Republic of Rwanda

RWANDA ENVIRONMENT MANAGEMENT AUTHORITY (REMA)

FEASIBILITY STUDY, BASELINE STUDIES AND DETAILED DESIGNS FOR WETLAND REHABILITATION IN THE CITY OF KIGALI

Detailed Proposed Rehabilitation Designs Report – Final Version

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List of acronyms

BOD	Biochemical Oxygen Demand
CBD	Central Business District
COD	Chemical Oxygen Demand
CoK	City of Kigali
DO	Dissolved Oxygen
EDCL	Energy Development Corporation Limited
ESCP	Environmental and Social Commitment Plan
ESF	Environmental and Social Framework from the World Bank (2018)
ESIA	Environmental and Social Impact Assessment
ESMF	Environmental and Social Management Framework
ESMP	Environmental and Social Management Plan
GoR	Government of Rwanda
HCB	Hexachlorobenzene
IUCN	International Union for Conservation of Nature
KUUT/KUUP	Kigali Urban Upgrading Team/Project
LODA	Local Administrative Entities Development Agency
LVEMP II	Lake Victoria Environmental Management Project
MINALOC	Ministry of Local Government
MININFRA	Ministry of Infrastructure
MINISPORT	Ministry of Sports
NBS	Nature-Based Solutions
NUDOR	National Union of Disability Organizations of Rwanda
O&M	Operation and Maintenance
PAH	Polycyclic Aromatic Hydrocarbons
PCB	Polychlorinated biphenyls
PID	Project Information Document
PPP	Public-Private Partnership
RAP/LRP	Resettlement Action Plan/Livelihood Restoration Plan
RECOR	Rwanda Environmental Conservation Organization
REMA	Rwanda Environment Management Authority
RFA	Rwanda Forestry Authority
RLMA	Rwanda Land Management and Use Authority
RTDA	Rwanda Transport Development Authority

RUDP II	Rwanda Urban Development Project, Phase II
RWB	Rwanda Water Resources Board
SWMMP	Stormwater management master plan
TOR	Terms of Reference
WASAC	Water and Sanitation Corporation

1. INTRODUCTION

This document is the Detailed Design of Proposed Rehabilitation Report for the project "Feasibility Study and Detailed Designs for Wetland Rehabilitation in the City of Kigali" (the "Study"). This project is part of the Rwanda Urban Development Project, Phase II (RUDP II). As part of this second phase, the Government of Rwanda (GoR) will receive funds from the World Bank, the Global Environmental Facility (GEF) and the Pilot Program for Climate Resilience and Nordic Development Fund (NDF).

This document is intended for Rwanda Environment Management Authority (REMA), the "Client" and the Implementing Agency of the Study.

This Study is part of Subcomponent 1b of the RUDP II and will support its implementation, the other RUDP II components are as follow:

- Component 1: Support to the City of Kigali
  - Subcomponent 1a: Integrated urban planning for resilient, inclusive infrastructure delivery
  - Subcomponent 1b: Evidence-based, sustainable wetland management, flood risk management and greenhouse gas monitoring in the City of Kigali
- Component 2: Support to Secondary Cities
  - Subcomponent 2a: Infrastructure and service delivery
  - Subcomponent 2b: Institutional capacity development
- Component 3: Institutional Capacity Development and Project Management
  - Subcomponent 3a: Institutional capacity development at national level
  - Subcomponent 3b: Project management
- Component 4: Contingency Emergency Response

REMA launched call for tender for the Study in February 2021 and IBC Group/SGI Ingénierie SA (the "Consultant") won the tender and signed a contract with REMA to undertake the Study in November 2021.

This report is the third deliverable of the Study. It was undertaken after the Inception report, which was validated by REMA in March 2022 and the Feasibility Study, Baseline Studies and Preliminary Proposed Rehabilitation Designs Report which was approved after two validation workshops with stakeholders held in June and September 2022 and a high level consultative meeting held in October 2022 with the Minister of Environment, Minister in charge of emergency, Lord Mayor of CoK, Permanent Secretary of the ministry of infrastructure, Representative of Ministers, Director General of respective institutions, RUDP II Team REMA, and Consultant Team.

1.1 PROJECT RATIONALE

The City of Kigali (CoK) experiences frequent floods. High intensity storms lead to fast runoff along the steep slopes of Kigali, resulting in flash flooding in the city. Floods cause damage to people's homes and industrial properties, disruption of traffic flow and economic activity in the city. They increase water pollution through the spreading of contaminated water and garbage during rainfall. Furthermore, many urban poor populations tend to reside in low lying flood prone areas and reclaimed wetland areas, increasing their vulnerability to flooding of cropland.

According to the Project Information Document (PID) for the RUDP II, poorly managed urbanization is threatening the state of environment leading to increased vulnerability to flood risks, land degradation and biodiversity loss. In addition, the city's extensive network of wetlands has shrunk from 100 km^2 in 2013 to the current level of 72 km^2 due to encroachment by activities such as industry and urban agriculture. Reduce wetland surface, encroachment and the degradation of the state of wetlands have impaired their ability to buffer storm-water runoff and floods.

The Government of Rwanda (GoR), will address some of the flood hazards in Kigali through targeted investments in stormwater management and Nature-Based Solutions (NBS), including targeted wetland rehabilitation. REMA, the City of Kigali and other relevant stakeholders, identified five priority urban wetlands designated for rehabilitation: Rwampara, Gikondo, Rugenge-Rwintare, Kibumba and Nyabugogo Lower wetlands. These wetlands are hydro-connected and part of the Nyabugogo River Catchment.

In response to flooding challenges, this study evaluates possible wetland rehabilitations and NBS as a mean to mitigate floods and associated impacts.

The following table shows the wetlands, their surface, the main waterbody flowing through them and the administrative districts where they are located.

Wetland Name	River/Stream	Area (ha)	Administrative Districts
Gikondo	Rugenge	162	Kicukiro and Gasabo
Rwampara	Rwampara	65	Nyarugenge and Kicukiro
Rugenge-Rwintare	Rugenge-Rwintare	65	Nyarugenge and Gasabo
Kibumba	Kibumba-Rwezangoro	68	Gasabo
Nyabugogo Lower	Nyabugogo	131	Nyarugenge and Gasabo

TABLE 1-1 WETLAND SURFACE AND ADMINISTRATIVE DISTRICTS

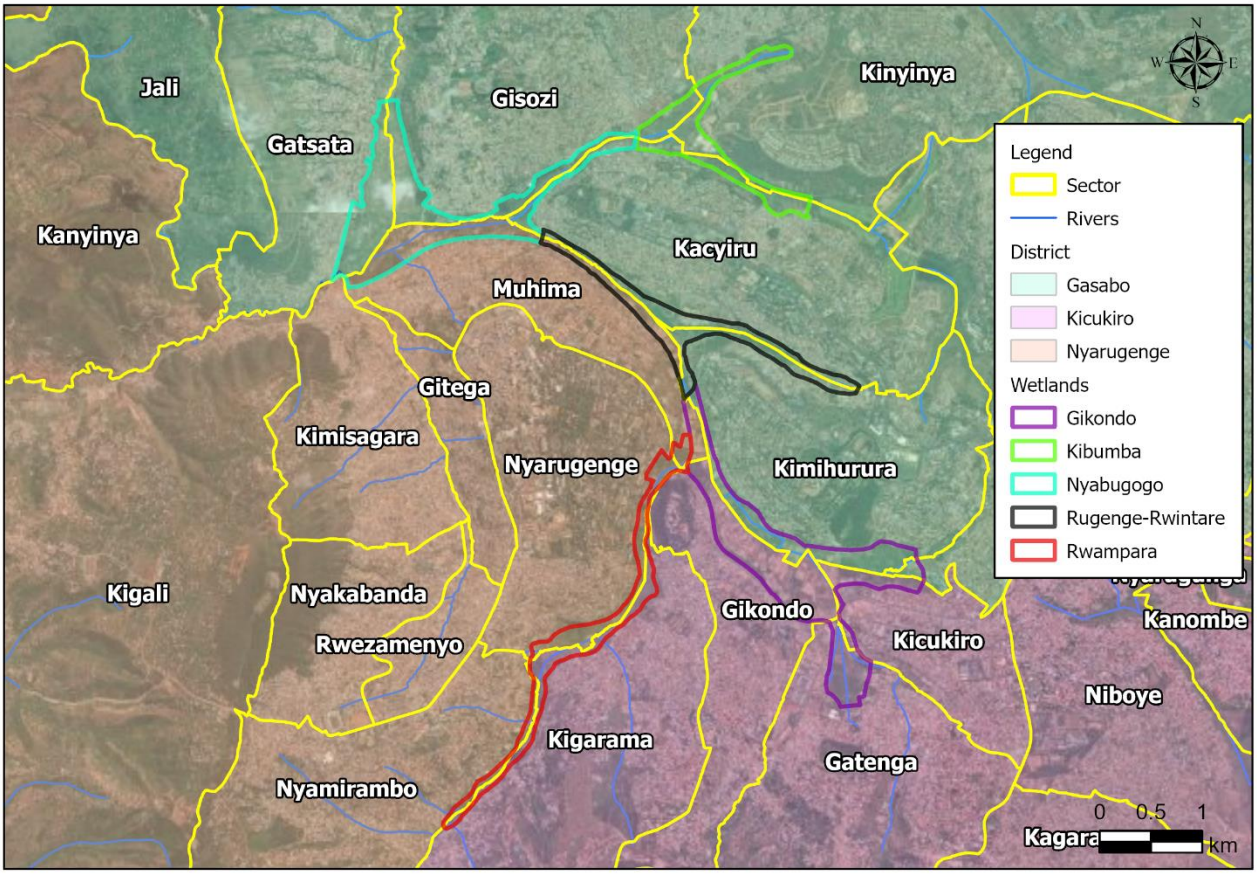

FIGURE 1-1 STUDY AREA AND ADMINISTRATIVE DIVISIONS (DISTRICTS AND SECTORS)

1.2 REMINDER OF THE REHABILITATION PROJECT'S OBJECTIVES

The main objectives of wetland rehabilitation as described in the study's terms of reference are as follows:

- Flood mitigation acknowledging climate changes.
- Improvement of wetlands' biodiversity.
- Water quality improvement.
- Enhancement of the city's landscape and development of recreational activities.

Whenever feasible, these objectives will be accomplished through Nature-Based-Solutions of wetland rehabilitation.

The achievement of the main objectives stakeholders' views and opinions took into account and were finetuned through baseline studies.

1.3 REMIDER OF THE CONSULTANT'S ASSIGNEMENT AND OBJECTIVES

The Consultant's objective is to develop a wetland rehabilitation feasibility and detailed design to meet the project objectives. The Study is informed by both primary and secondary data and existing master plans of the water, wetland, and urban planning sectors as well as the RUDP II activities.

The Consultant's approach follows a logical framework which included studying the wetlands hydrology, hydraulic, functions and characteristics to develop wetland rehabilitation scenarios based on criteria and engagement with stakeholders. The Consultant has then designed the interventions based on a preferred option for each wetland.

This report is the third deliverable, the first being the Inception report which presented the methodological approach for the Study. After this report, the third deliverable will be the Detailed design and tender documents for wetland rehabilitation.

1.4 REPORT STRUCTURE

This report is composed of the following chapters.

- Chapter 1: Introduction
- Chapter 2: Objectives of the Detailed Proposed Rehabilitation Designs Report
- Chapter 3: Reminder of Proposed Actions
- Chapter 4: Detailed Design of Proposed Actions
- Chapter 5: Technical Specifications
- Appendices

2. OBJECTIVES OF THE FEASIBILITY STUDIES, BASELINE STUDIES AND PRELIMINARY PROPOSED REHABILITATION DESIGNS REPORT

This report studies the detailed engineering requirements for the implementation of the approved priority 1 actions for the rehabilitation of the five wetlands.

The objectives of this study report are to:

- Provide a reminder of the approved actions in each wetland
- Provide a guide plan for the overall project
- Determine general layouts with the interventions planned for each wetland
- Develop detailed designs for each action
- Estimated the cost of each intervention
- Develop the Terms of Reference for the Construction Supervision of the works.

The detailed designs are based on the preferred option selected during the Feasibility stage of the process (Variant 1), including all subsequent discussions and revisions held in the Final Feasibility Study, Baseline Studies, and Preliminary Proposed Rehabilitation Designs Report, approved in October 2022, but also include modifications to the former proposal specifically requested by the Client and other stakeholders during the Detailed Design workshop held in December 2022, and the technical Workshops held in February and March 2023.

3. REMINDER OF THE APPROVED ACTIONS

3.1 INTRODUCTION

The approach for the development of rehabilitation scenarios is aligned with international best-practice guidelines including the recently published International Principles & Standards for the Practice of Ecological Restoration (2019). This technical guideline on wetland restoration includes eight principles upon which wetland restoration shall be based:

- Principle 1: Ecological restoration engages stakeholders.
- Principle 2: Ecological restoration draws on many types of knowledge.
- Principle 3: Ecological restoration practice is informed by native reference ecosystems, while considering environmental change.
- Principle 4: Ecological restoration supports ecosystem recovery processes.
- Principle 5: Ecosystem recovery is assessed against clear goals and objectives, using measurable indicators.
- Principle 6: Ecological restoration seeks the highest level of recovery attainable.
- Principle 7: Ecological restoration gains cumulative value when applied at large scales.
- Principle 8: Ecological restoration is part of a continuum of restorative activities.

From these 8 principles, the rehabilitation proposals of each wetland put forward are based on an approach that built heavily on stakeholder inputs and compiled the requirements of diverse users into different categories of interventions, or “Master Plans”:

- Landscape Master Plan: All interventions related to environmental improvement
- Hydraulic Master Plan: All interventions relating to flows of water and wastewater
- Public Space Plan: All interventions that relate to the flows of people and usages of the wetlands (educational, recreational, etc.)

Each category contains a variety of actions, which were compiled into Action Sheets per Wetland which can be found in the annexes of the previous report. Each type was attributed a number, which remains coherent throughout each wetland. Since each wetland has its own tailor-made intervention, not all actions will be repeated in each wetland.

3.2 REHABILITATION ACTIONS

The figure below presents a bird's eye view of the actions proposed in the study zone.

3.2.1 Gikondo

The proposed actions are presented in the table and graphically in the zoning map below. The graphic representation at greater scale is provided in Annex 1.1

Hydraulic Actions	
G01	Water conveying structure to block and channel water to the main stream
G02	Water spreading structure to spread water into the wetland
G03	Sediments trap for blockage of sediments into the wetland
G04	Spillways to divert low flows
G05	Blocking of surface drains (agriculture ditch)
G06	Reprofiling the river with the creation of meanders
G12	Creation of Ponds to support wildlife and aesthetic appearance
G18	Transition structure with hotspots
G20	Creation of low flow channel to supply waterponds
Landscape Actions	
G07	Creation of landscape cascade structure to stabilize soil
G08	Planting of banks with the native plant species
G09	Planting of native plant species adapted to the wetland environment
G10	Planting of native plant species adapted to the riparian area
G13	Creation of island for aesthetic appearance
G19	Soil reshaping for wetland creation
Public Space Actions	
G14	Creation of suspended walkway for accessibility purpose in the wetland
G15	Creation of walking/cycling circuits (benches, lighting, plants, interpretation trail)
G21	Green belt

TABLE 3-1 REHABILITATION ACTIONS IN GIKONDO WETLAND

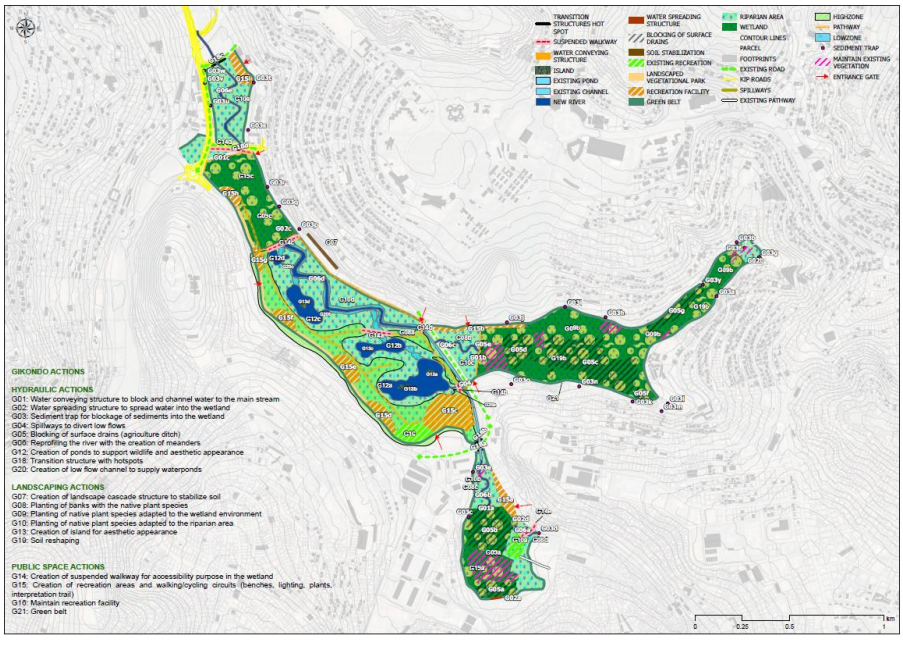

FIGURE 3-1 ZONING MAP OF GIKONDO WETLAND

Following the identification and localisation of the proposed actions, a Master Plan for Gikondo Wetland (see below) was produced in order to guide the detailed design process. A representation of the Master Plan at a greater scale is provided in Annex 1.1. The detailed design of these activities is presented in chapter 5.

FIGURE 3-2 MASTER PLAN FOR THE REHABILITATION OF GIKONDO WETLAND

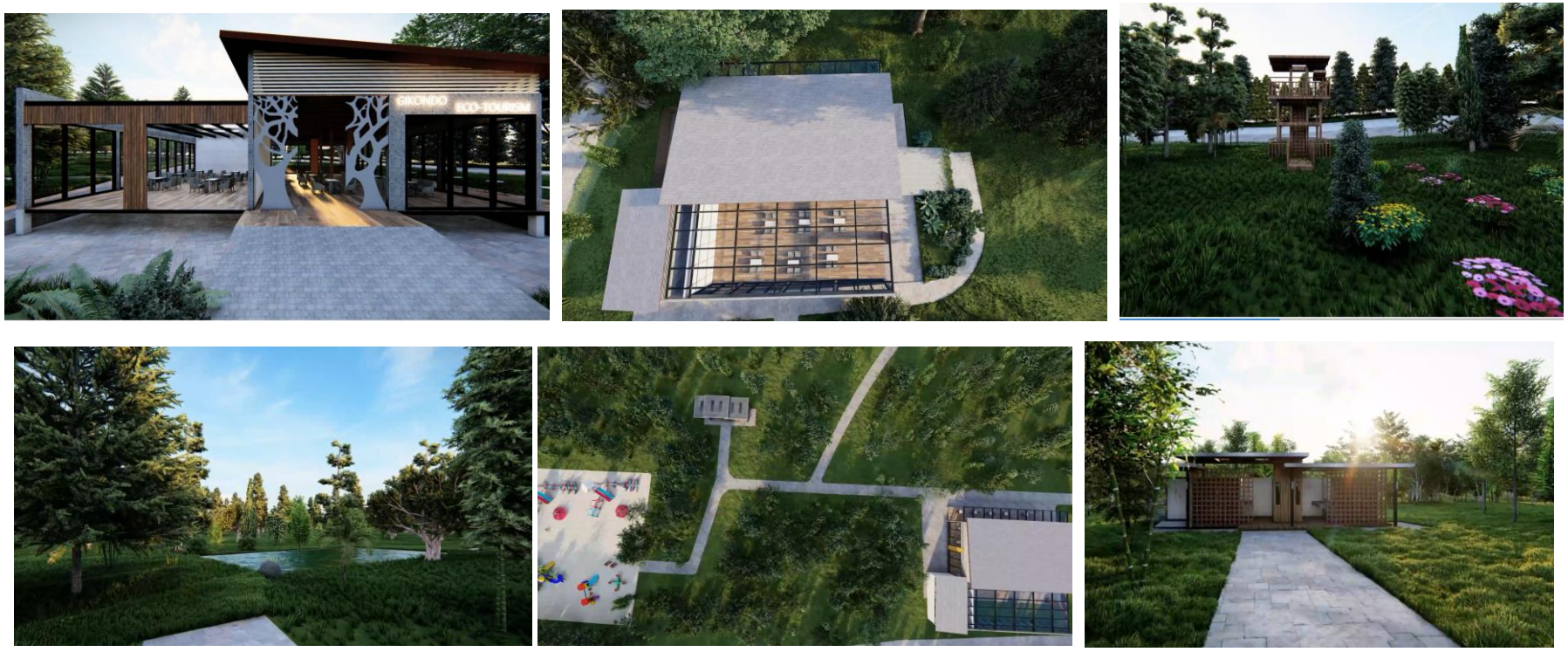

FIGURE 3-3 DETAILS OF GIKONDO WETLAND MASTER PLAN

3.2.2 Rwampara

The proposed actions are presented in the table and graphically in the zoning map below. The graphic representation at greater scale is provided in Annex 2.1.

Hydraulic Actions	
RW01	Creation of detention basin at the inlet of the wetland
RW02	Sediment Trap for blockage of sediments into the wetland
RW03	Water conveying structure to block and channel water to the main stream
RW04	Water spreading structure to spread water into the wetland
RW05	Creation of successive gabion walls
RW06	Blocking of surface drains (agriculture ditch)
RW07	Creation of ponds to support wildlife and aesthetic appearance
RW08	Reprofiling the river with the creation of meanders
RW09	Creation of dike for neighboring communities protection
RW10	Soil stabilization to stabilize banks of the river
RW19	Transition structure with hotspots
RW20	Spillway for retention
RW24	Reshaping of the channel to prevent against erosion
RW25	Blocking channel with gabions walls
Landscaping Actions	
RW11	Planting of native plant species adapted to the riparian area
RW12	Planting of native plant species adapted to the wetland environment
RW13	Planting native forest
RW14	Planting of banks with the native plant species
RW22	Soil reshaping for wetland creation
RW23	Creation of island for aesthetic appearance
Public Space Actions	
RW16	Creation of walking/cycling circuits (benches, lighting, plants, interpretation trail)
RW18	Cultural and Exhibition Center
RW21	Green belt

TABLE 3-2 REHABILITATION ACTIONS IN RWAMPARA WETLAND

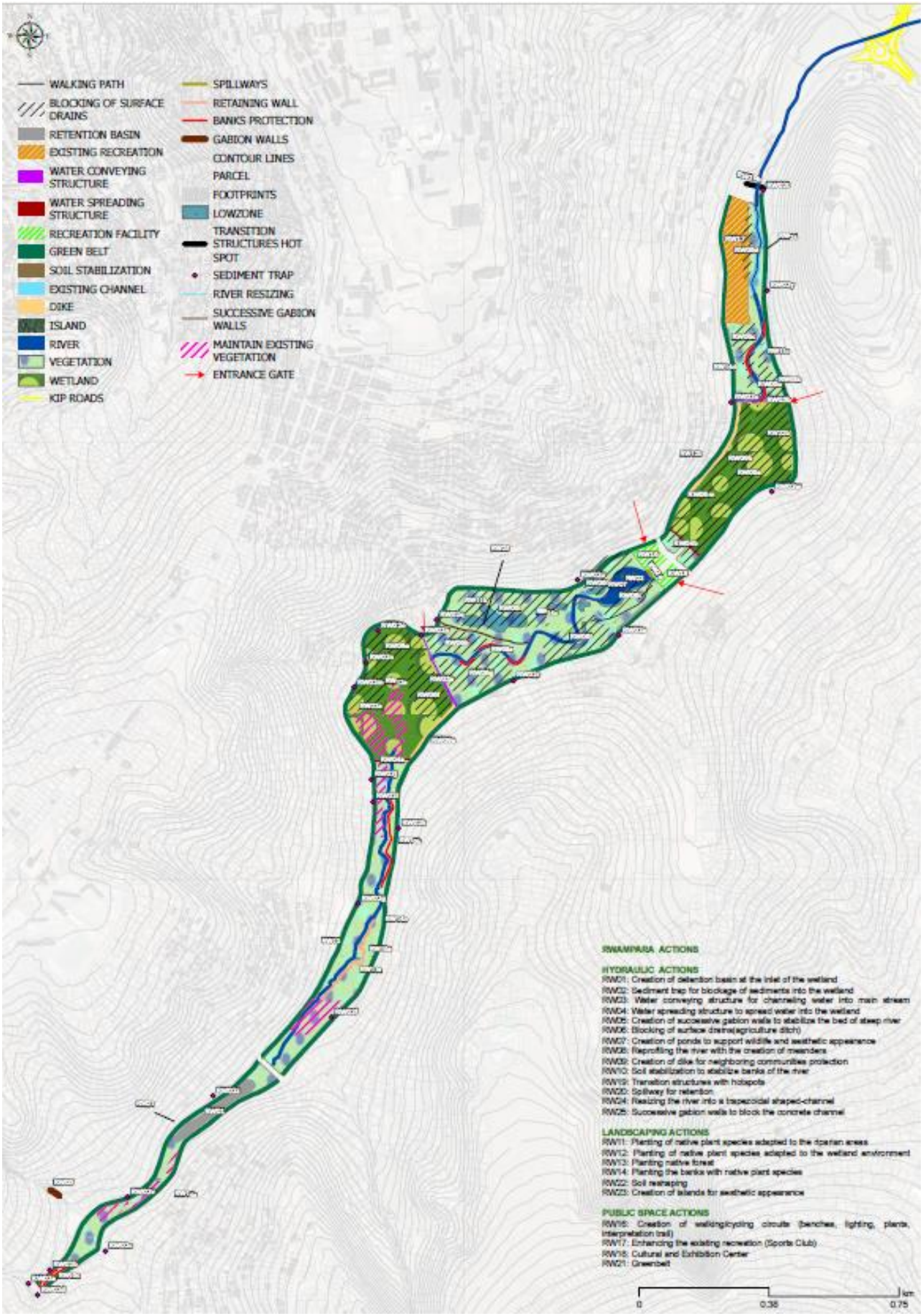

FIGURE 3-4 ZONING MAP OF RWAMPARA WETLAND

Following the identification and localisation of the proposed actions, a Master Plan for Rwampara Wetland (see below) was produced in order to guide the detailed design process. A representation of the Master Plan at a greater scale is provided in Annex 2.1. The detailed design of these activities is presented in chapter 5.

FIGURE 3-5 MASTER PLAN FOR THE REHABILITATION OF RWAMPARA WETLAND (DETAILED AERIAL PERSPECTIVE)

3.2.1 Rugenge-Rwintare

The proposed actions are presented in the table and graphically in the zoning map below. The graphic representation at greater scale is provided in Annex 3.1.

Hydraulic Actions	
RU01	Sediment Trap for blockage of sediments into the wetland
RU02	Water conveying structure to block and channel water to the main stream
RU03	Water spreading structure to spread water into the wetland
RU04	Reprofiling the river with the creation of meanders
RU05	Blocking of surface drains (agriculture ditch)
RU09	Creation of ponds to support wildlife and aesthetic appearance
RU14	Transition structure with hotspots
RU19	Reshaping of the channel to prevent against erosion
Landscaping Actions	
RU06	Planting of native plant species adapted to the wetland environment
RU07	Planting of native plant species adapted to the riparian area
RU07	Planting of native plant species adapted to the riparian area
RU08	Planting of banks with the native plant species
RU10	Creation of island for recreation and aesthetic appearance
RU11	Maintain bamboo
RU15	Soil reshaping for wetland creation
Public Space Actions	
RU12	Creation of suspended walkway for accessibility purpose in the wetland
RU13	Creation of opportunity node &walking/cycling circuits (benches, lighting, plants, interpretation trail)
RU18	Green belt

TABLE 3-3 REHABILITATION ACTIONS IN RUGENGE-RWINTARE WETLAND

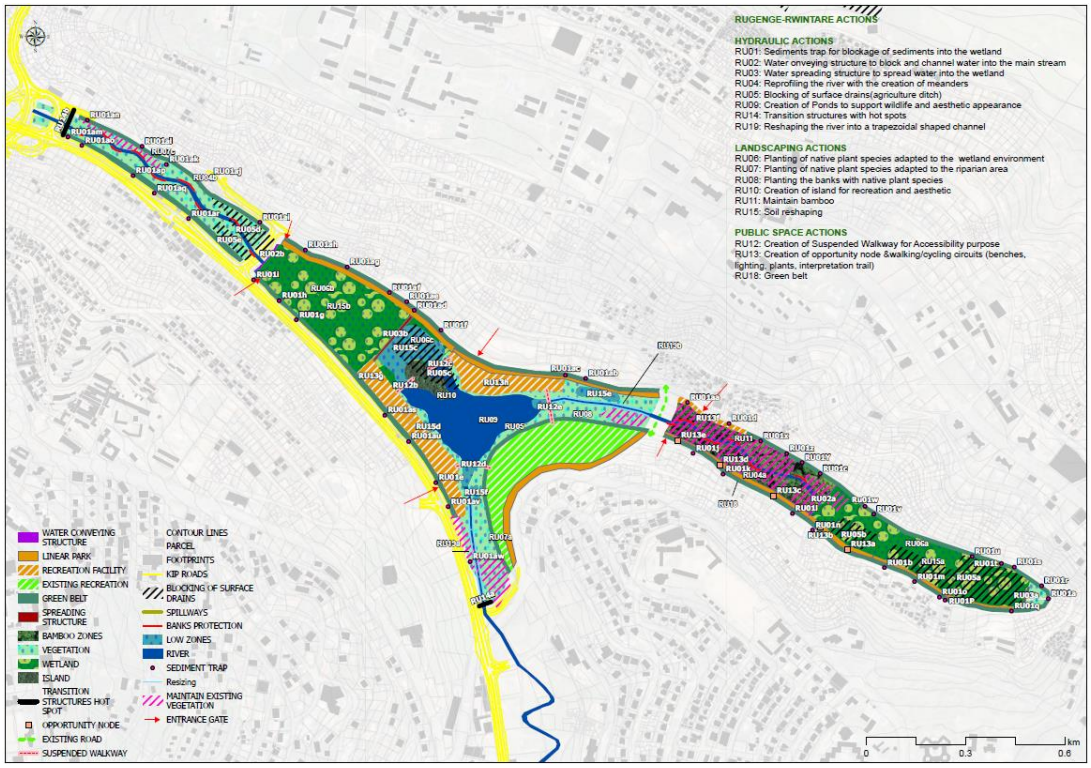

FIGURE 3-6 ZONING MAP OF RUGENGE-RWINTARE WETLAND

Following the identification and localisation of the proposed actions, a Master Plan for Rugenge-Rwintare Wetland (see below) was produced in order to guide the detailed design process. A representation of the Master Plan at a greater scale is provided in Annex 5.1. The detailed design of these activities is presented in chapter 5.

FIGURE 3-7 MASTER PLAN FOR THE REHABILITATION OF RUGENGE-RWINTARE WETLAND (DETAILED AERIAL PERSPECTIVE OF THE WETLAND)

3.2.2 Kibumba

The proposed actions are presented in the table and graphically in the zoning map below. The graphic representation at greater scale is provided in Annex 4.1.

Hydraulic Actions
K01 Sediment Trap for blockage of sediments into the wetland
K02 Water conveying structure to block and channel water to the main stream
K03 Blocking of surface drains (agriculture ditch)
K04 Water spreading structure to spread water into the wetland and channel protection
K05 Creation of ponds to support wildlife and aesthetic appearance
K09 Maintain existing pond
K10 Reprofiling the river with the creation of meanders
K19 New spillway
K20 New channel
Landscaping Actions
K06 Planting of native plant species adapted to the wetland environment
K07 Planting of native plant species adapted to the riparian area
K08 Landscaped vegetational park
K11 Planting of banks with the native plant species
K13 Soil reshaping for wetland creation
K14 Creation of Islands to support wildlife and aesthetic appearance
Public Space Actions
K12 Enhancing recreational area and walking/cycling circuits (benches, lighting, plants, interpretation trail)
K16 Green belt

TABLE 3-4 REHABILITATION ACTIONS IN KIBUMBA WETLAND

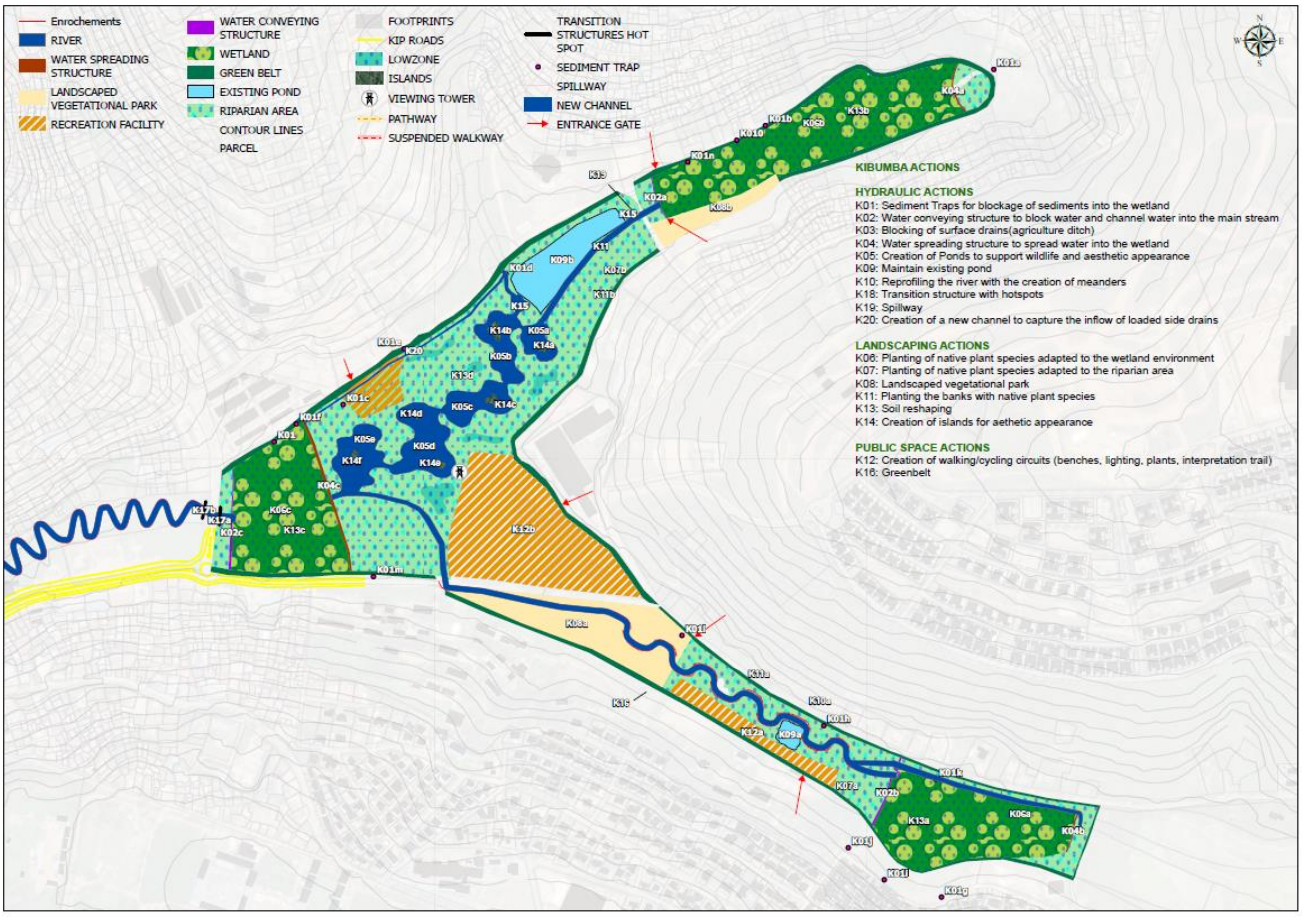

FIGURE 3-8 ZONING MAP OF KIBUMBA WETLAND

Following the identification and localisation of the proposed actions, a Master Plan for Kibumba Wetland (see below) was produced in order to guide the detailed design process. A representation of the Master Plan at a greater scale is provided in Annex 3.1. The detailed design of these activities is presented in chapter 5.

FIGURE 3-9 MASTER PLAN FOR THE REHABILITATION OF KIBUMBA WETLAND (AERIAL PERSPECTIVE SAMPLE)

3.2.3 Nyabugogo

The proposed actions are presented in the table and graphically in the zoning map below. The graphic representation at greater scale is provided in Annex 5.1.

Hydraulic Actions
N01 Sediment Trap for blockage of sediments into the wetland
N02 Blocking of surface drains (agriculture ditch)
N03 Reprofiling the river with the creation of meanders
N04 Expansion of the Existing Lake
N13 Water spreading structure to spread water into the wetland
N14 Transition structure with hotspots
Landscaping Actions
N05 Planting of native plant species adapted to the wetland environment
N06 Planting of native plant species adapted to the riparian area
N07 Planting of banks with the native plant species
N08 Creation of island for recreation and aesthetic appearance
N15 Landscaped vegetational park
N16 Soil reshaping for wetland creation
Public Space Actions
N09 Creation of suspended walkway for accessibility purpose in the wetland
N10 Creation of Education center for reading and other educative purpose
N10 Creation of Education center for reading and other educative purpose
N11 Creation of recreation, walking/cycling circuits (benches, lighting, plants, interpretation trail)
N17 Green belt

TABLE 3-5 REHABILITATION ACTIONS IN NYABUGOGO WETLAND

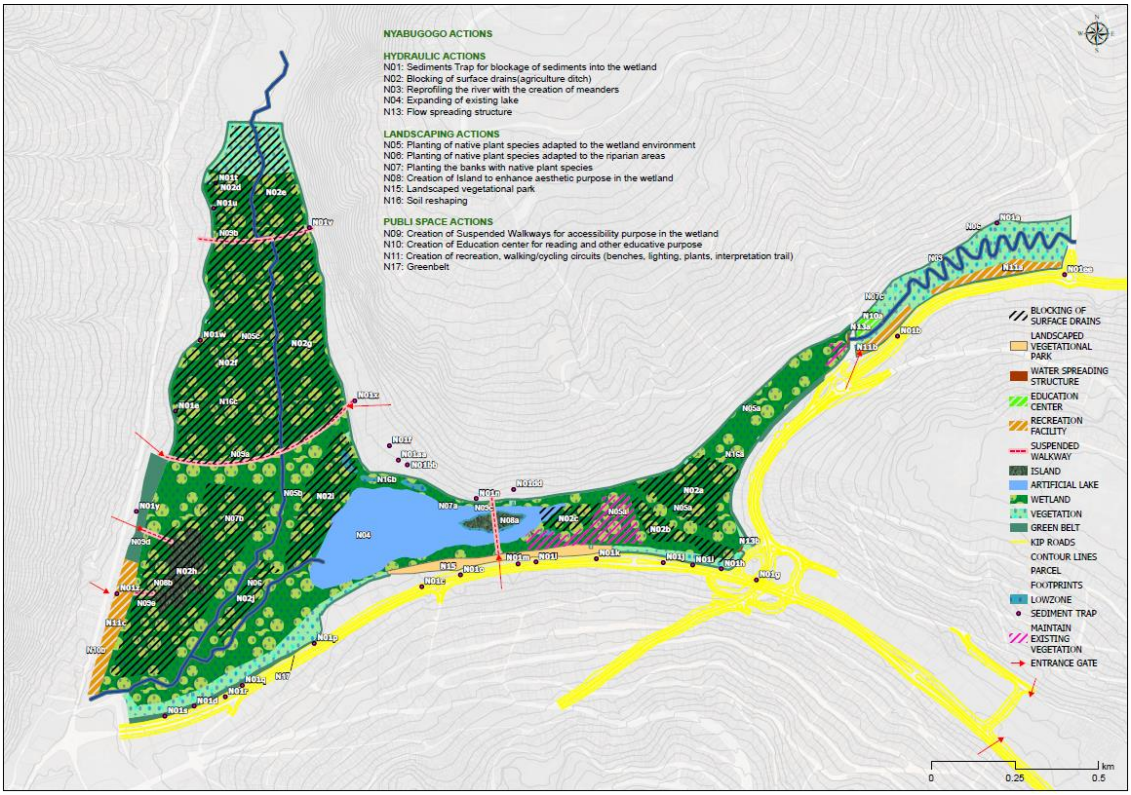

FIGURE 3-10 ZONING MAP OF NYABUGOGO WETLAND

Following the identification and localization of the proposed actions, a Master Plan for Nyabugogo Wetland (see below) was produced in order to guide the detailed design process. A representation of the Master Plan at a greater scale is provided in Annex 4.1. The detailed design of these activities is presented in chapter 5.

FIGURE 3-11. NYABUGOGO WETLAND AERIAL PERSPECTIVE OF THE ISLAND AND SUSPENDED WALKWAY

4. COORDINATION WITH STAKEHOLDERS AND OTHER PROJECTS

The Wetland Rehabilitation Project does not exist in a vacuum. The wetlands and throughout the project, the Consultant has sought to ensure maximum coordination with stakeholders as well as other parallel studies and projects.

The information gleaned from this continued process has allowed the project to:

- Consider the concurrent and conflicting desires for the future of the wetlands,
- Identify and integrate additional data into the overall analysis,
- Tailor the rehabilitation actions to achieve the highest level of satisfaction to the stakeholders, whilst meeting its environmental objectives,
- Learn from the experience of past projects,
- Ensure coherence and cohesion with past projects,
- Take account of current and future projects that will directly or indirectly affect the wetlands.

As such the Consultant has coordinated with the following entities:

- Ministry of Infrastructure (MININFRA) as the coordinator of the RUDPII project,
- World Bank as the technical and financial partner of the RUDPII project, with significant technical proposals and inputs into the design.
- Rwanda Housing Authority (RHA) to take into consideration resettlement requirements,
- Rwanda Transport Development Authority (RTDA) to discuss points of flooding (e.g., Kinamba roundabout) and to integrate future road development projects in and near the wetlands,
- Water and Sanitation Corporation (WASAC) to coordinate the rehabilitation project with the existing and planned water and sanitation infrastructure,
- City of Kigali (CoK); Kigali Urban Upgrading Team (KUUT) managing the flooding hotspot study,
- Rwanda Forestry Authority (RFA) to discuss nurseries, reforestation of the wetlands, and obtain general feedback on their experience of the rehabilitation of natural areas,
- Rwanda Water Resources Board (RWB) as they manage the gauging stations and modelling of rivers,
- Rwanda Land Management and Use Authority (RLMA) whi manage GIS data and landu use,
- Ministry of Local Government (MINALOC), including Local Administrative Entities Development Agency (LODA and the National Council of Persons with Disabilities,
- Ministry of Sports for recommendations on recreational activities and the development of foot and cycle paths,
- Districts of Gasabo, Nyarugenge and Kicukiro where the wetlands are located,
- International Union for Conservation of Nature (IUCN) for their inputs and recommendations of habitats and biodiversity protection,
- National Union of Disability Organizations of Rwanda (NUDOR) to integrate issues of accessibility to the wetlands,
- Energy Development Corporation Limited (EDCL) to discuss potential interference of the rehabilitation project with the utility's infrastructure,
- Yellow River Engineering Consultancy Co. Ltd (YREC), who are conducting the flooding hotspot study. The results of their work were to be carefully considered by the wetland rehabilitation project. In agreement with all parties it was decided to leave a boundary of 15m either side of the hotspot for YREC to carry out their design
- Environmental and Social Impact assessment of the Kigali wetland Rehabilitation project to take due consideration of the risks and opportunities and mitigate any negative impacts.
- Nyandungu Wetland Rehabilitation project, in order to build on the experience of this pilot project,

The result of this coordination is a wetland rehabilitation project that has been discussed with an exhaustive list of stakeholders, thus ensuring that all future development projects are taken into consideration by the

wetland rehabilitation project, that the proposed multi-disciplinary interventions meet the standards required both nationally and according to best practice, and that all the actors that will directly or indirectly be affected by the project are informed of the proposed interventions, and have had an opportunity to contribute their concerns and expertise.

5. DETAILED DESIGN OF THE REHABILITATION ACTIONS

5.1 GENERAL PRESENTATION OF THE DESIGN FOR THE 5 WETLANDS

The 5 wetlands should be considered as 5 different universes which will be an integral part of Kigali and which will highlight the particularities and richness of each sector of the city.

The consultant worked in collaboration with REMA to highlight the ecological and landscape values of each area, defining 5 specific designations for all the wetlands:

Gikondo	The wetland of observation and ponds
Rwampara	The wetland of forest and meanders
Rugenge-Rwintare	The wetland of pond and island
Kibumba	The wetland of fishing and exchange
Nyabugogo	The wetland of water and big island

5.1.1 Gikondo

As with each of the wetlands, Gikondo wetland is designed to retain water inside it with the objective of providing space for replanting of indigenous plant species, limiting flooding downstream, naturally treating water and recharging the aquifer, whilst generating habitats for a variety of local fauna.

Gikondo's specificity lies in the access it provides to Rwandans through the numerous elevated viewing points that have been harmoniously integrated into the landscape, and which provide privileged observation opportunities to the wetland below.

This overhead scenery provides a macroscopic view, demonstrating the vastness of the space and the interconnectedness of the open water areas. With landscaped lakes, into and from which water flows in a continuous natural cycle, such a vista generates feelings of calmness and wellbeing for the observer who will have space to reflect and better appreciate the beauty of the wetland.

Gikondo will be the wetland of observation and lakes.

FIGURE 5-1: GIKONDO : THE WETLAND OF OBSERVATION AND LAKES

5.1.2 Rwampara

As with each of the wetlands, Rwampara wetland is designed to retain water inside it with the objective of providing space for replanting of indigenous plant species, limiting flooding downstream, naturally treating water and recharging the aquifer, whilst generating habitats for a variety of local fauna.

Rwampara's specificity lies in the rigorous selection of indigenous forest and the beauty of the meandering streams present their beauty in all its glory. The wetland is designed not only as a place to support tree growth, but as a space for them to thrive. The arboreal character of this natural space accentuated by its winding and meandering watercourse will create a unique atmosphere for humans to enjoy.

The wetland will play on the use of light and shade, providing coolness and humidity in the hottest of months. Soft natural scents and the sounds of birds and other wildlife will combine with the sound of the trickling water to entice the nose and ears as well as the eyes as you pass through on its discrete natural footpaths.

Rwampara will be the wetland of forest and meanders.

FIGURE 5-2: RWAMPARA: THE WETLAND OF THE FOREST AND MEANDERS

5.1.3 Rugenge-Rwintare

As with each of the wetlands, Rugenge-Rwintare wetland is designed to retain water inside it with the objective of providing space for replanting of indigenous plant species, limiting flooding downstream, naturally treating water and recharging the aquifer, whilst generating habitats for a variety of local fauna.

Rugenge-Rwintare's specificity lies in the vastness of the pond and the island which have been specifically created in this wetland. The marriage of both the terrestrial and lacustrine worlds into a harmonious whole over such a large expanse will showcase the sheer diversity of habitats that nature can create.

Wandering through this natural area, Rwandans will enjoy the varied experiences such ecological biodiversity enables, leaving plenty of new discoveries for following visits. Ultimately, they will leave this wetland with a greater understanding and appreciation of the terrestrial and aquatic worlds.

Rugenge-Rwintare is the wetland of pond and island.

FIGURE 5-3: RUGENGE-RWINTARE: THE WETLAND OF POND AND ISLAND

5.1.4 Kibumba

As with each of the wetlands, Kibumba wetland is designed to retain water inside it with the objective of providing space for replanting of indigenous plant species, limiting flooding downstream, naturally treating water and recharging the aquifer, whilst generating habitats for a variety of local fauna.

Kibumba's specificity lies in the balance it maintains between the beauty of nature and the space made available for human activity. While performing all the required ecological functions, Kibumba wetland focusses on providing leisure opportunities to the residents of Kigali, who will come to enjoy the numerous services available in a beautiful natural landscape.

Delicately embedded in the sumptuous greenery are spaces for fishing activities and recreation made available to bring people together and provide enjoyment and relaxation to all who venture in.

Whether seeking amusement from the daily routine, tilapia for dinner or simply general restoration after a difficult working week, this wetland will provide leisure relaxation. Be it children and parents meeting at the playpark, or adults unwinding with at coffee bar, Kibumba wetland will bring people together, creating new links and reinforcing the old. Kibumba is the wetland of fishing and exchange.

FIGURE 5-4: KIBUMBA: THE WETLAND OF FISHING AND EXCHANGE

5.1.5 Nyabugogo

As with each of the wetlands, Nyabugogo wetland is designed to retain water inside it with the objective of providing space for replanting of indigenous plant species, limiting flooding downstream, naturally treating water and recharging the aquifer, whilst generating habitats for a variety of local fauna.

Nyabugogo's specificity lies in its conscientious emphasis on the watercourse that traverses it, demonstrating that not only on land can nature show off its beauty.

The aquatic nature of this wetland highlights not only the importance of water not only to sustain life, but the aesthetic bonus and the calming effects of the flowing water that will be felt by those who experience it.

Nyabugogo's main attraction is its lake providing a beautiful open expanse for the eyes to feast upon, whilst providing a habitat for fish and aquatic plants can flourish. The nearby island is specifically designed to be appealing to the eye, a romantic spot in a natural environment just minutes away from the hustle and bustle of the city.

Nyabugogo will be the wetland of lake and islands.

FIGURE 5-5: NYABUGOGO: THE WETLAND OF LAKE AND ISLANDS

5.2 DESIGN PRINCIPLES

5.2.1 Approach

A primary objective of the project is to boost the resilience of Kigali City through the rehabilitation of its wetlands. Urban resilience is about making a city more resistant to multi-hazard impacts, including impacts of climate change, for the benefit of all city residents. Urban resilience is the ability to maintain continuity through shocks and stresses, while positively adapting and transforming towards sustainability. Resilient cities are better positioned to protect and enhance people's lives, secure development gains, foster an investible environment, and drive positive change.

Wetlands are critical in supporting urban resilience. Progressive and holistic approaches to are required to address the impacts of climate change and rapid urbanization in those areas.

Whenever feasible, the objectives of the project will be accomplished through Nature-Based-Solutions (NBS) of wetland rehabilitation, including the following examples and principles.

- The introduction of green walls and roofs are to be encouraged to reduce noise pollution through absorption, cool the air through evapotranspiration, provide shade and improve air quality.
- Locally sourced and durable materials should be prioritized both for surfacing and built elements. When choosing materials, the full life cycle span of the development shall be considered.
- Indigenous vegetation is to be used for all types of planting.
- Hardscape and paved surfaces are to be minimized by using permeable materials and increasing the amount of landscaped surface to enhance the potential for evapotranspiration.
- Pedestrian trails should ensure continuity with and offer interesting views of the wetlands.
- Trails are to prioritize pedestrian and cycling movement.
- Reforestation should allow for well-considered permeability through the wetlands.
- Public and private space shall be well defined through conscious design of buildings and landscape.
- Any barriers are preferable to be permeable (e.g., live fences).
- Include NBS features in footpath designs: vegetation, permeable pavement.
- Include NBS features in open and public space designs: extra vegetation, permeable surface cover, protection of erodible steep slopes by reforestation (urban forests), add to the urban quality by designing linked recreational and educational spaces.

5.2.2 High level design criteria

The Consultant has determined the required design criteria for sizing and modelling of the infrastructure which will guide the design process.

The criteria are broken down as follows:

High-level criteria:

- Flood mitigation criterion relates to hydraulic performance at infrastructure locations (at selected culverts and bridges).
- Biodiversity enhancement criterion relates to the performance of the wetland to sustain viable plant communities and biodiversity.
- Improvement of water quality criterion relates to the capacity of the wetlands to naturally filter pollutants and settle turbidity in surface water.
- Development of recreational activities and improvement of the city's landscape criterion relates to the aesthetic and recreational value of the wetland.

Cost and technical criteria:

- Investment cost: Capital cost to build the scenario.
- Maintenance cost: Cost to operate and maintain the scenario.
- Long term technical reliability.
- Convenience of operation and maintenance requirements of the scenario.
- Sizing criteria: detailed hereafter:

As a reminder, the variant chosen during feasibility phase was the one having the best score in respect to high level criteria. It should be noted that in order to balance these criteria, modifications of actions from the feasibility study were proposed during December 2022 workshop. These modifications have been included in the current report.

5.2.3 Ecological design

Wetlands are designed to host a series of natural habitats where a variety of animal and plant species can thrive. They are characterised by a succession of compartments covered by a surface of herbaceous stratum, within which water flows by gravity. These different facilities offer specific but often complementary functionalities: water areas, tall grass meadows, reedbeds, sedge meadows, etc.

The diversity of natural habitats created will welcome a wide variety of species which will find conditions that are favourable to their sustained development.

5.2.3.1 Implementation methods

Water inlets will comprise sediment traps that will ensure that silt is not carried into the wetlands, and the outlet of these structures will be lined with 400mm diameter material (riprap) to promote the spreading of the water into the wetland to increase residence time and improve treatment.

The implementation of the aggregate embankments will be carried out by mechanical and manual means, without compaction. The objective is to limit the risks of erosion at each water inlet, as developed in paragraph 5.2.4.

The parts of the wetlands that are not submerged (dikes, embankments, top of banks, etc.) may need to be covered with topsoil to a thickness of approximately 0.15m. No topsoil will be added to the compartments covered by buffer zone/riparian vegetation.

In the other parts of the wetlands, the soil will be in permanent contact with the rainwater from the urban catchment areas. Due to their high organic content (nitrogen and phosphorus), the plants will have sufficient nutrients to grow.

The implementation of topsoil embankments will be carried out by mechanical and manual means, without any compaction.

The vegetated berms and groynes will be made of compacted earth, except for those in direct contact with the water inlet, which may require riprap up to the water level. The watertightness of the first merlon is not an objective to be achieved, as it will mainly act as a flow breaker and distribute the water in the following compartments.

The overflows will be sized for a peak flow less than or equal to a two-year peak flow.

5.2.3.1 Planting

Field visits were conducted to all study sites to supplement the literature study. A list of identified plant species was established for all wetlands. Recommended species for wetlands rehabilitation were based on following criteria:

- Ecological adaptation of the species

- Typology of the habitat (permanent wetland, seasonal wetland…)
- Expected function of the species (e.g., removal of pollutants, recreation, riverbanks stabilization…)
- Indigenous species to Rwanda

5.2.3.1.1 Herbaceous Stratum

Plant specificity is selected according to wetland characteristics:

- Banks, sectors, and compartments under the cover of a reed bed or sedge meadow:

  Optimise the soil/root interface with micro-organisms by encouraging total coverage of the compartments by a dominant species such as reeds or typha and by extending the hydraulic path as much as possible with the use of dikes.

  This will improve the capacity of the plants to assimilate pollutants and benefit biodegradation mechanisms at the rhizosphere level. In these banks, sectors or compartments the water depth should be lower than 10cm. Within the wetlands, these habitats will constitute the largest surface areas.

- Dikes and embankments under cover of tall grass vegetation:

  These natural habitats are composed by heterogeneous, diverse, dense, taller or shorter herbaceous formations. They are often located in alluvial zones on cool, non-acidic, rather eutrophic, moist soil. They can be periodically flooded but only for brief periods of time.

  The typical plants of this tall-grass vegetation can vigorously colonize wetlands, particularly in light-exposed situations, and across soils that are waterlogged for most of the year.

  This vegetation should be heterogeneously distributed in the wetlands so that they can serve as a refuge for many species of birds and play a determining role in the functioning of the wetland ecosystem.

- Water areas:

  Create favorable zones for various hydrophytic plant species. These zones will also contribute to the qualitative treatment of water.

Planting must be carried out in the form of clumps during favourable periods (meaning not during heavy rainfall). Half of the surface of the planned habitats will be planted in a patchwork with the cumulative surface of the patchworks representing half of the total surface of these habitats. The other unplanted locations will be spontaneously colonized by plants or covered with already existing plants.

With respect to the planted locations, the clods will be installed in a hole made with a planter or a pickaxe and carefully positioned in the hole. Before planting, the plants will be soaked in water before installation and then packed in the ground. ~~The plants in cups will be distributed by spots at a rate of approximately 2 plants per m².~~

Planting will follow the specific directions below:

- All plants supplied by the Contractor shall be of the species and variety requested, free of wounds and pests. They shall be separated by destination compartment and by species to facilitate distribution and verification.
- The plants must be replanted as soon as possible after delivery. It will be advisable for the contractor to have a sufficient team so that all the plants are planted in the week following the delivery. The watering and any eventual maintenance required while waiting for the planting will be the responsibility of the contractor.
- The contractor will offer a guarantee of plant recovery. The assessment of the recovery of the plants will be carried out every six months for the first two years after the implantation.

5.2.3.1.2 Shrub To Tree Stratum

This type of vegetation relates to the willow and riparian buffer strip planned between the wetlands and streams.

As with other wetland habitats, the plant species planned for the new riparian buffer strip will be local and native species, as shown in the specifications in paragraph 5.

The planted species may be the result of different techniques:

- Planting of shrubs derived from seed harvests made from species naturally occurring in the area. The plantings will be bare root shrubs of 100/120cm.
- Planting of branch segments (diameter of about 5 cm and length of 100-120 cm), with a high capacity of rejection. Cutting uses the ability of some plants to develop adventitious roots from a piece of branch separated from the mother plant. These cuttings can be taken from nearby wetlands.

The planting of the riparian/buffer strip must respect the following characteristics:

- Planting with mulch (mulch or collar);
- Planting with mulch (shredded or collared); Installation of stiles with game protection for the trees;
- Average density of 1 plant per 6 m² or 4 cuttings (forming 1 plant) per 6 m².
- Planting works must include the safe loading and unloading of the supplied plants, the distribution on the site, as well as liability for the entire installation process: the opening of the hole, the preparation of the plant, the plantation, the filling of the hole with fine soil, etc.
- Pruning of the roots may potentially be carried out on the dry or wounded roots. The pruning of the foliage will be done only if the Contractor judges that the volume of the branches is not in proportion with the root system.

5.2.3.1.3 Herbaceous vegetation on the restored banks of the hydraulic outfalls

The species selection will be the same as those targeted for planting the banks, sections and compartments under a reed bed or sedge meadow cover.

Planting must be carried out in the form of clumps during favourable periods (meaning not during heavy rainfall). Half of the surface of the planned habitats will be planted in a patchwork with the cumulative surface of the patchworks representing half of the total surface of these habitats. The other unplanted locations will be spontaneously colonized by plants or covered with already existing plants.

With respect to the planted locations, the clods will be installed in a hole made with a planter or a pickaxe and carefully positioned in the hole. Before planting, the plants will be soaked in water before installation and then packed in the ground.

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- All plants supplied by the Contractor shall be of the species and variety requested, free of wounds and pests. They shall be separated by destination compartment and by species to facilitate distribution and verification.
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- The contractor will offer a guarantee of plant recovery. The assessment of the recovery of the plants will be carried out every six months for the first two years after the implantation.

5.2.3.2 Wetland management

5.2.3.2.1 Operating principles

Wetlands are environmental engineering devices mobilizing ecosystem services. Based on the functioning of living organisms, they are not fixed in time, and tend to evolve under the impulse of ecological dynamics (seasonal and interannual variations).

This evolution can be beneficial, resulting in the permanent establishment of a diversified vegetation typical of wetlands and the housing of associated fauna. On the other hand, it can have perverse effects, inducing dysfunctions (closure of the environment by vegetation, creation of hydraulic short-circuits, landing of shallow areas, landslides, etc.) that are likely to lead to a modification of the performance of the areas, including a degradation of the discharge quality.

These dysfunctions can be avoided by means of an adapted management system, which follows the natural evolution of the area while preserving its functionalities.

The methods of implementation are based on:

- Interventions by a service provider specialized in the management of wetlands and aquatic environments. Given the specificity of wetlands, the service provider must be able to understand the ecological dynamics of these environments and be able to intervene in accordance with the recommendations of a differentiated management.
- Regular monitoring of wetlands in order to establish management recommendations and guidelines.

5.2.3.2.2 Routine maintenance

The proper functioning of wetlands depends above all on the manager's strong knowledge of the wetland and its functioning.

The manager must be able to detect anomalies as early as possible and intervene before problems occur. In concrete terms, this means regular and comprehensive visits throughout the entire span of the wetland to confirm it is in good general condition.

This verification includes:

- Examination of the general state of the wetland (state of the banks, embankments, vegetation, etc.) and identification of anomalies and remedial actions to be taken;
- Identification of the presence of harmful and invasive species and uprooting and disposal;
- Identification of hydraulic plugs at the level of water threads and their removal if possible;
- Examination of the hydraulic structures (hydraulic plugs, dislodging of the structures...);
- Collection of macro-waste.

5.2.3.2.3 Differentiated management of vegetation

By design, constructed wetlands contain a wide variety of vegetation cover. Their management must therefore take this diversity into consideration and propose appropriate operating methods for each type of vegetation cover. Well adapted operation methods will best guide the evolution of the site.

Mowing or cutting of the herbaceous stratum must be carried out to a minimum height of 10cm, so as to push the fauna towards the refuge zones of the uncut sectors. All cuttings must be removed from the wetland to avoid enriching the environment with degradable organic matter and nitrogen and to limit the colonization of nitrophilous species.

Particular attention must be given to the development of any invasive woody shoots that can compete with the helophytes planted on the banks or within the compartments. The identification of such species can be done during periodic visits or by the contractor in charge of the interventions. The methods to be used to deal with these proliferations vary according to the characteristics of the species. The impacts of some interventions on one species may be harmful to other species.

The equipment used by the service provider must also be the subject of vigilance. It must be compatible with use in wetlands. For example:

- it is important that the remnants of cuttings are released as macro-waste to allow for the removal of the bulk of the green waste from the wetland.
- it is important to ensure that the use of heavy machinery and/or machinery without load distribution does not lead to bank subsidence or the creation of ditches.

The recommendations of differentiated management interventions presented in this section are for mature areas.

During the first few years after impoundment, management recommendations should be adapted according to the actual development of the vegetation. Depending on the growth rate during the first few years, it may be more appropriate to let the vegetation develop and focus resources on the management of undesirable ruderal species whose development is favoured on recently mobilized land.

5.2.3.2.4 Management

Water-logged areas

Water-logged areas may be colonized by hydrophytes such as duckweed (Lemna sp.). These species have a strong capacity for colonization, especially in a wetland where conditions are favourable to their development (stagnant water, nutrients, sunshine). However, given the variability of water levels according to flow and seasonality, the water areas are more likely to be progressively colonized by heliophytes (mainly reeds and typha).

In order to promote an excessive development of hydrophytes (for example totally covering of the zone in water), management measures must be put into place. This will help to ensure that the quality of the water is not significantly degraded (release of non-degraded organic matter, production of suspended solids, decrease of photolysis, anoxia of the environment).

It is important to notice that not all hydrophytes are invasive, and some species have a strong ecological value (aquatic buttercup, water plantain...). Ecological monitoring of the wetlands by a qualified person will ensure a good analysis of the plant communities and will help to determine the specific actions that will need to be undertaken.

The management of invasive hydrophytes must intervene when their proliferation risks impacting the physico-chemical balance of the environment (anoxia, advanced eutrophication...). It is triggered as soon as the concerned areas are completely covered. Two operating modes are possible:

- Progressive drying of the wetland by diverting the water supply and harvesting then exporting the microphytes kept at the bottom of the compartments.
- Manual harvesting in the compartment still in water using nets and drip trays. In both cases, the harvested microphytes must be exported.

Herbacious stratum

Management of the herbaceous stratum helophytes will aim to contain vegetation development to:

- Maintain the hydraulic functionality of the wetland (by reducing the potential for hydraulic plugging at the stream channel and overflow structure, maintaining access to the hydraulic structure, and reducing the deposition of undecomposed organic matter during fanning) ;
- Maintain plant diversity in the area by selectively pressuring helophytes in favour of slower growing ones.

The cutting of the helophytes will have to be programmed annually. The operation consists of selectively cutting the aerial parts of the plants and removing all the residues (stems and debris) outside the wetland. Depending on the location of the plants (immersed or not), the selective cutting must be carried out at 10 cm from the surface of the ground or water.

Riparian buffer strip
The management of the riparian/buffer strip aims to promote the development of a plant formation that fulfills the expected ecological functions (structuring a tree biotope) without risk to the integrity of the area.

During the first years of operation, actions on the riparian zone will consist of encouraging the development of planted shrubs and trees by ensuring late annual mowing of the herbaceous layer. The objective of this approach is to limit the competition between the herbaceous plants and the young plants. As with the other compartments of the herbaceous layer, the products of the mowing will be removed off-site.

Thereafter, maintenance will consist of pruning, which is to be adjusted according to the actual development of the trees. Depending on the objective of the riparian buffer strip management actions will be more or less intense. Re-cutting actions could be considered at a later stage if it appears necessary to rejuvenate the afforestation.

Invasive plant species

Monitoring of invasive species, which may invade the wetlands, should be carried out by a qualified person in order to avoid significant colonization.

If an invasive species is encountered in the wetlands, it is imperative to eliminate the populations as soon as possible when they are still controllable (small, circumscribed populations). Their elimination will involve careful stump removal to remove all rhizomes or manual removal for aquatic species.

Dredging

Siltation of wetlands threatens their hydraulic functioning but also leads to a process of fermentation, emitting greenhouse gases. Dredging may therefore be necessary and should be carried out every five to ten years. In addition, this operation allows the extraction of certain pollutants accumulated in the sediments (metals or phosphorus for example).

The materials will be completely and rapidly exported off-site after the cleaning work. However, given the shallowness of the compartments and if the cut vegetation is properly exported during annual management, almost no cleaning is possible in these wetlands.

Dewatering

The supply of water to the wetlands can be totally diverted to allow rest periods. This action will ensure dewatering to facilitate the management of the compartments.

These dry-out periods could be useful to:

- Mineralize the sediments deposited at the bottom of the compartments.
- Dry out the wetlands to improve the bearing capacity before a maintenance intervention.

In the current state, the hydraulic behaviour of the zones remains theoretical, in particular with regard to infiltration and water table.

Thus, the implementation of these dewaterings will have to be reviewed once the works are completed and the wetlands stabilised and should then be adapted to the reality of the functioning of the wetlands.

5.2.4 Landscaping Design

5.2.4.1 General approach

The landscape design objective will be to create an authentic wetland leisure and learning experience. Walking, Jogging, cycling, picnicking, and playing in a world of water, reeds, lilies, and birds.

Cool, Common Ground for Picnics

Wetlands apart from fulfilling a necessary civil engineering function for safe drainage and water cleaning can equally become both intriguing and exciting physical play areas for children of all ages.

Reeds and woodland and water meadows can also create authentic, nature-based play areas with physically challenging play opportunities across a range of ages.

Seasonal Thematic Focal Areas:

SOUND	SIGHT	TOUCH	SMELL	TASTE	SILENCE
Falling water	Bold colours	Soft leaves	Sweet scent Bad scent	Sweet fruit	Still water
Running water	Soft colours	Hard leaves	Lemon Grass	Sour fruit	Rocks
Rapids	White	Fine bark	Acrid scent	Herbs	Logs
Rustling trees	Flowers	Rough bark		Spices	Sculpture
	Fruit	Smooth stones			Reflections
	Bark	Rough stones			
		Prickly leaves			

It is intended to create an authentic habitat for birdlife and a compassionate, tangible landscape for visitors, humans, recreation, and renewal.

Human emotions, happiness, and health are by sensual stimulation in natural environments. The appreciation of the 5 human senses will be woven into the design and detail of each of the 5 nodal parks.

The 6th Node will attempt to embrace silence…in smooth stone and symbolism yet to be determined.

Essentially easily accessible, gently contoured walking and cycling routes, will meander through the park, sometimes separated, sometimes side by side, sometimes paved, sometimes grass dictated by the topography of the original or modified landform, drainage routes, and obstacles, such as trees, rocks, cliffs, or water.

Either can be used for paths, access roads, or hardened spaces. Neither should be designed as straight, civic boulevards, but rather as serpentine routes in nature.

Public transport, by taxi, bus or other forms, should be restricted to the formal network at the definable edge of the park. The intention is to make the park a largely traffic free zone, only accessible to park staff and officials, by vehicle, limited to a very low speed limit with concessions for the disabled on certain routes. Public parking should be relegated to pocket car parks around the periphery of the park. It too should be well landscaped with large canopy trees, in order to create a shady, subtle forest edge condition that buffers the park from the access roads and the parking areas from the green park.

5.2.4.2 Physical actions for visitors

The landscape design objective will be to create an authentic wetland leisure and learning experience. Walking, Jogging, cycling, picnicking, and playing in a world of water, reeds, lilies, and birds.

New Green Spaces for People to enjoy.



Wetlands apart from fulfilling a necessary civil engineering function for safe drainage and water cleaning can equally become both intriguing and exciting physical play areas for children of all ages. Reeds and woodland and water meadows can also create authentic, nature-based play areas with physically challenging play opportunities across a range of ages.

We intend to create an authentic habitat for birdlife and a compassionate, tangible landscape for visitors, recreation, and renewal. Human emotions, happiness, and health are by sensual stimulation in natural environments. The appreciation of the 5 human senses will be woven into the design and detail of each of the 5 nodal parks. The 6th Node will attempt to embrace silence…in water, stone and the symbolism of orchids.

5.2.4.3 Mobility

Mobility into the wetlands is a crucial issue.

Hereafter some examples are given to illustrate the vision developed for Kigali.

Reinforced grass parking areas with central drainage swales are more ecologically friendly

e.g. Model No: Saturn, Source Regent Lighting Solutions, RSA, Cape Town

Park light must not be too intense, a reflecting tilting pan adjustable downlighter is recommended

Recessive paving, no patterns, strong herringbone bonds for coping with curvilinear routes

Low order lawn grass tracks for meandering walking loops

Clay brick or exposed aggregate, concrete pathways, herringbone pattern paving compliment more natural mown grass walking tracks. Essentially easily accessible, gently contoured walking and cycling routes, will meander through the park, sometimes separated, sometimes side by side, sometimes paved, sometimes grass dictated by the topography of the original or modified landform, drainage routes, and obstacles, such as trees, rocks, cliffs, or water.

Either can be used for paths, access roads, or hardened spaces. Neither should be designed as straight, civic boulevards, but rather as serpentine routes in nature.

Paving Material, Exposed Aggregate or Broomed, Tinted Surface Finish and Curvilinear Form Options

- Potential Foot Path / Bicycle Routes Options
- 70mm thick paving specification
- Preferably interlocking
- Exposed natural volcanic stone aggregate, tinted concrete, or interlocking clay brick paver dependent on budget.

Tinted concrete exposed aggregate block pavers, best used in herringbone pattern to navigate bends

Local brick paving in single colour

Baked red brick paving blocks, interlocked, but this pattern may be difficult around bends

A herringbone laying pattern is significantly better for both strength and for the construction of curvilinear footpaths.

It forms a tighter, stronger bond than regular brick forms and can follow easy curves without weakness in the jointing, or laid in situ, exposed aggregate concrete in 3 – 3.5 wide strips with curvilinear sheeting to follow the natural curves of the landscape.

Public transport, by taxi, bus or other forms, should be restricted to the formal network at the definable edge of the park. The intention is to make the park a largely traffic free zone, only accessible to park staff and officials, by vehicle, limited to a very low speed limit with concessions for the disabled on certain routes. Public parking should be relegated to pocket car parks around the periphery of the park. It too should be well landscaped with large canopy trees, in order to create a shady, subtle forest edge condition that buffers the park from the access roads and the parking areas from the green park.

5.2.5 Hydraulic Design

5.2.5.1 Design Criteria

Flow rates and water levels

In order to perform the modelling required to ensure floods are effectively prevented in the design, the primary design criteria are the flowrates and levels of water flowing through the wetlands.

As agreed with the Client, the design criteria for infrastructure are the flowrates and water levels that occur with a T2 rainfall. These data have been extracted from the Wflow and SOBEK models. The following table presents the flowrates and water levels for a T2 rainfall at various locations which have been used to inform the design.

Sizing criteria		
Return period T2		
N°	Q (m3/s)	H (mAD)
Rwampara		
1	28.8	1448.9
Gikondo		
2	2.4	1405.2
3	13.05	1406.6
4	6.3	1396.3
Rugenge		
6	21.1	1377.6
7	0.54	1387.1
Kibumba		
10	4.4	1388.3
11	2.5	1383.1
Nyabugogo		
8	21.3	1371.9
9	2.6	1371.3
12	58	1371.9

FIGURE 5-6 FLOWRATES AND WATER LEVEL DESIGN CRITERIA

Meandering & ponds

For the development of the meandering river, the following criteria were determined to be suitable.

λ: Wavelength between 10W and 15W
A Amplitude (or width of the meandering envelope) between 6W and 10W
R_c: Radius of curvature, 2W

The lengths and widths of the river will be defined according to these criteria.

In order to favour water retention and ensure the aesthetic value of the wetlands, the supply of water to ponds will be prioritized compared to the main branch from which it will be supplied. The flow into the ponds will be regulated by a weir, which will be sized in order to capture all water from a flow up to a T2 rainfall. Water levels exceeding this criterion will flow through the main branch. Therefore:

H_{weir}: Water level at T2 rainfall

5.2.5.2 Meandering Design Methodology

The following paragraphs detail the methodologies employed for the meandering design and bank protection with riprap.

To design the meanders, relationships between various variable as the distance between two curves are the amplitude of the meanders, have been developed (see below).

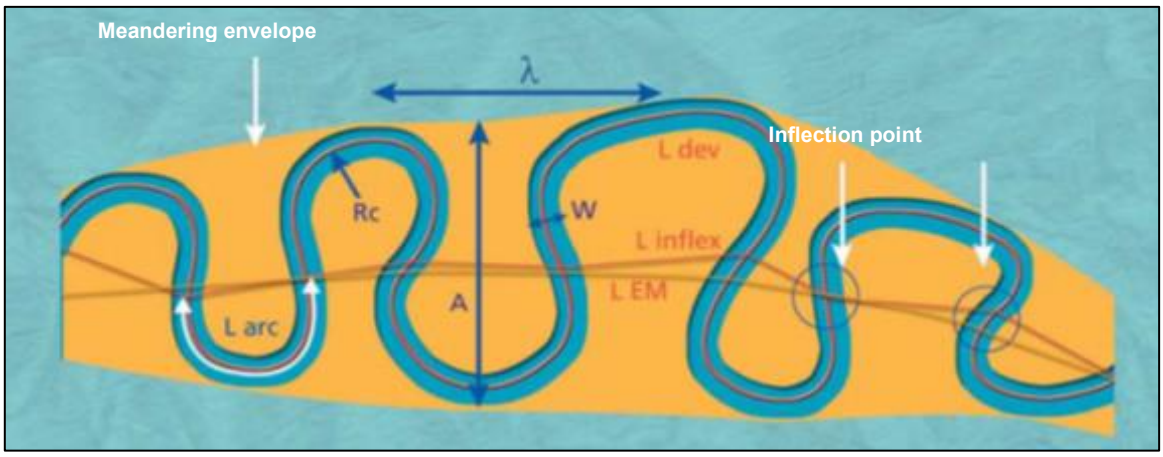


FIGURE 5-7: CHARACTERISED VARIABLES OF MEANDERS

With:

L_{dev}:	Developed length of the watercourse
P	Sinuosity: L_{dev} / L_{EM}
L_{EM}:	Length along the axis of the meandering envelope
L_{inflex}:	Length of meandering envelope through the inflection points
W:	Width at full bank
λ:	Wavelength: Usually between 10W and 15W
A	Amplitude (or width of the meandering envelope) usually between 6W and 10W
R_c:	Radius of curvature, 2W
L_{arc}	Length W

The constraint is mainly the amplitude of the meandering which should not be too wide due to lack of space at some location and the topography. Thus, the width of the channel is being defined by the amplitude of the meander. The wavelength of the meander will not be fixed and mainly defined by the sinuosity P of the meander. The current channels have a mean sinuosity close to 1 since it is mainly channelized. The new meanders will increase the sinuosity of the river between 1.1 and 1.6 which correspond to a meandering river.

Additionally, the meanders have been design depending on the following constraints:

- Presence of existing bridges
- Presence of buildings / houses
- The topography: encouraging a preferential path of the river through low points.

For the sake of simplicity, the cross section of the new channel will be calculated with a trapezoidal shape. The project discharge is set to make the channel overflow in the wetland for rain event with a return period equal or greater than 2 years. The dimensions of the trapeze are calculated using the Manning-Strickler formula with a Manning coefficient of K = 25.
Ripraps will be placed at the outside curves of meander in order to stabilize the banks. Below are the formulas used to design the ripraps.

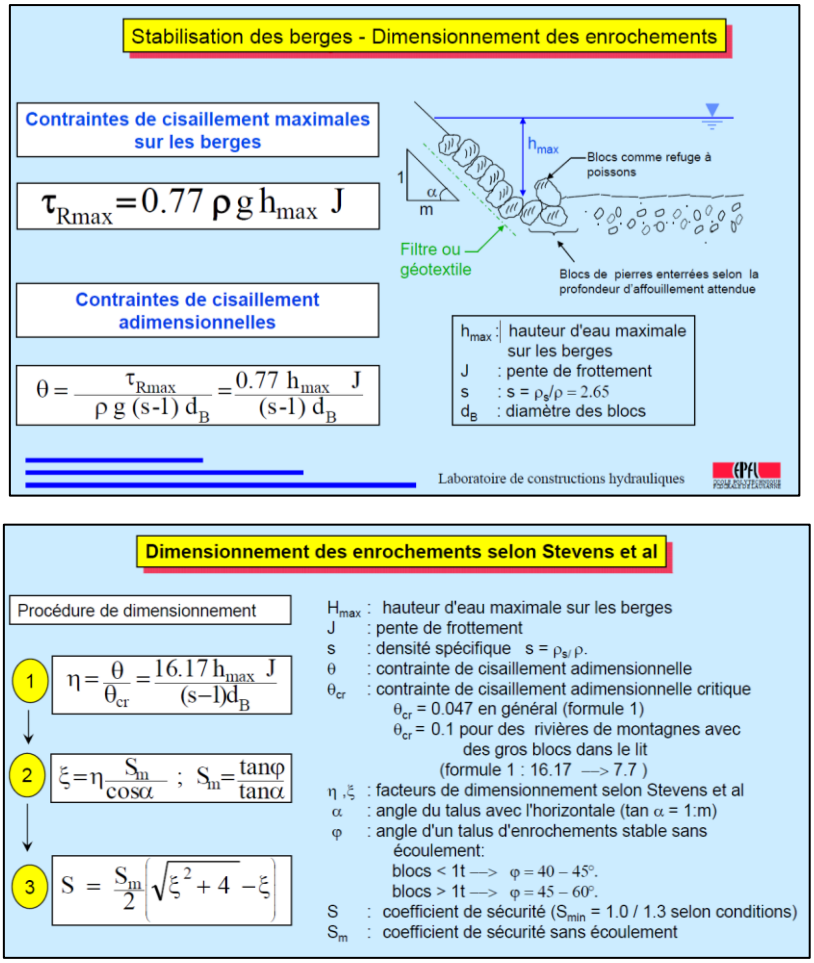


FIGURE 5-8: RIPRAP DESIGN METHODOLOGY

5.2.5.3 Wetland reshaping design methodology

The wetland reshaping action consists in modifying the ground level in order to create high zones and lower zones. The variation in elevations creates habitat diversity which then promotes biodiversity.

