REPUBLIC OF RWANDA

MINISTRY OF AGRICULTURE AND ANIMAL RESOURCES (MINAGRI)

LAND HUSBANDRY, WATER HARVESTING AND HILLSIDE
IRRIGATION PROJECT (LWH)

ENVIRONMENTAL MANAGEMENT PLAN
(EMP) FOR NYANZA 23 SUB PROJECT.

DRAFT REPORT

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ACRONYMS AND ABBREVIATIONS

- ARAPs: Abbreviated Resettlement Action Plans
- EMP: Environment Management Plan
- ETo: Evapotranspiration
- HCFs: Health Care Facilities
- FAO: Food and Agriculture Organization
- ISAR: Institut des Sciences Agronomiques du Rwanda
- IPM: Integrated Pests Management
- MINAGRI: Ministry of Agriculture and Animal Resources
- MININFRA: Ministry of Infrastructure
- MINISANTE: Ministry of Health
- LWH: Land Husbandry, Water Harvesting and Hillside Irrigation
- PAPs: Project Management Unit
- RAPs: Resettlement Action Plans
- PMF: Probable Maximum Flood
- REMA: Rwanda Environment Management Authority
- RPF: Resettlement Policy Framework
- WB: World Bank
ENVIROMENTAL MANAGEMENT PLAN FOR NYANZA – 23 SUB PROJECT

1. INTRODUCTION

This EMP should be implemented by several institutions, which are directly or indirectly involved in this subproject. These institutions are MINAGRI as the project implementer or borrower and sub contractors who were commissioned to construct the irrigation infrastructure and the subproject beneficiaries (farming communities in the area).

The persons and institutions responsible for implementing the plan will include cooperative/association members, LWH, MINAGRI, MININFRA, MINISANTE, REMA and contractors building the Nyanza 23 dam and drainage network.

This Nyanza 23 subproject EMP was prepared as part of other reports including the Resettlement Policy Framework (RPF), the Environmental and Social Management Framework (ESMF) and a full Environmental Impact Assessment (EIA) for the whole LWH program. Nyanza 23 LWH subproject is one of the 8 subprojects selected to be implemented during the 1st phase of the LWH program. These subprojects include 2 sites in Karongi, 2 sites in Bugesera, 2 sites in Gatsibo, 1 site in Kayonza and 1 site in Nyanza.

The objectives of this Environmental Management Plan (EMP) are:
1. To bring the project into compliance with applicable national environmental and social legal requirements and the World Bank’s environmental and social policies OP 4.01;
2. To outline the mitigating/enhancing, monitoring, consultative and institutional measures required to prevent, minimize, mitigate or compensate for adverse environmental and social impacts and/or to enhance the subproject beneficial impacts;
3. To address capacity building requirements to strengthen the Borrower’s environmental and social capacities if necessary.

2. PROJECT DESCRIPTION AND LOCATION

2.1 Land use categories in Nyanza 23

For the sake of planning and implementation of the different land-husbandry options with distinct influence to the overall irrigation program, the entire watershed is partitioned and categorized into the following 5 major categories.
1. Water-catchment---- areas of the entire watershed that are the main source of the water to be harvested in the down-catchment reservoir and drains through the Silt-Trap zone.
2. Silt Trap-zone — a land part of the Water-catchment as it contributes to the water that drains directly to the Reservoir, and which is designed to filter the silt that comes from the water catchment to the reservoir

3. Reservoir — land designed to be filled by water draining from the Water-catchment and the Silt-trap Zone. This zone is further partitioned onto three sub-zones.

4. Command-area Catchment — land which is up-hill of the command area that could contribute runoff and flood to the down-catchment command area

5. Command area — lands designed to be irrigated in dry seasons by the water to be harvested in the reservoir during the rainy seasons.

Figure 1: Location of Nyanza dam watershed.

2.2 Description of different land types categories

2.2.1 Water-catchment area

The water catchment of Nyanza-23 project site is about 235 ha including the silt trap zones and the water catchment covers 33% of the total land area of the project site. As shown in Table 2-3, in the water-catchment area, agricultural land covers 52% of the water catchment. The topographic feature of the water catchment includes slope ranges up to 40% and the agricultural land distributed in the three slope category 53, 62 and 10 hectares of agricultural land in 0-6, 6-16 and 16-40% of slope category respectively. To this
effect, all types of physical and biological soil conservation measures including radical terraces are recommended for the Nyanza-23 project area.

Table 1. Land use /land cover of different slope categories of the water-catchment (including the silt-trap zones)

<table>
<thead>
<tr>
<th>Existing land cover</th>
<th>Valid slope ranges</th>
<th>TOTAL</th>
<th>% of land use</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-6%</td>
<td>6-16%</td>
<td>16-40%</td>
</tr>
<tr>
<td>Agricultural land</td>
<td>31.87</td>
<td>44.79</td>
<td>45.95</td>
</tr>
<tr>
<td>Bush and Shrubland</td>
<td>9.46</td>
<td>13.82</td>
<td>18.67</td>
</tr>
<tr>
<td>Grassland</td>
<td>5.39</td>
<td>7.74</td>
<td>12.52</td>
</tr>
<tr>
<td>Natural forest</td>
<td>1.66</td>
<td>1.73</td>
<td>9.78</td>
</tr>
<tr>
<td>Planted forest</td>
<td>2.95</td>
<td>8.54</td>
<td>5.54</td>
</tr>
<tr>
<td>Riverine vegetation</td>
<td>0.34</td>
<td>0.67</td>
<td>0.35</td>
</tr>
<tr>
<td>TOTAL</td>
<td>51.67</td>
<td>77.29</td>
<td>92.81</td>
</tr>
<tr>
<td>% of land cover</td>
<td>21.93</td>
<td>32.81</td>
<td>39.40</td>
</tr>
</tbody>
</table>

2.2.2 Silt-trap zone

As it stands today, 65% of the area (22 ha) is agricultural land which can be a huge source of silt to down-catchment reservoir. As a blessing in a disguise, significant portion of this land unit is in slope range of 0-6 percent which indicates that the water propelling into the reservoir after the rain is not flowing rapidly as it could have been if the slope range was very steep. No land is in slope category of >40% slope.

Some 35% of the area (~12.6 ha) is covered by natural vegetation. Though it surrounds the outlet of the Water-Catchment, there is no riverine vegetation identified in this land unit. Compensation of the agricultural land is an issue here as this may be the only source of food crop for some families.

The land covered by bush and shrub is significant. It accounts for 18.4% of this land unit or 6.24 hectare. The quality and stalking density is poor and requires good attention for improvement. Stalk refinement operations and enrichment planting is required. Those in the tree-belt would have to be enriched by tree planting while those in the shrub-belt would have to be enriched with quality shrub seedlings. Those in the grass-belt would have to be replaced by sawing or sodding grass sods or sods respectively.

Grassland is part of the land use already. Some 2 ha or 6.5% of this land unit is already covered by grass vegetation. However, the grass to be planted in this catchment must be having a quality of erect and spreading Culm such as Elephant Grass. Therefore, replacing may be necessary.

Land owners have already the experience of planting trees in this land unit. Therefore conducting comparative assessment of the best alternative tree species of commercial value and up-scaling the tree planting effort would contribute to successful Silt-Trap zone establishment.

Because some 35 % of the land is already covered by perennial vegetations, changing the total land use into perennial cover may not be difficult. However, one needs to consider fruit plants, palatable and known feed quality shrubs and fodder grasses which can fetch comparatively better income for the land users.
Table 2. Land use /land cover of the Silt-trap zones in the different slope categories.

<table>
<thead>
<tr>
<th>Land use</th>
<th>0-6%</th>
<th>6-16%</th>
<th>16-40%</th>
<th>TOTAL</th>
<th>% OF LANDUSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural land</td>
<td>7.75</td>
<td>6.76</td>
<td>7.56</td>
<td>22.07</td>
<td>65.2</td>
</tr>
<tr>
<td>Bush and Shrubland</td>
<td>3.08</td>
<td>1.96</td>
<td>1.2</td>
<td>6.24</td>
<td>18.4</td>
</tr>
<tr>
<td>Grassland</td>
<td>0.43</td>
<td>1.07</td>
<td>0.69</td>
<td>2.19</td>
<td>6.5</td>
</tr>
<tr>
<td>Natural forest</td>
<td>0.03</td>
<td>0.19</td>
<td>0.49</td>
<td>0.71</td>
<td>2.1</td>
</tr>
<tr>
<td>Planted forest</td>
<td>1.33</td>
<td>0.94</td>
<td>0.37</td>
<td>2.64</td>
<td>7.8</td>
</tr>
</tbody>
</table>

2.2.3 Reservoir area/ Command area

In the proposed and designed command area, nearly 75% of the area is already covered by agricultural land including the alternately cropped riverine lands 23%. The grassland coverage is significant totaling 18.32 ha or 15.2 of the total command area. The total land area that can easily be changed into irrigable land becomes 90% when it includes the grass land.

The portion of the land that is covered by plantation and natural vegetations accounts for some 10%. This requires clearing and causes change of land use/land cover. However, because the land is to be planted with perennial crops that also play similar ecosystem conservation role, no environmental change is expected. Actually, because the existing plantation is Eucalyptus, it positive change is expected to come.

Most of the land in the command area (67.7%) occurs in slope ranges of less than 16 %. Therefore, leveling for irrigation could be achieved by soil buds that are not costly. But quite substantial amount of the topography is in slope ranges of 16-40% sloe where radical terracing would be required. Land above 40% is almost inexistent. Please refer to the land use and their respective slope classes in Table 3.

Table 3. The existing land use/ land cover of the Command area of Nyanza-23 site

<table>
<thead>
<tr>
<th>Land use</th>
<th>0-6%</th>
<th>6-16%</th>
<th>16-40%</th>
<th>40-60%</th>
<th>TOTAL</th>
<th>% by land use type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural land</td>
<td>9.06</td>
<td>32.49</td>
<td>20.57</td>
<td>0.08</td>
<td>62.2</td>
<td>51.6</td>
</tr>
<tr>
<td>Riverine land (alternately cropped)</td>
<td>7.28</td>
<td>13.52</td>
<td>6.66</td>
<td>0.22</td>
<td>27.68</td>
<td>23.0</td>
</tr>
<tr>
<td>Bush and Shrubland</td>
<td>0.17</td>
<td>0.78</td>
<td>0.27</td>
<td>0.02</td>
<td>1.24</td>
<td>1.0</td>
</tr>
<tr>
<td>Grassland</td>
<td>1.59</td>
<td>8.35</td>
<td>8.02</td>
<td>0.36</td>
<td>18.32</td>
<td>15.2</td>
</tr>
<tr>
<td>Natural forest</td>
<td>1.28</td>
<td>6.12</td>
<td>1.39</td>
<td>0</td>
<td>8.79</td>
<td>7.3</td>
</tr>
<tr>
<td>Planted forest</td>
<td>0.15</td>
<td>2.04</td>
<td>0.13</td>
<td>0</td>
<td>2.32</td>
<td>1.9</td>
</tr>
<tr>
<td>TOTAL</td>
<td>19.53</td>
<td>63.3</td>
<td>37.04</td>
<td>0.68</td>
<td>120.55</td>
<td></td>
</tr>
<tr>
<td>% of slope</td>
<td>16.20</td>
<td>52.51</td>
<td>30.73</td>
<td>0.56</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

2.2.4 Command-Area Catchment

The command area catchment is more than 334 hectares and accounts for 47% of the entire project site. Both plantation and natural forests account for less than 20 % of the area and the forest stalk is very poor where stalk refinement and improved mangemnt would make significant difference in its economic contributions to the owners.
Nearly 59% of the command area catchment is intensively cultivated. More than half of this is situated in slope ranges of 16-40% slope where radical terracing is designed. Even in higher slopes of 40 – 60%, the contribution of agriculture is dominating as compared to other land uses. Therefore, unless comprehensive land-husbandry is put in place, the fact that majority of this catchment is under agriculture poses significant danger to down-catchment irrigable fields.

Most of the lands in the command area are in slope ranges of 16 – 40%. This is typical land topography of Rwanda. This is also where we have recommended and designed to be the cropping limit for annual crops unless otherwise intercropped along with perennial crops. Lands in slope ranges of greater than 60% are negligible in size and are occupied by natural bushy vegetation and Grasses. However, in the entire catchment, the coverage of grasslands, natural forest and plantations forest is 11.2, 9.2, and 9.5% respectively. Please refer to Table 4 for the coverage of the different land use types in the respective topography (slope) classes.

Table 4. Land use/land cover types of the Command-area Catchment at Nyanza-23 site

<table>
<thead>
<tr>
<th>Existing land cover</th>
<th>0-6%</th>
<th>6-16%</th>
<th>16-40%</th>
<th>40-60%</th>
<th>60-120%</th>
<th>TOTAL</th>
<th>% by land use type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural land</td>
<td>20.58</td>
<td>61.54</td>
<td>103.80</td>
<td>10.45</td>
<td>0.00</td>
<td>196.37</td>
<td>58.7</td>
</tr>
<tr>
<td>Bush and Shrubland</td>
<td>2.56</td>
<td>6.42</td>
<td>8.74</td>
<td>0.92</td>
<td>0.00</td>
<td>18.64</td>
<td>5.6</td>
</tr>
<tr>
<td>Grassland</td>
<td>5.41</td>
<td>12.62</td>
<td>18.56</td>
<td>1.43</td>
<td>0.00</td>
<td>38.02</td>
<td>11.4</td>
</tr>
<tr>
<td>Natural forest</td>
<td>0.92</td>
<td>6.75</td>
<td>19.25</td>
<td>3.47</td>
<td>0.09</td>
<td>30.48</td>
<td>9.1</td>
</tr>
<tr>
<td>Planted forest</td>
<td>4.62</td>
<td>8.25</td>
<td>13.86</td>
<td>4.49</td>
<td>0.72</td>
<td>31.94</td>
<td>9.5</td>
</tr>
<tr>
<td>Riverine vegetation</td>
<td>1.57</td>
<td>8.84</td>
<td>8.51</td>
<td>0.44</td>
<td>0.00</td>
<td>19.36</td>
<td>5.8</td>
</tr>
<tr>
<td>Total</td>
<td>35.66</td>
<td>104.42</td>
<td>172.72</td>
<td>21.2</td>
<td>0.81</td>
<td>334.81</td>
<td>100</td>
</tr>
<tr>
<td>% by soil depth</td>
<td>10.65</td>
<td>31.19</td>
<td>51.59</td>
<td>6.33</td>
<td>0.00</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>
Figure 2. Land Cover Map of Nyanza 23.

