cane workers in Nicaragua and El Salvador. They found that the laborers routinely worked in conditions exceeding the recommended heat standards of the U.S. Occupational Safety and Health Administration (OSHA), and even though some of them drank up to one to two liters per hour, the researchers found they still suffered serious dehydration on a daily basis.[208] All interviewees regarded occupational and environmental exposure to sun and heat, and dehydration as critical factors associated with the occurrence of CKD. Health professionals indicated that reluctance among workers to hydrate might be influenced by perceptions of water contamination. The study highlighted several potential contributors to CKD in Nicaragua including heat stress and use of potential nephrotoxic medications, supporting the plausibility of a multi-factorial cause of CKD.[209]

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[205] Kalinga Tudor Silva, Siri Hettige, Ramani Jayathilake, Chandani Liyanage and K. Sociological Aspects of CKD (UE) in Sri Lanka. National Science Foundation (2014)

[206] Benjawan Tawatsupa, Lynette Lim, Tord Kjellstrom,Sam-ang Seubsman,Adrian Sleigh, and the Thai Cohort Study Team corresponding Author. "Association between Occupational Heat Stress and Kidney Disease among 37 816 Workers in the Thai Cohort Study (TCS)." Www.ncbi.nlm.nih.gov. May 5, 2012. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3798627/.

[207] Eureka Alert. " Mysterious disease may be tied to climate change, says CU Anschutz researcher". 8-OCT-2015. http://www.eurekalert.org/pub_releases/2015-10/uoca-mdm100815.php

[208] The Guardian. "Nicaraguans demand action over illness killing thousands of sugar cane workers" February 16, 2015. http://www.theguardian.com/world/2015/feb/16/-sp-nicaragua-kidney-disease-killing-sugar-cane-workers

[209] Miguel Almaguer MD, Raúl Herrera MD PhD DrSc, Carlos M. Orantes MD. "Chronic Kidney Disease of Unknown Etiology in Agricultural Communities." April 2014.

Annex 5: EARLY WARNING AND WEATHER FORECASTING SYSTEMS

SPECIFICATIONS FOR AUTOMATIC WATER LEVEL RECORDER - (Radar Level Sensor Type)

Radar Level Sensor:

Measuring Range	1.5 to 30 m (electrical output programmable to any lower full scale and offset range, typical relative value: 0 to 10 m)
Beam width	< ± 23°
Resolution	1 mm
Maximum dead range	1.5 m
Measuring time	30 seconds
Accuracy	0.1% F.S. (±1 cm @ 10 m F.S.)
Output Signal	4-20 mA or SDI-12
Maximum electrical cable length	200 m
Operating Temperature	-10°C to 30°C
Environment protection	IP66 for humid environment
Operating Voltage	10.0 to 16.0 VDC
Current	< 4 mA (average) in SDI mode
Mounting	Pole mounted, Pole shall be anchored to a 600mm x 600mm concrete base
Power supply	Typically 12/24 V DC

Data Logger:

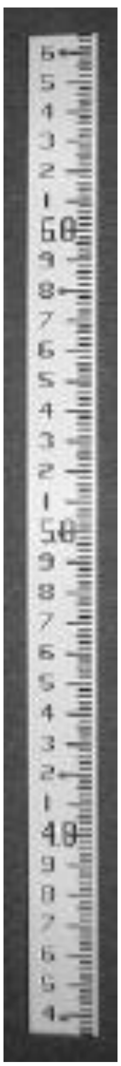
Inputs	Two to three sensors using Analog, SDI-12, Tipping bucket event counter
Interface	Standard RS232 and USB thumb drive
Readings	120,000 values per sensor
Time Stamp	Individually with 1 sec. resolution
Data storage	Non-Volatile
Display	LCD display with backlight
Battery internal	Internal back-up battery
Enclosure	IP 66 enclosure for a humid environment
Protection	Lighting, over voltage, and reverse voltage
Operating Voltage	10.0 to 16.0 VDC

