Irrigation Development and Management

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US $1.00 = MMK 1,273

ABBREVIATIONS
ACC - Agricultural Coordinating Committee
AMD - Agricultural Mechanization Department
CDC - Cross drainage culvert
CDZ - Central Dry Zone
DALMS - Department of Agricultural Land Management and Statistics
(DALMS) (formerly SLRD)
DICD - Department of Industrial Crops Development
DO - Direct Outlet
DOA - Department of Agriculture
DY - Distributary Canal
ET - (Crop) Evapo-transpiration
FFS - Farmers’ Field School
FLC - Front Line Center
GAD - General Administration Department
ID - Irrigation Department
LMC - Left Main Canal
LSL - Lump sum limit
OM - Ordinary maintenance
RD - Reduced Distance (= foot)
RMC - Right Main Canal
SLRD - Settlement and Land Records Department
SR - Special repairs
WC - Watercourse
WDC - Water distribution committee
WUA - Water User Association
WUG - Water User Group

GLOSSARY
bintha - Field staff of Irrigation Department
myaunggaung - Farmer leader of watercourse irrigation system
selesu - Leader farmer (representing 10 households)
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EXECUTIVE SUMMARY

1. This document presents the overall approach to irrigation development and management in a sector context. The irrigation components of feasibility studies for two core sub-projects, Chaungmagyi and Natmauk, are included as Annexes, and the document makes reference to other documents which describe the agricultural components (SD2), economic and financial analysis (LD7), initial environmental assessment (LD11), and social assessment (LD7 and SD9).

2. The report is structured as follows, in five chapters:
   
   (i) Irrigation Sector Overview, providing a brief summary of the current status of irrigation infrastructure across the country and in the Central Dry Zone (CDZ).
   
   (ii) Irrigation Infrastructure, describing the current condition of infrastructure in the CDZ and setting out the rationale for intervention and the activities to be undertaken under the project in relation to rehabilitation and modernization. This sets out the overall approach but the details are specific to individual sub-projects which are described in separate standalone annexes.
   
   (iii) Irrigation Management, describing the existing arrangements and procedures and setting out the rationale for intervention and the activities to be undertaken under the project in relation to improving irrigation management and increasing participation by water users. This draws on a review of experiences for management reforms in South/South East Asia and sets out a detailed approach to be followed in all sub-projects.
   
   (iv) Hydrological Context, which examines the available water resources in the CDZ and assesses the potential impact of climate change.
   
   (v) Sector Approach, setting out the overall rational, approach and implementation program, with the core sub-projects as examples, and describing how other sub-projects are to be identified and implemented.

3. The core sub-project reports for Chaung Magyi follow a standard structure, each with nine chapters, to cover the irrigation aspects of the feasibility studies:
   
   (i) Sub-project Area
   (ii) Condition and Performance Assessment
   (iii) Consultations
   (iv) Water Resources and Requirements
   (v) The Subproject, with overview of physical works and management improvements
   (vi) Irrigation Design, describing the design criteria and methodology
   (vii) Expected Outcomes and Benefits
   (viii) Costs
   (ix) Engineering Designs

4. Climate change has been carefully considered in these designs and plans. To a large extent, the requirements for adaptation to the likely range of potential impacts are covered by normal good practice, particularly given the availability of storage. However, drainage crossings will be sized to suit more intense rainfall. A major potential impact would result in delays to the
onset of the monsoon. This will be addressed through better management of reservoirs, to ensure water availability at the start of the monsoon season, coupled with more flexible canal controls. This is already important but will become more critical as climate change impacts become more apparent.
I. IRRIGATION SECTOR OVERVIEW

A. National Context

Myanmar has good potential for agricultural growth with its abundant land and water resources. The average farm size is about 5 acres, which is relatively high for the region, and the average water availability of over 20,000 cubic meter (m$^3$) per capita is much higher than the Asian average of 4,000 m$^3$ per capita. However, the average annual rainfall in the Central Dry Zone (CDZ), where 25% of the population live, is just 30 inches with a pronounced dry season and negligible rainfall for six months of the year. This makes irrigation essential even for securing a good monsoon season crop as well as for growing a dry season crop. Despite the abundant water resources, the topography limits access to water for most parts of the country and the CDZ is only able to access small tributary stream rather than the main rivers. Irrigation, drainage and flood management infrastructure is thus indispensable for ensuring farm productivity.

The first irrigation works in Myanmar were undertaken near Bagan in the CDZ in the eleventh and twelfth centuries, usually in the form of diversion systems on tributaries of the Ayeyarwady, and were designed to provide security to the main season rice crop. More recently flood protection and drainage facilities in the Ayeyarwady delta enabled the development of rice cultivation on a much larger scale and made Myanmar a major rice-exporting country before the Second World War.

Recognizing that the availability of adequate water is a critical factor for agricultural production, the Ministry of Agriculture, Livestock and Irrigation (MOALI) has developed a strategy to raise irrigation coverage from the current figure of around 20% to 25% of the net sown area through construction of new reservoirs and dams and better management of existing facilities as well as increases in lift irrigation; and use of groundwater (MOALI, 2015)

There has been rapid construction of dams and irrigation since the 1960s and particularly after 1990, but the currently developed area is still just over 20% of the potential area of about 25 million acres. Over 2.5 million acres has been brought under irrigation since 1988 (Table 1) bringing the total to 5.2 million acres in 2014 (MOALI, 2015) – almost doubling the total area in 25 years. It has been reported, however, that the quality and completeness of systems have been compromised as a result of pressure to finish construction as quickly as possible. In common with much of South and East Asia, groundwater irrigation has increased sharply, more than doubling since 1995. 42% is now supplied by canals and tanks 7% from groundwater, 37% by lift from surface sources and 14% by other methods.

Despite the increase in irrigation, 80%-85% of the total sown area is still unirrigated, and even irrigated land has a low average cropping intensity, typically 120%-130%.
Table 1: New Irrigation Projects in Myanmar (1988-2014)

<table>
<thead>
<tr>
<th>State/region</th>
<th>Nos projects</th>
<th>Area (acres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kayah</td>
<td>2</td>
<td>3,150</td>
</tr>
<tr>
<td>Kayin</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>Chin</td>
<td>1</td>
<td>500</td>
</tr>
<tr>
<td>Sagaing</td>
<td>26</td>
<td>377,745</td>
</tr>
<tr>
<td>Thanitaryi</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Bago</td>
<td>51</td>
<td>900,470</td>
</tr>
<tr>
<td>Magway</td>
<td>48</td>
<td>301,485</td>
</tr>
<tr>
<td>Mandalay</td>
<td>56</td>
<td>408,120</td>
</tr>
<tr>
<td>Mon</td>
<td>11</td>
<td>113,800</td>
</tr>
<tr>
<td>Rakhine</td>
<td>6</td>
<td>6,450</td>
</tr>
<tr>
<td>Yangon</td>
<td>20</td>
<td>304,690</td>
</tr>
<tr>
<td>Shan</td>
<td>7</td>
<td>114,675</td>
</tr>
<tr>
<td>Ayeyarwady</td>
<td>10</td>
<td>322,420</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>240</strong></td>
<td><strong>2,472,110</strong></td>
</tr>
</tbody>
</table>

The rate of increase in irrigated area appears to have declined recently (Table 2) and there has been a slight decline in the total area which reached a peak of 5.8 million acres in 2009 (MOALI), with the reductions being mainly in tank and pump irrigation (which is constrained by the cost and availability of power). However, these figures relate to formal systems and may underestimate the areas irrigated informally or by small-scale privately managed groundwater systems.

### Table 2: Irrigation by Type (2012-2012) (’000 acres)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Canal</td>
<td>1,537</td>
<td>1,606</td>
<td>1,712</td>
<td>1,641</td>
<td>1,611</td>
<td>1,606</td>
</tr>
<tr>
<td>Tanks</td>
<td>628</td>
<td>744</td>
<td>815</td>
<td>793</td>
<td>682</td>
<td>586</td>
</tr>
<tr>
<td>Groundwater</td>
<td>257</td>
<td>259</td>
<td>297</td>
<td>341</td>
<td>381</td>
<td>366</td>
</tr>
<tr>
<td>Surface Lift</td>
<td>1,769</td>
<td>1,641</td>
<td>2,086</td>
<td>2,142</td>
<td>2,221</td>
<td>1,950</td>
</tr>
<tr>
<td>Other</td>
<td>427</td>
<td>509</td>
<td>633</td>
<td>702</td>
<td>768</td>
<td>722</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>4,618</td>
<td>4,759</td>
<td>5,543</td>
<td>5,619</td>
<td>5,663</td>
<td>5,230</td>
</tr>
</tbody>
</table>

Management of irrigation systems is based on a traditional, top-down, supply-led approach aimed at maximising rice production. There is no single law on water resources, and the development and management of irrigation is still governed by 1905 Canal Act which does not recognise the need for modern concepts such as effective participatory irrigation management, a user-oriented service delivery approach, and sustainable arrangements for cost recovery.

Climate change represents an increasing challenge for Myanmar's agriculture. The country is already experiencing increased climate variability and has suffered increasingly from extreme events which have caused extensive flooding. Temperatures are increasing and, despite heavier total rainfall, there are emerging signs of longer dry spells and delays to the onset of the monsoon. The high dependence on agriculture with nearly 70% of the population living in rural areas, coupled with a high sensitivity of local agriculture to the climate make Myanmar very vulnerable to climate change.

1. **The Central Dry Zone**

The CDZ comprises Mandalay, Magway and southern Sagaing regions. The Irrigated Agriculture Inclusive Development Project (IAIDP) area potentially includes all of this area, although sub-projects identified to date by the Irrigation Department (ID) in the CDZ all fall within Magway District of Magway Region, Meiktila and Yamethin Districts of Mandalay Region, and Shwebo District of Sagaing Region. Irrigation projects in these regions are summarized in
Table 3, which indicates that 60% of the formally irrigated area in the CDZ has been developed in the past 25 years.

<table>
<thead>
<tr>
<th>District</th>
<th>Type of Project</th>
<th>More than 25 yrs old</th>
<th>Built since 1988</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kayah</td>
<td>Weir</td>
<td>10</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>Dam</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>Sagaing</td>
<td>Weir</td>
<td>491</td>
<td>169</td>
</tr>
<tr>
<td></td>
<td>Dam</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magway</td>
<td>Weir</td>
<td>209</td>
<td>137</td>
</tr>
<tr>
<td></td>
<td>Dam</td>
<td>137</td>
<td></td>
</tr>
<tr>
<td>Mandalay</td>
<td>Weir</td>
<td>116</td>
<td>694</td>
</tr>
</tbody>
</table>

A large proportion of the irrigated area is in the Dry Zone, and most is supplied from dams. The availability of storage (Table 4) should make these systems resilient, particularly in the face of emerging climate change, but many function below their potential because of inappropriate operation of reservoirs, incomplete irrigation and drainage infrastructure, and a lack of responsive on-farm irrigation system management.

<table>
<thead>
<tr>
<th>Division</th>
<th>District</th>
<th>Large Reservoirs</th>
<th>Small Reservoirs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Storage ('000 acre ft)</td>
<td>Number</td>
</tr>
<tr>
<td>Sagaing</td>
<td>Shwebo</td>
<td>5</td>
<td>2,941</td>
</tr>
<tr>
<td>Sagaing</td>
<td>1</td>
<td>5</td>
<td>26</td>
</tr>
<tr>
<td>Monywa</td>
<td>12</td>
<td>197</td>
<td>92</td>
</tr>
<tr>
<td>Magwe</td>
<td>Pakokku</td>
<td>17</td>
<td>41</td>
</tr>
<tr>
<td>Magwe</td>
<td>14</td>
<td>198</td>
<td>51</td>
</tr>
<tr>
<td>Minbu</td>
<td>6</td>
<td>1,795</td>
<td>9</td>
</tr>
<tr>
<td>Thayet</td>
<td>4</td>
<td>162</td>
<td>35</td>
</tr>
<tr>
<td>Mandalay</td>
<td>Kyauk Se</td>
<td>1</td>
<td>873</td>
</tr>
<tr>
<td>Meiktila</td>
<td>1</td>
<td>Nd</td>
<td>582</td>
</tr>
<tr>
<td>Myingyan</td>
<td>1</td>
<td>73</td>
<td>87</td>
</tr>
<tr>
<td>Nyaung U</td>
<td>nd</td>
<td>nd</td>
<td>9</td>
</tr>
<tr>
<td>Yamethin</td>
<td>nd</td>
<td>nd</td>
<td>92</td>
</tr>
</tbody>
</table>

Total: 62 | 6,290 | 1,978 | 828

Source: IWMI component 1 report
nd: no data/incomplete data

There are large variations in storage across each district: the figures are 3.6 feet for Natmauk and 4.7 feet for Chaung Magyi, but in many locations there is much less storage. The large volume in Shwebo District is due to the very large reservoir at Thaphanseik dam which is for hydropower as well as for the 120,000 acre Ye-U irrigation system.

In addition to formally irrigated areas managed by the ID, there are significant areas of small-scale informal and village managed irrigation as well as groundwater irrigation. Estimates of the current irrigated area in the CDZ are given below (Table 5), but both are underestimates. The ID data only includes formal ID-managed schemes, whereas the IWMI data shows areas that were actually irrigated from all sources in the dry

---

1 Source
2 LIFT (2012).
season 2012. However the area irrigated in the monsoon is generally much greater than in the dry season.

### Table 5: Estimates of Irrigated Area in CDZ Districts (acres)

<table>
<thead>
<tr>
<th>Division</th>
<th>District</th>
<th>Estimated irrigated area (acres)</th>
<th>Irrigation Department</th>
<th>Delineated by IWMI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sagaing</td>
<td>Shwebo</td>
<td>133,000</td>
<td>228,000</td>
<td></td>
</tr>
<tr>
<td>Sagaing</td>
<td></td>
<td>3,500</td>
<td>77,000</td>
<td></td>
</tr>
<tr>
<td>Sagaing</td>
<td>Monywa</td>
<td>58,500</td>
<td>20,460</td>
<td></td>
</tr>
<tr>
<td>Magwe</td>
<td>Pakokku</td>
<td>33,500</td>
<td>30,390</td>
<td></td>
</tr>
<tr>
<td>Magwe</td>
<td></td>
<td>87,900</td>
<td>27,100</td>
<td></td>
</tr>
<tr>
<td>Magwe</td>
<td>Minbu</td>
<td>177,000</td>
<td>107,400</td>
<td></td>
</tr>
<tr>
<td>Thayet</td>
<td></td>
<td>31,000</td>
<td>14,200</td>
<td></td>
</tr>
<tr>
<td>Mandalay</td>
<td>Kyauk Se</td>
<td>211,700</td>
<td>15,000</td>
<td></td>
</tr>
<tr>
<td>Mandalay</td>
<td>Meiktila</td>
<td>14,300</td>
<td>25,500</td>
<td></td>
</tr>
<tr>
<td>Mandalay</td>
<td>Myingyan</td>
<td>38,300</td>
<td>73,700</td>
<td></td>
</tr>
<tr>
<td>Mandalay</td>
<td>Nyaung U</td>
<td>200</td>
<td>15,350</td>
<td></td>
</tr>
<tr>
<td>Mandalay</td>
<td>Yamethin</td>
<td>61,800</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>850,700</strong></td>
<td><strong>1,327,100</strong></td>
<td></td>
</tr>
</tbody>
</table>

Most systems are small, generally less than 10,000 acres, with very few more than 25,000 acres. They are supplied from small streams which have been dammed to provide some storage to smooth out short term fluctuations in flow and to enable some summer cropping. Water shortage is a major constraint and the systems are generally only able to provide partial, supplementary irrigation. The older schemes (mainly in Mandalay) are often in worse condition than the newer schemes (notably in Magway) although some areas have been upgraded resulting in considerable variation in the condition within individual schemes. There are numerous pumped irrigation systems from the Ayeyarwady River, but these are all quite small (rarely exceeding 1,000 acres). This river is too deeply incised to be used for gravity irrigation.
II. IRRIGATION INFRASTRUCTURE

A. Irrigation Infrastructure in the Project Area

1. Overview

This section describes the design and condition of irrigation infrastructure based on a review of a pipeline of projects which have been assessed to prefeasibility level as listed below and indicated on the map.

<table>
<thead>
<tr>
<th>Region / State</th>
<th>System</th>
<th>Storage volume (acre-ft.)</th>
<th>Net command area (acre)</th>
<th>Storage per unit command area (feet)</th>
<th>Average Water Use (acre-ft.)</th>
<th>Cropping Intensity average</th>
<th>Cropping Intensity dry year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kayah</td>
<td>Moby</td>
<td>580,000</td>
<td>17,917</td>
<td>32.37</td>
<td>28,568</td>
<td>17,847</td>
<td>85</td>
</tr>
<tr>
<td>Kayah</td>
<td>Ngwe Daung</td>
<td></td>
<td>6,291</td>
<td></td>
<td>140,255</td>
<td>102,664</td>
<td>119</td>
</tr>
<tr>
<td>Magway</td>
<td>Natmauk</td>
<td>88,400</td>
<td>25,380</td>
<td>3.48</td>
<td>25,212</td>
<td>14,906</td>
<td>130</td>
</tr>
<tr>
<td>Magway</td>
<td>Sun Chaung</td>
<td>24,576</td>
<td>7,125</td>
<td>3.45</td>
<td>28,956</td>
<td>16,414</td>
<td>115</td>
</tr>
<tr>
<td>Magway</td>
<td>Saddan</td>
<td>18,000</td>
<td>10,500</td>
<td>1.71</td>
<td>24,437</td>
<td>1,625</td>
<td>108</td>
</tr>
<tr>
<td>Magway</td>
<td>Yanpe</td>
<td>35,140</td>
<td>10,845</td>
<td>3.24</td>
<td>28,956</td>
<td>16,414</td>
<td>129</td>
</tr>
<tr>
<td>Magway</td>
<td>Kinpuntaung</td>
<td>10,520</td>
<td>5,190</td>
<td>2.03</td>
<td>13,882</td>
<td>6,651</td>
<td>111</td>
</tr>
<tr>
<td>Mandalay</td>
<td>Thin Pone</td>
<td>13,059</td>
<td>8,728</td>
<td>1.50</td>
<td>13,882</td>
<td>6,651</td>
<td>96</td>
</tr>
<tr>
<td>Mandalay</td>
<td>Meiktila</td>
<td>17,209</td>
<td>26,297</td>
<td>0.65</td>
<td>17,549</td>
<td>10,506</td>
<td>10</td>
</tr>
<tr>
<td>Mandalay</td>
<td>Chaung Gauk</td>
<td>3,250</td>
<td>6,614</td>
<td>0.49</td>
<td>12,909</td>
<td>8,635</td>
<td>64</td>
</tr>
<tr>
<td>Mandalay</td>
<td>Chaung Magyi</td>
<td>33,200</td>
<td>7,255</td>
<td>4.58</td>
<td>30,534</td>
<td>21,909</td>
<td>129</td>
</tr>
<tr>
<td>Mandalay</td>
<td>Thitsone</td>
<td>39,965</td>
<td>12,345</td>
<td>3.24</td>
<td>27,134</td>
<td>13,569</td>
<td>73</td>
</tr>
<tr>
<td>Sagaing</td>
<td>Kyee pinakkk</td>
<td>38,700</td>
<td>5,458</td>
<td>7.09</td>
<td>36,075</td>
<td>22,739</td>
<td>118</td>
</tr>
</tbody>
</table>
2. Infrastructure Design

a. Main system

All subprojects are backed by reservoirs, providing essential storage to enable a timely start to the monsoon and an irrigated summer crop. In many cases, the dams are some way upstream of the irrigation areas. Water is released back into the river and then diverted by a weir at the head of the irrigation system. In some cases, such as Natmauk, there is also a large unregulated flow into the river between the dam and the weir (providing around 25% of the water on average, but this is largely in flood events and thus difficult to use effectively). In others, such as Thin Pone there may be multiple dams and weirs, sometimes with small irrigation areas between the dam and the main command area. There are also numerous small tanks or reservoirs, some of which are integrated into the large systems (providing additional local storage); others, such as Palin which overlaps with Natmauk, are essentially separate systems. This was built later and its command area has been formally separated from Natmauk. The topography makes separation advantageous to enable reliable delivery over the subsidiary command area. Yet others, such as Thitsone, provide water to other tanks outside the formal command area through a link canal.

The schemes usually have reasonably well-structured canal layouts: main canals, distributary canals and minor canals down to watercourse outlets. There are, however, a large number of
direct outlets from the main canals which tend to receive a disproportionate amount of water
resulting in relative shortages further down the system.
The design of infrastructure is generally suited to extensive irrigation of uniform cropping,
usually paddy. Many main canals do not receive their design discharge, even during the
monsoon, and they are never operated at full discharge in the summer season. It is only
possible to command offtakes in this situation if there are cross regulators to raise the water
level at times of low flow, but many cross regulators are in poor condition or are not operable.
This is even a problem for uniform rice cropping, but it is much more serious for diversified
crops: there are too few control structures to deliver water with the flexibility and precision that is
required for a mixed cropping pattern, and there is insufficient control to command all land at
low flows. Many regulators rely on stoplogs rather than gates. Whilst this is acceptable for small
canals, provided stoplogs can be kept available on site, the large canals need gated regulators.
Most distributary canals are quite small (typically 500-2,000 acres), but those towards the tail of
the larger systems may cover substantial areas resulting in relative difficulties in managing
water supplies to those areas. The command areas may have been delineated and partially
developed beyond the limits of reliable water availability, a problem compounded by the
relatively sparse density and poor condition of canals and flatter topography. This results in poor
cropping and generally such tail-end areas only receive water in the monsoon, partly relying on
drainage; the limited water availability would make summer cultivation impractical even if
infrastructure were improved. Access to water in the monsoon is variable across the command
areas but there is not generally a simple pattern of declining availability towards the tail. Many
factors contribute to this variable performance: topography, command levels, drainage reuse,
additional local water sources as well as completeness and condition of infrastructure and
management arrangements. Water is a limiting factor in the summer season, and thus cropping
is usually confined to the head of the system (i.e. the upper part of the upper distributary canals
and direct outlets).
A significant issue is that minor canals and direct outlets from the main canals are often ungated
and this can substantially distort water distribution patterns: there are many such offtakes,
creating a risk of very inequitable distribution of water – governed more by local topography and
outlet configuration than as a result of planned operation. This can cause local conflict (for
example, in Padigon and Thigon villages in Myothit; M6 and DY5 on Natmauk LMC are adjacent
but M6 is just upstream and ungated and thus takes a greater proportion of the flow – farmers
from DY5 sometimes intervene in M6 to offset this risk).
In some cases additional unofficial low level outlets have been provided adjacent to the formal
outlet so that at least part of the command area can be irrigated at times of low flow in the main
canal. This is particularly evident in the head reach of canals, such as at D1 of Natmauk LMC
(Talokpin village), but, being unofficial, these are ungated and thus distort the overall water
distribution pattern. Such low level ungated offtakes may take more than their share of water,
even when the main canal flow is low – possibly even more than is required which can result in
losses direct to drains.
There are very few measurement structures. Approximate measurement is possible from staff
gauges in the canals, but these are rarely recalibrated, and there are almost no dedicated
measurement structures – even at the dam outlets or main canal intakes. Flows are not
monitored at any locations for water management purposes, and only total water diversions are
monitored for the purpose of annual reporting.
Topography and sometimes the use of natural channels as distributary canals affect the ability
to command some land: as a result there are many complexities to water distribution at a local
level. This requires, for example, a large number of small aqueducts to ensure command of
areas which are higher than the adjacent canal – as can be seen across the Distributary canal
at Ngwe Daung where high land is fed from tertiary canals or field ditches from the more distant
main canal rather than the adjacent but much lower distributary. Such arrangements may be
either private/individual or officially sanctioned by the ID. In other cases, drainage water from the upstream canals enters the downstream canal system to augment flows. Despite the formal layout, there may also be supplementary water sources, such as the traditional intake from the Yin River in the middle reach of Natmauk (in Ywar Thit and Tatkon villages) which collects return flows from upper parts of the system. Tributary streams from outside the project area may cross the main canal through culverts and be used directly for irrigation – as seen in Mobyre Right Bank lateral canal 1, sometimes in addition to official outlets. Such complications of layout make systematic management quite difficult and much relies on local knowledge and experience as well as formal calculation of canal water requirements, measurement of flows and adjustment of control structures to deliver the calculated water volumes.

In most places, structures are built from masonry although some of the main structures are built from concrete. Cut-offs are often too shallow, whether due to inadequate geotechnical investigations, deficient design or poor quality construction. This has resulted in the failure of many canal structures – particularly in the secondary canals. Some ad hoc structures are improvised using sandbags or palm trunks to offset the deficiency, but these are grossly insufficient to provide adequate water control.

There are significant problems of flood damage to contour canals during the monsoon. High flows from the streams draining the hills to the east and west of the project area are intercepted, for example by the main and some distributary canals for Natmauk and Yanpe, and there is inadequate provision for cross drainage. This has resulted in the canal banks being severely damaged in several locations. Protection of the main canals is a pre-requisite for any form of irrigation since damage will affect the entire area downstream of any canal breach. Canals constructed through sandy areas, such as Lelu in Myothit township (Natmauk RMC) have weak canal banks which are very vulnerable to collapse as well resulting in high seepage losses. Canals are mostly earthen and unlined, but no data is available either of the magnitude of conveyance losses or of their relative importance compared to other losses. Some lining has cracked and deteriorated and thus probably has little impact on reducing losses. Some losses can be recovered by pumping from groundwater (see section c below). Some lining (brick or concrete) has been provided in some locations, typically close to roads, but this is not necessarily in the most critical places and not all sandy reaches are lined.

Although the reservoirs presumably trap a significant proportion of the sediment load in the rivers, sedimentation is a serious problem in the canal systems, reducing canal capacity and requiring frequent removal. With better configuration of intakes and operation during floods, sediment entry could be reduced. There are no sediment settling basins.

b. Tertiary / on-farm

The formal network extends down to the minor canals which typically command 50 to 500 acres – these either offtake directly from the main canal or from the distributary canals. These can best be regarded as tertiary canals and are the limit of ID responsibility. The next tier of canals, usually described as watercourses, take water directly from the main or distributary canals or from minors and may also be referred to as tertiary canals. Minors from the main canal differ from distributary canals in their smaller size and the fact that their intakes are typically ungated. For the purposes of this report, the areas irrigated from watercourses are referred to as ‘tertiary units’.

Watercourses/tertiary units, whether from a minor canal or directly from a distributary or main canal are all farmer-managed. They supply water to farm ditches through a number of ungated outlets, and watercourse command areas are of the order of 25-75 acres. This irrigation is managed entirely by the farmers through informal cooperation arrangements lead by a myaunggaung (see para 0). There are generally some field ditches but the extent and quality of
the channels is very variable, so much irrigation is field-to-field. In the case of non-rice crops which should not be flooded, small temporary channels may be dug along field boundaries to convey water to downstream plots. Field-to-field irrigation is the normal practice within tertiary units but this is only adequate for monsoon season rice cultivation (where it is preferred as it enables reuse of drainage by adjacent fields, rather than loss back to the river or other users much further downstream). In the dry season, some diversified cropping is possible by constructing temporary farm ditches, but this is not common. There is no comprehensive system of individual watercourses at a village/tertiary canal level, which would enable control of water deliveries to farm plots as would needed for diversified cropping. There are negligible areas of drip irrigation and all plots are irrigated from farm ditches or adjacent fields.

c. Groundwater irrigation

Groundwater is increasingly used, mainly for high value crops such as grapes or vegetables which require water outside the main monsoon season. This occurs on a small scale in all systems, but particularly in Meiktila district where there is a relatively good marketing system and demand for the produce. The deeper groundwater is slightly saline and is a limited resource, but there is also recycling of canal losses which can be recovered by pumping from groundwater, which is mainly used for high-value water-sensitive crops. More extensive groundwater irrigation is from deeper groundwater usually adjacent to the rivers and less likely to be directly related to canal losses. It is common at the tail of Natmauk and the head of Chaung Magyi, where there are large areas of onions and tomatoes grown in the dry season. District level statistics suggest that there is still scope to expand this significantly, with abstraction up to about 50% of recharge generally being regarded as sustainable. Aquifer conditions are variable, with the Irrawaddy and Alluvial aquifer units being generally good and the Pegu unsatisfactory - Table 7 (IWMI, 2012). The sub-project command areas are generally in areas with adequate aquifers suggesting scope for expansion of groundwater irrigation. However, there is some concern over the salinity of the alluvial aquifer, with the Irrawaddy aquifer being more reliable in terms of quality. This would exclude almost all sub-project areas, apart from the upstream part of Thitsone (it may not be coincidence that this is the area where there is intensive use of groundwater for grape cultivation). However, the existing successful development of groundwater on a small scale in other sub-projects does suggest significant unexploited potential.