This action requires the backfilling of the existing main stream to promote a more widespread flow over surface the wetlands. Note that the agricultural drains located in the target zones are also backfilled but this is considered under another action type.

Below are the main principles used for designing the zones:

- A low zone is placed at the exit of a sediment trap: the low zone acts as a biofiltration retention area treating water coming from urban water drain,
- Optimization of the existing ground:
    - The existing ponds or low points are including into the low zones,
    - The existing high points are including into the high zones,
- The low zones are excavated to the lowest point in the surrounding area,
- The excavated earth on of the low zone side is used to backfill the projected high areas and to backfill the existing watercourses,
- Two areas are levelled: the mainstream is backfilled with the excavated earth of the side in order to create a zone of equal elevation.
- The slope of the contours of the zone is set at 1:2.

5.2.6 Botanical Design

A list of plant species was established for all wetlands. Recommended species for wetlands rehabilitation were based on following criteria:

- Ecological adaptation of the species
- Typology of the habitat (permanent wetland, seasonal wetland…)
- Expected function of the species (e.g., removal of pollutants, recreation, riverbank stabilization…)
- Indigenous species to Rwanda.

5.2.6.1 Urban forests

The urban forest is a densely planted area, usually with spontaneous flora, which differs from an open green space or other urban green spaces by its different status in terms of maintenance and management.

The urban forest is in a way a limited reminder of the wooded landscape of the city of Kigali before its urbanisation. The urban forest can sometimes have a private status and therefore not being totally accessible to the public. It plays an active role in the city's green network and, depending on its size, botanical diversity, and degree of maturity, is an important support for biodiversity, providing a sanctuary for many plants and animal species, in particular insects and birdlife.

The five wetlands being located in urban areas, it will be important not only to create opportunities for wildlife habitat but also to integrate design elements that improve landscape aesthetics. In this sense, naturalistic features including curving boundaries and natural organic shapes are added to the design. Reforestation "niches", create a mix of formal and natural gardens and dense reforestation areas.

Another important aspect will be to improve attractivity by developing opportunities for a variety of uses (recreation, education, etc.). Strategically located trails for human access completed with observation decks and open spaces will provide interesting views of the wetland and contribute to the sensitisation of users on aspects of wetland preservation.

General recommendations:

- Reforestation will alternate native species for ground cover (grasses, shrubs, herbs, etc.) to improve the soil quality, following the planting of native trees in specific areas, creating niches of urban forests.
- Areas of steep slopes will also be planted with dense native trees and vegetation (urban forests) to improve infiltration capacity, stabilize the soil and prevent erosion and landslides.
- The sequence of urban forests and low green open spaces will create a special landscape dynamic. Offering interesting views over the wetlands at strategic places and offering plants and wildlife natural habitats where a variety of species can thrive protected from the surrounding urban environment.
- The conditions for each species must be met when choosing the location of the urban forest. urban forest.
- Forest species should be favored.

Management requirements:

- Punctual: pruning of potentially dangerous dead branches at the edge of or near paths or urban areas.

Regular (weekly/monthly): permanent monitoring, differentiated management of woodlands, waste management.

5.2.6.2 Green open spaces / ground cover

A green open space is a determined area not occupied by buildings and mainly planted with species chosen for their decorative aspect in the form of herbaceous, shrub and woody strata. The vegetation cover depends on the layout of the green space. Generally, the green open spaces are accessible to the public. but in some cases, for the sake of protection of wetland recovering areas, public access can be restrained.

In either case, green open spaces can offer a privileged place for urban life, a public space where meetings, contemplation, leisure or relaxation can take place. A clear view field across the lawn and towards the watercourse will be provided.

General recommendations:

- Distance to the road network of at least 10m for primary trees.
- Distance to the nearest buildings of at least 20m for primary trees.

Management requirements:

- Regularly (weekly/monthly): lawn mowing, maintenance of plants beds, differentiated management
- Dry season: watering of fragile plants, collection of dead leaves and fruit, composting.
- Rainy season: more regular maintenance
- Occasional/emergencial: pruning of potentially dangerous dead branches and replacement of dead plants.

EXAMPLES OF RENATURALISATION USING SENEGALIA POLYACANTHA

5.2.6.3 Green open spaces/ground cover

The banks of rivers, streams and the river itself are natural areas that form a barrier in the event of water overflowing into the major riverbeds and reduce the risk of flooding.

Plants and trees placed along riverbeds stabilize the banks, providing favorable environments for the reproduction and feeding of (birds, fish, amphibians, insects, etc.) and form green corridors along the watercourses, forming a green and blue mesh that promotes biodiversity.

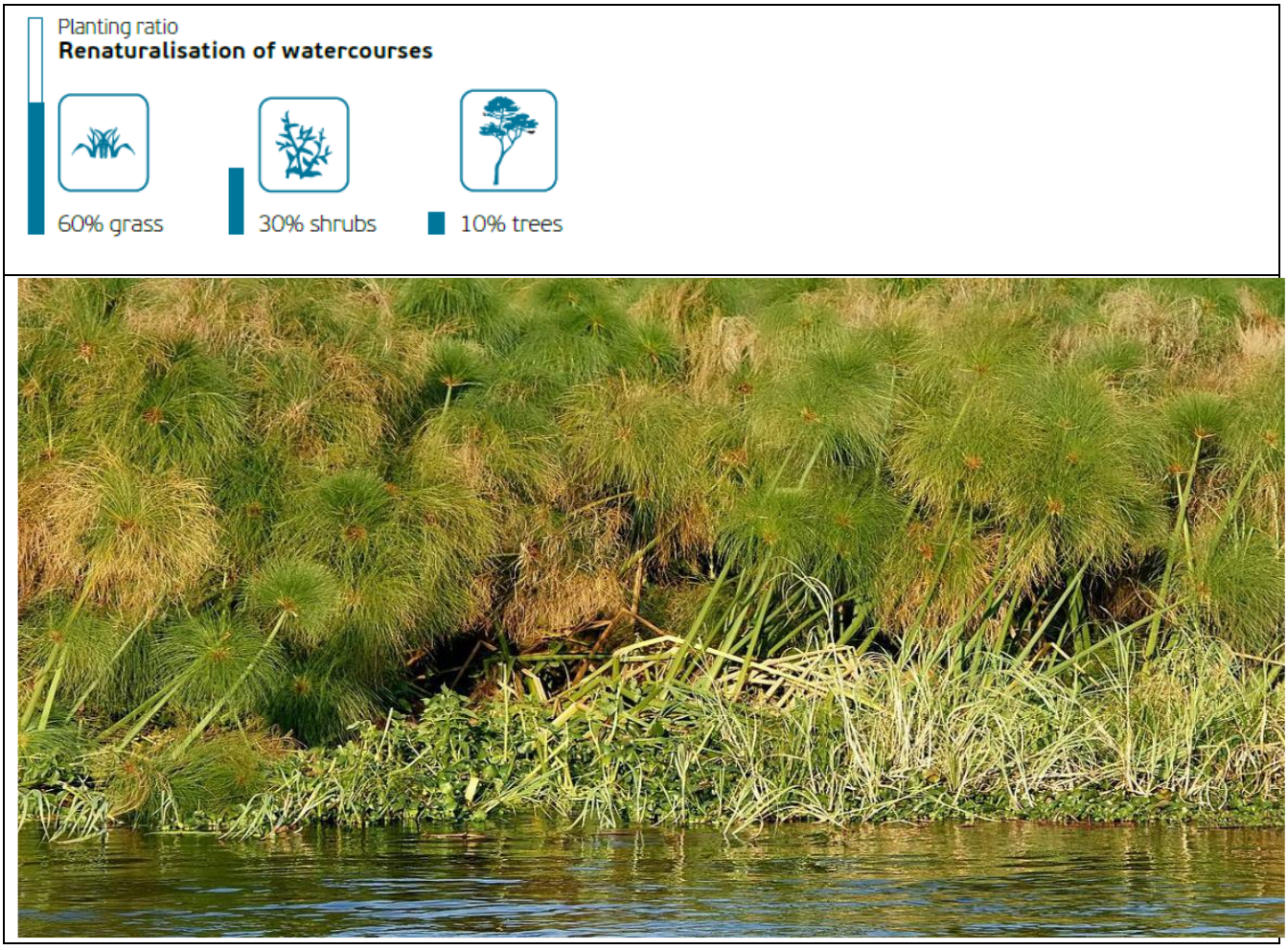
The species adapted to the conditions necessary for NBS Renaturalisation of watercourses are presented in the "Planting" section on page 13.

General recommendations:

- The recommended distance from the road network is of at least 10m from primary trees.
- Slope no greater than 35% for banks.
- Minimum distance of 30m from the hydrographic network (riverbanks and edges, streams, rivers, etc.

Management requirements:

- No particular maintenance requirements other than protection of the planted areas.
- Waste management.



EXAMPLES OF RENATURALISATION USING CYPERUS PAPURUS

The choice of the species was made according to a very specific logic taking into account the very specific functions for the needs of the different actions recommended. Illustrations are presented in Appendix 6. The detail is presented in the table below:

Species	Life form	Expected function
Acacia kirkii	Tree	Locally rare tree and already present in Nyabugogo, it is adapted to wet areas and will be planted for wetland restoration
Aeschynomene elaphroxylon	Shrub	Riverbanks stabilization
Bambusa vulgaris	Tree	To be kept in Rugenge-Rwintare where it is in abundance

Blighia unijugata	Tree	Locally rare tree, adapted to wet areas and will be planted for aesthetic purposes on the green belt, linear park and road reserve.
Brachiaria brizantha	Herb	Soil stabilization
Brachiaria humidicola	Herb	Grass planted for wetland restoration
Brillantaisia cicatricosa	Shrub	Adapted to wet areas, it will be planted for the restoration of riparian areas.
Croton megalocarpus	Tree	It will be planted as ornamental tree in the green belt, linear park and road reserve, and as shade tree in recreational areas.
Cyperus articulatus	Herb	Sedge planted for wetland restoration
Cyperus denudatus	Herb	Sedge planted for wetland restoration
Cyperus dives	Herb	Sedge planted for wetland restoration
Cyperus latifolius	Herb	Sedge planted for wetland restoration
Cyperus papyrus	Herb	Sedge planted for wetland restoration
Delonix elata	Tree	It will be planted as ornamental tree in the green belt, linear park and road reserve, and as shade tree in recreational areas.
Dodonaea viscosa	Shrub	It will be planted as ornamental tree in the green belt, linear park and road reserve, and as shade tree in recreational areas.
Echinochloa pyramidalis	Herb	Grass planted for wetland restoration
Elaeis guineensis	Tree	It will be planted as ornamental tree in the green belt, linear park and road reserve, and as around the ponds.
Entada abyssinica	Tree	It will be planted as ornamental tree in the green belt, linear park and road reserve, and as shade tree in recreational areas.
Eragrostis racemosa	Herb	Soil stabilization
Ficus vallis-choudae	Tree	It will be planted as ornamental tree in the green belt, linear park and road reserve, and as shade tree in recreational areas.
Ficus sycomorus	Tree	It will be planted as ornamental tree in the green belt, linear park and road reserve, and as shade tree in recreational areas.
Juncus effusus	Herb	Rushes planted for wetland restoration
Kigelia africana	Tree	It will be planted as ornamental tree in the green belt, linear park and road reserve, and as shade tree in recreational areas.
Leersia hexandra	Herb	Grass planted for wetland restoration
Ludwigia abyssinica	Herb	Herb adapted to wet areas and will be planted for wetland restoration
Maesopsis eminii	Tree	It will be planted as ornamental tree in the green belt, linear park and road reserve.
Markhamia lutea	Tree	It will be planted as ornamental tree in the green belt, linear park and road reserve, and as shade tree in recreational areas.
Nymphaea nouchali	Herb	It will be planted as floating plant on ponds for aesthetic purposes
Olea europea subsp. *africana*	Tree	It will be planted as ornamental tree in the green belt, linear park and road reserve, and as shade tree in recreational areas.
Panicum maximum	Herb	Grass planted for wetland restoration
Persicaria decipiens	Herb	Herb adapted to wet areas and will be planted for wetland restoration
Phoenix reclinata	Tree	It will be planted as ornamental tree around the ponds.
Phragmites mauritianus	Shrub	Riverbanks stabilization
Podocarpus latifolius	Tree	It will be planted as ornamental tree in the green belt, linear park and road reserve, and as shade tree in recreational areas.
Polycias fulva	Tree	It will be planted as ornamental tree in the green belt, linear park and road reserve, and as shade tree in recreational areas.
Pterygota mildbraedii	Tree	It will be planted as ornamental tree in the green belt, linear park and road reserve, and as shade tree in recreational areas.

Senegalia polyacantha	Tree	It will be planted as ornamental tree in the green belt, linear park and road reserve, and as shade tree in recreational areas. It will also be planted on the proposed island in Rugenge-Rwintare and serve to host birds.
Sesbania sesban	Shrub	Riverbanks stabilization
Setaria homonyma	Herb	Grass planted for soil formation and stabilization on the island in Rugenge-Rwintare
Spathodea campanulata	Tree	It will be planted as ornamental tree in the green belt, linear park and road reserve, and as shade tree in recreational areas.
Sporobolus pyramidalis	Herb	Soil stabilization
Sterculia tragacantha	Tree	It will be planted as ornamental tree in the green belt, linear park and road reserve, and as shade tree in recreational areas.
Syzygium guineense	Tree	It will be planted as ornamental tree in the green belt, linear park and road reserve, and as shade tree in recreational areas.
Typha domingensis	Herb	Cattail planted for wetland restoration

TABLE 5-1 PLANT FUNCTIONS

5.2.7 Public Space Design

The rehabilitation project seeks not only to transform the 5 wetlands into ecologically and hydraulically sound locations, but to encourage the people of Kigali to commune with nature and gain a greater understanding and appreciation for the wetlands and allowing the wetlands to become a more active part of people's lives.

Developments within the five studied wetlands in the City of Kigali will be guided by the following principles:

Human Scale

Built elements are to be optimized for human use. The scale and detailing of trails, open spaces and built elements are to add to the human experience and to the wellbeing of users.

Compatibility & context

The built environment is to be sensitive of the natural context. Landscape development and open public areas are to create qualitative and diverse urban environments that promote the preservation of natural habitats.

Connectivity

Soft mobility trails are intended to offer seamless connectivity within and across wetlands that enhance their physical and visual continuity.

Walkability

Amenities and open spaces are to enhance and support universally linked and comfortable pedestrian activity.

Aesthetic qualities

Preserve valuable open spaces and provide qualitative built elements for ecological, educational and recreational purposes.

The design therefore incorporates areas that allow for the interaction of the population with the wetlands as explained below. The detailed design is provided below, with relevant drawings provided in Annex 4.5.

5.2.7.1 Pedestrian / Cycling Trails

Soft mobility networks will be created to improve permeability, accessibility, connectivity and pedestrian comfort. Wetland trails are to be retrofitted to prioritize and encourage pedestrian movement, and where possible including accessibility for individuals with impaired mobility.

Design:

- A clear hierarchy is to be developed for easy wayfinding and sense of place.
- Two types of signage are to be installed along the trails: (i) informative signage, providing basic information such as opening hours, location plans, delimitating trails on the ground, etc.) and (ii) interpretative signage (aiming at wetland protection sensibilization, with information on plants and animal species and areas of special interest).
- Where possible, trails can ensure the continuity between interconnected wetlands.
- All pedestrian circulation shall be fully accessible to the disabled.
- Trails are to be planted with native and/or plants.
- Rest areas with benches should be installed at a maximum distance of 500 meters from each other for improved accessibility.
- Cycling lanes can be added to trails where possible to promote the use of bicycles as means of transportation for short journeys.
- Where possible, trails should delimitate the wetland and create a buffer zone that prevents future encroachment and associated reduction of wetland functions.
- Trees, grass and shrubs should be planted along the trails to improve experience and delimited the circuits.

FIGURE 5-9 TRAIL AT NYANDUNGU ECO PARK, KIGALI, RWANDA

FIGURE 5-10 PUB AND RESTAURANT FACILITY AT RWINTARE

5.2.7.2 Urban esplanades and observation decks

Public open spaces are the backbone of a city. Where public spaces are inadequate, due to insufficient space, poor design, irregular/inconsistent maintenance, there is often less interaction between the various groups that cohabit in a determined city. The public realm provides opportunities for interaction and recreation, contributing to building strong neighborhoods and communities, improve micro-climate and strengthening urban resilience.

In this sense, a network of open spaces is planned to improve permeability across the wetlands, provide distribution, connectivity, locational accessibility, programmatic diversity. A city-wide system needs to be well coordinated adding up to more than the sum of its parts.

Design:

- Open spaces shall be designed for multiple use to accommodate different user groups regardless of gender, religion, and age.
- Open spaces and recreational facilities should be designed to supplement the cultural preferences of the local community.
- The design of open spaces should consider seasonal changes and provide quality space both during dry and rainy season. For recreational areas, climatic restrictions on physical activity should be mitigated through conscious design and maintenance.
- Existing green areas and large existing trees shall be preserved or compensated for with adequate quality green space.

As an alternative to the observation decks and in areas with steep slopes, observation towers can be installed. The choice of design will vary according to the context and site. Below different examples of conceptual designs and observation towers that could be developed for other wetlands according to their environment.

FIGURE 5-11 EXAMPLES OF WETLAND OBSERVATION TOWERS

5.2.7.3 Public furniture

Public furniture in the wetlands should:

- Implement simple, unified, coherent furniture system
- Privilege the use of natural material over artificial
- Limit material selection and follow a unique colour palette to enhance the identity of the wetlands
- Ensure high quality craftsmanship
- Choose from locally available, regionally produced sustainable materials

The proposed furniture includes:

- Signage
- Solar Lighting
- Benches
- Litter containers
- Bicycle racks
- Protective guarding

5.2.7.4 Buildings

A variety of buildings are proposed throughout the 5 wetlands of the project. These include:

- Eco-tourism Centre
- Restaurants
- Coffee Bars
- Toilets

The designs for these structures are presented in the annexes of the relevant wetland. However, it should be noted that all buildings rely on passive cooling measures which remove the need for air-conditioning, in line with the environmental purpose of the project.

It is inevitable that human waste will be generated at these sites. In order to avoid pollution of the wetlands, the Consultant has therefore proposed the waste be collected in septic tanks which will be periodically emptied by truck, through a competent service provider.

5.2.7.5 Wastewater management in the wetlands

An appropriate wastewater management into the wetland is to be considered for all the future buildings of the wetlands : restaurants, coffee shops, education centres…

Existing wastewater network is not available near the wetlands, and in all cases, it would have been difficult to connect the buildings which are at low points (necessity to pump).

Taking into account four realist solutions were considered:

- Solution 1 : Sewage storage tank and regular pumping by trucks
- Solution 1 bis : Black water storage tank and regular pumping by trucks
- Solution 2 : Septic tank and regular pumping by trucks
- Solution 3 : Sewage lagoon in the wetlands

The characteristics are the following :

	Sewage Storage tank	Blackwater storage tank	Septic tank	Sewage lagoon
Principle	The sewage will be managed through an open-air storage tank, only used to collect the sewage. No specific treatment is foreseen in the storage tank. The stored sewage shall be extracted by trucks on regular basis to a proper wastewater treatment plant	For this solution, the idea is to separate the greywater (coming from sinks, showers, laundry without harsh chemicals) and the blackwater (coming from toilets) and to store only the blackwater to reduce the volume to be stored.	Sceptic tank is an underground chamber used for non-collective sanitation. A sceptic tank shall be installed for each concerned housing.	The sewage lagoon is a pond in which bacteria degrade sewage and wastewater.
Process	No specific treatment is foreseen in the sewage storage tank. It means that if the sewage is stored for too much time, sludge will decant in the tank and will create foul odours. To avoid this, trucks shall extract the wastewater and the decanted sludge on very regular basis. As the wastewater extraction is managed by trucks, the discharge of non-treated effluent in the natural environment shall be limited. However, if the trucks don't extract sufficient volumes of wastewater, overflows of polluted effluent in the natural environment could happen. As there is no treatment, this kind of pond does not need electromechanical equipment. A mobile pump could be used to drain off the tank. **=> This solution needs a WWTP nearby**	No specific water treatment is foreseen in the wastewater storage tank. It means that if the wastewater is stored for too much time, sludge will decant in the tank and will create foul odours. The extraction by trucks shall be more regular than in the solution 1 because the sludge is more concentrated. However, the volumes to extract will widely reduce. In this solution, the odour will be one of the main issues. In order to prevent it, the tank shall be closed, and a deodorisation system shall be implemented. Apart from the deodorisation system, there is no need of electromechanical equipment. A mobile pump could be used to drain off the tank. As for the Solution 1, if the trucks don't extract sufficient volumes of wastewater, overflows of highly polluted effluent in the natural environment could happen. **=> This solution needs a WWTP nearby**	The sceptic tank is used to treat domestic effluent for individual housing in underground precast chamber. After anaerobic digestion in the chamber, the liquid effluent is commonly disposed in a sceptic drain field, which provides further treatment. Nonetheless, groundwater pollution may occur and can be a problem. The sceptic tank is not suitable for effluent charged with grease (e.g. effluent from restaurants). **=> This solution does not need a WWTP but could generate soil and ground water solutions**	The sewage lagoon is usually made of three lagoons in order to treat the wastewater. As this type of solution needs a lot of space to get a efficient treatment, it is used for small neighbourhoods. The first lagoon is the main site for the removal of the carbonaceous pollutant load. At the outlet of this tank, the concentration of microscopic algae can be significant. The second lagoon allows for nitrogen and phosphorus abatement and a reduction in the concentration of concentration of algae. The third lagoon continues the abatement obtained in the second lagoon. It also allows to maintain good treatment quality in the case of an incident (malfunction) or a maintenance operation (cleaning) on the first basin. The natural lagoon can be subject to malfunctions leading to foul odours. In order to reduce these risks, this system should only receive domestic effluent transiting through preferably combined. **=> This solution does not need a WWTP but could generate soil and ground water solutions**

		Solution 1 Sewage Storage tank	Solution 1 bis Blackwater storage tank	Solution 2 Septic tank	Solution 3 Sewage lagoon
3	**Construction works**	The storage tanks do not need to be a concrete works. However, a waterproof membrane shall be installed at the bottom of the pond to avoid any pollution of the soil through infiltrations of wastewater. Moreover, for non-concrete pond, the invert level of the pond shall be higher than the groundwater level. In the opposite case, a layer of concrete shall be created at the bottom of pond to prevent the waterproof membrane to rise up. **=> Easy to construct**	As it needs to be closed, the tank shall be a concrete work. However, by separating greywater and blackwater upstream, the storage capacity will be reduced compared with the Solution 1. The concrete work shall be designed to prevent any issue with the groundwater level. **=> Needs civil works**	A sceptic tank shall be implemented for each housing. **=> Easy to implement but in many places**	The sewage lagoons do not need to be a concrete works. However, a waterproof membrane shall be installed at the bottom of the pond to avoid any pollution of the soil through infiltrations of wastewater. Moreover, for non-concrete lagoons, the invert level of the pond shall be higher than the groundwater level. In the opposite case, a layer of concrete shall be created at the bottom of pond to prevent the waterproof membrane to rise up. **=> Easy to construct**
4	**Operation**	This solution is very easy to operate as it only needs trucks to extract the wastewater to a proper a wastewater treatment plant. The storage tank shall be drained off at least once a year for complete cleaning. **=> Easy to operate but need a lot of trucks**	This solution is easy to operate as there are few electromechanical equipment (only for ventilation and air treatment). The storage tank shall be drained off at least once a year for complete cleaning. As tank is closed, access point shall be created. **=> Easy to operate but need a lot of trucks**	Usually, operation of sceptic tanks is the responsibility of the property owner. If maintenance is not properly, the discharge effluent could pollute soils and underground water. **=> Operation and maintenance done by the property owners**	This solution is very easy to operate as it almost does not need any maintenance. Extraction of sludge from the over depth at the head of the first lagoon must be done once a year. Complete cleaning of the system shall be done every ten years. **=> Easy to operate**
5	**CAPEX**	Capex shall be moderated. The volume of the tank depends on the number of truck turnovers. With a non-concrete pond, the investment cost will be mostly earthworks. **=> Medium CAPEX**	CAPEX could be high as the tank depending on the required capacity, as the tank shall be a concrete works. The investment cost will mainly come from earthworks, civil works and the odour treatment system. **=> High CAPEX**	CAPEX could be high depending of the number of housings to be equipped. The investment cost will mainly come from earthworks, the precast chambers and the drainpipes. **=> High CAPEX**	Capex shall be moderated as the investment cost will mainly consists on earthworks. **=> Medium CAPEX**
6	**OPEX**	OPEX could be quite expensive depending on the number of trucks used to extract the wastewater and depending on how far the closest wastewater treatment plant is. **=> High OPEX**	OPEX could be quite expensive depending on the number of trucks used to extract the wastewater and depending on how far the closest wastewater treatment plant is. A operation cost shall be added for energy and chemicals consumption. **=> High OPEX**	There shall be no OPEX as the maintenance is the responsibility of the property owner. **=> No OPEX**	OPEX is low as the operation and maintenance activities are limited. **=> Low OPEX**

Considering these characteristics, a multicriteria analysis was implemented to compare the different solutions according to the specificity of Kigali wetlands.

The results of this study is presented in the table below.

Item	Criteria	Weight	Description	Solutions			
				Solution 1	Solution 1bis	Solution 2	Solution 3
Technique	Process	2	Efficiency of the proposed process	+	- -	o	+ +
	Construction works	1	Difficulty in carrying out the works	+ + +	o	- -	+
	Operation and maintenance	1	Difficulty in operating the facilities	+	o	+ + +	+ +
Financier	CAPEX	2	Investment costs	+ + +	o	- -	+
	OPEX	2	Operation and maintenance costs	+	+	+ +	+
			Total +	**14**	**2**	**7**	**11**
			Total -	**0**	**-4**	**-6**	**0**
			Balance	**14**	**-2**	**1**	**11**

According to the result of the multicriteria analysis, the solution 1 : **Sewage storage tank and regular pumping** by trucks is the most appropriate for the context of Kigali wetlands.

5.3 GIKONDO WETLAND

One parculiarity of Gikondo is the presence of a former industrial zone in the southern branch of the wetland is well, which resulted in significant soil contamination as shown by the study in Annex 6 but presented in the figure below.

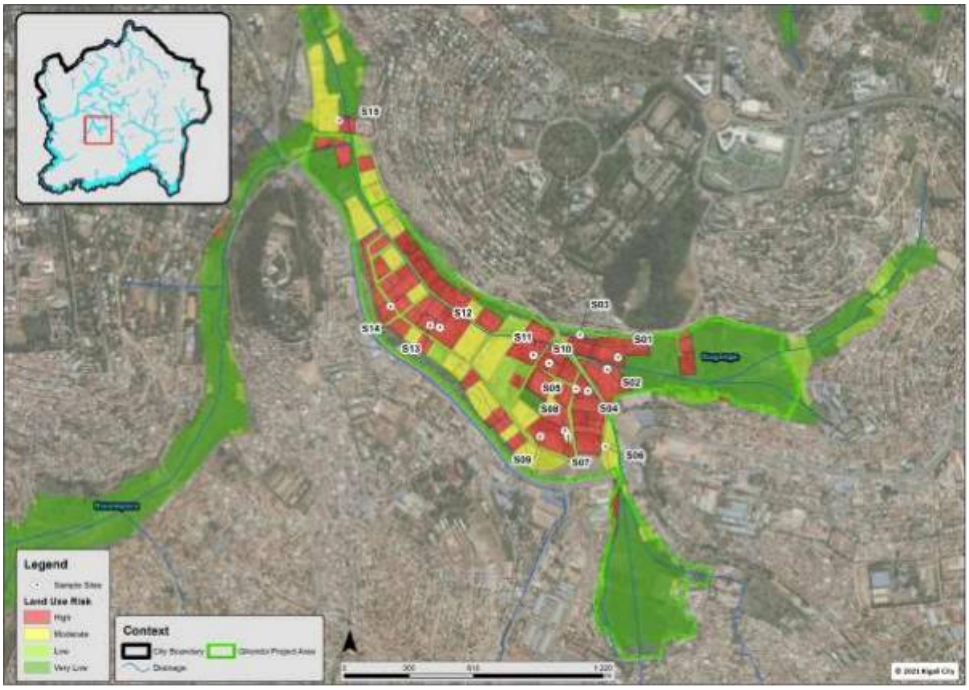


FIGURE 5-12: SOIL CONTAMINATION IN GIKONDO WETLAND

The mechanical clean-up of the area will require significant earthworks to excavate, evacuate and dump the contaminated soil as well as to backfill with an appropriate replacement. It will also have significant environmental impacts both in terms of dumping grounds for the contaminated soil and in terms of borrow pits for the replacement soil.

In line with the environmental objectives of the project, and to reduce the risk of harm to workers, the Consultant recommends phytoremediation as the most viable option, which would require leaving the contaminated soil undisturbed and achieve the natural rehabilitation of the soil through suitable plants that will allow the space to recover its pre-industrial condition over time, through the planting of relevant indigenous species. This natural rehabilitation process is projected to take between 5 and 10 years, after which the proposed recreational facilities can be constructed.

However, the Client has stated their preference for a faster, more involved, remediation process. It was therefore agreed to separate this specific component from the detailed design of the wetland rehabilitation, in order to provide a more in-depth methodology for the remediation of contaminated soils across the five wetlands considered as part of the project.

A considerable body of work has already been completed, as is presented in of the present report, and the completed study will be submitted at a later stage in order to permit the launching of tenders. As a result remediation of contaminated soil is not considered as an action in this report.

5.3.1 Landscaping actions

5.3.1.1 Landscaping concept

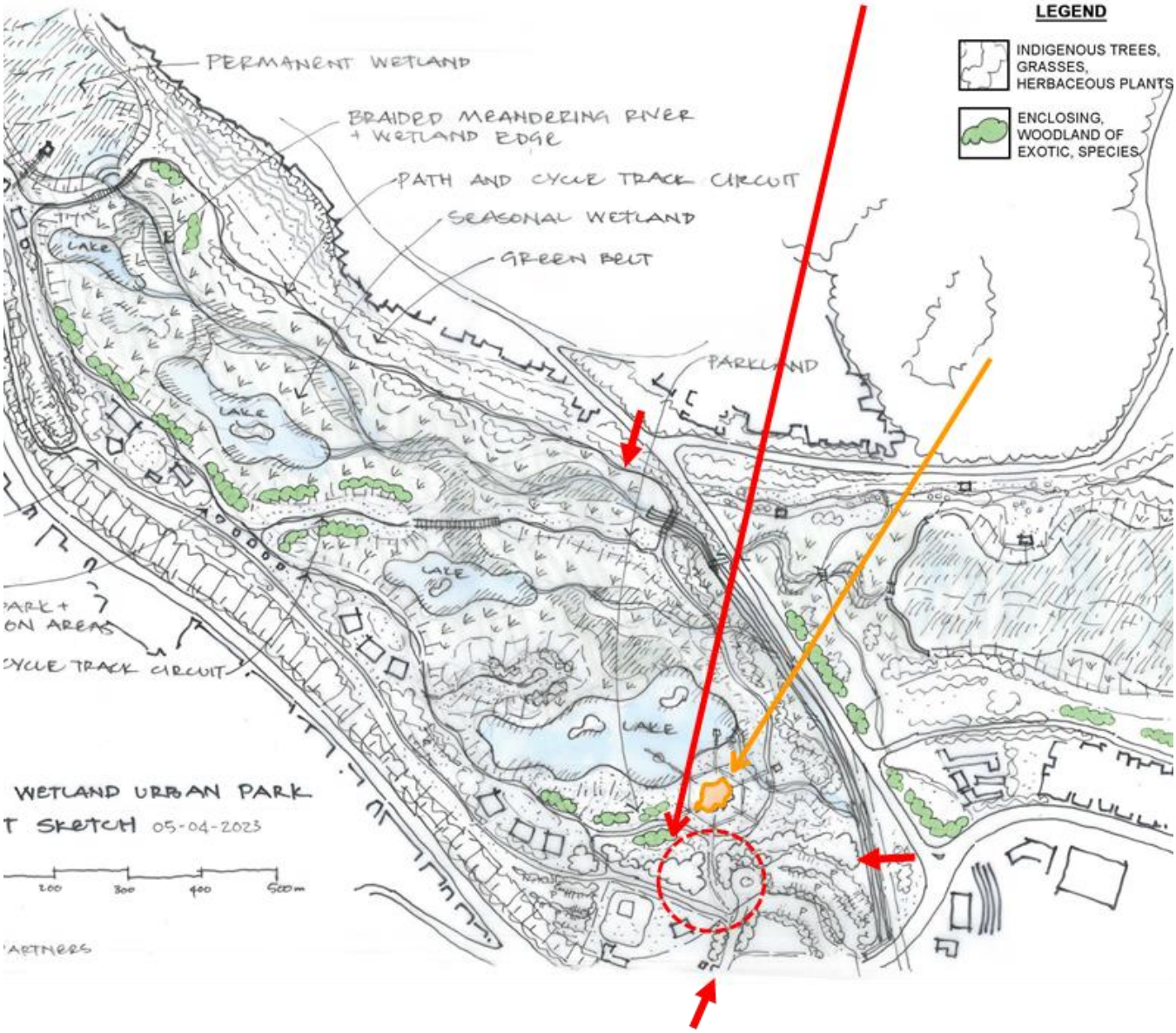


FIGURE 5-13: LANDSCAPING SKETCH OF GIKONDO WETLAND

5.3.1.2 Garden of sound

A pattern of Formal Fountains, and Giant Tree Ferns or/and Forest Cycads, and Seating Representing the Edge of the City's Grid and the beginning of a natural water web and an entrance to the park. 5No Circular, Tumbling, aerated, fountain jets in moulded receiving bowls, interspersed with matching circular, combination planter seating modules. High-quality, off-white finishing. E.g., Classic Stone, Cape Town, South Africa or similar.

The wetland of observation and lakes. A lively arrangement of splashing fountains and a vibrant water wall welcomes visitors to a special place of water, plant life and people.

FIGURE 5-14: GARDEN OF SOUND - GIKONDO

5.3.1.3 Relief map

A 3D relief map of Rwanda is also proposed in Gikondo Wetland for educational, aesthetic and recreational purposes. The proposed construction is similar to the map presented below, which was constructed in South Africa.

FIGURE 5-15: EXAMPLE OF A RELIEF MAP

5.3.1.4 Creation of a cascade landscape structure to stabilise soil.

Mumyembe was identified as a location outside of the study area, but that was subject to significant erosion risks. In order to protect this area it was proposed to create a cascade landscaping as follows.

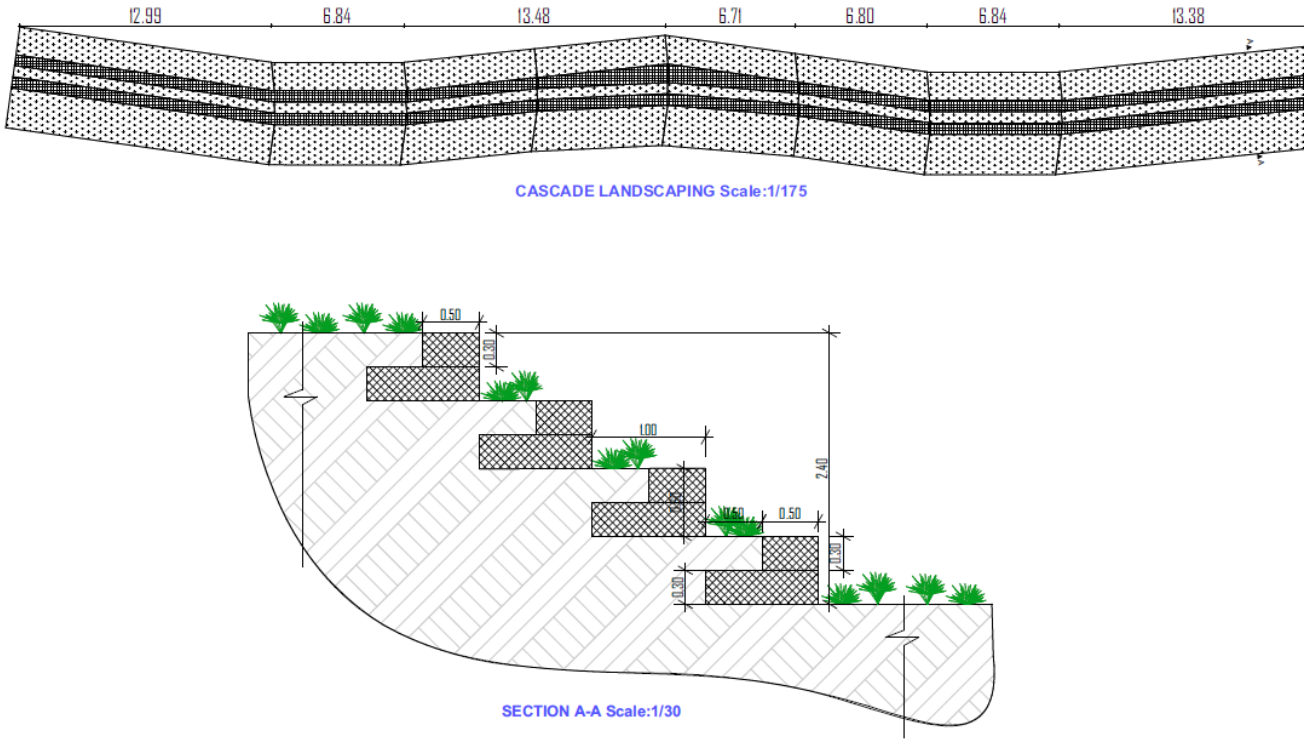


FIGURE 5-16 CASCADE LANDSCAPING IN MUMYEMBE

The detailed designs are provided in Annex 1.2.

5.3.1.5 Proposed planted species

The ecological rehabilitation of Gikondo Wetland will entail the planting of the following species, in the following areas. Further details can be found in the Technical Specifications (chapter 8) and in Annex 1.2.

For the purpose of detailed description of the site, Gikondo can be subdivided into 3 main branches: Northern & Western branch, Eastern branch and Southern branch.

5.3.1.5.1 Northern & Western branch

6 habitat typologies/target functional habitats have been identified in this area.

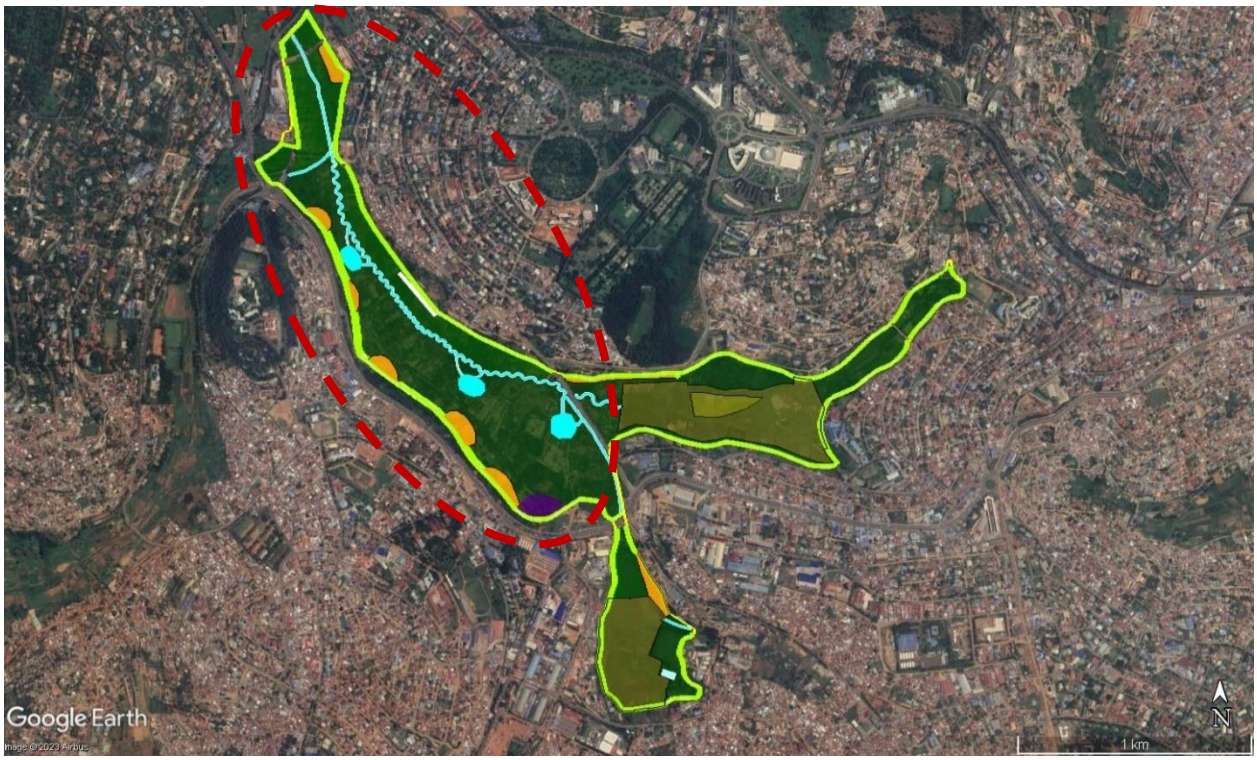


FIGURE 5-17: LOCATION OF GIKONDO NORTHERN & WESTERN BRANCH

The following table shows the list of species suggestions for each typology. Life forms and expected functions for each species can be found in Chapter 8.1.

Habitat type/function	Plant species
1. Seasonal wetland: Proposed native plant species adapted to the wetland environment are selected to enhance wetland restoration efforts. The species were identified based on their ecological function for wetland restoration through water retention, regulating water flow, filtering pollutants, soil stabilization, etc., and maintaining the health and biodiversity of these habitats in general.	*Cyperus latifolius* *Cyperus articulatus* *Leersia hexandra* *Brachiaria humidicola* *Echinochloa pyramidalis* *Brillantaisia cicatricosa*
2. Green belt & Linear park: These are upland strips along the wetland. Proposed species will primarily serve to enhance urban biodiversity, provide habitat for wildlife that use the wetland for food or shelter, and provide cultural services with focus on ornamentals amenities.	*Blighia unijugata* *Croton megalocarpus* *Delonix elata* *Dodonaea viscosa* *Elaeis guineensis* *Entada abyssinica* *Ficus sycomorus* *Ficus vallis-choudae* *Kigelia africana* *Maesopsis eminii* *Markhamia lutea* *Olea europea* subsp. *africana* *Podocarpus latifolius* *Polycias fulva* *Pterygota mildbraedii* *Senegalia polyacantha* *Spathodea campanulata* *Sterculia tragacantha* *Syzygium guineense*

3. Recreational areas: Proposed species for these areas will offer opportunities to accommodate visitors to the wetland and provide facilities such as shades for parking lots and picnic areas. These will also serve to educate visitors about the wetland ecosystem and importance of wetland conservation.	*Croton megalocarpus* *Ficus sycomorus* *Kigelia africana* *Maesopsis eminii* *Olea europea* subsp. *africana* *Podocarpus latifolius* *Polycias fulva* *Pterygota mildbraedii* *Senegalia polyacantha* *Spathodea campanulata* *Sterculia tragacantha*
4. Stream banks: The stream banks will be covered in vegetation to play a role of stabilizing stream banks, providing habitat for wildlife, and filtering pollutants.	*Phragmites mauritianus* *Aeschynomene elaphroxylon* *Sesbania sesban*
5. Pond areas: Floating plants of water lilies are proposed for ornamental purposes. These will also serve to improve water quality in the ponds and reduce the growth of algae and other harmful organisms. It is recommended to regularly control the lilies to maintain a healthy ecological balance and avoid oxygen depletion in the water. The African oil palm will be planted for ornamental purposes around the ponds	*Nymphaea nouchali* *Elaeis guineensis*
6. Cascade areas: Proposed areas will serve to stabilize the soil in the sloping parts of the upland zone.	*Brachiaria brizantha* *Eragrsotis racemosa* *Sporobolus pyramidalis*

TABLE 5-2 LIST OF PLANT SPECIES IN GIKONDO WETLAND'S NORTHERN AND WESTERN BRANCH

5.3.1.5.2 Eastern branch

6 habitat typologies/target functional habitats have been identified in this area.

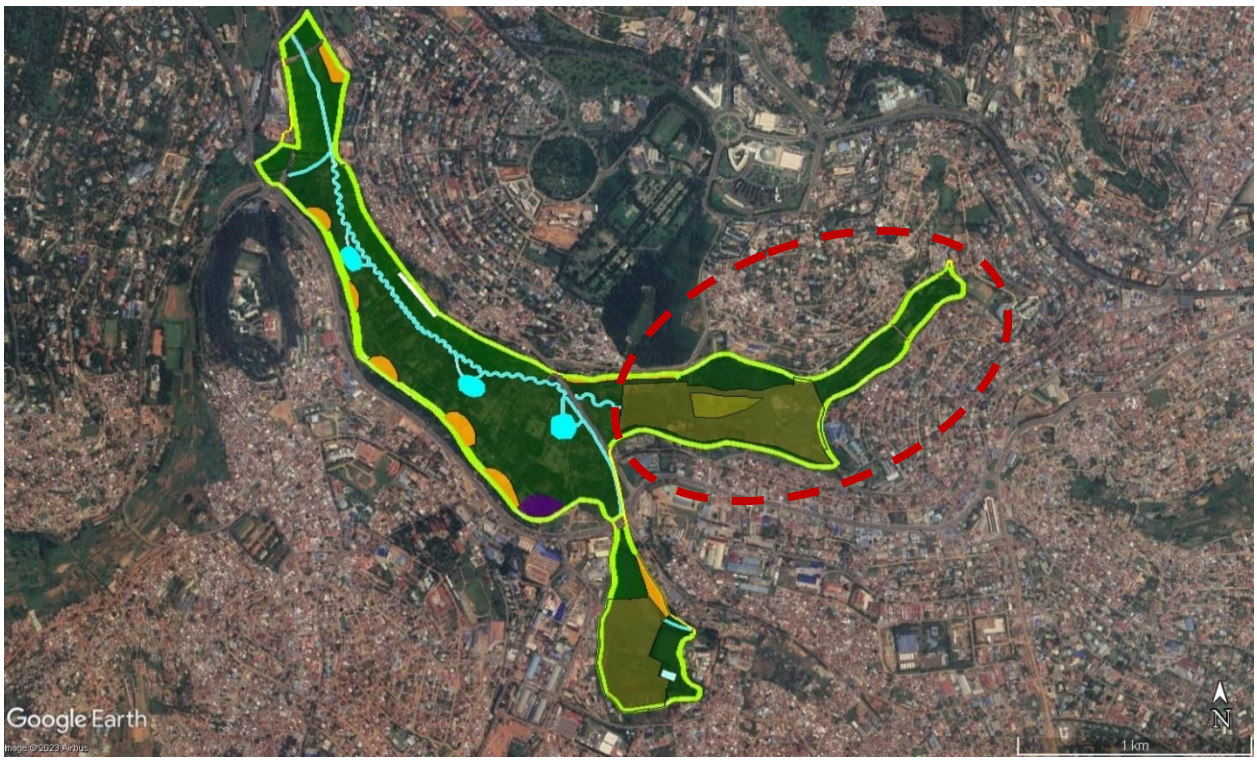


FIGURE 5-18: LOCATION OF GIKONDO EASTERN BRANCH

The following table shows the list of species suggestions for each typology. Life forms and expected functions for each species can be found in Chapter 8.1.

Habitat type/function	Plant species
1. Permanent wetland Proposed native plant species adapted to the wetland environment are selected to enhance wetland restoration efforts. The species were identified based on their ecological function for wetland restoration through water retention, regulating water flow, filtering pollutants, soil stabilization, etc., and maintaining the health and biodiversity of these habitats in general.	*Cyperus papyrus* *Typha domingensis* *Cyperus denudatus* *Cyperus dives* *Juncus effusus*
2. Seasonal wetland: Proposed native plant species adapted to the wetland environment are selected to enhance wetland restoration efforts. The species were identified based on their ecological function for wetland restoration through water retention, regulating water flow, filtering pollutants, soil stabilization, etc., and maintaining the health and biodiversity of these habitats in general.	*Cyperus latifolius* *Cyperus articulatus* *Leersia hexandra* *Brachiaria humidicola* *Echinochloa pyramidalis* *Brillantaisia cicatricosa*
3. Green belt & Linear park: These are upland strips along the wetland. Proposed species will primarily serve to enhance urban biodiversity, provide habitat for wildlife that use the wetland for food or shelter, and provide cultural services with focus on ornamentals amenities.	*Blighia unijugata* *Croton megalocarpus* *Delonix elata* *Dodonaea viscosa* *Elaeis guineensis* *Entada abyssinica* *Ficus sycomorus* *Ficus vallis-choudae* *Kigelia africana* *Maesopsis eminii* *Markhamia lutea* *Olea europea* subsp. *africana* *Podocarpus latifolius* *Polycias fulva* *Pterygota mildbraedii* *Senegalia polyacantha* *Spathodea campanulata* *Sterculia tragacantha* *Syzygium guineense*
4. Recreational areas: Proposed species for these areas will offer opportunities to accommodate visitors to the wetland and provide facilities such as shades for parking lots and picnic areas. These will also serve to educate visitors about the wetland ecosystem and importance of wetland conservation.	*Croton megalocarpus* *Ficus sycomorus* *Kigelia africana* *Maesopsis eminii* *Olea europea* subsp. *africana* *Podocarpus latifolius* *Polycias fulva* *Pterygota mildbraedii* *Senegalia polyacantha* *Spathodea campanulata* *Sterculia tragacantha*
5. Stream banks: The stream banks will be covered in vegetation to play a role of stabilizing stream banks, providing habitat for wildlife, and filtering pollutants.	*Phragmites mauritianus* *Aeschynomene elaphroxylon* *Sesbania sesban*
5. Pond areas: Floating plants of water lilies are proposed for ornamental purposes. These will also serve to improve water quality in the ponds and reduce the growth of algae and other harmful organisms. It is recommended to regularly control the lilies to maintain a healthy ecological balance and avoid oxygen depletion in the water. The African oil palm will be planted for ornamental purposes around the ponds	*Nymphaea nouchali* *Elaeis guineensis*

TABLE 5-3 LIST OF PLANT SPECIES IN GIKONDO WETLAND'S EASSTERN BRANCH

5.3.1.5.3 Southern Branch

5 habitat typologies/target functional habitats have been identified in this area.

FIGURE 5-19: LOCATION OF GIKONDO SOUTHERN BRANCH

The following table shows the list of species suggestions for each typology. Life forms and expected functions for each species can be found in Chapter 8.1.

Habitat type/function	Plant species
1. Permanent wetland Proposed native plant species adapted to the wetland environment are selected to enhance wetland restoration efforts. The species were identified based on their ecological function for wetland restoration through water retention, regulating water flow, filtering pollutants, soil stabilization, etc., and maintaining the health and biodiversity of these habitats in general.	*Cyperus papyrus* *Typha domingensis* *Cyperus denudatus* *Cyperus dives* *Juncus effusus*
2. Seasonal wetland: Proposed native plant species adapted to the wetland environment are selected to enhance wetland restoration efforts. The species were identified based on their ecological function for wetland restoration through water retention, regulating water flow, filtering pollutants, soil stabilization, etc., and maintaining the health and biodiversity of these habitats in general.	*Cyperus latifolius* *Cyperus articulatus* *Leersia hexandra* *Brachiaria humidicola* *Echinochloa pyramidalis* *Brillantaisia cicatricosa*
3. Green belt & Linear park: These are upland strips along the wetland. Proposed species will primarily serve to enhance	*Blighia unijugata* *Croton megalocarpus* *Delonix elata*

urban biodiversity, provide habitat for wildlife that use the wetland for food or shelter, and provide cultural services with focus on ornamentals amenities.	*Dodonaea viscosa* *Elaeis guineensis* *Entada abyssinica* *Ficus sycomorus* *Ficus vallis-choudae* *Kigelia africana* *Maesopsis eminii* *Markhamia lutea* *Olea europea* subsp. *africana* *Podocarpus latifolius* *Polycias fulva* *Pterygota mildbraedii* *Senegalia polyacantha* *Spathodea campanulata* *Sterculia tragacantha* *Syzygium guineense*
4. Recreational areas: Proposed species for these areas will offer opportunities to accommodate visitors to the wetland and provide facilities such as shades for parking lots and picnic areas. These will also serve to educate visitors about the wetland ecosystem and importance of wetland conservation.	*Croton megalocarpus* *Ficus sycomorus* *Kigelia africana* *Maesopsis eminii* *Olea europea* subsp. *africana* *Podocarpus latifolius* *Polycias fulva* *Pterygota mildbraedii* *Senegalia polyacantha* *Spathodea campanulata* *Sterculia tragacantha*
5. Stream banks: The stream banks will be covered in vegetation to play a role of stabilizing stream banks, providing habitat for wildlife, and filtering pollutants.	*Phragmites mauritianus* *Aeschynomene elaphroxylon* *Sesbania sesban*

TABLE 5-4 LIST OF PLANT SPECIES IN GIKONDO WETLAND'S SOUTHERN BRANCH

5.3.1.6 Creation of an island for aesthetic appearance

At the request of the Client, four landscaped islands are proposed to be constructed in Gikondo wetland (G13a, G13b, G13c, G13d). This will provide an elegant form emerging from the ponds and lakes in this wetland increasing biodiversity.

Detailed designs can be found in Annex 1.2.

5.3.1.7 Soil reshaping for wetland creation

The objective of this action is to carry out earthworks that will modify the topography of the wetland for ecological and aesthetic purposes.

Existing low points in the wetlands will be identified and the surrounding areas will be excavated in order to expand these locations into low areas that will preferentially accumulate water. Excavated soil will be used to backfill the existing water course as well as to enhance nearby high points.

The immediate outcome of this action will be a sloped but unchanneled terrain which will allow water to flow diffusely and slowly through the wetland. The final result is the creation of different areas of wetland based on their elevation. Specifically, this will result in permanent wetlands in the low points where the soil will be constantly waterlogged, and seasonal wetlands which will periodically receive inflows of water.

The greater retention time of water in the low points mean that it provides an excellent opportunity for the treatment of inflows coming from upstream or neighbouring built-up areas, a process which can be accentuated by the planting of appropriate plant species.

The difference in water content of the soil due to elevation differences will also promote the creation of a variety of flora, which will have two co-benefits:

- Additional habitat creation for local fauna, promoting biodiversity,
- The wide diversity of plant species will allow for a more varied beautification of the site.

Proposed wetland reshaping actions are located as per the zoning maps under labels G19a, G19b and G19c and are illustrated in the figures below. The detailed site plans and cross sections are provided in Annex 1.2.

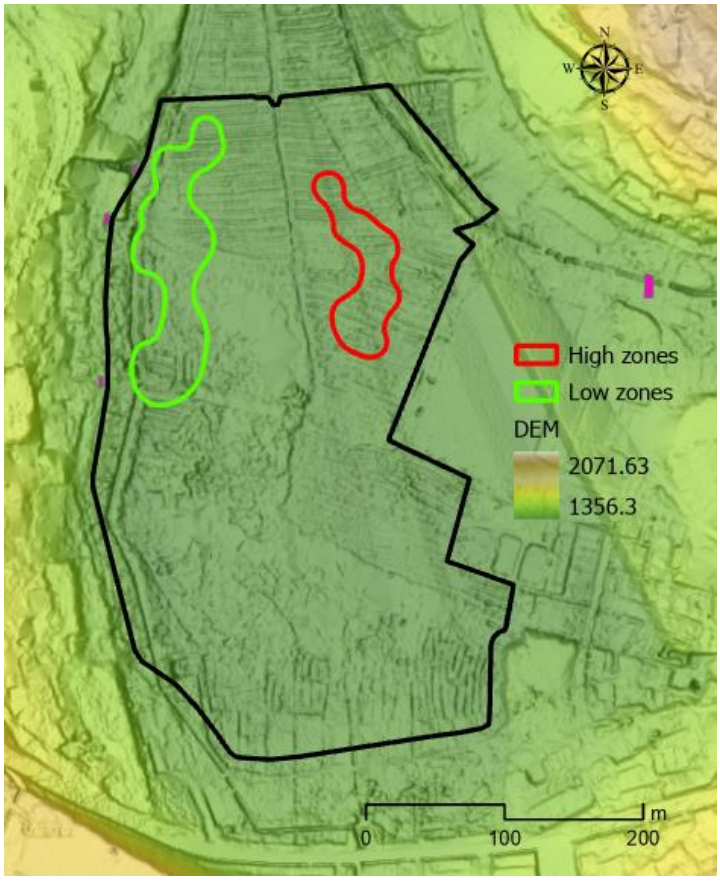


FIGURE 5-20: WETLAND RESHAPING – G19A

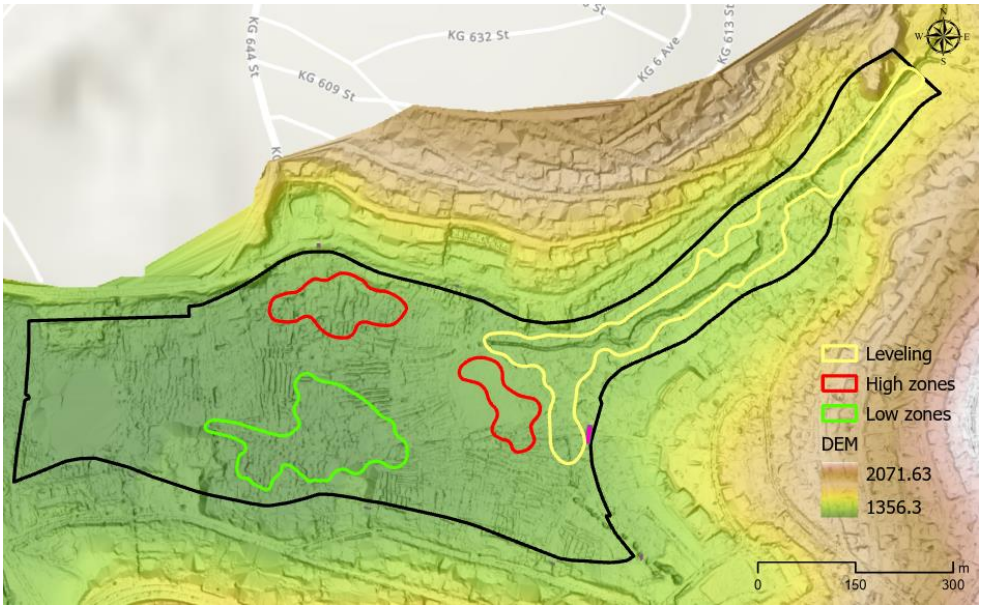


FIGURE 5-21: WETLAND RESHAPING - G19B

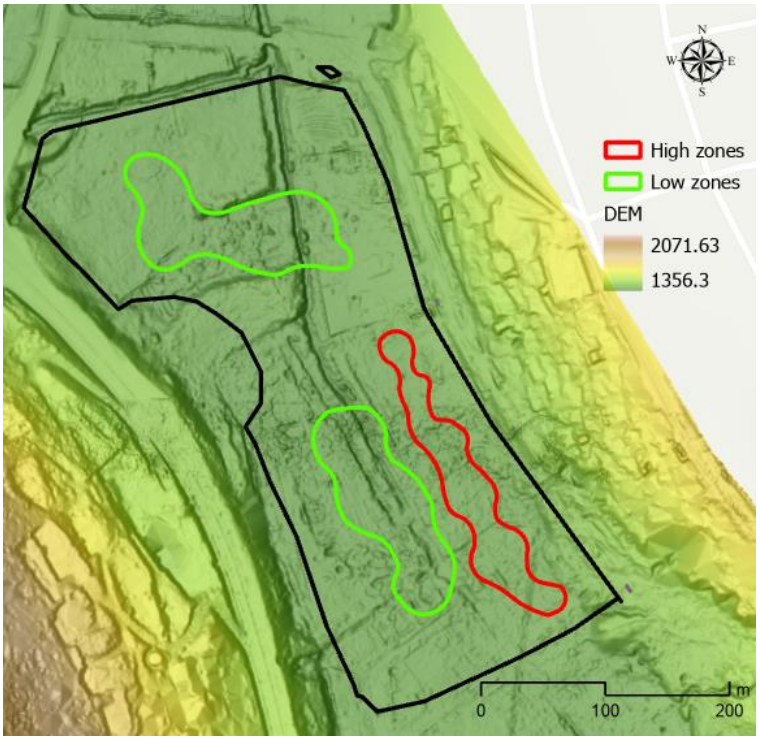


FIGURE 5-22: WETLAND RESHAPING - G19C

5.3.2 Hydraulic actions

The hydraulic actions designed in this project seek to reinstate or enhance the hydraulic functioning of the 5 wetlands, mostly through modifications of the flows through the project area with the following objectives:

- Promoting water retention in the wetlands to prevent damaging flooding events,
- Reducing the flow through the wetlands to limit erosion,
- Spreading of water flows to provide maximum absorption and reduce downstream flows and velocities,
- Provide favorable aquatic environments for fauna and flora,
- Improve water quality.

As explained in paragraph 3.2.3, a variety of actions are planned with each wetland receiving interventions tailored to the wetland's objectives.

In accordance with the Master Plan for Gikondo (Annex 1.1), the detailed design was carried out as below for the specific interventions proposed for the wetland, which is developed hereunder. Further details can be found in the Technical Specifications (chapter 8) and in Annex 1.3.

5.3.2.1 Water conveying structure to block and channel water to the main stream

The intervention consists in the construction of a dike spanning the width of the valley at the outlet of the wetland to collect and concentrate the water flowing out of the wetland, which will effectively create an artificial lake. A channelling structure will be constructed as part of the dike to convey all the water towards the meandering watercourse downstream.

The Consultant has considered employing nature-based solutions as much as possible. As such, the dike will be constructed of compacted earth, covered in turf. Volcanic paving stones will be used to create the path along the top of the dike with wooden handrails for safety reasons.

However, for the critical element of the conveying structure, the space allowing the passage of water collected by the dike into the subsequent channel it was necessary to retain concrete for the construction. This was to ensure the long-term sustainability of the structure, which would be affected by two main factors:

- The strength requirements in order to withstand the static and dynamic (hydraulic) loads.
- The risk of erosion by water velocity through the structure.

The use of concrete is minimized insofar as the outlet of the conveying structure consists of gabion walls (with wire mesh coated with green PVC) and river stones that will prevent shearing and erosion of the banks at the entrance to the downstream channel.
An example of the proposed water conveying is provided in the image below.

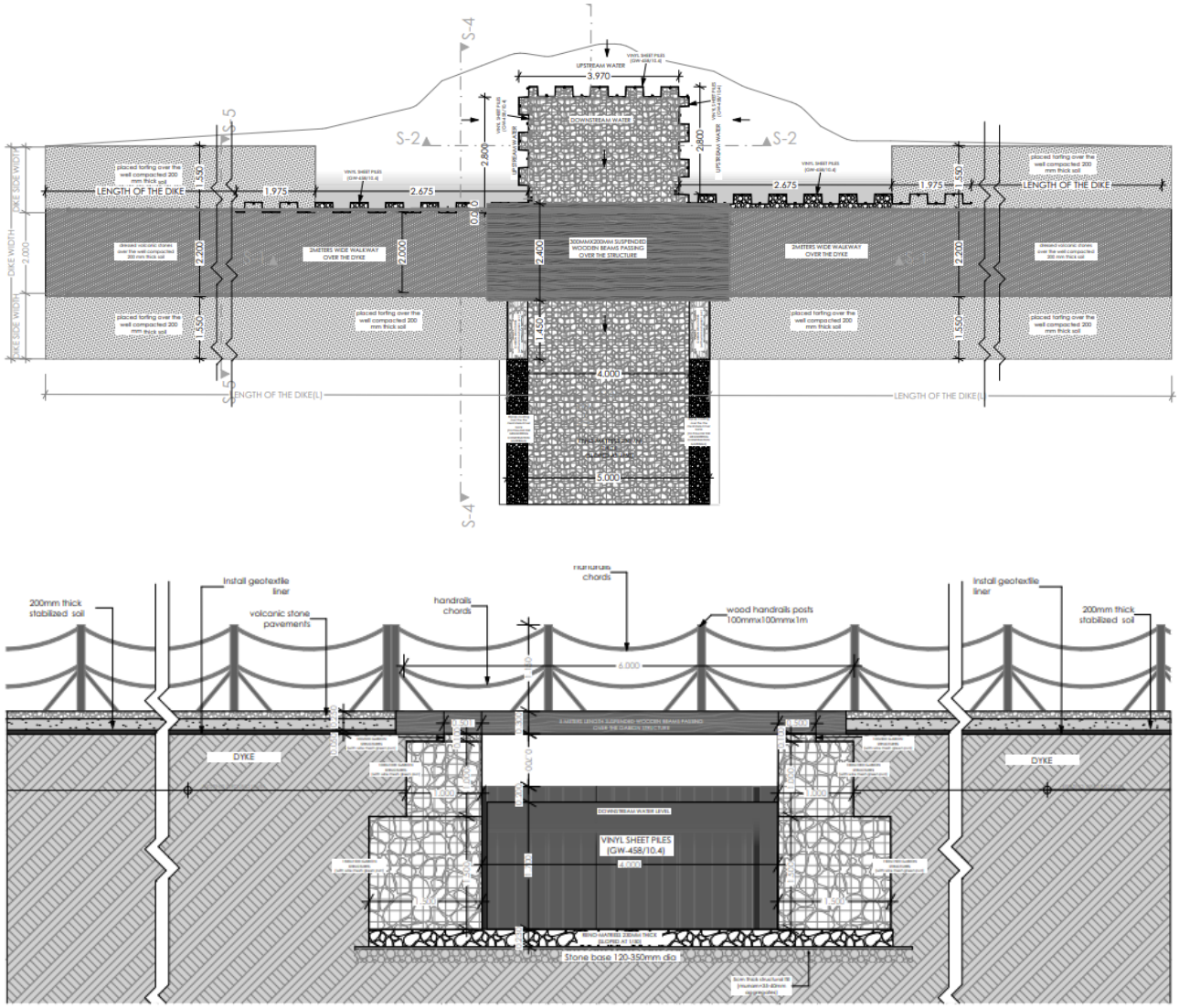


FIGURE 5-23: EXAMPLE OF A WATER CONVEYING STRUCTURE

The Contractor will be responsible for the verification of the structural stability and quantities required for the structure's construction, based on the real conditions identified during implementation.

The Consultant verified the impact of the blocking and channeling structure on the flow of water through the wetland, by:

- Modelling dam with corresponding height
- Considering rainfalls of increasing intensity (T2 and T10 at current urbanisation levels, and T2, T10, T50 with 2050 urbanisation projections)
- Considering modifications by YREC following their hotspot study.

In this case, only low intensity return periods are relevant, however it is still interesting to see how the modifications will also react to high intensity flood.

The results for a T2 rainfall before and after intervention are presented in the image below, however the complete modelling results are provided in Annex 1.4.

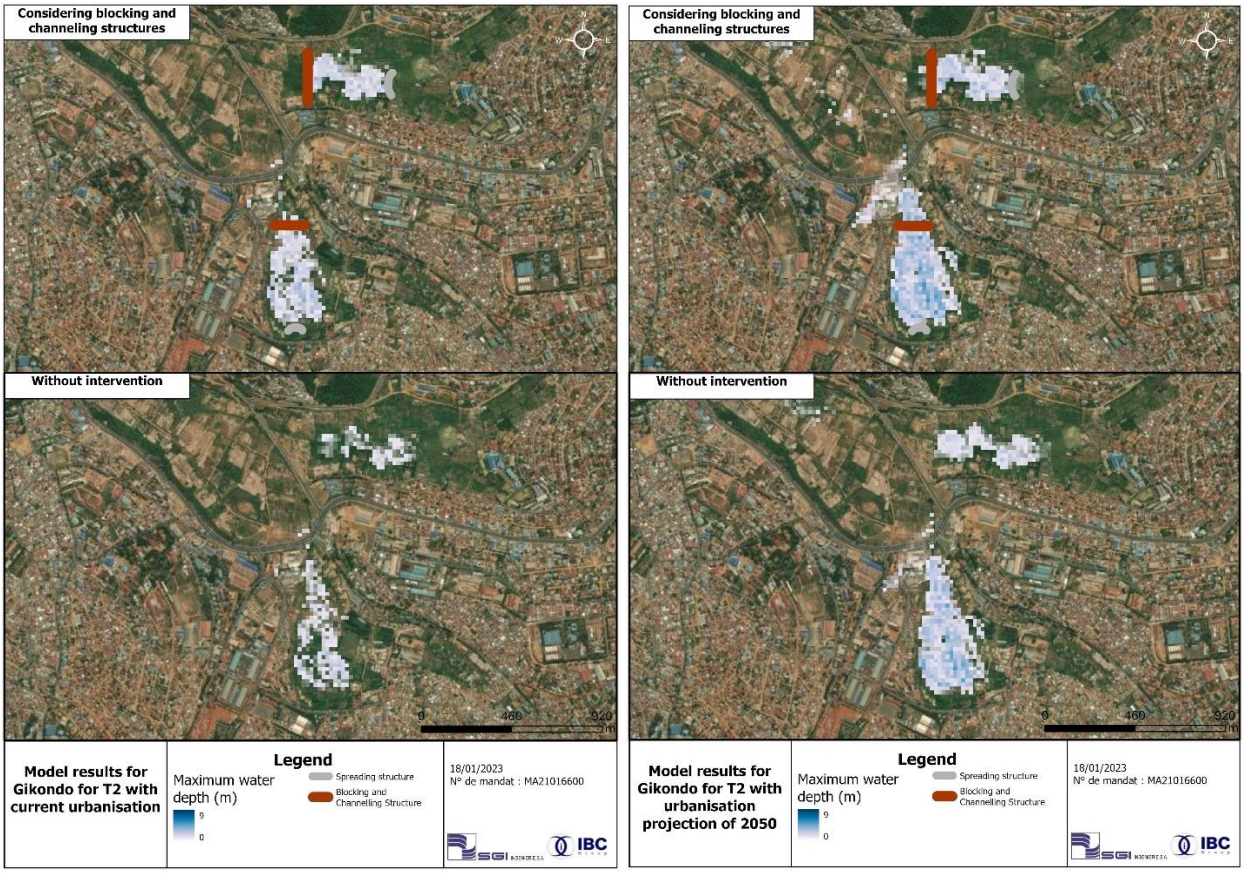


FIGURE 5-24: WATER DEPTHS FOR A T2 RAINFALL BEFORE AND AFTER INTERVENTION IN GIKONDO WITH CURRENT AND 2050 URBANISATION LEVELS

5.3.2.2 Water spreading structure to spread water into the wetland

The intervention consists in the modification of the flow of water out of the channel from which it originates into a more diffuse flow that spreads across the wetland. The objective of this intervention is to ensure an even spreading of the water throughout the wetland to achieve maximum speed and flow reduction, which will not only prevent flooding, but also improve water quality and retain water in the wetland site to better promote growth and habitat creation.

The Consultant has considered employing nature-based solutions as much as possible, and relies on a two-pronged approach to force the flow to diverge:

- Earthworks: At the approach to the wetland area, the soil will be mechanically shaped into a slightly conical form that will encourage water to flow laterally through gravity.
- Gabion walls: To further encourage the water to spread laterally across the wetland floor, gabion walls of increasing length will be constructed across the wetlands to reinforce the redirection of the flow as the water passes through them.

This construction will have the following impacts:

- Even spreading of the incoming water across the span of the wetland, making maximum use of the available space.
- Reduction in the speed of water limiting erosion and promoting sedimentation.
- Increased absorption and raised level of the water table.

- Improved water quality.

An example of the proposed spreading structure is provided in the image below.

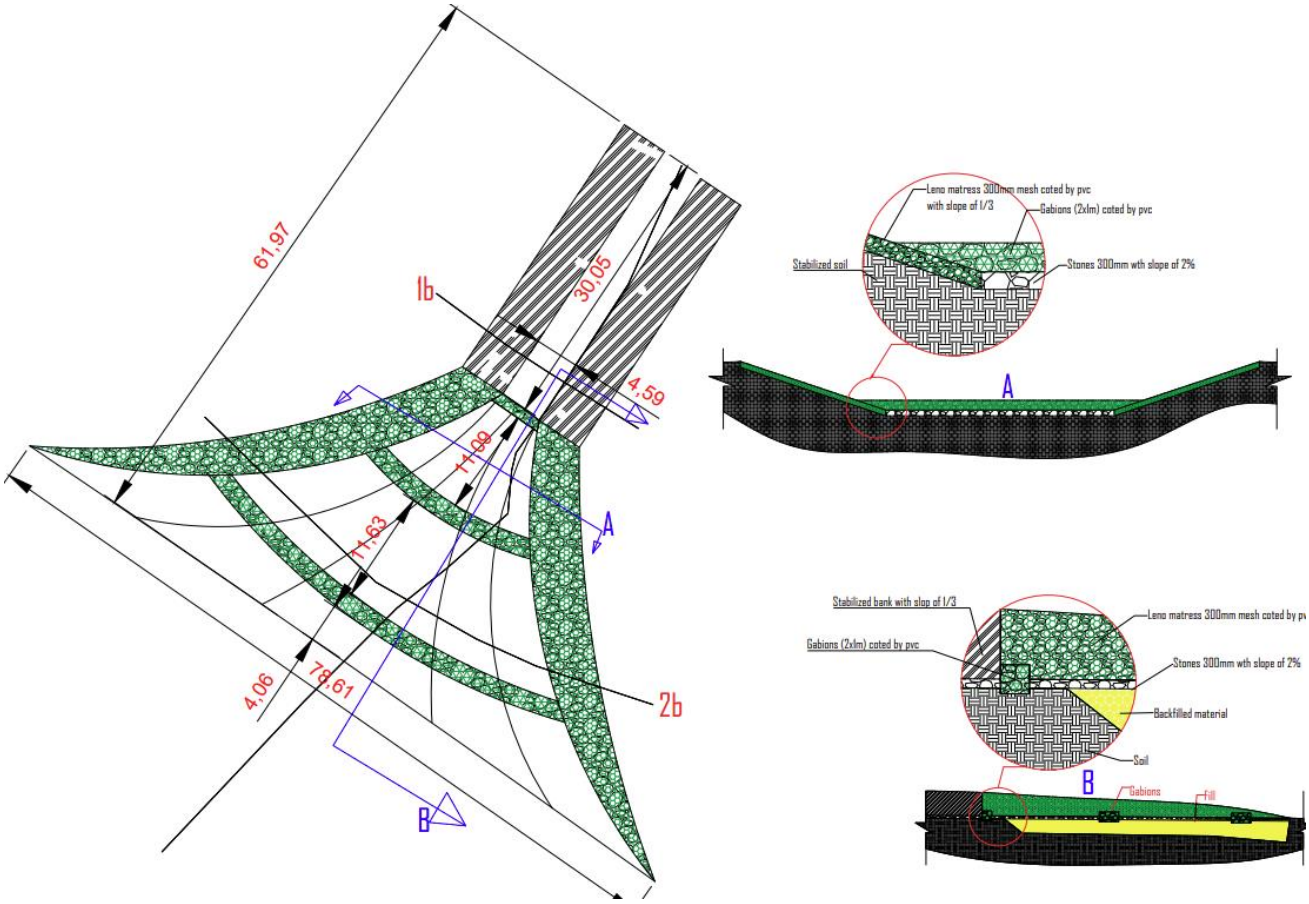


FIGURE 5-25: EXAMPLE OF A FLOW SPREADING STRUCTURE

The contractor will be responsible for the verification of the structural stability and quantities required for the structure's construction, based on the real conditions identified during implementation.

5.3.2.3 Sediment traps for blockage of sediments into the wetland

The hydraulic outfalls from lateral drainage carry effluents from the neighbouring urbanized areas, which are charged with sediment, and convey them into the wetland. Originally built to drain plots for agricultural purposes they are relatively deep (about 2m) and consequently convey water rapidly downstream, which is in opposition to the role and functioning of the wetland.

The construction of sediment traps is therefore proposed to counteract this effect. A sediment trap is a containment area that allows sediment in collected storm water to settle out during the runoff is discharged through a stabilized spillway/dewatering pipe.

Due to the very large amount of waste of varying sizes coming from the sides, and the lack of a large-scale collection system over most of the study area, sediment traps will be installed at each drain stop in the wetland.

It is very important to note that each sediment trap was designed specifically, depending on the reality of each drain. The drawings are given in Annex 1.3, examples are provided hereunder.

The Consultant considered the use of vegetation on the gabions forming the sediment trap elements. This solution was not retained for the following reasons:

- the water arrives at a high speed which requires the installation of gabion mats with a tight mesh to ensure stability
- in these conditions, vegetation would not be able to develop properly and would represent a significant hindrance to the maintenance of the structures.

3 types of sediment traps were defined according to the context, here is an example:

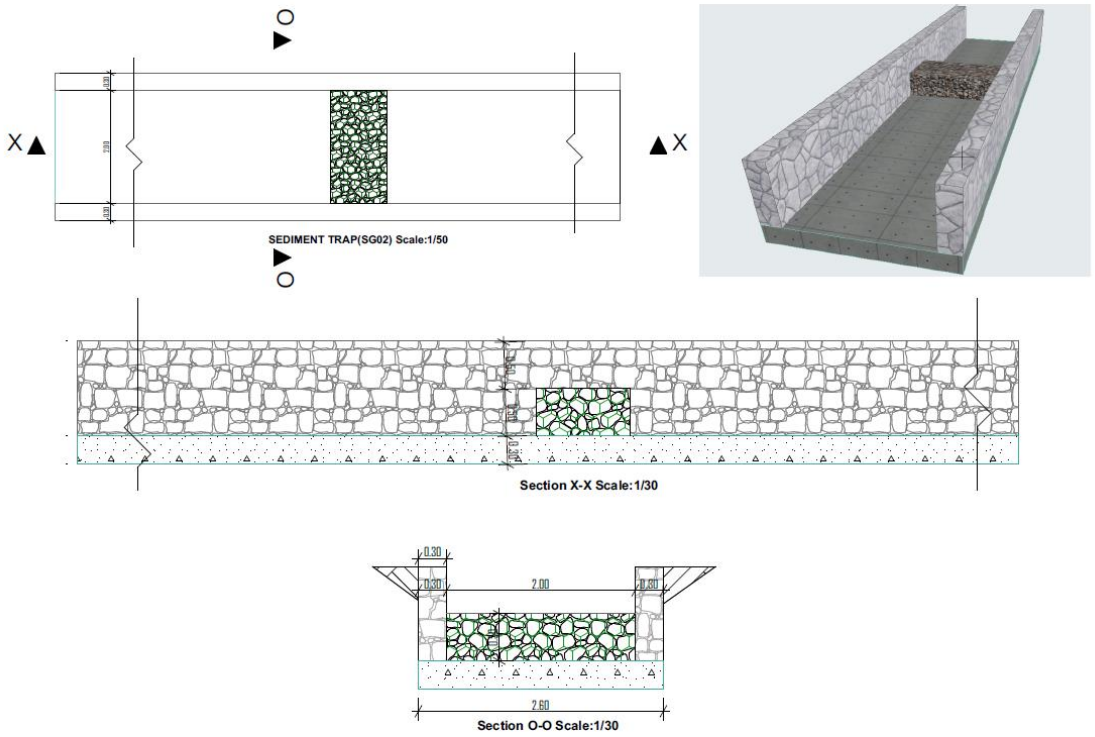


FIGURE 5-26: EXAMPLE OF SEDIMENT TRAP

At the outlet of the structure, a gabion wall filled with river stones will ensure that the flow is spread across the floor of the wetland. This will combine with the landscaping action G19 “soil reshaping for wetland creation” which specifically incorporates interventions to receive inflows from lateral drainage. This will limit its velocity thereby retaining it in the wetland, where it can be naturally treated of other pollutants (chemical and biological). This treatment is reinforced by appropriate plant selection as explained in paragraph 5.3.1.

