Consultancy for conducting feasibility study for Flood Risk Mitigation Options in Bardere City:

Flood risk mitigation options & recommendations report

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List of abbreviations

BRCiS	Building Resilient Communities in Somalia
CBA	Cost-Benefit Analysis
CCCM	Camp Coordination and Camp Management
DAC	Disaster affected communities
DTM	Digital elevation model
EAD	Expected Annual Damage
EWS	Early warning system
FAO	Food and Agriculture Organization
FGS	Federal Government of Somalia
FGD	Focus group discussion
IDP	Internally displaced people
IOM	International Organization for Migration
KII	Key informant interviews
NBS	Nature-based solutions
SoDMA	Somalia National Disaster Management Agency
TERRA	Towards Regenerative Resilience and Climate Adaptation for Displacement-Affected Communities in Somalia)
SOP	Standard of Protection
SWALIM	Somalia Water and Land Information Management
TOR	Terms of reference
UNHCR	United Nations High Commissioner for Refugees
WSE	Water surface elevation

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1. Introduction

Objectives, structure and contents of the report

This report presents the findings and recommendations of a flood risk mitigation options assessment conducted for Bardere City. It is the final deliverable under the consultancy commissioned by Concern Worldwide. The primary objective is to outline a set of potential flood risk mitigation options that can be considered for advancement toward implementation in a future phase. The report builds on a flood risk assessment carried out in the previous phase, which included technical analyses and extensive stakeholder engagement.

The report is structured into six main sections. Following this introduction, Section 2 describes the final phase of stakeholder engagement, including a one-day in-person workshop held in Bardere with local authorities, community members, and NGOs, as well as a virtual validation workshop with national and regional stakeholders. Section 3 summarizes the findings of the flood risk assessment, drawing on hydrological and hydraulic modelling, and structured around the Source–Pathway–Receptor–Consequence (SPRC) framework, which was used to identify and prioritize areas of flood risk.

Section 4 outlines a range of general flood mitigation measures, including non-structural approaches, nature-based solutions, institutional improvements, and early warning and preparedness initiatives, many of which apply to both fluvial and pluvial flood risk. These are complemented by Section 5, which presents more detailed assessments of physical flood mitigation options, categorized separately into fluvial and pluvial measures. Each option is evaluated in terms of feasibility, indicative cost, and anticipated impact. The analysis emphasizes that a combined approach—including both structural interventions and lower-cost "soft" measures—is key to developing a holistic and cost-effective flood risk strategy for Bardere.

Finally, Section 6 presents overarching conclusions and key recommendations for next steps. It highlights the importance of further technical refinement through pre-feasibility studies, stronger institutional coordination, and sustained investment in both infrastructure and community-based resilience. The report aims to provide a practical foundation for advancing flood risk mitigation in Bardere

2 Stakeholder engagement

This section reports on the final phase of stakeholder involvement, in which an online validation workshop was held with a range of key participants and a face-to-face community stakeholders' workshop was organized by Raagsan with the local authorities, development and flood committees and other groups that were part of the data collection processes. This represents the final stage of the stakeholder engagement.

It builds on the findings of the key informant interviews and focus group discussions previously discussed in the Consultancy's Assessment Report, Section 3: Institutional and governance context. 13 key informant interviews were carried out using the questionnaires targeted at the specific groups:

- State government: District field officer of Ministry of Energy and Water Resources of Jubaland state of Somalia;
- Local government (Bardere District Authority): Deputy District Commissioner, former District Commissioner and Head of humanitarian coordination in Bardere;
- NGOs: representatives of ACTED, Islamic Relief and Lifeline Gedo;
- Community groups/civil society: Local committees: Deputy chairperson cooperatives; Chairperson and Deputy chair District Development /Flood Committee; Clan leader; Clan elder-Marehan; Farmers cooperatives member.

Additionally, 4 focus group discussions were held with women' s groups (Kaskey and Camp Barwaqo); Kurman Village hosting group; and Buulo Ceesan IDP Camp.

The initial fieldwork provides a detailed picture of the region's vulnerability to flooding and the ongoing challenges in managing flood risks. A key concern is the collapse of the Bardere Bridge, which had far-reaching economic and social consequences. Its loss disrupted trade, cut off access to essential services, and isolated communities, severely impacting livelihoods and public well-being. Local fundraising and community-led initiatives have emerged in response, but there is widespread agreement that external financial and technical support is urgently needed. The fieldwork also revealed that certain harmful practices—such as dike-breaking and deforestation—have contributed to increased flood risk, though education efforts have helped reduce these in some areas.

The findings highlight significant barriers to effective flood mitigation, including a lack of technical expertise, limited financial resources, fragmented government involvement, and inadequate infrastructure maintenance. Communities emphasize the urgent need for protective structures, improved drainage, and rehabilitation of flood-prone areas like the Kurman Valley. Strengthening early warning systems and community awareness were also seen as critical. While NGOs have played a key role in providing emergency support and training, there is a clear call for long-term, coordinated strategies involving government leadership, external investment, and sustained community engagement to build resilience in Bardere.

Validation workshop

The validation workshop was held online on 28th May with 20 participants from Concern Worldwide, BRiCS, Jubaland State Ministry of Energy and Water Resources, IOM and the Swedish Embassy (see Appendix 6.2). The meeting was focused on gathering feedback on the draft Assessment Report and structured around the PowerPoint presentation by the study team summarising its findings.

BRCiS context: Isaiah Sciford, representing the BRCiS CMU, outlined the objectives of the Bardere flood study, which seeks to investigate the root causes of chronic flooding in Bardere. He noted that in partnership with Concern and Lifeline Ghetto as the focal points in the Gedo region, BRCiS has been responding to very severe flooding in Bardere for the greater part of a decade and this study is seen as critical in understanding the root causes of the flooding.

In partnership with Concern International, the study is part of the Terra Project, funded by the Swedish Embassy, and aims to connect rural and urban areas in addressing disaster risk and climate issues. The study is intended to showcase the thinking of what Terra is seeking to do with regards rural and urban areas linkages around the critical issues of disaster risk management in the context of climate change. Wider stakeholder collaboration has enhanced the study's scope, and there is a strong emphasis on engaging a wide range of stakeholders for future discussions.

IDP concerns: The meeting discussed challenges faced by the internally displaced population in Bardere, particularly concerning flood risks and the socio-economic impacts of rapid urban expansion. This highlighted the emergency response framework, emphasizing the role of the early warning system and the need for community engagement through local initiatives like the Flood Committee.

Preparedness and response efforts: The involvement of international agencies and NGOs in building resilience against floods was also noted, alongside the innovative use of technology to enhance preparedness and response efforts.

Fluvial and pluvial risk concerns: A detailed flood risk assessment was presented distinguishing between fluvial and pluvial risks and identifying gaps in data and infrastructure that complicate effective flood management.

The need for targeted measures: This highlighted the critical need for targeted measures to address financial constraints and technical expertise shortages, as well as the importance of community capacity building and improved drainage systems. Recommendations included recalibrating gauge data, enhancing early warning systems, and considering large-scale physical measures such as a dam or diversion around Bardere. The discussion also touched on the necessity of reinstating a bridge for economic and community interactions, with ongoing efforts to secure funding for this project.

Regulatory framework: Ahmed Hassan, Technical Advisor, Jubaland State Ministry of Energy and Water Resources, raised a query regarding including a recommendation to support the state to come up with water regulation that can include flood zoning for riparian laws. This could be a soft component that can be quickly implemented and operationalized. This was noted and will be referred to although water regulations are usually driven towards agricultural practices, riparian laws, focused on water shortage as opposed to having too much water during a flood so not within the technical remit of the study.

Importance of collaboration and coordination of efforts: The validation workshop concluded with a focus on the need for collaboration among organizations to maximize data effectiveness and address the complexities of flood risk management in the region.

Community stakeholder workshop

Following on from the validation workshop, various groups at the local level involved in fieldwork and flood management in Bardere were targeted to attend a one-day workshop held in Bardere city on June 2nd. The objectives of the community workshop were as follows:

1. To present the preliminary findings from the interviews, flood modeling and desk review processes, discuss key findings and gather feedback from the proposed recommendations.
2. Provide a platform for stakeholders to share knowledge, gather their feedback, and contribute to refining the research outputs.

In addition to two members of the Raagsan team (Field Researcher and DRM Officer), the list of participants included the District Authority Humanitarian Coordinator Officer (HCO), IDP camp and village leaders, representatives of the local authority women's groups, farmers groups and other community members, totalling 22 attendees.

The findings and outcomes from the consultation workshop generated from the key discussion sessions that were conducted, focused in particular on the impact of the most recent pluvial floods on the Kurman Valley. This resulted in the following recommendations as follows. These have been critically reviewed and assessed from the perspective of technical feasibility in the section 5.2 on Pluvial Measures.

Expansion of the Kurman Valley: The valley could be expanded on its flanks to increase its water-carrying capacity. It is recommended to dig deeper to enhance the depth so that floodwater can pass through without flooding the town. (This point is addressed in Section 5.1.3)

Sediment removal: Community members have emphasized the critical need to remove sediment and debris brought by previous floods. These elements limit the valley's capacity during severe floods and pose a danger to those evacuating using vessels or attempting to swim across the valley, as was witnessed in the last floods.

Diversion of the Kurman Valley stream: Workshop participants have discussed the potential diversion of the valley to redirect it to a river outside of the town settlements. However, they highlighted challenges associated with this approach, citing concerns that massive settlements and farmlands could be impacted due to the lack of available empty space for diverting the valley. Additionally, they noted challenges related to distance and crossing main roads like the primary route to Mogadishu, which would require significant culvert construction if this option were to be pursued.

