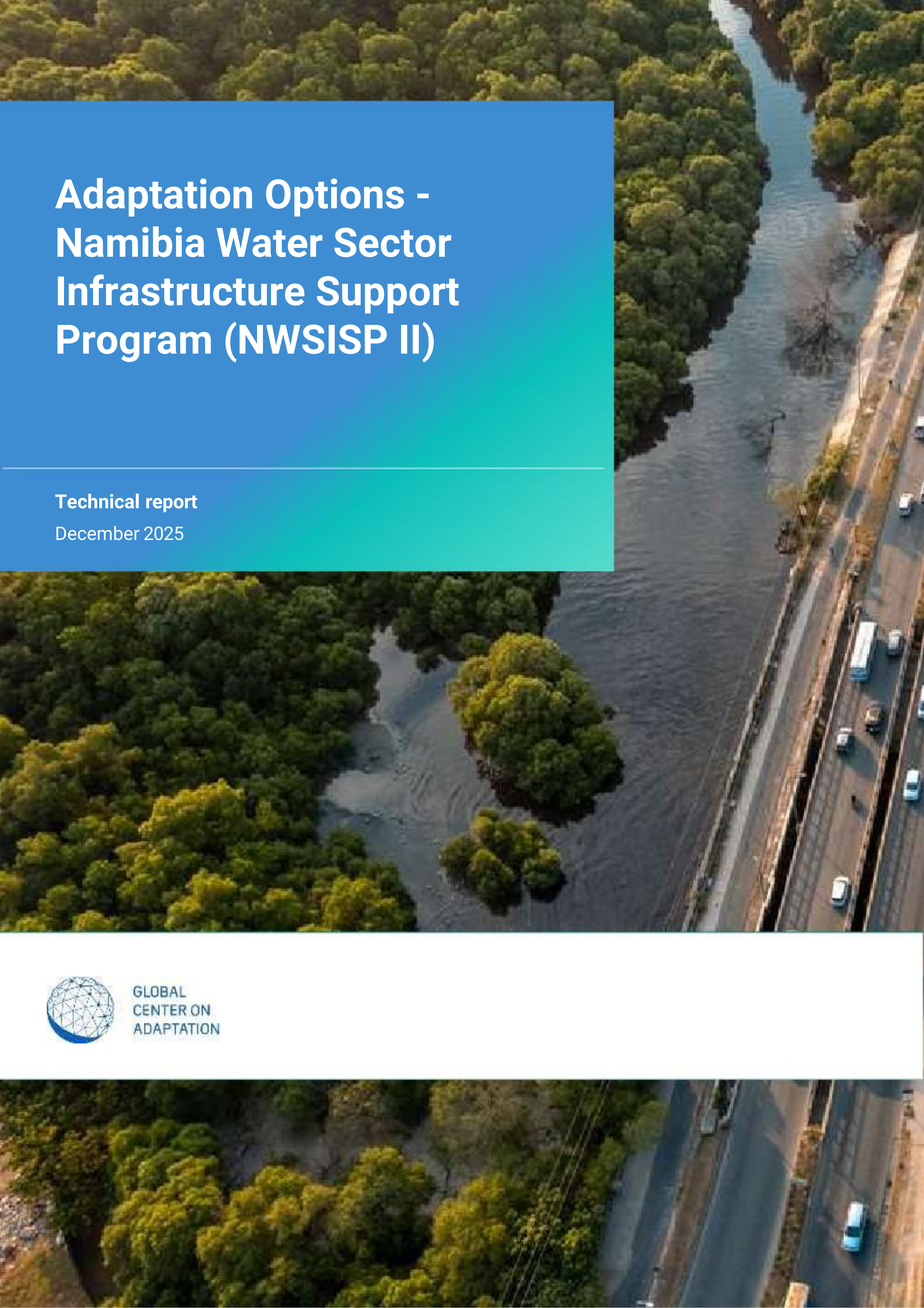
Adaptation Options - Namibia Water Sector Infrastructure Support Program (NWSISP II)

Technical report

December 2025



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The Global Center on Adaptation (GCA) is an international organization, hosted by the Netherlands, which works as a solutions broker to accelerate action and support for adaptation solutions from the international to the local, in partnership with the public and private sector, to ensure we learn from each other and work together for a climate resilient future

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LIST OF ACRONYMS

AfDB	African Development Bank
AF	Adaptation Fund (UNFCCC)
BMC	Basin Management Committee
CAW	Climate Action Window (African Development Fund)
CBA	Cost-Benefit Analysis
CRVA	Climate Risk and Vulnerability Assessment
EIF	Environmental Investment Fund of Namibia
GCF	Green Climate Fund
GEF	Global Environment Facility
KOH-2	Kalahari–Ohangwena II Transboundary Aquifer
MAWLR	Ministry of Agriculture, Water and Land Reform (Namibia)
MCA	Multi-Criteria Assessment
MEFT	Ministry of Environment, Forestry and Tourism (Namibia)
M&E	Monitoring and Evaluation
MRV	Measurement, Reporting and Verification
NDC	Nationally Determined Contribution (under Paris Agreement)
NDC-ISAP	NDC Implementation Strategy and Action Plan
NPC	National Planning Commission
PPP	Public-Private Partnership
RWSSI	Rural Water Supply and Sanitation Initiative (AfDB)
SADC	Southern African Development Community
UNDP	United Nations Development Programme
WSASP	Water Supply and Sanitation Policy (Namibia)

EXECUTIVE SUMMARY

Namibia's water sector is highly exposed to climate change due to extreme aridity, strong interannual variability, increasing temperatures and a growing frequency of droughts and flood events. These pressures pose significant risks to water availability, water quality and the reliability of water supply and sanitation infrastructure, particularly in the northern regions of the country where dependence on climate-sensitive surface and groundwater resources is high. In this context, strengthening climate resilience within the Namibia Water Sector Infrastructure Support Programme – Phase II (NWSISP II) is both urgent and essential to safeguard long-term water security and service continuity.

This Adaptation Options Report constitutes a key component of the Climate Risk Assessment for NWSISP II and builds directly on the findings of the Climate Risk and Vulnerability Assessment (CRVA). The report translates identified climate risks, exposure patterns and systemic vulnerabilities into a structured and prioritized set of adaptation options that are technically feasible, economically sound and context-appropriate for Namibia's water sector. Particular emphasis is placed on Nature-based Solutions (NbS) and hybrid interventions that combine green and grey infrastructure, reflecting their potential to deliver robust climate risk reduction while generating environmental, social and economic co-benefits.

The report follows a transparent and evidence-based methodology. An initial inventory of adaptation options was developed through a review of CRVA findings, national policies and strategies, ongoing and planned water-sector initiatives, and internationally tested NbS suitable for arid and semi-arid contexts. These options were subsequently assessed using a Multi-Criteria Assessment (MCA), applying weighted criteria covering effectiveness in reducing climate risk, technical feasibility, economic and financial viability, social and gender benefits, and environmental sustainability. This process enabled a systematic comparison and ranking of measures across basin-level, project-level and cross-cutting interventions.

Based on the MCA results, the highest-ranked adaptation measures were further examined through a simplified Cost–Benefit Analysis (CBA), applied to the top five prioritized options. The CBA provided an economic pre-feasibility appraisal, estimating indicative capital and operational costs, expected benefits, net present values, benefit–cost ratios and payback periods. The results confirm that several measures—particularly Managed Aquifer Recharge, Basin Management Committees, Floodplain Management, Community Rainwater Harvesting and Soil Conservation, and Drought-Proof Rural Water Supply Schemes—offer strong economic justification while also delivering significant resilience and development benefits.

To support implementation planning, the report complements the MCA and CBA with a qualitative, desk-based assessment of technical feasibility. This step provides indicative implementation timelines (short ,medium- or long-term) for the shortlisted measures. While these timelines are indicative, they offer a practical basis for sequencing and investment planning under NWSISP II.

The final output of the report is a structured catalogue of prioritized adaptation options, presented using a standardized fact-sheet template. Each entry summarizes the measure's purpose, geographic and climatic context, expected benefits and co-benefits, analytical results from the MCA and CBA, and indicative implementation horizon. Together, the catalogue serves both as a technical record of the screening and appraisal process and as a practical implementation guide to inform future project preparation, financing discussions and decision-making.

Overall, this Adaptation Options Report provides a coherent, evidence-based framework for integrating climate resilience into water sector investments. By combining climate risk analysis, multi-criteria prioritization, economic appraisal and practical implementation considerations, the report supports informed, strategic and scalable adaptation planning aligned with Namibia's national priorities and long-term water security objectives.

1. INTRODUCTION

Namibia faces extreme aridity, high climate variability and recurrent droughts that affect the availability and quality of water, water supply systems and sanitation services, particularly in northern regions where communities rely on climate-sensitive water resources exposed to hazards such as El Niño and La Niña. These pressures—combined with aging infrastructure, environmental degradation and increasing demand for water—require the urgent integration of climate resilience into water sector planning and investments. In response, the Government of Namibia, with the support of the African Development Bank (AfDB), is implementing the Namibia Water Sector Infrastructure Support Program – Phase II (NWSISP II). As part of this initiative, the Global Center on Adaptation (GCA), through the Africa Adaptation Acceleration Program (AAAP), is providing technical assistance to strengthen climate-informed planning through a Climate Risk and Vulnerability Assessment[1] (CRVA), a Gender and Social Vulnerability Analysis, and the identification and prioritization of adaptation solutions.

This Adaptation Options Report is the third key product of this process and is directly informed by the findings of the CRVA, which identified priority climate hazards, exposure patterns and systemic vulnerabilities affecting water resources, critical infrastructure and the communities that depend on them. Building on this evidence base, the report transforms risk findings into a structured set of feasible, cost-effective and context-appropriate adaptation options capable of enhancing the climate resilience of NWSISP II investments across both levels of analysis: the Kunene and Okavango basins and the Okavango Link – CAN Water Supply Project and the Rundu Water Project.

Given the high dependence on ecosystem services and the fragility of northern watersheds, the report places particular emphasis on Nature-based Solutions and hybrid interventions that combine green and grey infrastructure. These approaches offer multiple benefits, positioning them as low-regret, high-impact measures suitable for the context of increasing climate uncertainty.

The report follows a clear and coherent structure that presents the full process of identifying, analyzing, and selecting climate adaptation measures. After this introduction, the report sets out its objectives and clarifies how this work builds on the previous phases of the Climate Risk and Vulnerability Assessment. It then offers a contextual overview of Namibia's water resources, projected climate conditions and the specific project locations that were identified as climate hotspots.

Building on this foundation, the report describes the methodology used to gather, classify and assess possible adaptation solutions, leading to the creation of an organized inventory of options. This is followed by two complementary analytical stages: a Multi-Criteria Assessment (MCA), which compares the options in terms of their effectiveness, feasibility, long-term sustainability and social and environmental benefits; and a Cost-Benefit Analysis (CBA), which evaluates their economic performance and relative advantages. The final section presents a consolidated catalogue of priority adaptation options, outlining their relevance, potential applications and suitability for implementation across the target areas.

1 This Climate Vulnerability and Risk Assessment was developed under the Climate Risk Assessment for the Namibia Water Sector Infrastructure Support Program (NWSISP II). The objective of this assessment is to evaluate current and future climate risks to Namibia's water sector, focusing on the Kunene and Kavango basins, by identifying hazard patterns at national and regional scales and analysing exposure, asset vulnerability, and risk at regional and local levels to highlight factors that threaten the resilience and sustainability of water infrastructure and services.

2. OBJECTIVES

The overall objective of this report is to support the integration of climate adaptation and resilience into the design, planning, and implementation of the Namibia Water Sector Infrastructure Program – Phase II (NWSISP II). Building on the foundations established in the Climate Risk and Vulnerability Assessment, the report aims to provide a robust, evidence-based set of adaptation solutions that can enhance the long-term resilience, reliability, and sustainability of water and sanitation infrastructure across the project sites. In doing so, it contributes directly to strengthening the climate rationale of NWSISP II and to equipping decision-makers with actionable, context-specific options that address the intensifying climate risks affecting Namibia's water sector today and under future scenarios.

The specific objectives of the Adaptation Options Report are:

- Identify and document feasible, cost-effective, and scalable adaptation options, with a focus on water-related NbS and hybrid solutions.
- Support informed decision-making for climate-resilient water investments.
- Provide a consolidated catalogue of adaptation solutions to guide future implementation and financing efforts.

3. CONTEXT

3.1 Overview of Namibia's water resources

Namibia is the driest country in Sub-Saharan Africa, characterized by extremely low and variable rainfall, limited perennial surface water and a strong dependence on transboundary basins. Total national water demand was estimated at approximately 334 million m³ in 2008, with projections suggesting an increase to around 772 million m³ by 2030 driven by population growth, agricultural expansion and urbanization[2].The country relies almost equally on groundwater and surface water, while reclaimed water and desalination contribute roughly 2% of total supply[3]. Groundwater remains a strategic resource, yet only about 1.5% of renewable groundwater is currently exploited, partly due to limited recharge, salinity issues and logistical barriers[4]. Agriculture is the largest water user, with approximately 213 million m³ per year, including 136 million m³ for irrigation and 77 million m³ for livestock production[5].

Namibia's hydrological systems face multiple management challenges, including minimal natural storage capacity, high evaporation losses, ageing conveyance infrastructure and disparities in water access between urban and rural areas. Long-distance transfer systems, groundwater wellfields and surface-water abstraction points are increasingly stressed by recurrent droughts and climatic variability. Rural schemes are particularly vulnerable to operational interruptions, limited maintenance capacity and salinity increases under prolonged dry conditions. These pressures reinforce the structural water scarcity that shapes national water security.

The Kunene Basin is one of Namibia's most critical hydrological systems, supplying northern regions through the Calueque–Oshakati canal and supporting hydropower generation at Ruacana. CRVA analyses highlight that its flows depend almost entirely on rainfall in Angola, making the basin highly vulnerable to multi-year droughts, low-flow seasons and disruptions in intake submergence. Rising temperatures and evaporation exacerbate losses along open canals, while extreme rainfall events can cause sedimentation, turbidity spikes and physical damage to embankments and control structures.

The Okavango Basin is similarly sensitive to climatic fluctuations, with its runoff generated mainly in the Angolan highlands. The basin supports domestic water supply, irrigation and rural livelihoods in Kavango East and West, yet its complex hydrology and ecological importance make it highly vulnerable to both drought-driven low flows and intense rainfall events that increase flood risk, erosion and contamination of water sources.

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[2] Atlas of Namibia. (2024). *Water access, demand and supply: Water demand*. Namibia University of Science and Technology. https://atlasofnamibia.online/chapter-4/water-access-demand-and-supply/water-demand/

[3] GIZ. (2022). *Wastewater management in Namibia*. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. https://www.giz.de/en/downloads/giz2022-de-namibia-abwasser.pdf

[4] SADC-GMI. (2024). *Groundwater profile: Namibia*. Southern African Development Community – Groundwater Management Institute. https://sadc-gmi.org/wp-content/uploads/2024/09/Namibia.pdf

[5] Water Action Hub. (n.d.). *Namibia country water data*. Pacific Institute. https://wateractionhub.org/geos/country/152/d/namibia/

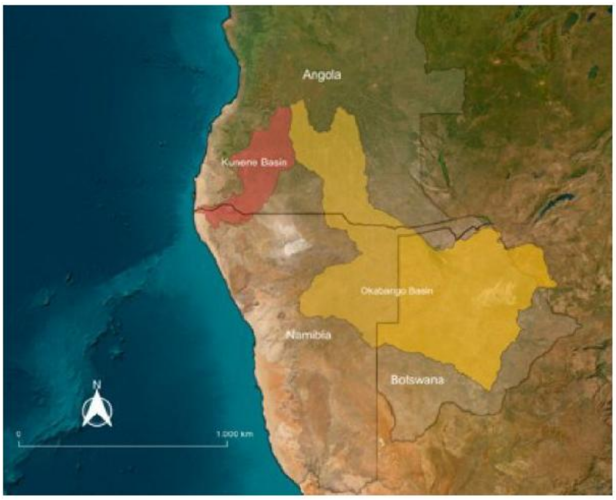

Figure 1: Kunene and Okavango Basin. Source: CRVA

Within this context, the Rundu Water Project aims to improve access to safe and reliable potable water for dispersed rural communities within an approximate 100 km radius of Rundu. The project builds on the existing Rundu Water Treatment Plant, which currently has a capacity of around 19,073 m³/day and is projected to increase to 35,321 m³/day by 2037, with additional capacity expected from a new treatment plant planned for operation in early 2026. While the project strengthens service coverage and regional water security, its performance remains closely linked to the hydrological dynamics and climate sensitivity of the Okavango Basin.

At a larger, inter-basin scale, the Okavango Link (CAN Water Supply Project) is a strategic infrastructure scheme designed to augment supply to the Central Area of Namibia (CAN), including Windhoek. Its feasibility, however, is closely tied to the hydrological behavior of the Okavango Basin. Projected increases in flow variability, potential reductions in dry-season discharge and higher evaporation losses pose significant risks for long-term reliability. Infrastructure associated with the scheme, including intake structures, pumping stations and transmission pipelines, would be exposed to drought-induced low flows, sedimentation during intense rainfall events and broader uncertainties linked to climate-driven hydrological shifts. These risks underline the need for enhancing system flexibility, incorporating nature-based and hybrid solutions and strengthening catchment management upstream.

3.2 Climate context and projections

Namibia's climate is characterized by persistent aridity, high interannual rainfall variability and increasing temperatures. Observed climate trends show a clear warming trajectory across all regions, with rising frequency and duration of heatwaves and a steady increase in warm days and nights. Climate projections from the CRVA indicate that mean annual temperatures are expected to rise by 2–4°C by mid-century under high-emission scenarios, with more intense warming in the northern interior. These changes will significantly increase evapotranspiration rates, exacerbate soil moisture deficits and intensify thermal stress on water infrastructure and ecosystems.

Rainfall projections remain uncertain, but climate models consistently indicate greater variability, including longer dry spells, delayed onset of the rainy season, and more frequent multi-season droughts. Estimates suggest that average rainfall may decline by up to 7% by 2050 and 14% by 2100, while intense short-duration rainfall events are expected to become more frequent, particularly in the northern basins. These dynamics imply more frequent pluvial flash floods, higher sediment loads and episodic spikes in turbidity affecting water treatment operations. Basin-level assessments for the Kunene and Okavango further confirm heightened exposure to hydrological extremes, including prolonged low-flow periods that threaten the reliability of surface and groundwater supplies.

The next table summarizes the key climate hazards relevant to the water and sanitation sector, highlighting the specific infrastructure components at risk and the types of impacts anticipated under projected climate conditions.