The result is primarily to improve the quality of the water, but it will also contribute to increasing the height of the water table and limiting flooding downstream.

The construction of these traps can only be carried out with the use of concrete for the base and walls of the structure; however gabion and river stones are also incorporated into its construction to constitute the trap. The trap will require periodic manual emptying to ensure it remains effective, as once it is full the sediment will simply continue its path into the wetland.

5.3.2.4 Spillways to divert low flows

Spillways are flow control structures that orient the water in different directions according to their design.

For this project the spillway’s role is to ensure that consistent low flows are diverted from the existing channel towards the newly created ponds and lakes (Action G12) to ensure renewal of water, which will provide a healthy environment for habitat creation. High flows will be conveyed towards a channel from where it will flow downstream, which will prevent overloading of the pond.

Gikondo lake (action G12a) is supplied by two streams of water from the northern and southern branches of the wetland.

Southern Branch

The maximum discharge to be diverted to the lake from the southern branch was defined as the flow that received from a 2-year return period, which corresponds to a flow of 12 m3/s. As explained above, flows in excess of 12m3/s will be diverted to the diversion channel. A plan view of the spillway that regulates this flow (G04a) is presented in the image below.

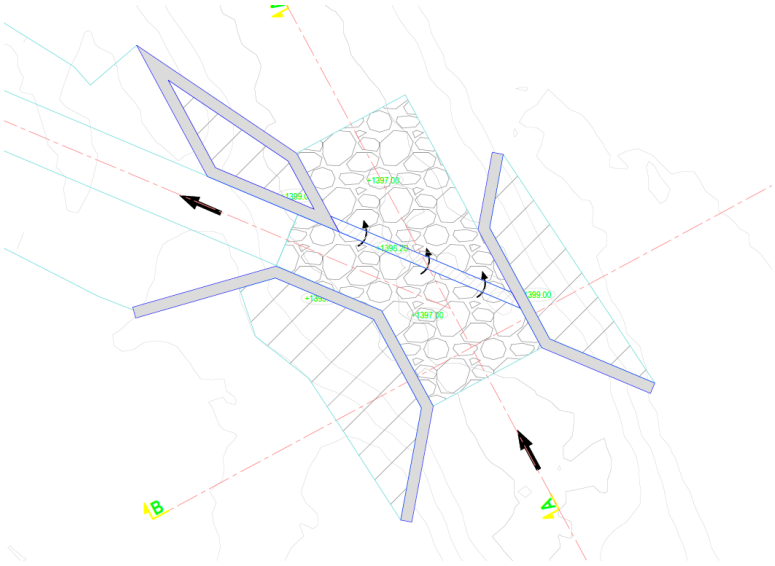


FIGURE 5-27 – EXAMPLE OF SPILLWAY

Since the spillway diverts the flow into a 2.5m wide rectangular channel, the spillways therefore require a height of 1.2m.

Northern Branch

The northern branch has a small catchment area, and therefore provides only limited flow of stormwater. The flows modelled would not require a spillway. However, since this stream crosses the southern branch's existing diversion channel a spillway of identical height (G04b) is required to ensure the 2-year return period is respected. A plan view of the structure is illustrated below.

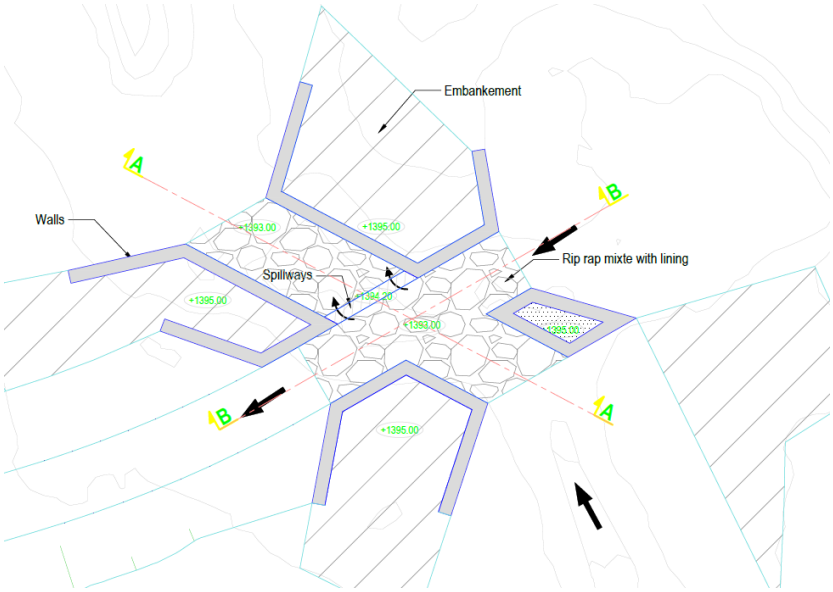


FIGURE 5-28 - SPILLWAY G04B

Detailed designs of the spillways are provided in Annex 1.3.

5.3.2.5 Blocking of surface drains (agriculture drains)

Previous agricultural use has resulted in the creation of drains, originally constructed to facilitate the development of intensive agriculture, thereby strongly impacting the hydraulic dynamics of the wetland and its waterlogging.

The objective of the drains is to convey water rapidly downstream, away from farmed areas, which contributes to the lowering of the water table and the rapid drying of the soil. In addition to excavated drains, soil embankments raise the channel level above natural ground level in order to prevent the flooding of crops during heavy rains. However, with the repurposing of the wetland site for flood management, ecological and aesthetic purposes, it is essential to retain water within the wetland, which is in firm opposition to the existing land use.

The objective of this action is therefore to prevent water from flowing in preferential paths, but to flow diffusely through a restored homogenous surface of the wetland. The water's flow rate will consequently be reduced as will associated erosion problems, and the water table will rise to provide a better environment for fauna and flora.

In order to achieve this objective, the ground level will be restored to a homogenous generally flat surface, devoid of drainage network. This will require two distinct actions illustrated in the images below:

- The backfilling of the agricultural ditches with soil
- The removal of soil embankments above natural ground level.

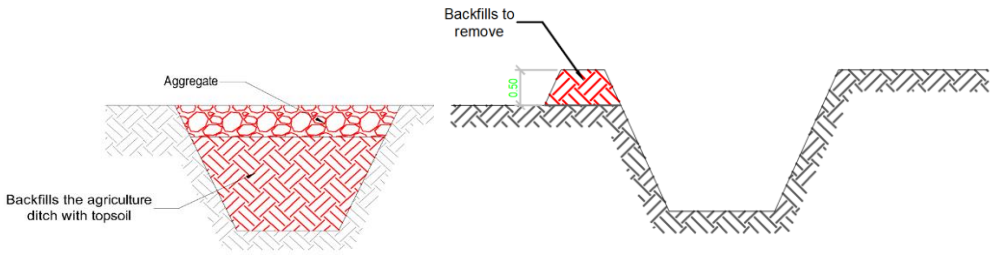


FIGURE 5-29: CROSS-SECTION OF AGRICULTURAL DRAINS

The soil from the embankments can be used to infill the drains however the available volume will be insufficient, and soil importation will be required. The topsoil used for this purpose must be free of any invasive plant species or pollutants. The agriculture drains located in Gikondo will be completely backfilled.

The volume of topsoil needed to fill the trapezoidal shaped drains is calculated with the following formula:

$$V = S \cdot l \cdot n \quad \text{with } S = h \cdot (\text{a} + \frac{b-a}{2})$$

Where:

- l is the length of the drains
- S the surface of the drain
- n the number of drains,
- h the depth of the recharge bed
- a and b the channel width at the base and surface respectively.

In Gikondo, the drains have a mean width of 1.5m at the base and 2.3m at ground level, and a height of 1.5m, resulting in a cross section of 2.59m^2. The volume of channel to be backfilled is presented in the table below.

Channel	Length of drainage (m)	Section of channel (m2)	Volume of backfill (m3)
G05a	570.4	2.59	1475.9
G05b	1794.0	2.59	4642.1
G05c	3467.7	2.59	8972.6
G05d	810.5	2.59	2097.2
G05e	51.4	2.59	132.9
G05f	121.6	2.59	314.7
G05g	721.1	2.59	1865.8

TABLE 5-5 VOLUME OF BACKFILL IN AGRICULTURAL DRAINS IN GIKONDO

From this volume is removed the available soil from the embankments. The backfill sections have a mean section of 0.14m^2. The volume represented by this infill is calculated as per the following equation and is presented in the table below.

$$V = \text{number of drains} \cdot \text{length of the drain} \cdot \text{mean section surface of the backfill}$$

Channel	Length of drainage (m)	Volume of infill (m3)
G05a	570.4	79.9
G05b	1794.0	251.2
G05c	3467.7	485.5
G05d	810.5	113.5
G05e	51.4	7.2
G05f	121.6	17.0
G05g	721.1	101.0

TABLE 5-6 VOLUME OF SOIL IN EMBANKMENTS IN GIKONDO

Since the soil from the embankments can be utilized to backfill the drainage, the table below presents the balance of soil to be imported from elsewhere for the complete backfilling of the agricultural ditches.

Channel	Volume of soil to import (m3)
G05a	1396.1
G05b	4390.9
G05c	8487.1
G05d	1983.7
G05e	125.7
G05f	297.6
G05g	1764.8

TABLE 5-7 VOLUME OF SOIL TO BE IMPORTED FOR BLOCKING OF AGRICULTURAL CHANNELS

5.3.2.6 Re-profiling the river with the creation of meanders

The action of re-meandering within the framework of this wetlands consists in artificially recreating this natural functionality of the river, altered by past human interventions. The purpose of such an intervention is multiple since it aims:

- To mitigate the impacts linked to the incision of the minor bed (lowering of the water table, lowering of the surface area of the flooded zones, acceleration of the flows...).
- To slow down the dynamics of water allowing to reduce the flood wave downstream.
- To lengthen the line of the watercourse and thus to multiply the contacts between ground and water (ecotone*), possible places of purification.
- To find a diversity of natural habitats for animal species which is much more important in meandering streams than in straight streams. The work of the banks in different levels (height defined according to the flows of reference floods) will also allow to support this diversification.

For this action to be implemented, the primary space of the river need to be restored as per the methodology presented in paragraph 5.2.4.2. Large banks need to be designed which will act as a buffer zone during the rainfall storm events, and riprap will be installed at the outer curves of the meanders to prevent erosion as illustrated in the figure below.

FIGURE 5-30: EXAMPLE OF RIVER MEANDERING AND EXTERNAL BANKS PROTECTION WITH GABIONS

River meandering in Gikondo wetland has been designed in five areas (G06a, G06b, G06c, G06d, G06e), which are described hereafter. Detailed drawings are provided in Annex 1.3.

G06a

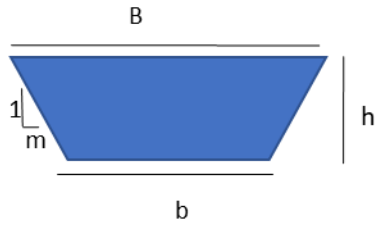
Four cross sections have been extracted in order to determine the mean width of the existing river. This will be used in order to design the meandering of this river section.

The current channel is 3.8m wide. As per the methodology, this corresponds to a meander amplitude of 38m.

FIGURE 5 -31: MEANDER G06A

The discharge through this channel is 11.1 m^3/s, therefore the dimensions of the channel are as follows:

S0	m	b (m)	h (m)	B (m)
0.0106	0.50	2	1.8	3.8



Due to high velocities, it will be necessary to protect the outer curves of the river from scouring and erosion. In order to respect the environmental spirit of the project, the Consultant is proposing to use riprap for this purpose. The riprap at the outside curve of the meanders should at least have a diameter of 0.08 m.

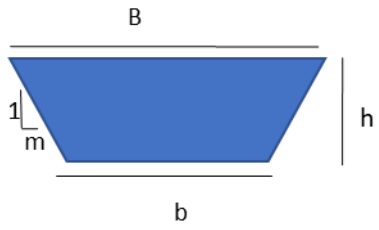
G02b

For the second meander, the space is more restricted as the wetland narrows and the terrain is flatter. This enables a 65m wide amplitude, which results in a new 6.5 m wide channel with a sinuosity of 1.25.

FIGURE 5-2: MEANDER G06B

The discharge through this channel is 13.1 m3/s, and therefore the dimensions of the channel are as follows:

S0	m	b (m)	h (m)	B (m)
0.0070	0.58	5	1.3	6.5



Due to high velocities, it will be necessary to protect the outer curves of the river from scouring and erosion. In order to respect the environmental spirit of the project, the Consultant is proposing to use riprap for this purpose. The riprap at the outside curve of the meanders should at least have a diameter of 0.05 m.

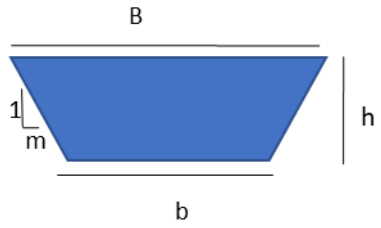
G06c

For this third meander, the chosen amplitude is of 45 m with a wavelength of 70 m which increase the sinuosity of the river to 1.25.

FIGURE 5-3: MEANDER G06C

The discharge through this channel is 5.4 m^3/s, therefore the dimensions of the channel are as follows:

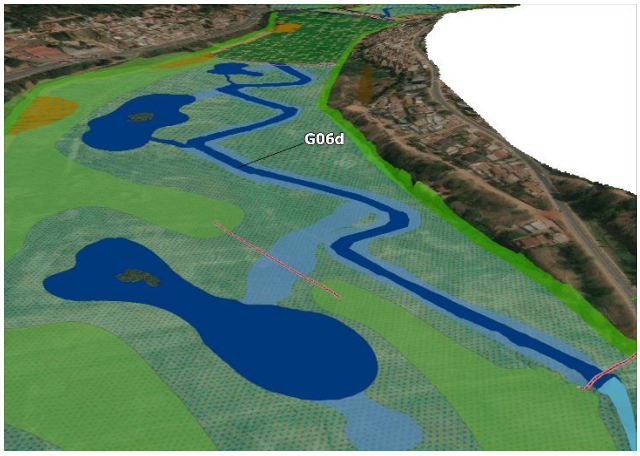
S0	m	b (m)	h (m)	B (m)
0.0013	0.42	3	1.8	4.5



Due to high velocities, it will be necessary to protect the outer curves of the river from scouring and erosion. In order to respect the environmental spirit of the project, the Consultant is proposing to use riprap for this purpose. The riprap at the outside curve of the meanders should at least have a diameter of 0.06 m.

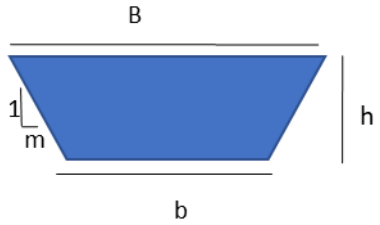
G06d

The current channel is 7m wide which correspond to an amplitude of 70m.



As per the flow through the channel the characteristics of the channel are determined as follows:

S0	m	b (m)	h (m)	B (m)
0.006	2	1.3	1.5	7.3



Due to high velocities, it will be necessary to protect the outer curves of the river from scouring and erosion. In order to respect the environmental spirit of the project, the Consultant is proposing to use riprap for this purpose. The riprap at the outside curve of the meanders should at least have a diameter of 0.05 m.

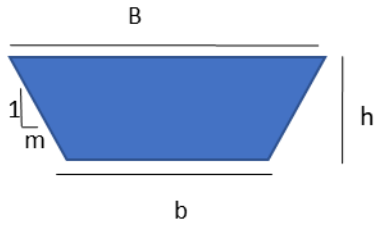
G06e

The current channel is 9m wide, which corresponds to an amplitude of 90m.

FIGURE 5-3: MEANDER G06E

As per the flow through the channel the characteristics of the channel are determined as follows:

S0	m	b (m)	h (m)	B (m)
0.0038	1.25	3	2.4	9.0



Due to high velocities, it will be necessary to protect the outer curves of the river from scouring and erosion. In order to respect the environmental spirit of the project, the Consultant is proposing to use riprap for this purpose. The riprap at the outside curve of the meanders should at least have a diameter of 0.08 m.

5.3.2.7 Creation of ponds to support wildlife and aesthetic appearance.

At the request of the Client, ponds have been added to the wetland, in order to provide a viable habitat for wildlife, as well as to enhance the natural beauty of the site.

The ponds are design based on a residence time of the water of 24 hours, which allows for sufficient renewal to support aquatic life, while also providing some water quality benefits, such as sedimentation and treatment.

The first pond will be supplied preferentially compared to the main branch of the river to ensure water renewal and will supply the second pond. This requires the construction of water inlet in the main branch of the river which will divert water towards the pond through a spillway (Action G04) into a specifically designed channel (Actions G20s). The inlet will be sized to allow flows that do not exceed a T2 rainfall, as per the hydraulic design criteria. Flows in excess of this will continue in the main river watercourse. At the outlet of the lake, the output channel will eventually also return to the main river.

As the parts of the main river used for diversion will only be filled with water during rainfall above a T2 return period, it must be serviced to prevent it becoming overgrown with vegetation.

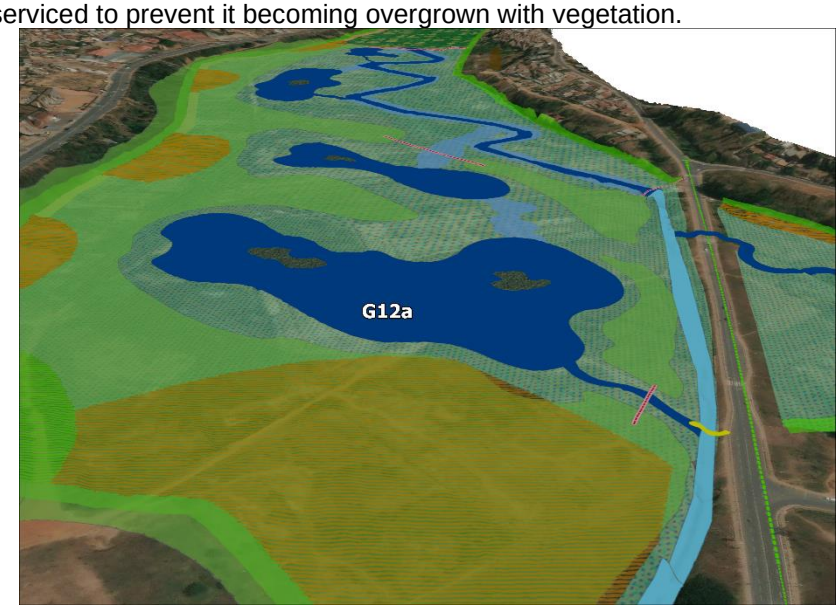


FIGURE 5-32 – PONDS AT GIKONDO WETLAND

5.3.2.8 Transition structure with hotspots

Specific infrastructure defined through flood hotspots project (under the supervision of CoK) will be constructed in the wetland area. It is important to define a precise coordination for the execution of the works so that the different companies have sufficient flexibility, and the works can be carried out in a consistent manner.

It was agreed that:

- A band of 15m upstream and 15m downstream the limit of the future hotspots infrastructure is defined without and action form wetland project, keeping the required flexibility.
- The transition structure between the rivers/canals of the wetlands and the future culverts/canals of the hotspot project are included in the wetlands actions (see specific detail plan)
- For a perfect coordination the following information is given for each wetland: altitude and section of the channel upstream and downstream of the sectors with hotspot action

At the location where there is hotspot structure, the link between the structure for road crossing (culvert or bridge) a transition structure is needed for energy dissipation and prevent the erosion of the canal at then inlet and outlet of the structure due to the turbulence generated as these transition sections.

At the upstream part, the transition is a contraction of the channel from a trapeze section to a rectangular section. This contraction increases the flow speed threatening the riverbed with erosion. In order to protect the channel, this section needs to be reinforced by ripraps of a size calculated the same way as defined in part

At the downstream part, the transition is the opposite with an expansion from a rectangular shape to a trapeze. As the flow slow down, the energy dissipation can erode the riverbed, hence some ripraps to protect the bed.

The length of the transition section is defined by L = 2B where B is the width of the channel.

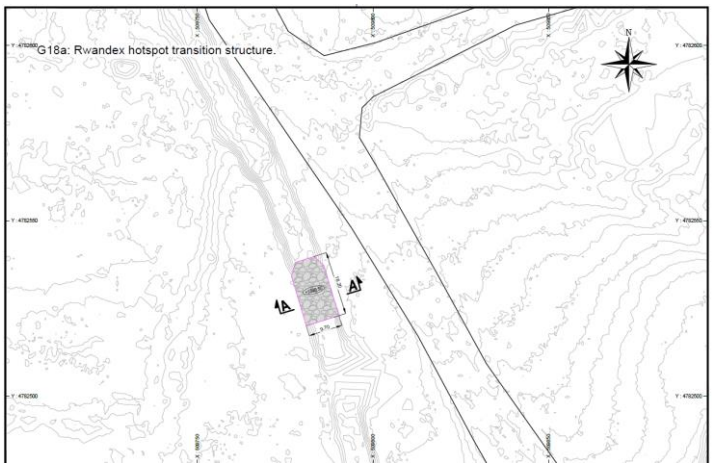


FIGURE 33 - G18A RIPRAP OF 0.05M

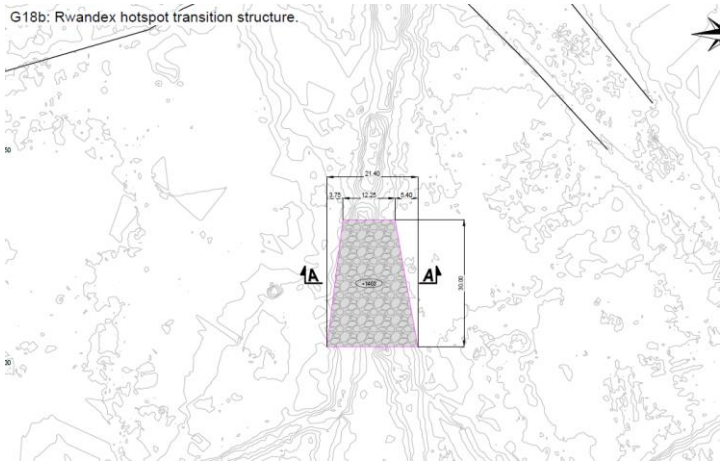


FIGURE 34 - G18B RIPRAP OF 0.05M

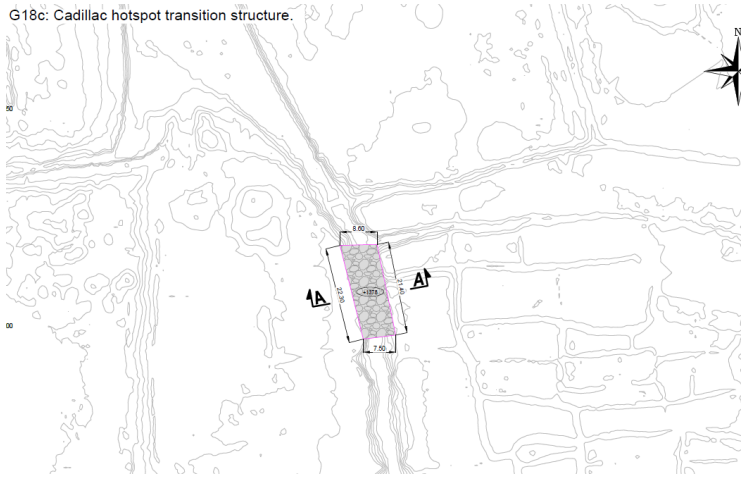


FIGURE 35 - G18C RIPRAP OF 0.05M

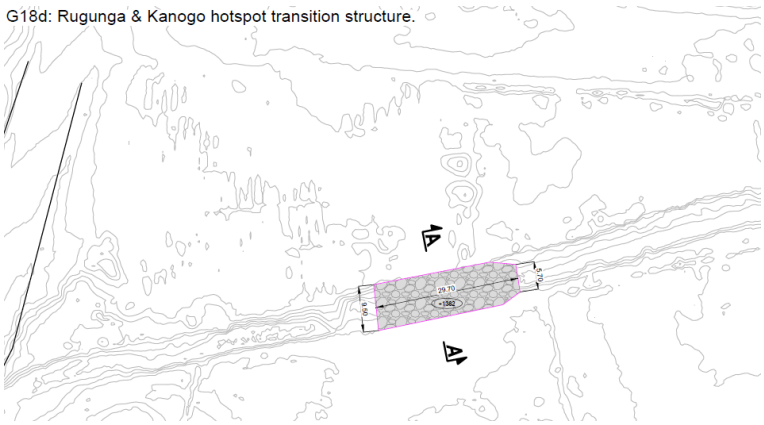


FIGURE 36 - G18D RIPRAP OF 0.11M

5.3.2.9 Creation of low flow channels to supply ponds

The Consultant has designed new channels that are capable of conveying explicitly with the purpose of supplying the newly created ponds (action G14). The water is diverted by means of spillways (action G04) which were treated earlier in this report.

The section of these new channels is designed to convey a flow capacity equivalent to the discharge from their associated spillways.

The dimensions of the channels are calculated using the Manning Strickler formula:

$$Q = \sqrt{I} \cdot K \cdot A \cdot R_h^{2/3}$$

For a trapezoidal section the equivalent section is defined as follow: b: 2.5 m, B: 8.5 m and h: 1.5 m with a 2:1 slope embankment.

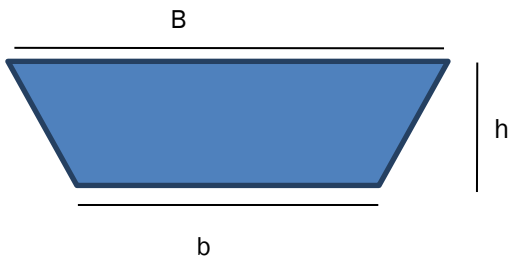


FIGURE 5-37: CHANNEL DESIGN

The slope of the channels is therefore calculated to be 0.01008.

For the supplying channels of the 2 other ponds, the dimension of the channels should be sized for a discharge corresponding to the residence time of the water of 24h.

- For the pond G12c, it corresponds to a discharge of 0.3 m3/s, hence a trapezoidal section the equivalent section is defined as follow: b: 1 m, B: 2 m and h: 0.4 m with a 4:5 slope embankment.

For pond G12d, it corresponds to a discharge of 0.08 m3/s, hence hence a trapezoidal section the equivalent section is defined as follow: b: 0.5 m, B: 1 m and h: 0.5 m with a 1:0.8 slope embankment.

	b	B	h
Pond G12a	2.5m	5m	1.5m
Pond G12c	1m	2m	0.5m
Pond G12d	0.5m	1m	0.5m

5.3.3 Public space actions

In order for the wetland to be accessible to and appreciated by the general public, a number of public space actions are proposed. These will bring the population into closer contact with the natural environment boosting their enjoyment of the site. These actions are detailed in the following paragraphs, and further details can be found in the Technical Specifications (chapter 8) and in Annex 1.5.

5.3.3.1 Creation of a suspended walkway

In order for the population to enjoy the beautification of Gikondo wetland, at the request of the Client, the Consultant has included the construction of a suspended walkway, which will allow people to move through the wetland without disturbing the natural environment, and with the elevation providing an impression of immersion whilst enjoying an overhead view of the location.

The image below provides an illustration of the structure to be built.

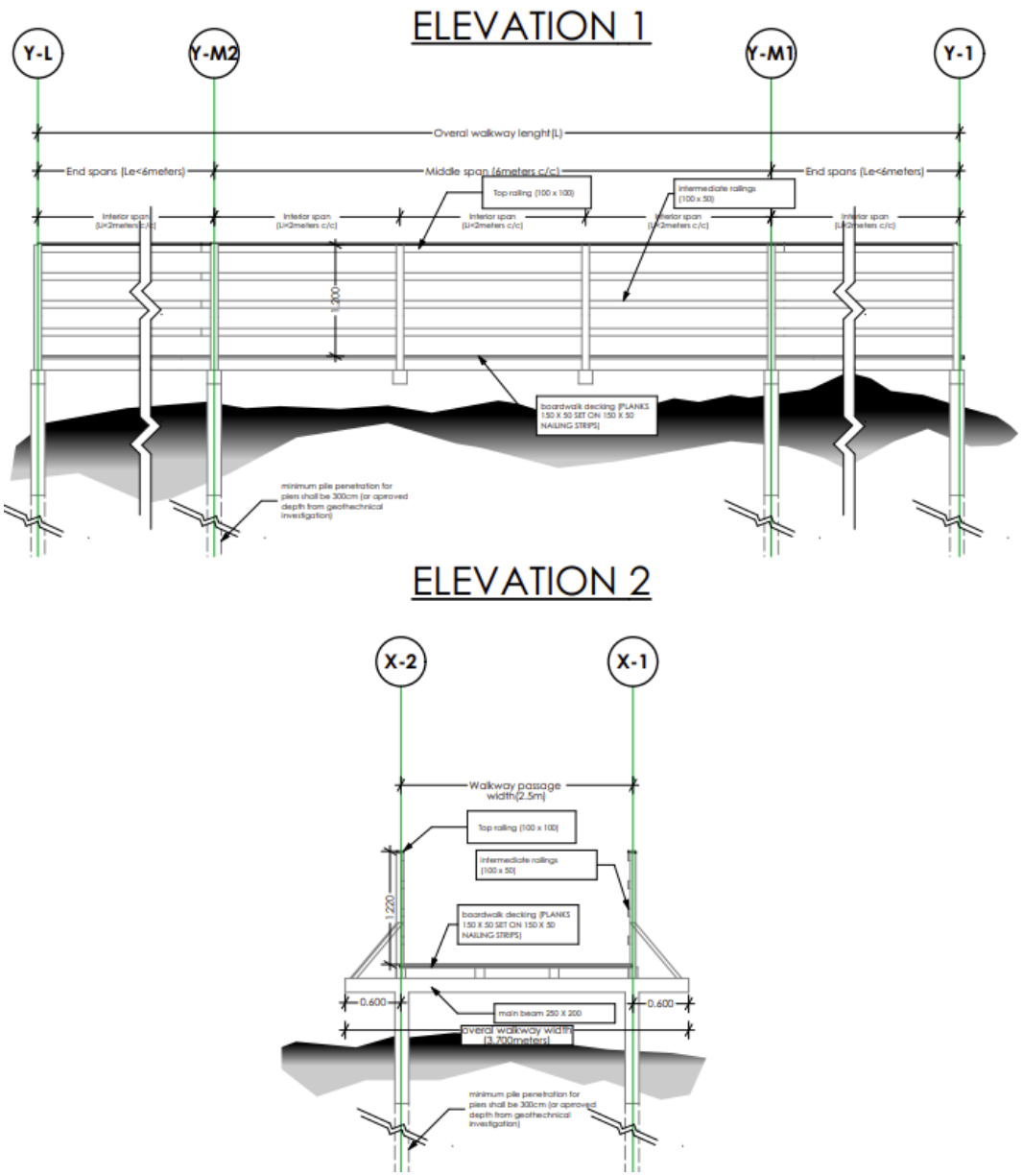


FIGURE 5-38 SUSPENDED WALKWAY IN GIKONDO

The design of this structure was carried out with reference to the flood modelling in Annex 1.4 to ensure that regardless of the intensity of rainfall, the walkway is consistently above the water level. This is both to ensure the stability and sustainability of the structure, as well as to ensure constant pedestrian access to the wetland for the population to discover the wetland in its variety of hydraulic states.

The suspended walkway will be equipped with guardrails for safety of both people and the natural habitats, and - in keeping with the environmental nature of the project - the suspended walkway will be constructed mostly out of treated timber. Concrete footings be necessary to ensure the stability of the structure, however these will remain buried and not visible.

Detailed drawings of the suspended walkway can be found in Annex 1.2

5.3.3.2 Pedestrian / Cycling Trails

Pedestrian and cycling trails are to be constructed in Gikondo wetland to provide human access into the natural space enabling the population to enjoy the beauty of the wetland without risking any damage to the surrounding wildlife.

The trails can be used not only for access through and across the wetland but will enable leisure and sporting activities by promoting interconnectedness between the various services provided by the wetland, such as recreational areas, coffee bars, restaurants, sporting, educational and cultural facilities, and viewing areas.

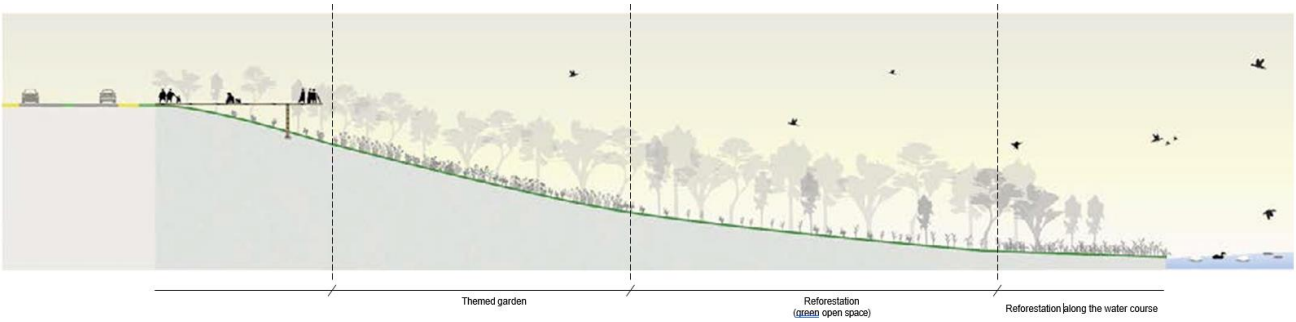


FIGURE 5-39 EXAMPLE OF A PEDESTRIAN/CYCLE PATH

The proposed pathways for Gikondo wetland will be enhanced with public furniture to render it more accessible and useful. This will include:

- Directional signage to indicate routes and destinations,
- Interpretive signage for educational purposes about the wetland,
- Lighting of pathways for ease of access and safety,
- Benches to allow people to sit and rest,
- Litter containers for the collection of refuse to avoid pollution of the environment,
- Bicycle racks to encourage soft mobility by ensuring the security of bicycles,
- Protective guarding along decks and other elevated structures.

Detailed designs of these interventions are provided in Annex 3.5

5.3.3.3 Maintain recreation facility

Gikondo wetland already contains a recreational facility (G16), which the wishes to maintain as existing for use by the population. The existing recreational area provides the following services:

- A wedding reception area, enabling the union of a newlywed couple to be celebrated in a natural environment,
- An enhanced Resto-Bar for the provision of food and drink,
- A newly landscaped site for the beautification of the area, to ensure that nuptial celebrations take place against an idyllic romantic backdrop.

5.3.3.4 Green belt

The construction of a green belt surrounding Gikondo Wetland is proposed as it will have numerous benefits:

- Delineation of the wetland itself,
- Protection of the wetland from pollution originating in adjacent communities,
- Pedestrian/cycle access around the wetland,
- Elevated location providing views of the natural environment.

The principle is to produce a nature-based contour of the wetland that will provide these services. As such the area will be levelled, with a grassy space and treeline that will absorb runoff before it reaches the wetland, next to pedestrian pathway covered in volcanic paving stones, and a compacted laterite soil cycle path. Detailed designs are provided in Annex 1.5.

5.4 RWAMPARA WETLAND

5.4.1 Landscaping actions

5.4.1.1 Landscaping concept

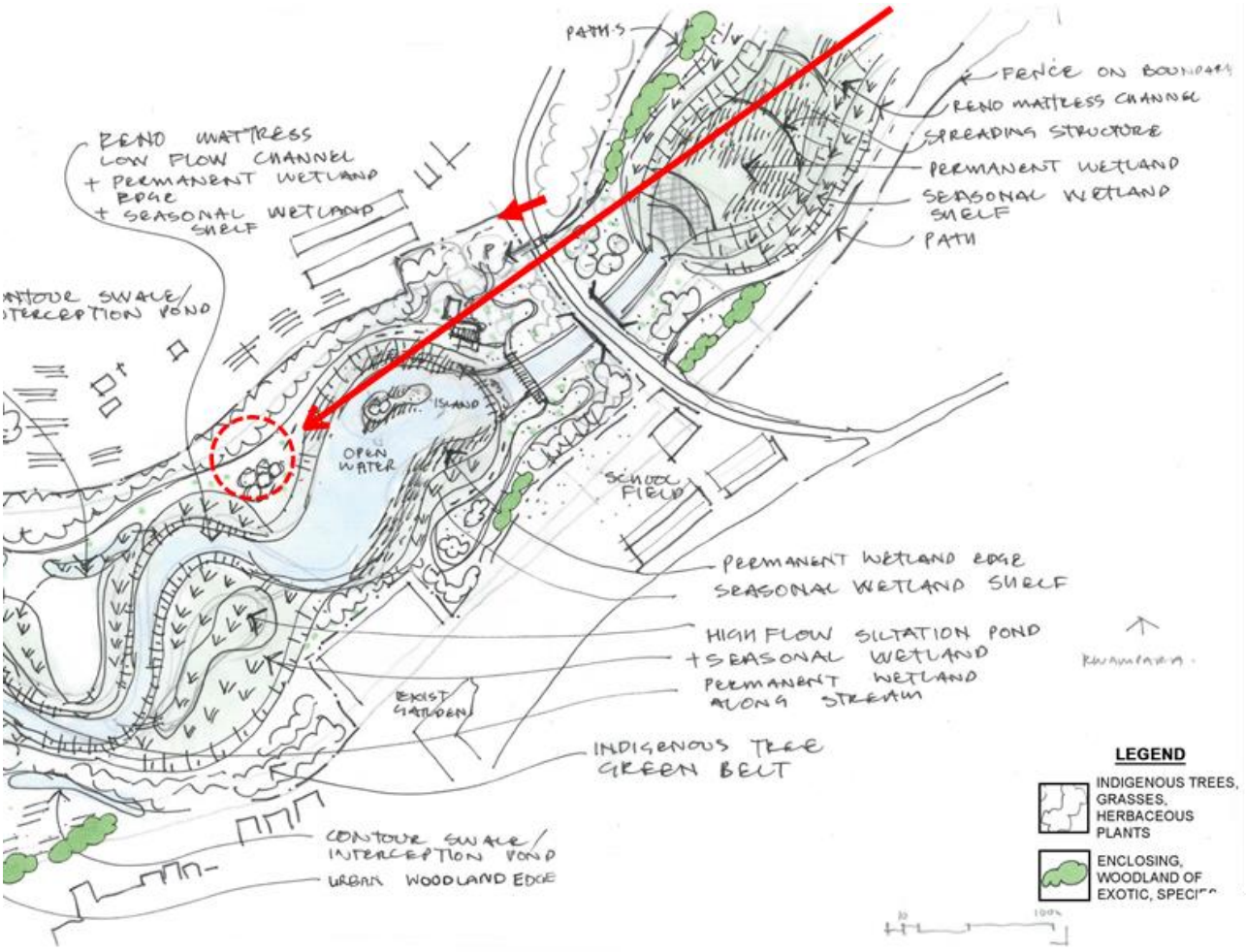


FIGURE 5-40: LANDSCAPING SKETCH OF RWAMPARA WETLAND

5.4.1.2 Garden of sight

A vibrant artisanal artwork celebrating the magnific birds of Kigali's wetlands and woods accessible, tactile, and colourful.

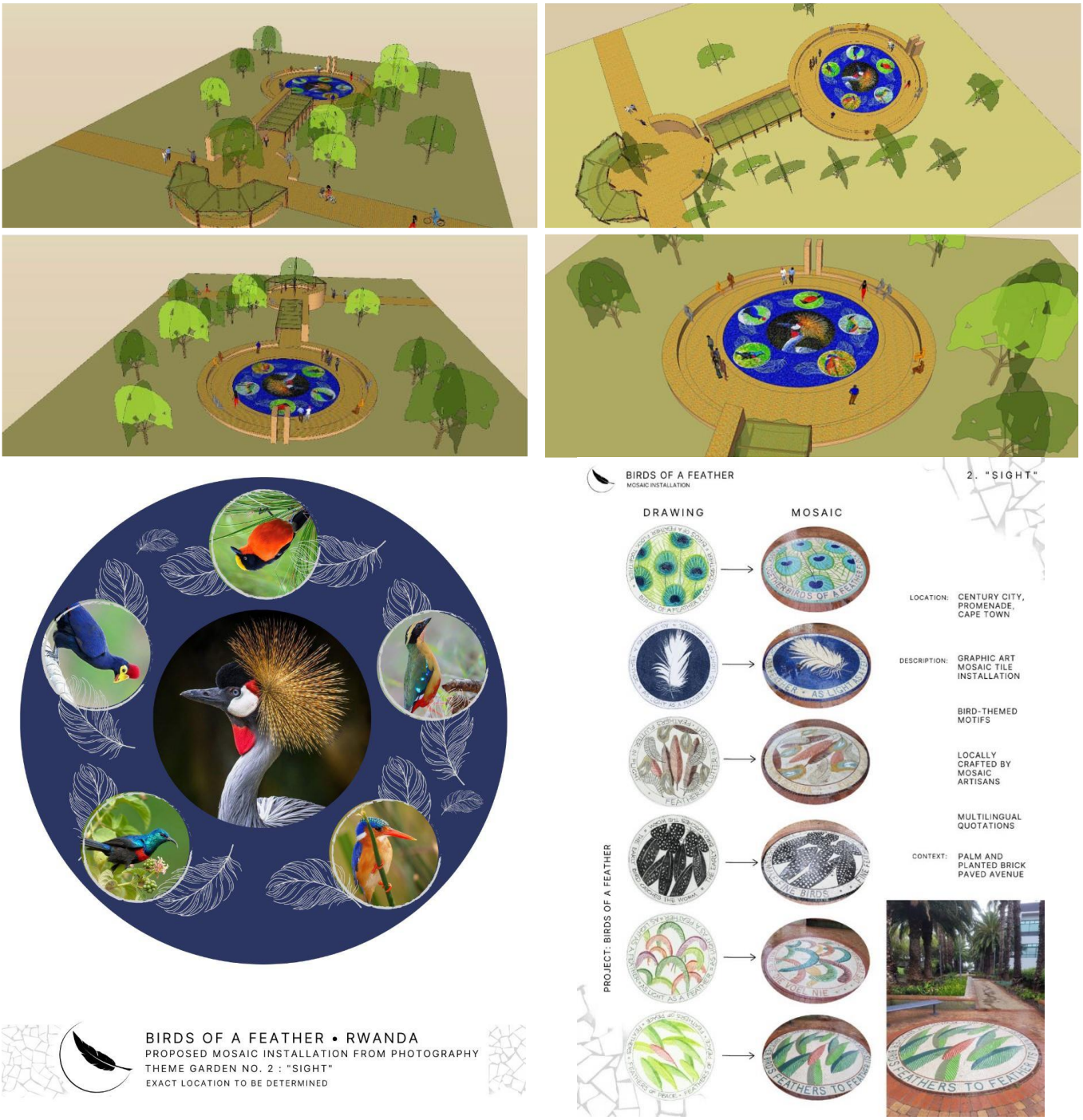


FIGURE 5-41 - GARDEN OF SIGHT RWAMPARA WETLAND

5.4.1.3 Proposed planted species

The ecological rehabilitation of Rwampara Wetland will entail the planting of the following species, in the following areas. Further details can be found in the Technical Specifications (chapter 8) and in Annex 2.2.

7 habitat typologies/target functional habitats have been identified in this area.

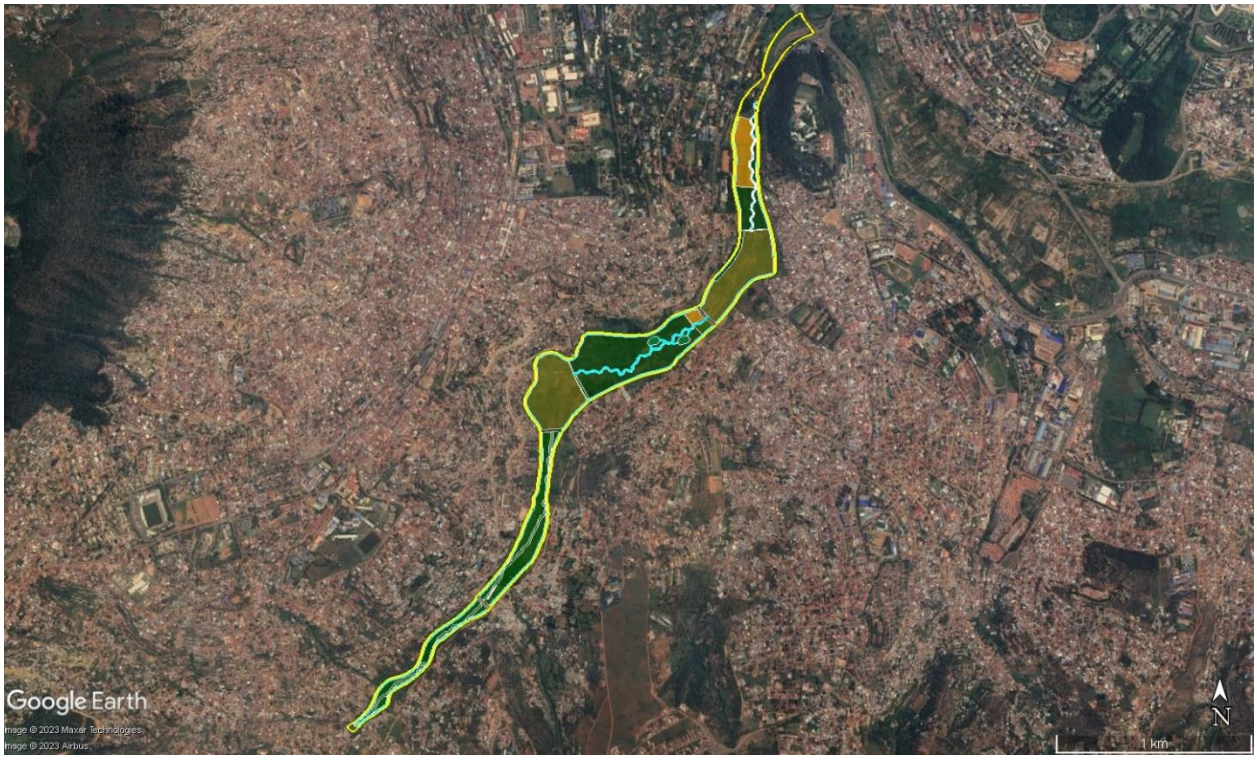


FIGURE 5-42: LOCATION OF RWAMPARA WETLAND

Table 8 shows the list of species suggestions for each typology. Life forms and expected functions for each species can be found in Chapter 8.1.

Habitat type/function	Plant species
1. Permanent wetland: Proposed native plant species adapted to the wetland environment are selected to enhance wetland restoration efforts. The species were identified based on their ecological function for wetland restoration through water retention, regulating water flow, filtering pollutants, soil stabilization, etc., and maintaining the health and biodiversity of these habitats in general.	*Cyperus denudatus* *Cyperus dives* *Cyperus papyrus* *Juncus effusus* *Ludwigia abyssinica* *Persicaria decipiens* *Typha domingensis*
2. Seasonal wetland: Existing bamboos in this area will be maintained. They are well-adapted to growing in this wet environment. Bamboos contribute to soil stabilization, water quality improvement, habitat creation for a variety of wetland species, etc.	*Cyperus latifolius* *Cyperus articulatus* *Leersia hexandra* *Brachiaria humidicola* *Panicum maximum* *Echinochloa pyramidalis* *Brillantaisia cicatricosa*
3. Green belt: These are upland strips along the wetland. Proposed species will primarily serve to enhance urban biodiversity, provide habitat for wildlife that use the wetland for food or shelter, and provide cultural services with focus on ornamentals amenities.	*Blighia unijugata* *Croton megalocarpus* *Delonix elata* *Dodonaea viscosa* *Elaeis guineensis* *Entada abyssinica* *Ficus sycomorus* *Ficus vallis-choudae* *Kigelia africana* *Maesopsis eminii* *Markhamia lutea* *Olea europea* subsp. *africana* *Podocarpus latifolius*

	Polycias fulva *Pterygota mildbraedii* *Senegalia polyacantha* *Spathodea campanulata* *Sterculia tragacantha* *Syzygium guineense*
4. Recreational areas: Proposed species for these areas will offer opportunities to accommodate visitors to the wetland and provide facilities such as shades for parking lots and picnic areas. These will also serve to educate visitors about the wetland ecosystem and importance of wetland conservation.	*Croton megalocarpus* *Ficus sycomorus* *Kigelia africana* *Maesopsis eminii* *Olea europea* subsp. *africana* *Podocarpus latifolius* *Polycias fulva* *Pterygota mildbraedii* *Senegalia polyacantha* *Spathodea campanulata* *Sterculia tragacantha*
5. Stream banks: The stream banks will be covered in vegetation to play a role of stabilizing stream banks, providing habitat for wildlife, and filtering pollutants.	*Phragmites mauritianus* *Aeschynomene elaphroxylon* *Sesbania sesban*
6. Ponds: Floating plants of water lilies are proposed for ornamental purposes. These will also serve to improve water quality in the ponds and reduce the growth of algae and other harmful organisms. It is recommended to regularly control the lilies to maintain a healthy ecological balance and avoid oxygen depletion in the water. The African oil palm and the wild date palm will be planted for ornamental purposes around the ponds	*Nymphaea nouchali* *Elaeis guineensis* *Phoenix reclinata*
7. Forest area: There is an existing grove of a few large trees that surround an abandoned residential building. The trees cover an area of approx. 1.8 ha, and include the species of *Markhamia lutea, Cedrela serrata, Grevillea robusta* and avocados. We recommend that these trees be kept on site and expand the area for afforestation with these other species.	*Blighia unijugata* *Croton megalocarpus* *Delonix elata* *Dodonaea viscosa* *Elaeis guineensis* *Entada abyssinica* *Ficus sycomorus* *Ficus vallis-choudae* *Kigelia africana* *Maesopsis eminii* *Markhamia lutea* *Olea europea subsp. africana* *Podocarpus latifolius* *Polycias fulva* *Pterygota mildbraedii* *Senegalia polyacantha* *Spathodea campanulata* *Sterculia tragacantha* *Syzygium guineense*

TABLE 5-8 LIST OF PLANT SPECIES IN RWAMPARA WETLAND

5.4.1.4 Soil reshaping for wetland creation

The objective of this action is to carry out earthworks that will modify the topography of the wetland for ecological and aesthetic purposes.

Existing low points in the wetlands will be identified and the surrounding areas will be excavated in order to expand these locations into low areas that will preferentially accumulate water. Excavated soil will be used to backfill the existing water course as well as to enhance nearby high points.

The immediate outcome of this action will be a sloped but unchanneled terrain which will allow water to flow diffusely and slowly through the wetland. The final result is the creation of different areas of wetland based on their elevation. Specifically, this will result in permanent wetlands in the low points where the soil will be constantly waterlogged, and seasonal wetlands which will periodically receive inflows of water.

The greater retention time of water in the low points mean that it provides an excellent opportunity for the treatment of inflows coming from upstream or neighbouring built-up areas, a process which can be accentuated by the planting of appropriate plant species.

The difference in water content of the soil due to elevation differences will also promote the creation of a variety of flora, which will have two co-benefits

- Additional habitat creation for local fauna, promoting biodiversity,
- The wide diversity of plant species will allow for a more varied beautification of the site.

Proposed wetland reshaping actions are located as per the zoning maps under labels RW20a and RW20b and are illustrated in the figures below. The detailed site plans and cross sections are provided in Annex 2.2.

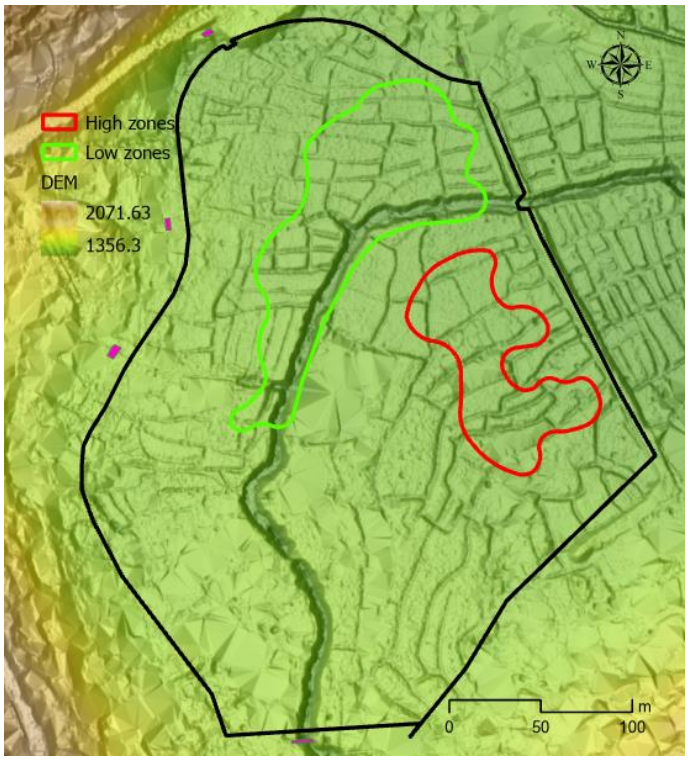


FIGURE 5-43: SOIL RESHAPING FOR WETLAND CREATION– RW20A

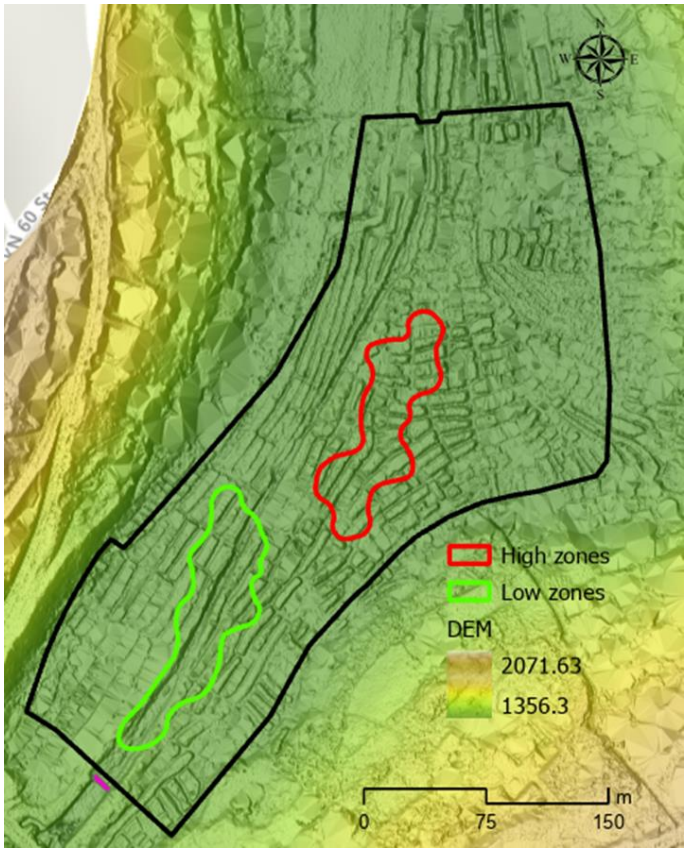


FIGURE 5-44: SOIL RESHAPING FOR WETLAND CREATION – RW20B

5.4.1.5 Creation of an island for aesthetic appearance

At the request of the Client, a landscaped island is proposed to be constructed in Rwampara wetland (RW23). This will provide an elegant form emerging from the ponds and lakes in this wetland increasing biodiversity.

Detailed designs can be found in Annex 2.2.

5.4.2 Hydraulic actions

The hydraulic actions designed in this project seek to reinstate or enhance the hydraulic functioning of the 5 wetlands, mostly through modifications of the flows through the project area with the following objectives:

- Promoting water retention in the wetlands to prevent damaging flooding events,
- Reducing the flow through the wetlands to limit erosion,
- Spreading of water flows to provide maximum absorption and reduce downstream flows and velocities,
- Provide favorable aquatic environments for fauna and flora,
- Improve water quality.

As explained in paragraph 3.2.3, a variety of actions are planned with each wetland receiving interventions tailored to the wetland's objectives.

In accordance with the Master Plan for Rwampara (Annex 2.1), the detailed design was carried out as below for the specific interventions proposed for the wetland, which is developed hereunder. Further details can be found in the Technical Specifications (chapter 8) and in Annex 2.3.

5.4.2.1 Creation of detention basin at the inlet of the wetland

At the request of the client, a detention basin is set at the upper section of the Rwampara wetland. The location of the basin has been chosen in the part of the wetland with a terrain as flat as possible. The basin is designed with a low slope (0.5%) and with a pipe outlet at the bottom downstream. That way, for average flow, the basin stays empty. During flood, as the flow increases the pipe cannot evacuate all the flow and the basin is filled. Once the basin is filled at its maximum level (1439.5 mAD), a storm spillway evacuates the overflow out of the basin in the channel.

The diameter of the outlet pipe is calculated so the detention time of the basin is of 12h.

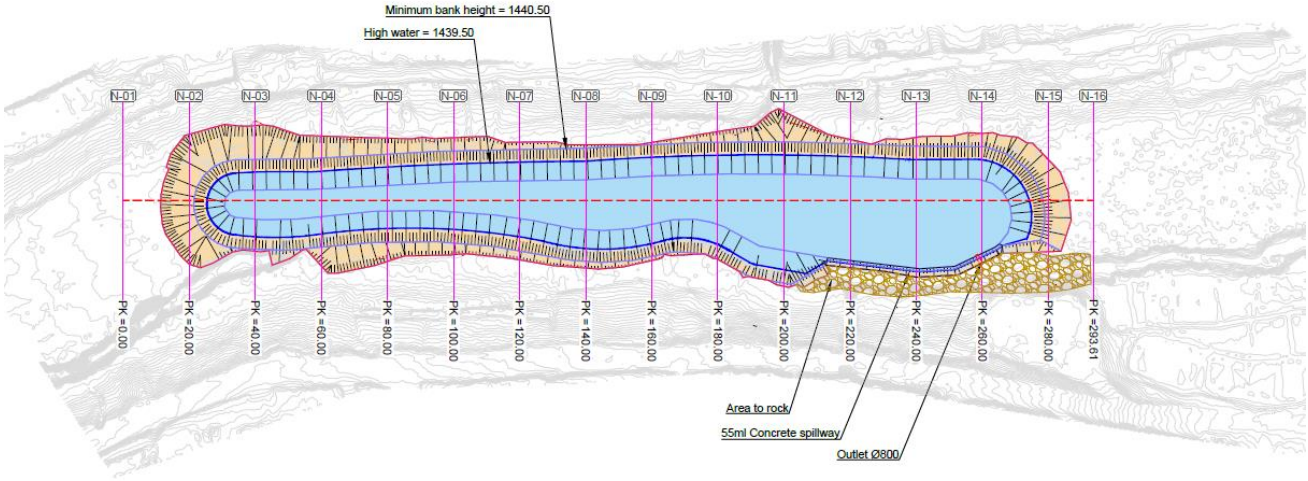


FIGURE 45: DETENTION BASIN IN RWAMPARA WETLAND

The width of the spillway is then calculated using the standard weir formula:

$$Q = L_d \cdot m \cdot \sqrt{2g} \cdot h^{3/2}$$

with a weir coefficient m = 0.4, L_d the width of the spillway and h the water height above the spillway. The spillway is sized to evacuate a discharge up to 70 m3/s without making the basin overflow. This leads the basin to absorb 7 286m3 of the flood that are progressively released during the 12h that follows. As the basin will be open air, its embankment slopes are of 4:1 for safety.

5.4.2.2 Sediment traps for blockage of sediments into the wetland

The hydraulic outfalls from lateral drainage carry effluents from the neighbouring urbanized areas, which are charged with sediment, and convey them into the wetland. Originally built to drain plots for agricultural purposes they are relatively deep (about 2m) and consequently convey water rapidly downstream, which is in opposition to the role and functioning of the wetland.

The construction of sediment traps is therefore proposed to counteract this effect. A sediment trap is a containment area that allows sediment in collected storm water to settle out during the runoff is discharged through a stabilized spillway/dewatering pipe.

Due to the very large amount of waste of varying sizes coming from the sides, and the lack of a large-scale collection system over most of the study area, sediment traps will be installed at each drain stop in the wetland.

It is very important to note that each sediment trap was designed specifically, depending on the reality of each drain. The drawings are given in Annex 2.3, examples are provided hereunder.

The Consultant considered the use of vegetation on the gabions forming the sediment trap elements. This solution was not retained for the following reasons:

- the water arrives at a high speed which requires the installation of gabion mats with a tight mesh to ensure stability
- in these conditions, vegetation would not be able to develop properly and would represent a significant hindrance to the maintenance of the structures.

3 types of sediment traps were defined according to the context, here is an example:

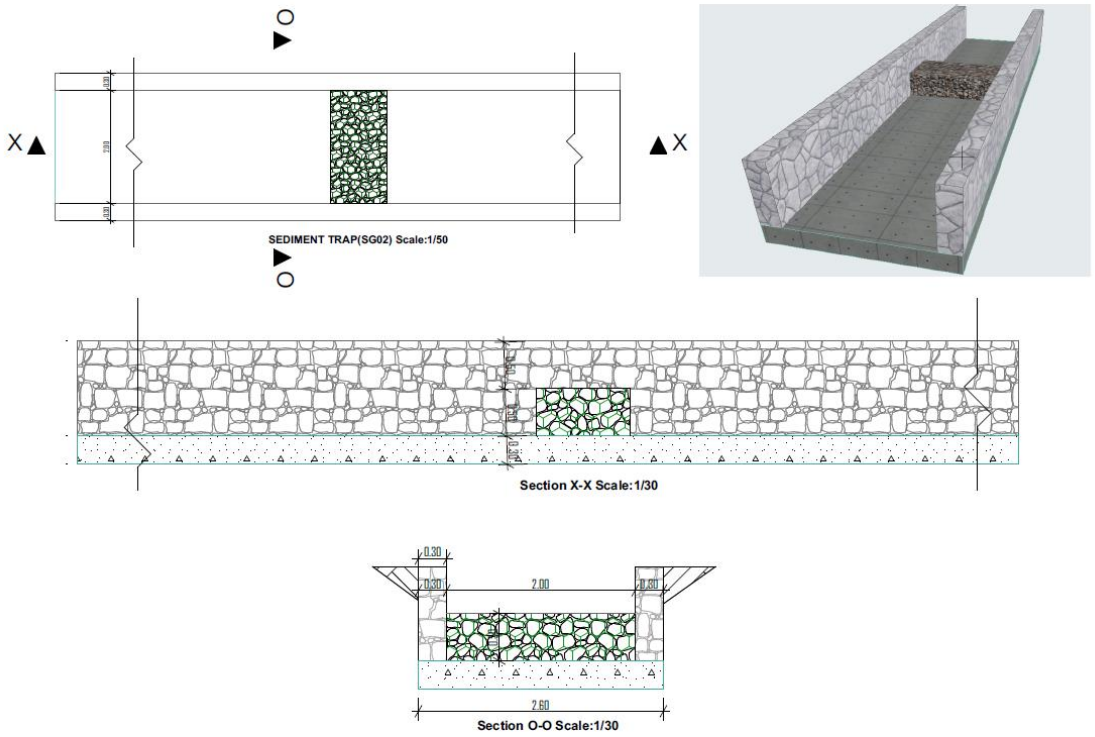


FIGURE 5-46: EXAMPLE OF SEDIMENT TRAP

At the outlet of the structure, a gabion wall filled with river stones will ensure that the flow is spread across the floor of the wetland. This will combine with the landscaping action RW23 “soil reshaping for wetland creation” which specifically incorporates interventions to receive inflows from lateral drainage. This will limit its velocity thereby retaining it in the wetland, where it can be naturally treated of other pollutants (chemical and biological). This treatment is reinforced by appropriate plant selection as explained in paragraph 5.3.1.

The result is primarily to improve the quality of the water, but it will also contribute to increasing the height of the water table and limiting flooding downstream.

The construction of these traps can only be carried out with the use of concrete for the base and walls of the structure; however gabion and river stones are also incorporated into its construction to constitute the trap. The trap will require periodic manual emptying to ensure it remains effective, as once it is full the sediment will simply continue its path into the wetland.

5.4.2.3 Water conveying structure to block and channel water to the main stream

The intervention consists in the construction of a dike spanning the width of the valley at the outlet of the wetland to collect and concentrate the water flowing out of the wetland, which will effectively create an artificial lake. A channelling structure will be constructed as part of the dike to convey all the water towards the meandering watercourse downstream.

The Consultant has considered employing nature-based solutions as much as possible. As such, the dike will be constructed of compacted earth, covered in turf. Volcanic paving stones will be used to create the path along the top of the dike with wooden handrails for safety reasons.

However, for the critical element of the conveying structure, the space allowing the passage of water collected by the dike into the subsequent channel it was necessary to retain concrete for the construction. This was to ensure the long-term sustainability of the structure, which would be affected by two main factors:

- The strength requirements in order to withstand the static and dynamic (hydraulic) loads.
- The risk of erosion by water velocity through the structure.

The use of concrete is minimized insofar as the outlet of the conveying structure consists of gabion walls (with wire mesh coated with green PVC) and river stones that will prevent shearing and erosion of the banks at the entrance to the downstream channel.
An example of the proposed water conveying is provided in the image below.

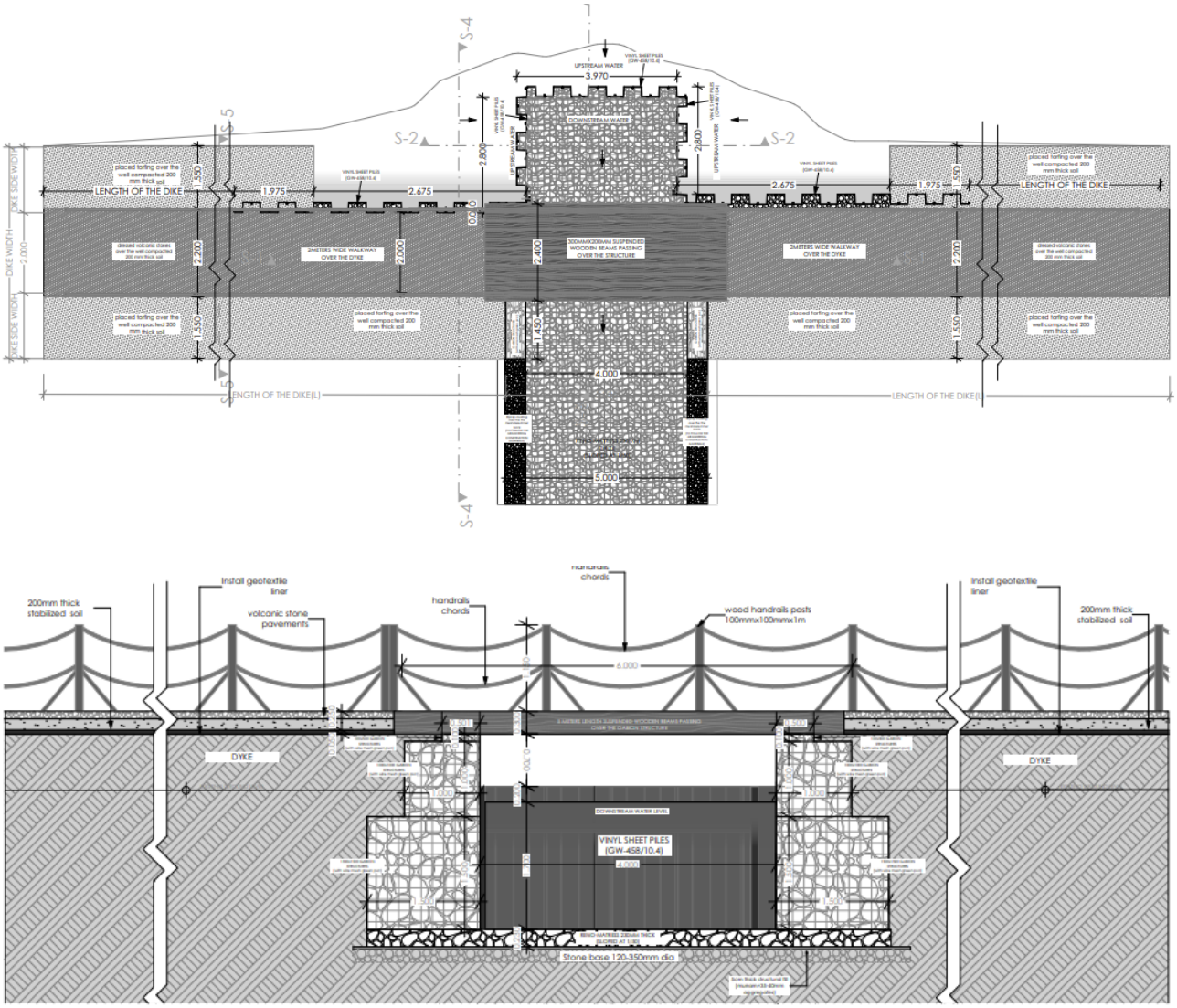


FIGURE 5-47: EXAMPLE OF A WATER CONVEYING STRUCTURE

The Contractor will be responsible for the verification of the structural stability and quantities required for the structure's construction, based on the real conditions identified during implementation.

The Consultant verified the impact of the blocking and channeling structure on the flow of water through the wetland, by:

- Modelling dam with corresponding height
- Considering rainfalls of increasing intensity (T2 and T10 at current urbanisation levels, and T2, T10, T50 with 2050 urbanisation projections)
- Considering modifications by YREC following their hotspot study.

In this case, only low intensity return periods are relevant, however it is still interesting to see how the modifications will also react to high intensity flood.

The results for a T2 rainfall before and after intervention are presented in the image below, however the complete modelling results are provided in Annex 2.4.

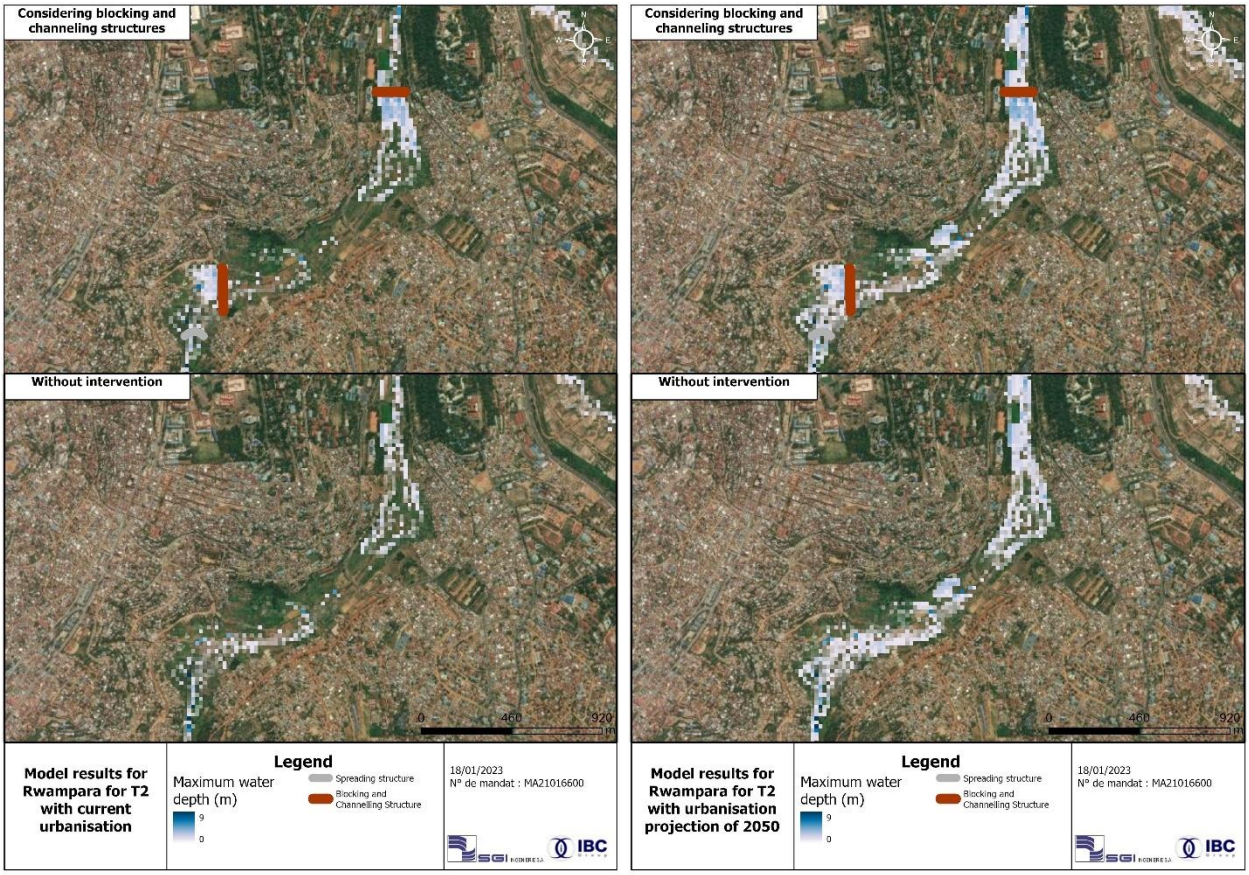


FIGURE 5-48: WATER DEPTHS FOR A T2 RAINFALL BEFORE AND AFTER INTERVENTION IN RWAMPARA WITH CURRENT AND 2050 URBANISATION LEVELS

5.4.2.4 Water spreading structure to spread water into the wetland

The intervention consists in the modification of the flow of water out of the channel from which it originates into a more diffuse flow that spreads across the wetland. The objective of this intervention is to ensure an even spreading of the water throughout the wetland to achieve maximum speed and flow reduction, which will not only prevent flooding, but also improve water quality and retain water in the wetland site to better promote growth and habitat creation.

The Consultant has considered employing nature-based solutions as much as possible, and relies on a two-pronged approach to force the flow to diverge:

- Earthworks: At the approach to the wetland area, the soil will be mechanically shaped into a slightly conical form that will encourage water to flow laterally through gravity.
- Gabion walls: To further encourage the water to spread laterally across the wetland floor, gabion walls of increasing length will be constructed across the wetlands to reinforce the redirection of the flow as the water passes through them.

This construction will have the following impacts:

- Even spreading of the incoming water across the span of the wetland, making maximum use of the available space.
- Reduction in the speed of water limiting erosion and promoting sedimentation.
- Increased absorption and raised level of the water table.

- Improved water quality.

An example of the proposed spreading structure is provided in the image below.

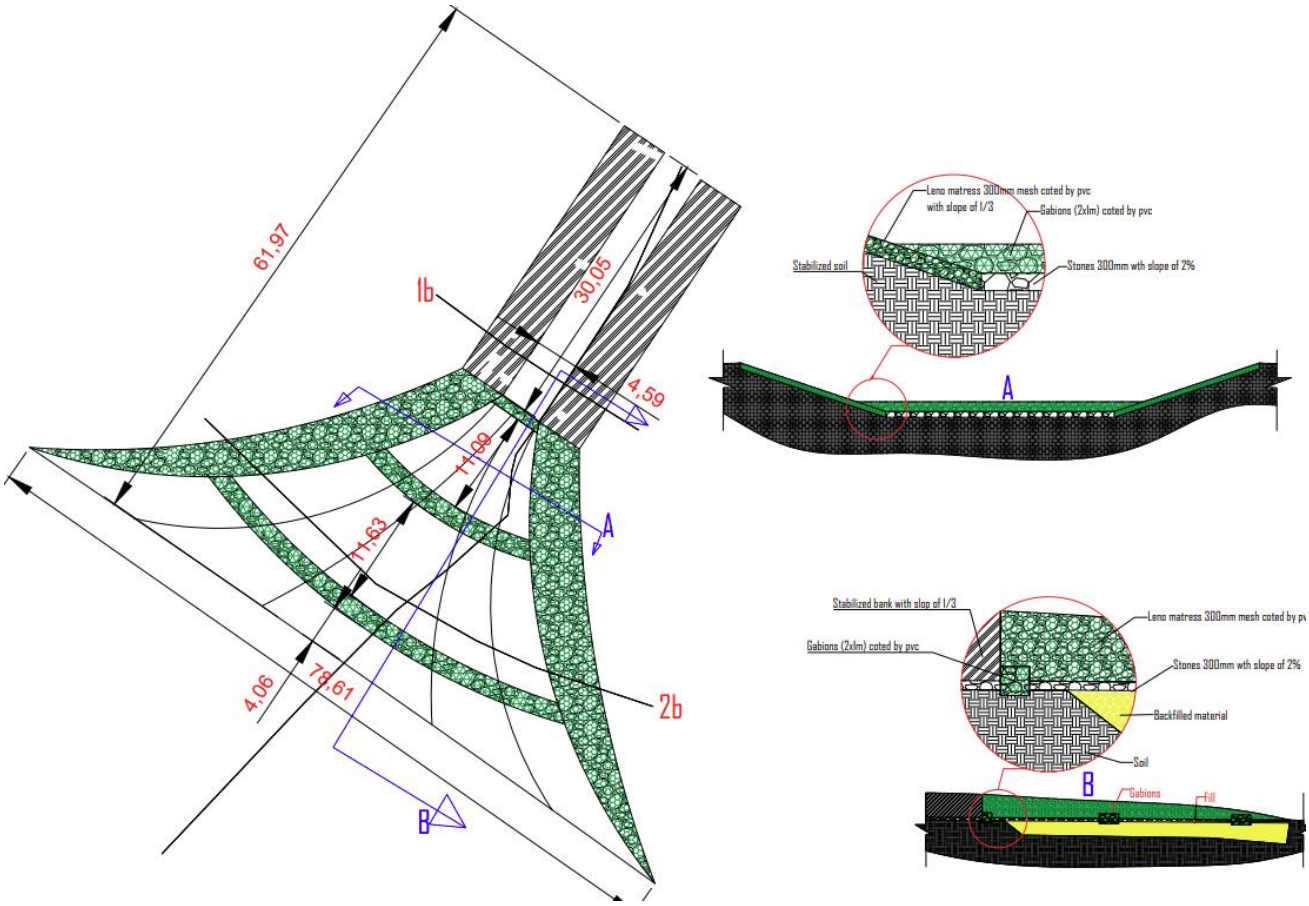


FIGURE 5-49: EXAMPLE OF A FLOW SPREADING STRUCTURE

The contractor will be responsible for the verification of the structural stability and quantities required for the structure's construction, based on the real conditions identified during implementation.

5.4.2.5 Creation of successive gabion walls

On the upper part of Rwampara wetland, a very steep drain has been identified, which causes significant erosion which can lead to significant damage to some inhabited areas nearby. This is outside of the study zone but the Client considered the issue important enough to treat as part of the project.