Power Consumption	< 3 mA quiescent
Operating Temperature	-10°C to 60°C
Other Facilities Facility to integrate with a GPRS transmitter, so that with a SIM it can send data to a central data server	

Warranty

Minimum two years comprehensive warranty including voltage fluctuations, lightning and flood etc

Manual Water Level Recorders – Staff Gauge type



A staff gauge could be used to measure the depth of water of a minor tank or in an irrigation canal. For minor tanks the gauge has to be fixed close to the sluice.
Gauge type: Made of iron plate or timber post finished with a special porcelain enamel to ensure easy reading and resist rust or discoloration. Each gauge is accurately graduated and has holes for easy fastening to walls, piers and other structures.

SPECIFICATIONS FOR AUTOMATIC WEATHER STATION

Solar Powered Integrated Sensor Suite:

The sensor suite should include following:

- Rainfall collector: Rain collector should be self-emptying aluminum- plated tipping bucket reading rainfall in 1mm increments
- Temperature and humidity sensors enclosed in solar powered, 24 hour fan-aspirated radiation shield to combine active and passive aspiration to minimize the effects of radiation
- Anemometer with 12m anemometer cable and mounting pole
- Solar radiation sensor
- Mounting hardware
- Sensor suite should be powered by solar energy with backup battery life span of 1-2 years

Display Console Unit:

Console should be powered by AC adapter with 3 "C" backup batteries. Batteries should last up to one year under normal use
Updated weather information should be provided on a LCD screen of approximately 75 x 150mm size

Transmission

Transmission mode should be wireless with facility of retransmitting information from one console to another
Effective wireless transmission range should be up to 300m, line of sight with typical range through walls etc of 50 – 120m
Should be operated on frequency-hopping spread spectrum of 900 to 930 MHz
Should provide optional repeaters to increase the wireless transmission range from 30 – 300m each depending on terrain
The transmitter and battery to be housed inside a weather resisted shelter
Wireless range is up to 300m for outdoors, line of sight
All wireless repeaters for distances up to 2.5 km

Data Logger and a PC:

The data logger and PC should be linked to the station. Data Logger and Soft Ware: Should be provided

Weather information:

- Inside and outside air temperature

Rainfall – hourly, daily and monthly
Relative humidity and dew point temperature
Wind speed and direction
Barometric pressure
Solar radiation measurement

Maximum temperature accuracy should be with the 24 hour aspirated radiation shield that protects sensors from harmful reflected or radiated heat day and night
Should have the capability of measuring maximum anemometer wind speed rated in excess of 175kmph

Others

Detailed instruction manual and technical support should be provided
All electronic components are to be housed in a weather-resistant shelter

Manual Rain Gauges

Manual rain gauges are a simple tube, closed on one end and calibrated in inches or millimeters to indicate the amount of rainfall collected in it. A manual rain gauge must be hand-emptied after each precipitation event in order to ensure correct measurements. Rainfall amount is described as the depth of water reaching the ground, typically in inches or millimeters.

Specifications for AGMET stations

Thermometers

Instrument	Range	Accuracy	Graduation	Dimensions	Medium

Ordinary mercury thermometer on plastic scale	-20^0 to $+55^0C$	±0.1 ^0C	0.5^0C	330X48X12 mm	Mercury
Maximum mercury thermometers in wooden mount	-10^0 to $+65^0C$	±0.1 ^0C	0.5^0C	345X87X28 mm	Mercury
Minimum alcohol thermometers in wooden mount	-25^0 to $+50^0C$	±0.1 ^0C	0.5^0C	345X87X28 mm	Colorless spirit

Cup counter anemometer (counter display angled downwards) in km
Cup size : 127 mm (approximately)
Turning radius: 150 mm
Counter scale : 0 to 9999.99
Starting speed : 1 m/s (approximately)

Rain gauge (splayed base type)
Diameter of aperture : 127 mm
Rainfall capacity : 140 mm
Dimensions : 490 (H) X 216 (D) mm

