Climate Resilient Development Pathways: Final CRDP Guidance

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Quality Assurance Checklist

In preparing this document CRIDF can confirm that it has followed CRIDF's internal general procedures, including appropriate CRIDF generic scope of work and that it has undergone appropriate quality assurance (QA) and quality control (QC) procedures as detailed in CRIDF's QA manual. Furthermore, CRIDF can confirm the applicable specific internal process and procedures have been followed including:

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- CRIDF's Climate vulnerability mapping methodology has been applied as appropriate;
- CRIDF's Climate Change Risk Assessment (CCRA) protocol have been applied as appropriate;
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List of Acronyms

Acronym	Long-Form
CIVAT	Climate Impact Vulnerability Assessment Tool
CORB	Cubango-Okavango River Basin
CRDP	Climate Resilient Development
CRIDF	Climate Resilient Infrastructure Development Facility
DPSIR	Drivers, Pressures, State, Impacts and Responses
GCM	Global Circulation Model
GTAP	Global Trade Analysis Project
ITCZ	Intertropical Convergence Zone
IPCC	Intergovernmental Panel on Climate Change
IPF	Infrastructure Prioritization Framework
IWRM	Integrated water resources management
LIMCOM	Limpopo Watercourse Commission
MSIOA	Multi-Sector Investment Opportunity Analysis
NPV	net present value
OKACOM	Permanent Okavango River Basin Water Commission
RBO	river basin organisations
RCM	Regional Circulation Model
RCP	Representative Concentration Pathways
RESILIM	Risk, vulnerability and resilience in the Limpopo River Basin
SADC	Southern African Development Community
SOM	Self-Organising Maps

TDA	Transboundary Diagniostic Analysis
TRB	Transboundary River Basin

1. Introduction

Across southern Africa, the ambitions of millions of people are stacked against a land that is unique in its richness and diversity but vulnerable to the impacts of global and local change, including but not limited to climate change. The African continent is rich in large river systems, most of which span multiple countries and involve transboundary, as well as traditional hydrological and land management considerations. There has been a culture of river-basin based management in Africa, more so than most places in the world. The development of Southern Africa's river basins, and enhancement of current investments in already developed river basins, presents an opportunity to fulfil the needs of millions of people in poverty.

However, development of these basins must be sustainable and balanced against the risks that poorly conceived, designed and implemented development initiatives may pose to people and the environment. Moreover, it is not enough to consider only present day risks. Most development, particularly infrastructure projects, have multi-decade implications. Given their time scales and high costs, such projects tend to lock river basins into development trajectories whose economic and non-economic impacts—both positive and negative—society will have to live with for decades to come. Projecting and understanding these risks and the possible impacts of different development trajectories as early as possible in both the policy and project planning cycle is therefore essential not only for sustainability, but also essential for good business.

Climate change is a particularly important risk for water infrastructure projects in southern Africa, given the uncertainty of how it will occur, the expected multiple impacts, negative implications for the most vulnerable populations, and its potentially devastating effect on both nature and society. In locations such as the Okavango basin, for example, it has been projected that climate change may lead to a reduction in water flow in the Okavango River of between 14% and 20% from 2020 to 2050 (Andersson et al., 2006).

It is within this context that the Climate Resilient Infrastructure Development Facility (CRIDF) has initiated the Climate Resilient Development Pathways (CRDP) initiative. Its objective is to establish a regionally appropriate process for informing the creation of climate resilient water infrastructure development and investment plans by river basin organisations (RBOs) and member states of the Southern African Development Community (SADC). It is expected that the developed process will:

- Enable decision-makers to systematically take into account the projected impacts of climate change on infrastructure development, planning and management alongside other, traditional development criteria.
- Enable decision-makers to manage the trade-offs between multiple, water dependent sectors.
- Use a combination of qualitative and quantitative methods to inform strategic decision-making processes.

The developed approach was tested in the Okavango river basin in collaboration with the Permanent Okavango River Basin Water Commission (OKACOM) in a process that included an expert-lead phase to compile an evidence base and a participatory phase to validate and enrich results through a stakeholder workshop on March 8-9, 2017 in Windhoek, Namibia. This work complements work already under way as part of the Multi-Sector Investment Opportunity Analysis (MSIOA), a transboundary planning process led by the

World Bank that is working in collaboration with OKACOM and its member states to support evidence-based water infrastructure decision-making. The aim of the CRDP process was to integrate high quality climate change analysis and deliberation into the MSIOA process of assessing different development scenarios for the basin. Lessons from the Okavango test case are incorporated into this generalised CRDP approach for use in other river basins in the SADC region.

The CRDP approach presented in this report is informed by an awareness of existing tools and methods relevant for assessing the climate resiliency of infrastructure investments in Southern Africa's transboundary watersheds. It has subsequently been refined in light of a pilot assessment in the Okavango Basin. The draft CRDP approach was developed based on a review of other approaches and review of regionally relevant information from the region. Before introducing the CRDP approach, this report provides a brief overview of relevant knowledge that informed the CRDP's design, namely:

- Literature published by Southern Africa's RBOs and related organizations regarding their vulnerability to the impacts of climate change.
- Tools and approaches that enable assessments of the vulnerability and resilience of water-related infrastructure investments at the river basin and transboundary scale.
- Tools and approaches for scenario and transition pathway analysis.
- Relevant tools previously developed by CRIDF that may be integrated into the CRDP approach.

A review of relevant OKACOM and MSIOA documents was also undertaken to inform the context within which the CRDP process was applied in the pilot.

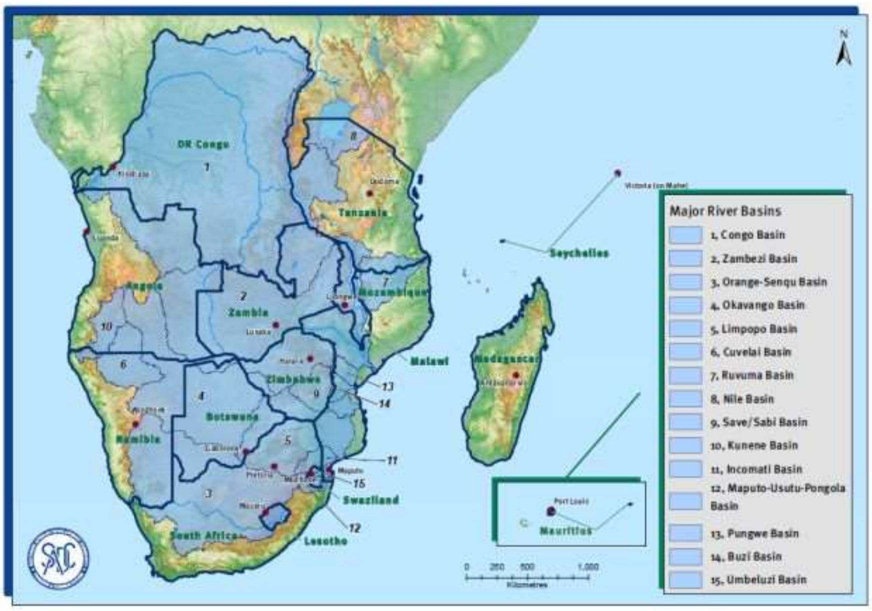
Taking into consideration outcomes of this research as well as the research team's knowledge of broader approaches to climate vulnerability, risk reduction, adaptation, adaptive policies and scenario planning, Sections 5 and 6 respectively describe the proposed CRDP approach, including lessons from its pilot application in the Cubango / Okavango River Basin (CORB), to assist in application in other Transboundary River Basins (TRBs) in the SADC.

2. Background Information

Collaborative management of water resources is vital for sustainable economic and social development in Southern Africa given that over 70% of the region's fresh water resources are shared between two or more countries. The large, transboundary basins of the SADC region are illustrated in Figure 1. The transboundary nature of water resources in the region has been the basis for the development and adoption of a series of regional instruments to support the cooperative management and development of shared water courses (SADC, 2012). Some broader instruments for water management include the Regional Water Policy (2005), Regional Water Strategy (2006), and the Regional Strategic Action Plan on Integrated Water Resources and Development Management (developed in 1998 to run in five-year phases).

SADC has also responded to the risk that climate change poses for development in the region in general, and specifically for its water resources. In 2011 it released the strategy paper, "Climate Change Adaptation in SADC: A strategy for the water sector" that highlights some specific challenges that SADC will face in its water sector based on climate change projections (SADC, 2011). It notes, for example, the different risks that climate change poses for the drought-prone areas of Namibia, Botswana and Zimbabwe and the more humid areas of Mozambique and Zambia. The strategic framework highlights the need for multi-faceted effort across political boundaries to enable adaptation in the water sector. The SADC water adaptation cube highlights a three dimensional approach that includes levels of intervention (local, river basin, and regional) and areas of intervention (governance, development, management) at different stages of adaptation (preparation, response and recovery). These are highlighted as being applicable for water governance, infrastructure development and water management.

Figure 1 **Transboundary basins in SADC**



Source: SADC, 2012

Complementing these policy commitments at the SADC level, a number of RBOs have been established to enable cooperative management of shared resources, as identified in Table 1. These organizations have also begun to look at the risk that climate change poses for achievement of their development goals. For instance, the Limpopo Watercourse Commission (LIMCOM) has undertaken a climate impact analysis for the Limpopo basin (Risk, vulnerability and resilience in the Limpopo River Basin [RESILIM]) and identified four orders of climate-related impacts from physical to human (Petrie *et. al.,* 2014). This is briefly described in Table 2 as part of our reviewed literature on water and climate change related literature. In addition to RBOs, SADC countries are looking closely at their climate-related vulnerabilities, particularly in the water sector. Indicative of this is a study in Zimbabwe, where the impacts of climate change on water resources relevant to the country are examined (Davis & Hirji, 2014). This study is collaboration between the government Zimbabwe and the World Bank. Due to the high relevance of the Zambezi River and the Limpopo River to Zimbabwe's economy, the study highlights the importance of transboundary management on these systems.

Table 1 **Transboundary basins in the SADC.**

Transboundary Basin	Commission	Countries
Congo Basin	Commission Internationale du Bassin Congo-Oubangui-Sangha (CICOS)	Democratic Republic of the Congo, Cameroon, Republic of Congo, Central African Republic
Kunene	Permanent Joint Technical committee (PJTC)	Angola, Namibia
Limpopo	Limpopo Watercourse Commission (LIMCOM)	Botswana, Mozambique, Namibia, Zimbabwe
Okavango	OKACOM	Angola, Botswana, Namibia, Zimbabwe
Orange-Senqu	The Orange-Senqu River Commission (ORASECOM)	Botswana, Lesotho, Namibia, South Africa
Zambezi	The Zambezi Watercourse Commission (ZAMCOM)	Angola, Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia, Zimbabwe

Source: SADC, 2012

Several studies have projected the potential changes in climate in SADC over the coming years. These studies and their projected changes include:

- Li *et al.* (2015), which projects for the Okavango Basin:
  - Temperature: to 2029, there will be increased winter temperatures by 0.2-0.6ºC relative to 1990 values, and increased summer temperatures by 0.4-1.0ºC relative to 1990 values, for a net annual increase of 0.4-0.8ºC. A greater increase in temperatures is expected in Angola than Namibia/Botswana, especially in summer.

    - Precipitation: to 2029, no change in winter precipitation is projected; summer precipitation is projected to decrease over Angola by -10 to -20%, and increase over Botswana by +5%
    - Runoff: These changes correspond to a decrease in runoff by -25% in Angola and Namibia, and increase in runoff by +50->75% in Botswana (but from a low base).
- Niang *et al.* (2014), looking at the southern Africa region, project:
    - Temperature: by mid-century, temperature could increase by 1.5ºC for Representative Concentration Pathways (RCP) 2.6) and +2.5ºC for RCP8.5. By 2100, temperatures could increase by 1.5ºC for RCP2.6 and +4.0ºC for RCP8.5.
    - Precipitation: by mid-century, could decrease by -10% under both RCP scenarios. By 2100, there is strong agreement that precipitation could decline by 10% under RCP2.6 and by 20% under RCP8.5.
- Dike *et al.* (2015), whose findings are similar to those of Niang *et al*.:
    - Temperature: for the period 2073 to 2098, increase in summer and winter temperatures of 1ºC to 2ºC for RCP2.6 from 5-6ºC (winter) to 5-7ºC (summer) under RCP8.5.
    - Precipitation: for the period 2073 to 2098, under RCP2.6, -0.2 to -0.5 mm/day for Angola, Namibia and +0.5-1.0 mm/day for northern Botswana in the summer and no change in the winter. For RCP8.5, precipitation change of -0.2 to -0.5 mm/day across the region in the summer, and no change in the winter.

These findings are summarised in section 4.4 in the context of describing the MSIOA scenarios process.