Table 1: Overview on relevant climate hazards in the water and sanitation sector. Source: CRVA

Climate Hazard	Asset / Components Potentially Affected	Impacts in the area (Kunene and Okavango)
Heat Stress (Heatwaves and extreme heat)	• Water treatment plants (process units, chemical dosing, chlorination rooms). • Open reservoirs and canals. • Pumping stations, motors and electrical panels (incl. SCADA cabinets). • Boreholes (submersible pumps, controllers). • Solar PV arrays, inverters, batteries. • Plastic pipelines (HDPE/PVC), operator facilities.	• Higher evaporation from canals/reservoirs giving reduced yields. • Overheating/derating of pumps and electrical gear; faster battery degradation. • Lower PV output at high temperatures. • Softening/deformation of plastic pipes and joints. • Reservoir stratification, algal blooms, reduced chlorine residuals. • Higher water demand (cooling/household); reduced worker productivity and more H&S incidents during O&M.
Droughts (multi-season rainfall deficits)	• Raw-water sources low flows. • River intakes (insufficient submergence). • Groundwater/boreholes (well screens, pumps). • Irrigation and livestock points. • Service reservoirs.	• Water scarcity for domestic, agricultural and industrial uses. • Intakes stranded, higher intake outage frequency. • Declining groundwater levels, dry boreholes, increased pumping lifts. • Rising TDS/salinity and source temperature. • Competition/conflict between users; emergency rationing/water trucking; ecological stress downstream.
Pluvial Flash Floods (short-duration, high-intensity rainfall)	• Surface water schemes and canal embankments. • Sediment basins and raw-water inlets. • Rural latrines/on-site sanitation systems. • Access roads/culverts to assets.	• Localized flooding and scouring of embankments. • Sediment and debris load clogging. • Intakes/canals; turbidity spikes at WTPs (chemical over-run). • Latrine overflow/collapse contaminating shallow groundwater and river margins. • Road washouts blocking O&M and emergency repairs.
Fluvial Floods	• Boreholes near floodplain (wellhead seals) • River intakes and pumphouses • Transmission mains at river crossings/supports. • Elevated tanks foundations; kiosks near banks	• Inundation of intakes/electrical rooms; prolonged downtime • Bank erosion undermining pipelines and supports • Fecal/chemical contamination of sources • Service interruptions for floodplain settlements; structural damage to tank pedestals
Strong winds and storms (including dust storms)	• Elevated tanks (roofing, ladders, fall protection). • Exposed pipelines and fittings. • Water kiosks and latrine structures • Overhead power to sites; PV arrays and mounting. • SCADA/telemetry masts and antennas.	• Physical damage to lightweight structures. • Debris/treefall on mains and service lines. • Dust fouling PV modules, reducing pump output; sand abrasion on gates and valves. • Lightning/surge damage to PLC/RTU; communication outages; unplanned downtime.
Wildfires	• HDPE/PVC pipelines; GRP/PE tanks. • Remote solar equipment and cabling; meter boxes. • Vegetation around assets; wooden kiosks.	• Melting/burning of plastic components; tank/pipe failure. • Loss of power/control at remote pumps. • Access routes blocked; longer repair times; need for firebreaks and cleared asset perimeters.

The hazards listed—including heat stress, droughts, pluvial and fluvial floods, strong winds and wildfires—have direct implications for water availability and infrastructure resilience. Heatwaves and extreme heat will increase evaporation from open reservoirs and canals, reduce water yields and cause overheating or derating of pumps, electrical components and solar infrastructure. Multi-season droughts threaten raw-water availability, groundwater levels and intake operations, while increasing salinity and competition between users. Flash floods may damage embankments, overwhelm canal systems, disrupt rural sanitation facilities and impede access for operations and maintenance. Fluvial flooding poses risks to boreholes, river intakes, pump houses and transmission mains, potentially causing structural damage and long service interruptions. Strong winds and storms can affect elevated tanks, lightweight structures and PV systems, while wildfires threaten plastic pipelines, tanks and remote power/control installations.

Taken together, these projected changes indicate that Namibia's water and sanitation systems will face intensifying pressures driven by both chronic and acute climate hazards. This reinforces the need for robust adaptation strategies—such as reinforced design standards, diversification of supply, improved storage, early-warning systems and integrated catchment management—to safeguard long-term water security and service reliability across NWSISP II project areas.

3.3 Climate-risk hotspots at basin scale and across key water supply projects (Okavango Link – CAN and Rundu Water Project)

The Climate Risk and Vulnerability Assessment examined climate-risk patterns across the Kunene and Okavango river basins, two of Namibia's most climate-sensitive regions and the only perennial systems sustaining significant rural and urban populations. These basins differ markedly in their climatic and hydrological regimes, yet both exhibit high sensitivity to climate variability and change, particularly in relation to water supply and sanitation (WASH) infrastructure.

The Kunene Basin is characterized by hyper-arid conditions in its lower reaches, with mean annual rainfall often below 50 mm/year, extremely high evaporation rates, and strong dependence on upstream inflows from Angola. It is a strategic basin for Namibia's bulk water transfers through the Calueque–Oshakati canal and for hydropower generation at Ruacana. In contrast, the Okavango Basin lies largely within a sub-humid climatic zone, receiving approximately 600 mm/year, and supports denser settlements, small-scale irrigation, tourism, and mixed rural livelihoods in Kavango East and Kavango West. Despite higher average rainfall, the Okavango system remains highly vulnerable due to its reliance on upstream hydrological conditions, floodplain dynamics, and increasing demand pressures.

The CRVA identifies recurrent multi-hazard hotspots across both basins, where heat stress, drought, pluvial flash floods, fluvial floods and wildfires converge. These hotspots represent areas of heightened exposure for WASH infrastructure and surrounding communities, particularly where assets are located within floodplains, low-lying corridors, or groundwater-dependent rural schemes.

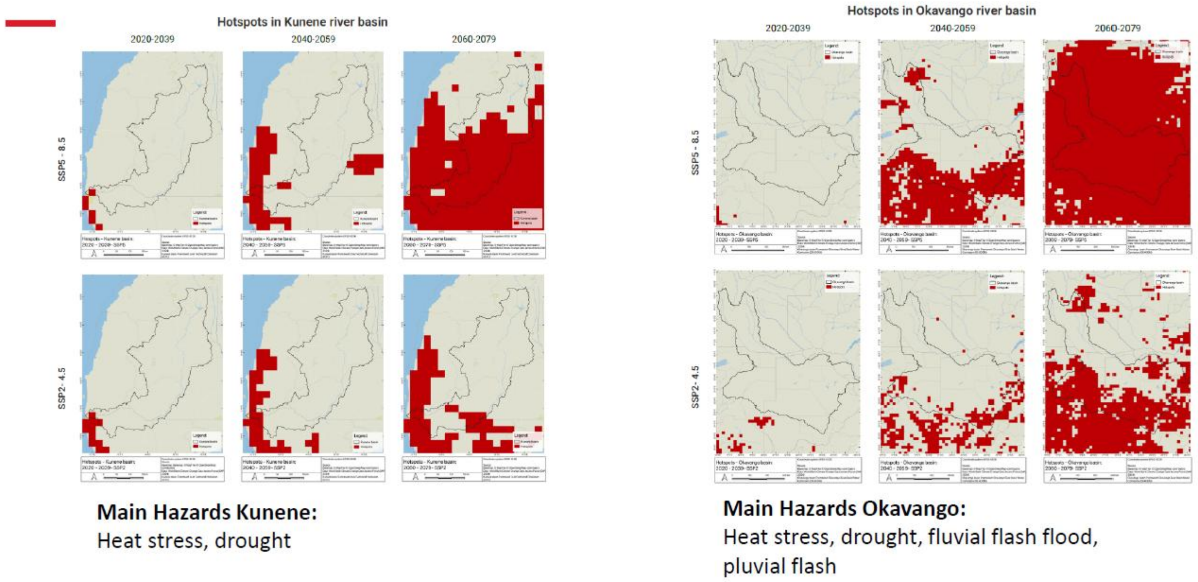

Figure 2: Climate-risk hotspots in the Kunene and Okavango river basins under SSP2-4.5 and SSP5-8.5 (2020–2039, 2040–2059, 2060–2079). Source: CRVA

The figure illustrates the progression from localized to basin-wide hotspot patterns, with heat stress and drought becoming near-universal by mid-century, while flood-related hazards concentrate along river corridors and settlement axes.

Specifically, in the **Kunene Basin**, hotspot patterns emerge initially as localized clusters in the south-western lowlands during the near-future period (2020–2039). These clusters progressively expand eastwards and inland by mid-century (2040–2059) and late-century (2060–2079), especially under the high-emissions scenario (SSP5-8.5). By the late-century horizon, large portions of the basin fall within High to Extreme multi-hazard zones.

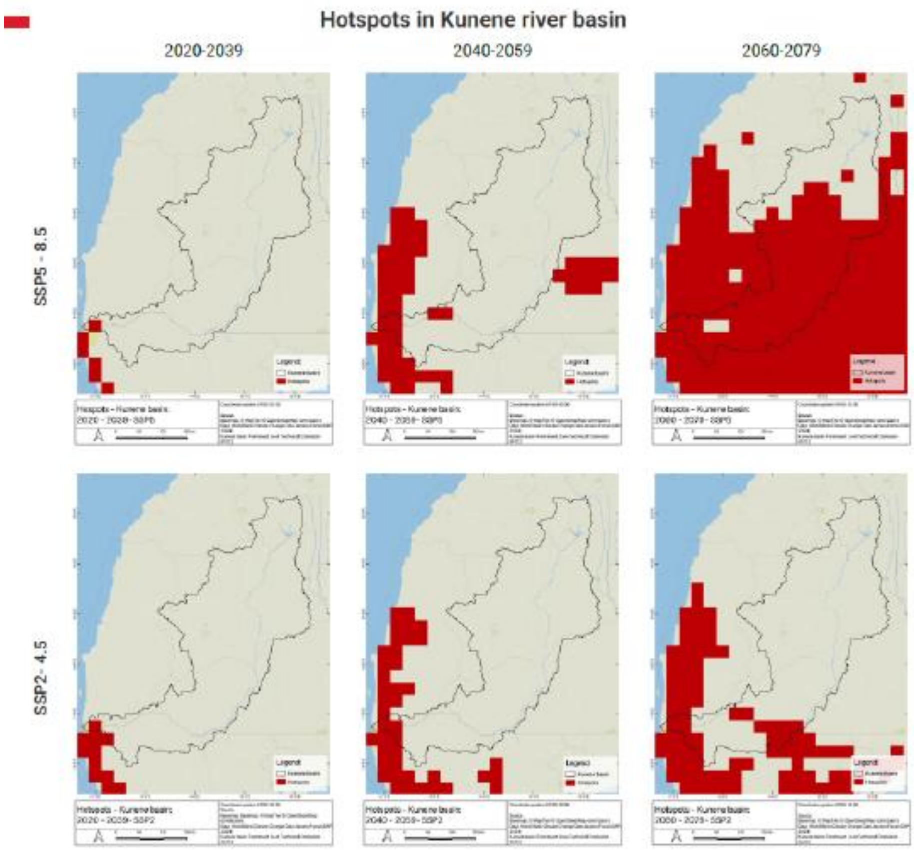

Figure 3: Kunene River Basin Hotspots under SSP2-4.5 and SSP5-8.5 (2020–2039, 2040–2059, 2060–2079). Source: CRVA

Constituencies such as Khorixas, Opuwo, Kamanjab, Sesfontein and Outjo present a high concentration of boreholes, wells, tanker points, dams and public taps located within these hotspot areas. The concurrence of prolonged drought, rising temperatures and increasing wildfire risk is particularly pronounced, while episodic pluvial and fluvial flash flooding affects access roads, crossings and low-lying infrastructure. The CRVA indicates that by 2060–2079, most water points in these constituencies are exposed to persistent multi-hazard stress, threatening both domestic water security and pastoral livelihoods that depend heavily on groundwater and riparian ecosystems.

From a hazard-specific perspective, temperature-related risks show a strong and consistent signal.

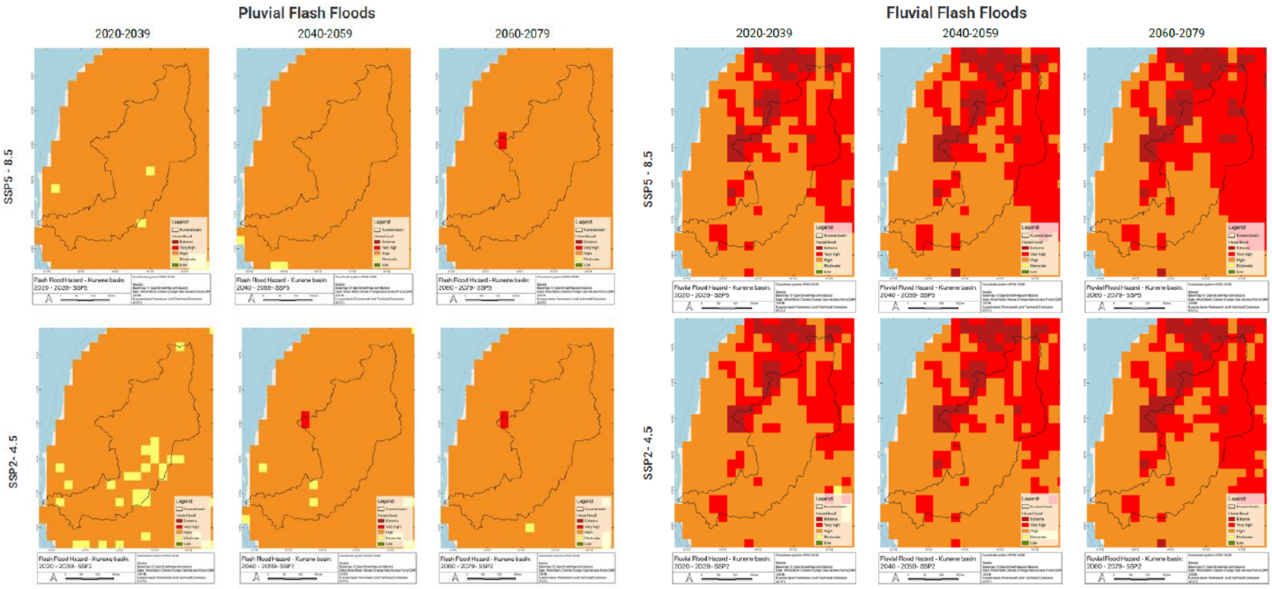

Figure 4: Hazard-specific maps for the Kunene River Basin under SSP2-4.5 and SSP5-8.5 (2020–2039, 2040–2059, 2060–2079). Source: CRVA

Maximum daily temperatures increase substantially over time, raising extreme-temperature ceilings and intensifying thermal stress on assets and operations. Heatwave analyses indicate a lengthening of warm spells, with direct implications for worker safety, cooling and ventilation requirements, and the operational stability of heat-sensitive components. These conditions contribute to accelerated derating and thermal fatigue of electro-mechanical equipment, higher cooling demand, and elevated water-quality risks due to faster disinfectant decay.

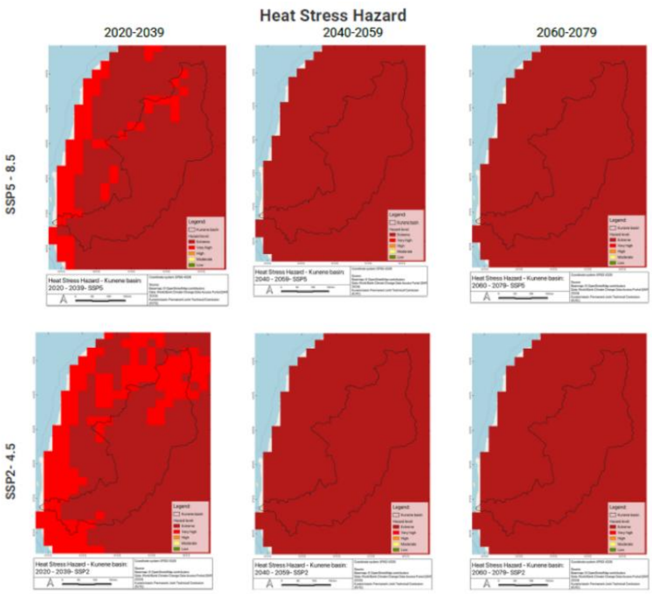

Figure 5: Hazard-specific maps for the Kunene River Basin under SSP2-4.5 and SSP5-8.5 (2020–2039, 2040–2059, 2060–2079). Source: CRVA

Drought-related indicators reveal the strongest negative anomalies concentrated over the western and central Kunene Basin and extending into the northeastern headwaters. Increasing numbers of consecutive dry days lengthen seasonal dry spells, heightening pressure on baseflows, reservoir inflows and groundwater recharge. These trends imply growing risks of supply deficits, increased reliance on demand management, water trucking, and conjunctive surface–groundwater use, while also amplifying wildfire risk during the dry season (June–September).

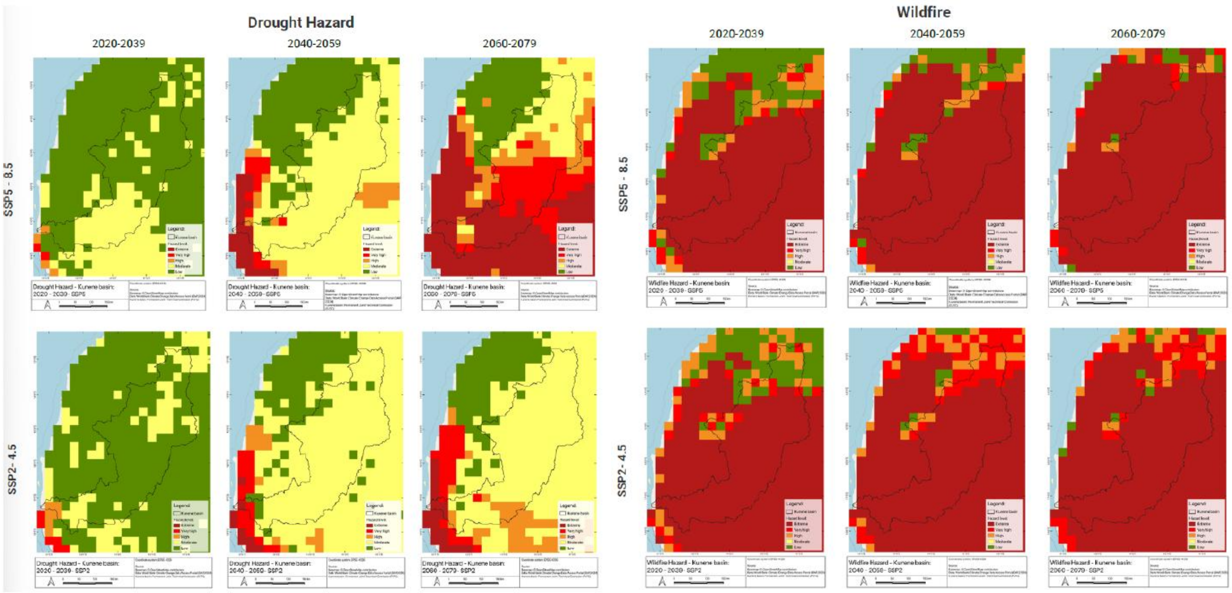

Figure 6: Hazard-specific maps for the Kunene River Basin under SSP2-4.5 and SSP5-8.5 (2020–2039, 2040–2059, 2060–2079). Source: CRVA

In the Okavango Basin, hotspot evolution follows a similar multi-hazard trajectory but with a more rapid spatial coalescence of risk around populated corridors. Early-century scattered hotspot patches intensify into a near-continuous belt by 2040–2059, particularly along Rundu, Nkurenkuru, and the southern interior of Kavango East and Kavango West. By late century, extensive hotspot coverage emerges across most of the basin under SSP5-8.5.

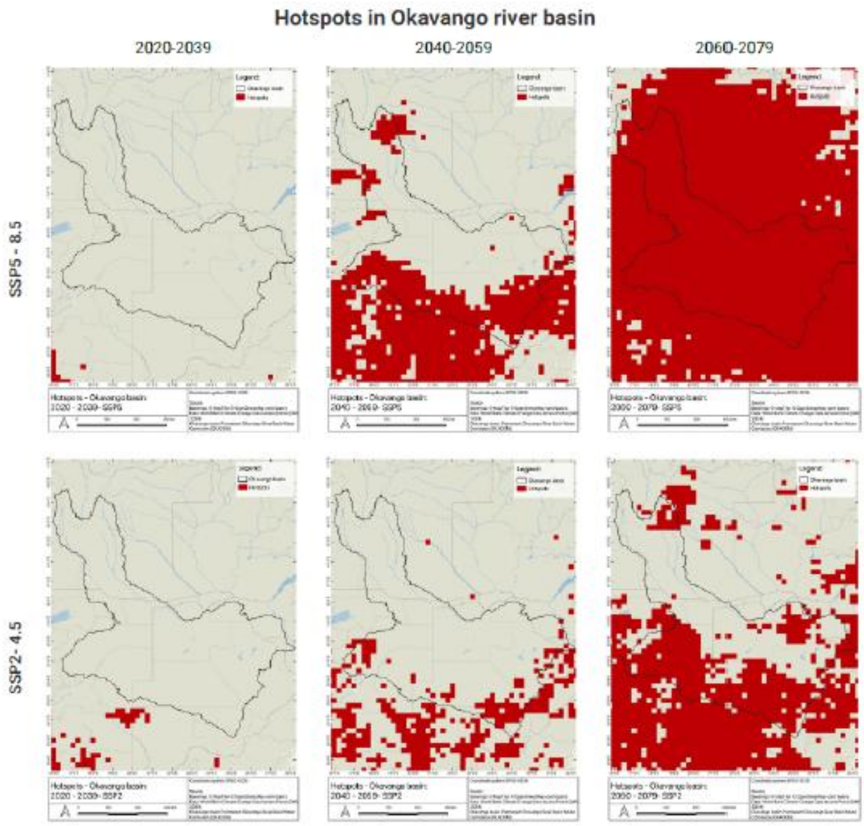

Figure 7: Okavango River Basin Hotspots under SSP2-4.5 and SSP5-8.5 (2020–2039, 2040–2059, 2060–2079). Source: CRVA

Heat stress becomes a dominant hazard across all time horizons. Maximum daily temperature analyses indicate higher extreme temperature ceilings, leading to greater heat-stress risks for communities and operations, higher evaporative losses, and reduced safety margins for heat-sensitive processes. Lengthening warm spells further exacerbate risks to worker safety, cooling requirements and equipment reliability, while accelerating disinfectant decay and water-quality degradation.

