Government of Nepal

Water and Energy Commission Secretariat

Singhdurbar, Kathmandu

Water Resources Development Strategy for the Kamala River Basin, Nepal

August 2021

Commonwealth Scientific and Industrial Research Organisation, Australia (CSIRO)

in association with JVS and PEI Nepal

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Front cover photograph: Irrigated paddy rice field and local farmer at Baramajhiya
Credit: Auro C. Almeida

Forewords

Nepal is rich in water resources. But the Nepalese people have yet to benefit from this wealth. Instead, most are challenged by the extremes of the water cycle: deficit and drought in the dry season and flood, erosion, and inundation during the monsoon. Water quality and pollution are additional issues. The path to understanding and improving this situation lies in better planning, allocation, use and management of national water resources.

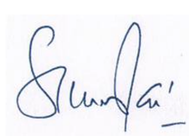
The Government of Nepal recognises the need for reforms in the water sector, according to the National Constitution 2015 and National Water Resources Policy 2021. This involves all three levels of government and extensive stakeholders' engagement. Planning and management of water resources will be undertaken for each river basin, and needs to include both surface water and groundwater. As well as dry season water shortages and rainy season floods, the degradation of the Chure (Siwalik Hill) region is serious, and solutions are complex. This important document presents the Water Resources Strategy for the Kamala River Basin in the south-east of Nepal. It is a notable example of collaboration between Australian and Nepali experts and basin stakeholders, jointly applying processes and tools to guide the planning and decision-making for the sustainable management of basin water resources.

The setting of goals and objectives for the development of the Kamala River Basin Water Resources Strategy was very participatory. The WECS facilitated and coordinated with the many concerned agencies and stakeholders at national and basin level. The agreed three strategic goals and their supporting framework are considered effective and appropriate. The experts, with basin stakeholders, continued to apply participatory methods and tools to define strategic pathways to achieve the agreed goals. These pathways provide direction and guidance for improvements in water availability for human consumption, agricultural productivity to possible commercialisation, strengthened watershed management and biodiversity (aquatic and terrestrial), conservation of the Chure and reducing erosion and inundation during flooding.

It is expected that the methods used in developing this strategy, including engagement with all three tiers of government, as well as civil society and local stakeholders, will contribute to the next stages of implementation. The strategy does set out recommended actions and next steps to continue the processes for sustainable water resources management of the Basin. It also serves as an example for use in other river basins in Nepal.

I sincerely congratulate and thank the Commonwealth Scientific and Industrial Research Organisation (CSIRO, Australia), WECS as the agencies that led the project and their team contributors, the International Centre for Water Resources Management (ICE WaRM, Australia), Jalsrot Vikas Sanstha (JVS, Nepal) and Policy Entrepreneurs Incorporated (PEI, Nepal), and extending to agencies from all levels of government. Special thanks to the stakeholders, communities, and locally-based who provided valuable support, input, and cooperation.

From the perspective of the Government of Nepal, we appreciate the support of the Australian Government and collaboration with Australian colleagues. We look forward to continuing opportunities to work together, hopefully including implementing the next steps in planning and management of the water resources of the Kamala River Basin.



Sagar Kumar Rai
Secretary
Water and Energy Commission Secretariat (WECS)

Australia has been a longstanding partner of Nepal in the sustainable management of its water resources. From 2014, collaboration in the water resources sector between the Government of Nepal and the Government of Australia was strengthened through the Department of Foreign Affairs and Trade's Sustainable Development Investment Portfolio (SDIP).

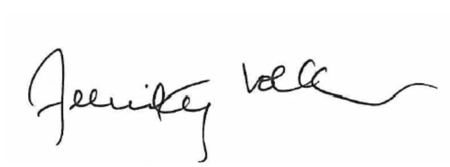
Under the Australian-funded SDIP, Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Nepal's Water and Energy Commission Secretariat (WECS) have partnered to promote capacity development in basin planning and to improve water resources management.

Our collaboration has been focused on the Kamala River Basin Initiative in the southeast of Nepal.

This Water Resources Development Strategy is the final document produced under this joint initiative. It provides a comprehensive framework for planning and decision-making in this important and complex sector. Importantly, the development of the Strategy has been inclusive and highly participatory, supported by national consultants, local and provincial governments, universities, NGOs, and community representatives. As such, it demonstrates the application of best practice and innovative participatory tools and methods.

This Strategy is a significant step towards improved planning and management of water resources for Nepal. It provides direction and options for water resource goals identified by stakeholders and for future developments. It makes recommendations for next steps, in terms of infrastructure, non-physical investments, activities, priorities and alternatives of water supply. This Strategy provides the foundation for continuing work in the Kamala River Basin, which in turn can be applied to other basins across Nepal.

On behalf of the Australian Government, I am pleased to commend this Strategy, and wish the Government of Nepal every success in their pursuit of inclusive and sustainable management of the Kamala River Basin and water resources nationally.



Felicity Volk
Australian Ambassador to Nepal

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Abbreviations and key terms

Abbreviation	Description
ADB	Asian Development Bank
AKC	Agriculture Knowledge Centre
CAD	Command Area Development
CASI	Conservation Agriculture Based Sustainable Intensification
CBO	Community Based Organisation
CBS	Central Bureau of Statistics
CCC	Coordination, Cooperation, Collaboration
CDAFN	Community Development and Advocacy Forum Nepal
CITES	Convention on International Trade in Endangered Species
CMIASP	Community Managed Irrigated Agriculture Sector project
CMIP	Coupled Model Inter-comparison Project
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CT	Conventional Till
CIMMYT	International Maize and Wheat Improvement Centre
DADO	District Agriculture Development Office
DCC	District Coordination Committee
DEM	Digital Elevation Model
DFO	District Forest Organisation
DFRS	Department of Forest Research and Survey
DHM	Department of Hydrology and Meteorology
DoED	Department of Electricity Development
DoI	Department of Irrigation
DTW	Deep Tube Well
DWIDM	Department of Water Induced Disaster Management
DWIDP	Department of Water Induced Disaster Prevention
DWRI	Department of Water Resources and Irrigation
DWSS	Department of Water Supply and Sewerage
EIA	Environmental Impact Assessment
FAO	Food and Agriculture Organization
FMIS	Farmer Managed Irrigation System

Abbreviation	Description
GDP	Gross Domestic Product
GoA	Government of Australia
GoN	Government of Nepal
GW	Groundwater
GWP	Global Water Partnership
GWRDB	Ground Water Resource Development Board
HA	Hectare
IBT	Inter Basin Transfer
ICIMOD	International Centre for Integrated Mountain Development
IPE	Institutional and political economy
ISF	Irrigation Service Fee
ISP	Irrigation Sector Project
IWRM	Integrated Water Resources Management
JICA	Japan International Cooperation Agency
JMP	Joint Monitoring Programme
JVS	Jalsrot Vikas Sanstha
KIP	Kamala Irrigation Project
MCM	Million Cubic Meters
MDG	Millennium Development Goal
MIP	Medium Irrigation Project
MIS	Management Information System
MoALMAC	Ministry of Agriculture, Land Management and Cooperation
MoFAGA	Ministry of Federal Affairs and General Administration
MoFE	Ministry of Forest and Environment
MoITEF	Ministry of Industry, Tourism, Forests and Environment
MOM	Management Operation and Maintenance
MoPID	Ministry of Physical Infrastructure Development
MoUD	Ministry of Urban Development
MoWS	Ministry of Water Supply
MSP	Multi-stakeholder platform
MUS	Multiple Use System
MW	Mega Watt
NARC	Nepal Agriculture Research Centre
NEA	Nepal Electricity Authority

Abbreviation	Description
NGOs	Non-governmental Organisations
NPC	National Planning Commission
NPR	Nepalese Rupee
NRM	Natural Resource Management
NWP	2005 Nepal Water Plan
NWSC	Nepal Water Supply Corporation
PEI	Policy Entrepreneurs Incorporated
PCTMCDB	President Chure Terai-Madhesh Conservation Development Board
PVA	Poverty and Vulnerability Assessment
RBO	River basin organisation
RCP	Representative concentration Pathway
SAF	Sustainable Assessment Framework
SDG	Sustainable Development Goal
SDIP	Sustainable Development Investment Portfolio
SISP	Second Irrigation Sector project
SSP	Shared Socio-Economic Pathway
STW	Shallow Tube Well
SWMO	Soil and Watershed Management Office
UNDP	United Nations Development Program
VDC	Village Development Committee
WASH	Water Sanitation and Hygiene
WB	The World Bank
WECS	Water and Energy Commission Secretariat
WHO	World Health Organisation
WRD	water resource development
WRS	2002 Water Resources Strategy *N*epal
WUA	Water Users Association
WUSC	Water Users and Sanitation Committee

Key terms

Term	Definition	Further details
Basin level	Refers to actors or institutions, operating in the Kamala Basin, whose authority is derived from the local or provincial level of governance in Nepal or non-state actors operating within the Kamala Basin	
Climate scenario	A plausible future climate state	Section 4.2
Development pathways	A development pathway is an argument for public and private action. It takes the form of a 'practical' argument whose components include values; goals (descriptions of the future in which values are realised); knowledge about the development context; and means-to-goal actions. Perspectives on these components will differ among stakeholders, requiring reasoned communication to reach agreement.	
Exploratory scenarios	Refers to a set of 4 contrasting storylines about the future development of the Kamala Basin. Each scenario represents one alternative future for the Basin's agricultural and non-agricultural sectors for the period 2020 to 2040. Each storyline explores alternative futures of the economy, climate, and society of the Basin or of Nepal, influenced by forces beyond the control of basin planners.	Section 1.5 Section 4.2
Federal level	Refers to state actors or institutions whose authority is derived from the federal level of governance in Nepal or non-state actors operating primarily at national level	
Institution	Institutions are stable and collective patterns of dealing with basic social functions (e.g. rules for how people may access water). They may be 'formal' (officially recognised) or 'informal' (e.g., self-organised and resourced, not always recognised by higher levels of governance). Institutions do not have a physical presence and are *not* identical to organisations.	Section 5.2.1
Multi-stakeholder platform	A multi-stakeholder platform (MSP) is a process designed to support state and non-state actors to communicate for the purpose of exploring a public issue. Ideally, an MSP is socially inclusive, and supports sincere and reasoned communication.	Section 7.5.1
River basin organisation	A river basin organisation (RBO) is an organisation which supports communication and coordination among diverse state and non-state actors with interests in a river basin.	
Strategic actions	A strategic action is a set of means-to-goal actions	Chapter 5
Water resources development option	Refers to socio-technical options for water resources development.	Chapter 4 Chapter 5

Acknowledgements

The team of CSIRO, JVS and PEI would like to acknowledge the kind support of all those individuals and organisations who contributed their time, ideas, data, and information to this document.

We are very thankful to the officials of the Water and Energy Commission Secretariat (WECS) Nepal for their support and cooperation during this work assignment and for entrusting us to undertake this project. We extend our special thanks to the current and formers Joint Secretaries of WECS, Mr Sagar Kumar Rai, Mr Hari Ram Shrestha, Mr Madhav Belbase, Dr Rishi Ram Sharma, for their kind cooperation and openness and contribution to this report, and to Dr Kapil Gnawali from WECS. We thank the Nepal–Australia Joint Advisory Committee (JAC) on Water Resources Management members for guiding the Kamala Basin Initiative.

We are also grateful to all local and project level officials of Dhanusha, Sindhuli, Siraha and Udaypur districts for their kind support during our field visits and providing us with data and information. We thank the contributions from the reviewers that helped to improve the quality of the document.

We particularly thank the former Australian Ambassador to Nepal, His Excellency Peter Budd, for his active engagement and deep interest in these activities, and especially for his chairing of the Nepal-Australia Joint Advisory Committee on Water Resources Management which has guided our activities in the Nepal water sector.

We thank the support of Emma Stone from DFAT. We also thank Shahriar Wahid for his contribution as the CSIRO Director of the Sustainable Development Investment Portfolio (SDIP) (which sponsored this activity), the CSIRO colleagues, Sreekanth Janardhanan, Antonia Gamboa Rocha, David Fleming, Perry Poulton and the ICE WaRM team, Darryl Day, Andrew Johnson and Ian Reid and consultants Megan Dyson and Diane Favier for their contribution to the project.

Gender and diversity

Development of this Strategy and related activities has been supported by the Australian aid program through its Sustainable Development Investment Portfolio which has the goal of increasing water, food and energy security in South Asia to support climate resilient livelihoods and economic growth, benefiting the poor and vulnerable, particularly women and girls. Gender equality and women's empowerment is a priority of Australia's foreign policy and both Nepal and Australia are signatories to the United Nation's Sustainable Development Goals, with SDG 5 being to achieve gender equality and empower all women and girls.

Inclusive basin planning, of which the development of this Strategy is a key component, should benefit all, regardless of gender and social and economic status, and those benefits should be distributed equitably. When reading and interpreting the information in this Strategy, the reader is reminded of the need to be gender-aware when considering impacts and anticipated outcomes to avoid reinforcing gender inequities.

User guide to this document

A STRATEGY is a way of 'planning the future direction or outcome of something' (OUP 2000)

This document provides communities and planners with the information they need to develop a basin-scale Water Resources Development (WRD) Strategy within the context of water resources policy in Nepal. In the case of the Kamala River Basin, this is a water resources development strategy; however, the information is equally relevant to the development of other strategies. In fact, the Kamala River Basin Strategy is a combination of many smaller strategies that address specific issues of concern and interest in the Kamala River Basin.

In this document, you will read how to develop a WRD strategy, how the process of developing the strategy was undertaken in the Kamala River Basin (through the exercise called the Kamala Basin Initiative); and the Strategy that emerged from the process. These are interwoven as a process best described through practical examples.

Topics covered in chapters are those agreed to by the stakeholders in the Kamala Basin. They are not pre-set and emerge during the process. Another strategy document may have very different topics and chapter headings.

Numbering of topics (goals, development options, scenarios) does not indicate a preference or order – numbering is merely a way to assist with cross-referencing.

Ordering of chapters reflects the sequence in which the process unfolded in the Kamala exercise. So, the chapter that describes options and pathways to achieve Goal 1 comes after those describing Goals 2 and 3. This will be different in each strategy development exercise.

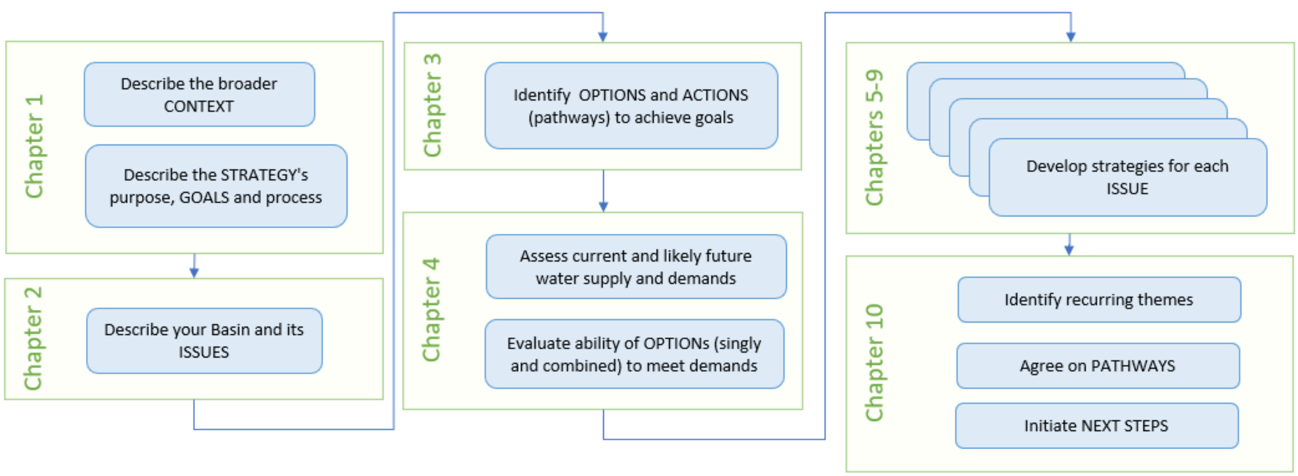


Figure Ordering of chapters as relevant in the Kamala Basin Initiative process

Language. This document is written in (Australian) English and reflects contemporary Australian government accessibility and readability guidelines. Except where the topic being discussed refers specifically to 'men' or 'women', gender-neutral language is used.

Summary

This Water Resources Development Strategy sets out a pathway to the sustainable development and management of basin water resources in the Kamala River Basin to improve the wellbeing of the population and the environment.

The Strategy is a result of more than 5 years of collaboration between the Government of Nepal (GoN) and the Government of Australia (GoA) on water resources management in Nepal, including issues arising with enactment of the new national Constitution in 2015. As requested by the GoN, the last 4 years of the collaboration have focused on the Kamala River Basin in southeast Nepal, to provide a practical demonstration of basin planning in the new era.

This Strategy is the third and final document in the Kamala Basin Initiative: the first describes the current *State of the Kamala River Basin* and its water resources (WECS and CSIRO 2020), and the second sets out *Recommendations on Policy and Legal Instruments* for possible next steps in implementation of the development Strategy (Dyson et al. 2020).

The responsible GoN agency is the Water and Energy Commission Secretariat (WECS) and technical assistance has been provided by the GoA through CSIRO[1,] supported by national consultants, local and provincial governments, universities, Non-Governmental Organisations (NGOs) and community members.[2]

Purpose and approach

Identifying, selecting, and implementing optimal improvements to sustainable water resources management at catchment or basin scale involves a series of steps from concepts though planning, design, construction to operations. Each stage involves progressively more detailed assessments and refinement of options – technically, financially/ economically, institutionally, socially, and environmentally. The purpose of this Strategy document for the Kamala Basin is to take the first step on this path and provide sound direction and guidance for the preparation of a Basin Plan, and subsequent implementation of the agreed development and management actions.

For many previous decades, worldwide, river basin planning has been a 'top-down' activity by experts, undertaking assessments of a range of water resources development options, and the definition of recommended steps to achieve the stated aims, generally involving one or more infrastructure investment projects. Most development assistance agencies followed the same approach, including in Nepal. Many such plans failed to generate local commitment, and were never implemented. Since enactment of the new Constitution in 2015, the whole system of government in Nepal has been and is continuing to be restructured, with responsibilities being decentralised.

This provides the opportunity to adopt a more inclusive approach to basin water resources development and management, incorporating significant representation of current water users in the definition of goals and objectives, and contributions to the assessment processes. The rationale for such engagement is to ensure the agreed strategies have the ownership necessary to assure sustainable outcomes.

A parallel objective is to strengthen existing capabilities among water users, through local, provincial and central government agencies, non-

[1] The Commonwealth Industrial and Scientific Research Organisation (CSIRO) is Australia's national science agency

[2] Those organisations that have contributed to the development of this Strategy are listed in Acknowledgements

government and informal networks, to enable their effective engagement in the strategic planning process, and continuing participation in subsequent processes of implementation of actions to meet a variety of water-related development objectives. The approach is complemented by external technical assistance and national government inputs.

The Kamala Basin

The Kamala Basin, almost 2,100 km^2 in area, is located in the southeast of Nepal, the southern tip of the catchment boundary being the international border with India. The Kamala River is a tributary of the Ganges, the major river of India. Geographically the Kamala Basin comprises 3 defined landscape types in Nepal: the Middle Mountains, Chure [3] and Terai. The unstable, often steep slopes of the Chure (or Siwalik) region throughout southern Nepal present particular challenges. It has been the focus of special conservation and development requirements, though terrace agriculture is widely practised. The Chure region covers almost two-thirds of the Kamala Basin. The gently sloping to flat Terai is where the population and agriculture are more concentrated, as is the economic activity of the Basin.

Administratively, the Basin intersects all 3 eastern provinces of Nepal and contains 4 districts: Sindhuli and Udayapur in the upper catchment, Dhanusha and Siraha in the lower reaches. The Basin also contains 23 municipalities, for a population of approximately 610,000 in 2011. Although the Basin is medium sized in Nepal, its population density is 40% higher than the national average. According to the 2011 data, about 80% of households reported a male head, though more recent national statistics suggest a significant increase in female-headed households, as more males out-migrate for paid employment (WECS and CSIRO, 2020).

The Kamala Basin experiences significant water-related issues, including monsoonal floods, high sediment loads increasing flood risks and damaging infrastructure, water unavailability during the dry season and accessibility constraints, and infrastructure services not meeting demands. These, combined with significant capacity and governance challenges, provide a comprehensive basis for setting out a strategy to improve water-related development and management.

Development of goals and pathways to achieve them

To support and guide the Strategy, readily available base data of the region was assembled, some new data were collected locally, and a stakeholder mapping and engagement plan was conducted. The strategic planning process commenced with facilitated basin-level workshop sessions with key representatives of the Kamala Basin communities, to explore and build consensus around the highest priority water-related development issues and future requirements and aspirations. The results of this activity were taken to another facilitated workshop at the national level with representatives from the responsible GoN institutions.

These participatory processes resulted in agreement on 3 goals for the Basin:

Goal 1: Sustainable management of the Chure and its natural resources for livelihood support and reduced vulnerability to water-induced disasters

Goal 2: Improved availability, use and allocation of water resources for livelihood generation, well-being, and economic growth

Goal 3: Commercial and scientific agriculture for local economic prosperity and livelihood security.

In continuing consultation with community representatives, these 3 goals were further broken down into more specific sub-goals or objectives, also defining the key actions required to achieve each objective. These actions, together with their details of how, what and by whom, defined in practical terms as the pathways for achieving the objectives

[3] The Chure region, below the Middle Mountains zone, is geologically very fragile due to its steep slopes coupled with less stabilised rock and soil, as it is one of the youngest mountain systems in the world. The Chure is also ecologically vulnerable and sensitive. Degradation of the Chure region has important impacts on the sedimentation, flooding of rivers and loss of agricultural lands in the downstream plains (Terai).

and goals. The resulting structure of goals and pathways were presented and discussed to wider range of local governments and community groups through a roaming participatory workshop, to build awareness and ownership, and continue to refine and prioritise elements of the structure.

Development of assessment of pathways to achieve goals

The Strategy team then considered how best to undertake the analyses necessary to properly assess each element of the Goals and pathways defined by the stakeholders. It was decided to focus initially on gaining a quantitative understanding of the Basin's water resources, including major current and possible future development and beneficial uses. This initial effort therefore provided the basis for early assessment of key elements of Goal 2 pathways. The results also contributed to the subsequent assessment of the pathways for achieving Goal 1 and Goal 3 outcomes.

Thus, the sequencing of the analyses and assessments did not follow the same order as the framework, i.e. Goal 1, followed by Goal 2 and Goal 3. For ease of understanding, this report describes the processes and outcomes in the same logical sequence as they were undertaken, and drawn together in the concluding chapter.

The overall Strategy formulation process is illustrated in Figure (i), which includes the steps beyond this document leading to a Basin Plan and implementation and evaluation.

A river system model was used for the quantitative analysis of whole-of-Basin water resources, as well as defining the current status quo of the natural hydrology and surface flows, including the dominant (more than 90%) use for irrigation. The modelling allowed quantitative assessment of water supply options defined in the consultative workshops, and of a range of future development scenarios ('Exploratory scenarios'). The defined options were modelled individually and also in combination of the options and respective timing of implementation.

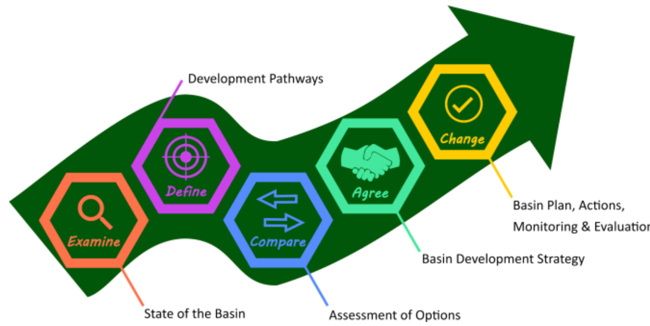


Figure (i) Strategy formulation pathway and beyond

Understanding the magnitude and timing of surface water flows also provided a quantitative basis for further supporting assessments of sustainable management of the Chure (Goal 1) and agricultural improvements (Goal 3).