2.3 Project Description /Components
This section describes the different components of the project, design and construction equipment description.

2.3.1 Dam Component
The project area is located by the side of the all-weather road about 7-10 km from the district office in Nyanza town on the left and right banks of Gisuma River. The dam axis is located on 0468128E, 9741736N and elevation 1711 masl.

The Gisuma River at the proposed Nyanza dam site has a catchment area of 2.94 km2. The steep slopes of the watershed are moderately vegetated. The river has a defined course in the vicinity of the dam site with bottom width about 3.5 m and a depth 1.8 m with silt bed and bank.

A zoned dam of 16.00 total height, 8m top width and 180m crest length is designed taking the hydrological, geological, geotechnical and geophysical inputs into consideration. It has a clay core, a maximum positive cutoff of 2.5m depth, granular soil upstream and downstream shells. Filters are provided at the interfaces of the core and the shells to protect the core and maintain stability. A toe drain is provided to collect seepage passing through the dam body and conduct it to a drainage channel. The upstream shell face is reinforced
with riprap to protect it from wave attack. The downstream slope has two berms placed at 5m vertical interval and the surface is provided with biological erosion protection (natural grass cover). The upstream and downstream slopes of the dam are 3H:1V and 2H:1V. All the dimensions of various components and slopes of the dam are obtained according to renowned standards and practices by rigorous analyses and computations.

A chute spillway is provided cutting the rock through the left abutment for flood evacuation. It has a 29m long approach channel and 103m long supercritical discharge channel, 5.5m long energy dissipation basin and 32m long exit channel. Spillway control structure is disregarded to reduce excavation cost, but the discharge channel is designed as a supercritical channel to carry the discharge efficiently. The channel parts that cut through rock are lined with 10cm thick C20 blinding concrete while those cutting through soil are lined with 40cm masonry. A standard Type IV energy dissipation basin is designed to reduce the energy of the flow coming from a very steep slope.

A 400mm diameter 112m length steel drop-inlet outlet pipe with a butterfly valve is designed to regulate the flow according to predetermined design discharge of 250 lit/s to the hill-side irrigation. The pipe can also be used to evacuate the reservoir when unforeseen situation occurs. It passes through the right abutment as a cut and cover conduit. It is provided with a reinforced concrete casing to reduce external soil pressure, and collars to reduce seepage around it. It is also provided with a trash rack to prevent entry of particles of size larger than 4cm into the outlet and irrigation pipe system. A simple movable wooden guard gate is designed for use in case of an emergency situation such as malfunctioning of the control valve. The dam is planned to be constructed in three months duration during the dry period.

The Nyanza-23 earth dam is designed by satisfying the following criteria for safe design of an earth dam:

- The dam must be safe against overtopping during occurrence of flood and also by wave action.
- The seepage line should be well within the downstream face.
- The upstream and downstream slopes should be stable under critical or adverse conditions.
- The foundation shear stresses should be within safe limits.
- There should be no opportunity for the free passage of water from the upstream to the downstream face.
- The dam and foundation should be safe against piping.
- The upstream slope must be protected against erosion by wave action and the crest and downstream slope must be protected against erosion due to wind and rain.
Salient features

Location
- Easting: 467968.73 UTM
- Northing: 9741511.23 UTM
- Altitude: 1699.79 masl

Reservoir
- Area submerged: 12.37ha at NPL and 13.16ha at MWL
- Maximum water level (MWL): 1714.40 masl
- NPL and Storage: 1714.00 masl, 0.69 Mm³
- MDDL: 1704.00 masl

Dam
- Type: Zoned earth fill dam
- Crest length: 180m
- Height: 16.00m

Spillway
- Type: Chute
- Width: 4m
- Approach channel length: 29m
- Discharge channel length: 103m
- Energy dissipation length: 5.5m
- Exit channel length: 32m

Outlet
- Pipe diameter: 400mm
- Pipe length: 112m

2.3.1.1 Dam Safety Instrumentation
The condition of the dam and its overall safety will need to be checked regularly to demonstrate that the dam is performing safely in accordance with the design assumptions. Dam Safety Instrumentation shall give meaningful information and clues to the various problems and play an important role in checking the safety of structures. Their prime function will be to reveal abnormalities, which may have the potential to develop into serious incidents or failure. Hence solution will be given to the problem accordingly.

2.3.1.2 Types of Measurement
The parameters that are necessary in monitoring dam condition are:
- Pore water pressure and uplift
- Internal and External movement
- Seepage and Leakage
- Strains and stresses
- Seismic forces

Pore water pressure
Pore water pressure measurement enables to know the seepage pattern in the embankment and foundation after the reservoir impoundment. It will give Valuable information of dam pore pressure at end of construction, at steady and draw down condition. The measured data helps to take remedial measures.

The vibrating wire piezometer is one of a device for measuring pore water pressure in a foundation and embankment. It is proposed to install the pore pressure piezometer at different levels, i.e. 4 in numbers at the foundation level, 5 numbers in the embankment section at different levels. All these are connected together through tubes and led to the terminal well located on the downstream side.
**Seepage and leakage**
Measurement of seepage through the dam body, foundations & abutments of the dam indicates erosion or blocking of downstream drains. Seepage measurements also indicate the fault zone which is labile to erosion of fill material and at higher level creation of piping. It provides useful information about the performance of the structure and seepage control measures. V-notch has to be installed in the surface drain at the toe of dam to measure seepage discharge at regular interval of time.

**Movements**
Measurement of internal and external movements created due to deformations of upstream and downstream slopes under different conditions of reservoir operations is necessary. It indicates the likely development of shear failure at weak points in the body of the embankment.

The measurement of surface movement of the embankment dam shall be made by means of installing 6 number of surface settlement points of which 3 of them are along the crest of the dam and the other are on downstream slope and shall be monitored by surveying instrument referenced to fixed bench mark.

**Strains and stresses**
Strains can be calculated from displacement or measured directly however stress measurement in earthen dam is difficult due to complex distribution. To use the measured data it needs considerable judgment in data interpretation.

The installations of instruments for measuring movements are provided at important locations. Maximum vertical movement normally occurs at mid height of structure and maximum horizontal movement at middle of slopes. Therefore two horizontal movement instrument at mid slope of structure and two vertical movement instruments are provided. For recording vertical movement cross arms installation has been proposed. Similarly inclinometer instruments have been proposed for registering horizontal movements.

**Seismicity**
Instruments for measuring and monitoring the intensity of ground motions during the earthquake are required to be installed. Measurement of seismicity is important as it causes sudden dynamic loading. The instruments for recording of seismic events proposed to be installed for the dam consists of one accelerograph and structural response recorder at the top of the dam.
Others
Other measurements aid in interpretation of the main instrumentation data. Reservoir water level, wave height, meteorological data, silt deposit recorder are helpful in analyzing the main instrument observation.

Climatological station having rain gauge, thermometer, evaporation, wind speed and direction measurement has to established. Wind setup recorder has also to be installed near up stream face of the dam.

2.3.2 Irrigation Component
The project area is located in Southern province Nyanza District in Rwabicuma sectors which is around 80 km far from Kigali and 8 km from nearest town Karambo-A. The project site is in the right and left bank of the river. The geographical location of the command area lies between 9741587 North and 467941 East. The project is designed to irrigate 120ha. The location map of the project area is shown on Figure 3 below.

![NYANZA-23 CATCHMENT UNITS](image)

Figure 3: LWH Project Nyanza Site Location

2.3.2.1 Irrigation System Design
The objective is to plan and design an irrigation system such that it is technically feasible, economically viable, socially acceptable and environmentally sustainable. The engineering component i.e. the layout of different components of the system is dictated by the topography and has to fit appropriately into the topography of the command area. The agricultural sub-system has to be planned and designed in such a
way that it fits into the prevailing land and soil characteristics, and climatic factors besides other socio-
economic and agro-economic condition.

The criteria to be adopted for the planning and design of Nyanza irrigation project are discussed below.

- Engineering sub-system- comprising various structures for storage and diversion of water and
canal/pipe networks for water conveyance and distribution.
- Agricultural sub-system comprising the cultivated field with different types of crops, farming system
and agricultural practices including the application of irrigation water and Land husbandry.

The main objective of the irrigation system is to provide the stored water from the reservoir to field units with
efficient method. The irrigation system proposed consists of a closed conduit Main Pipe (MP) line serving a
number of secondary pipes (SP). The secondary pipes transport the water to the turn out points where it will
be conveyed by open field channels to the irrigated fields. This combined arrangement of closed pipes for
primary and secondary lines and open channel for field level would decrease the overall investment cost of
the project.

Therefore the main objective of Hillside Irrigation Engineering design is to provide the stored water to the
field unit with efficient method by providing closed conduit for the Main and Secondary Pipe Line and when
water reaches just to the irrigation unit, it will be conveyed by an open canal called Field Canal. Irrigation
network has been planned for commanding the entire command area with the available head with deficit
irrigation system. The Main Pipe Line off taking from the left flank of the Nyanza Dam serves the part of
command area located on the right side of the river and on the left side of the river by crossing the river at
appropriate place.

The distribution system consists of network comprising Secondary Pipe Line (SP) offtaking from the Main
Pipe Line, Field Canal offtaking from the Secondary Pipe Line and feeds to the basin system.

2.3.2.2 Alignment of Main Canal

In order to minimize the excavation work the alignment of Main Pipe Line follows the contour of the
topography. Meanwhile, since the material for Main and Secondary Pipe line is PVC, the design work is
carried to be buried by avoiding the exposure to surface. Furthermore, the rout of Main Pipe Line and
Secondary Pipe Lines are designed for the maximum capacity to supply the command area. The Main and
Secondary Pipe lines are nomenclature as MP and SP respectively. The Main and Secondary Pipe lines are
prefixed as MP-1, MP-2, SP-1-1, SP-1-2, SP-1-3, SP-1-4, SP-2-1, and etc.
There are two Main Pipe line serves for the two banks. Main Pipe (MP-1) which serves the left side of the
command area and 3.66km long with discharge capacity 0.168m3/s. The Main Pipe (MP-2) which serves
the right side of the command area is 1.87km long with discharge capacity 0.037m3/s.

2.3.2.3 Alignment of Secondary Pipe

Thirty seven secondary pipe lines are laid out at the ridge across the contour off taking from the Main and
Secondary Pipe lines and supply water to Field Canal. Due to the topographic condition, most Secondary
Pipe lines are planned to irrigate the farm lands in two directions. The width of the irrigation filed is variable
and the length on the average is 200 m. Secondary Pipes are buried under ground in order to protect from
high temperature stress

2.3.2.4 Alignment of Field Channel

Irrigation will take place on bench terraces designed with variable terrace width. Filed Channels are directly
offtakes water from the secondary and conveys water to irrigation farm. Water will be delivered to basin
system from the field Canal.
2.3.2.5 Water Control System
Water control, which is crucial in the use of terraces, consists of careful adjustment of the volume of water in
the beginning and, hence, its distribution throughout the system of field units making up the terraced series.
The system must therefore be able to bring in the required volume of water at any time during the growing
season.

The flow in the main pipe is controlled at the outlet, and at the end by means of stop valves. Each
secondary pipe is also provided with a gate valve at the head to regulate and control the flow. Moreover,
additional stop valve at an average interval of 200m are fixed on long secondary pipes to regulate the flow
to enable diversion to the turnouts.

A flow meter will be installed at the head of the main pipe to measure the flow supplied for the command
area.

2.3.2.6 Trenches
PVC pipes must always be laid permanently underground, protected from high or very low ambient
temperatures and solar radiation and hazards imposed by traffic, farming operations, etc. All the main and
secondary pipes will be buried in trenches. The proposed minimum depth of cover above the top of the pipe
for the main pipe line is 0.6m and a minimum depth of cover of 0.4 m for secondary pipes. An embedment
material with a thickness of 5 cm is proposed at the bottom of the pipe. The trench should be as uniform as
possible, firm, relatively smooth and free of large stones and other sharp edged material.

2.3.2.7 Flushing of the system
Sediment particles or dirt materials and algae deposited in the main pipe can easily clog components of the
system. Silt could settle and form algae within the pipe networks through time. Therefore, it is required to
flush all silts and dirt in the main pipe periodically. Hence, flushing system at the end of sub main is provided
in design. Because of higher velocities and down the hill alignment of secondary pipes, settlement of silt and
dirt materials will not occur. The secondary pipes need no flushing arrangements.

2.3.2.8 Turnouts and Risers
The secondary pipes that convey and distribute irrigation water to the individual terraced benches are
buried, and are so protected from farming operations and traffic hazards. Turnout pipes which take off from
both sides of a secondary pipe are installed at each terraced bench according to the planned layout. A gate
valve will be installed at the end of each riser pipe, which marks the termination point of the pressurized pipe
system and the transition to open channel. To make standard 50mm diameter of PVC pipe is proposed for
the each Turnout and the Tee joints is used at the Secondary.

2.3.3 Land Husbandry Component
LWH is an investment project devoted to integrated soil conservation, water-harvesting  and hillside-
irrigation management throughout the project site. It is focused to demonstrating possibilities for future
intensified investments. Demonstrating integrated LWH in 1750 ha of Nyanza 23 watershed is hoped to
ignite such a comprehensive and integrated development throughout the district.