Building flood walls: Participants also suggested implementing flood walls on the Kurman valley sides to act as flood protection embankments and barriers that could restrict floods from expanding into neighboring settlements. (Flood barriers are addressed in Section 5.2.2)

Financial support: In order to implement effective flood management structural strategies in Bardere, the community emphasizes the necessity of substantial financial support to fund the proposed structural measures. These initiatives have the potential to significantly mitigate the impact of floods in Bardere, ultimately saving lives and reducing the destruction of homes and properties.

Flood zoning: regulating human settlement development: The community advocates for flood zoning to alert residents residing near riverbanks, valleys, and other flood-prone areas. This measure can be implemented effectively if the government formulates policies that restrict settlements in high-risk flood areas, thus reducing the risk of loss of lives and property damage. (This is referred to in Section 4).

During the workshop, participants compared the current floods with those in the past. Several attendees noted that previously, floodwaters simply flowed through the city without spreading into urban and agricultural areas. They attributed this change to the development of human settlements over time, which have obstructed small streams and waterways, exacerbated the floods and inundated significant portions of the city. This type of development in the North Kurman area is starkly illustrated in Figure 5 on page 9 and Figure 6 on page 10 of the earlier Assessment Report where there has been extensive residential development to the south of the tributary between 2007 and 2025.

Effective collaboration: Maintaining consistent collaboration between the local district authorities and community groups is recognized as a crucial step in flood preparedness, prevention, and response. During the workshop, community members highlighted that robust coordination and collaboration between these entities is instrumental in flood mitigation efforts. They stressed the importance of fostering high levels of community engagement and participation in the implementation of recommended flood mitigation strategies.

Political stability in the Gedo Region: Throughout the current and preceding administrations in Somalia, political issues and conflicts have plagued the Gedo region. These disputes predominantly involve the federal government of Somalia and the Jubaland State, of which Gedo is a part. The community perceives that these ongoing political tensions detrimentally impact the region's economy and the effectiveness of local administrations. The frequent changes in positions due to the unrest have impeded active flood management initiatives in Bardere.

Community trust in and accountability of implementing agencies: The community's trust in implementing agencies is notably low, as they firmly believe that there is a high level of corruption and insufficient accountability within these organizations. They highlighted the substantial funds allocated for flood mitigation measures and structures in Bardere, yet the persistent challenges posed by floods indicate ineffective implementation of past projects. During the workshop in Bardere, several participants expressed that corruption forms an interconnected chain from high-ranking officials to the local level, impacting implementation activities in Bardere through collusion among local implementing agencies and higher authorities.

3. Overview of flood risk assessment

The flood risk assessment is discussed in detail in the previously submitted Flood Risk Assessment report. There, reference is made to the SPRC (source-pathway-receptor-consequence) framework for flood risk management measures. Since these terms are referred to in relation to the measures discussed below, the definition is again provided.

- Source: measures to reduce the amount of water at source.
- Pathway: measures that prevent water reaching areas of exposure.
- Receptor: measures that reduce the impact of flooding on areas or buildings.
- Consequences: measures that help reduce the impact of flooding after it has occurred.

In the assessment report, the various model inputs and methods are described which lead to the fluvial and pluvial assessments.

The fluvial assessment shows that frequent (i.e. low return period) events primarily affect agricultural land north and south of the city. These events are likely to be worsened by man-made breakages in the banks for irrigation purposes. Extreme (i.e. high return period) events can impact large parts of the city, as seen in the November 2023 event.

The pluvial assessment shows that the most vulnerable region is the Kurman Valley stream coming from the associated catchment to the east of the Airport. Even frequent events can cause inundation to a large extent of the residential areas and have proven to be dangerous in terms of human life, for example during an event in March 2025.

Initial analyses of how to reduce this flood risk were discussed in the flood risk assessment report, and have since been developed in detail, based on feedback from BRCiS during the validation workshop held on 28th May. These proposed measures are described in detail in the sections below, and an overall summary of recommendations is given in the final section.

4. Flood risk mitigation measures - general

Introduction

A broad list of possible measures was initially considered to reduce flood risk in Bardere. This included physical infrastructure, Nature-based solutions (NbS), as well as 'softer' measures related to capacity building, early warning systems (EWS), institutional procedures, etc. Information from the flood risk assessment, the stakeholder interviews and the institutional analysis provided context on which of these were most necessary, feasible and desirable. At the request of BRCiS, the physical measures related to NBS and infrastructure have been analysed in detail. However, various softer measures are also considered highly valuable in reducing flood risk in Bardere, and brief summaries of each of these are presented below. Background information on these measures can be found in the Flood Assessment report.

It should be noted that many of these measures act on the last two parts of the flood risk framework described in section 3, i.e. the receptors and the consequences. The benefit of this is that they are generally applicable to both pluvial and fluvial floods.

Bridge design

The social and commercial importance of reinstating the bridge as soon as possible is discussed in the final section. A key aspect of the rebuild process is the safety standard or Standard of Protection (SoP) to which the new bridge is designed. Bridges are usually designed to a certain SoP related to a return period of flood, such as the 1 in 100 years or 1 in 200 years flood. This means they should withstand the hydraulic conditions (flow, water level) associated with that extreme event.

As discussed in detail in the Flood Assessment report, there is considerable uncertainty related to the characteristics of extreme fluvial events. This uncertainty is due to three main sources:

1. The gauge was washed away with the bridge in the November 2023 event,
2. the gauge data up to that point appears to be incorrect, and
3. the extreme nature of the 2023 event suggests that historical data may not represent future or even current climate dynamics.

We therefore suggest that improved estimates of return period flooding in Bardere need to be generated. This should feed into the design of the bridge, and could even be part of the Terms of Reference during the tender process of the rebuild.

A useful first step in this process would be to conduct detailed 'stage-discharge' measurements during the upcoming flooding season. For this, a survey team would have to take water surface measurements in relation to a known datum during a specific period in which a high water event occurs. They would also need to take bathymetry and velocity measurements to make reasonable estimates of discharge.

The survey data could also include a desk study of the 2023 event and estimated flows. From this information a stage-discharge relationship could be derived.

Figure 4.1: Bridge at Bardere showing gauge.

This information would then be used to recalibrate the old gauge data that is available up to November 2023. The old gauge data could then be re-analysed and improved estimates of extreme events generated. Finally, an adjustment should be made to the extreme value analysis to account for climate change. The 2023 event was likely extreme due to a severe el Niño event that year, but this might become more regular in the future.

Institutional collaboration

A number of institutions and organizations are working to improve the conditions in Bardere and the Juba region. Unfortunately, a lack of oversight over all these projects means that work can sometimes be doubled and data is often not efficiently shared. Within the scope of the current project, two such situations arose which could have been avoided had a central organisation had an overview of the research projects being conducted.

The initial scope of the project included building both a hydraulic and hydrological model for Bardere and the upstream catchment. During the data collection phase (see Flood Assessment report) it was discovered that significant work and data was already available in relation to these tasks by FAO in combination with SWALIM. Luckily, through contact with FAO via Paolo Parron, we were able to best utilize the data and models, and ensure work was not doubled. One of the benefits to this connection was the use of better resolution data. The images below show the difference in quality between the DTM (terrain) data that would have been used for the models had this connection not been made.

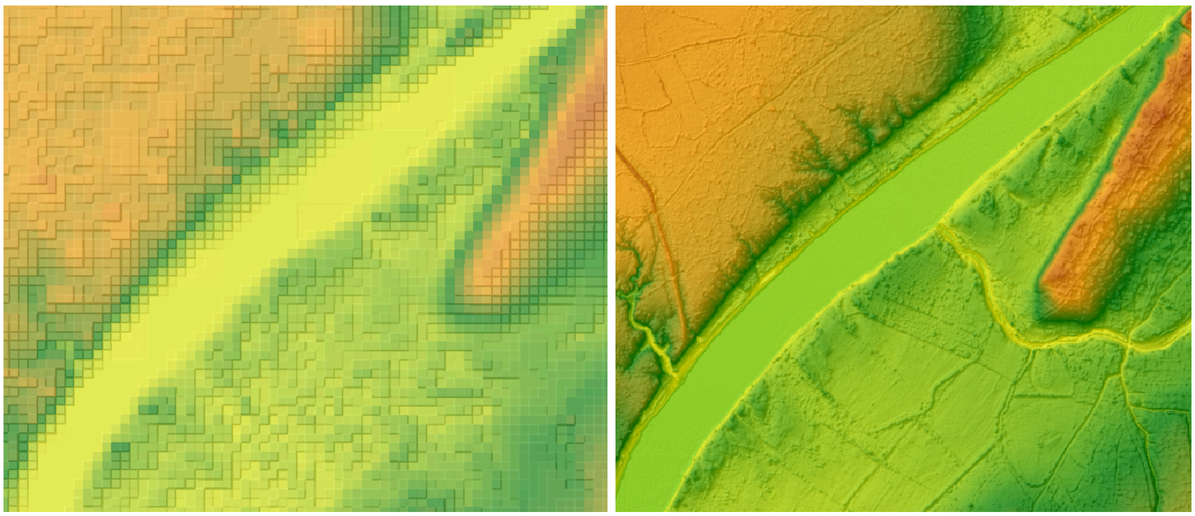


Figure 4.2: Terrain data for Juba river showing the difference between freely available data (left) and data obtained through collaboration (right).

Another incident that highlighted the need for central oversight was the publication of Baardheere Strategic Urban Plan for Durable Solutions to Displacement report (UN-Habitat, 2025)[1] with a similar scope to the current project. While the focus of that report is not flood risk, many of the analyses conducted to develop the plan are likely to have been (partly) repeated in the current study. This includes the development of a flood model and an analysis on urban growth.