3. Assessment of Tools and Approaches

A range of vulnerability assessment processes and approaches have been developed as awareness of the risks associated with climate change has grown and, with it, the desire by a broad range of actors to understand its potential implications for their activities. These assessments provide a systematic means by which to understand "what to adapt to and how to adapt" (Füssel & Klein, 2006, p.5) to both reduce exposure to potential risks and take advantage of emerging opportunities. A broad array of vulnerability assessment processes now exist that may be applied at different geographic scales (e.g., community, company, city, watershed, and country), for different sectors (e.g., health, forestry and agriculture), at different stages of the decision making processes (e.g., strategic, portfolio and project levels), and for different purposes (e.g. awareness raising, allocating resources, policy development, and monitoring adaptation progress). They range from being high-level analyses conducted over a short period of time to highly detailed assessments that draw upon in-depth analysis completed over a period of months. Generally, all vulnerability assessments use a combination of qualitative and quantitative information (Hammill *et al.*, 2013).

The proliferation of vulnerability assessment guidance and tools has led to a paradoxical situation. On the one hand, it is often challenging to identify the specific tool or process that is most suitable to one's individual context given the array of options from which to choose. On the other hand, finding an "off the shelf" vulnerability assessment approach that meets one's own particular needs is uncertain given the diversity of adaptation contexts. Consequently, vulnerability assessment processes are generally tailored to the specific circumstances in which they are to be applied, modifying and building on existing guidance, tools and information.

Within this context, a practice-oriented review of vulnerability assessment tools and approaches was undertaken to inform development of the CRDP approach. While giving consideration to some general assessment tools and approaches, the review focused primarily on those developed to support decision-making related to the water and infrastructure sectors, and those developed for use in Southern Africa. The review sought to understand:

- The purpose of the tools and how this could be related to development of the CRDP approach;
- The strengths and weaknesses of the tools relative to efforts to develop the CRDP approach;
- The extent to which their objectives and structure differed from or are the same as the envisioned CRDP approach; and
- Their potential complementarity with the planned CRDP approach.

The literature reviewed is presented in Annex 1. Although developed for different purposes, the vulnerability assessment tools and approaches reviewed shared a number of common elements. In general, they were designed to help users:

- Clearly define the scope, objectives and approach for the assessment, the reason for undertaking the assessment, and its objectives in terms of understanding the *vulnerability of what* (e.g., a specific group, region, economic sector, ecosystem), *to what hazard(s)* within a particular time period, and *who should be engaged*;

- Identify relevant hazards and attributes of concern (both climatic and related non-climatic) and understand the sensitivity of a system to these hazards and concerns;
- Assess vulnerability to a hazard over time, taking into consideration uncertainties, the underlying drivers of vulnerability and potential social, economic and ecological impacts; and
- Identify, assess and prioritize potential risk reduction strategies.

Of the sources of guidance examined, none appear to fully meet the needs of the CRDP project, namely a climate risk assessment methodology that: **integrates concerns related to the vulnerability of water infrastructure, and the people and communities that surround them, to the impacts of climate change, as outlined in a series of development scenarios; addresses in an integrated matter social, economic and ecological concerns; and is appropriate for participatory use within a transboundary watershed context.**

While there is much work covering the techno-economic risks and adaptation options associated with water infrastructure development such as hydropower or irrigation systems, even advocating the use of scenario planning to identify and proactively addressing emerging climate risks (e.g., Cervigni *et al.*, 2015), there is a tendency to leave broader ecological and social concerns unaddressed. The use of narrow framing that restricts scope to engineering and revenue stream concerns and does not systematically engage stakeholders may miss vital issues – both challenges and opportunities – that may then lead to sub-optimal or downright unsustainable investment performance.

Assessment methodologies such as that developed by Morchain & Kelsey (2016) provide helpful guidance regarding how to conduct community-level vulnerability assessments that engage vulnerable groups in the process and are informed by an underlying understanding of the local drivers of vulnerability.

The review also identified common approaches that could be used to inform development of the planned CRDP process. Mapped against the general stages of the planned CRDP pathway, these elements include:

Stage 1: Scoping

Scoping is a standard component of assessment that helps establish the boundaries of issues under consideration in the specific case in the conceptual, physical/spatial, temporal and institutional sense (what's in and what's out). Scoping presents an early and important opportunity for interaction between science, policy, business, and crucially, the concerns of interests of directly or indirectly affected stakeholders. Even though scoping has a profound effect on the overall approach and course of the assessment, it is an area whose importance is often under-appreciated and where practice may fall behind the conceptualizations and ambitions of science (Snell and Cowell 2006).

Stage 2: Information and data gathering

Vulnerability and adaptation (V&A) are multi-dimensional concepts and their assessment requires both quantitative and qualitative data. In terms of quantitative data, the assessment typically relies on series of V&A indicators at different levels of aggregation and applying to all conceptual dimensions of V&A analytic frameworks, from climatic and non-climatic stress, exposure, impact, adaptive capacity and vulnerability (e.g., Adger, 1999; Brooks *et al.* 2005; Adger *et al.* 2004; Smit & Wandel, 2006). Quantitative data can be spatial and non-spatial and may include map-based overlays of present or projected climate stress and social stress such as level of poverty, access to know-how, or broader livelihood measures. Qualitative data may require direct interaction with stakeholders selected through stakeholder mapping and the use of data gathering techniques such as interview or survey methods or participatory engagement of stakeholders in focus group or workshop settings.

Standard sets of climate data related to temperature, precipitation and other climate variables are normally required with detail on the baseline and variability of spatial and temporal patterns, changes in the amplitude patterns of extreme values, moving averages and other statistical parameters (e.g., National Oceanic and Atmospheric Administration, 2016). Climate change indicator projections are derived from Global and Regional Circulation Models (GCMs or RCMs and their combinations), typically using various RCPs adopted by the Intergovernmental Panel on Climate Change (IPCC). As a specific methodology applicable to analyzing the potential stress associated with climate change, self-organizing maps (SOMs) can be used to track common patterns across a range of climate futures (i.e., multiple scenarios). SOMs can both provide a visually straightforward image of the direction and magnitude of change in climate variables, and help identify trends that are more likely to be robust across different scenario projections (e.g., Van Schalkwyk & Dyson 2013; Hewitson & Crane, 2006).

Information and data collection in the CRDP process will be informed in part by the existing CRIDF Climate Change Risk Assessment (CCRA) process and tools, which provide access to information and climate vulnerability indices specific to Southern Africa. This includes the online CRIDF Climate Vulnerability Mapping Tool (CRIDF, n.d.), which provides high level projections of climate risk for different SADC locations and is intended to help inform an initial climate vulnerability assessment in the scoping and screening stages of proposed infrastructure investments.

A common set of climate change projections for Southern Africa in the short-term (2016-2035) and medium term (2046 to 2065) along with likely impacts of these projected changes in five agri-climatic zones was developed to inform CRIDF's CCRA process. For each zone, high-level information is provided regarding projected changes in precipitation variability, temperature variability, and extreme events in the near- and medium-terms, and their potential impacts on agriculture and health (CRIDF, 2016).

Stage 3: Impact assessment

Impact assessment covers social, economic, ecological and institutional dimensions and their combinations, as these do not normally appear as distinct and clearly separable. Impact assessment often involves the identification of baselines and the analysis of impacts associated with alternative development options under different climate scenarios. They may build on and combine quantitative indicators with qualitative data, as described earlier.

Reviewed sources that could inform this stage of a vulnerability assessment include:

- The World Bank's *Enhancing the Climate Resilience of Africa's Infrastructure* document describes a framework and process for evaluating the potential costs of climate change on water and power investments and how investment plans could be modified to mitigate risks and maximize benefits (as indicated by economic outcomes) across a range of futures.
- *Climate Change and Water Resources Planning, Development and Management in Zimbabwe* highlights a preliminary assessment of the impacts of climate change in water resources in Zimbabwe including specific impacts on water availability and resources for 2050 and 2080 as well as case studies on water supply, dam operations, irrigation, and hydropower development in parts of the country. Finally, connecting with specific water policies and potential market mechanisms such as water trading have been linked to water-based climate adaptation.
- In the RESILIM framework for the Limpopo Basin, a 1st-to 4th order impact framework is defined: 1st order being basic climatic parameters, 2nd order including physical and chemical parameters, 3rd order being ecosystem services and 4th order including human health, livelihoods, economy, etc.
- The water-food-energy-ecosystems nexus approach for transboundary basins highlighted by the UNECE focusses on inter-sectoral linkages and synergies that could be leveraged through policy measures for improving international relations and promoting greater policy coherence. Specific areas of action based on pilot applications included institutions, information, instruments, infrastructure, and international coordination and cooperation.
- Wilks and Kgathi (2007) include a methodology for assessing five key components of vulnerability at the local level: initial well-being, livelihood resilience, self-protection, societal protection, and social capital.

Stage 4: Vulnerability assessment

Vulnerability assessments aim to determine the degree to which a system is susceptible to the impacts of climate change, often appearing in combination with other forms of non-climatic change (e.g., technological, institutional etc.). Its key elements include the earlier discussed exposure and sensitivity that together result in potential impacts, adaptive capacity and actual adaptation responses. One of many possible representations of the linkages between these components is shown on the figure below.

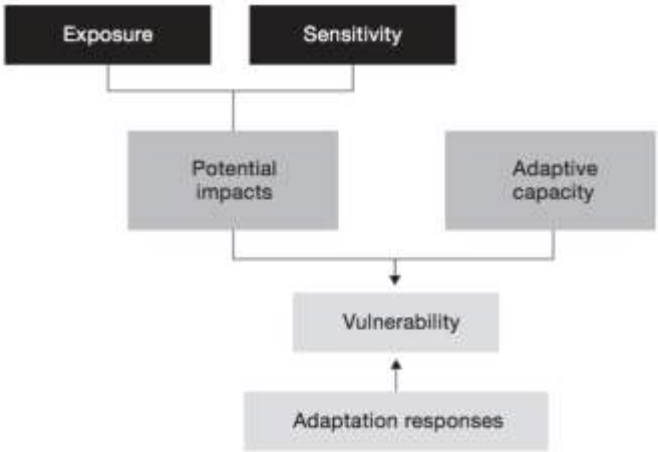


Figure 2 **Representation of the components of vulnerability to cilmate change and their interlinkages (Allen Consulting reported in Bizikova et al. 2009)**

Following this, or the many other similar frameworks, vulnerability assessments use available climate projections to understand potential future climatic changes in a particular location and the potential capacity of local systems to adapt to these changes. The assessment enables identification of those parameters that are likely be to more vulnerability to the impacts of climate change (e.g. high sensitivity, high exposure and/or low adaptive capacity) to prioritize impacts of particular concern in light of the purpose for which the assessment is being undertaken (e.g., assessing the vulnerability of infrastructure development in a transboundary watershed).

The analysis typically is further informed by a risk assessment that examines how potential impacts of climate change may influence the achievement of planned development outcomes. Using a risk rating system (e.g. low, medium, high), the assessment considers the *likelihood* of a potential event or outcome occurring and the *severity* or *consequence* of an event should it occur. Assessed values for each parameter examined can be rolled up either qualitatively or quantitative to identify the most important risks, and therefore potential priority areas, for actions to reduce vulnerability. These assessments may be done solely based on expert input or can be informed by more in-depth research to better understand the likelihood or potential severity of an impact.

An assessment of adaptive capacity is obviously important for the analysis of climate resilient development pathways. At a community level, for example, this could be a function of issues, such as household income and assets, or it could be assessed at a species level in terms of thresholds against key environmental parameters like temperature. For a broader appreciation of this issue, particularly in terms of the ability of institutions to manage environmental concerns, it is also proposed that institutional adaptive capacity is assessed. An approach to this has been developed for transboundary river basins (Milman et al, 2013) which looks at dimensions such as authority, national-level governance, common perspectives, risk planning and provision, basic information exchange and linkages. It is proposed that this approach be experimented within this project to assess whether it adds value to the outputs, and if so what improvements to it could be made.

Of note, these assessments focus primarily on climate risk; they do not necessarily take into consideration other factors, such as development trajectories or political changes, which could significantly alter the adaptive capacity, for example, of a sector or population. A scenario planning process may be used to fully explore these interactions.

Taking into consideration these generic characteristics of vulnerability and risk assessments, the CRDP approach is expected to be informed by available methods, such as LIMCOM's RESILIM assessment and its 1st-to-4th order impact framework and the process by which country-specific climate indices were developed by Knight (2016) for Angola, Namibia and Botswana.