The locations of the five catchment units of the Nyanza-23 watershed are shown in Figure 4 above. Majorly,
five function-based land units form the entire watershed. These are the Water-catchment (nearly 202 ha),
the silt-trap zone (some 33 ha), the Command-area catchment (nearly 335 ha) and the command area
which is 120 ha. The Silt-trap zone is again partitioned into: grass layers, shrub layer and tree layers as we
go further away from the periphery of the Reservoir. A live fence that is situated between along the outside
perimeter of the grass strip and the inside perimeter of the shrub-layer is contained within the same Grass-
Please refer to the area coverage data of these catchment units of the entire watershed in Table 5 below.

Table 5. Area coverage of different land –type category of Nyanza-23 project site

<table>
<thead>
<tr>
<th>Category of the entire watershed</th>
<th>Area in hectares</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Water catchment</td>
<td>202</td>
</tr>
<tr>
<td>2 Silt trap</td>
<td>33</td>
</tr>
<tr>
<td>2-1 Silt trap- Tree-zone</td>
<td>17</td>
</tr>
<tr>
<td>2-2 Silt-trap-Shrub-zone</td>
<td>11</td>
</tr>
<tr>
<td>2-3 Silt–trap-Grass-zone</td>
<td>5</td>
</tr>
<tr>
<td>3 Reservoir</td>
<td>12</td>
</tr>
<tr>
<td>1-3 total Total water catchment area for the reservoir</td>
<td>247</td>
</tr>
<tr>
<td>4 Command Area catchment</td>
<td>335</td>
</tr>
<tr>
<td>5 Command Area</td>
<td>120</td>
</tr>
<tr>
<td>Total entire watershed</td>
<td>702</td>
</tr>
</tbody>
</table>

Figure 4: Different sections of the entire Nyanza 23 watershed as discussed in the following paragraphs of this project design

In the project formulation process, the land-husbandry program is intentionally decided to be at a watershed setting because watershed approach accommodates both the human and the physical environment in an integrated manner. Under the project situation, the agriculture system in both the water-catchment and the
Command-area Catchment will remain rain-fed while the command area is intensively cultivated under supplementary irrigation. In such a case, the yield increment for the watersheds would come from the improved agricultural management of the rainfed catchments and from implementations of comprehensive land-husbandry program. Still, in this scenario, land-husbandry would have to be practiced in all except at the area where it will be inundated by the reservoir.

2.3.3.1 Land husbandry at the water catchment

The water catchment, excluding the Silt-trap zones is about 196 ha in land coverage. In terms of soil depth, 58.48% of the water catchment is covered by shallow soils and the remaining balance is covered by soils with deep profiles. In this water catchment the shallow soils covers 58% of the catchment while the balance is covered by the deep soils. The dominant of the topography of the watershed lies in between 6-16% slope which is relatively suitable for agricultural activities.

Check-dam constructions: One of the activities to arrest the soil movement is to retard the velocity of the run off in the intermittent streams. It is estimated that 20% of the length of the secondary-level streams, occurring at the start of the streams is a dry drainage system that can easily be treated by gully reshaping and planting with perennial grasses, shrubs and trees. Therefore, it is assumed that gully treatment is requiring in 80% of the secondary-level streams (drainage systems). Based on this assumption the stream length that needs treatment appears to be 1459 km. However, the 3586 meters is that of the two primary streams that need not be interfered because treating their tributaries could be easier, more practical and effective.

On 0-6% slopes

Nyanza-23 project site 67 ha is situated on flat to hilly topography of the water catchment In this slope category the erosion hazard is not creating as such serious problem and this is where more than 33.4% of the water catchment lays. On this slope category, only grass strips will be effective enough in retarding the velocity of the possible runoff water on none farm land and where appropriate on cultivated lands to use residue of crops and other trashes to trap the runoff water and to encourage the in situ infiltration in the farm plots. The size of the grass strip is estimated to be 14 km taking 1 km/ha density of the strip which has 1 meter width. To improve the physical and chemical properties of the soils it is advised to plant leguminous and none leguminous plants /crops in the form of intercropping. The role of green manuring and application of house reject and manure in the soil improvement process is significant. On top of these, it is recommended to apply well prepared compost to enhance the organic contents of the soils and to improve the water holding capacity in this slope category.

On the same slope category on 13ha of land under annual crops such as Maize, Sorghum and Beans will be planted on farm plots where agricultural lime is added to raise the pH and to reduce the effect of acidity of the soils. The reclamation of the acid soils is expected to raise available phosphate and enhance the functions of beneficial micro and macro organisms of the soils so that to improve the physical and chemical properties and consequently, to improve the production and productivity of the annual crops.

In the same slope category in the 8 ha of natural and artificial forests reforestation program of the project will be undertaken to upgrade the standard of planted trees through focused and improved management. In this regard, the type and quality of the current forest will be improved to attain the required densities of the plantation to maximize the income of the growers.

On 6-16% slope

Soil bund shall be constructed on 113 ha of land on an average at one meter vertical interval and the total length of the bund in the water catchment is estimated to be 102 km considering 0.9 km/ha density of the bund. During bund construction special attention will be given to construct the edges of the bunds- so that the riser to be constructed in such a way that it has to be inclined against the slope and maintain 1.04 meter
height. To strengthen the inclined risers grass will be planted on the risers. And also to protect and strengthen the risers in addition to the planted grass, trees will be planted just underneath the inclined riser at 1 meter interval. Thus, total area of the riser will be 10.6ha and the trees will be 102,000.

On the same slope category 6-16% slope cutoff drain is proposed to intercept the surface runoff from the higher slopes of the catchment and to divert the runoff into grass covered water way so that to filter the runoff and safely transport the water into the reservoir. The average length of the cut-off drains is 200m and the depth of cut-off-drain ditch shall be trapezoidal where the base width is 30 cm and the top width is 60 cm while the sides are inclined in the ratio of 3:10 for a height of 50 cm. The total area which falls under this slope category is 113 hectares.

It is estimated that around 15 ha are under Maize, Sorghum and Beans and these farm plots is advised to be treated by agricultural lime so that to raise the pH and to reduce the effect of acidity of the soils. The reclamation of the acid soils is expected to raise available phosphate and enhance the functions of beneficial micro and macro organisms of the soils. Consequently this improves the physical and chemical properties of the soil and improves the production and productivity level of the annual crops.

In the same slope category in the 14 ha of natural and artificial forests reforestation program of the project will be undertaken to upgrade the standard of planted trees through focused and improved management. In this regard, the type and quality of the current forest type and the respective densities will be improved to maximize the income of the grower.

On 16-40 slopes
On this slope category the major activity will focus on construction of Radical terraces on 36 ha. Here, on this slope category the Radical terraces will have 2.3 km/ha density and the total radical terrace will be 82.8 km. The radical terrace will be constructed in such a way that the edge of the terrace will be constructed in such a way that the risers will inclined against the slope. On these risers the grass will be planted and underneath the risers trees will be planted. The total riser will be 86km and the number of trees will be 82800. The technology will also be integrated with other biological measures. Just after the terraces construction leguminous crops will be planted for at least three consecutive seasons so that to enhance the fertility status of the disturbed top soils. On the constructed terraces farmers will be advised to plant fruit trees to minimize the soil disturbances. Under the fruit trees, the soil will be covered by annual legumes such as green beans and by different moisture conservation measures such as mulching. Composting and or manuring.

2.3.3.2. Silt-trap system design and management
The silt-trap zone is intentionally designed to avoid silt coming with the water that originates from the water-catchment and from the silt-trap-zone itself. It covers the perimeter which is a drainage contact with the reservoir down-slope. The silt-trap zone of the Nyanza-23 project site is 34 ha which is partitioned into three distinct sub-zones (Figure 4-1). The first and outermost layer is the Tree-zone which is further-down adjoined by shrub-zone. The tree zone covers 17.13 ha while the shrub-zone accounts for 11.25 ha. The zone between the reservoir and the shrub-zone is a 5.47 ha grass covered strip. Between the Grass strip and the shrub-zone, a 50 cm-wide live fence is to be constructed along the perimeter between the shrub and the grass-belt zones. By doing so, the reservoir and the grass-zone are completely excluded from any human and livestock interferences and drowning dangers. The explanations of each zone and the design components are detailed section by section in the following pages.
The tree belt is the outer and upper part of the silt-trap zone and covers an area of 17.13 hectares. This is the zone which is to filter out and contain the boulders that are coming with run-off during the rains. As it has been discussed earlier in this Sub-volume, the water catchment will be given the necessary catchment treatment measures including gully rehabilitation works. However, experience has shown that the catchment –treatment may not be done as prescribed in the study documents and treatment procedures may be violated that up-stream run-offs may contain gravels and boulders when flowing down-stream. This will be environmentally detrimental to the fishes in the reservoir and life-span of the reservoir itself. Hence, filtering the boulders with the tree-crop becomes a necessity.

The trees will be planted along the contour in a spacing of 1.0 meters along the same contour. The same spacing is recommended for the spacing of consecutive contour lines on which lines of trees will be planted. The total number of lines in one meter spacing in this 17.13 ha land is 17.13 km. At a one meter spacing between trees in the same contour lines which are spaced 1 meter apart from each other, the total number of seedling requirement becomes 17130. However, fruit trees will be planted at every third raw and in every third meter in the same line. The remaining will be trees of forage or could be construction materials. Hence, the need for grafted seedling per hectare becomes 1110 while for forage becomes 8,890 seedlings. This indicates that the total number of grafted fruit seedlings required for the entire tree-zone would be 19014 and the other common seedlings would be about 152286. Commercial rainfed fruit tree species that...
are suited to Dry Lowland agroclimatic zone such as Citrus medica, Casimiroa edulis, Tamarindus indica, and Ziziphus mauritiana, are recommended.

Design of shrub-belt
The shrub belt is the middle part of the silt-trap zone and covers an area of 11.25 hectares. This is the zone which is to filter out and contain the gravels that are rolling to the Silt trap from over laying terrains. Therefore, the movement of boulders in this kind of slope terrain is very limited and with limited force of crawling (if any during heavy rains). Therefore, it can be handled by the shrub-belt effectively.

The forage value shrubs will be planted along the contour in a spacing of 1.0 meters along the same contour line. The same spacing is recommended for the spacing of consecutive contour lines on which lines of shrubs will be planted. The difference between the tree-belt and the shrub-belt is that the individual shrubs are multiple stems which can densely fill up the line creating a good blockage that serves as a barrier to the gravels escaping the tree-belt and coming down to this zone.

Similar to the tree belt, fruit-value shrubs will be planted every third row and in every three meter spacing. Therefore, the fruit-value shrubs to be planted per hectare become 1110. In total, the 11.25 ha land will require 12210 fruit seedlings.

The remaining forage value seedlings will be planted at the rate of 8890 seedlings per hectare making a total 97790 forage value species that do not need to be grafted. Forage and fruit value species that also do well under rainfed conditions in Dry Lowland agroclimatic zone such as Ehretia cymosa, Citrus medica, and Zimenia americana are recommended here.

Design of Grass-belt
The grass belt is the inner and lower part of the silt-trap zone and covers an area of 5.47 hectares. This is the zone which is to filter out and contain the silt that is escaping through the tree and shrub belt of the Silt-trapping zones.

This layer needs to be very thick to contain the silt and release only the filtered water down to the reservoir. In addition to protection of the reservoir from the silt deposition, this zone serves as a buffer zone for protecting the dam from any contaminant and hazard happenings. In order to avoid any such hazard, a tight live fence will be constructed at the outer layer of the Grass-belt and this is estimated to be 2.261 km. In the live-fence construction, Zimenia americana and / or Dovyalis abyssinica will be planted in a spacing of 0.5 cm distance in a line and in two lines that are spaced 0.5 meters apart. The Erythrina brucei will be planted in a spacing of 1 meter within the planting of the Dovyalis or Zimenia and it will be in between the two lines that are planted in a staggered fashion. The Zimenia Americana and the Dovyalis abyssinica will be planted from seedlings while the Erythrina brucei will be planted from cuttings immediately after the rain period is completed. Erythrina cuttings required for the live-fence will be 2261 while the Zimenia or Dovyalis seedlings needed for this purpose are 4522.

In between the live fence and the water body, grasses that have course-culm and spreading-sod such as Elephant Grass and Rhodes Grass will be planted along the contour. Cuttings of the Elephant grass will be planted in a spacing of 0.25 meters along the line and 20 cm between the adjacent lines. All lines will be oriented along the contours. The coverage of grass in slope ranges of no more than 16% will on 99% of the grass belt. For the first 25m width, grasses will be planted regardless of the slope range; but along the contour.

2.3.3.3 Land Husbandry in the Command Area Catchment
This area is situated uphill of the command area. The agricultural activity accounts for 59% of the total catchment and extended up to 40% slope. The largest area is situated in slope category of 6–16% and the
terrain as well as the agricultural practices extends up to 40% slope. Thus, the land husbandry interventions which will be proposed in Nyanza-23 include all possible practices as it is found to be relevant.

**On 0-6% slopes**
Agricultural land in this slope category is 46 ha. On this land, trash line of crop residues and/or grasses will be made lined along the couture and grass strips shall be planted on the remaining none farm lands in the same fashion as the trash line. The total length of the grass strip will be 46 km based on 1 km/ha density. On these farm plots, well prepared manure or compost, will be applied regularly as per recommended rates. In the first project implementation period leguminous crops shall be planted and at or before flowering the green legume shall be incorporated into the soil so that to enhance organic matter of the soil and this shall be repeated for three to four consecutive seasons.

On this slope category it is estimated that 11 ha of land covered by annual crops such as Maize, Sorghum and Beans and this land is proved to be covered by acid soils thus, the farm plot under these crops will be treated by agricultural lime so that to raise the pH and to reduce the effect of acidity on crops. The reclamation of the acid soils is expected to raise available phosphate and to enhance the functions of beneficial micro and macro organisms of the soils so that to improve the physical and chemical properties of the soil and to improve the production and productivity of the annual crops.

In the same slope category in the 12 ha of natural and artificial forests reforestation program of the project will be undertaken to upgrade the standard of planted trees through focused and improved management. In this regard, the type and quality of the current forest will be improved to maximize the income of the grower.