Our recommendation is that the oversight of these tasks be undertaken by a designated government department, with support of the World Bank or another international organization. All agencies involved in humanitarian and development projects should register their projects with this department, to prevent double work and ensure data is efficiently shared and disseminated.

Early warning

A thorough explanation of our recommendations related to the early warning system can be found in the Flood Assessment report. Those recommendations have been summarised and updated below:

- Assess and support the informal early warning network that is in place. This is mostly in the farming community, and implemented through direct calls.

[1] UN-Habitat (2025) Baardheere Strategic Urban Plan for Durable Solutions to Displacement. Available in: https://www.mopwhjss.so/wp-content/uploads/2025/03/Baardheere_Strategic_Plan_Report_Final.pdf

- Consider mechanisms for improving the functioning of the EWS, including who would be responsible and how warnings would be disseminated. Even if such a system is not immediately implementable, such an analysis would be useful during future events.
- Integrate the design of the EWS into capacity building initiatives. This works in two ways; it helps in the design of the EWS, and informs people how a warning will be received.
- Upgrade the gauge at Luuq to a telemetered station so it can be incorporated into an EWS that is not reliant on localised checks.
- Install a telemetered rain gauge in the most eastern part of the Kurman catchment. Due to the prevailing wind direction in Somalia (from the Northeast) as well as the elevated topography in that location, that is often the first location rainfall will occur during a storm.

Capacity and awareness building

A thorough explanation of our recommendations related to capacity and awareness building can be found in the Flood Assessment report. Those recommendations have been summarised and updated below:

- Provide tailored capacity building programmes for IDP camps. This is required due to the low-lying nature of the camps, as well as the lack of resources and infrastructure.
- Given the comments from the stakeholder interviews, information about the problem debris causes in the streams and drains may also need to be provided to the camps and wider population.
- Consider specific stakeholder engagement sessions with farmers, both along the Juba River and upstream in the Kurman Valley catchment. The farmers along the Juba river should be made aware of the issue with breakages, while those in the Kurman valley should be consulted about potential measures.
- Information for locals affected by floods should focus on warning systems, evacuation and recovery. Given the reports of people crossing bridges and swimming across the Kurman stream during floods, the dangers of flooding should be emphasized.
- Providing this information for locals should also include other aspects of Flood Risk Management mentioned, such as how an EWS should be interpreted, and which regions are considered vulnerable based on flood zones.
- Another important aspect of the capacity building is providing information to local authorities and those responsible during a flood event. This could include ‘training the trainer’, through which those responsible are also trained in how to disseminate information locally.

Flood zoning and flood proof buildings

A thorough explanation of our recommendations related to flood zoning and flood proof building can be found in the Flood Assessment report. Those recommendations have been summarised and updated below:

- Define flood zone maps from existing studies, such as the map developed as part of the current project, or the one developed in the UN-Habitat report previously mentioned.

- Utilise these flood maps as part of planning, but also as part of raising awareness in local communities that are vulnerable to flooding.
- Consider methods to flood proof existing buildings at an administrative level (i.e. raising foundations, resilient materials, etc.).
- Develop methods to get these flood proofing methods implemented by locals, through incentives or community projects.

5. Flood risk mitigation measures - physical

Introduction

Given the significant focus on 'soft' measures such as capacity building in previous years, the current project was tasked with focusing on developing physical measures to mitigate flood risk in Bardere. These measures are presented below, for both fluvial and pluvial risk. In each section one 'primary' measure is described in detail, along with dimensions, timelines and costing. Other measures that were considered are also discussed, as well as the reasons they are not considered as useful.

The measures can be considered to be applicable to the 'pathway' for flooding. For this reason they are only really applicable for one flood type (pluvial or fluvial). There are no practical physical measures available that significantly reduce the flooding from both events. In fact, measures like dikes close to the entrance of the Kurman stream may increase flooding, as they could prevent efficient outflow from the stream. This again highlights the efficacy of the 'softer' measures discussed above, which are generally applicable to both flood types.

5.1 Fluvial measures

5.1.1 Primary measure – river widening

The primary measure we have looked at is widening a section of the Juba river, downstream of Bardere. The idea behind this measure is that it allows more water to be 'conveyed' or transported over that section. The increased conveyance draws water from upstream into the widened section, bringing the upstream water level down. This is called a 'backwater effect'.

Design

The backwater effect is usually largest at the start of the widened section, and for this reason the proposed starting location is just downstream of the bridge in Bardere, as shown in Figure X below. In general, the proposed widening increases the cross-sectional width by about 75% (90 – 120m). This increase is shown for the cross section in location A (Figure 6.1) in the Appendix.

Figure 5.1: Proposed sections for river widening, shown in green on (left) satellite data and (right) terrain data).

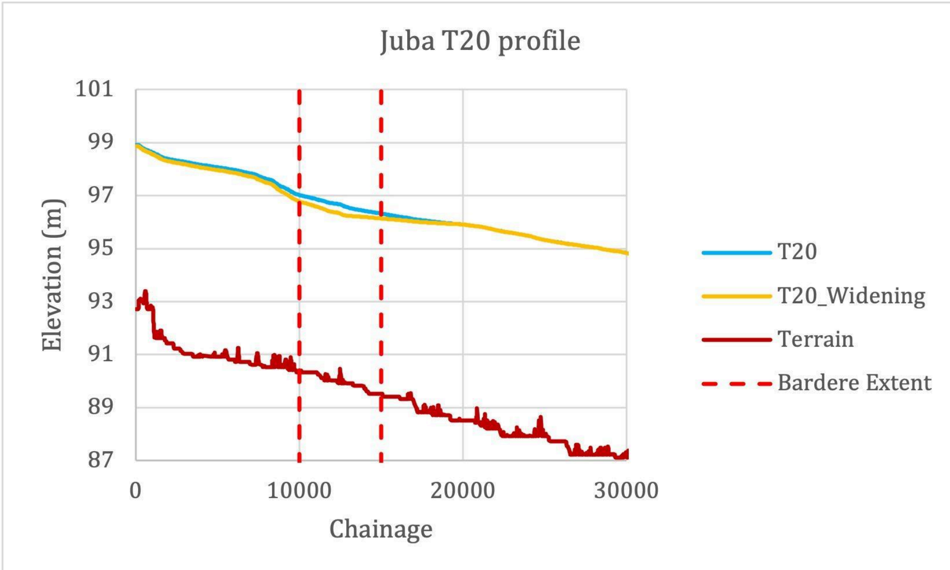
The sections are defined so as to obtain this width increase while also taking land use and topography into account. For example, the widening on the west bank is split into two due to an area of high terrain in the middle. Similarly, the widening on the east bank stops earlier due to a large amount of agricultural land close to the river. Images from both these examples are shown in the Appendix 6.1.

The current design is proposed as a proof of concept and can be optimised in terms of its spatial location as well as the profile of the river after widening. The current profile assumes almost vertical cuts in the terrain, but a more reasonable approach is to introduce a gradient in the cut, or a stepped / terraced profile. This latter approach may even facilitate farming of certain crops that can be regularly inundated.

An improved design should also consider what to do with the excavated material. One option for this would be to use it to rebuild dikes along the farmland. As shown in Figure 6.3 in the Appendix, the widened rivers often cut through elevated banks immediately beside the river, which may need to be replaced further back. The excavated material could also be used to simply elevate the farmland areas slightly, as it is likely to be alluvial nutrient-rich soil.

Effect on flood hazard

The effect of the proposed measure can be seen in Figure 5.2 below, where the water surface elevation (WSE) for a 1 in 20 year event with the current terrain is compared to the same event with the widening implemented. This comparison is made for a 30km section of the river, north and south of Bardere. In the top figure, the overall change in elevation is seen. As this change is difficult to see, the bottom figure shows the change relative to the original water surface.



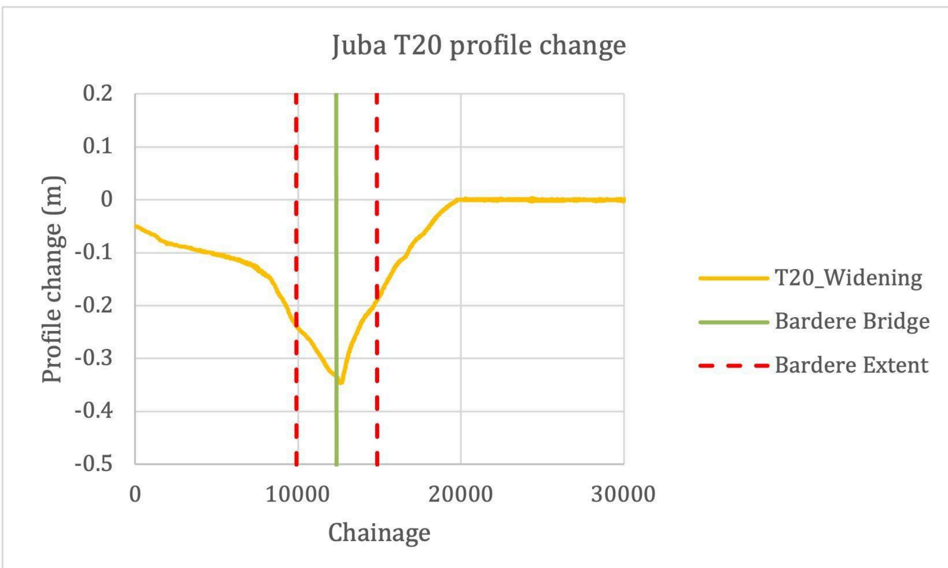


Figure 5.2: Change in water surface elevation for a T20 flood due to river widening proposal. Top: Overall change, bottom: change relative to original water surface.

The above figures demonstrate that the proposed measure creates a drop in the water surface of between 0.2 - 0.3m in the region of Bardere, with the biggest effect being at the start of the measure, at the bridge.