The methodology for the next phase of analysis set out to define a set of strategic actions for implementation of each development option. In turn each strategic action was broken down into 'governance functions' to be implemented by capable 'actors' who may be individuals or institutions whether created formally or informally. This allowed detailed multi-factor analysis with comprehensive outputs, covering the minutiae of each strategic action, clarifying responsibilities, barriers and recommended solutions, and providing a more complete understanding of the issues to be addressed for the successful implementation of each defined option.

This framework was applied initially to the water resources development (supplementary supply) options defined collaboratively and already modelled. This added comprehensive detail to the pathways for achieving objectives under Goal 2.

The same multi-factor analysis framework was applied to defining pathways to achieve sustainable management of the Chure (Goal 1), and key agriculture improvements under Goal 3.

Supplementary direct methods of analysis were applied as appropriate to complement the modelling and multi-factor analysis outputs, to complete the detail of each element of the pathways, and better define emerging possibilities and complementarities.

Examples include household water and sanitation options, and institutional arrangements.

Goal 2 assessments

Stakeholders in the initial participatory workshops identified 4 representative water resources development (WRD) options for detailed assessment:

Option 1: Revitalisation of the existing Kamala Irrigation Project

Option 2: Sustainable utilisation of groundwater

Option 3: Construction of small to medium water storages in the upper Basin

Option 4: Development of an inter-basin water transfer scheme (the Sunkoshi–Kamala diversion and multi-purpose project)

- The Kamala Irrigation Project (KIP), constructed in the 1970s, is currently serving its command area poorly in the wet season, and hardly at all in the dry season. Major revitalisation works are required, and operations improved to raise access and efficiencies
- The Terai is an alluvial plain with significant groundwater resources, currently exploited well below its sustainable recharge
- Above the Terai, smaller scale irrigation could potentially increase with the construction of small to medium water storages
- The Sunkoshi to Kamala Diversion and inter-basin transfer Scheme is part of a large multi-purpose project proposed in the 1980s which did not proceed, though the concept was widely discussed and has remained a possibility.[4]

These 4 representative WRD options are of different complexity, scope, and commitment. They serve distinct targets and involve different timescales for implementation and longevity. As such they are not directly comparable nor competitive (i.e. either-or). They are complementary.

The river system model was used to explore the ability of the 4 options, separately and in combination, to meet a range of future water demands. This range was informed by a process of socio-economic scenario analysis. To represent alternative futures and associated water demands for the Basin's agricultural and non-agricultural sectors for 2020 to 2040, 4 Exploratory scenarios were formulated:

Scenario 1: 'Business as usual' (total demand of water for dry season irrigation = 79 Million-Cubic-Meters, MCM)

Scenario 2: 'Commercial smallholder agriculture' (demand of 182 MCM)

Scenario 3: 'Agribusiness' (demand of 228 MCM)

Scenario 4: 'Stagnant agriculture' (demand of 94 MCM)

Note: Demands refer to 2040 dry season. 2020 dry season demand, with third crop, estimated at 56 MCM

These scenarios differ with respect to assumptions of national and global economic growth and structural diversification; as well as assumptions about the capability of local, provincial, and federal level agencies to address challenges facing agriculture.

The modelled outcomes of each WRD option were compared against the water demand of each of the exploratory scenarios, with focus on net water availability to support demand and respective income estimates. An example output, providing estimates of water 'shortage' (projected 2040 demand less supply volume, in MCM) for each WRD option and demand under 4 Exploratory scenarios is illustrated in Figure (ii).

[4] The Sunkoshi to Kamala Diversion Multi-purpose Project is one of several proposals for major dams and diversion works within the Sunkoshi River basin. This is the only such scheme with possible benefits for the Kamala Basin, and thus a candidate option for consideration and assessment for this Strategy. In time perhaps similar assessments may be undertaken in relation to water resources development options within the Koshi Basin.

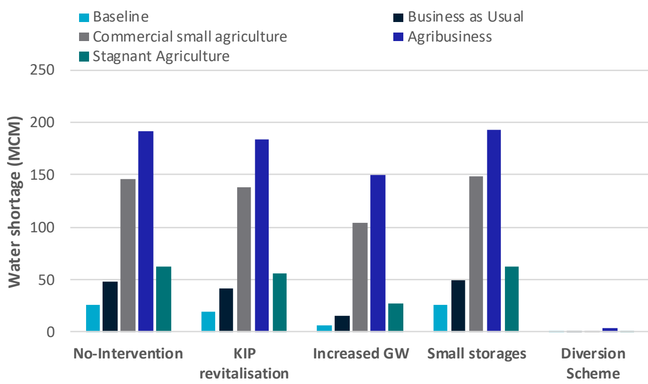


Figure (ii) Estimated water shortage for the Kamala Basin in 2040: comparing supply from 4 WRD options against water demand in baseline and 4 Exploratory scenarios

The analysis covered possible practical combinations of the proposed WRD option for each of the demand scenarios in 2040. The combination with the greatest compatibility and benefits was Option 2 (increased groundwater in the Terai) together with Option 3 (improved surface water systems using small to medium storages), i.e. the conjunctive use of groundwater and surface water. A further refinement has been considered with scheduling of WRD options, individually and/or in combination, such that corresponding improvements occur incrementally, and acknowledging scope for adaptive changes in water use practices to improve efficiencies and costs.

Quantitative modelling also included appropriate estimates of costs, which illustrated that development costs can be lowered by postponing investment in the costliest infrastructure options. Early in the planning period, investments in groundwater, particularly in the Terai, are preferred, because they are scalable and relatively low cost. Further identification of low-cost and flexible demand-side options is recommended.

The early investment in simulation modelling to provide this base understanding of water resources management in the basin was considered appropriate. The necessary caveat in using quantitative modelling outputs is to acknowledge the substantial level of uncertainty of the input data and influence on the results. Notwithstanding, modelling will remain a useful tool to inform and support a broader decision-making process, in this case including active participation at all levels, from water users and local government to national institutions, supported by additional multi-factor analysis. This is especially relevant to very complex options such as the inter-basin transfer scheme, for which the formidable technical challenges may be overshadowed by the institutional, legal, financial, social, and environmental impacts, including an international dimension.[5]

Through the application of multi-factor analysis, several strategic actions identify the recurring need for resolving issues at the whole-of-basin scale, and new organisations for doing so are crucial to identify and guide the actions.

The analysis described above was focused on overall basin water resources and their major productive use for irrigation. Of higher priority in terms of access and reliability, though in much smaller quantities, is household water use, which also generates wastewater. Nepal has been applying international experience in the management of these matters holistically as WASH: water supply and sanitation, together with household hygiene. Institutional arrangements are complex and evolving, service levels in the basin are low, with significant technical challenges and resource constraints. Nationwide, government agencies at all 3 levels have ambitious plans to raise service levels but physical implementation is seriously constrained. In the meantime, householders individually and collectively are being encouraged to adopt safer practices in relation to drinking water, latrine use and living arrangements. Household- and community-level efforts are likely to be most effective in improving health and well-being until more advanced facilities and services are able to be provided.

[5] For additional details of challenges arising for the proposed option, refer to the companion report *Recommendations on Policy and Legal Instruments* (Dyson et al, 2020)

Goal 1 assessments

The supporting analysis of pathways to achieve Goal 1 – *Sustainable management of the Chure and reduced vulnerability to water-induced disasters* – built upon the basin-scale modelling and applied a similar multi-factor analysis as described above. The conservation and management of the Chure is of long-term national concern, and some response mechanisms have been established. Identified strategic actions specific to the Kamala Basin take full account of existing ongoing programmes and institutional arrangements. Basin stakeholders are also aware that improving slope stability and erosion prevention upstream will have downstream benefits in reduced sediments and aggradation of streambeds, and support whole-of-basin mechanisms for implementation.

An accompanying issue highlighted by the process is riverbed materials extraction, both official and unofficial, at unsustainable levels which has significant impacts on river morphology, and more importantly on riverine ecosystems. Concerns are widely shared, and is another example of the need for a consultative and coordinated policy, regulation, and monitoring process – a new governance framework – involving all 3 levels of government, recognising that Local Governments are direct beneficiaries of the status quo. The recommendation for this, and other whole-of-basin matters, is an inter-governmental River Basin Organisation, with an annual Multi-Stakeholder Platform (MSPs).

Another important issue which falls is the reduction of vulnerability and impacts of water-induced disasters. There is a history of severe water-induced disaster events, respective response measures taken and investments in infrastructure (river-training and erosion control works) to ameliorate their impacts, nationally and within the Basin. Such events are becoming more intense and more frequent, due to climate change and local factors including land degradation, and rapid population growth is resulting in more settlements in prone areas. Specific objectives under Goal 1 are to improve early warning systems, and structural and non-structural measures to minimise impacts of water-induced events. Because of the instability of the Chure, and heavy river sediment loads, physical flood control works are technically very challenging, and not made easier by complexities in institutional, legal, economic, and social settings. This analysis is consistent with the consideration of Chure conservation described above.

The high priority strategic action recommendation is to implement flood forecasting and early warning systems, to be followed by hazard mapping, community awareness raising and plans for actions before and during emergencies. Infrastructure such as disaster management centres are included in longer-term measures.

Goal 2 and Goal 3 assessments

Goal 3 is focused on agricultural improvements. Estimates of the possible scope of future water resources scenarios, with corresponding impacts on irrigated agriculture, are discussed above under Goal 2, and contribute directly to agricultural sector sub-goals or objectives. The additional strategic actions, expand on the more effective and economically productive use of water and other inputs, to improve agriculture and its benefits to livelihoods, specifically the sustainable intensification of crop production, diversification alternatives based on high value crops and supporting collective farmers' access to land, water and knowledge. The analysis of these strategic actions highlighted existing constraints including subsistence-level farming of grain crops, with typically very small areas and land tenure issues, and consequent limited knowledge base, access to capital and resources for improving practices. The benefits and challenges of collective farming and diversification options were examined in relation to both access and intensification issues. The results pointed to MSPs as a recommended way forward; this is also consistent with the recommendations arising in relation to Goals 1 and 2. MSPs are an effective instrument to support collaborative actions, often innovations. The analysis details the application of MSPs to the implementation of both the strategic actions identified for Goal 3.

Necessary actions

There are common themes emerging from the consultations and supporting analyses undertaken, and the recommended strategic actions for implementation in pursuit of the agreed goals. These are highlighted here as essential elements of the recommended future development pathway:

Action 1. Formal institutional reform

Action 2. Increased collaboration across boundaries

Action 3. Enhanced policy processes

Action 4. Supportive organisational structures.

Some of the issues giving rise to these recommendations are very long-standing and pre-date the declaration of the new national Constitution in 2015, and consequent reform of the overall governance framework. Indeed, the recommendations highlight perhaps unfinished or unforeseen matters arising from such fundamental changes. Water inevitably crosses administrative boundaries of all kinds, resulting in complexities which must be addressed for the sustainable development and management of water and related resources.

Formal institutional reform, with particular needs for multi (state and non-state) actor coordination, was a recurring theme in the implementation of strategic actions for all 3 goals. Resource limitations and interdependencies often dictate that no individual or organisation can act unilaterally; effective progress is most likely when frameworks allow and encourage collaboration. This is not limited to cooperation between governments and government agencies at all levels: it includes meaningful engagement with non-government and informal organisations at community level.

In some cases, new organisations are recommended to enable better integration; for example, a new River Basin Organisation will facilitate and promote cooperation between stakeholders and agencies at all levels. Policy and planning processes in turn need to harness the coordinated inputs from multiple parties, especially from the field level upwards, consistent with the approach to basin planning demonstrated in this Strategy. The Multi-Stakeholder Platform is a recurring process recommendation for several key strategic actions. Indeed, the unifying intent of all the findings, and perhaps the overall message, is about strengthening, harnessing, and directing collaboration between *all* stakeholders to achieve mutually agreed objectives.

Next steps

This Strategy highlights development pathways and the challenges encountered and/or anticipated, with recommended approaches towards implementation. Preconditions for further steps have been identified as necessary actions, together with strategic actions to guide and focus subsequent efforts to enable key decision-making and confirmation of preferences. The recommendations for implementation include substantial physical (infrastructure) and non-physical (capability strengthening) components; both are essential to the way forward. Also identified is the sequencing – the order and timing of options individually and in combination.

It is anticipated that the next formal step will be compilation of a Basin Plan, which will fill identified gaps and better inform the selection and implementation of preferred development programmes. It is acknowledged that, for reasons not known nor even contemplated as this Strategy was being compiled, details of the selected development pathway may differ from those presented here, or in a subsequent Basin Plan. The Strategy provides a solid basis for consistent consideration and incorporation of such refinements.

An implicit recommendation arising from the experience of this Strategy, and the outcomes, is that the next phases of activity should continue to be based on participatory approaches. Specific tools and methods for doing so are demonstrated in undertaking this Strategy, and are recommended.

कमला नदी बेसिनको लागि जलस्रोत विकास रणनीति

यो जलस्रोत विकास रणनीतिले जनता र वातावरणको सुधारका लागि कमला नदी बेसिनको जलस्रोतको दिगो विकास र व्यवस्थापनको मार्ग निर्धारण गर्दछ ।

नेपालमा जलस्रोत व्यवस्थापन लगायत वि.सं. २०७२ सालमा नयाँ संविधान जारी भएपछि देखिएका सवालहरुलाई सम्बोधन गर्न नेपाल सरकार र अष्ट्रेलिया सरकारबीच ५ वर्षभन्दा बढी समयको सहकार्यको नतिजास्वरुप यो रणनीति बनेको छ । नेपाल सरकारको अनुरोध बमोजिम नयाँ अवस्थामा बेसिनको व्यावहारिक योजना तर्जुमा गर्न गत ४ वर्षको सहकार्यमा नेपालको दक्षिण-पूर्वस्थित कमला नदी बेसिनमा ध्यान केन्द्रित गरिएको थियो ।

कमला नदी पहलकदमी अन्तर्गत यो रणनीति तेस्रो र अन्तिम प्रतिवेदन हो । पहिलो पहलकदमीमा कमला नदी बेसिन र यसको जलस्रोतको विद्यमान अवस्थाको वर्णन भएको छ । विकास रणनीतिको कार्यान्वयनको लागि सम्भावित निकटतमचरणमा नीति र कानुनी संयन्त्रसम्बन्धी सुझावलाई दोस्रो पहलकदमी भनिएको छ ।

यसको लागि नेपालको जल तथा ऊर्जा आयोगको सचिवालयले जिम्मेवार निकायको कार्य र अष्ट्रेलिया सरकारको तर्फबाट सी.एस.आइ.आर.ओ. ले प्राविधिक सहयोग प्रदान गऱ्यो । यस कार्यमा राष्ट्रिय परामर्शदाता, स्थानीय र प्रादेशिक सरकार, विश्वविद्यालय, गैर सरकारी संघ-संस्था एवम् सामुदायिक सदस्यहरुको सहयोग प्राप्त भयो ।

उद्देश्य र उपागम

जलाधार वा बेसिनतहमा जलस्रोत विकासको दिगो व्यवस्थापनका लागि पहिचान, छनौट तथा उच्चतम सुधारका कार्यहरु कार्यान्वयन गर्न अवधारणादेखि योजना, डिजाइन, निर्माण र सञ्चालन जस्ता चरण संलग्न हुन्छन् । यी चरणमा प्रगतिशीलखालका विस्तृत मूल्याङ्कन तथा प्राविधिक, आर्थिक/वित्तिय, संस्थागत, सामाजिक र वातावरणीय उपायहरु परिष्कृत हुन्छन् । यो रणनीतिक दस्तावेजको उद्देश्य अग्रगमनका लागि कमला बेसिनको प्रथम चरण पुरा गर्दै बेसिन योजना तर्जुमा गर्न स्पष्ट निर्देश र मार्गदर्शन प्रदान गर्ने तथा सहमति बमोजिमका विकास र व्यवस्थापनका कार्यहरुको क्रमशः कार्यान्वयन गर्नु रहेको छ ।

विगतमा कैयन दशकसम्म विश्वभर "माथि"बाट निर्देश भए बमोजिम जलस्रोत विकासका उपायहरुको मूल्याङ्कन, निर्धारित लक्ष्य प्राप्तिका लागि सुझावित तहलाई परिभाषित गर्दै एक वा बढी लगानीका पूर्वाधार आयोजना संलग्न गरी नदी बेसिनको योजना विज्ञद्वारा तयार हुन्थे । धेरैजसो विकास सहयोगका निकायहरुले नेपाल लगायतमा यस्तै उपागम (एप्रोच) अप्नाउँछन् । धेरै योजनाहरुमा स्थानीयको प्रतिवद्धता नरहेकोले ती योजना कहिल्यै प्रभावकारी रुपमा कार्यान्वयन भएनन् । वि.सं. २०७२ सालमा नयाँ संविधान आएपछि, नेपालमा पनि जिम्मेवारी विकेन्द्रित गरी सरकारको सम्पूर्ण प्रणालीमा पुनर्संरचना तथा परिमार्जन भइरहेको छ ।

यस प्रक्रियाले बेसिनको जलस्रोत विकास तथा व्यवस्थापन लगायत लक्ष्य र उद्देश्य परिभाषित गर्न विद्यमान पानीका उपभोक्ताको उल्लेखनीय प्रतिनिधित्व एवम् मूल्याङ्कन प्रक्रियामा समाबेशी उपागम अवलम्बन गर्न अवसर दिएको छ । यस्तो संलग्नताबाट मतैक्य रणनीतिमा अपनत्व सुनिश्चित गर्न र दिगो नतीजा निश्चित हुन्छ ।

स्थानीय, प्रादेशिक र केन्द्रिय सरकारका निकायहरु, गैर सरकारी र अनौपचारिक सञ्जालमार्फत पानीका उपभोक्ताको विद्यमान क्षमता सुदृढ गर्ने र रणनीतिक योजना प्रक्रियामा ती उपभोक्ताको प्रभावकारी संलग्नता बढाउँने तथा जलविकासका विभिन्न उद्देश्य प्राप्तिसँग सम्बन्धित कार्यक्रमको कार्यान्वयनमा तिनको सहभागितामा निरन्तरता प्रदान गर्ने यो अध्ययनको एक समानान्तर उद्देश्य रहेको छ । यो उपागमलाई बाह्य प्राविधिक सहयोग र राष्ट्रिय सरकारबाट अन्य सहयोग रहेको छ ।

कमला बेसिन

करिब २१०० बर्ग किलोमिटरमा फैलिएको कमला बेसिन नेपालको दक्षिण-पूर्वमा अवस्थित छ । जलाधारको दक्षिणी सीमाना भारतसँगको अन्तर्राष्ट्रिय सीमानामा जोडिएको छ । कमला नदी, भारतको मुख्य नदी - गंगा नदी - प्रणालीको एक शाखा हो । भौगोलिक दृष्टिले कमला बेसिनमा मध्य पहाड, चुरे र तराई गरी ३ भू-आकृति पर्दछन् । नेपालको दक्षिणी भागमा रहेको अस्थिर र भिरालो पाखा भएको चुरे क्षेत्र विशेष चुनौतीपूर्ण छ । गह्रा बनाई कृषि कार्यको अभ्यास भएतापनि यो क्षेत्रमा संरक्षण र विकासका विशेष आवश्यकतामा ध्यान केन्द्रित भएको छ । चुरे क्षेत्रले कमला बेसिनको करिव दुई-तिहाई भू-भाग ओगटेको छ । जनसङ्ख्या र कृषि केन्द्रित तराईको समथर तथा कम भिरालो भागमा बेसिनको मुख्य आर्थिक कृयाकलाप भएका छन् ।

प्रशासकीय दृष्टिले यो बेसिनमा पूर्वको प्रदेश १ र २ का ४ जिल्ला पर्दछन् । सिन्धुली र उदयपुर जिल्ला उपल्लो जलाधारमा पर्छन भने धनुषा र सिराहा जिल्ला तल्लो भू-भागमा पर्छन । यो बेसिनमा २३ नगरपालिका र सन् २०११ को जनगणना अनुसार करिव ६ लाख १० हजार जनसङ्ख्या छन् । यो बेसिन मध्य-आकारको भए तापनि यसको जनसङ्ख्याको घनत्व सरदर राष्ट्रिय घनत्वभन्दा ४० प्रतिशत बढी छ । सन् २०११ को तथ्याङ्क अनुसार करिव ८० प्रतिशत घरधुरीमा पुरुषको नेतृत्व रहेको थियो । पुरुषहरु रोजगारीको लागि बाहिर गएकाले विद्यमान राष्ट्रिय तथ्याङ्क अनुसार महिला घरमूलीको सङ्ख्या उल्लेखनीय मात्रामा बढेको छ ।

कमला बेसिनले उल्लेखनीय जलजन्य सवालहरु लगायत मन्सुनी वर्षाजन्य बाढी, सेडिमेन्टको भारबाट सिर्जित बाढीको जोखिम तथा पूर्वाधारको नोक्सानी, सुख्खा मौसममा पानीको अपर्याप्तता तथा पहूँचमा समस्या, पूर्वाधार सेवाको माग आपूर्ति नभएको अनुभव गरेको छ । यो बेसिनको संयोजित रुप एवम् क्षमता र सुशासनको चुनौतीले गर्दा जलजन्य विकास र व्यवस्थापनमा सुधार गर्न व्यापक प्रकृतिको रणनीतिको आवश्यकताको आधार तयार भएको छ ।

लक्ष्यको विकास र प्राप्तिका लागि मार्गनिर्धारण

रणनीतिलाई सहयोग र निर्देश गर्न, बेसिन क्षेत्रमा सजिलै उपलब्ध भएका आधारभूत तथ्याङ्कलाई जम्मा गरियो । केही तथ्याङ्क स्थानीयस्तरमा सङ्कलन गरियो, सरोकारवालाहरुको नक्साङ्कन र संलग्नता योजना तयार भयो । कमला बेसिनमा बसोवास गर्ने समुदायका मुख्य प्रतिनिधिहरुको सहभागितामा सम्पन्न बेसिनतहको कार्यशाला सञ्चालन गरी जलजन्य विकासका प्राथमिकताका सवालको पहिचान, भावी आवश्यकता र आकांक्षा वारे मतैक्य हुन रणनीतिक योजना प्रकृया शुरु भयो । यो कृयाकलापको नतिजालाई नेपाल सरकारका जिम्मेवार संस्थाका प्रतिनिधिहरुको सहभागितामा सम्पन्न राष्ट्रियस्तरको अर्को कार्यशालामा प्रस्तुत भयो ।

यी सहभागितात्मक प्रकृयाबाट प्राप्त मतैक्य नतिजाबाट बेसिनको लागि निम्न ३ वटा लक्ष्य प्राप्त भएका छन् । ति हुनः

लक्ष्य १ः जीविकोपार्जनमा सहयोग गर्न एवम् जलजन्य विपद्को सङ्कटासन्नता घटाउँन चुरे र यस्को प्राकृतिक स्रोतको दिगो व्यवस्थापन गर्ने ।

लक्ष्य २ः जीविकोपार्जन, कल्याणकारी कार्य तथा आर्थिक बृद्धिको लागि जलस्रोतको उपलब्धता, उपयोग तथा बाँडफाँटमा सुधार गर्ने ।

लक्ष्य ३ः स्थानीय आर्थिक सम्बृद्धि तथा जीविकोपार्जनको सुरक्षाका लागि व्यावशायिक तथा बैज्ञानिक कृषिमा जोड दिने ।