**On 6-16% slopes**
On this slope category soil bunds shall be constructed on 171 ha of land both on agricultural and none agricultural lands. The bund will have an average of one meter vertical interval and the density will be 0.9km/ha. Based on these assumptions, the total length of the bund in the command area catchment is estimated to be 154 km. The edges of the bunds will be constructed to be inclined against the slope having 1.04 meter vertical height. To stabilize the bund, on the inclined surface or on the riser grass will be planted, in addition to the planted grass, trees will also be planted just underneath the inclined riser at one meter interval. Thus, the length of the risers will be 154 km and the area will be 15.4 ha while there will be 154,000 trees or an area which covered by trees will be 34.6 ha on agricultural land all biological practices prescribed for the other slope categories will be applied.

**On 16-40 slopes**
On this slope category, the major activity will focus on construction of radical terraces which will be done on 82ha of land. Here, on this slope category it is suggested to construct radical terraces considering 2.5km/ha average density of the terraces. Based on this density the length of the terrace which is going to be constructed will be 205 km. The riser which is part of the terraces will have an area of 20.5 ha. To enhance the fertility status of the disturbed top soils, just after the terrace construction leguminous crops will be planted on the newly constructed terraces for at least three consecutive seasons. On the constructed terraces farmers will be advised to plant fruit trees to minimize the soil disturbances. During the project implementation period extension dissemination will be strengthened and farmers shall be trained on the fruit tree and on land management issues.

On this slope category it is estimated that 10 ha of land covered by annual crops such as Maize, Sorghum and Beans and this land is proved to be covered by acid soils thus, the farm plot under these crops will be treated by agricultural lime so that to raise the pH and to reduce the effect of acidity of the soils. The reclamation of the acid soils is expected to raise available phosphate and to enhance the functions of beneficial micro and macro organisms of the soils and also to improve the physical and chemical properties of the same consequently, to improve the production and productivity of the crops.
In the same slope category in the 13ha of natural and reforestation program of the project will be undertaken to upgrade the standard of the natural forest through stock refinement and enrichment planting. In this regard, the type and quality of the current forest will be improved to maximize the income of the forest owners.

An average spacing of 12 meters is suggested for the soil bund. Therefore, for the 22 ha, 1916 meters earth bud is required. The trees to be planted here are at a spacing of 1 meter. Therefore, the number of tree seedlings required will be 1916 seedlings. In the study, the fact that we did not budget for central nurseries in the watershed is intentional. Producing the seedlings in Farmer-group nurseries would give farmers a chance for seeding entrepreneurship and we encourage that the seedlings are produced by farmers. In consideration of the incentives needed to motivate the farmers into seedling production, the price of seedlings is put at US$0.30. The total budget alone for this intervention is estimated at US$575.

2.3.3.4 Land Husbandry in the command area

Land Management

The irrigable (command) area of Nyanza-23 project site is 120ha. The existing topography of Nyanza-23 site is composed of flat, gentle and steep. Lands in slope range of 0 -6% are above 16%. Grass strips of 1 meter width and spaced in every 10 m is planned for these lands. The grass strips will be inter-spaced by trash lines of half meter width and 20 cm height that are spaced in 5 meter interval either with the grass strip or adjacent trash line.

Lands in slope range of 6 – 16 % are the dominant (52.5%). Soil bunds of 1 meter height that are spaced in one meter vertical interval are recommended and budgeted. The risers of the bunds are level in a horizontal vertical ratio of 1:3 and the surface is planted with fodder-value perennial grasses and/or herbs. For all bund/terrace stabilization Ciratro, green-leaf desmodium, Elephant grass, Rhodes grass, Phalaris, and any other to be approved by the Client are recommended.

Lands that require radical terraces for leveling (16 – 40) are also significant. About 37 ha or 30.76% of the command area is in this slope range. The major leveling possibility here is construction of radical terraces. Radical terrace construction, often buries the top soil. Usually, putting aside first the top soil and spreading it over the top surface after leveling is completed is advised. However, this often said than done. It is practically difficult and time consuming. In order to minimize such a problem, the cutting will be started from the upper half of the lowest terrace that needs to be added to the lower untouched surface of the next above terrace. This will minimize but not avoid burial of the top soil. However, in Nyanza site, except in slopes of less than 16%, the top soils of all lands above 16% are lost by water erosion. Luckily, the B-horizon and even part of the C-horizon are often deep and homorganic. Therefore, burying the top soil is not possible for it is already gone.

Lands that exceed 40% slope are only 0.5 % or less than 0.7ha in area. These are also found in scattered form that is identified in the irrigation infrastructure layout. Therefore, no special land husbandry would be designed.

Just after construction of the different slope reduction strips, bunds and terraces plus the installation of the irrigation schemes, the improved coffee and plantain will be planted as per the recommended spacing. After the seedlings coffee and plantain seedlings are planted, lime shall be side dressed around the seedlings to help the planted coffee and plantain seedlings can grow well and afterwards develop tolerance to acidic nature of the soil in the area.
To alleviate the constraints of the soil resources and to utilize the resources in a sustainable manner, it is required to improve the soil reaction, water holding capacity and the statues of the chemical contents of the soils employing natural and commercial fertilizers as well as soil property amending materials like lime for annuals.

To enhance the general fertility status of these soils it is indispensable to apply organic matter. A huge amount of well-decomposed manure and compost preparation and application are recommended and budgeted for this purpose. The organic matter from these sources improves water holding capacity, the structure of the particles and the nutrient supply conditions. It reduces the pH and other toxic effects of other elements.

2.4 Equipment and Material Description

The following equipment and materials are planned for use during the construction phase of the project.

2.4.1 Equipment

Earth moving equipment including excavators, tractors, graders, trucks, local excavation implements for trenches like forks, spades, wheelbarrows, Dozer, crushers, mixers, dump trucks, etc.

2.4.2 Materials that will be used in the construction works include

Cement, sand, water, boulders, wire mesh, PVC etc. Most of these materials are readily available in the local markets in Kigali however; local material will be sources as defined in the section below in order to reduce costs.

2.4.2.1 Identification of Natural Construction Materials

A search for natural construction materials has been conducted within the vicinity and outside the dam site. The search includes identifying fine-grained soil for the impervious core of a zoned dam or for the entire body of a uniform embankment dam, materials for the shell of a zoned dam, filter sand, stones for rip rap, sand and aggregates for concrete, and water for construction. The results of the search are presented in the following sections.

Material for Impervious Core

As described in the previous sections, the majority of the reservoir area is made up of sandy soil, which is not suitable for an impervious core. For this reason, it was necessary to explore availability of potential borrow sites for such a purpose outside the reservoir area. It was, however, difficult to identify such a borrow area in the immediate vicinity (within a kilometer distance) of the dam site as the site is dominated by the residual sandy soil described above as a result of weathering of the predominant granite intrusion that is typical of the region. A suitable material is located at a location northwest of the dam site about half way the height of the seemingly tallest hill in the surrounding. The site is located at about 1.5 to 2 km from the dam site in a locality called Igachu. Its geographic coordinates are 9742724mN and 0468120mE with an elevation of 1793 masl. It is accessible with an existing all-weather dust road having moderate slope.

The selected soil covers an area of more than 10 hectares, but the majority of the site is inhabited and cultivated. There are, however, pockets of land covered with eucalyptus trees owned by individuals that can be considered for the intended purpose. An area of about 2 to 3 hectares of such lands can be delineated. Since the thickness of the soil is estimated at more than 4 m, about 100,000 m3 of the material can be borrowed without difficulty. Exploitation of such a volume of soil from a hilly area like this one, would have adverse effects like facilitation of erosion, slope instability and creation of unwanted water ponds, Therefore, the environmental impact needs to be properly addressed.
Shell Material
Source area for granular soil that can be used for shell zone of the dam is available within a distance 100 m both upstream and downstream of the dam site. The upstream continuation of the foot of the left abutment hill and the downstream continuation of the foot of the right abutment hill are mainly composed of completely weathered granite that can be borrowed for this purpose. Two specific borrow areas have been delineated: one at about 70 m upstream of the left abutment peak on the left side of the small intermittent tributary stream closest to the dam; the second site is proposed at about the same distance downstream, at the foot of a continuation of the right abutment hill following the dust road. As much material as needed can be exploited from these sites. The soil is similar in composition to the residual sandy soil described earlier.

The proposed borrow areas for the shell material is free from human settlement and agricultural activities, except that they are covered by sparsely distributed eucalyptus trees. The environmental effect appears to be kept at a minimum. In addition the soil from essential excavation for the foundation of the dam, especially the portion below 1 m, can be used as a shell material as this has a similar property as the selected shell material described above. A schematic location of the borrow areas is shown in Figure 1.

Figure 6: Schematic location map of the construction materials

2.4.2.2 Rock source for Various Purposes
A quarry site for extracting stone for different purposes, like for masonry, rip-rap, rock toe and concrete works has been identified at about 2.5km north west of the dam site, at the peak of the mountain, where the impervious material is also located. It has the geographic co-ordinates of 9743010mN and 04672391mE,
with elevation of 1861 masl. The site, locally known as Rubona, can be accessed on a rugged dust road; which will require rehabilitation and rerouting for better performance.

The proposed site is dominated by outcrops of quartzite Rock, which is one of the strogents and chemically inert rocks in the metamorphic rock category. The rock is exposed over a wide area forming rather long (more than half a kilometre) isolated ridge.

The identified site is a properly selected existing quarry site, which is being actively exploited and conveniently located in view of minimizing adverse environmental impact. However, since the site is located on the slope of a steep hill, the risk of rock sliding and rock fall needs proper attention.

Filter Sand
Generally, sandy soil that can be used for concrete works and as a filter material cannot be found from stream beds in sufficiently large quantity as the streams transporting capacity is low. The main sources for sands and gravel in the region including this project are related to in-situ weathering of quartzite and other quartz-rich rocks like granite. Such a site is proposed about 2 km downstream of the dam site, at a locality called Rwabieumg of Gasizuab Umudugudu. The geographic coordinates of the source area are 9740786mN and 0466227mE with elevation of 1644 masl. It is accessed by the same allweather soil road passing by the dam site and crossing the stream there.

The sand at this site is uniformly graded covered at the top by a silt-rich soil horizon of about 1m thick that needs stripping. The area is also being utilized by the local people for construction purposes, but is limited in extent, as it is in the middle of an inhabited locality. An area of about a hector can possibly be delineated. The gradation parameters are presented in section 3.4. Since the site is located amidst a cluster of

Picture 2: Outcrop of quartzite at a place some 2.5 km northwest of the dam site
residential houses, its further use may have adverse environmental effects like ponding of water. Thus, the actual consequences and the necessary measures need further considerations.

2.4.3 Water for Construction

Water for the purpose of compaction, concrete works and other construction activities can be found from the project stream itself as it shows a sufficient amount of base flow during the investigation period in the driest season of the surrounding.
3. BASELINE ENVIRONMENT/BACKGROUND OF THE AREA

3.1 Climate and Hydrology

The closest meteorological stations for the Nyanza LWH project site are Nyanza, Butare, Gikongoro, Mweya and Rubona Colline. These stations do not have long term record (> 30 years). Kigali Airport station data, which has only missed data for 5 months from May 1994 to September 1994, are used as base station in transposing data to the dam site. Time series plot of Kigali rainfall data has shown that the data is homogenous with no trend (Figure 7).

![Figure 7 and 8: Time series plot of Kigali Airport Rainfall (mm)]
3.1.1 Other Climatic data

3.1.1.1 Temperature
From the above table, one can see mean monthly maximum temperature ranging from 25.7°C to 27.9°C, showing that the area lies in tropical climate zone and hence only tropical climate suited crops are grown. Moreover, July, August and September are considered the hottest months of the year, where potential evapo-transpiration (ETp) is recorded up to 4.53 mm/day. The data of minimum (mean) monthly temperature suggests that it remains around 15.4 degree centigrade. However, the range is between 14.70C to 15.9 C in the months of July and May respectively.

3.1.1.2 Relative Humidity (RH)
The maximum relative humidity during the 1st and 2nd rainy season in April, May and November & December is 82.6, 79.6, 81.0 and 79.1 % respectively. The minimum relative humidity is in dry and hot months of June 68.3, July 59, 5 and August 60.1 %. The average for the year works out to 73.7%, which is in the maximum range for this tropical region.

3.1.1.3 Wind Speed (µ)
The highest wind speed recorded in the month of August and September, which are 184.9 and 176.3 km/day respectively. As the general trained, it decreases from September to February and then starts increasing from June to August onward. It is in the medium wind speed ranging from 2 to 5 m/s (145-175 km/day ).

3.1.1.4 Sunshine Hours (Sn)
From the data, it is observed that the maximum daily sunshine hours is 6.7 (July) followed by 6.5 (August) 6.2 in September and 6.1 in October and so on. In the rainy season April (5.0 hrs), May (5.5 hrs), November (5.5hrs) and December (5.4hrs) is less because of being cloudy weather.

3.1.1.5 Radiation (Rn)
During the day time due to high energy received from sun the evaporation and transpiration are much than the night. However, clouds and dusts in the atmosphere can reduce the amount of solar energy (sunlight) that reaches the plant. The elevation may also affect the amount of energy received since at higher elevation there is less absorption of energy by the atmosphere. As shown in the table solar radiation increase from the month of June- to October, 16.9, 17.7, 18.5, 18.9, and 18.9 MJ/m2 /day respectively.