Stage 5: Identification of risk reduction and adaptation strategies

Based on the definition of present or projected vulnerabilities, given adequate capacity, society can develop adaptive responses. The intensity of responses may vary from minor adjustments to deeper structural changes that qualify as true adaptation or coping strategies if the level of stress is beyond the adaptive capacity. Risk reduction and adaptation measures may take many different forms and be spontaneous or planned and operate at different levels, from individual to organizational or political, up to global. During an assessment, adaptive responses can be identified in response to risk and vulnerability through an expert or consultative process with stakeholders, based on criteria that take both the suitability of the response to the problem and it sufficiency into account. Adaptive responses to expected future risks and vulnerabilities can be tested using integrated model assemblies with representation of development options, impacts in various relevant categories and the effects of climate change.

4. Identification of Thematic Assessment Methodologies

Beyond the generic stages of the assessment described above, assessment methodologies for assessment in key thematic categories have been developed, namely:

- Economic impact assessment
- Social impact assessment
- Ecological impact assessment
- Aggregate climate vulnerability and resilience based on pre-defined infrastructure development scenarios (such as MSIOA in the Okavango case)

4.1 Economic impact assessment

The economic impact of water and realted adaptation projects is typically considered by using a combination of qualitative and quantitative project-specific information derived from expert input or previous studies. Quantitative variables like net present value (NPV) or financial internal rate of return are usually calculated based on a small number of benefits that derive either directly from the project (i.e. the shadow or actual price of water provided) or activities benefitting from projects (i.e. the value of increased agricultural output as a result of access to water). These quantitative variables are then combined with qualitative indicators (like changes in access to services, proximity to population centres, etc.) using statistical or multi-criteria decision analysis methods to create composite indicators of economic impact (Cervigni, Liden, Neumann, & Strzepek, 2015; Marcelo, Mandri-Perrott, House, & Schwartz, 2016; United States Agency for International Development, 2014).

The Infrastructure Prioritization Framework (IPF), described in Marcelo *et al.* (2016), is an example of an approach that could be relevant to a CRDP initiative. It is a quantitative multi-criteria prioritization approach that combines project-level financial, economic, social, and environmental indicators into two composite indices, namely a social-environmental index and a financial-economic index. In compiling the two indices, both quantitative and qualitative information is used, and monetized benefits are combined with non-monetized benefits. This allows inputs from various common assessment methods, like cost-benefit analysis and expert judgements, to be combined in a structured way.

A weighted additive model is used to construct the two composite indices. A number of projects within a sector can be compared using a graphical display that plots the relative performance of projects along two axes defined by the composite indices. In a pilot of the IPF in Vietnam during which the approach was used to prioritize public sector infrastructure investments in the transport, irrigation and urban sectors, for example, the following five indicators were combined to develop the social-environmental index: Direct Jobs Created; Number of Direct Beneficiaries; People Affected by Repurposing of Land Use; Cultural and Environmental Risks: and Pollution, in terms of CO_2 equivalent emissions.

The financial-economic index was also developed by combining five indicators, namely: internal rate of return; multiplier effects generated by an Input-Output model; a qualitative score indicating the presence (or not) of a project in Priority Economic Zones; a qualitative measure of implementation risk; and a qualitative indication of the extent to which investments would complement, or be in competition with existing infrastructure. Marcelo *et al.* (2016) point out that the IPF methodology can also be used where this level of input information is not available. In a pilot in Panama the social-environmental index was constructed from three indicators (number of direct beneficiaries; the number of direct jobs created; and the number of individuals that would benefit from the new infrastructure living below the poverty line) and the financial-economic index from only one component indicator (the benefit-cost-ratio emerging from a financial cost-benefit analysis). In the case of the financial-economic index, the cost-benefit ratios were only standardised between projects, and no additive combination of indicators was undertaken.

While the use of an Input-Output model in the Panama example above suggests that the economy-wide impact of projects was considered, the economy-wide impacts of specific adaptation projects is often neglected outside of the use of integrated assessment models (and even there it is rare) (Productivity Commission, 2012). This is in contrast to the standard way in which the economic impact of mitigation projects (and infrastructure projects more broadly) is considered, which typically includes an assessment of the economy-wide impact of projects using economic models. Where economy-wide models have been used to quantify economic impact in adaption studies, it has typically been to look at sector or macro-level impacts rather than project-specific impacts. Furthermore, where the economy-wide impact of specific sectoral adaption measures has been considered, this usually involves considering the impact of a preselected list of interventions rather than trying to prioritise specific interventions (The World Bank Group, 2010).

Watkiss (2015) mentions that a consensus on best practice techniques for economic appraisal of adaptation activities has not yet emerged. While partly due to differences in general economic appraisal practices in developing countries, this also reflects the increased number of organisations and actors becoming involved in adaptation activities – many of whom have different views of how economic appraisal should be undertaken. A greater focus on mainstreaming adaptation into existing policy and development planning, as opposed to treating adaptation as a singular activity, however, will lead to greater use of existing sector and development planning practices. This is expected to lead to standard economic appraisal approaches and methods used in development and policy planning becoming more prevalent within the adaptation field.

A particular class of economy-wide impact models, Computable General Equilibrium models, which is widely used in policy analysis and development planning, is suitable to modelling the economy-wide effects of planned adaption activities, and has recently been applied to the adaptation literature by considering water resources and irrigation as production factors in the agriculture and other sectors (ECONADAPT, 2016; Liu *et al.*, 2016). This area of study, however, is still fairly limited (ECONADAPT, 2016). While a number of Computable General Equilibrium models have been used for this purpose, the multi-region Global Trade Analysis Project (GTAP) model has been particularly prevalent. Multi-regional models are well-suited to modelling water-related issues and water scarcity, since it typically affects multiple countries and involve cross-border water trade (Calzadilla *et al.*, 2011; Liu *et al.*, 2014; Taheripour *et al.*, 2013).

In order to facilitate the study of water scarcity, the water-focused GTAP-BIO-W model was created that includes information on rain-fed versus irrigated agriculture coverage, cropland area and yields, and water use by river basin (Liu *et al.*, 2016; Taheripour *et al.*, 2013). However, not all river basins (such as the Okavango) are included in the GTAP-BIO-W database. This is possibly due to the fact that while Namibia and Botswana are included in the latest GTAP database as individual regions, Angola is grouped with the Democratic Republic of the Congo.

For application of a basic CRDP approach to a region such as the Okavango river basin it is recommended that the basic version of the GTAP database is used to generate additional indicators of the potential economic impact of different development scenarios[1]. In the case of the Okavango pilot this was used to supplement the MSIOA NPV values[2].

The economic expert should then engage with the technical and modelling experts to understand the likely impacts of the different development scenarios on water use and how this will influence sectors like agriculture, tourism or industry. The GTAP model can then generate a range of economic indicators showing the economy-wide impact of counties in a river basin as a result of trade flows, multiplier effects and other linkages between the national economies within a river basin.

Box 1: Using GTAP and the Okavango Case Study:

In the Okavango pilot, the impacts in Angola had to be estimated from the modelling results for the Angola-Democratic Republic of the Congo region based on the relative size of these two economies. Depending on the modelling results, and how the GTAP output is received by stakeholders, it would then be possible to decide whether it is worth considering collaborating with GTAP to create a separate Angola region within the GTAP database that could also potentially lead to the updating of the GTAP-BIO-W model.

Ideally in the future economic appraisals within a CRDP process could also include the value of monetary and non-monetary ecosystems services and natural capital stocks. While the methods, techniques and literature relating to the valuation of natural capital and ecosystems services have grown exponentially in recent years, significant data gaps still exist – particularly with respect to nonmarket values (Guerry *et al.*, 2015; Productivity Commission, 2012). Polasky *et al.* (2016) mention that a lack of standards to define terminology, acceptable data sources and methods, and reporting requirements is hampering the use of ecosystems services and natural capital information to inform policy development. Consequently, the authors acknowledge there is little adoption of ecosystem information in the key decision processes of public or private sector institutions. Guerry *et al.* (2015) share this view, and state that the use of ecosystems service and natural capital information into general development policy decisions is still relatively rare. Thus, while this is a promising area of study (see, for example, Watkiss and Cimato (2016) for examples of studies where the valuation of ecosystem services has been included in adaption assessments), it is suggested that the emphasis of CRDPs for the time-being be on generating the type of economic indicators that will enable adaptation projects to be mainstreamed into standard development planning processes.

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[1] In the case of the CRDP pilot in the Okavango the development scenarios were generated by the MSIOA process. CRIDFS CRDP process then analysed them from a climate resiliency perspective

[2] During the CRDP pilot, rather than have the model generate changes in water use, (irrigated agriculture etc.), changes in these variables were taken from the MSIOA models and run in conjunction with the climate projection scenarios, to show the likely physical impacts of climate change. The likely sectoral implications of these physical impacts were then be fed into the GTAP model as inputs

4.1.1 Potential economic impact indicators

The usefulness of the NPV values for different development pathways should be investigated. One possibility is to show some NPV values in a disaggregated way to emphasise the gains and trade-offs that are expected for different development options. The extent to which this can be done will depend on whether it will be possible to access development scenario data sheets, and how easy it is to manipulate the underlying information.

The following macroeconomic indicators can be obtained from the GTAP model:

- Changes in GDP
- Changes in welfare[3]
- Changes in aggregate employment
- Changes in wages (according to five skill levels – which can be used as a proxy for income equality)
- Changes in sectors not directly affected by the planned dams
- Changes in imports and exports (balance of trade impact)
- Changes in government revenues
- Changes in household income

The last two indicators would also provide an indication of the resources that will be available to allow communities to adapt to the impacts of climate change.

4.2 Ecological impact assessment

Choosing the appropriate ecological assessment approach to assist the institutions and communities in river basins to analyse and assess different development paths, under different climate change scenarios, will depend on a number of different factors. These factors include their ability to accurately describe the ecological systems and their key elements, the ability to accurately relate the analysis to the types of projects that the development path involves, what work has been before on the system (including what data exists) and can climate change projections be integrated with it to provide impact predictions that are credible and evidence-based.

There is no perfect methodology. This is particularly true when considering that as the success of any process to define climate resilient development pathways is also a function of facilitating effective stakeholder input into the pathway development process. This means that the approach has to make sense to key stakeholders so that they can analyse and interpret potential impacts. This is never easy, so the proposed approach needs to be useful not only for carrying out background research but also to be used in a workshop context with

[3] This is a relatively technical composite indicator that looks at how economic efficiency is impacted by policy actions. There is a risk that it will not be possible to describe this indicator in terms that are easy to engage with, and if that is the case this indicator may have to be removed from the list of focus economic indicators. The constituent parts of the welfare effect are:

- the allocative efficiency effect (which effectively represents the removal of distortions in the economy, with better use being made of existing resources),
- the endowment effect (arising from changes in the use of primary factors, such as unskilled labour),
- terms of trade effect (changes in relative prices of exports and imports), and
- the investing-savings terms of trade (reflecting the impact of the change in price of investment).

stakeholders and policymakers. Furthermore, it also has to produce conclusions that can inform strategy and policy development and implementation on the ground.

Rivers are living systems, and their flow regimes are commonly seen as the master variable that drives their nature and functioning. As river flow changes, the river itself responds with potential changes in its channel, banks, floodplains, estuary, water quality, flora and fauna. These changes in turn impact people who live along the river and depend on it in some way for their livelihoods, as well as affecting any wider body of people who value the river.

Environmental Flow (EFlow) Assessments emerged as a discipline in the 1970-80s and recognise that the river's future is of concern to society at large and that this future should be agreed in a system of discussion and negotiations that considers the costs as well as the benefits of water-resource development and guides the eventual nature of the development (King *et al.* 2014). EFlows are now seen as the pattern of flows (timing, magnitude, frequency, duration, variability), both intra-annually and inter-annually, agreed for river maintenance. They reflect the trade-off between conservation and development of that river at that time as agreed by its government(s) and other stakeholders. EFlows can be set for any part of a riverine system, including its floodplains and estuary.

EFlow Assessments are increasingly being done at the basin scale (Brown *et al*. in press), which is crucial when river basins are shared by more than one country. Positioned at the heart of Integrated Water Resource Management (IWRM), they reveal opportunities and risks not apparent or available at the level of single project assessments. They can guide basin planning, and highlight potential biodiversity offsets and other mitigation measures not possible at the project scale.

EFlows are now a legal requirement in many countries and by most international funders. They have been, or are being included, in basin level planning in several developing countries, many of them trans-boundary, including the Ganges Basin, Mekong Basin, Nile Basin, Northern Aral Sea, Okavango Basin, Orange-Senqu Basin, Tarim Basin, Senegal Basin, Pangani Basin, Yangtze Basin and Zambezi Basin (Hirji and Davis 2009).

For the purposes of assessing the impacts on the natural environment a small number of indicators need to be selected to predict how they might change from baseline (Present Day) for the most significant sites/scenario assembly. Performance under each indicator is then scored on a 7-point scale between -3 and +3. The positive and negative label assumes, in EFlows work, that the system is moving back toward natural (i.e. POSITIVE: a degraded ecosystem is being rehabilitated) or away from natural (i.e. NEGATIVE: the ecosystem is moving away from natural). In the case of the Okavango, which is near natural, most predicted change will be negative.