Erosion will be minimised by reducing the slope (and therefore the velocity) of the water emerging from this lateral drain (Action RW05).

In order to stabilize the bed and reduce the slope, three successive gabion walls are to be constructed, with each wall spreading the entire width of the channel. These walls act as weirs over which the water will overflow. The water level will then rise to the level of the gabion providing the required reduction in slope.

Sediment from this channel will naturally settle in the basins created by the wall filling them up and replacing the water with silt and soil which will need to be removed once a year. Large coarse rocks will be placed downstream the walls to stabilize the bed against erosion of the falling water flowing over the weir.

The wall characteristics are described below, and the specifications are given in the layout out in Annex 2.3.

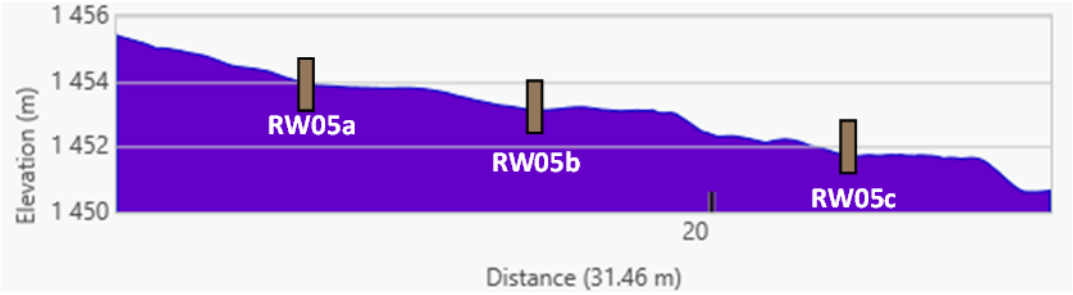


FIGURE 5-50: LONGITUDINAL PROFILE OF RW05

	X	Y	Gabion wall height
RW05a	505911.41	4780458.72	1.1 m
RW05b	505917.05	4780454.17	0.6 m
RW05c	505926.28	4780448.70	1.0 m

TABLE 5-9 CHARACTERISTICS OF THE GABION WALLS IN RW05

5.4.2.6 Blocking of surface drains (agriculture drains)

Previous agricultural use has resulted in the creation of drains, originally constructed to facilitate the development of intensive agriculture, thereby strongly impacting the hydraulic dynamics of the wetland and its waterlogging.

The objective of the drains is to convey water rapidly downstream, away from farmed areas, which contributes to the lowering of the water table and the rapid drying of the soil. In addition to excavated drains, soil embankments raise the channel level above natural ground level in order to prevent the flooding of crops during heavy rains. However, with the repurposing of the wetland site for flood management, ecological and aesthetic purposes, it is essential to retain water within the wetland, which is in firm opposition to the existing land use.

The objective of this action is therefore to prevent water from flowing in preferential paths, but to flow diffusely through a restored homogenous surface of the wetland. The water's flow rate will consequently be reduced as will associated erosion problems, and the water table will rise to provide a better environment for fauna and flora.

In order to achieve this objective, the ground level will be restored to a homogenous generally flat surface, devoid of drainage network. This will require two distinct actions illustrated in the images below:

- The backfilling of the agricultural ditches with soil
- The removal of soil embankments above natural ground level.

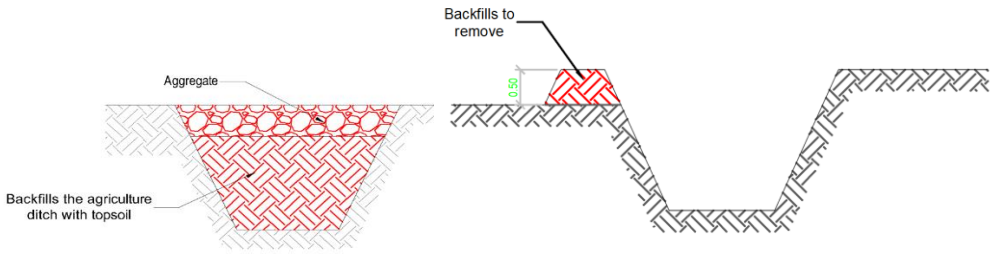


FIGURE 5-51: CROSS-SECTION OF AGRICULTURAL DRAINS

The soil from the embankments can be used to infill the drains however the available volume will be insufficient, and soil importation will be required. The topsoil used for this purpose must be free of any invasive plant species or pollutants. The agriculture drains located in Rwampara will be completely backfilled.

The volume of topsoil needed to fill the trapezoidal shaped drains is calculated with the following formula:

$$V = S \cdot l \cdot n \quad \text{with } S = h \cdot (\text{a} + \frac{b-a}{2})$$

Where:

- l is the length of the drains
- S the surface of the drain
- n the number of drains,
- h the depth of the recharge bed
- a and b the channel width at the base and surface respectively.

In Rwampara, the drains have a mean width of 1.5m at the base and 2.3m at ground level, and a height of 1.5m, resulting in a cross section of 2.59m^2. The volume of channel to be backfilled is presented in the table below.

Channel	Length of drainage (m)	Section of channel (m2)	Volume of backfill (m3)
RW06a	1865.2	2.59	4826.3
RW06b	269.3	2.59	696.9
RW06c	309.5	2.59	800.9
RW06d	193.3	2.59	500.2
RW06e	982.4	2.59	2542.0
RW06f	547.7	2.59	1417.1
RW06g	645.7	2.59	1670.9
RW06h	385.9	2.59	998.6
RW06i	1202.6	2.59	3111.6
RW06j	627.6	2.59	1623.8
RW06k	448.8	2.59	1161.3
RW06l	281.3	2.59	727.9
RW06m	735.3	2.59	1902.5

TABLE 5-10 VOLUME OF BACKFILL IN AGRICULTURAL DRAINS IN RWAMPARA

From this volume is removed the available soil from the embankments. The backfill sections have a mean section of 0.14m^2. The volume represented by this infill is calculated as per the following equation and is presented in the table below.

$$V = \text{number of drains} \cdot \text{length of the drain} \cdot \text{mean section surface of the backfill}$$

Channel	Length of drainage (m)	Volume of infill (m3)
RW06a	1865.2	261.1
RW06b	269.3	37.7
RW06c	309.5	43.3
RW06d	193.3	27.1
RW06e	982.4	137.5
RW06f	547.7	76.7
RW06g	645.7	90.4
RW06h	385.9	54.0
RW06i	1202.6	168.4
RW06j	627.6	87.9
RW06k	448.8	62.8
RW06l	281.3	39.4
RW06m	735.3	102.9

TABLE 5-11 VOLUME OF SOIL IN EMBANKMENTS IN RWAMPARA

Since the soil from the embankments can be utilized to backfill the drainage, the table below presents the balance of soil to be imported from elsewhere for the complete backfilling of the agricultural ditches.

Channel	Volume of soil to import (m3)
RW06a	4565.2
RW06b	659.2
RW06c	757.6
RW06d	473.2
RW06e	2404.5
RW06f	1340.5
RW06g	1580.5
RW06h	944.6
RW06i	2943.3
RW06j	1535.9
RW06k	1098.4
RW06l	688.5
RW06m	1799.5

TABLE 5-12 VOLUME OF SOIL TO BE IMPORTED FOR BLOCKING OF AGRICULTURAL CHANNELS IN RWAMPARA

5.4.2.7 Creation of ponds to support wildlife and aesthetic appearance

At the request of the Client, a pond has been added to the wetland, in order to provide a viable habitat for wildlife, as well as to enhance the natural beauty of the site.

The pond is design based on an expansion of the existing riverbed with a spillway at its outlet. The pond will have a depth of 2m and the design of the spillway is detailed in a section below.

FIGURE 4-3: POND OF RWAMPARA

5.4.2.8 Re-profiling the river with meanders and banks

The action of re-meandering within the framework of this wetlands consists in artificially recreating this natural functionality of the river, altered by past human interventions. The purpose of such an intervention is multiple since it aims:

- To mitigate the impacts linked to the incision of the minor bed (lowering of the water table, lowering of the surface area of the flooded zones, acceleration of the flows...).
- To slow down the dynamics of water allowing to reduce the flood wave downstream.

- To lengthen the line of the watercourse and thus to multiply the contacts between ground and water (ecotone*), possible places of purification.
- To find a diversity of natural habitats for animal species which is much more important in meandering streams than in straight streams. The work of the banks in different levels (height defined according to the flows of reference floods) will also allow to support this diversification.

For this action to be implemented, the primary space of the river need to be restored as per the methodology presented in paragraph 5.2.4.2. Large banks need to be designed which will act as a buffer zone during the rainfall storm events, and riprap will be installed at the outer curves of the meanders to prevent erosion as illustrated in the figure below.

FIGURE 5-52: EXAMPLE OF RIVER MEANDERING AND EXTERNAL BANKS PROTECTION WITH GABIONS

River meandering in Rwampara wetland has been designed in three areas RW08a and RW08b according to the wishes of the Client. Each meandering zone is described hereafter, and the detailed designs can be found in Annex 2.3)

RW08a

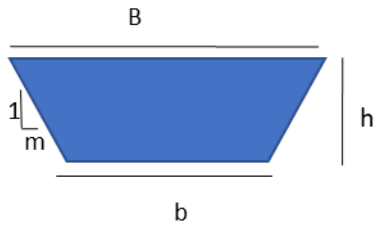
This meandering section requires a simple increase in amplitude and sinuosity to exaggerate the curves of the existing meandering river. In addition, the existing riverbed has been filled and reshaped to allow the river to overflow more frequently.

FIGURE 5-7: MEANDER RW08A

The discharge through this channel is 17.8 m3/s, therefore the dimensions of the channel are determined as follows:

S0	m	b (m)	h (m)	B (m)

0.0108	0.29	4	1.7	5.0



Due to high velocities, it will be necessary to protect the outer curves of the river from scouring and erosion. In order to respect the environmental spirit of the project, the Consultant is proposing to use riprap for this purpose. The riprap at the outside curve of the meanders should at least have a diameter of 0.14 m.

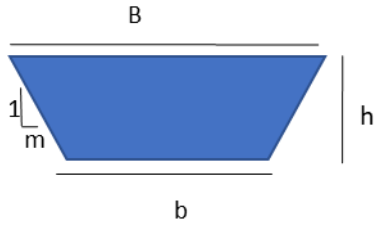
RW08b

For the second meander, the terrain does not allow a wide amplitude as it is located in a very narrow section. Additionally, the recreational area at the outlet of the meander constrains its shape. Bearing in mind these constraints, the new sinuosity is therefore of 1.11.

FIGURE 5-53: MEANDER RW08B

The discharge through this channel is 12.7 m3/s, therefore the dimensions of the channel are determined as follows:

S0	m	b (m)	h (m)	B (m)
0.0050	0.29	4	1.7	5.0



Due to high velocities, it will be necessary to protect the outer curves of the river from scouring and erosion. In order to respect the environmental spirit of the project, the Consultant is proposing to use riprap for this purpose. The riprap at the outside curve of the meanders should at least have a diameter of 0.11 m.

5.4.2.9 Creation of a dike for neighbouring communities protection

Following the hydraulic modelling carried out, the results of which are available in Annex 2.4, some inhabited areas are vulnerable to flooding events. As a result two dikes are proposed to protect the neighbouring communities from rising flood waters, RW9a and RW9b.

The dikes will be constructed in gabion, and the principle will be very similar to that used for the conveying structures (paragraph 5.4.2.3).

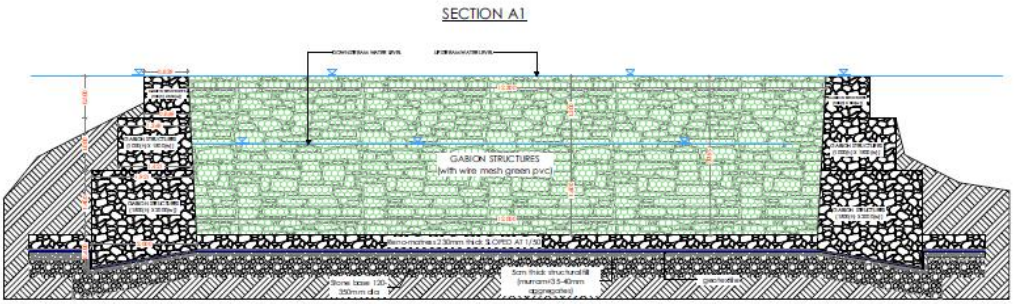


FIGURE 5-54: CREATION OF A DIKE IN RWAMPARA

5.4.2.10 Soil stabilization of the banks of the river

In two locations erosion heavily affects the banks of the river flowing through Rwampara wetland. In order to prevent further erosion of the watercourse a cascade with gabions (RW10) is proposed to provide a harder surface that water cannot incise and scour, as show in the figure below.

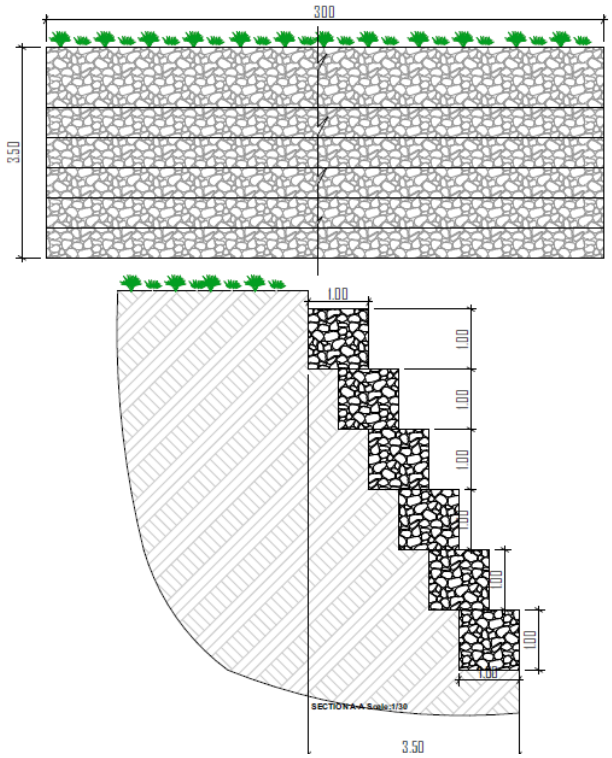


FIGURE 5-55: CASCADE OF GABION IN RW10

Detailed designs are provided in Annex 2.3

5.4.2.11 Transition structures with hotspots

Specific infrastructure defined through flood hotspots project (under the supervision of CoK) will be constructed in the wetland area. It is important to define a precise coordination for the execution of the works so that the different companies have sufficient flexibility, and the works can be carried out in a consistent manner.

It was agreed that:

- A band of 15m upstream and 15m downstream the limit of the future hotspots infrastructure is defined without and action form wetland project, keeping the required flexibility.
- The transition structure between the rivers/canals of the wetlands and the future culverts/canals of the hotspot project are included in the wetlands actions (see specific detail plan)
- For a perfect coordination the following information is given for each wetland: altitude and section of the channel upstream and downstream of the sectors with hotspot action

At the location where there is hotspot structure, the link between the structure for road crossing (culvert or bridge) a transition structure is needed for energy dissipation and prevent the erosion of the canal at then inlet and outlet of the structure due to the turbulence generated as these transition sections.

At the upstream part, the transition is a contraction of the channel from a trapeze section to a rectangular section. This contraction increases the flow speed threatening the riverbed with erosion. In order to protect the channel, this section needs to be reinforced by ripraps of a size calculated the same way as defined in part

At the downstream part, the transition is the opposite with an expansion from a rectangular shape to a trapeze. As the flow slow down, the energy dissipation can erode the riverbed, hence some ripraps to protect the bed.

The length of the transition section is defined by L = 2B where B is the width of the channel.

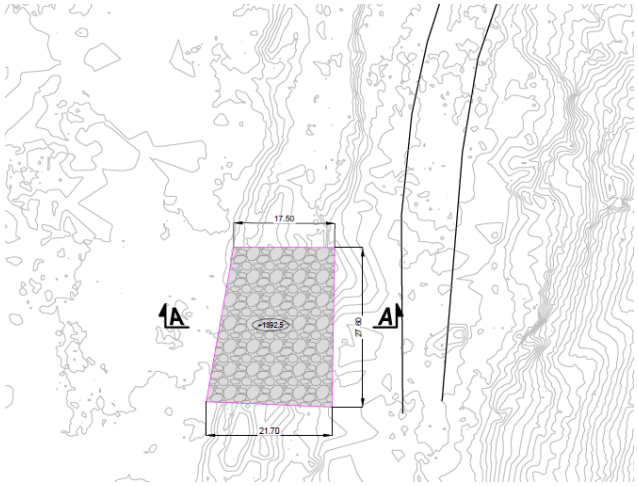


FIGURE 56 - RW19 RIPRAP OF 0.11M

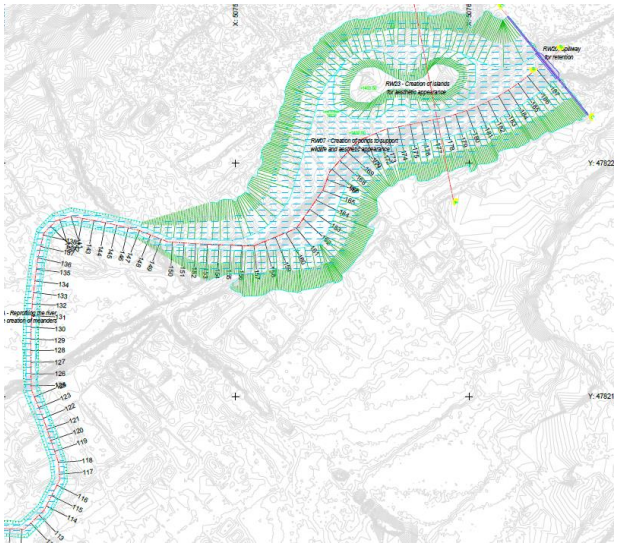
5.4.2.12 Spillway for retention

Spillways are flow control structures that orient the water in different directions according to their design.

The width of the spillway is the size of the channel at the outlet of the pond which correspond to a width of 17m. the height of the spillway is then the only parameter usable to modify the discharge that the spillway can evacuate. Using the standard weir formula :

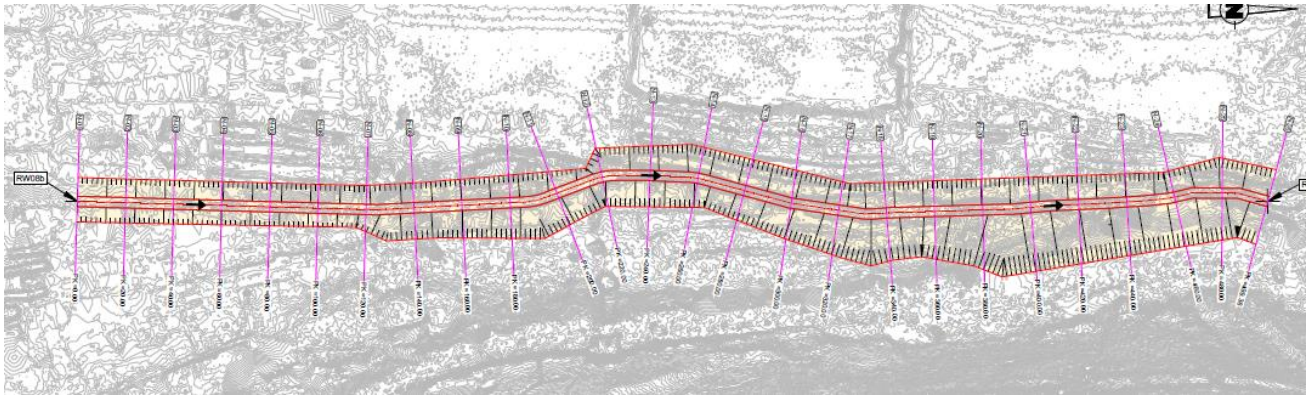
$$Q = L_d \cdot m \cdot \sqrt{2g} \cdot h^{3/2}$$

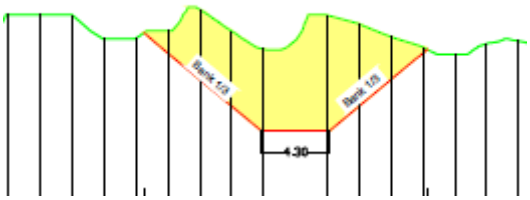
with a weir coefficient m = 0.4, L_d the width of the spillway and h the water height above the spillway. The spillway is sized to evacuate a discharge up to 55 m3/s without making the pond overflow.



5.4.2.13 Reshaping of the channel

In order to prevent channels against erosion it is necessary to rehape the square channels into trapezoidal ones. It will be the base for the lower part of this wetland.





5.4.3 Public space actions

In order for the wetland to be accessible to and appreciated by the general public, a number of public space actions are proposed. These will bring the population into closer contact with the natural environment boosting their enjoyment of the site. These actions are detailed in the following paragraphs, and further details can be found in the Technical Specifications (chapter 8) and in Annex 2.5.

5.4.3.1 Pedestrian / Cycling Trails

Pedestrian and cycling trails are to be constructed in Rwampara wetland to provide human access into the natural space enabling the population to enjoy the beauty of the wetland without risking any damage to the surrounding wildlife.

The trails can be used not only for access through and across the wetland but will enable leisure and sporting activities by promoting interconnectedness between the various services provided by the wetland, such as recreational areas, coffee bars, restaurants, sporting, educational and cultural facilities, and viewing areas.

The proposed pathways for Rwampara wetland will be enhanced with public furniture to render it more accessible and useful. This will include:

- Directional signage to indicate routes and destinations,
- Interpretive signage for educational purposes about the wetland,
- Lighting of pathways for ease of access and safety,
- Benches to allow people to sit and rest,
- Litter containers for the collection of refuse to avoid pollution of the environment,
- Bicycle racks to encourage soft mobility by ensuring the security of bicycles,
- Protective guarding along decks and other elevated structures.

Detailed designs of these interventions are provided in Annex 2.5

5.4.3.2 Cultural and Exhibition Centre

Rwampara Wetland will be equipped with a Cultural and Exhibition centre in order to showcase the history and talent of the Rwandan people, as illustrated in the image below.

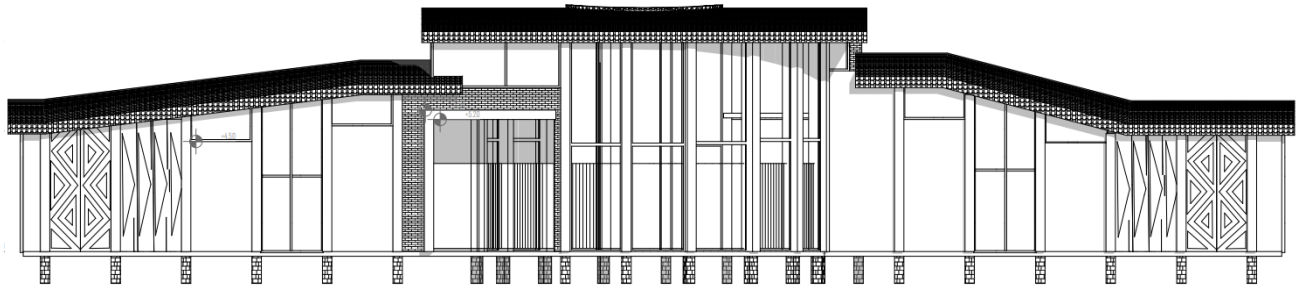


FIGURE 57 – RWAMPARA CULTURAL AND EXHIBITION CENTRE

Detailed designs are available in Annex 2.5

5.4.3.3 Green belt

The construction of a green belt surrounding Rwampara Wetland is proposed as it will have numerous benefits:

- Delineation of the wetland itself,
- Protection of the wetland from pollution originating in adjacent communities,
- Pedestrian/cycle access around the wetland,
- Elevated location providing views of the natural environment.

The principle is to produce a nature-based contour of the wetland that will provide these services. As such the area will be levelled, with a grassy space and treeline that will absorb runoff before it reaches the wetland, next to pedestrian pathway covered in volcanic paving stones, and a compacted laterite soil cycle path. Detailed designs are provided in Annex 2.5.

5.5 RUGENGE-RWINTARE WETLAND

5.5.1 Landscaping actions

5.5.1.1 Landscaping concept

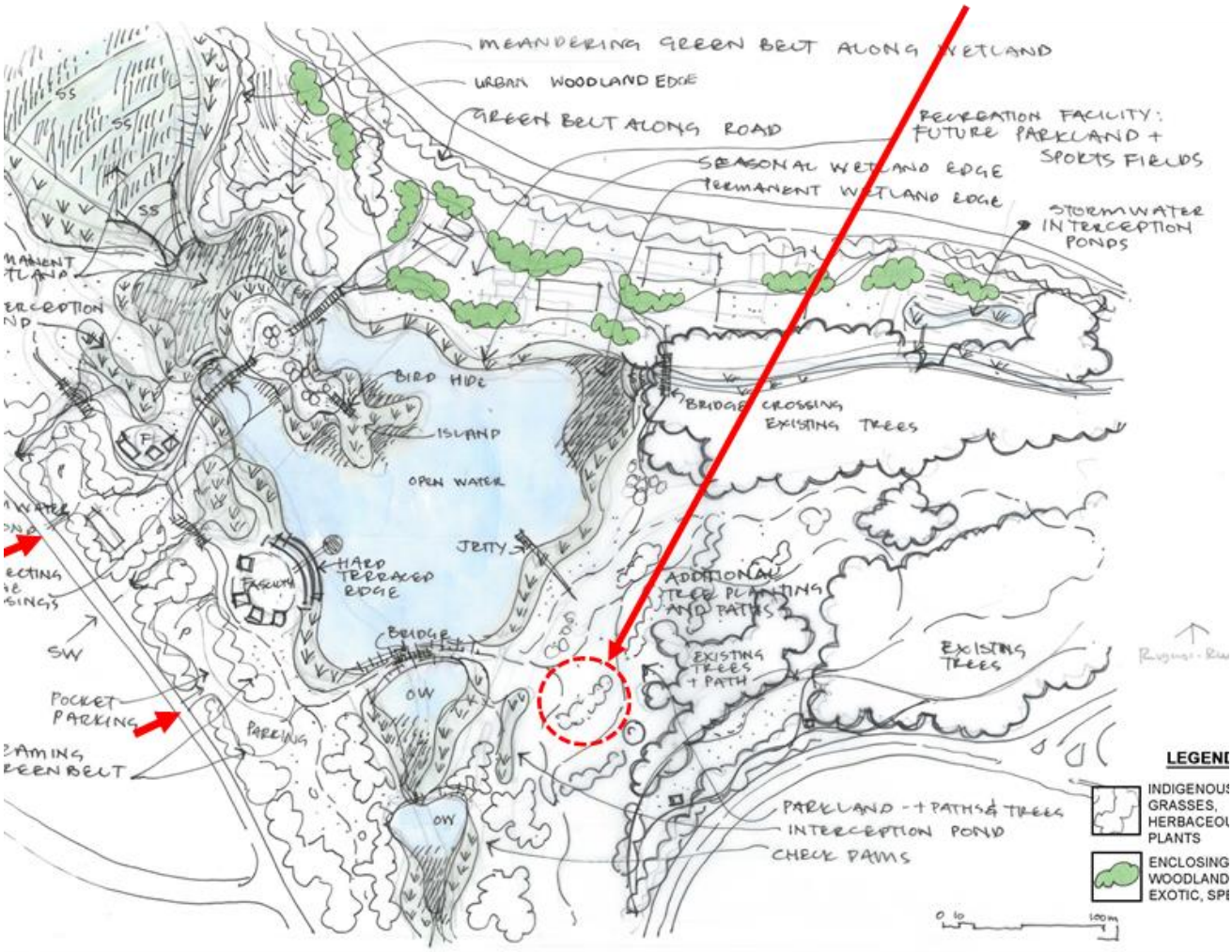


FIGURE 5-58: LANDSCAPING SKETCH OF RUGENGE-RWINTARE WETLAND

5.5.1.2 Garden of touch

A garden for both the sighted and the blind. Tactile plants, by leaf, stem, flower form, and texture, engage the fingers of visitors in an exploration of the world of plants, their seasonal textures. Rough and smooth, rocks and boulders reveal various textures and even sculptural forms carved in their surfaces.

FIGURE 5-59: GARDEN OF TOUCH OF RUGENGE-RWINTARE WETLAND

Composed social space for people, locals and tourists and blind people, in a sculptural composed landscape and social space. One that is defined by smooth boulder formations for seating in circles or wave benches running riverside.

One where the wavy benches mimic the rolling forms of river waves and currents.

Naturalistic Art in the Park as intriguing focal points and pauses for thought.

Beautifully finished concrete park seating smooth to the touch

Coarse and fine, rough, hairy and smooth, a tactile grouping of plants that are exciting and informing for both the sighted and the blind. Botanic information provided in bold and conspicuous plant labelling and in braille.

5.5.1.3 Proposed planted species

The ecological rehabilitation of Rugenge-Rwintare Wetland will entail the planting of the following species, in the following areas. Further details can be found in the Technical Specifications (chapter 8) and in Annex 3.2.

For the purpose of detailed description of the site, Rugenge-Rwintare can be subdivided into 2 main branches: Eastern branch, and Western branch.

Eastern branch

5 habitat typologies/target functional habitats have been identified in this area.

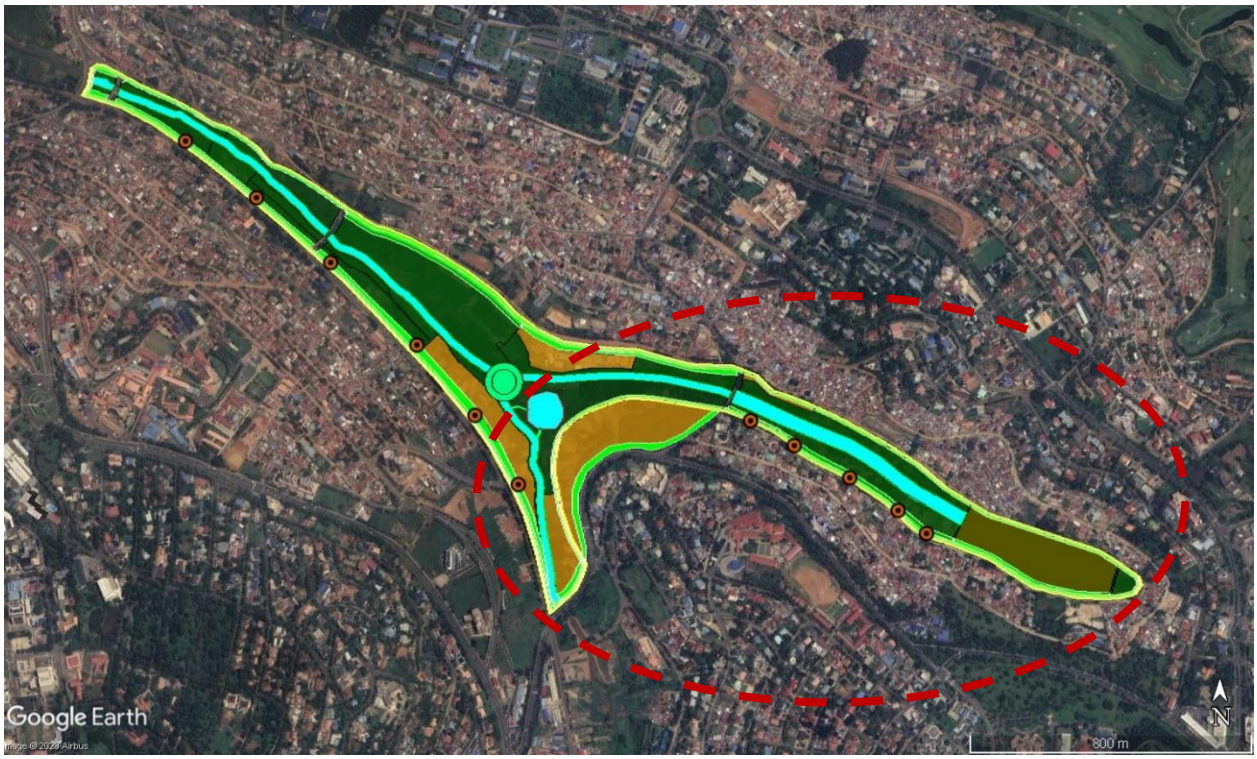


FIGURE 5-60: LOCATION OF RUGENGE-RWINTARE EASTERN BRANCH

The following table shows the list of species suggestions for each typology. Life forms and expected functions for each species can be found in Chapter 8.1.

Habitat type/function	Plant species
1. Permanent wetland: Proposed native plant species adapted to the wetland environment are selected to enhance wetland restoration efforts. The species were identified based on their ecological function for wetland restoration through water retention, regulating water flow, filtering pollutants, soil stabilization, etc., and maintaining the health and biodiversity of these habitats in general.	*Cyperus denudatus* *Cyperus dives* *Cyperus papyrus* *Juncus effusus* *Ludwigia abyssinica* *Persicaria decipiens* *Typha domingensis*
2. Seasonal wetland: Existing bamboos in this area will be maintained. They are well-adapted to growing in this wet	*Bambusa vulgaris*

environment. Bamboos contribute to soil stabilization, water quality improvement, habitat creation for a variety of wetland species, etc.	
3. Green belt, linear park and opportunity nodes: These are upland strips along the wetland. Proposed species will primarily serve to enhance urban biodiversity, provide habitat for wildlife that use the wetland for food or shelter, and provide cultural services with focus on ornamentals amenities.	*Blighia unijugata* *Croton megalocarpus* *Delonix elata* *Dodonaea viscosa* *Elaeis guineensis* *Entada abyssinica* *Ficus sycomorus* *Ficus vallis-choudae* *Kigelia africana* *Maesopsis eminii* *Markhamia lutea* *Olea europea* subsp. *africana* *Podocarpus latifolius* *Polycias fulva* *Pterygota mildbraedii* *Senegalia polyacantha* *Spathodea campanulata* *Sterculia tragacantha* *Syzygium guineense*
4. Recreational areas: Proposed species for these areas will offer opportunities to accommodate visitors to the wetland and provide facilities such as shades for parking lots and picnic areas. These will also serve to educate visitors about the wetland ecosystem and importance of wetland conservation.	*Croton megalocarpus* *Ficus sycomorus* *Kigelia africana* *Maesopsis eminii* *Olea europea* subsp. *africana* *Podocarpus latifolius* *Polycias fulva* *Pterygota mildbraedii* *Senegalia polyacantha* *Spathodea campanulata* *Sterculia tragacantha*
5. Stream banks: The stream banks will be covered in vegetation to play a role of stabilizing stream banks, providing habitat for wildlife, and filtering pollutants.	*Phragmites mauritianus* *Aeschynomene elaphroxylon* *Sesbania sesban*

TABLE 5-13 LIST OF PLANT SPECIES IN RUGENGE-RWINTARE WETLAND'S EASTERN BRANCH

Western branch

6 habitat typologies/target functional habitats have been identified in this area.

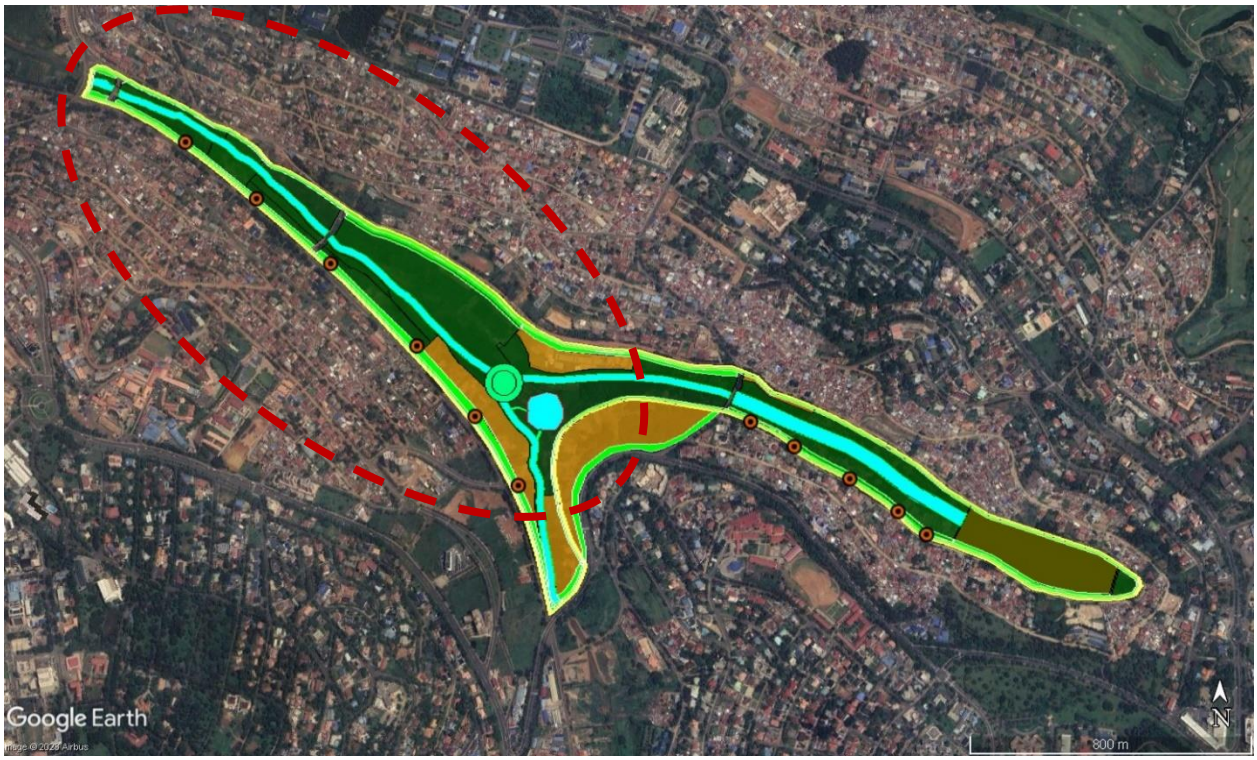


FIGURE 5-61: LOCATION OF RUGENGE-RWINTARE WESTERN BRANCH

The following table shows the list of species suggestions for each typology. Life forms and expected functions for each species can be found in chapter 8.1.

Habitat type/function	Plant species
1. Seasonal wetland: Proposed native plant species adapted to the wetland environment are selected to enhance wetland restoration efforts. The species were identified based on their ecological function for wetland restoration through water retention, regulating water flow, filtering pollutants, soil stabilization, etc., and maintaining the health and biodiversity of these habitats in general.	*Brachiaria humidicola* *Brillantaisia cicatricosa* *Cyperus articulatus* *Cyperus latifolius* *Echinochloa pyramidalis* *Leersia hexandra* *Panicum maximum*
2. Green belt, linear park and opportunity nodes: These are upland strips along the wetland. Proposed species will primarily serve to enhance urban biodiversity, provide habitat for wildlife that use the wetland for food or shelter, and provide cultural services with focus on ornamentals amenities.	*Blighia unijugata* *Croton megalocarpus* *Delonix elata* *Dodonaea viscosa* *Elaeis guineensis* *Entada abyssinica* *Ficus sycomorus* *Ficus vallis-choudae* *Kigelia africana* *Maesopsis eminii* *Markhamia lutea* *Olea europea* subsp. *africana* *Podocarpus latifolius* *Polycias fulva* *Pterygota mildbraedii* *Senegalia polyacantha* *Spathodea campanulata*

	Sterculia tragacantha *Syzygium guineense*
4. Stream banks: The stream banks will be covered in vegetation to play a role of stabilizing stream banks, providing habitat for wildlife, and filtering pollutants.	*Phragmites mauritianus* *Aeschynomene elaphroxylon* *Sesbania sesban*
3. Recreational areas: Proposed species for these areas will offer opportunities to accommodate visitors to the wetland and provide facilities such as shades for parking lots and picnic areas. These will also serve to educate visitors about the wetland ecosystem and importance of wetland conservation.	*Croton megalocarpus* *Ficus sycomorus* *Kigelia africana* *Maesopsis eminii* *Olea europea* subsp. *africana* *Podocarpus latifolius* *Polycias fulva* *Pterygota mildbraedii* *Senegalia polyacantha* *Spathodea campanulata* *Sterculia tragacantha*
5. Pond areas: Floating plants of water lilies are proposed for ornamental purposes. These will also serve to improve water quality in the ponds and reduce the growth of algae and other harmful organisms. It is recommended to regularly control the lilies to maintain a healthy ecological balance and avoid oxygen depletion in the water. The African oil palm will be planted for ornamental purposes around the ponds	*Nymphaea nouchali* *Elaeis guineensis*
6. Islands: Proposed species will serve to preserve some of locally rare species and possess recreational values. Others are for birds habitat, etc.	*Dodonaea viscosa* *Kigelia africana* *Panicum maximum* *Pterygota mildbraedii* *Senegalia polyacantha* *Setaria homonyma* *Sterculia tragacantha*

TABLE 5-14 LIST OF PLANT SPECIES IN RUGENGE-RWINTARE WETLAND'S WESTERN BRANCH

5.5.1.4 Creation of an island for aesthetic appearance

At the request of the Client, a landscaped island is proposed to be constructed in Rugenge-Rwintare wetland (RU10). This will provide an elegant form emerging from the ponds and lakes in this wetland increasing biodiversity.

Detailed designs can be found in Annex 3.2.

5.5.1.5 Soil reshaping for wetland creation

The objective of this action is to carry out earthworks that will modify the topography of the wetland for ecological and aesthetic purposes.

Existing low points in the wetlands will be identified and the surrounding areas will be excavated in order to expand these locations into low areas that will preferentially accumulate water. Excavated soil will be used to backfill the existing water course as well as to enhance nearby high points.

The immediate outcome of this action will be a sloped but unchanneled terrain which will allow water to flow diffusely and slowly through the wetland. The final result is the creation of different areas of wetland based on their elevation. Specifically, this will result in permanent wetlands in the low points where the soil will be constantly waterlogged, and seasonal wetlands which will periodically receive inflows of water.

The greater retention time of water in the low points mean that it provides an excellent opportunity for the treatment of inflows coming from upstream or neighbouring built-up areas, a process which can be accentuated by the planting of appropriate plant species.

The difference in water content of the soil due to elevation differences will also promote the creation of a variety of flora, which will have two co-benefits

- Additional habitat creation for local fauna, promoting biodiversity,
- The wide diversity of plant species will allow for a more varied beautification of the site.

Proposed wetland reshaping actions are located as per the zoning maps under labels RU15a and RU15b and are illustrated in the figures below. The detailed site plans and cross sections are provided in Annex 3.2.

FIGURE 5-62: SOIL RESHAPING FOR WETLAND CREATION – RU15A

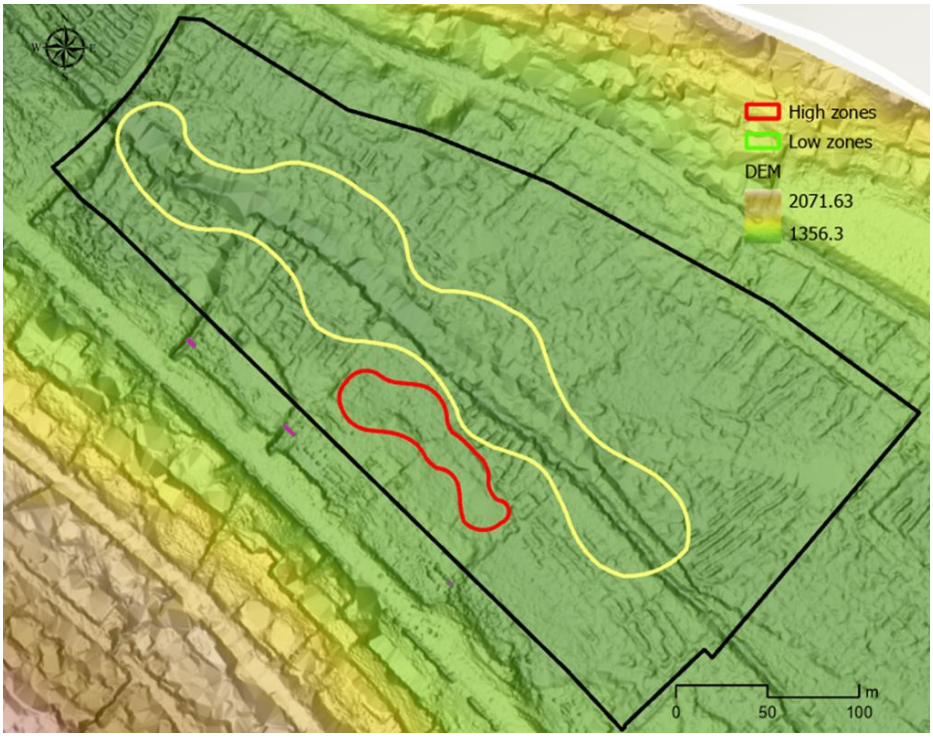


FIGURE 5-63: SOIL RESHAPING FOR WETLAND CREATION – RU15B

5.5.2 Hydraulic actions

The hydraulic actions designed in this project seek to reinstate or enhance the hydraulic functioning of the 5 wetlands, mostly through modifications of the flows through the project area with the following objectives:

- Promoting water retention in the wetlands to prevent damaging flooding events,
- Reducing the flow through the wetlands to limit erosion,
- Spreading of water flows to provide maximum absorption and reduce downstream flows and velocities,
- Provide favorable aquatic environments for fauna and flora,
- Improve water quality.

As explained in paragraph 3.2.3, a variety of actions are planned with each wetland receiving interventions tailored to the wetland's objectives.

In accordance with the Master Plan for Rugenge-Rwintare (Annex 3.1), the detailed design was carried out as below for the specific interventions proposed for the wetland, which is developed hereunder. Further details can be found in the Technical Specifications (chapter 8) and in Annex 3.3.

5.5.2.1 Sediment traps for blockage of sediments into the wetland

The hydraulic outfalls from lateral drainage carry effluents from the neighbouring urbanized areas, which are charged with sediment, and convey them into the wetland. Originally built to drain plots for agricultural purposes they are relatively deep (about 2m) and consequently convey water rapidly downstream, which is in opposition to the role and functioning of the wetland.

The construction of sediment traps is therefore proposed to counteract this effect. A sediment trap is a containment area that allows sediment in collected storm water to settle out during the runoff is discharged through a stabilized spillway/dewatering pipe.

Due to the very large amount of waste of varying sizes coming from the sides, and the lack of a large-scale collection system over most of the study area, sediment traps will be installed at each drain stop in the wetland.

It is very important to note that each sediment trap was designed specifically, depending on the reality of each drain. The drawings are given in Annex 3.3, examples are provided hereunder.

The Consultant considered the use of vegetation on the gabions forming the sediment trap elements. This solution was not retained for the following reasons:

- the water arrives at a high speed which requires the installation of gabion mats with a tight mesh to ensure stability
- in these conditions, vegetation would not be able to develop properly and would represent a significant hindrance to the maintenance of the structures.

3 types of sediment traps were defined according to the context, here is an example:

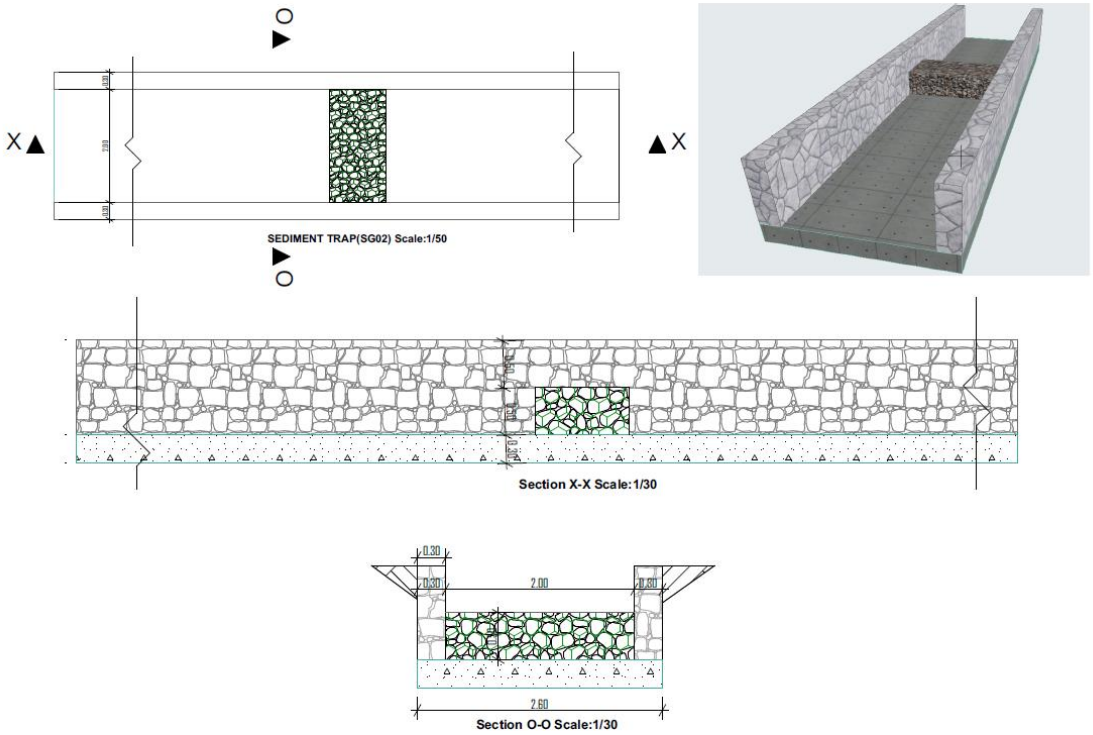


FIGURE 5-64: EXAMPLE OF SEDIMENT TRAP

At the outlet of the structure, a gabion wall filled with river stones will ensure that the flow is spread across the floor of the wetland. This will combine with the landscaping action RU15 “soil reshaping for wetland creation” which specifically incorporates interventions to receive inflows from lateral drainage. This will limit its velocity thereby retaining it in the wetland, where it can be naturally treated of other pollutants (chemical and biological). This treatment is reinforced by appropriate plant selection as explained in paragraph 5.3.1.

The result is primarily to improve the quality of the water, but it will also contribute to increasing the height of the water table and limiting flooding downstream.

The construction of these traps can only be carried out with the use of concrete for the base and walls of the structure; however gabion and river stones are also incorporated into its construction to constitute the trap. The trap will require periodic manual emptying to ensure it remains effective, as once it is full the sediment will simply continue its path into the wetland.

5.5.2.2 Water conveying structure to block and channel water to the main stream

The intervention consists in the construction of a dike spanning the width of the valley at the outlet of the wetland to collect and concentrate the water flowing out of the wetland, which will effectively create an artificial lake. A channelling structure will be constructed as part of the dike to convey all the water towards the meandering watercourse downstream.

The Consultant has considered employing nature-based solutions as much as possible. As such, the dike will be constructed of compacted earth, covered in turf. Volcanic paving stones will be used to create the path along the top of the dike with wooden handrails for safety reasons.

However, for the critical element of the conveying structure, the space allowing the passage of water collected by the dike into the subsequent channel it was necessary to retain concrete for the construction. This was to ensure the long-term sustainability of the structure, which would be affected by two main factors:

- The strength requirements in order to withstand the static and dynamic (hydraulic) loads.
- The risk of erosion by water velocity through the structure.

The use of concrete is minimized insofar as the outlet of the conveying structure consists of gabion walls (with wire mesh coated with green PVC) and river stones that will prevent shearing and erosion of the banks at the entrance to the downstream channel.

An example of the proposed water conveying is provided in the image below.

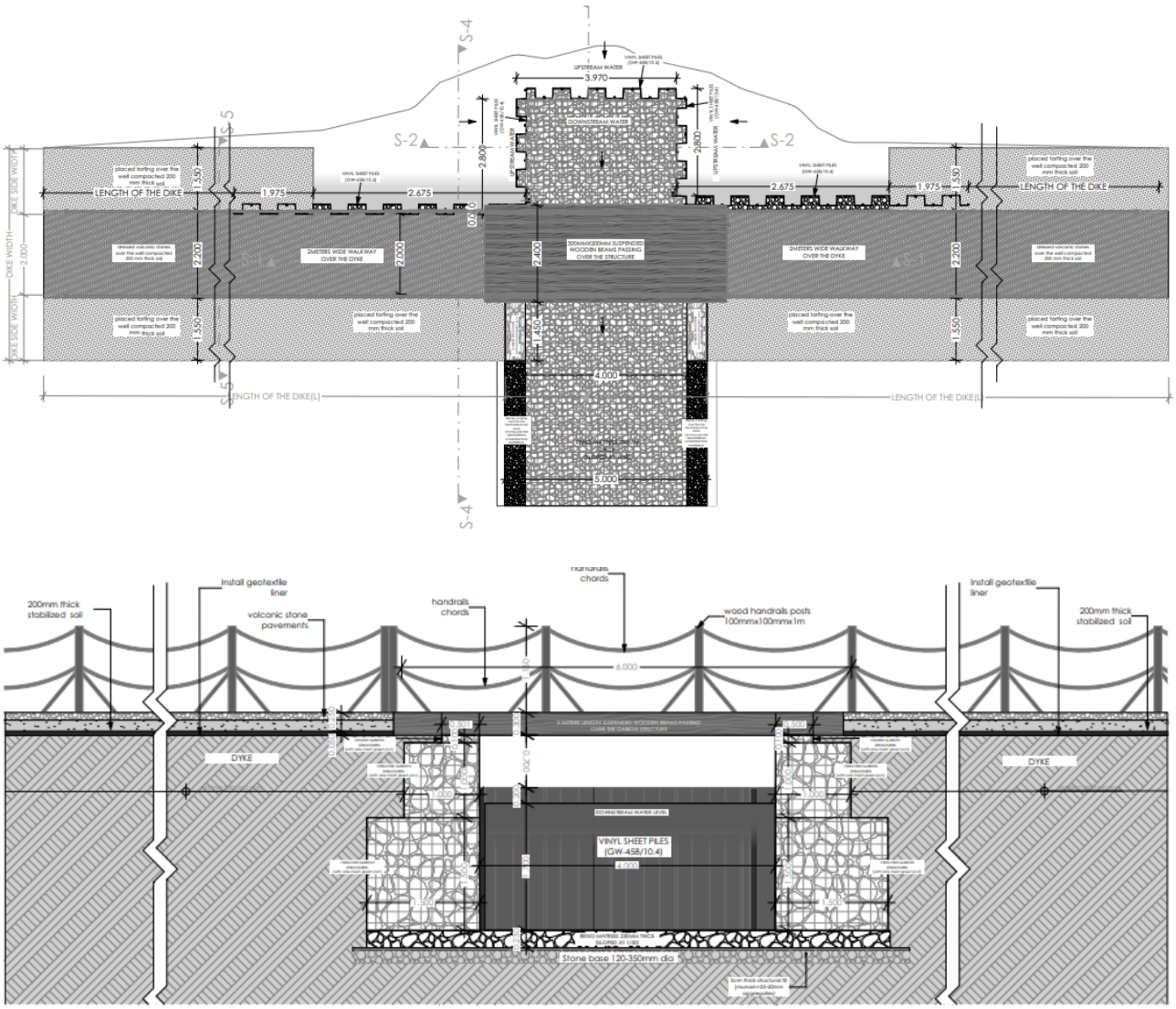


FIGURE 5-65: EXAMPLE OF A WATER CONVEYING STRUCTURE

The Contractor will be responsible for the verification of the structural stability and quantities required for the structure's construction, based on the real conditions identified during implementation.

The Consultant verified the impact of the blocking and channeling structure on the flow of water through the wetland, by:

- Modelling dam with corresponding height
- Considering rainfalls of increasing intensity (T2 and T10 at current urbanisation levels, and T2, T10, T50 with 2050 urbanisation projections)
- Considering modifications by YREC following their hotspot study.

In this case, only low intensity return periods are relevant, however it is still interesting to see how the modifications will also react to high intensity flood.

The results for a T2 rainfall before and after intervention are presented in the image below, however the complete modelling results are provided in Annex 3.4.

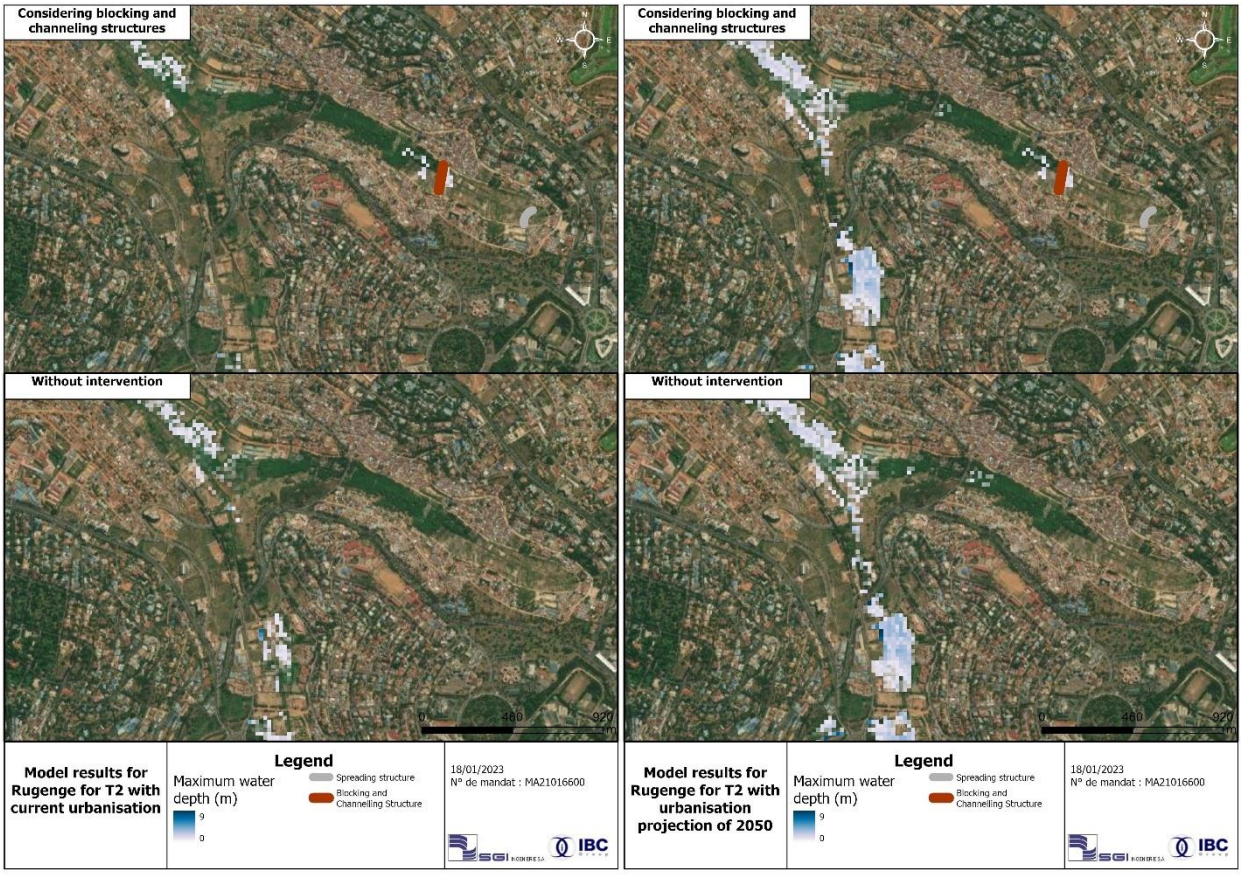


FIGURE 5-66: WATER DEPTHS FOR A T2 RAINFALL BEFORE AND AFTER INTERVENTION IN RUGENGE-RWINTARE WITH CURRENT AND 2050 URBANISATION LEVELS

5.5.2.3 Water spreading structure to spread water into the wetland

The intervention consists in the modification of the flow of water out of the channel from which it originates into a more diffuse flow that spreads across the wetland. The objective of this intervention is to ensure an even spreading of the water throughout the wetland to achieve maximum speed and flow reduction, which will not only prevent flooding, but also improve water quality and retain water in the wetland site to better promote growth and habitat creation.

The Consultant has considered employing nature-based solutions as much as possible, and relies on a two-pronged approach to force the flow to diverge:

- Earthworks: At the approach to the wetland area, the soil will be mechanically shaped into a slightly conical form that will encourage water to flow laterally through gravity.
- Gabion walls: To further encourage the water to spread laterally across the wetland floor, gabion walls of increasing length will be constructed across the wetlands to reinforce the redirection of the flow as the water passes through them.

This construction will have the following impacts:

- Even spreading of the incoming water across the span of the wetland, making maximum use of the available space.
- Reduction in the speed of water limiting erosion and promoting sedimentation.
- Increased absorption and raised level of the water table.
- Improved water quality.

An example of the proposed spreading structure is provided in the image below.

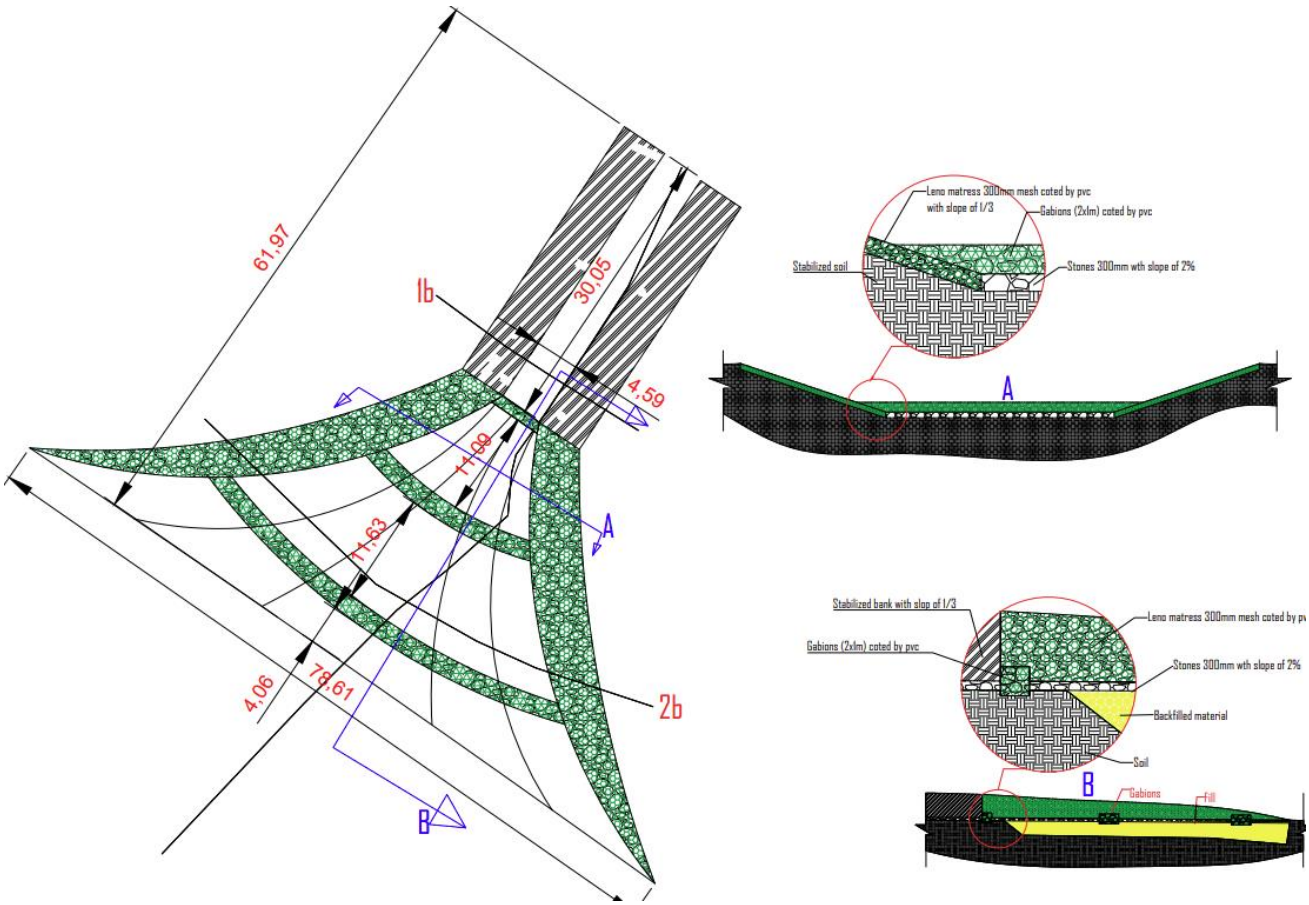


FIGURE 5-67: EXAMPLE OF A FLOW SPREADING STRUCTURE

The contractor will be responsible for the verification of the structural stability and quantities required for the structure's construction, based on the real conditions identified during implementation.

5.5.2.4 Re-profiling the river with meanders and banks

The action of re-meandering within the framework of this wetlands consists in artificially recreating this natural functionality of the river, altered by past human interventions. The purpose of such an intervention is multiple since it aims:

- To mitigate the impacts linked to the incision of the minor bed (lowering of the water table, lowering of the surface area of the flooded zones, acceleration of the flows...).
- To slow down the dynamics of water allowing to reduce the flood wave downstream.
- To lengthen the line of the watercourse and thus to multiply the contacts between ground and water (ecotone*), possible places of purification.
- To find a diversity of natural habitats for animal species which is much more important in meandering streams than in straight streams. The work of the banks in different levels (height defined according to the flows of reference floods) will also allow to support this diversification.

For this action to be implemented, the primary space of the river need to be restored as per the methodology presented in paragraph 5.2.4.2. Large banks need to be designed which will act as a buffer zone during the rainfall storm events, and riprap will be installed at the outer curves of the meanders to prevent erosion as illustrated in the figure below.

FIGURE 5-68: EXAMPLE OF RIVER MEANDERING AND EXTERNAL BANKS PROTECTION WITH GABIONS

River meandering in Rugenge-Rwintare wetland has been designed in two areas, RU04a and RU04b. Each meandering zone is described hereafter, and the detailed designs can be found in Annex 3.3.

RU04a

RU04a is located in the bamboo zone in which has the effect of limiting the possible amplitude of the meander. The amplitude is set to 40m implying a 4 m wide river with the following characteristics:

S0	m	b (m)	h (m)	B (m)
0.0072	0.11	3.5	2.2	4.0

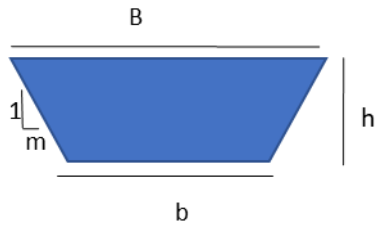


FIGURE 5 -69: MEANDER RU04A

Due to high velocities, it will be necessary to protect the outer curves of the river from scouring and erosion. In order to respect the environmental spirit of the project, the Consultant is proposing to use riprap for this purpose. The riprap at the outside curve of the meanders should at least have a diameter of 0.14 m.

RU04b

RU04b is 4m wide, implying the following meandering characteristics:

S0	m	b (m)	h (m)	B (m)
0.0019	0.33	6.3	2.6	8

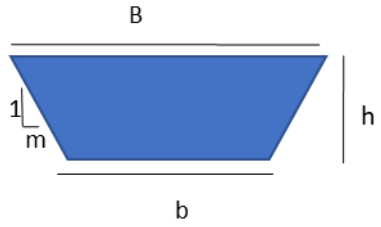


FIGURE 5 -70: MEANDER RU04B

Due to high velocities, it will be necessary to protect the outer curves of the river from scouring and erosion. In order to respect the environmental spirit of the project, the Consultant is proposing to use riprap for this purpose. The riprap at the outside curve of the meanders should at least have a diameter of 0.04 m.

5.5.2.5 Blocking of surface drains (agriculture drains)

Previous agricultural use has resulted in the creation of drains, originally constructed to facilitate the development of intensive agriculture, thereby strongly impacting the hydraulic dynamics of the wetland and its waterlogging.

The objective of the drains is to convey water rapidly downstream, away from farmed areas, which contributes to the lowering of the water table and the rapid drying of the soil. In addition to excavated drains, soil embankments raise the channel level above natural ground level in order to prevent the flooding of crops during heavy rains. However, with the repurposing of the wetland site for flood management, ecological and

aesthetic purposes, it is essential to retain water within the wetland, which is in firm opposition to the existing land use.

The objective of this action is therefore to prevent water from flowing in preferential paths, but to flow diffusely through a restored homogenous surface of the wetland. The water's flow rate will consequently be reduced as will associated erosion problems, and the water table will rise to provide a better environment for fauna and flora.

In order to achieve this objective, the ground level will be restored to a homogenous generally flat surface, devoid of drainage network. This will require two distinct actions illustrated in the images below:

- The backfilling of the agricultural ditches with soil
- The removal of soil embankments above natural ground level.

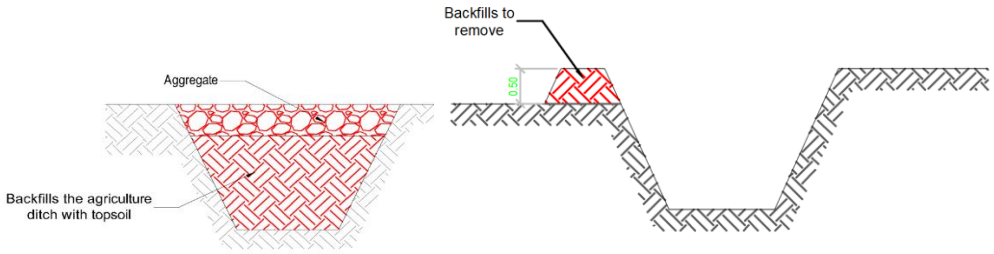


FIGURE 5-71: CROSS-SECTION OF AGRICULTURAL DRAINS

The soil from the embankments can be used to infill the drains however the available volume will be insufficient, and soil importation will be required. The topsoil used for this purpose must be free of any invasive plant species or pollutants. The agriculture drains located in Rugenge-Rwintare will be completely backfilled.

The volume of topsoil needed to fill the trapezoidal shaped drains is calculated with the following formula:

$$V = S \cdot l \cdot n \quad \text{with } S = h \cdot (\text{a} + \frac{b-a}{2})$$

Where:

- l is the length of the drains
- S the surface of the drain
- n the number of drains,
- h the depth of the recharge bed
- a and b the channel width at the base and surface respectively.

In Rwampara, the drains have a mean width of 1.5m at the base and 2.3m at ground level, and a height of 1.5m, resulting in a cross section of 2.59m^2. The volume of channel to be backfilled is presented in the table below.

Channel	Length of drainage (m)	Section of channel (m2)	Volume of backfill (m3)
RU05a	1418.4	2.59	3670.1
RU05b	290.4	2.59	751.4
RU05c	753.8	2.59	1950.4
RU05d	387.8	2.59	1003.5
RU05e	173.9	2.59	450.0

TABLE 5-15 VOLUME OF BACKFILL IN AGRICULTURAL DRAINS IN RUGENGE-RWINTARE

From this volume is removed the available soil from the embankments. The backfill sections have a mean section of 0.14m^2. The volume represented by this infill is calculated as per the following equation and is presented in the table below.

$$V = \text{number of drains} \cdot \text{length of the drain} \cdot \text{mean section surface of the backfill}$$

Channel	Length of drainage (m)	Volume of infill (m3)
RU05a	1418.4	198.6
RU05b	290.4	40.7
RU05c	753.8	105.5
RU05d	387.8	54.3
RU05e	173.9	24.3

TABLE 5-16 VOLUME OF SOIL IN EMBANKMENTS IN RUGENGE-RWINTARE

Since the soil from the embankments can be utilized to backfill the drainage, the table below presents the balance of soil to be imported from elsewhere for the complete backfilling of the agricultural ditches.

Channel	Volume of soil to import (m3)
RU05a	3471.5
RU05b	710.8
RU05c	1844.9
RU05d	949.2
RU05e	425.6

TABLE 5-17 VOLUME OF SOIL TO BE IMPORTED FOR BLOCKING OF AGRICULTURAL CHANNELS IN RUGENGE-RWINTARE

5.5.2.6 Creation of ponds to support wildlife and aesthetic appearance.

At the request of the Client, a number of ponds have been added to the wetland, in order to provide a viable habitat for wildlife, as well as to enhance the natural beauty of the site.

The ponds are design based on a residence time of the water of 24 hours, which allows for sufficient renewal to support aquatic life, while also providing some water quality benefits (such as sedimentation).

Each pond will be supplied preferentially compared to the main branch of the river to ensure water renewal. The pond will receive the entirety of the flow from the wetland.

The pond of Rugenge is at the junction between the two river flows.

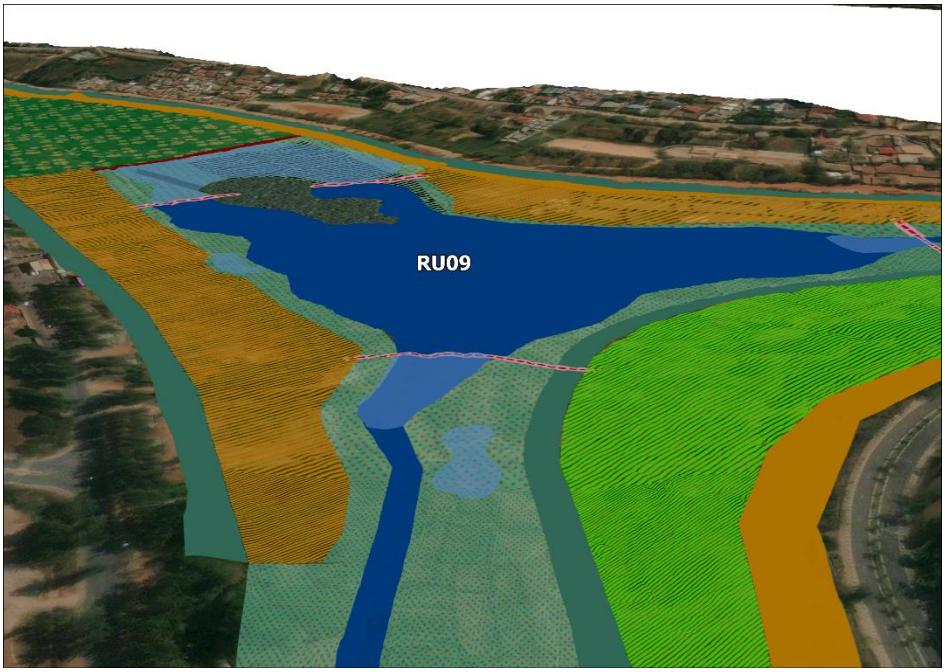


FIGURE 5-72: LOCATION OF THE TWO PONDS IN RUGENGE-RWINTARE WETLAND

5.5.2.7 Transition structures with hotspots

Specific infrastructure defined through flood hotspots project (under the supervision of CoK) will be constructed in the wetland area. It is important to define a precise coordination for the execution of the works so that the different companies have sufficient flexibility, and the works can be carried out in a consistent manner.

It was agreed that:

- A band of 15m upstream and 15m downstream the limit of the future hotspots infrastructure is defined without and action form wetland project, keeping the required flexibility.
- The transition structure between the rivers/canals of the wetlands and the future culverts/canals of the hotspot project are included in the wetlands actions (see specific detail plan)
- For a perfect coordination the following information is given for each wetland: altitude and section of the channel upstream and downstream of the sectors with hotspot action

At the location where there is hotspot structure, the link between the structure for road crossing (culvert or bridge) a transition structure is needed for energy dissipation and prevent the erosion of the canal at then inlet and outlet of the structure due to the turbulence generated as these transition sections.

At the upstream part, the transition is a contraction of the channel from a trapeze section to a rectangular section. This contraction increases the flow speed threatening the riverbed with erosion. In order to protect the channel, this section needs to be reinforced by ripraps of a size calculated the same way as defined in part

At the downstream part, the transition is the opposite with an expansion from a rectangular shape to a trapeze. As the flow slow down, the energy dissipation can erode the riverbed, hence some ripraps to protect the bed.

The length of the transition section is defined by L = 2B where B is the width of the channel.

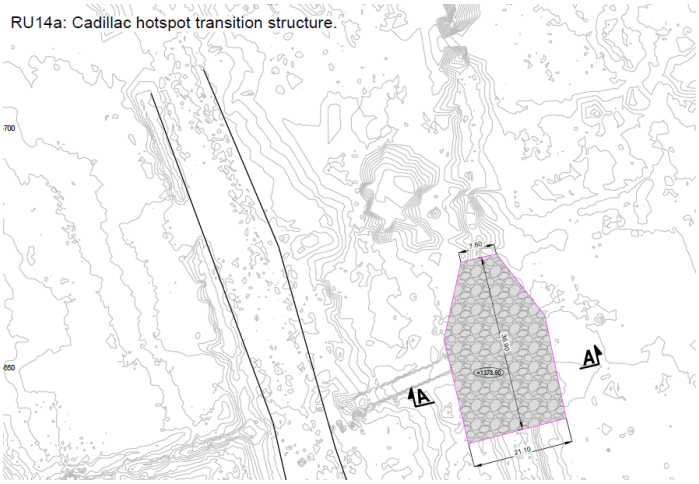


FIGURE 73 - RU14A RIPRAP OF 0.05M

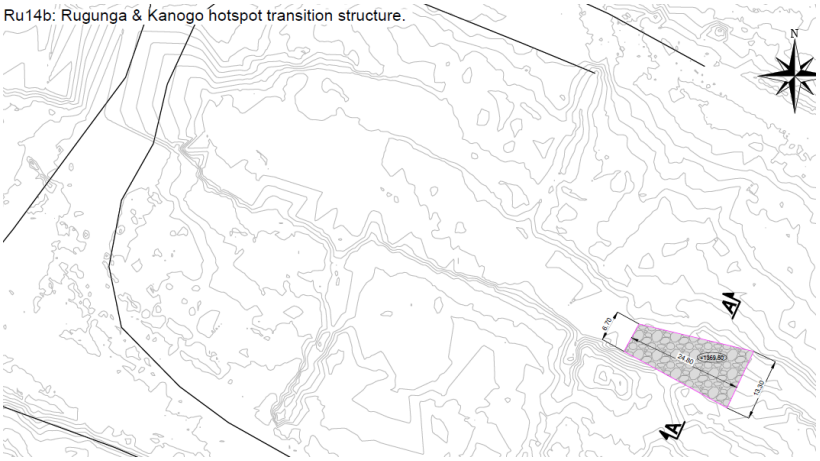
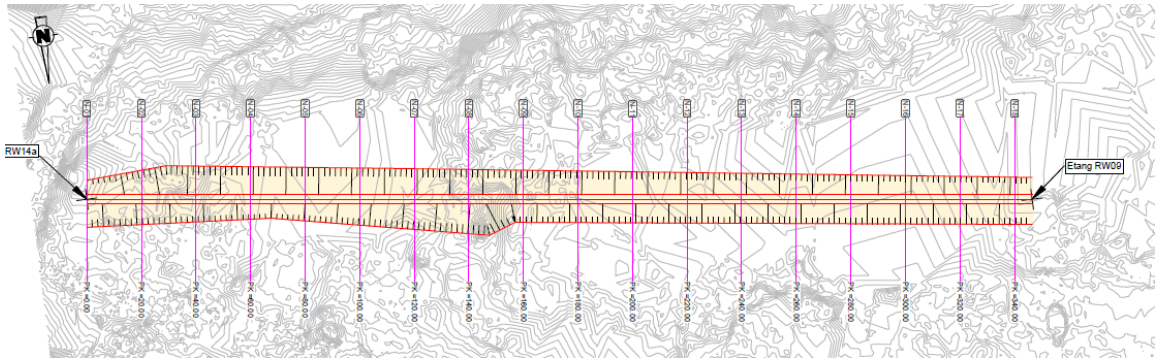
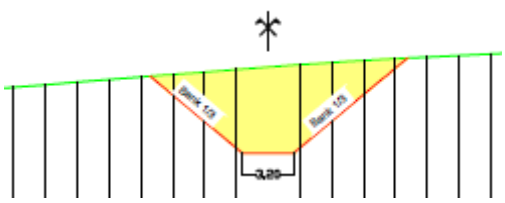


FIGURE 74 RU14B RIPRAP 0.05M

5.5.2.8 Reshaping of the channel

In order to prevent channels against erosion it is necessary to reshape the square channels into trapezoidal ones. It will be the base for the upper part of this wetland.