<table>
<thead>
<tr>
<th>Table 6. Climatic data of Nyanza-23</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
</tr>
<tr>
<td>Max Temp</td>
</tr>
<tr>
<td>Relative Humidity</td>
</tr>
<tr>
<td>Wind speed</td>
</tr>
<tr>
<td>Sun Shine</td>
</tr>
<tr>
<td>Wind speed</td>
</tr>
</tbody>
</table>
3.2 Geology and Geotechnique

Unlike in the majority of the project sites, the local geology of Nyanza 23 is not characterized by metamorphic rocks. Rather, it is underlain by an igneous intrusion of granitic composition as part of the intrusions covering areas of significant size southeast and southwest of Kigali. During the present investigation, such intrusions have been observed in the eastern portion of Bugesera and the central Nyanza districts. The Nyanza site is totally underlain by the igneous intrusion. Unlike the case of the Bugesera 3 site, fresh outcrops of the intrusion are observed at the Nyanza 23 site in addition to weathered parts. The weathered rock is exposed all along nearby road cuts and in existing excavations, whereas fresh rock outcrops are visible along the stream bed, river banks and some parts of the hill slopes. It is noted that the rock is rich in quartz with a significant amount of mica minerals, predominantly of the muscovite variety.

The local soil formation is dominated by sand to gravelly sand of mainly residual and partly colluvial origin. The depth of weathering varies significantly and thus the thickness of the overburden as well. It is much thicker at the left abutment hill than it is at the valley floor and at the right abutment.

3.2.1 Dam and Spillway Site

The various parts of the dam site including the abutments and the valley floor area have been investigated by inspecting surface exposures and by opening hand-dug test pits supplemented by geophysical surveying. Existing excavations by local dwellers and road cuts were also examined. For the purpose of subsurface investigation of the foundation condition, four hand dug test pits, designated NTP1 to NTP4, have been opened along the dam axis. From the logs of the trial pits and existing exposures, three main engineering geological units have been identified. These include:

- An alluvial silty formation; and
- A residual sandy formation; and
- The granite bed rock.

The alluvial silty formation
This soil unit covers a narrow strip of the central valley floor area of the dam site, on both side of the stream bed. The valley area has no more than 20m total width including the active streambed. This alluvial deposit is relatively young and reddish brown in color. Its average thickness is estimated at 1 m and rarely reaches 2.5 m at the stream banks, beyond which it diminishes fast. It is inorganic loose, semi-pervious sandy silt soil with some a small fraction of clay. Normally, this upper layer is underlain by a residual silty sand soil that is derived from weathering of the prevalent granite rock. At least the top 1 m may not be suitable as a foundation material and need to be removed at least under the impervious core section of the dam.

The residual sandy formation
This soil covers the entire portion of both abutments and the adjoining valley floor areas not covered by the alluvial soil. It is the result of high to moderate degree of weathering of the underlying granitic bedrock. Its thickness could not be exactly known from the trial pits, but it generally becomes more difficult to excavate with increasing depth after few meters.

The thickness is maximum at the left abutment hill, where it is expected to be well more than six meters. It is shallower near the stream and at the right abutment. The granite has been weathered highly to result in this quartz sand formation with some content of gravel and silt. The degree of weathering typically decreases with increasing depth so that relics of the granite rock characterized by coarse-grained particles are expected at deeper depths. This horizon will be the major foundation material for the dam.

From visual observation, the soil is rich in quartz, dense in structure and of very good strength. It may, however, be permeable due to its granular nature demanding a positive cutoff of variable depth, the maximum being on the left abutment.
The granite bedrock

The granitic bedrock is exposed at the streambed and some portion of its right bank. A large area of bare rock is seen some 70 to 80m downstream of the dam axis (see Picture below).

![Picture 1: Exposure of the granite bedrock at the stream bed about 70 m downstream of the dam axis](image)

3.2.2 Reservoir Site

The reservoir has a circular shape and gentle to moderate slope in the upstream direction and gentle to moderate up-slope. The majority of the reservoir area is covered by the same soil types described above in an identical sequence. Outcrops of the granite bedrock are visible in some parts, notably to the right of the stream.

3.3 Seismic Assessment of the Site

By extracting the data from the Global Seismic Hazard Map prepared by the Global Seismic Hazard Assessment Program (GSHAP) explained in the Executive Summary of the LWH projects, the corresponding map for Rwanda is provided in Figure 2. According to this map, Rwanda may be divided into three zones: Zone 3, Zone 2 and Zone 1. The project site of Nyanza 23 lies in Zone 3 with the range of PGA of 0.8 to 1.6 m/s² or 8.1 to 16.3% of gravitational acceleration. The design PGA of this site may thus be taken as 0.11g.
In terms of topographic configurations, Nyanza-23 watershed shows three distinct slope categories. These are: the undulating plain (0-6%) that covers 16.02% of the watershed, 6-16% that covers 35.71% of the watershed, 16-40% slope which covers 42.92% of the watershed, 40-60% slope that covers 4.89% of the watershed and 60-120% slope that covers 0.45% of the watershed. Within the respective slope categories, the shallow soil depth coverage in % is, watershed the shallow soils and deep soils divide this slope category in to equal parts. The other slope class which covers more than 46% of the project area is in the range between 6-16% slopes.

This is hilly topography, where the major portion of the watershed is found and its area surpasses 325 ha. Almost 1/3rd of this area is covered by deep soils while the other 2/3rd is covered by shallow soils units. The third slope class which is found in the watershed is in between 16-40% slope which covers around 120 ha and 90% of this slope category is covered by shallow soils. Details of the land coverage of the different slope classes are given in Table 7 below.
Table 7. Area coverage of the different lands of various topographies (slope ranges) in the different soil depth categories

<table>
<thead>
<tr>
<th>SLOPE</th>
<th>Area in hectare by soil depth</th>
<th>% by slope range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;=50cm</td>
<td>&gt;50cm</td>
</tr>
<tr>
<td>0-6%</td>
<td>58.76</td>
<td>53.77</td>
</tr>
<tr>
<td>6-16%</td>
<td>149.52</td>
<td>102.44</td>
</tr>
<tr>
<td>16-40%</td>
<td>221.82</td>
<td>80.33</td>
</tr>
<tr>
<td>40-60%</td>
<td>31.36</td>
<td>1.33</td>
</tr>
<tr>
<td>60-120%</td>
<td>2.58</td>
<td>0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>464.04</td>
<td>237.87</td>
</tr>
<tr>
<td>% by soil depth</td>
<td>66.11</td>
<td>33.89</td>
</tr>
</tbody>
</table>

Nearly 60% of the total watershed is occupied by two soil types that are having greater than 50 cm soil depth: Humic Acrisols and Hapalic Acrisols. When we consider the four different kinds of soils which contribute in different amounts, soils of greater than soil depth are well above 70%. Naturally, Dystric Cambisols is found at greater depth than 50 cm. However, due to the severity of soil erosion in Nyanza site and due to its susceptibility nature to erosion, the Dystric Cambisols which is having less than 50 cm soil depth is 4.48% of the entire watershed or covers 31.5 ha. This is one of the reasons why land-husbandry in this watershed is crucially essential. The lands having shallow soil depth (less than 50cm) account for 27.5% of the entire watershed. Out of this proportion, Haplic Acrisols covers 21.13% of it.

Figure 10. Soils map of the entire project site
3.4.1 Topography and Soils of the Water-Catchment

The water catchment of Nyanza-23 is surrounded by the ridge of mountains to the North eastern side of the Dam site. The topography of the water catchment is rugged with good size of land in the different slope categories. Majority of the land is slope range of 16-40% slope where radical terrace is needed for correction. The flat to gently flat topography which does not need any physical measure or where biological measure alone can be effective is not more than 20%.

Table 8. Area coverage of the different lands of the different topographies (slope categories) with respect to their soil depth

<table>
<thead>
<tr>
<th>SLOPE</th>
<th>Area coverage of slopes by soil depth</th>
<th>% by slope category</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;=50cm</td>
<td>&gt;50cm</td>
</tr>
<tr>
<td>0-6%</td>
<td>23.92</td>
<td>15.36</td>
</tr>
<tr>
<td>6-16%</td>
<td>32.42</td>
<td>33.88</td>
</tr>
<tr>
<td>16-40%</td>
<td>47.76</td>
<td>34.47</td>
</tr>
<tr>
<td>40-60%</td>
<td>11.38</td>
<td>0.17</td>
</tr>
<tr>
<td>&gt;60%</td>
<td>2.45</td>
<td>0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>117.93</td>
<td>83.88</td>
</tr>
<tr>
<td>% by soil depth category</td>
<td>58.44</td>
<td>41.56</td>
</tr>
</tbody>
</table>

The water catchment is also constrained by soil depth. The proportion of the land having less than or equal to 50 cm soil depth is over 58%. This is more significant for slope ranges of 16-40% which require radical terrace for slope correction. In this case, radical terracing can definitely affect the workable soil depth especially if one tries to grow annual crops whose roots are week to penetrate and survive by using it as a growing media. Therefore, in this slope range, the land use of the water catchment is strongly advised to be planting with perennial crops or plants.

On the other hand, the fact that the majority of the topography is in steep to very steep slopes above 6 and surpassing 40% is guaranty for high water yield to the reservoir located at the outlet of this catchment.

In addition to the topographic situations and soil depth of the water catchment which influences the erosion hazard and the rooting depth, the nature of the soil determines nutrient availability and to plants to be grown in the catchment. Therefore, studying and characterizing the soils of the water catchment was considered seriously. According to the study, the catchment is covered by three soil units namely Dystric Leptosols, Dystric Cambisols and Haplic and Humic Acrisols. Their percentage distribution in the water catchment and in the soil depth categories is indicated in Table 9.

Table 9: Distribution of the different soil types in area coverage in the different soil-depth categories of the water catchment

<table>
<thead>
<tr>
<th>SOIL TYPE</th>
<th>Area by soil depth categories</th>
<th>% by soil type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;=50</td>
<td>&gt;50</td>
</tr>
<tr>
<td>Humic Acrisols</td>
<td>53.14</td>
<td>0</td>
</tr>
<tr>
<td>Dystric Leptosols</td>
<td>31.73</td>
<td>0</td>
</tr>
<tr>
<td>Dystric Cambisols</td>
<td>33.06</td>
<td>0</td>
</tr>
<tr>
<td>Haplic Acrisols</td>
<td>0</td>
<td>26.34</td>
</tr>
<tr>
<td>Ferric lixisols</td>
<td>0</td>
<td>57.54</td>
</tr>
<tr>
<td>TOTAL</td>
<td>117.93</td>
<td>83.88</td>
</tr>
<tr>
<td>% by soil depth category</td>
<td>58.44</td>
<td>41.56</td>
</tr>
</tbody>
</table>
3.4.2 Topography and Soils of the Silt Trap Zones

The topography of the silt-trap zone is ideal in that it is more of gentle in slope. The coverage of flat to gently flat slope range is more than 1/3rd of the area (37.5%). Virtually, there is no land in slope category of exceeding 40% (Table 3-5). The combined area coverage of less than 16% accounts for nearly 70%. Such topography has a lot of importance for the effectiveness of the silt-trap zone in arresting the silt. The silt will not travel in gravity-aided speed and challenge the resistance of the vegetation in the silt-trap. Such gentle slope topography will serve as a landing strip instead. Because of its topography that helps it to be a depositional site, the soil depth of greater than 50 cm is significantly high in this land unit (Table 11).

<table>
<thead>
<tr>
<th>Area coverage in hectare by soil depth</th>
<th>SLOPE</th>
<th>&lt;=50cm</th>
<th>&gt;50cm</th>
<th>TOTAL</th>
<th>% by slope category</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-6%</td>
<td></td>
<td>1.94</td>
<td>10.75</td>
<td>12.69</td>
<td>37.49</td>
</tr>
<tr>
<td>6-16%</td>
<td></td>
<td>6.21</td>
<td>4.67</td>
<td>10.88</td>
<td>32.14</td>
</tr>
<tr>
<td>16-40%</td>
<td></td>
<td>4.95</td>
<td>5.32</td>
<td>10.27</td>
<td>30.34</td>
</tr>
<tr>
<td>40-60%</td>
<td></td>
<td>0</td>
<td>0.01</td>
<td>0.01</td>
<td>0.03</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>13.1</td>
<td>20.75</td>
<td>33.85</td>
<td>100.00</td>
</tr>
<tr>
<td>% by soil depth category</td>
<td></td>
<td>38.70</td>
<td>61.30</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

There are virtually only two types of soils that dominate this land unit: the Acrisols and the Cambisols. The Acrisols occupy almost 92.5% of the entire land unit. However, as much as there is deposition, the soil erosion in this area cannot be underestimated. More than 1/3rd of the area is having less than 50 cm soil depth. This more so in the land covered by the erosion-susceptible soil type: Cambisols. Similar to the other catchment categories, the dominant soil type even in the Silt-trap zones is Humic Acrisols.

Topography and Soils of the Command-area Catchment

Similar to the water catchment, the command area catchment has also rugged topography. The sloping terrains occur in the four slope categories from flat (zero) to steep (60%). The dominant slope terrain is in the slope class of 16 – 40% slope where radical terracing is needed for correcting it. But most of this occurs in soil depth category of less or equal to 50 cm only. When it is the case, radical terracing of 1 meter height riser at a 1 meter vertical interval will expose the soil to the parent material.

<table>
<thead>
<tr>
<th>Area coverage of the different topographic/slope classes with their respective soil depth of the command-area catchment</th>
<th>Area coverage in ha by slope category</th>
<th>% by slope category</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLOPE</td>
<td>&lt;=50cm</td>
<td>&gt;50cm</td>
</tr>
<tr>
<td>0-6%</td>
<td>27.84</td>
<td>7.97</td>
</tr>
<tr>
<td>6-16%</td>
<td>86.58</td>
<td>18.64</td>
</tr>
<tr>
<td>16-40%</td>
<td>152.58</td>
<td>20.47</td>
</tr>
<tr>
<td>40-60%</td>
<td>19.87</td>
<td>0.86</td>
</tr>
<tr>
<td>Total in ha</td>
<td>286.87</td>
<td>47.94</td>
</tr>
<tr>
<td>% by soil depth</td>
<td>85.68</td>
<td>14.32</td>
</tr>
</tbody>
</table>

As depicted in Table 11, the majority of the soil of the Command-area catchment is having a depth of less than 50cm. This indicates that there is significant erosion threat to the downstream command area.
The same soils that are discussed under the water catchment occur in the Command-area catchment with almost the same proportion. Since the climatic variables and the topography is similar at large the soil characteristic and type is very similar. Humic Acrisols are the dominant covering over 54% of the catchment. They occur only in less than 50 cm soil depth category. With Haplic Acrisols which occur in deep soil depth category, this soil group accounts for nearly 68% of the water catchment. Dystric Cambisols is the second dominant soil occurring in the Command area catchment. It occurs in both soil depth categories and it's relatively least occurrence is in soil depth group of >50cm. As it has been described under the Water Catchment section, the fact that this soil is found in lesser proportion in deeper soil group indicates that the catchment has been severely affected by water erosion.