The decision of how to rate each site/scenario/climate change model/time step permutation is based on the following information using expert judgment:

- the coarse hydrological predictions, which provide:
  - monthly volumes, rather than daily flows as normally used in detailed EFlows work
  - the percent deviation of these monthly volumes from the present-day situation
  - a summary of how the simulated monthly volumes would probably manifest in terms of hydrological indicators that ecologists can use

- the Transboundary Diagnostic Analysis (TDA) biophysical predictions in the DRIFT decision support system as used in the MSIOA project.

The decisions on climate-related change were entered into an Excel based assessment tool described later in this volume.

As the ecological assessment builds on the precautionary approach, Indicators need to be chosen that show a high sensitivity to flow change.

Selection of EFlows Indicators lessons from the CRDP Pilot in the Okavango

In the MSIOA study of the Okavango, colour-coded tables of predicted change for both the flow regime and 70 biophysical indicators revealed which indicators were likely to change the most. Based on this, five indicators were chosen for the Okavango CRDP pilot, three for the river section of the basin and two for the Delta/outflow[4].

River section indicators

Two major state changes could occur in the river: 1) a change from perennial to seasonal flow; and 2) the loss of floodplains in this flood-pulse driven system. All other changes will be gradual ones around those thresholds. Based on this and the colour coding in Table 14, two hydrological indicators of ecological relevance and one biological indicator were chosen:

Dry season low flow and duration. Almost all aquatic species cannot survive a dry river bed so species would leave the area or their life cycles would fail. There would be no passage to wetter parts of the system, and fish and other species would be fished out of isolated pools. Unit: Change from Baseline (Present Day) of 100.

Flood volume. This is a first indication of whether or not floods are changing in timing, volume or nature, and whether floodplains will continue to be flooded. Without floodplains, there will be a great loss of: groundwater recharge; dry-season flows released into the lower river; and floodplain productivity. Unit: Change from Baseline (Present Day) of 100.

The fish assemblage. Up to a 70% decrease in present-day fish stocks was predicted for some sites under some MSIOA scenarios. Fish reflect the health of the whole system that supports them (geomorphology, chemistry, vegetation and invertebrates) through their habitat and food needs, and are in turn a major food source for the birds and mammals of the system (tourism). An earlier version of this analysis showed that large birds and river-dependent wildlife showed very similar trends to fish through the sites/scenarios. Unit: Change from Baseline (Present Day) of 100.

Delta and outflow (Delta) indicators

Following the same rationale as for the Highlands, two indicators were chosen:

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[4] During the Okavango pilot the River Basin was split in two to take account of the fact that the basin straddles two agri climatic zones. In short over 90% of the water in the system arises from the Angolan highlands where the head waters of the Okavango River start. For more information see CRDP Pilot report on [www.cridf.com/]

(1) **Savanna.** The fundamental nature of the Delta is its wetness; any shrinkage of the wetted area is a loss of Delta and all that that implies. As the various wet habitat types of the Delta shrink and expand in the different MSIOA scenarios, the one clear trend is the advance of arid savanna grasslands. Unit: percent of total Delta under savanna.

(2) **Delta outflow.** The Thamalakane/Boteti River receives outflows from the Delta and is highly susceptible to the flooding regime of the Delta and the state of groundwater aquifers. It experiences dry and wet years of several years duration. When wet, it provides substantial support to fishing and agricultural activities and wildlife. Unit: percent of 200 km of river length that is dry.

4.3 Social impact assessment

The development of hydrological infrastructure in transboundary river basins may affect people's life in fundamental ways. Some of these impacts are captured by standard economic models and they are related to issues such as income and employment. However, social impacts can involve changes that are less tangible for economic analyses but still fundamentally important for assessing the risks and opportunities associated with the investment. Climate change adds another layer of complexity that affects people's lives and livelihoods either directly (e.g., through heat stress, water contamination) or indirectly (e.g., through the impact of drought on food production that affects income and nutritional conditions). These impacts can be multi-dimensional and involve not only quantitative but also qualitative impacts (both positive and negative) that call for using customized analytic methods. Collectively, they represent impacts that may significantly alter the preferences associated with specific development scenarios.

This section on integrating social impacts assessments into a CRDP process is structured as follows:

1) An overview and suggested frameworks for comprehensively understanding and analysing a projects' social context;
2) An overview of typical social issues and pressure points associated with water infrastructure and general infrastructure projects;
3) An indicative example of how social impacts might be ranked and presented; and
4) Outlines indicators that can be used to track adaptation to social impacts and specifically, the social aspects of climate change.

4.3.1 Suggested Social Impact Assessment Frameworks

There are several frameworks that allow for a holistic understanding of the social context in which developments take place, thus extending consideration beyond limited quantitative data, such as demographics, number of employed and unemployed people, extent of social services and social infrastructure, and so on. By understanding the local context in a more holistic fashion, the social assessment lead is in a better position to understand the different ways in which people are impacted, how best to intervene or mitigate these impacts, and which social indicators are most meaningful to track.

The frameworks below are divided into two groups: those that aid understanding of the baseline social conditions; and those that help measure the impact pathways between project aspects (or activities) and the associated changes to the receiving environment.

4.3.2 Understanding the baseline

The Five Capitals Model, Adaptation Coalition Framework and the Multi-Dimensional Wellbeing Model together provide comprehensive, high level frameworks for assessing the existing (baseline) social conditions in a community or other unit of assessment. All of these models share the notion of a "community[5]" being comprised of a variety of different forms of capital/assets/ dimensions of wellbeing. In this sense, they all seek to create a holistic, integrated understanding of baseline conditions.

The Five Capitals Model (Forum for the Future, n.d.) identifies five types of capital that make up the total assets within a particular context or community (natural capital, human capital, social capital, physical/manufactured capital, and financial capital). This framework allows for consideration of linkages between different forms of capital and knock-on effects of one capital in relation to another e.g. loss of natural capital (environmental resources) impacting social capital (resultant strain on relationships within a community). This helps to ensure that the capitals typically described in a socio-economic baseline (i.e. human, social, manufactured and financial) are not divorced from their integral connection to and dependence on natural capital/environment.

The Adaptation Coalition Framework includes two additional forms of social capital. These are Bonding Social Capital (strengthening of internal organization and capacity to take collective action based on the common backgrounds and experiences of the individuals or groups involved) and Bridging Social Capital (the linking of local groups or institutions to resources and external partners with similar goals regarding adaptation to climate change). These elements, which are critical in a climate change context, could be incorporated into the social capital category, or as additions to the existing five capitals (Ashwill, Flora, & Flora, 2011).

The Multi-Dimensional Wellbeing framework, developed by the National Wellness Institute (based in Wisconsin, USA), adds emotional and spiritual dimensions to the considerations of the social context. These dimensions can be especially critical in the context of water infrastructure and climate change due to the psychological effects of the changing environment, livelihoods, and hopes about future wellbeing. This model allows for considerations on the individual level and the community level, which is a valuable distinction as impacts on the two can be different (National Wellness Institute, n.d.).

4.3.3 Measuring impacts and effects of linkages

The Sustainable Livelihoods Framework was developed by DFID and built on prior work of other organisations like Oxfam to create a more dynamic framework to understand poverty (Fig. 3). It incorporates the Five Capitals model but includes consideration of the vulnerability context (shocks, trends, seasonality); the capital/assets that are put at risk; the impact of access to transforming structures and processes on people's ability to cope with project changes; the livelihood (and other) strategies that need to be put in place to address the impacts and associated vulnerabilities – all of which are shaped by the outcomes that one hopes to achieve (Harvard Humanitarian Initiative, n.d.).

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[5] It is recognised that communities are **very rarely homogenous**. They are **heterogeneous**, comprising groups and sub-groups, who align themselves around differing and changing interests and issues. This is particularly important to note in the context of development projects and climate change, where people are not affected similarly.

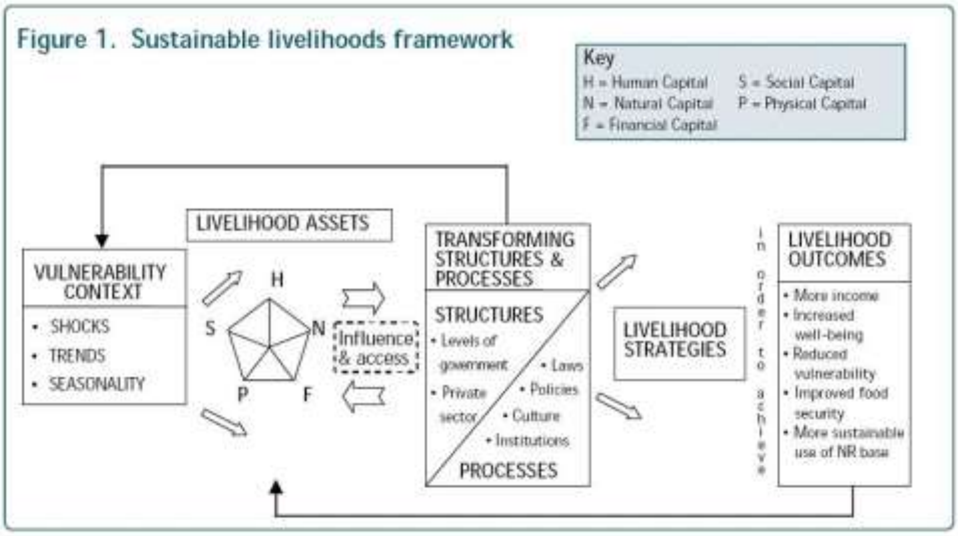

Figure 3 **Sustainable livelihoods framework**

According to the Harvard Humanitarian Initiative web page, “the framework aims to present these primary factors, their significance, and the nature of their interactions.” This website provides further details on how the framework can be applied (Harvard Humanitarian Initiative, n.d.)

Principle 10 of the 1992 Rio Declaration for environmental democracy provides a framework for assessing the accessibility and integrity of the structures and processes referred to in the Sustainable Livelihoods Framework. Principle 10 seeks to ensure that every person has access to information, can participate in the decision-making process and has access to justice in environmental matters, with the aim of safeguarding the right to a healthy and sustainable environment for present and future generations. These are important components for structures and processes governing water infrastructure management in the context of climate change (Economic Commission for Latin America and the Caribbean, n.d).

The DPSIR Framework can help to analyse the flow of causes/impacts and their feedbacks. This framework can be useful in further analysing the vulnerability context within the Sustainable Livelihoods Model (Kristensen, 2004). Further, an ISO 14001-based framework (see below) for analysing the links between project aspects and socio-economic context can be useful. This type of framework can track pathways between aspects and affected stakeholders, and is another format for an analysis similar to DPSIR.

Project aspect/activity	Relevant baseline characteristics and/or vulnerabilities	Resulting impact	Associated secondary or knock-on effects	Affected stakeholders	Proposed mitigation measure	Relevant indicator for tracking climate change resilience (and management or effect of the impact)

In all, the Sustainable Livelihoods Model is the most comprehensive and dynamic, with five capitals that combine to account for all necessary parts of a sustainable livelihood, and factors that account for context and trends (which influence the ability to access the five capitals). However, it is recommended that the precise indicators under each of the five capitals are improved by borrowing from the other models listed here, such as indicators around gender equality, good governance, bonding and bridging social capital, emotional and spiritual wellbeing, and others. This would ensure that the resulting framework is comprehensive and relevant to the specific context and considerations of this project.

4.3.4 Typical Social Impacts and Pressure Points in the Context of Water Infrastructure

Typical social impacts of water infrastructure, especially in contexts similar to the CRDP pilot in the Okavango River basin, revolve around the local populations' dependence on natural resources for their livelihoods. For example, river/wetland-based natural resources contribute as much as 19%, 32%, and 45% to household income in Angola, Namibia and Botswana, respectively (Barnes, 2009). Future water development might significantly affect these communities' access to/and quality of water and water-related resources, impacting on financial and in-kind earnings, nutrition, health, and leading to other knock-on effects. These impacts can be categories into the following dimensions:

- Aggregate livelihood impacts (loss of access to agricultural water or material changes in stream flow patterns, with effects on species that local communities rely on for food, etc.)
- Equity of access (who benefits from new water infrastructure, who loses access, considerations for downstream impacts, etc.).

Typical social impacts common to most infrastructure projects are listed in Annex 2. These impacts can be exacerbated by the uncertainty introduced by climate change, especially for individuals and communities that are already most vulnerable. Annex 3 provides some example considerations for assessing the significance of social impacts. In actual application, such ratings will however be context-dependent.