Measuring cylinders to be used with 127 mm rain gauge
Pattern : flat bottom
Rainfall capacity : 10 mm
Divisions : 0.1 mm
Dimensions : 200 X 60 mm
Minimum readable value : 0.1 mm

Evaporation tank (galvanized iron tank)
Diameter : 1,220 mm
Height : 254 mm

Hook gauge
Range : 0 to 100 mm
Resolution : 0.02 mm

Still well
Height : 215 mm

Annex 6: Extracts from Weather and Seasonal Forecasts by Department of Meteorology, Sri Lanka

Probabilistic Rainfall Forecast for Second Inter-Monsoon (October-November) 2015

The probabilistic rainfall forecast for Second Inter-Monsoon season (October –November) 2015 for Sri Lanka as given below.

Consensus forecast was prepared considering,

(1) District wise and station wise probabilistic rainfall forecasts,

(2) Prevailing global climate conditions such as El Nino situation and

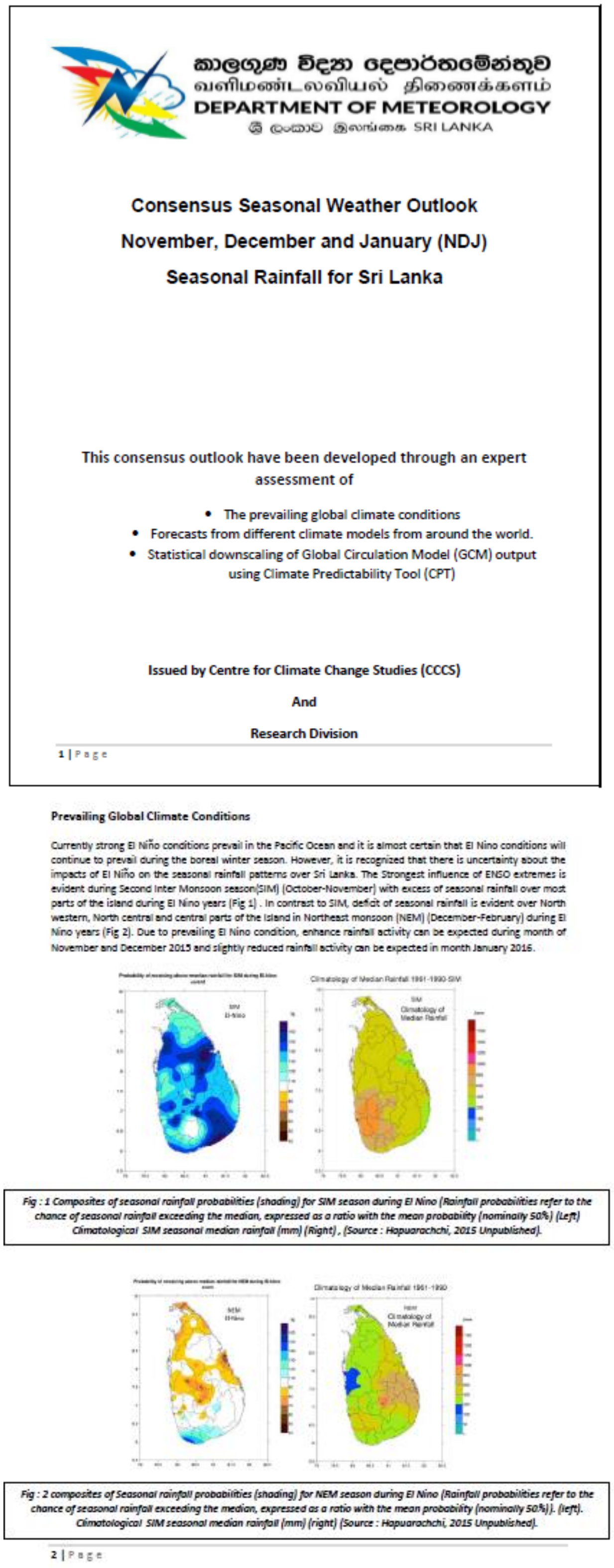
(3) Different empirical and dynamical climate model forecasts.