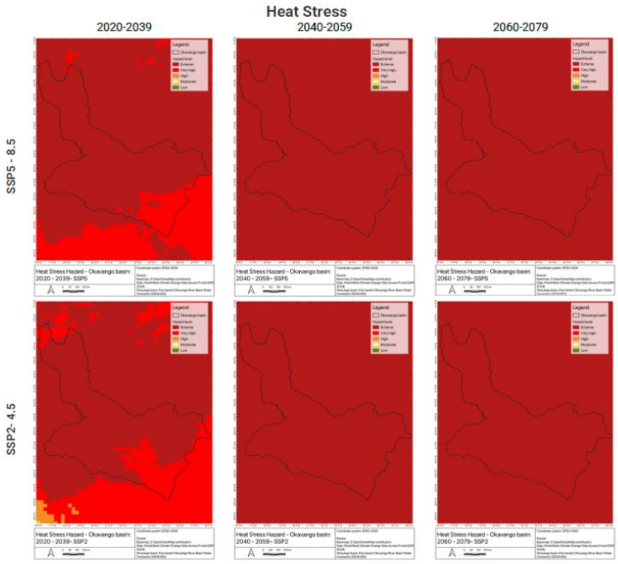

Figure 8: Hazard-specific maps for the Kunene River Basin under SSP2-4.5 and SSP5-8.5 (2020–2039, 2040–2059, 2060–2079). Source: CRVA

Precipitation-related hazards in the Okavango Basin display a more nuanced signal. Mean maximum 1-day precipitation indicates a greater likelihood of short-duration pluvial surges under SSP5-8.5, particularly affecting headwater towns and upper-basin catchments. These events increase the risk of localized overtopping at road and canal crossings, impacts on small catchments, culverts and compound drainage systems. In contrast, maximum 5-day precipitation shows limited changes relative to historical conditions, suggesting that flood-risk planning should continue to emphasize hydrological variability and local controls. Heavy-precipitation indices (>20 mm and >50 mm) remain largely localized, with modest increases in orographic headwaters, reinforcing the need for targeted drainage and erosion-control upgrades rather than basin-wide redesign.

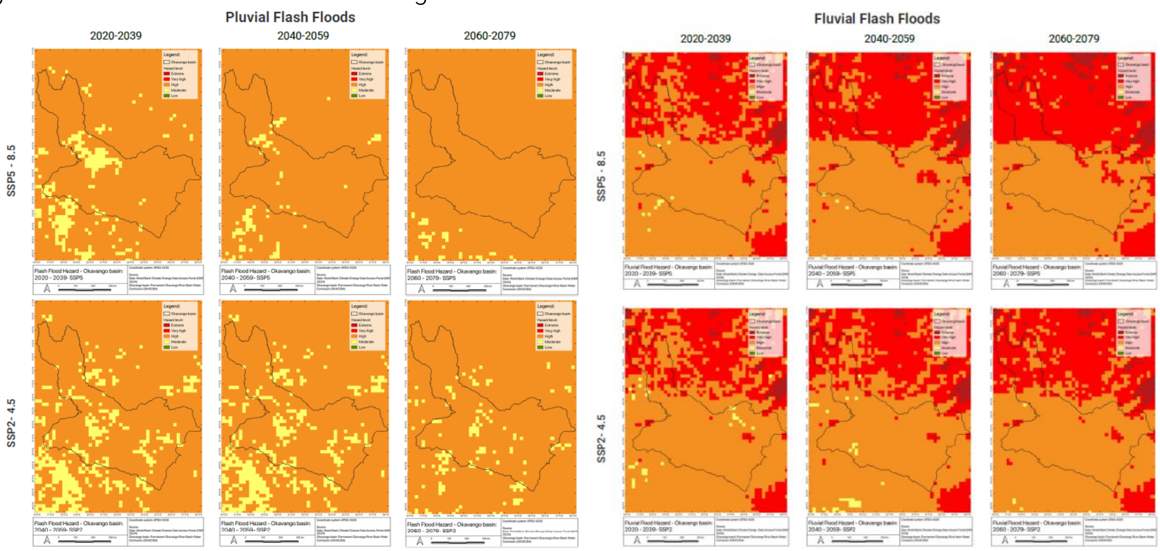

Figure 9: Hazard-specific maps for the Kunene River Basin under SSP2-4.5 and SSP5-8.5 (2020–2039, 2040–2059, 2060–2079). Source: CRVA

Drought indices indicate pronounced hydrological deficits across northern and central Okavango sectors. Increasing consecutive dry days raise the likelihood of multi-season drought stress for both surface- and groundwater-fed WASH systems, leading to storage drawdowns and heightened reliance on conjunctive-use strategies, especially for small surface sources and shallow aquifers.

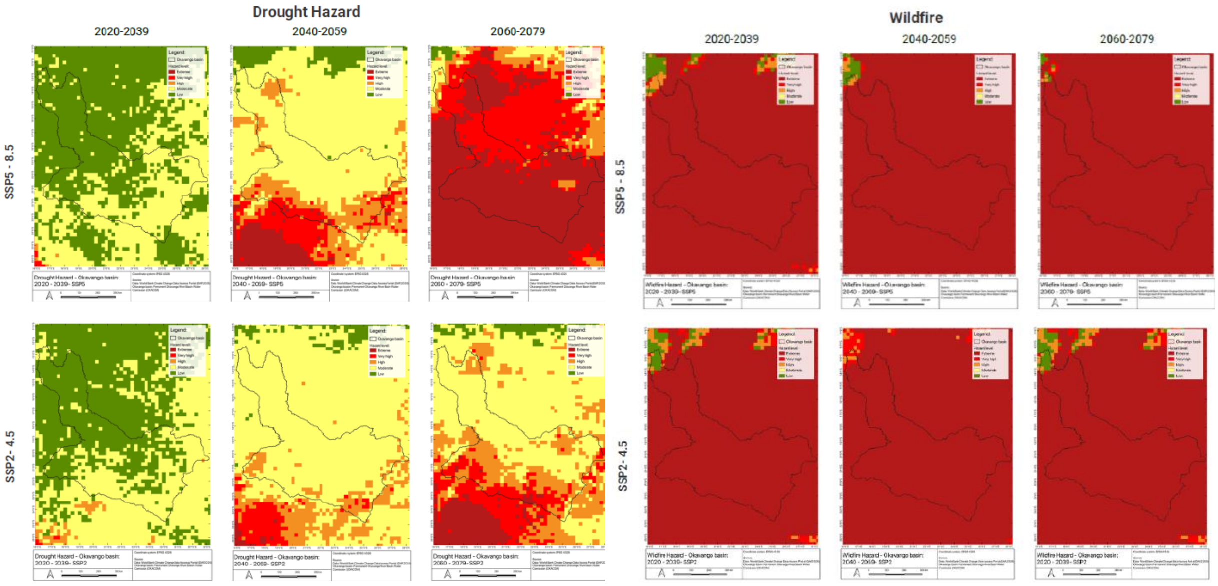

Figure 10: Hazard-specific maps for the Kunene River Basin under SSP2-4.5 and SSP5-8.5 (2020–2039, 2040–2059, 2060–2079). Source: CRVA

These basin-scale climate-risk hotspots intersect directly with the **priority project sites** identified under NWSISP II, notably the **Kavango Link – CAN Water Supply Project** and the **100 km Rundu Water Project**. In both cases, basin-level hazards translate into concrete, asset-specific vulnerabilities that require tailored adaptation responses:

The **Kavango Link** project aims to transfer water abstracted from the Okavango River at Rundu to Grootfontein to address projected future demand gaps, estimated at approximately 30 Mm³/year by 2050. The scheme comprises a river abstraction at Rundu and a 277 km pipeline, including a base pump station, multiple booster pump stations and a terminal pump station.

To operationalize climate-risk analysis, the CRVA applied a five-part segmentation (S0–S5) aligned with asset typology and exposure context. Across all segments, risk indices increase from the near future (2020–2039) to the mid-century horizon (2040–2059) and are consistently higher under SSP5-8.5 than SSP2-4.5, reflecting stronger signals of extreme heat, rainfall variability and aridity.

At Segment S0 (intake and river pump station), the dominant risks are fluvial and pluvial flooding affecting the upstream floodplain, combined with drought-driven multi-season low-flow conditions that curtail abstraction days and propagate service-delivery constraints along the transfer system. Segments S1–S2 are primarily exposed to heat stress affecting MCC rooms, pumps and VFDs at the base pump station and Booster 1, with additional pluvial flash flood and erosion risks along hardstands, valve chambers and early trunk-main reaches, as well as localized wildfire exposure along vegetated servitudes. Segments S3–S4 face short-duration pluvial flash flooding at ephemeral crossings, slope instability on steeper cut-and-fill sections, and cumulative heat stress on Booster 2 and Booster 3. At Segment S5, risks concentrate around pluvial flood inflows to interface chambers and combined heat and dust impacts on control rooms and outdoor instrumentation.

Design-check implications therefore focus on flood-proofing intakes and chambers, ensuring adequate freeboard and drainage capacity, recalculating heat balances for higher ambient temperatures, verifying equipment derating allowances, and strengthening protection against dust, lightning and wildfire.

Figure 11: Kavango Link – CAN Water Supply Project alignment, segmentation (S0–S5) and associated climate-risk exposure. Source: CRVA

The Rundu Water Project seeks to improve access to safe and reliable water for dispersed rural communities surrounding Rundu. Current water treatment plant (WTP) capacity is approximately 19,073 m³/day, with projections of 35,321 m³/day by 2037. A new Rundu WTP, expected in early 2026, will add to existing capacity and is intended to enable potable water supply within a 100 km radius of the plant.

Preliminary climate-risk screening indicates that assets within this service area are embedded within high to very high multi-hazard corridors, particularly under SSP5-8.5. River abstraction infrastructure is exposed to fluvial flooding, bank erosion, and alternating extremes of low river levels and high sediment loads. Treatment facilities face access disruptions, elevated flood risk and operational stress during extreme heat events. Pump stations and pressure-boosting infrastructure are vulnerable to flooding where installed below ground level, equipment failure due to high ambient temperatures, and power outages during storms and wildfires.

Distribution infrastructure, including trunk mains, crossings and storage reservoirs, traverses multi-hazard hotspots where sequential drying and flooding can induce ground movement, scour at crossings and thermal damage to pipes. Disinfection systems face concurrent stresses from power interruptions, access constraints, higher chlorine demand during warm and post-storm conditions, and temperature-sensitive degradation of chemical agents.

These findings emphasize the importance of resilient intake positioning, elevated and sealed structures, redundancy in power supply and storage, climate-resilient material selection, and proactive operational strategies to maintain service continuity under compound hazard conditions.

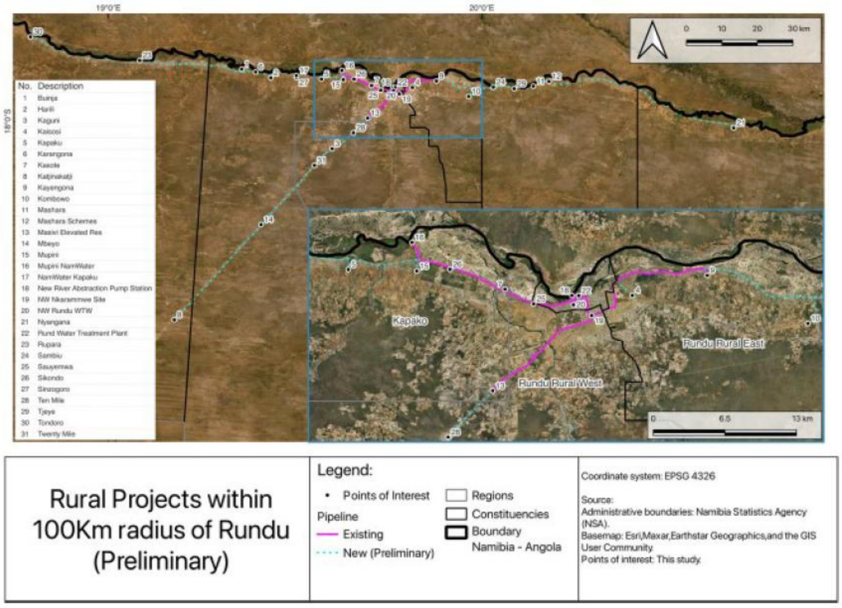

Figure 12: Preliminary climate risk screening and asset exposure for the 100 km Rundu Water Project service area. Source: CRVA

Collectively, the basin- and project-level analyses demonstrate that climate risks in the Kunene and Okavango systems are systemic, compounding and intensifying over time. Heat stress and drought emerge as pervasive background hazards, while flood-related risks concentrate along river corridors, floodplains and infrastructure crossings. These dynamics necessitate the integration of climate-resilient design standards, multi-hazard preparedness, adaptive operations and strengthened maintenance capacity across all basin-level and project-level interventions to safeguard long-term water security for Namibia's urban and rural populations.

4. IDENTIFICATION OF ADAPTATION OPTIONS

4.1 Methodological approach

The identification of Adaptation Options for the water sector in Namibia followed a structured, stepwise approach designed to ensure that the proposed measures are robust, context-appropriate and aligned with national priorities.

The methodology applied a systematic screening and appraisal process to confirm that all selected options are technically sound, policy-aligned, climate-resilient, and feasible for implementation within Namibia's institutional and socio-ecological context. This process involved:

- Extraction of adaptation measures emerging from the Climate Vulnerability and Risk Assessment[6], given that these reflect the most recent evidence on basin-specific hazards, exposure, and infrastructure vulnerabilities. This was complemented with relevant entries from the World Bank Catalogue of Nature-Based Solutions for Urban Resilience[7], particularly those suitable for arid and semi-arid environments.
- A comprehensive review of existing literature from which adaptation measures applicable to the current context were extracted. This step considered Namibia's position as the driest country in Sub-Saharan Africa, characterized by erratic rainfall, high climatic variability, and reliance on transboundary water resources.
- Identification and analysis of ongoing and planned adaptation projects in Namibia, selecting those measures and practices that are relevant or replicable for the basins and for the projects. This step was complemented by a review of regionally and globally tested Nature-based Solutions (NbS) and hybrid interventions designed for arid and semi-arid environments, ensuring the inclusion of proven, scalable approaches suitable for Namibia's climatic and hydrological conditions.

Together, these steps resulted in a consolidated inventory of adaptation options oriented towards strengthening resilience both at the basin level and for the Kavango Link Project.

Key focus areas for data collection

The definition of adaptation options also considered a set of thematic focus areas that consistently emerged from national policy documents, basin-level analyses, and the CVRA findings. These areas helped frame the types of measures considered relevant for strengthening climate resilience

	Water Resources Management and Infrastructure Resilience: Measures to improve system efficiency and resilience, including reduced water losses and strengthened reliability under drought and heat stress.
	Catchment, Groundwater, and Ecosystem Protection: Actions to protect recharge zones, monitor aquifers, and restore ecosystems to safeguard water quality and long-term hydrological sustainability.
	Flood and Drought Risk Management: Nature-based and technical interventions to manage extreme rainfall and drought events, such as infiltration ponds, rainwater harvesting, and erosion control.

[7] A catalogue of Nature Based Solutions For Urban Resilience

	Community-Based Water Governance and Capacity Building: Promoting conservation practices, traditional knowledge integration, and local capacity for climate-resilient water management.

Screening principles for adaptation option selection

To ensure the relevance and feasibility of each measure, the following screening principles were applied during the selection process:

1. Alignment with National Policies and Water Governance Frameworks

Adaptation options must be consistent with Namibia's legislative and policy landscape.

2. Suitability for Arid and Highly Variable Hydro-Climatic Conditions

Options should be technically appropriate for Namibia's predominantly dry climate, highly variable rainfall patterns, and increasing frequency of extreme climate events.

3. Preference for Low-Water, Low-Maintenance, and Nature-Based Solutions (NbS)

Priority is given to interventions that minimize water consumption, require limited operational inputs, and incorporate nature-based or ecosystem-enhancing design principles.

4. Institutional and Community Feasibility

Selected options must be manageable within existing governance structures, institutional capacities, and community systems, ensuring that implementation, operation and maintenance are realistic and locally supported.

5. Evidence-Based Measures with Clear Co-Benefits

Options should demonstrate proven effectiveness in similar contexts and deliver measurable co-benefits, including enhanced climate resilience, improved livelihoods, gender and social inclusion outcomes, and ecosystem sustainability.

The following section presents the key findings derived from each component of the methodological process applied for the identification of adaptation options.

4.2 Review and systematization of Adaptation Options

The main objective of this section is to identify, document, and analyze the existing, ongoing, and planned adaptation measures relevant to Namibia's water sector.

Findings from the Climate Vulnerability and Risk Assessment

The CVRA confirms that Namibia's climate is characterized by persistent aridity, pronounced interannual variability, and increasing amplification of extremes. Rising temperatures—projected to increase by 2–4°C by mid-century—are expected to intensify evapotranspiration and reduce effective rainfall, exacerbating already severe water scarcity. Droughts are projected to become more frequent and prolonged, particularly in the central and northern regions where water demand is growing. When rainfall does occur, it is increasingly concentrated in short, high-intensity events, raising risks of flash floods, soil erosion, and damage to rural water infrastructure. These dynamics threaten agricultural productivity, groundwater recharge, and the long-term reliability of bulk water transfer systems that support both rural and urban populations.

The CVRA highlights that the *Kavango Basin* faces growing uncertainty due to more erratic rainfall patterns and increased temperatures. Although comparatively wetter than other regions of Namibia, the basin is highly dependent on precipitation in the Angolan highlands, which generate most of its discharge. Projected reductions in upstream rainfall could reduce downstream flows, affecting water security, riparian ecosystems, and flood-recession agriculture. At the same time, more frequent extreme rainfall events may heighten the risk of riverine flooding in low-lying settlements, damaging intakes, pump stations, and rural water-supply systems.

For the *Kunene Basin*, the CVRA identifies high vulnerability due to the basin's strong seasonality, reliance on Angolan rainfall, and increasing drought likelihood. Projected warming and declining rainfall may reduce river discharge, threatening critical assets such as the Calueque–Oshakati canal system. Although extreme rainfall events may remain infrequent, their projected intensification increases the risks of erosion, slope instability, and structural damage to conveyance infrastructure. Variability in cross-border flows creates additional strategic challenges for bilateral water management and for maintaining reliable supply to northern population centres.

Across both basins, the assessment found that rural households, livestock farmers, small-scale irrigation systems, and bulk water infrastructure (boreholes, pipelines, reservoirs, treatment plants) are highly exposed to climate hazards, with limited redundancy and systemic weaknesses in operation and maintenance. Women, youth, and marginalised groups face disproportionate impacts due to limited access to resources, climate information, and decision-making processes.

Overall, the CVRA results underscore the urgent need to strengthen climate-resilient water resources management, climate-proof critical water infrastructure, diversify supply sources, and reinforce early-warning systems, contingency planning, and community-based adaptation.