Table 5.1 below shows the effect of this water level reduction in terms of the buildings impacted by flooding. For the T20 event about 15% fewer buildings are affected by flooding, with the largest change in the houses inundated to a depth of more than 2m.

Table 5.1: Buildings affected by flooding at various depths, for a T20 event with the current terrain and the proposed widening.

	Buildings affected by flooding to a given depth (m)					
Category	**0.01-0.3**	**0.3-0.5**	**0.5-1**	**01-Feb**	**>2**	**Total**
Base T20	164	279	689	1034	748	2914
Widening T20	131	291	672	918	522	2534

An estimation of monetary value of the overall reduction in Expected Annual Damage (EAD) can be generated for this measure, and could be used in a Cost-Benefit Analysis (CBA). However, as outlined in the *Flood Assessment* report, there are several limitations to this approach. First, the return-period water levels remain uncertain, which affects the accuracy of any damage estimates. Second, the damage sustained by many buildings may appear relatively minor in monetary terms, as the areas most vulnerable to flooding are often poorer communities with low-value housing. As a result, traditional CBAs may significantly underestimate the true impact of flooding on poorer households, whose losses, though smaller in monetary terms, can be far more severe in real-life consequences.

To address this, the concept of 'utility' can be introduced—where damage is weighted relative to the total value of the asset. For example, $500 in damage to a $1,000 home represents a much greater loss in utility than the same amount of damage to a $10,000 home. If a CBA is undertaken, it should consider incorporating this utility-based weighting, along with indirect costs (e.g., commercial losses from disrupted transport) and intangible costs (e.g., fatalities, displacement, and the emotional toll of disaster events). This more holistic approach would better reflect the real impact on vulnerable populations.

Costs and impacts

Assuming a price per m3 of $5 for each cubic metre excavated and replaced, the current project would come close to $8 million. This is obviously a huge cost for a measure that only reduces the number of houses affected by 15% or so. By developing a more efficient design that is not as long and uses a stepped or graded profile, similar results may be possible for half or even one third of the excavation costs. Even at these reduced costs, the project needs to carefully consider the issues mentioned above, and perhaps develop a CBA or an adjusted CBA accounting for utility.

As well as the direct construction costs, other impacts need to be considered. The current design tries to reduce the amount of agricultural land lost, and an improved design can further reduce this. However, losses to land are unavoidable, and locals would have to be compensated.

The widening of the Juba River could also have an impact on navigation, but this could be minimised by using an efficient cross-section design (see examples in Appendix 6.1) in which the reduction in water level is only observed for flood events.

The widened sections may be more susceptible to silting, which means that over time the river returns to its original shape. This can also be minimised through the design, both for the cross section and the spatial extent. For this latter aspect, attention should be paid to the inside of bends, where water velocities are slower, and silting is more likely to occur.

5.1.2 Other feasible measures

Downstream diversion

Similar to the river widening, the idea behind a downstream diversion is to cause a ‘backwater effect’ upstream of the diversion, resulting in lower water elevations during floods. This is in contrast to a flood diversion around the city, where the objective is to simply divert water away from the city during flood events. This latter idea is not considered feasible and discussed later.

The proposed downstream diversion utilises the bend in the river southwest of Bardere to divert flows directly downstream during flood events. The defined route makes use of less elevated terrain (maximum depth is 15m), thereby reducing construction costs. However, as the proposed length is over 4 kilometers, the overall costs are likely to be similar to those for river widening.

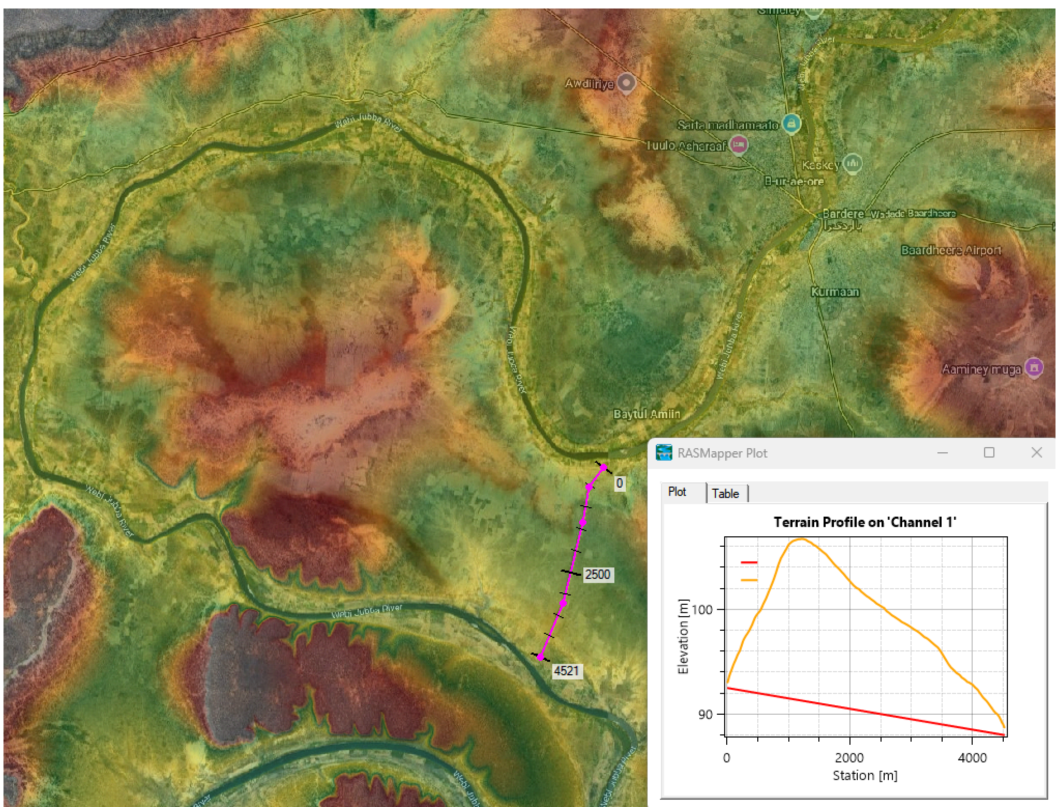


Figure 5.3: Proposed downstream diversion channel in pink. Bardere is in the top right (Northeast) of the picture. Inset: existing (yellow) and proposed (red) elevation of diversion channel.

As seen in Figure 5.4 below, the diversion results in a 0.1-0.2m drop in the water surface elevation in Bardere. This is smaller than the river widening proposal because it starts further away from the city centre. The diversion would be designed to only function during flood events. This has the advantage that there are no morphological effects but also means that its impact will be reduced for smaller events.

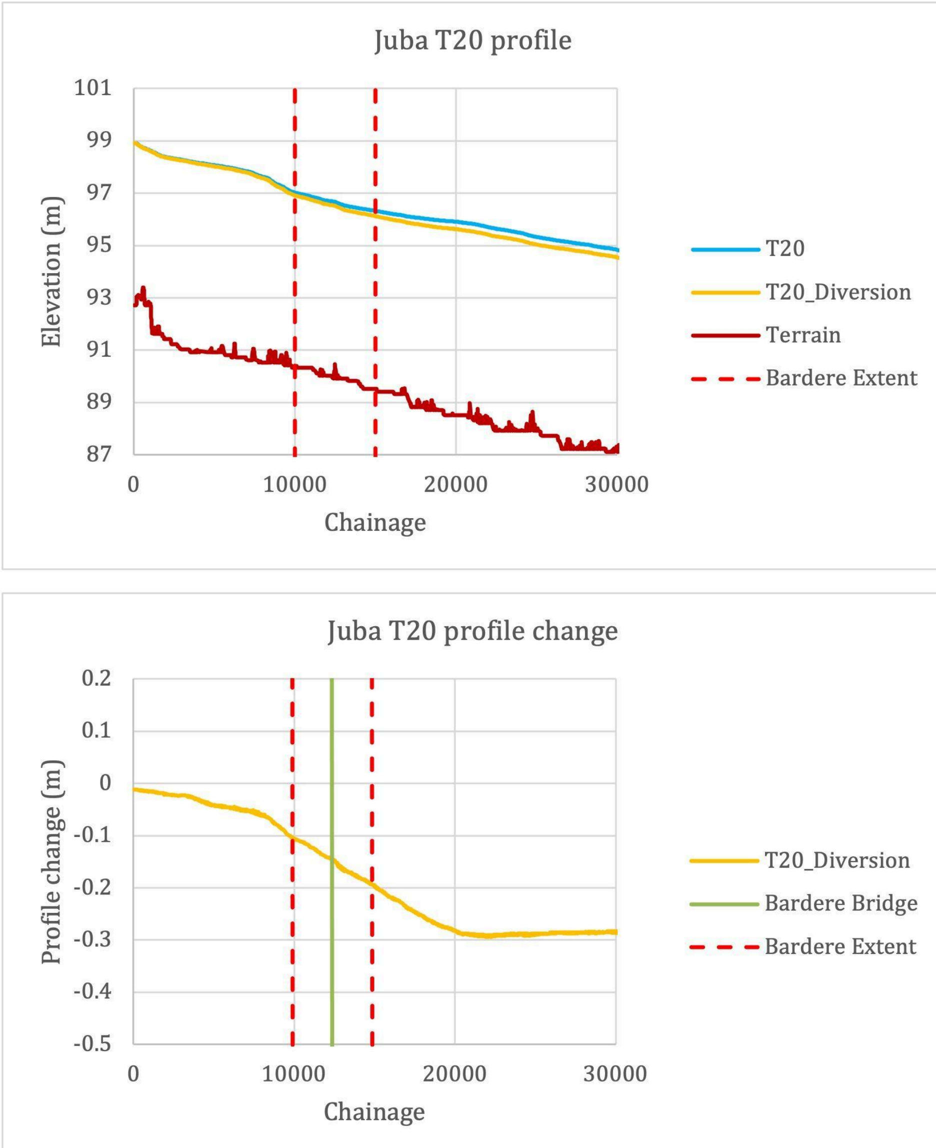


Figure 5.4: Change in water surface elevation for a T20 flood due to downstream diversion proposal. Top: Overall change, bottom: change relative to original water surface.