5.5.3 Public space actions

In order for the wetland to be accessible to and appreciated by the general public, a number of public space actions are proposed. These will bring the population into closer contact with the natural environment boosting their enjoyment of the site. These actions are detailed in the following paragraphs, and further details can be found in the Technical Specifications (chapter 8) and in Annex 3.5.

5.5.3.1 Creation of a suspended walkway

In order for the population to enjoy the beautification of Rugenge-Rwintare wetland, at the request of the Client, the Consultant has included the construction of a suspended walkway, which will allow people to move through the wetland without disturbing the natural environment, and with the elevation providing an impression of immersion whilst enjoying an overhead view of the location.

The image below provides an illustration of the structure to be built.

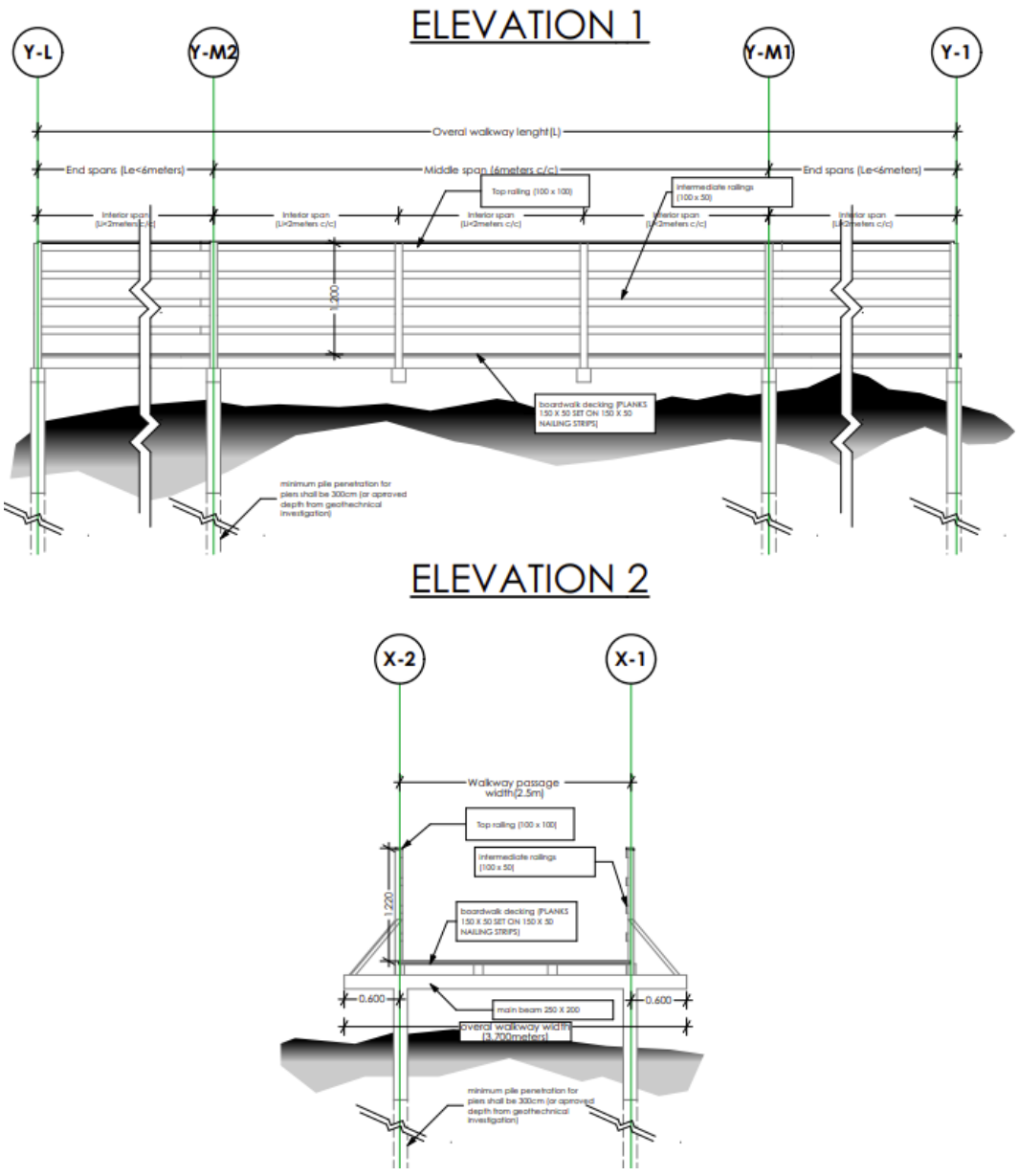


FIGURE 5-75 SUSPENDED WALKWAY IN RUGENGE-RWINTARE

The design of this structure was carried out with reference to the flood modelling in Annex 3.4 to ensure that regardless of the intensity of rainfall, the walkway is consistently above the water level. This is both to ensure

the stability and sustainability of the structure, as well as to ensure constant pedestrian access to the wetland for the population to discover the wetland in its variety of hydraulic states.

The suspended walkway will be equipped with guardrails for safety of both people and the natural habitats, and - in keeping with the environmental nature of the project - the suspended walkway will be constructed mostly out of treated timber. Concrete footings be necessary to ensure the stability of the structure, however these will remain buried and not visible.

Detailed drawings of the suspended walkway can be found in Annex 3.2

5.5.3.2 Opportunity node with pedestrian / cycling trails

In line with the wishes of the Client, Rugenge-Rwintare will be equipped with opportunity nodes which will provide income generating activities for local entrepreneurs. Kiosks will be constructed that will be rented out as concessions to be operated by individuals or companies for financial gain. The specific services to be provided is to be determined by the Client at a later stage, but could include food and drink, souvenirs, bookstands, etc. In order to fit any intended use the spaces are designed to be multipurpose and adaptable, not tailored to a single usage.

Additionally, pedestrian and cycling trails are to be constructed in Rugenge-Rwintare wetland to provide human access into the natural space enabling the population to enjoy the beauty of the wetland without risking any damage to the surrounding wildlife.

The trails can be used not only for access through and across the wetland but will enable leisure and sporting activities by promoting interconnectedness between the various services provided by the wetland, such as recreational areas, coffee bars, restaurants, opportunity nodes, sporting, educational and cultural facilities, and viewing areas.

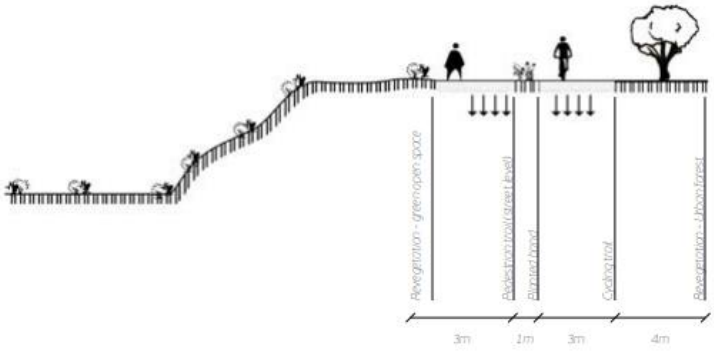


FIGURE 5-76 EXAMPLE OF A PEDESTRIAN/CYCLE PATH

The proposed pathways for Rugenge-Rwintare wetland will be enhanced with public furniture to render it more accessible and useful. This will include:

- Directional signage to indicate routes and destinations,
- Interpretive signage for educational purposes about the wetland,
- Lighting of pathways for ease of access and safety,
- Benches to allow people to sit and rest,
- Litter containers for the collection of refuse to avoid pollution of the environment,
- Bicycle racks to encourage soft mobility by ensuring the security of bicycles,
- Protective guarding along decks and other elevated structures.

Detailed designs of these interventions are provided in Annex 3.5

5.5.3.3 Green belt

The construction of a green belt surrounding Rugenge-Rwintare Wetland is proposed as it will have numerous benefits:

- Delineation of the wetland itself,
- Protection of the wetland from pollution originating in adjacent communities,
- Pedestrian/cycle access around the wetland,
- Elevated location providing views of the natural environment.

The principle is to produce a nature-based contour of the wetland that will provide these services. As such the area will be levelled, with a grassy space and treeline that will absorb runoff before it reaches the wetland, next to pedestrian pathway covered in volcanic paving stones, and a compacted laterite soil cycle path. Detailed designs are provided in Annex 3.5.

5.6 KIBUMBA WETLAND

5.6.1 Landscaping actions

5.6.1.1 Landscaping concept

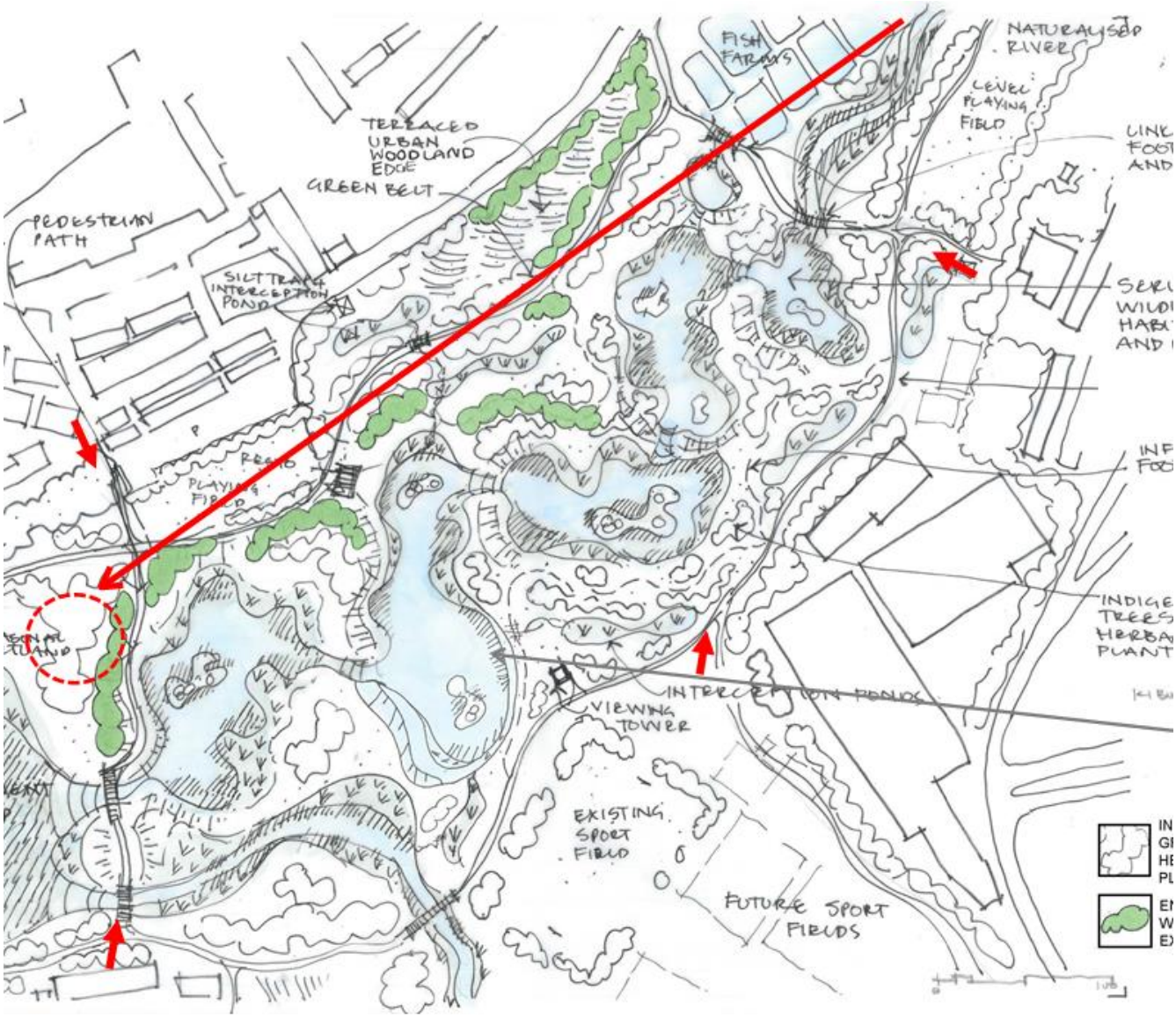


FIGURE 5-77: LANDSCAPING SKETCH OF KIBUMBA WETLAND

5.6.1.2 Garden of smell

A pattern of interlocking circular pergolas, supporting fragrant climbing and creeping plants and grasses. Wind sheltering pergolas, that capture the airborne scents of flowering creepers, aromatic shrubs, and the scented leaves of grasses, such as Lemon Grass and Vetiver planted in a leaf motif pattern.

FIGURE 5-78: GARDEN OF SMELL - KIBUMBA WETLAND

5.6.1.3 Proposed planted species

The ecological rehabilitation of Kibumba Wetland will entail the planting of the following species, in the following areas. Further details can be found in the Technical Specifications (chapter 8) and in Annex 4.2.

6 habitat typologies/target functional habitats have been identified in this area.

FIGURE 5-79: LOCATION OF KIBUMBA WETLAND

The following table shows the list of species suggestions for each typology. Life forms and expected functions for each species can be found in Chapter 8.1.

Habitat type/function	**Plant species**
1. Permanent wetland: Proposed native plant species adapted to the wetland environment are	*Cyperus papyrus* *Typha domingensis*

selected to enhance wetland restoration efforts. The species were identified based on their ecological function for wetland restoration through water retention, regulating water flow, filtering pollutants, soil stabilization, etc., and maintaining the health and biodiversity of these habitats in general.	*Cyperus denudatus* *Cyperus dives* *Juncus effusus* *Persicaria decipiens* *Ludwigia abyssinica*
2. Seasonal wetland: Proposed native plant species adapted to the wetland environment are selected to enhance wetland restoration efforts. The species were identified based on their ecological function for wetland restoration through water retention, regulating water flow, filtering pollutants, soil stabilization, etc., and maintaining the health and biodiversity of these habitats in general.	*Cyperus latifolius* *Cyperus articulatus* *Leersia hexandra* *Brachiaria humidicola* *Panicum maximum* *Echinochloa pyramidalis* *Brillantaisia cicatricosa*
3. Green belt: This is an upland strip along the wetland. Proposed species will primarily serve to enhance urban biodiversity, provide habitat for wildlife that use the wetland for food or shelter, and provide cultural services with focus on ornamentals amenities.	*Blighia unijugata* *Croton megalocarpus* *Delonix elata* *Dodonaea viscosa* *Elaeis guineensis* *Entada abyssinica* *Ficus sycomorus* *Ficus vallis-choudae* *Kigelia africana* *Maesopsis eminii* *Markhamia lutea* *Olea europea* subsp. *africana* *Podocarpus latifolius* *Polycias fulva* *Pterygota mildbraedii* *Senegalia polyacantha* *Spathodea campanulata* *Sterculia tragacantha* *Syzygium guineense*
4. Recreational areas: Proposed species for these areas will offer opportunities to accommodate visitors to the wetland and provide facilities such as shades for parking lots and picnic areas. These will also serve to educate visitors about the wetland ecosystem and importance of wetland conservation.	*Croton megalocarpus* *Ficus sycomorus* *Kigelia africana* *Maesopsis eminii* *Olea europea* subsp. *africana* *Podocarpus latifolius* *Polycias fulva* *Pterygota mildbraedii* *Senegalia polyacantha* *Spathodea campanulata* *Sterculia tragacantha*
5. Stream banks: The stream banks will be covered in vegetation to play a role of stabilizing stream banks, providing habitat for wildlife, and filtering pollutants.	*Phragmites mauritianus* *Aeschynomene elaphroxylon* *Sesbania sesban*
6. Pond areas: Floating plants of water lilies are proposed for ornamental purposes. These will also serve to improve water quality in the ponds and reduce the growth of algae and other harmful organisms. It is recommended to regularly control the lilies to maintain a healthy ecological balance and avoid oxygen depletion in the water. The African oil palm will be planted for ornamental purposes around the ponds	*Nymphaea nouchali* *Elaeis guineensis*
7. Landscape park: Proposed species will primarily serve to enhance urban biodiversity, provide habitat for wildlife that use the wetland for food or shelter, and provide various cultural services.	*Blighia unijugata* *Croton megalocarpus* *Delonix elata* *Dodonaea viscosa*

	Elaeis guineensis *Entada abyssinica* *Ficus sycomorus* *Ficus vallis-choudae* *Kigelia africana* *Maesopsis eminii* *Markhamia lutea* *Olea europea* subsp. *africana* *Podocarpus latifolius* *Polycias fulva* *Pterygota mildbraedii* *Senegalia polyacantha* *Spathodea campanulata* *Sterculia tragacantha* *Syzygium guineense*

TABLE 5-18 LIST OF PLANT SPECIES IN KIBUMBA WETLAND

5.6.1.4 Soil reshaping for wetland creation

The objective of this action is to carry out earthworks that will modify the topography of the wetland for ecological and aesthetic purposes.

Existing low points in the wetlands will be identified and the surrounding areas will be excavated in order to expand these locations into low areas that will preferentially accumulate water. Excavated soil will be used to backfill the existing water course as well as to enhance nearby high points.

The immediate outcome of this action will be a sloped but unchanneled terrain which will allow water to flow diffusely and slowly through the wetland. The final result is the creation of different areas of wetland based on their elevation. Specifically, this will result in permanent wetlands in the low points where the soil will be constantly waterlogged, and seasonal wetlands which will periodically receive inflows of water.

The greater retention time of water in the low points mean that it provides an excellent opportunity for the treatment of inflows coming from upstream or neighbouring built-up areas, a process which can be accentuated by the planting of appropriate plant species.

The difference in water content of the soil due to elevation differences will also promote the creation of a variety of flora, which will have two co-benefits

- Additional habitat creation for local fauna, promoting biodiversity,
- The wide diversity of plant species will allow for a more varied beautification of the site.

Proposed wetland reshaping actions are located as per the zoning maps under labels K13a, K13b and K13c and are illustrated in the figures below. The detailed site plans and cross sections are provided in Annex 4.2.

FIGURE 5-80: SOIL RESHAPING FOR WETLAND CREATION – K13A

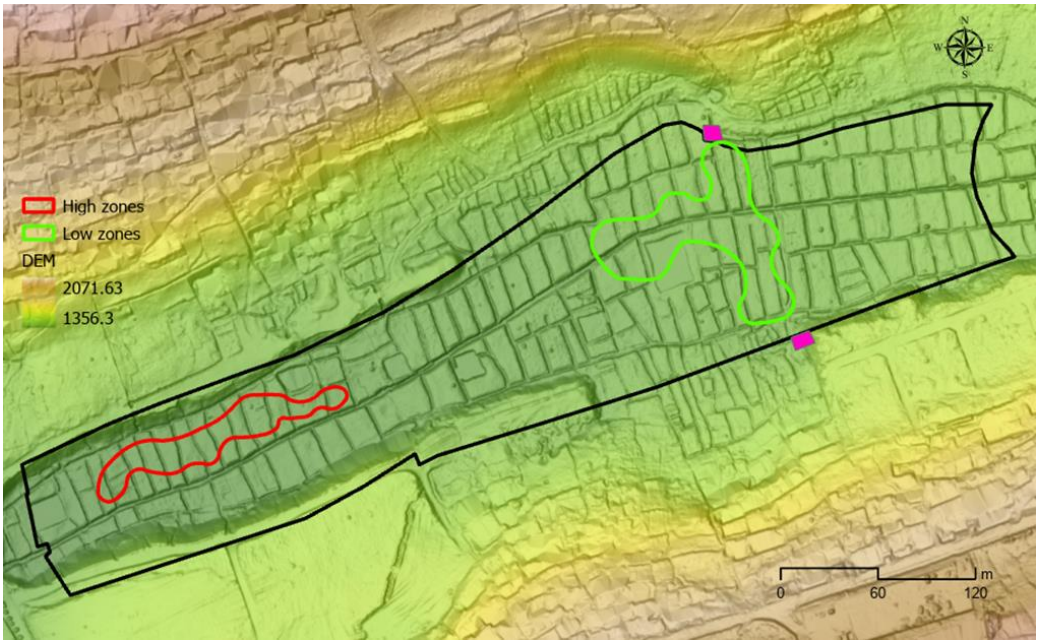


FIGURE 5-81: SOIL RESHAPING FOR WETLAND CREATION - K13B

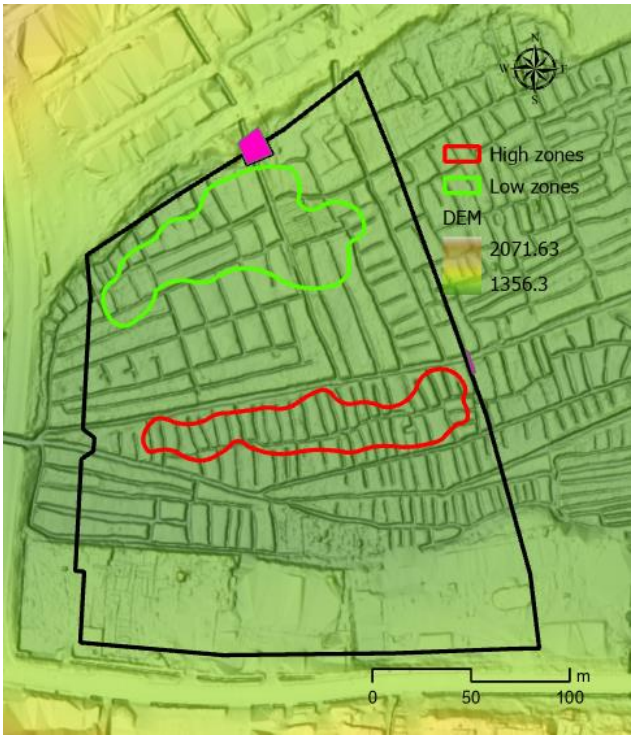


FIGURE 5-82: SOIL RESHAPING FOR WETLAND CREATION – K13C

5.6.1.5 Creation of an island for aesthetic appearance

At the request of the Client, six landscaped islands are proposed to be constructed in Kibumba wetland (K14a, K14b, K14c, K14d, K14e, K14f). This will provide an elegant form emerging from the ponds and lakes in this wetland increasing biodiversity.

Detailed designs can be found in Annex 4.2.

5.6.2 Hydraulic actions

The hydraulic actions designed in this project seek to reinstate or enhance the hydraulic functioning of the 5 wetlands, mostly through modifications of the flows through the project area with the following objectives:

- Promoting water retention in the wetlands to prevent damaging flooding events,
- Reducing the flow through the wetlands to limit erosion,
- Spreading of water flows to provide maximum absorption and reduce downstream flows and velocities,
- Provide favorable aquatic environments for fauna and flora,
- Improve water quality.

As explained in paragraph 3.2.3, a variety of actions are planned with each wetland receiving interventions tailored to the wetland's objectives.

In accordance with the Master Plan for Rugenge-Rwintare (Annex 4.1), the detailed design was carried out as below for the specific interventions proposed for the wetland, which is developed hereunder. Further details can be found in the Technical Specifications (chapter 8) and in Annex 4.3.

5.6.2.1 Sediment traps for blockage of sediments into the wetland

The hydraulic outfalls from lateral drainage carry effluents from the neighbouring urbanized areas, which are charged with sediment, and convey them into the wetland. Originally built to drain plots for agricultural purposes they are relatively deep (about 2m) and consequently convey water rapidly downstream, which is in opposition to the role and functioning of the wetland.

The construction of sediment traps is therefore proposed to counteract this effect. A sediment trap is a containment area that allows sediment in collected storm water to settle out during the runoff is discharged through a stabilized spillway/dewatering pipe.

Due to the very large amount of waste of varying sizes coming from the sides, and the lack of a large-scale collection system over most of the study area, sediment traps will be installed at each drain stop in the wetland.

It is very important to note that each sediment trap was designed specifically, depending on the reality of each drain. The drawings are given in Annex 4.3, examples are provided hereunder.

The Consultant considered the use of vegetation on the gabions forming the sediment trap elements. This solution was not retained for the following reasons:

- the water arrives at a high speed which requires the installation of gabion mats with a tight mesh to ensure stability
- in these conditions, vegetation would not be able to develop properly and would represent a significant hindrance to the maintenance of the structures.

3 types of sediment traps were defined according to the context, here is an example:

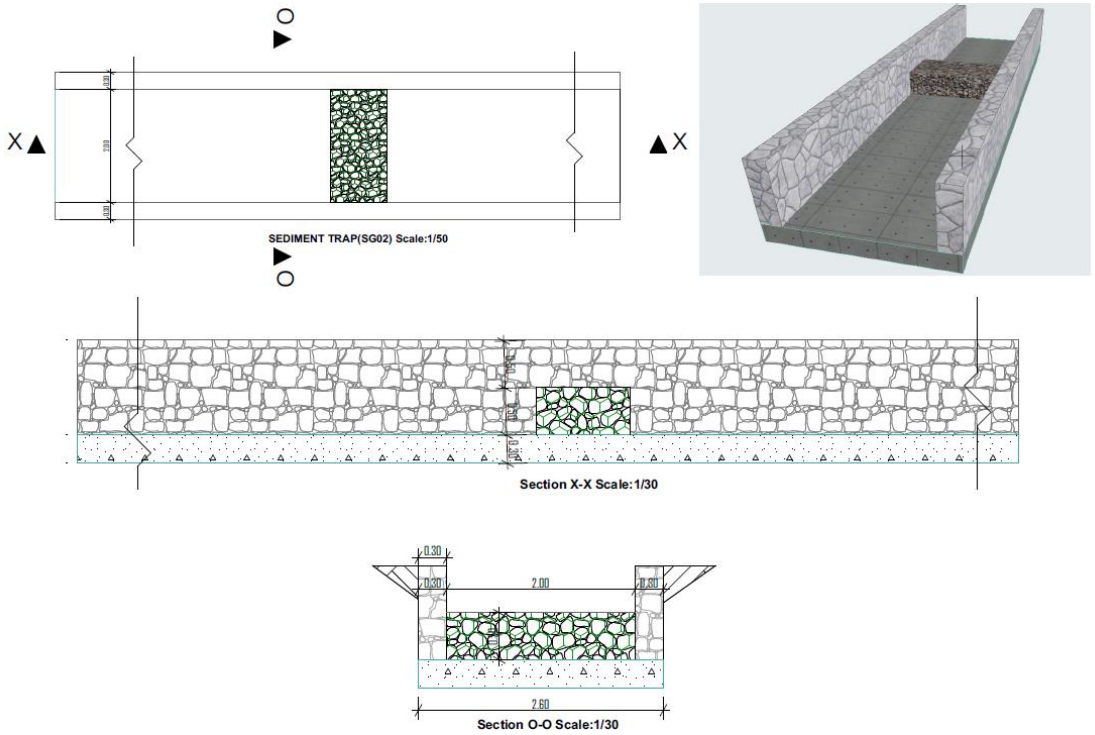


FIGURE 5-83: EXAMPLE OF SEDIMENT TRAP

At the outlet of the structure, a gabion wall filled with river stones will ensure that the flow is spread across the floor of the wetland. This will combine with the landscaping action K13 “soil reshaping for wetland creation” which specifically incorporates interventions to receive inflows from lateral drainage. This will limit its velocity thereby retaining it in the wetland, where it can be naturally treated of other pollutants (chemical and biological). This treatment is reinforced by appropriate plant selection as explained in paragraph 5.3.1.

The result is primarily to improve the quality of the water, but it will also contribute to increasing the height of the water table and limiting flooding downstream.

The construction of these traps can only be carried out with the use of concrete for the base and walls of the structure; however gabion and river stones are also incorporated into its construction to constitute the trap. The trap will require periodic manual emptying to ensure it remains effective, as once it is full the sediment will simply continue its path into the wetland.

5.6.2.2 Water conveying structure to block and channel water to the main stream

The intervention consists in the construction of a dike spanning the width of the valley at the outlet of the wetland to collect and concentrate the water flowing out of the wetland, which will effectively create an artificial lake. A channelling structure will be constructed as part of the dike to convey all the water towards the meandering watercourse downstream.

The Consultant has considered employing nature-based solutions as much as possible. As such, the dike will be constructed of compacted earth, covered in turf. Volcanic paving stones will be used to create the path along the top of the dike with wooden handrails for safety reasons.

However, for the critical element of the conveying structure, the space allowing the passage of water collected by the dike into the subsequent channel it was necessary to retain concrete for the construction. This was to ensure the long-term sustainability of the structure, which would be affected by two main factors:

- The strength requirements in order to withstand the static and dynamic (hydraulic) loads.
- The risk of erosion by water velocity through the structure.

The use of concrete is minimized insofar as the outlet of the conveying structure consists of gabion walls (with wire mesh coated with green PVC) and river stones that will prevent shearing and erosion of the banks at the entrance to the downstream channel.

An example of the proposed water conveying is provided in the image below.

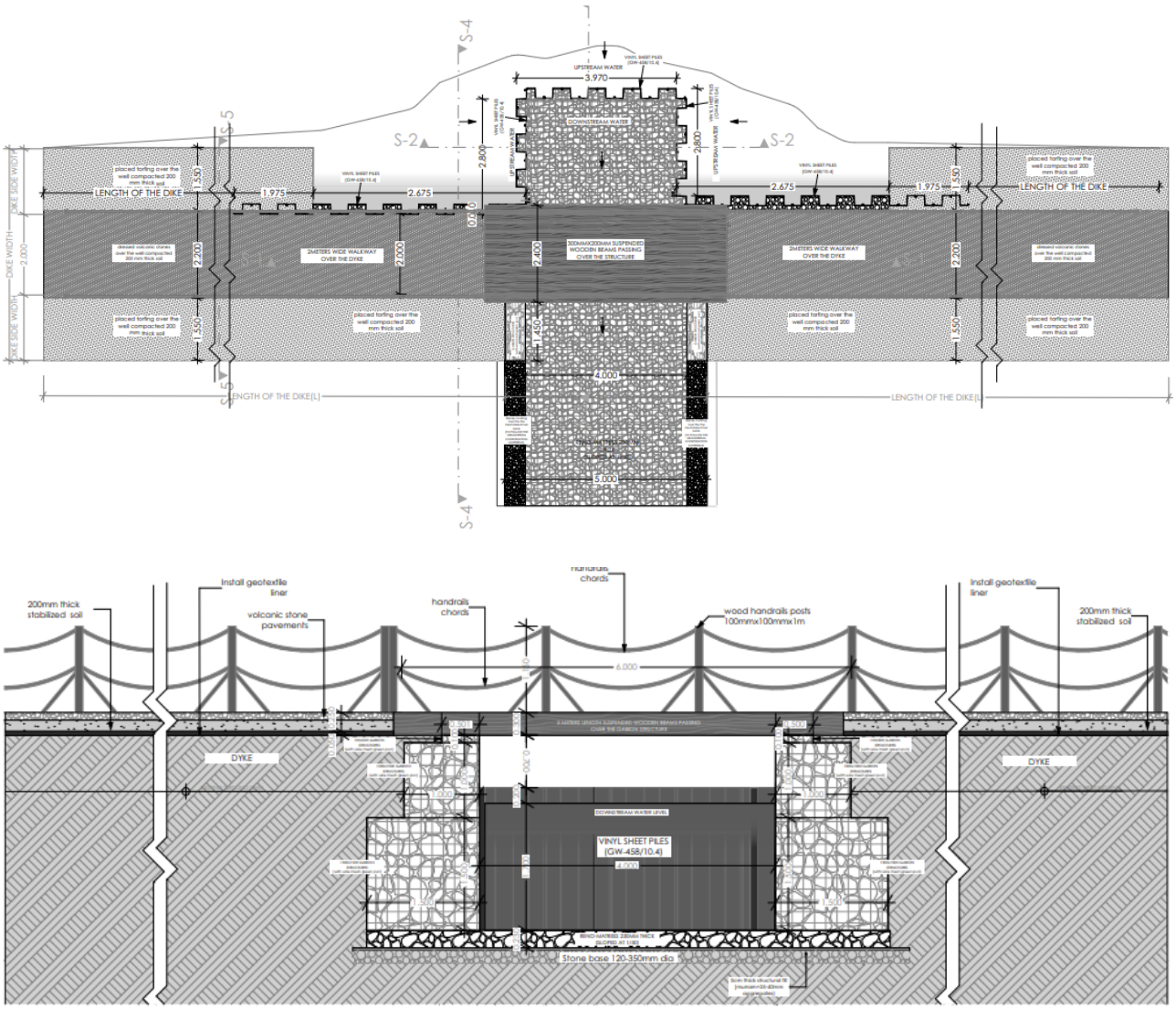


FIGURE 5-84: EXAMPLE OF A WATER CONVEYING STRUCTURE

The Contractor will be responsible for the verification of the structural stability and quantities required for the structure's construction, based on the real conditions identified during implementation.

The Consultant verified the impact of the blocking and channeling structure on the flow of water through the wetland, by:

- Modelling dam with corresponding height
- Considering rainfalls of increasing intensity (T2 and T10 at current urbanisation levels, and T2, T10, T50 with 2050 urbanisation projections)
- Considering modifications by YREC following their hotspot study.

In this case, only low intensity return periods are relevant, however it is still interesting to see how the modifications will also react to high intensity flood.

The results for a T2 rainfall before and after intervention are presented in the image below, however the complete modelling results are provided in Annex 4.4.

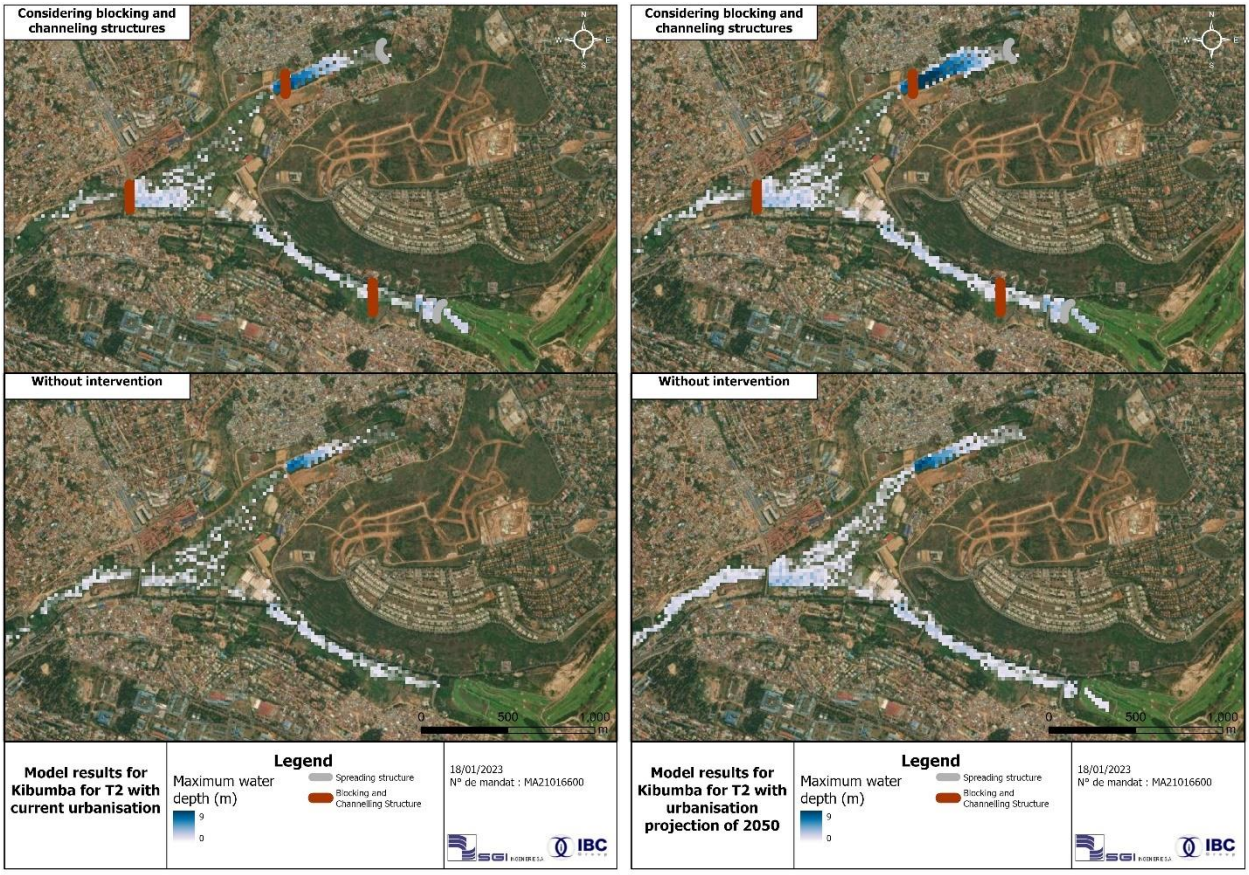


FIGURE 5-85: WATER DEPTHS FOR A T2 RAINFALL BEFORE AND AFTER INTERVENTION IN KIBUMBA WITH CURRENT AND 2050 URBANISATION LEVELS

It has been identified that the implementation of a spreading structure in the upper south of the wetland could generate a risk of backflow in the golf that is upstream during the floods. To prevent this issue, a diversion channel has been designed to divert the flood discharge before the spreading structure. For this purpose, a lateral spillway is placed before the spreading structure and sized to spill every discharge higher than 2 years return period into the diversion channel.

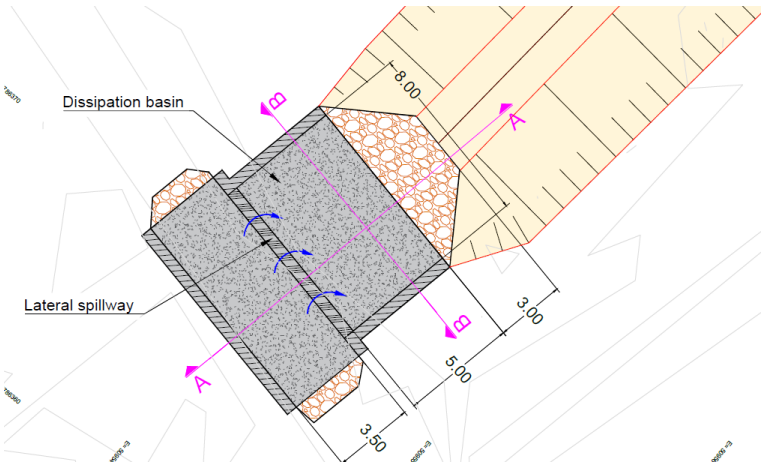


FIGURE 86 - LATERAL SPILLWAY FOR THE DIVERSION CHANNEL

At this location the riverbed is about 3.5m wide. The structure is then a rectangular channel with a length of 10m and a depth of 2m. The 2 years discharge is about 11 m^3/s and corresponds to a water height of 1m in

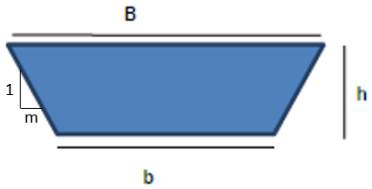
the structure which will be the height of the spillway. The width of the spillway is then calculated using the standard weir formula:

$$Q = L_d \cdot m \cdot \sqrt{2g} \cdot h^{3/2}$$

with a weir coefficient m = 0.4, L_d the width of the spillway and h the water height above the spillway.

The spillway will be 7m wide which will allow to divert the majority of the flow during flood, see the graph here after:

The diversion channel is sized for such discharges as a trapezoidal channel with a bottom width of b:3m, an embankment slope of 2:1 and a depth of h:2m.



As the diversion channel will not always be filled with water, it will need to be serviced to prevent overgrowth of vegetation in it.

5.6.2.3 Blocking of surface drains (agriculture drains)

Previous agricultural use has resulted in the creation of drains, originally constructed to facilitate the development of intensive agriculture, thereby strongly impacting the hydraulic dynamics of the wetland and its waterlogging.

The objective of the drains is to convey water rapidly downstream, away from farmed areas, which contributes to the lowering of the water table and the rapid drying of the soil. In addition to excavated drains, soil embankments raise the channel level above natural ground level in order to prevent the flooding of crops during heavy rains. However, with the repurposing of the wetland site for flood management, ecological and aesthetic purposes, it is essential to retain water within the wetland, which is in firm opposition to the existing land use.

The objective of this action is therefore to prevent water from flowing in preferential paths, but to flow diffusely through a restored homogenous surface of the wetland. The water's flow rate will consequently be reduced as

will associated erosion problems, and the water table will rise to provide a better environment for fauna and flora.

In order to achieve this objective, the ground level will be restored to a homogenous generally flat surface, devoid of drainage network. This will require two distinct actions illustrated in the images below:

- The backfilling of the agricultural ditches with soil
- The removal of soil embankments above natural ground level.

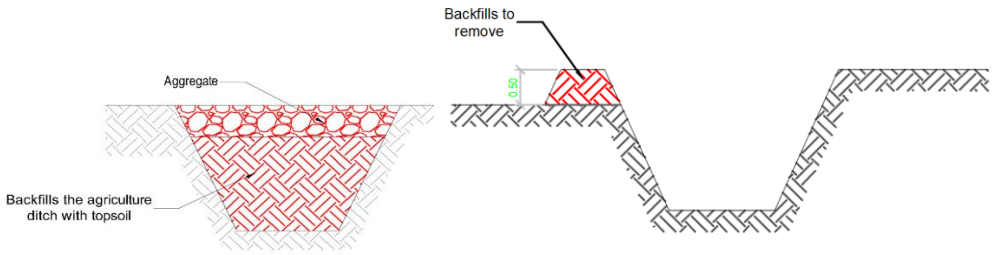


FIGURE 5-87: CROSS-SECTION OF AGRICULTURAL DRAINS

The soil from the embankments can be used to infill the drains however the available volume will be insufficient, and soil importation will be required. The topsoil used for this purpose must be free of any invasive plant species or pollutants. The agriculture drains located in Kibumba will be completely backfilled.

The volume of topsoil needed to fill the trapezoidal shaped drains is calculated with the following formula:

$$V = S \cdot l \cdot n \quad \text{with } S = h \cdot (\text{a} + \frac{b-a}{2})$$

Where:

- l is the length of the drains
- S the surface of the drain
- n the number of drains,
- h the depth of the recharge bed
- a and b the channel width at the base and surface respectively.

In Rwampara, the drains have a mean width of 1.5m at the base and 2.3m at ground level, and a height of 1.5m, resulting in a cross section of 2.59m^2. The volume of channel to be backfilled is presented in the table below.

Channel	Length of drainage (m)	Section of channel (m2)	Volume of backfill (m3)
K03a	1329.1	2.59	3439.0
K03b	2102.0	2.59	5439.0
K03c	2406.8	2.59	6227.6
K03d	3221.6	2.59	8335.9
K03e	1158.6	2.59	2997.9

TABLE 5-19 VOLUME OF BACKFILL IN AGRICULTURAL DRAINS IN KIBUMBA

From this volume is removed the available soil from the embankments. The backfill sections have a mean section of 0.14m^2. The volume represented by this infill is calculated as per the following equation and is presented in the table below.

$$V = \text{number of drains} \cdot \text{length of the drain} \cdot \text{mean section surface of the backfill}$$

Channel	Length of drainage (m)	Volume of infill (m3)
K03a	1329.1	186.1
K03b	2102.0	294.3
K03c	2406.8	336.9
K03d	3221.6	451.0
K03e	1158.6	162.2

TABLE 5-20 VOLUME OF SOIL IN EMBANKMENTS IN KIBUMBA

Since the soil from the embankments can be utilized to backfill the drainage, the table below presents the balance of soil to be imported from elsewhere for the complete backfilling of the agricultural ditches.

Channel	Volume of soil to import (m3)
K03a	3253.0
K03b	5144.8
K03c	5890.6
K03d	7884.9
K03e	2835.7

TABLE 5-21 VOLUME OF SOIL TO BE IMPORTED FOR BLOCKING OF AGRICULTURAL CHANNELS IN KIBUMBA

5.6.2.4 Water spreading structure to spread water into the wetland

The intervention consists in the modification of the flow of water out of the channel from which it originates into a more diffuse flow that spreads across the wetland. The objective of this intervention is to ensure an even spreading of the water throughout the wetland to achieve maximum speed and flow reduction, which will not only prevent flooding, but also improve water quality and retain water in the wetland site to better promote growth and habitat creation.

The Consultant has considered employing nature-based solutions as much as possible, and relies on a two-pronged approach to force the flow to diverge:

- Earthworks: At the approach to the wetland area, the soil will be mechanically shaped into a slightly conical form that will encourage water to flow laterally through gravity.
- Gabion walls: To further encourage the water to spread laterally across the wetland floor, gabion walls of increasing length will be constructed across the wetlands to reinforce the redirection of the flow as the water passes through them.

This construction will have the following impacts:

- Even spreading of the incoming water across the span of the wetland, making maximum use of the available space.

- Reduction in the speed of water limiting erosion and promoting sedimentation.
- Increased absorption and raised level of the water table.
- Improved water quality.

An example of the proposed spreading structure is provided in the image below.

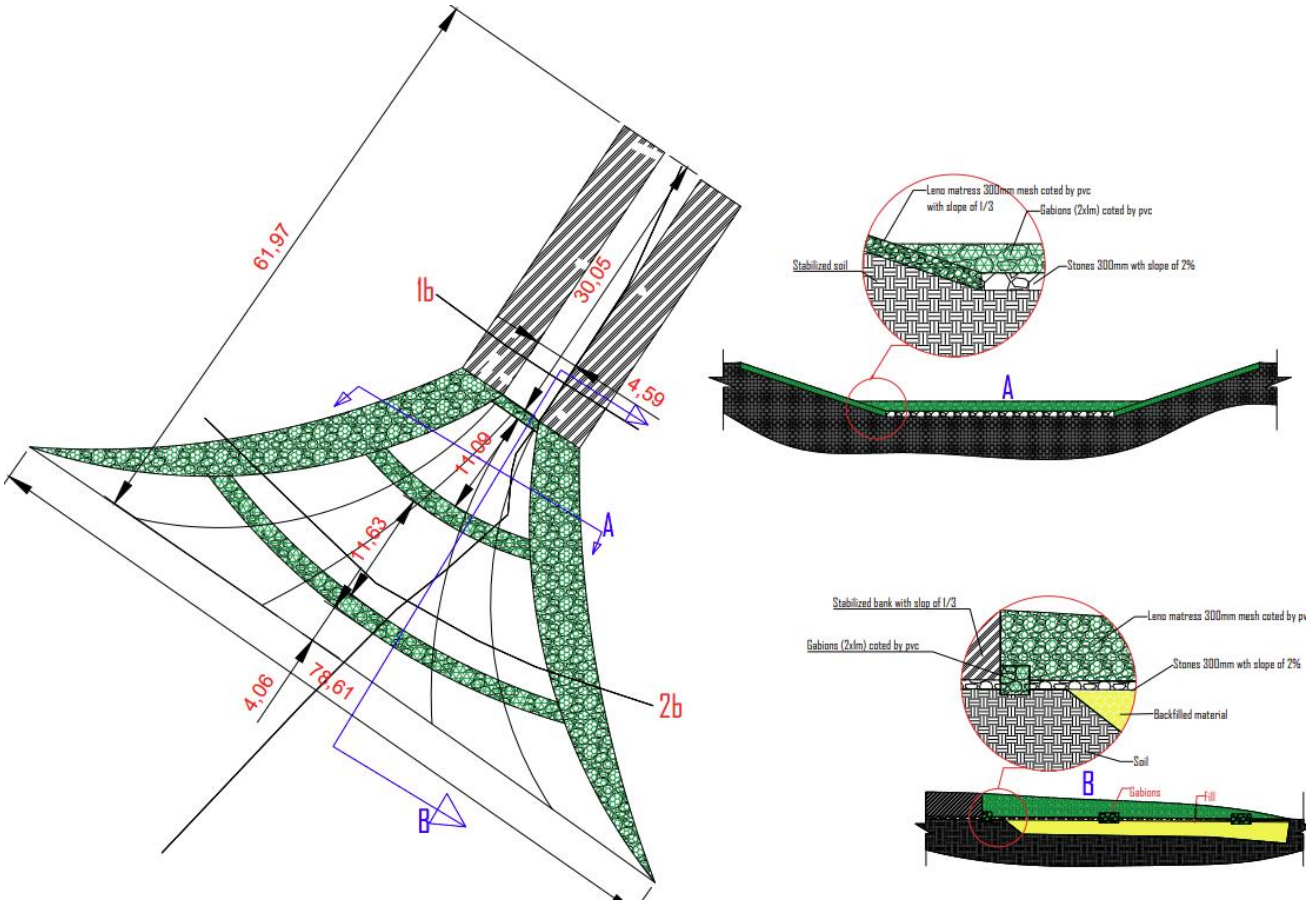


FIGURE 5-88: EXAMPLE OF A FLOW SPREADING STRUCTURE

The contractor will be responsible for the verification of the structural stability and quantities required for the structure's construction, based on the real conditions identified during implementation.

5.6.2.5 Creation of ponds to support wildlife and aesthetic appearance

At the request of the Client, a cascade of small ponds with island have been added to the wetland, in order to provide a viable habitat for wildlife, as well as to enhance the natural beauty of the site.

The ponds are design based on a residence time of the water of 24 hours, which allows for sufficient renewal to support aquatic life, while also providing some water quality benefits (such as sedimentation).

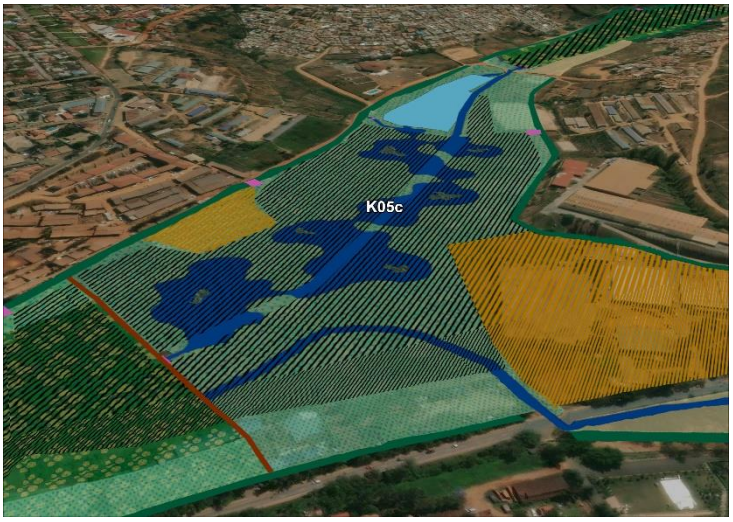


FIGURE 5-89: LOCATION OF THE TWO PONDS IN KIBUMBA WETLAND

5.6.2.6 Re-profiling the river with meanders and banks

The action of re-meandering within the framework of this wetlands consists in artificially recreating this natural functionality of the river, altered by past human interventions. The purpose of such an intervention is multiple since it aims:

- To mitigate the impacts linked to the incision of the minor bed (lowering of the water table, lowering of the surface area of the flooded zones, acceleration of the flows...).
- To slow down the dynamics of water allowing to reduce the flood wave downstream.
- To lengthen the line of the watercourse and thus to multiply the contacts between ground and water (ecotone*), possible places of purification.
- To find a diversity of natural habitats for animal species which is much more important in meandering streams than in straight streams. The work of the banks in different levels (height defined according to the flows of reference floods) will also allow to support this diversification.

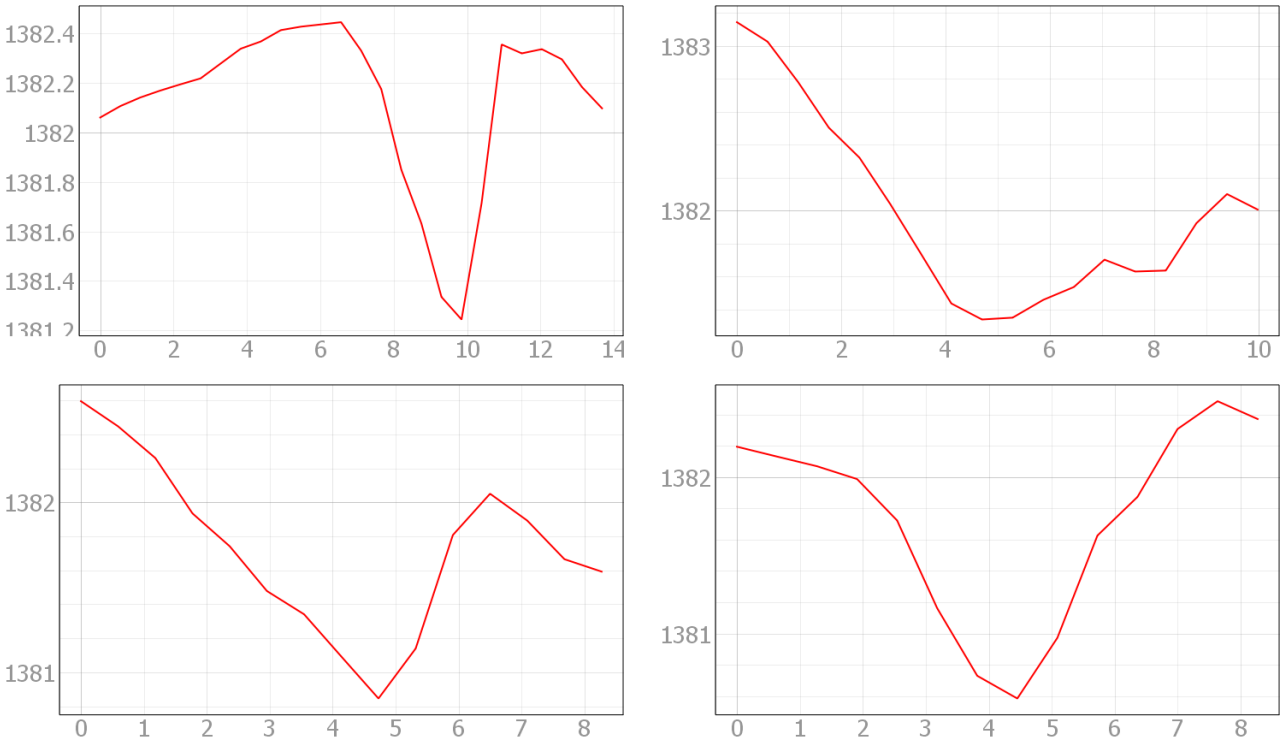
For this action to be implemented, the primary space of the river need to be restored as per the methodology presented in paragraph 5.2.4.2. Large banks need to be designed which will act as a buffer zone during the rainfall storm events, and riprap will be installed at the outer curves of the meanders to prevent erosion as illustrated in the figure below.

FIGURE 5-90: EXAMPLE OF RIVER MEANDERING AND EXTERNAL BANKS PROTECTION WITH GABIONS

River meandering in Kibumba wetland has been designed in one area according to the wishes of the Client. Meandering zone K10 is described hereafter, and the detailed designs can be found in Annex 4.3.

Seven cross sections have been extracted in order to find the mean width of the existing river. This will be used in order to design the meanders of this river section.

FIGURE 5-91: CROSS SECTIONS LOCATION IN THE EXISTING RIVER SECTION WHERE MEANDERS 1 WILL BE IMPLEMENTED



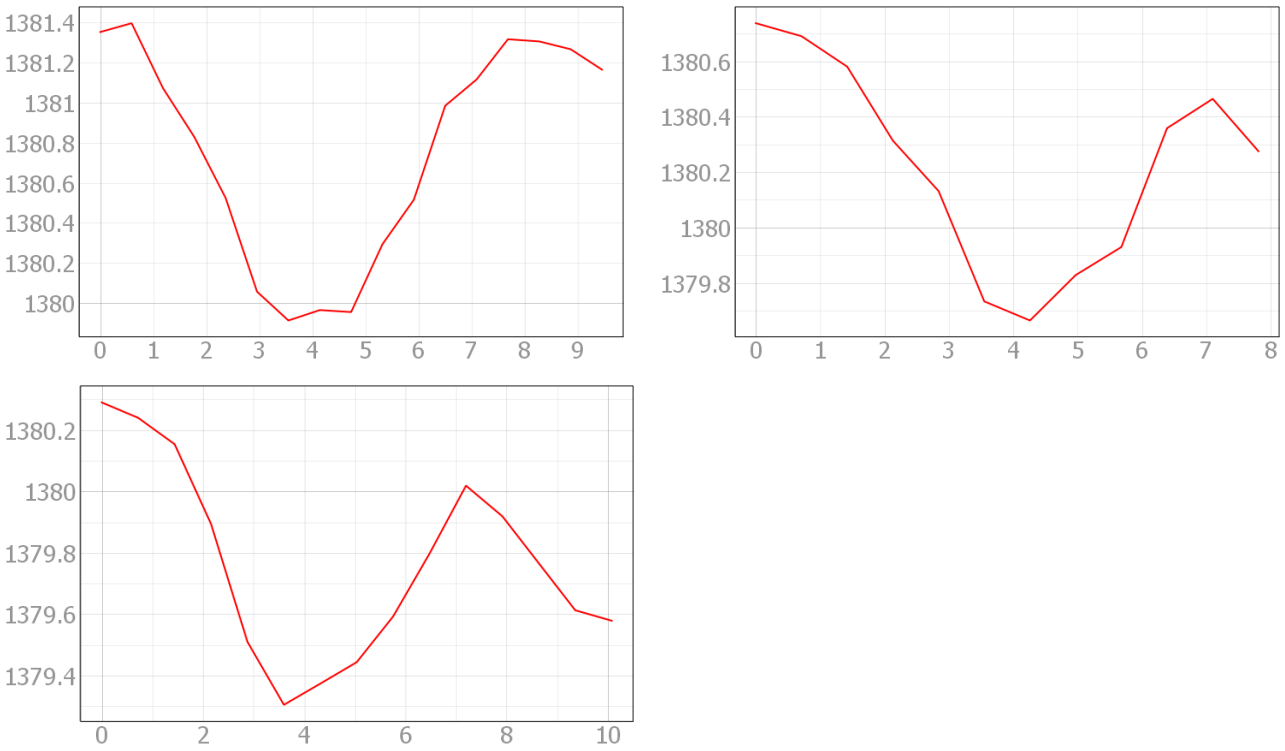


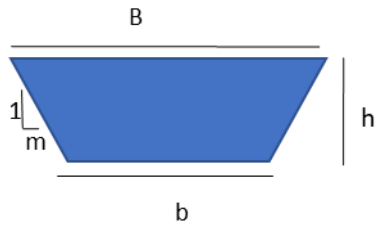
FIGURE 5-92: CROSS SECTIONS PROFILE IN THE EXISTING RIVER SECTION WHERE MEANDERING K10 WILL BE IMPLEMENTED

The space available for river meandering is limited to an amplitude of 30m, which results in a channel with a 3m width at ground level. To avoid the existing pond the wavelength of the meander needs to be above 90m, hence the new sinuosity of the channel P = 1.23.

FIGURE 5-10: MEANDER IN KIBUMBA

The discharge through this channel is 2.2 m3/s, therefore the dimensions of the channel are determined as follows:

S0	m	b (m)	h (m)	B (m)
0.0035	0.28	2.5	0.9	3.0



Due to high velocities, it will be necessary to protect the outer curves of the river from scouring and erosion. In order to respect the environmental spirit of the project, the Consultant is proposing to use riprap for this purpose. The riprap at the outside curve of the meanders should at least have a diameter of 0.03 m.

5.6.2.7 Transition structures with hotspots

Specific infrastructure defined through flood hotspots project (under the supervision of CoK) will be constructed in the wetland area. It is important to define a precise coordination for the execution of the works so that the different companies have sufficient flexibility, and the works can be carried out in a consistent manner.

It was agreed that:

- A band of 15m upstream and 15m downstream the limit of the future hotspots infrastructure is defined without and action form wetland project, keeping the required flexibility.
- The transition structure between the rivers/canals of the wetlands and the future culverts/canals of the hotspot project are included in the wetlands actions (see specific detail plan)
- For a perfect coordination the following information is given for each wetland: altitude and section of the channel upstream and downstream of the sectors with hotspot action

At the location where there is hotspot structure, the link between the structure for road crossing (culvert or bridge) a transition structure is needed for energy dissipation and prevent the erosion of the canal at then inlet and outlet of the structure due to the turbulence generated as these transition sections.

At the upstream part, the transition is a contraction of the channel from a trapeze section to a rectangular section. This contraction increases the flow speed threatening the riverbed with erosion. In order to protect the channel, this section needs to be reinforced by ripraps of a size calculated the same way as defined in part

At the downstream part, the transition is the opposite with an expansion from a rectangular shape to a trapeze. As the flow slow down, the energy dissipation can erode the riverbed, hence some ripraps to protect the bed.

The length of the transition section is defined by L = 2B where B is the width of the channel.

FIGURE 93 - K17A RIPRAP 0.05M

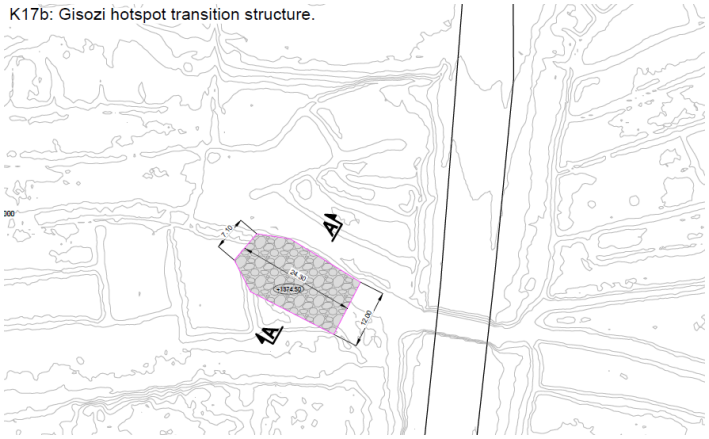


FIGURE 94 - K17B RIPRAP OF 0.05M

5.6.3 Public space actions

In order for the wetland to be accessible to and appreciated by the general public, a number of public space actions are proposed. These will bring the population into closer contact with the natural environment boosting their enjoyment of the site. These actions are detailed in the following paragraphs, and further details can be found in the Technical Specifications (chapter 8) and in Annex 4.5.

5.6.3.1 Enhancing recreational area and walking/cycling trails

In order for the population to enjoy the beautification of Kibumba wetland, at the request of the Client, the Consultant has included the construction of a suspended walkway, which will allow people to move through the wetland without disturbing the natural environment, and with the elevation providing an impression of immersion whilst enjoying an overhead view of the location.

The image below provides an illustration of the structure to be built.

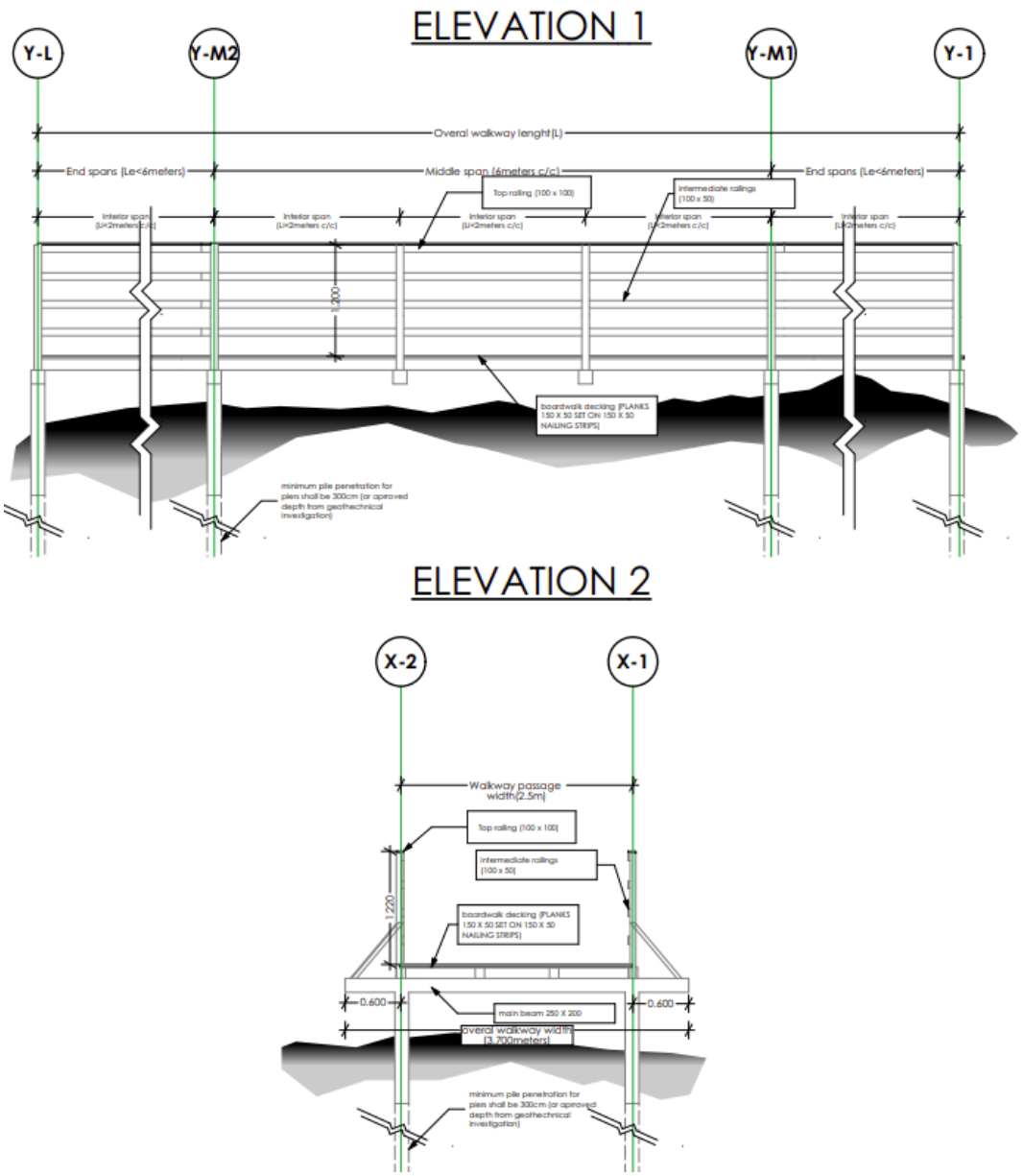


FIGURE 5-95 SUSPENDED WALKWAY IN KIBUMBA

5.6.3.2 Pedestrian / Cycling Trails

Pedestrian and cycling trails are to be constructed in Kibumba wetland to provide human access into the natural space enabling the population to enjoy the beauty of the wetland without risking any damage to the surrounding wildlife.

The trails can be used not only for access through and across the wetland but will enable leisure and sporting activities by promoting interconnectedness between the various services provided by the wetland, such as recreational areas, coffee bars, restaurants, sporting, educational and cultural facilities, and viewing areas.

FIGURE 5-96 EXAMPLE OF A PEDESTRIAN/CYCLE PATH

The proposed pathways for Kibumba wetland will be enhanced with public furniture to render it more accessible and useful. This will include:

- Directional signage to indicate routes and destinations,
- Interpretive signage for educational purposes about the wetland,

- Lighting of pathways for ease of access and safety,
- Benches to allow people to sit and rest,
- Litter containers for the collection of refuse to avoid pollution of the environment,
- Bicycle racks to encourage soft mobility by ensuring the security of bicycles,
- Protective guarding along decks and other elevated structures.

Detailed designs of these interventions are provided in Annex 4.5

5.6.3.3 Green Belt

The construction of a green belt surrounding Kibumba Wetland is proposed as it will have numerous benefits:

- Delineation of the wetland itself,
- Protection of the wetland from pollution originating in adjacent communities,
- Pedestrian/cycle access around the wetland,
- Elevated location providing views of the natural environment.

The principle is to produce a nature-based contour of the wetland that will provide these services. As such the area will be levelled, with a grassy space and treeline that will absorb runoff before it reaches the wetland, next to pedestrian pathway covered in volcanic paving stones, and a compacted laterite soil cycle path. Detailed designs are provided in Annex 4.5.

5.7 NYABUGOGO WETLAND

5.7.1 Landscaping actions

5.7.1.1 Landscaping concepts

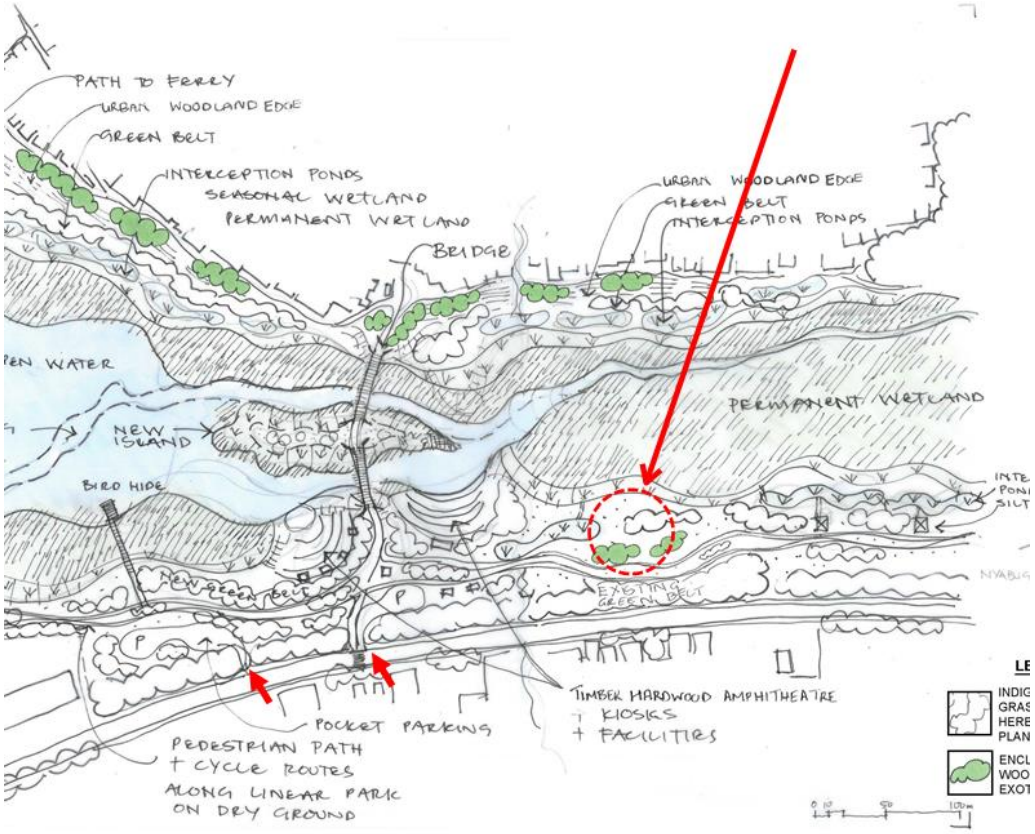


FIGURE 5-97: LANDSCAPING SKETCH N° 1 OF NYABUGOGO WETLAND – GARDEN OF TASTE

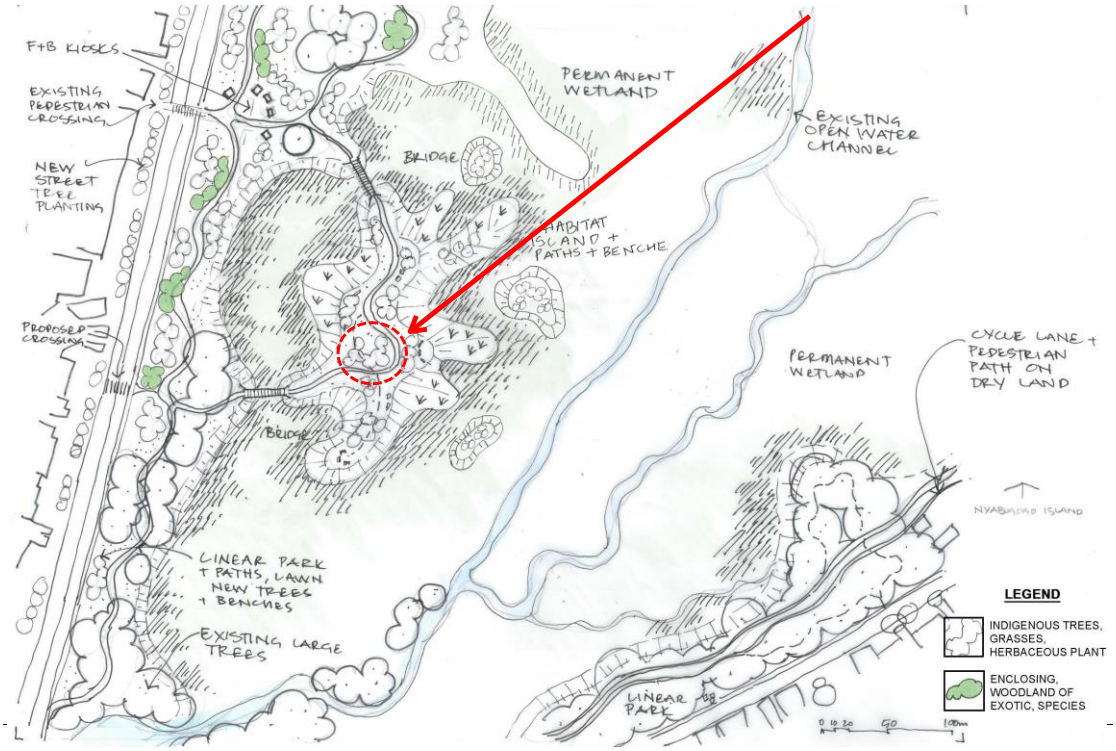


FIGURE 5-98: LANDSCAPING SKETCH N° 2 OF NYABUGOGO WETLAND – GARDEN OF SILENCE

5.7.1.2 Garden of taste

A heady plant recipe of taste, texture for the tongue.

FIGURE 5-99: GARDEN OF TASTE - NYABUGOGO WETLAND

An organic orchard of edible, indigenous fruits and fungi that may be tasted in an organised educational tour according to season. Includes fruit bearing vines, and catch crops, such as bananas, litchis, and other tropical fruits around the edges of circular spaces. Beneath the central circular pavilion there is a pedagogic display explaining the story of coffee and tea and perhaps even a café and exhibition space. Above sits an accessible rooftop garden built out of recycled plastic crates as per the picture above, to encourage positive waste recycling. Completed by a fungus under canopy in 'Dark Walk'.

5.7.1.3 Garden of silence

A simple, circular garden court centred on a circular, ripple basin and slow spout.

A place of calm and quiet with a narrow slot view onto the world outside. In season lilies bloom then disappear.

This last garden is a simple contemplative space in which to reflect on silence, scenery, and space. It is an enclave made of local stone. A shelter with a scenic outlook point. Insite a large, heavy basin catches an unpredictable occasional drop of water.

One that sends out ripples round our world. Just as each of us do…

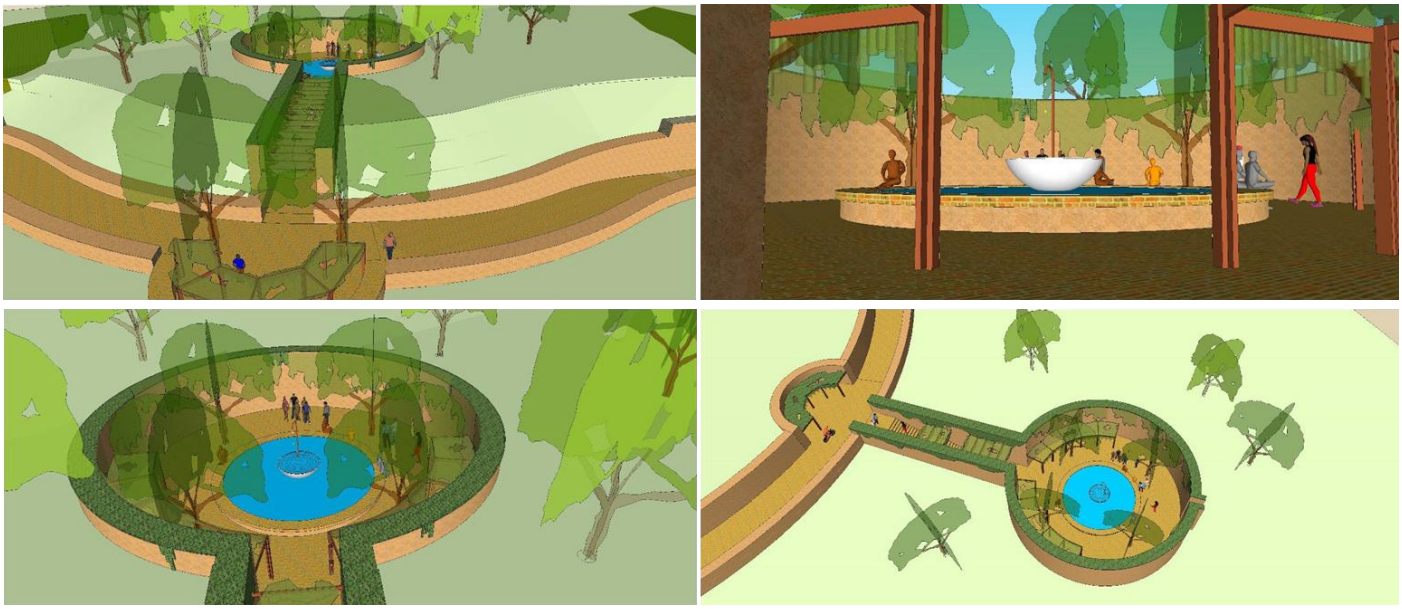


FIGURE 5-100: GARDEN OF SILENCE - NYABUGOGO WETLAND

5.7.1.4 Proposed planted species

The ecological rehabilitation of Nyabugogo Wetland will entail the planting of the following species, in the following areas. Further details can be found in the Technical Specifications (chapter 8) and in Annex 5.5.

7 habitat typologies/target functional habitats have been identified in this area.