<table>
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<tr>
<th>Division</th>
<th>District</th>
<th>Recharge</th>
<th>Industry</th>
<th>Agriculture</th>
<th>Domestic</th>
<th>Total</th>
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<td>4.9</td>
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<td>37%</td>
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<td>Meiktila</td>
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<td></td>
<td>Myingyan</td>
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<td>11</td>
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<tr>
<td>Division</td>
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<td>Recharge</td>
<td>Industry</td>
<td>Agriculture</td>
<td>Domestic</td>
<td>Total</td>
<td>Amount used</td>
</tr>
<tr>
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<td>Dry Zone Total</td>
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<td>11.1</td>
<td>91.5</td>
<td>514</td>
<td>614</td>
<td>16%</td>
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Source: IWMI component 1

Canal seepage losses may also be recovered on a small scale through shallow dug wells (less than 20 feet) through manual bucket or pump arrangements, for vegetable production on the outskirts of towns such as Pyawbwe and Loikaw.

Groundwater management is institutionally separate from surface water although arrangements are in flux as Water Resources Utilization Department (WRUD) has recently been merged with ID. However, groundwater in the project area is managed privately and not conjunctively with the canal system.

d. **Drainage**

There is rarely a constructed drainage system as the topography and natural drainage channels largely suffice, particularly since rice is the dominant crop. Drainage may need to be improved in some areas to enable diversification. Inadequate cross-drainage can result in severe damage to canals, and prolonged disruption to irrigation. This was evident in July 2015 where widespread flood damaged many canals but with relatively little damage to standing crops in the sub-project areas.

3. **Infrastructure Construction and Condition**

a. **Physical condition of infrastructure**

Most canals are earthen unlined channels, with masonry structures although the main weirs may be reinforced concrete. Maintenance budgets are low and thus structures have often deteriorated since original construction. There is little appreciation of concepts of asset management, and little evidence of systematic maintenance planning or implementation. However, standards even of original construction were not good, and thus most structures and canals are now in a very poor condition. In some cases the design was not appropriate for modern requirements — for example cross regulators fitted with stoplogs rather than gates, and minor canal offtakes which are uncontrolled. It is generally difficult to repair these structures now, and impossible if gates need to be retrofitted: in most cases structures now need to be rebuilt rather than rehabilitated.

Distributary canals are generally in much worse condition than the main canals, which may superficially appear sound. The majority of DY canal regulators have been bypassed as insufficient cut-offs, and inadequate scour protection, was provided. Farmers usually have to improvise with temporary sandbags or tree trunk checks, and thus suffer from problems in commanding outlets and offtaking channels.

Intense rainfall in the catchment areas causes high flood flows which have damaged many of the main canals. Inadequate cross drainage has been provided and thus critical reaches of the main canals have been damaged or destroyed, causing severe disruption to downstream irrigation.

The deterioration is caused by a combination of inadequate design (underestimating flood flows and cross-drainage capacity), inappropriate design (lack of gated regulators, leading to damage by users), poor quality construction, and weak management and maintenance systems.

Although the systems have mostly been built in recent decades, they are often built on longer-established traditional systems, partly incorporating and partly replacing the old canals. Some of these old channels may still be used either as a supplement or replacement for the newer canals — this can be seen in Natmauk where the old intake from the river in Ywar Thit village is
still used and feeds part of DY5 via a drain and farmers have requested that this should be upgraded. This potentially provides a more reliable access to water than the official system. A similar situation can be seen in the tail of DY7 in Chaung Magyi, but in this case water may be deliberately released from the Chaung Magyi headworks down the river to be diverted further downstream directly into DY7 rather than via the canal system.

b. **Irrigation Efficiency and Productivity**

Irrigation efficiency is a complex issue, as losses are often reused particularly in the Mandalay sub-projects which all drain into the Samon river system where there are numerous formal and informal systems further downstream, including reservoirs. The value in increasing efficiency in this situation is to enable delivery to fields at the time and quantity required – particularly in the tail of distributary canals. There is less impact in terms of water saving in absolute terms since many losses would anyway have been recovered further downstream. There is a risk that improving efficiency will reduce water availability to downstream users, but this is not considered significant as there are reservoirs which can store flood flows which would otherwise flow down the Ayeyarwady river.

The Magway sub-projects drain more directly to the Ayeyarwady river with little scope for reuse of losses downstream, so any savings that can be used within subprojects area and should enable an increase in irrigation intensity.

Low efficiency is caused by a combination of factors – conveyance losses through canal seepage, operational losses due water delivery at times or locations it is not required, and field application losses. All of these can be reduced but not eliminated – maintenance of canals will reduce seepage losses (even unlined canals), better planning and management of deliveries will reduce direct losses to drains and is likely to be the largest potential saving; and better control of field applications (with better coordination within tertiary units) will reduce application losses.

c. **Sedimentation**

Sediment loads in the source rivers are high as a result of the geology, poor watershed conditions and intensity of rainfall. Although it is likely that much of this is deposited in the reservoirs it still has a significant impact on the canal system reducing canal capacities and requiring frequent cleaning (which consumes a large proportion of the maintenance budget).

Sediment in some critical canal reaches reduces overall usable capacity of the canal system and hence contributes to water shortages.

There is considerable weed growth in some canals as well as sedimentation. Scouring of the bed or slumping of the canal banks are also common problems. Inadequate scour protection downstream of control structures contributes to bank instability as well as undermining structures. All systems need a combination of cleaning, sediment removal, canal re-sectioning and possibly lining.

d. **Flood damage**

Flood damage is a particular concern in the main canals - both left and right main canals of Natmauk are frequently damaged near the head, and the right main canal of Yanpe is also very vulnerable. Such damage cannot easily be repaired until after the end of the season and thus there may be a significant impact on water supply in the latter part of the monsoon season with an impact on crop yields. Smaller canals may also be affected by flood damage.
e. Roads and bridges

The main canal roads are generally provided with a *kankar* surfacing and are a useful access route through the sub-project areas. Distributary canal banks are usually smaller, weaker and unsurfaced, making them of less use for access roads. In some places the road is at the toe of the bank, but in this case it generally gets waterlogged and causes damage to tertiary outlets. Few regulators incorporate bridge decks and there are too few bridges. Access in tertiary units is *ad hoc*, with little regard for the ditch layout. There are almost no culverts over farm ditches, which are then damaged by traffic and need frequent reconstruction.

Roads are generally in poor condition, with even main canal inspection roads often being of low quality. Some tarmac roads cross the sub-project areas, linking townships, but most other roads are earthen and more suited to bullock carts and tractors. Access during the monsoon is thus particularly problematic.

B. Irrigation Department Capacity

The ID is the largest department within MOALI, which is responsible for both agricultural support services and management of irrigation and drainage infrastructure. The structure of the Union MOALI is shown in Figure 2 and the regional organization in Figure 3. With a staff of about 70,000, it is one of the largest ministries and covers a wide range of activities, including water resources management, irrigation, mechanization, and settlement and land records as well as agriculture.

![Figure 2: Organization of MOALI](image)

![Figure 3: Regional Organization of MOALI](image)
Some changes are anticipated in 2015 as the WRUD will join the ID. The WRUD was previously a separate department under MOALI responsible for groundwater and pumped irrigation. Merger with the ID will require some reorganization, but not all of the details have been confirmed yet.

The ID is spread across the country, with offices in all regions and states. In 2014, the Department comprised:

(i) a head office, split between Yangon and Naypyitaw, with 12 divisions (including planning, investigation, hydrology, design and procurement divisions, plus the Irrigation Technology Centre (ITC);

(ii) 17 maintenance divisions (including one in each of the project regions, Mandalay, Magway, Sagaing and Kayah);

(iii) nine construction divisions (with Magway and Pyinmana being the most relevant to the project area); and

(iv) four mechanical divisions.

The main responsibilities of the Department are set out in the ID outline document (MOALI, 2015). The responsibilities include:

(i) Design formulation for new irrigation projects based upon hydrological investigations and topographic survey data;

(ii) Planning and implementation of new irrigation projects;

(iii) Operation and Maintenance of existing irrigation and drainage systems, flood protection, embankments and polders;

(iv) Seasonal and temporary measures for summer paddy cultivation;

(v) Technical assistance to village embankments and village irrigation works for rural development;
(vi) Installation of micro-hydro power generation plants along the irrigation canals;
(vii) Providing the on-farm water management development training for farmers water user associations; and
(viii) Conducting training for irrigation staff.

In 2014/15 fiscal year, the ID received 65% of MOALI Union level budget (with about 70% of the budget for capital expenditure) and has a staff of over 12,000 people. By contrast the Department of Agriculture (DOA) which is responsible for agricultural extension, seed production, soil management, plant protection and bio-technology, received about 8% of the MOALI budget and has about 8,000 staff. The Department of Agricultural Research received just 2% (World Bank, 2015).

1. System Design

The ID has a design unit in Yangon which until recently undertook design of all new and rehabilitation projects but more recently some national consulting firms have emerged albeit still with very limited capacity and resources. Only designs for relatively minor repairs are undertaken at regional or district level. Prior to 1988 there was some involvement by international consultants but this was fairly limited and did not have a substantial impact on local design capability. Very few international consultants were involved from 1988 until around 2010. Local designs are prepared on a traditional basis for the main and distributary canals, with little innovation to improve water control, and little done for tertiary units. Until recently farmers were required to cultivate paddy on all irrigated land and there was no need to consider design requirements for other crops. Concepts of irrigation performance benchmarking or of systematic rehabilitation and modernization such as that proposed by FAO in the MASCCOTE manual are not locally recognized.

International isolation since 1988 has interrupted the development of modern irrigation design practice. There is an older generation with knowledge of traditional systems and an emerging younger generation who are capable but inexperienced, but overall there is a lack of rigorous design capacity. Involvement of ID design unit and district level staff in this project will create an opportunity to start to rectify this imbalance in local capacity. International expertise will be needed to support this.

The Planning and Works Branch comprises one Director, three Deputy Directors, four Assistant Directors, 15 Staff Officers and totalling 160 staff to take care of National Regional and sector irrigation development planning; overseeing budget utilization and expenditure of on-going and new irrigation projects; irrigation maintenance works; and rural irrigation and drainage works; and frontier rural development concerned with irrigation and drainage.

The Design Unit is headed by two Directors, five Deputy Directors, six Assistant Directors and 24 Staff Officers with a total of 206 staff, and is responsible for design of new irrigation Projects based upon hydrological investigations and topographic survey data; on-going works. Ongoing major projects include:

(i) Phyu (around 100,000 acres in Taungoo district);
(ii) Myogyi (to make use of Zawgyi dam to improve irrigation in Kyaukse district);
(iii) Myittha (around 20,000 acre, from new dam in (Kalay district, Sagaing); and
(iv) Yazagyo Dam (5,000 new irrigation and total 20,000 acres, in Kalay district).

Additional projects are undertaken with international consultants, including West Bago dams and irrigation rehabilitation, and the Panhlaing sluice rehabilitation.

2. System Construction

Limited capacity in design is mirrored in the capacity to construct or supervise construction of irrigation infrastructure. There are few local contractors with relevant expertise and even fewer
international contractors who are locally established or experienced. Most construction is undertaken by force account rather than by contract, and this relies on the ID managing materials, labor and plant. The low staffing levels at district and township levels mean that construction is slow and of poor quality. There are weak systems for quality control, and particularly for compliance with environmental or health and safety requirements. The construction and mechanical divisions of ID are responsible for implementation of new projects, with maintenance being undertaken by the regional offices. The Work Inspection Branch, comprising one Director, one Deputy Director, two Assistant Directors and six Staff Officers, with total staff of 30, manages inspection works related to irrigation construction and maintenance. This is very low given the scale of works under construction, and is small even in comparison to the numbers in the design branch.

3. System Maintenance

The maintenance divisions are responsible for operation and maintenance of completed Irrigation Schemes. There is a small budget for routine maintenance, but budgets for repairs are generally inadequate. Annual maintenance plans are drawn up but rarely implemented in full. This can result in incomplete works and a failure to complete flood damage repairs in time for the next irrigation season, let alone make interim arrangements for keeping irrigation operational immediately after the flood recedes. As a result, standards of maintenance are below that required to keep systems in good operating condition. This is a consequence of weak planning, inadequate finance and limited capacity for construction. The lack of an asset database and of an understanding of asset management procedures means that maintenance plans are not optimized and non-critical works (such as canal lining) may be prioritized over essential repairs. Maintenance is undertaken by ID down to the outlets from minor/tertiary canals and owing to limitations of budget and other resources has not been undertaken comprehensively - some parts of the systems are in good condition, and others are more severely degraded. Little maintenance is done below the main canals, and thus distributary canals have deteriorated badly. Farmer maintenance of tertiary systems is largely limited to cleaning of farm ditches.

4. Research and Training

The Irrigation Technology Centre (ITC) at Bago and Patheingyi is the main institute responsible for research into improved design, but its main focus is on providing refresher training for ID engineers. This training covers irrigation management, and new concepts such as water user groups (WUGs), as well traditional aspects of design and construction. It provides some advanced training, and organizes workshops and symposia. Mechanical Training Centers at Yangon and Mandalay provide training in operation, maintenance and repairs of heavy machinery.

C. Proposed Intervention to Improve Infrastructure

1. Rationale for the Intervention

The infrastructure modernization and rehabilitation component aims to relieve certain critical water-related issues which affect agricultural production. Provision of infrastructure alone will not solve these problems, and infrastructure needs to be combined with improvements to management arrangements (section II, below) which will then enable planned and predictable
water supplies. This would still not be sufficient to ensure maximum agricultural productivity and there are many activities proposed under the agricultural component (SD2) which are also needed. The synergy of these three components should enable a significant increase in production (through cropping intensity, changing cropping patterns and higher yields). Whilst land consolidation and commercialization of agriculture might maximize productivity, protection of local livelihoods is important and thus the project rationale is based on improved smallholder agriculture with some diversification of cropping. However the improvements will be implemented in a way which will not constrain future commercialization.

Water supply is a major limiting constraint for agriculture. No significant change to the total volume of water can be expected, and large annual fluctuations are inevitable. There is, however, scope to improve the utilization of water and thereby increase the cropped area. There is also scope to diversify crops which would enable cultivation of a larger area with the same volume of water, especially in the summer and winter seasons. Both would require different and better standards of management and a willingness to change; this is addressed in the irrigation management section.

The original concept for this project emphasized the completion of the tertiary and on-farm systems; however, this will be ineffective unless the main system is brought into proper operation. This in turn requires some improvement and modernization before it will fully effective. The majority of the activities and expenditure (over 90% of infrastructure costs) will thus be on the main systems.

The irrigation infrastructure component will aim to ensure quality and resilience of irrigation infrastructure, and specifically that:

(i) infrastructure is designed and built in a manner which is consistent with future management arrangements and evolving agricultural requirements;
(ii) design and construction is of high quality and in accordance with up-to-date standards; and
(iii) infrastructure is robust, with maintenance requirements kept to a realistic level, and within the capacity of the ID at township level, and the farmers (where possible organised into user groups).

The immediate objectives for the infrastructure are to improve the facilities for management of water in the sub-project areas, and specifically to:

(i) Improve water control within irrigation systems, so that it can be made available in a planned manner throughout the command area, particularly at low flows, for which new types of gated regulator may be needed;
(ii) Enable systematic control of flows into outlets, by provision of gated check structures and gates to outlets so that they can be closed at times of low demand or during rotations, or provision of modular intakes which can without adjustment deliver a planned amount of water regardless of the upstream water level;
(iii) Control sediment at intakes, which can otherwise significantly reduce flows in main canals;
(iv) Provide cross drainage to reduce flood damage which can curtail irrigation at critical times, and reduce water losses through canal lining;
(v) Provide flow measurement so performance can be monitored and used as a basis for management, combined with the ability to control flows at these points; and
(vi) Improve access within the irrigated areas to link farms to the main road network and markets.

Physical changes are relatively easy but will only lead to a sustainable improvement in performance if management arrangements are improved at the same time. Maintenance standards and financing mechanisms need to be improved to ensure that the infrastructure does
not simply deteriorate rapidly, and operational procedures will need to be enhanced to ensure that the system is operated to meet agricultural objectives (Section II).

2. Intervention Activities and Outputs

a. Options

Interventions to infrastructure can be undertaken in several different ways: rehabilitation, completion and improvement / modernization. Rehabilitation refers to restoring the system to its original state. This is not always sufficient as there may be a need for completion of partially constructed systems, or improvement or modernization to make them effective. Many systems are dysfunctional not just because of poor maintenance but due to incomplete construction or out of date or inappropriate designs which do not meet current requirements. These problems then become manifest in rapidly declining standards of maintenance, particularly at the tail of the system where they cannot be operated effectively and are damaged by dissatisfied farmers. Simple rehabilitation is not sufficient in such situations. However, there are some situations where rehabilitation to the original design may be sufficient, such as provision of additional scour protection downstream of structures which are otherwise in good condition, or gate repair in places where spindles have been bent or seals broken.

The newer systems are generally built to a relatively better standard, but some consistent problems can be seen and to some extent these systems can be regarded as incomplete: there are insufficient distributary/minor canals at the tails of some systems - notably Natmauk and Mobye; there are insufficient control structures to deliver the required volume of water, which is likely to contribute to the poor utilization of water even in systems such as Mobye where supply is essentially unlimited. In many cases, the original design included inadequate provision for cross drainage systems, resulting in the damage which can be seen at Natmauk and Yanpe - such damage needs to be repaired, but additional cross-drainage structures need to be provided at the same time otherwise the failure will simply recur.

Improvement and modernization is a more extensive program and is usually required since the requirements have changed since the original construction. Some of the issues would not have been problems when the systems were designed as they were aimed at low intensity extensive irrigation, for rice. It was probably anticipated that the tail would just get supplementary irrigation plus drainage flows, and thus a sparse network of canals is usually provided at the tail. Few cross regulators were needed as canals were planned to be operated at full supply level or empty. However, under the current conditions, performance is relatively weak and significant improvements need to be made as well as to rehabilitate what has already been built.

Several options can therefore be envisaged for the infrastructure component:

(i) A: do nothing (continue with limited program of maintenance and ad hoc emergency repairs;
(ii) B: repair/rehabilitate existing infrastructure, without change to design concept;
(iii) C: rehabilitate and modernize main system infrastructure to provide better water control and enable diversified cropping;
(iv) D: as C but with full tertiary unit development, to enable precise control of water deliveries and mechanized agriculture on all individual plots; and
(v) E: as C but with a more limited program of tertiary improvement to improve control on summer irrigable areas, without requiring land acquisition or consolidation.

The 'do nothing' option [Option A] will not meet the objectives of systematic water control needed for crop diversification in the summer season, nor will it enable reliable and equitable distribution of water to all parts of the system in the monsoon season. It will thus not contribute to the agricultural objectives of the project and is not considered further.
A more comprehensive repair program which would restore the infrastructure to its original design condition would be possible [Option B]. This would include the full backlog of deferred maintenance, but it would not address problems in the original design and it would not provide the control needed for equitable water delivery or for diversification. This would resolve some of the major problems of flood damage, but would not enable improved management and hence it would not contribute to agricultural development. It would not be possible to upgrade critical structures as the standards of design and construction would not permit, for example, installation of gates on existing structures. This option is also considered unsustainable, as structures would continue to need informal interventions to operate them, and they would deteriorate rapidly.

Rehabilitation and modernization would be a more comprehensive program [Option C], entailing reconstruction of many structures, with modernization of the system so that it can be reliably and efficiently managed to meet farmer requirements. This would extend down to and include the outlets to farmer-managed tertiary canals/watercourses. This is the minimum needed to meet the overall objectives of the project.

This program could be extended to include full redevelopment of tertiary systems, with land consolidation and levelling [Option D] which would enable the most efficient possible use of water and permit easy access for mechanization. However, it would have large social impacts and require extensive land acquisition and reallocation. The costs and unwillingness to undertake an extensive program of this nature mean that it could not be undertaken within the project timescale over the project area. This is not considered a realistic option for this project. Such redevelopment is being tested under other programs and could be considered at a later stage if those pilots are successful.

The final Option [E] includes full rehabilitation and modernization of the main system, but just limited works at tertiary canal level. These would enable greater control of water at farm level and hence permit some diversified cropping in the summer, as well as better access to the road network, but would not require any land reallocation. These limited tertiary works would only be undertaken in a sample of tertiary units in parts of the system where summer irrigation is possible, initially on a pilot basis - the selection and design would be undertaken in a participatory manner to ensure that it is only done where requested and in a way that meets local requirements. Detailed consultations in each affected tertiary unit would be undertaken at detailed design stage. This is the preferred option and the only one which could fully meet the project objectives.

Within this broad approach there are, however, many further alternatives of detail – for example decisions on the type of structure, the degree of automation, the extent of canal lining and so on. The recommended approach is to make the minimum intervention consistent with the overall objective. Where existing structures are functional and existing canals are stable they will not be changed. However, where the structures do not permit the required level of control (or in most cases any degree of control), they will be upgraded. This often then means reconstruction as the existing structures are generally not in good enough condition to be modified.

The decision on which canal reaches to line is potentially the most controversial as it is expensive and there is generally a high demand. Whilst lining is often requested for saving water – in which case a cost benefit analysis to compare the cost of lining directly with the value of water saved would be possible in theory. However, the impact of lining on overall water saving is hard to calculate, and the benefit decreases rapidly if lining is allowed to deteriorate. In this project it is only proposed to line canals to ensure their stability and thus protect them against collapse – for example in the sandy areas of Natmauk RMC and DY6.

Additional lining could be added incrementally at a later stage should the benefits be considered sufficient to justify the cost.
### b. Automated Control Structures

The incorporation of advanced irrigation technology into the main systems has been considered as part of this study, but is not recommended at this stage. Automated control and remote monitoring systems would be limited by the availability of the expertise and materials required for their maintenance in the future, such that their continued medium or long term use is unlikely. The adoption of systems which offer varying degrees of automation was considered. Such systems could be provided under this sub-project and maintained by the ID at a basic level in the short term (following training delivered as part of the sub-project) to allow, initially, for local control only. There would remain scope for the development of these systems in time into increasingly automated systems providing networked control as the technical capacity of the ID increases. However, any such development would be beyond the scope of this sub-project. The adoption of such systems was ultimately rejected as the benefits provided by remote control are unlikely to outweigh the significant setup, operation and maintenance costs. While remote monitoring of canal flows throughout the system has the potential to improve transparency in water distribution which would lead to more equitable distribution, the installation and recurrent costs of flow monitoring systems, such as SCADA, are unlikely to be economically viable in a system such as Natmauk which is limited by available water resources. In addition, significant changes to the basic administrative management of irrigation systems in the CDZ would be required to support any remote monitoring or remote control system.

Alternative control methods on the main system have also been considered. The system is currently designed to operate under upstream control (where a constant water level at the upstream side of a regulator is the operational target). Adoption of downstream control (where constant water level at the downstream side of a regulator is the operational target) has been considered.

The most significant benefit of downstream control is the short response time of the system. Within upstream controlled systems, a requirement for additional supplies at the tail of the system requires operation of gates at the headworks and progressive adjustment of any gated cross-regulators down the system in order to maintain required water levels. There is a considerable time lag between changes to the headworks and any increase or decrease in flow at the tail of the system, at which time the water may no longer be required, resulting in wastage of water. Within downstream controlled systems, dynamic storage is provided throughout the system – an increase in demand from an offtake is immediately met through use of this dynamic storage, allowing for immediate response.

A second significant benefit of downstream control is the reduction in system management requirements. Downstream control gates are well suited to passive automation (meaning that the gates are acted upon by the water, i.e. self-regulation – no electrical control is required) and as such allow a reduction in system management requirements and operational losses within the system that are inherent in manually operated systems. Given the constant water levels in the main system that downstream control aims to achieve, secondary offtakes can also be sized for a constant discharge, resulting in minimized requirements for operation of these offtakes also.

However, the benefits of downstream control can be outweighed, not only by the higher cost of the gates and costly construction and maintenance requirements, but also in systems suffering from inconsistencies in inflow, sediment inflow and situated in steep terrains – all of which are true for the Natmauk system. Within downstream control systems, any shortages of flow favor the downstream reaches of the system – passively controlled gates shall adjust to ensure target water levels are achieved first in the downstream reaches, at the expense of water supplies in the upstream reaches of the system. Properly managed upstream controlled systems allow for more proportional distribution of reduced inflows throughout the system through the manual operation of gates. Similarly, the provision of storage within the canals coupled with passive
regulation that responds to changes in downstream water level leaves a downstream system very susceptible to water theft, especially in the downstream reaches. A downstream controlled system shall respond to the over extraction of discharges at offtakes in the tail of the system by automatically opening upstream gates to provide additional discharges to the downstream reach at the expense of upstream water supplies.

Upstream controlled systems allow for the operation of canals under normal flow conditions, meaning that systems can be designed with reasonably constant flow velocities that will ensure that the majority of sediment carried in the canal discharge shall remain in suspension throughout the system. Conversely, downstream control relies on ponding water levels at a constant level along each reach – this results in a reduction in flow velocities which shall cause any sediment carried in suspension to be deposited on the canal bed. This sedimentation reduces the storage capacity of the system and reduces the benefit of shortened response time of the system.

Ponded water levels within downstream controlled systems also require the provision of level embankments, and the cost to provide these is higher than to provide embankments that follow the bed gradient that are possible in upstream controlled systems. Such costs are increased within steep terrains (as exist within reaches of the Natmauk system). Within steep terrains, there is a balance to be struck between embankment height, and the provision of a step change in the canal level. Indeed, this is true for both upstream and downstream controlled systems. However, the cost to provide a drop structure (even a gated drop structure) on an upstream controlled system is far lower than the cost to provide downstream control gates. Furthermore, the maximum elevation step change that can be provided by a passively controlled downstream control gate is far lower than can be provided by a simple drop structure, resulting in the need to provide a greater number of downstream controlled gate complexes to achieve the same change in elevation.

Given the inconsistencies in inflow, sediment inflow and steep terrains present in areas of the Natmauk system, as well as the additional costs of a downstream controlled system, continued adoption of upstream control is proposed for this system.

c. Tertiary Pilot Areas

The sub-project would however support pilot advanced field irrigation techniques, which are required to allow flexibility in cropping for the farmers, improving efficiency of field applications of water. Tertiary pilot schemes will introduce improved irrigation methodologies which should lead to improvements in irrigation efficiency through low and high pressure drip irrigation systems to support agricultural diversification (see SD2) and hence increased farmer income. This will be undertaken on pilot demonstration basis, with the new irrigation techniques to be promoted more widely once demonstrations have proven to be successful.

Examples of drip irrigation systems are illustrated below, one taken from Toro, a major international supplier, and the other a much simpler system set up by a non-government organization (NGO) (IDE) in Nepal.

Figure 4:
For non-commercial smallholders, the area required is small and the low cost simple technology is appropriate. Larger-scale farmers may be able to afford the more sophisticated high pressure systems for irrigation of crops on a commercial scale (for example grapes in Yamethin). A study in Cambodia (Prewitt, 2105) analysed the benefits and constraints to drip irrigation as presented below. Price is a constraint, but it is only one of many factors and there is little awareness of the systems particularly of the low cost systems which are available in Myanmar at around MMK 42,000 for a one fourth acre unit. They require a water source to fill the tank, but this can be the canal system when it is flowing or groundwater when it is not.

Figure 5:
d. Locations

There are numerous potential irrigation systems in the project area which could be considered. A long list of sub-projects in two districts in Mandalay region and one district in Magway region has been prepared by the ID, as one in Sagaing region. Sub-projects for inclusion will be selected in accordance with the process and selection criteria presented in section V.A.2.

e. Activities

The component would finance the improvement and rehabilitation of irrigation and drainage infrastructure, including the main conveyance, control and sediment management structures, provision of cross drainage, embankment repairs and strengthening, de-siltation of irrigation and drainage systems, and improvements to rural access. The project would also support improvement of farmer-managed tertiary and farm-level infrastructure to help enable cropping diversity for the farmers and more equitable water distribution between upstream and tail farmers within tertiary units. This will reduce conflict between farmers which is common in traditional field-to-field water distribution. This will, however, not avoid the need for coordinated management and cooperation between farmers, which will be addressed in the irrigation management component. The specific works to be undertaken will be determined based on participatory studies during the survey and design stages.

The detailed planning of each sub-project would be undertaken in consultation with local stakeholders at township and water user level to ensure that the layout is sound and meets local requirements. Recommendations for improved data collection regarding operational performance will be made in advance of designs to improve the basis for designs, and a benchmarking exercise will be undertaken at the outset of the detailed design stage. Topographical surveys and geotechnical investigations will be needed for the detailed designs.

f. Outputs

The output for the infrastructure component will be measured as the area of improved irrigation systems. The core sub-projects cover areas of 24,995 acres at Natmauk and 6,908 acres at
Chaung Magyi. The total area of the current pipeline projects is 75,000 acres, but the funds allocated to the project are likely to be sufficient for 50 to 60,000 acres. It is in any case recommended to proceed cautiously and build up capacity gradually to ensure that rehabilitation and modernization is undertaken to high standards. A gradual approach will provide opportunities to learn from the experience of rehabilitation and optimize the investment.
III. IRRIGATION MANAGEMENT

A. Existing Irrigation Institutional Arrangements

1. Context

Physical changes are relatively easy but changing the infrastructure will not have a sustained or beneficial impact if management arrangements are not improved at the same time. Institutional improvements must be introduced at the same time; maintenance standards and financing mechanisms need to be improved to ensure that the infrastructure does not simply deteriorate rapidly; and operation needs upgrading to ensure that water is distributed fairly and that upstream farmers do not exploit the improved control structures to take an excessive share of the total water supply. Irrigation needs to be managed in the context of overall resources and demands for water (for all purposes) and of agricultural development. Water is critical input for agriculture but there are many other requirements, and thus coordination between ID and DOA is critical. In common with many countries, there is a parallel structure of local government (reporting ultimately to the Ministry of Home Affairs) and technical agencies (under MOALI); both are important for irrigation management.