Dikes

As discussed in the assessment report, a proposal for dikes in the north of the city has been investigated as part of this research. In this proposal, the dikes are built up to levels that would protect against regular floods, like the 1 in 2 year event. Heightening the dikes to a high standard of protection is not advisable, as it doesn't make financial sense for the farmland area, and will also have negative effects for the urban areas of the city.

Specifically, it removes the storage capacity of that farmland during flooding, and increases the risk of a breach. Currently river floods occur slowly (over a number of days / weeks), giving locals time to prepare. A breach means that large areas can become inundated over minutes and hours, increasing the risk of damage and fatalities.

The farmland areas to the south could also be protected, but dikes should not be placed in the area of the Kurman stream tributary. The tributary itself needs to outflow as efficiently as possible to the river, and dikes protecting from river floods will likely impede that.

Figure 5.5: Kurman stream tributary. The area floods from the river, but it is not advised to try and block this flooding.

5.1.3 Unlikely measures

As discussed in the flood assessment report, a number of other measures were investigated but not considered practical enough for detailed research. Nature-Based solutions in the Juba catchment, such as reforestation, would require cross-border initiatives outside the scope of this project.

The dam that has been discussed upstream of Bardere is another option, which may also help with drought issues. Dams also pose new problems, such as environmental concerns, maintenance requirements, breaching risk, etc. In either case, the costs of the dam would be well in excess of any measure in the current scope.

A diversion around Bardere was also considered, but the terrain is too high, and the topography of the river means that diverted flows may actually back up the river, removing any benefit of the diversion.

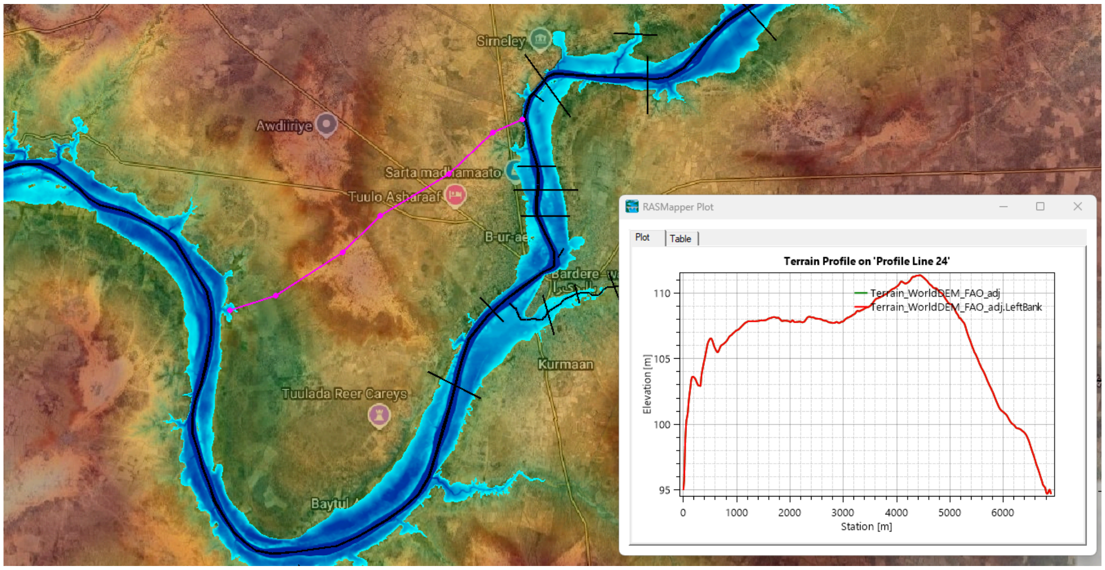


Figure 5.6: Potential diversion channel in pink, north of Bardere.

5.2 Pluvial measures

5.2.1 Primary measure – Large check dams

The pluvial risk in Bardere is most prominent in the Kurman valley stream, where flow forms from rainfall in the associated subcatchment of about 200 km^2. Detailed terrain data is not available for all of this catchment but from satellite imagery and low-resolution DTM data it appears to have three main subcatchments that converge east of the raised area where the airport sits, Figure 5.7. Since this is an ephemeral stream (it is very often dry), the stream routes can change, but estimated general routes are shown in blue.

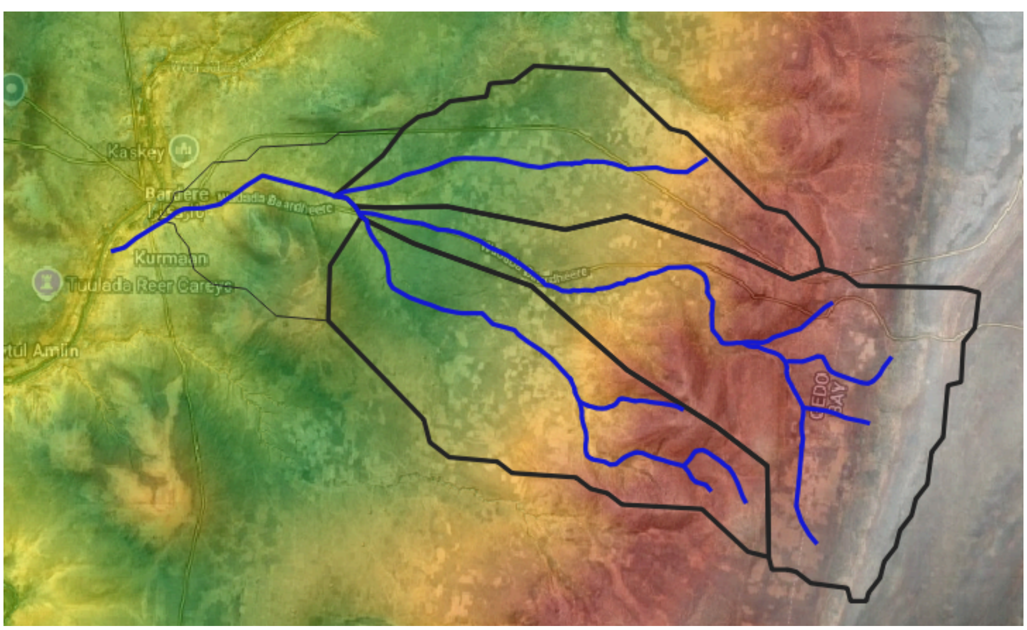


Figure 5.7: Kurman catchment and subcatchments, with estimated river catchments. Streams shown in blue.

Although the middle catchment is the largest, the northern and southern subcatchments together contribute most of the flow to the peak of the floodwave for the events that occur in Bardere. This is because they are fast-acting (they take a more direct route), and have very similar timings in terms of when their floodwaves reach the confluence. For this reason, large check dams were investigated for these locations.

Design

As mentioned in the Flood Assessment report, check dams with a V-shape have been used successfully in the Shabelle river, and can be considered an NBS because of their minimal impact on the normal-flow dynamics of the river. Therefore, check dams are proposed at five locations. The locations are selected to allow for a significant storage capacity, and to utilize existing elevated features (both natural and artificial) to reduce construction costs.

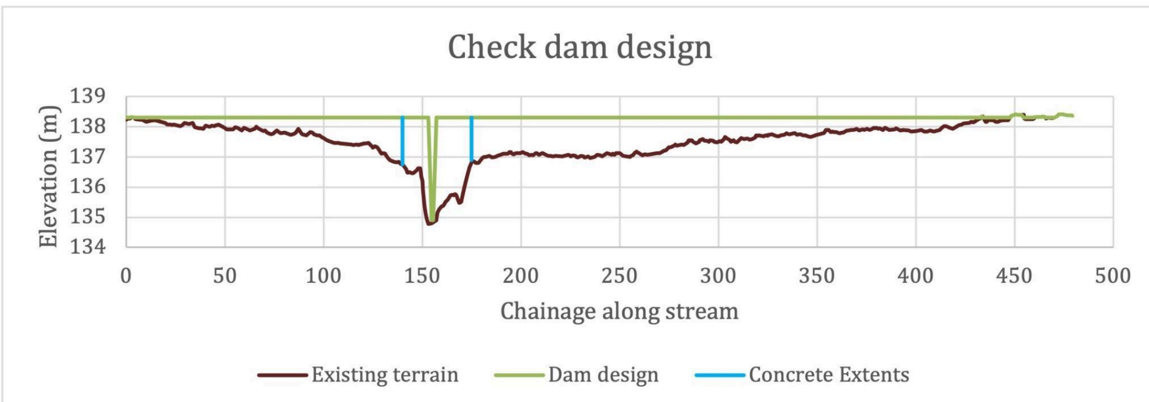


Figure 5.8: Example design of checked dam, utilizing existing wall between farmland (red arrows of left image). Bottom: proposed design and existing terrain of example dam, including earthen section and concrete section with v-shaped weir.

In the initial flood risk assessment in this project, we attempted to maintain the widths to 50m, for ease of construction. However, the desired reduction in flooding was not achieved, due to the shallow valleys where the measures will be situated. Longer designs have therefore been proposed, ranging from 400m up to almost 1000m, which include earthen and concrete sections (see Figure 5.8). At all locations they utilize elevated features, such as the small embankment or bund that separates one farm from the next. A detailed design has not been developed, but for cost estimates bottom and top widths of 2 m and 0.5 m are assumed, respectively.