In this regard, several priority adaptation needs emerge for strengthening the resilience of water supply, sanitation and WASH-related infrastructure in the Kunene and Kavango regions, as well as along the Okavango Link – CAN Water Supply Project and the Rundu Project. The following section summarises the key needs identified:

Table 2: Key needs identified. Source: Own elaboration considering results from the CRVA

Strengthening drought resilience across both basins	WASH (Water, Sanitation and Hygiene) systems must be designed assuming Moderate–High drought conditions over their full lifetime. This requires expanding raw-water storage, applying conjunctive use of surface and groundwater, and integrating demand-management measures. In groundwater-fed schemes, safeguards such as conservative safe yields, borehole step-testing, and continuous salinity monitoring are essential to reduce depletion and saltwater intrusion risks.
Addressing rising temperatures and heat-related stresses	Persistent and increasing heat requires significant adjustments in project design and operations. Priority needs include: • heat-safe work protocols for operators, • shading and ventilation improvements at pump houses, • equipment and electrical systems selected for high-temperature performance and derating, • thermal protection for control panels and battery banks, and • measures to reduce reservoir and canal evaporation. These elements are critical for maintaining the reliability of water systems under projected temperature increases.
Managing pluvial and riverine flood risks—particularly in the Okavango Basin	The CVRA identifies flash floods from short, high-intensity rainfall as a major hazard. Adaptation needs include strengthening conveyance at known pinch-points, improving stormwater inlet capacity, upgrading drainage systems in exposed settlements, and continuously updating IDF curves for design checks. Additionally, culvert and bridge capacity reviews and systematic drainage maintenance are needed in priority hotspots.
Reducing wildfire, erosion and storm-related infrastructure damage	Both basins require measures to address landscape hazards such as wildfires, dust storms, and erosion surges. Needs include: • vegetation management and defensible space around facilities, shielding or burying critical conduits, fire-weather operating triggers, upgraded HVAC (Heating, Ventilation and Air Conditioning) and filtration systems to manage smoke and particulates, erosion

	protection at vulnerable slopes and crossings, especially along the Okavango Link alignment.
Basin-specific needs for the Kunene Basin	The Kunene Basin is particularly sensitive to seasonal flow intermittency, sediment pulses, and drought-driven declines in recharge. Adaptation needs include flood-proofing and stabilizing riverbank intakes, installing bypass channels, upsizing storage to withstand multi-week low-flow periods, and enhancing conjunctive surface–groundwater operations. For sanitation, raised and sealed containment systems and flood-protected access routes are needed to minimize failure during flash events.
Basin-specific needs for the Okavango Basin	The Okavango system requires adaptation to strongly seasonal hydrology, high sediment loads during pluvial bursts, and flood-prone settlements. Priority needs include resilient intakes set back from the main channel, floating or adjustable screening systems, coarse pre-sedimentation, modular treatment plants with duty–standby configurations, and groundwater monitoring in areas affected by pit latrines. In floodplain areas, sanitation systems must be elevated and located outside hazard zones.
Multi-hazard adaptation priorities across both basins	The CVRA highlights the importance of expanding storage autonomy, improving monitoring systems, implementing raised or flood-proofed assets, protecting power supply and electrical systems, and upgrading drainage and surface-water management structures. Priority constituencies repeatedly identified include Opuwo, Mpungu, Khorixas, Rundu Rural West, Mukwe, and Ndiyona, where multi-hazard pressures converge.
Project-level needs for the Okavango Link – CAN Water Supply Project	Across all sections of the pipeline—from intake to terminal interface—specific design checks are required to address flood, heat, dust, and structural hazards. Key needs include verifying platform elevations, chamber sealing, slope stability, erosion protection at crossings, temperature-corrected heat balance calculations for pump stations, storm-resistant enclosures, and coordinated operational protocols. These ensure resilience along the entire 276 km alignment.
Project-specific needs – Rundu 100-km Rural Water Supply Project	The Rundu service area requires targeted adaptation to combined fluvial flooding, prolonged drought stress and rising temperatures. Key needs include flood-resilient abstraction and treatment infrastructure, elevated and sealed pump stations, increased storage autonomy to buffer supply interruptions, heat-resilient electromechanical equipment, protection of long distribution pipelines crossing flood-prone and erosion-sensitive areas, and strengthened operational protocols for sediment management, low-flow periods and extreme heat events.

Comparative Assessment with World Bank (2021) NbS Catalogue

The World Bank (2021) *Catalogue of Nature-Based Solutions for Urban Resilience* provides a global reference framework for NbS typologies that can be adapted to urban and rural environments facing flood risks, water scarcity, land degradation, and increasing climate variability. For Namibia's arid and semi-arid conditions the most relevant NbS families include permeable surfaces, bio-retentive systems, restored ephemeral channels, riparian buffer systems, natural infiltration structures, sand dams, and constructed wetlands. These solutions support multiple co-benefits, including groundwater recharge, reduced flood peaks, soil retention, improved water quality, microclimate regulation, and enhanced biodiversity.

In contrast, high-water-demand NbS typologies such as large vegetated green roofs, intensive urban parks, and vertical gardens are generally unsuitable for Namibia's climate and water availability but may be piloted on a small scale at selected public buildings or institutions where irrigation and maintenance can be guaranteed.

Table 3: Comparative assessment of World Bank (2021) NbS typologies and their applicability to Namibia

Source: Own elaboration

NbS Typology (World Bank 2021)	Description	Applicability to Namibia	Justification	Replication Potential in CRVA Hotspots
Permeable Pavements	Porous pavers allowing infiltration	High	Works well in sandy, high-infiltration soils; low irrigation needs	Rundu urban hardscapes; school and clinic compounds; informal settlement upgrading
Bioswales & Bio-retention Areas	Vegetated channels capturing runoff	High	Supports stormwater infiltration; drought-tolerant species available	Stormwater corridors; peri-urban runoff management; road edges in hotspot communities
Constructed Wetlands (CW)	Engineered wetlands for water treatment	High	Ideal for wastewater polishing; aligns with Okavango ecology	Small-scale CW in Mukwe, Ndonga Linena, Cuma
Restored Ephemeral Rivers	Stabilization of seasonal channels	High	Namibia has multiple ephemeral systems; increases infiltration	Tributaries feeding Okavango; Mukwe flash-flood zones; erosion-prone channels
Riparian Buffer Restoration	Vegetated strips along rivers	High	CRVA shows riparian degradation; NbS effective with native species	Along Okavango riverbanks—Mukwe, Shadikongoro, Mashare
Floodplain Reconnection	Restoring natural floodplain flow paths	High	Similar hydrology to Cuvelai; reduces flood risks	Low-lying riparian areas in Kavango East
Urban Green Corridors	Linear green strips for cooling	Medium	Viable with drought-tolerant species; requires minimal irrigation	Rundu growth areas; school & health-center buffer zones
Street Trees & Urban Greening	Shade trees and vegetated areas	Medium	Requires drought-resistant native/tree species	Public spaces in Rundu and Divundu
Green Roofs	Vegetated rooftops	Low	High irrigation and structural load requirements	Pilot only on municipal buildings
Vertical Gardens	Vegetated wall systems	Low	Water- and maintenance-intensive	Limited demonstration projects only
Urban Agriculture NbS	Gardens, agroforestry, composting systems	Medium	Works with greywater recycling	Community drip-irrigated gardens in Rundu & Ndiyona

NbS Typology (World Bank 2021)	Description	Applicability to Namibia	Justification	Replication Potential in CRVA Hotspots
Natural Water Retention Measures	Retention basins, infiltration ponds	High	Compatible with local soils, enhances recharge	Shallow aquifer recharge zones in Ndiyona, Mashare
Sand Dams & Subsurface Dams	Water stored in sand-filled channels	High	Proven in Kenya and Ethiopia; ideal for seasonal rivers	Small tributaries in Kavango West
Dune & Rangeland Rehabilitation	Grass reseeding, erosion control measures	High	Namibia already implements similar techniques	Upland erosion hotspots in Kavango West
Rain Gardens / Micro-catchments	Pocket infiltration gardens	Medium	Low water use with native drought-tolerant plants	Schools, clinics, and clustered homesteads
Green Belts & Windbreaks	Rows of drought-resistant trees	High	Reduces wind erosion; lowers evapotranspiration	Rangeland restoration sites in Kavango West

The World Bank NbS Catalogue includes over 50 adaptation measures, of which approximately one-third are particularly suitable for Namibia's arid and semi-arid context. The most relevant measures—aligned with the CRVA findings on flooding, erosion, sedimentation, declining groundwater recharge and land degradation—include permeable pavements, bioswales, constructed wetlands, riparian buffers, natural infiltration ponds, sand and subsurface dams, windbreaks, and rangeland rehabilitation techniques. Other measures such as rain gardens, urban green corridors and agroforestry systems have moderate applicability, whereas intensively irrigated green roofs or vertical gardens are generally less suitable for Namibia, except as small-scale pilots.

Opportunities for replication across CRVA-identified hotspots include the use of flood attenuation and aquifer recharge NbS (bioswales, restored floodplains, infiltration basins, sand dams) in Kavango East; rangeland rehabilitation and ephemeral river restoration in Kavango West; and urban stormwater and recharge solutions (permeable pavements, bioswales, infiltration facilities) in peri-urban Rundu. Collectively, these measures offer scalable, low-maintenance interventions to reduce climate risks and strengthen resilience in the most exposed areas of the two basins.

Review of NbS and Hybrid Adaptation Options Implemented in Namibia

Namibia has adopted several Nature-based and hybrid adaptation solutions in the water sector that combine ecological processes with engineered infrastructure to improve water security, build ecosystem resilience, and reduce vulnerability to climate variability. The following examples highlight measures with proven effectiveness in Namibia, supported by sectoral reports, scientific studies, and project documentation, and demonstrate their potential transferability to the hotspots identified.

Table 4: NbS and Hybrid Adaptation Options Implemented in Namibia
Source: Own elaboration

Title	Type of Measures	Description	Relevance and Transferability to CRVA Hotspots
Managed Aquifer Recharge	Hybrid adaptation; infrastructure–nature interface;	Windhoek's Managed Aquifer Recharge system injects highly treated surface water and reclaimed wastewater into the	The CRVA identified declining groundwater recharge, stressed boreholes, and climate-driven variability in

Title	Type of Measures	Description	Relevance and Transferability to CRVA Hotspots
(MAR) – Windhoek	artificial recharge; groundwater protection; monitoring systems.	Windhoek Aquifer to create a strategic drought buffer. According to *City of Windhoek Water Management Reports* and *GIZ-supported MAR feasibility studies* (2008–2022), this system integrates engineered injection wells, infiltration basins, and natural aquifer storage to enhance groundwater availability during multi-year droughts. Independent assessments by CSIR and associated scientific studies confirm that the MAR scheme increases aquifer resilience, reduces over-abstraction, and stabilizes water security in a hyper-arid urban environment.	shallow aquifers in areas including Ndiyona, Mpungu, and Mashare. While large-scale MAR like in Windhoek may not be feasible, the principles are transferable through small-scale infiltration trenches, sand dams, managed recharge basins, and direct infiltration zones. These locally adapted MAR solutions can strengthen drought resilience and stabilize rural water supplies in groundwater-dependent settlements.
Basin Management Committees (BMCs) under the Water Resources Management Act	Governance-based NbS; catchment restoration; erosion control; institutional strengthening; community ecosystem management.	BMCs, mandated through the *Water Resources Management Act (2013)* and described in the *Integrated Water Resources Management Plan (MAWLR, 2010)*, implement a range of ecosystem-based adaptation measures including erosion control, wetland restoration, controlled grazing, riverbank stabilization, and coordinated land-use planning. Project documentation from various basins (e.g., Kuiseb, Omaruru) demonstrates that BMC-led interventions improve soil retention, reduce sediment loads, strengthen riparian ecosystems, and enhance local stewardship of water resources.	The CRVA for Kavango East and West identified multiple hotspots exposed to riverbank erosion, riparian vegetation loss, and degradation of natural floodplains along the Okavango River. The BMC approach is highly transferable, as it complements existing community structures and supports co-management of vulnerable ecological buffers. Applying similar governance-led NbS in Mukwe, Ndonga Linena, and Mashare would enable riparian restoration, reduce erosion risk, and improve ecosystem resilience to extreme climate events.
Cuvelai–Etosha Floodplain Management	Ecosystem-based flood management; wetland restoration; natural retention systems; vegetated floodways; hybrid drainage.	The Cuvelai–Etosha floodplain system—documented in *MAWLR's Cuvelai Basin Flood Management Plans* and *UNDP/GEF-supported flood resilience projects (2012–2020)* integrates vegetation-lined flood channels, natural drainage networks, wetland buffers, and rehabilitated oshanas to slow, disperse, and filter floodwaters. These NbS interventions reduce structural damage, maintain	The lower Okavango River floodplain exhibits similar hydrological behaviour, and the CRVA identified recurrent seasonal flooding, sedimentation, and inundation risks in riparian communities such as Mukwe and Ndiyona. The Cuvelai model is directly transferable: vegetated floodways, natural retention zones, wetland buffer strips,

Title	Type of Measures	Description	Relevance and Transferability to CRVA Hotspots
		ecological function, and support local livelihoods by preserving wetland productivity.	and community-managed drainage wetlands could be adapted to Kavango's flood-prone zones to reduce flood intensity while maintaining ecological integrity.
Ohangwena II (KOH-2) Transboundary Aquifer Protection	Groundwater protection zoning; land-use regulation; recharge-zone conservation; monitoring; hydrogeological mapping.	Studies of the KOH-2 transboundary aquifer by *MAWLR and the Federal Institute for Geosciences and Natural Resources (BGR)* emphasize groundwater protection through mapped recharge zones, restricted land uses, pollution controls, and continuous water-quality monitoring. Project documentation and technical reports highlight the importance of regulating agricultural expansion, settlements, and borehole density around sensitive recharge areas.	The CRVA identified contamination risks, especially near peri-urban Rundu, and stressed aquifers in areas where land-use pressure is increasing. The KOH-2 experience provides a transferrable model for: • Groundwater protection zoning • Regulating settlement encroachment • Protecting recharge zones along the Okavango River • Monitoring abstraction and water quality

Regionally and globally tested NbS and hybrid solutions for arid contexts

Namibia can draw valuable lessons from a range of successful adaptation practices implemented in other arid and semi-arid regions worldwide. These solutions combine engineered designs with natural processes to enhance water security, reduce climate risks, and build ecosystem resilience. The following examples drawn from Africa, the Middle East, Australia, and the southwestern United States highlight approaches that are particularly relevant and transferable to the CRVA-identified hotspots.

Table 5: Regionally and Globally Tested NbS and Hybrid Solutions for Arid Contexts
Source: Own elaboration

Title	Regions	Key sources	Practical Example	Relevance to hotspots
Groundwater Recharge and Protection Zones through Vegetated Infiltration Basins	India (Rajasthan), Middle East (Jordan), Australia (Western Australia)	CSIRO (Australia), Jordan Water Authority, ICRISAT (India), FAO case studies	In Rajasthan, India, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has implemented vegetated recharge basins, check dams, and infiltration trenches to enhance monsoon infiltration and restore depleted aquifers. Local vegetation such as vetiver and acacia stabilize infiltration zones	Similar infiltration-based recharge zones could strengthen groundwater resilience in areas where the CRVA identified declining borehole yields notably Ndiyona, Mashare, and areas west of Nkurenkuru.

Title	Regions	Key sources	Practical Example	Relevance to hotspots
			and reduce sedimentation. Outcomes include measurable increases in groundwater levels, improved well yields, and reduced dry-season water shortages. In Jordan, the Water Authority implemented recharge zoning and protected abstraction areas, supported by vegetation buffers around wadis to reduce contamination and improve infiltration.	
Ephemeral River and Floodplain Restoration	Sahel (Burkina Faso, Niger), Southwestern United States (Arizona, New Mexico), South Africa (Namaqualand)	USGS, UNEP Sahel Ecosystem Restoration Programme, South African Water Research Commission	In Niger and Burkina Faso, the UNEP-supported Farmer-Managed Natural Regeneration (FMNR) and zai pit systems restore ephemeral riverbanks and improve infiltration during flash floods. These interventions have reduced soil erosion, increased infiltration, and improved agricultural productivity in extremely dry environments. In Arizona (USA), the Watershed Management Group restored ephemeral streams using one-rock check dams, gabions, and vegetated buffers, resulting in reduced flash flood velocity and improved soil moisture.	The lower Okavango experiences similar seasonal flash flooding. These practices support sediment control, infiltration enhancement, and reduced flood energy—highly applicable to Mukwe, Shadikongoro, and surrounding riparian communities.
Soil and Rangeland Rehabilitation (Contour Bunds, Vetiver Grass, Reseeding)	Sahel (Niger, Mali), Kenya (Laikipia), Ethiopia (Tigray), South Africa (Limpopo)	FAO, UNEP, World Agroforestry Centre, African Rangelands Initiative	The Tigray Region of Ethiopia implemented large-scale soil and water conservation using contour bunds, vetiver strips, half-moons, and reseeding. Evaluations by FAO and the Ethiopian Ministry of Agriculture show reductions in erosion, increased soil	CRVA results highlighted erosion, declining vegetation cover, and land degradation especially in communal rangelands. Similar measures could stabilize soils, support water retention, and strengthen ecosystem productivity in Kavango

Title	Regions	Key sources	Practical Example	Relevance to hotspots
			moisture, and the recovery of degraded grazing lands. In Niger, contour bunds increased infiltration and re-greened previously barren rangelands across hundreds of thousands of hectares.	West and the upland areas of Kavango East.
Water-Sensitive Urban Design (WSUD) with Drought-Tolerant Bioswales & Permeable Surfaces	Australia (Perth, Adelaide), United States (Nevada, Arizona), Middle East (Dubai)	CSIRO WSUD Framework, Australian National Water Commission, US EPA Green Infrastructure reports	In Perth, Australia, local governments integrated bioswales, permeable pavements, rain gardens, and drought-resistant native vegetation into municipal water planning. These systems reduce stormwater runoff, enhance infiltration, lower heat stress, and improve groundwater recharge. CSIRO reports show that WSUD interventions significantly reduced urban flooding and improved aquifer recharge in sandy, semi-arid environments.	Urbanizing centers like Rundu face rising flooding risks, stormwater management challenges, and groundwater pressure. WSUD principles could be adapted using local species (e.g., Terminalia, Acacia, Hyphaene palms) to create green corridors and infiltration zones.
Hybrid Evaporation Loss Reduction (Vegetative Shading + Windbreaks + Reservoir Compartmentalization)	Middle East (Oman, UAE, Saudi Arabia), Australia, Southwestern USA	International Water Management Institute (IWMI), Desert Research Institute (Nevada), Australian Water Corporation	In Saudi Arabia, IWMI-led trials used windbreaks (Prosopis, Acacia) combined with reservoir compartmentalization and surface shading structures to reduce evaporation losses from water storage facilities. Similar hybrid systems in Western Australia reduced evaporation by up to 30%, according to trials by the Australian Water Corporation.	Evaporation from small reservoirs and open tanks is a growing issue in Kavango East and West. Implementing vegetative shading, local windbreak species, and compartmentalized storage could significantly reduce losses in community water schemes and agricultural points.

Findings from literature review and data sources

This review draws upon a comprehensive set of national and international references to ensure analytical robustness and alignment with established climate-planning frameworks. Core national documents include reports to the UNFCCC such as *Namibia's Fourth National Communication (NDC) (2020)*, the *Second Update of the Nationally Determined Contribution (NDC) (2023)*, as well as sectoral strategies, plans and policies such as the *National Climate Change Policy (2011)*, the *Water Resources Management Act 11 of 2013*, and the *Integrated Water Resources Management Plan (IWRMP) (2010)*. It also integrates insights from the *GCF Readiness Proposal on Adaptation Planning and Coordination (2023)* and relevant sectoral strategies and investment plans. Across these sources, key adaptation measures were identified, forming the basis for the proposed recommendations.