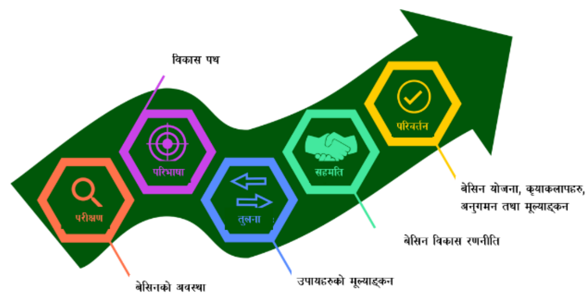
समुदायका प्रतिनिधिहरुसँगको परामर्शमा निरन्तरता दिन, यी ३ लक्ष्यलाई अझै विशिष्ठ उप-लक्ष्य वा उद्देश्यमा विभाजन गरी प्रत्येक उद्देश्य प्राप्तिका लागि मुख्य कार्यहरु परिभाषित गरियो । यी कार्यहरुलाई व्यवहारिक रुपमा कसरी, के र कस्ले गर्ने भन्ने वारेमा विस्तृत रुपमा परिभाषित गरी उद्देश्य र लक्ष्य प्राप्तिका लागि मार्ग निर्धारण गरियो । लक्ष्य र निर्धारित मार्गको संरचनालाई स्थानीय सरकार र सामुदायिक समूहहरुको सहभागितामा "घुमन्ते" सहभागितात्मक कार्यशालामा प्रस्तुतीकरण र छलफल गरी जनचेतना अभिबृद्धि र अपनत्व हुने एवम् यो संरचनाका अवयवलाई प्राथमिकीकरण र परिष्कृत गरियो ।

लक्ष्य प्राप्तिका लागि मार्ग मूल्याङ्कनको विकास

रणनीति टोलीले सरोकारवालाहरुले परिभाषित गरेको लक्ष्यका प्रत्येक अवयव र निर्धारित मार्गको उपयुक्त प्रकारले कसरी विश्लेषण गर्ने भन्ने विचार गर्‍यो । प्रारम्भमा बेसिनको जलस्रोतको परिमाणात्मक बुझाई लगायत विद्यमान र सम्भावित भावी विकास र लाभदायक उपयोगमा ध्यान दिने निर्णय भयो । यो प्रारम्भिक प्रयासले लक्ष्य २ को लागि निर्धारित मार्गको मुख्य अवयवको शिघ्र वा अपेक्षित समयभन्दा अगावै मूल्याङ्कन गर्न आधार तयार भयो । यसको नतिजाले लक्ष्य १ र ३ को परिणाम प्राप्तिका लागि निर्धारित मार्गको मूल्याङ्कन गर्न सहज भयो ।

यसरी विश्लेषण र मूल्याङ्कनका अनुक्रमले अन्य संरचनाको जस्तो लक्ष्य १ पछि लक्ष्य २ र त्यसपछि लक्ष्य ३ को विश्लेषण गर्ने कार्यको अवलम्बन गरेन । बुझाईलाई सहज बनाउँन, यो प्रतिवेदनमा प्रकृया र परिणामलाई उस्तै तर्कसंगत क्रममा हेरी निष्कर्षको अध्यायमा राखिएको छ ।

यो रणनीतिको समग्र तर्जुमा प्रक्रियालाई चित्र १ मा दिइएको छ जस्मा बेसिन योजना तर्जुमा, कार्यान्वयन र मूल्याङ्कन जस्ता चरण दिइएको छ ।



चित्र (१) रणनीति तर्जुमा मार्ग र मार्ग पश्चातको अवस्था

बेसिनको जलस्रोत, विद्यमान प्राकृतिक जल र सतह बहावलाई परिभाषित गर्न लगायत ९० प्रतिशतभन्दा बढी पानीलाई सिँचाईमा प्रयोग गर्नका लागि समग्रमा परिमाणात्मक विश्लेषण गर्न नदी प्रणालीमा आधारित नमूना (मोडेल) को प्रयोग गरियो । यो नमूनाले परामर्श कार्यशालामा परिभाषित पानी वितरणका उपायहरु र भावी विकास रुपरेखा ("खोजमूलक परिदृश्य") को परिमाणात्मक मूल्याङ्कन गर्न सहयोग पुग्यो । परिभाषित उपायहरुलाई एक एक उपाय वा संयोजित उपायहरु र समयबद्ध कार्यान्वयन सँगै राखी नमूनाबाट विश्लेषण गरियो ।

सतह पानीको प्रवाहको परिमाण र अवधिको बुझाईले चुरे क्षेत्रको दिगो व्यवस्थापन (लक्ष्य १) र कृषि सुधार (लक्ष्य ३) को परिमाणात्मक आधारमा थप मूल्याङ्कन गर्न सहयोग पुग्यो ।

विकासका प्रत्येक उपायको कार्यान्वयनका लागि दोस्रो चरणको विश्लेषणमार्फत रणनीतिक कृयाकलापलाई परिभाषित गरियो । तत्पश्चातः प्रत्येक रणनीतिक कृयाकलापलाई औपचारिक वा अनौपचारिक रुपमा कार्यरत क्षमतावान संस्था वा व्यक्तिबाट कार्यान्वयन गराउँनका लागि "सुशासनका काम" मा विभाजन गरियो । यसबाट बहू-कारक पक्षको विस्तृत विश्लेषण गरी व्यापक प्रकृतिको नतिजा प्राप्त गर्न सहयोग पुग्यो । यो विश्लेषण गर्दा प्रत्येक रणनीतिक कार्यको सुक्ष्म पक्षलाई समावेश गरी जिम्मेवारी स्पष्ट पारी, अवरोधक र तिनको समाधानका सुझाव लगायत सम्बोधन गर्नु पर्ने सवालको पूर्ण बुझाईबाट परिभाषित भएकोले प्रत्येक उपायको सफल कार्यान्वयनमा सहयोग पुग्नेछ ।

यो संरचनालाई सुरुमा परिभाषित र नमूनाकृत जलस्रोत विकासका उपायहरुमा प्रयोग गरियो । यसले लक्ष्य २ अन्तर्गतका उद्देश्यहरु प्राप्त गर्न व्यापक एवम् विस्तृत मार्ग निर्धारणमा थप सहयोग पुग्यो ।

चुरे क्षेत्रको दिगो व्यवस्थापन (लक्ष्य १) र लक्ष्य ३ अन्तर्गतको मुख्य कृषि सुधार प्राप्तिका लागि मार्गहरु परिभाषित गर्न सोही बहु-कारक विश्लेषणको संरचना प्रयोग गरियो ।

मार्गको प्रत्येक अवयवको विस्तृत विश्लेषण पुरा गर्न र पछि प्रकट हुने खालका सम्भावित र पूरक पक्षको राम्ररी परिभाषित गर्न उपयुक्तता अनुसार नमूना र बहू-कारक विश्लेषणबाट परिणाम प्राप्त गर्न प्रत्यक्ष तरिकाबाट थप विश्लेषण गरियो । उदाहरणको रुपमा, घरेलु पानी र सरसफाईका उपाय र संस्थागत व्यवस्थालाई लिन सकिन्छ ।

लक्ष्य २ को मूल्याङ्कन

सुरुको सहभागितात्मक कार्यशालामा सरोकारवालाहरुले विस्तृत मूल्याङ्कन गर्ने जलस्रोत विकासका लागि ४ वटा प्रतिनिधिमूलक निम्न उपायहरु पहिचान गरे:

उपाय १: विद्यमान कमला सिँचाइ आयोजनाको पूर्ण क्षमतामा पुनः सञ्चालन गर्ने ।

उपाय २: भूमिगत जलस्रोतको दिगो उपयोग ।

उपाय ३: बेसिनको माथिल्लो भागमा सानादेखि मध्यम खालका जल भण्डारण गर्ने ।

उपाय ४: अन्तर-बेसिन पानी पथान्तरणको विकास गर्ने (सुनकोशी-कमला डाइभर्सन तथा बहूउद्देश्यीय आयोजना) .

- सन् १९७० को दशकमा निर्माण भएको कमला सिंचाई आयोजनाबाट वर्षायाममा अति न्यून सिँचाई हुन्छ र सुख्खायाममा सिँचाई हुँदैन । यसको पुनः सञ्चालनका लागि यथेष्ठ कार्यहरु कार्यान्वयन गरी सञ्चालनमा सुधार गरी पहूँच र क्षमता अभिबृद्धि गर्नु पर्छ ।
- नदीले बगाएर ल्याएको बालुवायुक्त माटोको कारण तराईको समथर भागमा उल्लेखनीय मात्रामा भूमिगत जलस्रोत छ तर यस्को दिगो पुनर्भरणभन्दा कम उपयोग भएको छ ।
- तराई क्षेत्रभन्दा माथिको भू-भागमा सानादेखि मध्यमखालका जल भण्डारण निर्माण गरी साना सिँचाइको क्षमता बृद्धि गर्न सकिन्छ ।
- सुनकोशी-कमला डाइभर्सन तथा अन्तर-बेसिन पथान्तरण स्किम सन् १९८० को दशकमा प्रस्तावित भएको तर कार्यान्वयन नभएको ठूलो बहुउद्देश्यीय आयोजनाको एक भाग हो । यो अवधारणामा व्यापक छलफल भएको छ र यस्को सम्भाबना[6] यथावत छ ।

यी ४ वटा जलस्रोत विकासका प्रतिनिधिमूलक उपायहरुका जटिलता, क्षेत्र र प्रतिवद्धता भिन्न छन् । यिनको स्पष्ट लक्ष्य र भिन्न समयावधिमा कार्यान्वयन हुँदा दीर्घायुका हुनेछन् । ती उपायहरु प्रत्यक्षरुपमा तुलनात्मक र प्रतिस्पर्धात्मक छैनन् तर एक-अर्काका सहयोगी छन् ।

पानीको भावी मागको आवश्यकता पुरा गर्न वेग्ला-वेग्लै वा संयुक्त रुपमा यी ४ उपायहरुको क्षमताको खोजी गर्न नदी प्रणाली नमूनाको प्रयोग भएको थियो । पानीको भावी मार्गबारेमा सामाजिक-आर्थिक परिदृश्य विश्लेषणको प्रक्रियाबाट प्राप्त सूचनाको प्रयोग भयो । बेसिनको कृषि र गैर-कृषि क्षेत्रको पानीको भावी मार्गका विविध विकल्पहरुका लागि निम्न खोजमूलक परिदृश्यहरु तर्जुमा भए:

परिदृश्य १: "हालकै अवस्थाको निरन्तरता" (सुख्खा समयमा सिँचाइको लागि पानीको कूल माग ७ करोड ९० लाख घन मिटर) ।

परिदृश्य २: "साना किसान व्यावशायिक कृषि" (पानीको माग १८ करोड २० लाख घन मिटर) ।

परिदृश्य ३: "कृषि व्यवशाय" (पानीको माग २२ करोड ८० लाख घन मिटर)

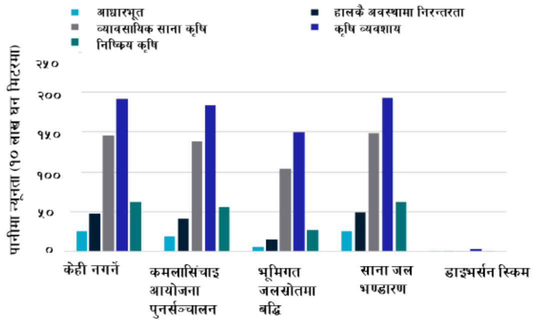
परिदृश्य ४:"स्थिर (निष्क्रिय) कृषि" (पानीको माग ९ करोड ४० लाख घन मिटर)

पुनश्च: पानीको मागले सन् २०४० सम्मको सुख्खा ऋतु समेटेको छ । तेस्रो बाली समेत संलग्न गरी सन् २०२० को सुख्खा समयको माग ५ करोड ६० लाख घन मिटर अनुमान गरिएको छ ।

नेपाल तथा विश्वको आर्थिक बृद्धि र संरचनागत बिबिधिकरण सम्बन्धी धारणा एवम् कृषि क्षेत्रले भोगको चुनौतीलाई सम्बोधन गर्नका लागि स्थानीय, प्रादेशिक र सङ्घीय तहका निकायहरुको क्षमता सम्बन्धी धारणाका आधारमा यी परिदृश्यहरु भिन्न हुन्छन् ।

पानीको अनुमानित माग र आम्दानीलाई सहयोग पुऱ्याउन पानीको वास्तविक उपलब्धतामा ध्यान दिइ जलस्रोत विकास सम्बन्धी प्रत्येक उपायको नमूनागत नतिजालाई पानीको माग सम्बन्धी प्रत्येक खोजमूलक परिदृश्यसँग तुलना गरिएको थियो । जलस्रोत विकास सम्बन्धी प्रत्येक उपायमा कमी हुने पानी र मागको अनुमान (सन् २०४० मा बढी मागको अनुमान र आपूर्तिमा कमी) लाई उदाहरणीय नतिजाको रुपमा चित्र (२) मा खोजमूलक परिदृश्यहरु प्रवर्द्धन गरिएको छ ।

[6] सुनकोशीदेखि कमलासम्मको डाइभर्सन बहुउद्देश्यीय आयोजना सुनकोशी नदी बेसिनमा प्रस्तावित अन्य ठूला मुख्य बाँध र डाइभर्सन कार्यको एक भाग हो । कमला बेसिनको लागि यो सम्भावित लाभदायक स्किम हो र यो रणनीतिको सोचाइ र मूल्याङ्कनको लागि उपयुक्त उपाय हो । कुनै समयमा सायद, कोशी बेसिनमा पनि जलस्रोत विकासका उपायहरुको पहिचान गर्न यस्तै प्रकारको मूल्याङ्कन गर्न सकिन्छ ।



चित्र (२) सन् २०४० मा कमला बेसिनमा पानीको न्यूनताः पानीको आधारभूत माग तथा जलस्रोत विकासका ४ उपायहरुको तुलना र ४ वटा खोजमूलक परिदृश्यहरु

सन् २०४० को लागि सम्भावित व्यावहारिक संयोजनमा ध्यान दिई प्रस्तावित जलस्रोत विकासका उपायहरुको प्रत्येक मागको परिदृश्यलाई यो विश्लेषणले समेटेको छ। यो विश्लेषणले उपाय ३ (सानादेखि मध्यम जल भण्डारण बनाई सतह पानी प्रणालीमा सुधार) सँगै उपाय २ (तराईमा भूमिगत जल वृद्धि) उपयुक्त र लाभदायक ठहऱ्याएको छ, अर्थात भूमिगत र सतह जलको संयोजित उपयोग उपयुक्त हुन्छ। यसमा जलस्रोत विकासका उपायहरुको चरण निर्धारण, उपायहरुको क्रमशः सुधार तथा मूल्य र कुशलता सुधारमा पानीको उपयोगलाई अनुकूलित परिवर्तन गर्ने थप परिष्कृत गर्ने कार्यमा ध्यान दिइएको थियो।

परिमाणात्मक नमूनाकृत अध्ययनले मूल्यको उपयुक्त अनुमान समावेश गरेको छ। यसमा बढी लागत लाग्ने खालका पूर्वाधार निर्माण कार्यलाई अलि पछाडि धकेलेर विकास बजेट घटाउँन सकिने देखिन्छ। तुलनात्मक रुपमा कम मूल्य लाग्ने र क्षमता बढाउँन सकिने भएकोले र तराईका भू-भागमा भूमिगत जलमा लगानी गर्न सकिने भएकोले योजना तर्जुमाको सुरुकै अवस्थामा यसमा ध्यान दिन सकिन्छ। अझै कम खर्च र लचिलो मार्गको पहिचानलाई सुझाव गरिएको छ।

बेसिनमा जलस्रोत व्यवस्थापन गर्न नमुनाको प्रयोगका लागि सुरुमै लगानी गर्नु उपयुक्त हुने देखियो। प्रयोगमा आएका तथ्याङ्कको उल्लेखनीय अनिश्चितता र नतिजामा तिनको प्रभावलाई विचार गर्दा परिमाणात्मक नमूनाको नतिजा उपयुक्त नै देखियो। निर्णय प्रक्रियामा सहयोग तथा सूचना उपलब्धतामा थप बहू-कारक विश्लेषण लगायत पानीका उपभोक्तादेखि स्थानीय सरकारदेखि राष्ट्रियस्तरका संस्थासम्म सबै तहमा सक्रिय सहभागिताका लागि नमूना एक उपयोगी औजारको रुपमा रहि रहनेछ। अन्तर-बेसिन पथान्तरण स्किम जस्ता जटिल उपायहरुका लागि यस्को उपयुक्तता स्पष्ट रहेको छ। कुनै अवस्थामा संस्थागत, कानुनी, वित्तिय, सामाजिक तथा वातावरणीय प्रभाव लगायत अन्तर्राष्ट्रिय कारणले समेत अत्यन्तै आवश्यक प्राविधिक चुनौती पनि छायाँमा पर्ने गरेका छन्।

बेसिनतहका सवाललाई सम्बोधन गर्नका लागि आवश्यक विभिन्न रणनीतिक कार्यहरुको पहिचान बहू-कारक विश्लेषणको उपयोगबाट गरियो। विभिन्न कार्यहरुको पहिचान तथा निर्देश गर्न नयाँ संस्थाको महत्त्वपूर्ण भूमिका रहन्छ।

माथि उल्लिखित विश्लेषणले सम्पूर्ण बेसिनको जलस्रोत र सिँचाइको लागि उत्पादनशील उपयोगमा ध्यान दिएको थियो। सानै परिमाणमा झोल-फोहोर निश्काशन भए पनि घरेलु जल उपयोगमा पहूँच र विश्वसनीयतामा उच्च प्राथमिकता दिइयो। नेपालमा पानीको आपूर्ति र सरसफाई तथा घर सफासुग्घर राख्नका लागि यी सवालको व्यवस्थापनमा अन्तर्राष्ट्रिय अनुभवको उपयोग भइआएको छ। संस्थागत व्यवस्था जटिल छन् तर विस्तारै विकसित हुँदैछन्। उल्लेखनीय प्राविधिक चुनौती र स्रोतको अभावका कारण बेसिनमा सेवाको तह न्यून छ। राष्ट्रिय परिप्रेक्ष्यमा, सेवाको स्तर बढाउँन तिनै तह (राष्ट्रिय, प्रादेशिक र स्थानीय) का सरकारी निकायहरुका महत्वाकाँक्षी योजना छन् तर यिनको भौतिक कार्यान्वयन गम्भीर छ। यसैसमयमा, खानेपानी, चर्पीको प्रयोग र वासस्थानका बारेमा सुरक्षित अभ्यासको अवलम्बन गर्न घरमूलीहरुलाई एक्लै वा सहकार्य गर्न प्रोत्साहित गरिएको छ। घरेलु तथा सामुदायिक तहका प्रयासहरु अत्याधुनिक सुविधा तथा सेवा उपलब्ध नभएसम्म स्वास्थ्य सुधार र कल्याणकारी कार्यमा बढी प्रभावकारी हुने अपेक्षा गरिएको छ।

लक्ष्य १ को मूल्याङ्कन

लक्ष्य १ (जलजन्य विपद्को सङ्कटासन्नता घटाउँने र चुरेको दिगो व्यवस्थापन) को प्राप्तिको लागि मार्गको सहयोगी विश्लेषण बेसिनको नमूनाबाट विकास गरिएको थियो। माथि उल्लेखित बहू-कारक विश्लेषणको उपयोग गरियो। चुरे क्षेत्रको संरक्षण र व्यवस्थापन दीर्घकालीन राष्ट्रिय चासोको रुपमा रहेकोले यस्को सम्बोधनका लागि केही संयन्त्र स्थापना भएका छन्। कमला बेसिनको लागि पहिचान भएका विशिष्ट रणनीतिक कार्यहरुले विद्यमानमा कार्यान्वयन भइरहेका कार्यक्रम र संस्थागत व्यवस्थालाई पूर्ण ध्यान दिएकाछन्। बेसिनको माथिल्लो भागमा भिरालोपनाको स्थिरीकरण तथा भू-क्षय रोकथाम गर्दा तल्लोतटीय क्षेत्रमा बालुवा थेग्रिने र खोलाको तह बढ्ने क्रम घट्दा फायदा हुने तथा बेसिनको सम्पूर्ण भागमा कार्यान्वयन गर्ने संयन्त्रलाई सहयोग पुग्ने बारेमा बेसिनका सरोकारवालाहरुको चेतना अभिबृद्धि भएको छ।

यो प्रक्रियामा औपचारिक तथा अनौपचारिक रुपमा दिगो नहुने गरी नदी सतहको सामग्री उत्खनन् गरिएको सवाल उजागर भएको छ। यसबाट नदीको आकृति लगायत मुख्यतया नदीको पारिस्थितिकीय प्रणाली (इकोसिष्टम) मा उल्लेखनीय प्रभाव परेको छ। व्यापक परामर्श गरी समन्वययुक्त नीति, कानुन र अनुगमन प्रक्रिया सम्बन्धी चासोको बारेमा सरोकारवालाहरुलाई पनि जानकारी दिइएको थियो। विद्यमान अवस्थाको प्रत्यक्ष फायदा स्थानीय सरकारलाई भएको ठम्याउँदै नीति, कानुन र अनुगमन प्रक्रियालाई तिन तहका सरकारको नयाँ सुशासन संरचनाको रुपमा लिइएको छ। सम्पूर्ण बेसिनका सवाललाई सम्बोधन गर्नका लागि अन्तर-सरकारी नदी बेसिन संस्था लगायत बहुसरोकारवालाहरुको बार्षिक मञ्चको सुझाव दिइएको छ।

अर्को महत्वपूर्ण सवालमा जलजन्य विपद्‌को प्रभाव र सङ्कटासन्नता घटाउने रहेको छ । राष्ट्रियस्तर तथा बेसिन क्षेत्रमा जलजन्य विपद्‌का गम्भीर घटनाका प्रभाव घटाउँनका लागि सम्बोधनका उपायहरुको कार्यान्वयन तथा पूर्वाधारमा (नदी किनार तटबन्ध तथा भू-क्षय नियन्त्रण सम्बन्धी कार्यहरु) लगानी गर्नु पर्छ । यस्ता घटना जलवायु परिवर्तन र भू-अपकर्षण जस्ता स्थानीय कारणबाट चाँडो-चाँडो घटेका र तीब्र प्रकृतिका देखिएका छन् भने तीब्र जनसङ्ख्या बृद्धिबाट यस्ता घटना घट्नसक्ने ठाउँमा बसोवास क्षेत्र बढ्दै गएकाछन् । लक्ष्य १ अन्तर्गतको निर्दिष्ट उद्देश्यमा जलजन्य घटनाबाट हुने प्रभावलाई न्यून गर्दै पूर्व सचेतना प्रणालीमा सुधार र संरचना तथा गैर-संरचनागत उपायहरु संलग्न गरिएका छन् । चुरे क्षेत्रको अस्थिर अवस्थाका कारण, नदीमा बालुवा गेग्रानको यथेष्ठ भार, बाढी नियन्त्रण सम्बन्धी भौतिक कार्यहरु प्राविधिक दृष्टिले ज्यादै चुनौतीपूर्ण छन् तथा संस्थागत, कानुनी, आर्थिक तथा सामाजिक अवस्थाको जटिलताको कारण यी कार्यहरु कार्यान्वयन गर्न सजिलो छैन । चुरे संरक्षणको लागि माथि बर्णन भए बमोजिम यो विश्लेषण मिल्दो-जुल्दो छ ।

बाढीको भविष्यबाणी तथा पूर्व सचेतना प्रणालीको कार्यान्वयन गर्न उच्च प्राथमिकताको रणनीतिक कार्यको सिफारिसको साथै प्रकोपको नक्साङ्कन, समुदायको चेतना अभिबृद्धि लगायत आकस्मिक सङ्कट अगाडि र पछाडि कार्ययोजनाको कार्यान्वयन गर्न सिफारिस गरिएको छ । विपद् व्यवस्थापन केन्दहरु जस्ता संरचनालाई दीर्घकालीन उपायहरुमा समावेश गरिएको छ ।