The district wise average rainfall is given in the column 2 of the table 1. Chance (probability) of receiving below/about/above average is given in the columns 3, 4, and 5 respectively in the table 1. All the districts have more chance (higher probability) of receiving above average rainfall during the Second Inter-Monsoon season 2015.

District	Average rainfall (mm) –(2nd IM)		Probability %	
		Below	Normal	Above
Colombo	732.5	12	24	64
Kalutara	866.8	13	24	63
Galle	799.2	13	25	62
Matara	680.9	10	25	65
Hambantota	396.9	10	26	64
Ampara	444.3	15	28	57
Batticaloa	485.4	16	29	55
Trincomalee	511.2	14	28	58
Mullaithivu	513.3	16	28	56
Jaffna	552.2	22	30	48
Killinochchi	540.6	21	29	50
Mannar	428.1	15	27	58
Puttalam	464.4	14	25	61
Gampaha	675.6	12	23	65
Kegalle	855.0	10	23	67
Ratnapura	741.7	8	24	68
Monaragala	527.0	12	26	62
Badulla	598.3	10	26	64
Pollonnaruwa	510.6	12	27	61
Vavuniya	500.5	16	28	56
Anuradapura	466.5	11	26	63
Kurunegala	558.6	12	24	64
Matale	569.4	8	26	66
Kandy	652.2	10	24	66
Nuwaraeliya	621.5	10	25	65

Table 1

Figure 42: An extract from forecast for a rainfall season



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வளிமண்டலவியல் திணைக்களம்
DEPARTMENT OF METEOROLOGY
ශ්‍රී ලංකාව இலங்கை SRI LANKA

Consensus Seasonal Weather Outlook
November, December and January (NDJ)
Seasonal Rainfall for Sri Lanka

This consensus outlook have been developed through an expert assessment of

- The prevailing global climate conditions
- Forecasts from different climate models from around the world.
- Statistical downscaling of Global Circulation Model (GCM) output using Climate Predictability Tool (CPT)

Issued by Centre for Climate Change Studies (CCCS)

And

Research Division

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Prevailing Global Climate Conditions

Currently strong El Niño conditions prevail in the Pacific Ocean and it is almost certain that El Nino conditions will continue to prevail during the boreal winter season. However, it is recognized that there is uncertainty about the impacts of El Niño on the seasonal rainfall patterns over Sri Lanka. The Strongest influence of ENSO extremes is evident during Second Inter Monsoon season(SIM) (October-November) with excess of seasonal rainfall over most parts of the island during El Nino years (Fig 1) . In contrast to SIM, deficit of seasonal rainfall is evident over North western, North central and central parts of the Island in Northeast monsoon (NEM) (December-February) during El Nino years (Fig 2). Due to prevailing El Nino condition, enhance rainfall activity can be expected during month of November and December 2015 and slightly reduced rainfall activity can be expected in month January 2016.

Fig : 1 Composites of seasonal rainfall probabilities (shading) for SIM season during El Nino (Rainfall probabilities refer to the chance of seasonal rainfall exceeding the median, expressed as a ratio with the mean probability (nominally 50%) (Left) Climatological SIM seasonal median rainfall (mm) (Right) , (Source : Hapuarachchi, 2015 Unpublished).

Fig : 2 composites of Seasonal rainfall probabilities (shading) for NEM season during El Nino (Rainfall probabilities refer to the chance of seasonal rainfall exceeding the median, expressed as a ratio with the mean probability (nominally 50%)). (left). Climatological SIM seasonal median rainfall (mm) (right) (Source : Hapuarachchi, 2015 Unpublished).