4.3.5 Potential social impact indicators

Social indicators should account for short-term and long-term impacts, as well as consider impacts at different levels (individual, household, community, etc.). They can also be direct and indirect, and some may overlap between categories (such as educational and economic). It is also important that one has a mix of input, output, outcome and impact indicators. An indicative list of possible indicators to be adapted under the above models, and how they might be measures, is provided in Annex 4.

5. Key Requirements of the CRDP Approach

Development pathway planning at the scale of transboundary river basins is always an integrated, multi-dimensional exercise that must take a wide range of socio-political, techno-economic, administrative and ecological conditions into account. By definition, the time horizon of development pathways at this scale extends to multiple decades, and while rooted in established baselines, it must factor in risks and uncertainties that may emerge along the path. A key assumption underlying the CRDP approach is that climate change will result in shifting baselines and a materially different risk environment that strategy development and planning processes must anticipate and to which they much adaptively respond. Resilience in the context of the CRDP is thought of as a result of successful adaptation. Instead of being a static end-point, it is thought of as a dynamic attribute of the river basin's socio-ecological complex with inherent capacities for anticipating and recognizing risk and course correction at an early stage in the policy / planning cycle.

The following are requirements of the CRDP approach in the context of river basins in general. Like the CRDP itself, they build to the extent necessary and possible on existing assessment and pathway development approaches and high-level integrated assessment principles such as BellagioSTAMP (Pinter et al. 2012). Most guidance documents emphasize the need for a participatory approach to ensure its relevance and legitimacy, have a flexible framework to enable tailoring to local circumstances, and highlight additional tools and processes to complement the analysis undertaken. It is noted that a well-designed assessment process should account for current conditions and development priorities and "consider the full range of socio-economic and political factors that not only shape people's vulnerability to current and future climate hazards, but also incentivise or impede adaptation action" (Hammill *et al.*, 2013, p.9).

Taking these factors into consideration, it is put forward that the CRDP approach will reflect the following principles:

River basins as open systems: while recognizing their clear boundaries, accept that TRBs are open systems that are exposed to internal and external forces of change that often cut across multiple scales.

Ecosystem-based: Incorporating an approach that recognizes the full array of interactions within an ecosystem, including humans and the ecosystem services connecting ecosystem functions with human well-being.

Policy relevance and decision support: ensure the CRDP delivers information that is useful for adaptation-related decision-making, whether at the technical, investment, policy or social/behavioural level.

Time horizon: explicitly recognize the time horizon of the development pathway under consideration and time slices as necessary to prepare projections for interim implementation measures and outcomes.

Integrated perspective: both the factors contributing to, enduring and adapting to risk are associated with multiple, interacting elements and forces in the TRB and therefore must be take into account; this includes but is not limited to climate change.

Vulnerability and adaptation framework: build CRDP around a formal (generic) V&A framework that builds on accepted best practice.

Vulnerability quantification: recognize the need to quantify where possible the components of vulnerability, including stress factors, impact metrics and capacity for adaptation through the construction of suitable indicators and indices.

Uncertainty: while trying to reduce it where possible, recognize that uncertainty is an inherent characteristic of long-term, complex TRB development pathways, make them explicit and address them through adaptive policies and planning.

Scenario assemblies: building on alternative climate change projections and development scenarios construct scenario assemblies that combine in all possible permutations climate and development futures; use scenario assemblies as heuristics to identify robust policies, technical or other interventions; build on existing climate and investment or development scenarios where available.

Critical thresholds: wherever possible, take into account the presence of critical thresholds beyond which TRBs may experience irreversible restructuring and unacceptable risk and impact.

Impact assessment: using impact assessment methods suitable to the social, economic or ecological domains quantify impacts associated with techno-economic or socio-ecological elements of the chosen pathway scenarios.

Qualitative information: complement quantitative information with soft data collected thought social research methods where possible.

Stakeholder involvement: engage with relevant and representative stakeholders early, substantively and throughout the CRDP process, and ensure they have a genuine say in determining vulnerabilities and adaptive options.

6. Outline of the Proposed CRDP approach

The generic CRDP approach has been developed to assess the climate vulnerability of potential river basin infrastructure development scenarios in the SADC region. The scenarios mostly focus on hydraulic infrastructure developments that have wide ranging potential consequences for other economic sectors, livelihoods and human well-being, and the environment. The impacts unfold over multi-decade time scales and an integrated approach is required to understand the vulnerabilities and adaptation options associated with them.

The intended geographic scale for the purposes of this approach is a transboundary river basin (TRB), focussing on those in the SADC region. This proposed approach incorporates lessons from existing vulnerability assessments and adaptation frameworks, and a pilot application in the Okavango Basin.

The CRDP is designed to provide stakeholders of a given TRB with a perspective on the climate vulnerability and resilience of whatever policy and planning frameworks are in place either at the national and basin level. As such it does not include a stage in which these plans will be generated.

The approach assumes the need to design a process that accommodates the presence of diverse policy and planning frameworks within TRBs. At one end of this spectrum are TRBs with reasonably well-formed infrastructure development or integrated water resources management (IWRM) plans with some projection of impacts. At the other end are cases where no coherent framework is identifiable, the picture is fragmented and has to be pieced together from applicable national legislations, international programs or plans for standalone infrastructure projects. Comprehensive, credible projections of socio-economic and ecological impacts in this case are therefore limited or nonexistent.

The CRDP is intended to work in parallel and in close interaction with infrastructure planning processes, preferably from an early stage to maximise its potential for positive influencet. It informs decision-makers of the climate vulnerability and resilience implications of plans, policies and programs, helping them sketch out adaptive alternatives to mitigate the impacts of climate change, but it stops short of producing alternative plans per se; it leaves these to the decision-makers in charge.

Vulnerability to climate change and its projection over time along alternative development pathways is a central point of attention for CRDP. For the purposes of assessing climate change vulnerability at the scale of TRBs in Southern Africa, it is defined as a function of stress from climate factors combined with the impacts associated with hydraulic infrastructure development, sensitivity of the given TRB, and adaptive capacity of the socio-economic and ecological part of the system. The alternative scenarios give rise to baseline and projected impact profiles in social, economic and ecological domains, and overall vulnerability as shown in Figure 5 below. Successful adaptation that results in low levels of vulnerability represents a resilient outcome. Key factors affecting the unfolding of investment program impacts on vulnerability and adaptation over time.

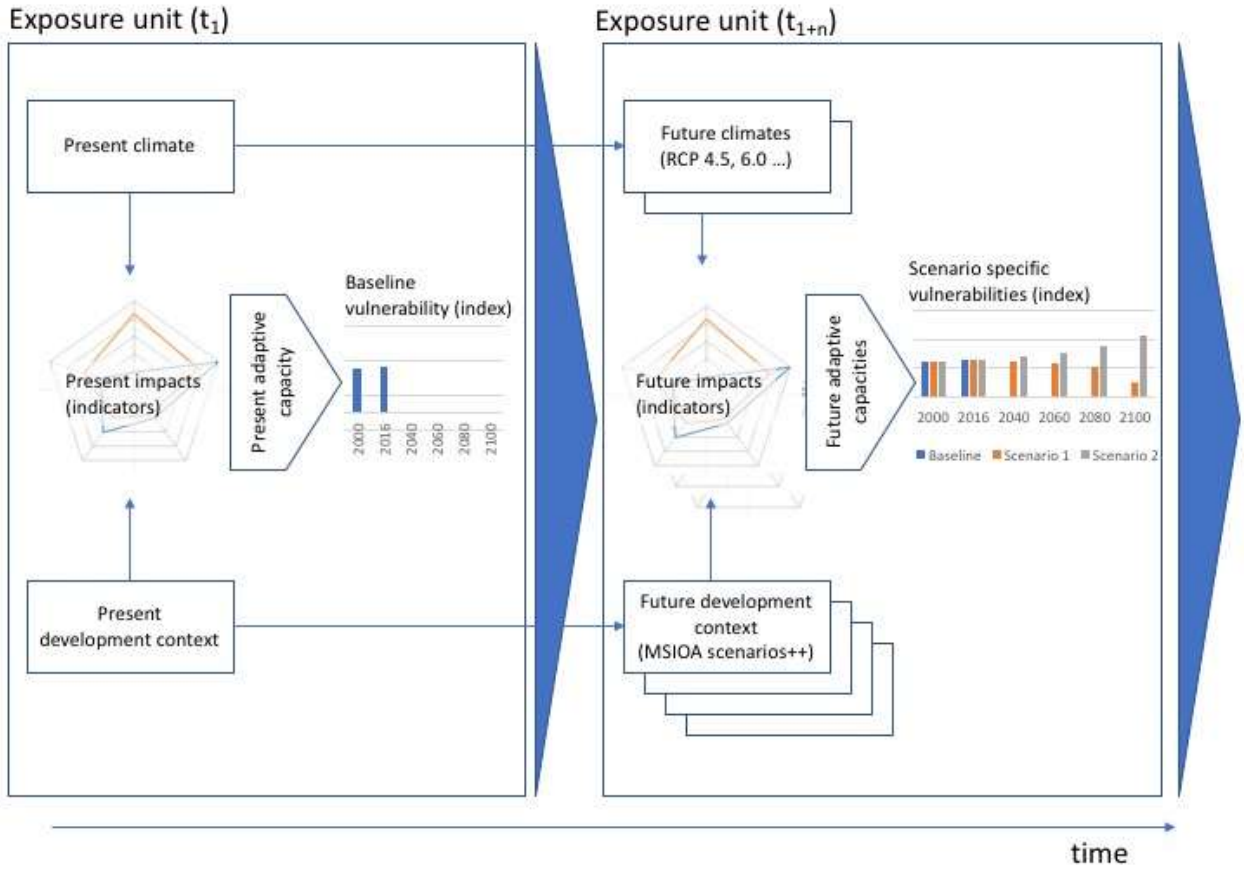

Figure 4 **Visualization of the evolving links between climate change, the impact of development pressure and adaptive capacity as determinants of vulnerability over time.**

The proposed CRDP approach will proceed in the following five stages, taking into account the initial research and the lessons learned from the Okavango pilot test with the MSIOA process. The rest of this section provides guidance on the development and combined use of the evidence base produced through different lines of enquiry related to the vulnerability assessment of selected water infrastructure development scenarios under the MSIOA program for the Okavango Basin. This multi-stage approach is shown in Figure 5.

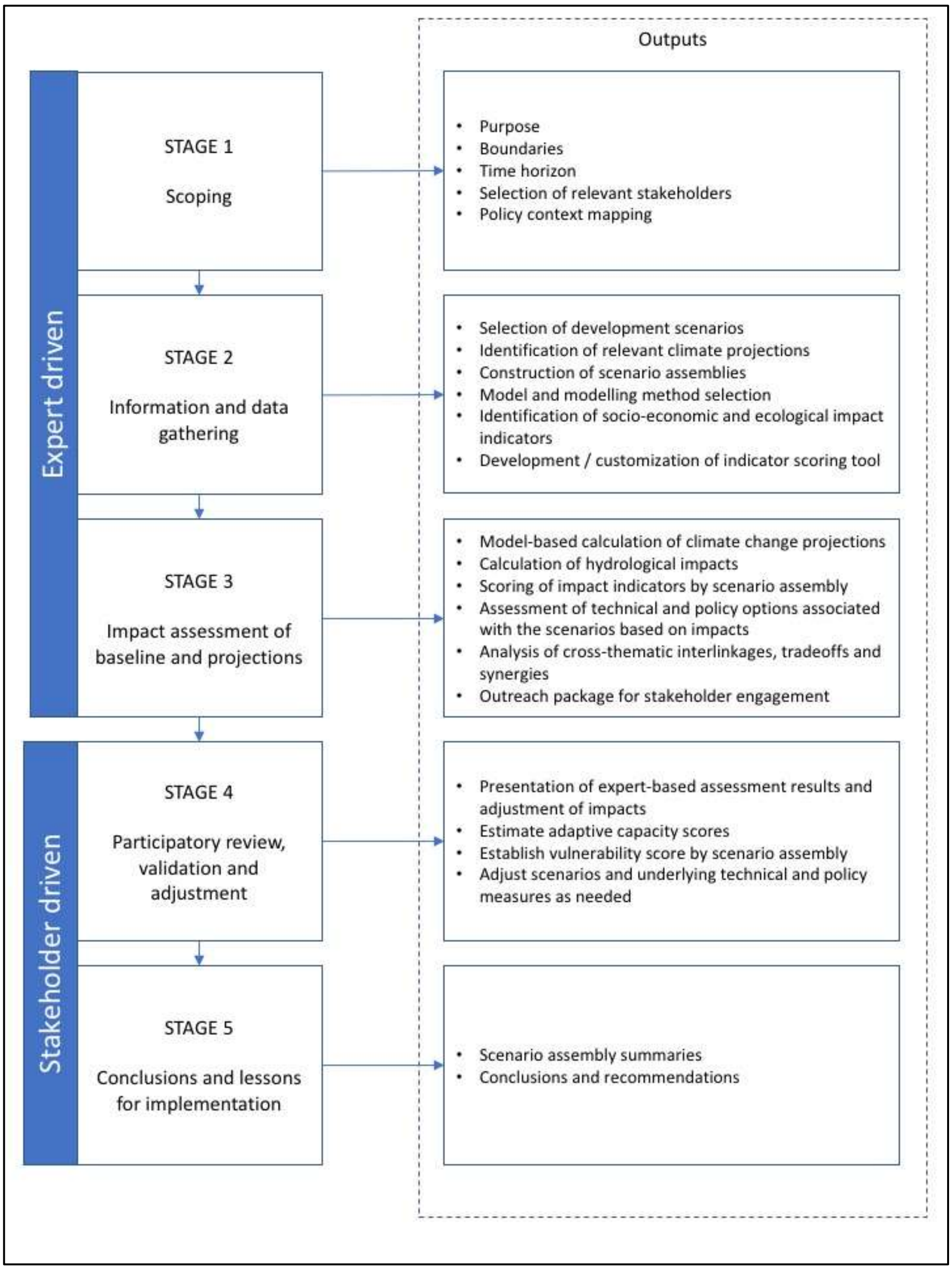

Figure 5 **Outline of the CRDP Approach**

Stage 1: Scoping

1.1 Formulate the purpose and mandate of the CRDP assessment

The purpose and mandate of the assessment are defined based on the expectations of a client, whether it is an RBO, a government agency, an international development bank or other. For the purposes of scoping, the following table / checklist may act as guidance on establishing boundaries and appropriate scale for applying the CRDP approach.