Effect

Given the existing problem of flash floods, the dams have been developed to mitigate the most frequent events. In the figure below, they are seen to reduce the peak of a 1 in 2 year event significantly, and have a reasonable impact of the 1 in 10 year event. The effect of this in terms of this flow reduction in terms of flooded houses is shown in Table 5.2.

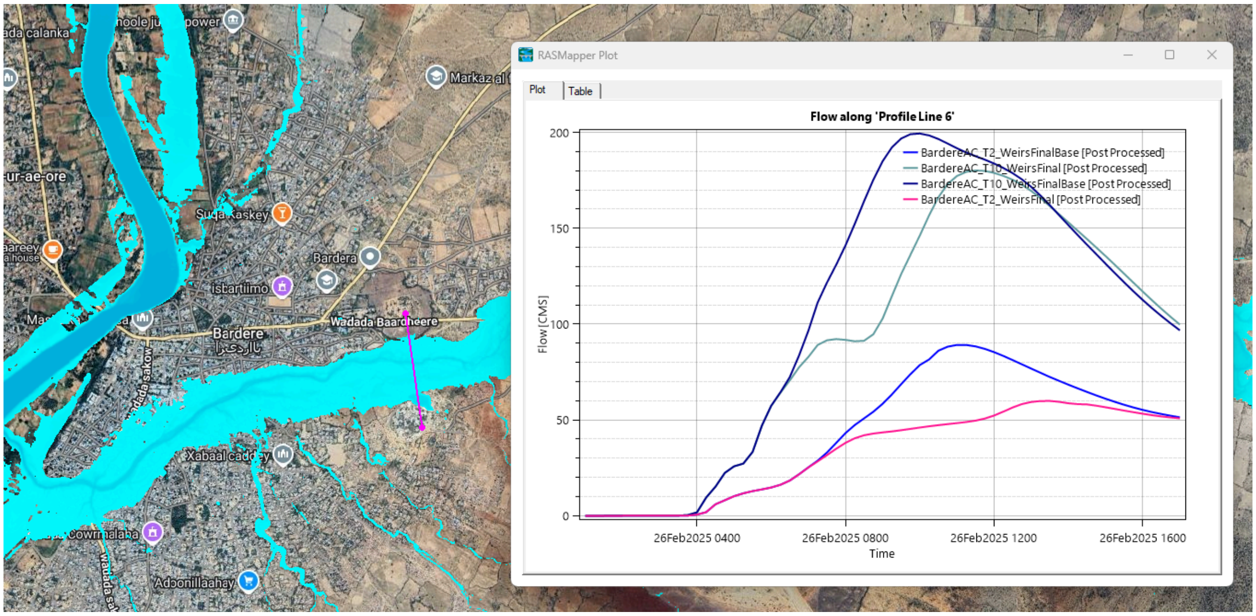


Figure 5.9: Flows expected in Kurman valley. Navy: T10 – baseline, Green: T10 with dams, Blue: T2 Baseline, Pink: T2 with dams.

Table 5.2: Buildings affected by flooding by a T2 event, with and without the dams measure.

	Buildings affected by flooding to a given depth (m)					
Category	**0.01-0.3**	**0.3-0.5**	**0.5-1**	**1-2**	**>2**	**Total**
Base T2	195	159	69	7	430	195
Dams T2	46	24	11	2	83	46

As well as this flood risk reduction, studies of check dams in ephemeral streams in Cyprus[2] have shown combined concrete and earthen dams to have benefits in terms of groundwater recharge. This will have benefits for agriculture in the region, and may help to encourage 'buy-in' from the landowners in the region.

Check dams are often considered to also have ecosystem benefits, by creating a retention area behind them. However, the streams are dry most of the year, and the V-shaped design allows most flows to pass through unhindered. Therefore, ecosystem benefits are not expected for this design.

[2] Djuma, H., Bruggeman, A., Camera, C., Eliades, M., & Kostarelos, K. (2017). The Impact of a Check Dam on Groundwater Recharge and Sedimentation in an Ephemeral Stream. *Water*, *9*(10), 813. https://doi.org/10.3390/w9100813.

Costs and Impacts

Based on the preliminary design of the dams, 300 m3 of concrete is expected to be required, and 1000 m3 of earth works. Rough estimates of overall cost amount to $500,000, including design. This will impact fewer houses than the river widening measures proposed (Table X). However, the measures target more frequent events, meaning the benefits of flood reduction will be observed more regularly.

As with the primary fluvial measure, an Expected Annual Damage value could be calculated as an input to a Cost-Benefit Analysis when assessing this measure. While the rainfall estimates are more certain than those of the fluvial events, other uncertainties in the hydrology (land cover, upstream terrain) mean the scale of the events is difficult to estimate for the CBA. Furthermore, the issue of house pricing remains, which may result in an unfavourable ratio for the CBA. If a CBA is undertaken, it should include the concept of utility previously introduced (see section 5.1.1) as well as the indirect and intangible benefits, such as the reduced fatality flood risk.

By using the current farmland divisions in the spatial design of the dams, it is hoped that impacts associated with land ownership will be minimised. The V-shaped design of the weirs also ensures that the general flow of the river is impacted as little as possible. This can be seen at the start of the floodwaves in Figure 5.9, in which the flows with and without the measure is the same for the first few hours

5.2.2 Other feasible measures

Afforestation

Increasing the tree cover of the catchment has a number of effects that will reduce the scale of peak flood events. The trees intercept rainfall, reducing the amount of water that reaches the streams, their roots allow for more infiltration, and they create rougher terrain for rainfall to flow over, slowing the flow to the streams. Often, they are combined with terraces on the slopes which further increases the infiltration and roughness.

To test the effectiveness of this measure, large areas were identified in which reforestation could take place. These areas (shown in Figure 5.10) avoid being directly placed on the main stream lines (which would skew the results of the model), and also try to avoid taking up too much farmland. In some cases (like the eastern part of area 3) this was unavoidable. The afforestation areas also target the northern and southern subcatchments, as indicated in Figure 5.7, above. As mentioned, these catchments contribute the largest portion of the flow to floodwaves.

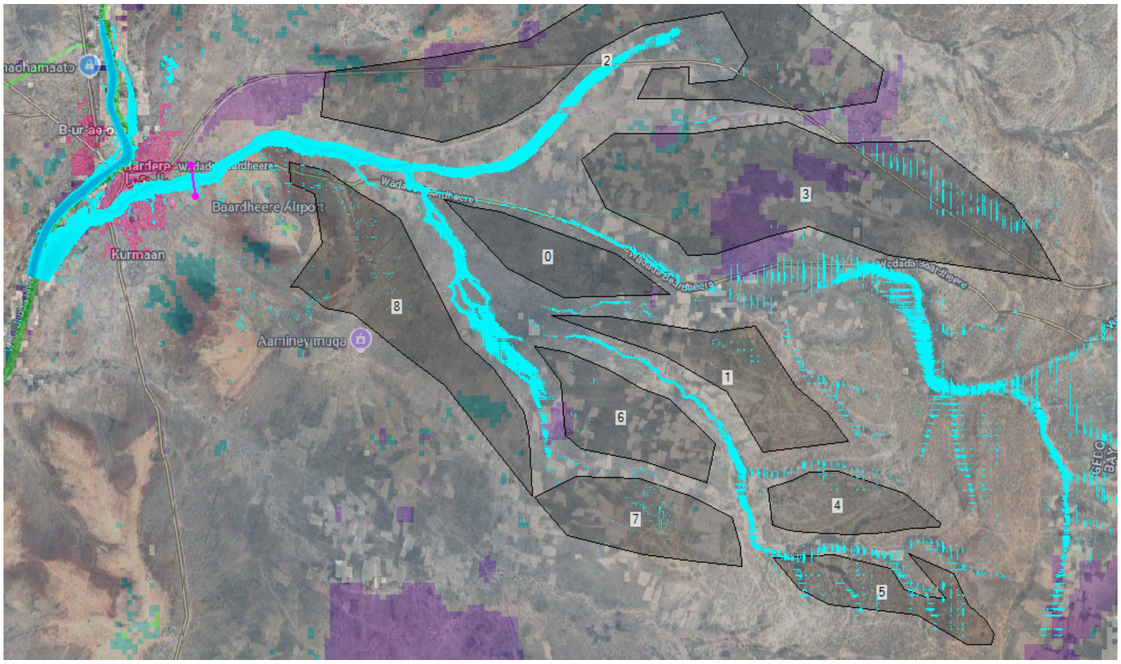


Figure 5.10: Potential areas for afforestation, highlighted in grey.

The results of this measure are shown below in Figure 5.11. For the T10 event, the reduction in peak flow is similar to that observed for the check dams (Figure 5.9), although the reduction in the T2 event is not as severe. While the results are encouraging, extreme values were used to achieve this, to test if any improvement was even possible. For example, the afforestation areas cover over one third of the catchment (70 km2), and the changes to roughness and infiltration are assumed to be at the high end of a realistic potential range, even when accounting for terracing.