लक्ष्य २ र लक्ष्य ३ को मूल्याङ्कन

लक्ष्य ३ ले कृषिको सुधारमा ध्यान दिएको छ । जलस्रोतको भावी रुपरेखाको सम्भावित कार्यक्षेत्रको अनुमान लगायत सिँचित कृषिमा हुन सक्ने प्रभावलाई लक्ष्य २ अन्तर्गत माथि बर्णन गरिएको छ । यसले कृषि क्षेत्रको उप-लक्ष्यहरु वा उद्देश्यहरुको प्राप्तिमा प्रत्यक्ष योगदान पुग्दछ । पानी र अन्य सामग्रीको ज्यादै प्रभावकारी र आर्थिक दृष्टिले उत्पादनशील प्रयोग बढाउँने, कृषिको सुधारबाट जिविकोपार्जनमा फायदा पुऱ्याउँने, बालीको तीब्र उत्पादनलाई दिगो बनाउँने, उच्च मूल्य भएका बालीको आधारमा बिबिधिकरणका विकल्प अवलम्बन गर्ने तथा जमीन, पानी र ज्ञानमा सामूहिक रुपमा किसानको पहूँचमा सहयोग गर्ने जस्ता थप रणनीतिक कार्यहरु समेटिएका छन् । यी रणनीतिक कार्यहरुको विश्लेषणले विद्यमान अवरोध लगायत जीवन धान्न मात्रै पुग्ने गरी खाद्यान्न बालीको खेती हुने अभ्यासलाई सुधार गर्न सानो कृषि क्षेत्र तथा जमीनको स्वामित्व, न्यून ज्ञान, पूँजी र स्रोतमा पहूँचजस्ता सवालहरुलाई राम्ररी उजागर गरेको छ । पहूँच र तीब्रता सम्बन्धी सवाललाई ध्यान दिई सामूहिक खेती र बिविधिकरणका उपायहरुको फायदा र चुनौतीको परीक्षण गरिएको थियो । यसको नतीजामा मझौला खालका आयोजनाहरु सिफारिस भएका छन् जुन लक्ष्य १ र २ को सिफारिससँग मिल्दछ । मझौला खालका आयोजनाहरु सहकार्य र प्रवर्तन सम्बन्धी कार्यहरुलाई सहयोग पुऱ्याउँन प्रभावकारी संयन्त्र हुनेछन् । यो विश्लेषणले लक्ष्य ३ का लागि पहिचान भएका रणनीतिक कार्यहरुको कार्यान्वयनका लागि मझौला खालका आयोजनाको प्रयोगलाई विस्तृत गरेको छ ।

आवश्यक कार्यहरु

परामर्श तथा सम्पन्न सहयोगी विश्लेषणहरुबाट साझा विषयहरु तथा सहमति भएका लक्ष्य प्राप्तिको लागि रणनीतिक कार्यहरु कार्यान्वयन गर्न सिफारिस भएका छन् । यहाँ सिफारिस भएका भावी विकास मार्गका आवश्यक अवयवहरुलाई सबैभन्दा राम्रो पक्षको रुपमा उजागर गरिएको छ ।

कार्य १. औपचारिक संस्थागत सुधार ।

कार्य २. सिमाना वरपार सहकार्य बढाउँने ।

कार्य ३. नीति प्रकृयालाई वढावा दिने ।

कार्य ४. सहयोगी संगठनात्मक संरचनाहरु ।

सिफारिसमा परेका केही सवालहरु लामो समयदेखिका तथा नेपालको संविधान २०७२ को घोषणा पूर्व उठेका हुन् र सम्पूर्ण सुशासन संरचनाको सुधारका परिणाम पनि हुन् । वास्तवमा, मौलिक परिवर्तनबाट सिर्जित तर नसकिएका वा नदेखिएका पक्षहरुलाई समेत यी सिफारिसमा उजागर भएका छन् । पानीले सबै प्रकारका प्रशासकीय सिमाना सहजै वारपार गर्ने भएकोले जल र जलस्रोतको दिगो विकास र व्यवस्थापनका लागि यसबाट सिर्जित जटिलतालाई सम्बोधन गर्नै पर्छ ।

तीनवटै लक्ष्यको प्राप्तिका लागि रणनीतिक कार्यहरु कार्यान्वयन गर्न राज्यका विभिन्न निकायहरु (सरकारी तथा गैरसरकारी संस्था) बीच समन्वयको आवश्यकतालाई ध्यान दिई औपचारिक संस्थागत सुधार गर्नु पर्ने विषय धेरैपटक उठ्यो । स्रोतको सिमितता र अन्तर-निर्भरताका कारण कुनै एक व्यक्ति वा संस्थाले एक्लै कार्य गर्न सक्दैन, संरचनाले सहकार्यलाई प्रोत्साहन गर्दा प्रभावकारी प्रगति हुने अपेक्षा गरिएको छ । सबैतहका सरकार र सरकारी निकायहरुबीचको समन्वय सिमित छैन । समुदाय तहका गैर सरकारी तथा अनौपचारिक संस्थाहरुको अर्थपूर्ण संलग्नतालाई यसमा समावेश गरिएको छ ।

केही विषयमा, एकीकृतका लागि बढावा दिन नयाँ संस्थाको सिफारिस गरिएको छ । उदाहरणको लागि, नयाँ नदी बेसिन संस्थाले सबैतहमा सरोकारवालाहरु र निकायहरुबीच समन्वय प्रवर्द्धन गर्न सहज गर्नेछ । बेसिनको योजनाको लागि यो रणनीतिको उपागमसँग मिल्ने गरी योजना प्रकृयामा विशेषत: स्थलगत क्षेत्रका बहू-पक्षहरुबाट समन्वयात्मक सहयोग लिनु आवश्यक छ । बिभिन्न रणनीतिक कार्यहरुको लागि बहूसरोकारवालाहरुको मञ्च पुनराबृत्ति प्रक्रियाको रुपमा रहेको छ । वास्तवमा, सबै नतिजालाई एकीकरण गर्न तथा सम्पूर्ण सन्देश, सबैको सहमति भएका उद्देश्यहरुको प्राप्तिका लागि सबै सरोकारवालाहरुबीच समन्वय, सुदृढीकरण, दोहन तथा निर्देश गर्ने तर्फ लक्षित छन् ।

आगामी चरण

सामना वा प्रत्याशा गरिएका चुनौतीहरुलाई ध्यान दिई यो रणनीतिले विकास मार्गको राम्रो पक्षलाई उजागर गरेकोले सिफारिस भएका उपागम कार्यान्वयन हुनेछ। निर्णय प्रक्रिया र चाहना लगायत पछिका प्रयासलाई निर्देश तथा ध्यान दिन रणनीतिक कार्यहरु लगायत आवश्यक कार्यहरु समावेशगरी निकटतम चरणका पूर्वशर्तहरु पहिचान गरिएका छन्। मजबूत भौतिक (पूर्वाधार) तथा गैर-भौतिक (क्षमता सुदृढीकरण) अंगहरु संलग्न गरी कार्यान्वयनको लागि सिफारिस भएका छन्। यि दुवै अंगहरु अग्रिम कार्यको लागि आवश्यक छन्। यिनको बेग्ला-बेग्लै वा सँग-सँगै कार्यान्वयन गर्ने क्रम र समय पनि पहिचान भएका छन्।

बेसिन योजना बनाउँनु आगामी औपचारिक कदम हुने प्रत्याशा गरिएको छ। यसले पहिचान भएका कमी कमजोरी र रुचाइएका कार्यक्रमको छनौट र कार्यान्वयनलाई राम्ररी सूचित गर्नेछ। यो रणनीति बनाउँदा केहि कारणबाट अन्जानका वा तिरष्कृत भएका पक्षहरु प्रति कृतज्ञता प्रकट गर्दै छनौट भएका विकास मार्गको व्यापकता यहाँ प्रस्तुत भएका वा पछि तयार हुने बेसिन योजनाभन्दा फरक हुन सक्छन्। यो रणनीतिले सोच-विचार नबदल्न र यस्ता परिस्कृत पक्षलाई समावेश गर्न एक ठोस आधार तयार गरेको छ।

यो रणनीतिको अनुभवबाट अव्यक्त सिफारिस र नतिजा अनुसार सहभागितात्मक उपागमको आधारमा आगामी चरणका बिभिन्न कार्यहरुलाई निरन्तरता दिनु पर्छ। यसका लागि यो रणनीतिमा विशिष्ट औजार र तरिका समावेश भएका र सिफारिस गरिएका छन्।

1 Introduction

1.1 Background to development of the Strategy

Integrated Water Resource Management (IWRM) was adopted by Nepal in its *2002 Water Resources* Strategy and subsequent *2005 National Water Plan.* However, there is little evidence that the inclusive principles of IWRM have been practised to date. This is changing with the current development of river basin plans for all provinces in Nepal by the Water and Energy Commission Secretariat (WECS), under World Bank assistance. WECS is an agency of the Federal Government of Nepal (GoN) with responsibility for plan and policy formulation in Nepal's water and energy sectors. A planning exercise for multiple river basins, largely being undertaken by international and national consultants, began in 2018 and is expected to be completed in 2021.

IWRM provides a framework for collectively identifying and managing opportunities and trade-offs for multiple water use objectives, promoting sustainable and adaptive management of current and future water requirements. It facilitates the identification and mitigation of risks, minimises unanticipated consequences of future developments, and meets the intended development goals.

Formulating the river basin plan process with an integrated approach is somewhat new to WECS and other related GoN agencies, and required upskilling of staff in technical and stakeholder engagement practices to be able to effectively monitor the quality of the basin planning exercises. This has been achieved through a Kamala River Basin Initiative (herein 'Kamala Basin Initiative'). This Strategy is the third and final document in the Kamala Basin Initiative: the first describes the current *State of the Kamala River Basin* and its water resources (WECS and CSIRO 2020), and the second sets out *Recommendations on Policy and Legal Instruments* for possible next steps in implementation of the development Strategy (Dyson et al. 2020).

This Basin was selected as it is of medium-size, with sufficient complexity, including water deficit, multiple land uses, geological and topographical diversities, impacted by floods during the monsoon, and limited land size by farmers (WECS and CSIRO 2020). It is in this context that this *Water Resources Development* Strategy *for the Kamala River Basin* has been prepared under the technical assistance and coordination of the Government of Australia (GoA) in collaboration with the GoN. Even though the Strategy formulation process (hereinafter referred to as 'the project') was taken up to enhance the capacity of WECS and other relevant GoN agencies, the project intended that the resulting product of the capacity building process would be in the form of a river basin Strategy which, in turn, would be the basis on which a detailed river basin plan could be formulated for the Kamala Basin and other basins in Nepal.

On behalf of the GoA, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) executed the project, with WECS as the nodal agency for the GoN on all the necessary coordination and collaboration and national consulting firms of Jalsrot Vikas Sanstha (JVS) and Policy Entrepreneurs Incorporated (PEI) supporting the project execution. Other GoN agencies participated through involvement in workshops.

Traditionally, water resources development plan for a basin focussed on water availability and potential, technical infrastructure designs and associated costs and economic benefits. Little attention was paid to stakeholders and their willingness as to the possible uses and involvement in development and management of resources. Interconnection between water and other resources within the basin was seldom considered. Even the concept of a basin as a hydrological unit and the interplay between its surface water and groundwater were rarely considered, many times due to a scarcity of reliable data. This traditional approach yielded sub-optimal utilisation of water resources, and quite often ended up with adverse environmental consequences and severe dissatisfaction and conflicts among stakeholders. Thus, the traditional approach was lopsided. In the IWRM approach, stakeholders – including water users, government and non-government agencies – within and without the basin are thoroughly engaged in the consultation process right from the beginning so that resulting products have a balanced integration of evidence-based scientific analysis of various natural resources and environment, with economic and social aspects that include considerations of gender, climate, potential and desired developments, and capture the diversity of opinion and values. It is with such an approach that this *Water Resources* Strategy *for the Kamala River Basin* has been prepared.

In the process of formulating this Strategy, issues related to water resources were first identified and defined with the effective engagement and participation of a full range of stakeholders. Relevant data and information were collected and analysed; and the results and propositions discussed with stakeholders. During this process, potential problems and future development options were identified, together with several alternative pathways to resolve problems and compare options. With stakeholders' input, the most suitable pathway to resolve each of the problems was identified. The collection of these pathways and respective activities to be implemented, in sequence in different timeframes, with a mechanism of continuous monitoring and adjustment is, in fact, the Strategy. Details of every step followed in formulating the Strategy is described in this document. As the Strategy has been formulated following a scientific and integrated approach, it is expected that development and management of water resources in the Basin following the Strategy will meet the requirements and aspirations of the stakeholders with adequate economic and social benefits and with little or controllable adverse impacts including environmental ones.

1.2 Objectives and scope of the Kamala Basin Initiative

The objectives of the Kamala Basin Initiative are to:

- enhance the capacity of the GoN to undertake strategic water resources planning and management in river basins, through building the capabilities of GoN agency staff
- prepare a *Kamala River Basin Water Resources Development* Strategy document, to support ongoing and detailed river basin planning to:
  - improve access to water resources across the basin
  - improve quality of life and environmental standards
  - improve quality and reliability of water for multiple uses and users
  - establish rules and options of current and future water use
  - improve equity for women and men
  - include minorities and marginalised people in decision making.

1.3 Objective of the Strategy

This Strategy development seeks to enhance the range of planning and technical capacities required in Nepal around strategic water resources planning and management in river basins, with participation from 2 levels of governance: the national (Federal) level, and the basin level. The basin level includes elected heads of local government bodies (rural and urban municipalities), the private sector, and civil society organisations representing ultimate beneficiaries of basin planning.[7]

This Strategy is a non-legally binding document. However, once the detailed basin plan is prepared on the basis of this Strategy, together with the basin plans of other basins, it is recommended that it be approved by GoN; and that there be a legal provision for all levels of government (federal, state, local) to adhere to such approved plan. The underlying principle is that all water resources activity, whether developed and/or managed directly

[7] The project established that a minimum of 30% of participants from within the basin be from female and under-represented groups.

under Government agencies or under private sector or communities, needs to be consistent with the approved basin plan. It is also recommended that water sector reforms need to be geared to this effect. These and related matters are expanded in more detail in the companion document, *Recommendations on Policy and Legal Instruments* (Dyson et al. 2020).

1.4 Strategic goals of the Strategy

Managing water resources in a river basin requires the establishment of clear goals and development of a Strategy to achieve these goals.

As part of the development of the Strategy, a stakeholder mapping and engagement plan was carried out, which included planning of the Basin Stakeholder Participation to seek opinions of municipalities and communities on issues, and their concerns and priorities for development involving water resources. Local data were also collected in parallel to the engagement process.

A basin-level stakeholder consultation workshop was conducted in Janakpur on 12 July 2018 with 71 representatives from all 4 districts that share the Basin. To set the stage, the project team presented the relevant existing data describing the Basin as documented in the companion *State of the Kamala River Basin* (WECS and CSIRO, 2020). This report is the basis for the development of the Strategy.

Five themes were identified and goals and development pathways for each theme formulated:

- agriculture
- irrigation and land
- soil conservation and water induced disaster
- drinking water, health and sanitation
- livelihood and migration.

Results were taken to a federal level workshop, organised by WECS in Kathmandu on 27 July 2018, to allow policy level stakeholders representing key GoN agencies working on water resources planning to comment. They identified some overlaps in the 5 themes, resulting in 3 goals:

Goal 1: Sustainable management of the Chure and its natural resources for livelihood support and reduced vulnerability to water-induced disasters

Goal 2: Improved availability, use and allocation of water resources for livelihood generation, well-being and economic growth

Goal 3: Commercial and scientific agriculture for local economic prosperity and livelihood security

1.5 Integrated Water Resources Management in water policy and planning in Nepal

The Global Water Partnership (GWP) defines Integrated Water Resources Management (IWRM) to be

> *'a process which promotes the co-ordinated development and management of water, land and related resources in order to maximise economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems and the environment'.*[8]

Thus, IWRM deals with water resources in a broad perspective where water resources are viewed in the context of the entire economic, social and ecological systems of a region and the IWRM leads to a process of change from unsustainable to sustainable resource management.

In Nepal, IWRM, and accordingly basin-wide water resource development and management, was first recognised during the water resources strategy formulation process in the late 1990s, and embedded as a cardinal principle in its *2002 Water Resources Strategy Nepal* and *2005 National Water Plan*, the latter being the action plan to implement the *2002 Water Resources Strategy Nepal*.

The *2002 Water Resources Strategy Nepal* identified policy principles in line with IWRM which can be widely grouped into 3 categories:

- IWRM through basin-wide approach in planning
- stakeholders' participation through decentralisation process
- economic efficiency and social equity through governance, co-ordination and transparency.

Thus, the principles imply total integration of water resources with economic and social development. Although the GoN has clearly accepted the need for IWRM, there are several actions required to transform its water sector development process to a true IWRM concept. These actions include reform of the government's institutional structure in line with basin planning approach, redrafting of legal arrangements to be compatible with IWRM principles, and strengthening the knowledge base for adopting IWRM.

At project implementation level, the knowledge base required for adopting a basin-scale approach is lacking. Reliable information on the availability of water resources, current use, resources having potential to use water for economic growth and other opportunities for utilising water in a basin-wide basis, reforming institutions and redrafting legal arrangements are necessary steps to move towards development and implementation of IWRM.

Despite the commitment to IWRM, the *2002 Water Resources Strategy* and *2005 National Water Plan* are more focussed on investment in infrastructure development. Also, these documents have rarely been referenced when periodic plans and annual programmes have been prepared. It seems that one of the main reasons for this is that these 2 documents do not have legal backing, resulting in no compulsion to adhere to them or their principles.

Following the promulgation of the new Constitution in 2015, a new policy and legal regime is warranted, partly to give effect to the provisions of the Constitution in accordance with which rights and responsibilities of governments, at the 3 levels, have to be clearly defined; and also to ensure that the river basin plans and use-specific master plans under preparation are implemented and enforceable with policy and legal instruments.

Prior to any basin plan and use-specific master plan formulation, a Strategy for the development and management of the basin must be developed through a systematic and thorough stakeholder engagement

[8] About IWRM - GWP. GWP is an international network involved in water resources management

process. The Strategy and the plans prepared thereafter must be based on scientifically acquired and analysed data and information about the basin characteristics and resources.

This *Kamala Basin Water Resources Development Strategy* is the first of this kind in Nepal. The experience, skills development and lessons learned in its development will inform the preparation of all river basin plans in Nepal. The process adopted and the exercise carried out in the Kamala Basin Strategy formulation have also directly and indirectly contributed to the drafting of the *National Water Resources Policy*. A similar contribution is expected to be made to the drafting of federal and provincial water resources related legislations.

1.6 Strategy formulation process

Strategy refers to *'the art or practice of planning the future direction or outcome of something ... especially of a long-term or ambitious nature'* (OUP 2000). To make strategy means to formulate courses of action to realise development values.[9] This means articulating goals, major means-to-goal actions and responsible parties (Figure 1.1, 'development pathways'). Strategising further involves critical assessment of strengths and limitations of major sets of actions to reach a goal (Figure 1.1, 'Development Options'). To formulate this Strategy, such assessment was conducted using a range of techniques. Examples of assessment techniques include literature review; expert interviews; hydrological modelling; multi-criteria analysis; ecological analysis; workshops with stakeholders; and cost analysis.

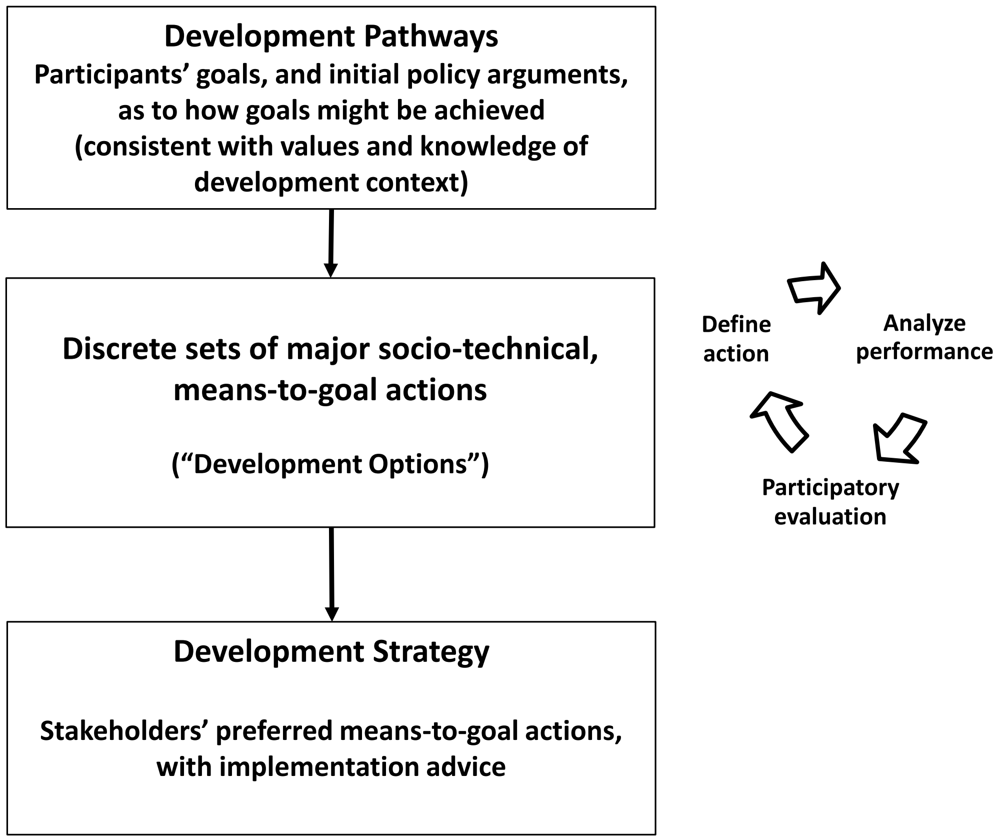


Figure 1.1 Participatory river basin planning: conceptual elements
Source: based on Foran et al. (2019)

Four scenarios for water resources and agricultural development were described, quantified, and prioritised using the above assessment techniques (Chapter 4). Four socio-technical options then received institutional

[9] Goals are descriptions of future states in which values are realized. Values are topics which matter (or arguably could matter) to a person (Fairclough and Fairclough 2012); for example providing equitable access to water resources across the basin, considering the differentiated needs and capabilities of women, as well as socially marginalized groups.

and political economy analysis to identify how they could be implemented (i.e. strategic advice for implementation). This type of analysis was also conducted to provide strategic advice on how to implement major actions associated with sustainable development of the Chure landscape (Chapter 6). Resource constraints prevented the project team from providing a full IPE analysis to support the chapters on agricultural development (Chapter 7), water-induced disaster management (Chapter 8), or drinking water supply (Chapter 9). These chapters are however informed by recent international research findings applicable to the Kamala Basin (Chapter 7); the sectoral experience of contributing authors (Chapter 8 and Chapter 9); and a discussion of recurring themes (strategic issues) which cut across multiple chapters (Chapter 10). The resulting *Kamala Basin Water Resources Development Strategy* has the status of a non-binding document. It is intended to mobilise further action and investment.

Figure 1.2 depicts an overview of the process used to develop a water resources development strategy for the Kamala Basin.