2. Water Resources Management

There is no institution responsible for the overall management of national water resources in Myanmar, and there are no overarching laws, policies or institutional arrangements governing water resources management in Myanmar, although this is under development. A National Water Resources Committee (NWRC) was formed in 2013 with an Expert Group under the Ministry of Transport. This was approved in 2014 to provide guidance on:

(i) policy development on water resources or subjects that relate to water resources;
(ii) development of legal instruments;
(iii) system of institutions and laws to protect and manage Myanmar’s water resources; and
(iv) Strategies, master plans, development plans, and projects that relate to water resources.

Irrigation is still guided by the Burma Canal Act of 1905. It is not referred to in the Conservation of Water Resources and Rivers Law (2006) which focuses on river navigation and the role of the Ministry of Transport.

There are key departments under at least five ministries concerned with water resources and their utilisation. These include:

(i) Department of Meteorology and Hydrology, Ministry of Transport;
(ii) Irrigation Department, Ministry of Agriculture, Livestock and Irrigation (MOALI);
(iii) Department of Hydroelectric Power, Ministry of Electric Power Hydropower Generation;
(iv) Water Resources Utilization Department (WRUD) MOALI;
(v) Department of Environmental conservation, Ministry of Environmental Conservation and Forestry; and
(vi) General Administration Department (regional, district, and township government)

MOALI has the mandate to develop agriculture and irrigation, and has several departments specifically involved in water resource management:

(i) Irrigation Department: is responsible for the operation and maintenance of irrigation works, construction of new projects, and investigation, design and implementation of proposed projects, as long as surface water is used.
(ii) Water Resources Utilization Department: is responsible for groundwater use (for both irrigation and rural water supply), irrigation by pumping in rivers, and the development of sprinkler and localized irrigation.

(iii) Settlement and Land Records Department: is responsible for collecting agricultural statistics and land administration.

(iv) Agricultural Planning Department: is in charge of planning, monitoring and evaluation of all agricultural projects, including irrigation and drainage projects.

Department of Meteorology and Hydrology is in charge of collecting hydrological and meteorological data, while the ID has its own hydrological network.

Irrigation systems in a river basin are managed separately by the ID at township level, and in the project area there is generally no requirement to consider releases for downstream users or for environmental flows. At present, return flows from irrigation systems are relied on for these purposes.

3. Overall Arrangements for Irrigation Management

The Burma Canal Act of 1905 and the Irrigation Manual of 1948 remain the key legal documents. The Act distinguishes between canal [systems] managed by the government and village canal [systems] managed at village level. 'Canal' systems are managed by a hierarchy of canal officers, down as far as outlets to watercourses which are not managed (maintained) by the government. There are, however, now a greater variety of types of irrigation, with pumped irrigation being more important.

Government schemes account for 53% of diversion schemes and 81% of storage schemes and include all large schemes. There is no minimum size for government management of irrigation, although almost all Government schemes are over 100 acres and most more than 1,000 acres. Groundwater and lift irrigation are mainly private, although possibly originally constructed with Government assistance. Farmers are responsible for all aspects of private schemes, but may receive technical or financial assistance from the ID or the WRUD [FAO]. Farmers are also responsible for management of the terminal units of public schemes, as described in the Act.

The structure of MOALI and ID was set out in Section I.B. The 17 regional maintenance divisions of ID are responsible for operation and maintenance of completed irrigation schemes at regional and district level, although this responsibility is coordinated with regional, district and township administration and other departments at this level. The Deputy Commissioner at District Level and Administrators at township and village tract level, who all report to the General Administration Department (GAD) under the Union Ministry of Home Affairs, also have key roles.

4. Management of Individual Irrigation Schemes

a. Management System

Irrigation is largely managed by the ID at township level, but there is an elaborate structure of committees to enable coordination with DOA and others, and representation by farmers in the process of management. Most systems fall within a single township, but large systems which cross township boundaries will be coordinated by the ID at district level.

The Agricultural Coordinating Committee (ACC) and Frontline Centers (FCs) are important for irrigation planning and provide forums for identification and resolution of problems. The ID, which is represented on the ACC and FCs, is then responsible for delivery of water in accordance with the plans, and for maintenance of the main systems. Farmer representative organizations are responsible for management within tertiary units (i.e. water courses and direct outlets). Figure 7 shows current typical actual local arrangements for irrigation management.
There are some differences between regions, but these are mainly of detail rather than substance.

The ACC (Section c) is a township level committee drawing on all departments related to agriculture and the township administrator. The FCs (Section d) are lower level committees, at sub-township level, with a similar core membership but with the difference that farmers and farmer representatives are invited to attend. These are informal meetings but provide a valuable forum and mechanism for coordination. The findings of the FC are presented to the ACC for approval, and if necessary to the township administration for ratification.

At farmer level, canal leaders (myaunggaungs) are responsible for irrigation management at tertiary level, and in some places ‘leader farmers’ (selesu, representing 10 farm households) have also been identified. In Natmauk, water user associations (WUAs) were established in 2014 at village tract level, comprising the village tract leader as chairman and all selesu and myaunggaungs as members but their role has not been well-defined and this arrangement has not been sustained. The Village Tract leader and myaunggaungs often attend FC meetings and this is seen as a forum which could be used to agree the role for WUAs. WUAs or WUGs may sometimes be reported to exist elsewhere, but they remain largely theoretical. This structure is shown in Figure 8.

In addition, there should be Water Distribution Committees (WDC), but these do not exist in practice in the project area, and their role is currently taken on by the ID and Village Administration. The distinction between the WDC – a government coordinating committee and the WUA – a water user representative body - is not clearly understood or articulated at present as neither exists in practice and the two are sometimes confused.
b. Irrigation Department

At a District level, the ID is headed by an Assistant Directors (also known as executive engineer). The Assistant Director sometimes covers two districts, as in the case of Meiktila and Yamethin if the irrigated area is small. The townships are headed by an Assistant Engineer (also known as Staff Officer). The Assistant Engineer is responsible for supervision of operation and maintenance staff, water distribution, coordination with farmers and resolution of farmer water disputes in all systems in the township. Where a system irrigates part of two townships, coordination is facilitated by the District Office. At District level there is also a Canal Revenue Assistant who is responsible for operation and is staffed by canal inspectors, revenue surveyors and ‘binthas’. Both branches are assisted by ‘binthas’ and laborers who work at field level and are assigned to individual canals or systems. ‘Binthas’ are responsible for individual distributary canals, although in practice they generally have to manage several such canals. They report to the Sub-Assistant...
Engineers for maintenance activities and to the canal inspectors for operation. The organizational structure is illustrated in Figure 8. There are very few operation and maintenance (O&M) staff, suggesting a need for greater involvement by farmers in management. The Irrigation Manual defines the key staff responsible for management, and the principles remain largely applicable although the terminology has changed.

<table>
<thead>
<tr>
<th>1948 Manual</th>
<th>Current Practice</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Divisional officer (Executive Engineer)</td>
<td>Assistant Director</td>
<td>Head of District ID</td>
</tr>
<tr>
<td>Canal Revenue Assistant</td>
<td>Canal Revenue Assistant</td>
<td>District level technical supervision of township revenue staff</td>
</tr>
<tr>
<td>Sub-divisional officer (Assistant Engineer)</td>
<td>Staff Officer</td>
<td>Head of Township ID</td>
</tr>
<tr>
<td>Canal Overseer</td>
<td>Sub-Assistant Engineer</td>
<td>Maintenance at Township level</td>
</tr>
<tr>
<td>Canal Inspector Assistant Canal Inspectors</td>
<td>Assistant Canal Inspectors</td>
<td>Operation / water distribution at system level (within township)</td>
</tr>
<tr>
<td><em>Bin gaung</em> (head <em>binth</em>)</td>
<td><em>Bin gaung</em></td>
<td>Only relevant for large systems</td>
</tr>
<tr>
<td><em>Bintha</em></td>
<td><em>Bintha</em></td>
<td>Gate operation</td>
</tr>
<tr>
<td><em>Myaunggaung</em></td>
<td><em>Myaunggaung</em></td>
<td>Farmer leader for WC management</td>
</tr>
</tbody>
</table>

Figure 8: Organization structure of Township Irrigation Department
c. **Agricultural Coordinating Committee (ACC)**

The ACC operates at township level and covers all irrigation systems in the township (as well as non-irrigated agriculture). It is a key organization, making many important decisions - including which areas to cultivate in each season. In theory farmers are free to grow the crops of their choice, but in practice many decisions are taken by the ACC (on which the farmers are not formally represented) which decides on the areas to be irrigated.

The annual targets for cultivation of each crop and village are prepared by the ACC and presented at a general meeting attended by all relevant departments and the administrators of village tracts. The meeting is chaired by the Township administrator and held in the last week of May or early June, before the beginning of the monsoon season. The decision on cultivation of crops in each village is based on the assumption of normal (average) weather condition and actual storage in the Dam at that time.

The meeting is held sometime before the start of the monsoon and before irrigation needs to be released (July), so the storage at the time of the meeting may be very low and is likely to be significantly less than anticipated at the actual start of the season. The ID needs to make an estimate of what the storage will be at the time irrigation season will start, typically on the basis of the previous year’s inflow.

Some villages may express difficulty in fulfilling the target, in which case a new target is negotiated between the Township committee and villages. Although farmers now have nominal freedom of choice of their crops, it appears that the village/township still needs to meet their overall target.

The ACC monitors the progress of cultivation of planned crops (especially monsoon paddy) on a weekly or bi-weekly basis, and assesses any problems and actions to be taken (drawing on the FC findings). This will include solving disputes between farmers or villages regarding water distribution, and other agricultural issues (such as pest infestation, disease incidents).

The ACC ensures that the WDC or, in its absence, the ID undertakes equitable distribution of irrigation water especially when the weather is dry and water supply is insufficient. It also encourages the activities of *myaunggaungs* and emergent WUAs.

If weather condition is dry, the reservoir storage may not reach the expected level at the start of the monsoon cropping season and even monsoon crop production may not reach the target. Late monsoon rains may however still augment storage in the reservoir in time for the summer season. The ACC will revise targets if necessary at the start of the monsoon season if the rains are delayed, and again before the start of the summer crop (mainly summer paddy).

The composition and responsibility of the ACC in Mandalay region is presented below (Table 9). The arrangements in Magway region are slightly different from Mandalay and the ACC is entirely staffed from various MOALI departments under the leadership of DOA. In this case, the ACC is supervised by an Agricultural Supervising Committee (ASC) chaired by Township Administrator, with comprehensive township level representation from all related departments, with the Staff Officer of DOA as secretary. There are no farmer representatives.
### Table 9: Structure and Role of ACC

<table>
<thead>
<tr>
<th>Position</th>
<th>Role in ACC</th>
<th>Related responsibility in parent Department</th>
</tr>
</thead>
<tbody>
<tr>
<td>Township Administrator (chairman):</td>
<td>Organizes and supervises the activities of members, presides over mass meeting with villages, assigns crop targets to each village, confirms cultivation schedule (especially planned acre for monsoon paddy and starting date for irrigation)</td>
<td></td>
</tr>
<tr>
<td>Planning Officer</td>
<td>Develops crop plans in coordination with DOA and farmers</td>
<td></td>
</tr>
<tr>
<td>Staff Officer of DOA (secretary)</td>
<td>Collects water demand letters from villages and recommends to Staff Officer of ID to release the irrigation water from reservoir, giving dates and area. Proposes alternative plan if the original plan fails, especially for monsoon paddy.</td>
<td></td>
</tr>
<tr>
<td>Staff Officer ID</td>
<td>After receiving the demand of water from DOA on behalf of ACC, calculates the amount of water to be released. Compiles data on irrigated areas and actual grown acre</td>
<td>Assign Binthas (permanent / temporary) to operate at dam, weir, and distributary canals. Arrange management and repair works.</td>
</tr>
<tr>
<td>Staff Officer DALMS</td>
<td>Prepare statistics of planned and actual crop areas, irrigated areas, etc. Solve issues related to land acquisition and crop area assignment to individual farmer.</td>
<td>Prepares the tax tickets of actual irrigated farms as water tax, and other tax tickets for Land Revenue matters.</td>
</tr>
<tr>
<td>Staff Officer AMD</td>
<td>Organizes utilization of farm machines, including contracts with private dealers to meet farmer requirements. Provides manual for operation.</td>
<td>Disburses agricultural Loans to farmers according to the crop area of individual farmers which is verified by ACC (by SO (DOA) and SO (DALMS))</td>
</tr>
<tr>
<td>Manager, Agri. Bank</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In addition to township ACCs, there are district ACCs which comprise the District Administrator as chairman and Assistant Directors of DOA, ID, DALMS, AMD and WRUD as members. The District ACC coordinates between townships who share irrigation water from a Dam. In Mandalay region there is a district level ACC in both Yamethin and Meiktila districts, but the EE for Meiktila District is a member of the Yamethin District ACC since he is responsible for ID activities in both districts. This ACC is reported to meet on every Wednesday.

d. **Frontline Centers**

The Frontline Centers (FC) *(Shaedan nsekan)* are an important interface between the Government and farmers. They implement the decisions of the ACC, provide information on good agricultural practice, and also discuss and resolve issues related to irrigation management at farmer level (shortage of water, water sharing between farmers, malfunction of structures and canals, watercourse repairs). These meetings are held weekly for Natmauk and bi-monthly for Chaung Magyi.
Each FC is headed by one of the Township ACC members (generally DOA), and sub-township level field staffs of ID, DOA, DALMS, AMD are members (Table 10). The FC meetings are attended by all members, village administrators and clerks, myaunggaungs and some active farmers – typically 40-50 farmers attend. The FC meetings at Natmauk are held each Saturday, followed by ACC meetings every Sunday and Township meetings every Monday where the Township Administrator presides and are attended by all Township level Departmental offices. Fewer meetings are planned for Chaung Magyi (bimonthly for FC and monthly for ACC).

Table 10: Irrigation Systems and Front Line Centers in Selected Townships

<table>
<thead>
<tr>
<th>Township</th>
<th>Irrigation Systems</th>
<th>Front line centers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyawbwe</td>
<td>8</td>
<td>4 (1 related to Chaung Magyi)</td>
</tr>
<tr>
<td>Thazi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natmauk</td>
<td>3</td>
<td>4 (1 related to Natmauk system)</td>
</tr>
<tr>
<td>Myothit</td>
<td>5</td>
<td>4 (3 related to Natmauk system)</td>
</tr>
</tbody>
</table>

e. Water Distribution Committee

The water distribution committee (WDC) is nominally a committee comprising government staff at township level and village level (and not at District level). Its responsibility is to supervise the distribution of water in accordance with the agricultural plans prepared by the ACC. In theory, there are township/system level and village/secondary canal WDCs, but neither exists in practice and the role is taken on by ID. Like the ACC it does not have any farmer representation - although it should include the Village Administration Committee head who is a local person. The WDCs should plan water distribution down to outlet level, and the plan would then be implemented by the ID who are responsible for delivery of water to the head of each field channel (i.e. to the jurisdiction of each myaunggaung who then manages water in the field channel, including canal cleaning and sharing water amongst the group. Even without the WDC, there is a plethora of committees. With the requirement for weekly or biweekly meetings the burden of attendance is potentially considerable, and establishment of WDCs would likely duplicate the work of other committees or organizations, and it is not surprising that they do not exist.

f. Local government

The District and Township administration has a major role in local governance and is important for irrigation management, as the township administrator heads the ACC. The district administrator is a GAD officer (under the Ministry of Home Affairs), and heads the District General Administrative Office which supervises the townships, which are critical building blocks of administration in Myanmar (UNDP, 2014). The township administrator, who is always the GAD officer, manages each township and provides direction to village tract administrators (who are paid by GAD but are not GAD staff members). Collection of the four main types of taxes (land, excise, mineral, and irrigation) is generally the responsibility of the Land, Excise and Revenue Division of GAD. The irrigation tax is much the smallest of these, and the responsibility for collection of it was transferred from the GAD to the Irrigation Department in May 2007 (Kyi Pyar Chit Saw, 2014)The responsibility is likely to return to GAD in 2015, but arrangements are still under discussion. The Township administration has the legal authority to resolve disputes if these cannot be resolved by informal arrangements under the guidance of the myaunggaung, or where they exist, the WUGs – neither of whom have the formal authority for law enforcement.
At a village and distributary canal level, the Village Administration Committee head (thugyi - a local person, but and selected by the community but paid an allowance by GAD) is a key person, together with his clerk who is a GAD staff member. The thugyi has considerable authority level. He attends the FLC meetings and thus provides a link between Government and farmers, but his duties cover all aspects of village administration and not just irrigation. The village committee role is defined in Village Tract Administration Law of 2012, and is largely administrative and related to law and order, but it does include a role in developmental activities.

g. Farmer Organizations

The key farmer representatives specifically for irrigation management are known as myaunggaungs (canal leader). Farmers are legally responsible for managing water below an outlet, and maintaining the watercourses: this is led by myaunggaungs who are unpaid but get preferential access to water and exemption from maintenance obligations in return for their role in management. They form the primary means of communication with the ID, which is via the myaunggaungs and binthas (most junior ID staff at field level).

The traditional arrangement of 'myaunggaung' is defined in the 1969 Irrigation Departmental Instructions and is in accordance with the 1905 Burma Canal Act. The myaunggaung is selected by and represents farmers along a field channel. The appointment of myaunggaung is usually informal but he may have a letter from the ID confirming his tasks. The role is often hereditary, passing from father to son (they are all men). The myaunggaung does not have legal authority to enforce penalties to resolve conflicts, and thus such issues are referred to the Thugyi.

There is usually one myaunggaung for each watercourse, although there may be other more junior myaunggaungs for subsidiary channels (field channels/farm ditches). This arrangement is now sometimes referred to as WUGs or Ye Thone Thu Mya Ah Phwe although it is not yet an actual group and is a not yet a well-defined organization. The WUG should be headed by the main myaunggaung and include all farm households as ordinary members. Where there are other myaunggaungs they would together comprise an informal committee. In practice, however, such a group does not differ from the traditional arrangements. There is as yet no legal basis for such groups, and thus they will remain informal until a sound framework is established. They can still play a useful role as informal groups, but will lack powers for development and enforcement of regulations, or for financial management.

There is as yet no concept of higher level WUA to coordinate between all WUGs along a distributary canal, let alone take over management of distributary canals. Such WUA (Ye Thone Thu Mya Ah Thin), have been proposed in the past for this purpose but these are rarely in existence. They have been set up in Myothit on a village tract basis; these are informal groupings of thugyi, selesu and myaunggaungs but with as yet no formal structure, clarity of roles or even definition of membership.

However, although water delivery in the distributary canal down to the outlet is managed entirely by the ID, in practice there is usually more involvement by myaunggaungs and farmers at a secondary level. However, any such involvement is essentially ad hoc.

Secondary canal cleaning and maintenance is undertaken by ID laborers, but there is a funding and staff shortage and hence this task is neglected. As a result, the distributary canal condition is generally poor, but the ID consider that it would be beyond the capacity of farmers to take on any additional responsibilities, given that they find it difficult even to keep watercourses clear.
B. Irrigation Management Procedures and Performance

1. Dams and Reservoirs

Irrigation water is released from dams for cultivation to supplement rainfall in the monsoon, in accordance with the annual plan drawn up by the ACC before the start of the season. The responsible person at the dam converts this crop water requirement into flows (expressed as cubic feet/sec) which are then released. In some cases, the water is released back to the natural stream, from where the water is diverted to the main canals some way further downstream. However, the distance between the dam and weir and additional uncontrolled inflows between the dam and the weir make the management complex. There are no formal operating rules for most small dams, and hence their operation is not optimized - particularly in relation to reducing outflows at times of rainfall. There appears to be significant scope for improving management of reservoirs, although it is likely that the dam operators working on the basis of their experience are able to make better adjustments already than they are formally required to do. There is some data of dam operation recorded, but flow measurements are generally made using staff gauges in canals which have not been recalibrated since original construction, and there is little use of current metering or float gauging (although the irrigation manual gives detailed guidance on the procedures for float gauging). Even this limited data does not appear to be used rigorously for active management. It is compiled and sent to regional offices for record keeping and forwarding to Yangon for annual statistical purposes. Although supplementary irrigation during the monsoon season enables a larger area to be irrigated (as a large part of the crop demand is met from rainfall), summer cultivation is totally dependent on irrigation and thus there is pressure from the farmers and township government to release as much water as possible for summer cropping. This means that the reservoirs are generally empty at the end of the summer season, and the monsoon crop area depends on the timing of the start of the monsoon. The area cannot be predicted accurately in advance, and if the monsoon is delayed farmers often prefer to grow rainfed crops rather than a late paddy crop. The reservoirs are operated largely independently, both of each other and of downstream users. The sub-projects identified by the ID for this project are all in the head reaches of their sub-catchments, with the Yin River in Magway District (five sub-projects) flowing 25 miles west from the to the Ayeyarwady, and the Samon River in Mandalay Region (five sub-projects) flowing around 100 miles north from the to the Ayeyarwady. Irrigation losses largely return to the same rivers and there is no formal practice or requirement to retain a certain proportion in the river for environmental flows or downstream users. Although the entire river flow may be diverted at the weir, users are able to divert additional flows from the river just a short distance further downstream. In some cases this may be through old traditional canals which predate the formal irrigation system, but in Mandalay there are several formal ID managed systems on the Samon river.

2. Main System

Irrigation plans are drawn up by the Township ACC in accordance with current practice for the entire command area and on the basis of standard duties. These plans generally allow only for paddy, cotton and sesame as other crops are not officially irrigated. Cotton and sesame are generally only partially irrigated to protect the crop rather than meet full water requirements. An annual plan is drawn up in April/May for the monsoon and may be updated in December for the summer season, on the basis of reservoir storage at the date of the meeting.
The ACC calculates the seasonal water requirement and sends this to the Irrigation Department to convert to a schedule of releases from the reservoir. The timing of the decision is partly to suit the financial calendar, since the subsequent summer irrigable area cannot be confirmed until the storage available at the end of the monsoon is known, when there is often a supplementary meeting.

Required flows in each distributary canal are calculated in the same way according to the planned crop area. If there is sufficient water, it is released in full as per demand, with simultaneous supply to all laterals / distributaries and minors. In case of insufficient release (due to insufficient storage at the dam, or due to losses in the canal), a rotation system is practiced. However, it should be noted that many of the offtaking canals are uncontrolled making rigorous application of any rotation difficult, with some canals taking consistently more than their share and others less.

While the main canals are generally in functional condition, the distributaries and lower level canals have more problems due to limited maintenance. This results in uneven water distribution, ineffective water use and water shortages at the tail-end of the canals during the dry season but sometimes inundation during the rainy season due to lack of drainage.

3. Farmer systems

Whilst operation of the dam and main system is the responsibility of ID, operation below the outlet from the minor/distributary is the responsibility of the farmers. However, there is often no formal means of controlling flows into the watercourse as structures are rarely gated and have to be closed with sandbags or mud whenever there is a rotation schedule (due to water shortage). Although this is the responsibility of the staff of ID, but operation in practice is by the farmers using mud and sand bags as there are almost no gates on these structures.

Below the outlet of the watercourses, where the management of water is entirely the responsibility of the farmers, there are no structures and all control is achieved by mud, bamboo, sand bags and so on.

Farmers should maintain and operate the terminal units including watercourses and field ditches under the leadership of myaunggaungs who also convey water requests and water management issues to the ID field staff (binthas). Options for strengthening this arrangement including the formation of informal WUGs and WUAs are discussed in Section D.4. Maintenance is particularly weak, and the condition of watercourses is generally poor with considerable sedimentation and weed growth.

The farmers irrigate their individual plots/farms via their own field ditches which are taken from the respective watercourse - there may be three or four or more field ditches. Generally these ditches will not get irrigation water simultaneously, in which case the farmers negotiate with each other to develop an operational rotation schedule. The field ditches do not extend to all fields, and some farmers get irrigation water via flooding from plot to plot.

In parallel with poor access to water, farmers may lack skills or access to inputs such as fertilizers, pesticides, improved seeds or machinery. There is scope for increasing agricultural productivity while reducing vulnerability to weather variability through better farming technologies, use of higher quality inputs, diversification of crops, adoption of more sustainable land and water management techniques, and reduce labor costs through farm mechanization. All this requires improved farm advisory services. Provision of such services should be coordinated with support to WUGs (see section D.4.d.ii).

Agriculture in the CDZ is a low yield, low margin enterprise so many farmers are not willing to invest much time in optimizing it. They rely heavily on off-farm activities - which in turn limit their willingness to get involved in management even though that might ultimately enable them to diversify and grow better yielding and more profitable crops, and hence be less dependent on...
off-farm activities. This is a vicious cycle which cannot easily be broken, but one which an integrated package of WUG and agricultural develop can hope to tackle gradually.

Farmers are supposed to pay irrigation service fees (tax) to cover scheme operation and maintenance costs, but the fee levels were set many years ago and would be insufficient even if collected in full – and would barely cover the costs of collection. In practice they have hardly been collected since 2007 (dropping from 70% collection to less than 1% in 2013), although new arrangements have recently been initiated.

Farmers are also required to contribute labor for cleaning the watercourse. This is not formally quantified but, given prevailing labor rates and amount of work required, this is a greater contribution than the official fees.

Farmers are evidently willing to pay more for a fully predictable and reliable water supply; the cost of pumping groundwater for an onion crop is of the order of MMK 50,000 per acre.

4. Performance Monitoring

Performance data is compiled on an annual basis largely for retrospective reporting purposes rather than active management. Data for two core sub-projects is presented in Table 10 below. There is a correlation between total paddy irrigated area and rainfall and Natmauk, but little consistent relationship at Chaung Magyi. Crop areas are essentially determined by the storage at the start of the season.

Rainfall in the catchment areas may be significantly different from in the command areas, but records are not used to make adjustments to dam releases or to individual canal flows. There are not sufficient data collected to enable a more systematic approach.

<p>| Table 11: Crops and water utilization records at Natmauk and Chaung Magyi |
|---|---|---|---|---|---|---|---|---|
| Year | Area (acres) | Water supply (ac-ft) | Rainfall (inches) | Area (acres) | Water supply (ac-ft) | Rainfall (inches) |</p>
<table>
<thead>
<tr>
<th></th>
<th>Paddy</th>
<th>Sesame</th>
<th>Monsoon</th>
<th>Summer</th>
<th>Paddy</th>
<th>Cotton</th>
<th>Monsoon</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>20,090</td>
<td>5,313</td>
<td>0</td>
<td>122,864</td>
<td>26.16</td>
<td>6,583</td>
<td>72</td>
<td>4,766</td>
</tr>
<tr>
<td>2005</td>
<td>22,709</td>
<td>3,880</td>
<td>0</td>
<td>121,876</td>
<td>22.89</td>
<td>6,972</td>
<td>626</td>
<td>4,529</td>
</tr>
<tr>
<td>2006</td>
<td>25,610</td>
<td>6,916</td>
<td>1,471</td>
<td>156,710</td>
<td>27.65</td>
<td>7,281</td>
<td>1,000</td>
<td>3,141</td>
</tr>
<tr>
<td>2008</td>
<td>25,195</td>
<td>7,599</td>
<td>125</td>
<td>161,822</td>
<td>25.10</td>
<td>7,138</td>
<td>1,143</td>
<td>3,390</td>
</tr>
<tr>
<td>2009</td>
<td>25,280</td>
<td>300</td>
<td>17</td>
<td>103,554</td>
<td>16.14</td>
<td>4,987</td>
<td>490</td>
<td>2,966</td>
</tr>
<tr>
<td>2010</td>
<td>25,380</td>
<td>8,414</td>
<td>125</td>
<td>169,082</td>
<td>35.01</td>
<td>110,605</td>
<td>720</td>
<td>7,288</td>
</tr>
<tr>
<td>2011</td>
<td>25,380</td>
<td>7,511</td>
<td>192</td>
<td>161,992</td>
<td>47.10</td>
<td>5,721</td>
<td>1,000</td>
<td>728</td>
</tr>
<tr>
<td>2013</td>
<td>19,478</td>
<td>7,575</td>
<td>254</td>
<td>139,020</td>
<td>35.69</td>
<td>4,474</td>
<td>195</td>
<td>2,673</td>
</tr>
<tr>
<td>max</td>
<td>25,380</td>
<td>8,414</td>
<td>1,471</td>
<td>169,082</td>
<td>47.10</td>
<td>7,301</td>
<td>1,143</td>
<td>4,529</td>
</tr>
<tr>
<td>Min</td>
<td>19,478</td>
<td>300</td>
<td>-</td>
<td>101,258</td>
<td>16.14</td>
<td>4,474</td>
<td>195</td>
<td>728</td>
</tr>
<tr>
<td>Average</td>
<td>23,858</td>
<td>6,159</td>
<td>239</td>
<td>140,255</td>
<td>28.60</td>
<td>6,151</td>
<td>756</td>
<td>2,893</td>
</tr>
</tbody>
</table>

5. Irrigation Finance

Responsibilities for revenue assessment and collection have changed in recent years. Before 2007, the ID assessed water use, SLRD prepared the water tickets and GAD collected the fees, but then the arrangements were changed so that ID became responsible for collecting the fee and depositing this in the bank – but without the right to use the funds collected. This gave no incentive to use water efficiently or care about water losses, or even to collect the fees. As a
result there has been very low collection since then. The arrangements are currently being changed being to giving the responsibility back to GAD, but the fees collected will still be sent to Union Government and there will still be no direct relationship with cost recovery for O&M. Water fees are not set out in any legislation and thus their collection cannot be enforced: this is reported to be the main reason for the sharp drop in collection rates over the last decade.