Table 6: Summary of key documents reviewed and adaptation measures identified. Source: Own elaboration

Document / Year	Summary / Focus	Key Adaptation Measures Identified
Reports to the UNFCCC		
Namibia's Fourth National Communication (NC4) to the UNFCCC (2020)[8]	Namibia's NC4 (2020) presents updated national circumstances, greenhouse gas inventories, and evidence of rising climate risks, particularly droughts and water scarcity. It outlines vulnerabilities across key sectors such as agriculture, energy, health and ecosystems, and evaluates ongoing and planned adaptation and mitigation measures. The document emphasizes Namibia's commitment to a low-carbon, climate-resilient development pathway, while underscoring persistent gaps in institutional capacity, data systems and finance, and calling for strengthened international support to meet UNFCCC obligations.	Namibia's NC4 identifies priority water-sector adaptation measures including conjunctive use of surface and groundwater, stricter groundwater control, improved water-demand management, and stronger legal and institutional frameworks. Additional measures include flood-mitigation infrastructure, rainwater harvesting, wastewater reuse, expanded monitoring systems, sustainable irrigation, transboundary cooperation, and renewable-energy-powered desalination pilots, all aimed at enhancing long-term water security under increasing climate variability.
Namibia's Nationally Determined Contribution (NDC) Second Update (2023)[9]	Namibia's 2023 NDC update strengthens its mitigation and adaptation commitments for 2021–2030, aiming to enhance its national sink capacity while addressing high climate vulnerability. It outlines economy-wide mitigation across all IPCC sectors and introduces 36 priority adaptation measures. The update emphasizes water scarcity, recurrent droughts, social inequalities, gender integration, and the need for substantial international finance, technology and capacity support to meet its Paris Agreement obligations.	Namibia´s NDC has identified 5 water-sector measures, comprising 12 actions to be implemented by 2030: Measure 1: Integrated Water Resources Management Plan • Quantify hydrological resources (surface and groundwater). • Develop a national water resources management plan. Measure 2: Water Infrastructure Development, Maintenance and Rehabilitation • Rehabilitate existing water points. • Construct new boreholes. • Extend water-supply infrastructure. • Improve rural water-supply coverage. • Construct reservoirs and dams. Measure 3: Water Recycling

[8] Namibia's Fourth National Communication (NC4) to the UNFCCC (2020)

[9] Namibia's Nationally Determined Contribution (NDC) Second Update (2023)

		• Develop reticulation systems for secondary wastewater treatment in 10 towns of 40,000 people. • Reuse treated water for agriculture, industry, or aquifer recharge. • Install stand-alone water-treatment systems for 100,000 households. Measure 4: Establishment and Restoration of Riparian Buffers • Establish and/or restore 5,000 ha of Okavango riparian buffer. Measure 5: Desalination • Commission six coastal or inland desalination systems to treat sea or brackish water.
Sectoral strategies, plans and policies		
National Policy on Climate Change/ National Climate Change Policy for Namibia (NCCP) (2011)[10]	Namibia's National Climate Change Policy (2011) establishes a national framework to guide adaptation and mitigation, recognizing the country's extreme vulnerability to droughts, water scarcity, and climate variability. It prioritizes safeguarding natural resources, strengthening institutional capacity, mainstreaming climate change across sectors, enhancing disaster risk management, and ensuring sustainable development. The policy emphasizes evidence-based planning, public awareness, technology transfer, and securing financial resources to protect vulnerable populations and support long-term climate-resilient development.	The policy highlights water as Namibia's most critical resource and prioritizes adaptation measures that secure sustainable access. Key measures include expanding water harvesting and capture during rainy periods, improving efficient water use across sectors, strengthening integrated water resources management, protecting and managing scarce groundwater, and enhancing planning to reduce risks from prolonged droughts and evaporation losses. These interventions aim to safeguard water security amid worsening climate variability.
Water Resources Management Act 11 of 2013[11]	The Water Resources Management Act 11 of 2013 establishes Namibia's legal framework for the sustainable management, development, protection and conservation of all water resources. It mandates equitable access to safe water, integrated water resources management, pollution control, groundwater protection, dam safety regulation, efficient water-services oversight, and enhanced data collection. It also strengthens	Adaptation-relevant measures in the Act include strengthening integrated water resources management; protecting aquifers and controlling groundwater abstraction; preventing pollution and enforcing effluent-discharge licensing; safeguarding riparian zones and wetlands; establishing water protection areas; regulating dam safety and flood-risk prevention; and improving water-demand management through conservation and efficiency strategies. These provisions support long-term

[10] National Policy on Climate Change/ National Climate Change Policy for Namibia (NCCP) (2011)

[11] Water Resources Management Act 11 of 2013

	institutional governance through basin committees, a Water Regulator, and clear licensing systems for water use and effluent discharge.	climate resilience by securing water availability, reducing environmental degradation, and improving overall water governance across Namibia.
Integrated Water Resources Management Plan (IWRMP) (2010)[12]	The 2010 IWRMP provides Namibia's national framework for sustainably managing scarce water resources under increasing climatic variability. It outlines principles, sector priorities, and a comprehensive Strategy and Action Plan focused on policy reform, institutional strengthening, stakeholder engagement, resource assessment, water demand management, monitoring, and investment. The plan emphasizes efficient infrastructure operation, groundwater protection, unconventional water sources, and adaptive management to ensure long-term water security.	Adaptation-linked measures include upgrading and constructing water infrastructure, improving water-supply scheme efficiency, promoting demand management, expanding research on groundwater and artificial recharge, enhancing flood-management capacity, and improving hydrological monitoring, modelling, and data systems. The plan also prioritizes unconventional water sources such as seawater desalination, continuous awareness-raising, and capacity building for new technologies, all essential to strengthen resilience under increasing climatic stress.
GCF Readiness Proposal: Strengthening Adaptation Planning and Coordination in Namibia (2023)[13]	Namibia's 2023 GCF Readiness Proposal seeks to strengthen national and sub-national adaptation planning by improving governance, coordination, data systems, and capacity. It targets vulnerabilities driven by droughts, aridity and water scarcity, aiming to mainstream adaptation across sectors, enhance stakeholder engagement, and create enabling conditions for private-sector participation. The proposal also develops financing strategies, tracking mechanisms and institutional arrangements to guide the National Adaptation Plan.	Although not a water-specific project, the proposal identifies key adaptation priorities relevant to water planning, including strengthening governance for water and agriculture, improving access to hydrological and vulnerability data, integrating climate risks into water-sector planning, enhancing early-warning systems for drought and floods, and supporting decentralized adaptation capacity. It also draws on lessons from water-related projects such as drought-resilient water-point rehabilitation and pilot desalination initiatives.

The resulting analysis provides a comprehensive foundation for developing the Adaptation Options Inventory presented in the subsequent section, which consolidates all relevant measures existing, proposed, or emerging that can enhance water security and climate resilience.

4.3 Adaptation Options inventory

The main purpose of this section is to present a structured inventory of adaptation measures that could be applied within Namibia's water sector, particularly in the Kunene and Okavango basins and along the Okavango Link, and within the Rundu water supply system and its surrounding rural service area. This inventory serves as a key reference tool for identifying feasible interventions, assessing implementation gaps, and supporting the prioritization of future climate-resilient investments.

The inventory consolidates diverse adaptation initiatives classified under four strategic areas that encompass the main adaptation priorities:

[12] Integrated Water Resources Management Plan (IWRMP) (2010)

[13] GCF Readiness Proposal: Strengthening Adaptation Planning and Coordination in Namibia (2023)

Water Resources and Infrastructure Resilience (WR)

ID	Adaptation Measure / Project	Type	Geographic Coverage	Lead Institution(s)	Status / Remarks	Description	Source	Rationale for application to basins, hotspots and priority projects
WR1	Windhoek Managed Aquifer Recharge (MAR)	Hybrid	Windhoek & Central Area	City of Windhoek, NamWater, MAWLR	Operational; improves drought resilience	Hybrid system injecting treated surface and reclaimed water into the Windhoek Aquifer to build strategic reserves and stabilize supply during multi-year droughts.	National project reports (CoW, GIZ, CSIR); literature review	CRVA results identified increasing groundwater stress and prolonged drought conditions across northern Namibia. While implemented in Windhoek, the MAR approach provides transferable principles for strategic groundwater recharge, drought buffering and storage management that are relevant for informing climate-resilient groundwater planning across multiple basins and projects.
WR2	Water Reuse and Recycling Programme	Hybrid	Urban centers nationwide	City of Windhoek, NamWater	Implemented and expanding	Reuse of treated wastewater for non-potable uses (industry, irrigation) and, in some cases, indirect potable reuse to reduce pressure on freshwater sources.	National water-sector documentation; city-level plans	CRVA identifies increasing water demand, climate-driven variability in supply, and infrastructure stress. Reuse and recycling programs can reduce abstraction from vulnerable sources and free water for climate-stressed hotspots.
WR3	Drought-Proof Rural Water Supply Schemes	Engineering + NbS	Northern Communal Areas	MAWLR – Rural Water Supply Directorate	Ongoing; includes solar boreholes and storage	Development and upgrading of rural schemes combining solar-powered boreholes, elevated storage tanks, and in some cases protective fencing and basic recharge/erosion control around infrastructure.	MAWLR RWS program reports; donor project documents	CRVA findings showed that rural communities in the Kunene Basin face high exposure to prolonged droughts, groundwater depletion and service interruptions. Climate-resilient rural schemes combining solar-powered boreholes, elevated storage and basic nature-based protection directly address these vulnerabilities in dispersed settlements.
WR4	Building Smarter Water Intakes	Engineering	Okavango basin	To be defined during project design	New – Proposed Project	Installation of stronger, smarter water intake systems designed to withstand climate change-exacerbated riverine floods. Measures include elevating intake structures above known flood levels or moving them to safer locations, sediment traps, and automated shut-off valves to protect the wider water system from sediment blockage when floodwaters are high.	Identified need based on CRVA findings	CRVA findings identified recurrent fluvial flooding, sediment surges and riverbank erosion along the Okavango River. Smart intake systems reduce sediment ingress, limit flood-related damage and improve operational continuity in flood-prone basin reaches.

ID	Adaptation Measure / Project	Type	Geographic Coverage	Lead Institution(s)	Status / Remarks	Description	Source	Rationale for application to basins, hotspots and priority projects
						Water level sensors and remote monitoring systems (SCADA) will trigger automated sediment protection systems. Pump units will feature strong anchors and debris deflection to resist impact damage and where installed below the flood line will feature equipment suitable for submersion. Pump station intake will be positioned at the lowest feasible point. Electrical and mechanical systems are climate-proofed to withstand increased ambient temperatures, including appropriate motor selection (e.g. SynRM), liquid or water-cooled equipment where feasible, effective natural ventilation and HVAC systems dimensioned for future climate conditions. Infrastructure design considers suitable materials, protection of pipelines from thermal exposure, safe housing of disinfection equipment, and electrical network specifications accounting for de-rating and insulation degradation under higher temperatures.		
WR5	Submerged River Intake Pumps	Engineering	Okavango basin	**To be defined during project design**	New – Proposed Project	Installation of reinforced, submersible and auto-filtering water pumps in the Okavango River. The solution is the	Identified need based on CRVA findings	CRVA analysis showed increasing exposure of river abstractions to fluctuating water levels, debris and sedimentation. Submerged and reinforced intake pumps reduce vulnerability by operating below dynamic flood

ID	Adaptation Measure / Project	Type	Geographic Coverage	Lead Institution(s)	Status / Remarks	Description	Source	Rationale for application to basins, hotspots and priority projects
						installation of heavy-duty, smart submersible pumps that operate safely below the water's surface, avoiding shifting water levels and floating debris. The pumps will benefit from reinforced housing to withstand the force of floodwaters and debris, special filters and anti-clogging systems to handle sediment surges and will anchor in the safest spots identified by a river survey and always deep below the water level. Electrical and mechanical systems are climate-proofed to withstand increased ambient temperatures, including appropriate motor selection (e.g. SynRM), liquid or water-cooled equipment where feasible, effective natural ventilation and HVAC systems dimensioned for future climate conditions. Infrastructure design considers suitable materials, protection of pipelines from thermal exposure, safe housing of disinfection equipment, and electrical network specifications accounting for de-rating and insulation		conditions, improving abstraction reliability in the Okavango Basin.

ID	Adaptation Measure / Project	Type	Geographic Coverage	Lead Institution(s)	Status / Remarks	Description	Source	Rationale for application to basins, hotspots and priority projects
						degradation under higher temperatures.		
WR6	Strategic emergency water storage	Engineering	Kunene basin	**To be defined during project design**	New – Proposed Project	Creation of strategic emergency water storage to guarantee water provision for at least two days during water cuts caused by climate change-exacerbated droughts or damages to water management systems. Measures include constructing or expanding new and existing water reservoirs at elevation and ground level and connecting these reservoirs to existing and planned rural water schemes, along with smart controls such as monitoring systems to manage water release efficiently during emergencies. Pipes will be encased in concrete where pipelines pass through rivers to protect against flash flooding, and the electromagnetic water meters will be specified to be submergible where installed below ground level. Finally, reservoirs must have a sufficient water level to prevent excessive expansion and contraction during elevated ambient air temperatures, which may cause leaks.	Identified need based on CRVA findings	The CRVA identified limited storage capacity and high sensitivity to multi-week dry periods in the Kunene Basin. Strategic emergency storage increases system autonomy and buffers acute supply interruptions during drought-dominated conditions.

ID	Adaptation Measure / Project	Type	Geographic Coverage	Lead Institution(s)	Status / Remarks	Description	Source	Rationale for application to basins, hotspots and priority projects
WR7	Backup Power for Water Pumps	Engineering	Kunene and Okavango basins, with priority application along the Okavango Link (CAN Water Supply Project) and within the Rundu water supply system (urban and rural schemes).	To be defined during project design	New – Proposed Project	Reinforcement of pumping stations' power supply and operational resilience against climate-exacerbated power outages and extreme weather. Measures include auto-switching battery backup systems (minimum 48-hour autonomy), preferably paired with solar panels, surge protection in motor control centers (MCCs), and switchgear protection against lightning strikes. End-user water storage of at least 48 hours is provided to buffer supply interruptions. Electrical and mechanical systems are climate-proofed to withstand increased ambient temperatures, including appropriate motor selection (e.g. SynRM), liquid or water-cooled equipment where feasible, effective natural ventilation and HVAC systems dimensioned for future climate conditions. Infrastructure design considers suitable materials, protection of pipelines from thermal exposure, safe housing of disinfection equipment, and electrical network specifications accounting for de-rating and insulation	Identified need based on CRVA findings	CRVA findings indicated that climate-exacerbated heat, storms and flooding increase the frequency of power outages, directly affecting water pumping operations. Backup power systems enhance operational continuity and resilience of water services across basins, linear infrastructure and nodal systems, making this a cross-cutting priority.

ID	Adaptation Measure / Project	Type	Geographic Coverage	Lead Institution(s)	Status / Remarks	Description	Source	Rationale for application to basins, hotspots and priority projects
						degradation under higher temperatures.		
WR8	Climate-Resilient Upgrade of Rundu Water Treatment Plant (WTP)	Engineering	Rundu	To be defined during project design	New – Proposed Project	Climate-proofing of the existing and new Rundu WTP to address heat stress, flooding and turbidity spikes. Measures include elevated electrical rooms, flood-protected platforms, modular duty–standby treatment units, enhanced pre-sedimentation, and thermal protection of control systems.	Identified need based on CRVA findings and project-level climate screening	CRVA highlights high fluvial flood exposure, sediment loads and rising temperatures in Rundu. Upgrading the WTP is critical for maintaining potable water supply reliability under multi-hazard conditions.
WR9	Distributed Storage and Pressure-Zone Reinforcement for Rundu Rural Supply (100 km radius)	Engineering	Rundu	To be defined during project design	New – Proposed Project	Installation of elevated sectional steel tanks and reinforced ground reservoirs providing minimum 48-hour storage autonomy, linked to rural schemes supplied from Rundu. Includes pressure zoning to reduce pipe failures during drought and heat extremes.	Identified need based on CRVA findings and project-level climate screening	CRVA highlighted recurrent drought stress and service interruptions in Rundu's rural supply area. Distributed storage and pressure management enhance resilience under prolonged dry spells and heat extremes.
WR10	Heat-Resilient Pumping Stations and Electrical Systems for Rundu Supply Network	Engineering	Rundu	To be defined during project design	New – Proposed Project	Retrofitting of pump stations with heat-resistant motors, HVAC sized for future temperatures, shaded structures, surge protection, and derating-compliant electrical components. Includes protection of disinfection systems against thermal degradation.	Identified need based on CRVA findings and project-level climate screening	CRVA projections showed rising temperature extremes threatening electro-mechanical systems. Heat-resilient retrofits reduce failure rates and extend asset life in Rundu's water network.
WR11	Flood-Resilient River Abstraction	Engineering	Rundu	To be defined during project design	New – Proposed Project	Reinforcement of intake structures through submerged or adjustable intakes, debris	Identified need based on CRVA findings and	CRVA results indicated high fluvial flood exposure at Rundu's abstraction point. Flood-resilient intake protection reduces operational disruption and infrastructure damage during high-flow events.

ID	Adaptation Measure / Project	Type	Geographic Coverage	Lead Institution(s)	Status / Remarks	Description	Source	Rationale for application to basins, hotspots and priority projects
	and Intake Protection at Rundu					screens, anti-clogging filters, bank stabilization, and erosion protection. Includes remote shut-off systems during extreme flood events.	project-level climate screening	
WR12	Climate-Resilient Conjunctive Surface–Groundwater Operations	Hybrid	Kunene Basin	To be defined during project design	New – Proposed Project	Design and implement conjunctive operation schemes that combine surface water and groundwater sources to optimise supply reliability under highly variable hydrological conditions. Measures include defining operational rules for source switching during drought periods, setting abstraction thresholds based on river flows and groundwater levels, integrating strategic storage to buffer low-flow periods, and strengthening basic hydrological and groundwater monitoring to support adaptive operation.	Identified need based on CRVA findings and project-level climate screening	CRVA results highlighted strong seasonal flow intermittency and declining recharge in the Kunene Basin. Conjunctive use of surface and groundwater sources reduces reliance on single abstractions and enhances drought resilience under highly variable hydrological conditions.
WR13	Climate-Resilient Pipeline Crossings and River Interfaces	Engineering	Okavango Link	To be defined during project design	New – Proposed Project	Upgrade and climate-proof pipeline crossings and river interfaces along the Okavango Link alignment to reduce flood and erosion risks. Measures include reinforced foundations and encasement at river crossings, scour and erosion protection at embankments and slopes, verification of hydraulic capacity under extreme flood scenarios, and stabilization of erosion-prone sections to prevent structural	Identified need based on CRVA findings and project-level climate screening	CRVA results highlighted river crossings and erosion-prone sections as critical vulnerability points along linear infrastructure. Climate-resilient crossing design reduces flood, scour and structural failure risks along the Okavango Link alignment.

ID	Adaptation Measure / Project	Type	Geographic Coverage	Lead Institution(s)	Status / Remarks	Description	Source	Rationale for application to basins, hotspots and priority projects
						damage and service interruptions.		
WR14	Heat, Dust and Wildfire Protection for Linear Infrastructure	Engineering	Okavango Link	To be defined during project design	New – Proposed Project	Protect linear water infrastructure against extreme heat, dust exposure and wildfire risks. Measures include selecting heat-rated mechanical and electrical equipment, providing shading and ventilation at critical installations, sealing and filtering control panels against dust and smoke, implementing vegetation clearance and firebreaks along exposed corridors, and applying operational restrictions during extreme heat or fire-weather conditions.	Identified need based on CRVA findings and project-level climate screening	CRVA projections identified increasing heat, wildfire risk and dust exposure along surface infrastructure corridors. Protective measures enhance operational reliability and reduce climate-related damage along the pipeline alignment.