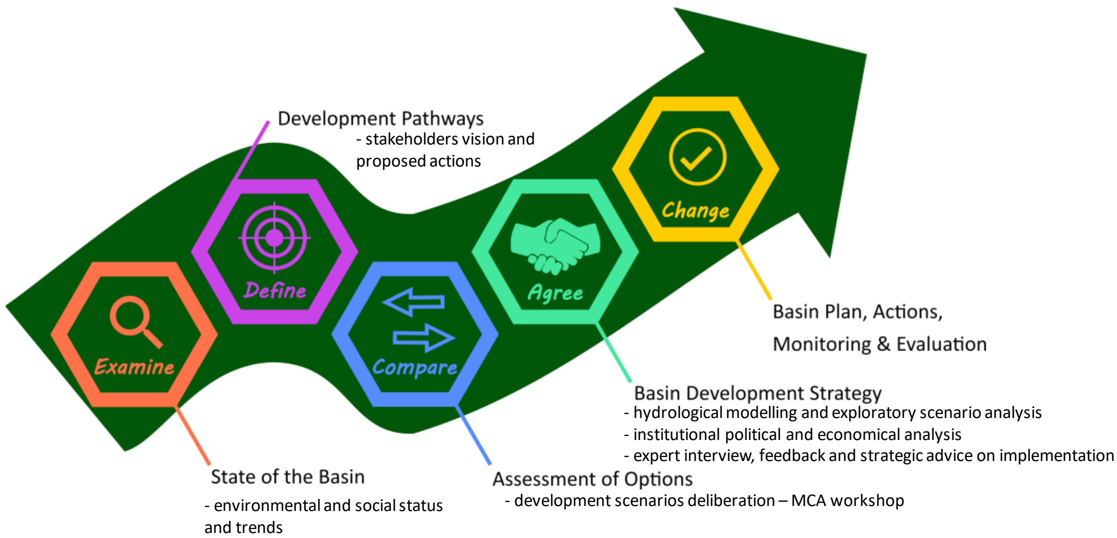


Figure 1.2 Strategy formulation pathway (adapted from WECS and CSIRO, 2020)

The following set of activities contributed to formulating the Strategy.

Activity 1: Data collection and review

Activity 2: Planning for stakeholder participation

Activity 3: Participatory formulation of basin development goals and pathways

Activity 4: Participatory deliberation on development options (multi-criteria analysis)

Activity 5: Modelled scenario assessment

Activity 6: Institutional and political economy analysis

Activity 1: Data collection and review

Primary and secondary data have been collected to quantify and qualify the current state of the water resources in the Basin. Synthesis of these data is presented in the *State of the Kamala River Basin* (WECS and CSIRO, 2020) and provides the basis for the elaboration of the Strategy. The datasets consist of spatial location and temporal trends on water use and water quality, land use, sedimentation, agriculture and irrigation infrastructure and practices, demography, labour migration livelihood, labour force, urban settlements and districts' economy; basin infrastructure; and local and national governance.

Activity 2: Planning for stakeholder participation

As stakeholder engagement is key to strategy formulation and basin planning, the process of engagement itself must be systematic in order to identify relevant stakeholders and their representatives and gather their opinions and aspirations in an effective way. When planning for the stakeholder engagement, the following points were considered:

- identifying and mapping diverse stakeholders (including organisations and informal community leaders) and their direct and indirect interests in basin water resources
- documenting and analysing initial perceptions, experiences, expectations, and ideas of stakeholders on water-linked basin ecology, economy and livelihood and desired future development
- stakeholders classified in accordance with their relevance, representation (government, private or civil society and federal or provincial level)
- preparation of stakeholder engagement plan establishing objectives and expectations, communication, and participation process.

Activity 3: Participatory formulation of basin development pathways

A multi-stakeholder workshop was organised in Janakpur in July 2018. During this basin-level workshop, 3 strategic Goals (introduced in Section 1.4) were formulated. Participants also identified sub-goals and major courses of action for achieving their goals, based on the following discussion questions:

- What might the future landscape and society look like when the goal has been realised?
- What issues or problems would make the goal difficult to achieve? What are the causes of those issues?
- What actions (sub-goals) would be necessary to achieve the stated goal?

Participants also discussed the Basin's technical, financial, social and political context; the timeframe for implementation; and social, economic and environmental risks associated with each goal and sub-goal.

A second multi-stakeholder workshop (primarily for federal policy actors) was held in Kathmandu in July 2018. The federal-level stakeholders supported most goals, and many actions, proposed by the basin-level participants, and brought a political, policy and economic lens to reformulate some of the text from the basin-level workshop. The main contribution from the federal-level workshop was to place water resources at the centre of the Kamala basin's development agenda.

The project team prepared a revised document consolidating the federal and basin stakeholder contributions, then organised a set of basin-level stakeholder workshops in November 2018 to consult with local governments. Eleven Municipalities and one Rural Municipality participated, represented by Mayors, Deputy Mayors, CEOs, Planning Officers, Ward Chairpersons and other community representatives.

This second round of basin-level workshops discussed the Goals and Pathways formulated during the first round workshops, and discussed the policies and plans of local governments to evaluate the Goals and Pathways and assure they were consistent with expressed needs and aspirations of people in the basin.

Activity 4: Participatory deliberation on development options (multi-criteria analysis)

Multi-criteria analysis (MCA) is a decision support methodology typically used to rank or select-options from a given portfolio of alternatives based on an assessment of how they would perform against a set of evaluation criteria. When implemented with the participation of relevant stakeholders, it can support decision-makers to understand the interests and preferences of stakeholders, to build legitimacy of decisions, as well as to support the formulation of actions with higher chances of implementation success.

The project's 2019 MCA workshop was organised to guide a first round of multi-stakeholder deliberation. The specific purpose of the workshop was to explore the relative performance of 4 water resources development options to meet agricultural water demand (Chapter 4). Each option was a means to meet development objectives stated within Goal 2 of the basin Development Pathway:

Option 1: Revitalisation of the existing Kamala Irrigation Project

Option 2: Increasing use of groundwater (in the Terai)

Option 3: Constructing small to medium water storages in the upper catchment

Option 4: The Sunkoshi to Kamala Diversion and inter-basin transfer Scheme.

Each option was assessed by the project team against a set of 10 evaluation criteria (e.g. investment cost/ha; impact on agricultural income; time to implement; institutional and political complexity). Each participant in the workshop assigned weights to each evaluation criterion. These weights represent the importance of each criterion as reported by each participant. The MCA workshop provided the project team with information regarding which evaluation criteria would be useful to guide subsequent analysis (e.g. the cost analysis in Section 4.8). It also provided insight regarding the full range of evaluation criteria which participants believed relevant to assessing different options to meet agricultural water demand.

Activity 5: Modelled scenario assessment

The project team developed four exploratory scenarios (that is, contrasting storylines) of future water demand and cropped area in the Kamala Basin. To generate these scenarios, the team created a framework based on a literature review of important trends and future uncertainties (both domestic and transnational) relevant to Nepal's rural development. The four exploratory scenarios represent alternative futures, and associated water demands, for the Basin's agricultural and non-agricultural sectors for the period 2020 to 2040:

Scenario 1: 'Business as Usual' (79 Million-Cubic-Meters, MCM)

Scenario 2: 'Commercial smallholder agriculture' (182 MCM)

Scenario 3: 'Agribusiness' (228 MCM)

Scenario 4: 'Stagnant agriculture' (94 MCM)

Note: Demand refers to year 2040. The 2020 dry season demand estimated at 56 MCM

These scenarios differ with respect to assumptions of national and global economic growth and structural diversification; as well as assumptions about the capability of local, provincial, and federal level agencies to address challenges facing agriculture.

In parallel, estimates of current (baseline) and potential future agricultural water requirements were prepared using a hydrological model combined with available observed data, drawing on information compiled in WECS and CSIRO (2020). A hydrological model was developed to quantify water demand and supply under current and future scenarios. The model was used to explore the ability of the four water resources development options to meet future agricultural water demand under each of the four exploratory scenarios, resulting in alternative scenarios for crop production, and crop income.

The use of a hydrological model provides reliable information to manage water resources under current and past climate and allows to make predictions under future climatic scenarios. Water availability and water use by different sectors are presented in Chapter 4. The modelling of water resources in the Basin used as baseline the existing limited historical data from 2 hydrological stations and most recent measurements. The hydrological modelling used Source, Australia's national hydrological modelling platform.

Activity 6: Institutional and political economy analysis

Institutional and political economy (IPE) analysis was used to formulate detailed advice on how to implement major sets of actions, which were previously identified by the Kamala Basin Initiative participants, during the Basin development goals and pathways phase (Activity 3). The IPE analysis demonstrates a method to understand and address the institutional and political challenges of pursuing any major development objective in the Basin.

The IPE analysis was based on the water governance frameworks of Pahl-Wostl (2015) and Ostrom (2009), as detailed in Chapter 5. The IPE analysis generated findings about strategic issues which cut across multiple chapters. Those recurring issues are: (1) a need for specific policy or institutional reforms; (2) a need for collaboration across boundaries (within and across state and non-state organisations); (3) a need for specific enhanced policy or planning processes; (4) a need for supportive organisational structures (Chapter 10).

2 Overview of Kamala River Basin

2.1 Basin characteristics and administrative boundaries

The Kamala Basin is located in the south-east of Nepal and has a drainage area of about 2,084 km^2. Administratively, the basin area intersects 3 provinces and 4 districts. The district of Udayapur in Province-1, Siraha in Province-2, Dhanusha in Province-2 and Sindhuli in Province-3 cover 19%, 20%, 14% and 47% of the total basin area, respectively. The Kamala River originates from the Mahabharat Range or Middle Mountains, and flows through Chure to the Terai plains before entering India. The elevation of the basin ranges from 70 masl in the southern most part to 2,180 masl in the north-west. About 67% of the basin area lies below 600 masl and 27% lies between 600 masl and 1,200 masl, while the reminder, 6% of the area, lies above 1,200 masl (Figure 2.2). With such variation of elevation, the Kamala Basin covers 3 physiographic zones – Middle Mountains (20%), Chure or Siwalik (64%), and Terai (16%) (Figure 2.4), with areas of 412 km^2, 1,336 km^2 and 336 km^2, respectively. According to the physiographic conditions, Dhanusha and Siraha fall in Terai plain while Sindhuli and Udayapur have Chure (Siwalik) hills and Mahabharat range, and also the valleys formed by them. The topographic characteristics have a strong influence on the economic activities and population distribution in the Basin.

The Kamala Basin is accessible with the Dhulikhel-Sindhuli-Bardibas Highway (BP Highway) from Kathmandu. The BP Highway, at its southern end, meets Nepal's East West Highway, which crosses the basin at Bandipur in Siraha and Portaha in Dhanusha districts. The interior parts of the Basin are also accessible with rural gravel and black topped roads. The nearest airport is that of Janakpur which is 63 km from Sindhuli and 87 km from Bandipur. The Kamala Basin is 'T' shaped with wider parts at the headwaters and starts narrowing from the middle part where it emerges into the Terai plain. The basin is narrow at the tail end where it enters into India. The location map of the Kamala Basin is presented in Figure 2.1.

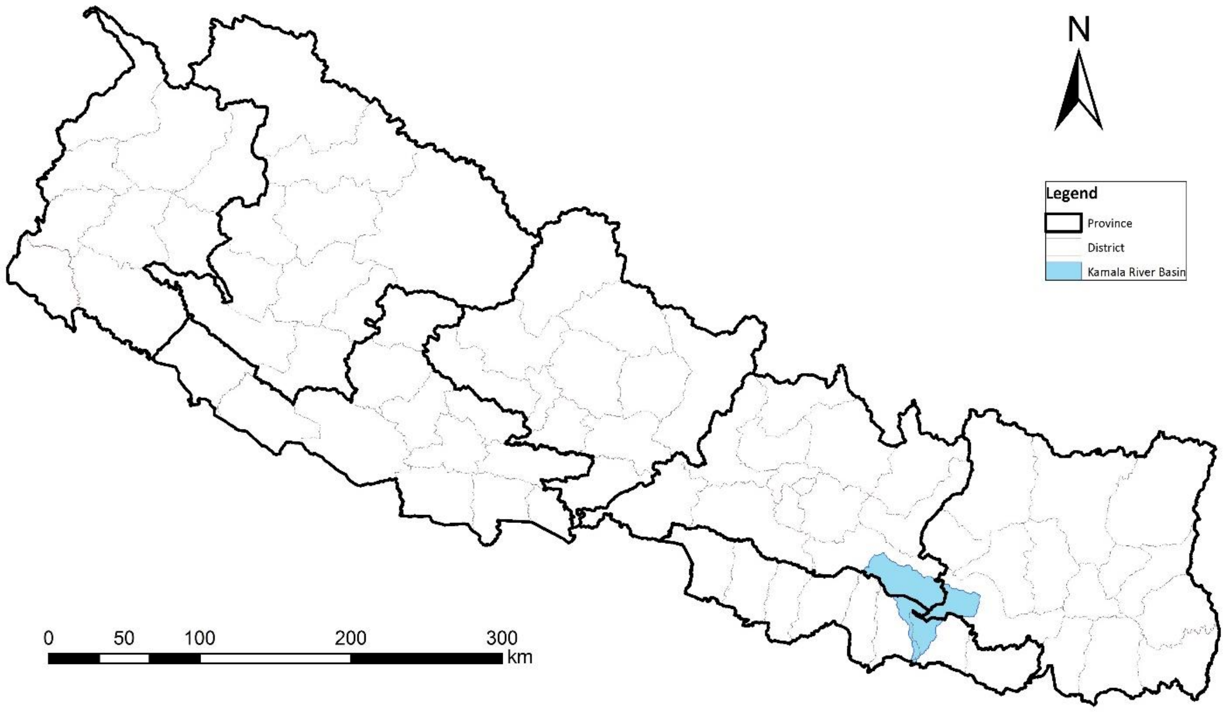


Figure 2.1 Kamala Basin location in Nepal

The dominant land use pattern of the Kamala Basin is such that the approximate coverage of forest and agricultural areas are 59% and 35% respectively. The other less dominant land cover are depicted by barren land, grassland, water bodies, shrubland and built-up areas with 2.4%, 1.8%, 0.8%, 0.5% and 0.4% of the total area, respectively. Of the 2 typical water induced problems, riverbank erosion and landslide are found in the upstream part, whereas inundation is common during the monsoon season in the downstream plains.

2.2 Hydrology and basin characteristics

The Kamala River originates from Mahabharat Range; flows through Siwalik Range; and then to the plain Terai area before entering into India. The Basin lies below the elevation of 3,000 masl, so snowfall does not contribute to the hydrology of the Basin. The hydrology is dominated by the summer monsoon that enters Nepal from the east and progresses towards the west. The monsoon phenomenon in Nepal results in heavy rainfall during the months from June through September with its share of 70% to 80% of the annual rainfall. There is a significant spatial variation in the annual rainfall from 940 mm to 2,594 mm, the highest being recorded at the Sindhuli Gadhi rainfall station at the northern and uppermost part, within the Basin. Figure 2.2 depicts the distribution of the average annual rainfall over the Basin.

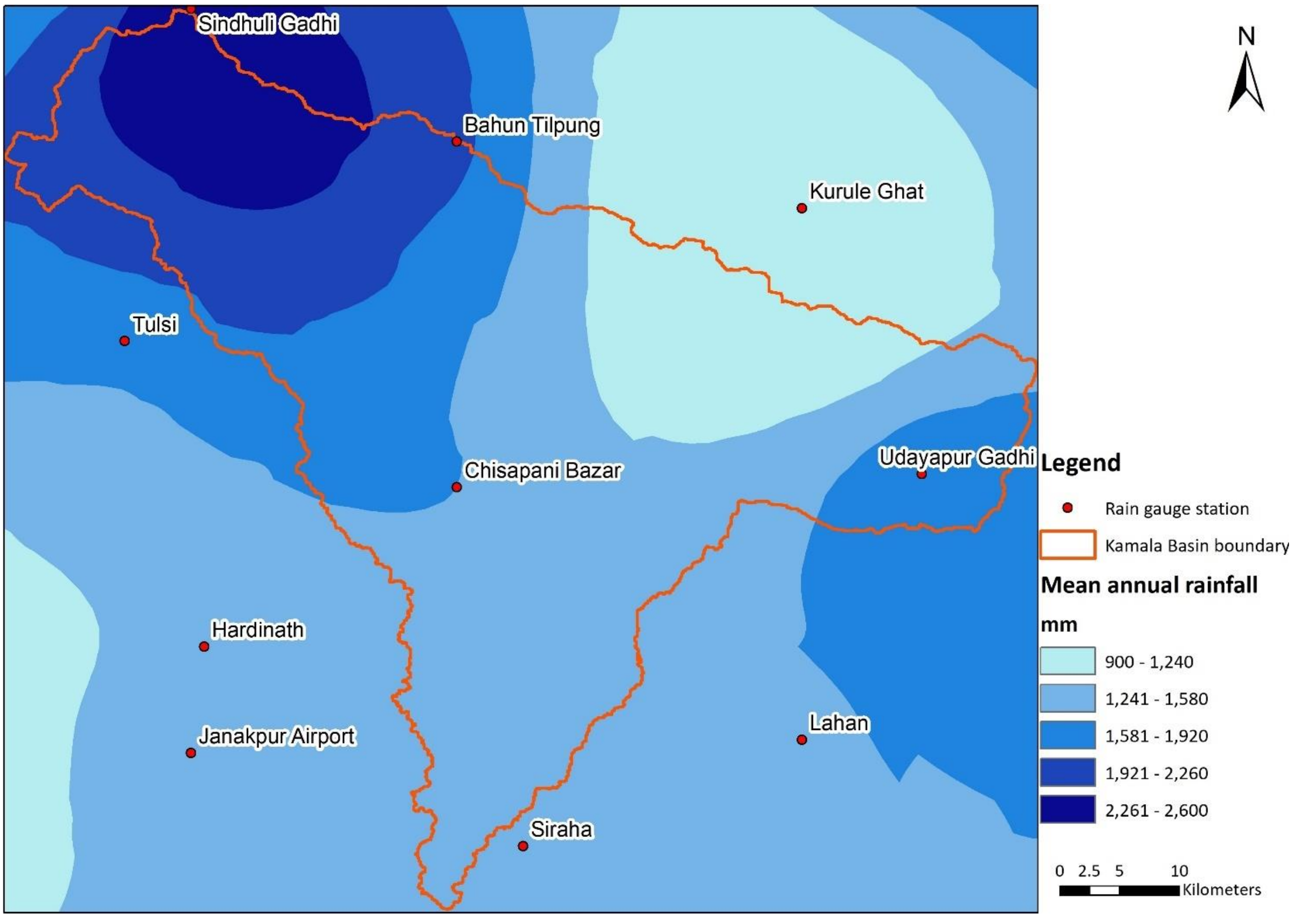


Figure 2.2 Mean annual rainfall across the Kamala Basin over a period of 1970 to 2012

Source: Prepared by CSIRO

There are limited available data on surface water in the Kamala Basin. Discharge was measured at the Chisapani (26.421 N, 86.175 E) hydrological station in the Dhanusha district, which remained in operation from 1956 to 1970 and from 2000 to 2004. The annual mean flow data of the Kamala River obtained from the *Koshi Basin Master Plan Study* (JICA 1985) from 1956 to 1970 at Chisapani station (station 598) was 44.70 m^3/s.

The variations in minimum, maximum and mean monthly flows over this period are shown in Figure 2.3. During the dry season the rivers that originate in the Chure have either a very low volume of water or no surface water flowing at all. In contrast, during the wet season, rivers carry high volumes of water and sediments, varying with rainfall intensity during the monsoon season. However, even in the monsoon season, these rivers quickly change streamflows a few hours after rainfall events. Due to the high level of infiltration and permeability, and relatively steep riverbed slopes and short lengths of the rivers in the Basin, the discharge in the rivers increases and decreases quickly.

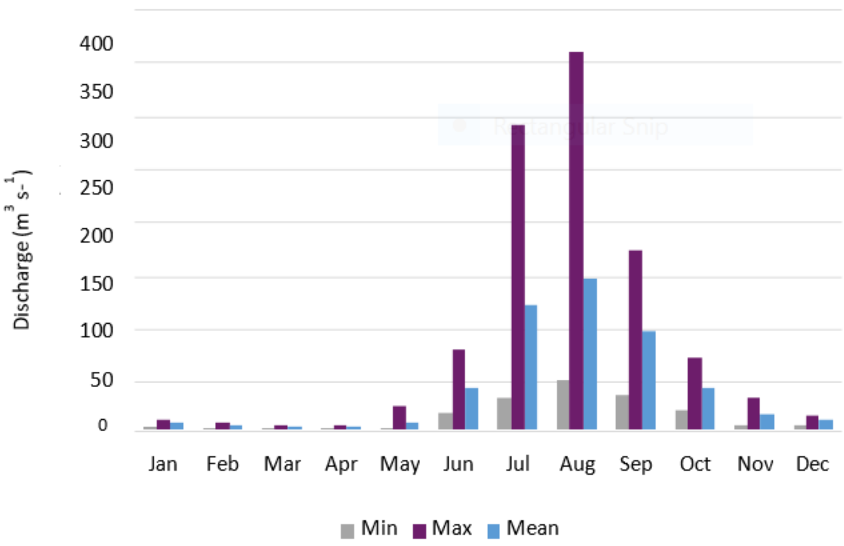


Figure 2.3 Mean, minimum and maximum monthly discharge of the Kamala River at Chisapani station (1956 –70)
Source: adapted from WECS and CSIRO (2020)

The surface water available in the Basin is the major source of water for irrigation. The Kamala Irrigation Project (KIP), with a design discharge of 32 m^3/sec, is the main irrigation infrastructure in the Basin. Springs in the upper part and groundwater tube wells in the Terai plain are mainly used for drinking water.

Hydrogeology

The hydrogeology of the Terai plains in the Kamala Basin is composed of 2 major depositional units – the Bhabhar zone (towards the north) and the Terai (Shreshta et al, 2018). The Bhabhar zone is situated in the foothills of the Chure, consisting of alluvial and colluvial coarse sediments. The Bhabhar zone has an unconfined aquifer with generally deep watertable. Intersection of the Bhabhar zone and the Terai plain marks the northern boundary of the Ganga Basin. The southern part of the Basin is underlain by recent alluvium with an average thickness of 1,500 m formed by the deposition of sediments in the rivers running from the northern part of the Basin. The rivers and streams frequently shift along the plain, sometimes over kilometres. Consequentially, the sediments are cross bedded, eroded, reworked and redeposited, resulting in aquifers that provide valuable groundwater resources. With the favourable hydrogeology, groundwater forms a significant component of the total water resources in the Terai zone of the Kamala Basin. In Dhanusha and Siraha, groundwater supplies 85% of household domestic water needs and around 70% of households use groundwater for irrigation (Okwany et al, 2013). GoN (2017) reports that there are 6,293 shallow tube wells in Dhanusha, and 5,932 shallow tube wells and 48 deep tube wells in Siraha. The groundwater recharge rate in the Terai zone of Kamala Basin is considered to be far more than the current rate of extraction, hence, considered sustainable, and expansion is being promoted widely. Annual groundwater recharge in the Siraha and Dhanusha districts was estimated to be in the range of 122 to 279 MCM/year for Siraha (Kansakar, 1992) and 145 to 352 MCM/year for Dhanusha (Shrestha, 1992).

Estimates of groundwater consumption for the Kamala Basin were not available. Analysis of data from observation bores of Dhanusha and Siraha districts suggests that shallow groundwater occurs across the Terai areas of the Kamala Basin and water levels come close to the ground surface in and after the rainy season. Over the period 2004 to 2013, the observation bores indicated that groundwater levels varied in the range 0.1 to 7.5 m below ground, with seasonal patterns of filling during the monsoon and drying during the winter. Based on the observed minimum and maximum water levels, it is estimated that annual replenishable groundwater could support irrigation of at least 9,250 ha of land in the Kamala Irrigation Project area. Increased usage may also favour availability of more storage for groundwater recharge.