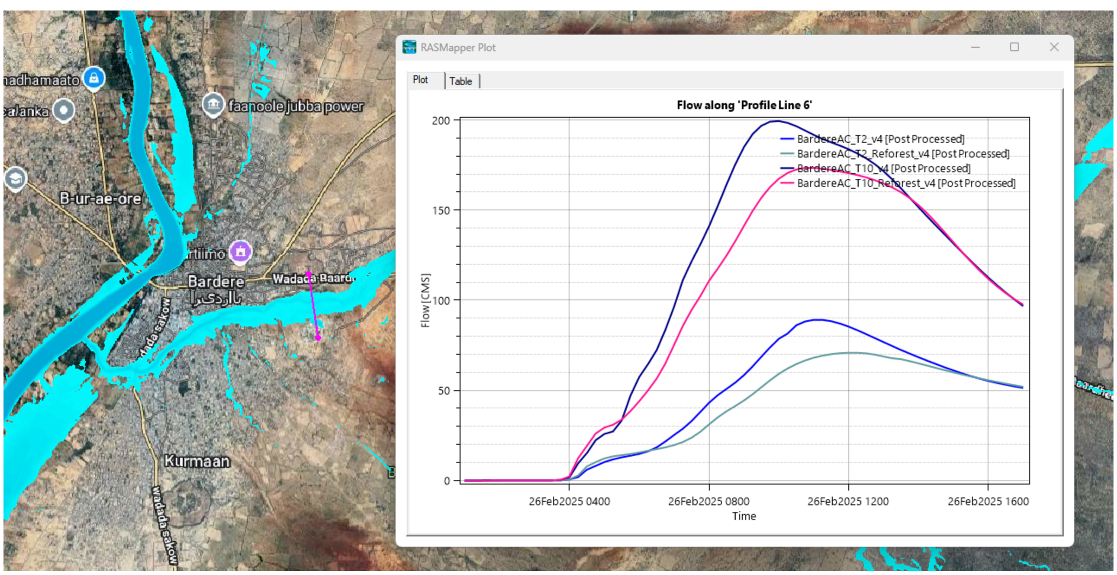


Figure 5.11: Flows expected in Kurman valley. Navy: T10 – baseline, Pink: T10 with afforestation, Blue: T2 Baseline, Pink: T2 with afforestation.

Detention area

A potential location for an off-line (i.e. not in the line of the stream) detention area has also been investigated. This utilises an elevated section of road east of the airport. It would also require an overflow diversion from the stream coming from the southern subcatchment. The impact on the floodwave is not considered significant enough, however, and overflow of the dike could cause access issues along the road.

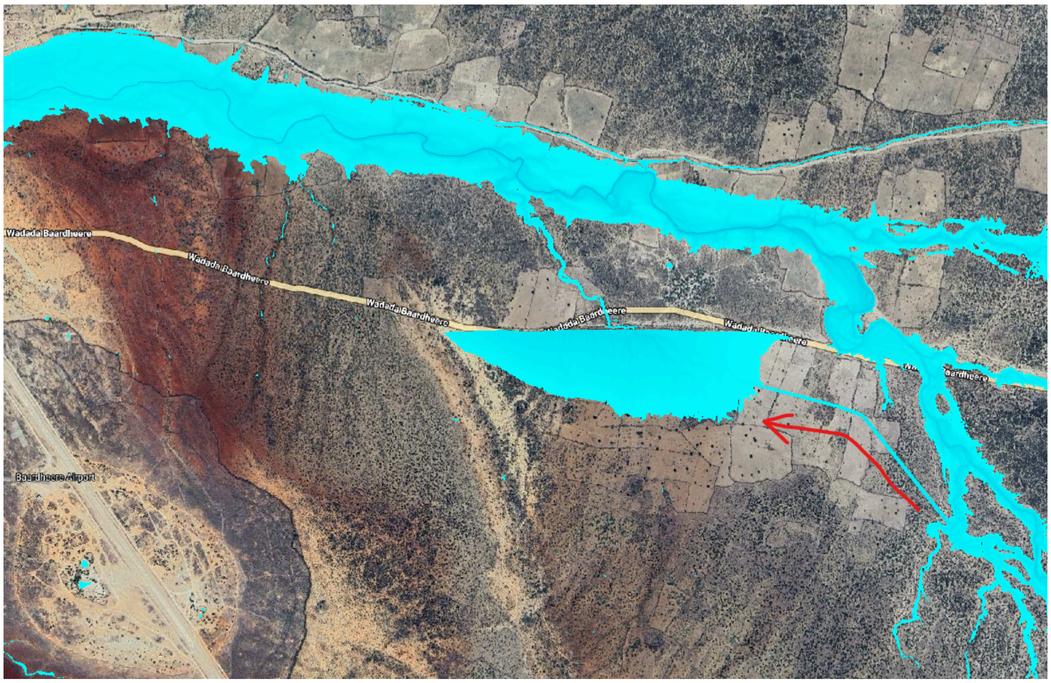


Figure 5.12: Potential offline detention area, west of the airport. A diversion channel used to fill it is indicated with a red arrow.

Dikes / Embankments

Dikes have also been mentioned as a possible solution to the flooding in Kurman valley, and the terrain suggests they would not have to be exceedingly high (e.g. 2m to protect against a 1 in 10 year rainfall event), as seen in Figure 5.13.

One potential issue is the drainage of water behind the dikes. As seen in Figure X, below, a number of small streams run to the Kurman stream from the south, through the city. These would have nowhere to drain to unless they were also partly embanked.

Another issue is the maintenance of these dikes. As the river is mostly dry, there are many dirt roads across the river used by locals daily. All of these would need to be rebuilt (perhaps with bridges) if the same level of accessibility is desired. If this is not done, frustration may lead to locals removing protection at certain locations and thereby defeating the whole purpose of the dike.

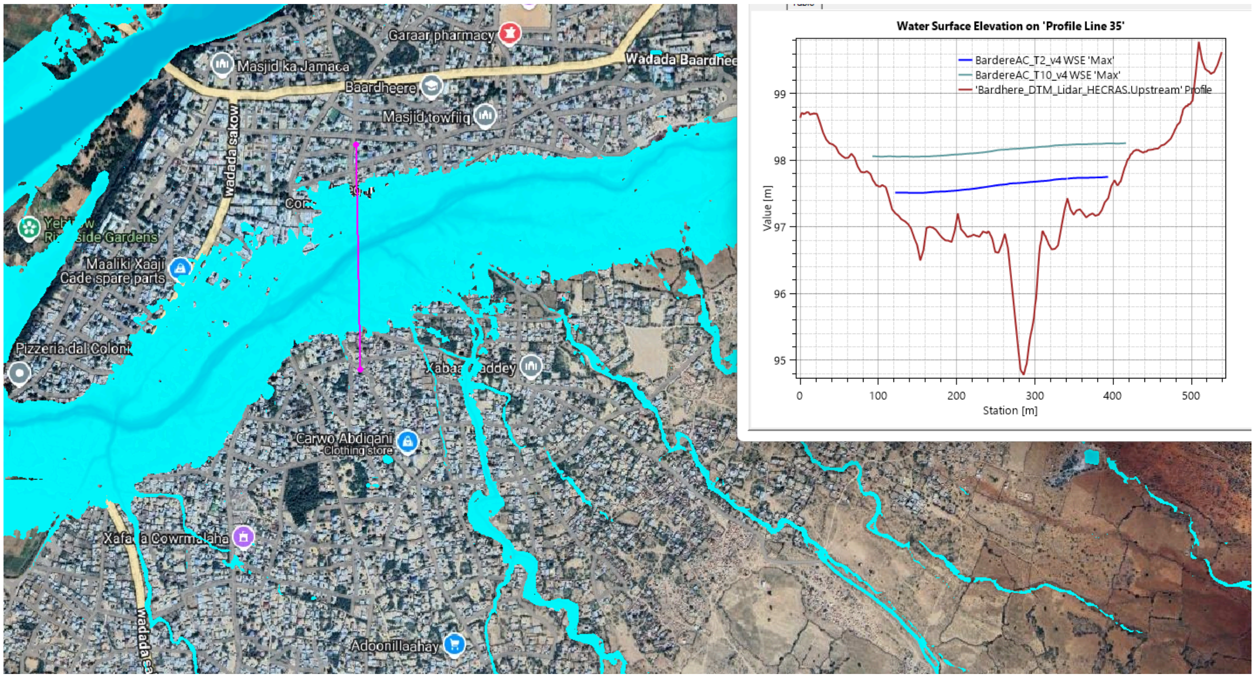


Figure 5.13: Flooding in Kurman valley for a T10 event. Inset shows water levels for a T2 and T10 event at the pink line.

Small check dams

Similar to the check dams already discussed, smaller check dams slow and retain water, reducing the floodwave downstream. These have not been fully investigated in the current study, for a number of reasons.

Small check dams are small scale interventions, which means that to make a significant impact on flood risk, a large number would have to be placed (e.g. more than 100). The ownership and maintenance of so many structures would be an issue, especially considering that many farmers will object to the upstream storage of water.

Small check dams generally use locally sourced materials to slow the flow. For wooded areas these are logs, and for tropical areas coconut fibre (coir) logs are often used. In the Kurman catchment, the areas that are not farmed are mostly scrub. Scrub and rocks have been used for check dams, but there is less research on how effective the measure is with these materials. However, if this measure was done together with afforestation, logs could be used.

5.1.3 Unlikely measures

Channel deepening

While this is a popular measure with locals, it is not obvious that it will be effective. To properly convey the flows associated with T2 (~80m3/s) or T10 events (~200m3/s), the channel would have to be unreasonably large, and potentially even require buildings to be removed (although they are likely too close to the stream anyway).

Furthermore, deep channels can be problematic with ephemeral flash flood catchments. Flash floods often carry a lot of sediment, which means the channel will probably have to be deepened again after 2/3 events. Ephemeral rivers also have no baseflow to maintain the cut depth, which means the channel will have to be concrete lined to prevent it reverting back to its original form.

6. Conclusion and Recommendations

It is clear that flood risk mitigation measures addressed in this study need to be reviewed in the larger context of the economic and social functioning of the Bardere urban area and how it relates to the wider surrounding rural area and the wider region. Adapting and responding to the growing impacts of climate change, both in terms of growing flood risk, as well as alternating prolonged drought, exacerbating forced displacement to urban centres and accelerating urbanisation and associated housing and urban economic development challenges, is a key concern. Resilient urban and rural communities are far better equipped to manage and mitigate flood risk than those continuing to suffer from the prolonged after effects of major flood events.