<table>
<thead>
<tr>
<th>Table 12: Irrigation Tax (National Collection Rate)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Year</strong></td>
</tr>
<tr>
<td>2006-07</td>
</tr>
<tr>
<td>2007-08</td>
</tr>
<tr>
<td>2008-09</td>
</tr>
<tr>
<td>2009-10</td>
</tr>
<tr>
<td>2010-11</td>
</tr>
<tr>
<td>2011-12</td>
</tr>
<tr>
<td>2012-13</td>
</tr>
</tbody>
</table>

The water tariff is very low (MMK 1,950/acre paddy) for the gravity irrigation systems and does not recover the cost of maintenance work (across the country, it would cover just 2.5% of total recurrent expenditure in 2013/14) which is therefore almost entirely paid for by the government and is under-resourced (Naing, 2005).

The water tariff for the WRUD river pumping systems is higher than for gravity systems, and allowing for the cost of pumping paid for directly by farmers, the water price for pumped irrigation is 150 to 300 times greater than for gravity irrigation. Farmer willingness to pay for a reliable water supply is evidenced by the large numbers of privately managed tubewells and pumps from drains within the command area.

Actual total expenditure on ordinary maintenance and special repairs is around MMK 15 million (MMK 2,000/acre) over the past 10 years at Chaung Magyi, although it has risen slightly in recent years and has been supplemented by much larger capital grants in 2013/2014 and 2014/15. This is comparable in order of magnitude to the fees that should be payable in accordance with current regulations (MMK 1,950/areas) but much less than the actual requirement.

The vast majority of expenditure is on staff costs (around MMK 6,000/acre in addition to OM and SR costs). Most of the routine maintenance requirements are for labor, but there are insufficient laborers employed by the ID to carry this out in full, and thus a greater involvement by farmers is required to ensure that secondary and tertiary canals are kept clear.

Irrigation fees are unlikely to be raised in the short term, and the economic value of good maintenance far outweighs the costs incurred, and thus it is recommended that O&M costs should continue largely to be borne by the government. However, collection of fees should be restarted to give a signal to farmers that water has a cost and should be managed efficiently.

O&M of tertiary units is the responsibility of the farmers, but conditionality should be introduced so that water is only released to tertiary canals which are in good condition. A gradual increase in farmer involvement in cleaning secondary canals, which largely requires unskilled labor and is within the capacity of the farmers, will be facilitated through the project.

<table>
<thead>
<tr>
<th>Table 13: O&amp;M costs and Fees for Chaung Magyi (MMK ‘000)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Year</strong></td>
</tr>
<tr>
<td>2003-04</td>
</tr>
<tr>
<td>2004-05</td>
</tr>
<tr>
<td>2005-06</td>
</tr>
<tr>
<td>2006-07</td>
</tr>
<tr>
<td>2007-08</td>
</tr>
<tr>
<td>2008-09</td>
</tr>
</tbody>
</table>


6. Impact of Irrigation Management Performance

There is clearly a shortage of water which limits the extent of irrigation, and poor performance in sharing this limited water is exacerbated by a cycle of incomplete or poor quality construction, under-funded and delayed maintenance, and weak operation. Our observations confirm the findings of others (IWMI, 2012) that "unequal water distribution causes crop failures and conflicts".

Shortage of water is a major constraint even during the monsoon, when farmers often report inadequate water. There should be sufficient water at that time, given the prevailing paddy cropping pattern. There are also significant gaps in standards of maintenance which limit the ability to control water, and there may be flood damage which can destroy sections of main canal and hence completely disrupt irrigation.

However, irrigation does continue to be operated and where water is made available it does not appear to be the critical determinant of crop yields. However, there are large areas which do not receive water at all in the summer and some even in the monsoon, and there is evidence that poor farmers are less able to access water that richer farmers.

These observations confirm the need for improved irrigation management. There is a management system which can be improved as basis for improving performance. Options are, however, constrained in the short term by the limited staff and funds available, a weak system of fee collection, and low levels of farmer involvement.

The performance of the irrigation system has significant impacts on social and agricultural outcomes. Access to water in the dry season is largely confined to small areas at the head of the system, but even in the monsoon there are significant variations in access to water and hence on agricultural outcomes. A socio-economic survey conducted from 5-17 June provided information on the performance of the system in relation to socio-economic outcomes.

There is no simple relationship between head and tail of the system and access to water. The main canal is generally in relatively good condition and thus supplies to the tail can be readily assured. Distributary canals are in much worse condition and thus access to water at the tail of distributary canals may differ substantially from the head. Differences in command level and the length of distributary canals are important determinants.

<table>
<thead>
<tr>
<th>Location</th>
<th>Chaung Magyi</th>
<th>Natmauk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Farm Area</td>
<td>Canal Irrigable land</td>
</tr>
<tr>
<td>Head</td>
<td>2.5</td>
<td>1.6</td>
</tr>
<tr>
<td>Mid</td>
<td>3.0</td>
<td>2.6</td>
</tr>
<tr>
<td>Tail</td>
<td>2.6</td>
<td>2.3</td>
</tr>
<tr>
<td>Overall</td>
<td>2.7</td>
<td>2.3</td>
</tr>
</tbody>
</table>

181. Although there are differences in land holding size according to location there is no simple pattern (Table 14). Farm sizes and irrigated proportion decline from head to tail at Natmauk (Table 14),
but the largest areas are in the middle at Chaung Magyi and smallest at the head (Table 16). There is a more striking relationship between wealth and holding size (see and Table 16). Although agriculture is a relatively small part of total income, the rich generally have better land and a greater proportion of it irrigable from canals.

Table 15: Natmauk – average crop areas per household (acres)

<table>
<thead>
<tr>
<th>Location</th>
<th>Irrigation (SW)</th>
<th>Partially irrigated (SW)</th>
<th>GW irrigated</th>
<th>Rainfed</th>
<th>Crop area</th>
<th>Crop intensity (annual)</th>
<th>SW irrigation intensity (monsoon)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Monsoon Paddy</td>
<td>Summer Paddy</td>
<td>Cotton</td>
<td>Sesame</td>
<td>Onion</td>
<td>Pulses</td>
<td></td>
</tr>
<tr>
<td>Head (RB)</td>
<td>2.14</td>
<td>0.04</td>
<td>0.14</td>
<td>1.45</td>
<td>0.00</td>
<td>0.93</td>
<td>4.68</td>
</tr>
<tr>
<td>Mid (LB)</td>
<td>2.02</td>
<td>0.03</td>
<td>0.00</td>
<td>0.83</td>
<td>0.00</td>
<td>0.08</td>
<td>2.96</td>
</tr>
<tr>
<td>Tail (RB)</td>
<td>1.64</td>
<td>0.00</td>
<td>0.05</td>
<td>1.55</td>
<td>1.18</td>
<td>0.47</td>
<td>4.89</td>
</tr>
<tr>
<td>Overall</td>
<td>1.96</td>
<td>0.04</td>
<td>0.10</td>
<td>1.53</td>
<td>0.51</td>
<td>0.72</td>
<td>4.19</td>
</tr>
<tr>
<td>Female Headed*</td>
<td>1.76</td>
<td>0.00</td>
<td>0.11</td>
<td>1.33</td>
<td>0.27</td>
<td>0.73</td>
<td>3.74</td>
</tr>
<tr>
<td>Male headed*</td>
<td>2.12</td>
<td>0.05</td>
<td>0.07</td>
<td>1.49</td>
<td>0.49</td>
<td>0.77</td>
<td>4.41</td>
</tr>
</tbody>
</table>

The middle reach of Natmauk appears to be most disadvantaged, as the tail has good access to groundwater. However, those in the tail without access to groundwater face problems with water supply for the monsoon crop and are thus doubly disadvantaged with smaller areas and lower yields. Access to groundwater is probably confined to a relatively small area in the tail mostly close to the river, and farmers on the right bank have very poor access to irrigation in either season.

Farm sizes in the middle reach are smaller, but these have the highest intensity of surface irrigation and the highest yields in the monsoon. Farmers in the head are able to have the highest annual cropping intensity with a larger dry season area which is probably preferred to maximizing the monsoon crop. Although Natmauk is generally a less prosperous area, farm sizes are slightly higher than at Chaung Magyi, particularly at the head, but a smaller proportion is irrigated.

Female-headed households appear to be disadvantaged. Overall, they offset the lower paddy area with more horticulture, but most female-headed households are in the head of the system. Male headed households in this same part of the system are able to grow more vegetables with groundwater as well as irrigate a greater proportion of their land from the canal system.

Table 16: Chaung Magyi – average crop areas per household (acres)

<table>
<thead>
<tr>
<th>Location</th>
<th>Irrigation (SW)</th>
<th>Partially irrigated (SW)</th>
<th>GW irrigated</th>
<th>Rainfed</th>
<th>Crop area</th>
<th>Crop intensity (annual)</th>
<th>SW irrigation intensity (monsoon)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Monsoon Paddy</td>
<td>Summer Paddy</td>
<td>Cotton</td>
<td>Sesame</td>
<td>Onion / Tomato</td>
<td>Pulses</td>
<td></td>
</tr>
<tr>
<td>Head (RB)</td>
<td>1.41</td>
<td>0.06</td>
<td>0.62</td>
<td>0.75</td>
<td>0.52</td>
<td>0.14</td>
<td>3.49</td>
</tr>
<tr>
<td>Mid (LB)</td>
<td>2.43</td>
<td>0.00</td>
<td>1.19</td>
<td>0.83</td>
<td>0.11</td>
<td>0.06</td>
<td>4.62</td>
</tr>
<tr>
<td>Tail (RB)</td>
<td>2.41</td>
<td>0.00</td>
<td>0.16</td>
<td>0.59</td>
<td>0.03</td>
<td>0.05</td>
<td>3.25</td>
</tr>
<tr>
<td>Overall</td>
<td>2.15</td>
<td>0.02</td>
<td>0.73</td>
<td>0.76</td>
<td>0.26</td>
<td>0.09</td>
<td>3.99</td>
</tr>
<tr>
<td>Female Headed</td>
<td>1.50</td>
<td>0.00</td>
<td>0.75</td>
<td>0.67</td>
<td>0.42</td>
<td>0.08</td>
<td>3.42</td>
</tr>
</tbody>
</table>
Paddy is the dominant crop in the monsoon in Natmauk, but even then there is insufficient irrigation, with shortages in the head (possibly due to command level problems) and the tail. The middle reaches are able to irrigate the whole area, but still suffer from a water shortage and has the lowest overall cropping intensity as there is much less rainfed agriculture or groundwater irrigation. The tail areas are short of surface water, but some farmers are able to offset this by growing vegetables using groundwater. Sesame is an important crop throughout the system (about 65% of the paddy area), but especially in the tail. It can be grown on residual moisture and rainfall, but is sometimes supplemented by light irrigation.

The pattern is similar in Chaung Magyi although there is a higher monsoon irrigation intensity at the tail, where there is a supplementary intake for part of the system. Paddy yields are very variable but largely unrelated to position in the system and likely affected by a range of water and non-water related factors. There is less sesame grown at Chaung Magyi but more cotton which is higher value and well-suited to the local agro-ecological conditions.

Table 17), although poor farmers achieve a higher surface water irrigation intensity. There is a much greater range in paddy areas at Chaung Magyi (Table 16) with the very poor farmers growing much lower areas of paddy and an even lower total crop area. Their access to surface water is also much lower.

In both systems, the indication is the poor farmers have poor access to irrigation water, fewer alternatives and have less productive agriculture. Improving access to canal irrigation should help relieve this situation, and making surface irrigation available for high value crops in the dry season should be particularly valuable.

High value crops are mostly grown in winter/summer and irrigated from groundwater – tomatoes and onions are the preferred crops. Other summer crops, mainly sesame and cotton, are mostly grown on residual moisture with a small amount of supplementary surface irrigation. Groundwater use is probably constrained by availability of a suitable aquifer, but also by the wealth of the farmer. At Natmauk, onion cultivation and hence tubewells are concentrated at a location adjacent to the river in the tail of the system. At Chaung Magyi most groundwater irrigation is at the head but again close to the river channel.

### Table 17: Poverty and Paddy Irrigation - Natmauk

<table>
<thead>
<tr>
<th>HH Income (MMK ‘000/yr)</th>
<th>no</th>
<th>Paddy yield</th>
<th>Paddy area</th>
<th>Crop area</th>
<th>SW irrigation intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>very poor (&lt;300)</td>
<td>10</td>
<td>975</td>
<td>1.6</td>
<td>2.9</td>
<td>95%</td>
</tr>
<tr>
<td>poor (&lt;1,000)</td>
<td>54</td>
<td>856</td>
<td>1.9</td>
<td>3.3</td>
<td>94%</td>
</tr>
<tr>
<td>medium (&gt;1,000)</td>
<td>77</td>
<td>1,056</td>
<td>2.3</td>
<td>4.7</td>
<td>92%</td>
</tr>
<tr>
<td>rich &gt;2,000</td>
<td>23</td>
<td>1,030</td>
<td>2.1</td>
<td>4.8</td>
<td>80%</td>
</tr>
</tbody>
</table>

### Table 18: Poverty and Paddy Irrigation – Chaung Magyi
The relationship between water and poverty indication is supported by data on surface and groundwater irrigation (Table 17 and Table 18). Although poor farmers at Natmauk have surface supplies to a greater proportion of their land than rich farmers their absolute land areas are lower, and their access to groundwater is much lower. The reverse is true at Chaung Magyi where access to canal irrigation is closely related to wealth, but groundwater irrigation is more uniform. Crop yields are generally lower at Natmauk where there is a greater reliance on rainfed crops by all groups. Improvements in surface water supply can be expected to have a greater impact at Natmauk, but equally it will be more difficult to achieve.

Table 19: Poverty and Irrigation - Natmauk

<table>
<thead>
<tr>
<th>HH Income (MMK '000/yr)</th>
<th>Farm area</th>
<th>Canal Irrigated Area</th>
<th>GW Irrigated Area</th>
<th>Rainfed area</th>
</tr>
</thead>
<tbody>
<tr>
<td>very poor (&lt;300)</td>
<td>1.9</td>
<td>1.7</td>
<td>1.0</td>
<td>0.9</td>
</tr>
<tr>
<td>poor (&lt;1,000)</td>
<td>2.5</td>
<td>2.0</td>
<td>1.5</td>
<td>1.6</td>
</tr>
<tr>
<td>medium (&gt;1,000)</td>
<td>3.6</td>
<td>2.5</td>
<td>2.1</td>
<td>1.7</td>
</tr>
<tr>
<td>rich &gt;2,000</td>
<td>3.7</td>
<td>2.6</td>
<td>2.8</td>
<td>1.7</td>
</tr>
</tbody>
</table>

Table 20: Poverty and Irrigation – Chaung Magyi

<table>
<thead>
<tr>
<th>HH Income (MMK '000/yr)</th>
<th>Farm area</th>
<th>Canal Irrigated Area</th>
<th>GW Irrigated Area</th>
<th>Rainfed area</th>
</tr>
</thead>
<tbody>
<tr>
<td>very poor (&lt;300)</td>
<td>1.5</td>
<td>1.4</td>
<td>1.5</td>
<td>0.5</td>
</tr>
<tr>
<td>poor (&lt;1,000)</td>
<td>1.9</td>
<td>1.8</td>
<td>1.4</td>
<td>0.9</td>
</tr>
<tr>
<td>medium (&gt;1,000)</td>
<td>2.9</td>
<td>2.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>rich &gt;2,000</td>
<td>3.0</td>
<td>2.6</td>
<td>1.6</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Given these findings it is not surprising to note the general dissatisfaction with performance of the systems. Two thirds of all farmers get too little, and the situation deteriorates markedly down the system. About one quarter report water arriving too late, possibly a consequence of problems in delivering design discharges down silted main canals and an over-reliance on reuse of drainage water. 30-50% of respondents reported problems of low water levels, a consequence of insufficient control structures and inadequate operational arrangements. There is little difference between the two systems in these regards, although Natmauk is slightly worse (Table 19 and Table 20) Problems get worse both down the main system and down distributary canals.
The shortages occur in all months, and are worst in Chaung Magyi (Table 23) in July and August – probably because of the exceptional conditions in 2014 and 2015. Very bad water supply conditions are reported throughout the summer season in Natmauk (Table 24). In most locations and months, the situation deteriorates towards the tail.

Most respondents indicated that the water management system at farm level at Natmauk is very simple, relying largely on small informal groups (Table 23 to Table 26). A higher proportion recognizes the existence of WUGs at Natmauk but few people regard themselves as members. A substantial number state that there are no WUGs, but that they are members – possibly
indicating confusion over the terminology or simply that they recognize a degree of local cooperative management.

Table 25: User Groups at Natmauk

<table>
<thead>
<tr>
<th>Arrangements for water management</th>
<th>head</th>
<th>mid</th>
<th>tail</th>
</tr>
</thead>
<tbody>
<tr>
<td>individual</td>
<td>14</td>
<td>7</td>
<td>35</td>
</tr>
<tr>
<td>informal group</td>
<td>11</td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td>WUG</td>
<td>25</td>
<td>38</td>
<td>15</td>
</tr>
</tbody>
</table>

Size of group: 14 23 8

Table 26: User Groups at Chaung Magyi

<table>
<thead>
<tr>
<th>Arrangements for water management</th>
<th>head</th>
<th>mid</th>
<th>tail</th>
</tr>
</thead>
<tbody>
<tr>
<td>individual</td>
<td>34</td>
<td>24</td>
<td>20</td>
</tr>
<tr>
<td>informal group</td>
<td>9</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>WUG</td>
<td>25</td>
<td>19</td>
<td>23</td>
</tr>
</tbody>
</table>

Size of group: 14 10 12

As perceived ‘membership’ is linked to household heads, a large majority of members are male. However there is also a lack of clarity as to whether membership means a ‘committee’ member (essentially myaunggaungs, who are all male) or general membership which would include all households.

There is a greater reliance on individual management at the tail (where tubewells are common) and greatest evidence of coordination between farmers in the middle. Although some farmers report the existence of WUGs this is not consistent – even amongst farmers who are ostensibly members of the same group. Some farmers indicated that the WUG was registered, but as there is no legal basis for registration this probably indicates a slightly better structured and established group (possibly with an ID-recognized myaunggaung).

Table 27: User Groups at Natmauk

<table>
<thead>
<tr>
<th>Location</th>
<th>Response</th>
<th>Existence of Groups for Water Management</th>
<th>Average Number of members</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>WUA?</td>
<td>Registered?</td>
</tr>
<tr>
<td>Overall</td>
<td>Yes</td>
<td>123</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>53</td>
<td>95</td>
</tr>
<tr>
<td></td>
<td>Don’t know</td>
<td>3</td>
<td>59</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>Response</th>
<th>Existence of Groups for Water Management</th>
<th>Average Number of members</th>
</tr>
</thead>
<tbody>
<tr>
<td>head</td>
<td>Yes</td>
<td>36</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>19</td>
<td>20</td>
</tr>
<tr>
<td>mid</td>
<td>Yes</td>
<td>46</td>
<td>4</td>
</tr>
</tbody>
</table>
Although such groups seem to be organized nominally at distributary canal level, the size and scope of activities seems to be more consistent with tertiary or outlet groups. Given the very weak nature of the groups and the fact that membership is related to households rather than individuals, the low female participation is not surprising (1.8 female members as compared to 8.7 male). The functions of these groups are almost exclusively related to water management and ditch cleaning, although only 50% of respondents could name any function. The ACC is seen to be the most important single body for coordination between farmers and system managers, particularly at Natmauk (Table 27) but this lacks any formal representation of the farmers and thus there is a very low level of formal participation in the irrigation system. The ID is also seen as a key organization, and is regarded as more important at Chaung Magyi (Table 30).

Table 28: User Groups at Chaung Magyi

<table>
<thead>
<tr>
<th>Location</th>
<th>Response</th>
<th>Existence of Groups for Water Management</th>
<th>Average Number of Members</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>WUA?</td>
<td>Registered?</td>
</tr>
<tr>
<td>Overall</td>
<td>Yes</td>
<td>89</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>98</td>
<td>67</td>
</tr>
<tr>
<td></td>
<td>Don’t know</td>
<td>7</td>
<td>59</td>
</tr>
<tr>
<td>head</td>
<td>Yes</td>
<td>36</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>35</td>
<td>26</td>
</tr>
<tr>
<td>mid</td>
<td>Yes</td>
<td>25</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>34</td>
<td>21</td>
</tr>
<tr>
<td>tail</td>
<td>Yes</td>
<td>28</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>29</td>
<td>20</td>
</tr>
</tbody>
</table>

Table 29: Responsible Agencies – Perceptions at Natmauk

<table>
<thead>
<tr>
<th>Organisation</th>
<th>cropping</th>
<th>water delivery</th>
<th>water manage</th>
<th>canal maintenance</th>
<th>Conflict resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID</td>
<td>6</td>
<td>36</td>
<td>36</td>
<td>26</td>
<td>12</td>
</tr>
<tr>
<td>DOA</td>
<td>14</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>ACC</td>
<td>30</td>
<td>49</td>
<td>39</td>
<td>43</td>
<td>62</td>
</tr>
<tr>
<td>ID + DOA</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>ID + ACC</td>
<td>5</td>
<td>24</td>
<td>22</td>
<td>22</td>
<td>7</td>
</tr>
<tr>
<td>DOA + ACC</td>
<td>8</td>
<td>15</td>
<td>15</td>
<td>14</td>
<td>15</td>
</tr>
</tbody>
</table>
There is an overwhelming preference for growing paddy in the monsoon, and given the nature of the system and infrastructure this is almost inevitable (Table 29 to Table 30). A much greater diversity of interest in the summer season, particularly in Chaung Magyi where cotton is favored. However, these preferences reflect what is possible at present and those who are able to grow diversified crops prefer to do so, suggesting that if the infrastructure and management can be improved then more farmers will diversify. The results suggest that there is scope for better cotton production at Chaung Magyi and increased areas of onions and tomatoes in both systems if the surface water system can be made sufficiently flexible and reliable.

### Table 30: Responsible Agencies – Perceptions at Chaung Magyi

<table>
<thead>
<tr>
<th>Organisation</th>
<th>cropping</th>
<th>water delivery</th>
<th>water manage</th>
<th>canal maintenance</th>
<th>Conflict resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID + DOA + ACC</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Organisation</th>
<th>cropping</th>
<th>water delivery</th>
<th>water manage</th>
<th>canal maintenance</th>
<th>Conflict resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID</td>
<td>8</td>
<td>77</td>
<td>83</td>
<td>60</td>
<td>21</td>
</tr>
<tr>
<td>DOA</td>
<td>49</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>ACC</td>
<td>32</td>
<td>36</td>
<td>36</td>
<td>40</td>
<td>57</td>
</tr>
<tr>
<td>ID + DOA</td>
<td>11</td>
<td>8</td>
<td>8</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>ID + ACC</td>
<td>4</td>
<td>16</td>
<td>15</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>DOA + ACC</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>ID + DOA + ACC</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

### Table 31: Chaung Magyi – preferred crops (Number of households)

<table>
<thead>
<tr>
<th>Crop</th>
<th>monsoon</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>total</td>
</tr>
<tr>
<td>paddy</td>
<td>168</td>
<td>72</td>
</tr>
<tr>
<td>sesame</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>cotton</td>
<td>6</td>
<td>75</td>
</tr>
<tr>
<td>tomato</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>onion</td>
<td>0</td>
<td>13</td>
</tr>
</tbody>
</table>

### Table 32: Natmauk – preferred crops (Number of households)

<table>
<thead>
<tr>
<th>Crop</th>
<th>monsoon</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>total</td>
</tr>
<tr>
<td>paddy</td>
<td>163</td>
<td>124</td>
</tr>
<tr>
<td>sesame</td>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>cotton</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Crop</td>
<td>monsoon</td>
<td>Summer</td>
</tr>
<tr>
<td>------------</td>
<td>---------</td>
<td>--------</td>
</tr>
<tr>
<td></td>
<td>total</td>
<td>head</td>
</tr>
<tr>
<td>tomato</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>green gram</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>onion</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td>chick-pea</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>bean</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

There is a relationship between quality of infrastructure, standards of water management, and social and agricultural outcomes. It is not a simple situation of declining yields and declining agricultural productivity from the head to tail of the system but a more complex relationship affected by local variations in many factors but nonetheless one where improvements in water supply should be a precondition for increased production and increased equity of production.

C. Management Capacity

1. Irrigation Department

The ID has been managing irrigation effectively for many years with little external support. It is, however, constrained in several ways. Staff numbers are very low in comparison to the need, and there are weak arrangements for sharing responsibilities with water users; staff skills are limited to traditional methods for irrigation management with little regard for concepts such as benchmarking performance, agreeing and implementing a service delivery approach, asset management. Financial resources are limited, and there is little long term planning. Annual plans are drawn up, but generally severely curtailed due to budget limitations. These weaknesses apply across the districts and townships.

Finance is constrained by annual government allocations from the regional budget for O&M. There is no concept of payment for service delivery, and water fees are essentially not collected.

Improvements to infrastructure will provide an opportunity to develop skills in management whilst the physical condition is still good. Involvement in planning and supervision will build an understanding of assets and their management, and capacity building particularly for township and field level staff will enable them to become much more effective. Improved infrastructure with more systematic involvement by water users will reduce the pressures on ID field staff to operate all structures on a daily basis and enable them to focus more on higher level activities for ensuring compliance with a service delivery plan.

The wider reform programs under way in Myanmar will provide an opportunity for better and more predictable budget allocation for O&M.

2. Agricultural Coordination Committee

The township ACC is a key organization and is perceived to the main point of contact for most farmers. Members are drawn from township level offices of MOAI departments, thus enabling coordination between agricultural and water management and other activities, and also with township level administration. Farmers and even myaunggaungs are not directly represented on the ACC, but their needs and opinions may be expressed via the FLCs.
This indirect link with the farmers is perceived to be a weakness in the current system, even though the FLCs and ACC meets frequently both for seasonal planning and for in-season adjustments to plans.

3. **Water Users**

Water users currently rely on ID field staff for most aspects of irrigation O&M, but they intervene in an *ad hoc* manner when their interests require them to do so. *Myaunggaungs* are the key people for this, but they do not exist in all locations and they variable in their levels of activity and skills (technical, communication, managerial, etc). Nonetheless this system does provide a basis for improving management at tertiary unit level. Participatory techniques need to be used to understand current weaknesses and needs and thereby build capacity across the board. This will be a very important part of the irrigation management component, and one which should draw on extensive international experience of the sector.

D. **Proposed Intervention to Improve Irrigation Management**

1. **Rationale for the Intervention**

Irrigation is underperforming across the CDZ: standards of maintenance are declining; infrastructure failures (due to poor construction or maintenance) have disrupted agriculture; and reliability and timeliness of deliveries to individual farmers are inadequate for productive cropping. With more reliable water services, farmers would be increasingly willing to invest in agriculture, but without that they are unable to secure livelihoods from their land holdings and rely increasingly on off-farm activities. Improvement of irrigation infrastructure and its management is not the only intervention required, with major reforms and improvements to service delivery needed in the agriculture sector. However, it is a prerequisite for stronger agriculture in a drought-prone region which is increasingly likely to be affected by climate change.

Inadequate and unreliable water supplies were reported by a majority of water users in this study. This is a very common global problem, but there is no consensus on how best to solve it. It is generally relatively easy to develop or improve small-scale solutions for water management, but in this project the objective is to improve water management on large schemes. The project seeks to improve overall management by simultaneously improving main system management by the ID, enhancing coordination with tertiary unit managers, and making tertiary unit management more responsive to user needs.

Surface irrigation is difficult to manage so the project aims both to repair infrastructure and to improve management systems so that it can be sustained. The cost of irrigation and human resources needed for management are high, so standards slip. As performance declines so does the willingness to invest, creating a vicious cycle of underinvestment and deterioration. This leads to informal interventions, theft of water and inequity.

Good performance and sustainability of irrigation management component depends on new and repaired infrastructure being planned in conjunction with water users and managers so that it meets local requirements and is consistent the future management arrangements. It will rely on there being good local capacity in relevant government agencies as well as amongst water users.