Catchment and Groundwater Protection (CG)

ID	Adaptation Measure / Project	Type	Geographic Coverage	Lead Institution(s)	Status / Remarks	Description	Source	Rationale for application to basins, hotspots and priority projects
CG1	Basin Management Committees (BMCs) for IWRM	Enabling / NbS	Cuvelai, Kuiseb, Okavango, Omatako	MAWLR, Basin Agencies	Active in multiple basins; promoting ecosystem protection	Decentralized basin-level governance structures coordinating land-use, erosion control, wetland restoration, and catchment protection measures.	Water Resources Management Act; IWRMP; basin reports	CRVA results showed that land-use pressures, erosion and ecosystem degradation amplify climate risks across multiple basins. Basin-level governance mechanisms support coordinated planning, ecosystem protection and adaptive management, strengthening resilience beyond individual projects or locations.
CG2	Ohangwena II (KOH-2) Transboundary Aquifer Study	Hybrid (technical + regulatory)	Ohangwena & Omusati	MAWLR, BGR, SADC-GMI	Ongoing; includes recharge-zone protection plans	Hydrogeological assessment and protection zoning for the deep Kalahari/Ohangwena II aquifer, including	MAWLR–BGR technical reports; regional groundwater studies	CRVA highlights groundwater contamination risks and pressure on shallow aquifers (e.g. near Rundu). KOH-2 approaches offer a transferable model for groundwater-source protection and recharge zoning in Kavango hotspots.

ID	Adaptation Measure / Project	Type	Geographic Coverage	Lead Institution(s)	Status / Remarks	Description	Source	Rationale for application to basins, hotspots and priority projects
						monitoring, land-use controls and recharge-area conservation.		
CG3	Riparian Buffer Zones and Wetland Rehabilitation	NbS	Okavango and Kunene basins	To be defined during project design	Planned	Restoration of riverbanks and wetlands using natural solutions to reduce soil erosion and improve water retention during heavy rains made more frequent and volatile by climate change. Measures include replanting native trees and plants along vulnerable stretches to hold the soil in place during flash floods and restoring degraded wetlands and their ability to retain water during heavy rains. The programs will be delivered in close partnership with local communities via stewardship agreements which continually protect these critical zones. Success will depend on partnering with Traditional Authorities and local environmental agencies in order to obtain permission and set up long-term monitoring systems.	Identified need based on CRVA findings	CRVA results highlighted erosion and wetland degradation as key drivers of sedimentation and flood impacts. Riparian restoration enhances natural buffering, improves water quality and reduces flood damage within the basin.

ID	Adaptation Measure / Project	Type	Geographic Coverage	Lead Institution(s)	Status / Remarks	Description	Source	Rationale for application to basins, hotspots and priority projects
CG4	Groundwater Protection and Monitoring around Rundu	Hybrid	Rundu peri-urban and rural areas	To be defined during project design	New – Proposed Project	Establishment of groundwater protection zones, systematic water-quality monitoring (salinity, nitrates), and regulation of pit latrine siting near abstraction points.	Identified need based on CRVA findings	CRVA identified risks to shallow aquifers near Rundu due to drought stress and sanitation pressures. Protection measures safeguard long-term groundwater availability.
CG5	Community Rainwater Harvesting & Soil Conservation	NbS	Kavango, Omaheke, Otjozondjupa	NGOs, MEFT, GIZ – BMCC / CCIU-EU	Implemented since 2018	Community-led interventions using rooftop and surface rainwater harvesting, contour bunds, mulching and small-scale soil conservation to improve water availability and reduce erosion.	Donor project reports (GIZ BMCC/CCIU-EU); NGO documentation	CRVA highlighted land degradation, erosion and rainfall variability affecting water availability and livelihoods. Community-led rainwater harvesting and soil conservation reduce runoff and enhance soil moisture resilience under variable climate conditions.

Flood and Drought Risk Management (FD)

ID	Adaptation Measure / Project	Type	Geographic Coverage	Lead Institution(s)	Status / Remarks	Description	Source	Rationale for application to basins, hotspots and priority projects
FD1	Cuvelai–Etosha Floodplain Management	NbS	Northern Namibia	MAWLR, UNDP, DMS	Implemented; focuses on oshana drainage and flood mitigation	Ecosystem-based flood management using vegetated floodways, drainage channels, wetland buffers and community-based preparedness to reduce flood risk while maintaining ecological functions.	Cuvelai flood management plans; UNDP/GEF project reports	CRVA identified similar floodplain dynamics in the Okavango. Transferable ecosystem-based flood management approaches reduce flood impacts while maintaining ecological functions in basin hotspots.
FD2	Green Infrastructure for Stormwater Management	Hybrid	Windhoek and regional towns	Local Authorities, MEFT	Pilot projects using bioswales and permeable paving	Application of permeable pavements, bioswales, bio-retention areas and vegetated channels to reduce	Local authority project documentation; World Bank NbS Catalogue	CRVA notes growing urban and peri-urban flood risk (e.g. around Rundu). Green infrastructure solutions can be replicated to reduce flash flooding and improve infiltration in hotspot settlements.

ID	Adaptation Measure / Project	Type	Geographic Coverage	Lead Institution(s)	Status / Remarks	Description	Source	Rationale for application to basins, hotspots and priority projects
						runoff, enhance infiltration and lower urban flood risk.		
FD3	Artificial Recharge and Small Dams Rehabilitation	Hybrid	National	NamWater, AfDB, GCF	Planned under national water-security investment	Rehabilitation of small dams, introduction of controlled artificial recharge structures and improved operation to reduce evaporation losses and increase resilience during drought.	NWSIP II and related AfDB/GCF project documents	CRVA projections indicated increasing drought frequency and declining natural storage in Kunene. Rehabilitation of small dams and localized recharge structures improves water retention, reduces evaporation losses and strengthens long-term drought preparedness.
FD4	Community-Based Early Warning Systems	Engineering / Institutional	Rural communities in the Okavango Basin	To be defined during project design	New – Proposed Project	Creation of early warning system, incorporating climatic and fluvial monitoring stations, lines of accessible communication and community-led emergency protocols. Creation of community-focused early warning system and emergency protocols for local community leaders. Measures include the design of critical alerts, warning messaging, clear action plans and emergency protocols for floods and droughts. Warning systems will alert villagers to incoming flood or droughts using SMS and local radio in an	Identified need based on CRVA findings	CRVA results indicated limited warning capacity for floods and droughts in rural Okavango communities. Community-based early warning systems enable timely response and reduce climate impacts at settlement level.

ID	Adaptation Measure / Project	Type	Geographic Coverage	Lead Institution(s)	Status / Remarks	Description	Source	Rationale for application to basins, hotspots and priority projects
						accessible format with clear action plans and must connect with national warning frameworks. Emergency protocols will be developed via collaboration with and training of local disaster committees.		
FD5	Urban and Peri-Urban Drainage Upgrades for Rundu	Engineering / Hybrid	Rundu	To be defined during project design	New – Proposed Project	Upgrade of stormwater drainage systems, culverts and road crossings to accommodate short-duration, high-intensity rainfall. Includes erosion protection and routine maintenance protocols.	Identified need based on CRVA findings	CRVA identified pluvial flash flooding as a growing risk in Rundu. Drainage upgrades protect WASH assets and improve service continuity during intense rainfall.
FD6	Early Warning and Emergency Response System for Rundu Water Supply	Engineering / Institutional	Rundu	To be defined during project design	New – Proposed Project	Installation of hydrometeorological and river-level monitoring stations linked to early warning protocols for droughts and floods, with clear operational triggers for water utilities and communities.	Identified need based on CRVA findings	CRVA highlighted limited warning capacity for floods and droughts. Early warning systems improve preparedness and reduce service disruption.
FD7	Flood-Proofed Rural Sanitation and Access Protection	Hybrid	Kunene basin	To be defined during project design	New – Proposed Project	Flood-proof rural sanitation facilities and access routes to reduce service failure and public health risks during flash flood events. Measures include elevating and	Identified need based on CRVA findings	Although flooding is episodic in Kunene, CRVA results showed that flash floods cause disproportionate damage to sanitation facilities and access routes. Flood-proofed sanitation and protected access reduce service failure and public health risks during extreme events.

ID	Adaptation Measure / Project	Type	Geographic Coverage	Lead Institution(s)	Status / Remarks	Description	Source	Rationale for application to basins, hotspots and priority projects
						sealing sanitation units, protecting or rerouting access paths, improving local drainage, and applying nature-based measures such as revegetation and runoff control to reduce erosion and flow velocities in flood-prone areas.		
FD8	Climate-Smart Operations and Emergency Response Protocols	Institutional / Operational	Okavango link	To be defined during project design	New – Proposed Project	Develop and implement climate-smart operational and emergency response protocols for critical water supply infrastructure. Measures include defining procedures for floods, heat waves, power outages and structural failures, establishing clear communication and decision-making chains, integrating early warning information into operations, and training operational staff to activate and manage contingency responses effectively.	Identified need based on CRVA findings	CRVA findings underscored the need for coordinated operational responses to floods, heat waves and structural disruptions along critical water corridors. Climate-smart protocols reduce downtime and cascading failures along the Okavango Link.

Community-Based Governance and Capacity Building (CB)

ID	Adaptation Measure / Project	Type	Geographic Coverage	Lead Institution(s)	Status / Remarks	Description	Source	Rationale for application to basins, hotspots and priority projects
CB1	Water Point Committees and Community Water Plans	Social / Institutional / NbS	Nationwide (communal areas)	MAWLR – RWS Directorate	Operational; 3,500+ committees established	Community-level structures responsible for local O&M of water points, tariff agreements, basic resource protection and conflict resolution.	RWS program reports; community water governance documentation	CRVA analysis highlighted that governance and O&M gaps exacerbate climate impacts on rural water systems. Strengthened community-level water governance improves reliability, local ownership and adaptive capacity across basin hotspots.
CB2	Climate-Smart Water Governance, Operations and Data Coordination	Social / Institutional	Kunene and Okavango basins	*To be defined during project design*	New – Proposed Project	Creation of stronger, more collaborative water management systems for the Kunene and Okavango river basins that improve water system governance. Measures include Climate-Smart Protocols that prepare for climate hazards like floods and droughts, expert training delivered to water operators, and improved data sharing protocols that improve inter-agency communication and decision-making.	Identified need based on CRVA findings	CRVA results identified institutional capacity gaps and weak coordination as systemic drivers of climate vulnerability. Shared protocols, trained operators and improved data exchange enhance adaptive capacity and system reliability across basins and projects.

ID	Adaptation Measure / Project	Type	Geographic Coverage	Lead Institution(s)	Status / Remarks	Description	Source	Rationale for application to basins, hotspots and priority projects
						Climate-Smart Protocols will include specific operation and maintenance (O&M) guides for water management, including protocols in the event of floods or droughts. Training will equip water operators with skills in groundwater monitoring, asset management, and emergency response. And improved data sharing practices will include shared data platforms which provide ministries, councils and utilities access to the same information.		
CB3	Gender-Responsive Adaptation in the Water Sector	Social / Institutional	National	GCF, UNDP, MAWLR, GCA	Planned under NWSISP II GAP implementation	Integration of gender analysis and gender action plans into water-sector adaptation projects, including targeted support for women, youth and vulnerable groups in planning,	GCF proposals; NWSISP II Gender Action Plan; GCA guidance	CRVA and gender assessments showed disproportionate climate impacts on women, youth and marginalized groups. Gender-responsive adaptation ensures inclusive decision-making and equitable resilience outcomes across all intervention areas.

ID	Adaptation Measure / Project	Type	Geographic Coverage	Lead Institution(s)	Status / Remarks	Description	Source	Rationale for application to basins, hotspots and priority projects
						access and decision-making.		
CB4	Climate-Resilient WASH Management and O&M Training for Rundu Communities	Social / Institutional	Rundu	To be defined during project design	New – Proposed Project	Capacity-building for water point committees and local operators focused on drought response, flood recovery, asset maintenance under heat stress, and emergency water management.	Identified need based on CRVA findings	CRVA findings showed that operational and maintenance gaps amplify climate impacts. Targeted training strengthens local capacity to manage droughts, floods and heat stress.

4.4 Selected adaptation measures for basin- and project-level implementation

Building on the broader adaptation options inventory, this section presents a refined set of adaptation measures specifically proposed for implementation in the Kunene and Okavango basins, along the Okavango Link (CAN Water Supply Project), and within the Rundu water supply system and its surrounding rural service area.

The measures are organised by basin and project location in order to ensure a clear alignment between identified climate risks, spatial exposure patterns and targeted responses. This location-based structuring facilitates prioritisation, supports context-specific design and implementation, and strengthens the relevance of proposed measures to the distinct hydrological, climatic and institutional conditions of each area.

The selected measures are based on their direct relevance to the climate risks identified through the CRVA, their technical feasibility, and their potential to enhance climate resilience at both basin and project level, while generating operational, social and environmental co-benefits.

Kunene Basin: The Kunene Basin is characterised by high climate sensitivity due to its strong dependence on transboundary inflows, pronounced seasonal variability, recurrent droughts and increasing heat stress. According to the CRVA, the basin faces heightened risks related to declining baseflows, groundwater stress, wildfire exposure and localised flash flooding affecting rural water supply systems. The proposed adaptation measures for the Kunene Basin focus on strengthening drought resilience, protecting critical intakes and conveyance infrastructure, improving operational reliability under heat extremes, and enhancing ecosystem-based and institutional approaches to manage climate variability and cross-border uncertainties.

ID	Adaptation Measure	Category	Type	Description	Climate threat addressed	Expected benefits and co-benefits
WR3	Drought-Proof Rural Water Supply Schemes	Water Resources and Infrastructure Resilience	Engineering + NbS	Design and upgrading of climate-resilient rural water supply schemes in drought-prone communities of the Kunene Basin. Measures include solar-powered boreholes, elevated storage tanks providing minimum 48-hour autonomy, protection of abstraction points, fencing and basic erosion control around infrastructure, and integration with drought-response and emergency supply protocols.	Recurrent and prolonged droughts; declining groundwater recharge; high temperature stress on infrastructure; service interruptions in remote rural settlements.	Improved reliability of rural water supply under drought conditions; reduced dependence on diesel and grid electricity; enhanced resilience of WASH services; strengthened livelihood security for pastoral communities; lower operational costs and emissions.
WR6	Strategic Emergency Water Storage	Water Resources and Infrastructure Resilience	Engineering	Construction and upgrading of elevated and ground-level reservoirs providing at least two days of emergency water supply during droughts or infrastructure failure, using climate-resilient materials.	Recurrent or prolonged drought, fluvial or riverine flooding, more intense heat stress on physical structures	Emergency buffering; improved resilience of rural schemes
WR12	Climate-Resilient Conjunctive Surface–Groundwater Operations	Water Resources and Infrastructure Resilience	Hybrid	Design and implement conjunctive surface–groundwater operation schemes to improve water supply reliability under variable hydrological conditions. Measures include source-switching rules during droughts, abstraction thresholds based on river flows and groundwater levels, strategic storage to buffer	Recurrent and prolonged drought; strong seasonal flow intermittency; declining groundwater recharge under	Improved drought resilience through diversified water sources; reduced reliance on single abstractions; enhanced supply reliability during low-flow periods; strengthened adaptive water resources

ID	Adaptation Measure	Category	Type	Description	Climate threat addressed	Expected benefits and co-benefits
				low-flow periods, and basic monitoring to support adaptive operation.	increasing temperature and rainfall variability.	management and operational flexibility.
FD3	**Artificial Recharge and Small Dams Rehabilitation**	Flood and Drought Risk Management	Hybrid	Rehabilitation of small dams and artificial recharge structures to improve drought resilience and reduce evaporation losses.	Recurrent or prolonged drought and more variable rainfall patterns	Increased storage efficiency and reduced water supply disruption
FD7	**Flood-Proofed Rural Sanitation and Access Protection**	Flood and Drought Risk Management	Hybrid	Flood-proof rural sanitation facilities and access routes to improve service continuity and reduce public health risks during flash flood events, through elevated and sealed sanitation units, protected access paths, improved drainage, and targeted erosion control measures.	Episodic flash flooding causing damage to sanitation facilities and access routes, leading to service disruption and contamination risks in rural areas.	Reduced sanitation system failure during extreme events; improved access and service continuity; lower public health and contamination risks; enhanced resilience of rural WASH infrastructure under flood conditions.

Okavango Basin: The Okavango Basin experiences a complex combination of climate risks, including increasingly erratic rainfall, fluvial and pluvial flooding, high sediment loads, prolonged dry spells and rising temperatures. The CRVA identifies significant exposure of water supply and sanitation systems—particularly in floodplain settlements and along the Rundu corridor—to multi-hazard conditions. Adaptation measures proposed for the Okavango Basin aim to enhance flood-resilient abstraction and treatment systems, strengthen emergency storage and drainage capacity, protect groundwater quality, and improve preparedness and early-warning mechanisms, while safeguarding the basin's critical ecological functions.

ID	Adaptation Measure	Category	Type	Description	Climate threat addressed	Expected benefits and co-benefits
WR4	**Building Smarter Water Intakes**	Water Resources and Infrastructure Resilience	Engineering	Construction or relocation of climate-resilient river intake structures along the Okavango Basin, incorporating elevated or flood-safe positioning, sediment traps, debris deflectors, automated shut-off valves, and SCADA-linked water-level sensors.	Riverine flooding, more frequent and intense sediment surges, frequent or exacerbated heat stress on electrical components	Improved intake reliability; reduced sediment damage; improved water quality and reduced disruption
WR5	**Submerged River Intake Pumps**	Water Resources and Infrastructure Resilience	Engineering	Deployment of reinforced, submersible, auto-filtering pumps anchored below variable flood levels in the Okavango River, designed to withstand debris impact and sediment surges.	Riverine flooding, more frequent and intense sediment surges, flood debris, more intense heat stress on above-surface	Reduced water supply disruption during and after floods; reduced equipment repair costs

ID	Adaptation Measure	Category	Type	Description	Climate threat addressed	Expected benefits and co-benefits
					electrical components	
CG3	**Riparian Buffer Zones and Wetland Rehabilitation**	Catchment and Groundwater Protection	NbS	Restoration of riverbanks and wetlands through native vegetation, erosion control, delivered via community stewardship agreements with Traditional Authorities.	Riverine flooding, more frequent and intense sediment surges	Reduced soil erosion; improved water quality; ecosystem services
CG5	**Community Rainwater Harvesting & Soil Conservation**	Catchment and Groundwater Protection	NbS	Community-led interventions using rooftop and surface rainwater harvesting, contour bunds, mulching and small-scale soil conservation to improve water availability and reduce erosion.	Rainfall variability (drought/fluvial flooding), soil erosion	Improved household water security; improved soil retention
FD1	**Floodplain Management**	Flood and Drought Risk Management	NbS	Application of ecosystem-based floodplain management approaches (vegetated floodways, wetland buffers, and controlled drainage) as a transferable model for managing flood risks and sedimentation in flood-prone riparian areas relevant to the Okavango Basin.	Fluvial flooding, more frequent and intense sediment surges	Reduced flood impacts; maintained or improved ecological functions; lower sediment loads
FD4	**Community-Based Early Warning Systems**	Flood and Drought Risk Management	Engineering / Institutional	Development of early warning system, incorporating climatic and fluvial monitoring stations, lines of accessible communication connected with national warning frameworks and community-led emergency protocols.	Fluvial or riverine flooding, recurrent or prolonged drought	Earlier response; reduced loss and damage; community knowledge

Okavango Link – CAN Water Supply Project: The Okavango Link (CAN Water Supply Project) is a strategic bulk water transfer system exposed to multiple climate hazards along its alignment, including extreme heat, flooding at river crossings, sedimentation, erosion and power supply disruptions. The CRVA highlights the need to ensure long-term operational reliability under increasing climate variability. Adaptation measures for the CAN Project focus on climate-proofing infrastructure design, protecting intakes and crossings, strengthening power and control systems, enhancing storage autonomy, and integrating robust operational protocols to manage droughts, floods and extreme temperatures along the full length of the system.

ID	Adaptation Measure	Category	Type	Description	Climate threat addressed	Expected benefits and co-benefits
WR13	**Climate-Resilient Pipeline Crossings and River Interfaces**	Water Resources and Infrastructure Resilience	Engineering	Climate-proof pipeline crossings and river interfaces along the Okavango Link alignment to reduce flood- and erosion-related risks, through reinforced foundations, scour protection and stabilisation of erosion-prone sections.	Riverine flooding, erosion and scour affecting pipeline crossings and river interfaces, increasing the risk of	Reduced risk of pipeline failure at critical crossings; improved structural integrity under extreme flood events; enhanced reliability and continuity of bulk water transfers.