Table 2 **Scoping for CRDP**

Geographic area	
Political context	
Time scale	
Development scenarios	
Climate scenarios	
Hydrological projections	

1.2 Identify the boundaries of the TRB from both the biophysical and socio-political point of view

Precisely delineate the latitude and longitude of the TRB under consideration, identify the boundaries of political jurisdictions closest to the biophysical boundaries and note transboundary areas. The TRB with the boundaries will be considered as the 'exposure unit' where the most direct impacts associated with the investment program are expected to be noticed and unfold over time.

1.3 Establish relevant time horizons

For the assessment both the overall time horizon and in-between time slices need to be identified along which a transition pathway can be delineated. Consider making the time horizon and time slices consistent with major policy frameworks (e.g., IPCC). Consider the relationship between the time horizon and uncertainties in the assessment and the lifespan of the interventions, such as large water infrastructure projects.

1.4 Selection of relevant stakeholders

Use formal or informal methods and criteria to delineate the range of stakeholders to be involved in the assessment, being aware of the important consequences of these choices for the engagement approaches used throughout the assessment, the issues at stake and also the implications for the ownership of results (e.g., Murray-Webster and Simon 2006).

1.5 Policy context mapping

Take note of and if necessary formally document the existing policy context relevant for the jurisdiction(s) of the infrastructure development program. This may involve broad policy frameworks such as integrated development plans or sustainable development strategies and specific sector policies regarding technical, financial and other key aspects of the initiative (e.g. Pinter *et al.* 2007).

Stage 2: Information and data gathering

Stage 2 involves the development of the CRDP scenario assemblies and setting up the technical details of the analytic framework such as models and indicators. In the case of the application in the Okavango basin pilot, two, high probability climate projections plus present day climate were combined with three development scenarios to create nine *scenario assemblies.*

2.1 Selection of development scenarios

These should cover the core documents with the description of the infrastructure development plan with the necessary strategic, technical and financial details and the results of any pre-existing impact assessments. In the Okavango context these included the core MSIOA scenarios and the accompanying models and modeling results. In other basins they may include options developed as part of national spatial planning or a transboundary integrated water resources planning process.

Building on the earlier stakeholder identification, also take note of the key actors associated with the infrastructure development plan, their possible interests and involvement and role in the process.

Prepare a practice-oriented review of key infrastructure development program documents that cover the proposed development options.

2.2 *Identification of relevant climate projections*

Select the specific climate change projections to be used to assess the feasibility and impacts associated with various infrastructure development options. It is well known that climate projections are not precise, meaning that policy making often has to be undertaken in a situation of deep uncertainty. For example in northern parts of Southern Africa there is a split in the climate models over precipitation, with some projecting an increase whilst others a decrease. Using a scenario planning approach can help manage this uncertainty. In the case of the Okavango basin the self-organizing maps (SOM) approach was used to develop a cluster of higher probability and a lower probability climate projection scenarios, in addition to using present day climate for comparative purposes. Lessons from the Okavango pilot suggest that ideally there should be a baseline (current climate), a couple of higher probability scenarios and then an extreme scenario to help sensitivity test the assessment. In addition, an extreme scenario helps communicate the range of uncertainty more effectively to the policy makers. Without an extreme scenario one of the more likely scenarios may be mistakenly taken as an extreme scenario.

2.3 *Undertake a vulnerability and adaptive capacity analysis*

Identify key vulnerabilities of the basin and its population based on an understanding of exposure and sensitivity as well as adaptive capacity.

Box 2: Deep dive into vulnerability, adaptation and resilience

While vulnerability and adaptation are global concerns, they are usually manifested under conditions that are intensely local and often personal. Impacts that appear as tolerable at the higher level may turn out to be unsurmountable when communities and families face them through the true complexities of their life, with choices constrained by commitments, cultural factors, capacity gaps, lack of understanding and myriads of other factors that are hard to measure and represent in technical models and analyses.

Therefore, in order to validate and colour the findings that are derived from a hybrid expert – stakeholder process, the assessment of infrastructure development impacts should be combined with a detailed looked at these issues. This requires a place-based, fine-scale study combining quantitative and qualitative methods to answer a series of questions that are also relevant at the macro scale:

- What are key livelihood patterns in the region that organically connect people to the natural resource base?

- Are people noticing any signs of climate change? Are they noticing any impacts?

- Are they able to adapt? What is their adaptive capacity?

- How may the proposed infrastructure development scenarios be addressing these gaps and vulnerabilities? How would benefits stack up against costs? What types of impacts would people expect and how they think they would need to respond? Could they respond and if they can't what are their residual options?

- How would these perspectives affect their livelihoods and their perspective on the attractiveness and feasibility of the different infrastructure development scenarios? How could these scenarios be modified or what new scenarios could be developed to address their concerns?

Comparing the results of a deep-dive field study with the high-level, coarse scale assessment would help identify opportunities, contradictions, uncertainties and other issues that would help sharpen the analysis and produce results that are more robust and possibly have better ownership among stakeholders.

2.4 Construction of scenario assemblies

Identify key documents and supporting technical tools such as computer models that provide details of infrastructure development ideas, potentially presented in the context of alternative future development scenarios. Details should be both qualitative (scenario narratives) and quantitative (projections of key development and possibly impact indicators with relevant temporal and spatial coverage). The scenarios should be internally coherent with key assumptions and underlying objectives identified. In the context of the Okavango, the scenarios have been developed in the MSIOA process using a combination of participatory and technical methods, with emphasis on hydrology-related conditions and development measures.

Unless directly integrated into development scenarios, climate change scenarios would typically be downscaled from global or regional climate models (GCMs or RCMs) to the relevant level, and based on assumptions about shared socio-economic pathways (SSPs) and representative concentration pathways (RCPs) that are consistent with the projected levels of emission and climate impacts. In order to help manage the uncertainty inherent in climate modelling it is advisable to identify climate change patterns that are robust across a wider range of climate scenarios and build their results into the analysis and scoring of climate impacts.

Building on the alternative climate projections and the development scenarios selected, this step involves the construction for all possible permutations of the scenario assemblies. As the Okavango pilot involved three climate change scenarios (present day, high probability, low probability) and three hydraulic infrastructure development scenarios, there was a total of nine combinations. Extreme climate projections represented an additional climate possibility, but this was not developed in the same level of detail and was not systematically considered for all MSIOA scenarios due to a constraint on resources in the pilot.

2.5 Model and modelling method selection

This step involves the identification of models that support the assessment with quantitative analysis. Model selection has to be informed by the analytic framework and priority issues related to the specific river basin context and hydraulic infrastructure development plans. In the absence of a single highly integrated model that covers both key socio-economic, environmental and climatic dimensions, this would normally involve the selection of multiple pre-existing models that are or could be customized and parametrized with variables and indicators related to the project area.

By definition, this would require the selection of a global climate model or climate model assemblies to provide projections of key climate change indicators for the selected climate scenarios and time scales; a hydrological model – in the case of the Okavango the Pitman model – to provide projections of water flow based on both present day climate and climate scenarios; and thematic models that can work with adjusted runoff and flow data from hydrological models to show possible impacts as a function of both climate projections and development scenarios. In the Okavango pilot models were available for the ecological and economic themes (GTAP and Eflows explained in 4.1 and 4.2 above), while the assessment of social impacts built on hydrological and climate projections using expert judgment (see section 4.3).

Stage 3: Impact assessment of baseline projection(s)

This stage can involve a combination of quantitative and qualitative methods to create an understanding of climate and development trends, and their impacts in the context of TRBs. For instance in the CORB, stage 3 involved a combination of climate and hydrologic modelling, development scenarios, indicators and information-based expert judgements to establish an understanding of trends and drivers of change in the basin.

3.1 Model-based calculation of climate change projections

Using the climate models or climate model assemblies selected, develop projections for all climate scenarios relevant for the assessment. Projections are expressed both spatially and statistically through selected climate change indicators as relevant for the study area and taking into account the data requirements of the hydrological model used in the next step.

3.2 Calculation of hydrological impacts

Calculation of climate change impacts on the hydrological system using the selected hydrological model(s) and climate change indicators. Model results are expressed through standard indicators such as mean monthly hydrographs, flow duration curves and the calculation of the level and distribution of extremes. Ideally the climate modelling should provide monthly precipitation (perhaps if possible less evaporation) figures by climate scenario. This will enable a better informed /evidenced set of flow duration curves to be constructed by the hydrological model. In the absence of the monthly precipitation figures from the climate modellers the annual average % change can be applied uniformly across the months (i.e. an annual reduction in precipitation of 25% will be applied uniformly across each month).

3.3 Development of scoring tool

In order to standardize risk assessments related to social systems, the economy and a broader range of ecosystem conditions the CRDP project developed an Excel-based Climate Impact Vulnerability Assessment Tool (CIVAT). CIVAT is composed of a series of five interlinked modules explained later in this report (see also Annex 5) . The tool requires the selection of indicators in the next step to measure impact under all three themes and requires the scoring of each indicator using a standardized scale as shown below. Results are rolled up by theme and scenario assembly using simple arithmetic average and colour coded for easy visual comparison.

Table 3 **Colour coding of indicator scores**

Score	Impact	Color scheme
3	strong positive	
2	positive	
1	weak positive	
0	neutral	
-1	weakly negative	
-2	negative	
-3	strong negative	

3.4 Identification and scoring of impact indicators by scenario assembly

Using social, economic and ecological indicators earlier identified establish the severity of actual and future expected impact of climate change, combined with the effects of other forms of assumed global change. Using baseline and alternative infrastructure development and climate projections (and their relevant combinations) identify key driving forces and pressures and the exposure of socio-economic and ecological elements of the transboundary river basin to such driving forces. Along the lines of the ‘double exposure’ concept recognize that ecosystem and social systems can come under pressure of both climate change and other, non-climate related change (O’Brien and Leichenko 2000).

If possible, determine the level of certainty associated with the calculated impact, taking into account synergies across different impact categories. Assign color coding based on the level of impact to the indicators. Complement quantitative calculations and scoring with qualitative information, if possible, using qualitative research methods such as focus groups, survey, interviews or others. In order to score economic impacts, the use of the Global Trade Analysis Project) GTAP model is one approach suitable for a CRDP analysis which can generate possible economic impact figures in monetary terms. It is important to realize that the GTAP model is not the only possible tool and like most others, has limitations.

Recognizing that standard economic models normally miss non-market impacts, full cost accounting that includes the quantification of social and ecological capital not normally covered by standard economic accounts may be used to come up with approximate impact figures for a wider range of ecological and social factors critical for getting a more realistic picture of the future of the river basin. Techniques such as ecosystem services assessment and natural capital accounting offer promising approaches.

3.5 Assessment of technical and policy options associated with the scenarios based on impacts

Identify potential impact hotspots based on the impact scores in each theme. Compare differences between themes under different scenario assemblies and identify the possible explanations, including their possible attribution to climate change, hydraulic infrastructure development or some other contextual factor. Establish the baseline level of adaptive capacity of exposed elements of the river basin using indicators that capture the status of capacity in a broad sense, including technological, institutional, social and other elements (e.g., Yohe & Tol, 2002) based on the analysis conducted in stage 2 above. Identify illustrative policy or technical intervention options related to the development scenarios that may address some of the key impacts that could serve as a starting point for discussion of alternatives in stakeholder engagement.