2. **Lessons from other regional programs**

There have been many programs across South and East Asia to improve surface irrigation. Very large areas of land and numbers of farmers depend for their livelihoods on irrigated
agriculture, but past efforts to improve performance in many countries have had mixed results. Most recent studies have found that large to medium-scale public irrigation systems in Asia generally perform well below their potential, with many problems typically arising from inappropriate design and poor O&M. Many systems were initially designed around rice production making it difficult for farmers to diversify into higher-value dry-season crops. More flexible systems are needed to allow farmers greater control and autonomy of irrigation scheduling, thereby encouraging diversification of farming activities (IWMI, 2010)

In recent decades, participatory irrigation management (PIM) and Irrigation Management Transfer (IMT) have been promoted to tackle this problem, and the widely recognised issues of under-performance, inadequate resources for maintenance, and pressures on government budgets. These programs have rarely lived up to initial expectations and increasingly there is recognition that new approaches are needed, giving a greater focus on the capacity of the main system managers rather than the end users.

PIM has been initiated across South and South East Asia with very high expectations that voluntary water user groups could be formed to take on many management activities from the government and at the same time improve overall performance. Although there have been notable successes, the achievements have usually been much less than had been hoped. For example, in a recent study of Cambodia, IWMI (2015) report that "a remarkable amount of hope and expectation has been placed on this policy, when one considers that it is expected to: contribute significantly to the effective and sustainable management of irrigation systems, promote food security and economic growth; increase the role of farmers and ease the burden on the government, build local capacity to manage irrigation, and bring about uniformity and consistency among donor, government and non-governmental organization (NGO) strategies for irrigation development and management."

The ambitions set out in the 1990s when PIM first became widespread drew on the perceived successes of traditional farmer-managed irrigation and paid scant regard to the different nature and history of government-managed irrigation. It was a even more remarkable ambition given that WUA are only usually only given responsibility for small parts of the system, with the government remaining responsible for reservoirs and main canals. Unfortunately, but predictably, IWMI found that "the overall achievement of the primary purpose of FWUCs in managing, maintaining and operating small- and medium-scale irrigation schemes in a sustainable manner was not being reached... FWUCs acted as a mediator between farmers and PDoWRAM, rather than carrying out their principal mandate of competently managing the schemes. They found that the performance of key tasks such as: maintaining infrastructure, allocating water from primary and secondary canals, and collecting irrigation service fees, were inconsistent and often absent". WUGs have been useful – particularly in improving communications between farmers and government, but not to the full extent that had originally been envisaged.

This is despite many years of effort in PIM programs and despite some local successes. The response to this poor performance in many countries is often just to provide more support and more training to WUAs, without addressing structural reasons for their poor performance: poor service delivery to the WUA, the lack of supportive institutional environment, and weak internal governance. There is also limited willingness among users to get involved: smallholder agriculture is a marginal activity providing only a small, albeit critical, part of livelihoods and many farmers do not have the desire or time to become deeply involved in management. Participation can become a burden rather than empowerment, and quotas for women and for minority groups can have a disproportionately adverse impact on the people they are designed to help.

There is now widespread recognition that standard top-down bureaucratic approaches for establishing WUAs do not work. Verzijl and Dominguez (2015) note that (in Peru) “In mainstream thinking, institutions, such as WUAs, are manifested as having a clear purpose,
defined boundary and incentive to participate; with transparent roles, rules and accountability. Local activities are functional, predictable and amendable; which allows crafting and designing of robust and sustainable institutions.” However, they found that such attempts at “the imposition of bureaucratic culture onto the local irrigation institutions that relied on historically and culturally embedded practices, customs and (ritual) performances” was largely unsuccessful. Where they found a successful WUA it differed markedly from the prescribed model: “Rather than being designed and clearly defined, we see natural resource institutions as continuously performed and patched together, through heterogeneous elements and practices, by those that live, experience and enact these institutions every day and by those who make sense of them”. There have been effective NGO-led programmes which have a much better record (see for example, Mott MacDonald, 2007, Howarth et al, 2015) but these are very intensive and expensive. These factors leave the challenge of improving management unresolved, and there is a temptation to regard large scale irrigation as a ‘wicked problem’ or ‘too difficult to solve’ and focus instead on smaller projects. IWMI, for example, recommend "more innovative approaches such as smaller scale simple water resources management projects that are easier to implement under the evolving institutional capacity of the country".

Small-scale groundwater irrigation has become very popular and now accounts for about half of all irrigation in both India and China. Cheap pumps enable individual farmers to get reliable access to water. They are prepared to pay for this because of the inability of large-scale government-managed systems to provide water required for intensive, diversified agriculture. However, overuse of groundwater has led to questions of the sustainability of this, and water quality is a problem in many places – as it is in parts of the CDZ.

Whilst there is scope for developing smaller projects, there is evidently a need for a new approach for the larger systems as well, not only in Myanmar but also in other countries. This will depend on better arrangements for establishing and supporting WUAs but crucially it will require more attention on the institutional environment that they operate in, and on ensuring that they are given a reliable supply of water from a well-managed main system.

Following the Comprehensive Assessment of Water Management for Agriculture (IWMI, 2009), ADB, FAO and IWMI supporting a program for revitalizing irrigation in Asia (Mukherji et al, 2010). This recognised the poor performance of large-scale government managed irrigation and called for a paradigm shift in thinking on irrigation. The study recognised that there have been some successes with IMT and PIM programs but noted that that these were the exception rather than the norm and that they have rarely been rigorously evaluated. They were found more likely to succeed for diversified crops than for paddy and where NGOs are deeply involved in implementation. This increases the costs, but there is little doubt that quick programs delivered by government agencies rarely have an impact. They concluded that there were structural weaknesses in the IMT model, and particularly the expectation that officials who have been unsuccessful in managing systems should be able to hand over responsibilities to users without the “reforms [needed] to better align the incentives of the irrigation managers with the users”. They also examined other models, including private-public partnerships but found these to face many of the same constraints as IMT, and major pricing reforms, with volumetric charging, but these too have proved ineffective and politically unacceptable (Molle and Barker, 2007).

The experience of PIM/IMT to date can thus be summarised as

- Unrealistic expectations for local user groups, which ignore their context as part of a larger system and the need to improve the main systems;
- Inadequate methods for establishing groups, which ignore power relations, multiple livelihoods and so on.

More recently private sector management has been seen as the way forward: the government agency becomes the regulator, an independent private contractor manages the main system
and farmer organisations the end units. This has been effective on commercial agriculture in North Africa and Latin America, but not yet in Asia where most irrigation is for subsistence by smallholders who pay very little for their water making commercial arrangements difficult. New ideas are now being tested in Bangladesh (ADB) and have been proposed in Nepal (Lahmeyer, 2015) and India (Varma, 2012). Given the early stage of testing these ideas private sector management of irrigation is not recommended in the short term in Myanmar. There is little local contracting experience and most irrigation construction is still undertaken by force account. Whilst local capacity may be built up over the next few years, there is no realistic prospect of establishing independent private management in the short term, nor any mechanisms for procuring and financing it.

Table 33: Lessons from previous Irrigation Management programs

<table>
<thead>
<tr>
<th>Lesson</th>
<th>Response</th>
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<tbody>
<tr>
<td>Overall</td>
<td>Coordinated planning of rehabilitation and management. Focus on designing infrastructure which can be managed by existing organizations. Avoidance of innovations which are unlikely to be within capacity of ID (automatic gates, SCADA systems). Ensuring that management arrangements are realistic, understood and agreed prior to construction of new infrastructure</td>
</tr>
<tr>
<td>Little motivation for management reforms and over-concentration of effort on rehabilitation</td>
<td></td>
</tr>
<tr>
<td>Excess focus on low level organizations with too little regard for main system infrastructure and performance</td>
<td>Realistic definition of roles and sharing of responsibilities. Building capacity of ID as well as WUAs</td>
</tr>
<tr>
<td>Imperfect agreements on water delivery between water management organizations and WUAs, taking into consideration resources and interests of both sides.</td>
<td>Better agricultural planning and reservoir management so that reliable and implementable water allocations and delivery schedules can be prepared and agreed through structures such as the ACC,</td>
</tr>
<tr>
<td>WUAs</td>
<td>Gradual approach to interventions, building on existing institutions such as myaunggaungs, and emerging local governance reports (UNDP, 2015). Initial work will be in pilot areas selected where there is greatest local interest in reforms and existing capacity</td>
</tr>
<tr>
<td>Driven by external pressures from donors and to reduce government budget</td>
<td></td>
</tr>
<tr>
<td>Expectation that WUAs can improve management even with poor conditions of on-farm irrigation infrastructure and unreliable water supply to WUA</td>
<td>Participation in design of infrastructure to ensure that critical issues are identified and resolved through the infrastructure component, including not only water control and delivery, but also related services such as access to farms</td>
</tr>
<tr>
<td>Lack of measuring systems and therefore it is hard to ensure economic water use;</td>
<td>Provision of measurement at the head of distributary canals, and water control structures (gates) at each outlet</td>
</tr>
<tr>
<td>Lack of legal authority for WUA and confused relationship with local administration</td>
<td>Gradual development of informal institutions and building their capacity, in line with emerging capacities.</td>
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Climate change is an important consideration for planning irrigation programmes, but as IWMI (2010) point out it is important to remember that there is a high degree of uncertainty surrounding the pace and direction of changes in water availability, and there are many other non-climate changes occurring very rapidly at the same time “There are no defined boundaries between climate-specific and non-climate-specific adaptations”. Strategies must be formulated in the light of this wider context, considering both planned changes such as macroeconomic policies) and autonomous adaptations (such as decisions by individual producers to change crops in the face of fluctuating prices and demand).

3. Implications for Irrigation Management in IADP

The recommendations from the Comprehensive Assessment study referred to above were fivefold:

- Modernize old schemes, both technically and institutionally to be responsive to farmer demands, including use of groundwater recharge and use of intermediate storage
- Support farmer initiatives to scavenge water by using pumps to recycle losses and groundwater
- Benchmarking to increasing the accountability of managers to users, and possibly outsourcing O&M services to private sector providers
- Boosting knowledge and training (at all levels)
- Invest outside the sector in ways which will positively irrigation.

These principles have guided the proposals for development of the irrigation sector in this project, which takes account of better infrastructure, greater involvement by water users, better management of reservoirs, more efficient use of resources for main system management, and integration with the wider agricultural sector. More specifically this means:

- Irrigation management involves many stakeholders; improvements to management require reforms and activities at many levels;
- Infrastructure should be completed, repaired and modernized so that it is in a condition to be well-managed. There should be sufficient user participation in planning this rehabilitation that they understand the limitations and management requirements for the system, with an agreed sharing of responsibilities;
- Active involvement of farmers in the planning and design of infrastructure should be matched with their involvement in developing institutional arrangements (probably with intensive and long term support from NGOs);
- Attitudes to participation need to be understood in the historical context of centralized government, and realistic objectives should be set for WUAs with good entry point activities are needed to ensure interest in them;
- There must be adequate resources for management of the main system, which are unlikely to be collected from user fees. However, the economic benefit of investing in O&M is very great and the wider benefit justifies continued government support until fees can be increased.
- The introduction of benchmarking and asset management, through capacity-building of the ID and as part of a wider training program can help ensure that resources are targeted where they are most needed.
- Water should be recognized as just one input to agriculture, and must be complemented by adequate attention to input supply, markets as well as wider reforms to the sector (see Supplementary Document 3).

Reform and revitalization of formal irrigation systems will depend on a "clear definition and understanding of the roles, responsibilities, tasks and expectations of the government and the communities, keeping in mind the history of the development of irrigation infrastructure. This will likely require an increase in capacity across the board" (IWMI, 2012).

Although the ID staff at township are skilled and capable of managing the systems, their numbers are limited and resources for active management insufficient. They are effectively limited to crisis management for maintenance and very simple arrangements for operation which is only suited to low intensity agriculture. Once the infrastructure is improved, there will be scope to use the limited resources more wisely and the activities proposed for ID capacity building are aimed at that (see section 54 below)

There is also for much greater and more formal involvement of water users, initially through informal groups and later via systematic Water Users' Associations. It is essential that this is arranged in a way that is not perceived as transferring tasks without the skills, resources or authority to undertake the tasks. International experience suggests that this is not easy and takes a lot of time and patience to build the capacity and willingness to share responsibilities - both ID and water users need to change their ways of working.

The long term approach is to set up formal WUAs (with legal status) for each distributary canal and adjacent minors and direct offtakes from the main canal. Coordination at this level is
essential to improve water management; this WUA needs to agree an operating schedule with the main canal inspector which is consistent with their requirements and the overall system water delivery schedule. Management below the outlet should remain the responsibility of the farmers, as at present. The existing farmer groups could be formalized into Water User Groups as subsidiary groups within the WUA. The ID should remain responsible for operation of gates on the main canal to ensure delivery of water in accordance within the agreed plan, but the WUA and farmers should be responsible for subsequent management. This is a change in theory from the current situation (where the ID manages Distributary canals), but may not differ in practice. The details and implications of this change will be examined at the feasibility stage. In due course WUAs should be federated along the main canal to form a project committee which will be actively involved in system planning and management, including developing cropping and watering plans. This will affect the ACC as well, and thus will be a longer term objective, and will be examined further at the detailed design stage and during implementation. Financing arrangements for WUAs are a common reason for them to fail, particularly in places where water charges are low or nominal. Since the infrastructure will be rehabilitated, the initial maintenance requirements and costs will be low, but this time must be used to develop sustainable financing arrangements both for the WUA organization itself and for its activities (especially maintenance). Water charges are politically sensitive, difficult to manage in a way which provides any incentive to use water efficiently, and rarely cover even a small proportion of operating costs. O&M should not be compromised by weak cost recovery, so it is anticipated the government should continue to pay for main system O&M.

There is a risk that formalization of the current arrangements as official WUGs would result in a plethora of committees if implemented comprehensively, but still only achieve low-level participation in irrigation management and no capacity for any other activities. A project the size of Natmauk would have 1,000+ WUGs, and thus would be rather cumbersome and bureaucratic. Thus these low level groups should remain as informal groups, although they should ultimately form part of larger WUAs established at project [1], main canal [2] or distributary [17] levels. It is premature to consider establishment of these, but in general only higher-level organizations should be legally registered, have formal structures of committees etc. However, arrangements for such larger associations can be discussed and developed on a pilot basis during project implementation. Existing arrangements of 'WUGs'/ myaunggaungs should fit into this new structure. This will take time to introduce as there is no legal basis for it, and it may well be resisted by farmers who may be reluctant to take over what are officially ID responsibilities. It will also require a change in roles for the ID at township level, thus requiring substantial work in defining and agreeing new roles and responsibilities, and in capacity building.

There should be caution in proposing extensive new arrangements as they are unlikely to be effective or sustainable until the need (and desire) for them is recognized locally. External imposition of WUAs has, internationally, a poor record of success, unless supported by a very intensive and participatory process of irrigation reform and capacity building. There is a precedent at Natmauk where a WUG structure was created when the project was completed in 1993, with 17 WUGs being established. These were based on villages rather than canals and are headed by the village tract administrator. In addition, they included a number of selesu (leader farmers, representing 10 farmers) and myaunggaungs. However, the operation in practice is no different from the traditional arrangements as these organizations have no legal status or authority and were not given any significant support after establishment. WUGs have also been set up on paper in other older systems, such as Chaung Magyi, but these are indistinguishable with the previous arrangements with the myaunggaungs continuing to operate the canals in the traditional way.

Agriculture is not the main source of livelihood for most people, and thus it will be difficult to persuade them to take on more extensive roles in operation and maintenance of canals.
However, there is scope for significant improvement in management, and arrangements for WUAs should be improved as part of the project. The details will need to be worked out in a consultative way in pilot areas before extensive application. They will be useful for informal consultation with farmers on local aspects such as irrigation layouts and designs, to help ensure local buy-in to the project. Consultations via myaunggaungs will be needed on designs even in places which are not selected as pilots for strengthened WUAs.

The current, albeit somewhat theoretical arrangement for WUAs was indicated in Figure 3. A potential arrangement which might be adopted in future is illustrated below in Figure 5. This is similar to that proposed but not yet implemented by LIFT. It is proposed as a basis for discussion, rather than as a definitive recommendation. Any new arrangements will need to be developed gradually on a consultative basis, building on existing relationships. This figure represents one potential long-term arrangement rather than a specific recommendation for implementation in the project. First the existing arrangements will be formalised into water users’ groups at tertiary level, and then coordination between WUGs at secondary canal level will be encouraged with a view to establishing WUAs in the longer term.

**Figure 9: Potential Future Management Structure**

There is a need to involve women in decision-making around water management and canal maintenance; they are heavily involved in agriculture, but rarely in decision making around water. This is already an important gap but is becoming increasingly so as a result of male...
migration and the feminization of agriculture. Most programs set quotas for women in WUA committees but most evaluations report this approach to be ineffective. However, this is in a large part because WUAs are ineffective for men as well as women; requiring women to join an organisation which is not effective does not add any value. The critical need is to set up WUAs in a way that ensures that they address local needs, of both men and women and have a meaningful role in irrigation management. This requires an intensive approach such as that set out below. It is important to address women’s needs explicitly, recognizing the differences from men’s needs, and it may still be necessary to set quotas but that is not sufficient on its own (Radwan, 2010, WRDMAP, 2010). Participation is a means to an end – reliable access to water for agriculture. If it does not achieve that it becomes a burden rather than empowerment.

4. Intervention Activities and Outputs

a. Options

Several options can be envisaged for the irrigation management component:

- A: Do nothing (continue with current management system)
- B: Establish PIM according to a standard model across the entire command area
- C: Strengthen ID management with full management down to tertiary outlet level
- D: Build on current arrangements for participation through myaunggaungs, to test an improved system and gradually extend across the command area

The ‘do nothing’ option [Option A] will not meet the requirements for sustainable management of infrastructure constructed through the project. It will thus not contribute to the objectives of the project, would result in the investment in infrastructure being largely wasted, and is not considered further.

Establishment of PIM across the command area [Option B] would not be possible in the short term. There is not yet a legal basis for water users associations, there is little local appreciation of the implications of such groups, and the practicalities of establishing user groups across the entire area would make this option unrealistic.

Although the existing system assumes that the ID is fully responsible down to the outlet to farmer managed watercourses, in practice they have too few field staff to be fully effective and there are too few control structures. The limitations of control structures will be relieved through the infrastructure component, but these will require more operation than at present rather than less. Government funding constraints preclude deployment of significantly more staff and thus management is likely to remain weak unless participation by water users is increased. Option C is thus not considered a viable option.

Although the short term maintenance needs will be relatively low, this time needs to be used for building up water user capacity for management to ensure sustainability. Option D will allow for a gradual build-up of local capacity for operation from distributary canal downwards and free ID resources for asset management. This is the preferred option.

The proposed interventions in this option are focused from Districts down to the level of individual water users. Actions to strengthen management capacity at township levels and amongst water users will additionally reveal reforms needed to the wider institutional and regulatory framework, including for example arrangements for irrigation financing and registration of water user groups. However, the focus of the projects is on developing what exists and building on current capacity rather than to attempt radical innovations from the outset.

Activities will be undertaken at several levels to strengthen management of the main system by the ID and other agencies, and to improve communications with users. Thus the component will look at management of all parts of the system and will not only focus on WUAs. Activities will include institutional strengthening and capacity building all with the main organisations:
• ACC and FLC:
  o improved coordination between DOA, ID, DALMS, water users and others;
  o better crop planning and encouragement of crop diversification to optimize water use.
• Irrigation Department:
  o Systematic asset management to ensure sustainability of infrastructure;
  o Operation planning to meet user requirements within the constraints of water availability, including better management of reservoirs;
  o Monitoring of water distribution and reconciliation with plans;
  o Improved communications with farmers, and coordination with other departments.
• Water users/WUGs:
  o Enhanced role in planning, coordination, conflict resolution and management in tertiary units;
  o Gradual formalization of current arrangements to make more participatory and comprehensive;
  o More systematic involvement in secondary canal operation.

b. Agricultural Coordination Committee

The ACC is a key organization at township level with responsibilities for irrigation planning, management and coordination between related sectors. The project will strengthen this committee and make it more responsive to farmer needs and interests. Activities will include a range of awareness meetings, planning workshops and coordination meetings

**ACC awareness meetings.** These will inform the ACCs at District and Township level about the project as a whole, the sub-projects on the project and their relationship to other activities under the project, particularly related to agricultural development. Two meetings per district/township are planned in the early stages of the project.

**Facilitation of ACC Workshops.** These will be more detailed meetings to introduce the concepts of PIM and the way this can be introduced in the subprojects. These workshops will lead to a definition of composition, roles and responsibilities of strengthened ACCs at each level, including any new members proposed to meet the overall objectives. The importance of direct representation by farmers and other water users will be stressed and procedures for recruiting them will be agreed. There will be a series of facilitated workshops for district and township during the preparatory phase. It is anticipated that there will be two-monthly meetings from the start of the detailed design phase for each sub-project. There will be periodic but less frequent meetings during the construction phase to ensure continuity between planning and management phases. These are to sustain interest in management and reduce the risk that the focus will become purely related to construction of infrastructure.

**Irrigation management planning, coordination and supervision meetings.** The capacity of the ACC for management of irrigation in the longer term will be developed, with detailed activities starting towards the end of the construction phase. Some improvements in management are possible before completion, but most work on building capacity for systematic decision-making on crop planning, water allocation and distribution will be done once the infrastructure is complete. This will be undertaken through facilitation of seasonal and monthly ACC meetings which will build capacity ‘on the job’, with increasing involvement by farmers and ensuring effective formal representation by water users.

An important part of this will be introduction of improved procedures for seasonal planning on the basis of reservoir storage and predicted inflows. Alternative reservoir operating rules will be introduced and discussed with the Township administration as well as ACC. The need and
options for changes to current procedures which typically result in the reservoirs being empty at the end of the summer season will be discussed and developed further. This will include considerations of productivity of irrigation water (expressed as MMK/acre-ft), which may be higher during the monsoon because it is supplementary to rainfall although this gain may be offset by higher yields and more options for diversified crops in the dry season. The equity gains of extensive paddy irrigation in the monsoon will need to be balanced with the benefits to a smaller number of people from high-yielding summer irrigation. As part of this exercise the benefits of modern drip irrigation trials will be evaluated to identify the scope for high value, water-efficient irrigation in the summer.

The projected impact of climate change, as reported in the NAPA, include a delay to the start of the monsoon, a shorter monsoon, more intense rainfall and higher temperatures. These changes will require better management of reservoirs in order to ensure water availability in time for the start of the monsoon season. This would be beneficial even under present climate and will be of increasing importance as the effects of climate change become more pronounced.

c. Irrigation Department

The ID is represented on the ACC, and thus the ACC awareness raising program will cover the ID, but there are additional people in the ID who need a detailed understanding of the project and the way management can be improved at the same time as infrastructure. This will familiarize the full range of staff, from Regional Director down to binthas from all of the various offices, with irrigation modernization and management and with their roles and responsibilities in this.

The role of the ID in design and supervision of the infrastructure is covered in Section II.C.2. ID capacity will also need to be strengthened in a range of topics related to irrigation management and system O&M. Three important topics are: the role of ID as a service provider to water users; asset management, to ensure physical sustainability and affordability; and water management to ensure reliability and equity of water distribution. These will be covered by training programs in parallel with the water user training.

Irrigation as a service. The primary role of the ID should be to deliver an irrigation service to water users. The normal arrangement is for water user groups to be provided with a guaranteed supply of water by the ID, for which they pay a fee with terms of service delivery and payment defined in a Service Agreement. In Myanmar where water fees are very low and there are weak arrangements for collection and management, it will be some time before this ideal situation can be reached.

Nevertheless, there are significant opportunities for increasing agricultural production, water use efficiency and productivity of water if the Irrigation Department can adopt a service delivery culture. At present the ID operates in a ‘top-down’ way, based too much on the cropping patterns and water allocations prescribed in the original project designs and reiterated by the ACC. Instead they should evaluate current cropping patterns and farmers’ demands, and take account of the potential for conjunctive use of surface and groundwater. They need to develop effective procedures for high levels of service delivery based on liaison, dialogue, participation, agreement and partnership with water users.

Even without direct payment for the service, it is possible to set out the service to be delivered with key performance indicators related to crop areas, reliability, timeliness and equity of water supply, O&M expenditure, and canal maintenance.

It is, however, only possible to achieve this if the level of service can be measured against targets. As there are only a small number of relatively small systems, improved monitoring and benchmarking should be possible using simple techniques and without recourse to sophisticated technology. Provision for flow measurement has been included in the
infrastructure component, and training will be needed to ensure that this is operated correctly and actually used to monitor and improve performance.

**Asset management.** Systematic maintenance of irrigation assets is critical for the efficient operation and management, but there is not yet an effective institutionalized process for regular planning and execution of system maintenance. Maintenance works are planned in an ad hoc manner with long periods of neglect interspersed with emergency repairs. An Asset Management Planning approach is proposed to institutionalize medium to long-term maintenance of irrigation systems and thereby assure efficient and optimal operation.

Asset management planning seeks to maximize potential benefits by applying engineering and management procedures which identify the function, utility, cost, value and current condition and performance level of each asset (irrigation canals, drains, structures) and thus of the asset base as a whole. Analysis of the information on all assets leads to the development of the asset management plan.

A word of caution is however required. Asset management is a management tool; how it is used, and how effective it is, depends entirely on who uses it, and in what context. In the wrong context, where management is weak or lacks control over finances and budgeting, asset management will not work. What asset management can do, if used correctly, is identify infrastructural constraints to performance, and formulate plans to address them within the context of the ability and willingness of the users to pay for a specified level of service.

The process cannot be introduced quickly or easily, but the process of planning and implementing rehabilitation will provide an opportunity for the ID to learn the process and gradually apply it. The steps involved in preparing an Asset Management Plan include:

- Conducting asset surveys;
- Preparing and maintaining an asset database;
- Preparing a historical costs profile;
- Conducting performance surveys to identify current levels of service;
- Agreeing with the users on standards and desired level of service provision;
- Conducting an engineering survey to restore the structures to required design;
- Formulating the asset management plan;
- Implementing the asset management plan; and
- Monitoring and evaluation of implementation of the AMP and service delivery.

Asset Management training will focus on knowledge of asset management procedures to enhance efficiency of O&M and effectiveness of expenditure. It will include development of an inventory of fixed assets in irrigation and drainage networks and use this as a basis for preparation of systematic five-year and annual O&M and budget plans. Simple methods using standard computer software such as spreadsheets will be used for this, rather than specialized programs.

**Water Management.** The rather crude infrastructure, and limited staff and other resources available to the ID at present mean that water delivery is operated simply, with canals flowing continuously at constant flow depending on availability further upstream. Rotations are introduced when water is scarce. The situation will change after infrastructure is improved, and it will be possible to control deliveries much more precisely. The small number of ID field staff will mean that water user representatives will take on a bigger role in operating new structures – for which they will need training and support.

The ID role will become one of planning distribution and assuring delivery down to secondary canal level, and ensuring that WUGs take on their new role diligently. Simple gate structures should be well within the capacity of farmer groups to operate but they do create opportunities for abuse and theft of water. The ID will retain a role in DY canal management, with binthas advising myaunggaungs on operation of the new structures, but this should be an advisory role and gradually decline in importance as emergent WUGs grow in confidence, ability and trust.
Modernization of secondary canals provides an opportunity for a changed role in management. The modernization will be planned with the users, during which their capacity and willingness to take over management will be assessed and fostered. To facilitate the handing over process the ID will prepare a detailed layout map of the distributary canal and including the operational details such as design flow and discharge levels of canal, weirs, outlet points, channels, drains, etc.

ID staff at Township and field levels will need training on how to manage this change in their role, and to foster a better understanding of PIM and the resulting changes in their procedures and processes. Improved communications with water users will also be encouraged.

d. Participation by Water Users

A cautious approach towards the development of formal water users associations will be promoted through the sub-project. The role of myaunggaung will be analysed and developed to ensure that the interests of all farmers are represented. This will draw on lessons learned from other projects in the region as well as in Myanmar.

The process will start with an information campaign to ensure that there is a general understanding by farmers and village authorities with regard to the project and its objectives to improve livelihoods. This should be undertaken through mass publicity campaigns (including village meetings, radio/television, brochures, etc). Following this, distributary canals will be identified from which pilot villages for intensive activities will be selected, and criteria will be prepared for the final selection of pilot WUGs from those interested, leading to recommendation of preferred villages to ACC for ratification. The pilot tertiary units will be used as a focus for learning for application across the selected distributary canals.

This will be followed by a more intensive three stage process for management strengthening at tertiary unit level. This is a more responsive process than the normal approach of mass training programmes for large numbers of WUGs; it takes more time and resources but ensures that the program meets local needs. Too often training programs are highly prescriptive and not sufficiently appropriate to the local situation, and thus have much less impact than hoped for (as reported by IWMI in Cambodia). This more gradual approach has been tested effectively in Nepal (Mott MacDonald, 2007). It is not so much a new technique so much as careful application of well-tested approaches; it draws on successful community-driven development programs but recognises the much greater complexity of large-scale irrigation management.