3.5 Vegetation and Crops
Farmers in the study area had diversified their production evidenced by different crop enterprises within the same piece of land where they practiced mixed cropping, as monocrops or intercrops. Sixty seven percent (67%) of the households had at least 4 enterprises while 33% had 3. The mean number of enterprises per household was 4.5. The types of crops grown were as shown in Table 4. Beans and cassava production were the most common enterprises for majority of the households, while sweet potatoes and Irish potatoes were the third and fourth respectively. Adoption of improved varieties was by 3% of the households who grew bananas.
*Indicates one of the high-value crops proposed for the command area.

3.6 Socio-economics
The dam site is intensively cultivated and covered with perennial crops. The hillsides are covered mainly with tree plantations. The crops grown in the area include sorghum, maize and sweet potatoes intercepted with cassava. The source of the water for irrigation is the drainage structures constructed along the road in the project area. Currently there is no house in the reservoir and in the command area that needs to be relocated.

The community is aware of the proposed development advantages and welcomes the project. However, the shortage of land could be worrisome, especially for those basing their livelihood on the proposed reservoir and the dam sites, unless the mitigation measures are taken.

4. POTENTIAL ENVIRONMENTAL AND SOCIAL IMPACTS
This section describes the potential significant positive and negative (adverse) impacts of the proposed project at different phases including design and planning and design, construction, operation and decommissioning phase.

4.1 Significant Positive Impacts
The Land Husbandry, Water Harvesting and Hillside Irrigation document identifies many of the positive impacts of the proposed activities. These include poverty reduction, food security, hillside restoration, rural development, irrigation efficiency among others.

4.1.1 Catchment Rehabilitation and Management
Soil erosion has been indirectly caused by degradation of catchments through farming and deforestation. The LWH project component on marshland and hillside development through reforestation and terracing of the hillsides is to a great extent a sound practice for protecting the catchments.
4.1.2 Crop diversification:
The implementation of the project will introduce new crop-husbandry practices that have not been used in the area previously, or even lead to expansion of existing crop enterprises. Within the entire water catchment area and command area catchment, land husbandry practices that will improve crop production will be adopted, but the prevailing cropping patterns will be maintained.

However, in the command area (120.55 ha), two high value crops will be grown, i.e. Avocado and Plantain, with Avocado occupying 80% of the command area and Plantain occupying 20%. As a result, there will be an increase in the value of output from the command area (120.55 ha) by RWF 781,355,192 (US$ 1,433,679) (gross margins of the projected yields of the high value crops valued using exporters’ farm-gate prices as compared to gross margins of the current yields under the current cropping pattern valued using the local prices).

4.1.3 Flood Control
According to the socio-economic feasibility survey conducted it revealed that 13% of households within the project site experienced flooding in their farms which they indicated was detrimental to their crops. Houses falling within the command area were also affected by the flowing water during heavy rains. The dam to be constructed will help in controlling the effects of flash floods downstream by storing excess water during heavy rains. This is helping to minimize the flood related impacts downstream that could include crop and property destruction.

4.1.4 Water Resources Conservation
The Land Husbandry and Hillside Irrigation project investment by way of reforestation and terracing bunding etc will reduce soil erosion and in effect protecting the hydrological systems from sedimentation, flooding and contamination.

4.1.5 Birdlife Habitat
The dam reservoir area will attract birdlife in the project area. This is a beneficial impact on the biological environment of the project area.

4.1.6 Improved soil conservation
Improved soil conservation as a result of reduced erosion through slowed down run-off and through putting up soil conservation measures to contain the run-off. As a result from livestock diversification, there will be an increase in the volumes of manure used to replenish soil fertility. Continued use of this manure will improve the soil quality and sustainably enhance soil fertility thus improving the yields. Improved soil conservation through improved land husbandry practices in the command area catchment (334.81 ha) and half of the water catchment area (100.8 ha) would lead to improved crop production resulting in an increase in output.

4.1.7 Improvement of previously water-logged areas
Areas that had previously been water-logged during the rainy season would be put into productive use without the risk of losing the entire crop as was previously the case, when submerged in the water. These were mainly the command area.

4.1.8 Increased farm incomes from crop output
An increase in farm incomes as a result of increased marketed crop output is anticipated. This would additionally be due to better and reliable market access of high-value crop produce that would fetch a good selling price as well as increased volumes of marketable output of different crops. An increase in output
value by 220% from the current crop production in the command area based on gross margins of the projected high value crop output at the exporter’s prices and the current output’s gross margins.

4.1.9 Environmental Protection
The project promotes intensification of agriculture as opposed to extension. This is arguably protecting marginal areas as more food is being produced in a smaller area. Sustainable agricultural intensification is not only important to increased employment and income, but also is critical to protecting the environment.

4.1.10 Revegetation
The LWH activities propose the protection of the hillsides which is a long term strategy of improving the vegetation of these erosion susceptible areas.

4.1.11 Livestock Development
Major constraints hampering the development of the livestock sector include Inadequacy of animal feed both in quality and quantity, which arises due to poor and narrow pastures and water shortage among other issues (MINAGRI, 2008). The implementation of the project interventions will indirectly lead to the development of the livestock subsector as a result of increased quality fodder production which will be harvested from fodder trees and perennial forage legumes intended for the water catchment protection through the project interventions, thus improving the low productivity of livestock on these farms. This will complement the government’s initiative on one-cow one-family thus improving the welfare of the farmers within the project site, through provision of required nutrients at household level and income that may be used to purchase essential goods and services. Availability of fodder for livestock will be an incentive for farmers to diversify and expand their livestock enterprises and enhance adoption rates of improved breeds which are early maturing and high yielders. Livestock development is envisaged to have a potential to contribute to poverty reduction through increased farm incomes. Livestock development projects often act as catalysts that enable farm households to join the market economy and thus to achieve a decent standard of living (ILRI, 2007). In addition to contributing to household level welfare, the increased milk production will have a positive effect on the national dairy sector.

4.1.12 Food Security
The project will increase food production thus making it possible for community members to acquire available food. This would imply that if the production is improved, there will be more food thus resulting in a decrease in prices hence making it affordable to all the members within the community to have access to food.

4.1.13 Poverty Alleviation
The Rwandan Poverty Reduction Strategy Paper (PRSP, Rwanda, 2002) identifies five potentially competitive crops that will be targeted for expansion in addition to the traditional cash crops of coffee and tea. These are rice, maize, potatoes, soya and beans. Based on the Rwanda LWH, the project is in line with the objective of tackling poverty through promotion of agriculture.

At the local level, the irrigation infrastructure project will promote increased agricultural productivity, diversification of agricultural crops and commercialization of agriculture from subsistence. Improvement in crop productivity will raise the income for the rural poor above the poverty line of less than a dollar a day. This is an indirect impact that will take a long process that will be felt after many years.
4.1.14 Raise Rural Income

According to the socio-economic feasibility study conducted, Ninety one percent (91%) of the sample households indicated that the implementation of the project will introduce new crop-husbandry practices that have not been used in the area previously, or even lead to expansion of existing crop enterprises. Within the entire water catchment area and command area catchment, land husbandry practices that will improve crop production will be adopted, but the prevailing cropping patterns will be maintained.

4.1.15 Improved access to water for domestic purposes

Provision of water in the reservoir will save the community from fetching water from far distances even during the dry season thus utilizing the time saved in tending to livestock, crop enterprises or household chores. They beneficiaries intend to use this water for livestock as well as domestic purposes such as washing clothes, bathing, cleaning and feeding livestock.

This implies that the project interventions will indirectly lead to better hygiene practices which are vital in ensuring good health.

4.1.16 Improved nutrition

All the farmers were optimistic that through the project they would increase food production thus making it possible for community members to acquire available food. This would imply that if the production is improved, there will be more food thus resulting in a decrease in prices hence making it affordable to all the members within the community to have access to food.

4.1.17 Water for domestic use - washing clothes, bathing livestock

The farmers indicated that they intended to utilize the irrigation water for livestock. Feeding livestock was mainly in men’s domain hence they also fetched water for the livestock. Fetching water for livestock from the water reservoir would reduce the time they spend fetching it from far water sources. However, fetching of water for livestock was also done by women and children. This improved access to water for domestic purposes implies that there will be a general improvement of cleanliness within the homes hence healthier families. It also implies that it will be a time-saving strategy that has a potential of contributing to the improved participation of women in CCPIG meetings.

4.1.18 Other benefits

Appreciation of the value of land

Nominal land prices may increase thus making the high value irrigable land useful for cultivation and marketable which was otherwise less favored due to flooding. The current value of land was RWF 1,200,000 (US$2200), but as a result of the improved potential of its productivity, then it would appreciate in value.

Employment creation for community members

The project would not only benefit farmers within the irrigable area but would also create employment opportunities for other community members who will participate in labor provision in the farms (casual laboring) as well as stockists who will provide inputs and shopkeepers who stock household necessities.

Provision of fuelwood

Provision of fuelwood is another benefit that would accrue to them through the project.

Empowerment of farmers

Empowerment of the farmers in the course of the implementation of the project, farmers will be sensitized and trained on the use of water and production of different crops, thus imparting skills to them for improved production as well as to access markets, which they will utilize even after the project’s exit.
4.2 Significant Adverse (Negative) Impacts

Significant negative impacts are those effects that will as a result of the implementation of the activities contribute to unintended results. These impacts have been described in the different phases of the project and are further categorized in terms of impact duration, magnitude and type respectively.

4.2.1 Design and Planning Phase

The design phase of this sub project involved identification of a suitable site for the infrastructure and undertaking of a detailed feasibility study. There are no adverse impacts expected during this stage, however, best practice was incorporated at this stage to ensure that the design takes into account the environmental issues to consider.

4.2.2 Construction Phase

4.2.2.1 Destruction of Vegetation

All the crop enterprises and trees established in the project area would have to be destroyed. This is because they were in areas that would be inundated by water at the reservoir. They PAPs would lose benefits which they were already reaping from these enterprises including getting food for home consumption, getting produce for sale and getting fodder for livestock.

Mitigation Measure(s)

This impact is unavoidable and will be mitigated through compensation for crop and vegetation loss through the preparation of Resettlement Action Plans (RAPs).

4.2.2.2 Relocation Impacts

One of the major concerns of the households was whether there would be compensation for land parcels that would be affected by the water reservoir. There are 6 households’ housing structures located within the reservoir. An additional 5 households are recommended for relocation since their houses are very close to the proposed reservoir area.

As mentioned earlier, implementation of the LWH project at the Nyanza-23 project site will have resettlement implications, with the affected households falling in two categories:

- Households owning farms within the proposed reservoir area (11.99 ha), will lose their land permanently. Based on the average farm sizes (1.68 ha/household) in the area, it is estimated that 8 households will be affected.

- Households with housing structures within the proposed reservoir. There are 6 households settled within the proposed reservoir area who will be required to relocate. Additionally, there are 5 households located very close to the water reservoir, recommended for relocation. Thus, a total of 11 households.

- Farmers with land parcels surrounding the water reservoir. An estimated 21 farmers (based on the average farm sizes (1.68 ha/household) with farms surrounding the reservoir area will change their land-use. This will be the silt-trap zone (33.85 ha), comprising of a grass-zone, shrub-zone and tree-zone protecting the water reservoir from siltation. The proposed reservoir area and the silt trap zone has mainly been used for crop production mainly for subsistence purposes, with little surplus for sale. After the vegetation within the silt-trap zone is established and becomes productive, households owning those pieces of land will control the benefits. Though the grass-covered fields could yield within three months time, the shrub and tree zone will generate income after 4 years. Therefore, these farmers will be compensated accordingly.
**Mitigation Measure(s)**
This impact is unavoidable and will be mitigated through compensation for crop and vegetation loss, land and housing through the preparation of Resettlement Action Plans (RAPs) and guided by the Resettlement Policy Framework (RPF) document.

**4.2.2.3 Borrow Pit Impacts**
Borrow pit are generally associated with scaring of the general environment and landscape owing to the excavation related works. If not backfilled immediately and replanted, the borrow pits end up becoming a health hazard and a source of spread of water borne related diseases like bilharzia, malaria etc. This is because the pits end up collecting water that stagnate and hence becoming a rich breeding ground for the disease vectors. Borrow pits are also known to be potential sources of hazards especially accidental drowning of livestock and human beings.

**Mitigation Measure(s)**
This site is an existing borrow area, which is being actively exploited and conveniently located. The environmental effect due to the additional exploitation is thus kept at a minimum.

**4.2.2.4 Soil Erosion**
During the construction of the dam and its ancillary facilities which will involve clearing of vegetation, excavation works etc the soil will be exposed to the agents of erosion, mostly water. This impact occurs during project construction and operational phase.

**Mitigation Measure(s)**
Institution of soil control measures during construction is necessary.

**4.2.3 Operation Phase**
The operation phase entails the actual irrigation of the hillsides after the water has been harvested. The potential adverse impacts in this phase include;

**4.2.3.1 Reduced Water Flow/Down Stream Flooding**
Dam construction for irrigation and construction involves blocking and deviation of the flow of water to the marshlands or valleys. Due to this the downstream water users might experience temporary shortfall (until the reservoirs fill) in the amount of water available therefore disrupting activities and sources of livelihood that depend on the waters. This is a short term impact that only happens when the water will be diverted to the dam. The impact will change flood plain, land use and ecology downstream for a short period especially in the Gisuma River.