ID	Adaptation Measure	Category	Type	Description	Climate threat addressed	Expected benefits and co-benefits
					structural damage and service interruptions.	
WR14	**Heat, Dust and Wildfire Protection for Linear Infrastructure**	Water Resources and Infrastructure Resilience	Engineering	Protect linear water infrastructure against extreme heat, dust and wildfire risks through heat-rated equipment, shading and ventilation at critical assets, sealed and filtered control systems, and vegetation management along exposed corridors.	Increasing heat stress, dust exposure and wildfire risk affecting surface infrastructure corridors under projected climate change conditions.	Improved operational reliability under high-temperature conditions; reduced climate-related damage and equipment failure; extended asset lifespan and lower maintenance requirements.
FD8	**Climate-Smart Operations and Emergency Response Protocols**	Flood and Drought Risk Management	Institutional / Operational	Develop and implement climate-smart operational and emergency response protocols to manage floods, heat waves, power outages and structural disruptions affecting critical water supply infrastructure.	Multi-hazard climate risks, including floods, extreme heat and infrastructure disruptions, leading to cascading failures along critical water corridors.	Reduced downtime during extreme events; improved coordination and decision-making; strengthened system-wide resilience and emergency preparedness.

Rundu Water Supply System and Surrounding Rural Service Area: The Rundu water supply system and its surrounding rural service area are identified as a critical climate-risk hotspot due to high exposure to fluvial flooding, sedimentation, drought stress, rising temperatures and growing water demand. The CRVA underscores vulnerabilities in treatment capacity, intake protection, storage autonomy, groundwater quality and institutional capacity, particularly for dispersed rural communities within a 100 km radius of Rundu. Adaptation measures proposed for this area prioritise climate-resilient upgrading of water treatment and abstraction infrastructure, expanded storage and backup systems, flood- and heat-proofing of assets, strengthened early-warning and emergency response mechanisms, and targeted capacity-building to ensure reliable and equitable water service delivery under multi-hazard conditions.

ID	Adaptation Measure	Category	Type	Description	Climate threat addressed	Expected benefits and co-benefits
WR8	**Climate-Resilient Upgrade of Rundu Water Treatment Plant (WTP)**	Water Resources and Infrastructure Resilience	Engineering	Climate-proofing of Rundu WTP through elevated electrical rooms, flood-protected platforms, enhanced pre-sedimentation, modular treatment units, and thermal protection of controls.	Fluvial or riverine flooding, increased sedimentation, more intense heat stress on buildings and water treatment electrical systems	Reliable potable water supply under multi-hazard conditions
WR9	**Distributed Storage and**	Water Resources	Engineering	Installation of elevated tanks and reinforced reservoirs	Recurrent or prolonged	Improved continuity of rural water services

ID	Adaptation Measure	Category	Type	Description	Climate threat addressed	Expected benefits and co-benefits
	Pressure-Zone Reinforcement for Rundu Rural Supply	and Infrastructure Resilience		providing minimum 48-hour storage autonomy for rural schemes supplied from Rundu.	drought, more intense heat stress	
WR10	Heat-Resilient Pumping Stations and Electrical Systems for Rundu Supply Network	Water Resources and Infrastructure Resilience	Engineering	Retrofitting of pump stations with heat-resistant motors, shaded structures, and HVAC sized for future temperatures.	More intense heat stress on electro-mechanical systems, power supply	Reduced equipment failure; longer asset lifespan
WR11	Flood-Resilient River Abstraction and Intake Protection	Water Resources and Infrastructure Resilience	Engineering	Reinforcement of intake structures through submerged or adjustable intakes, debris screens, anti-clogging filters, bank stabilization, and erosion protection. Includes remote shut-off systems during extreme flood events.	Riverine flash flooding, more frequent and intense sediment surges	Reduced disruptions during floods, reduced debris damage to equipment
FD5	Urban and Peri-Urban Drainage Upgrades	Flood and Drought Risk Management	Engineering / Hybrid	Upgrade of stormwater drainage systems, culverts, and erosion protection to manage high-intensity rainfall.	Fluvial flooding, riverbank erosion	Reduced flood damage to WASH and improved pedestrian access infrastructure
FD6	Early Warning and Emergency Response System for Rundu Water Supply	Flood and Drought Risk Management	Engineering / Institutional	Installation of hydro-climatic monitoring stations linked to operational triggers for utilities and communities.	Fluvial or riverine flooding, recurrent or prolonged drought	Faster response; reduced water supply service interruptions
CG4	Groundwater Protection and Monitoring around Rundu	Catchment and Groundwater Protection	Hybrid	Establishment of groundwater protection zones, water-quality monitoring, and regulation of sanitation siting near abstraction points.	Recurrent or prolonged drought, contamination	Safeguarded groundwater reserves; public health benefits
CB4	Climate-Resilient WASH Management and O&M Training for Rundu Communities	Community-Based Governance and Capacity Building	Social / Institutional	Capacity-building for water point committees and operators focused on drought response, flood recovery, emergency water management and asset maintenance under heat stress.	Governance gaps (Cross-cutting)	Improved system reliability, local knowledge building and local ownership

Cross-basin / Cross-project (Transversal): This category includes adaptation measures that are applicable across both river basins and project areas, addressing systemic vulnerabilities common to Namibia's water sector. These measures respond to cross-cutting climate risks such as rising temperatures, recurrent droughts, institutional capacity constraints, energy insecurity and limited early-warning and response systems. Transversal measures aim to strengthen governance, operational resilience, climate-proofing standards, and preparedness across multiple locations, thereby reinforcing the overall robustness and adaptability of the water sector.

ID	Adaptation Measure	Category	Type	Description	Climate threat addressed	Expected benefits and co-benefits
WR1	Adapt Managed Aquifer Recharge (MAR)	Water Resources and Infrastructure Resilience	Hybrid	Application of managed aquifer recharge to enhance groundwater storage and drought buffering across multiple basins, through recharge of treated surface or reclaimed water and basic groundwater monitoring to support climate-resilient water supply.	Recurrent or prolonged drought, groundwater depletion	Improved drought resilience of groundwater-dependent communities; strategic groundwater storage; reduced pressure on surface water sources,
WR7	Backup Power for Water Pumps	Water Resources and Infrastructure Resilience	Engineering	Installation of solar-paired battery backup systems (minimum 48-hour autonomy), surge protection, and lightning-resilient switchgear at pumping stations supplying Kunene and Okavango Basin schemes, with end-user storage buffers to maintain service during grid outages and extreme heat. Electrical systems are specified for high ambient temperatures and de-rating.	Power outages, more intense heat stress disrupting power supply, recurrent or prolonged drought	Continuity of water supply during outages; reduced diesel dependence; extended asset lifespan
CG1	Basin Management Committees	Catchment and Groundwater Protection	Enabling / NbS	Strengthening basin-level coordination for erosion control, wetland protection, and land-use management.	Governance gaps, more frequent and intense sediment surges	Integrated catchment protection, greater ecosystem resilience
CB1	Water Point Committees and Community Water Plans	Community-Based Governance and Capacity Building	Social / Institutional / NbS	Support to community structures managing O&M, tariffs, and local resource protection under climate stress.	Governance gaps, recurrent or prolonged drought	Better collective water governance; improved community relations
CB2	Climate-Smart Water Governance, Operations and Data Coordination	Community-Based Governance and Capacity Building	Social / Institutional	Application of climate-smart operational protocols and inter-utility data-sharing frameworks for improved water management	Governance gaps, recurrent or prolonged drought	Reduced operational risk; improved coordination
CB3	Gender-Responsive Adaptation in the Water Sector	Community-Based Governance and Capacity Building	Cross-cutting	Integration of gender analysis and action plans into water-sector adaptation investments and decision making fora.	Social vulnerability	Equitable access and inclusion

5. MULTI-CRITERIA ASSESSMENT (MCA)

The Multi-Criteria Assessment constitutes a central element of the decision-making framework, providing a systematic, transparent and replicable method for evaluating and ranking all adaptation options identified in the Adaptation Inventory. Its purpose is to ensure that the selection of priority measures is grounded in evidence, aligned with Namibia's climate-risk context, and responsive to national priorities.

By integrating technical, environmental, social, gender and economic dimensions, the MCA enables a balanced appraisal of diverse adaptation options—Nature-based Solutions, hybrid interventions and grey infrastructure—and ensures that all measures included in the inventory are assessed on equal terms.

The MCA is structured around a set of evaluation criteria that reflect the key dimensions of climate-resilient water planning in Namibia. Each criterion assesses a distinct aspect of adaptation performance, ensuring that selected measures are not only technically robust but also feasible, sustainable, socially inclusive and capable of addressing the climate risks identified in the CRVA.

Table 7: MCA criteria. Source: Own elaboration

Criterion	Description and Rationale
Effectiveness in reducing climate risk	Measures the capacity of the option to reduce exposure or sensitivity to key hazards identified in the CRVA (drought, floods, heat, erosion, sedimentation, wildfires).
Technical feasibility and maturity	Assesses whether the measure is technically sound, proven under similar conditions, and compatible with Namibia's water sector systems and institutional capacity.
Economic and financial viability	Evaluates cost-effectiveness, capital and operational costs, long-term maintenance requirements, and potential for funding through mechanisms such as AfDB, GCF or GEF.
Social and gender benefits	Examines the degree to which the option enhances inclusiveness, reduces differentiated vulnerabilities and improves opportunities for women, youth and marginalized groups.
Environmental co-benefits and sustainability	Assesses the contribution of the option to ecosystem protection, restoration, groundwater recharge, biodiversity and the long-term sustainability of water resources.

To ensure consistency and transparency, each adaptation option was assessed using a standardized and replicable approach, allowing for a systematic comparison across measures of different nature and scale.

A common scoring scale ranging from 1 (very low performance) to 5 (very high performance) was applied to each adaptation option against each evaluation criterion. In parallel, each evaluation criterion was assigned a specific weight between 0 and 1, reflecting its relative importance in the decision-making process. The sum of all weights equals 1, ensuring a balanced overall assessment framework.

Interpretation of MCA results

The complete set of MCA scores and rankings for all assessed measures is presented in the Annex.

In general, higher MCA scores indicate adaptation options with stronger potential to reduce priority climate risks identified in the CRVA, while also demonstrating higher technical feasibility, financial viability, social and gender benefits, and environmental sustainability. Lower-scoring measures may remain relevant in specific contexts; however, their limitations and implementation constraints require explicit consideration during subsequent stages of project design.

The prioritized measures emerging from the MCA are summarized in the next table:

Rank	ID	Adaptation Measure	MCA Score	Location	Primary rationale
1	CG1	Basin Management Committees	4.5	Cross-basin / Cross-project	Strengthens basin-level governance and coordination to address cross-cutting climate risks, including drought, sedimentation and land-use pressures, enabling integrated planning, ecosystem protection and adaptive water resources management across multiple basins and projects.
2	FD1	Floodplain Management	4.4	Okavango Basin	Reduces flood risk and sediment-related impacts in flood-prone areas through ecosystem-based floodplain management, enhancing natural buffering capacity, protecting water infrastructure and settlements, and maintaining critical ecological functions in the Okavango Basin.
3	CG5	Community Rainwater Harvesting & Soil Conservation	4.3	Okavango Basin	Enhances local water security and climate resilience by reducing runoff and erosion, improving soil moisture retention and supplementing household water supply under variable rainfall conditions, while delivering strong environmental and livelihood co-benefits.
4	WR3	Drought-Proof Rural Water Supply Schemes	4.2	Kunene Basin	High effectiveness in reducing drought risk for dispersed rural communities through integrated engineering and nature-based solutions, providing storage autonomy, energy resilience and protection of critical abstractions under recurrent drought conditions.
5	WR1	Adapt Managed Aquifer Recharge (MAR)	4.1	Cross-basin / Cross-project	Improves drought resilience and long-term water security by increasing strategic groundwater storage and buffering capacity, reducing pressure on surface water sources and enabling climate-resilient groundwater management across multiple basins under prolonged drought conditions.
6	CB4	Climate-Resilient WASH Management and O&M Training	4.0	Rundu system and rural area	Addresses systemic operational and maintenance constraints that significantly amplify climate impacts on water services, delivering rapid, scalable improvements in system reliability, local capacity and adaptive response under multi-hazard conditions.
7	FD4	Community-Based Early Warning Systems	3.9	Okavango Basin	Strengthens preparedness and response capacity at community level by enabling timely action for floods and droughts, thereby reducing loss and damage to WASH infrastructure and livelihoods in high-exposure floodplain settlements.
8	WR12	Climate-Resilient Conjunctive Surface–Groundwater Operations	3.8	Kunene Basin	Enhances drought resilience by diversifying water supply sources and reducing reliance on single abstractions, improving system flexibility and reliability under strong seasonal flow intermittency and declining recharge conditions.
9	FD6	Early Warning and Emergency Response System	3.7	Rundu system and rural area	Improves operational preparedness and continuity of water services through integrated monitoring and operational triggers, reducing service interruptions and cascading failures during floods, droughts and extreme events.
10	WR13	Climate-Resilient Pipeline Crossings and River Interfaces	3.6	Okavango Link – CAN Project	Addresses critical structural vulnerabilities at river crossings and erosion-prone interfaces along nationally significant bulk water infrastructure, significantly reducing the risk of flood-induced failures, erosion damage and system-wide service disruptions.

6. COST-BENEFIT ANALYSIS (CBA)

The Cost–Benefit Analysis (CBA) provides an economic pre-feasibility assessment of the top-ranked adaptation measures in Namibia's water sector. It determines whether each intervention is expected to deliver measurable resilience, socio-economic and environmental benefits that justify investment by government, AfDB, GCF, GEF, and other development partners

The CBA applied a simplified pre-feasibility methodology suitable for early-stage investment screening to the top five MCA-ranked options which collectively covered all locations, reflecting their relative performance in terms of climate risk reduction, feasibility and investment relevance. By comparing indicative capital, operation and maintenance (O&M), and institutional strengthening costs against projected benefits such as avoided climate-related losses, enhanced water security, and improved community wellbeing, the CBA supports evidence-based decision-making consistent with:

- Namibia's Updated NDC (2021 & 2023 updates)
- The National Water Sector Investment Plan (NWSIP I & II)
- The Water Resources Management Act (2013; 2023 Regulations)
- National prioritization processes under MAWLR and MEFT

The first step is to define the analytical scenarios. The baseline scenario represents a continuation of current conditions: existing water supply performance, governance and management arrangements, operational practices, and degree of exposure to climate risks (such as droughts, floods or groundwater decline). The intervention scenario, by contrast, describes the expected situation after implementing the adaptation measure. For instance, a MAR expansion would result in increased groundwater recharge and higher system reliability, while a strengthened basin management intervention would improve catchment protection and reduce land degradation. The comparison between the baseline and intervention scenarios enables the CBA to estimate the incremental benefits generated by each measure, relative to the incremental costs.

Defining Baseline and Intervention Scenarios

- Baseline: continuation of existing water supply conditions, governance structures, climate risks (drought, floods, groundwater decline), and projected socio-economic impacts.
- Intervention: implementation of the proposed adaptation measure (e.g., WR1 MAR expansion, CG1 enhanced basin management).

The second step consists of identifying and categorizing all relevant cost components. These cost elements are derived from national investment plans and NWSIP II and AfDB project templates to ensure methodological consistency. The main categories are:

- Capital expenditure (CAPEX): Includes infrastructure works, civil engineering, equipment, and nature-based interventions. These represent the initial investment required to establish or expand the measure, as well as any end-of-life decommissioning costs.
- Operation and maintenance (O&M): Covers the recurrent costs necessary to keep the system functional, such as routine servicing, repairs, monitoring, pumping, solar system maintenance, and technical oversight.
- Capacity development: Encompasses training programs, community mobilization, institutional strengthening and governance support—critical for successful long-term implementation.
- Environmental and social safeguards: Costs related to mitigation measures, environmental compliance, land management requirements, and social protection activities.
- Monitoring and evaluation (M&E): Resources needed to track performance, collect data, implement indicators, and evaluate outcomes over time.

The third step involves identifying and quantifying the benefits associated with each intervention. Scoped benefits include avoided losses from climate-related events, improvements in water security and reliability, enhanced ecosystem services, and social or gender co-benefits. Benefits were assessed based on international adaptation-economics guidelines from institutions such as AfDB, the World Bank and the GCF. These include:

- Attributable avoided drought losses (water shortages, borehole failures, livestock losses)

- Attributable avoided flood damages (to households, crops, transport and water infrastructure)
- Improved water availability (enhanced groundwater recharge, reduced outages)
- Additional environmental co-benefits (wetland restoration, soil health, biodiversity)
- Additional gender and social co-benefits (reduced time burden, safety, improved governance)
- Additional economic productivity gains (agriculture, fisheries, tourism, trade)

In the **fourth step**, the CBA calculates the main economic performance indicators, using discount rates between 6–10% to reflect investment conditions in Namibia. These indicators provide a preliminary understanding of whether each adaptation measure is likely to generate net economic value over its lifetime. The key indicators assessed are:

- Net Present Value (NPV): Measures the difference between the discounted benefits and discounted costs over the analysis period. A positive NPV shows that the measure yields a net economic gain and contributes to long-term value creation.
- Benefit–Cost Ratio (BCR): Compares the present value of total benefits with the present value of total costs. A BCR greater than 1 indicates that the intervention generates more benefits than costs and is therefore economically justified.
- Payback Period: Estimates the number of years required for cumulative benefits to recover the initial investment. Shorter payback periods indicate quicker returns and lower financial risk.
- Internal Rate of Return (IRR): Represents the discount rate at which the NPV becomes zero. When data availability allows its calculation, the IRR provides an indication of the project's profitability relative to alternative investment opportunities.

Finally, a **sensitivity analysis** is conducted to test the robustness of results under different assumptions. This includes changes in rainfall and recharge patterns, variations in CAPEX and O&M costs, expected benefits, commodity price fluctuations, or delays in institutional implementation. Given high climate and economic uncertainty in arid regions, sensitivity tests were run for:

- Variations in rainfall recharge
- The effectiveness of the adaptation measure
- Capital and maintenance cost overruns
- Commodity price changes
- Delays in institutional implementation
- Diverging valuations of social and environmental benefits and of ecosystem services

These analyses help identify measures that remain robust under changing climate and economic conditions.

Portfolio construction:

When presenting the most economically attractive adaptation options, it is important to consider interactions between them if more than one option is to be implemented. Thus, it is necessary to return to the MCA to identify to what extent a combination of measures may provide resilience against different climate hazards, avoid risks to the total economic returns of the investment, or achieve strategic social or environmental goals.

Data Sources and Validation

The assessment drew on a combination of **national datasets, technical studies, donor reports, and scientific literature**, including:

- *National Water Investment Plan (2020)*
- *WRMA (2013; 2023 Regulations)*
- *Windhoek MAR feasibility studies* (City of Windhoek, GIZ, CSIR)
- *AfDB Climate Risk Screening & Adaptation Review (CRiSTAL) Tool*
- *World Bank Adaptation Guidance (2021–2023)*

- *UNDP and GIZ adaptation project datasets*
- The **Kavango East & West CRVA datasets**, produced under MAWLR and MEFT
- Spatial climate exposure, vulnerability, and hazard datasets from DMS and SASSCAL

Assumptions were validated through national expert consultations and triangulated with AfDB project benchmarks.

CBA Results

ID	Adaptation Measure	Indicative CAPEX (N$ million)	Annual O&M (N$ million)	Estimated Annual Benefits (N$ million)	NPV (10-year, 6–10% discount)	BCR	Payback Period (years)	Notes / Assumptions
WR1	Adapt Managed Aquifer Recharge (MAR)	350–450	20–25	110–140	Positive under all rates (approx. N$ 300–450m)	1.8 – 2.4	5–7	Based on Windhoek MAR benchmarks; scalable to northern basins
CG1	Basin Management Committees	40–60	6–10	25–40	Positive (approx. N$ 90–170m)	1.6 – 2.1	3–5	Low-cost, high-return institutional + NbS measure
FD1	Floodplain Management	120–180	10–15	60–90	Positive (approx. N$ 150–260m)	1.5 – 1.8	4–6	Includes flood buffers, wetland rehabilitation, drainage control
CG5	Community Rainwater Harvesting & Soil Conservation	15–25	2–3	8–12	Moderately positive (approx. N$ 20–50m)	1.3 – 1.6	3–5	High social co-benefits; low infrastructure requirements
WR3	Drought-Proof Rural Water Supply Schemes	80–110	5–8	30–45	Moderately positive (approx. N$ 60–100m)	1.2 – 1.5	6–8	Based on NWSIP II solar borehole costing; depends on groundwater reliability

Interpretation of CBA Results

Most economically attractive options

- WR1 – MAR Expansion
- CG1 – BMC Strengthening

These options exhibit the highest economic performance, with strong benefit–cost ratios (BCRs above 1.6), robust positive NPVs across discount rates, and relatively short payback periods. The results confirm their cost-effectiveness and reinforce their prioritization under the MCA as high-impact, scalable interventions for strengthening long-term climate resilience of the water sector.