The three stages are:
- Analysis
- Intensive capacity building
- Longer term support

Each stage will be facilitated by a locally-based NGO, possibly working in association with a national NGO. The role of NGOs is to ensure that advanced skills in facilitation and promoting participation are used. A team comprising a community mobiliser, agricultural specialist, water resources/irrigation specialist, and social development specialist will be brought together. Some additional specialists may be drawn from the staff of the relevant agency (ID, DOA, etc) to act as resource people to the meetings; this will help strengthen relations between farmers and officials. Although many local NGOs have good skills in community mobilization, they are not familiar with large-scale irrigation or the application of participatory techniques to such projects. International technical assistance will be needed at the outset to establish the process but most of the skills required are transferrable from other sectors.
i. **Analysis**

The analysis stage will be to make a rapid assessment of the tertiary unit reviewing problems, constraints and potential solutions in the context of livelihoods, including any existing organization structure, past and current activities, and frequency and way of communication with their member farmers. The aim of the assessment is to identify the need for strengthening and capacity-building. The assessment is estimated to take three days per unit and will result in a plan for works to be included under the infrastructure component of the sub-project as well as for actions to be taken to improve management within the tertiary unit and to improve coordination with main system management. Methods will use a range of PRA techniques and ensure that all social groups are engaged with, particularly including any vulnerable groups such as female-headed households or landless farmers. This will use resource mapping, wealth ranking, crop calendar, gender task analysis, problem analysis, transect walks, FGDs, etc, and lead to identify interim leader or 'champion'. This stage will also include a technical assessment of the extent, functionality and condition of the irrigation and drainage system in the WUG territory and its present management. This will be based on a joint inspection by water users and the ID and other ACC members. It will include a description of the existing I&D facilities and their management in the potential WUG territory, making a map of the existing layout, preparation of an inventory of condition and functionality, identification of problems and constraints. It will also cover identification of any land implications of canal / farm ditch repair or extension if required, including any need for land swap or voluntary donation.

The findings will be synthesized into a simple summary report and then the analysis stage will be concluded through a facilitated community meeting, to report the results and endorse the findings including the inventory of problems and constraints to water distribution and delivery to be addressed under the infrastructure component.

This stage will be completed during the detailed design phase, but the outcomes will be reviewed immediately prior to construction as some time may have elapsed and the situation may have changed. By the end of this stage, there should be a good appreciation of rights, roles and responsibilities of WUGs, and confirmation by pilot villages of their willingness to participate in the project.

Although a small number tertiary units will be selected for pilot implementation of management reforms, canal walkthroughs and farmer consultations will be undertaken in all distributary canals to ensure that local knowledge and requirements are reflected in the detailed designs.

ii. **Capacity Building**

The intensive capacity building stage will be undertaken at the end of the construction phase, in preparation for management of the new facilities. Subject to the construction program, some parts of the system may be complete and operational before the overall completion, and thus it is envisaged that this stage will be spread over two years. The approach proposed for this capacity building is a modified form of farmer field schools (FFS), but with a greater focus on water management and on user group strengthening than is normal practice. The inclusion of agricultural activities is valuable, for stimulating farmer interest in the program and balances the rather dry and uninteresting but still necessary topics around user group management and governance. Since the FFS runs for an entire season, typically meeting for half a day per week it enables observation and resolution of real problems as they occur. An 18 week program with rotating sessions on infrastructure management, water distribution, agriculture and user group management provides good coverage of the important issues and can interpret them in the right local historical and political context. It will be structured in a way which is convenient and accessible to women as well as to men.
First an inventory will be made at the regional and district levels of existing trainers, their range of training topics with respect to irrigation management, and the quality and relevance of any existing training materials for an FFS approach to capacity building. These will not cover all the topics required and where necessary, training modules and materials will be updated and new training modules and materials will be prepared. Training-of-trainers will be conducted for the updated training topics, modules and materials, and crucially in techniques for facilitation of field schools.

The combination of agricultural and water management activities is effective for stimulating interest and building an appreciation of the role of a user group. The FFS will be facilitated by the same NGO-led group, with participants self-identified during the analysis phase whilst ensuring broad representation. This will lead to formation of an informal group, incorporating existing myaunggaungs which could form the basis of a WUG. Decisions on the structure and governance of the group and the need for registration will be taken at that stage. It is anticipated that the areas to be managed by each group will be largely as delineated in the analysis stage, but there is some scope for flexibility - particularly in the way direct outlets or minor canals are combined into potential WUGs in logical hydraulic and social units. This may take some time to be finalized during the FFS, during which the pilot WUG boundaries will be confirmed and the potential membership ratified. All farmers within the hydraulic boundary will automatically be members and have the right to select leaders and an executive committee. This will still be an informal WUG until the legal framework for formalization of user groups is established, but the roles, rights and responsibilities should be agreed and a representative selected to interact with ID, FLC, ACC, DOA etc. This is likely to be one of the myaunggaungs.

The FFS will include a range of topics related to agriculture, infrastructure maintenance, water distribution and monitoring, and user group governance. It is only at this stage that detailed arrangements for WUG governance will be confirmed, including general assembly, committee structure and representation (women, ethnic minority, other vulnerable group representation), financial arrangements, roles and responsibilities of general members and committee, relations with ID and adjacent WUGs, participatory monitoring.

The FFS also provide an effective demonstration to other farmers. Participants should be encouraged to disseminate their learning to their neighbours, and they should put it into practice whilst ensuring equitable water distribution throughout the tertiary unit during the season that the FFS is operational. It is recommended that two FFS should be held in each selected unit, either in the monsoon and following summer season or in successive monsoon seasons. This enables topics to be covered in sufficient depth and gives enough time to learn from and build on the early findings.

iii. Longer term support

Longer term support will be largely provided via the Front Line Centers, drawing on staff from the ID and DOA, facilitated by the NGO where appropriate. This will include a limited training program to ensure sustainable O&M within tertiary units, coordinated with planned management of the main system; rational procedures for crop planning and water allocation and distribution; maintenance of the tertiary system by users; and effective coordination with the ACC.

The approach outlined above will be followed in the pilot tertiary units and distributary canals. A more limited capacity-building program is proposed for other tertiary units. The pilot tertiary units will serve as demonstrations for other units, and the NGO-led team will also provide a limited program of training on coordination with the ACC and ID, irrigation planning, water management and maintenance at tertiary level to representatives of each distributary canal.

Depending on the progress with establishing informal WUAs and enabling them to take on responsibilities for the operation, maintenance and management of distributary canals, each WUA will be trained to prepare an action plan for higher level management. This will lead
towards detailing its responsibilities and those of the ID, defining arrangements for receiving
bulk water on volumetric basis, preparing irrigation plan for the command area, managing
irrigation service to its members, equitably distributing water to farmers, improving on farm
water application, collecting and remitting water charges to the ID, and maintaining the minor
canal and CAD system to design standards. It is anticipated that significant progress towards
this will be achieve in a pilot area in the lifetime of the project.
The ID will prepare guidelines and training with simple and standard formats for requisite data
collection for seasonal crop planning and water demand estimation, irrigation scheduling and
rotational supply to outlets, farmer crop area estimation for collecting water charges and
maintenance plan (including a participatory bench marking format to integrate this with the ID
asset management plan).
IV. HYDROLOGICAL CONTEXT

A. Hydrology of the Central Dry Zone

1. Background

Most of Myanmar has plentiful rainfall, with annual averages of 3,000mm or more in many places. In the Central Dry Zone (CDZ), however, annual rainfall is generally less than 1,000mm, and in some places is as low as 600mm. The CDZ is part of the central plain of Myanmar, lying between mountains to the west and highlands to the east. The low rainfall in the CDZ results from a rain shadow effect which inhibits rainfall during the south-west monsoon from May to October. Because of the relatively low rainfall, farming and crop yields are sensitive to variations in rainfall (and to a lesser extent other climatic variables). Irrigation schemes that are supported by reservoirs provide a degree of protection against climate variability, but even in such systems yields remain sensitive to rainfall variation because the reservoirs generally only provide limited water to supplement rainfall.

The key features of the seasonal climate are illustrated in Figure 10 using data for Mandalay which lies very close to the edge of the CDZ and has broadly similar rainfall and temperature patterns. Temperatures peak in April just before the onset of the wet season, then drop gradually through the wet season before a more substantial drop during the northern hemisphere winter. The wet season lasts for about six months and typically shows a bimodal pattern with a relatively dry period in July.

Figure 10: Typical rainfall and temperature patterns
An extensive assessment of the CDZ was undertaken by IWMI and NEPS in 2013\(^3\). Some of the analysis of data presented in this report is compared to the conclusions of that report, hereafter referred to as the IWMI report.

2. **Available Data**

Key data for assessing irrigation schemes are rainfall and river flows (water availability) and evaporation (water requirements). Where evaporation data is not measured it can be estimated using climate data such as temperature, sunshine, wind speed and relative humidity. Data is available for various locations across the CDZ.

Rainfall and flow data collected and reviewed for this study covers 13 schemes, ranging from relatively small catchments with tank storage to large reservoirs. The catchment areas and the periods of available rainfall and flow data are shown in Table 34.

<table>
<thead>
<tr>
<th>Scheme</th>
<th>Area (km(^2))</th>
<th>Rainfall data</th>
<th>Flow data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ngwe Taung Tank</td>
<td>58</td>
<td>2006-14</td>
<td>2006-14</td>
</tr>
<tr>
<td>Kyeepinakk Dam</td>
<td>166</td>
<td>2006-14</td>
<td>2006-14</td>
</tr>
<tr>
<td>Yanpe Dam</td>
<td>218</td>
<td>2001-14</td>
<td>2006-14</td>
</tr>
<tr>
<td>Kinmundaung Dam</td>
<td>74</td>
<td>2001-14</td>
<td>1988-2014</td>
</tr>
<tr>
<td>Natmauk Dam</td>
<td>1121</td>
<td>2006-14</td>
<td>1995-2014</td>
</tr>
<tr>
<td>Saddan Dam</td>
<td>350</td>
<td>2006-14</td>
<td>1998-2014</td>
</tr>
<tr>
<td>Sun Dam</td>
<td>201</td>
<td>2006-14</td>
<td>2001-14</td>
</tr>
<tr>
<td>Thitson Dam</td>
<td>311</td>
<td>2006-14</td>
<td>1969-2014</td>
</tr>
<tr>
<td>Chaung Magyi Dam</td>
<td>241</td>
<td>2006-14</td>
<td>1962-2014</td>
</tr>
<tr>
<td>Chaung Gauk Dam</td>
<td>201</td>
<td>2006-14</td>
<td>1998-2014</td>
</tr>
<tr>
<td>Thinpone Dam</td>
<td>148</td>
<td>2006-14</td>
<td>2006-14</td>
</tr>
</tbody>
</table>

Note: Data complete for stated years except for 1982/83 flows at Meiktila; Mobye rainfall from nearest available station at Loikaw, other rainfall data from dam sites.

In order to assist with placing these mostly relatively short-term data sets in a longer term context, rainfall data has also been collected for Mandalay; this data is daily for 1967-2014. Further data was obtained for Mandalay from the Climate Explorer website (www.klimexp.knmi.nl), giving a combined series with about 115 years of data. This data is included in the Appendix to this report.

Monthly climate data was obtained for several stations across the region, covering standard variables including temperature, humidity, sunshine, wind speed and evaporation. It should be noted that most data records in Myanmar are in imperial units (inches, feet, cubic feet per second (cusecs), acres and acre-feet). This is reflected in this report, though where processing has been undertaken some outputs are in metric units.

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\(^3\) Water Resource Assessment of the Dry Zone of Myanmar, International Water Management Institute & National Engineering and Planning Services Ltd
3. Data Review

a. Rainfall

There is an inherent risk in the interpretation of rainfall records when the record shows "-", since a dash is widely used to say that there is no information, whereas it may be used to represent zero rainfall. Given the seasonal nature of rainfall in the CDZ, it is generally reasonable to interpret a dash as zero rainfall in the period from December to March, but when it occurs in April or November it is difficult to be sure. From May to October zero monthly rainfall is very unlikely, so that a dash probably indicates missing data; however, a completely dry month is not impossible.

In the Mandalay record the zero rainfall for September 1983 is believed to be incorrect; September has the highest average rainfall of all months and in the remaining 47 years of daily data the minimum September rainfall is 24mm and the minimum number of raindays is 6. The minimum September value in the extended monthly series from 1889 (total 114 years) is 23mm. The only other station with rainfall data for 1983 shows rainfall approximately 70% of its long-term average, and on this basis a value of 120mm has been estimated for Mandalay. The Climate Explorer website shows missing data for this period at Mandalay.

For most of the 13 schemes under review for this study the data has been taken as stated, but with one scheme (Thinpone) the stated annual average rainfall of 382mm was considered very low. Closer examination showed a significant incidence of probable missing data, and it is considered that the available data is too intermittent to be of value.

Across the remaining 12 schemes the average annual rainfall is 872mm which is very close to the long-term figure for Mandalay (853mm). There is significant variation between the schemes (from the varying periods of data), from 667 to 1243mm, also illustrated in the graphical presentation (Figure 7). Most stations show the dip in rainfall in July observed in the Mandalay record. The highest annual value is for Kinmungdaung; since nearby sites (Yanpe, Saddan, and Sunchaung) have significantly lower values caution is needed in using the Kinmungdaung data. (However, there can be substantial differences in rainfall between places quite close together, so data should not automatically be discounted just because it is different. The perception of the ID is that the rainfall at Kinmungdaung is indeed somewhat higher than other locations nearby.)

The long-term rainfall data for Mandalay shows little trend in annual rainfall (Figure 9). The linear best-fit line shown in the graph slopes slightly downwards, but this is very largely driven by the exceptionally low rainfall in 2014 and the trend is not considered significant.

More detailed analysis suggests that there may be a slight downward trend in dry season rainfall. Rainfall from November to April averages around 100mm (about 12% of the annual total); the data suggests that this has declined from around 105mm in the 1890s to just over 90mm in the early years of the present century. This dry season decline was not shown in the IWMI report, but this may be related to the way that the dry season was defined for that study (based on the retreat and onset of the wet season rather than specific calendar dates). IWMI reported that the major change in recent decades was a reduction in June rainfall; this is confirmed in the longer-term data for Mandalay (Figure 9). This is significant under the current operating arrangements whereby reservoirs are drawn down to almost completely by the end of the dry season and monsoon cropping is dependent on a timely start to the monsoon in June.
Figure 11: Average rainfall patterns across the CDZ

Figure 12: Annual rainfall at Mandalay
The daily data since 1967 suggests a decline in the number of raindays and consequently an increase in the average rainfall on days when it rains (Figure 14). There is no information on rainfall intensities, but it is likely that this change will indicate an increase in rainfall intensity (rather than increased duration of rainfall on days when rainfall occurs).

Figure 13: June rainfall at Mandalay
Figure 14: Annual number of raindays at Mandalay
The seasonality of rainfall is clearly shown by the average monthly rainfalls (Figure 7). The wet season lasts for about 6 months with fairly consistent average rainfalls of around 120-150mm/month, except for a drier period in July. There is some rainfall in the transition months of April and November, and very little rainfall from December to March. Extreme daily rainfalls are not unusual; the annual maximum daily rainfall quite often exceeds 100mm, and on one occasion exceeded 250mm (Figure 11).

Figure 15: Annual maximum daily rainfall at Mandalay

The onset and retreat of the wet season were assessed for a range of threshold conditions. The results when the criterion was defined as a minimum 50mm in 10 days are shown in Figure 12. There appears to be a slight trend for both the onset date and the end date to have got slightly earlier. However, this is unlikely to be statistically significant, matching the conclusions of IWMI.
b. Runoff

In order to facilitate comparison of flow data across schemes of differing catchment areas the flow values were converted to runoff in mm over the catchment area. It should be noted that in most cases no checks have been made of the stated catchment areas, although there is no reason to suspect that they are incorrect, and in two cases that have been checked the stated value was supported. The average runoffs are shown in Figure 13. Nearly all the peak flows occur in October, and the peak is more pronounced than that for rainfall. This is also illustrated in the comparison of average rainfall and runoff across all schemes excluding Thinpone (Figure 18). Some caution is required in relation to this graph because in most of the schemes the period of flow data is not the same as the period of rainfall data. Some stations with very long records showed substantial changes across the period of record. At Chaung Magyi, for example, flow values before about 1980 were very high compared to recent years; it is understood that inflows have only been based on a water balance since 1985, and that earlier ones were derived using a rating curve. With no information on the rating curve it was considered sensible to exclude the earlier data there, and all data before 1980 at other stations. The overall average runoff is about 210mm or about 25% of the average rainfall. In the peak month the runoff is just under 40% of rainfall. Based on experience elsewhere, the calculated average runoff is within the expected range.
Figure 17: Average runoff patterns

Figure 18: Average rainfall and runoff
The runoff data described above represents reservoir inflows, in almost all cases derived from a reservoir water balance. Although this method is subject to significant uncertainties, it may in fact be more reliable than data from a gauging station where the reliability of flow estimates is dependent on application of a rating curve which may involve extrapolation well beyond the range of measured flows (or the use of an out-of-date rating curve when regular discharge measurements have been discontinued).

The essential principle of the water balance calculation is that inflow may be estimated as the sum of outflow and change in storage. Outflows comprise releases (usually for irrigation) and discharges over the spillway when the reservoir is full. The releases can usually be determined reasonably accurately from records of gate openings and water level, using an empirical formula or table. Similarly, spills can be calculated from the design formula. Whilst this may not be very accurate if the reservoir level changes rapidly, the amount of spill is generally not very important as by definition it occurs when there is surplus water and the size of such a surplus is not important for operation and management of an irrigation system.

The change in storage is determined from the reservoir level and a lookup table showing reservoir level and storage (and sometimes also surface area). The reliability of such tables is often uncertain as they are usually based on pre-construction information such as a survey or estimates from a map, and have generally never been updated to account for sediment deposition within the reservoir.

The water balance calculations can in theory be done for any time step, but for a short time step (e.g., daily, or less) the derived inflow series may show substantial fluctuations because a small change in reservoir level (possibly influenced by the wind) may represent a large change in storage. When the time step is longer (e.g., a month) this is much less of a consideration.

An important consideration, particularly in a hot country, is whether evaporation and other losses are considered in the water balance, and similarly rain falling on the reservoir surface. It is possible to estimate evaporation (as an outflow) and rainfall (as an inflow) from local climate station data and the estimated reservoir area, but it is often simpler (as done in the CDZ) to ignore these factors and thereby calculate the net inflow. This could be negative in any particular time period if the true inflow is very small and is less than the evaporation losses. The way that any negative values are dealt with is likely to be critical in determining the reliability of the resulting inflow series. If negative values are replaced by zeroes then the overall inflow may be overstated. From the records that have been reviewed in more detail there is evidence of some inconsistency in relation to evaporation and/or derived negative values.

c. Evaporation and climate

Average evaporation for five stations in the CDZ is illustrated in Figure 15. There is a fair amount of variability, probably due to the difficulty of accurately measuring evaporation when there is significant rainfall, but the general pattern is reasonably consistent. The peak occurs in April. The main climatic driver for evaporation is generally temperature, and the maximum temperatures also occur in April (Figure 20). The annual evaporation averaged across the five stations is about 1,800mm.
Average climate parameter data for Mandalay is shown in Table 35.

Table 35: Climate averages – Mandalay

<table>
<thead>
<tr>
<th></th>
<th>max temp (°C)</th>
<th>min temp (°C)</th>
<th>mean temp (°C)</th>
<th>sunshine (hours/day)</th>
<th>relative humidity (%)</th>
<th>wind speed (km/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>30.0</td>
<td>14.4</td>
<td>22.2</td>
<td>8.8</td>
<td>79</td>
<td>10</td>
</tr>
<tr>
<td>Feb</td>
<td>33.6</td>
<td>16.6</td>
<td>25.1</td>
<td>8.5</td>
<td>66</td>
<td>20</td>
</tr>
<tr>
<td>Mar</td>
<td>37.3</td>
<td>21.3</td>
<td>29.3</td>
<td>8.1</td>
<td>57</td>
<td>49</td>
</tr>
<tr>
<td>Apr</td>
<td>39.3</td>
<td>25.5</td>
<td>32.4</td>
<td>7.9</td>
<td>60</td>
<td>71</td>
</tr>
<tr>
<td>May</td>
<td>36.7</td>
<td>26.3</td>
<td>31.5</td>
<td>7.4</td>
<td>70</td>
<td>66</td>
</tr>
<tr>
<td>Jun</td>
<td>35.6</td>
<td>26.5</td>
<td>31.1</td>
<td>6.7</td>
<td>73</td>
<td>100</td>
</tr>
<tr>
<td>Jul</td>
<td>35.5</td>
<td>26.5</td>
<td>31.0</td>
<td>5.2</td>
<td>75</td>
<td>101</td>
</tr>
<tr>
<td>Aug</td>
<td>34.5</td>
<td>25.8</td>
<td>30.2</td>
<td>5.5</td>
<td>79</td>
<td>64</td>
</tr>
<tr>
<td>Sep</td>
<td>34.1</td>
<td>25.6</td>
<td>29.8</td>
<td>5.5</td>
<td>81</td>
<td>42</td>
</tr>
<tr>
<td>Oct</td>
<td>33.5</td>
<td>24.3</td>
<td>28.9</td>
<td>7.0</td>
<td>82</td>
<td>19</td>
</tr>
<tr>
<td>Nov</td>
<td>31.9</td>
<td>20.4</td>
<td>26.1</td>
<td>8.2</td>
<td>79</td>
<td>10</td>
</tr>
<tr>
<td>Dec</td>
<td>28.8</td>
<td>16.4</td>
<td>22.6</td>
<td>8.1</td>
<td>81</td>
<td>6</td>
</tr>
<tr>
<td>Year</td>
<td>34.2</td>
<td>22.5</td>
<td>28.3</td>
<td>7.2</td>
<td>73</td>
<td>47</td>
</tr>
</tbody>
</table>
Temperature data for Mandalay (1932-2014, though with some gaps) shows a clear rising trend averaging more than 0.1°C per decade (Figure 20).

**Figure 20: Average annual temperature at Mandalay**

![Graph showing average annual temperature at Mandalay from 1930 to 2020 with a rising trend](image)

### d. Flood flows

There is limited information available on flood flows within the CDZ. Records of major floods are kept at the reservoirs, and these can be used to demonstrate the extent of flood protection provided by the reservoirs for the benefit of areas downstream. Reservoirs generally fill infrequently, with the result that downstream areas are fully protected against minor/moderate flood events. Major flood events are usually substantially attenuated, and it is possible for some warning to be given to people in downstream locations, based on the reservoir level and the speed with which it is rising towards the spill level. At Natmauk reservoir a major flood event in 2011 is estimated to have had an inflow peak of over 18,000ft³/s and an outflow peak of about 9,000ft³/s.

### 4. Reservoir operation

Reservoirs in the CDZ are annual rather than multi-year. This means that there is no expectation of storage being carried over from one year to the next (for water-years starting prior to the monsoon). However, the variability of the climate means that in some years there is significant storage remaining, and this influences the planning for the next irrigation season, in terms of the area to be irrigated and/or the choice of crops, and perhaps the date on which planting can begin.
Once the agricultural plans have been made, the plan for reservoir releases is prepared. With large areas to be planted with rice, which has a particularly large water requirement during land preparation, the theoretical water requirements (and hence required reservoir releases) are likely to be very high initially but to drop substantially as the cropping season proceeds. Unless the system is very well managed a pattern such as this may cause major difficulties for farmers when the releases are reduced. Consequently, it may in practice be better to plan a more even pattern of releases, implicitly forcing more efficient usage of water during the times of peak theoretical demand.

Historic records of reservoir releases do show relatively even patterns of releases, probably reflecting local experience that this is the easiest way to manage the system. It may, however, not be the most efficient in terms of crop yields relative to available water. During the cropping season there should be close communication between operators in the irrigation area and those at the dam. If there is surplus water at any time (perhaps because of local rainfall in the irrigation area) then reservoir releases should be reduced in order to conserve supplies. This should allow a larger area to be cropped in the next season. There is, however, little evidence of such pro-active management.

As noted in the previous section, when the reservoir level is rising the situation should be closely monitored in order that appropriate warnings of impending spill can be given to communities downstream.

B. Climate Change

1. Current climate

Myanmar has tropical monsoon weather with three distinct seasons; hot, rainy and cool seasons. Rainfall is strongly influenced by the monsoon, and annual totals vary from about 5,000mm in the coastal regions to less than 750mm in parts of the CDZ. Myanmar’s annual temperature ranges from 10°C to 32°C, with average mean values of 21°C in the northern lowlands, but much lower averages in the highlands and higher averages near the coast. In the CDZ the hottest period (April) has average maximum temperature of around 40°C, with extreme values higher than this.

It has been reported\textsuperscript{4,5} that the country has already experienced changes in its climate over recent decades, including:

a) Average temperature increasing by 0.7°C over the two decades to 2012.

b) An observed increase in total rainfall (with regional exceptions).

c) Longer dry seasons due to a decrease in the duration of the south-west monsoon season.

d) an increase in the prevalence of drought events.

e) an increase in intensity and frequency of cyclone/strong winds.

f) rainfall variability including erratic and record-breaking intense rainfall events.

g) an increase in the occurrence of flooding (including in August 2015) and storm surges.

h) an increase in extreme high temperatures.

Changes have not been uniform across the country. The analysis of rainfall data for Mandalay presented in section A.3.a above suggests that recorded trends there are minor, both in terms of total rainfall quantity and the timing of the monsoon. Similarly, IWMI questioned the evidence for changes to the timing of the monsoon. Mandalay temperature data does confirm the

\textsuperscript{4} Myanamar’s Initial National Communication under the United Nations Framework Convention on Climate Change; Ministry of Environmental Conservation and Forestry, 2012

\textsuperscript{5} Myanamar’s National Adaptation Programme of Action (NAPA) to Climate Change, Department of Meteorology and Hydrology, Ministry of Transport, 2012
increasing trend, though rather less rapidly than the 0.35°C per decade referred to in the previous paragraph.

There is some evidence to support the observations about the increasing prevalence of drought events. The Mandalay data was processed to determine the period (of a specified duration) in each year with the lowest total rainfall, for a range of durations. This analysis suggests a downward trend in the rainfall amount, for each duration studied (from 4 to 6 months). The results for 5 months (150 days) are shown in Figure 21.

Figure 21: Rainfall at Mandalay in driest 150-day period in each year

Myanmar is one of the most vulnerable countries to climate impacts (one Global Climate Risk Index ranks it as 2nd out of 178 countries), mostly as a result of its susceptibility to cyclones, strong winds, floods, storm surges, intense rains, extreme high temperatures, drought and wildfire. The devastating Cyclones Mala (2006), Nargis (2008) and Giri (2010) claimed thousands of lives, and Nargis ranks as one of the most devastating natural disasters in history with over 100,000 deaths caused along with significant economic damages. Climate-related impacts such as these have a discernible impact on economic growth and livelihoods for rural and urban areas.

Although the major impacts of cyclones are not directly experienced in the CDZ they do have impacts across the whole country because of many factors such as disrupted communications and transport.

2. Climate Vulnerability

Myanmar is particularly vulnerable to climate change as a result of the following compounding factors:

a) Employment and the national income is dependent on climate-sensitive sectors such as agriculture, forestry and natural resources;
b) Human populations and economic activities are concentrated in the coastal zone as well as in low-lying lands and are therefore exposed to long-term climatic impacts such as sea-level rise as well as an increase in cyclones and storm surge/flooding;
c) Exposure to both geological and meteorological hazards (e.g. earthquakes, floods, cyclones and tsunamis) as a result of the country’s location;
d) High poverty levels which affect the capacity of the country to respond to climate change related impacts; and
e) Limited technological capacity to prepare for the impacts of climate change or the consequences of climate change related events.

Specific impacts to groups in Myanmar as a result of climate change include:
a) Farmers will be greatly affected by an increase in intensity and severity of droughts and floods;
b) Fishermen will be affected by the impacts of extreme weather events (e.g. cyclones) on fish stocks;
c) Retail businesses will suffer as consumer goods and food crops increase in price as productivity decreases;
d) Poor households with limited access to health care will be increasingly vulnerable as the availability of work on farms decreases and the occurrence of infectious diseases increases; and
e) Women and children will be particularly vulnerable as they have been found to be more susceptible to the economic/livelihood losses as well as risk of abuse/violence/exploitation after extreme weather events, and poor households will struggle to send their children to school.

Climate change has the potential to combine with other environmental stresses including both anthropogenic and natural pressures to cause impacts for a range of socio-economic sectors.