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Figure 43: An extract from a three-month forecast

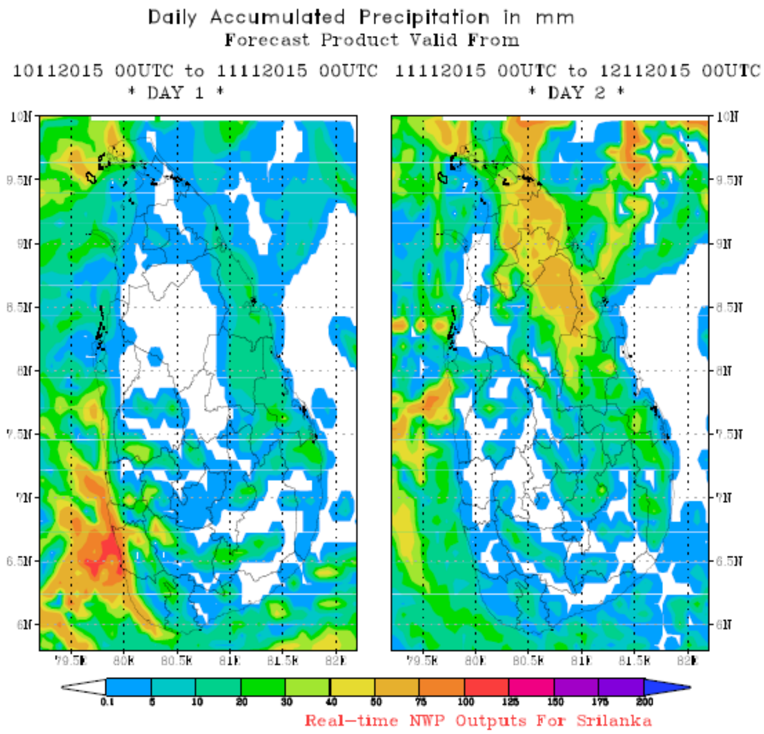

Figure 44: Extract from a 10 day forecast

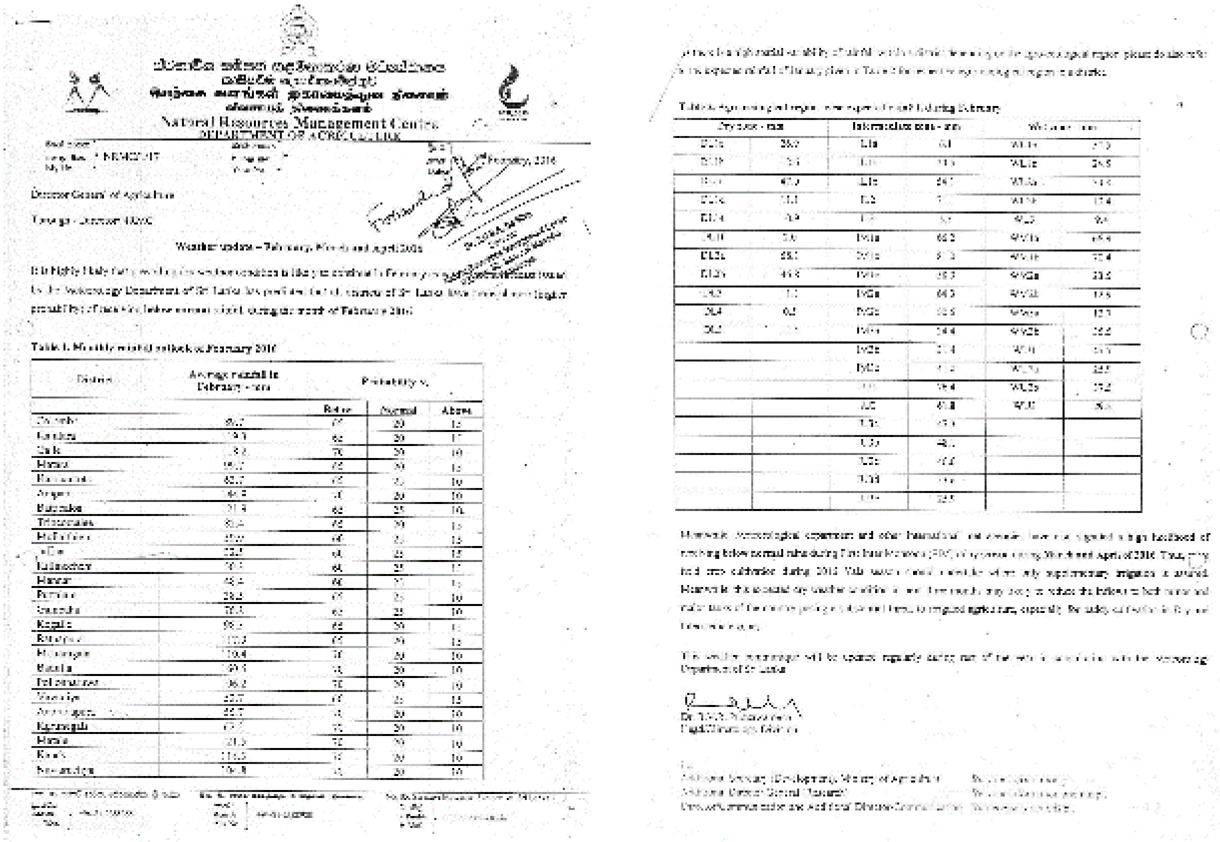

Figure 45: An extract from weekly Agro-meteorological Bulletin

Annex 7: Stakeholder Consultations

Meeting	**Date**	**Time**	**Venue**	**Objective**	**Participants**
Initial GCF meeting at the UN Compound	8th of October 2015	2.00pm	UN Compound	There was a brief overview of the Green Climate Fund (GCF), and it was highlighted at this meeting that water has been prioritized by the Government of Sri Lanka. Further, thematic areas- Irrigation, drinking water and disaster management- were taken up for discussion.	Representatives from the Ministry of Agriculture, National Water Supply and Drainage Board, Meteorological department.
Initial GCF meeting at the Presidential Secretariat	13th Oct 2015	9.00am	Presidential Secretariat	Formation of a Technical Working Group	Secretary to the President, Mr.P. Abeykoon and representatives from the Ministry of Mahaweli Development & Environment, Department of Irrigation, National Water Supply and Drainage Board, Ministry of Irrigation, Ministry of Foreign Affairs, Ministry of Agriculture, National Planning Department, Ministry of Health, Ministry of Disaster Management, Ministry of City Planning and Water Supply, Department of Meteorology, Department of Agriculture
1st Technical Working Group	16th Oct 2015	9.30am	Ministry of Mahaweli Developme nt and Environme nt	The main focus of this meeting was to narrow the scope and geographical focus	Representatives from the Ministry of Mahaweli Development & Environment, Department of Irrigation, National Water Supply and Drainage Board, Ministry of Irrigation, Ministry of Foreign Affairs, Ministry of Agriculture, National Planning Department, Ministry of Health, Ministry of Disaster Management, Ministry of City Planning and Water Supply, Department of Meteorology, Department of Agriculture
2nd Technical Working Group	29th Oct 2015	2.00pm	Ministry of Mahaweli Developme nt and Environme nt	The objective of this meeting was to view the progress of the Project Team in drafting the Technical Feasibility Report	