Recorded discharges of the shallow tube wells in Dhanusha district range from 9 litres/sec to 16 litres/sec while it was 11 litres/sec in the Siraha district. This indicates a high groundwater yield, favouring extraction using irrigation tube wells and pumps.

Pumping

IFPRI (2016) reports that most shallow tube wells in Dhanusha use a 4.8 HP diesel pump. One pump costs approximately NPR20,000 and can service around 4.8 ha. Farmers rent out their pumps to other farmers and, on average, one pump serves about 9 farmers within a radius of 1.8 km. Operating hours vary across seasons and districts. For example, in Dhanusha a pump runs for an average of 81 hours during Kharif season, 104 hours during Rabi and about 17 hours in summer.

Sugden (2014) reports that inequalities in landlord-tenant relations also affect the capacity of farmers to access groundwater from shallow tube wells. Typically, a landlord owning a larger landholding bores a well to access water and buys a pump set to extract the water (though some bores are collectively managed). In Dhanusha around 30% of farmers owning 3 ha of land also own a pump set. For tenants, they typically rent the well and/or pump set from the landlord to irrigate their crops. The inequality reveals itself as increased usage costs for renters compared to owners and an increased capacity for owners to pump groundwater compared to renters.

Prospects

Despite opportunities to profitably irrigate land using shallow tube wells, the purchasing of pumps in Dhanusha appears to have plateaued since 2010 (IFPRI 2016). The water to diesel price ratio is much higher than in neighbouring countries (3.2 for Nepal vs 2.2 for Bihar vs 2.0 for Bangladesh). Use of deep tube wells is also limited because of the equipment required for drilling as well as the high costs involved in maintenance. Construction of deep tube wells is subsidised by the Government with 0% to 5% of the total costs paid by the farmers. The Government's allocation of funds to the deep tube well scheme is insufficient to meet all requests for new projects. The small number of operational schemes means that maintenance costs remain high, and most schemes fall into disrepair.

Irrigation systems

Kamala Irrigation Project (KIP)

The Kamala Irrigation Project (KIP) was constructed during 1975–80 and is jointly managed by the Department of Water Resources and Irrigation through the Kamala Irrigation Management Division and the Water Users Association (WUA). The Project provides irrigation to a design command area of 25,000 ha of lands in Dhanusha and Siraha districts. For the winter crops, however, the irrigated area drops down to 10,000 ha. The 650 m long diversion weir of the KIP is located at Portaha from where the 2 main canals with a design capacity of 16 m^3/s each offtake on the 2 sides of the river. The salient features of physical infrastructure of KIP are presented in Table 2.1.

Table 2.1 Main characteristics of Kamala Irrigation Project

DESCRIPTION	EASTERN MAIN CANAL	WESTERN MAIN CANAL	TOTAL
Maximum design discharge (m^3/s)	16	16	32
Length of main canal (km)	31	30	61
Length of concrete lining (km)	1.5	2.2	3.7
Number and length of secondary canals (number / km)	3 / 75	8 / 63	11 / 138
Number and length of tertiary canals (number / km)	14 / 32	8 / 17	22 / 49
Command area development (CAD) (ha)	7,500	No CAD	7,500

Although the KIP has undergone revitalisation over time, the headwork is again in a dilapidated condition waiting for major revitalisation. The canals also require cleaning and reshaping and the overall structure needs revitalisation. Only about 60% of the water users have been paying irrigation service fees that vary from NPR150/ha to NPR300/ha. Water management in the irrigation system is carried out jointly by the GoN agency and a federated WUA. Of the collected irrigation service fees, 20% goes to the GoN and the remaining 80% to the WUA to spend on the operation and maintenance of the main (50%), secondary (25%) and tertiary (25%) canals. The KIP has an annual operation and maintenance budget of NPR18,545,000, most of which is contributed by the Government.

Hardinath Irrigation Scheme

This Scheme lies in Dhanusha district on the west side of the KIP. The scheme is taken care of by the Kamala Irrigation Management Division. The Jalad River or Hardinath is the water source for this system where 80.6 m long headwork has been constructed to divert the water on 2 intakes on both banks of the river. Both eastern and western canal systems are designed to irrigate 1,000 ha each. The main canals have capacities of 1.0 m^3/sec and the water duty is estimated to be 1.0 litre/sec/ha. The eastern main canal is 6 km long and 4 field channels with a combined length of 3.2 km offtake from it. Likewise, the western main canal is 10 km long and 7 field channels with a total length of 4.3 km offtake from it.

Although the reported cultivable command area of this system is 2,000 ha, currently it is providing monsoon irrigation for only 1,200 ha and winter irrigation for about 300 ha. About 3,000 farmers (population 15,000 inhabitants) are benefitted by this Scheme. In the command area, farmers usually grow only 2 crops: paddy and wheat. In some small areas (about 30 ha) farmers grow 3 crops: maize, paddy and wheat.

Farmer Managed Irrigation Systems (FMISs)

Irrigation in the Kamala Basin has been practised since time immemorial with the construction of Farmer Managed Irrigation Systems (FMISs) withdrawing water from nearby rivers and streams (listed in Table 2.2). The GoN with its first *Irrigation Policy* in 1992 initiated revitalisation of many of these FMISs through various projects and programs such as Irrigation Sector Project (ISP), Second Irrigation Sector Project (SISP), and Community Managed Irrigated Agriculture Sector Project (CMIASP), all assisted by the Asian Development Bank (ADB). Two schemes were rehabilitated in Dhanusha, 4 in Siraha, 24 in Sindhuli and 10 in Udayapur, servicing total command areas of 940 ha, 1,220 ha, 3,027 ha and 2,170 ha respectively.

Table 2.2 Farmer Managed Irrigation Systems in Kamala Basin

S. N.	NAME OF SCHEMES	DISTRICT	PROGRAM	COMMAND AREA (HA)
1	Charnath IP	Dhanusha	ISP	420
2	Kajipaini IP	Dhanusha	CMIASP	520
	Sub-total			940
1	Kamala Paini IP	Siraha	ISP	300
2	Bataha IP	Siraha	ISP	260
3	Mainawati IP	Siraha	ISP	340
4	Devipur Mainawati IP	Siraha	DOI	320
	Sub-total			1,220
1	Bhalu Khola IP	Sindhuli	ISP	52
2	Dandi IP	Sindhuli	ISP	73
3	Dhamile IP	Sindhuli	ISP	64
4	Gadyauli Khola IP	Sindhuli	ISP	91
5	Harsahi	Sindhuli	ISP	239
6	Kamala Maisthan IP	Sindhuli	ISP	42
7	Panchsaya Majhitar IP	Sindhuli	ISP	72
8	Bardeotar IP	Sindhuli	SISP	59
9	Chadaha IP	Sindhuli	SISP	290
10	Chanduli	Sindhuli	SISP	74
11	Dhap IP	Sindhuli	SISP	90
12	Dudauli IP	Sindhuli	SISP	363
13	Tandi IP	Sindhuli	SISP	667
14	Bhiman IP	Sindhuli	DOI	110
15	Gwang Khola	Sindhuli	DOI	63
16	Koliyachauki IP	Sindhuli	DOI	67
17	Kudule IP	Sindhuli	DOI	54
18	Kuduletar IP	Sindhuli	DOI	23
19	Majhuwa IP	Sindhuli	DOI	40
20	Nigale IP	Sindhuli	DOI	35
21	Balhatta IP	Sindhuli	MIP	71
22	Kogti IP	Sindhuli	MIP	217
23	Dhami IP	Sindhuli	CMIASP	165
24	Paire	Sindhuli	CMIASP	6
	Sub-total			3,027
1	Hadaiya Kulo IP	Udaypur	CMIASP	680
2	Mate Khola IP	Udaypur	SISP	310
3	North Tawa IP	Udaypur	SISP	50

S. N.	NAME OF SCHEMES	DISTRICT	PROGRAM	COMMAND AREA (HA)
4	Tawa Khola Baliya IP	Udaypur	SISP	135
5	Risku IP	Udaypur	CMIASP	49
6	Sughare Aaptar IP	Udaypur	CMIASP	12
7	Nepaltar IP	Udaypur	DOI/MIP	177
8	Panchawati IP	Udaypur	DOI/MIP	392
9	Tawakhole IP	Udaypur	DOI	63
10	Tawa Khola IP	Udaypur	SISP	294
	Sub-total			2,170
	Total			**7,357**

2.3 Land cover

The natural vegetation pattern including land use of the Kamala Basin is influenced by the landscape, climate, elevation, rainfall distribution, and soil characteristics. Land cover in Nepal over different periods (1990, 2000 and 2010) was estimated by ICIMOD (2013) using Landsat satellite images with a spatial resolution of 30 m. Within the Basin the forests, mainly with broad leaf and hard wood species, have the highest coverage of 59% of the total Basin area. They are in Middle Mountains and Chure areas. Agricultural lands occupy 35% of the Basin. They are in all the physiographic zones of the Basin, as is shrubland (0.5% of total Basin area). Other land with sub-categories of settlements (0.4%), barren lands (2.4%), water bodies (0.8%) and grassland (1.8%) (Figure 2.4).

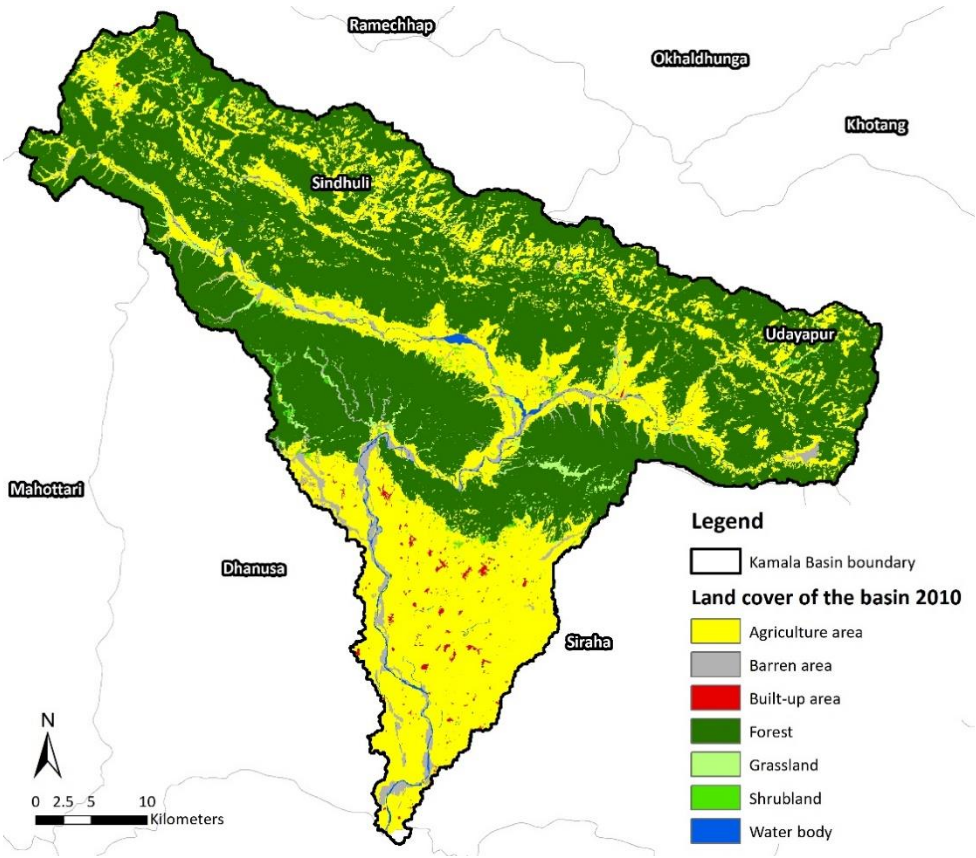


Figure 2.4 Spatial distribution of land cover categories in the Kamala Basin as at 2010
Source: adapted from WECS and CSIRO (2020)

No systematic study on the land use change of the Basin has so far been conducted. However, ICIMOD's regional database shows that about 2,800 ha of forest land turned into other land use types between 2000 and 2010. During the fieldwork visits, a general response from stakeholders was that forest land and agricultural land, to some extent, are under constant threat from activities and events such as overgrazing, forest fire, wood product extraction for energy, in-migration, floods, and encroachment.

The land cover pattern in the Kamala Basin is summarised in Table 2.3.

Table 2.3 Land cover in Kamala Basin districts (ha)

LAND COVER	DHANUSHA	SINDHULI	SIRAHA	UDAYPUR	TOTAL
Agriculture – level terrace		7,513		1,919	9,432
Agriculture – sloping terrace	0.2	2,745		3,841	6,586
Agriculture – valley, Terai	10,402	14,122	23,368	6,300	54,192
Barren land	24	96	1,847	92	2,059
Forest land	14,040	60,857	4,315	34,967	114,179
Residential area	375	594	1,477	2	2,448
Sand/ gravel/ boulders	2,817	4,722	1,259	2,322	11,119
Shrubland/ grassland/ degraded land	2,295	6,217	1,333	341	10,186
Total	29,953	96,865	33,598	49,783	210,200

Source: JVS and PEI (2018) derived from Land Resources (DOI, 2017)

2.4 Social and economic

Demography and settlements

The Basin's population in 2011 was roughly 610,000 in 120,000 households. In contrast with the country's overall population density of 204 people/km^2 in 2017 (World Bank 2019), the Basin's population density was somewhat higher at 290 people/km^2 in the same year (CBS 2019). Ethnically, the Basin has a heterogeneous mix of caste and ethnic groups comprising Brahmin, Chhetri, Janajati of hill, Newar and Dalits dominating the hilly region, with Terai/Madhesis such as Yadav, Muslim, Koiri/Kushbaha, Mushar and Teli dominating the Terai region (CBS 2019). More than half of the households in the Basin have a landholding size of smaller than 0.5 ha. The landholding size is larger in Terai districts; for example, 4% of households in Siraha have landholdings larger than 3 ha, whereas the corresponding percentage of households in Sindhuli is only 0.1%.

Temporary out-migration of youths and, in many cases, the heads of households into foreign labour markets, especially, Japan, Korea, Malaysia and Gulf countries, is rampant. A survey indicates that about one-fourth of the households have sent their labour force abroad for work, and on average, the contribution from the remittances to the household income is nearly 50% (WECS and CSIRO 2020).

Nepal and innately the Basin have a long way to go in educating people and removing gender inequalities. The inequality is reflected by the country being ranked 118 out of 189 by the United Nations Development Program (UNDP) in terms of its gender inequality index. In the 1990s quotas for women's participation in water decision-making were established in Nepal. These quotas varied between 22% and 33% and were mostly limited to local Water Users Associations (WUAs). More recently, the expectation for quotas in participation has extended to all levels, including senior level positions such as Chairperson or Vice-chairperson (Koirala and Shakya 2019).

Table 2.4 presents the population, municipalities and other statistics of the Basin across each of the 4 districts.

Table 2.4 Key indicators across the 4 Kamala Basin districts

INDICATOR	DHANUSHA	SINDHULI	SIRAHA	UDAYAPUR	TOTAL
Number of urban municipalities	5	2	6	2	15
Number of rural municipalities	1	3	2	2	8
Number of wards	30	42	62	23	157
Number of households	22,214	57,544	42,913	17,511	119,535
Number of land holdings	96,004	51,233	88,527	54,919	290,685
Land holdings below 0.5 ha	41,250	28,979	31,554	31,868	41,250
Total population	118,933	179,911	224,264	85,137	608,245
Female population	59,711	94,459	116,042	45,030	315,302
Multi-dimensional poverty rank[1]	n.a.	8	12	9	

Sources: CBS (2019) and Gerlitz et al. (2015). Note: 1.The higher the ranking, the higher the multi-dimensional poverty incidence in the district. Ranking constructed out of a total of 23 analysed districts. The Poverty and Vulnerability Assessment (PVA) data does not record observations from households in the district of Dhanusha, so it is not possible to measure its multi-dimensional poverty

The reader is referred to WECS and CSIRO (2020) for details of the socio-economy of the Kamala Basin.

2.5 Agricultural systems

Agriculture is the main economic activity in the Basin and is predominantly dependent on irrigation, particularly in the Terai region. Crop production uses 94% of the water in the Basin in irrigation systems. Crop production is predominantly undertaken by smallholders, with subsistence farming primarily producing traditional crops of rice, wheat and maize (WECS and CSIRO 2020).

Agricultural practices are based on farmers' experience and tradition, limited by the work force, land size, water availability during the dry season and family needs. Some changes have been observed, mainly the introduction of horticulture in the vicinity of the urban settlements and where irrigation facilities are available. The changes in agriculture practices include in cropping patterns, a rise in cropping intensities and yields. In addition, noticeable changes have occurred in use of chemical fertilisers and improved seeds. The farmers of both the hills and Terai have been exposed to different techniques of farming practices and are applying these as far as possible and affordable. Agriculture tools such as tractors, threshers and harrow are also being used by some farmers.

The most traditional cultivation is rice planted at the beginning of the monsoon season followed by wheat that depends on the presence of irrigation. If irrigation water were available during the dry season, farmers have indicated that they would produce a third crop. This would provide a significant economic benefit and facilitate diversification of crops. Despite the majority of subsistence farming being dominated by smallholders, there are examples of crop diversification (such as vegetables, mustard, peas, millet, potato) in those parts of the Basin where irrigation is available. However, the production of these commodities is small scale and generally localised in the vicinity of urban settlements.

Crop production practices vary across the Basin depending on water availability and farmer resources. The cropping practices of the Chure and Middle Mountains are based on terraced farming since access to irrigation is limited. Alternative crops such as barley, mungbean and buckwheat are more common in these regions.

In the Terai, rice-based cropping is cultivated in irrigated lowlands while maize-based cropping patterns are practised in uplands. After rice, wheat is grown to a large extent in irrigated fields during winter (November to March) depending on access to water. Other crops such as potato and mustard are also grown during winter.

Maize is grown in both irrigated and rainfed areas and the area under maize and interest has been increasing (Jalsrot Vikas Sanstha and Policy Entrepreneurs Inc. 2018).

Crop productivity and water use efficiency are in general low compared with highly intensive systems. Large quantities of water are lost due to inefficient water use and poor condition of the irrigation systems.

Improving water use efficiency or the agriculture systems may result in significant economic benefit to the region. Some viable alternatives are discussed in Chapter 7.

2.6 Biodiversity

Nepal, with only 0.1% of the global area, supports 3.0% and 1.1% of earth's known flora and fauna, respectively (Ministry of Forests and Soil Conservation 2014). Nepal is rich in freshwater ecosystems which cover 5% of its total land surface (MoFSC 2012). Freshwater ecosystems across the physiographic zones provide excellent habitats for approximately 230 species of fish, 102 species of phytoplankton, 109 species of zooplanktons, 192 species of molluscs, 53 species of amphibians and 284 vascular plants (Nesemann 2007, Rajbanshi 2013, MoFSC 2014). According to the 2003 IUCN Red List, 123 globally threatened species occur in Nepal, of which 42 species (34%) are found in, or dependent on, freshwater ecosystems. Seventeen of 20 vertebrate species in Nepal are freshwater dependent (IUCN 2004). The only globally threatened species, the 'Relict Himalayan Dragonfly' occurs in rivers of the High and Middle Mountains (Nesemann et al. 2011, Tachamo Shah et al. 2012), highlighting the significance of preservation of freshwater ecosystems in the country (IUCN 2004).

Species richness along the elevational gradients increases at the altitude of 1,000 to 1,500 masl and declines with increasing elevation. However, richness of endemic and sensitive species increases with increases in elevational gradient and is most pronounced above 3,500 masl (Shrestha 1990, Vetaas and Grytnes 2002, Jüttner et al. 2010, Tachamo Shah et al. 2015, Li et al. 2016).

Despite significant species richness and the ecological importance of these freshwater ecosystems, they are highly vulnerable, mainly due to human actions. These include water drainage and encroachment for agriculture, settlement and infrastructure development, diversion and abstraction of water for irrigation, unsustainable exploitation of resources including overfishing and destructive fishing, widespread mining of gravel from streams and riverbeds, water pollution from households and industrial discharges and agricultural run-off, growth of invasive species, illegal hunting of wildlife, siltation, channelling and damming of rivers in the country.

A study across Nepal's Chure forest zone indicated substantial biodiversity in this zone with 281 tree species, 186 shrub species and 322 herbaceous plant species (DFRS 2014). However, in the absence of a detailed study specific to the Kamala Basin, it is difficult to establish whether these species are all present in the Basin. Sal forest, tropical deciduous riverine forest and tropical evergreen forest occur within the Savanna and Grasslands ecoregion. Tall grasses grow in riverine grasslands and forests (Paudel et al. 2012).

Water availability in the Kamala River across seasons affects taxa richness (Tachamo Shah et al. 2019a). A recent study recorded a total of 84 taxa of aquatic invertebrates belonging to 61 families of 19 orders in which *Ephemeroptera* (Mayfly), *Trichoptera* (caddisfly) and *Diptera* (flies) were the most dominant groups (Tachamo Shah et al. 2019a). Local faunal studies undertaken within the Basin indicate the presence of key mammal species such as Asiatic elephant as well as grassland species such as hog deer and barking deer. Studies suggest there are up to 29 fish species, one of which is near threatened; 26 reptiles and amphibians (Shah and Tiwari 2004, Aryal et al. 2010), 3 of which are vulnerable. The birds reported in the Basin are 64 species belonging to 31 families of 10 orders (Parajuli 2013) including the globally threatened and nationally endangered lesser-adjutant stork (*Leptoptilo javanicus*); and 46 mammals, with 2 endangered, 2 vulnerable and 6 near threatened.

Osprey, black kite and black shouldered kite which are listed in Appendix II of the *Convention on International Trade of Endangered Species* (CITES) have been observed in the Basin. Peregrine falcon (*Falco peregrinus*) listed as most endangered (CITES Appendix I) has been documented along the Kamala River (Parajuli 2013). A total of 27 fish species are reported in the headwaters of the Kamala River (Jha et al. 2018). Endangered species, *Macrognathus pancalus* (Local name: bam) and *Mastecembelus spp*. have been reported in the Basin (Tachamo Shah et al. 2019a). Similarly, vulnerable species such as *Botia sp*. (baghi) are commonly documented species (Tachamo Shah et al. 2019a). A rare invertebrate belonging to family Baetidae - *Platybaetis spp*. exists in the upstream sections of the River.

2.7 Managing water for sustainable outcomes

Rivers are integral for supporting people, plants, and animals. Rivers are not only important for the sustenance of human livelihoods but also for supporting and regulating natural ecosystems through nutrient supply and absorption, maintaining groundwater levels, and for mitigating harmful flood impacts. They play a crucial role in transporting nutrients and materials from upstream to downstream, and maintaining river connectivity allowing migratory species, especially fishes, to move upstream during spawning periods.

Rivers are a key indicator for the economic development of a country. Detailed assessment is needed to better understand the opportunities and impacts of current and future development, considering water quantity and quality and interrelationship with biodiversity. To effectively manage water resources, it is important to understand the consequences of changes in water abstractions, infrastructure development, and agricultural practices. This is particularly important given the GoN's objective to ensure sustainable river basin management as well as hydropower development[10] (WECS 2013).

Environmental flows

Environmental flows is a concept and framework for supporting the sustainable management of rivers and floodplains for both people and ecosystems. Environmental flows describe:

> '*the quantity, quality and timing of water flows required to sustain ecosystem services (river health), and human wellbeing and livelihoods that depend on these ecosystems.'*
> (Brisbane Declaration 2007)

River discharge, water quality and river connectivity are the major requirements for maintaining environmental flows in a river.