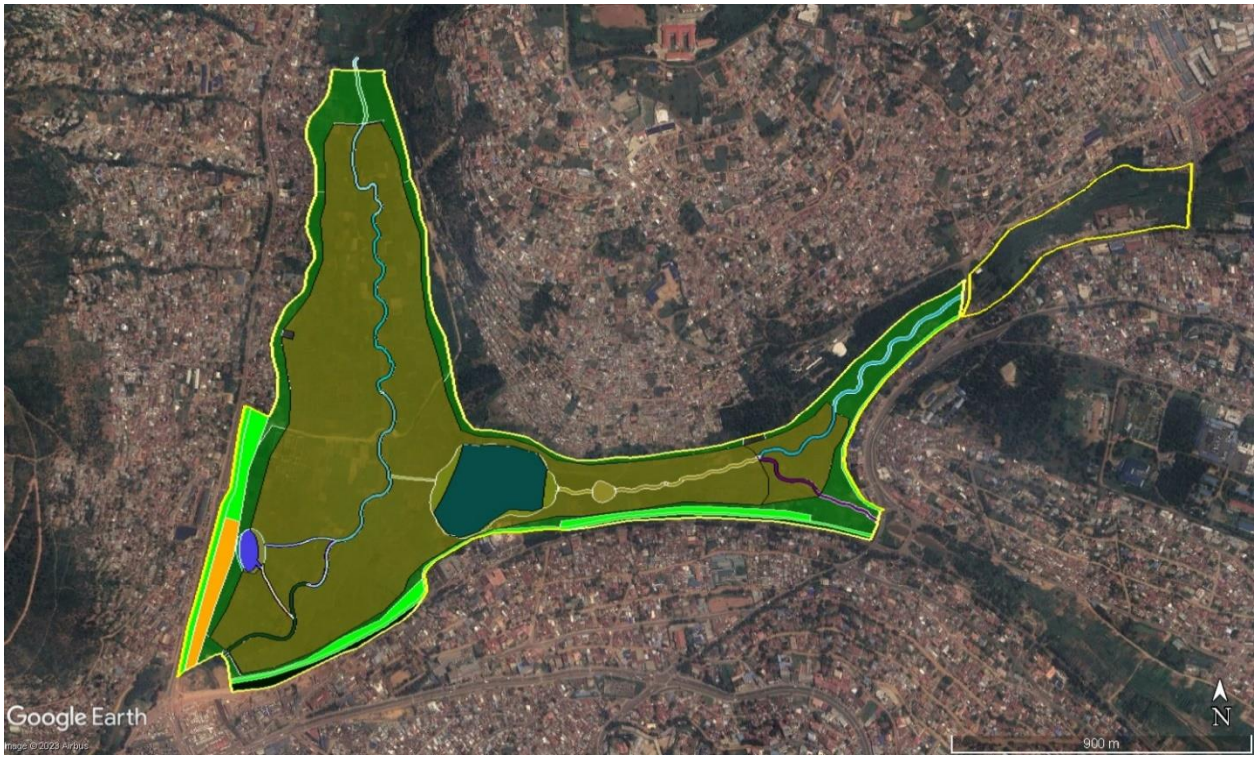


FIGURE 5-101: LOCATION OF NYABUGOGO WETLAND

The following table shows the list of species suggestions for each typology. Life forms and expected functions for each species can be found in Chapter 8.1.

Habitat type/function	Plant species

1. Permanent wetland: Proposed native plant species adapted to the wetland environment are selected to enhance wetland restoration efforts. The species were identified based on their ecological function for wetland restoration through water retention, regulating water flow, filtering pollutants, soil stabilization, etc., and maintaining the health and biodiversity of these habitats in general.	*Cyperus papyrus* *Typha domingensis* *Cyperus denudatus* *Cyperus dives* *Juncus effusus* *Persicaria decipiens* *Ludwigia abyssinica*
2. Seasonal wetland: Proposed native plant species adapted to the wetland environment are selected to enhance wetland restoration efforts. The species were identified based on their ecological function for wetland restoration through water retention, regulating water flow, filtering pollutants, soil stabilization, etc., and maintaining the health and biodiversity of these habitats in general.	*Acacia kirkii* *Cyperus latifolius* *Cyperus articulatus* *Leersia hexandra* *Brachiaria humidicola* *Panicum maximum* *Echinochloa pyramidalis* *Brillantaisia cicatricosa*
3. Green belt, linear park and road reserve: These are upland strips along the wetland. Proposed species will primarily serve to enhance urban biodiversity, provide habitat for wildlife that use the wetland for food or shelter, and provide cultural services with focus on ornamentals amenities.	*Blighia unijugata* *Croton megalocarpus* *Delonix elata* *Dodonaea viscosa* *Elaeis guineensis* *Entada abyssinica* *Ficus sycomorus* *Ficus vallis-choudae* *Kigelia africana* *Maesopsis eminii* *Markhamia lutea* *Olea europea* subsp. *africana* *Podocarpus latifolius* *Polycias fulva* *Pterygota mildbraedii* *Senegalia polyacantha* *Spathodea campanulata* *Sterculia tragacantha* *Syzygium guineense*
4. Recreational areas: Proposed species for these areas will offer opportunities to accommodate visitors to the wetland and provide facilities such as shades for parking lots and picnic areas. These will also serve to educate visitors about the wetland ecosystem and importance of wetland conservation.	*Croton megalocarpus* *Ficus sycomorus* *Kigelia africana* *Maesopsis eminii* *Olea europea* subsp. *africana* *Podocarpus latifolius* *Polycias fulva* *Pterygota mildbraedii* *Senegalia polyacantha* *Spathodea campanulata* *Sterculia tragacantha*
5. Stream banks: The stream banks will be covered in vegetation to play a role of stabilizing stream banks, providing habitat for wildlife, and filtering pollutants.	*Phragmites mauritianus* *Aeschynomene elaphroxylon* *Sesbania sesban*
6. Pond areas: Floating plants of water lilies are proposed for ornamental purposes. These will also serve to improve water quality in the ponds and	*Nymphaea nouchali* *Elaeis guineensis* *Phoenix reclinata*

reduce the growth of algae and other harmful organisms. It is recommended to regularly control the lilies to maintain a healthy ecological balance and avoid oxygen depletion in the water. The African oil palm and the wild date palms will be planted for ornamental purposes around the ponds.	
7. Landscape park: Proposed species will primarily serve to enhance urban biodiversity, provide habitat for wildlife that use the wetland for food or shelter, and provide various cultural services.	*Blighia unijugata* *Croton megalocarpus* *Delonix elata* *Elaeis guineensis* *Entada abyssinica* *Ficus sycomorus* *Ficus vallis-choudae* *Kigelia africana* *Maesopsis eminii* *Markhamia lutea* *Olea europea* subsp. *africana* *Podocarpus latifolius* *Polycias fulva* *Pterygota mildbraedii* *Senegalia polyacantha* *Spathodea campanulata* *Sterculia tragacantha* *Syzygium guineense*
8. Islands: Proposed species will serve to preserve some of locally rare species and possess recreational values.	*Dodonaea viscosa* *Kigelia africana* *Sterculia tragacantha* *Pterygota mildbraedii*

TABLE 5-22 LIST OF PLANT SPECIES IN NYABUGOGO WETLAND

5.7.1.5 Creation of island for recreation and aesthetic appearance

At the request of the Client, two landscaped islands are proposed to be constructed in Nyabugogo wetland (N08a, N08b). This will provide an elegant form emerging from the ponds and lakes in this wetland increasing biodiversity.

Detailed designs can be found in Annex 1.2.

5.7.1.6 Soil reshaping for wetland creation

The objective of this action is to carry out earthworks that will modify the topography of the wetland for ecological and aesthetic purposes.

Existing low points in the wetlands will be identified and the surrounding areas will be excavated in order to expand these locations into low areas that will preferentially accumulate water. Excavated soil will be used to backfill the existing water course as well as to enhance nearby high points.

The immediate outcome of this action will be a sloped but unchanneled terrain which will allow water to flow diffusely and slowly through the wetland. The final result is the creation of different areas of wetland based on their elevation. Specifically, this will result in permanent wetlands in the low points where the soil will be constantly waterlogged, and seasonal wetlands which will periodically receive inflows of water.

The greater retention time of water in the low points mean that it provides an excellent opportunity for the treatment of inflows coming from upstream or neighbouring built-up areas, a process which can be accentuated by the planting of appropriate plant species.

The difference in water content of the soil due to elevation differences will also promote the creation of a variety of flora, which will have two co-benefits

- Additional habitat creation for local fauna, promoting biodiversity,

- The wide diversity of plant species will allow for a more varied beautification of the site.

Proposed wetland reshaping actions are located as per the zoning maps under label N16 and are illustrated in the figures below. The detailed site plans and cross sections are provided in Annex 5.2.

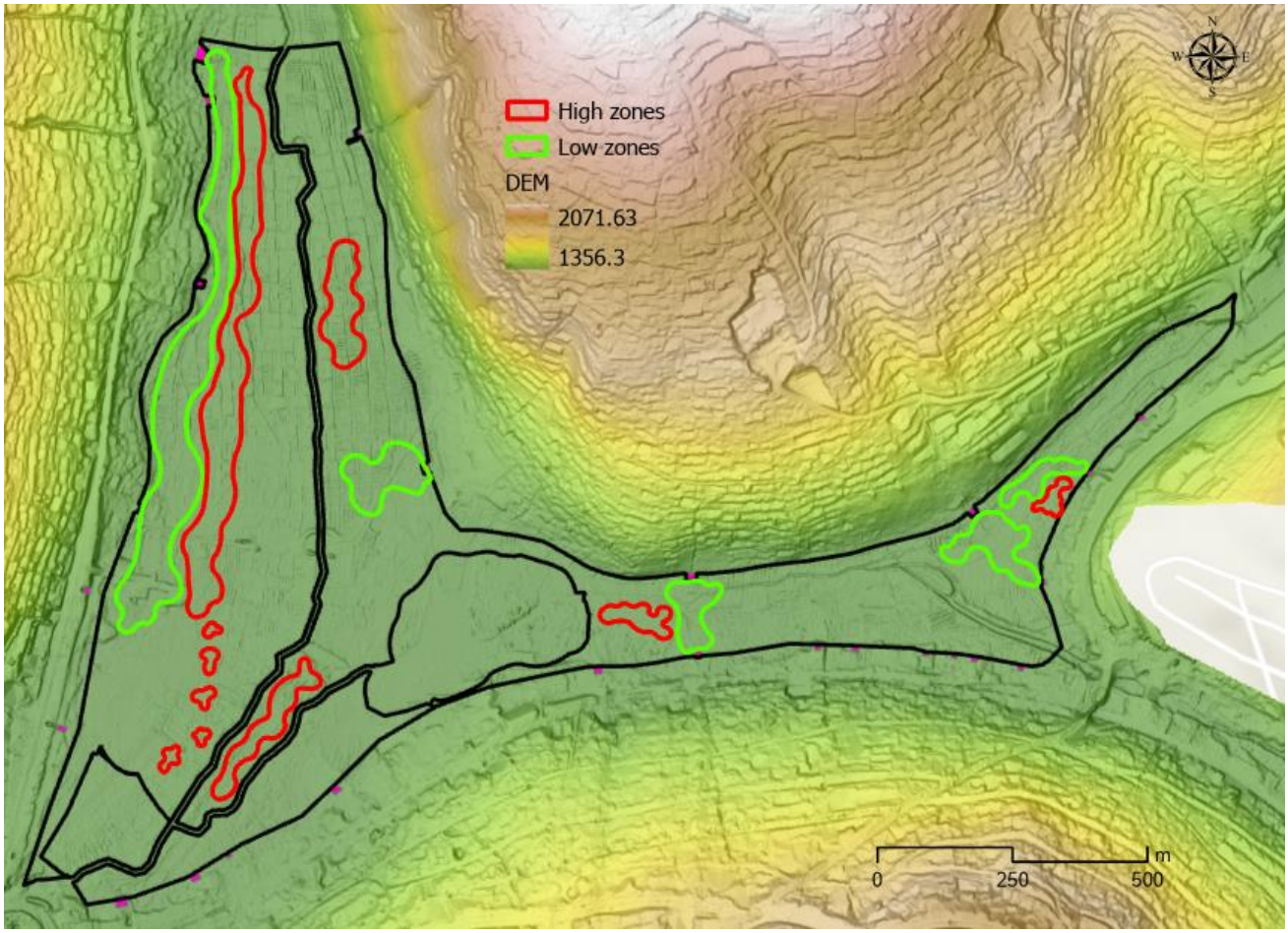


FIGURE 5-102: SOIL RESHAPING FOR WETLAND CREATION – N16

5.7.2 Hydraulic actions

The hydraulic actions designed in this project seek to reinstate or enhance the hydraulic functioning of the 5 wetlands, mostly through modifications of the flows through the project area with the following objectives:

- Promoting water retention in the wetlands to prevent damaging flooding events,
- Reducing the flow through the wetlands to limit erosion,
- Spreading of water flows to provide maximum absorption and reduce downstream flows and velocities,
- Provide favorable aquatic environments for fauna and flora,
- Improve water quality.

As explained in paragraph 3.2.3, a variety of actions are planned with each wetland receiving interventions tailored to the wetland's objectives.

In accordance with the Master Plan for Nyabugogo (Annex 5.1), the detailed design was carried out as below for the specific interventions proposed for the wetland, which is developed hereunder. Further details can be found in the Technical Specifications (chapter 8) and in Annex 5.3.

5.7.2.1 Sediment traps for blockage of sediments into the wetland

The hydraulic outfalls from lateral drainage carry effluents from the neighbouring urbanized areas, which are charged with sediment, and convey them into the wetland. Originally built to drain plots for agricultural purposes they are relatively deep (about 2m) and consequently convey water rapidly downstream, which is in opposition to the role and functioning of the wetland.

The construction of sediment traps is therefore proposed to counteract this effect. A sediment trap is a containment area that allows sediment in collected storm water to settle out during the runoff is discharged through a stabilized spillway/dewatering pipe.

Due to the very large amount of waste of varying sizes coming from the sides, and the lack of a large-scale collection system over most of the study area, sediment traps will be installed at each drain stop in the wetland.

It is very important to note that each sediment trap was designed specifically, depending on the reality of each drain. The drawings are given in Annex 5.3, examples are provided hereunder.

The Consultant considered the use of vegetation on the gabions forming the sediment trap elements. This solution was not retained for the following reasons:

- the water arrives at a high speed which requires the installation of gabion mats with a tight mesh to ensure stability
- in these conditions, vegetation would not be able to develop properly and would represent a significant hindrance to the maintenance of the structures.

3 types of sediment traps were defined according to the context, here is an example:

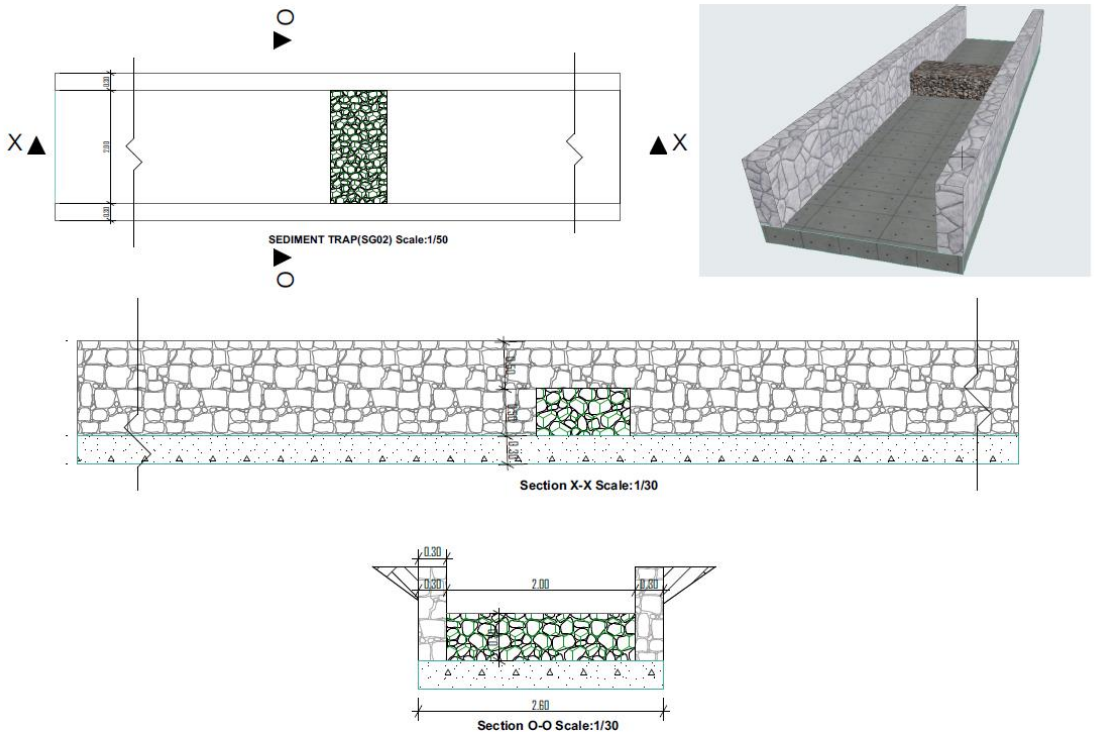


FIGURE 5-103: EXAMPLE OF SEDIMENT TRAP

At the outlet of the structure, a gabion wall filled with river stones will ensure that the flow is spread across the floor of the wetland. This will combine with the landscaping action N16 “soil reshaping for wetland creation” which specifically incorporates interventions to receive inflows from lateral drainage. This will limit its velocity thereby retaining it in the wetland, where it can be naturally treated of other pollutants (chemical and biological). This treatment is reinforced by appropriate plant selection as explained in paragraph 5.3.1.

The result is primarily to improve the quality of the water, but it will also contribute to increasing the height of the water table and limiting flooding downstream.

The construction of these traps can only be carried out with the use of concrete for the base and walls of the structure; however gabion and river stones are also incorporated into its construction to constitute the trap. The trap will require periodic manual emptying to ensure it remains effective, as once it is full the sediment will simply continue its path into the wetland.

5.7.2.2 Blocking of surface drains (agriculture drains)

Previous agricultural use has resulted in the creation of drains, originally constructed to facilitate the development of intensive agriculture, thereby strongly impacting the hydraulic dynamics of the wetland and its waterlogging.

The objective of the drains is to convey water rapidly downstream, away from farmed areas, which contributes to the lowering of the water table and the rapid drying of the soil. In addition to excavated drains, soil embankments raise the channel level above natural ground level in order to prevent the flooding of crops during heavy rains. However, with the repurposing of the wetland site for flood management, ecological and aesthetic purposes, it is essential to retain water within the wetland, which is in firm opposition to the existing land use.

The objective of this action is therefore to prevent water from flowing in preferential paths, but to flow diffusely through a restored homogenous surface of the wetland. The water's flow rate will consequently be reduced as will associated erosion problems, and the water table will rise to provide a better environment for fauna and flora.

In order to achieve this objective, the ground level will be restored to a homogenous generally flat surface, devoid of drainage network. This will require two distinct actions illustrated in the images below:

- The backfilling of the agricultural ditches with soil
- The removal of soil embankments above natural ground level.

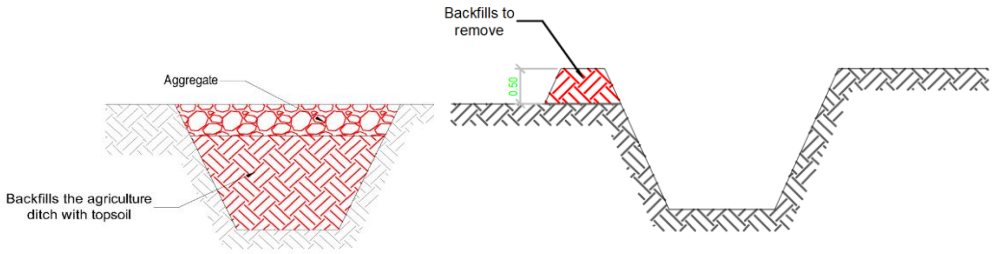


FIGURE 5-104: CROSS-SECTION OF AGRICULTURAL DRAINS

The soil from the embankments can be used to infill the drains however the available volume will be insufficient, and soil importation will be required. The topsoil used for this purpose must be free of any invasive plant species or pollutants. The agriculture drains located in Nyabugogo will be completely backfilled.

The volume of topsoil needed to fill the trapezoidal shaped drains is calculated with the following formula:

$$V = S \cdot l \cdot n \quad \text{with } S = h \cdot (\text{a} + \frac{b-a}{2})$$

Where:

- l is the length of the drains
- S the surface of the drain
- n the number of drains,
- h the depth of the recharge bed
- a and b the channel width at the base and surface respectively.

In Rwampara, the drains have a mean width of 1.5m at the base and 2.3m at ground level, and a height of 1.5m, resulting in a cross section of 2.59m^2. The volume of channel to be backfilled is presented in the table below.

Channel	Length of drainage (m)	Section of channel (m2)	Volume of backfill (m3)
N02a	1427.4	2.59	3693.3
N02b	651.3	2.59	1685.2
N02c	428.6	2.59	1109.1
N02d	1525.0	2.59	3946.0
N02e	1328.4	2.59	3437.2
N02f	6290.4	2.59	16276.3
N02g	3411.5	2.59	8827.3
N02h	4983.3	2.59	12894.2
N02i	1618.8	2.59	4188.6
N02j	486.9	2.59	1259.8

TABLE 5-23 VOLUME OF BACKFILL IN AGRICULTURAL DRAINS IN NYABUGOGO

From this volume is removed the available soil from the embankments. The backfill sections have a mean section of 0.14m^2. The volume represented by this infill is calculated as per the following equation and is presented in the table below.

$$V = \text{number of drains} \cdot \text{length of the drain} \cdot \text{mean section surface of the backfill}$$

Channel	Length of drainage (m)	Volume of infill (m3)
N02a	1427.4	199.8
N02b	651.3	91.2
N02c	428.6	60.0
N02d	1525.0	213.5
N02e	1328.4	186.0
N02f	6290.4	880.6
N02g	3411.5	477.6
N02h	4983.3	697.7
N02i	1618.8	226.6
N02j	486.9	68.2

TABLE 5-24 VOLUME OF SOIL IN EMBANKMENTS IN NYABUGOGO

Since the soil from the embankments can be utilized to backfill the drainage, the table below presents the balance of soil to be imported from elsewhere for the complete backfilling of the agricultural ditches.

Channel	Volume of soil to import (m3)
N02a	3493.5
N02b	1594.1
N02c	1049.1
N02d	3732.5
N02e	3251.2
N02f	15395.6
N02g	8349.7
N02h	12196.5
N02i	3962.0
N02j	1191.6

TABLE 5-25 VOLUME OF SOIL TO BE IMPORTED FOR BLOCKING OF AGRICULTURAL CHANNELS IN NYABUGOGO

5.7.2.3 Re-profiling the river with meanders and banks

The action of re-meandering within the framework of this wetlands consists in artificially recreating this natural functionality of the river, altered by past human interventions. The purpose of such an intervention is multiple since it aims:

- To mitigate the impacts linked to the incision of the minor bed (lowering of the water table, lowering of the surface area of the flooded zones, acceleration of the flows...).
- To slow down the dynamics of water allowing to reduce the flood wave downstream.
- To lengthen the line of the watercourse and thus to multiply the contacts between ground and water (ecotone*), possible places of purification.
- To find a diversity of natural habitats for animal species which is much more important in meandering streams than in straight streams. The work of the banks in different levels (height defined according to the flows of reference floods) will also allow to support this diversification.

For this action to be implemented, the primary space of the river need to be restored as per the methodology presented in paragraph 5.2.4.2. Large banks need to be designed which will act as a buffer zone during the rainfall storm events, and riprap will be installed at the outer curves of the meanders to prevent erosion as illustrated in the figure below.

FIGURE 5-105: EXAMPLE OF RIVER MEANDERING AND EXTERNAL BANKS PROTECTION WITH GABIONS

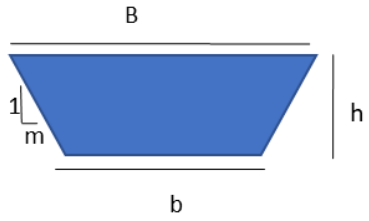
River meandering in Nyabugogo wetland has been designed in one area according to the wishes of the Client. Meandering zone N03 is described hereafter, and the detailed designs can be found in Annex 5.3.

At the junction between Kibumba and Nyabugogo, the width available allows an amplitude of 44m.

FIGURE 5-11: MEANDER N10 IN NYABUGOGO

The discharge through this channel is 5.9 m3/s, therefore the dimensions of the channel are determined as follows:

S0	m	b (m)	h (m)	B (m)
0.0016	0.29	3.4	1.7	4.4



Due to high velocities, it will be necessary to protect the outer curves of the river from scouring and erosion. In order to respect the environmental spirit of the project, the Consultant is proposing to use riprap for this purpose. The riprap at the outside curve of the meanders should at least have a diameter of 0.04 m.

5.7.2.4 Expansion of the existing lake

At the request of the client, the existing lake of Nyabugogo will be extended. The natural terrain at this location is already flat and will be part of a permanent wetland.

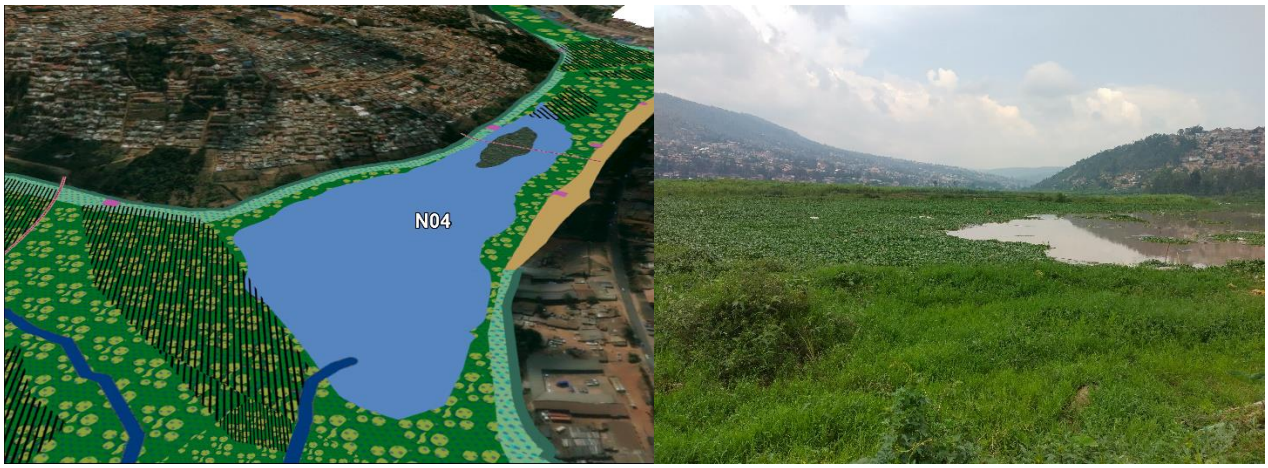


FIGURE 106 - EXPANSION OF THE EXISTING LAKE

This action consists in the gradual expansion of the existing riverbed to meet the existing lake. At the beginning of the lake a part of the terrain will form an island for aesthetic purposes with a suspended walkway.

Most of the lake expansion is done by the removal of invasive plants in this area, water hyacinth.

5.7.2.5 Water spreading structure to spread water into the wetland.

The intervention consists in the modification of the flow of water out of the channel from which it originates into a more diffuse flow that spreads across the wetland. The objective of this intervention is to ensure an even spreading of the water throughout the wetland to achieve maximum speed and flow reduction, which will not only prevent flooding, but also improve water quality and retain water in the wetland site to better promote growth and habitat creation.

The Consultant has considered employing nature-based solutions as much as possible, and relies on a two-pronged approach to force the flow to diverge:

- Earthworks: At the approach to the wetland area, the soil will be mechanically shaped into a slightly conical form that will encourage water to flow laterally through gravity.

- Gabion walls: To further encourage the water to spread laterally across the wetland floor, gabion walls of increasing length will be constructed across the wetlands to reinforce the redirection of the flow as the water passes through them.

This construction will have the following impacts:

- Even spreading of the incoming water across the span of the wetland, making maximum use of the available space.
- Reduction in the speed of water limiting erosion and promoting sedimentation.
- Increased absorption and raised level of the water table.
- Improved water quality.

An example of the proposed spreading structure is provided in the image below.

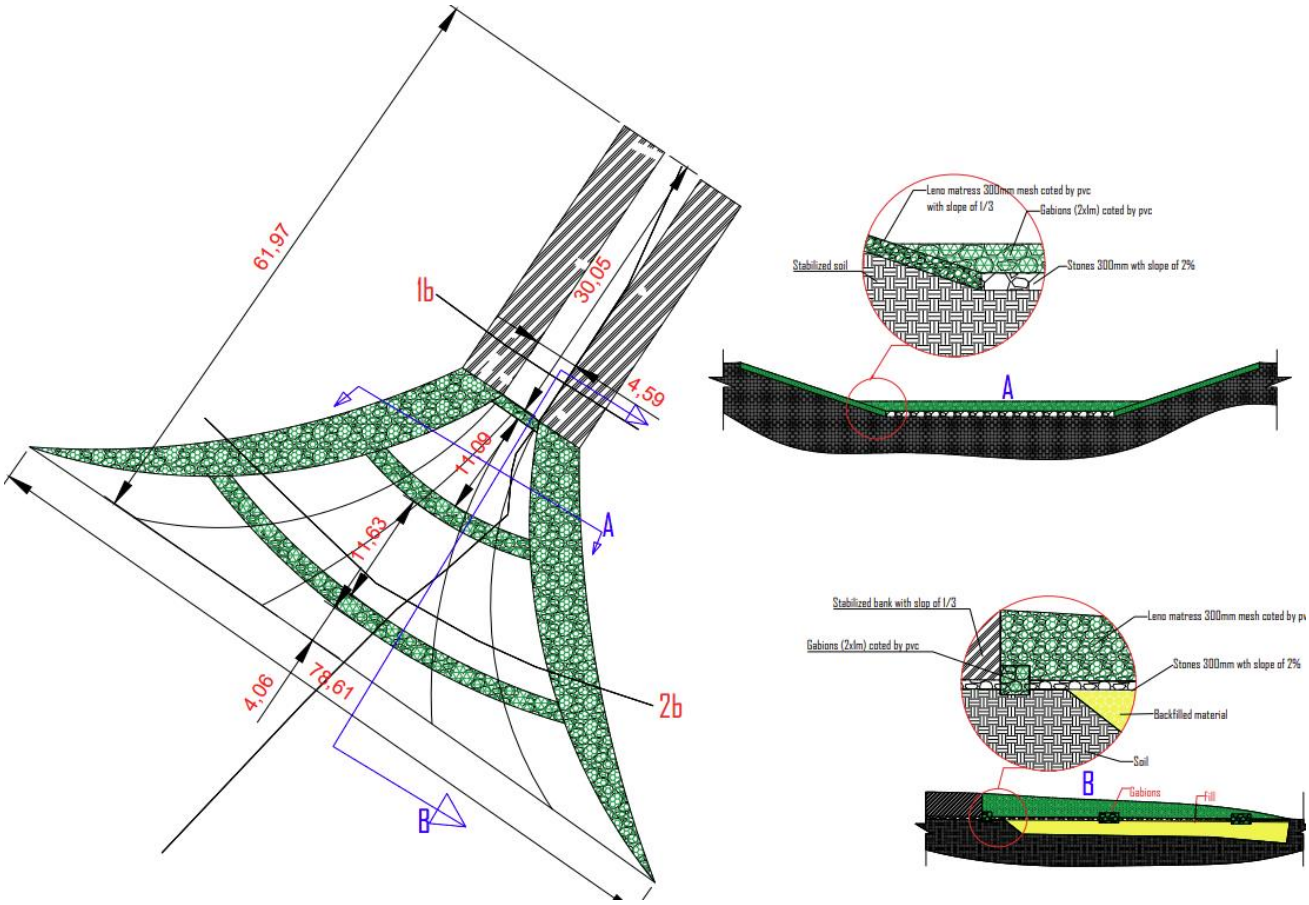


FIGURE 5-107: EXAMPLE OF A FLOW SPREADING STRUCTURE

The contractor will be responsible for the verification of the structural stability and quantities required for the structure's construction, based on the real conditions identified during implementation.

5.7.2.6 Transition structures with hotspots

Specific infrastructure defined through flood hotspots project (under the supervision of CoK) will be constructed in the wetland area. It is important to define a precise coordination for the execution of the works so that the different companies have sufficient flexibility, and the works can be carried out in a consistent manner.

It was agreed that:

- A band of 15m upstream and 15m downstream the limit of the future hotspots infrastructure is defined without and action form wetland project, keeping the required flexibility.
- The transition structure between the rivers/canals of the wetlands and the future culverts/canals of the hotspot project are included in the wetlands actions (see specific detail plan)
- For a perfect coordination the following information is given for each wetland: altitude and section of the channel upstream and downstream of the sectors with hotspot action

At the location where there is hotspot structure, the link between the structure for road crossing (culvert or bridge) a transition structure is needed for energy dissipation and prevent the erosion of the canal at then inlet and outlet of the structure due to the turbulence generated as these transition sections.

At the upstream part, the transition is a contraction of the channel from a trapeze section to a rectangular section. This contraction increases the flow speed threatening the riverbed with erosion. In order to protect the channel, this section needs to be reinforced by ripraps of a size calculated the same way as defined in part

At the downstream part, the transition is the opposite with an expansion from a rectangular shape to a trapeze. As the flow slow down, the energy dissipation can erode the riverbed, hence some ripraps to protect the bed.

The length of the transition section is defined by L = 2B where B is the width of the channel.

Public space actions

In order for the wetland to be accessible to and appreciated by the general public, a number of public space actions are proposed. These will bring the population into closer contact with the natural environment boosting their enjoyment of the site. These actions are detailed in the following paragraphs, and further details can be found in the Technical Specifications (chapter 8) and in Annex 5.5.

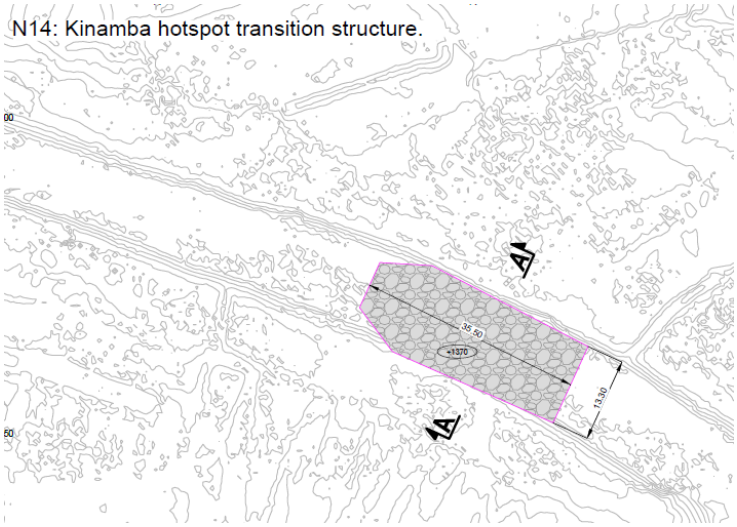


FIGURE 108 - N14 RIPRAP OF 0.05M

5.7.2.7 Creation of suspended walkway for accessibility purpose in the wetland

In order for the population to enjoy the beautification of Nyabugogo wetland, at the request of the Client, the Consultant has included the construction of a suspended walkway, which will allow people to move through the wetland without disturbing the natural environment, and with the elevation providing an impression of immersion whilst enjoying an overhead view of the location.

The image below provides an illustration of the structure to be built.

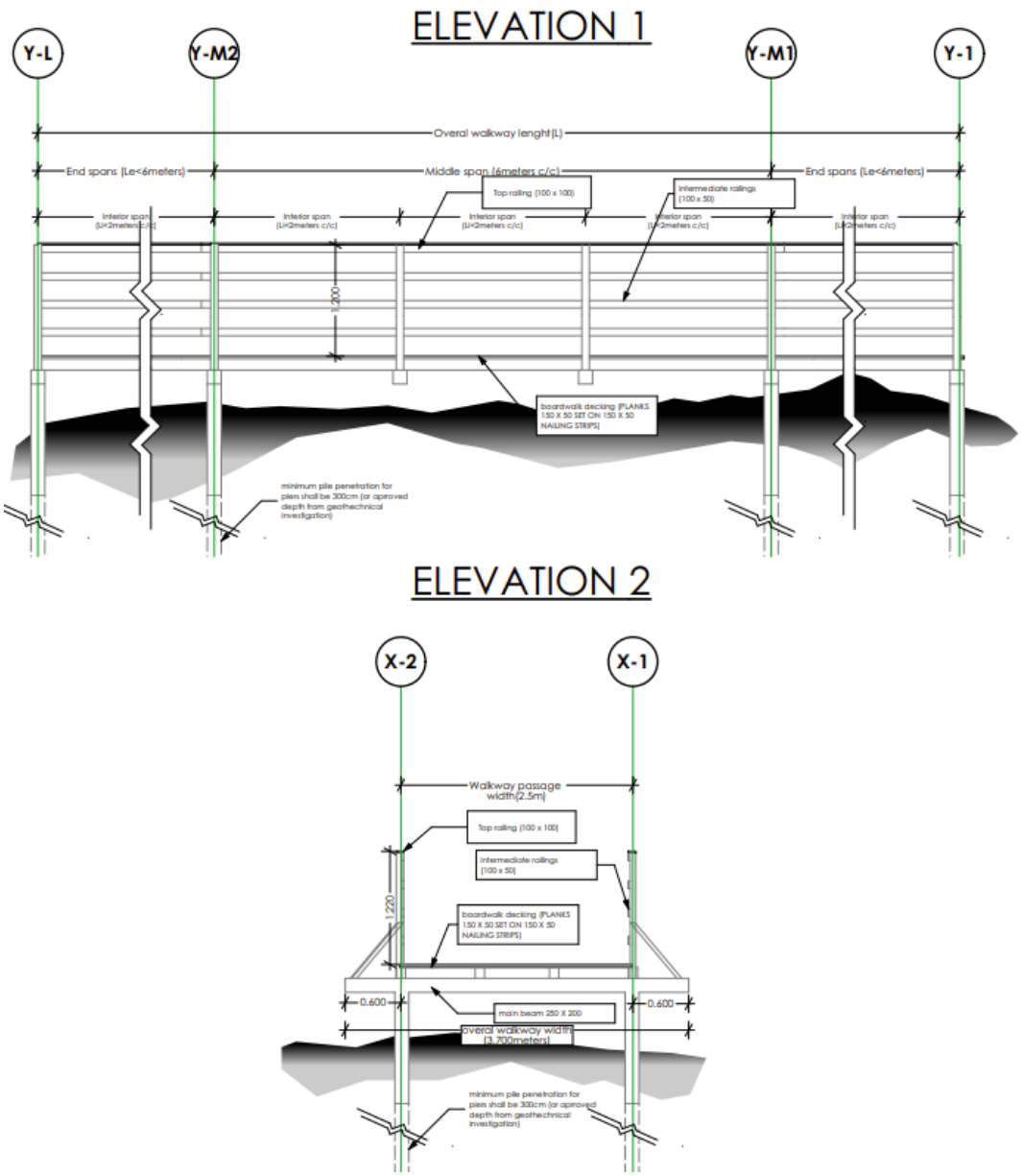


FIGURE 5-109 SUSPENDED WALKWAY IN NYABUGOGO

The design of this structure was carried out with reference to the flood modelling in Annex 5.4 to ensure that regardless of the intensity of rainfall, the walkway is consistently above the water level. This is both to ensure the stability and sustainability of the structure, as well as to ensure constant pedestrian access to the wetland for the population to discover the wetland in its variety of hydraulic states.

The suspended walkway will be equipped with guardrails for safety of both people and the natural habitats, and - in keeping with the environmental nature of the project - the suspended walkway will be constructed mostly out of treated timber. Concrete footings be necessary to ensure the stability of the structure, however these will remain buried and not visible.

Detailed drawings of the suspended walkway can be found in Annex 5.2

5.7.2.8 Creation of recreation, pedestrian / cycling trails

As per the wishes of the Client, recreation areas are to be constructed in Nyabugogo wetland to enhance the experience for the local population. Many services are to be provided which can range from picnic areas to restaurants and coffee bars, children's play parks, etc. The objective is to provide a space that allows for the population to enjoy themselves surrounded by the beauty of a natural landscape.

Additionally, pedestrian and cycling trails are to be constructed in Nyabugogo wetland to provide human access into the natural space enabling the population to enjoy the beauty of the wetland without risking any damage to the surrounding wildlife.

The trails can be used not only for access through and across the wetland but will enable leisure and sporting activities by promoting interconnectedness between the various services provided by the wetland, such as recreational areas, coffee bars, restaurants, sporting, educational and cultural facilities, and viewing areas.

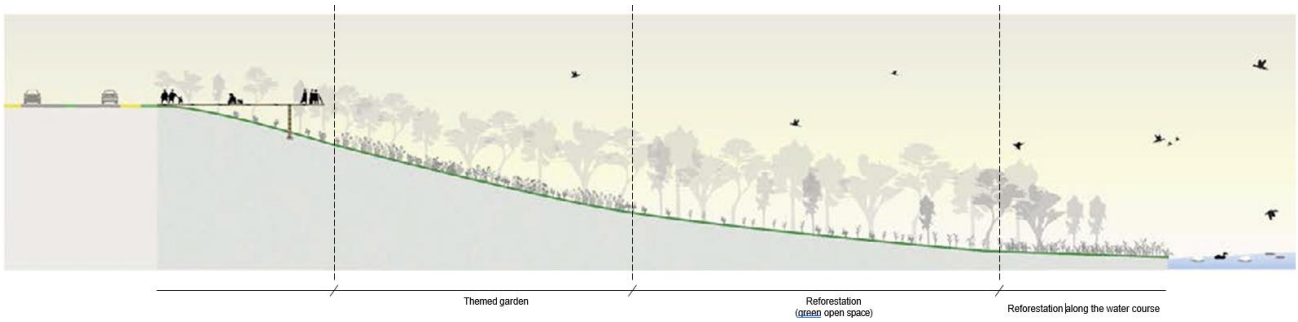


FIGURE 5-110 EXAMPLE OF A PEDESTRIAN/CYCLE PATH

The proposed pathways for Nyabugogo wetland will be enhanced with public furniture to render it more accessible and useful. This will include:

- Directional signage to indicate routes and destinations,
- Interpretive signage for educational purposes about the wetland,
- Lighting of pathways for ease of access and safety,
- Benches to allow people to sit and rest,
- Litter containers for the collection of refuse to avoid pollution of the environment,
- Bicycle racks to encourage soft mobility by ensuring the security of bicycles,
- Protective guarding along decks and other elevated structures.

Detailed designs of these interventions are provided in Annex 3.5

5.7.2.9 Green Belt

The construction of a green belt surrounding Nyabugogo Wetland is proposed as it will have numerous benefits:

- Delineation of the wetland itself,
- Protection of the wetland from pollution originating in adjacent communities,
- Pedestrian/cycle access around the wetland,
- Elevated location providing views of the natural environment.

The principle is to produce a nature-based contour of the wetland that will provide these services. As such the area will be levelled, with a grassy space and treeline that will absorb runoff before it reaches the wetland, next to pedestrian pathway covered in volcanic paving stones, and a compacted laterite soil cycle path. Detailed designs are provided in Annex 5.5.

5.8 COORDINATION WITH FLOOD HOTSPOTS PROJETS

5.8.1 Hydraulic calculation verification

A separate study was performed in parallel to the Wetland Rehabilitation project in order to identify hotspots for flooding and propose mitigation measures, carried out by YREC. In order to ensure sufficient space for the incorporation of the proposed hotspot infrastructure, as stated in Chapter 4, it was agreed to provide a 15m buffer both upstream and downstream of each hotspot location.

Following the hotspot study, the Consultant has reviewed the impact of the proposed hydraulic interventions of the wetland rehabilitation project on these hotspots.

This was carried out by comparing the results of the water level and discharge in the channel at various hotspot locations through the SOBEK model, for various rainfalls, before and after intervention.

It is important to note that the water level and discharge presented hereafter are for the channel and only the channel, it does not consider the overland values.

5.8.1.1 T2 Rainfall

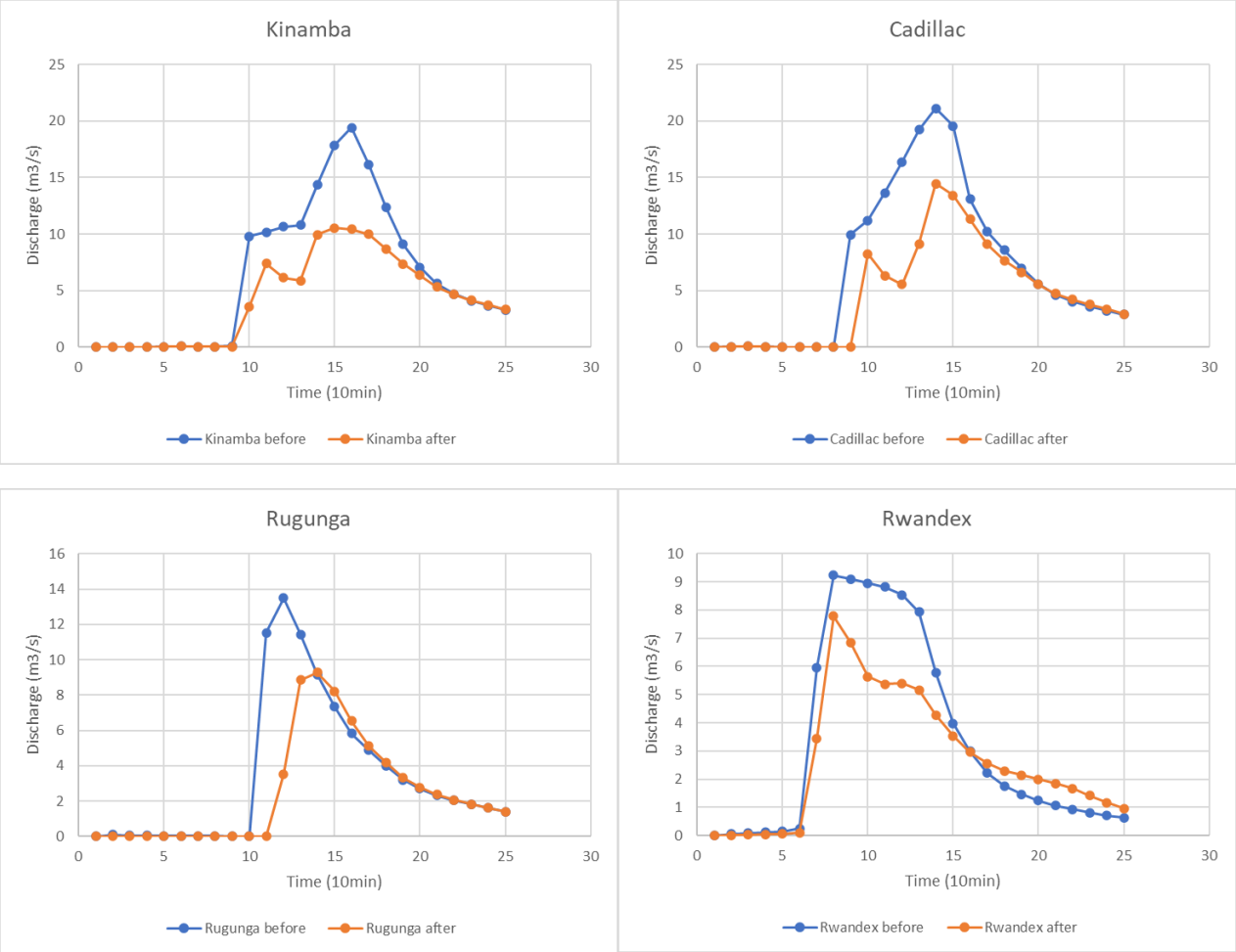


FIGURE 5-111 DISCHARGE MODELLING RESULTS AT HOTSPOTS FOR T2 RAINFALL

5.8.1.2 T10 Rainfall

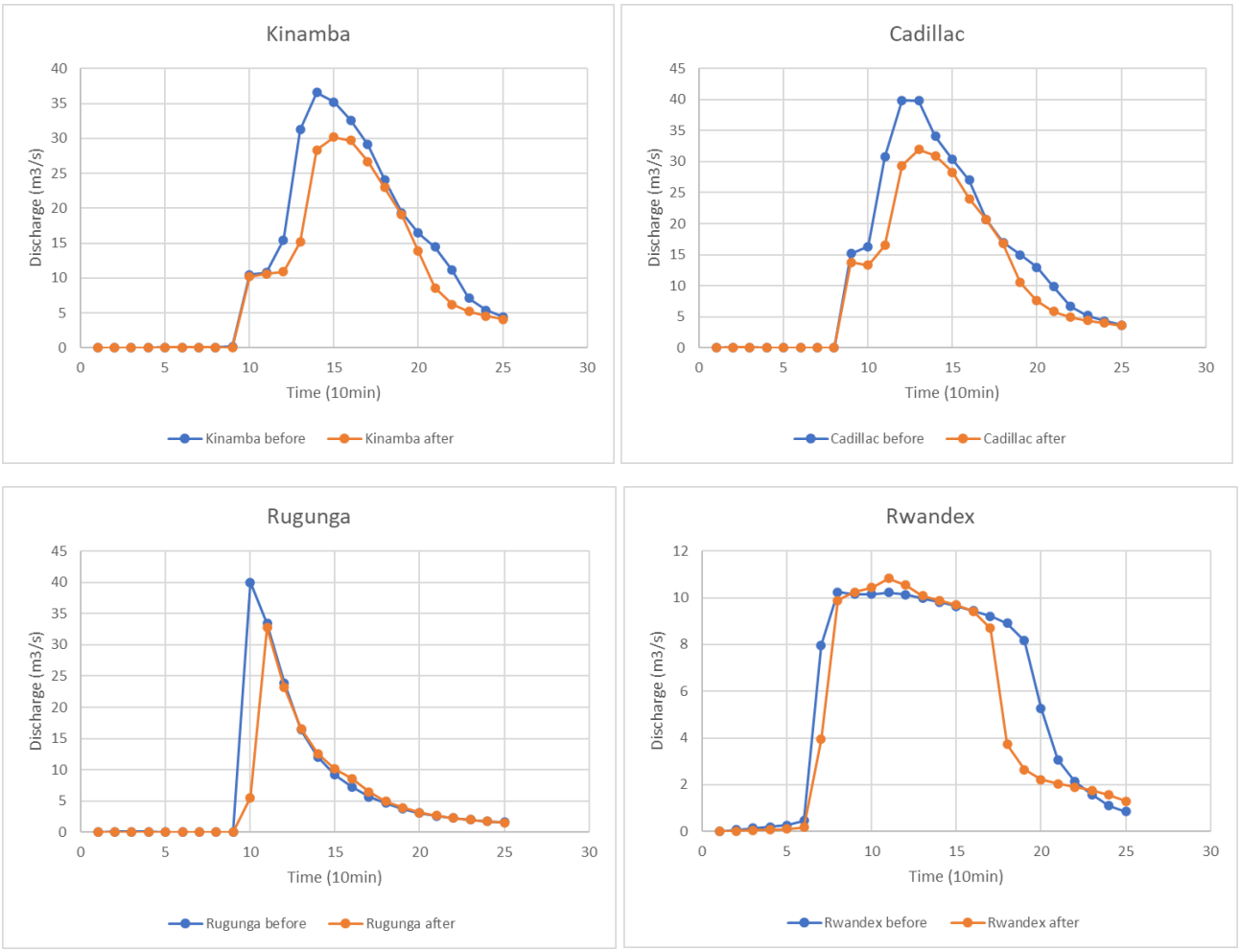
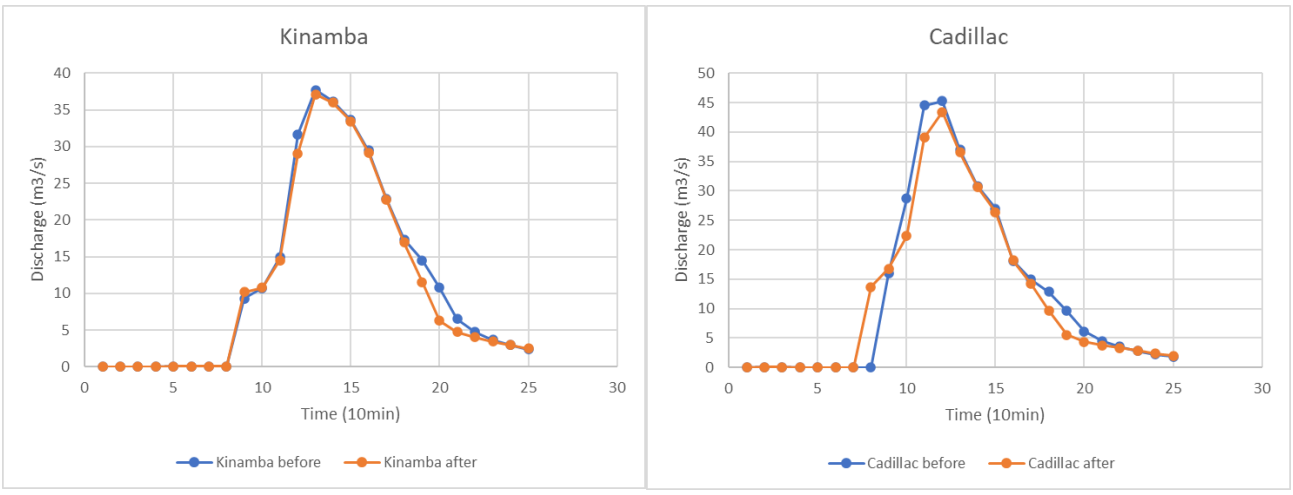


FIGURE 5-112 DISCHARGE MODELLING RESULTS AT HOTSPOTS FOR T10 RAINFALL

5.8.1.3 T2 Rainfall with 2050 urbanisation projection



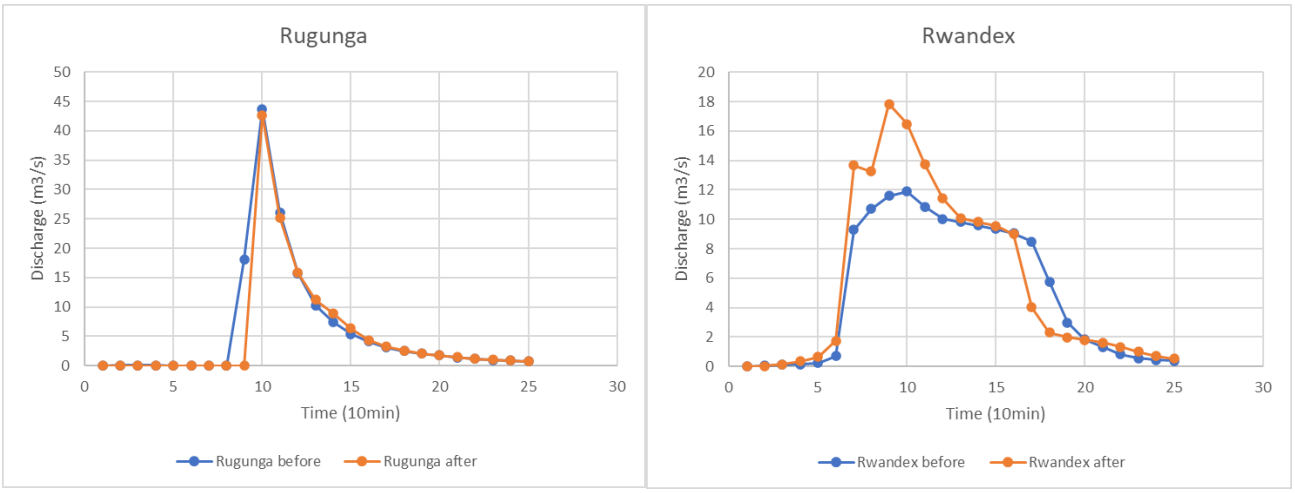


FIGURE 5-113 DISCHARGE MODELLING RESULTS AT HOTSPOTS FOR T2 RAINFALL WITH 2050 URBANISATION PROJECTION

5.8.1.4 T10 Rainfall with 2050 urbanisation projection

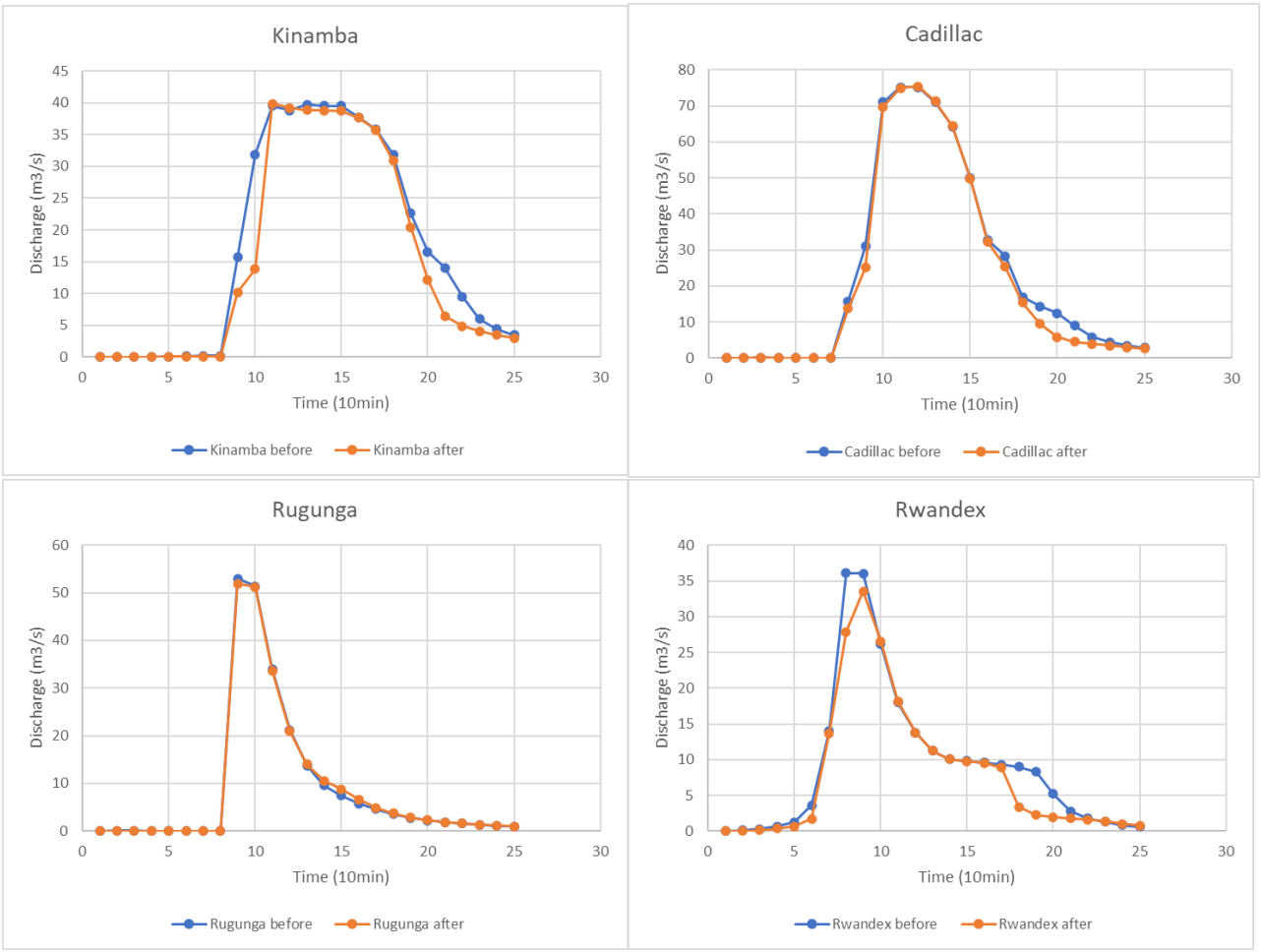


FIGURE 5-114 DISCHARGE MODELLING RESULTS AT HOTSPOTS FOR T10 RAINFALL WITH 2050 URBANISATION PROJECTION

5.8.1.5 T50 Rainfall with 2050 urbanisation projection

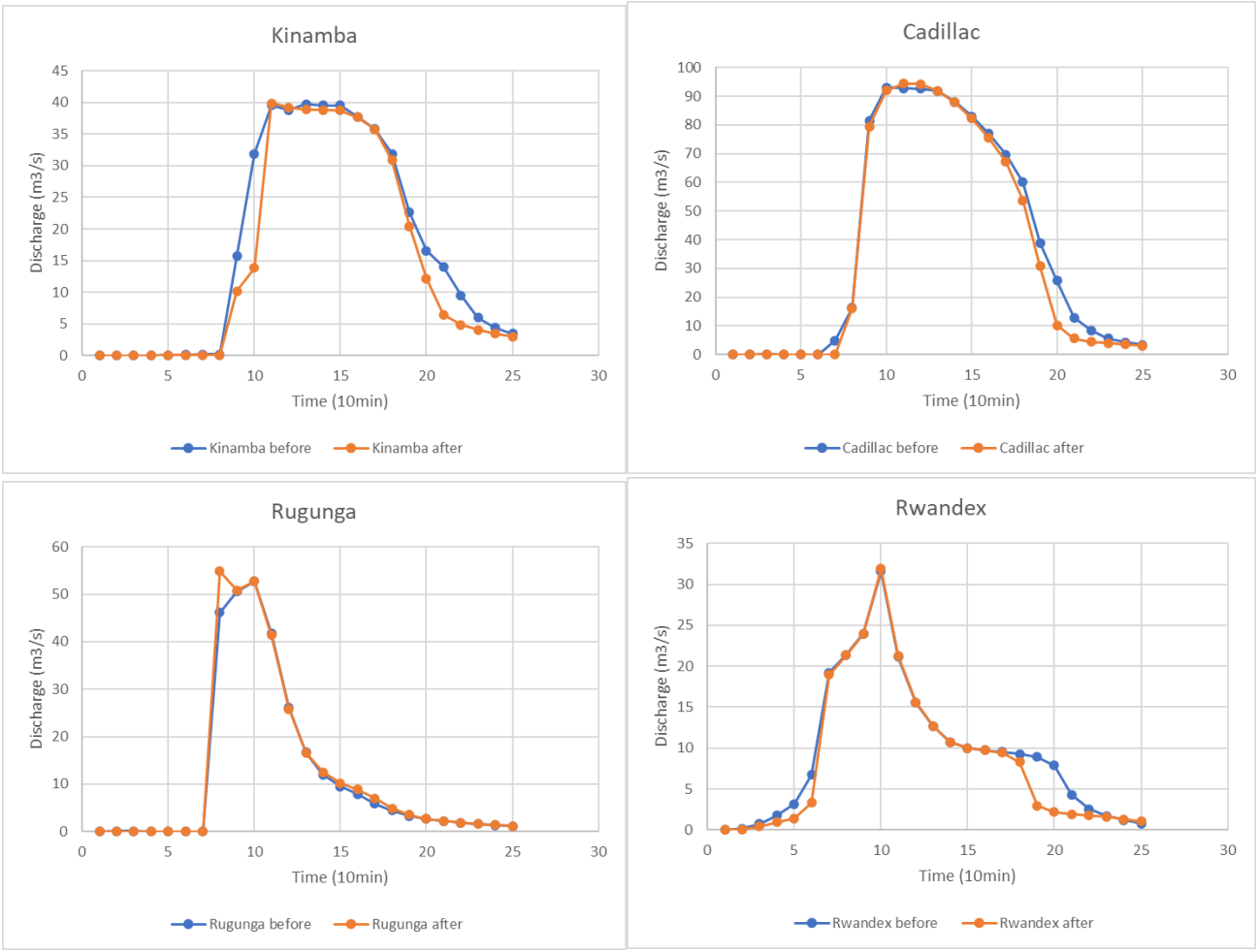


FIGURE 5-115 DISCHARGE MODELLING RESULTS AT HOTSPOTS FOR T50 RAINFALL WITH 2050 URBANISATION PROJECTION

From the above results, it appears that the proposed structures have a visible impact on a T2 return period at current urbanisation levels. The same is true for a T10 return period but to a lesser extent.

Considering a greater return period or with urbanisation projection of 2050, flooding is extreme, and the structures have no impact. Furthermore, at these higher return periods, the model is not precise enough to determine how the structures will react to such high flows.

The height of the structures varies with the wetland considered, specifically:

- For Rwampara, the height is 2m to have a visible impact.
- For the rest of the wetlands 1m is high enough to see the impact and avoid causing to high water level in the wetland.

The flow channeling structure that is close to the golf course in Kibumba wetland is prone to cause flooding. Remedial measures will have to be considered to protect this site or the intervention abandoned.

The channeling structure of the Rugenge-Rwintare wetland has a minor impact because the discharge is particularly low in this location.

6. ENVIRONMENTAL AND SOCIAL MANAGEMENT PLAN

An environmental and social management plan (ESMP) was produced in order to avoid and/or mitigate any negative impacts caused by the construction of the project.

Impacts were categorised as of low, medium or high, and for each potential impact, mitigation measures to be implemented are proposed, with the responsibilities for each measure explicit in the tables.

Since the document is too voluminous to include in this report, the complete document can be found in Annex 8.

It is important to remember that the following key measures will have to be implemented :

- Pre-construction phase : land acquisition, livelihood restauration (to be determined by RAP)
- Construction and operation phase : Air quality and noise pollution monitoring, occupational health and safety (under the responsibility of the contractor)
- Environmental and social monitoring plan, to be addressed after works completion : mid-term project evaluation, water quality, soil quality and ecological monitoring

Close collaboration was established between the two consulting teams, in particular on the following aspects :

- definition of actions for environmental and social impact and PAR
- definition of methodology for decontamination master plan

7. SOIL DECONTAMINATION

7.1 GENERAL CONSIDERATIONS

Heavy metals contamination of soil is an issue of global concern that ultimately results in toxicity and diseases in humans and animals through consumption of food crops from contaminated soil. The toxic effects of these metals, even though they do not have any biological role, remain present in some or the other form harmful for the human body and its proper functioning. Heavy metals in the soil and water refers to some significant heavy metals of biological toxicity, including Cobalt (Co), Cadmium (Cd), Lead (Pb), Chromium (Cr), and Arsenic (As) etc. With the development of the global economy, both type and content of heavy metals in the soil and water caused by indiscriminate use for human purposes has altered their geochemical cycles and biochemical balance.

There are many known sources of harmful metals, including the earth, which releases them into food, air, and water, and anthropogenic activities, such as the application of fertilizer in agriculture, the use of pesticides and herbicides, and irrigation. Other sources are automobile emissions, paints, cigarette smoking, industries, and sewage and waste disposal. This soil and water contamination management plan gives the overview of the soil and water contamination in the five wetlands under rehabilitation process in Kigali city, potential health risks of some selected heavy metals identified in Kigali and a contamination management plan including the selected most cost benefit remediation techniques.

7.2 OVERVIEW OF THE SOIL AND WATER CONTAMINATION IN THE FIVE WETLANDS

7.2.1 Heavy metals in water of Kigali wetlands (Cu, Pb and Hg)

7.2.1.1 Mains metals

The results considered in this document are the one found in the preliminary study conducted by Macfarlane et al 2021 which compares other previous studies such as Similar Nhapi et al. (2011) and Sekomo et al. (2011).

Macfarlane et al 2021 (see Annex 6) shows that the level of metal pollution by copper and lead is an issue in all the nine sites of Kigali wetlands. Thus, water in Kigali wetlands is not suitable for irrigation, aquatic ecosystem protection and livestock watering as it contains high level of Cu and Pb.

These results indicate that the level of copper in rivers of Kigali wetlands have increased in comparison with the findings of Sekomo et al. (2011), who found the level of Cu complying with the 2008 World Health Organisation (WHO) and 2009 Environment Protection Agency (EPA) standards for drinking water in all the sampling points (Nyabugogo wetland transect, Nyabugogo River inflow, Nyabugogo River outflow, Ruganwa and Kibumba streams).

The effects of high levels of copper-contaminated soils among others include crop yield reduction and crops failure. However, copper does not generally accumulate in edible parts of the plants to levels that are dangerous to consumers, though root crops such as potatoes have been shown to concentrate copper. Copper is found naturally in chalcopyrite minerals, igneous rocks and sedimentary rocks, and is generally released in aquatic environment by weathering processes or by dissolution of copper minerals and native copper.

Human activities generating copper comprise effluent from wastewater treatment plants, corrosion of brass and copper pipes, discharges from mining, smelting, refining iron and steel-producing industries as well as pesticides in the treatment of soils. The toxicity of copper in water is highly dependent on local water quality conditions including water hardness. Thus, in Kigali wetlands the toxicity of copper decreases as the hardness of water is high (between 85 and 189 mg/L of total hardness, see Annex 1) and its toxicity can be accelerated by declining levels of dissolved oxygen.

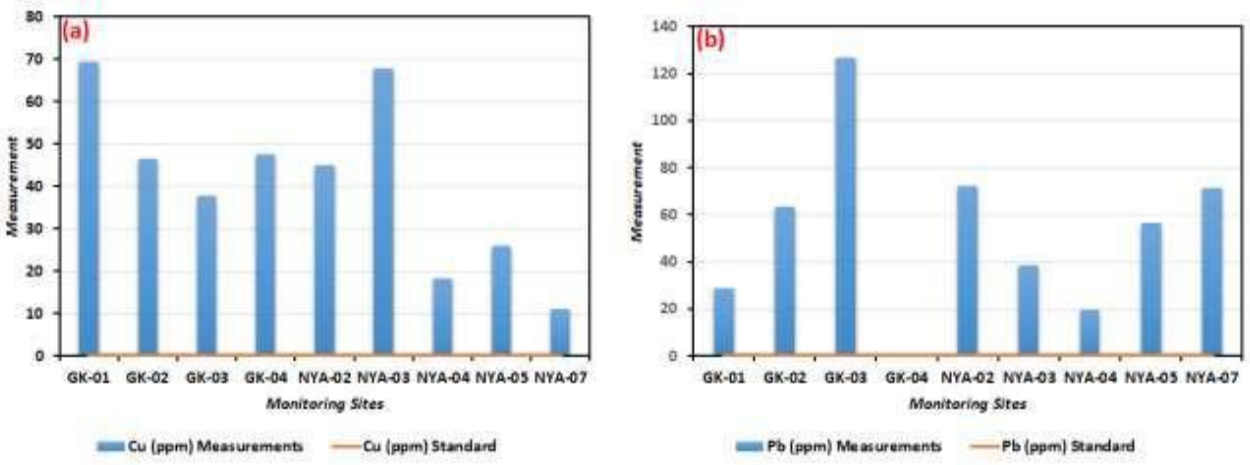


FIGURE 7-1 LEVELS OF CU AND PB IN KIGALI WETLANDS.

High levels of Pb were recorded across most sampling locations . Similar results have also reported in other previous studies, for example Nhapi et al. (2011) and Sekomo et al. (2011). Furthermore, significant values of Pb have been also found in soil samples and in the three crops (sweet potatoes, amaranth and taro) commonly grown in Nyabugogo wetlands.

Higher levels of Lead in surface water of Kigali could be ascribed to the presence of car garages, petrol stations, presence of tanneries using huge quantities of chemicals, geological formations and effluent containing oil which is directly discharged in the wetlands (Nhapi et al. 2011; Nhapi et al. 2012). Street runoff and dust associated with lead emission from gasoline-powered motor vehicle, manufacturing of batteries, previous use of lead in water distribution pipes and industrial wastewater are amongst other possible contamination sources.

The high accumulation of heavy metals in fish and crops of Nyabugogo wetlands (especially Pb, Cr and Cd) could pose deleterious health risks of using water in the wetlands for crop watering, direct human consumption and eating fish (Sekomo et al. 2011; Etale and Drake 2013; Nteziyaremye and Omara 2020).

Handling and analysing of mercury in water samples is challenging and this may account for the limited information related to mercury pollution of surface water in Kigali wetlands. During this investigation, three sites, GK-01, GK-4 and GK-07 have recorded the concentrations of Hg of 333 ppb, 34 ppb and 512 ppb, respectively which are very high in comparison to the guidelines for the protection of aquatic ecosystem and livestock watering (Figure 5-20). Mercury and organo-mercury are severely neurotoxic and their bioaccumulation in fish and food can pose a risk to human beings. Though, a firm conclusion cannot draw based on one single sampling and measurement, these levels of Hg indicate that such water is unfit use for human consumption, livestock and irrigation. Additional water sampling campaigns are however required to validate these results.

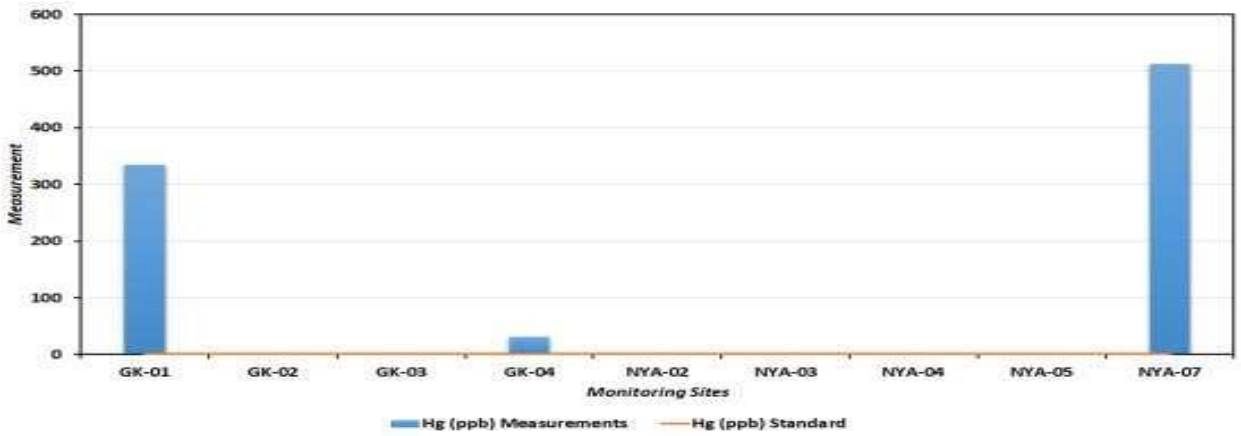


FIGURE 7-2 LEVEL OF MERCURY IN WATER SAMPLES

7.2.1.2 Other heavy metals

Though previous studies indicated that water in Kigali wetlands is polluted by other heavy metals, water samples collected during this investigation showed the levels of As, Cd, Cr and Zn are below the laboratory method detection limits . This is likely to be attributed to the recent removal of industries in Gikondo wetland which included car garages, petrol stations and other buildings that pose a high-water pollution risk.

7.2.1.3 Conclusion

For the seven metals analysed only Cu and Pb were highlighted as an issue in the area, while the remaining metals are below the detection limits of the measuring instruments. High concentrations of mercury are reported in three sites. The wide-spread use and poor disposal of batteries and waste products and use of mercuric oxide batteries could be contributing sources.

The levels of Hg, Cu and Pb in water samples largely exceed the threshold values for the protection of aquatic ecosystem and crop watering. The implication is that it may not be safe to eat fish and irrigated crops sourced from these wetlands.

The level of As, Cd, Cr and Zn was found to be below the detection limits of analytical methods, therefore,

high precision laboratory methods are suggested to confirm the presence of these metals

Whilst the baseline water quality information for Gikondo and Nyabugogo wetlands presented in this report is not sufficient to draw firm conclusion on the status of water quality, it does provide an important snapshot of information to inform planning and decision making. It serves to highlight the significant water quality risks posed to wetland and downstream users. This highlights the importance of customizing wetland rehabilitation designs to promote pollutant assimilation whilst designs will also need to take cognisance of the risks posed by contaminated water for recreational and productive uses (e.g., fish farming and agriculture).

7.2.2 Heavy metals of soil contamination in the Kigali wetlands

The laboratory results showed that concentrations of three heavy metals namely Arsenic, Copper and Lead exceeded acceptable standards for SSV1 (All Lands Uses) across most sampling sites. Standards for SSV2 (Standard Residential) were occasionally exceeded whilst that for Ecosystem Health and Agricultural use were also exceeded in some sampling sites. Whilst values for other metals were generally within acceptable ranges, high levels of Chromium were recorded at two sites in the Gikondo wetland whilst one of these sites (S05) also exhibited high concentrations of Manganese, Nickel and Zinc.

Arsenic

Contamination levels were highest at sample site S11, located in part of the industrial zone of the Gikondo wetland. Apart from this site, only two other sites showed contaminant levels that were unsuitable for residential or agricultural purposes. Thus, whilst contamination levels may not be acceptable for all land uses, contamination levels are not regarded as a major concern for general recreational-type activities being contemplated across much of the target wetlands.

Copper

Soil concentrations of copper exceeded acceptable SSV1 standards and those for the protection of ecosystem health across most sites. Concentrations were highest in the Gikondo and Kibumba wetlands although it is worth noting that contamination levels only exceed those suitable for agricultural production at two of the fifteen sample sites in the Gikondo wetland.

Lead

Levels of lead contamination were again highest in Gikondo wetland, with contamination levels exceeding standards for agricultural use and ecosystem protection at four of the sites sampled. Whilst contamination levels were generally above SSV1 levels across most sites, contamination only

exceeded agricultural limits in one of the Nyabugogo sites, whilst levels were generally quite low for all sampling sites in the Kibumba wetland.

Chromium

Contamination levels for Chromium were generally low although elevated levels were recorded at two of the fifteen sampling points in the Gikondo wetland.

Manganese

Contamination levels for Manganese were also generally low although elevated levels were recorded at sample site S05 in the old industrial zone of the Gikondo wetland.

Nickel

Contamination levels for Nickel were also generally low although elevated levels were also recorded at sample site S05 in the old industrial zone of the Gikondo wetland.

Vanadium

Contamination levels for Vanadium were generally low, and not highlighted as an aspect of concern across all but one site in the Gikondo wetland.

Zinc

High levels of Zinc were also detected at site S05 in the Gikondo wetland. Apart from this instance, recorded levels of Zinc were within an acceptable range.

Based on the results of the Macfarlane et al 2021 study, it is obvious that Gikondo wetland has the most contaminated soil and the study gives a clear direction on how soil decontamination campaign can be oriented. The consultant based this soil contamination available evidences to recommend the soil and water contamination management plan that will guide the contractor and the supervisor who must have all the expert in health and safety to accompany them to deal with contaminated soil especially in Gikondo wetland.

7.3 POTENTIAL HEALTH RISKS OF SOME SELECTED HEAVY METALS

Heavy metals become toxic when they are not metabolized by the body and accumulate in the soft tissues (Sobha et al., 2007) Toxicity of heavy metals refers to the harmful effects that result from exposure or consumption of excessive amounts or more than the daily recommended limits. Although individual metals exhibit specific signs of toxicity, the general signs associated with cadmium, lead, arsenic, cobalt, Nickel, zinc, copper, and aluminium poisoning include gastrointestinal disorders, diarrhoea, stomatitis, tremor, hemoglobinuria, ataxia, paralysis, and vomiting, and convulsion, depression, and pneumonia when vapours and fumes are inhaled (Jaishankar et al., 2014).

Arsenic (As): Arsenic is a metalloid in group VA and period 4 of the periodic table that occurs in a wide variety of minerals, mainly as As2O3, and can be recovered from processing of ores containing mostly Cu, Pb, Zn, Ag and Au. It is also present in ashes from coal combustion (Singh et al., 2007). Arsenic is one of the most important heavy metals causing disquiet from both ecological and individual health standpoints (Smith et al., 1995). It has a semi metallic property, is prominently toxic and carcinogenic, and is extensively available in the form of oxides or sulfides or as a salt of iron, sodium, calcium and copper. (Singh et al., 2007). Arsenic is the twentieth most abundant element on earth and its inorganic forms such as arsenite and arsenate compounds are lethal to the environment and living creatures. Arsenic is a protoplastic poison since it affects primarily the sulphydryl group of cells causing malfunctioning of cell respiration, cell enzymes and mitosis (Smith et al., 1995).