3rd Technical Working Group	11th Nov 2015	1.30pm	Conference Hall "SapthParisaraManadapaya" of Ministry of Mahaweli Development and Environment	Proposed outputs and activities were revised	Representatives from the Ministry of Mahaweli Development & Environment, Department of Irrigation, National Water Supply and Drainage Board, Ministry of Irrigation, Ministry of Foreign Affairs, Ministry of Agriculture, National Planning Department, Ministry of Health, Ministry of Disaster Management, Ministry of City Planning and Water Supply, Department of Meteorology, Department of Agriculture
Higher Level Ministerial Meeting	19th Nov 2015	9.30am	Presidential Task Force	It was agreed upon that the Host/Sponsor of this project would be the Ministry of Mahaweli Environment and Development. In addition, Ministry of Agriculture, DAD, Ministry of Water Supply and City Planning, National Community Water Supply Department, Ministry of Disaster Management agreed upon to take up responsibilities in the implementation of the 3 outputs.	
Mark Tadross Mission (Roundtable Discussion)	3rd Dec 2015		Ministry of Disaster Management	Dr. Mark Tadross, technical specialist on climate information and early warning systems, UNDP, was on mission in Sri Lanka from the 2nd of December to 4th of December 2015, where he had discussions with key stakeholders.	Academic scholars and representatives from the Ministry of Mahaweli Development & Environment, Ministry of Disaster Management

Field Consultations	3rd and 4th November	Anuradhapura and Puttalam	Visited Tank Alisthana and the Thirappane Cascade System, followed by a meeting with Dr. Tennakoon, South Asia Partnership Sri Lanka (SAPSRI) Discussion with Mr. Seneviratne, member of the International Union for Conservation of Nature (IUCN) Visited Parasangaswewa Reverse Osmosis (RO) plant run by women headed CBO, operating under the supervision of the National Community Water Supply Department Discussion at Madurankuliya, Rural Water Supply scheme run by a CBO, operating under the supervision of the National Community Water Supply Department	Dr. Tennakoon, South Asia Partnership Sri Lanka (SAPSRI), Mr. Seneviratne, member of the International Union for Conservation of Nature (IUCN) and members of the Community Based Organizations
Field Consultations	19th and 20th of January 2016	Kurunegala	In order to further strengthen the Technical Feasibility Report, community consultations were held in Kurunegala	Provincial Director- Provincial Department of Agriculture, Deputy Commissioner of Agrarian Services Department, Divisional Officers, Regional Engineers and Farmer Organization Office Bearers and the community- around 20 males and 15 females

Bi-Lateral Meetings

Name	Designation	Date	Time	Venue
Mr. Mudalige	Director General, Department of National Planning	**October 5 th- 10th 2015**		

Mr. M. I.M Rafeek	Secretary, Ministry of National Policy and Economic Affairs	**October 5th- 10th 2015**		
Mr. Priyantha Ratnayake	Director General, Department of External Resources			
Mr. Harsha de Silva	Deputy Minister of Foreign Affairs			
Mr. Udaya R. Seneviratne	Secretary, Ministry of Mahaweli Development and Environment			
Mr. B.M.S. Batagoda	Secretary, Ministry of Power and Energy			
Mr. Ranjith Wirasinha	Adviser on Water Affairs	16th October 2015	3pm	UNDP
Mr. B.M.U.D. Basnayake,	Secretary to the Ministry, Ministry of City Planning and Water Supply	17th November 2015	2pm	Ministry of City Planning and Water Supply
Mr. Janaki Amarathunga	Director, Ministry, Ministry of City Planning and Water Supply			
Mr. Rajkumar	Deputy General Manager, National Water Supply and Drainage Board			
Mr. M.I.A.Lathiff	Director General, Department of National Community Water Supply			
Mr. Prabath Vitharana	Head, Water Mgt Division,	-18th October 2015	9.30am	Department of Agrarian Development
		-2nd December 2015	3pm	Ministry of Disaster Management

	Department of Agrarian Development	-27th January 2016	9.30am	Department of Agrarian Development
Mr. Lalith Chandrapala	Director General, Department of Meteorology	2nd of December 2015	1pm	Disaster Management Centre
Mr. Premlal	Director, Research and Training Department of Meteorology			
Ms. Janaki Meegasthenna	Director, Irrigation Department Water Management Division	18th of November and 2nd of December 2015	10.30am	Irrigation Department
Dr. Herath Manthrithilake	Head, Sri Lanka programmes at International Water Management Institute	2nd December 2015	9.30am	IWMI