3. Projected changes

Projected changes are taken from Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects – Asia, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

a. Temperature

Average temperatures are projected to increase, for instance increases in annual average temperatures of 1.4-1.7ºC by 2021-2050, compared to the 1971-2000 period. There are, however, regional variations in the warming trends, as well as seasonal variations. Warming is expected to be more pronounced in December – May, and in the Central and Northern regions. Available data for Mandalay (1932-2014) suggests an overall rate of rise of about 1.1ºC per century; there are signs of increase throughout the period, but with the rate of increase possibly higher since about 1990; the projected rise of 1.7ºC in 50 years looks high but is plausible.

b. Precipitation

The overall projected trends are for an increase in rainfall variability during the rainy season including an increase across the whole country from March – November (particularly in Northern Myanmar), and decrease between December and February. For instance, for 2051-2100, the whole country could receive a 10% increase in precipitation from March to November, but a decrease of up to 80% from December to February. Because rainfall is already very low from December to February the overall annual change would be an increase of close to the 10% indicated for March to November.
c. Other aspects

Other projected changes include an increase in clear sky days, exacerbating drought periods, and an increase in the occurrence and intensity of a range of extreme events.

4. Impact on water resources and irrigation

Increased rainfall will lead to increased runoff, but without detailed hydrological models it is difficult to quantify the likely change. In general, percentage changes in runoff would be expected to be greater than percentage changes in rainfall, but when consideration is given to increased evapotranspiration in the catchments (due to the projected higher temperatures and to the greater availability of water from the higher rainfall) it may be unwise to project an increase in runoff of any more than 10%.

In systems supported by reservoirs an increase in runoff will lead to an increase in potential cropping intensity, but this will not be proportionate to the increase in runoff because the available reservoir storage is fixed, and with increased runoff there will be a disproportionate increase in the amounts lost through spill. Model runs for example systems suggest that if all flows were to be increased by 10% (with no change to other variables) the cropping intensity might increase by around 5%.

In systems that are not supported by reservoirs it is not easy to generalize about the impact that an increase in runoff will have on cropping. This will depend on many factors, most importantly the timing of increases in runoff.

Crop water requirements will increase as a result of higher evapotranspiration rates (driven by higher temperatures, about which climate projections have little doubt), and direct evaporation losses from reservoirs would also increase. This means that the expected increase in cropping intensity would be scaled back.

Most climate projections suggest that there will be greater variability in conditions in future, both within a year (longer dry seasons or more severe flood flows, for example) and between years. Although a system supported by a reservoir has some in-built protection against climatic variability, it is probable that greater variability will have a negative impact on the average cropping intensity that can be supported, not least because the scale of potential reductions in intensity in dry years is greater than that of potential increases in wet years.

Taken together, it is considered that the projections for increased rainfall will have a beneficial impact on cropping intensities, but in percentage terms this will be much smaller than the change in rainfall. It would be unwise to make assumptions about increased cropping intensities, but it would be reasonable to conclude that climate change is unlikely to have a negative impact.

The expectation of greater variability in future conditions means that flood flows may increase. The reservoir will continue to provide alleviation of flood peaks, but the magnitude of flood events may increase. The climate projections do not contain sufficient detail to allow the increase to be quantified.

5. Mitigation

The fact that a reservoir provides flood protection (and possibly complete protection against moderate flood events) may, paradoxically, increase the risk from more severe events (even if the magnitude of flow in those events is attenuated by the reservoir). This is because communities downstream of a reservoir get used to the absence of flood events, so that when a flood does occur it has greater shock value. It is therefore very important that there are means of communication so that downstream communities can be given warning of impending floods. Monitoring of the water level in the reservoir should allow reasonable warnings to be given.
The increasing risk of flood events due to climate change reinforces the need for good communication so that appropriate warnings can be given.
V. SECTOR APPROACH

A. Proposed Sector-wide Intervention to Improve Irrigated Agriculture

1. Rationale for the Intervention

The irrigation components aim to ensure reliable and responsive delivery of irrigation services in selected systems and districts. This will include capacity building of the irrigation department, rehabilitation and modernization of the infrastructure, and improvement of management both by the ID and related agencies for the main system and the farmers for selected farmer-managed units (initially including all watercourses, and later selected secondary units).

The potential sub-projects are physically and hydrologically independent from each other (see Appendix 2). They are however linked institutionally, with the ID township offices each being responsible for several sub-projects, and they have many common agricultural features. DOA operates at a township level, and input suppliers and markets are also not specific to individual irrigation systems. For these and other reasons it is appropriate to develop a sector-wide approach.

Improved management by the ID across the District and Township will enable more systematic asset management across a number of systems which would ensure that limited funds will be prioritized according to need and hence assure sustainability. Enhanced procedures for irrigation management will be applicable to all systems in the respective township or district. Better agricultural services will benefit all irrigated areas (and also partially irrigated and rainfed lands). Measures to improve participation at tertiary canal level will strengthen social capital at village level, and hence facilitate access to a range of services and reduce the risk of local conflict.

The subproject comprising infrastructure and irrigation management improvements as set in this document should enable better water supply and hence have a direct impact on crop irrigated areas, which should increase through:
- Greater efficiency in dam operations and water use in the monsoon, reducing the amount of water used in the monsoon and hence increasing the volume stored for the subsequent summer season.
- Improvements in application and operational efficiency as a result of better infrastructure which enables better control of water.
- More systematic and timely arrangements for irrigation of marginal areas, with more reliable canal flows and less dependence on drainage from upstream areas.

Irrigation should have a wider impact through synergy with agricultural component activities which will be targeted at district level in the same areas. Improvements in water supply however should have a direct impact on crop yields through a combination of factors:
- More timely start to the irrigation season, in difficult to command areas.
- Reduction of drought-affected periods during the season.
- Avoidance of a decline in irrigation performance as infrastructure deteriorates.
- Avoidance of disruption to irrigation by flood damage and sedimentation.

Irrigation is just one of a number of interventions which will increase agricultural productivity. Few improvements are possible without a better water supply, but water alone is not sufficient. A range of agricultural interventions are proposed (Supporting Document 3) and together they should result in increased yields over a greater area and variety of crops.

There is potential to increase the summer crop areas - whether paddy or diversified crops. The saving in water in the monsoon combined with better water control at low flows should enable a significant increase in potentially irrigated area. There will be a benefit even if summer rice continues to be the preferred crop. However, a greater benefit can be achieved if non-rice crops
are grown, which will enable an even greater increase in area. The infrastructure will be
designed to make this possible, although actual diversification will depend on a range of other
factors and is not purely dependent on infrastructure or its management.
It is also recognized that flexibility on its own creates opportunities for greater misuse of the
system, increasing risks of water theft and conflict, but it has the potential to increase
productivity (for both individuals and as a whole). Capacity building for both water users and
systems managers is included in the program to ensure that these risks are avoided.

2. Intervention Activities and Outputs

The Project will finance investments in the irrigation and drainage sector, focusing on surface
gravity irrigation systems, with a target to enable crop diversification particularly in the summer
season. The Government has identified a list of priority projects in the CDZ which include
relatively large projects (5,000 to 25,000 acres mostly in two catchments in three districts
(Magway, Meiktila and Yamethin). These are relatively old projects where the irrigation system
needs extensive rehabilitation, and significant improvements to arrangements for water
management. Facilities in these two areas are in a poor state of repair and need urgent
rehabilitation.
Investments to strengthen agricultural value chains will be made as described in supplementary
document 3, since investments in water alone are not sufficient to increase agricultural
productivity.
Two core sub-projects have been identified and studied to feasibility level – Natmauk (24,955
acres) and Chaung Magyi (6,908 acres). The average cost per acre is estimated on the basis of
these two feasibility studies to be MMK 700,000 /acre (Table 34). It is therefore estimated that a
total of around 60,000 acres can be developed through this component of the project.
Table 36: Rehabilitation Costs by component (MMK/irrigated acre)

<table>
<thead>
<tr>
<th>Component</th>
<th>Main</th>
<th>Distributary</th>
<th>Tertiary</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Canal Structures</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Construction of Sediment Basins</td>
<td>90,483</td>
<td></td>
<td></td>
<td>90,483</td>
</tr>
<tr>
<td>b. Rehabilitation Siphons</td>
<td>477</td>
<td></td>
<td></td>
<td>477</td>
</tr>
<tr>
<td>c. Construction of Drop Structures</td>
<td>43,709</td>
<td>8,229</td>
<td></td>
<td>51,938</td>
</tr>
<tr>
<td>d. Rehabilitation of Drop Structures</td>
<td>114</td>
<td></td>
<td></td>
<td>114</td>
</tr>
<tr>
<td>e. New Check and Check-Drop Structures</td>
<td>77,623</td>
<td>45,689</td>
<td>13,745</td>
<td>137,057</td>
</tr>
<tr>
<td>f. Rehab. of Check and Check-Drop Structures</td>
<td>4,694</td>
<td>5</td>
<td></td>
<td>4,699</td>
</tr>
<tr>
<td>g. Construction of Head Regulators</td>
<td>38,928</td>
<td></td>
<td></td>
<td>38,928</td>
</tr>
<tr>
<td>h. Rehabilitation of Head Regulators</td>
<td>6,689</td>
<td>1,261</td>
<td></td>
<td>7,949</td>
</tr>
<tr>
<td>i. Construction of Direct Outlets</td>
<td>2,670</td>
<td>16,960</td>
<td></td>
<td>19,631</td>
</tr>
<tr>
<td>j. Rehabilitation of Direct Outlets</td>
<td>555</td>
<td></td>
<td></td>
<td>555</td>
</tr>
<tr>
<td><strong>Surface Water Drainage</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Construction of Cross-Drainage Culverts</td>
<td>4,602</td>
<td>11,293</td>
<td>272</td>
<td>16,167</td>
</tr>
<tr>
<td>b. Rehabilitation of Afflux Bunds</td>
<td>11,767</td>
<td></td>
<td></td>
<td>11,767</td>
</tr>
<tr>
<td><strong>Canal and Embankment Works</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Canal Resectioning</td>
<td>12,316</td>
<td>4,930</td>
<td>19,389</td>
<td>36,636</td>
</tr>
<tr>
<td>b. Embankment Strengthening</td>
<td>15,698</td>
<td>72,664</td>
<td></td>
<td>88,362</td>
</tr>
<tr>
<td>c. Jungle Clearance</td>
<td>-</td>
<td>23</td>
<td></td>
<td>23</td>
</tr>
<tr>
<td>d. Embankment Protection</td>
<td>5,510</td>
<td></td>
<td></td>
<td>5,510</td>
</tr>
<tr>
<td>d. Canal Lining</td>
<td>54,519</td>
<td>12,567</td>
<td></td>
<td>67,186</td>
</tr>
<tr>
<td><strong>Flow Measurement</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Measurement Flumes</td>
<td>5,824</td>
<td></td>
<td></td>
<td>5,824</td>
</tr>
<tr>
<td><strong>Advanced Irrigation systems</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Construction of Bridges</td>
<td>21,307</td>
<td>31,335</td>
<td>10,025</td>
<td>62,667</td>
</tr>
<tr>
<td>b. Rehabilitation of Bridges</td>
<td>211</td>
<td>6,022</td>
<td></td>
<td>6,232</td>
</tr>
<tr>
<td>c. Improvement of canal embankment roads</td>
<td>9,292</td>
<td>12,956</td>
<td></td>
<td>22,248</td>
</tr>
<tr>
<td>d. Rehabilitation of Dam Access Road</td>
<td>19,150</td>
<td></td>
<td></td>
<td>19,150</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>420,314</td>
<td>229,758</td>
<td>46,548</td>
<td>696,597</td>
</tr>
<tr>
<td>More than 5% of total cost: 54,519</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>More than 10% of total cost: 72,664</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

A further three to four sub-projects with an average area of 6,000 - 9,000 acres will be selected from the pipeline or others proposed by the ID and studied to feasibility level before confirming the selection. In order to ensure synergy with the agricultural component of the project, sub-projects will only be selected in districts where agricultural activities are to be undertaken. The outputs expected are improved irrigation infrastructure on about five irrigation systems in two or more districts of Mandalay and Magway region. The total area is expected to be at least 50,000 acres. Improved management arrangements will be set up to ensure the sustainability of the infrastructure and the ability to manage it in accordance with agricultural requirements without compromising other water users. A process for strengthening water user participation in system management will be initiated with pilot water user associations set up in three distributary canals in each system. The precise configuration of WUAs will be developed in a participatory manner.
Initially these will be informal groups at water course level based around existing myaunggaungs. These will be incrementally expanded and formalized through the project. A farmer representative body will be established, with an executive committee charged with undertaking day to day management of the watercourses and participation jointly with the ID on management of distributary canal. The ultimate objective is full management of DY canals by these new WUAs. The target during the lifetime of the project is WUA management in 15% of the area rehabilitated, to be used as demonstration for gradual extension of improved management across the entire project area. At least 30% of all farmer committees established will be female, including both female-headed households and female members of male-headed households as representatives.

The performance of the ID in managing the main system (including dams) will also be improved, through rationalization of the management committee structure and training of the township and field staff. Improved operational records will be maintained and used for ensuring that actual water distribution is in compliance with the plan. Key indicators will be the numbers of staff trained in asset management and irrigation operation, and the establishment of a comprehensive irrigation asset register and maintenance plan to ensure that infrastructure is kept in good condition.

B. Pipeline of Sub-projects

1. Screening Process Applied and List of Sub-projects

   a. Screening process

   A long list of potential projects will be drawn up by the PMU, including those screened to pre-feasibility and described below. Potential sub-projects will be identified from this list and within the project districts where agricultural component activities are ongoing or planned. Selection criteria are an essential part of an ADB Sector Project to guide the identification and selection of non-core subprojects to be financed under the Project. The selection criteria and the approval process for non-core subprojects to be financed under the Project are presented in Table 37 below. It is the PMU which shall review non-core candidate subprojects to be shortlisted using the Government confirmed criteria. Shortlisted projects will be studied to feasibility level to enable a final selection.

   b. Screening criteria

   Table 37: Sub-project screening criteria

<table>
<thead>
<tr>
<th></th>
<th>Sub-project screening criteria</th>
</tr>
</thead>
</table>
   1 | Sub-projects should be between 1,000 and 25,000 acres, and must have scope for improved overall irrigation efficiency and increased agricultural productivity |
   2 | The sub-project must have a command area that is conducive to diversification to higher-value crops, where farmers have the authority to diversify should they wish do so, and there should already be some evidence of actual diversified cropping in the summer season. |
   3 | There should be adequate physical access (roads and bridges) to input suppliers and markets, subject to minor improvements which are possible within the command area as part of the rehabilitation program |
   3 | The subproject must have adequate water available to meet the subproject’s irrigation water requirements for the proposed typical annual crop plan at least 4 out of 5 years |
   4 | Sub-projects should entail rehabilitating and upgrading an existing irrigation scheme. They may include new supplementary structures or canals within the existing |
command area, but should not require new canals to extend the command area.

5 The subproject must not have any significant negative social impact or cause conflict with established land or water users, including outside the sub-project area. There should be no requirement for involuntary land acquisition.

6 The subproject must not have any negative environmental impact for which affordable mitigation treatment cannot be incorporated into the subproject design. It should not have any major negative environmental impacts (including any negative impact on other users of the same source) which would require an environmental impact assessment study.

7 Social capital: sub-projects where farmers are willing to ensure maintenance and management of terminal units. Sub-projects having a good potential to form an effective WUA will be given higher priority (evidence of good existing cooperative arrangements, conflict resolution arrangements, local leadership, etc.).

8 The subproject must have projected incremental increase in farm income exceeding the projected incremental increase in annual production cost such as, but not limited to, agricultural inputs, and irrigation operation and maintenance.

9 Sub-projects must be technically feasible, financially and economically viable with economic internal rate of return (EIRR) of at least 12%.

10 There should be evidence of local demand for the project, with a formal request from the Township Administrator.

### 2. Summary Description of Non-Core Sub-Projects

13 schemes have been screened in four regions/states and assessed to prefeasibility level, as follows:

- The five schemes in Mandalay are grouped around Meiktila, spread across in five townships (Thazi, Wundwin, Meiktila, Pyawbwe and Yamethin), with most systems falling into more than one township (and hence management structure)
- The five systems in Magway are essentially contiguous areas in Myothit and Taungdwingyi townships, drawing water from the Yin River and its tributaries. Natmauk dam and weir is in Natmauk township but the irrigated area is in Myothit
- The single scheme in Sagaing at Kyeepinakk is adjacent to but separate from the much larger Shwebo irrigation system
- The two schemes in Kayah comprise the main irrigation areas around Loikaw, although there are a large number of smaller interlinked adjacent schemes drawing water from various rivers and tanks. The dam and upper part of Mobye is in Shan State.

Two of these have been studied to Feasibility Level (see Annexes I and II, and summaries in sections 3 and 4 below). Brief notes on the remaining eleven systems are presented here.
Figure 22  Overall location of pipeline projects

Irrigated Agriculture Inclusive Development Project

Segaing Sub-projects
Kyeepinakk

Magway Sub-projects
Natmauk
Sun Chaung
Saddan
Kinpuntaung
Yanpe

Mandalay Sub-projects
Thinpoine
Meiktila
Chaung Gauk
Chaung Magyi
Thitsone

Source: Overview Map of Myanmar
MIMU209v02
info.mimu@undp.org
**Thin Pone** is an old and complex scheme, incrementally developed over the last 50 years and now with three dams and extensive infrastructure but making considerable use of natural channels. As a result it has a relatively potential large command area relative to the water supply. The Thin Pone dam is furthest upstream and has a relatively large storage (21,000 acre ft), but it is supplemented by two downstream dams: Taung Pu Lu (13,465 acre ft) on the same river; and Tha Pyay Yoe (7,100 acre ft) on a tributary. These are close to the irrigation area but release water into the river from where it is diverted at the Inyin weir. In addition to the main command area (8,728 acres), there is a small area (300 acres) between Thin Pone and Tha Bo Yoe. Much of the lower part of the system is essentially rainfed but this is augmented by occasional supplementary irrigation during the monsoon plus drainage flows from the upper part of the system. The infrastructure in the tail is thus often in very poor condition and cannot be used to control flows reliably.

The main canal is short (2.23 miles) and in relatively good condition although the structures are in need of rehabilitation. There are four offtaking canals, with 7 minor canals. All need rehabilitation, although condition is variable – gate installation/replacement, scour protection, cleaning/resectioning are common problems.

The total reported cropping for the main irrigated crops is low (96% overall, including 10% in the summer which is almost entirely partly-irrigated cotton. The balance of the area is cultivated in the monsoon with other crops which are partially irrigated or rainfed. Even allowing for better use of rainfall, there is insufficient water for the command area. There is a small surplus which
could be saved and used for increased summer irrigation in some years, but this is an unusual event and thus will be difficult for farmers to plan around. Greater efficiency of water use in the monsoon should enable irrigation of a greater proportion of the monsoon crop.

**Meiktila Lake** dates back many centuries and is used for many purposes. With regard to irrigation, similar considerations as for Thin Pone apply to Meiktila lake, which has a smaller catchment and larger command area – and thus a very low irrigation intensity and poor condition of infrastructure. The lake is old and used for multiple purposes and has been studied as part of the Dutch-funded IWRM project. The poor condition of infrastructure, low intensity of irrigation and limited water resources mean that difficult decisions on prioritization of areas for rehabilitation would have to be taken. This would enable a small increase in the area irrigated (either fully or partially) during the monsoon but little or no change during the summer season.

The canals generally need significant rehabilitation, although there condition is very variable and there has been some investment in recent years. The irrigated cropping intensity is very low, as the command area (26,297 acres) has been overextended in comparison to the water supply so that much of the land probably gets a very sparse supply. Average paddy cultivation in the monsoon is just 2,700 acres with 600 acres of summer paddy and 250 acres of cotton. It would be more realistic to limit the command area to the maximum area which has been commanded in recent years in the monsoon (7,092 ha), with the balance being regarded as rainfed. Rehabilitation should thus be confined to just part of the system. However the cropping over even this area has been very variable.

**Chaung Gauk** is more modern (completed in 1996) than the first two schemes in Mandalay but still faces similar constraints to most of the systems in Mandalay region. The net irrigable area is 6,614 acres, but the average area irrigated in the monsoon is only 4,200 acres. The small area of monsoon paddy cropping (3,616 acres) is supplemented by some summer paddy (310 acres) and cotton (275 acres), but the annual average irrigation intensity is still less than 100%. The canals and structures are generally in poor condition and in need of rehabilitation, to improve control.

**Thitsone** is a large (10,748 acres) and relatively complex system in two townships. The dam and the upstream weir command a relatively small area in Yamethin township via 3 small distributary canals and around 37 direct outlets from the main canal. Water can then be diverted either from the river or from the main canal via a second weir into a more extensive canal network in Pyawbwe township and a further area in Yamethin.

The main infrastructure dates back to the 1950s, and where complete this is generally in good condition including extensive maintenance on the main canal in 2014. The three distributaries are being repaired (partly) in 2015, but the DOs are not being addressed and there is insufficient budget for Pyawbwe. The distributary canals are ungated and have no control structures – most outlets just pipes through banks, mostly blocked (and possibly abandoned). Most land is fallow in the summer season and is irrigated (for rice in the monsoon) from field to field with virtually no field channels.

The dominant crop in Yamethin is grape which is mainly irrigated by private tubewells and it is for this reason that the direct outlets are essentially abandoned - although they may be used for monsoon paddy on part of the area. There is some pumping from canals for grapes, but only adjacent to the main canal (both inside and outside the formal command area), but this probably provides a small proportion of the total water supply for grapes.

The main canal in Yamethin township has recently been repaired and cleaned. This is now in good condition although the offtaking canals lack gates – notably the link canal to a separate tank. The three distributary canals are undergoing repair at present, but these are simple unlined channels with no control structures. Irrigation is by cuts through the bank and then field to field. Most of this area is cultivated with a single crop of monsoon paddy, but there are some grapes. There are numerous direct outlets serving the grape area (further downstream), most of which appear to be either temporarily blocked or permanently abandoned. Some of the outlet
channels are overgrown or even cultivated over, suggesting that tubewell irrigation is dominant – most plots have a private well and there are several hundred in total.

The area within Pyawbwe township is irrigated from a second weir on the same river and can in theory also be supplied from the Yamethin main canal. This feeds into a network of natural and constructed distributary canals where there is a low intensity of irrigated cultivation and most of this land relies on rainfall and local drainage reuse rather than formal irrigation. A combination of limited water, poor water control and low command levels restricts the potential.

The cropping intensity is low, because of the shortage of water – just 5,711 acres monsoon paddy and 582 of summer paddy on average, plus 2,764 acres of cotton although this excludes grapes which are a very important and valuable crop which are largely irrigated from groundwater, even when within the formal command area of the system. There are reported to be around 2,000 acres, irrigated mainly via several hundred tubewells.

**Sun Chaung** is a small scheme completed in 2002, with a net command area of 7,125 acres and a reservoir with active storage of 24,576 ft (3.4ft over the command area, about 60% of the monsoon requirements). However, the reservoir spills in most years and the storage at the end of the monsoon is sufficient for a relatively large area of summer paddy.

There is a single main canal and five distributary canals, but almost half of the area is irrigated from direct outlets. This probably contributes to a low cropping intensity at the tail of the system. The canals are generally in good condition in the upper part of the system, but deteriorate significantly towards the tail – especially in the longest distributary canal (DY-3).

Given the reliability of water supply and the local preference for paddy, almost 100% monsoon paddy (6,725 acres) and large area of summer paddy (2,495 acres) is not surprising. Sesame is grown in small areas where some water is available but insufficient for paddy.

The low level of tertiary system development (10-20%) may have a limited impact as two crops of paddy are successfully grown over 30-50% of the area, but would limit the diversification needed to increase the intensity to 200%. The large areas directly irrigated from the tail of the main canal will also affect good water control over the whole system. The main immediate priorities are to improve the third distributary and its minor canals.

**Saddan** was built as part of the same programme as Natmauk but was not so extensively studied at feasibility level first. It is a smaller system, covering 10,550 acres and completed in 1998is in generally relatively good condition – although as is often the case the system deteriorates rapidly in the remote parts of the system at the end of long distributary canals. Like Sun Chaung this has a relatively good water supply, with reservoir storage at the end of the season being comparable to the annual utilization. However two of the driest years (2009) and 2012) had very little over-season storage and thus low summer cropping intensity. The main canal and structures are in good condition, although the distributaries are less functional – many structures have been bypassed (are missing), outlets do not have gates, canal banks are weak and inspection roads impassable even in the dry season. A small hydroelectric station has been installed on the main canal but is no longer in use.

Paddy is the preferred crop in both seasons, and generally 20% can be cultivated with two crops (10,100 in the monsoon and 2,000 in the summer, on average). Sesame may be grown on residual moisture on other land, with possibly a small amount of supplementary irrigation. Large areas of sesame can be seen in 2015 at the head of the system; this is given two light irrigations. Summer paddy is grown in the middle part of the system this year, with a small demonstration area for hybrid rice at the tail.

The main immediate priorities are to improve the distributary canals which are in poor condition, with weak banks and inadequate control structures. The banks would need to be strengthened and inspection roads reconstructed to enable these canals to function properly and command the offtakes, which mostly need reconstruction, including provision of gates. Without bank repairs it would not be possible to provide the require check structures in the distributary canals.
**Yanpe** is a 10,845 acre scheme completed in 2002, and is in very variable condition. The left main canal is quite good, but some of the distributaries in need of major rehabilitation and in some places virtual reconstruction. The right main canal has been badly affected by floods in 2013 which has disrupted irrigation even in the monsoon. In any case the reservoir is essentially empty now so there would be limited scope to increase irrigation even if the repairs are complete.

The left main canal is in reasonably good condition but the distributary canals are much less satisfactory with condition deteriorating to the extent that they are almost invisible at the tail in some cases. The right main canal cuts across drainage paths from Kinpuntaung and is very susceptible to flood damage as there are inadequate cross drainage works. This disrupts irrigation and hence the distributary canals are also poorly maintained with many non-functional structures.

Monsoon paddy cropping is close to 100% in most years, but summer cropping varies substantially depending on the previous year’s rainfall and averages 1,450 acres.

The Yanpe system is poor condition and has a poor water supply. No doubt poor service delivery contributes to poor standards of maintenance, but the cross drainage problems on the right main canal are the major constraint at present.

**Kinpuntaung** is one of the smallest systems under consideration, commanding just 5,190 acres and built in 1990. It has a rather erratic water supply, with a very high reported rainfall and flood flows from this area cause significant damage to the Yanpe system which is adjacent and runs across the tail of Kinpuntaung. There are large annual variations in rainfall and in inflow to the reservoir, which fills in about 50% of years. The storage at the end of the season is generally low and hence summer cropping is very variable. About 20% summer cropping is possible in six years out of 10.

The main canals are in adequate condition but the structures need significant repair. The same is true of the distributary canals where about half of the structures need repair. Quite large areas are irrigated by direct outlets from the main canal, which are ungated and thus create problems for water management.

The monsoon crop is relatively reliable (4,780 acres), which is not surprising given the high rainfall, but summer cropping is very variable (averaging 700 acres) as the reservoir storage is small (9,880 acre-ft, which is less than 2 ft over the command area).

The main immediate priorities are to improve the distributary canals which are in poor condition, with weak banks and inadequate control structures. The banks would need to be strengthened and inspection roads reconstructed to enable these canals to function properly and command the offtakes, which mostly need reconstruction, including provision of gates. Without bank repairs it would not be possible to provide the require check structures in the distributary canals.

**Kyeepinakk** is a small scheme in Sagaing Region adjacent to the much larger Shwebo irrigation system. Completed in 2002, it serves around 5,000 acres and may have an additional role for flood protection against to the Shwebo system. Like many areas this has suffered badly from drought over the last couple of years and was not even able to command the entire area in the monsoon in 2014 (a mid-monsoon 2014 image on google earth clearly shows the water level in the reservoir below the irrigation outlet level). In earlier years the area irrigated was quite high – with one of the highest cropping intensities of all sub-projects. However, the average inflow over the past three years has been less than 50% of the average since construction in 2002.

The reservoir has a capacity of 44,000 acre-ft, with a dead storage of 5,300 – thus a live storage of slightly greater than the annual release. The main canal is 43,900ft long with a capacity of 132 cusec, and with five distributary canals to irrigate 5,246 acres and 18 direct outlets to irrigate 212 acres. All canals need resectioning and repair, most structures are functional but many need repair.
The crops reported by the Irrigation Department show a good cropping intensity with 4,989 acres of monsoon paddy and 1,987 of summer paddy on average. This is a fairly new scheme which appears to have a relatively good water supply relative to command area, but has suffered from recent drought. The relatively large live storage (equivalent to 7.1 ft. over the command area) combined with high rainfall (39 inches) mean that there is sufficient water for further intensification of agriculture despite the relatively high cropping intensity at present.

**Mobye** is a 17,917 acre system in Kayah State taking water from a major reservoir, so water is essentially unlimited. Most water (around 90%) is diverted for hydropower and discharged directly to the Salween river, but there is ample for irrigation. It would be constrained by main canal capacity but these rarely operate at full discharge. Cultivation intensity is quite high in the middle reaches – essentially between the Shan/Kayah state boundary and Loikaw. The Shan state area is sparsely cultivated in the summer, as is the area south of Loikaw. These areas are slightly more remote from the villages and have less good access which may be a significant factor. There is sufficient water to cultivate the entire area in the summer, but the returns to agriculture make this less attractive than alternative employment.