**Mitigation Measure(s)**
The valley where the dam is going to be constructed has base flow. Though this base flow is intercepted by the dam, downstream use would not be affected at least for two reasons.
- The irrigation canal that conveys water from the dam serves primarily areas just downstream of the dam.
- In less than a 100m from the dam toe, branching valleys from the main dam valley contribute water for downstream users.

This impact is short term and will only be experienced during the initial operation phases of the project when the reservoir will require filling up.
4.2.3.2 Fear of an overflow of water if it rained so heavily
The PAPs interviewed during the public consultation exercise expressed fear of water overflowing out of the reservoir in case unusually heavy rains occurred causing havoc in the project area.

Mitigation Measure(s)
The project design has included spillways to address this potential adverse impact which is considered long term and expected to occur throughout the project operation phase. During the sensitization and awareness meetings, it will be important to reassure them of the intentions of having a spillway to address this.

Internal Seepage Control Measures
The design of adequate filters in zoned embankment dams is vital to control erosion of the earth core and dam foundations under the forces generated by seepage through and under the dam. These filters are essential to the performance of the dam. Their failure to perform satisfactorily can lead to piping failure of the dam.

Filters designated as “Critical” will be placed in areas of the embankment where the prevention of erosion is vital. Other Filters designated as “Non-Critical” will be also provided upstream of the earth fill core, beneath riprap and in other selected places.

As described by Indraratna and Locke (1999), to function correctly, filters must be:
- Sufficiently fine grained such that the pore constrictions (smallest opening between pores) are small enough to retain the core material which may wash out into the filter
- Sufficiently permeable to facilitate seepage flow out of the base soil, preventing the buildup of pore pressure
- Non-cohesive so that any cracks in the base are not propagated into the filter and they cannot develop cracks due to deformation.

The critical filters of the dam have been designed using the recommendations of Indraratna and Locke (1999). This is based on the work by Sherard and Dunnigan (1985) and some more recent research. Their works are summarized in Annex 2.

4.2.3.3 Increased Spread of Water Borne Diseases
Households feared that there would be an increase in the incidences of malaria because the water reservoir would serve as a breeding ground for mosquitoes. They also feared that there would be a “cool breeze” prevailing as a result of the water mass that would result in respiratory related problems due to continuous exposure of residents. They also cited stomach-related disorders specifically infestation by worms, as a result of young household members using the irrigation water for domestic purposes (drinking and cooking) when not supervised.

Mitigation Measure(s)
LWH should support the introduction of fish in the dam as a strategy for reducing the breeding of mosquitoes in order to contain malaria spread.

The LWH should develop a program in collaboration with the Ministry of Health (MINISANTE) and the local communities which undertakes bi-annual survey of health records in Health Care Facilities (HCFs) to ascertain the spread of malaria. This data should then be used to develop a malaria prevention project within LWH that could include use of Insecticide Treated Nets, Indoor Residual Spraying among others.

However, similar to the live fencing, the project implementation, this has taken into consideration and the
project design includes introduction of fish species that feed on mosquito larvae. Additionally, it includes planting of *Phytolaca decocandra* which will destroy the snails that serve as hosts of syphiliasis. This adds to diversification of income through fish farming. The study revealed that a few of the households (33 %) reported episodes of malaria attacks among household members where different categories of household members were affected. Nine percent (9%) of the households also reported water-related stomach disorders, specifically infestation by worms. The respondents indicated willingness to take precautions to avoid falling sick by use of mosquito nets, use of aerosols for killing the mosquitoes in their houses, and taking health insurance that would come in handy in case of sickness.

4.2.3.4 Canal Siltation
Canal siltation is an adverse impact that clogs the canals leading to less flow of water into the command area and farming fields and this can reduce the crop yields. Increased soil erosion and siltation is generally impacting the hydrology of the marshlands and rivers negatively. Furthermore, clogged canals could soon become possible breeding site for mosquitoes if not maintained and unclogged.

Mitigation Measure(s)
Silt traps have been included in the general design of the project and the canals will be flushed as frequent as possible to minimize this impact.

Training on maintenance of the water canals
The project team should provide training for the local farmers on how to operate and maintain the water intake points and canals to ensure that there is no blockages or flooding.

4.2.3.5 Dam Safety Impacts
The construction of the dam is faced with a potential collapse of the dam wall due to earth tremors, treks etc that can be a source of destruction of crops and property and even life if the walls fail and cause flooding downstream when there are heavy rains that the walls of the dam cannot withstand.

Mitigation Measure(s)
The dam site is located in a seismic zone of low intensity and there is no earthquake recording station in the vicinity of the project area. Records to show the earthquake events experienced in the project area are not there.

Seepage and leakage
Measurement of seepage through the dam body, foundations & abutments of the dam may indicate erosion or blocking of downstream drains and relief wells by increase or decrease of seepage respectively at constant reservoir level. Seepage and erosion may take place along the lines of poor compaction and through the cracks in formation and fills. This may be indicated by such measurement. Measurement of seepage water at interface of dam and its foundation will provide direct indication of the efficiency of cutoff and indicate about the necessary remedial measures. The chemical analysis of water will provide the information of seepage of water through the foundation drainage arrangement and any foundation material being washed out. Corrective measures could be planned. The wet spots on the downstream slope or at abutment locations would indicate seepage problem, and remedial measures could be suggested.

Surface movement measurement
The measurement of surface movement of the embankment dam shall be made by means of installing 6 number of surface settlement points on the dam slope, dam crest at 50.0 m center to center and shall be monitored by using a theodolite at regular intervals from bench mark established and readings each time taken shall be compared with the earlier reading to arrive at the settlement of the surface.
Earthquake Measurement
The dam site is located in a seismic zone of low intensity and there is no earthquake recording station in the vicinity of the project area. Records to show the earthquake events experienced in the project area are not there:

The instruments for recording of seismic events proposed to be installed for the dam consists of one acceleograph at the base of the dam and one at the top of the dam. Strong motion accelerographs and structural response recorder are to be installed at the base and at the top of dam. The location selected should be free from the background seismic noise erected due to vibrations of the appurtenant works. The instrument located at the top would provide information about responses of structure resulting from earthquake.

Spillway has been designed to have discharging capacity sufficient enough to pass the inflow floods corresponding to a return period of 1 in 100 years, as it is defined as large dam from the height aspect and a small one from the storage capacity aspect.

International standards (Indian Standards) specify that if the failure of dam poses danger to human life, the spillway must have sufficient capacity to accommodate the routed flood discharge corresponding to probable maximum Flood (PMF) and if the failure of dam would result only in heavy damage to property but does not pose appreciable risk to life then the spillway may be designed for flood discharge corresponding to 1 in 10,000 year return period.

The dam location is in an area where failure may probably remain restricted to the irrigation farms and the dam area itself. Loss to human life would probably be minimal. For such a situation and for the sake of economy, a routed flood discharge corresponding to 1 in 200 years return period has been considered as there is not much habitation downstream of the dam site. The flood with a return period of 1 in 200 years as computed in the hydrology resulted in a flood lift of 0.56 m and spillway width of 4.0 m. Hence, the spillway has adequate capacity.

Dam Safety Monitoring/Measuring Instruments
The program plans to buy and install instruments for recording seismic events. The instruments for recording of seismic events proposed to be installed for the dam consists of one acceleograph at the base of the dam and one at the top of the dam. Strong motion accelerographs and structural response recorder are to be installed at the base and at the top of dam. The location selected should be free from the background seismic noise erected due to vibrations of the appurtenant works. The instrument located at the top would provide information about responses of structure resulting from earthquake.

Other Measurements
Wave Height Recorders: Wave height Recorders installed would be helpful in finding the wave height and in deciding the free board requirements on a more realistic way.

Rainfall: measurement of rainfall will be helpful for interpretation of pore measurement and seepage development in earth dam.

4.2.3.6 Drowning of livestock and children
During the public consultation process respondents expressed fears in drowning incidents of children and livestock that they foresee with the implementation of the project. However, the project design includes a silt-trap and live fencing which will take care of these fears effectively. The study revealed that households within the project site had not experienced incidences of drowning for humans or livestock.

Mitigation Measure(s)
• The LWH should before the construction undertake education and awareness of the local communities and making them aware of the hazards related to unrestricted entry into the dam reservoir.

• LWH should fence the reservoir area, erect warning signs and control access of the dam while efforts should be put on teaching local people proper safety behavior and swimming.

• LWH should also construct water drinking points for the local communities as a strategy and a way for reducing increased access to the dam reservoir to get water which causes incidents.

4.2.3.7 Agro-Chemical Pollution
The use of fertilizers and pesticides in the farming areas is going to be a potential source of introducing nutrients into the water resource of the marshland and the stream that flows through the area. Runoff agrochemicals (compound of phosphate, nitrates and ammonium) and pesticides are most likely being dispersed downstream into confluence of the marshland which drains into the Gisuma River.

Mitigation Measure(s)
The LWH project is already preparing a Pest Management Plan for the entire project which will provide guidance on the judicious use of chemicals in the cultivation and production of crops.

Training and Capacity Building Mitigation Measures
Pesticide/Fertilizer Application Training
The LWH Agronomist and the provincial level field agronomist should conducting training to the local farmers on the safe application of pesticides and fertilizers. This is a practice that can immensely contributing to the reduction of possible chemical pollution of the marshlands. The training on pesticide application touches on the quantities to apply, timing (when), and protective gears to wear among others and should be incorporated in the Pest Management Plan that is under preparation.

Establishing Baseline Data for current water quality with respect to agrochemical pollution.
These baseline data should be collected before the LWH project begins. This will help in monitoring and controlling pollution caused by the use of Pesticides/Fertilizers.

5. ENVIRONMENTAL MANAGEMENT PLAN IMPLEMENTATION
This EMP will be implemented by the several institutions mentioned below who are directly or indirectly involved in this subproject.

5.1 World Bank
World Bank is the financier of the project including the implementation of the EMP within the budget of LWH. The main role of the bank is to ensure that compliance is achieved as per the requirements of the EMP.

5.2 Ministry of Agriculture and Animal Resources (MINAGRI)
Ministry of Agriculture and Animal Resources (MINIAGRI) through the LWH is the lead agency in the implementation of this EMP and the project. The role of the LWH is to implement mitigation measures, building the capacity of other actors in IPM, and in environmental management.
The LWH agronomist will be the focal point for training in IMP and agrochemical application and will liaise with the ministry of agriculture for technical support. It should be noted that all the capacity building activities should be hands-on through the FFS approach. The project should establish one farm in one of the project areas which will act as the field school.

The ministry through LWH will also supervise infrastructure design and construction including dams and drainage. The role of MINAGRI will to ensure that the dams and drainages are constructed according to the specifications international technical and safety standards.

**Training on IPM**
The training program will cover amounts of fertilizer to be applied per hectare of land and during what conditions should be undertaken before commissioning of the project. The types and amounts of pesticides should also be part of this training. This training should be a hands-on that can be introduced in the Farmer’s Field School (FFS) model adopted by the project. Food and Agriculture Organization (FAO) and ISAR and the RSSP II project have the capacity to undertake this activity and could be partners with LWH.

**Training in Fertilizer and Pesticides Application**
The training objective is to ensure beneficiary farmers in the project area do not pollute water resources through unsustainable application of inorganic fertilizers. This capacity building activity can undertake by MINAGRI with technical support from Institut des Sciences Agronomiques du Rwanda.

**5.3 Land Husbandry Hillside Irrigation and Water Harvesting Project**
Land Husbandry Hillside Irrigation and Water Harvesting Project (LWH) is the lead agency in the implementation of this EMP and the project. The role of the LWH will be to implement mitigation measures, coordination of monitoring activities maintenance of monitoring information, building the capacity of other stakeholders in collection and analysis of monitoring data.

The Environmental Officer of LWH will be the focal point for the EMP and will liaise with other stakeholders to execute the plan.

**5.4 Rwanda Environment Management Authority**
Rwanda Environment Management Authority is the oversight authority over the environment in Rwanda. Its role will be of monitoring environment indicators as identified in this EMP. The role of Rwanda Environment Management Authority (REMA) includes:

**Oversight Monitoring**
As the lead agency responsible for the protection of environment in Rwanda, REMA will play the leading oversight role of monitoring the activities of the project according to the Organic Law establishing REMA and its functions.

**Site Inspection Visits**
REMA will undertake regular site visits to inspect and verify for themselves the nature and extent of the impacts. REMA will undertake also undertake regular site visits to inspect and verify for themselves the extent to which the mitigation measures proposed in this EMP are being complied with or vice versa. They will then be expected to make viable recommendations based on their findings to the LWH.

**Periodic Reports**
REMA will prepare periodic environmental consolidated reports on the monitoring progress of the marshland development.
5.5 Community Group/Project Beneficiaries
The project beneficiaries being the people on the ground will have the role of execute some of the mitigation measures, collecting and monitoring the identified indicators and practicing sustainable farming as well as catchment rehabilitation and management. The project beneficiaries are organized in cooperatives which have management committees for water, production and maintenance.

5.6 Contractors
The contractor will be in charge of designing and constructing the infrastructure according to the World Bank operation policy on dam safety, restoring the borrow pits and degraded areas, ensuring the safety of the users and others.

5.7 Ministry of Health
Due to possible health impacts especially malaria and bilharzia in the subproject areas, the ministry of health comes into the picture of this project. The role of the ministry of health will be to promote environmental health, health prevention methods including sleeping in treated nets and monitoring incidences of malaria and bilharzia.

5.8 Local Authorities
The LWH subprojects are being implemented in several districts which are administered by the respective district authorities. These local authorities have jurisdiction over the subproject areas and control the marshlands including use and conservation. The marshland farmers pay taxes to the respective authorities for use of these areas. The department of agriculture and animal husbandry would be the focal point in the respective local authorities.