3.6 Outreach package for stakeholder engagement

In preparation for a stakeholder engagement event compile the results of impact and capacity and vulnerability assessment into an easy-to-follow communication package. Develop step-by-step blueprint for the use of the package in the next step.

Stage 4: Participatory formulation and impact assessment of alternative adaptation scenario(s)

4.1 *Presentation of expert-based assessment results and adjustment of impacts*

Conduct stakeholder engagement to introduce and validate projected impacts. Validate results by inviting stakeholders to respond to the projections under the alternative scenarios and complement or contradict expert-based assessment results based on their own knowledge and experience. This can be done in a variety of ways such as interviews, sending drafts for stakeholder comment, or as occurred in the Okavango Pilot a deliberative workshop

Box3: Okavango Pilot Workshop

The deliberative workshop undertaken as part of the Okavango River Basin CRDP pilot was organised over 2 days. It was structured so that the first part of the workshop focussed on providing detailed information on the climate projections and the two main scenarios for the basin. This was followed by the initial assessment of impacts by experts in themes (environment, economic and social). This was carried out in a “World Café Style” where participants went to different breakout rooms to be briefed by experts on the theme impacts and then question those experts. Participants then came back in plenary to discuss their understanding of the impacts.

The following day Participants again broke up into smaller groups to discuss what they thought were the positive and negative impacts by MSIOA scenario, based on their own understanding and the information that had received from the experts the day before. Breakout groups then came back in plenary and reported on the results of their breakout group discussions and a plenary discussion was used to develop some conclusions from the workshop.

The mix of expert information and participative discussion in both plenary and breakout worked well in terms of providing information to participants then gathering their views and priorities. It was particularly important to communicate the uncertainty over the climate projections. The use of climate scenarios helped to do this effectively. Nevertheless, the difference between the two main scenarios and the extreme scenarios still proved challenging to communicate.

Presentations and handouts from the workshop can be found on www.cridf.com/

4.2 *Estimate adaptive capacity scores*

Introduce the importance of adaptive capacity and have stakeholders identify adaptive capacity elements based on a standard capacity framework including economic resources, technology, information and skills, infrastructure, institutions, and equity. Have stakeholders establish scores for adaptive capacity elements using CIVAT and the same scoring approach applied to thematic impacts. Note the aggregate adaptive capacity scores for all scenario assemblies.

4.3 *Establish vulnerability score by scenario assembly*

Using CIVAT, note the automatically calculated vulnerability scores as a function of aggregate impact and aggregate adaptive capacity. Note significant patterns for all scenario assemblies and trace back the source of differences to impacts (climate change or infrastructure development) and adaptive capacity. Determine the attractiveness of scenario assemblies based on the aggregate vulnerability scores.

4.4 Adjust scenarios and underlying technical and policy measures as needed

Qualitatively assess, using stakeholder input, the adequacy of response capacity and adaptive response measures to the impacts and vulnerabilities associated with the selected combinations of climate change / development scenarios. Identify types of impacts, including their temporal and spatial characteristics that in the view of stakeholders and expert opinion are particularly problematic given available adaptive capacities. Using participatory methods and evidence from the baseline vulnerability assessment, explore the possibility for additional adaptation options by stakeholders, the adequacy of additional adaptation measures, the 'damage and loss' related to residual impacts and ways of addressing them (Warner & van der Geest, 2013).

4.5 Construct and score alternative adaptation scenarios

Based on the identification of vulnerability prioritise from the initial analysis and the stakeholder engagement identify possible mitigation actions for consideration. These should be scored alongside the existing options / development scenarios. In some circumstances a whole new development scenario may be prepared based on the finding of the CRDP process.

Stage 5: Conclusions and lessons for implementation

5.1 *Scenario assembly summaries*

Summarize the results of scenario analyses, taking additional adaptation measures into account for all relevant climate/development scenario permutations. Adjust vulnerability scores for all scenarios and scenarios components as required to come up with a post-adaptation assessment of all development options.

Assemble quantitative and qualitative information on the baseline and alternative infrastructure development scenarios (including built, natural and social infrastructure), clearly showing the differences in terms of costs / benefits, impacts and requirements for adaptation measures.

5.2 *Conclusions and recommendations*

Identify recommendations for mainstreaming outcomes of the process into existing and proposed policies, programs at the transboundary, national and sub-national levels.

In order to record indicator scores and to roll up results at different levels of aggregation, an Excel-based Climate Impact and Vulnerability Assessment Tool (CIVAT) was created. CIVAT is composed of a series of five interlinked modules as follows.

Modules 1-3 are designed to capture individual indicators and indicator scores under social, economic and environmental themes for all scenario assemblies, a baseline value and two future time periods (Table 4). In the default version five indicators are assumed. Indicator scores are entered both numerically and with the matching traffic light color. The tool calculates average scores for each theme, time period and scenario assembly. Unless credible information is available regarding differential weights, the indicator scores are weighted equally and the resulting thematic impact average applies the same color coding system as the individual indicators.

Table 4 **Illustration of the thematic indicator scoring modules 1-3 in CIVAT.**

MSIOA scenario: LS3				
Climate: No climate change				
Environmental impacts				
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values**	
			2016-2035	**2046-2065**
Savanna	Indicator value	10	13	13
	Indicator score	0	-1	-1
Length of dry riverbed (Boteti)	Indicator value	15	21	21
	Indicator score	0	-2	-2
Average impact scores / time period		0	-1.5	-1.5

MSIOA scenario: LS3				
Climate: High probability				
Environmental impacts				
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values**	
			2016-2035	**2046-2065**
Savanna	Indicator value	10	13	13
	Indicator score	0	-1	-1
Length of dry riverbed (Boteti)	Indicator value	15	21	21
	Indicator score	0	-2	-2
Average impact scores / time period		0	-1.5	-1.5

MSIOA scenario: LS3				
Climate: Low probability				
Environmental impacts				
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values**	
			2016-2035	**2046-2065**
Savanna	Indicator value	10	30	30
	Indicator score	0	-3	-3
Length of dry riverbed (Boteti)	Indicator value	15	100	100
	Indicator score	0	-3	-3
Average impact scores / time period		0	-3	-3

Module 4 is designed to roll up aggregate impact scores by theme separately for each development scenario and climate projection assembly and then calculate an equally weighted higher-level aggregate where the three thematic impact scores are also rolled up into a single impact score by each scenario assembly, as shown by Table 5. Aggregated impact scores are color-coded according to the same traffic light scoring system.

Table 5 **Structure of the thematic indicator scoring module 4 in CIVAT.**

MSIOA SCENARIO	CLIMATE SCENARIO	THEME	TIME PERIOD		
			Baseline	2016-2035	2046-2065
LS1	No climate change	*Environmental*	0	0	0
LS1	High probability	*Environmental*	0	0	0
LS1	Low probability	*Environmental*	0	-3	-3
LS3	No climate change	*Environmental*	0	-1.5	-1.5
LS3	High probability	*Environmental*	0	-1.5	-1.5
LS3	Low probability	*Environmental*	0	-3	-3
LS6	No climate change	*Environmental*	0	-3	-3
LS6	High probability	*Environmental*	0	-2	-2
LS6	Low probability	*Environmental*	0	-3	-3
LS1	No climate change	*Economic*	0.00	0.00	0.00
LS1	High probability	*Economic*	0.00	0.00	0.00
LS1	Low probability	*Economic*	0.00	-0.83	0.00
LS3	No climate change	*Economic*	0.00	0.00	0.00
LS3	High probability	*Economic*	0.00	0.00	0.00
LS3	Low probability	*Economic*	0.00	-1.00	0.00
LS6	No climate change	*Economic*	0.00	-0.17	0.00
LS6	High probability	*Economic*	0.00	-0.33	0.00
LS6	Low probability	*Economic*	0.00	-1.50	0.00
LS1	No climate change	*Social*	0	0	0
LS1	High probability	*Social*	0	0	0
LS1	Low probability	*Social*	0	0	0
LS3	No climate change	*Social*	0	0.25	0
LS3	High probability	*Social*	0	0.25	0
LS3	Low probability	*Social*	0	0.25	0
LS6	No climate change	*Social*	0	0.75	0
LS6	High probability	*Social*	0	0.75	0
LS6	Low probability	*Social*	0	0.5	0
LS1	**No climate change**	***Combined***	**0.00**	**0.00**	
LS1	**High probability**	***Combined***	**0.00**	**0.00**	
LS1	**Low probability**	***Combined***	**0.00**	**-1.28**	
LS3	**No climate change**	***Combined***	**0.00**	**-0.42**	
LS3	**High probability**	***Combined***	**0.00**	**-0.42**	
LS3	**Low probability**	***Combined***	**0.00**	**-1.25**	
LS6	**No climate change**	***Combined***	**0.00**	**-0.81**	
LS6	**High probability**	***Combined***	**0.00**	**-0.53**	
LS6	**Low probability**	***Combined***	**0.00**	**-1.33**	

As one of its elements, in Module 5 CIVAT carries forward the overall impact score for each scenario assembly for each scenario assembly and each time period, where a score has been calculated (Table 6). As another element, it captures the adequacy / inadequacy of adaptive capacity for each impact projection and scenario assembly using the same 7-level scoring system. Adaptive capacity elements adopted from the IPCC and include economic resources, technology, information and skills, infrastructure, institutions and equity. In the absence of quantitative data, scores for adaptive capacity are established through participatory methods by building on stakeholders' understanding of the scenario assemblies built up through a workshop process and their familiarity with baseline capacity available.

Table 6 **Structure of the adaptive capacity and vulnerability scoring module 5 in CIVAT.**

MSIOA SCENARIO	CLIMATE	VULNERABILITY ELEMENT	TIME PERIOD Baseline	2016-2035	2046-2065
LS1	No climate change	**Aggregate impact**	0	0.13333333	0
		Economic resources			
		Technology			
		Information and skills			
		Infrastructure			
		Institutions			
		Equity			
		Combined adaptive capacity	0	0	0
		VULNERABILITY	0	0.06666667	0
LS1	High probability	**Aggregate impact**	0	0.13333333	0
		Economic resources			
		Technology			
		Information and skills			
		Infrastructure			
		Institutions			
		Equity			
		Combined adaptive capacity	0	0	0
		VULNERABILITY	0	0.06666667	0
LS1	Low probability	**Aggregate impact**	0	-0.1333333	0
		Economic resources			
		Technology			
		Information and skills			
		Infrastructure			
		Institutions			
		Equity			
		Combined adaptive capacity	0	0	0
		VULNERABILITY	0	-0.0666667	0

In order to make operational use of the information developed through the thematic impact assessments, in the context of the workshop, three sets of *thematic worksheets* were prepared, each covering a specific theme for a given scenario assembly.

The worksheets are used in the workshop setting in a participatory exercise where following an introduction and broad overview of the MSIOA scenarios, climate change projections, and the CRDP approach participants work their way through the scenarios for each theme in a World Café exercise. The purpose of the exercise is to introduce stakeholders to the details of possible impacts per theme associated with each scenario in three ‘stations’. At each station they receive a printout of the relevant CIVAT modules, and a thematic expert walks them through the highlights of the given development scenario, reminding them of the MSIOA scenario details and projected impacts.

One possible issue to be aware of in aggregating the impacts under CIVAT from the different themes (environment social and economic) is that an averaging of scores may mask an isolated extreme impact in one particular theme. This should be picked up in the qualitative discussion of the scores and highlighted as appropriate. The aggregate impact table should act as a window to the rest of the assessment highlighting areas of possible impact that can be investigated in more detail as appropriate

7. Conclusions

Investment in water infrastructure in Africa's shared river basins has been conceived as a way of addressing a historic development deficit that is preventing hundreds of millions of people from receieving basic standards of living, keeping them in permanent poverty. Investment in water infrastructure can turn out to be one of the most significant interventions at the world's disposal to address the root causes of this poverty.

However, as the concerns at the heart of the CRDP approach show, investment in the wrong way and developing the wrong kind of infrastructure has the potential to backfire in significant ways. Climate related risks loom large on the horizon of long-term investments. Trying to understand, trying to reduce and trying to manage these risks is essential for good business – and it is essential for sustainability: investment in infrastructure development of the wrong kind can result in permanent damage to ecosystems, depleted underground aquifers, resource conflicts between upstream and downstream neighbours, hydropower stations with no water to drive them, and people falling ill due to poor water quality.

Scenario analysis combined with risk, vulnerability and adaptation analysis outlined in this report represent a complex, but low-cost and low-risk methodology – when compared with the alternative. While the literature section of the report showed that apart from agreement on some of the core conceptual elements, there is no gold standard for such assessments; it also showed that out of the growing number of tools and methods, assembling a custom-made approach that meets the needs of planned water infrastructure programs in transboundary water basins targeted at a specific region is possible. The method is imperfect and will need testing under field conditions and refinement, but promises a rate of return in economic, social and ecosystem sustainability terms.