There are two long main canals, both in quite good condition. The RMC in particular lacks sufficient cross-regulators and those that do exist are in poor condition. The lack of regulators and low water supply into the canals means that the area cultivated is much less than the potential. The RMC command a large area at the tail via long distributary canals where the topography is very flat and difficult to command entirely. A pump station raises the main canal level a small amount to command the tail, although this area can also be commanded by diversions from other smaller systems (in Demoso township).

It would not be practical to irrigate small plots within these areas due to the length of canal that would need to be operated with very low flows, and thus a logical decision appears to have been taken to cultivate them just in the monsoon. However, if a sufficiently high value crop could be identified and farmers persuaded to grow it on a fairly large scale, there appears to be little reason why water could not be provided. The improvement needed to the main canals to achieve this would be equally beneficial for the monsoon crop.

The topography is flat, resulting in problems of command at the tail, and requiring a pump station on the right main canal (managed by ID). The area downstream of the Pump Station is around 5,000 acres – almost one third of the total command area. There also significant areas of wetland in the upper part of the command, which are an important source of fish.

Although the monsoon crop has been fairly stable and probably represents a close approximation to the actual net command area, summer cropping has declined in recent years – for around 30% to 20-20%. As water is unconstrained this is presumably for other reasons – such as alternative employment opportunities - although the lack of control may be a significant factor.

There is clearly significant potential to increase irrigated agriculture at Mobye, and some improvements to the infrastructure would be needed to enable this. However, the decline in cropping has not been driven by deterioration of infrastructure and it is not clear that rehabilitation would be sufficient to reverse the trend. More lucrative off-farm opportunities are more likely to be the driver, and thus it is important to ensure that any proposed rehabilitation and agricultural developments fits in with other aspects of livelihoods.

**Ngwe Daung** is a much smaller and more water-constrained system immediately adjacent to Mobye in Kayah State. It takes water from a small reservoir and irrigates a small command area via a main canal and one distributary canal, via a number of minor canals and direct offtake. The main canal commands a narrow strip of land alongside the road between Loikaw and Demoso, which is quite intensively cultivated, while the distributary canal irrigates a larger area of land which is much more difficult to command – partly because of the condition of the canal and the topography but more importantly because of the way the canal is managed and the decisions on water allocation between the two canals.
Less operational data is available than for the other systems, but it appears to have a reasonably good water supply for the command area, which combined with rainfall enables good cropping in the monsoon and for part of the area in the summer. It is probably difficult to command all of the tail of some minors from the distributary canal which may, in practice, be largely rainfed or receive supplementary irrigation from adjacent run-of-river systems. Part of the distributary canal command is supplied by drainage from the main canal or directly be aqueducts from main canal minors but most of the land is not cultivated in the summer. Isolated patches of summer cultivation would not be practical, but it would in theory be possible to alternate between main and distributary canals each year. Improved canal regulation would be necessary to command some minors at low flows, but this would be a relatively small task. The decision would depend more on farmer preference – is it considered preferable for one group of farmers to get water each summer, leaving all others to seek alternative livelihoods every year, or would there be a preference to take it in turns to get summer irrigation. Paddy is the dominant crop in both seasons (4,700 and 1,700 acres respectively), although some areas of vegetables are grown, particularly close to Loikaw.

3. **Core Sub-project 1: Mandalay – Chaung Magyi**

Chaung Magyi is supplied from the Chaung Magyi River and regulated by the Chaung Magyi dam. The gross command area is 10,461 acres, with a net area of the order of 7,000 acres. The majority of the system is situated in the Pyawbwe Township (in the Yamethin district of Mandalay region), although approximately 11% of the command area is in Thazi Township (Meiktila District). The cropping pattern for Chaung Magyi based on agricultural surveys in the sub-project area in June 2015 (an unusually dry year), confirm that monsoon paddy predominates (81%), followed by sesame (29%, grown on residual moisture sometimes with a single supplementary irrigation) and cotton (27%). 9% of the area is under vegetables irrigated from groundwater. The overall cropping intensity was 150%. Summer paddy is also an important crop within the in some years, but not in 2015. Average cropping over the 10 years to 2013 was 6,040 acres monsoon paddy (94% of command area), 750 acres summer paddy (24%), and 3,000 acres cotton. Office statistics for sesame (partially irrigated), rainfed crops (pulses) and groundwater irrigated crops (onion and tomato) are not available.

Farm sizes within the Chaung Magyi system were reported to average 2.7 acres per household, comprising 2.1 acres irrigated from the canal system, 0.3 acres from groundwater and 0.4 acres rainfed. Almost half of household income comes from off-farm activities mainly migrant labor, minor trading and small scale income generating activities. On average, 54% of household income is from agriculture (36% from irrigated agriculture, 9% from rainfed agriculture, 2% from livestock and 6% from casual farm labor).

The Pyawbwe Township ID manages water distribution within and from the main canals and the current ID budget for operational staffing is not adequate to provide sufficient management throughout even the entire main system. Management of flows within and from the secondary canal systems is undertaken primarily by *Myaunggaungs* (who represent farmers within the tertiary systems), in coordination with *binthas* from the ID. *Myaunggaungs* are also responsible for management of water distribution throughout the tertiary systems, which is reported to be to the satisfaction of the majority of water users – however, problems due to shortages of water supplied from the main and secondary canal system are commonly reported.

Detailed infrastructure condition assessments were completed in July 2015 in study areas that comprised the main canal headworks (including the river weir), Left Main Canal (LMC), Distributary Canal 3 (DY 3) and Distributary Canal 7 (DY 7). Tertiary irrigation units within each of the distributary canal command areas were also studied. Topographic survey data collected
within the study areas was also studied as part of this assessment to gain a greater understanding of the nature of the system.
Consultations were carried out with ID staff (both Township and District level staff), ID staff members on the Agricultural Coordinating Committee (ACC), and farmers. Consultations focused on the perceived performance of the system, operation, maintenance, staffing, budgets and communication.
High concentrations of sediment and a lack of infrastructure at the head works to manage this results in significant deposition of sediment within the main and (to a lesser extent) the DY canals. This deposition reduces the conveyance capacity of the main canals to well below the design discharge, and reduces available flows within the system. There is a substantial recurrent cost in desilting the river as well the main and secondary canals which diverts funding away from maintenance of the water control infrastructure which is now failing throughout the system as a result, especially within the secondary canals.
Beyond the headworks, regulation of irrigation supplies throughout the system is poor. The provision of check structures within the system is inadequate, especially within the secondary canals. Where these are provided, they are ungated structures which offer no flexibility in the regulation of flow and maintain adequate water levels over a smaller range of canal discharges than gated structures are capable of. The majority of the regulating structures on the main canals have recently been rehabilitated, but the quality of works is sub-standard, and damage to these structures should be expected in the short term. Within the secondary canal system, the majority of the regulating structures have already failed and no longer offer any regulation benefit. None of the offtaking tertiary outlets are provided with any means of closure. These constraints result in a system which does not allow for reactive management in response to available water resources or irrigation demand, leading to inefficient use of available resources. The majority of field plots within tertiary systems rely on field to field flooding in order to receive irrigation water. The system of watercourses and field ditches within the tertiary units is currently insufficient to allow for the supply of irrigation water directly to each plot individually and therefore cannot fully support agriculture diversification.
The frequency of canal crossings is insufficient to meet the needs for transporting agricultural inputs and outputs across the DY canals. A number of existing bridges on the main and secondary canals are at risk of imminent failure, which shall further reduce the ability of the system to meet the community’s transportation needs. In addition, a number of informal crossings exist over the canal which pose a serious safety to risk to any who uses them. Staffing is inadequate to provide sufficient staff numbers to operate the canal system at the main and secondary level. Currently, laborers are undertaking the duties of Binthas in the operation of key irrigation infrastructure on the main canal while the management of flows within secondary canals is left largely to farmers and Myaunggaungs. Through low level involvement of farmer representation, the system management fails to adapt to the needs of farmers to overcome constraints to achieving higher agricultural incomes.
Some parts of the command areas at the tail of the system or at the tail of distributary canals get an unreliable supply. Some are supplied via secondary river weirs which are indirect and inefficient form of distribution of irrigation supplies.
The system is achieving cultivation over approximately 70% of its potential cultivatable area, and that the performance of the two main canals is similar. The performance of the DY canals varies from 24% to 113%, with the worst performing canals being situated at the tail of the LMC where water shortages appear to be felt most acutely due to inequities in supply to the secondary canals. On the RMC, there appears to be no strong correlation between the performance of a secondary canal and the distance along the main canal from which it offtakes. There is a clearly-defined wet season of duration about 6 months, building to a peak in October. The average annual rainfall is 670mm. Irrigation requirements range from 710mm for summer
paddy down to 139mm for gram. Monsoon paddy requires 485mm as only supplementary irrigation is required.

The sub-project is expected to result in improvement in effectiveness, efficiency, flexibility and reliability of canal irrigation supplies throughout the Chaung Magyi system command area. These improvements will be achieved through improvements to the system management, rehabilitation of the canal conveyance infrastructure, improved sediment management, provision of flexible water control infrastructure and development of tertiary command areas to support agricultural diversification.

The main expected measurable benefit is an increase in the average irrigated area. With a continuation of paddy cropping the additional area is estimated to be 640 acres in the monsoon and 690 acres in the summer season, a combined increase of 19% compared to the baseline. Alternatively, the summer increase could be over 2,000 acres if non-paddy crops are grown. Crop yields are expected to increase because of the greater reliability of supplies, and from synergy with changes recommended in the agricultural development component.

4. **Core Sub-project 2: Magway - Natmauk/Myothit**

The Natmauk irrigation scheme is fed by a dam on the Yin River and supplemented by a major unregulated tributary between the dam and the weir. The gross command area is around 36,000 acres with a net area of the order of 25,000 acres of cultivated land. The Palin reservoir separately supplies an area of around 1,000 acres within the boundary of the system. The entire system is situated in Magway District and Region; the dam, weir and headworks to the two main canals are all situated within Natmauk Township, while the majority of the command area (97% gross) is situated within the Myothit Township.

The cropping pattern for Natmauk based on agricultural surveys in the sub-project area in June 2015 (an unusually dry year), confirm that monsoon paddy predominates (61%), followed by sesame (40%, grown on residual moisture sometimes with a single supplementary irrigation) and pulses (15%). 13% of the surveyed area is under vegetables irrigated from groundwater, although this may be a slight overestimate of the overall situation. The overall cropping intensity was 135%. Summer paddy is also an important crop within the in some years, but not in 2015. Average cropping over the 10 years to 2013 was 23,900 acres monsoon paddy (94% of command area), 6,160 acres summer paddy (24%), and 240 acres sesame (1%). Official statistics for rainfed (pulses) and groundwater irrigated crops (onion and tomato) are not available.

Farm sizes within the Chaung Magyi system were reported to average 3.2 acres per household, comprising 2.2 acres irrigated from the canal system, 0.3 acres from groundwater and 0.8 acres rainfed. On average, 60% of household income is from agriculture (60% from irrigated agriculture, 15% from rainfed agriculture, 11% from livestock and 14% from casual farm labor). The remainder of household income comes from off-farm activities mainly migrant labor, minor trading and small scale income generating activities.

The irrigation system is managed primarily at an ID township level. Operation and maintenance of the dam and weir is undertaken by the Natmauk Township ID, while management of irrigation distribution downstream of the canal headworks is by the ID of Myothit Township (in which the majority of the command area lies). The current ID budget for operational staffing is not adequate to provide sufficient management throughout even the entire main system. Management of flows within and from the secondary canal systems is undertaken primarily by *Myaunggaungs* (who represent farmers within the tertiary systems), in coordination with *binthas* from the ID. *Myaunggaungs* are also responsible for management of water distribution throughout the tertiary systems, which is reported to be to the satisfaction of the majority of water users – however, problems due to shortages of water supplied from the main and secondary canal system are commonly reported.
Detailed infrastructure condition assessments were completed in July 2015 in study areas that comprised the main canal headworks (including the Yin river weir), Right Main Canal (RMC), Distributary Canal 3 (DY 3) and Distributary Canal 5 (DY 5). Tertiary irrigation units within each of the distributary canal command areas were also studied. Topographic survey data collected within the study areas was also studied as part of this assessment to gain a greater understanding of the nature of the system.

Consultations were carried out with ID staff in both townships and farmers. Consultations focused on the perceived performance of the system, operation, maintenance, staffing, budgets and communication.

The integrity of the embankments in the system is generally poor, with a number of breached sections and a number of at risk sections noted during field visits. The integrity of the canal embankments is a basic requirement for an irrigation system as it is integral to the distribution of water to the downstream areas. A breach of the canal embankment results in the partial or complete loss of downstream irrigation supplies. In addition, at least one continuous embankment is required in order to facilitate efficient inspection and management of the system. The issue of cross-drainage is also linked to embankment integrity insofar as failure to provide adequate cross-drainage on the main and DY canals is resulting in the breach of canal embankments. Furthermore, attempts to combine natural drainage flows into the main canals through spill-in weirs instead of bypassing the canal through a CDC, has resulted in damage to the canal prism and hydraulic structures.

The inflow of sediment into the main canals results in the deposition of this sediment within the DY canals and main canals themselves. Sediment deposition results in a reduced carrying capacity of the canals, and therefore reduces downstream availability of irrigation supplies. Sedimentation in downstream reaches of the Natmauk system are caused by a combination of factors, including Inflow of sediment from Yin River, overtopping / breaching of river embankments where these cross canal siphons, and erosion of canal banks, especially where the insitu material is non-cohesive.

Beyond the headworks, regulation of irrigation supplies throughout the system is poor. Head regulators are provided either with no gates, or poor quality gates which fail to seal adequately. None of the offtaking tertiary outlets are provided with any means of closure. This does not enable active management of the system in response to available water resources or irrigation demand, leading to inefficient use of available resources.

Throughout the system, ungated check structures are provided which offer no flexibility in the regulation of flow and maintain adequate water levels over a smaller range of canal discharges than gated structures are capable of. The majority of the regulating structures on the main canals are heavily damaged, and inadequate stilling provision is resulting in damage to downstream embankments which are at risk of breaching. Within the secondary canal system, the majority of the regulating structures have already failed and no longer offer any regulation benefit.

The majority of field plots within tertiary systems rely on field to field flooding in order to receive irrigation water. The system of watercourses and field ditches within the tertiary units is currently insufficient to allow for the supply of irrigation water directly to each plot individually and therefore cannot fully support agriculture diversification.

Rural connectivity. The frequency of canal crossings is insufficient to meet the needs for transporting agricultural inputs and outputs across the DY canals. As a result, vehicles are crossing via the canal bed of DY canals, causing damage to canal embankments. In addition, a number of existing bridges on the main and secondary canals are at risk of imminent failure.

Staffing is inadequate to provide sufficient staff numbers to operate the canal system at the main and secondary level. Currently, laborers are undertaking the duties of Binthas in the operation of key irrigation infrastructure on the main canal while the management of flows within secondary canals is left largely to farmers and Myaunggaungs. Through low level involvement
of farmer representation, the system management fails to adapt to the needs of farmers to overcome constraints to achieving higher agricultural incomes.

Some parts of the command areas at the tail of the system or at the tail of distributary canals get an unreliable supply – particularly the long DY canals towards the tail of the right bank. Some are supplied via secondary river weirs which are indirect and inefficient form of distribution of irrigation supplies.

There is a clearly-defined wet season of duration about 6 months, building to a peak in October. The average annual rainfall is 750mm. Irrigation requirements range from 750mm for summer paddy down to 45mm for gram. Monsoon paddy requires 340mm as only supplementary irrigation is required.

The sub-project is expected to result in improvement in effectiveness, efficiency, flexibility and reliability of canal irrigation supplies throughout the Natmauk system command area. These improvements will be achieved through improvements to the system management, rehabilitation of the canal conveyance infrastructure, improved sediment management, provision of flexible water control infrastructure and development of tertiary command areas to support agricultural diversification.

The main expected measurable benefit is an increase in the average irrigated area. With a continuation of paddy cropping the additional area is estimated to be 1400 acres in the monsoon and 2200 acres in the summer season, a combined increase of 14% compared to the baseline. Alternatively, the summer increase could be over 6,600 acres if non-paddy crops are grown. Crop yields are expected to increase because of the greater reliability of supplies, and from synergy with changes recommended in the agricultural development component.

C. Summary Due Diligence of the Core Sub-projects and the Whole Component

1. Technical

Technical due diligence included a comprehensive review of hydrological and hydraulic conditions, water requirements and the availability of water; the engineering and management aspects of irrigation; and consideration of agricultural issues. Topographic and surveys were conducted to complete the feasibility study of sample areas of the two core subprojects—the Chaung Magyi irrigation system with a command area of about 6,908 acres in Yamethin District or Mandalay Region, and Natmauk irrigation system with a command area of about 24,995 acres in Magway District of Magway region.

Project preparation considered (i) various technical options and their economic viability; (ii) the rationale for the proposed design, outcome, and outputs; (iii) options to maximize the cultivated and irrigated areas, and the benefits to farmers; (iv) measures to minimize adverse environmental and social impacts; and (v) past experience of ADB projects to make the project implementation arrangements robust. The project will use a participatory development approach under which the beneficiary farmers will be organized into emergent water users’ associations to take on gradually increasing roles in O&M of the secondary and tertiary canals.

The pipeline subprojects are generally similar in their technical features and performance and were reviewed in pre-feasibility studies. Detailed due diligence of each candidate sub-project will be undertaken as part of each feasibility study.

2. Economic and Financial

Economic and financial analysis for the two core subprojects and for the project as a whole has been undertaken and is presented in Supporting Document on Economic and Financial Analyses. The resulting estimated economic internal rates of return (EIRRs) for both core sub-projects are higher than the 12% cut-off rate for economic viability.
3. Governance

All procurement to be financed by ADB loan funds will be carried out in accordance with Procurement Guidelines (2015, as amended from time to time). Construction contracts will be procured through ICB bidding, and consulting services for feasibility studies, design, and supervision of construction will be procured using QCBS procedures. Topographical surveys and geotechnical investigations will be procured by LCB procedures.

4. Poverty and Social

By improving irrigation systems and providing a reliable supply of irrigation water to the farms, the project will substantially increase farm productivity and enhance the incomes and livelihoods of beneficiaries. Only one rice crop is currently grown in much of the project area each year, during the wet season, with much land relying on poor quality rainfed agriculture. The project will improve water supplies and enable a second crop in the dry season for a greater proportion of the project including some rice and cotton but particularly vegetables, and fruits. This will increase agricultural production and household farm incomes. The project is classified as effective gender mainstreaming. The project will enhance women's role in decision-making for water and agriculture management at the community level through participation in water users’ groups, and developing women’s leadership skills. Their capacity will also be built in improving on-farm water management, agriculture practices and coping with climate change. At least 25% of unskilled laborers employed in project civil works construction will be women who will be paid the same wages as men for similar work. The project will also provide training for women in administering water user groups, carrying out O&M, and managing water. A ‘gender action plan’ has been prepared which is in full compliance with ADB’s requirements. Specifically, women farmers will be guided in respect of entrepreneurial activities, business management, farming techniques, family nutrition, and pressure for equal opportunity in WUAs. Gender disaggregation will be applied within data collection for the sub-project’s performance evaluation. The gender action plan will also include improvements in gender fairness and relations among government offices as well as with farmer organizations.

5. Safeguards

Environment. The project is classified as category B for environment. The details of procedures to ensure that potential environmental impacts are mitigated are provided in the environmental assessment and review framework (EARF), and IEEs have been prepared for the two core subprojects. An environmental management plan has been prepared for the core subprojects to mitigate the impacts during construction and will be made part of any civil works contracts. IEEs and EMPs will be prepared for any additional subprojects prepared during implementation, and an IEE will be carried out for each. This will ensure that these subprojects are consistent with ADB’s Safeguard Policy Statement (2009). In the event of additional subprojects, environmental management plans will be included in the IEEs and civil works contracts. Adequate resources have been allocated for environmental safeguards preparation, implementation, monitoring, and reporting. There are no protected areas or original habitat within the sub-project area. Likewise, there are no known rare or endangered species within the area. Residual and fragmented forest habitat exists upstream of most sub-projects and is under potential threat from deforestation. The Magway and Mandalay sub-projects are all in the head reaches of the Yin and Samon rivers, respectively, which ultimately drain into the Ayeyardwady. There are substantial formal irrigation systems downstream on the Samon river, including several online reservoirs.
Samon is a tributary of the Pahlaing river which draws from the much wetter regions on the Shan plateau which are dammed at provide part of the drainage area of the Samon river. More efficient utilization of water in the sub-projects will not affect the availability further downstream as drainage flows return to the same river system and no total increase in water utilization or crop evapotranspiration is anticipated. The project rationale is to maximum the benefit this amount of water rather than to capture a greater proportion. Agro-chemicals, including insecticides, fungicides, and herbicides, are already in widespread use, whilst their usage is likely to increase in response to improved extension services and farming practices as well as to make best use of the better water supply. The risk of toxic bio-accumulation in humans from contaminated water is minimal, and greatly exceeded by the risk to farmers from primary application (dermal absorption and inhalation), especially from organochlorines and organophosphates. The sub-project will ensure that responsible selection, application, storage and disposal will be promoted through WUA and agricultural service channels, as well as introducing integrated pest management methods through farmer field schools.

**Involuntary resettlement.** The project is classified as category B for involuntary resettlement, and a resettlement framework has been prepared. Screening of the core sub-project irrigation systems has revealed no land acquisition or involuntary resettlement impacts, so no resettlement plans have been drawn up during project preparation. The requirement for there to be no involuntary resettlement has been made a selection criterion for subsequent pipeline projects. However, resettlement requirements will be verified during feasibility studies. Based on the application of the ADB Involuntary Resettlement (IR) check-list during a walkthrough of proposed irrigation infrastructure rehabilitation, no involuntary resettlement effects are expected for this sub-project. Development of canal roads and some improvement of tertiary irrigation networks are also planned, but these will be undertaken in a way which will not require involuntary resettlement. Field ditches will be improved along their existing alignments and will be confirmed by voluntary land donation agreements where appropriate. Access roads will be entirely confined with existing canal rights of way.

**6. Risks and Mitigating Measures**

There are a range of risks which could affect the impact of a project of this nature. The fact that it is a sector project in itself is a mitigation measure since sub-projects should draw on the lessons from earlier sub-projects, but the scale of sub-projects can still make this difficult as it will not be possible to wait for completion of the first project before embarking on subsequent projects. There are limited water resources and a relatively sparse network of monitoring stations, creating a risk that there will be insufficient water for the sub-projects. However, all projects are existing and functional and the project will improve them within the constraints of water limitations. The existence of reservoirs provides some resilience against variations in magnitude and timing of water availability. Improved reservoir operating rules have been proposed in each sub-project as a way of reducing the risks. There is also limited capacity and experience in modernizing irrigation, and national resources are sparse for planning and designing systems in the optimal way. International consultants have been proposed to provide appropriate expertise and also to build local capacity which will take increasing roles in later sub-projects. Infrastructure has been proposed which is generally similar to existing, but with significant improvements so that it can deliver the service required.
Simple, manually operated structures based on upstream control have been proposed throughout, with reliance on automatic gates which would be at risk of damage that they cannot be repaired locally. SCADA has also not been proposed for the same reason.

Increased participation by water users will be needed to ensure that the systems can be sustained, as there are likely be insufficient O&M funds from the Government in the long term for maintenance of the entire systems. There is little local precedent for effective water users’ organizations, but there is some experience with community-driven development. A patient and gradual approach will be adopted for building local willingness and capacity for greater involvement. This will be coupled with more systematic asset management planning to ensure that scarce resources are use most wisely.

Achievement of the full benefits will depend on coordinated implementation of irrigation and agricultural components, and the risk of fragmentation will be reduced by only implementing sub-projects in districts where agricultural component is implemented. Inclusion of an agricultural element in the irrigation FFS will further facilitate the coordination.

There is a lack of a strong legal framework for participation, coupled with a reluctance to get involved, especially by women, given the relative unprofitability of agriculture and the availability of off-farm employment opportunities. However, agriculture remains important for livelihoods, and hence the project will build local understanding of the need for greater involvement in irrigation management as a step towards greater participation. A long term capacity building program has been planned for this purpose. The need for a stronger legal basis will become clear during the implementation of the program.

O&M is essential for sustainability, but there are currently inadequate financing arrangements. Increased government budget allocations will be recommended, but the financing requirements will be reduced by systematic asset management which will enable the funds to be targeted and by greater participation by water users in secondary canal cleaning which is one of the main areas of weakness at present.

Small-scattered works can be difficult to implement and supervise effectively. Detailed planning with extensive consultation with users during designs and in the construction phase will aid quality control, and the ICB procurement procedures for contractors will ensure that only well-experienced and qualified contractors bid for the work.

D. Implementation of the Intervention

Feasibility studies for two core subprojects, Natmauk and Chaung Magyi are complete. Advance action will be required to prepare detailed designs and bidding documents for one system prior to loan effectiveness. Subject to the resources available for any advance actions, bidding documents may be prepared on the basis of detailed designs of part of the system. Completion of detailed designs for the remainder of the systems would be undertaken during construction by the Project Implementation Consultants working with the ID Design Unit. Topographic surveys will be undertaken prior to detailed design, with local stakeholder consultations undertaken in parallel by the advance action design team.

There is little local experience with systematic upgrading of irrigation infrastructure and management so it is important that lessons are learnt during the project. This is not straightforward as there will not be time to review performance of the first sub-projects before embarking on implementation of subsequent sub-projects, but there are opportunities. The procedures for walkthroughs/participatory studies for subsequent sub-projects will take account of the core-subproject and will be timed to enable observations of current performance or water distribution. A review of the entire detailed design process and outcomes will be undertaken at the tender stage of the first sub-project. This will be update prior to the start of all design packages. Construction will be confined to the dry seasons, to avoiding disruption to irrigation,
and will be undertaken in such a way that component areas will benefit as soon as construction is complete locally. The performance of these completed sub-areas will be reviewed in subsequent irrigation seasons so that any necessary modification can be made before any further construction.

Project Implementation Consultants (PIC) will be recruited to undertake feasibility studies and designs, and, with the ID, to supervise construction as well as to lead capacity building of the ID and WUGs. The estimated total requirement is 118 months of international consultants and 386 months of national consultants.

Prefeasibility studies of eleven other systems have been completed, indicating that seven of these are potentially feasible. The PIC will update these prefeasibility studies on the basis of more detailed information available in the two completed feasibility studies, and make a recommendation to the PMU for additional sub-projects. The PMU may propose additional sub-projects which will be screened to prefeasibility level by the PIC.

Potential sub-projects are quite large and thus the number to be implemented through the program will be small. Sub-projects will be selected from the ID long list and potentially others in the project area on the basis of the criteria given above. A feasibility study will be undertaken to confirm viability.
Feasibility studies of these non-core subprojects will be carried out by the PIC. The subprojects will be assessed on the selection criteria given above before making final decisions for investments. This will include preparation of an IEE for potential sub-projects and exclusion of any for which an EIA would be required or for which involuntary land acquisition would be required. Good practice for detailed design for irrigation requires detailed consultations at all levels. If good practice is followed, sub-projects will be consistent with safeguard requirements. This will, however, not be assumed and due diligence for each sub-project will be undertaken at the feasibility study stage for all sub-projects considered for inclusion in the pipeline.

Additional land requirement for the subproject improvement will be fulfilled through voluntary land donation by the beneficiaries. The PMU will screen for voluntary land donation during the feasibility study by completing the voluntary land donation screening checklist. Where subproject improvement requires canal extension or widening, the PMU will document the initial voluntary land donation due diligence and verify this diligence information during scheme detailed design and updated as necessary.

The subproject selection criteria will verify that the rehabilitation of an existing irrigation system is demand-led, and that members agree to voluntarily donate small parcels of their land (up to 10% of their agricultural land-holding in the command area) for irrigation enhancement. To address issues of coercion for donation of land, and for donation of land that exceeds 10% of agricultural land within the command area, the provisions of the grievance redress mechanism...
included in the Voluntary Land Donation Framework (VLDF) will be followed. An Indigenous Peoples screening due diligence will be carried out following the Indigenous Peoples Screening Framework, and any subproject not fulfilling the screening criteria will be dropped. After a subproject is assessed eligible and feasible as per the selection criteria, the feasibility study will be submitted for ADB’s concurrence prior to the start of the bidding process. After the detailed design, bidding documents will be prepared by the PMU with support from PMIC and bidding will be done according to the methods and procedures defined in the procurement plan. PMU will award the contracts and the ID at district level and PMIC will be responsible for on-site supervision of works. Environmental management plan for implementation and monitoring of the proposed mitigation measures will be prepared in accordance with the IEE. The overall schedule of activities related to irrigation infrastructure and management is set out below.

Figure 25: Implementation Schedule for Irrigation Component

References


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Appendix 1 Hydrological Data for Mandalay
Appendix 2  Hydrological Relationship between Pipeline Subprojects
Annex 1: Core Sub-project 1: Mandalay – Chaung Magyi (bound separately)
Annex 2: Core Sub-project 2: Magway - Natmauk/Myothit (bound separately)