All local stakeholders prioritise the restoration of the Bardere Bridge, and this is clearly a first step in enhancing the urban and rural resilience of Bardere and the surrounding region through improved rural-urban and intra-urban linkages. As noted, the destruction of the bridge in the 2023 Juba River flooding had far-reaching economic and social consequences.

As well as the local economic disruption, the region as a whole is severely impacted by the disruption of trade routes that were primarily dependent on the bridge for transporting goods to and from Mogadishu and other regions. The challenges of transporting goods from Mogadishu to Bardera has significantly hampered local economic activities and contributed to the loss of livelihoods

The loss of the bridge connection has cut off access to essential services, and isolated communities, severely impacting livelihoods and public well-being. Access to education and healthcare services have been impacted, with many individuals facing delays in receiving medical care. The collapse has led to significant social isolation, with families on either side of the river finding it increasingly difficult to maintain connections.

While local fundraising and community-led initiatives are to be commended, external financial and technical support is urgently needed. Most of the physical strategies require a better extreme value analysis for flooding. Therefore, the proposal to do this in conjunction with the bridge works is even more vital.

Building wider resilience and adaptive capacity includes addressing the key institutional and financial barriers to effective flood mitigation noted earlier in this report, including strengthening technical expertise and capacity and addressing limited financial resources and fragmented government involvement. Consistent and effective collaboration between the local district authorities and community groups is crucial in flood preparedness, prevention, and response. Strengthening early warning systems and community awareness are also critical.

While NGOs have played a key role in providing emergency support and training, there is a call for long-term, coordinated strategies involving government leadership, external investment, and sustained community engagement to build resilience. Wider institutional challenges including political stability in the Gedo Region and addressing community trust in and accountability of implementing agencies are clearly outside the scope of this technical study but remain important contextual factors in reviewing possible flood mitigation interventions.

Incorporating Nature based Solutions:

It was requested within the scope of the project to give special focus to Nature based Solutions. Measures suggested for the pluvial risk can be considered fully or partially 'nature-based', as discussed above, for example combining small check dams with afforestation

For the fluvial risk, NBS would need to be applied to the 'source' (the catchment) or the 'pathway' (the river). While measures could be implemented in the catchment, this would require a large cross-border project with Ethiopia.

NbS measures for rivers generally try to restore natural features of rivers, such as meanders and wide floodplains. Since the river has not had many major interventions, it follows a natural path, and remeandering is not really feasible. The suggested river widening measure can be considered nature-inspired however, as it tried to give more room for the river. This could be made more similar to natural river profiles by using a stepped approach, mimicking the natural floodplains of a river.

Flood mitigation strategies

It is important to recognize that an effective flood mitigation strategy consists of a range of complementary measures. While this report focuses on physical infrastructure, these interventions can be significantly strengthened by the inclusion of "softer" measures—such as early warning systems, capacity building, flood zoning, and improved local governance, as outlined in the report. These less costly, non-structural approaches are essential to a holistic strategy and can substantially enhance the overall effectiveness and long-term sustainability of flood risk management in Bardere.

Developing a strategy based on the above recommendations including at least some of the softer measures, as the extra cost will likely be a small percentage of the costs associated with the physical measures.

Future plans: next steps

The physical flood mitigation measures presented in this report are intended as preliminary recommendations and have not yet been developed to a pre-feasibility stage. They are based on high-level, qualitative assessments and are intended to guide the early stages of strategic planning. Detailed design parameters, engineering specifications, and cost estimates will need to be developed through a dedicated pre-feasibility phase, in line with the standards typically required for feasibility studies conducted by organizations such as the World Bank.

Efficient dissemination of this report and follow up with other stakeholders:

The flood mitirecommendations set out in this Final Report are targeted for discussion by the key actors at state, federal and international levels responsible for leading on any implementation measures, as well as guiding future stakeholder engagement at the local level.

We understand that BRCiS will be engaging with a wider group of key stakeholders following submission of the final report, with the aim of advancing the study's recommendations and identifying potential funding opportunities. The consultants are available to support Concern and BRCiS in presenting these preliminary measures to the relevant stakeholders and welcome the opportunity to support moving toward implementation in the next phase of this work.

6. Appendices

Appendix 6.1: River widening data

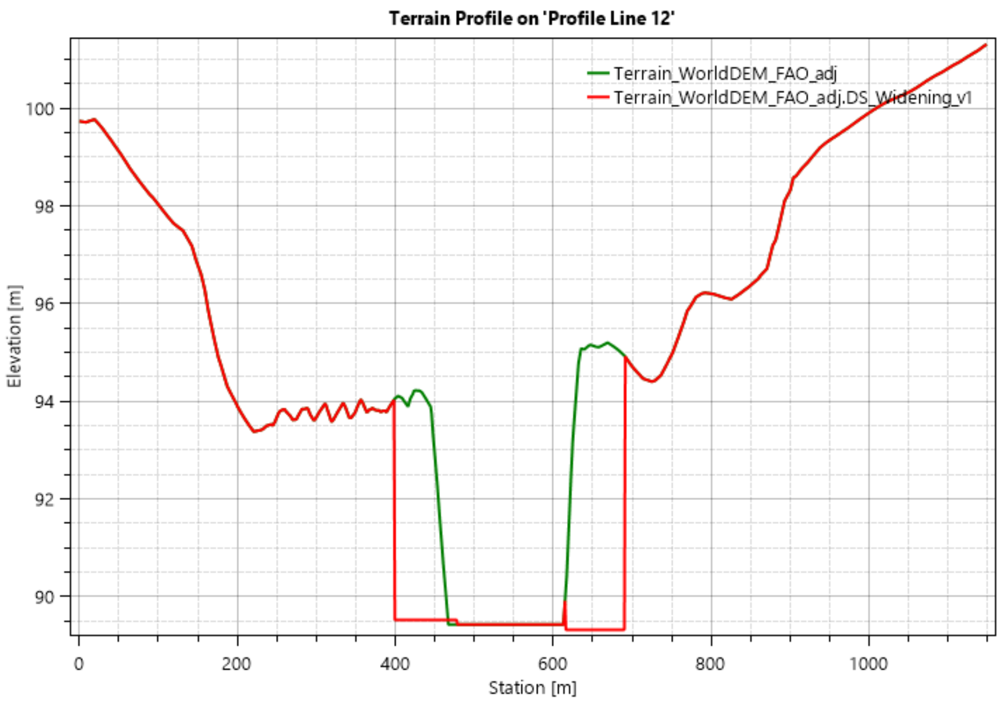


Figure 6.1: Cross section showing proposed widened river (red) and original terrain (green).

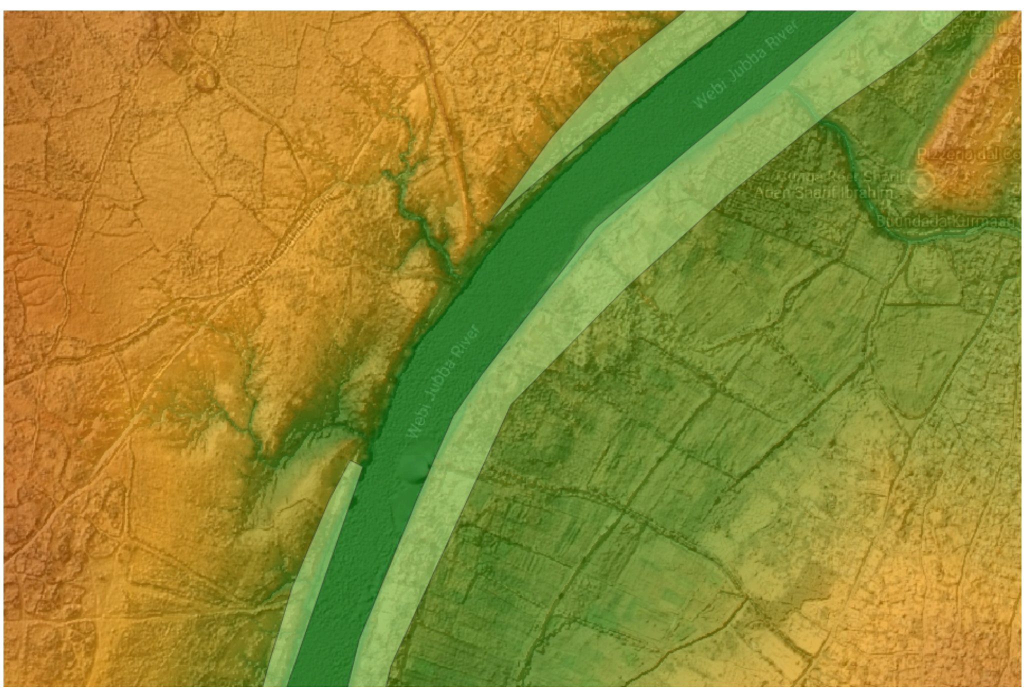


Figure 6.2: Gap in west bank of river widening sections, due to elevated terrain.

Figure 6.3: Close-up image of proposed river widening area in green, showing minimised impact on agricultural land.

Appendix 6.1: Virtual Validation Workshop

Date: 28th May 2025
Participant list:

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2. Berg, Kris van den, HKV
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4. Abdifatah Yusuf, Raagsan
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10. Giulia Pagani:Concern Worldwide
11. Joseph Odyek:Concern Worldwide
12. Isaiah Sciford, BRCiS, CMU
13. Anthony Dratre, BRCiS CMU
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16. Ahmed Hassan, Technical Advisor, Jubaland State Ministry of Energy and Water Resources

17. Correia, Joanna: IOM
18. Epsten, Andre Ruei-ming: IOM
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