The role of the local authorities will be to monitor and ensure sustainable utilization of the marshlands after the project period. They will be the agency close to the project and will ensure the EMP is implemented by the different stakeholders as indicated.
## CONSTRUCTION PHASE

<table>
<thead>
<tr>
<th>Activity</th>
<th>Adverse Impacts</th>
<th>Mitigation Measure(s)</th>
<th>Implementation Schedule</th>
<th>Responsibility</th>
<th>Budget (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Civil Works</td>
<td>Loss of crops, vegetation and trees. Loss of land</td>
<td>Compensate for property loss, crop loss and land loss</td>
<td>Compensation should occur in line with the ARAP and before construction commences.</td>
<td>LWH</td>
<td>Will be reflected in the ARAP.</td>
</tr>
<tr>
<td>Soil erosion.</td>
<td></td>
<td>Create contour drains during construction Soil Erosion Management strategies to include revegetation, creation of erosion berms</td>
<td>During the construction</td>
<td>Contractor</td>
<td>Factored in the contractor cost</td>
</tr>
<tr>
<td>Borrow sites create disease vector breeding ground and hazards</td>
<td></td>
<td>Backfilling and leveling of the borrow pits to prevent water percolation.</td>
<td>Immediately after the construction</td>
<td>Contractor</td>
<td>Factored in the contractor contract</td>
</tr>
<tr>
<td>Fugitive dust generated during excavation works could cause respiratory diseases</td>
<td></td>
<td>Wetting the surface during construction Providing all workers with PPEs</td>
<td>Construction process</td>
<td>Contractor</td>
<td>None as water is available and near the sites</td>
</tr>
</tbody>
</table>
## OPERATION PHASE

<table>
<thead>
<tr>
<th>Activity</th>
<th>Adverse Impacts</th>
<th>Mitigation Measures</th>
<th>Implementation Schedule</th>
<th>Responsibility</th>
<th>Budget (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reservoir filling</td>
<td>Reduced water flow downstream during the time that the reservoir will be filling up.</td>
<td>Control abstraction rates to half the river flow to replicate natural flooding regime. Proper design and operation of dam spillways and gates (timing and volume of discharges). Construct coffer dam Fill the reservoirs during wet season when there is high flow • Introduce fish in the dam • Create awareness on malaria prevention methods • Provide treated mosquito nets Increase overflow spill capacity</td>
<td>Design and operation phases</td>
<td>LWH staff</td>
<td>Part of the contract costs</td>
</tr>
<tr>
<td>Flooding</td>
<td>Increased spread of water borne disease vector including Malaria, Cholera, Bilharzia etc</td>
<td>• Fencing of the reservoir area • Provision of community water access points</td>
<td>Operation phase</td>
<td>LWH staff</td>
<td>None</td>
</tr>
<tr>
<td>Safety Hazards (drowning, flooding and breakage of dam wall)</td>
<td><em>FILLING</em></td>
<td>• Construction and Operation</td>
<td>Contractor and LWH</td>
<td>Included in the contract design document</td>
<td>Part of LWH budget for hillside interventions</td>
</tr>
<tr>
<td>Activity</td>
<td>Adverse Impacts</td>
<td>Mitigation Measures</td>
<td>Implementation Schedule</td>
<td>Responsibility</td>
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</tr>
<tr>
<td>Soil Erosion</td>
<td></td>
<td>• Conduct community awareness and sensitization&lt;br&gt;• Posting of a security guard</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Design of dam safety measures including dam instrumentation for seepage and leakage analyses, quake recording and movements analysis&lt;br&gt;Construct the dam to meet international technical and safety standards&lt;br&gt;Terracing of the sloppy areas of the land and plating of nappier grass along the canals&lt;br&gt;Contour drainage to slow down surface runoff&lt;br&gt;Land leveling to prevent erosion&lt;br&gt;Regulate water abstraction through practices and design of the intake structures&lt;br&gt;Undertake hydrological assessment of the catchments</td>
<td>During the Design and construction stage&lt;br&gt;During the Design Phase&lt;br&gt;Construction and Operation phase&lt;br&gt;During construction and operation&lt;br&gt;Should be done before project commissioning</td>
<td>LWH and contractors, Contractor (A clause in the contract)&lt;br&gt;Construction contractor&lt;br&gt;LWH &amp; Cooperative/association members&lt;br&gt;LWH &amp; contractor</td>
<td>Cost of the instruments are included in the contract document&lt;br&gt;None&lt;br&gt;Included in the contract document&lt;br&gt;None&lt;br&gt;LWH</td>
</tr>
<tr>
<td>Reduced Water Flow</td>
<td></td>
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</tbody>
</table>

LWH Environmental Management Plan: Nyanza 23
<table>
<thead>
<tr>
<th>Activity</th>
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<th>Implementation Schedule</th>
<th>Responsibility</th>
<th>Budget (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application of agrochemicals (fertilizer and pesticides)</td>
<td>Water Pollution and degradation through chemicals</td>
<td>• Prepare an Integrated Pest Management Plan (PMP).</td>
<td>Planning and operation stages</td>
<td>LWH</td>
<td>Part of the LWH budget</td>
</tr>
</tbody>
</table>
6. MONITORING PLAN

The monitoring plan defines and identifies monitoring activities will take place, when and by whom and identifies the indicators and data collection methods and identifies training and capacity building needs of the institutions and persons to implement the plan.

As indicated on the monitoring schedule below, monitoring will be done by numerous institutions and persons but coordinated by M&E division of LWH secretariat in Kigali and the focal person will be the Environmental Officer who should be employed by LWH immediately before the commencement of the project.

To ensure effective and reliable data collection, the key persons from the institutions to be involved in the monitoring will be trained on the indicators to be monitored, sampling methods, and data collection techniques to be used. The LWH M&E division will organize a 2 day training program in one of the project sites and train the participants. The key resource persons for this training will be the Environmental Officer and the M&E coordinator. Participants for this training will be from the institutions involved in implementation of the monitoring plan which are LWH M&E division, Environmental Officer, Agronomist, and irrigation engineer, REMA, Cooperative/association members from each subproject site, MINAGRI, Ministry of Health diseases surveillance division or public health and engineers from Ministry of infrastructure (MININFRA). LWH can commission a consultant to develop modules for M&E if need be.

The LWH M&E division will be the monitoring data depository and bank and will coordinate the collection of these data as described in the schedule. The division will need to install a monitoring and tracking system.

Technical data that might not be collected by the cooperative members /beneficiaries, LWH provincial M&E officers will be in charge of this.

LWH Project secretariat will need to facilitate the Environmental Officer to purchase sample collection equipment especially for water sample collection. The national metrological survey will be responsible for monitoring the river flows. A portable hydro flow meter (river flow measuring gadget) will be ideal for a project of this nature that has many sites to be monitored.

As the LWH has M&E component with budget, the cost of implementing this plan will be minimal as the plan will be integrated into the project component.

Food and Agriculture Organization seasonal crop assessments capacity can be used in monitoring food security indicators in all the subproject sites.

It should be noted that, LWH is a project of MINAGRI and as such it will come to an end after the already determined cycle, while the project operations will continue even after the end of the project. At the end of the project, the responsibility of monitoring the project impacts will rest with the respective agencies and REMA and the respective cooperative members.

6.1 Water Quality Monitoring

During the operation period, monitoring is proposed for water quality especially to determine the level and concentration of pesticides and fertilizer content in the command area.

The consultant proposes the identification of different points of the command area in order to monitor the quality of water. Periodic taking of water samples should be undertaken preferably twice a year during the cultivation season to determine water quality. Water sampling points should be at the beginning of the command area, middle and at the mouth of the marshland where it drains into the Lake Rimura. These
samples should be taken by the provincial agronomist to the LWH environmental officer who should then take them in an accredited laboratory for testing. The results should be used to design appropriate water quality mitigation programs. The same will apply to analysis of water quantities in relation to the abstraction impacts. Different stations will need to be identified and flow quantities recorded during different times of the year preferably during the wet and dry season respectively. The results should be used to deduce the impacts of the abstraction of water on the hydrology of the marshlands and the wider catchment basin.

6.2 Monitoring Diseases spread
In order to monitor the possible impacts of the marshland development to malaria and bilharzia spread in the area, the LWH sociologist together with the provincial LWH staff need to undertake periodic surveys of the health records around the marshland to ascertain prevalence of disease spread. The surveys should be done 2 times in a year. Even though it cannot be proven that the LWH project could be directly contributing to the spread of these diseases, the results can be used to assist LWH increase its interventions on malaria and bilharzia prevalence.

6.3 Monitoring Seepage and leakage
Measurement of seepage through the dam body, foundations & abutments of the dam may indicate erosion or blocking of downstream drains and relief wells by increase or decrease of seepage respectively at constant reservoir level. Seepage and erosion may take place along the lines of poor compaction and through the cracks in formation and fills. This may be indicated by such measurement. Measurement of seepage water at interface of dam and its foundation will provide direct indication of the efficiency of cutoff and indicate about the necessary remedial measures. The chemical analysis of water will provide the information of seepage of water through the foundation drainage arrangement and any foundation material being washed out.

6.4 Surface movement measurement
The measurement of surface movement of the embankment dam shall be made by means of installing 6 number of surface settlement points on the dam slope, dam crest at 50.0 m center to center and shall be monitored by using a theodolite at regular intervals from bench mark established and readings each time taken shall be compared with the earlier reading to arrive at the settlement of the surface.

6.5 Earthquake Measurement
The dam site is located in a seismic zone of low intensity and there is no earthquake recording station in the vicinity of the project area. Records to show the earthquake events experienced in the project area are not there:

The instruments for recording of seismic events proposed to be installed for the dam consists of one acceleograph at the base of the dam and one at the top of the dam. Strong motion accelerographs and structural response recorder are to be installed at the base and at the top of dam. The location selected should be free from the background seismic noise erected due to vibrations of the appurtenant works. The instrument located at the top would provide information about responses of structure resulting from earthquake.

Spillway has been designed to have discharging capacity sufficient enough to pass the inflow floods corresponding to a return period of 1 in 100 years, as it is defined as large dam from the height aspect and a small one from the storage capacity aspect.

International standards (Indian Standards) specify that if the failure of dam poses danger to human life, the spillway must have sufficient capacity to accommodate the routed flood discharge corresponding to probable maximum Flood (PMF) and if the failure of dam would result only in heavy damage to property but
The dam location is in an area where failure may probably remain restricted to the irrigation farms and the dam area itself. Loss to human life would probably be minimal. For such a situation and for the sake of economy, a routed flood discharge corresponding to 1 in 200 years return period has been considered as there is not much habitation downstream of the dam site. The flood with a return period of 1 in 200 years as computed in the hydrology resulted in a flood lift of 0.56 m and spillway width of 4.0 m. Hence, the spillway has adequate capacity.

6.6. Monitoring Framework
<table>
<thead>
<tr>
<th>Impact</th>
<th>Parameter</th>
<th>Indicator</th>
<th>Method</th>
<th>Frequency of Measurement</th>
<th>Responsibility</th>
<th>Costs Estimates (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Physical Environment</strong></td>
<td></td>
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<tr>
<td>Water pollution</td>
<td>Quality</td>
<td>Nutrient Load (Nitrates, phosphates, potassium, pesticide residue, COD &amp; BOD, Turbidity)</td>
<td>Bi-Annually during wet and dry season (samples should be taken from the inlet and outlet points of the developed area)</td>
<td>Seasonally</td>
<td>LWH</td>
<td>30,000.00</td>
</tr>
<tr>
<td>Reduced Water flow</td>
<td>Quantity</td>
<td>Flow rates per second</td>
<td>River/stream gauging</td>
<td>Seasonally</td>
<td>MINITERE &amp; LWH (Environmental Officer) &amp; REMA</td>
<td></td>
</tr>
<tr>
<td>Soil erosion</td>
<td>Soil cover loss</td>
<td>Soil productivity, gullies, water turbidity</td>
<td>Observation</td>
<td>Continuous</td>
<td>LWH, MINAGRI, REMA &amp; Community beneficiaries</td>
<td></td>
</tr>
<tr>
<td>Flooding</td>
<td>Area inundated</td>
<td>Flooding downstream of project area</td>
<td>Observation and reported cases of flooding</td>
<td>Continuous</td>
<td>Community beneficiaries &amp; LWH</td>
<td></td>
</tr>
<tr>
<td>Water wastage</td>
<td>Water availability</td>
<td></td>
<td>Install water meters in the intake point</td>
<td>Continuous</td>
<td>LWH, REMA &amp; contractor</td>
<td></td>
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<tr>
<td><strong>Socio-economic Environment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Water-borne Diseases</td>
<td>Disease prevalence</td>
<td>Increased cases of malaria and bilharzias among other waterborne</td>
<td>Review of health records</td>
<td>Quarterly</td>
<td>LWH (Social and Environmental Officer),</td>
<td></td>
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</table>

**LWH Environmental Management Plan: Nyanza 23**
<table>
<thead>
<tr>
<th>Impact</th>
<th>Parameter</th>
<th>Indicator</th>
<th>Method</th>
<th>Frequency of Measurement</th>
<th>Responsibility</th>
<th>Costs Estimates (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety Hazard</td>
<td>Safety of live stock and humans</td>
<td>Reported cases of incidences and accidents, Seepages and leakages reported or observed on the dam, Color, turbidity and change in seepage chemical content</td>
<td>Review and evaluation of incidents and accidents register, Instrumentation equipment including; Acceleograph, theodolite</td>
<td>Continuous monitoring of leakages, seepages, movements through instrumentation</td>
<td>LWH (engineer) &amp; MININFRA</td>
<td>Part of the project M&amp;E budget</td>
</tr>
<tr>
<td></td>
<td></td>
<td>diseases</td>
<td></td>
<td></td>
<td>community and Ministry of Health</td>
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</tbody>
</table>
7. CONCLUSION

The LWH Nyanza 23 sub project activities considered in this study are environmentally feasible due to the fact that proposed interventions are environmentally friendly e.g. hillside irrigation and land husbandry. In addition, the adverse impacts anticipated can be effectively managed by following the designed EMP which includes mitigation measures already thought out in the design and feasibility study phase.