In Nepal, few methods have been established to define or enforce environmental flows for a river. The minimum flow is legally defined in the *2001 Hydropower Development Policy* as 10% of mean monthly flow of the driest month of a year; or the minimum required as identified in the environmental impact assessment study report (MoWR 2001). This does not represent the flow variability required to sustain ecological functions in a river and this requirement may vary with respect to species (Tachamo Shah et al. 2020). Furthermore, it provides limited legal provision to conserve the river ecology.

A recent study conducted by the International Water Management Institute in partnership with the Aquatic Ecology Centre at Kathmandu University developed a method called the 'Environmental Calculator' for establishing environmental flows in western Nepal. This calculator was developed with reference to river discharge, socio-cultural values, and abundance and richness of benthic macroinvertebrates and has been incorporated in the *National Irrigation Master Plan* by the Department of Water Resources and Irrigation (DWRI 2020).

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[10] Nepal aims to develop about 25,000 MW by the end of 2030 (WECS 2013).

Despite this work, substantial effort is needed to better understand and implement environmental flow requirements across the Basin and in Nepal. The Strategy provides an opportunity to explore methods for evaluating the potential implications of development on environmental flows alongside more traditional forms of evaluation metrics such as economic cost.

Hydrological impacts

The Kamala River has many ecological and cultural values. Temples are built along the bank of the river such as Kamala Mai, Mahadevstha in Tritiya. The river supports critical habitats for many important endangered and vulnerable species.

The primary existing impacts in the upper Basin have been caused by riverbed mining, whilst the lower Basin has reduced dry season flows due to agricultural extractions and increased nutrients due to agricultural runoff and untreated sewage and wastewater (Tachamo Shah et al. 2019a). Additionally, there has been restricted floodplain inundation due to embankment construction.

Importantly, headwaters of the Kamala River are the predominant source of drinking water for people. River water is directly pumped to agricultural fields from the river upstream of the KIP while downstream has diverted river water into irrigation canals leaving little water in the main river channel. As a result of this extraction, maintaining environmental water in the river has become critical throughout the river. The KIP has had an observable impact on aquatic biota (Tachamo Shah et al. 2019a) and locals have not seen large fishes for some time. Diversity of benthic macroinvertebrates is also very low compared to the upstream river and mainly dominated by stress tolerant insects such as midges (*Diptera: Chironomidae)*.

Low to moderate level of changes in hydrological regimes might not have a significant impact on instream biota like fish and benthic macroinvertebrates and water quality. A study conducted in hydrologically altered rivers in western Nepal demonstrated that decreased flows in rivers resulted in a significant reduction in rheophilic benthic [11]macroinvertebrates, especially caddisfly (Tachamo Shah et al. 2019b).

A high level of change in flow regime caused by human activities may lead to poor water quality in rivers, affecting sensitive instream biota and favour pool-tolerant species that can survive in warm waters in relatively low oxygen.

In the absence of existing data on the water requirements of key indicator species within the Basin, a preliminary assessment of the potential impact of future development is presented in Chapter 4 using flow-based ecological metrics.

2.8 Governance, policy and institutions

Water related institutions

The institutional framework plays a vital role in the development and management of water resources. The water-related institutional arrangement in Nepal can be categorised broadly into: i) institutions for planning, policy making and coordination, (ii) implementing institutions, and (iii) operation-level institutions. In the Kamala Basin operation level institutions exist and planning and policy making institutions are at the centre.

[11] Rheophilic fauna prefer or live in flowing water. Benthic fauna are found on the bottom, or in the bottom sediments, of waterbodies.

Institutional arrangements

The institutions involved for planning, policy making, and coordination are mainly councils, commissions and line ministries including Parliament and Council of Ministers. The National Planning Commission (NPC) is the main central institution responsible for Nepal's economic planning with relevant federal ministries involved in formulation of respective sectoral (e.g. water, agriculture, hydropower) policies. In the water sector, responsibility for policy and legislation drafting is mainly undertaken by WECS. WECS is also engaged in preparation of basin plans and other plans related to water and energy sectors.

Water related institutions currently active include the Ministry of Energy, Water Resources and Irrigation, Ministry of Water Supply, Department of Water Resources and Irrigation, Department of Electricity Development, Department of Hydrology and Meteorology, Department of Water Supply and Sanitation, and the Department of Soil Conservation and Watershed Management. In a unitary system of governance up until the promulgation of the federal constitution of Nepal in 2015, most of the water-related field activities were implemented by the GoN through its district and division offices. Local bodies were also active to some extent in a decentralised system. With the introduction of the federal system, Provinces and Local levels have assumed their own governance system. However, in the present transition period, the rights and responsibilities in water resources development and management of the lower tiers of government are yet to be defined by a federal water legislation. Provincial Governments have taken over groundwater management from the centre, whereas federal institutions still have control over the KIP in the Basin.

Provincial organisations

The province level Ministries of Physical Infrastructure and Development take care of water resources development and management within the provinces. However, the largest consumer of water. Agriculture falls under the Ministry of Land Management, Agriculture and Co-operatives. Other organs responsible for implementation and management of various water-related activities are yet to be defined and their functions streamlined. At the local level, local governments are constituted in each of the municipalities and rural municipalities. They are now active in planning and implementing activities for meeting water demands and flood mitigation at the local level. Their activities are mostly governed by the *Local Government Operation Act 2074.* The Act mandates local governments licensing and development of hydropower schemes up to 1 MW, apart from irrigation, drinking water, flood mitigation activities at local level.

2.9 Synthesis of issues related to water resources management

Flood risk

Flood is common in the Terai region of Nepal due to intense monsoon rainfall coupled with weak geological formations and rugged topography. The impacts of flooding and inundation are vital not only to infrastructure such as roads, culverts, irrigation canals, agricultural lands and houses but also to the loss of lives and properties. In the past, the Kamala River had experienced several large floods which are still in the memories of the people (DWIDM 2008). Frequent flood devastation has been recorded in the river ever since recording began as early as 1873 on the Indian side in the downstream. In the recent past, massive flood devastation occurred in 1987 and 1993. Those floods caused heavy damages to properties and lives. The effects of a flood event are not only the destruction of the infrastructure at the time it occurs, but also its aftermath in the form of snake bites, disease outbreaks and other hardships that persist for a long time.

Riverbank erosion and inundation both occur in the Kamala River and its tributaries. Riverbank erosion and riverbed aggradation due to episodic sediment transports have been occurring mostly in the upstream mountainous stretch of the river, whereas inundation caused by overbank flow with occasional bank erosion has been taking place in the downstream Terai stretch. The Kamala River across the international border on the Indian side was artificially confined within continuous flood dikes on both banks. Such confinement caused a rise in the flood water level on the Nepal side and further increased inundation problems. The issue was taken up bilaterally, and as a solution to the problem, the Indian continuous dikes were extended on the Nepal side up to the vicinity of the East West Highway. The dike extension work implemented under Indian grant assistance has greatly reduced flood problems, but the works require continuous repair and maintenance for their effective use.

Within the Chure Range, the Kamala River and its tributaries have severe riverbed aggradation problems resulting in their vagaries including bank erosion. Riverbed material extraction is partly blamed for such aggradation and vagary. However, this explanation is controversial, as extraction, which itself is removal of materials artificially in addition to the river's own natural sediment transport, should have caused riverbed degradation.

River training works are found in various stretches of the river in the inner valleys, but their effectiveness is questionable. At places, they have even become counterproductive for want of proper layout and design.

Limited water availability and agriculture

The major livelihood of the people in the Basin is associated with agriculture, which is directly associated with water availability. In recent years, water availability has been declining adversely, affecting irrigation for agriculture. Extraction of groundwater for irrigation may increases the per unit cost of the production of rice that might impact the profitability if the small land holding farmers with subsistence agriculture as their livelihood.

Water needs and infrastructure

Irrigation is the major water use in the Basin. However, the water made available from the irrigation infrastructure is not sufficient to meet dry season water demands. For instance, the KIP, initially designed to supply irrigation water to 25,000 ha of land, has been providing water to 10,000 ha during winter due to insufficient water available in the river. Lack of sufficient funds for repair and maintenance decreases the effectiveness of the infrastructure creating a gap between the water need and the supply.

Agricultural products market price and labour

Inadequate market price, and hence, inadequate farm gate price, compounded with lack of a proper marketing network, have been discouraging farmers to be involved in farming activities. As a result, outward labour migration from Dhanusha, Siraha and Udayapur to gulf countries is rampant. Such outward migration is highest in Dhanusha and Siraha districts resulting in severe shortage of labour for the agricultural activities, which then has an adverse impact on crop production.

Coordination between institutions

As stated previously, a federal Water Resources Policy and federal and provincial Water Legislation, all consistent with one another and most importantly with the Constitution of Nepal 2015, need to be put in place. In the absence of these legal instruments, the rights and responsibilities of the various levels of government for water resources development and management are not clear.

Accessibility of safe drinking water

Even though there are various schemes of piped water supply to Basin households, a large number of people in the Basin rely on groundwater for drinking water. Areas such as the Chure and Siwalik regions depend on open wells and streams, and a large area of the Terai depends on groundwater. Arsenic contamination is considered a major source of low drinking water quality (Shrestha et al. 2018); other contaminants include iron, nitrates, pesticides, manganese and methane. Arsenic above the WHO guideline of 10 parts per billion was recorded in 4% of 56,531 tested shallow tube wells in Dhanusha (WECS and CSIRO 2020).

Risks to climate change

The Basin is expected to be significantly affected by climate change. With the changes observed in many other river basins, it is expected that temperatures will increase, while changes in rainfall and runoff may increase or decrease, depending on location within the Basin, in years to come. The predicted changes in rainfall and temperature could cause greater variability in the hydrological regime of the Kamala Basin. In the short-term, the climate variability change adds more uncertainty to the changes caused by the development activities. An increase in the risk of both floods and droughts is expected. Low-lying areas downstream of the Basin would be particularly at risk.

Protection of key environmental assets and ecosystem services

Despite the existing environment protection rules, in particular biodiversity and ecosystem services, have been impacted by the encroachment of Chure and illegal sand mining.

Biodiversity and valuable ecosystems have been impacted since the construction of the Sindhuli-Bardibas highway started. The analysis undertaken in this project and other assessments show that it is likely that environmental assets will be further impacted by developments not only within but also beyond the water sector. So far, joint efforts by the riparian states to preserve those prioritised valuable assets from a basin-wide economic, social and environment point of view have been limited.

Notwithstanding the considerable environmental losses that have occurred, there remain opportunities to sustainably manage the remaining naturally functioning ecosystems. This requires a common understanding of the functions and services of environmental assets within the Basin, followed by appropriate actions to protect the selected assets. It will inevitably involve a discussion of compromises between development and protection, with potential impacts in all water and related sectors.

Data availability

A synthesis of the main existing data related to water resources in the Basin has been presented in WECS and CSIRO (2020). However more continuous, long-term and consistent data are required to support predictions of future water resources in the Basin. Hydrological, meteorological and other water use data are scarce and concentrated to a limited period. More recently the Department of Hydrology and Meteorology (DHM) installed new automatic hydro-meteorological stations in the Basin. The data collected from these stations contribute to validation of water availability modelling across the Basin.

3 Participatory formulation of Kamala Basin development Pathways

A development pathway is an argument for public and private action. It takes the form of a 'practical' argument whose components include values; goals (descriptions of the future in which values are realised); knowledge about the development context; and means-to-goal actions (Fairclough and Fairclough 2012, Foran et al. 2019). Perspectives on these components will differ among stakeholders, requiring reasoned communication to reach agreement.

Stakeholder work to formulate the Kamala Basin Development Pathways began at the basin level in July 2018 (Section 1.5). The initial basin-level development pathways were assessed during a subsequent workshop involving federal-level GoN agencies working on water conservation and management. The study team analysed outputs from the federal-level workshop to draft an amended set of Development Pathways for the Kamala Basin.

Having assessed the need to re-engage with basin stakeholders to generate consent on the amended Development Pathways, as well as to generate additional information to support the formulation of strategy, a series of 'roaming' workshops was undertaken in the Kamala Basin in November 2018 with local government officers.

Outcomes of the November 2018 workshop are presented in Table 3.1 to Table 3.3. These tables synthesise the development goal and sub goals and major actions related to each sub goal, together with a brief description of how the actions can be developed, the main organisations involved and what is required to be done. More detailed explanation is presented throughout this document. A consolidated table is presented in Chapter 10 with the recommendations for implementations of the actions (Table 10.1).

Table 3.1 Basin development pathways for Goal 1: Sustainable management of Chure and its natural resources for livelihood support and reduced vulnerability to water induced disasters

ACTIONS	HOW IT CAN BE DONE	WHO NEEDS TO ACT	WHAT NEEDS TO BE DONE
Sub-goal 1: Watershed conservation and improvement			
Action 1: Spatial profiling and prioritisation of areas vulnerable to landslide and erosion	Survey and Study necessary for the planning and designing of water conservation measures. Mapping vulnerable zones and establishing risk of landslide and sedimentation Designing a monitoring and evaluation program to quantify and minimise sedimentation	Koshi Basin Watershed Office in coordination with relevant provincial Watershed Management Offices, Soil Conservation Offices, President Chure Terai-Madesh Conservation Development Board, and relevant Local Governments	Bringing on board academic and research institutions for the scientific study Provision of technical and financial support
Action 2: Gully protection at Chure head for minimising erosion and debris flow	Building check dams: Large scale check dam using reinforced cement concrete and boulder masonry	Provincial Watershed Management Offices, Soil Conservation Offices, President Chure Terai-Madesh Conservation Development Board	Detailed study in consultation with the indigenous community and technical personnel
	Building check dams: Medium and small scale (where relevant and possible, by using and promoting indigenous technologies and locally sourced	Soil Conservation Offices, relevant Local Governments, and	Allocation of fund for construction, operation and management of the structure

ACTIONS	HOW IT CAN BE DONE	WHO NEEDS TO ACT	WHAT NEEDS TO BE DONE
	materials to make structural interventions affordable and sustainable)	Community Forest Users Groups	Coordination committee in participation of local people for conflict management and monitoring
	Bio-engineering and improved vegetation	Soil Conservation Offices, relevant Local Governments, Community Forest Users Groups, Forest Offices	Bringing indigenous knowledge in light with technical knowledge
Sub-goal 2: Sustainable management and utilisation of natural resources			
Action 1: Improve conservation-livelihood linkages through reforestation, and promotion and production of non-timber forest products	Identify, develop and promote plantation of varieties that are suitable for the Chure region, and can support livelihood requirements	Soil Conservation Offices, Forest Officers, relevant Local Governments, and Community Forest Users Groups	Conservation of Chure area through regulation on illegal cutting of timber and non-timber forest products Mobilisation of youth groups in the conservation and monitoring
	Existing plant nurseries to be developed as multi-year nurseries to ensure saplings are big enough before plantation and can adapt to local conditions for regeneration		
Action 2: Regulation and management of cattle grazing and forest fires	Identify and regulate grazing zones Mobilise and aware public on impacts of over-grazing through local public forums and media Strictly enforce ban on grazing above (31° slope) to avoid vegetation loss at Chure head Aware public on forest fires	Community Forest Users Groups in coordination with Local Governments and Forest Offices	Making laws to regulate grazing areas Segregating areas for grazing
			Mobilising Community Forest Users Groups in awareness program
Action 3: Regulation and sustainable riverbed mining/extraction	Plan river channelisation and implement the necessary works Estimate annual deposition and allow extraction accordingly	Provincial and Local Governments The GoN (Federal Government) has to provide the technical know-how	River channelisation works need to be planned; Following the plans, a combination of conventional and bio engineering works need to be implemented with constant monitoring and revision of plans in response to the implemented works, as a dynamic process; bed sediment extraction needs to be regulated according to the dynamic plans

Table 3.2 Basin development and pathways for Goal 2: Improved availability, use, allocation of water resources for livelihood generation, well-being and economic growth

ACTIONS	HOW CAN IT BE DONE?	WHO NEEDS TO ACT?	WHAT NEEDS TO BE DONE
Sub-goal 1: Reliable measurement for effective management			
Action 1: Generate reliable hydro-meteorology data on the Basin for evidence-based water resource management	Install gauging stations at different locations (main river, tributaries, and canal systems) to document spatial and temporal variations at regular intervals	Department of Hydrology and Meteorology (DHM) in coordination with Kamala Irrigation project and other relevant agencies	Installation of quality equipment Provision of training for operators for record keeping and monitoring
Sub-goal 2: Reduced vulnerability from water induced disasters and control of bank erosion			
Action 1: Develop and adopt appropriate flood and landslide management, control and protection measures	Make assessment of the flood and landslide problems and prepare two separate flood management and control plan and landslide protection plan for the basin Segregate flood and landslide mitigation through non-structural measures and structural measures including bio-engineering in both the plans Prepare and adopt regulatory mechanisms and instruments viz policies and laws and institutions at Centre, Province and Local Levels as a part of the non-structural measures Assign rights and responsibilities of landslide and flood control and management to the governments at all 3 tiers by federal policy and legislation Prioritise the mitigation works, especially the structural measures according to the sensitivity and seriousness of the problems Implement mitigation measures, both structural and non-structural, according to the priority and assigned rights and responsibilities Let the affected people participate as much as possible at all stages of flood and landslide control and management process	Concerned government agencies at all the 3 levels DHM and Department of Irrigation and Water Resources District Administration Offices, Local Governments, Civil Society and communities	As flood fighting / management is a dynamic and a cyclic process of planning, implementation, monitoring and planning; the problem has no one shot solution with a blueprint approach. Therefore, concerned agencies need to work continuously involving the concerned stakeholders Integrating indigenous knowledge Installation of equipment with proper training to operate and maintenance in coordination with civil society and local media groups
Sub-goal 3: Conservation, development, and management of existing and potential water resources for improving consumptive use, and water use efficiency			
Action 1: Secure and develop water resources for current and future drinking water requirements	Assessment of current and future drinking water needs	Local Governments	Inclusion of women and marginalised communities in assessment, planning and training for conservation of drinking water source
	Locate water source and develop necessary infrastructure (storage and distribution)	Department of Water Supply and Sewerage, Water Supply and Sewerage Division Offices, Provincial Governments and Local Governments	

ACTIONS	HOW CAN IT BE DONE?	WHO NEEDS TO ACT?	WHAT NEEDS TO BE DONE
	Protection/conservation of drinking water source	Local governments, Drinking Water Users Groups, Community Forest Users Groups, Communities	
Action 2: Implement large-medium scale options for augmenting water availability for year-round irrigation use	Develop Sunkoshi–Kamala Diversion Scheme	Federal Government in coordination with Provincial Governments	In consultation with the water resource users group from riparian basin in planning the scheme
	Identify and build select small reservoirs in the basin for flood control and water augmentation	Federal Government in coordination with Provincial and Local Governments	
Action 3: Promote conjunctive use of surface and groundwater	Basin-wide focus on installation of shallow and deep tube wells through appropriate incentives/ subsidies/ support for farmers and farmer collectives	Projects and schemes under all levels of government, farmers (self-investment)	Provision for the coordination of small farmers with co-operatives, local governments to help in the installation of wells Training farmers to maintain the structures
Action 4: Improve efficiency of existing water use in irrigation	Promotion and adoption of lift and micro-irrigation schemes	Projects and schemes under all levels of government, Farmers (self-investment)	Introduction of cost effective, modern technologies to the farmer

Table 3.3 Basin development and pathways for Goal 3: Commercial and scientific agriculture for local economic prosperity and livelihood security

ACTIONS	HOW CAN IT BE DONE?	WHO NEEDS TO ACT?	WHAT NEEDS TO BE DONE
Sub-goal 1: Agriculture and productivity supportive land use policy and practice			
Action 1: Conserve agricultural lands by preventing encroachment from other uses	Timely formulation of policy and enactment of legislation at the national level	Government of Nepal	Coordination committee with inclusion of marginalised farmers
	At the local level, identify crop specific productive agriculture areas and work with relevant stakeholders including local governments and communities to enforce zoning	Provincial and Local Government in coordination with provincial Agriculture Directorate and local stakeholders	
Action 2: Identify productive areas and test land pooling for collective commercial farming; scale up on the basis of lessons and success	Identify and delineate crop specific productive areas	Provincial and Local Government in coordination with provincial Agriculture Directorate and local stakeholders	Effective dissemination of information at native language
	Aware on benefits of collective farming and incentivise farmers to pool land and form collectives		Provide technical training and subsidy to farmers on the use of modern technologies
	Provide necessary technical and management support to incubate farmer collectives		
Sub-goal 2: Improve farming practice and productivity			
Action 1: Train and build capacity of farmers to	Improve knowledge base on scientific farming through regular and effective extension service on seeds,	Agriculture knowledge Centres in coordination/participation with various agriculture	Provision of lab to test new varieties at the local environment

ACTIONS	HOW CAN IT BE DONE?	WHO NEEDS TO ACT?	WHAT NEEDS TO BE DONE
undertake scientific and market driven productive agriculture	fertilisers, pesticides, and farming techniques	extension officers, local farmers and collectives	Training on increasing value of products Easy access of information using communication medium
	Improve access of farmers to cheap and reliable soil test facility	Local governments in coordination with private sector	
	Promote farmers to adopt cash-crops and other high-value crops	Agriculture knowledge Centres in coordination/participation with various agriculture extension officers, local farmers and collectives	
	Identify and capitalise on emerging opportunities, including organic farming		
Sub-goal 3: Promote commercial farming and agriculture market development			
Action 1: Develop and implement necessary policies and frameworks for building an ecosystem for commercialisation	Develop localised policies and frameworks that best suit strengths and opportunities of local farmers, resource base, and farming conditions – local agriculture plans	Provincial Agriculture Directorate in coordination with Agri-business Centres, Local Governments, and farmers	
Action 2: Facilitate farmers and collectives to obtain required investments and inputs for commercialisation	Develop policies and provide supportive guarantees (price/insurance/subsidies)	Federal Government, Provincial Agriculture Directorate in coordination with Agri-business Centres, Provincial and Local government	Coordination of farmers with local government and agri-business to create smooth channel for the promotion and distribution of products at effective price
	Work with banks and financial institutions to channel low interest agriculture loans (deprived sector loans), and Small and Micro Enterprise Loans	Provincial Agriculture Directorate in coordination with Agri-business Centres, Provincial and Local governments, and financial institutions	Provision for the cooperatives and banks to provide loans without collateral to promote and empower women farmers

4 Assessment of Basin water resources and selected development options

4.1 Current water supply and demand

Irrigated agriculture is the highest water user in the Basin, estimated to be about 94%, followed by domestic water (4%), water for livestock (1%), and water for industry (<1%) (WECS and CSIRO 2020). Current agricultural water supply and demand were estimated to provide a baseline against which to compare potential future developments. Quantifying current agricultural production and water demand for the main crops cultivated in the Basin provides insights into the distribution of available and required water for agricultural production. Based on focus group discussions in Sindhuli and Udayapur, the main factors limiting agricultural development include a lack of reliable water supply during the dry season, insufficient irrigation facilities, soil quality, and land size.

Estimates of current (baseline) and potential future agricultural water requirements have been prepared using a hydrological model combined with available observed data, drawing on information compiled in WECS and CSIRO (2020). Driven by monsoonal climatic conditions, agricultural production is significantly influenced by extremes of high water availability and floods during the monsoon and water scarcity during the dry season. Water availability and irrigated agricultural production were modelled for 5 main regions within the Basin:

- Sindhuli district Farmer Managed Irrigation System (FMIS)
- Udayapur district FMIS
- Terai region FMIS
- East canal of command areas of the KIP (East KIP)
- West canal of command areas of the KIP (West KIP).

Location of these regions is shown in Figure 4.1 and mean monthly flow upstream of each of these areas shown in Figure 4.2. Given distinct differences in topography, geomorphology, hydro-climatology, and agricultural systems between the upper hilly region and the Terai, the 5 modelled regions are grouped into:

- Upper Basin (Sindhuli and Udayapur FMIS)
- Lower Basin (Terai FMIS, East KIP, West KIP).