High social and environmental returns

- FD1 – Floodplain Restoration
- CG5 – Community Rainwater Harvesting & Soil Conservation

Although their financial returns are more moderate than large-scale infrastructure investments, these measures deliver substantial social, livelihood and environmental co-benefits, including reduced flood risk, improved ecosystem services, enhanced water availability, and strengthened adaptive capacity at community level. Their positive NPVs and BCRs above unity support their inclusion as priority nature-based and community-oriented adaptation options.

Moderately attractive but strategically important

- WR3 – Rural Solar-Powered Schemes

This option shows moderate economic returns and longer payback periods, reflecting higher capital intensity and dispersed service delivery. Nevertheless, it remains strategically critical for ensuring basic water access and service continuity in drought-prone rural areas, where adaptation benefits extend beyond direct financial returns to include public health, social stability and livelihood security.

7. FINAL SELECTION OF ADAPTATION OPTIONS

The final selection of adaptation options builds on the results of the MCA and the CBA and is complemented by a desk-based qualitative assessment of technical feasibility. The objective of this step is to provide an indicative implementation horizon for each shortlisted measure, based on currently available evidence.

Each shortlisted option was reviewed against a set of feasibility factors reflecting technical, institutional, regulatory, environmental and logistical considerations. This assessment draws on the MCA criteria (particularly technical feasibility, institutional capacity and environmental safeguards), the CBA results (investment readiness and maturity), the CRVA findings, and existing sectoral knowledge and benchmarks relevant to Namibia's water sector.

Based on this qualitative screening, adaptation options were provisionally classified according to their likely implementation timeframe:

- Short-term (0–3 years): measures with high compatibility with existing systems, proven technologies, manageable regulatory requirements and strong investment readiness.
- Medium-term (3–7 years): measures requiring additional technical studies, permitting processes, capacity strengthening or logistical preparation.
- Long-term (7+ years): measures facing significant regulatory, technical, institutional or land-access constraints, or requiring substantial system transformation.

This classification is indicative and non-binding and is intended to support strategic sequencing and investment planning under NWSIP II. The final confirmation of implementation horizons, including any adjustments to timelines or scope, should be undertaken during subsequent project preparation and design phases, as part of detailed feasibility studies and formal institutional decision-making processes.

ID	Adaptation Measure	Indicative Timeline	Technical justification
CG1	Basin Management Committees	Short-term (0–3 years)	Primarily institutional and governance-based measure with low capital requirements, high compatibility with existing frameworks and minimal permitting needs. Can be implemented rapidly through administrative arrangements, capacity strengthening and coordination mechanisms.
CG5	Community Rainwater Harvesting & Soil Conservation	Short-term (0–3 years)	Proven, low-cost and modular interventions with high technical maturity and strong community-level applicability. Implementation is not constrained by complex permitting, advanced studies or specialized supply chains.
WR3	Drought-Proof Rural Water Supply Schemes	Short- to Medium-term (0–5 years)	Based on well-established technologies (solar boreholes, storage tanks), but implementation depends on site-specific groundwater conditions, borehole testing and local construction logistics, which may extend timelines in some locations.
FD1	Floodplain Management	Medium-term (3–7 years)	Requires site-specific hydrological assessments, land-use coordination and environmental safeguards, as well as phased implementation of ecosystem-based interventions across floodplain areas.
WR1	Adapt Managed Aquifer Recharge (MAR)	Medium- to Long-term (5–10 years)	Technically complex intervention requiring detailed hydrogeological studies, long-term monitoring, regulatory approvals and phased scaling. While highly cost-effective, implementation depends on data availability and institutional readiness.

The proposed implementation timelines are indicative and based on a desk-based feasibility screening drawing on MCA and CBA results, existing sectoral benchmarks and CRVA findings. Final sequencing and timelines should be confirmed during subsequent project preparation and detailed feasibility studies.

8. CATALOGUE OF ADAPTATION OPTIONS

The final Adaptation Options, prioritized through the MCA and subsequently assessed through the CBA, are presented as part of the final catalogue of recommended measures. The catalogue is structured using the template shown below, which provides a clear and consistent summary of each option, including its purpose, geographic and climatic context, expected benefits, analytical results, and indicative implementation timeline.

By presenting the prioritized measures in this standardized format, the catalogue facilitates comparability across options and serves as a practical reference to support planning, sequencing and investment decision-making under the NWSISP II.

Figure 13: Fact sheet template. Source: Own elaboration.

CODE AND TITLE OF THE ADAPTATION OPTION			
Description	*Provides a concise but comprehensive explanation of the adaptation measure's purpose, relevance and scope. The description should outline what the measure consists of and how it will be implemented, including a brief list or narrative of recommended specific activities required to operationalize the intervention. These activities are indicative and may be refined during detailed project design.*		
Type of measure	*Specifies the nature of the adaptation measure based on its primary implementation approach.*	Category	*Indicates the thematic grouping of the measure within the adaptation framework. Categories reflect the primary sectoral focus of the intervention.*
Location	*Defines the spatial scale and area of implementation of the adaptation measure.*		
Climate threat(s) addressed	*Identifies the main climate hazards and risks that the measure is designed to address, as identified in the CRVA.*		
Expected benefits and co-benefits	*Summarizes the anticipated environmental, social and economic benefits of the measure.*		
Timeline	*Indicates the expected implementation horizon of the measure based on technical, institutional and contextual considerations.*		
Multicriteria Analysis Results			
Provides a concise summary of the MCA outcome for the measure, highlighting its relative performance across key criteria.			
Cost-Benefit Analysis Results			
Summarizes the key findings of the cost–benefit analysis.			

Figure 14: Fact sheet 1. Source: Own elaboration.

<table>
<tr><th colspan="4">CG1 Basin Management Committees</th></tr>
<tr><td>Description</td><td colspan="3">Strengthening basin-level coordination for erosion control, wetland protection, and land-use management.
Specific activities
1. Establish or strengthen Basin Management Committees with clear mandates, roles and coordination mechanisms across sectors and jurisdictions.
2. Develop basin-level climate risk profiles and priority action plans addressing erosion, sedimentation and ecosystem degradation.
3. Implement coordinated catchment protection measures, including wetland conservation, riparian buffer management and erosion control interventions.
4. Strengthen data sharing and coordination protocols among water authorities, environmental agencies and local governments to support adaptive basin management.
5. Build institutional capacity through targeted training on integrated water resources management, climate risk management and nature-based solutions.</td></tr>
<tr><td>Type of measure</td><td>Enabling / NbS</td><td>Category</td><td>Catchment and Groundwater Protection</td></tr>
<tr><td>Location</td><td colspan="3">Cross-basin / Cross-project</td></tr>
<tr><td>Climate threat(s) addressed</td><td colspan="3">Governance gaps, more frequent and intense sediment surges.</td></tr>
<tr><td>Expected benefits and co-benefits</td><td colspan="3">Integrated catchment protection, greater ecosystem resilience.</td></tr>
<tr><td>Timeline</td><td colspan="3">Short-term (0–3 years)</td></tr>
<tr><th colspan="4">Multicriteria Analysis Results</th></tr>
<tr><td colspan="4">Ranked highest under the MCA due to strong effectiveness in addressing systemic climate risks, high institutional feasibility, low implementation barriers and significant environmental co-benefits.</td></tr>
<tr><th colspan="4">Cost-Benefit Analysis Results</th></tr>
<tr><td colspan="4">Low-cost, high-return measure with positive NPV under all discount rates, strong benefit–cost ratio and short payback period, reflecting high economic efficiency of institutional and NbS-based interventions.</td></tr>
</table>

Figure 15: Fact sheet 2. Source: Own elaboration.

<table>
<tr><th colspan="4">FD1 Floodplain Management</th></tr>
<tr><td>Description</td><td colspan="3">Application of ecosystem-based floodplain management approaches (vegetated floodways, wetland buffers, and controlled drainage) as a transferable model for managing flood risks and sedimentation in flood-prone riparian areas relevant to the Okavango Basin.
Specific activities
1. Delineate flood-prone areas and functional floodplains using existing hydrological data, CRVA outputs and flood hazard mapping.
2. Design and implement ecosystem-based flood management measures, including wetland restoration, vegetated floodways and riparian buffer zones, adapted to local floodplain dynamics.
3. Introduce controlled drainage and flow dispersion measures to reduce flood peaks and sediment transport in priority floodplain areas.
4. Strengthen coordination with local authorities to align floodplain management measures with land-use planning and ecosystem protection objectives.
5. Establish basic monitoring arrangements to track flood behavior, sedimentation trends and ecosystem performance over time.</td></tr>
<tr><td>Type of measure</td><td>NbS</td><td>Category</td><td>Flood and Drought Risk Management</td></tr>
<tr><td>Location</td><td colspan="3">Okavango Basin</td></tr>
<tr><td>Climate threat(s) addressed</td><td colspan="3">Fluvial flooding, more frequent and intense sediment surges</td></tr>
<tr><td>Expected benefits and co-benefits</td><td colspan="3">Reduced flood impacts; maintained or improved ecological functions; lower sediment loads</td></tr>
<tr><td>Timeline</td><td colspan="3">Medium-term (3–7 years)</td></tr>
<tr><th colspan="4">Multicriteria Analysis Results</th></tr>
<tr><td colspan="4">High MCA score reflecting strong risk-reduction effectiveness, substantial environmental benefits and good technical feasibility under basin conditions.</td></tr>
<tr><th colspan="4">Cost-Benefit Analysis Results</th></tr>
<tr><td colspan="4">Positive NPV and robust benefit–cost ratio, with benefits driven by avoided flood damages, reduced sediment impacts and ecosystem service preservation.</td></tr>
</table>

Figure 16: Fact sheet 3. Source: Own elaboration.

<table>
<tr><th colspan="4">CG5 Community Rainwater Harvesting & Soil Conservation</th></tr>
<tr><td>Description</td><td colspan="3">Expansion of rainwater harvesting, contour bunds, mulching, and small-scale soil conservation practices in Kavango East and West communities.
Specific activities
1. Identify priority communities and sites for rainwater harvesting and soil conservation interventions based on existing vulnerability and land degradation assessments.
2. Design and implement household- and community-scale rainwater harvesting systems adapted to local rainfall patterns and settlement layouts.
3. Introduce soil conservation measures, including contour bunds and mulching, to reduce runoff, erosion and soil moisture losses.
4. Provide practical training to community members on construction, maintenance and sustainable management of rainwater harvesting and soil conservation systems.
5. Establish simple monitoring and maintenance arrangements to ensure functionality and long-term performance of the interventions.</td></tr>
<tr><td>Type of measure</td><td>NbS</td><td>Category</td><td>Catchment and Groundwater Protection</td></tr>
<tr><td>Location</td><td colspan="3">Okavango Basin</td></tr>
<tr><td>Climate threat(s) addressed</td><td colspan="3">Rainfall variability (drought/fluvial flooding), soil erosion.</td></tr>
<tr><td>Expected benefits and co-benefits</td><td colspan="3">Improved household water security; improved soil retention.</td></tr>
<tr><td>Timeline</td><td colspan="3">Short-term (0–3 years)</td></tr>
<tr><th colspan="4">Multicriteria Analysis Results</th></tr>
<tr><td colspan="4">Top-ranked NbS measure under the MCA, combining high environmental sustainability, strong social benefits and good economic performance.</td></tr>
<tr><th colspan="4">Cost-Benefit Analysis Results</th></tr>
<tr><td colspan="4">Low capital and O&M costs with moderately positive NPV and benefit–cost ratio, reflecting high returns relative to investment scale.</td></tr>
</table>

Figure 17: Fact sheet 4. Source: Own elaboration.

<table>
<tr><th colspan="4">WR3 Drought-Proof Rural Water Supply Schemes</th></tr>
<tr><td>Description</td><td colspan="3">Design and upgrading of climate-resilient rural water supply schemes in drought-prone communities of the Kunene Basin. Measures include solar-powered boreholes, elevated storage tanks providing minimum 48-hour autonomy, protection of abstraction points, fencing and basic erosion control around infrastructure, and integration with drought-response and emergency supply protocols.
Specific activities
1. Identify priority rural communities and water supply schemes based on drought exposure, service reliability and groundwater stress indicators.
2. Design and construct or rehabilitate boreholes equipped with solar-powered pumping systems suitable for high-temperature and low-maintenance conditions.
3. Install elevated storage tanks providing at least 48 hours of water supply autonomy, integrated with existing distribution networks.
4. Protect abstraction points and associated infrastructure through fencing, erosion control and basic site stabilization measures.
5. Integrate rural water schemes into drought-response and emergency supply protocols, including basic operational guidance for low-water and extreme drought conditions.</td></tr>
<tr><td>Type of measure</td><td>Engineering + NbS</td><td>Category</td><td>Water Resources and Infrastructure Resilience</td></tr>
<tr><td>Location</td><td colspan="3">Kunene Basin</td></tr>
<tr><td>Climate threat(s) addressed</td><td colspan="3">Recurrent and prolonged droughts; declining groundwater recharge; high temperature stress on infrastructure; service interruptions in remote rural settlements.</td></tr>
<tr><td>Expected benefits and co-benefits</td><td colspan="3">Improved reliability of rural water supply under drought conditions; reduced dependence on diesel and grid electricity; enhanced resilience of WASH services; strengthened livelihood security for pastoral communities; lower operational costs and emissions.</td></tr>
<tr><td>Timeline</td><td colspan="3">Short- to Medium-term (0–5 years)</td></tr>
<tr><th colspan="4">Multicriteria Analysis Results</th></tr>
<tr><td colspan="4">High MCA score due to strong effectiveness in reducing drought risk, proven technical solutions and balanced social and economic benefits.</td></tr>
<tr><th colspan="4">Cost-Benefit Analysis Results</th></tr>
<tr><td colspan="4">Moderately positive NPV and benefit–cost ratio, with benefits linked to avoided service disruptions, reduced fuel costs and improved water security.</td></tr>
</table>

Figure 18: Fact sheet 5. Source: Own elaboration.

<table>
<tr><th colspan="4">WR1 Adapt Managed Aquifer Recharge (MAR)</th></tr>
<tr><td>Description</td><td colspan="3">Application of managed aquifer recharge to enhance groundwater storage and drought buffering across multiple basins, through recharge of treated surface or reclaimed water and basic groundwater monitoring to support climate-resilient water supply.
Specific activities
1. Screen and identify suitable locations for MAR based on existing hydrogeological information, groundwater stress levels and water availability.
2. Undertake targeted hydrogeological assessments to confirm aquifer suitability, recharge capacity and potential environmental risks.
3. Design and implement MAR systems using treated surface water or reclaimed water, adapted to local aquifer conditions and operational constraints.
4. Establish basic groundwater monitoring systems to track recharge performance, groundwater levels and water quality over time.
5. Integrate MAR operations into broader groundwater management and drought-response frameworks to support long-term water security.</td></tr>
<tr><td>Type of measure</td><td>Hybrid</td><td>Category</td><td>Water Resources and Infrastructure Resilience</td></tr>
<tr><td>Location</td><td colspan="3">Cross-basin / Cross-project (Transversal)</td></tr>
<tr><td>Climate threat(s) addressed</td><td colspan="3">Recurrent or prolonged drought, groundwater depletion</td></tr>
<tr><td>Expected benefits and co-benefits</td><td colspan="3">Improved drought resilience of groundwater-dependent communities; strategic groundwater storage; reduced pressure on surface water sources,</td></tr>
<tr><td>Timeline</td><td colspan="3">Medium- to Long-term (5–10 years)</td></tr>
<tr><th colspan="4">Multicriteria Analysis Results</th></tr>
<tr><td colspan="4">High MCA ranking reflecting strong effectiveness in addressing drought risk and strategic relevance for long-term water resources management.</td></tr>
<tr><th colspan="4">Cost-Benefit Analysis Results</th></tr>
<tr><td colspan="4">Strong positive NPV and high benefit–cost ratio across discount rates, indicating robust economic performance despite higher upfront investment requirements.</td></tr>
</table>

ANNEX[14]

ID	Adaptation Measure	Effectiveness (1-5)	Technical (1-5)	Economic (1-5)	Social & Gender (1-5)	Environmental (1-5)	MCA Score	Rank
CB1	Water Point Committees and Community Water Plans	3	5	5	5	2	3,90	7
CB2	Climate-Smart Water Governance, Operations and Data Coordination	3	5	5	4	2	3,80	8
CB3	Gender-Responsive Adaptation in the Water Sector	3	5	4	5	2	3,60	10
CG1	Basin Management Committees	4	4	5	5	5	4,50	**1**
WR1	Adapt Managed Aquifer Recharge (MAR)	4	3	5	3	4	4,10	**5**
WR7	Backup Power for Water Pumps	4	4	3	3	3	3,50	11
FD3	Artificial Recharge and Small Dams Rehabilitation	4	3	3	3	4	3,50	11
FD7	Flood-Proofed Rural Sanitation and Access Protection	3	4	3	4	3	3,20	14
WR12	Climate-Resilient Conjunctive Surface–Groundwater Operations	5	3	3	3	3	3,80	**8**
WR3	Drought-Proof Rural Water Supply Schemes	5	4	4	4	2	4,20	**4**

[14] Where multiple adaptation options achieved similar or identical MCA scores, additional prioritization was applied based on strategic relevance in line with the CRVA findings and the national significance of the assets concerned.

ID	Adaptation Measure	Effectiveness (1-5)	Technical (1-5)	Economic (1-5)	Social & Gender (1-5)	Environmental (1-5)	MCA Score	Rank
WR6	Strategic Emergency Water Storage	4	5	3	3	2	3,50	11
CG3	Riparian Buffer Zones and Wetland Rehabilitation	4	3	4	4	4	3,90	7
CG5	Community Rainwater Harvesting & Soil Conservation	4	4	5	4	4	4,30	**3**
FD1	Floodplain Management	4	4	5	4	5	4,40	**2**
FD4	Community-Based Early Warning Systems	4	4	4	5	2	3,90	**7**
WR4	Building Smarter Water Intakes	4	4	3	3	2	3,40	12
WR5	Submerged River Intake Pumps	4	4	3	2	2	3,30	13
FD8	Climate-Smart Operations and Emergency Response Protocols	4	5	3	3	2	3,50	11
WR13	Climate-Resilient Pipeline Crossings and River Interfaces	5	4	3	2	1	3,60	**10**
WR14	Heat, Dust and Wildfire Protection for Linear Infrastructure	3	4	3	2	3	3,00	15
CB4	Climate-Resilient WASH Management and O&M Training	4	5	4	5	2	4,00	**6**
CG4	Groundwater Protection and Monitoring	4	4	3	4	3	3,60	10
FD5	Urban and Peri-Urban Drainage Upgrades	4	4	3	4	2	3,50	11

ID	Adaptation Measure	Effectiveness (1-5)	Technical (1-5)	Economic (1-5)	Social & Gender (1-5)	Environmental (1-5)	MCA Score	Rank
FD6	Early Warning and Emergency Response System	4	4	4	4	1	3,70	**9**
WR10	Heat-Resilient Pumping Stations and Electrical Systems	3	4	3	3	2	3,00	15
WR11	Flood-Resilient River Abstraction and Intake Protection	5	4	2	4	1	3,50	11
WR8	Climate-Resilient Upgrade of Rundu WTP	5	4	2	4	1	3,50	11
WR9	Distributed Storage and Pressure-Zone Reinforcement	4	4	3	4	2	3,50	11