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Annex 1: Vulnerability assessment tools and approaches of relevance to the project reviewed

Author	Title	Purpose
General assessment methodologies		
CRIDF (2015)	Final Resiliency Screening and Climate Change Risk Assessment Guidelines (PROTOCOL)	Provides guidance to key stakeholders on how to develop climate resilient CRIDF projects. The guidance document is supported by four tools (the CRIDF climate vulnerability tool, risk matrix tools for the program's two application tracks, and a set of climate projections and impact statements). The guidance document notes when the tools should be used and their outputs incorporated into the decision-making process.
Morchain & Kelsey (2016)	Finding Ways Together to Build Resilience: The vulnerability and risk assessment methodology	Provide government stakeholders and development practitioners with guidance on how to conduct vulnerability assessments that enable "truly participatory, multi-stakeholder and cross-scalar contextual analysis that considers a wide range of hazards" to "facilitate an equitable, gender-sensitive, sustainable and appropriate design of pathways towards risk reduction and resilience." Places emphasis on understanding the underlying drivers of vulnerability and inequality (including structural inequalities).
Hinkel *et al.* (2013)	PROVIA Guidance on Assessing Vulnerability, Impacts and Adaptation to Climate Change	Provides a comprehensive overview of the means by which to assess climate change vulnerability, impacts and adaptation options and identifies tools and methods to support each stage of the adaptation learning cycle. It provides general guidance and is intended to be applicable to a wide array of assessment needs. (Guidance on tools identified by PROVIA can also be accessed via the MEDIATION Toolbox).

Infrastructure focused assessment literature		
Cervigni, Liden, Neumann, & Strzepek (2015)	Enhancing the Climate Resilience of Africa's Infrastructure: The power and water sectors	Examines the potential impacts of climate change on plans to expand hydropower and irrigation infrastructure in Africa's main river basins, including the Zambezi. Also looks at impacts on the electricity sector across four power pools, including Southern power pool.
Droogers, Neumann, Helleman-Melling, & Awadalla (2012)	Addressing Climate Vulnerability of Africa's Infrastructure. Stock-taking exercise: Overview of existing analytical work.	Documents outcomes of a stock-taking exercise in 2012 that looked at ongoing activities, data-sets and models related to climate change and infrastructure in Africa. Content developed to inform analysis presented in Cervigni *et al.* (2015).
Engineers Canada	Public Infrastructure Engineering Vulnerability Committee (PIEVC) Engineering Protocol	Developed for use in Canada but subsequently applied developing countries, the protocol provides step-by-step guidance for assessing the vulnerability of built infrastructure (e.g., roads, dams) to the impacts of climate change. This includes a triple-bottom line assessment of risk reduction options. It is intended for use by engineers to inform the design, development and management of existing and planned infrastructure.
Water and climate change focused literature		
African Ministers' Council on Water (2012)	Water Security and Climate Resilient Development: Strategic Framework	Highlights a four phased approach to integrate water security and climate resilience into development planning and investment decision-making processes. It aims at the development of 'no/low' regrets investments and financing strategies, as a starting point for embarking on water security for climate resilient growth and development. Apart from practical steps, it provides useful resources at every stage including specific organizations, available adaptation funds and tools for economic analyses.

United Nations Economic Commission for Europe (UNECE)	Water-Food-Energy-Ecosystems Nexus: Reconciling different resource uses in transboundary basins	Focuses on inter-sectoral linkages and synergies that could be leveraged through policy measures for improving international relations and promoting greater policy coherence. Specific areas of action based on pilot applications include institutions, information, instruments, infrastructure, and international coordination and cooperation.
World Bank (2014)	Climate Change and Water Resources Planning, Development and Management in Zimbabwe	This report focusses on Zimbabwe's water sector, summarises impacts of climate change on the country's water resources; highlights adaptation opportunities such as for water storage; addresses issues of water governance such as coordination between related ministries and water pricing; highlights water resources planning and management; water resources infrastructure, specially their ability to withstand extreme events, and the importance of information and education.
UNEP and the Water Research Commission	Methodology for the assessment of transboundary aquifers, lake basins, river basins, large marine ecosystems and the open ocean	Highlights the need for understanding the state of water, climate change and development trajectories, sectoral vulnerabilities (agriculture, hydropower, etc.), thematic risks (hunger, migration, etc.) to identify key risk areas. Identified 14 core indicators and 5 projected indicators including environmental water stress, human water stress, nutrient pollution, population density and river basin resilience.
LIMCOM	Risk, vulnerability and resilience in the Limpopo River Basin (RESILIM)	Alternative pathways for increasing resilience are based on the relations between the three issues of water, biodiversity and climate change (chosen because they are seen as foundational to resilience in the Limpopo). A 1st-to4th order impact framework is defined- 1st order being basic climatic parameters, 2nd order including physical and chemical parameters, 3rd order being ecosystem services and 4th order

		including human health, livelihoods, economy, etc. Specific climate impacts are identified for 8 parts of the basin and 4 orders of impacts are identified for each sub basin for specific climate impacts.
International Institute for Sustainable Development (IISD)	Lake Balaton Integrated Vulnerability Assessment, Early Warning and Adaptation Strategies	In the context of a UNDP-GEF project IISD undertook an integrated vulnerability and adaptation assessment initiative in Hungary's Lake Balaton region, as part of the GEF's Adaptation Pilot Mechanism. The methodology developed for the project was characterized by a recognition of climate risk and vulnerability as a combined outcome of external and internal factors, a participatory assessment using quantitative (indicator-based) and qualitative methods, and the participatory development of future scenarios that took already existing and potential future adaptation measures into account related to economic and ecological sectors relevant for the Lake Balaton watershed. Insights related to additional adaptation needs were built as criteria into calls for proposals for by public sector agencies in the region.

Annex 2: Some typical social impacts common to water infrastructure projects

- Strain on infrastructure and public nuisance - strain on transport networks and local infrastructure, community disruption and disturbance from noise, vibration and vehicle movements.
- Communicable diseases - spread of diseases to local/foreign populations.
- Cultural/archaeological heritage – damage to/destruction of cultural/archaeological sites/features.
- Clearance of vegetation - potential change to livelihood and subsistence activities (though potentially only in the short term).
- Land rights disputes.
- Community conflict (inter-community, with government, with company).
- Economic displacement and physical displacement.
- Loss of access to livelihood source (crops, farm land, access routes).
- Transformation of original community power structure.
- Cultural heritage loss and identity loss, feelings of powerlessness.
- Health impacts (increase in noise and dust on surrounding stakeholders and residential areas, water access and quality).
- Unmanaged influx of migrants via newly developed infrastructure.
- Community health and safety - transport routes/vehicle accidents, emissions/discharges (aqueous and gaseous), noise and dust.
- Construction and contractor workforce interference with populations.
- Socio-economic exclusion of ethnic minorities and Indigenous Peoples.
- Socio-cultural tensions between local and foreign workforce from influx and outflow of migrants/temporary workers and attraction of seasonal residents to project area
- Increase in social ills (alcohol and drug consumption, prostitution, school enrolment changes, etc.)

Annex 3: Assessing the significance of social impacts

Rating	Level	Possible social and community impact
1	**Very High Impact**	• Extreme, widespread social / socio-economic impact (negative or positive); • Massive consequence (positive or negative) affecting many different aspects of peoples' livelihoods (including employment, health, income, education and access to infrastructure); • Or, negative consequences are long term and stakeholders have limited ability to adapt to changes; • Or, risk of loss of life of more than 1 person; • Irreparable damage to highly valued cultural heritage; • Total Loss of community consent; • Public disorder.
2	**High Impact**	• Substantial consequences (negative or positive) affecting aspects of the livelihoods of the majority of people in one or more communities (including employment, health, income, education and access to infrastructure and health vulnerability). Consequences are long term but stakeholders are able to adapt to changes; • Or, activity or event causing long-term interference to other users of resources, change to demographics, employment, social service provision or lifestyle that is out of line with international guidelines or national policy affecting a large number of people and lasting considerably beyond programme lifetime; • Or, risk of major health effect/serious injury; • Or, accidents, which consultations with national government and stakeholders indicated would give rise to strong complaints; • Or, serious damage to or preservation of threatened cultural heritage; • Or, area of effect is extensive and/or encompasses an area that supports a significant proportion of a very highly or highly sensitive/important receptor, population or ecosystem; and • Or, community protests or demonstrations.
3	**Medium Impact**	• Moderate, medium term social impact (negative or positive) on local population; • Planned activity causes negative or positive change to demographics, employment, social service provision or lifestyle that may affect groups of local stakeholders during the project; • Or, consequences affecting (negative or positive) the livelihoods of a limited number of people in one or more communities. Consequences are medium term (1-3 years), but stakeholders are able to adapt to changes or take

		advantage of opportunities; • Or, accident causing medium-term interference to other users of resources; • Or, accidents, which local stakeholder consultations indicated would give rise to claims for compensation; • Or, moderate damage to heritage; • Or, reduced community co-operation; • Or, risk of minor health effect/injury; • Or, substantial adverse impact on a moderately sensitive/important receptor or area that supports such a receptor. Changes may exceed the range of natural variation though potential for recovery within a few years without intervention is good.
4	**Low Impact**	• Low, short term impact (negative or positive) on population and local heritage; • Or, elements of community opposition; • Or, minimal negative impact and disturbance to or preservation of cultural heritage; • Or, activity or accident that causes temporary interference with other users of resources, and accidents giving rise to some public concern, but not to formal complaints or claims for compensation; • Moderate negative or intermittent changes in specific social groups with potential of full recovery of livelihoods and health within a few months • Or, minor short-lived adverse changes in a moderately sensitive/important receptor.

Annex 4: Potential Indicators for Assessing Socio-Economic Impacts

The following is an indicative list of possible indicators that could be adapted for used in a selected socio-economic model and how they might be measured, which has been adapted and aggregated from Brillaud *et al.* (2008). The dimensions in the left-hand column link to one or several Sustainable Development Goals (United Nations, 2015), part of the global agenda to bring about sustainable development. The bullets in the right-hand column provide possible indicators for each dimension and examples of measurement.

Health **(SDG 3)**	• Reduction in number of cases of diarrhoea (number of diarrhoea cases in the community in the last two weeks), or diseases (malaria, bilharzia). • Reduction in number of deaths. • Decreased cost of healthcare. • Increased school attendance. • More productive income activities. • Increased vegetable and livestock productivity. • Time saved due to greater proximity to water source. • Increased nutrient and calorie intake (the number of households of the community who meet the minimum weekly requirements in terms of proteins). • Reduced instances of sickness.
Education (SDG 4)	• Alleviation of water collection responsibility leading to more time for education • Increase in study time by children. • Reduction in school absenteeism (number of school days missed in the last month) • Increased enrolment (net percentage of children of the appropriate age range enrolled in x-level education, x representing middle school, high school or university respectively). • Increased completion of education (net percentage of children in each appropriate age range with x-level of education being the highest completed school level, x being primary, middle school or high school).
Gender **(SDG 5)**	• Additional time for women to do other productive activities (calculate gender distribution of those responsible for water fetching for a household. Then calculate number of hours saved by the person who collects the water. Also can measure potential amount of income generated thanks to time savings.). • Decreased risk of sexual harassment. • Water governance structure can create opportunities for women to be in positions of community leadership.
Ownership / community management (Crosscutting,	• Level of empowerment of locals to get involved in management of water infrastructure and decision making. • Level of sense of ownership. • Level of access to participation and actual participation (percentage of respondents

but particularly SDG 10 & 16)	that have participated in meetings…). • Access to information. • Access to remediation.
Psychological (Crosscutting, but particularly SDG 3)	• Reduced tension from the safe arrival of female family member from water fetching. • Increase in student self-respect due to clean uniforms. • Increased sense of pride (when water = status symbol and generator of respect from other communities). • Positive psychological impacts due to 'beautification' of area (e.g. due to ability to plant more flowers, etc.).
Economic (SDG 1 and 8)	• Increased expected lifetime income (the expected lifetime income collectively earned in each community from different education completion levels). • Natural resource use (water lily use for food; sedge use for mat making, etc.).
Hygiene (SDG 3 and 6)	• Average number of bathing a week with a distinction between adult men and women, boys and girls. • Percentage of survey respondent washing their hands after using the latrine. • Percentage of survey respondents having babies who wash their hands after changing babies. • Percentage of survey respondents washing hands before cooking.
Food Security (SDG 1 and cross-cutting)	• Level of nutrition intake per week.

Annex 5: CIVAT Tool

See separate spread sheet.

CRIDF+