Cadmium (Cd): Cadmium is an important environmental pollutant present in soil, water, air and food. Anthropogenic sources add 3–10 times more cadmium to the atmosphere than natural sources (Okada, et al., 1997). Major occupational exposure occurs from nonferrous smelters during production and processing of cadmium, its alloys and compounds and the exposure is increasingly common during recycling of electronic waste (Okada, et al., 1997) as well as direct discharges from phosphate fertilizers and sewage sludge,

(ATSDR, 2007). Chronic exposure to the metal can lead to kidney disorders, anemia, emphysema, anosmia (loss of sense and smell), cardiovascular diseases, renal problems, and hypertension. Itaiitai disease appears to be a Cd-related disease, which is very painful and causes the wastage and embrittlement of bones (Nishimura et al., 2006). Cadmium is carcinogenic for number of tissue (Waalkes, 2000) and is classified as a human Carcinogen. Cadmium can enter into the brain parenchyma and neutrons causing neurological alterations in humans and animal models leading to lower attention, olfactory dysfunction and memory deficits (Nishimura et al., 2006).

Nickel (Ni): Nickel is silvery white metal that takes on a high polish; it is transition metal, hard and ductile. It occurs most usually in combination with sulphur and iron in pentalandite, with sulphur in millerite, with arsenic in the mineral nickeline and with arsenic and sulphur in nickel glance (Nestle et al., 2002). Nickel combined with other elements is present in all soils; the toxicity of nickel is dependent on the route of exposure (inhalation, oral or dermal) and the solubility of the nickel compounds (Reaves and Baker, 2000). Some of its health risk includes fibrosis, chronic bronchitis, impaired pulmonary function, and emphysema (IARC, 1990). Allergic contact dermatitis is the most prevalent effect of toxicity of nickel in the general population. All nickel compounds, except for metallic nickel have been classified as human carcinogens by the international agency for research on cancer (IARC, 1990) and US department of health and human service.

Lead (Pb): Lead is a metal belonging to group iv and period 6 of the periodic table with atomic number 82, atomic mass 207.2, density 11.4 g cm−3, melting point 327.4◦C, and boiling point 1725◦C. It is a naturally occurring, bluish gray metal usually found as a mineral combined with other elements, such as sulphur (i.e., PbS, PbSO4), or oxygen (PbCO3), and ranges from 10 to 30mg kg−1 in the earth's crust (Stephen, 2000). The main sources of Pb in the environment include, dust from leaded paints from older houses, leaded and tap water from soldered pipes (Coskun et al., 2006). Indoor chemicals and indoor smoking is also a source (Ganeshamurthy et al., 2008). Lead is probably the least mobile of the heavy metal and has low bioavailability, but due its long residence time in the soil it can be of environmental concern if the levels are high (Duffus, 2002).

Lead has negative influence on both children and adults. For children lead reduces the physical growth and mental growth. The intelligent quotient of children is diminished and symptoms of irritability and fatigue could be observed. Pregnant woman exposed to Pb can affect physical growth and can cause anemia, kidney damage, headache, hearing problems, speaking problems, fatigue or irritable mood (Coskun et al., 2006).

Chromium (Cr): Chromium is a first-row d-block transition metal of group VIB in the periodic table with the atomic number 24, atomic mass 52 and one of the less common elements and does not occur naturally in elemental form, but only in compounds (Smith et al., 1995). Chromium is present in rocks, soil, animals and plants (Zhao et al., 2012). Chromium occurs in several oxidation states in the environment ranging from Cr+2 to Cr+6 (Rodriguez et al., 2007). The most commonly occurring forms of Cr are trivalent Cr+3 and hexavalent Cr+6, with both states being toxic to animals, humans and plants (Mohanty and Kumar Patra, 2013). Its occurs naturally by the burning of oil and coal, petroleum from ferro chromate refractory material, pigment oxidants, catalyst, chromium steel, fertilizers, oil well drilling and metal plating tanneries (Ghani, 2011).

The presence of excess chromium beyond the permissible limit is destructive to plants since it severely affects the biological factors of the plant and enters the food chain on consumption of these plant materials (Ghani, 2011). Results obtained from different in vitro and in vivo experiments have shown that chromate compounds can induce DNA damage in many different ways and can lead to the formation of DNA adducts, chromosomal aberrations, sister Chromatid exchanges, alterations in replication and transcription of DNA(Scaragg, 2006). Generally Chromium is associated with allergic dermatitis in humans (Zhang et al., 2010).

7.4 CONTAMINATION MANAGEMENT PLAN

7.4.1 General principles

Controlling exposures to heavy metals in the five wetlands is vital to protecting both workers during rehabilitation activities and for future use of them. The hierarchy of controls is a way of determining which actions will best control exposures. The hierarchy of controls has five levels of actions to reduce or remove hazards. The preferred order of action based on general effectiveness is:

1. Elimination: physically remove the hazard
2. Substitution: Replace the hazard
3. Engineering controls: isolate people from hazard
4. Administrative controls: change the way people work
5. Personal protective equipment (PPE): Protect the workers with PPE

Using this hierarchy can lower and reduce human and environmental exposures.

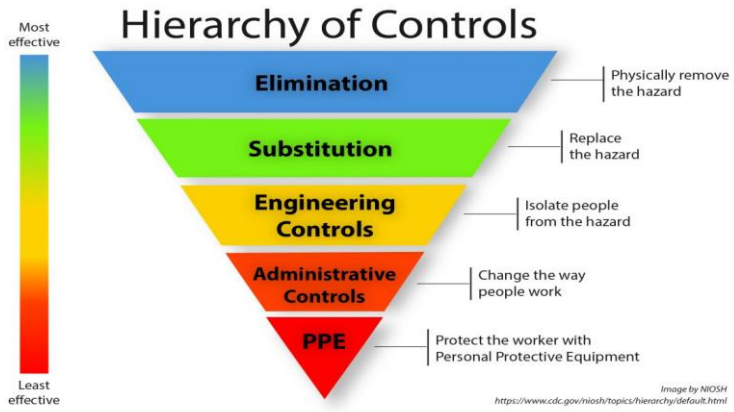


FIGURE 7-3 HIERARCHY OF CONTROL

7.4.2 Remediation techniques

The comprehensive objective of any soil remediation approach is to create a final solution that is protective of human health and the environment. The remediation strategies should incorporate reduction of metal bioavailability and the reduction should be demonstrated for a long term, only if the reduction of heavy metal is equated to reduced risk.

A successful process of remediation includes the following steps:

1) Technology pre-screening and treatability study scoping;
2) Remedial investigation of the contaminated site;
3) Feasibility study of pre-screened remediation technology;
4) Determination of best remediation method;
5) Design and implementation of remediation practices;
6) Evaluation and monitoring of remediation process;
7) Depletion in concentration and/or removal of toxic metal.

Various remediation techniques applied to soil can be employed via *ex-situ* or *in-situ* methodologies. Although the *ex-situ* methodology of soil remediation is less expensive, fast, and easier to apply, it generates a significant amount of waste product that must be treated before storing or releasing it in the landfill sites. While *in-situ* remediation methodology involves low land disturbance, applicable to a broad range of inorganic pollutants, lesser in cost, and reduced risk of spreading contamination. Broadly various remediation techniques known for improving the quality of contaminated soil are studied under three categories of their application:

- Physical Remediation Techniques
- Chemical Remediation techniques
- Biological Remediation Techniques

7.4.2.1 Physical remediation techniques

The remediation techniques that are applied through physical amendments to the soil are incorporated under this category. The physical techniques of remediation include the capping of contaminated sediments, washing, and excavation of soil.

Capping

It is a non-intrusive and cost-effective method for remediating contaminated sediment. The technique is utilized to decrease the solubility, mobility and transfer rate of heavy metals in the sediment. It is usually applied in sub-aqueous conditions. Sandy material and apatite are usually tiered in specific proportions, which are placed on the contaminated sediment like a cap. T

The cap is usually composed of a,

(i) stabilizing base layer which supports the added weight of cap;
(ii) an isolation base layer, it isolates the contaminants from the sediment;
(iii) a filter layer for hydraulic protection for the base layer;
(iv) an armor layer, it inhibits erosion for the protection of filter and base layer. Capping can be performed in two ways, Passively (inactive) or Reactively (active).

The former methodology includes a cap composed of clean and neutral material which provides a physical barrier between the environment and contaminated sediment. However, passive methods have been observed to cause leaks of toxic metals. The latter methodology includes the cap with reactive material which can reduce the mobility, toxicity, and bioavailability of contaminants in sediments. This technique is not appropriate for shallow water or marshes or water bodies with large water flows as the capping material can be washed away

Washing of soil

Sediment washing is a simpler technique that is performed *ex-situ*. In this technique, a solution is utilized to wash the contaminated sediment for the transfer of pollutants from sediment to an aqueous solution. This is achieved by mixing the soil with an aqueous solution of alkalis, acids, and surfactants.

Washing includes

i. excavation of highly contaminated sediment from the bulk soil;
ii. washing of sediment is processed with the help of aqueous mixtures;
iii. the solubilized contaminants are removed from aqueous solution through various chemical processes.

For performing this method more efficiently additives are added to the aqueous solution, depending upon the physicochemical nature of contaminated sediment. These additives should have high treatment efficiency and environmental compatibility. Common additives used are inorganic acids (sulfuric acid, nitric acid), organic acid (oxalic acid, ascorbic acids), and surfactants (sophorolipids and rhamnolipids) . EDTA has been reported as the additive for the removal of heavy metals, due to its versatile chelating nature, however, the toxic effect of EDTA on the environment and its low biodegradability has reduced its application widely . After washing, the sediment is considered contaminant depleted instead of contaminant free. Therefore, to make this technique successful, the number of contaminants treated should be quantified to be equivalent to the site-specific action limit. This technique is suitable for the contaminants which are weakly associated with sediments, and in coarse-grained sediments.

Excavation of soil

This technique includes physical removal of majorly contaminated soil from the bulk soil. There are several ways to perform this technique. It can be divided into three methodologies

i. substitution of polluted sediment by removing the soil and putting it in another soil. This method is more suitable for land contaminated in small areas;
ii. the deep excavation of contaminated sediment for natural degradation of heavy metals;
iii. importing new soil and mixed with contaminated soil for dilution of heavy metals. This technique is expensive and is efficiently applicable only on land with small areas of contamination

7.4.2.2 Chemical remediation techniques

This technique includes the utilization of chemical reagents, reactions, and principles for the removal of contaminants. Major methodologies used under this technique are solidification, immobilization, vitrification, and electro kinetics.

Immobilization

This methodology is used to stabilize heavy metals, can be applied *ex-situ* and *in-situ*. It often uses organic and inorganic reagents for the reduction of heavy metals mobility, toxicity, and bioavailability in the soil. The primary objective of this technique is to alter the bioavailable phases of metals into more geo-chemically stable phases, with the immobilization of chemicals. It is achieved through combined mechanisms of adsorption, complexation, and precipitation. The stabilizing effect of amendments is dependent upon the physical, chemical, and biological characteristics of sediment, heavy metal type, remediation time, remediation method, and evaluation method. The most common inorganic reagents used for immobilization are silico-calcium reagents, phosphates, iron-containing materials, aluminum salts, and mineral-based amendments. Organic reagents for immobilization of heavy metals include manure, biochar, biosolids, bark, wood chips, sawdust, sewage sludge, and turf. A complex formulation of inorganic and organic amendments can also be applied to the contaminated sediments for more efficient stabilization .

Solidification

It is a technique applied by mixing contaminated sediments with materials that impart physical stability to encapsulate contaminants in a solid product. Solidification is the physical encapsulation of contaminants in a solid matrix, which are formed by cement, bitumen, asphalt, fly ash and thermoplastic binders. During *In-Situ* remediation, a binding agent is added to contaminated sediment which is followed by an auger spin mixing to transform the soil into a solid matrix .

The stabilization of heavy metals includes chemical reactions which reduce their mobility in the environment. The entrapped toxic metals are not leachable as the solid block is impermeable to water. A mixture of various salts can be used for the solidification or stabilization of contaminants in soil *ex-situ* or *in-situ*. Several economically effective and environmentally friendly waste resources have been reported for their application in contaminated sediment.

These waste resources can also improve the quality of polluted soil, such as lime-based agents, calcined oyster shells, eggshells, waste mussel shells, and calcined cockle shells. However, the process does not extract the pollutant. So, over the long term, if the integrity of solid matrix is deteriorated due to natural weathering or any uncontrolled physical disaster the contaminants which are trapped can mobilize into the environment.

Therefore, this methodology is applied as a last option for remediation of soil. This technology is dependent on the concentration of contaminants present in the sediment, amount of water, and ambient temperature. These factors affect the binding reaction of contaminants to the solid material, it inhibits the binding and decreases the stability of the solid matrix.

Vitrification

This methodology of remediation is a type of stabilization/solidification technique. It requires high thermal energy in contaminated soil, at least 1400°C - 2000°C, for the removal of organic or volatile substances. It is achieved by mixing the contaminated sediments with glass-forming precursors, heating the mixture till its

liquid solution is formed. The steam produced by introducing high thermal energy and the products of pyrolysis are collected from exhaust gas . On the cooling of this solution, an amorphous homogenous glass is obtained. The contaminants can be stabilized by two ways of interactions with solid glass matrix, that is chemical bonding and encapsulation. For *in-situ* remediation, electrodes can be inserted directly into the contaminated sediments. This technique is efficient but expensive and complex to perform .

Electrokinetic remediation

In this technique, the electric field is applied to the wet contaminated sediments for the movement of ionized metals towards the cathode or anode. The pollutants are migrated towards electrodes through electro-migration (charged chemical movements), electro-osmotic flow (fluid movements), electrophoresis (charged particle movements), and electrolysis (chemical reaction due to electric field) procedures. On the completion of the remediation process, the contaminant concentrated electrodes can be treated through several techniques for treating the heavy metals. This technique performs more efficiently in fine-grained clayey soil, where heavy metals are present as soluble ions, because of high electric conductivity and strong electric field. To enhance the efficiency of this technique application of chelating agents can be performed, such as EDTA, nitrilinoacetic acid, succinic acid, citric acid.

7.4.2.3 Biological remediation

Biological remediation or bioremediation is a technique of transforming the heavy metals present in the contaminated soil, into a less toxic element. This technique uses biological phenomena that are intrinsic to plants and microorganisms, for the destruction, removal, or immobilization of hazardous contaminants from the polluted environment. Bioremediation is an eco-friendly and economically effective technique for heavy metal removal compared with the conventional chemical and physical methods, which are usually expensive and ineffective especially for sediments contaminated with low metal concentrations, in addition to producing significant amounts of toxic sludge .

The main objective of the bioremediation technique is to stimulate a favorable condition for microflora or plants at the contaminated site by providing suitable growth conditions. So, they can grow at their full potential and produce enzymes as secondary metabolites for immobilizing the toxic metals. During the bioremediation process of the contaminant, chemical bonds are broken, and energy is released, which is further utilized by the microorganisms for their growth. Various investigations show that the total transformation percentage of various heavy metals by microbes are Cr (27%), Co (20%), Cd (31%), Pb (22%) . Bioremediation technology is aided with several methodologies, such as bioventing, bioleaching, and land farming, bioreactor, composting, and bio augmentation, rhizo-filtration, and bio stimulation.

Therefore diverse metabolic activity inherent to microbes can be exploited for degradation, removal, or transformation of heavy metals in contaminated soil. Mostly bioremediation can be performed by utilizing microorganisms (algae, fungi, and bacteria), and plants (phytoremediation), or with the combinations of both.

Phytoremediation

This technique involves the use of various native, imported, or genetically modified plant species for the reduction, and removal of contaminants from soil, sludge, wastewater, sediments, and groundwater. This technique is best applicable when the contaminants are present around the rhizosphere and in a wide area of land. The basic principle in phytoremediation involves the disintegration through secondary metabolites or absorption by roots, and storing them in leaves of plants, of contaminants present in soil. Hyper accumulation and hyper tolerance are very important characteristic for a plant for their utilization in phytoremediation. Phytoremediation technique includes phytoextraction, Phytofiltration, Phytostabilization, Phytovolatilization, and Phytodegradation.

Phytoextraction/Photoabsorption/Phytosequestration/Phytoaccumulation refers to a biochemical process where the assimilation of heavy metal contaminants from the sediment or water is processed through roots and translocated to any harvestable part of the plant, based on the mechanism of hyperaccumulation. Hyper accumulators can concentrate 100 to 1000 times higher than those found in non-hyperaccumulators without suffering any apparent phytotoxic effect.

This method includes three steps

i. cultivation of suitable plant species in the contaminated land;
ii. harvesting of biomass concentrated with metal;
iii. post-harvest treatment for obtaining economic value .

The most used hyperaccumulators are from the family *Fabaceae, Brassicaceae, Lamiaceae, Cryophylaceae, Violaceae, Asteraceae, Cyperaceae, and Poaceae* .

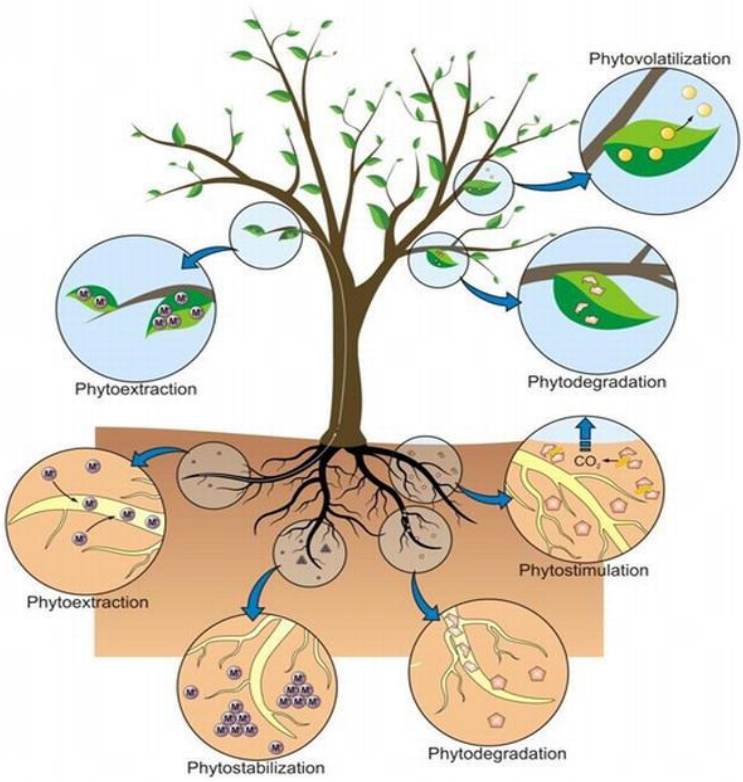


FIGURE 7-4 SCHEMATIC REPRESENTATION OF SEVERAL STRATEGIES INVOLVED IN PHYTOREMEDIATION TECHNIQUE

Phytofiltration is the cleanup method for a contaminated environment with the use of plant roots. It could be performed in three forms of rhizofiltration (plant roots), blastofiltration (seedlings), caulofiltration (excited plant shoots) .

Phytostimulation enhances the conditions of the rhizosphere for the efficient growth of microbes. It is performed for the removal of organic pollutants in the sediment.

Phytostabilization aims to the reduction of mobility and bioavailability of heavy metals in the environment by stabilizing the contaminants in the rhizosphere of plant species. It is performed by reducing the accessibility and mobility of heavy metals through precipitation, root sorption, metal valence reduction, and complexation. The efficiency of this technique can be enhanced by changing the pH and organic matter content in the sediment .

Phytodegradation is a technique utilized for degrading organic matter into non-hazardous chemicals through secondary metabolites or enzymes secreted by plants. Enzymes like nitro reductase and dehalogenases are used by plants for the degradation of organic matter. These enzymes are used only in optimal conditions (temperature, pH). This process can be performed more efficiently with the introduction of microorganisms in the contaminated soil, this technique is called Rhizodegradation.

Rhizofiltration is the process in which plants absorb and precipitate organic and inorganic contaminants through roots from contaminated wastewater, groundwater, and surface water. Major characteristic features of

plants are hypoxia tolerant, and large absorption surface area for a suitable application of this technique. Terrestrial plants are more efficient for this purpose than aquatic plants.

Microbial remediation

Microorganisms can absorb or adsorb the heavy metals present in the soil to transform its chemical nature and reduce its mobility, bioavailability, and solubility. This remediation technique by microbes can be carried out in two ways, through mobilization or immobilization. These processes are accomplished by mechanisms, like bio-precipitation, biosorption, bioaccumulation, bio-assimilation, bioleaching, biodegradation, and biotransformation. Commonly microbial species used for remediation methodology are *Bacillus, Arthrobacter, Pseudomonas, Enterobacter, Aspergillus, Penicillium, Rhizopus, Rhodotorula, Candida utilis*.

Biosorption is a mechanism where microbes either absorb or adsorb the inorganic contaminants on the cell surface or into the cell. While adsorption is performed on the surface of the cell, absorption involves an entire volume of material. Several mechanisms involved in biosorption are precipitation, the formation of stable complexes with organic ligands, and redox reaction. The process of adsorption involves forming a complex of the heavy metals and functional groups on the cell surface, from where they can be absorbed into the cell. Adsorption is executed by binding heavy metals to the cell surface through electrostatic interaction, complexation, and ion exchange. According to Jin et al., microbes perform adsorption predominantly in comparison to absorption.

Bioleaching is the mobilization of heavy metals from contaminated soil through biological dissolution, complexation, or bio-oxidation by microbial activity. The best-known microbes for bioleaching are *Thiobacillus* and *Leptospirillum ferrooxidans*. Various mechanisms of microbial metabolism produce several secretions, like low molecular organic acids. These organic acids have shown to effectively dissolve heavy metals and soil particles containing toxic heavy metals.

Bioaccumulation includes the agglomeration of contaminants into the microbe where it is concentrated, where metal is sequestered.

Bio-assimilation of heavy metals includes the active transport of microbial cell's siderophore for the chelation of toxic metals. Siderophores are biomolecules that are produced when microbes are present in iron-deficient media/environment. These biomolecules are specifically iron (Fe III) chelators which are finally transported into microbes by various uptake proteins. Many reports have suggested that if siderophores are bonded with other metals, they can still be recognized by uptake protein for its transportation into the microbial cell.

Bioprecipitation is a method that uses the mechanism of immobilization for the reduction of mobility and bioavailability of heavy metals in soil. It involves converting soluble heavy metals into insoluble hydroxides, carbonates, sulfides, and phosphates.

Biotransformation changes the chemical nature of heavy metals, altering their toxicity, mobility, and bioavailability. This methodology includes methylation, reduction, dealkylation, and oxidation of heavy metals for altering their soluble form into an insoluble form.

The applicability of these individual techniques in any specific soil remediation project is determined primarily by contamination site geography, characteristics of contaminants, the goal of remediation, cost-effectiveness, financial budget, readiness in implementing the technique, the time provided, and public acceptability as per below table. Integration of more than one technique has been experimentally proved to be more efficient, such as application of chemical remediation in highly heavy metal contaminated sediment, which can be followed by phytoremediation for further removal of remaining contaminants.

Methodology	Remediation Technique	Applicability	Advantages	Limitations
	Surface Capping	*In Situ*, in areas with excessive	Applicability is unchallenging, low	Limited to small land areas, and applicable at specific

Physical Remediation		heavy metal pollution	operating cost, high security	geographic locations, deprivation of land
	Landfilling	*Ex Situ*, applicable to areas with high metal pollution	Immediate restoration, high security	High capital cost, supplementary land is required for storing of the unproductive sediment
	Encapsulation	*In Situ*, applicable to areas with high heavy metal pollution	Isolation of heavy metal from contaminated sediment is effective, installation can be done quickly	Limited to small scale and shallow land areas, costly,
	Soil Washing	*Ex Situ*, applicable to soil with moderate to high heavy metal pollution	Efficiency is high, immediate remediation can be observed, cost-effective, removal of heavy metals are absolute	Effectiveness varies with the variation in physicochemical nature of soil, drastic soil disturbance has been observed
	Excavation of Soil	*Ex Situ,* applicable to areas with high heavy metal contamination	Removal of heavy metal is effective, Less time is required for completion of process	Production of harmful waste products which can have negative impact on soil, costly
Chemical Remediation	Stabilization	*In Situ*, applicable to areas with high heavy metal contamination	Affordable, easy to applicability, instantaneous effect on contaminated soil, covers a broad-spectrum of inorganic pollutants	Specific to different metals, temporary effectiveness, constant monitoring is required, remnants of contaminants will still be present in the soil
	Solidification	*In Situ* and *Ex Situ*, applicable to areas with high heavy metal contamination	Implementation is quick, high efficacy	High capital cost, treated land loses important ecological functions
	Vitrification	*In Situ* and *Ex Situ*, applicable to areas with high heavy metal contamination	High efficiency, easy to install, applicable to various contaminants	High capital cost due to energy requirement, limited to a small scale areas, treated land loses its environmental function
	Electrokinetics	*Ex Situ*, fine soil, applicable to soil with moderate to high heavy metal pollution	Application is easy, economically effective, deterioration of soil functions are minimum	Time-consuming, low efficiency, best for fine-textured soil with low permeability, pH of soil has to be controlled
Bioremediation	Phytoremediation	*In Situ*, applicable to soil with low to moderate heavy metal pollution	More public acceptance, economically effective, easy to apply	Limited to shallow land, time-consuming, restricted to specific metals, effectiveness depends on the growth conditions, and bioavailability of heavy metals.
	Contaminant transformation with the help of microbes	*In Situ*, applicable to soil with low to moderate-heavy metal pollution	Easy to implement, economical, disturbance to soil is low, remediation is less time consuming	Depends on microbes, soil, metal type, and plant, low efficacy

FIGURE 7-5 MECHANISMS, ADVANTAGES AND DISADVANTAGES OF THE AVAILABLE REMEDIATION TECHNIQUES FOR HEAVY METAL CONTAMINATED SOIL

7.4.3 Conclusion and recommendations

The currently available remediation techniques as discussed above for heavy metal contaminated soil demonstrate different advantages and disadvantages. The applicability of these recommended techniques in the rehabilitation of the five wetlands project in Kigali will be determined primarily by the contamination site geography, contamination characteristics, the remediation goal, cost effectiveness, financial budget, implementation readiness, time requirement, and public acceptability.

All these factors have been considered and comprehensively evaluated to select the best techniques for a specific soil remediation project. Therefore, an integrated use of two available soil remediation techniques at different stages and locations of a project will be necessary. Encapsulation will be practiced at severely contaminated sites to reduce the bioavailability and toxicity of high-concentration heavy metals in soil and allow plants to establish, followed by phytoremediation to gradually restore the ecosystem functions of the contaminated soil.

Encapsulation

This will be implemented by the contractors by immobilization of toxic metal solutions as an effective method to reduce hazardous material and their subsequent safe disposal as a landfill by encapsulating them in manageable solid blocks. As per the available data, the encapsulation will only be applied for the isolated areas where the heavy metals laboratory test results are above the normal threshold. Encapsulation technique will involve the mixing of the contaminated soils with other products, such as concrete, lime or asphalt. Thus the contamination of surrounding materials is prevented by immobilization of contaminated soil. Because of its easy availability, versality and cost effectiveness, cement is preferred for the best binding materials which are used in solid blocks formation.

Phytoremediation

Use of plants to remediate and revegetate the heavy metal contaminated sites known as phytoremediation. This technique is also known as botano remediation, vegetative remediation, green remediation and agro remediation. For removing the heavy metals from the contaminated sites, phytoremediation technique utilizes a variety of plant processes and the physical characteristics of plants.

In recent years, some special emphasis has been developed on phytoremediation. Since this property can be exploited for remediation of heavy metal polluted soils. It is one of the most cost effective, efficient and eco-friendly in-situ remediation technologies which is driven by solar energy. Also the exposure of polluted substrates to humans, wildlife and the environment is prevented by this remediation technology. Phytotransformation (An incomplete or absolute breakdown/degradation of complex organic molecules with in plant tissues), Phyto stimulation (A circumstance that allows the seepage of plant enzymes or secretion into the root zones to induce or enhance the metabolic activities of relevant microbes for the breakdown of organic pollutants), Phytostabilization (The choice that utilizes plants to diminish or restrict the movement of pollutants of interest

This process will be achieved by using plants as barriers to erosion, leaching or other runoffs as a way of mitigating bioavailability of the pollutants within the environment. Thus pollutant entry into ground water or food chain will be considerably minimized), Phytovolatilization (This process is the volatalization of pollutants or metabolites using plants. Most pollutants, especially the volatile organic carbons will be removed via this process. And also selenium & mercury are removed with this technology) are the diverse groups of phytoremediation techniques. Due to its efficacy and cost efficiency removal of heavy metals through phytoremediation, especially hyper accumulators to degrade and detoxify contaminants has received wide attention. Compared to other plants, hyper accumulators have been found to exhibit higher heavy metal tolerance and accumulating abilities . The following table highlights the recommendations of some literature on the type of plants and bacteria to be used by each individual heavy metals:

Heavy metal	Plant species	Degrading Microorganisms
Cd	*Salix spp. (Salix viminalis, Salix fragilis)*	*Alcaligenes sp, Pseudomonas sp*
Cu	*Populus spp. (Populus deltoids, Populus nigra)*	*Cardidatropicalis, Bacillus licheniformisc*
Pb	*Corn (Zea mays)*	*Penicillium chrysogenum*
Ni	*Jatropha (Jatropha curcas)*	*Bacillus subtilis, P.licheniformis*
Zn	*Populus canescens*	*Rhizopus arrhizus, Penicillium spinulosum*
Hg	*Populus deltoids*	*Penicillium chrysogenum*

During the 5 wetlands rehabilitation construction works, the contractor under the guidance of health and safety expert will follow the following essential steps to implement the encapsulation technique:

1) technology prescreening and treatability study scoping,
2) remedial investigation of the contaminated site,
3) feasibility study of prescreened remediation techniques,
4) determination of best remediation methods,
5) design and implementation of remediation practices,
6) evaluation of remediation performance .

Prescreening for feasible soil remediation techniques will be conducted at the very beginning of a project by searching the technology literature and consulting with experts. The feasibility of a prescreened remediation technique will be then evaluated through treatability studies after the contaminated site is carefully characterized for geographic and contamination information.

A treatability study has typically three sequential tiers:

1) screening tests at bench/small scales,

2) selection tests at small/pilot scales,

3) treatability tests at pilot/full scales

Bench/small scale screening tests will be conducted under conditions similar to those in the field operation scenario to initially assess the feasibility of the prescreened soil remediation techniques. Feasibility will be measured by how well a remediation technique achieves the performance goals that are pre-set based on the cleanup/remediation criteria. If all prescreened techniques will be rejected in the screening tests, the performance goals and even the remediation criteria need to be adjusted. Remedial alternatives will then be identified and tested. A technology passing the screening tests needs to be further evaluated by selection tests to assure its performance and to estimate the costs associated with full-scale implementation.

Selection tests are normally performed with pilot or full-scale equipment to confirm the feasibility of the screened remediation technique and investigate the optimal, equipment-specific operational parameters. Prior to intensive implementation, the feasibility of the selected remediation technique will be further validated by treatability tests, which are mostly performed by remediation contractors in the field with pilot- or full-scale equipment. The treatability tests also will generate detailed design, cost, and performance data, helping select the best contractor and remediation process. As far as encapsulation technique is concerned, the treatability study will not be necessary because we have sufficient data in the literature and the main outcome will be to isolate completely the contaminated soil.

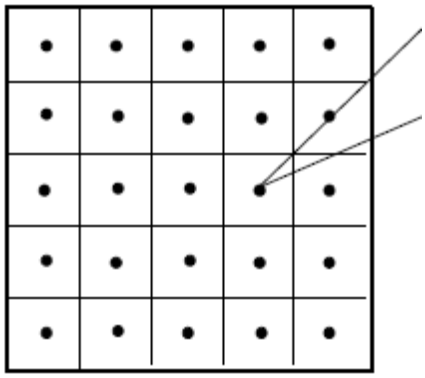
7.4.4 Example of sampling and testing methodology

The following methodology was used for Gikondo.

7.4.4.1 Sampling

Grid soil sampling consist of the development of site-specific topography global positioning systems (GPS) into a systematic grid pattern. For Gikondo wet land the grid sample points should be organized into a systematic grid-rectangle sampling pattern of 1.6 ha for better representation within commend area. Grid soil

samples will be taken within the grid cell at the center and other four samples far from the center following its diagonal line. In each grid 5 cores samples will be taken to form one soil composite.



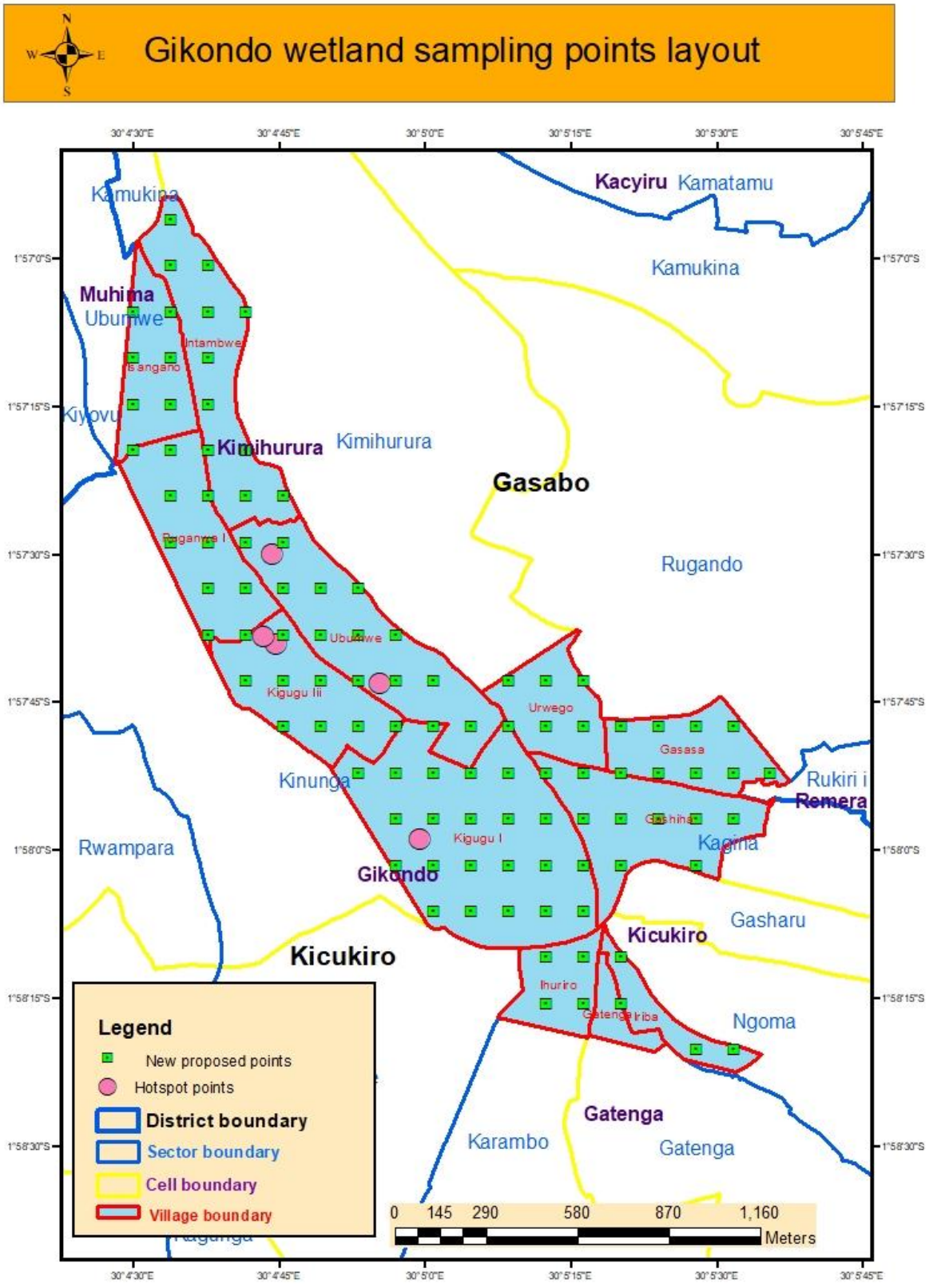
The first step in taking a soil sample is to remove the top surface materials (1 to 3 cm) to remove any organic debris. Since the purpose of this work is to estimate the actual heavy metals status in the formal industrial zone. An auger sampling to a depth of 0 to 30 cm will be taken into consideration. Samples will be collected into clean bucket and mixed thoroughly to get a homogeneous composite sample. All samples will be placed in individual sterile bags well labelled with waterproof marker, sealed and stored for laboratory analysis purposes. Soil sample labels will include the sampler's initials, location identification and date. The details of the samples will be filled on the information sheet according to Moberg, J.P. (2001) and soil samples will be taken to RAB analytical laboratory for heavy metals parameter analysis. According to our plan 100 soil composites will be collected to cover entirely the identified hot spots area

7.4.4.2 Laboratory analysis

The first step in taking a soil sample is to remove the top surface materials (1 to 3 cm) to remove any organic debris. Since the purpose of this work is to estimate the actual heavy metals status in the formal industrial zone. An auger sampling to a depth of 0 to 30 cm will be taken into consideration. Samples will be collected into clean bucket and mixed thoroughly to get a homogeneous composite sample. All samples will be placed in individual sterile bags well labelled with waterproof marker, sealed and stored for laboratory analysis purposes. Soil sample labels will include the sampler's initials, location identification and date. The details of the samples will be filled on the information sheet according to Moberg, J.P. (2001) and soil samples will be taken to RAB analytical laboratory for heavy metals parameter analysis. According to our plan 100 soil composites will be collected to cover entirely the identified hot spots area.

7.4.4.3 Data interpretation

The obtained data will be interpreted using the International Maximum Allowable Standards of metal concentrations (mg/Kg) in the soil guidelines for determining the safety of various land uses based on total soil metal concentrations (Haidula et al., 2011).


Gikondo wetland sampling points layout
N
W
E
S
30°4'30"E
30°4'45"E
30°5'0"E
30°5'15"E
30°5'30"E
30°5'45"E
1°57'0"S
1°57'15"S
1°57'30"S
1°57'45"S
1°58'0"S
1°58'15"S
1°58'30"S
Kamukina
Kacyiru
Kamatamu
Muhima
Ubumwe
Intambwe
Isangano
Kiyovu
Kimihurura
Gasabo
Rugando
Kigugu III
Urwego
Gasasa
Kinunga
Rukiri i
Remera
Kigugu I
Gashiha
Kagina
Rwampara
Gikondo
Gasharu
Kicukiro
Ihuriro
Gatenga Iriba
Ngoma
Gatenga
Karambo
Legend
New proposed points
Hotspot points
District boundary
Sector boundary
Cell boundary
Village boundary
0
145
290
580
870
1,160
Meters

8. TECHNICAL SPECIFICATIONS

The following paragraphs detail the technical specifications of the various proposed detailed designs for the 5 wetlands.

8.1 CONSTRUCTION TECHNIQUES FOR HYDRAULIC STRUCTURES AND ISLANDS

A specific attention has been given to the choice of the most appropriate technical construction methodology for hydraulic structures and islands. More specifically, the subject of the maintenance and support of farms is particularly sensitive because the technical, environmental and financial stakes are huge.

Different techniques were considered:

- Excavation with low slopes and soil compacting with topsoil: this technique is suitable for channel and low water pressure structures

- Construction of gabions walls with more important slopes: this is well adapted for bank protection as well as for spreading structures with low water pressure.

- Construction of concrete retaining walls: this could be useful to counteract major earth or water surges, including conveying structures or ponds.

- Creation of heavy or light sheet pile structures to maintain the soil or to create clear delimitation between soil and earth, adapted to conveying structures, ponds and islands.

The choice of soil compaction and gabion walls was the most appropriate for most of the structures. This choice was favored by the vast majority of structures because it is the most economically and environmentally advantageous :

- New channels, new spillways, meandering, water spreading structures, detention basin
- Bank protection (gabions walls), soil reshapings…

For heavier structures, a multi-criteria analysis was considered to define the most appropriate solution.

It is explained in the table hereunder.

It concerns:

- Water conveying structures
- Ponds
- Islands

Comparison of construction methodology for heavy structures								
Item	Criteria	Weight	Description	Solutions				
				Excavation and soil compacting	Gabion walls	Concrete retaining walls	Still piles	Vinyl piles
Technical criteria	Stability	2	Efficiency of the proposed solution for stability	-	+	+ + +	+ + +	+ + +
	Works difficulties - risk of blockage	1	Difficulty in carrying out the works	+ +	+	+	+ +	+ + +
	Works duration	2	Impact on time schedule for construction	- -	+	+	+ +	+ +
Environmental criteria	Nature of materials	1	Natural / renewable material used	+ + +	+ + +	- -	- -	+ +
	Plantation	1	Possibility to ensure plantations diversity	+ +	-1	-	+	+
	Wetland habitats	1	Connectivity for wetland habitats	+ +	+	+	+	+
Financial criteria	CAPEX	2	Investment costs	- -	+	-	- -	+
	OPEX	2	Operation and maintenance costs	+ + +	- -	+	+ +	+ +
			Total +	15	11	12	18	23
			Total -	-10	-5	-5	-6	0
			Balance	5	6	7	12	23

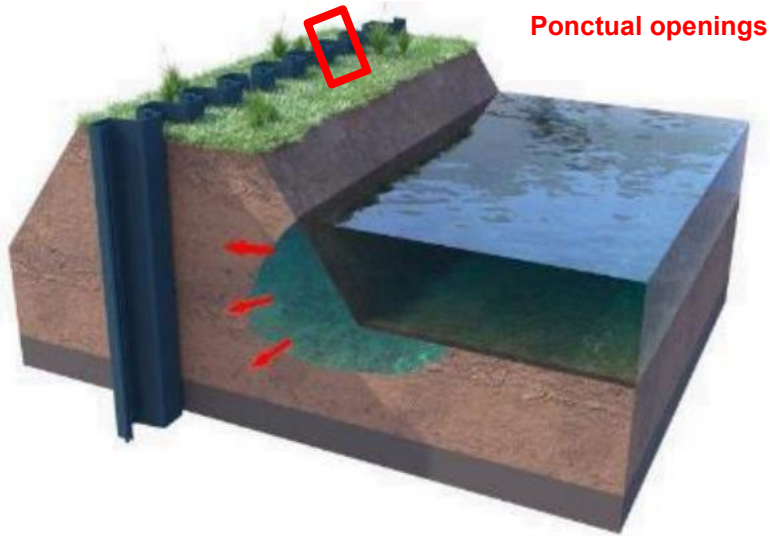
TABLE 8-1 MULTICRITERIA ANALYSIS FOR CONSTRUCTION METHODOLOGY OF HEAVY STRUCTURES

According to the analysis result, the most appropriate methodology for heavy structures construction is **the use of vinyl piles**.

The main advantage are :

- This solution is durable, resistant and water tight
- It allows to save time
- It is cost-effective
- It is environmentally friendly and aesthetical

In addition, it is important to precise that the connectivity will be fully ensured through the use of the following disposition of piles and punctual openings that will not have impact on the structure.



8.2 BOTANICAL SPECIFICATIONS

8.2.1 Revegetation areas

Wetland and surrounding plants should be selected according to their benefits to wildlife, people, landscape, and water quality.

The following selection proposes regionally or locally native plants that will thrive better in the Kigali wetland environment. These are mainly endemic and non-invasive species in order to promote soil protection.

- Species will be diversified in order to enrich the composition of the bedding, habitats and food resources for the flora and fauna.
- Specific areas will be planted with a different selection of trees and plants in order to create special natural habitats and aesthetically pleasing niches that will add landscape quality to the urban environment

- The use of submerged aquatic plants is also recommended as they can provide egg-laying substrate for insects such as dragonflies, etc.
- The use of non-native and invasive species must be avoided.
- The use of plants to remove, contain or render harmless environmental pollutants may offer an effective, environmentally friendly, and relatively low-cost remediation method for polluted land, especially in Gikondo.
- Works cannot be carried out during periods of prolonged heavy rainfall, as there is a risk of causing the bottom of the compartments to settle. This settlement could have an impact on the root development of the plants.

During the construction phase, no rainwater should reach the wetlands.

The following plants are proposed to be used in the wetlands according to their purpose.

FIGURE 8-1: PROPOSED PLANT SPECIES

Each of the above species has a specific function which is described in the following table. A gallery of the proposed species is also provided in Annex 5.

Species	*Type*	*Function*
Acacia kirkii	Tree	Locally rare tree and already present in Nyabugogo, it is adapted to wet areas and will be planted for wetland restoration
Aeschynomene elaphroxylon	Shrub	Riverbanks stabilization
Bambusa vulgaris	Tree	To be kept in Rugenge-Rwintare where it is in abundance
Blighia unijugata	Tree	Locally rare tree, adapted to wet areas and will be planted for aesthetic purposes on the green belt, linear park and road reserve.
Brachiaria brizantha	Grass	Soil stabilization
Brachiaria humidicola	Grass	Grass planted for wetland restoration
Brillantaisia cicatricosa	Shrub	Adapted to wet areas, it will be planted for the restoration of riparian areas.
Croton megalocarpus	Tree	It will be planted as ornamental tree in the green belt, linear park and road reserve, and as shade tree in recreational areas.

Cyperus articulatus	Grass	Sedge planted for wetland restoration
Cyperus denudatus	Grass	Sedge planted for wetland restoration
Cyperus dives	Grass	Sedge planted for wetland restoration
Cyperus latifolius	Grass	Sedge planted for wetland restoration
Cyperus papyrus	Grass	Sedge planted for wetland restoration
Echinochloa pyramidalis	Grass	Grass planted for wetland restoration
Elaeis guineensis	Tree	It will be planted as ornamental tree in the green belt, linear park and road reserve, and as around the ponds.
Eragrostis racemosa	Grass	Soil stabilization
Ficus vallis-choudae	Tree	It will be planted as ornamental tree in the green belt, linear park and road reserve, and as shade tree in recreational areas.
Juncus effusus	Grass	Rushes planted for wetland restoration
Leersia hexandra	Grass	Grass planted for wetland restoration
Ludwigia abyssinica	Grass	Herb adapted to wet areas and will be planted for wetland restoration
Maesopsis eminii	Tree	It will be planted as ornamental tree in the green belt, linear park and road reserve.
Nymphaea nouchali	Grass	It will be planted as floating plant on ponds for aesthetic purposes
Panicum maximum	Grass	Grass planted for wetland restoration
Persicaria decipiens	Grass	Herb adapted to wet areas and will be planted for wetland restoration
Phoenix reclinata	Tree	It will be planted as ornamental tree around the ponds.
Phragmites mauritianus	Shrub	Riverbanks stabilization
Polycias fulva	Tree	It will be planted as ornamental tree in the green belt, linear park and road reserve, and as shade tree in recreational areas.
Senegalia polyacantha	Tree	It will be planted as ornamental tree in the green belt, linear park and road reserve, and as shade tree in recreational areas. It will also be planted on the proposed island in Rugenge-Rwintare and serve to host birds.
Sesbania sesban	Shrub	Riverbanks stabilization
Setaria homonyma	Grass	Grass planted for soil formation and stabilization on the island in Rugenge-Rwintare
Spathodea campanulata	Tree	It will be planted as ornamental tree in the green belt, linear park and road reserve, and as shade tree in recreational areas.
Sporobolus pyramidalis	Grass	Soil stabilization
Typha domingensis	Grass	Cattail planted for wetland restoration

TABLE 8-2 FUNCTIONS OF THE DIFFERENT SPECIES

8.2.2 Origin of plants

In addition to the previous list, it is important to mention the following :

- Maximum vegetation (new) cover will be 80%. Therefore, suggested vegetation cover varies depending on already existing (desired) vegetation for all the wetlands
- Not all plants will be sourced from the site, the table below indicates potential origin of planting materials
- The propagation material is given as well for all species

No	Species	Strategy			Propagation Material
		From Kigali and surrounding wetlands	From other natural habitats	Buy from Kigali nurseries	
1	*Acacia kirkii*	Yes	Yes		Seedlings, direct seeding and wildings
2	*Aeschynomene elaphroxylon*		Yes		Seeds
3	*Bambusa vulgaris*	Yes	Yes	Yes	Culm cuttings
4	*Blighia unijugata*		Yes		Seeds
5	*Brachiaria brizantha*		Yes		Seeds and division
6	*Brachiaria humidicola*		Yes		Seeds and division of culms or root pieces
7	*Brillantaisia cicatricosa*	Yes	Yes		Seeds
8	*Croton megalocarpus*	Yes		Yes	Seeds
9	*Cyperus articulatus*	Yes	Yes		Seeds and division
10	*Cyperus denudatus*	Yes	Yes		Seeds and division
11	*Cyperus dives*	Yes	Yes		Seeds and division
12	*Cyperus latifolius*	Yes	Yes		Seeds and division
13	*Cyperus papyrus*	Yes	Yes	Yes	Seeds and division
14	*Delonix elata*		Yes		Seeds, cuttings and air layering
15	*Dodonaea viscosa*		Yes		Seeds, cuttings and air layering
16	*Echinochloa pyramidalis*	Yes	Yes		Seeds
17	*Elaeis guineensis*		Yes	Yes	Seeds
18	*Entada abyssinica*		Yes		Seeds and root suckers
19	*Eragrostis racemosa*	Yes	Yes		Seeds
20	*Ficus vallis-choudae*		Yes		Seedlings, wildings and cuttings
21	*Ficus sycomorus*		Yes		Cuttings and wildings
22	*Juncus effusus*	Yes	Yes		Seeding and division of rhizomes
23	*Kigelia africana*		Yes		Seedlings and wildings
24	*Leersia hexandra*	Yes	Yes		Seeds and division
25	*Ludwigia abyssinica*	Yes	Yes		Seeds
26	*Maesopsis eminii*		Yes	Yes	Seedlings, wildings or direct sowing
27	*Markhamia lutea*		Yes	Yes	Seedlings and root suckers

28	*Olea europea* subsp. *africana*		Yes		Seedlings and wildings
29	*Panicum maximum*	Yes	Yes		Seeds, sprigs and division
30	*Persicaria decipiens*	Yes	Yes		Seeds
31	*Phoenix reclinata*		Yes	Yes	Seedlings and suckers
32	*Phragmites mauritianus*	Yes	Yes	Yes	Seeds and division
33	*Podocarpus latifolius*		Yes	Yes	Seedlings, direct sowing and wildings
34	*Polycias fulva*		Yes	Yes	Seedlings and wildings
35	*Pterygota mildbraedii*		Yes		Seedlings and wildings
36	*Senegalia polyacantha*	Yes	Yes		Seedlings, direct sowing and wildings
37	*Sesbania sesban*	Yes	Yes		Seedlings, direct sowing and wildings
38	*Setaria homonyma*	Yes	Yes		Seeds
39	*Spathodea campanulata*	Yes	Yes	Yes	Seedlings, wildings and root suckers
40	*Sporobolus pyramidalis*	Yes	Yes		Seeds and division
41	*Sterculia tragacantha*		Yes		Seedlings and direct sowing
42	*Syzygium guineense*		Yes		Seedlings, direct sowing and wildings
43	*Typha domingensis*	Yes	Yes	Yes	Seeds and division

TABLE 8-3 ORIGIN OF THE SPECIES

8.3 PEDESTRIAN / CYCLING TRAILS

Soft mobility networks will be created to improve permeability, accessibility, connectivity and pedestrian comfort. Wetland trails are to be retrofitted to prioritize and encourage pedestrian movement, and where possible including accessibility for individuals with impaired mobility.

Design:

- A clear hierarchy is to be developed for easy wayfinding and sense of place.
- Two types of signage are to be installed along the trails: (i) informative signage, providing basic information such as opening hours, location plans, delimitating trails on the ground, etc.) and (ii) interpretative signage (aiming at wetland protection sensibilization, with information on plants and animal species and areas of special interest).
- Where possible, trails can ensure the continuity between interconnected wetlands.
- All pedestrian circulation shall be fully accessible to the disabled.
- Trails are to be planted with native and/or plants.
- Rest areas with benches should be installed at a maximum distance of 500 meters from each other for improved accessibility.
- Cycling lanes can be added to trails where possible to promote the use of bicycles as means of transportation for short journeys.
- Where possible, trails should delimitate the wetland and create a buffer zone that prevents future encroachment and associated reduction of wetland functions.
- Trees, grass and shrubs should be planted along the trails to improve experience and delimited the circuits.

FIGURE 8-2 OSO BAY WETLANDS PRESERVE, TEXAS, US & TRAIL AT NYANDUNGU ECO PARK, KIGALI, RWANDA

FIGURE 8-3 LOUGH BOORA DISCOVERY PARK, IRELAND

8.4 PUBLIC FURNITURE

8.4.1 Signage

Two types of signs can be installed along the trails, observation decks and arboretum:

(i) General information/wayfinding signs — provide name and description of the wetland/trail, provide useful information (e.g., hours of operation, house rules, etc.) and mark trail waymarking.

(ii) Interpretative signs — describe plants and animal species and areas of special interest

- For improved interaction, signs should be kept simple and convey clear information.
- Given the natural characteristics of the wetland's environment, weather resistant materials should be used for all signage.
- Signs should be placed in highly visible areas (e.g., at starting points of trails and/or adjacent to decks and public esplanades)
- Hardwood supports are recommended for their durability and to keep a coherent materials palette
- The installation of hardwood benches is recommended for their durability and to keep a coherent materials palette.
- Use of live fences to protect freshwater wetlands planted with trees/shrubs is recommended in strategic areas
- Street furniture is made almost entirely of locally sourced wood.
- Artificial lighting should be kept to a minimum to preserve natural habitat spaces of the wetlands. Light poles can be installed on viewing decks and along trails that are located close do urban settings.

FIGURE 8-4 WAYFINDING AND INTERPRETATIVE TACTILE SIGNAGE

8.4.2 Lighting

Artificial lighting should be kept to a minimum in order to not interfere with wildlife. Reducing the intensity of lights can often improve visibility for humans by reducing the contrast between light and shadow, allowing people to see a larger area than they might otherwise be able to discern.

Embedded lights will allow wayfinding with minimal intensity and good directional control. The more focused light can be on its target, the less it will affect other species.

FIGURE 8-5 SMALL LIGHT POLES & SPOTLIGHTS CAN BE INSTALLED ALONG TRAILS AND DECKS

8.4.3 Benches

FIGURE 8-6 EXAMPLES OF WOODEN BENCHES

8.4.4 Litter Containers

FIGURE 8-7 WEATHER-RESISTANT LITTER BIN IN WOOD

Material:

- Galvanized steel,
- Powder coating,
- Wood.

Dimensions:

- Width 38cm
- Length 38cm
- Height above ground 49 cm

To be cemented in place

FIGURE 8-8 WEATHER-RESISTANT WOOD LITTER BIN

Materials:

- Galvanized steel
- Weather-resistant wood

Dimensions

- Width 60cm
- Length 60 cm
- Height above ground 80 cm

To be cemented in place

8.4.5 Bicycle Racks

FIGURE 8-9 STEEL AND WOODEN BICYCLE RACKS

- Space for 2 units
- 1 galvanized steel arch
- Pole diameter 12 cm

Dimensions

- Width 86cm
- Diameter 12 cm
- Height above ground 90 cm
- Total height 120 cm
- To be cemented in place

8.4.6 Protective Guarding

FIGURE 8-10 SAFETY WOOD GUARDRAIL & LIVING FENCE

FIGURE 8-11 WOOD AND STAINLESS STEEL CABLES GUARDRAILS & LIVING BARRIER PROTECTING WATERCOURSES

8.5 CONSTRUCTION SPECIFICATIONS

8.5.1 Structure surface cover

Following our sustainability and ecological principles, we propose the use of local materials widely available either regionally or locally in Rwanda and whose implementation methods are known and mastered. As a general guidance and as to avoid the impermeabilization of surfaces, the use of laterite for all built surfaces is recommended. Laterite is a material that requires little work, maintenance, and it is more flexible and durable than other surface materials such as concrete or tarmac.

FIGURE 8-12 NATURAL HARD WOOD AND NATURAL HARDWOOD DECKING

FIGURE 8-13 LATERITE & STABILIZED SOIL

The treatment of the soil will have to be the subject of a precise study that will allow to:

- Limit the water sensitivity of the materials
- Ensure the accessibility of the work areas for construction equipment and for users
- Limit the effects of erosion

The rehabilitation project potentially a substantial charge to the government's maintenance requirements. The proposed design of landscapes seeks to limit these maintenance requirements and the resources associated:

- Limiting lawn to areas where it is absolutely required for facilities (such as immediately around observation decks). Where lawn is required, using drought tolerant hybrids or alternative groundcovers should be explored.
- Planting drought tolerant plants in formal landscapes and avoiding invasive species. Irrigating these landscapes with harvested rainwater

Surfacing of pedestrian/cycling trails will be composed by stabilized soil (mechanical stabilization) and laterite.

Urban esplanades and other Public urban areas will be treated in the same concrete mix but with a shot-blasted surface treatment, as well as by supporting the construction lines of the spaces (steps, steps, walls, etc.).

Decks and observation towers should be seamless and well-integrated in the landscape for improved aesthetics. The use of hardwood is recommended as a natural material that blends well into the natural landscape.

8.5.2 Earthworks

8.5.2.1 Material requirements

This chapter describes the gradation requirements of backfill and rip rap materials for the sides of gabion protections, upstream and downstream road crossing structures.

The fill materials shall in general be well graded within the specified gradation limits. Gap graded materials shall not be accepted.

Random Compacted backfill

The local material can be used for compacted backfill, except where granular material is specified as backfill. All materials used for compacted backfill of structure shall be approved by the Engineer. The compacted backfill at the structures shall be completed as shown on the Drawing and as required by the Engineer. Backfill will not be placed at any of the structure or structures until the Engineer has inspected this part or parts and given his final acceptance.

Embankments shall be constructed to the lines and grades shown on the Drawings, or as directed by the Engineer.

Material for construction of embankments shall be obtained from river or structure excavation as indicated on the Drawings, or from borrow areas as directed by the Engineer.

Only material, which in the opinion of the Engineer is suitable for embankment construction shall be used. Fill material shall be clean and free from any unsuitable material. Unsuitable material shall mean material other than suitable material and shall include:–

- Material from marshes
- Tree and plant stumps
- Perishable material
- Material of liquid limit exceeding 40% as determined by BS 1377
- Material of plasticity index exceeding 11% as determined by BS 1377
- Material subject to spontaneous combustion
- Soils containing more than 2% of organic matter
- Soils having more than 80% passing the 0.075 mm sieve

Material which has previously been compacted and thereafter excavated shall not be used for the construction of embankments.

The Engineer will designate which material shall be used for each section of embankment, and Contractor shall carry out the works accordingly.

Any unsuitable material deposited in the work shall be removed and replaced by acceptable material by the Contractor at his own expense. Material unsuitable for the embankment encountered in the river and structure excavation may be used as the Engineer may direct or may be completely rejected.

No direct payment will be made for any losses of material which may result from shrinkage, compaction, erosion, leakage or any other cause.

Liquid Limit and Plasticity Index

The fill material shall have a liquid limit not exceeding 60% and a plasticity index not exceeding 30 when determined in accordance with the requirements of AASHTO T-89 and T 90.

Maximum Particle Size

The fill material shall not contain particles with a maximum dimension exceeding two-thirds of the specified layer thickness after compaction, except in the case of rock fill.

Topsoil

Economy Grade could be used for this purpose (as per BS 3882 Specification for Topsoil). Economy Grade is derived from a topsoil of lower quality than general purpose grade topsoil or a material, such as subsoil or friable mineral matter which is suitable for plant growth, for example, Greensand, river silt or glacial moraine. It is divided into materials of 'low clay' and 'high clay' subgrades. This material is suitable for amenity woodland, wildlife conservation areas, less intensively used amenity grassland and agricultural land of low inherent productivity.

Grade of topsoil quality	Maximum Stone content % (m/m)			pH value
	>2mm	>20mm	>50mm	
Economy Grade	65	60	40	5.0-8.2

Topsoil material requirements Grade of topsoil quality Maximum Stone content % (m/m) pH value >2mm >20mm >50mm Economy Grade 65 60 40 5.0-8.2 2.2.3.

8.5.2.2 Excavation requirements

Lines, grades and cross-sections

All earthworks shall be performed accurately to the lines, grades and cross-sections as shown on or indicated by the Drawings or and directed by the Engineer.

The cross sections that are to be constructed in river shall be subject to variations from the typical sections shown on the Drawings as may be necessary to provide satisfactory compliance with the present specifications and requirements.

Stripping

Strip and remove all topsoil and organic material from the footprints of the channels, road crossing structures and other structures areas, borrow areas and from the other locations as shown on the drawings or as directed by the Engineer.

Perform stripping in the area of the channels, road crossing structures and other structures carefully to minimize the waste of underlying material meeting the specifications for embankment and foundation materials.

Haul topsoil/overburden material and store at designated stockpile areas to permit their recovery and reuse for restoration of borrow areas subsequent to completion of the works.

Where the upper portion of the embankment area, or excavation areas from which fill material will be taken, or borrow areas, contain excessive salt, they will be stripped to the depth as directed by the Engineer.

During the course of the Work protect the general environment from damage in accordance with environment protection practices followed by the Owner, or as directed by the Engineer.

Limits of excavation

Excavation shall be completed to the lines and levels shown on the drawings or as directed by the Engineer. Any revision and or modification of the excavation limits that the Engineer may find necessary will be paid for in accordance with the contract.

Carry out an additional Work with payment under the contractual provisions for variations if the revision requires additional excavation, or over-excavation, to be made after the excavation of such part has already been carried out to a point where the normal procedure for the main excavation cannot be reasonably used.

Excavation shall be carried out in a manner that will reduce over-break to a minimum and that will avoid disturbing the material outside final excavation lines and grades.

Do not deliberately excavate beyond the limits shown on the drawings without written approval by the Engineer. Any deliberate excavation beyond the required limits for any purpose will be at the expense of the Contractor. If such excavation should require backfilling, such backfilling will be done at the Contractor's expense with material similar to the fill to be placed against the excavated surface. Filling any over excavation will have the same or better properties than the in-situ material.

Methodology of excavation

The methods used in making excavation shall be such as will not shatter or loosen excavation slopes and as will leave the slopes accurately and smoothly trimmed. As far as practicable, the materials to be excavated shall be loosened by means of rooters and scarifies or shall be excavated without previous loosening.

Excavation shall not be carried on when conditions prevent the placing of the excavated materials at the specific location at which their use is prescribed by the Engineer.

Excavations for foundation of all structural work, either prefabricated or constructed in place, shall be excavated to the levels and dimensions shown on the Drawings or to such other levels as the Engineer may direct. Special care shall be taken not to disturb the bottom of the excavation, and to ensure that the last 15 cm is excavated by hand just before the structure is placed.

Procedures on Completion of Excavation

Upon substantial completion of excavation, clear the excavated surface of soil sufficiently to allow inspection. Do not commence final surface preparation procedure until the excavated level has been approved by the Engineer. Do not cover any excavated surface until approved. At no additional cost to the Owner, uncover any excavation which has been covered without such approval.

Classification and disposal of Excavated material

Classify excavated material as suitable or unsuitable for the Works. All suitable excavation material shall be utilized, as far as practicable, in embankment construction. Excavated material in excess of that required for fill, shall be disposed of as directed by the Engineer in a neatly finished manner, but shall not hinder the drainage of the surface water to borrow pits, ditches, or drains.

Haul and dispose unsuitable materials (waste) and excess materials not used in embankment at approved disposal areas. Spread the material in the areas in layers as directed by the Engineer. Compact such material to the maximum extent practical by routing the haulage traffic over the area.

Keep all such disposal areas neat and tidy and finish and grade surfaces to the extent necessary to provide surface drainage and prevent future erosion of the materials. Take all necessary and effective measures to prevent any objectionable accumulation of water resulting from the placement of unsuitable materials.

Excavated materials disposed of contrary to the requirements stated above, without the consent of the Engineer, shall be picked up and redeposit as the Engineer directs, and at the Contractor's expense.

Safety of excavations

Provide copies of the Contractor safety plan to the Engineer prior to the start of any excavation work. Take full responsibility for the stability and safety of all excavation works and methods of construction including temporary support of excavated surfaces, diversion of water, pumping, etc. Assume full responsibility for the safety and prevention of injury to personnel, for damage, and comply with relevant local regulations. Remedial work will be at the Contractor's expense in cases where the Engineer considers that reasonable preventive measures have not been exercised.

The sides of the pits and trenches shall, when required, be adequately timbered and supported to the satisfaction of the Engineer. The excavation around existing structures shall be done with special care as not to destabilize the existing structures.

Dewatering of excavations

Maintain all excavations satisfactorily free from water to the extent necessary for the execution of the works or in the interests of safety. Provide, install, operate and maintain all necessary equipment and/or water management techniques for this purpose.

Take all necessary precautions at points of discharge of water to avoid flooding or damage to the works, adjoining works or property; and to avoid pollution of watercourses. Properly maintain all drains and ditches. Replace any material which has been adversely affected by water.

8.5.2.3 Backfill requirements

Employ a nuclear density gauge for quick and frequent check of moisture content and in-situ density of all compacted fill materials. Calibrate periodically the results of the nuclear density gauge with other approved testing methods. Make available the results of all tests to the Engineer. In the case the nuclear density gauge does not provide reliable results, use sand cone or rubber balloon method for determination of in-situ density.

Shear vane testing will be performed on the compacted material in order to verify the design assumptions. A minimum value of undrained shear strength of 40 kPa is required.

Routine quality control laboratory tests shall be conducted on materials in the cutoff trench embankment during the construction time. The Engineer expressly reserves the right to order such controls which he would consider necessary, in any point and at any time.

Layers will be accepted if the results of the routine checks are in accordance with the specifications after compaction.

Depending on results of the measurements of water content, grading, in situ density and all other tests performed, it may be ordered at the expense of the Contractor, the removal and replacement of defective parts of recognized backfilling, i.e. not corresponding to the specifications contained in the present technical specifications.

No additional compensation or extension of time for completion shall be considered due to time required to take test samples, and to interpret results, or for additional compaction effort, or for changes in the compaction effort, or changes in the compaction methods required to meet the Specifications as indicated by the test results.

8.5.3 Concrete

The Contractor shall supply, mix, place and maintain the concrete and the materials for making concrete as specified herein, as shown in Drawings or as directed by the Engineer.

The Contractor shall submit to the Engineer full details of all materials that he proposes to use for making concrete. No concrete shall be placed in the permanent works until the Engineer has consented to the use of the materials of which it is composed.

The Contractor shall at his own expense carry out any tests requested by the Engineer to demonstrate compliance and shall at his own expense make any modifications required to sources of material including water to ensure compliance.

Prior to implementation the Contractor will provide the following list of documents

- Specific arrangements to adopt for all the construction Plant and Equipment, materials and construction procedures for the production, placing, consolidating, curing and finishing of concrete;
- Specific requirements for certification, source and site testing and approvals of materials used in the production and for quality control of concrete;
- Typical mill test reports for approval of cement before use, including the physical and chemical properties of the cement proposed, the certificates guaranteeing compliance with the Specifications with the date of arrival of each shipment at the plant, the quantity shipped, and the identification of the silo, lot or bin at the factory where the cement originated and chemical and physical analyses for each;

- Detailed memorandum for water;
- Program and test reports for aggregates before use including alkali aggregate reaction tests;–
- Technical specifications with a sample of each admixture intended to be used before the start of concreting;
- Concrete mix designs including proposed admixtures and extenders, for laboratory testing and for a series of concrete trial mixes to be carried out in the presence of the Engineer;
- Certified copy of mill test reports for steel reinforcement bars including physical and chemical analysis;
- Trial procedures;–
- Concrete placement schedules at the end of each work week that shall cover all concrete works planned for the following week giving the detailed locations of placement, approximate placement volume and type of mix, and anticipated date / time of placement;

Detailed reinforcing steel placing diagrams, Bar Lists and Bending Schedules shall be prepared by the Contractor in conformity with the size and spacing of the reinforcement shown on the Principle Reinforcement Drawings issued by the Engineer.

If the Contractor proposes to use bar sizes other than those shown on the Drawings, any costs for design work will be back-charged to the Contractor. The Detailed Reinforcement Drawings and Bar Lists and Bending Schedules shall be submitted to the Engineer for approval;

- Detailed drawings of the phases of concreting showing embedded parts, specifying the locations of the various construction joints, any particular arrangements which may be required, and the order of implementation of the different phases;
- Record of the concrete placed in the work including class and quantity of concrete placed, location of pour, date of pour, ambient temperature and concrete temperature measured where the concrete is placed, moisture content of aggregates, cement/water ratio, mass of aggregates and cementitious materials, amount of ice added, if any, batch numbers, and location of test sample points;
- Detailed works schedule to be updated following any construction planning change;
- As-built information (CAD files and PDF drawings) on a monthly basis.

8.5.3.1 Material requirements

Concrete

Exposure conditions will apply as follows:

- Class B: Blinding concrete of minimum strength 15 MPa, and minimum strength 10 MPa for concrete. Pavement. For this class, strength is only the requirement.
- Class C0: No risk of corrosion or attack - All non-reinforced concrete or Slab on Ground. (c) Class C1': All internal reinforced concrete in dry condition and protected against humidity and weather conditions.
- Class C1: Low Exposure - All other reinforced concrete in occasionally exposed to humidity. Concrete surfaces protected against weather or aggressive conditions.
- Class C2 Moderate Exposure - Concrete in contact with the ground or below ground, concrete at roof level and all exposed concrete. Concrete surfaces continuously under non-aggressive water. Concrete in contact with non-aggressive soil and subject to moisture condensation.
- Class C3: Severe Exposure - Concrete in contact with the ground, alternate wetting and drying or severe condensation. Exposed to chloride from airborne

- Class C 4: Aggressive Exposure – Concrete surfaces exposed to sea water spray or in sea water tidal zone. Occasionally exposed to sea water spray. Exposed to corrosive fumes. Exposed to abrasive action. Where chloride corrosion is the main effect of concrete such as in tidal zone, causeways and structural concrete in contact with water and chloride from airborne, the contractor shall assign a specialist to verify and predict the life cycle of concrete. And to follow ASTM E-917 for basic standard measuring and ACI 365 life-cycle costs of building and building systems.

Cement

The cement must conform to the Norm EN197-1:2000 “Cement: Composition, specifications and conformity criteria for common cements” (Type CEM I, CEM II/A-M, CEM II/A-L and CEM II/A-P). Unless it is specified otherwise in the contract or specified by the Engineer, the cement must have minimum typical strength at 28 days 42.5 MPa and must be type N. The Contractor must submit to the Engineer the type of cement that will be used for approval.

The Engineer reserves the right to demand at any time from the Contractor to carry out laboratory test to verify whether the quality of the cement delivered on the Site is according to the specifications. Whatever quantity of cement is not according to the specifications will not be used and will be removed from the site.

Aggregates

The sand and gravel must conform to the Norm EN12620:2002 “Aggregates for Concrete”, and the requirements listed in the following Table must be respected.

EN12620:2002: Aggregates for Concrete				
Paragraph Norm	**Characteristic**	**PRESCRIBED LIMIT**		
		Coarse Aggregates	**All-in Aggregates**	**Fine Aggregates**
4.4	Particle shape	Maximum allowable Class F120	Maximum Allowable class F120. It refers to coarse part	
4.2	Particle size	The ratio d/D of the product is declared	The ratio d/D of the product is declared	The ratio d/D of the product is declared
5.5	Particle density	The value shall not be smaller than 2,00Mg/m³ as dry density	The value shall not be smaller than 2,00Mg/m³ as dry density	The value shall not be smaller than 2,00Mg/m³ as dry density
4.6	Fines content	Maximum allowable class F1.5	Maximum allowable class F3	Maximum Allowable class F10. For natural sand produced from natural gravel maximum allowable class F3.
5.2	Resistance to fragmentation	Maximum Allowable class LA30	Maximum Allowable class LA30. It refers to the coarse part	
5.4.1	Resistance to polishing	The PSV class is declared for the concrete used as pavement for vehicles	The PSV class is declared for the concrete used as pavement for vehicles. It refers to the coarse part. (I)	
5.4.2	Resistance to abrasion	The AAV class is declared for the concrete used as pavement for vehicles	The AAV class is declared for concrete used as pavement for vehicles. It refers to the coarse (I)	
6.2	Chlorides	It is declared for aggregates used for reinforced concrete. The allowable content must not exceed 0.1%	It is declared for aggregates used for reinforced concrete. The allowable content must not exceed 0.1%	It is declared for aggregates used for reinforced concrete. The allowable content must not exceed 0.1%
6.3.1	Acid sulfates	Maximum Allowable class ASO.8	Maximum Allowable class ASO.8	Maximum allowable class ASO.8
6.3.2	Total sulfur	The value must not exceed 1%	The value must not exceed 1%	The value must not exceed 1%
5.5	Water absorption	The value must not exceed 4%	The value must not exceed 4%	The value must not exceed 4%
5.7.1	Durability against freeze-thaw	Maximum allowable category MS18	Maximum allowable category MS18	Maximum allowable category MS18
5.7.3	Durability against alkali silica reactivity	Specified for aggregates produced from natural gravels	Specified for aggregates produced from natural gravels	Specified for aggregates produced from natural gravels

Water

The water used for the concrete mixing must be from clean water supply. Non potable water may be used if it complies with EN1008:2002 “Mixing Water for Concrete. Specification for sampling, Contract for Construction of Bukeri diversion channel Page 107 of 192 testing and assessing the suitability of water, including water recovered from processes in the concrete industry as mixing water for concrete” or it is approved by the Engineer.

Additives – Admixtures

The concrete will be composed of cement, aggregates and water as it is specified. No other substance will be mixed in the concrete or the mortar without the approval of the Engineer. The use of chlorides is prohibited.

The Contractor may examine the use of natural pozzolans for the partial replacement of cement in the mix or alternatively the use of admixtures with hydraulic properties that will contain pozzolans and that in cases only of massive concretes.

These materials must conform to standards ASTM C618-73 “Standard Specification for coal fly ash and raw or calcined natural pozzolan for use in concrete” and ASTM C595-75“Standard Specification for blended hydraulic cements”, respectively, and will be tested in combination with the cement and/or the aggregates used on site so as to prove their beneficial properties to the satisfaction of the Engineer before the contractor may gain approval for their use.

If the Engineer approves the use of additives, such as retarders or plasticizers that comply with standards EN 480:2006 “Admixtures for concrete, mortar and grout. Test Methods” and EN 934:2001 “Admixtures for concrete mortar and grout. Concrete admixtures. Definitions, requirements, conformity, marking and labeling”, their use will be subject to the following rules:

- The average strength of the tested specimen shall not be lower than the average strength of the tested specimen without the use of additives.
- The quantity of the cement shall not be reduced below the minimum limit described for the specific concrete category.
- International approved tests will be carried out to determine the time of solidification, the workability and the strength of the concrete mixes that contain additives.
- The amount of additives added as well as the mixing time must follow the instructions of the manufacturer of the products, adjusted to the existing conditions on site.

Concrete quality

The concrete’s designed compressive strength and the size of aggregates used must comply with what is written on the drawings and the specifications.

The following concrete classes will be used: C10, C15, C20, C25, C30, C35 and C40. The above mentioned concrete classes must satisfy the requirements presented in the following table.

It should be stated that wherever in the drawings blinding concrete is written it is meant to be class C15. Other parts of the concrete structures, including 2nd stage concrete, is meant to be class C30.

Concrete class	C10	C15	C20	C25	C30
Maximum Aggregate Size (mm)	30	30	30	30	30
Minimum Cement Quantity (kg/m^3)	200	220	250	280	310
Slump (mm)	Mot more than 120				
Maximum Water/Cement Ratio	0.65	0.60	0.55	0.55	0.55
Specified Strength of 150 mm cube specimens					
Tested at 7 days (N/sq.mm)	6.5	10.0	13.5	16.5	20.0
Specified Strength of 150 mm cube specimens					
Tested at 28 days (N/sq.mm)	10	15	20	25	30
Preliminary Laboratory- Strength of 150 mm cube specimens	9	13	18	21	24
Tested at 7 days (N/sq.mm)*	(11)	(17)	(22)	(25)	(28)
Preliminary Laboratory Strength-of 150 mm cube specimens	13	20	27	32	37
Tested at 28 days (N/sq.mm)*	(17)	(25)	(33)	(38)	(43)

The values in brackets refer to concrete not produced in plants producing ready-made concrete.

NOTE: The maximum cement content in any mix shall not exceed 500 kg/m³ for normal structures and 425 kg/m³ for liquid retaining structures

Mix design

For concrete mixes with specified strength equal or greater than 20 N/ mm², the Contractor must submit a design mix report.

After the approval of the submitted design mix report, with the weight percentage of cement, water, sand and gravel clearly stated., the contractor shall perform 1÷3 trial mixes with the presence of the Engineer and following any orders the Engineer issues. From every trial mix two (2) to six (6) cube test samples (according to the Engineer's instructions) will be taken to be tested for their compressive strength. ¼ of the taken cube test samples will be tested at 7 days for their strength and the rest samples at 28 days. The strength of each cube test sample tested at 28 days must be considerably higher than the specified strength.

In the case that there are no previous data the average strength of the tested samples must be 3 N/mm² greater than the specified strength. As soon as the Engineer approves the design mix and is satisfied by the trial mixes and the tests carried out then the contractor is prohibited from changing the source and quality of the supplied materials and the mix proportions without prior approval of the Engineer. If for any reason any of the above mentioned parameters are altered then the contractor is obliged to submit a new design mix for approval.

Predetermined concrete mixes

Quality or Concrete Class	Maximum Aggregate Size (mm)*	40			20		
	Fluidity*	Low	Medium	High	Low	Medium	High
	Slump (mm)	0-30	30-60	60-180	0-30	30-60	60-180
C5 (W/C=0.7)	Minimum Cement Weight (kg)	-	180	200	200	210	230
	Minimum Aggregates Weight (kg)	-	1995	1940	1995	1920	1800
	Fine Coarse Aggregates (Sand) (%)	-	25-50	25-50	35-55	35-55	35-55
C10 (W/C=0.65)	Minimum Cement Weight (Kg)	-	210	230	220	240	260
	Minimum Aggregates Weight (kg)	-	1965	1925	1975	1890	1835
	Fine Coarse Aggregates (Sand) (%)	-	25-50	25-50	35-55	35-55	35-55
C15 (W/C=0.65)	Minimum Cement Weight (Kg)	235	270	290	255	300	320
	Minimum Aggregates Weight (kg)	1995	1900	1850	1940	1820	1775
	Fine Coarse Aggregates (Sand) (%)	25-50	25-50	25-50	35-55	35-55	35-55

*Specified by the Engineer

Reinforcement

The reinforcement shall consist of high or low tensile steel that conforms to Norms EN 10080:2005 "Steel for the reinforcement of concrete. Weldable reinforcing steel. General", EU8069 and EU-8085. The Engineer retains the right to demand from the Contractor to present certificates of quality control from the supplier. The steel bars bending shall be carried according to Norm EN 10080.

Reinforcement bars

Reinforcement shall be from an acceptable source. All main steel reinforcement bars shall comply with the requirements above with minimum grades of B500 MPa.

Plain reinforcement bars shall comply with the requirements of QS ISO 6935-1 with minimum grades of B300 MPa.

Welded wire mesh

Steel fabric reinforcement shall comply with the requirements of QS ISO 6935-3 or BS 4483 and shall be delivered to Site in flat mats.

Welded intersections shall not be spaced more than:

- 300 mm for plain round bars.
- 400 mm apart for deformed high yield bars in direction of calculated stress except when used as stirrups.

Formwork

Formwork shall be constructed of timber, sheet metal or other approved material depending on the class of finish to be obtained. The Contractor shall use only approved material for exposed surfaces of the same class of finish.

Ties shall be of the rod and cone or other approved proprietary type. Embedded material rods shall terminate not less than 50 mm inside the formed faces of the concrete. Wire ties shall not be permitted.

Ties for use in water retaining structures, which are continuous through the section, shall incorporate a diaphragm, not less than 50 mm diameter and 4 mm thick, welded normal to the midpoint of the tie, designed to prevent water passing along the tie.

8.5.3.1 Construction requirements

Concrete

Cement

Each shipment of cement shall be accompanied with a certificate stating the silo number from which the cement was taken, slag content as weight percentage, transporting unit number, time of loadout, date shipped and amount transported.

The Contractor must take all necessary measures to protect the cement from exposure to humidity. The Engineer reserves the right to demand the removal from the site of cement that has been influenced by humidity.

Cement of different types and from different sources shall be kept in clearly marked separate storage facilities. Cement delivered to the Site in drums or bags provided by the supplier or manufacturer shall be stored in the unopened drums or bags until used in the Permanent Works. Any cement in drums or bags that have been opened on the Site shall be used immediately, or shall be disposed of. Unless otherwise permitted, cement from not more than three plants shall be used and, in general, only the product of one plant shall be used in any particular section of the Permanent Works.

Aggregates

The Contractor shall provide means of storing the aggregates such that:

- Each nominal size range of coarse aggregate and the fine aggregate shall be kept separated at all times;
- Contamination of the aggregates by the ground or foreign matter shall be effectively prevented at all times, and ;
- Each heap of aggregate shall be capable of draining freely.

Aggregates that have been placed direct on soil will not be used in concrete mixes.

Rock ladders of satisfactory design or other appropriate measures shall be used with conveyor systems for stockpiling aggregate to prevent segregation and excessive breakage.

The Contractor shall ensure that graded coarse aggregates are tipped, stored and removed from store in a manner that does not cause segregation. No equipment shall be permitted to operate on storage piles except with express permission of the Engineer.

Fine aggregate, as delivered to the batching and mixing plant storage bin, shall have a uniform and stable free-moisture content, which shall not exceed 7%. Excessive moisture shall be removed mechanically or by the 3-pile drainage method.

The Contractor shall protect the piles of fine aggregate against inclement weather. Windbreaks shall be provided where aggregates might suffer contamination by wind-blown materials

The Engineer reserves the right to demand at any time from the Contractor to carry out laboratory test to verify whether the quality of the aggregates comply with the Norm EN 12620:2002.

The Engineer reserves the right to demand from the Contractor not to use aggregates that are not of his approval and to have them removed from the Site.

Additives – Admixtures Admixtures

shall be stored in suitable containers that will maintain them in uniform solution and will protect them from weather and contamination.

Admixtures that have been in storage for more than 6 months shall not be used unless retest proves them to be satisfactory. Costs of all such retests shall be borne by the Contractor. Rejected materials shall be removed immediately from the Site.

Concreting records

The Contractor is obliged to keep records regarding the concreting works. The specific record must be submitted every day to the Engineer for approval. The Engineer must note on the record the observations made on site and comments regarding the contractor's schedule. The record must include notes and data for the following:

- The names of the supervising engineers and their assistances assigned by the Contractor that will be involved during the specific concreting works.
- A description of the weather conditions, the temperature and the humidity. A list with the temperature of the water, the cement, the aggregates and the concrete itself must also be included.
- The invoices of the materials for the concrete mix on site delivered on site. (Quantities of materials, Cement brand name, etc.).
- Any specific instructions issued by the Engineer.
- The supervision by the Engineer.
- The time of starting and finishing the concreting works, mentioning also segments of implementation. The time of erection and removal of the formworks.
- The quantities of the cement, admixtures, fine and coarse aggregates and any additives used in every concreting work. The number of quality tests executed in the above-mentioned materials and the water used.

Transportation

The transportation from the batching plant to the site may be done with delivery concrete truck carriers (rolled mixer) or any other appropriate means indicated by the Engineer. In general the elapsing time between concrete mixing and pouring should not exceed 30 minutes. In case where retarding additives are used then the transportation time will be adjusted according to the instructions of the Engineer. During concrete casting, the concrete must have the predefined slump.

Concrete casting

The Engineer must be present during concrete casting. Formwork and reinforcement must have been checked and approved according to drawings. In no case should the concrete be left to fall free from a height exceeding 1.5 m. In no case should the concrete be placed in stagnant or running water unless it is approved by the Engineer.

The concrete must be compacted by mechanical vibrators. The vibrators must be embedded well in the concrete mass and in appropriate distances that ensure adequate concrete compaction without voids. The vibrators must be slowly drawn out from the poured concrete after their embedment so as to avoid air voids.

If the concrete is poured in the formwork with the use of a pump this should be taken into account in the concrete mix design. The concrete may be richer in fine aggregates and contain admixtures of the approval of the Engineer. The concrete must have a relative high slump (7-12 cm).

Construction joints

The concrete casting must be continuous till the completion of the scheduled works or till a pre-specified construction joint according to drawings. In case the concreting is stopped before a pre-specified construction joint the Engineer must be notified immediately for his approval and instructions. Before new casting takes place the hardened surface must be washed with water. Compressed air must be used to remove the previously applied water. The newly poured concrete must be placed near the hardened surface and vibrated adequately.

Concrete curing after casting

The concrete must be treated immediately after pouring so that it is protected from exposure to sun, wind and rain. The concrete protection may be done with one of the following measures:

- Covering the concrete surface with a saturated membrane. The membrane must be kept saturated for at least 7 days.
- Covering the concrete surface with wet sand. The sand must be kept wet for at least 7 days.
- Using different chemicals for concrete curing that have previously been approved by the Engineer.

Concreting Under Warm Weather

During warm weather the stockpiles of aggregates must be protected from solar radiation or watered. The water tank and distribution pipes must be insulated. The concrete's temperature during pouring must not exceed 32° C.

The formwork surfaces and the reinforcement must be wetted before casting takes place so that water is not absorbed from the concrete. Immediately after pouring the concrete surfaces must be protected according to the provisions set in the respective paragraph.

Preparation of surfaces prior to concreting

The surfaces at construction joints must be meticulously treated and loose aggregates should be removed from the top surface. The surfaces should be left undisturbed, clean without water, sand, loose materials etc. After concreting the hardened surface must be kept wet but without allowing the presence of stagnant water.

Reinforcement

The reinforcement bars must be clean, free of impurities, dust, oil and paint. The reinforcement must be placed and mantled with precision according to the drawings. Where it is not specified the concrete cover is set to 50 mm.

Steel reinforcement shall be stored clear of the ground and supported to prevent distortion and well covered to prevent moisture. The steel reinforcement bars shall be stored in such a manner that different diameters cannot be mixed. Storage yards shall be clean and designed in such a manner that none of the steel reinforcement is in contact with the ground or subject to damp conditions.

The reinforcement lap length will be at least 50 times the diameter bars unless otherwise specified in the drawings.

The reinforcement must be supported adequately so as not to deform and be able to carry loads during concreting. In order to ensure the appropriate cover concrete, plastic or other spacers approved by the Engineer must be used.

The overlapped bars will not be welded unless in specific cases approved by the Engineer.

Welding shall not be used unless authorised by the Engineer and recommended by the reinforcement manufacturer. Where welding is approved it shall be executed under controlled conditions in a factory or workshop and the bars will be welded according to standards EN 1011- 1:1998 “Welding. Recommendations for welding of metallic materials. General guidance for arc welding”, EN 1011-2:2001 “Welding recommendations for welding of metallic materials. Arc welding of ferritic steels” and EN 60974:2002 “Arc welding equipment” and IEC 60974-12:2005 “Arc welding equipment: Coupling devices for welding cables”.

Formworks

The formworks must comply with precision the shape, location, line and height required on site or specified in the drawings. The formworks must be supported adequately so as not to deform during concreting or compaction. The formwork joints must be watertight.

Top surface formworks must be used when concreting takes place on surface with inclination greater than 1:2.5.

Before the formwork is mounted it must be thoroughly checked and cleaned. The inner surface of the formworks must be oiled with special oil preferable before it is mounted and certainly before the reinforcement placement. The use of steel plates or small diameter reinforcement, embedded perpendicular in the concrete in order to facilitate the stability of the formwork, is prohibited. If this is required then special bolts and plastic tubes must be used or any other support method that in any case must have the prior approval of the Engineer.

Concrete casting is prohibited before the formwork and reinforcement are approved from the Engineer. The Engineer retains the right to demand, in certain cases (i.e. bridges), a calculation report proving the formwork/shuttering stability-rigidity. This report must be submitted 6 weeks before the scheduled concrete works. Although the Engineer issues the approval of the formwork/shuttering, its structural adequacy is full responsibility of the Contractor.

The Contractor is at all cases responsible for the stability of the formwork. The Contractor is responsible for all remedial works, compensations and time delays in case of accidents and unsatisfactory work due to inadequate formwork support.

The type of surface finishing of the concrete must comply with the one prescribed in the drawings, specifications or the Engineer instructions. All formwork joints shall be either vertical or horizontal as per the agreed pattern. Any holes serving support or spacing purposes shall be sealed with plastic covers or cement mortar identical to the poured concrete following the Engineer’s orders. The Engineer reserves the right to demand the placement of trowels, water cut offs or whatever is required to achieve the required result.

The removal of the formwork must be carried out carefully without causing damage to the concrete. The time for the formwork removal will be proposed by the Contractor and approved by the Engineer. The Contractor must take into account the type of cement used, the admixtures/additives added and the weather conditions. The indicative Table below provides formwork removal time for normal structures and weather conditions. Prior to the removal of the formwork, the Engineer must be notified well in advance. After the formwork removal no part of reinforcement must be visible. If so, remedial works of the Engineer’s approval must be carried. All costs regarding remedial works or even partial demolition will be covered by the Contractor.

Time for Formwork Removal	Days
Side Formwork	2
Slab Formwork (deck)	14
Columns for slabs, beams and frames	21-28
Columns under Cantilevers	28

Formed surfaces

Unless otherwise specified in the drawings, the formwork surfaces must comply with one of the following classes listed below:

- Class F1: It refers to cases where the concrete surfaces will be backfilled or covered with concrete. The formwork surface must be such that the loss of any of the concrete components is prohibited and allows for a compact top surface.
- Class F2: It refers to cases where the concrete surface will be permanently exposed unless otherwise specified in the drawings. The formwork surface must be such that the loss of any of the concrete components is prohibited and a durable lean surface is formed without discontinuities, cavities, etc. Although cavities are prohibited, small imperfections can be repaired with techniques and materials approved by the Engineer.
- Class F3: It refers to cases where the concrete surfaces will be in contact with water flow of specific requirements (high velocities, cavitation risk, etc.). The formwork surfaces must be such that a lean straight surface correctly aligned vertically and horizontally is achieved free of cavities and humps. The Engineer retains the right to demand the plastering of the surfaces with the appropriate mortar mix so as to achieve the desirable surface finish.

When a surface is partially backfilled and exposed then the surface finish of the exposed surface must extend 500 mm into the backfill.

Unformed surfaces

Unless otherwise specified in the drawings the finishing of surfaces concreted without the use of formwork must comply with one of the finish classes listed below:

- Class U1 (Screeded Surface): It refers to road pavement, foundations slabs or other structural elements backfilled that do not require better surface finish. This surface finish is a prerequisite for surfaces with a higher quality final finish such as class U2 and U3. The screeded finish will be achieved by hand sawing motion using a straight-edge timber of 50 mm thickness.
- Class U2 (Floated Surface): It refers to all exposed surfaces of permanent works unless otherwise specified in the drawings. The floated surface will be achieved by wood or bull float so as to allow abundance of fine aggregates on the top surface.
- Class U3 (Trowelled Surface): This class refers to all surfaces that will be subject to contact with water flow of specific requirements (high velocities, cavitation risk etc.). Surfaces finishing of class U1 and U2 must have already been implemented. Manual or mechanical steel trowelling must be applied on the floated surface after the concrete has sufficiently hardened. If required a custom made cover must be applied to protect the final surface from rain.

Ready made concrete mix

The Ready Made Concrete Mix will be transported from the Concrete Plant to the site with concrete mixer trucks or other appropriate vehicles approved by the Engineer. During the transport the mixer must be rotating continuously so as to avoid concrete segregation. The mixing speed during transport and haulage must be set at the specified limits. In generally the transport time (starting from loading the truck mixer and ending with the delivery on the site) shall not exceed 30 minutes. In case where retarding additives are used, then the transportation time will be adjusted according to the instructions of the Engineer. During concrete casting, the concrete must have the predefined slump. The loading time must be written on the Concrete's Delivery Invoice. Loading time starts when the cement is added on the aggregates.

Addition of water in the concrete mix is strictly prohibited during transport. When mixing takes place in truck mixers, then any water added at the batching plant or at site will be done under the supervision of an experienced and authorized technician.

With the approval of the Engineer ready mixed concrete may be used .The ready mixed concrete must comply with Norm EN 206-1:2006 "Concrete. Specification, performance, production and conformity" and Norm EN 12620:2002 "Aggregates for concrete".

8.5.3.2 Quality control and assurance

Cementitious materials

The delivery of each batch of cementitious material shall be accompanied by the manufacturer's specification conformance test report which shall be submitted to the Engineer.

The Contractor shall take a sample of extender once a week for the following quality control tests:

- Fineness (45 micro sieve);
- Specific gravity;
- Variability in fineness and specific gravity.

The Contractor shall take a sample of the blended mixture of Cement and extender for the following tests:

Schedule	Tests
Daily	percentage of extender (of blended before batching)
Every month	percentage of extender (of blended before batching) initial and final setting time on pure paste Blaine specific surface heat of hydration flexural and compressive strength at 2 and 28 days
At least once	chemical analysis mortar bar shrinkage alkali reactivity autoclave expansion

Each characteristic shall be taken as equal to the average of three measurements made under each test (except for compressive strength which shall be the average of 6 measurements).

A weekly 5kg sample of the blended cement and extender shall be kept in the laboratory for reference purposes until needed or for the duration of the Contract.

No cement shall be used before the flexural and compressive strength at 2 days, the initial and final setting times, and the Blaine specific surface are known.

Frequency of routine testing shall be decided according with the Engineer.

Frequency of testing might increase as per engineer request if testing results show inconsistency, and frequency might reduce if approved by engineer if materials are highly consistent.

Aggregates

- Normal frequency N
    - Every week of concrete if the volume of concrete manufactured ;
    - For every new delivery of a material of different origin or obtained by a different process.
- Frequency xN
    - For every x tests carried out at the normal frequency.
    - For every new delivery.
    - Tests to be performed on the aggregates:

Characteristics	Method ASTM	Field of application	Frequency
Grain size analysis	C136	Fine aggregates	Every day
Grain size analysis	C 136	Coarse aggregates	N
Water content	C566	Fine aggregates	Every day
Water content	C566	Coarse aggregates	Every day
Fineness modulus diagram	C136	All aggregates	6 N
Water absorption	C127	Coarse aggregates	5 N
Water absorption	C128	Fine aggregates	5 N
Los Angeles	C131 – C535	Aggregates > 2.5 mm	8 N
Organic matter	C40	Fine aggregates	6 N
Sand equivalent	D2419	Fine aggregates	Every day
Soundness	C88	All aggregates	8 N
Flakiness Coefficient	BS EN 933-3	Aggregates > 4 mm	5 N

The tests shall be performed on samples taken in accordance with the Engineer's instructions. Frequency of routine testing shall be decided according with the Engineer. Frequency of testing might increase as per engineer request if testing results show inconsistency, and frequency might reduce if approved by engineer if materials are highly consistent.

Immediately after commencement of the Works, the Contractor shall make preliminary tests as listed below together with a soundness test in accordance with ASTM C 88 to the satisfaction of the Engineer before the Engineer will give approval to the source of aggregates proposed by the Contractor. Alternatively, and subject to the approval of the circumstances by the Engineer, the Contractor may submit a Certificate from an independent laboratory.

During the performance of the contract the Contractor shall carry out testing of aggregates (the samples shall be taken in accordance with BS 812) in accordance with BS 812, BS 882 and BS 1377: Part 2:1990: Method 3.2, and ASTM methods including ASTM C 40. Special tests will be carried out concerning alkali-reactivity. Based on the test results, the alluvium are suitable to be used as concrete aggregate.

In addition to the routine testing set out above, the Contractor shall, from time to time at the request of the Engineer, carry out the following tests:

- Elongation index;
- Angularity number;
- Aggregate crushing value;
- Impact value;
- Ten percent fines value;
- Chloride content;
- Sulfate content;
- Active silica content combined with alkalinity reduction;
- Petrographic description;
- Clay lumps index

The Contractor shall supply the Engineer with a copy of each test result. Any rejected aggregate shall be promptly removed from Site.

Water

The Contractor shall take a sample of water for chemical analysis from the concrete batch plant every month or directed by the Engineer.

Concrete

The verification of the concrete compressive strength shall be based on the crushing of 150mm cube test samples. The maximum cement content in any mix shall not exceed 500 kg/m3 for normal structures and 425 kg/m3 for liquid retaining structures. The Contractor must have on site a cone so as to perform slump tests and a necessary number of cube molds so as to be able to fulfill the sequence of tests listed below:

- 1-3 cube test samples from each mix if the volume of concrete is of the order of 4-6 m3 .
- 1-2 cube test samples every 4 mixes if the volume of the concrete is of the order of 0.5 m3 .
- 1-2 cube test samples every 10 mixes if the volume of the concrete is smaller than 0.5 m3 .

The Engineer may alter the sampling sequence according to the quality of concrete and the type of works it is going to be used. All test samples must be numbered.

A small number of test samples will be tested at 7 days (approximately ¼ of the total number of samples) and the rest at 28 days. The results from the specimens tested at 7 days will be treated as indicative.

The concrete will comply with the specifications when both of the following criteria are satisfied:

- The average strength of the cube test samples of 4 consecutive tests* crushed at 28 days must be greater than 3N/sq.mm for concrete categories C20 and greater than 2N/sq.mm for categories lower than C20.
- The strength of any test sample crushed at 28 days must not be smaller than 3N/sq.mm for concrete categories C20 and smaller than 2N/sq.mm for categories lower than C20.

*Every crushing of a cube specimen is considered as a test.

The Engineer may demand the testing of cylindrical test samples from the laboratory for more appropriate results. The tests of the cylindrical samples will be executed in accordance to EN 12350:2000 “Testing fresh concrete”, EN 12390:2000 “Testing hardened concrete”, EN 12504:2000 “Testing concrete in structures” and EN 13791:2007 “Assessment of in situ concrete compressive strength in structures or in precast concrete components”.

In the case where the strength criteria set by the specifications are not met, the Engineer retains the right to demand the demolition of the structures. The Contractor is responsible for the cost and the delays caused. The Contractor must take all necessary additional remedial measures for improving the concrete’s strength following the Engineer’s Orders before new concreting takes place.

The Contractor is obliged to keep full records regarding the concrete’s category, the concreting date and location and all relative data and results for the cube and cylindrical test samples. The records must be at the disposal of the Engineer at any time.

The equipment used for the concrete mixing must be appropriate and in good condition. The Engineer retains the right to prohibit the concrete mixing and demand the removal or substitution of inappropriate equipment. The sampling, transportation, storage, protection and testing of the cube test samples will be executed according to Standards EN 12350, 12390, 12504 and 13791. The concrete’s workability will also be checked according to these standards.

Reinforcement

Inspection

Inspection of reinforcing steel and the installation thereof will be conducted by the Engineer. The Contractor shall give 24-hour notice to the Engineer before closing forms or placing concrete.

The Engineer may instruct the Contractor to break out and remove completely all sections of the work already constructed under any of the following circumstances:

- Reinforcing steel sample under test fails to meet the specification requirements at any time
- The Engineer considers that samples which were presented to him for test were not truly representative

- It becomes apparent that reinforcing steel which has not been approved has been used on the Works.

Sampling

Representative samples of all reinforcing steel that the Contractor proposes to use in the Works must be submitted, before work is commenced, to the Engineer for his written approval. Manufacturer's certificates stating clearly for each sample:

- Place of manufacture.
- Expected date and size of deliveries to site.
- All relevant details of composition, manufacture, strengths and other qualities of the steel.

The Engineer reserves the right to sample and inspect all reinforcement steel upon its arrival at the work site.

The Contractor shall provide a certificate confirming that samples taken from the bars delivered to the works pass the rebend test. Frequency of sampling and the method of quality control shall be in accordance with steel bars manufactured standard ISO 6935 or BS 4449.

Where epoxy coated steel is used 0.3 kg samples of the coating, material from each batch be supplied in an airtight container and identified by the batch number. Allow 14 days for Engineer’s review of samples.

Testing

If the Contractor does not have the Supplier's Certificate or mill certificates, or if the reinforcement appears to be in a deteriorated condition in the Engineer's opinion, the Contractor shall bear the cost of arranging for tests to be carried out in an approved laboratory. The tests will cover the following characteristics:

- Diameter (determined by weighing),
- Tensile strength,
- Bending tests.

Six samples per diameter shall be taken for determining each of the above-mentioned characteristics. If two tests of a given characteristic give unsatisfactory results, the reinforcement bars concerned shall be considered defective.

If one test of a given characteristic gives an unsatisfactory result, a new sampling of six samples from the same batch shall be taken for a new series of tests on the characteristic in question. If the results of the new tests are all satisfactory, the reinforcement bars will be accepted. If this is not the case, the bars shall be considered defective.

Acceptance tolerances of concrete surfaces

The abnormalities observed for the different classes of the formed and the unformed surfaces must be within the limits set by the subsequent Table. If the abnormalities exceed the pre-specified limits, the Engineer will issue orders so that this does not re-occur. If the abnormalities exceed the maximum pre-specified tolerances limits, the Engineer retains the right to reject totally or partially the executed works.

In the table below the number in the brackets under the type of abnormality refers to:

- The element dimensions (walls, columns, beams, etc.) where for construction purposes the deviation must be kept to the allowable tolerances specified for the alignment and levels.
- Consecutive abnormalities created from the wrong formwork alignment and dimensions that are specified in the drawings and are measured with a 3 m long trowel.
- Abrupt changes in the surface created from the formwork/shuttering wrong placement, loss of support and defective equipment or uneven surface in case of unformed shapes.

Abnormality	Type of Final Shape											
	Formed Surface						Unformed Surface					
	Allowable Tolerance			Maximum Limit			Allowable Tolerance			Maximum Limit		
	F1	F2	F3	F1	F2	F3	U1	U2	U3	U1	U2	U3
Deviation from the alignment and levels specified in the drawings	+20 -5	±5	±5	+25 -10	±10	±10	±5	±3	±3	±10	±5	±5
Deviation from the element dimensions (1)	+5 -3	+5 -3	+5 -3	+10 -5	+10 -5	+10 -5	-	-	-	-	-	-
Abrupt changes in Surface (3)	±5	±3	±1	±10	±5	±3	±5	±3	±1	±10	±5	±3
Deviation from the crawler (2)	±5	±5	±3	±10	±10	±5	±5	±3	±3	±10	±5	±5

8.5.4 Riprap

8.5.4.1 Construction materials

Stone for this work shall be hard angular quarry stones and have a percentage of wear of not more than fifty (50) at five hundred (500) revolutions as determined by ASTM C-535. The least dimension of any piece of stone shall be not less than one-fourth (1/4) its greatest dimension. Stones shall meet the following gradation requirement for the class specified:

Class I: No more than ten percent (10%) of the stones by total weight shall weigh more than fifty (50) pounds per piece and no more than fifty percent (50%) by total weight of the stones shall weigh less than twenty-five (25) pounds per piece.

Class II: No more than ten percent (10%) of the stones by total weight shall weigh more than four hundred (400) pounds per piece and no more than fifteen percent (15%) by weight of the stones shall weigh less than twenty-five (25) pounds per piece. The stones shall be evenly graded and a minimum of fifty percent (50%) by weight of the stones shall weight two hundred (200) pounds or more per piece.

Class III: No more than ten percent (10%) of the stones by total weight shall weigh more than one thousand four hundred (1,400) pounds per piece and no more than fifteen percent (15%) of the stones shall weigh less than twenty-five (25) pounds per piece. The stones shall be evenly graded and a minimum of fifty (50%) by weight of the stones shall weigh seven hundred (700) pounds or more per piece.

A footing trench shall be excavated along the toe of the slope when shown on the plans. The stones shall be handled or dumped into place so as to secure a stone mass of the thickness, height and length shown on the plans, or as staked with a minimum of voids. Undesirable voids shall be filled in with small stones or spalls. The rock shall be manipulated sufficiently by means of a bulldozer, rock tongs, or other suitable equipment to secure a reasonably regular surface and mass stability.

Riprap protection shall be placed to its full course thickness at one operation and in such manner as to avoid displacing the underlying material. Placing of riprap protection in layers or by dumping into chutes or by similar methods likely to cause segregation will not be permitted.

All material going into riprap protection shall be so placed and distributed that there will be no large accumulation or area composed largely of either the larger or smaller sizes of stone. Unless otherwise authorized by the Engineer, the riprap protection shall be placed in conjunction with the construction of the embankment with only sufficient lag in construction of the riprap protection as may be necessary to prevent mixture of embankment and riprap material.

The Contractor shall provide a level compact area of sufficient size to dump and sort typical loads of riprap at approved location(s). He shall further dump loads specified in this area and assist the Engineer as needed to sort and measure the stones in the load for the purpose of determining if the riprap is within specifications.

8.5.4.2 Construction Methodology

Fill Placement

Place riprap material in lift of 0.30 m. No gap-graded riprap shall be permitted at all times. Geotextile, as specified, shall be placed on foundation before riprap placement.

Place the riprap in such a way to avoid segregation and damage to the underlying geotextile. Placement shall achieve the thickness of the zone as shown on the Drawings.

Fill compaction

Compact riprap by tamping with the bucket of an excavator. Shaping on the outer surface will be required to the line and shape as shown on the drawings.

8.5.5 Geotextile

This specification describes the technical requirements for supply and installation of separation/filtration geotextile under gabions structures and between excavation and backfill, and anti-erosion geomat where appropriate.

The separation/filtration geotextile is a non-woven geotextile and provide the filtration and separation functions.

The anti-erosion geomat is a 3D structure that provide a reinforcement function to high velocity flow, resisting to erosion phenomena. It will be placed on the channel slopes (on the north branch and downstream branch) and covered by topsoil with turfing.

Geotextile and geomat installation works shall be completed in accordance with the drawings.

8.5.5.1 Documents to be submitted by the Contractor

The documents to be submitted by the contractor include:

- A thorough Method Statement before the start of the works for approval by the Engineer including in particular:
- All materials/products data sheet, instructions for storage, handling and installation
- References Standards and codes from a regulatory agencies and institutes listed in Chapter
- Detailed work sequence and methodology;
- Specific water management procedure for the Works to keep the foundation and surface of the geotextile dry and clean during installation;
- List of equipment and tools;
- List of Personnel;
- Trial procedures;
- Control plan;
- HSE policy;
- Detailed works schedule to be updated following any construction planning change;
- As-built information (CAD files and PDF drawings) on a monthly basis.

8.5.5.2 Material requirements

Approved supplier

The material will be provided from a manufacturer approved by the Engineer. The geosynthetics must be in accordance with ASTM Standards or equivalent.

Filtration/Separation geotextile

The Filtration/Separation geotextile should be made of a non-woven geotextile on one or two sides (if on one side only, the geotextile will be located on the ground side).

It shall present a flexible core structure, with low to medium thickness, very high void ratio and medium and compressive resistance. The product shall meet the following requirements or as specified by the Engineer:

Properties	Unit	Test method	Specified
Tensile strength	N	ASTM D-4632	Min. 700
Elongation at break	%	ASTM D-4632	≥ 50
Puncture strength	N	ASTM D-6241	Min. 400
CBR Puncture	N	ASTM D-6241	Min. 2000
UV resistance at 500 hours	%	ASTM D-4355	Min.70
Apparent opening size (AOS)	mm	ASTM D-4751	Max. 0.25
Permittivity	s^{-1}	ASTM D-4491	Max. 0.2
Mass per unit	g/m^2	ASTM D-5261, EN ISO 9864	Min. 200
Opening pore size O_{90}	micron	ISO 12956	Min. 70
Thickness at 2 kPa	mm	ISO 9863-1	Min. 10

Anti-erosion geomat

The anti-erosion geomat shall be three-dimensional structure having a biconal cuspidated shape characterised by a voids index not lower than 80% (or approved equivalent non-woven geotextile type).

It is used to prevent erosion and surface planar failure phenomena on slopes. It is also used in hydraulic / water channels to protect them from the abrasive and tractive forces applied by the stream flow. The product shall meet the following requirements or as specified by the Engineer:

Properties	Unit	Test method	Specified
Mass per unit	g/m^2	ASTM D-5261, EN ISO 9864	Min. 250
Tensile strength – length direction	kN/m	ISO 10319	Min. 1.2
Tensile strength – cross direction	kN/m	ISO 10319	Min. 0.5
Elongation at break	%	ASTM D-4632	≥ 50
Thickness at 2 kPa	mm	ISO 9863-1	Min. 10
UV resistance at 500 hours	%	ASTM D-4355	Min.70

It is necessary to cover the anti-erosion geomat by soil on a minimum thickness (10 cm) to protect it from UV radiations and ensure its long term performance.

A product that combines the filtration/separation and reinforcement usage may be proposed if it respects the requirements of both products. It will be subject to the approval of the Engineer.

Delivery, handling and storage

Receive at the site all equipment and materials necessary to complete the Work. Supply material in rolls wrapped in relatively impermeable and opaque protective covers, with straps for unloading. The rolls shall be store in dry and covered areas. They will only be unpacked before they are used.

After receipt of the rolls, the Contractor must provide a quality control certificate signed by an authorized representative. These certificates should include:

- Identification of geosynthetic type and roll number;
- Results of the quality control tests;
- Each roll must be identified and bear the following information:
    - Name of the manufacturer;
    - Type of geosynthetic ;
    - Thickness of the geosynthetic and the weight per m²;
    - Roll number;
    - Roll dimensions;
    - Date of manufacture. U

Unloading and storage of geosynthetic materials are the responsibility of the Contractor. The following points shall be verified by the contractor before unloading:

- Ensure that equipment used for unloading is not likely to damage geosynthetics;
- Ensure that personnel handle rolls carefully.

Once unloaded, the material shall be deposited on a soft surface free of any debris that can damage the geosynthetics.

The Contractor shall provide, at the site, a suitable place to store the geosynthetics. This location must be selected so as to minimize transport and handling on site. The storage space must be protected from vandalism, vehicle traffic and close to the work surface.

The rolls must be stacked in accordance with the manufacturer's recommendations. Geosynthetics shall be stored before use in a place on flat leveled and smooth surface where there is no risk of flooding.

Rolls must be stored in the original packing, in cool and dry areas, protected against UV rays and atmospheric agents.

Protect the geotextile at all times against exposure to the sun and against contamination from dirt, dust, and any other deleterious materials until it is installed. Ensure that the material is not affected by several months site storage at ambient air temperatures ranging from extremes.

8.5.5.3 Construction requirements

The water management procedure shall be followed carefully to keep the foundation and surface of the geotextile dry and clean during installation. The geotextile is to be placed in contact with the overburden foundation.

Separation/Filtration Geotextile

The site should be cleared of roots, large stones, and other sharp objects that could puncture the fabric. The subgrade surface to waterproof must be compacted, flat, clean, smooth, and dry with absence of grease and dust.

If the subgrade surface has irregularities, they must be eliminated before the laying of the geotextile.

We recommend smoothing and/or rounding the sharp edges of the stepped excavations prior to install the geotextile using chamfers (fine earthy material in feet of steps and breaking the high edges during the earthwork). This will facilitate geotextile installation and considerably reduce the risk of punching.

Carefully unroll the geotextile according to the manufacturer's instructions. Roll out and keep the geotextile relatively taut and aligned to minimize any wrinkles or folds in the material, especially along overlaps.

Install the geotextile as indicated in the drawings or as directed by the Engineer.

Anchor the geotextile at the top of the slope, and along the slope if required, with expandable pegs or anchor nails or by any other method approved by the Engineer. The number of pegs must be sufficient to prevent slipping or displacement of the geotextile and to guarantee the specified overlapping between panels.

The minimum overlap of the geotextile panels is 150 mm for sides and 300 mm for ends, minimizing the number of overlaps required and place so that overlaps are primarily downstream and downwind of any potential flow or wind directions. The panels will be assembled according to the manufacturer's instructions.

Traffic on the geotextile is prohibited. The method of installation will be subject to the approval of the Engineer. It is recommended to use the standard guidelines for installing the geotextile provided by the Geosynthetic Institute (GSI).

Anti-erosion geomat

The anti-erosion geomat should be installed over the entire surface of the portions of the channels indicated in the Drawings to protect them from the abrasive and tractive forces applied by the stream flow. The details of the anti-erosion geomat are provided in Drawings or as directed by the Engineer.

Carefully unroll the geomat according to the manufacturer's instructions. Roll out and keep the geomat relatively taut and aligned to minimize any wrinkles or folds in the material, especially along overlaps.

Anchoring of the geotextile is required. The minimum overlap of the geomat panels is 150 mm for sides and 300 mm for ends, minimizing the number of overlaps required and place so that overlaps are primarily downstream and downwind of any potential flow or wind directions. The panels will be assembled according to the manufacturer's instructions.

Traffic on the geomat is prohibited. The method of installation will be subject to the approval of the Engineer. It is recommended to use the standard guidelines for installing the geomat provided by the Geosynthetic Institute (GSI).

8.5.5.4 Quality control and assurance

Material

The proposed geosynthetics must include an identification form, which will specify the following characteristics:

- Brand;
- All technical characteristics;
- The geometric characteristics of the rolls;
- Serial number;
- Standard requirements.

Inspection and testing

The Contractor shall be responsible for Quality Control. The Engineer will examine the geosynthetics during placement to ensure that damaged or otherwise unsuitable materials are not placed.

Any material which has been torn across more than 10 percent of the roll width will be rejected. The Contractor may salvage the remainder of the roll by cutting out the torn area over the full width of the roll.

The welding check must be done when the material is cold; each time any irregularities or weak adhesion’s spots may appear, a new piece of the same material must be laid and the welding must be repeated.

The Engineer will examine the surface of all geosynthetics and mark any areas which require remedial action. Perform all necessary repairs, where required, at no cost to the Owner.

All inspection and testing should be carried out as per applicable standards. The Contractor should provide the inspection and testing procedures prior any geosynthetic installation.

8.5.6 Flood risk and water management during construction

The Contractor's attention is drawn to the fact that the whole of the works lies in a major drainage system and that if rainfall occurs the site will almost certainly be affected by floods.

The Contractor shall design, construct and maintain all temporary diversions and all protective works which are necessary for the prevention of surface erosion caused by rainfall and run-off affecting the foundation of the structures and works excavation. The Contractor shall not interfere with the natural flow of rivers or streams without prior approval. Diversion and protective works include but are not limited to cofferdams, contour banks, levee banks, channels, flumes, conduits, drains, pumps and settling ponds. Unless otherwise approved the location of these works shall not encroach on any area required for the works.

The Contractor shall design, construct and maintain all the diversion and protective works which are necessary to prevent surface drainage and groundwater from entering the various parts of the Works and, where necessary, settling ponds to prevent pollution in accordance with the relevant requirements of this Specification.

The Contractor shall design, furnish, install, maintain and operate pumping or other surface water dewatering systems to maintain the works free of water during construction and inspection of the works. All diverted and pumped water shall be discharged at locations on the surface from which it cannot re-enter the Works and in a manner that does not cause erosion, pollution or nuisance to landholders, or other persons within, downstream or adjacent to the Site.

The Contractor shall design, construct, maintain and operate suitable settling ponds, separating plant or other works necessary to prevent any discharge into rivers, streams or existing drainage systems of water containing polluting matter or visible suspended materials.

The Contractor shall assume responsibility for the design, construction, maintenance and removal of all necessary cofferdams, channels, flumes, drains, sumps and all temporary diversions and protective works required and shall furnish all materials required for this work.

On completion of the works all diversion and protective works, shall be removed and disposed of and all temporary works shall be levelled in an approved manner to give a sightly appearance and not interfere with the operation of the works.

The Contractor shall be fully responsible for any damage or delay to the works caused by failure of the diversion and protective works constructed by him in accordance with the requirements of this Clause and shall indemnify the Owner against claims by existing users of the stream or other persons, arising out of any such failure.

The Contractor shall be responsible for and shall repair or reinstate at his expense any damage to foundations, excavated slopes or any other parts of the Works caused by the failure of the diversion and protective works and/or surface water control and dewatering installation constructed in accordance with the requirements of this Clause.

The Contractor shall be deemed to have taken into account the risks of flooding in his programme of works and shall take all reasonable steps to safeguard the works.

8.5.7 Environmental protection and mitigation measures

The Contractor shall exercise care to preserve the natural landscape and shall conduct his construction operations so as to prevent any unnecessary destruction, scarring, or defacing of the natural surroundings in the vicinity of the work. Except where clearance of the site is required for permanent works, approved temporary works (access roads, excavation and earthworks operations, etc…), all trees, native shrubbery, and vegetation shall be preserved and shall be protected from damage by the Contractor's construction operations and equipment.

8.5.7.1 Clearance of site

The Contractor shall clear the parts of the Site subsequently to be occupied by the Works and shall maintain it clear of vegetation.

The Contractor shall not clear the Site of any structure or mature tree without the prior written permission of the Engineer. All trees and shrubbery which are not specifically required to be cleared or removed for construction purposes shall be preserved and shall be protected from any damage that may be caused by the Contractor's construction operations and equipment. Special care shall be exercised where trees or shrubs are exposed to damage by construction equipment, blasting, excavating, dumping, chemical damage, or other operations, and the Contractor shall adequately protect such trees by use of protective barriers or other methods approved by the Engineer.

The edges of clearings through trees, shrubbery, and vegetation shall be irregularly shaped to soften the undesirable visual impact of straight lines. Movement of labour and equipment within the right-of-way and over routes provided for access to the work shall be performed in a manner to prevent damage to grazing land, crops, or property.

All unnecessary destruction, scarring, damage, or defacing of the landscape resulting from the Contractor's activities shall be reinstated, replanted, reseeded or otherwise corrected as directed by the Engineer.

8.5.7.2 Reinstatement of site after clearance

The Contractor shall fill and make good with appropriate materials those cavities and losses of soil that result from clearing the parts of the Site not subsequently to be occupied by the Works.

When they are no longer required, all quarry sites, borrow pits and areas used for the disposal or storage of surplus materials and plants, shall be reinstated by landscaping including the replacement and spreading of topsoil as directed by and to the satisfaction of the Engineer.

8.5.7.3 Cleanup and disposal of waste materials

Cleanup

The Contractor shall, at all times, keep the construction area, including storage areas used, free from accumulations of waste materials or rubbish.

All wastewater and sewage from office, residential and mobile camps shall be piped to soak pits or other disposal areas constructed in accordance with local regulations, and, where and when such regulations require it, the Contractor shall obtain a permit or other appropriate documentation approving the disposal methods being used.

All used fuels, oils, other plant or vehicle fluids, and old tyres and tubes shall be collected to a central disposal point, on a regular basis and disposed of as specified below.

All household, office, workshop and other solid waste shall be collected to a central disposal area, on a daily basis and disposed of in a manner approved by the Engineer.

Servicing of plant, equipment and vehicles shall, whenever possible, be carried out at a workshop area. This workshop area shall be equipped with secure storage areas for fuels, oils and other fluids constructed in such a way as to contain any spillages which may occur, and similar storage where used fluids can be stored securely prior to their disposal.

When the servicing of plant, equipment and vehicles is carried out away from the workshop area it shall be done at locations and in such a manner as to avoid spillage and contamination of streams and other drainage courses. Any spillages shall be cleaned up by either burning in place or collecting the contaminated soils and burning them at the central disposal area, all to the satisfaction of the Engineer.

Prior to completion of the work, the Contractor shall remove from the vicinity of the work all plant facilities, buildings, rubbish, unused materials, concrete formworks, and other similar material, belonging to him or used under his direction during construction, All work areas shall be graded and left in a neat manner conforming to the natural appearance of the landscape.

Any residue deposited on the ground from washing out transit mix trucks or any similar concrete operations shall be buried or cleaned up in a manner acceptable to the Engineer.

In the event of the Contractor's failure to perform the above work, the work may be performed by the Contracting Authority, at the expense of the Contractor and his sureties shall be liable thereof.

Disposal of Waste Material

Waste materials including, but not restricted to, refuse, garbage, sanitary wastes, industrial wastes, and oil and other petroleum products, shall be disposed of by the Contractor. Disposal of combustible materials shall be by burying, where burial of such materials is approved by the Engineer; by burning, where burning of approved materials is permitted; or by removal from the construction area. Disposal of non-combustible materials shall be by burying, where burial of such materials is approved by the Engineer, or by removal from the construction area. Waste materials removed from the construction area shall be dumped at an approved dump.

Disposal of Material by Burying

Only materials approved by the Engineer may be buried. Burial shall be in pits and the location, size and depth of which shall be approved by the Engineer. The pits shall be covered by at least 600mm of earth material prior to abandonment.

Disposal of Material by Burning

All materials to be burned shall be piled in designated burning areas in such a manner as will cause the least fire hazards. Burning shall be thorough and complete and all charred pieces remaining after burning, except for scattered small pieces, shall be removed from the construction area and disposed of as otherwise provided in this Section.

The Contractor shall, at all times, take special precautions to prevent fire from spreading beyond the piles being burned and shall be liable for any damage caused by his burning operations. The Contractor shall have available, at all times, suitable equipment and supplies for use in preventing and suppressing fires and shall be subject to all laws and regulations locally applicable for presuppression, suppression, and prevention of fires.

Disposal of Material by Removal

Material to be disposed of by removal from the construction area shall be removed from the area prior to the completion of the work under the Contract. Materials to be disposed of by dumping shall be hauled to an approved dump. It shall be the responsibility of the Contractor to make any necessary arrangements with private parties and with local officials pertinent to locations and regulations of such dumping.

8.5.7.4 Prevention of water pollution

The Contractor's construction activities shall be performed by methods that will prevent the entry, or accidental spillage, of solid matter, contaminants, debris, and other pollutants and wastes into streams, flowing or dry watercourses, lakes, and underground water sources. Such pollutants and wastes include, but are not restricted to, refuse, garbage, cement, concrete, sanitary waste, industrial waste, radioactive substances, oil and other petroleum products, aggregate processing tailings, mineral salts and thermal pollution.

Dewatering work for structure foundations or earthwork operations adjacent to, or encroaching on, streams or watercourses shall be conducted in a manner to prevent muddy water and eroded materials from entering the streams or watercourses by construction of intercepting ditches, bypass channels, barriers, settling ponds, or by other approved means. Excavated materials or other construction materials shall not be stockpiled or deposited near or on stream banks, lake shorelines, or other watercourse perimeters where they can be washed away by high water or storm runoff or can in any way encroach upon the watercourse itself.

Increases in turbidity in a stream or other bodies of water that are caused by construction activities shall be strictly controlled. When necessary to perform required construction work in a stream channel, the turbidity may be increased, as approved by the Engineer for the shortest practicable period required to complete such work. This required construction work may include such work as diversion of a stream, construction or removal of cofferdams, specified earthwork in or adjacent to a stream channel, and construction of turbidity control structures. Mechanised equipment shall not operate in flowing water except as necessary to construct crossings or to perform the required construction.

Wastewater from aggregate processing, concrete batching, or other construction operations shall not enter streams, watercourses, or other surface waters without the use of such turbidity control methods as settling ponds, gravel-filter entrapment dikes, approved flocculating processes that are not harmful to fish, recirculation systems for washing of aggregates, or other approved methods. Any such wastewater discharged into surface waters shall contain the least concentration of settleable material possible. For the purpose of this Specification, settleable material is defined as that material which will settle from the water by gravity during a one hour quiescent detention period.

The Contractor shall comply with all applicable national laws, orders, regulations, and water quality standards concerning the control and abatement of water pollution.

8.5.7.5 Prevention of air pollution

The Contractor shall comply with applicable national laws and regulations concerning the prevention and control of air pollution. Notwithstanding the above in conduct of construction activities and operation of equipment, the Contractor shall utilise methods and devices as are, reasonably available to control, prevent, and otherwise minimise emissions or discharges of air contaminants.

The emission of dust into the atmosphere shall be strictly controlled during the production, handling, and storage of concrete and road aggregates, and the Contractor shall use such methods and equipment as are necessary for the collection and disposal, or prevention, of dust during these operations. The Contractor's methods of storing and handling cement and pozzolans shall also include means of eliminating atmospheric discharges of dust.

Equipment and vehicles that show excessive emissions of exhaust gases due to poor engine adjustments, or other inefficient operating conditions, shall not be operated until corrective repairs or adjustments are made.

Burning of materials resulting from clearing of trees and brush, combustible construction materials, and rubbish will be permitted only when atmospheric conditions for burning are considered favorable and when authorized by the Engineer. In lieu of burning, such combustible materials may be disposed of by other methods. Where open burning is permitted, the burn piles shall be properly constructed to minimise smoke, and in no case shall unapproved materials, such as tyres, plastics, rubber products, asphalt products, or other materials that create heavy black smoke or nuisance odours, be burned.

During the performance of the work required by this Specification or any operations appurtenant thereto, whether within the right-of-way provided by the Contracting Authority or elsewhere, the Contractor shall furnish all the labour, equipment, materials, and means required, and shall carry out proper and efficient measure, wherever and as often as necessary to reduce the dust nuisance, and to prevent dust which has originated from his operations from damaging crops, orchards, cultivated fields, and dwellings, or causing a nuisance to persons. The Contractor will be held liable for any damage resulting from dust originating from his operations under this Specification on the right-of-way or elsewhere. 'The Engineer may direct sprinkling or other measures for dust abatement if necessary to obtain adequate control. In particular in towns and villages water sprinkling will be required as often as necessary to reduce the dust nuisance.

To reduce the dust problem the Engineer may direct the Contractor to install temporary speed limit traffic signs on those sections of the road where dust development is considerable.

8.5.7.6 Prevention of air noise

The Contractor shall comply with applicable national laws, orders, and regulations concerning the prevention, control, and abatement of excessive noise.

Blasting, the use of jack hammers, rock crushing, or other operations producing high intensity impact noise may be performed at night only upon approval of the Engineer.

8.5.7.7 Prevention of light pollution

The Contractor shall exercise special care to direct all stationary floodlights to shine downward at an angle less than horizontal. These floodlights shall also be shielded so as not to be a nuisance to surrounding areas. No lighting shall include a residence in its direct beam.

The Contractor shall be responsible for correcting lighting problems when they occur as directed by the Engineer.

8.5.7.8 Pesticides

Pesticides include herbicides, insecticides, fungicides, etc., surface disinfectants, animal repellents, and insect repellents. Should the Contractor find it necessary to use pesticides in work areas of this Contract, he shall submit his plan for such use to the Engineer for written approval.

The Contractor shall read and comply with all labelling requirements when using pesticides.

8.5.8 Surveys

The Contractor shall be responsible for the proper and true setting – out of the works.

8.5.8.1 Contractual survey data

The Contractor shall carry out a survey in sufficient detail to produce a Digital Terrain Model (DTM) that accurately reflects the existing natural surface.

This survey shall be supplied to the Engineer as both a hard copy plan showing one (0.5) half metre contours, and in digital format suitable for reading by AUTOCAD. The limits of this survey shall be a line located ten (10) metres outside the areas shown to be affected by earthworks or right of way and any limits shown on the design drawings.

The Contractor shall compare the field survey data with the survey data used for design and advise the Engineer of any significant discrepancies between the two surveys which will impact on the construction of the works. Following receipt and review of the field survey and comments, the Engineer shall advise the Contractor which areas are approved for construction. No earthworks shall commence until the Engineer issues written approval.

When the Contractor's survey DTM is found to be a true representation of the existing ground surface then these Drawings will become the Drawings on which the quantities for the Works will be calculated.

8.5.8.2 Survey equipment

The Contractor shall provide all materials, equipment and labour required for surveying work, including, but not limited to, instruments, stakes, spikes, steel pins, templates, platforms, and tools, and except as required to be incorporated in the work or left in place, all such materials and equipment, shall remain the property of the Contractor. Surveying instruments shall be in perfect working condition and shall be subject to rigid inspection for proper operation at least after every two weeks of use. Defective instruments shall be promptly replaced or repaired and adjusted to the satisfaction of the Engineer.

8.5.8.3 Reference points, lines and levels

The Contractor shall establish primary survey control stations for construction, which shall also serve as permanent reference points for future survey measurements. These points shall be solid concrete blocks dowelled into a solid rock foundation. Blocks shall have a flat upper surface bearing a securely fixed brass plate with a cross hair clearly marking the centre of the plate. The plate and block shall be clearly marked with identifying text such as 'Control Station A', to be confirmed by the Engineer, and shall be painted white.

Slope stakes, reference lines and points shall be set out by the Contractor before the commencement of excavation and layout of structures and shall be re-established as required during the progress of Works.

8.5.8.4 Accuracy

Degree of accuracy for the survey works shall satisfy the following specified tolerances:

- Alignment of tangents and curves shall be within 0.1m for 100m i.e., an accuracy of 1:10,000 ;

- Structure points shall be set within 3mm accuracy from point to point, except where tighter tolerances are required ;
- Cross-section points shall be located within 30mm horizontally, and 3mm vertically.

8.5.8.5 Recording of data

Survey data shall be recorded in accordance with recognized professional surveying standards. Original field notes, computations, and other surveying data shall be recorded in the Contractor furnished field books. Notes or data not in accordance with standard formats will be rejected. Illegible notes or data, or use of erasures on any page of a field book will be considered sufficient cause for rejection of part or all of the field book. Copied notes or data will not be permitted; therefore, rejection of part or all of a field book may necessitate re-surveying. Corrections by ruling or lining out errors will be satisfactory.

8.5.8.6 Verification

The Engineer may make checks as the work progresses to verify lines and grades established by the Contractor and to determine the conformance of the work as it progresses with the requirements of the Drawings and Specifications. Such checking by the Engineer shall not relieve the Contractor of his responsibility to perform all work in accordance with the Drawings and Specifications and the lines and grades given therein.

8.5.8.7 Maintenance of survey points

The Contractor shall be responsible for maintaining all survey markers/monuments, and property corners. If any markers/monuments are destroyed or damaged, the Contractor shall arrange, at his own cost, to retrace and replace them to the entire satisfaction of the Engineer. If a monument cannot be replaced in its original position, the Contractor shall install a witness corner. The Contractor shall complete and file monument reference cards on all monuments as instructed by the Engineer. The Contractor shall employ experienced construction surveyors with adequate experience in the construction surveys similar in nature to that required by this Contract.

8.5.8.8 Survey for quantities

The Contractor shall perform such surveys and computations as are necessary to determine quantities of work performed or placed during each progress payment period, and shall also perform all surveys necessary for the Engineer to determine final quantities of work in place. The Engineer will determine final quantities based on original ground levels determined by the Contractor and agreed by the Engineer.

The Contractor shall notify the Engineer at least 24 hours before performing a quantity survey and, unless specifically waived, quantity surveys shall be performed in the presence of an authorized representative of the Engineer.

The Contractor shall within 28 days after the Date of Award, and prior to any construction work commencing, undertake a joint survey with the Engineer. This survey will be checked by the Engineer and when it is found to be a true representation of the existing ground surface then these Drawings will become the Drawings on which the quantities for the Works will be calculated.

8.5.9 Setting out of works

The Contractor shall be responsible for the true and proper setting out of the Works and for the correctness of the positions. Levels, dimensions and alignment of all parts of the Works and for the provisions of ail necessary instruments, appliances and labor in connection therewith. If at any time during the progress of the works, any error shall appear or arise in the position, levels, dimensions or alignment of any part of the Works, the Contractor, on being required to do so by the Engineer, shall at his own expense rectify such error to the satisfaction of the Engineer. The checking of any setting out or of any line or level by the Engineer shall not in any way relieve the Contractor of his responsibility for correctness thereof. The Contractor shall carefully protect and preserve all bench marks, sigh-rails, and other things used in setting out the works.

No separate payment will be made for this and the unit rates for the different items entered in the Bill of Quantities are deemed to cover all such expenditure.

8.5.10 Workmanship and quality control

It is the Contractor's responsibility to produce work, which conforms in quality and accuracy of dimensions to the requirements of the Specification and Drawings. The Contractor must implement his own quality control system with experienced staff, together with all necessary facilities, to ensure adequate supervision and positive control of the Works at all times.

If the Engineer has any doubt concerning the quality of any material to be used in the Works, he shall instruct the Contractor to carry out tests to prove the quality of material before it is used in the Works. The results of tests, which are carried out by the Contractor, shall be submitted to the Engineer on request.

8.5.11 Construction camp

The Contractor shall at his own cost provide, operate and maintain all offices, workshops, warehouses, residential colonies, and other camp and sub-camp facilities required by him and by the Engineer for the proper and efficient performance of the Contract. This shall include all access roads and services such as water and electricity.

The Contractor shall at his own cost furnish and equip buildings and other facilities in accordance with the laws and regulations of Rwanda, and as required for the proper functioning of each facility. All equipment shall be of a type normally used in similar construction and of a grade suitable for the required service.

All buildings constructed by the Contractor for his camps, workshops and warehouses and utilities shall be dismantled and removed from the Site on completion of the works, the Site restored to the original condition as far as possible, at no additional cost to the Owner.

The camps shall have the minimum possible impact on the local population.

The Contractor shall submit, for the approval of the Engineer, drawings and specifications of the proposed construction camps, colonies, facilities and each major building specified herein, required to be provided by him.

8.5.11.1 Facilities and utilities

Electricity supply

The Contractor shall provide such electricity as is required for the Works including labour camps, staff residences, offices and various camp facilities. The Contractor shall also provide sufficient standby electricity supply arrangements for his needs.

Water supply

The Contractor shall arrange for the water supply for all construction requirements and his staff residences, labour camps, site offices, work yards, workshops, and various camp facilities. Construction of pumps, treatment, storage tanks, overhead tank, distribution system, and their proper running and maintenance shall be his responsibility. Water shall be supplied to the camps 24 hours a day.

Water samples shall be tested periodically to ensure that it is fit for human consumption.

Sanitary facilities

The Contractor shall provide adequate temporary sanitary conveniences for the use of his employees and persons engaged on the work. He shall ensure that his employees and labour make proper use of the latrines and do not foul the Site.

In addition to toilet facilities, suitable and adequate washing facilities shall be provided.

Sanitary facilities shall be located as directed or approved by the Engineer and shall be maintained in a clean and sanitary condition during the entire course of the work.

The septic tank and/or temporary holding tank(s) shall be kept pumped out at such intervals that the tank(s) will not overflow and contaminate the ground, flowing streams or surface drainage.

On completion of the Works, sanitary facilities shall be properly disinfected and all evidence of same including temporary buried tanks and foundations removed from the site.

Drainage

The ground around the buildings shall be graded to slope away from building perimeters so as to provide adequate drainage and shall be thoroughly compacted. Excavated material shall be disposed of by filling in low areas or as otherwise directed by the Engineer.

Fencing of work area and security

All work areas, storage areas and such other areas where construction activity by the Contractor is proceeding shall be suitably fenced and guarded. It is the Contractor's responsibility under the conditions of contract to erect and maintain security barriers for the proper protection of the works and to ensure that no unauthorized entry or stock access the site.

Fencing shall be erected along the access road to segregate construction activities from the public traffic. The Contractor shall provide security guards and watchmen, and other personnel and facilities required for security and public safety. The cost of such fencing including all fence gates, braces, concrete and other items required for a complete installation and security arrangements shall be deemed to have been included in the rates and prices in the Bill of Quantities.

Fencing shall remain in position until either replaced by permanent fencing or, where none is required, completion of the related section of the works unless the Engineer permits its entire removal.

Telephone, e-mail system and fax facilities

The Contractor shall be responsible for arranging the telephone, email and fax connections installed as per his requirements. The Contractor shall inform the Owner through the Engineer about such connections. The Owner, if requested by the Contractor, will assist him in obtaining the connections. All charges, fees and expenses for these connections shall be borne by the Contractor.

The Contractor shall connect the public telephone system to the Project telephone system.

Operation and maintenance of the camps and facilities

For the purpose of operation and maintenance of the camps and facilities provided as above, the Contractor shall comply with all applicable provisions of the Rwanda Laws. The Contractor shall furnish, make arrangements for and carry out proper and adequate maintenance of the facilities required to be constructed by him so as to provide neat, well-kept, pleasant, healthful surroundings and conditions for all occupants. All areas shall be kept clean, well graded, free from undergrowth and bush and adequately drained. All landscaping shall be properly trimmed and cut. Roads and streets shall be kept in good repair, patched and sprinkled if and as necessary to keep down dust or a palliative may be employed as approved by the Engineer. Qualified operators and repairmen shall be provided for the operation and maintenance of all utilities. Utilities shall be properly operated and maintained to provide services and conditions meeting the requirements of the Specification and accepted good practice. Buildings shall be adequately and properly maintained. Janitorial services for public buildings shall be regularly provided. Equipment shall be checked periodically in accordance with the manufacturers' instructions and defective equipment shall be replaced at the Contractor's expense.

The Contractor shall at his own cost provide operate and maintain all these facilities and utilities.

8.5.11.2 Vacating camp

At such time when portions of the facilities provided by the Contractor are no longer required for the prosecution of the work, and in accordance with a schedule of time approved by the Engineer, the Contractor shall vacate the facilities and remove them completely leaving the areas concerned in a clean condition and restored to a state similar to the surrounding areas, at no additional cost to the Owner.

The Contractor will be permitted to retain possession of and use such portions of the facilities as he may reasonably require to carry out his obligations and work remaining under the Contract after the date of the Taking-over Certificate. This retention is limited to Defects Liability Period after which the Contractor shall remove those facilities leaving the areas to the original condition, at no additional cost to the Owner.

All the Contractor's installations, equipment, fittings and other salvage material will remain the property of the Contractor.

8.5.12 Construction utilities

In addition to the utilities for labour camps etc, the Contractor shall provide such water, electricity, telephone, power, lighting, compressed air and other utilities as required for construction and other uses in connection with work under this Contract. Before final acceptance of the Works, all temporary utilities shall be removed or suitably abandoned unless otherwise specified or directed.

The Contractor shall design, procure and install permanent electric overhead transmission lines to the site as an extension from existing remote and local substations. This will serve as a temporary supply for the construction works and subsequently will provide the permanent supply to the Works.

The Contractor shall provide all necessary transformers, lines, switchgear etc. to supply his operations and shall remove all temporary installations upon completion of the Works, leaving only such installations as are required to form part of the permanent works.

The Contractor shall be charged for the electricity supplied to him at the applicable tariff at the time of use for such power supply. The cost of electricity shall be included in the rates and lump sums in the Bill of Quantities.

Not less than fourteen days before commencing any portion of the Works, the Contractor shall, if ordered, submit to the Engineer for his approval complete drawings of all Temporary Works the Contractor may be proposing for the construction of that part of the Works.

Notwithstanding approval by the Engineer of any design for the Temporary Works, the Contractor shall be entirely responsible for their efficiency, security and maintenance and for all temporary works.

For the purposes of the Contract, everything provided by the Contractor in compliance with the present clause shall be deemed to be part of the Temporary Works or of the Contractor's Equipment (whether it is owned by or is on hire to the Contractor) and the permission of the Engineer's Representative for removal from the Site may be withheld until the issue of the Defects Liability Certificate.

8.5.13 Roads and traffic

The Contractor shall ensure that roads and thoroughfares used by him for the transportation of Constructional Plant, labour and materials are not dirtied as a result of such transport, and in the event of their becoming thus dirtied in the opinion of the Engineer, the Contractor shall take all necessary steps to clean them, at no extra cost to the Owner.

The Contractor shall at his own cost provide and maintain traffic facilities in the construction area, and in areas adjacent thereto, as is necessary for safe and adequate pedestrian and road traffic. The Contractor shall submit a plan of traffic operation, maintenance and protection for approval by the Engineer. At the completion of the Contract all roads and bridges provided by the Contractor shall become the property of the Owner.

8.5.13.1 Right of way for access and haul routes

The Contractor shall be responsible for providing and maintaining access for the Works. The right of way for access to the Works from existing roads will be provided by the Owner. The Contractor shall make his own investigations of the condition of available public or private roads and of clearances, restrictions, bridge load limits and other limitations that affect or may affect transportation and ingress and egress at the job sites.

The repair and reinstatement of roadways, bridges, drain and canal banks if damaged during operation shall be the responsibility of the Contractor without any additional cost to the Owner. At least 30 days prior to commencement of the Works the Contractor shall prepare and submit to the Engineer for approval a Traffic

Management Plan which will ensure the safe and easy passage of public and construction traffic through or around the Works at all times.

The Contractor should allow for maintaining through traffic at all times. In exceptional circumstances road closures of up to one-hour duration may be permitted by the Engineer. The Contractor shall give reasonable notice of any proposed road closures.

On completion of a day's work the Contractor shall leave the works in such a condition to allow the safe passage of through traffic. The Contractor shall be responsible for complying with all regulations relating to the temporary closure of roads.

8.5.13.2 Haul and construction roads

The Contractor shall provide and maintain such haul and construction roads as are necessary for the conduct of the work.

8.5.13.3 Haul roads from borrow areas or quarries

The Contractor shall develop adequate haul roads for haulage of the required construction materials from the Borrow areas or quarry sites or make suitable arrangements for obtaining materials from any other Borrow area or quarry and transporting them to the Site to meet his construction program.

The Contractor shall be responsible for the construction, upkeep and maintenance of the haul roads including shoulders, ditches and drainage structures through their entire lengths during the currency of the Contract.

8.5.13.4 Maintenance of existing access routes, roads and other services

The Contractor shall take over and maintain in suitable condition, as required by the Engineer, existing public access routes, roads and other services encountered within the construction area until such time as these public access routes and roads are diverted, or alternative arrangements made by the Contractor to the satisfaction of the Engineer.

If the Contractor finds it necessary or elects to use the existing public or private roads, he shall ensure the smooth flow of public traffic. Two-way traffic shall be ensured to ply on or pass through the existing public or private roads without any inconvenience and delay whether within these existing roads or by use of detour roads or by a combination of both. To the extent that an interface of the Contractor’s vehicular traffic with the general public traffic is inevitable, safe detours and or crossings as necessitated shall be constructed by the Contractor to conduct his operations so as to offer the smooth flow of public traffic without any obstruction and inconvenience.

Keeping in view the traffic load of his light and heavy vehicular equipment, and traffic load of public transport plying on public or private roads, the Contractor shall envisage the traffic hazards, and shall accordingly design, construct and maintain wherever necessary the appropriate detours and or crossings on these public or private roads catering for the requirements of such traffic loads ensuring smooth, safe and efficient public traffic flow without any interruption, interference, nuisance and occurrence of accident. The Contractor shall submit to the Engineer for approval his design for detours and or crossings together with proposals for control of traffic.

Prior to execution of Works, the Contractor shall construct, provide and maintain appropriate road diversions for all types of public traffic whether vehicular or pedestrian. The Contractor shall furnish and maintain signs, traffic barricades, torches, flagmen and other facilities as necessary for safe and efficient directing and handling of traffic and shall be responsible for ensuring that all roads and temporary facilities provided are sufficient to divert public traffic adequately and safely. The Contractor shall observe all relevant rules and regulations of the Rwanda and other local authorities.

8.5.13.5 Utility lines

The Contractor shall conduct his operations, make necessary arrangements, take suitable precautions and perform all required work incidental to the protection of and avoidance of interference with power, telegraph, telephone and natural gas lines and other utilities within the areas of his operations in connection with the

Contract and the Contractor shall save harmless and indemnify the Owner in respect of all claims, demands, proceedings, damages, costs, charges and expenses whatsoever arising out of or in relation to any such interference.

Whereever it is required or so directed by the Engineer, the Contractor shall arrange relocation or removal of utility lines with the concerned departments and organizations.

8.5.14 Existing drainage system and flows

The Contractor shall provide all temporary works and do all things which may be necessary to maintain those parts of the existing drainage system which may be affected by his operation. It is required to Condition of use shall not be less satisfactory than they were prior to the commencement of the works and shall maintain the normal flows therein at all times except when written permission to vary the flows has been obtained from the Engineer.

The cost of such temporary works and all other charges arising from applying this clause shall be deemed to be included in the rates of other items included in the Bill of Quantities, unless otherwise provided in the Bill of Quantities.

8.5.15 Existing public utilities

The Contractor shall carry out the necessary investigations to identify the location of all existing public utilities within the right-of-way and provide accurate records of such to the Engineer prior to commencement of the Works.

The Contractor shall notify the Engineer, and provide accurate records, of any public utilities encountered during the execution of the Works. He shall take all necessary steps to prevent damage to and safeguard any such services.

The Contractor shall co-operate with the public utility authorities in the removal and relocation of any underground or overhead services or facilities so as to safeguard and minimize disruption to the services. In the event of a utility service being interrupted as a result of damage caused by the Contractor, the Contractor shall promptly notify the authority concerned and be responsible for the cost of any repairs that are required to restore the services.

8.5.16 Permits

The Contractor shall be fully responsible and pay charges, if any, for obtaining all necessary permits and permissions, except those normally obtained by the Owner or Engineer, prior to commencement of the Works.

These permits which the Contractor shall be responsible and pay shall include but not limited to:

- General excavation permits ;
- Permits for spoil and dumping areas;
- Permits for stockpiling ;
- Provision of all necessary bonds required by the permits ;
- Permissions in respect of erection of site offices, labour camps, stores etc.

9. DRAWINGS AND ANNEXES

The table below is an index of all the drawings that have been produced throughout the detailed design, and their organization in the annexes for easy reference of the reader.

Annex	Project Component	Plans
0	3D Presentation of actions for all the wetlands	
1	Gikondo	
1.1	Master Plan	Zoning Maps
		Masterplans with specific actions
		Topographic Maps
		Animation
1.2	Landscaping Interventions	Botanical Map
		Section views of the wetland
1.3	Hydraulic Interventions	Hydraulic Detailed Design Gikondo Wetland
1.4	Hydraulic Modelling Results	Gikondo flooding for T2 Rainfall at current urbanisation
		Gikondo flooding for T2 Rainfall at 2050 urbanisation
		Gikondo flooding for T10 Rainfall at current urbanisation
		Gikondo flooding for T10 Rainfall at 2050 urbanisation
		Gikondo flooding for T50 Rainfall at current urbanisation
1.5	Public Space interventions	Site plan
		Public Space Detailed Design Gikondo Wetland
2	Rwampara	
2.1	Master Plan	Zoning Maps
		Masterplans with specific actions
		Topographic Maps
		Animation
2.2	Landscaping Interventions	Botanical Map
		Section views of the wetland
2.3	Hydraulic Interventions	Hydraulic Detailed Design Rwampara Wetland
2.4	Hydraulic Modelling Results	Rwampara flooding for T2 Rainfall at current urbanisation
		Rwampara flooding for T2 Rainfall at 2050 urbanisation
		Rwampara flooding for T10 Rainfall at current urbanisation
		Rwampara flooding for T10 Rainfall at 2050 urbanisation
		Rwampara flooding for T50 Rainfall at current urbanisation
2.5	Public Space interventions	Site plan
		Public Space Detailed Design Rwampara Wetland
3	Rugenge-Rwintare	
3.1	Master Plan	Zoning Maps
		Topographic Maps
3.2	Landscaping Interventions	Botanical Map
		Section views of the wetland
3.3	Hydraulic Interventions	Hydraulic Detailed Design Rugenge-Rwintare Wetland
3.4	Hydraulic Modelling Results	Rugenge-Rwintare flooding for T2 Rainfall at current urbanisation
		Rugenge-Rwintare flooding for T2 Rainfall at 2050 urbanisation
		Rugenge-Rwintare flooding for T10 Rainfall at current urbanisation
		Rugenge-Rwintare flooding for T10 Rainfall at 2050 urbanisation
		Rugenge-Rwintare flooding for T50 Rainfall at current urbanisation
3.5	Public Space interventions	Site plan
		Public Space Detailed Design Rugenge-Rwintare Wetland
4	Kibumba	
4.1	Master Plan	Zoning Maps

		Masterplans with specific actions
		Topographic Maps
4.2	Landscaping Interventions	Botanical Map
		Section views of the wetland
4.3	Hydraulic Interventions	Hydraulic Detailed Design Kibumba Wetland
4.4	Hydraulic Modelling Results	Kibumba flooding for T2 Rainfall at current urbanisation
		Kibumba flooding for T2 Rainfall at 2050 urbanisation
		Kibumba flooding for T10 Rainfall at current urbanisation
		Kibumba flooding for T10 Rainfall at 2050 urbanisation
		Kibumba flooding for T50 Rainfall at current urbanisation
4.5	Public Space interventions	Site plan
		Public Space Detailed Design Kibumba Wetland
5	Nyabugogo	
5.1	Master Plan	Zoning Maps
		Masterplans with specific actions
		Topographic Maps
5.2	Landscaping Interventions	Botanical Map
		Section views of the wetland
5.3	Hydraulic Interventions	Hydraulic Detailed Design Nyabugogo Wetland
5.4	Hydraulic Modelling Results	Nyabugogo flooding for T2 Rainfall at current urbanisation
		Nyabugogo flooding for T2 Rainfall at 2050 urbanisation
		Nyabugogo flooding for T10 Rainfall at current urbanisation
		Nyabugogo flooding for T10 Rainfall at 2050 urbanisation
		Nyabugogo flooding for T50 Rainfall at current urbanisation
5.5	Public Space interventions	Site plan
		Public Space Detailed Design Nyabugogo Wetland
6	Gallery of Plant Species	
7	Baseline assessment of soil quality	
8	Environmental and Social Management Plan	

TABLE 9-1 DRAWINGS AND LOCATIONS IN THE ANNEXES

10. COST ESTIMATE

The cost estimate for the proposed works is submitted alongside the report. The quantities were developed during the detailed engineering design, and unit prices were developed using the following sources:

- Nyandungu urban Wetland Eco-Tourism Park,
- Recent project for which the Consultant is currently implementing works supervision, with detailed BoQ available :
    - Sebeya retention dam project for flooding mitigation control project
    - Bukeri diversion channel project
    - Rubavu retention dyke project
- Local market survey for plant, materials and labour,
- Other previous experiences.

11. WORK PLAN

The overall works in all five wetlands are expected to be completed in 30 months.

This period will include:

- Contractor startup: 1 month, starting after contract signature,
- Development and approval of implementation plans: 8 months commencing after startup, with the first approval to be given by the end of the 5th month,
- Civil works: 18 months, commencing in Month 6,
- Hydraulic works, landscaping and construction of public facilities: 12 months, commencing in Month 16
- Commissioning and Handover: 3 months, commencing at Month 28.

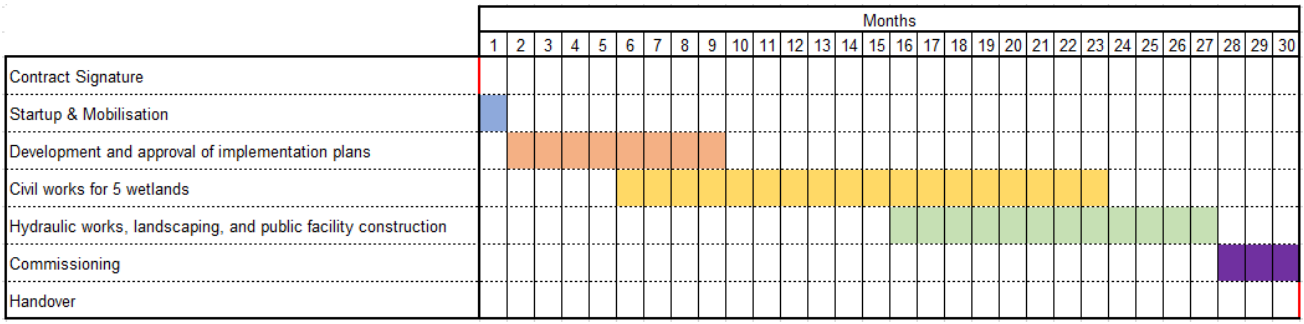


FIGURE 11-1: PROJECT WORKPLAN

This works schedule is approximate and will depend on the Resettlement Action Plan.

12. SUMMARY OF ACHIEVEMENTS

The table below presents the key tasks of the entire project according to the requirements of the ToR, as well as their status following the Consultant's activities.

Sub-task	Status	Time / details
Task 1: Project Inception		
Undertake preliminary site visits to contact key stakeholders and gather additional information about local site conditions.	Completed	First site visit January 2022
Collect and review all relevant baseline data and background documentation for the wetland sites.	Completed	Data collection January-March 2022 Summary in §4 of Feasibility study report
Review best international, national, and regional practices in wetlands restorations	Completed	Feasibility study report §3
Review and assess the outcomes and limitations of the available hydrological (Wflow) and hydraulic (SOBEK) models and associated reports	Completed	Inception report §3.5 Feasibility study report §4.8
Clarify the scope, methodology and allocated costs for additional baseline studies that need to be undertaken to inform the design phase, including the following Soil contamination study, Geotechnical investigations, Topographic surveys, Flow monitoring, Water quality monitoring, Comprehensive services search.	Completed	Inception report §4.1 Feasibility report §9
Prepare a schedule of planned consultation workshops for the design component	Completed	Defined through consultation workshop January 2022 Implemented between February and June 2022, cf Feasibility study report §4.12 Stakeholder view and opinion
Confirmation of national and international staffing and their task and time commitments.	Completed	Inception report §4.3
Preparation of a detailed Work Plan with a timeline, milestones, deliverables, project-specific quality control/assurance procedures, an overview of project risks and mitigation measures.	Completed	Inception report §4 and §5
Task 2: Feasibility studies including baseline studies and preliminary designs		
Oversee the successful and timeous completion of additional baseline studies.	Completed	Feasibility report §4
Undertake a rapid desktop review of selected comparable urban wetland restoration projects.	Completed	Feasibility report §4.15 – case study analysis
Set out the primary ecological and landscape criteria that will be used to refine or adapt the early concept designs.	Completed	Feasibility report §3.3.4
Review hydrological and hydraulic modelling output for the early concept plans.	Completed	Feasibility study report §4.8

Prepare a refined topographic map and DTM for hydraulic analysis.	Completed	Feasibility study report §4.6
Determine the range of flow regimes that will influence the design of the rehabilitated wetlands.	Completed	Feasibility study report §4.8
Further develop the preliminary rehabilitation scenarios in accordance with international ecological design best practice, informed by stakeholder inputs and site conditions including available baseline data for soil and water contamination.	Completed	Feasibility study report §5.1 to 5.8
Test the performance of alternative rehabilitation scenarios.	Completed	Feasibility study report §5.9 and §7
Adapt where necessary, the design and associated hydraulic model of the wetland system to test and optimize the flow distribution and hydraulic performance of the preliminary designs.	Completed	Feasibility study report §4.8
Evaluate and seek to optimize the implications of alternative scenarios on the provision of other secondary functions of the wetlands which may include: • Habitat and biodiversity values; • Direct use values such as subsistence cultivation and grazing values; • Recreational and tourism including the provision of walking tracks with wooden bridges, picnic tables and benches; and • Educational and recreational opportunities	Completed	Feasibility study report §5.9 and §7
Develop preliminary designs sufficiently for preliminary costing and cost benefit analyses.	Completed	Feasibility study report §8
Prepare a comparative analysis of the different options for discussion with the client and presentation to key stakeholders.	Completed	Feasibility study report §5.9 and §7
Develop the Preliminary Design Report presenting the content and outcomes of this process.	Completed	Feasibility study report §8
Task 3: Detailed Design and tender documents for wetland rehabilitation		
Oversee and carry out any site investigation studies that were deferred to the detailed design phase.	Completed	Geotechnical report February 2023
Ensure alignment with other RUDP initiatives including planned Nature Based Solutions and interventions in flooding hotspots at affected road crossing points.	Completed	Feasibility study report §6 Detailed design report §5.8
Integrate findings and recommendations from the ESIA and RAP.	Completed	Permanent collaboration with ESIA Consultant Detailed design report §6
Prepare Detailed Design Reports that clearly present all planned activities and associated objectives and a	Completed	Detailed design report

clear rationale for intervention selection and design elements for the wetland system.		
Refine and finalize hydraulic simulations to demonstrate the degree to which the selected designs are expected to contribute towards flood attenuation.	Completed	Detailed design report §5.8 Hydraulic simulations results in appendixes 1.4, 2.4, 3.4, 4.4 and 5.4 of detailed design report
Prepare a set of detailed drawings and specifications for earthworks, stabilization, revegetation and basic recreational infrastructure based on the approved preliminary designs and other available information and resources.	Completed	Detailed design report §5 and §8 Appendixes 1 to 5 of detailed design report
Develop phased implementation plans for the construction programme that accounts for social and environmental impacts, seasonal working conditions and budget availability.	Completed, though the Consultant was informed during the detailed design workshop of December 2022 that that budget was no longer his concern.	Detailed design report §11
Develop accompanying management, monitoring and maintenance plans for the construction phase.	Completed	Detailed design report §5 & §8
Prepare a priced bill of quantities for construction in a format approved by REMA and the Kigali City municipality.	Completed	Detailed BoQ part of tender documents
Prepare a full set of design drawings of construction requirements for wetland rehabilitation.	Completed	Site plans in Appendix 1 to 5 of detailed design report
Develop preliminary operational plans for the wetlands that include maintenance and monitoring requirements and indicative costings and responsibilities.	Completed	Detailed design report §5.2 Maintenance costs included in the BoQ
Prepare Tender Documentation in English for the implementation of rehabilitation requirements	Completed	Detailed design report and BoQ
Tash 4: Preparation of Terms of Reference for supervision and oversight of construction activities		
Terms of Reference will therefore need to be developed to aid the PIU in appointing a suitably qualified firm to provide supervision and oversight support after works start.	Completed	Final ToR version transmitted January 2023

APPENDIX 1: GIKONDO WETLAND

APPENDIX 2: RWAMPARA WETLAND

APPENDIX 3: RUGENGE RWINTARE WETLAND

APPENDIX 4: KIBUMBA WETLAND

APPENDIX 5: NYABUGOGO WETLAND

APPENDIX 6: GALLERY OF PROPOSED PLANT SPECIES

APPENDIX 7: SOIL ANALYSIS EXISTING STUDY

APPENDIX 8: ENVIRONMENTAL AND SOCIAL MANAGEMENT PLAN

APPENDIX 9: GEOTECHNICAL REPORT

APPENDIX 10: LANDSCAPE MASTERPLAN