The hydrological model was developed using the Source[12] software, to quantify water demand and supply under current conditions and future Exploratory scenarios[13]. Hydrological models allow the investigation of different scenarios of water availability and are applied to support decision making when used in combination with other sources of information and local knowledge.

The model was run over the 20-year (1990–2009) period and considered: major river flows generated using a rainfall–runoff model with gridded rainfall data; extraction of surface and groundwater for agricultural water requirements; major water infrastructure such as the KIP; and district-level aggregated agricultural areas focusing on the most representative current and potential future crops.

[12] Source is Australia's National Hydrological Modelling Platform. Details are available from https://ewater.org.au/products/ewater-source/

[13] In this context, Exploratory scenarios are plausible regional development of the Basin that will influence water demand. They provide a means to assess and compare alternate configurations.

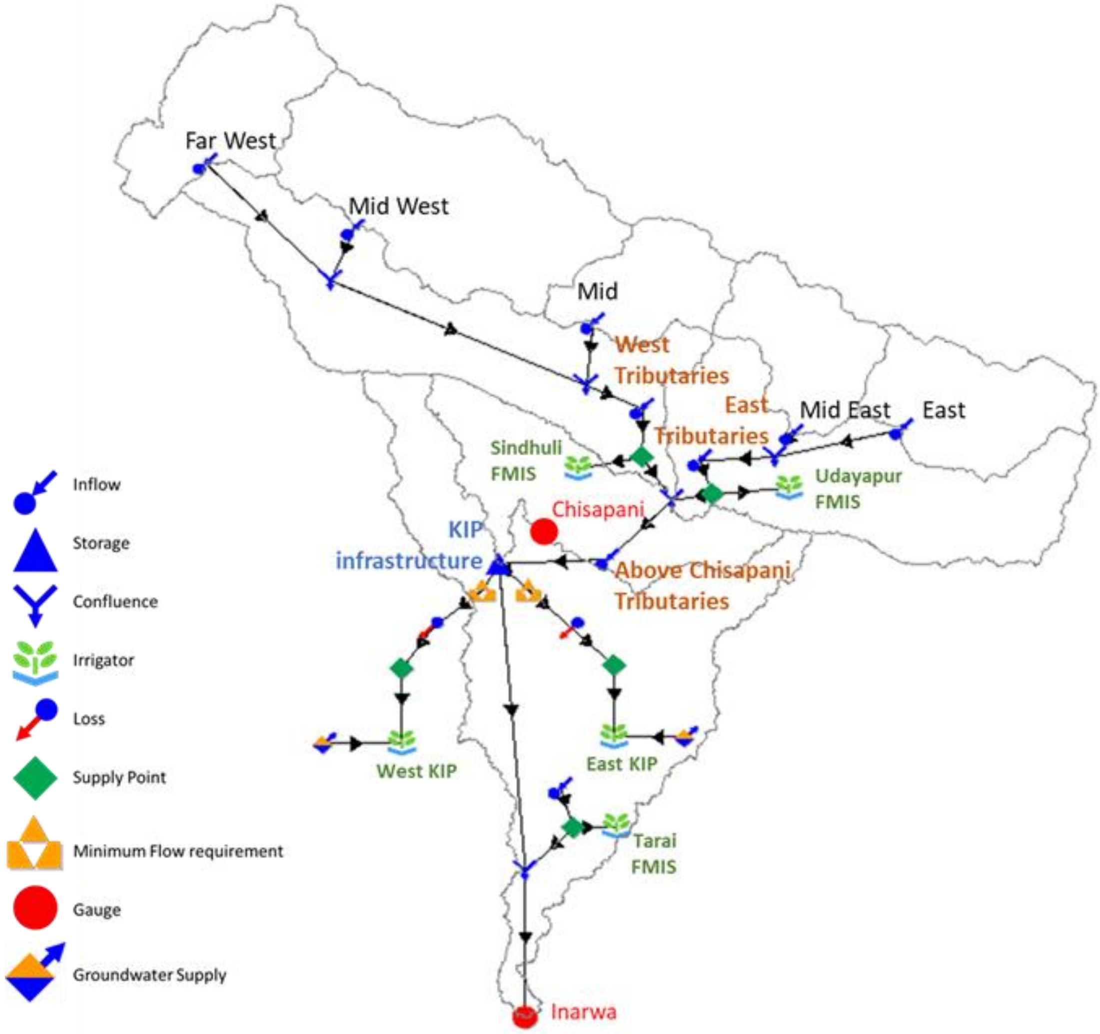

Figure 4.1 Hydrological model representation of the Kamala Basin showing the 5 modelled regions (identified by the green Irrigator icon), major inflows, and KIP infrastructure

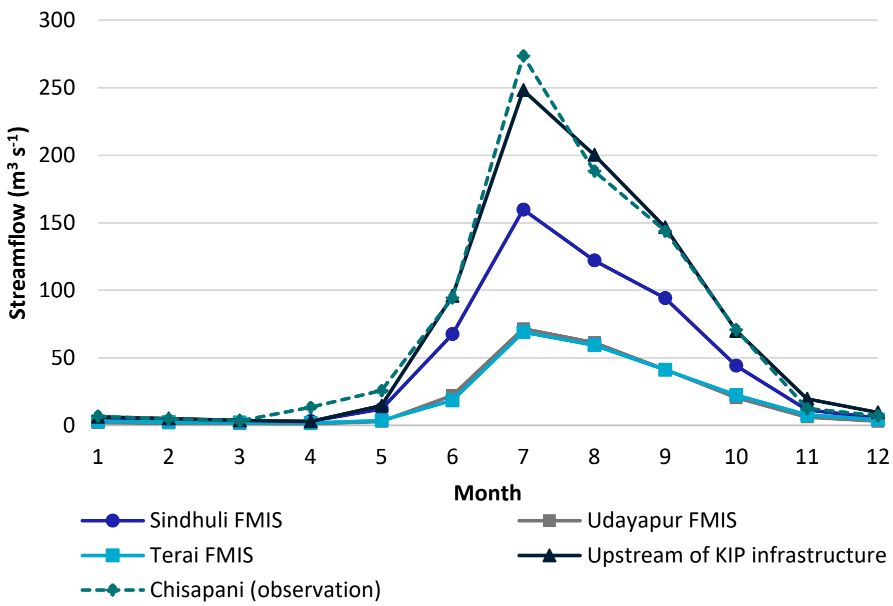

Figure 4.2 Modelled current mean monthly streamflow upstream of the 5 modelled regions over the 20-year period 2000-09

Water extraction[14] for crop irrigation (wheat and maize) during the dry season (November to June) was estimated at approximately 48 MCM, of which 34 MCM was from surface water and 14 MCM from groundwater (with groundwater assumed to be used only in the Lower Basin for wheat production) (Table 4.1). About 31 MCM of the 48 MCM was to supply irrigated crops.[15] The remaining 17 MCM is assumed to be 'lost' along canals and on farms as seepage, evaporation, or unaccounted extractions.[16]

Extracted water is also influenced by the capacity of irrigation canals. The canal capacity for FMIS areas was estimated based on a combination of field observation and calibration to observed crop yields. KIP canal capacities were based on design specifications, noting the actual capacity may be lower given build-up of sediment and vegetation.

Water shortage[17] is estimated to be highest in the West KIP command area [18], which also has the highest water demand due to the larger crop areas (Table 4.1). Water shortages also occur in FMIS areas. Water availability in FMIS is influenced by the capacity of the diversion canals. Other factors that may influence crop yield and have not been included in the modelling are soil type, temperature, and pests and disease.

Water demand and supply estimations are influenced by several assumptions, including crop water requirements, agricultural area, cropping duration and date of planting and harvesting, infrastructure capacity, and estimated surface and groundwater availability. Continuous measurements of water use and availability in FMIS and KIP areas would contribute to improved estimates and assist in identifying improvements in water distribution.

Table 4.1 Irrigated area (ha) and estimated water demand, supply, and shortage (in MCM) for dry season crops (maize and wheat) in each modelled region

REGIONS	IRRIGATED AREA (HA)	MODELLED CROP IRRIGATION WATER DEMAND[1]		DIVERTED SW[2]		EXTRACTED GW[2]	EXTRACTED TOTAL	SUPPLY[3] (SW+GW)		SUPPLY TOTAL	WATER SHORTAGE[4]
		MAIZE	WHEAT	MAIZE	WHEAT	WHEAT		MAIZE	WHEAT		
Sindhuli FMIS	2,700	6	-	7		-	7	5	-	5	2
Udayapur FMIS	1,500	3	-	3		-	3	2	-	2	1
Terai FMIS	300	-	1	-	1	-	1		<1	<1	<1
East KIP	6,600	-	16	-	10	6	16		10	10	5
West KIP	12,500	-	30	-	13	8	215		13	13	17
Total	23,600	10	47	10	24	14	48	7	24	31	25

1 Water demand is modelled water requirement for irrigation, and therefore excludes demand met through precipitation.
2 SW = surface water diverted from the river and GW = groundwater.
3 Supply is the volume of water applied to the crops as irrigation, which is the volume extracted minus losses.
4 Water shortage = water demand – water supply.
5 Any discrepancy in addition of values is due to rounding. This applies to all tables in this Chapter.

On average (for a 20-year period), it is estimated that the monsoon rainfall supplies the water demand for rice, with no further requirement for surface or groundwater irrigation. Across the 20-year baseline simulation, available rainfall was lower than the theoretical water demand for rice for 5% of the years for the 2 FMIS areas in the Upper Basin, 15% of the time for the Terai FMIS area and 40% for the KIP command area in the Lower

[14] Extracted refers to the amount of water diverted from the river or extracted from groundwater.

[15] Supply refers to the amount of water reaching crops, which is the extracted water minus any losses.

[16] Further details on assumptions on how losses were modelled are provided in Annex B.3.

[17] Water demand by the crop minus water supply.

[18] Command area is the area covered by the irrigation in the 2 main canals in the KIP.

Basin. Despite this difference between theoretical demand and modelled supply, rice yields were modelled as being ≥95% of the maximum potential yields for all years.

Theoretical water demand values are used for reporting rice demand since it is not an output in the hydrological model. Within the model, water demand is reported as being a combination of forecast irrigation requirements to maintain a specified ponding level, rather than the minimum water demand to keep the crop alive. Instead, the modelled rice yields have been used to indicate whether water availability is sufficient for growing paddy rice, and use theoretical values to report on estimated water demand (values used are shown in Annex B.2).

Average modelled **crop yields** are estimated to be 80% of the maximum yield for maize, 70% for wheat, and 100% for rice (Table 4.2) (assumed maximum yields and other modelled crop parameters are shown in Annex B.2). Both crop yield and production gaps are a direct result of the water shortages shown in Table 4.2.

Table 4.2 Estimated crop yield, production and production gap for maize, rice and wheat in each modelled region

REGIONS	MODELLED YIELD (TONNES/HA)			MODELLED PRODUCTION (TONNES)			PRODUCTION GAP[1] (TONNES)		
	MAIZE	RICE	WHEAT	MAIZE	RICE	WHEAT	MAIZE	RICE	WHEAT
Sindhuli FMIS	2.0	2.3		5,400	6,210		810 (13%)	0	
Udayapur FMIS	1.8	2.4	-	2,700	3,600		750 (22%)	0	
Terai FMIS		2.3	1.9		3,680	570		0	180 (24%)
East KIP		2.3	1.9		41,860	12,540		0	3,960 (24%)
West KIP		2.4	1.4		59,520	17,500		0	11,250 (39%)
Total				8,100	114,870	30,610	1,560	0	15,390

[1] Refers to theoretical maximum production less modelled production, where theoretical maximum production = irrigated area * potential maximum yield.

Crop income estimated within the Basin is NPR3,700 million, with a shortfall of NPR410 million (due to water shortages) relative to maximum estimated potential income (Table 4.3). Based on the *Nepal Human Development Report* (NPC and UNDP 2020), gross 2010/11 income for agriculture and forestry sectors was approximately NPR10,305 million in Dhanusha and NPR7,777 million in Sindhuli. The modelled crop income for KIP command areas is approximately 20% of the gross agricultural and forestry income in these 2 districts[19].

Table 4.3 Modelled income from maize, rice and wheat in each modelled region

REGION	MODELLED INCOME (MILLION NPR)			MODELLED TOTAL INCOME (MILLION NPR)	SHORTFALLS OF INCOME (MILLION NPR)
	MAIZE	RICE	WHEAT		
Sindhuli FMIS	113	151		265	17
Udayapur FMIS	57	88		144	16
Terai FMIS		90	14	104	4
East KIP		1,020	306	1,326	97
West KIP		1,451	427	1,877	274
Total	170	2,800	746	3,716	408

[19] Using 2011 agricultural census data (Government of Nepal 2012), it is estimated that the area under wheat in the Kamala Basin is approximately 30% for Dhanusha and 40% for Siraha; and the area under rice is approximately 40% for Dhanusha and 30% for Siraha

4.2 Evaluating future water demand

Future water demand in the Basin may vary substantially. With agriculture being the existing largest user of water, future demand will mainly be influenced by future agricultural development and practices. The future of agriculture will be influenced by structural changes in the regional economy and peoples' aspirations and opportunities, which influence the level of livelihood security that agriculture will be able to provide to households. These outcomes are uncertain, and hinge on the quality of innovation and technology applied in agricultural systems, available infrastructure, and supply chains. Accordingly, the *Water Resources Development Strategy* includes a range of futures, in which the composition of water demand varies.

The Strategy considers 2 types of scenarios:

- Exploratory scenarios
- Climate scenarios

A schematic representation of the Exploratory scenarios, Climate scenarios, and socio-technical options is shown in Figure 4.3.

Exploratory scenarios are simplified narratives which explore 'alternative futures' of the development context, for example, alternative futures of the economy, climate, and society of the Basin or of Nepal – futures which are driven by forces beyond the control of basin planners. This type of scenario deliberately goes beyond extrapolation of trends to explore 'what if' a particular set of driving forces took a particular value or manifestation in the future. For example, what if on-farm livelihood security in the future is low, compared to non-farm livelihoods?

Useful Exploratory scenario storylines are plausible (the future could look like this); internally consistent (elements in the storyline do not contradict each other); and insightful (the content stimulates thinking about future states that may be unexpected, or undesired). Use of exploratory scenarios is intended to motivate stakeholder discussion about risks and opportunities associated with any detailed development pathway. These discussions can support decisions regarding investment in development options. The study developed 4 Exploratory scenarios.

Exploratory scenarios were defined using a set of assumptions about important driving forces. Driving forces are trends or imagined future events (social, economic, political, environmental, technological) assumed to be beyond the control of water resource planners (Annex C).

Climate scenarios are plausible future climate states. To identify the influence of different drivers on water availability and crop production, the Strategy investigates climate scenarios independently of the Exploratory scenarios. Specifically, the 4 Exploratory scenarios are associated with a Baseline Climate scenario. Three future climate scenarios were selected for the Kamala Basin as detailed below (see 'Future Climate').

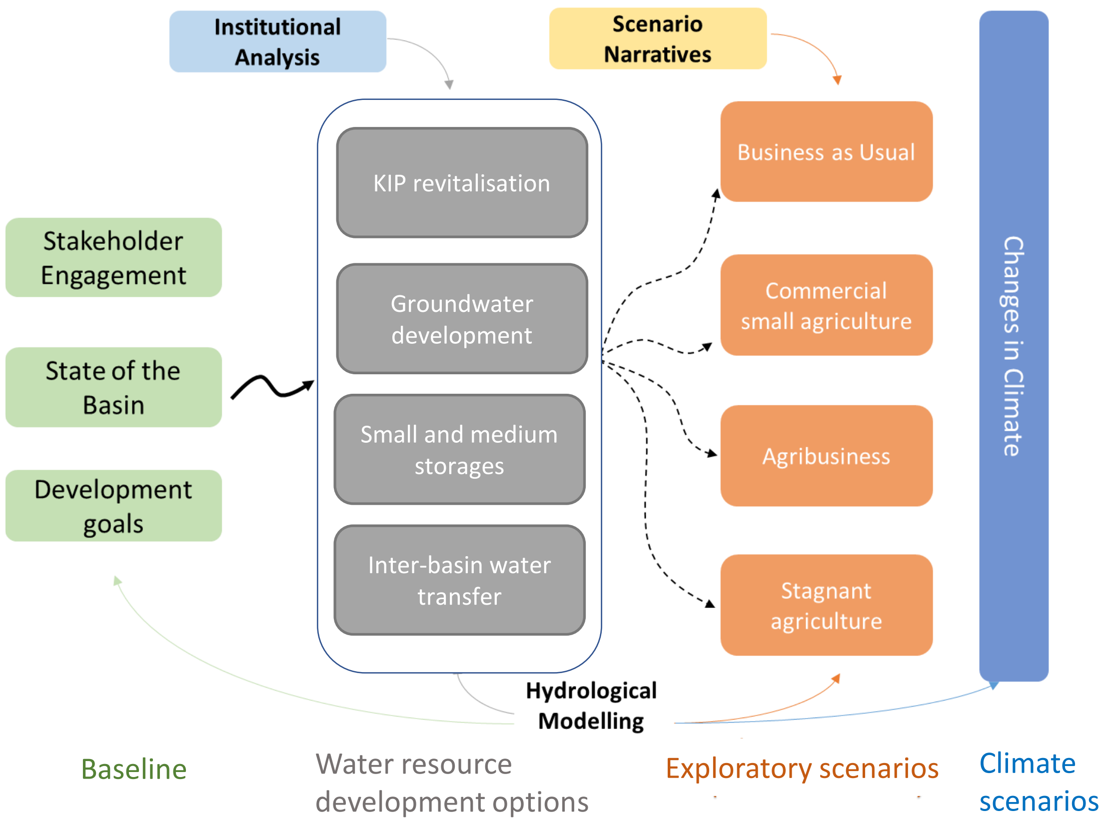

Figure 4.3 Adopted framework for water resource management scenario analysis showing the relationships between Exploratory and Climate scenarios and the water supply development options

Development goals and stakeholder knowledge of the current context was used to define a set of water resources development options. The effectiveness of these options can then be evaluated considering a range of plausible futures (in this case, the 4 Exploratory scenarios).

Qualitative and quantitative methods were used for investigating plausible future scenarios and potential impacts on different water supply options. Water supply options were identified by stakeholders during workshops and were described quantitatively based on available information.

Hydrological modelling was used to quantitatively explore both water resource development options and Exploratory scenarios. The accuracy of outputs from hydrological models are limited by the level of certainty in the input data, as well as feasibility in representing the complexity of current and future conditions that may differ from the input data.

Future agricultural yields and respective water use were estimated based at a district scale for areas within the Basin boundary and command area of the main irrigation projects.

A summary of modelled water demand considering potential future Climate and Exploratory scenarios is provided in the following section. Water resource development options are described in Section 4.3, and evaluated in Section 4.4 against each Exploratory scenario.

Future climate

Average annual mean temperature across Nepal is projected to increase by 1.3 to 1.8°C by mid-century (2036 to 2065) (WECS and CSIRO 2020), with significant variation between the global climate. For the Kamala Basin, projected changes in temperature for 2046 to 2075 range from 1.5 to 3.8°C, assuming changes continue at the current rate of greenhouse gas emissions. Projections are based on the Coupled Model Intercomparison Project (CMIP5) (Taylor et al. 2012), and use the Representative Concentration Pathway (RCP) 8.5 Scenario (which assumes the largest change of standard modelled scenarios). Global climate model projections show less agreement in potential change in precipitation and are estimated to range from a reduction of 5% to an increase of 35% for the Basin.

To explore the potential impact of a future climate on water availability, 3 climate model projections were selected from the total set of 74 to cover a range of possible changes (Table 4.4):

- warmer with a drier winter at 2040
- hotter with a wetter monsoon at 2040
- hotter with a drier winter at 2040.

All other model components were unchanged from the 1990–2009 baseline to identify the potential impact of a changing climate independent of other future changes.

Table 4.4 Characteristics of climate model projections analysed

VARIABLE	CLIMATE SCENARIO			
	BASELINE	WARMER WITH DRIER WINTER	HOTTER WITH WETTER MONSOON	HOTTER WITH DRIER WINTER
Model name or period	1990–2009	hadgem2-ao_r1i1p1_r85-ave.txt	canesm2_r1i1p1_r85-ave.txt	csiro-mk3-6-0_r4i1p1_r85-ave.txt
Precipitation (mean mm/year)	1,390	88% (during DJF)*108% (year)	98% (during DJF), 126% (year)	82% (during DJF), 106% (year)
Potential evapotranspiration (mm/year)	1,580	102%	108%	107%
Minimum temperature (°C)	19.6	+2.1	+3.6	+3.3
Maximum temperature (°C)	30.5	+2.3	+3.4	+2.8

* DJF = December, January, February

Using climate projections from the 3 models, changes in precipitation and evapotranspiration have the potential to increase monsoon streamflow in the Basin and reduce dry season streamflow (Figure 4.4). However, there is a significant difference between the 3 projections, indicating the need to consider the variability for adaptive and robust planning.

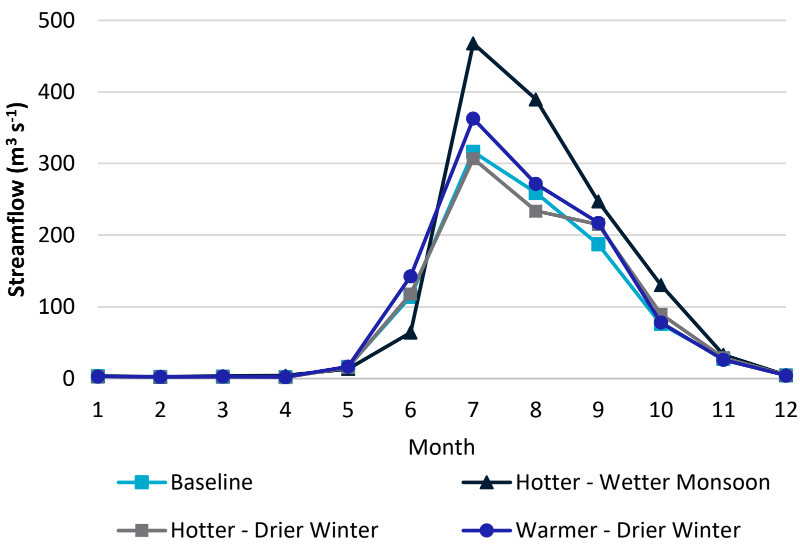

Figure 4.4 The mean monthly flow at the border between Nepal and India according to various climate projections. Baseline is mean monthly flow over the period 1990–2009. The future Climate scenarios are mean monthly flows over the period 2040 to 2075

The 3 climate scenarios show a projected increase in both mean annual water demand and supply compared with the baseline (Table 4.5), noting that projected changes vary seasonally (Figure 4.4). Potential water shortage is likely to increase, particularly in the Lower Basin under a hotter/drier climate with a projected increase in water shortage of 24% compared with the Baseline Climate scenario. These effects can be compounded by other future changes such as increasing agricultural, urban and industrial water demands. A reduction in overall water availability during the dry season is reflected in reduced projected crop yields and consequently crop income (Table 4.6).

Table 4.5 Projected 2040 changes in water demand, supply, and shortage (MCM) for irrigation of dry season crops in the Upper and Lower Basins under current (baseline) and 3 plausible future Climate scenarios

CLIMATE SCENARIO	WATER DEMAND (MCM)		WATER SUPPLY (MCM)		WATER SHORTAGE (MCM)	
	UPPER BASIN	LOWER BASIN	UPPER BASIN	LOWER BASIN	UPPER BASIN	LOWER BASIN
Baseline	10	47	7	24	3	22
Warmer/ drier	9	52	6	25	3	27
Hotter/ wetter	11	51	8	26	3	25
Hotter/ drier	11	53	7	25	4	28

Table 4.6 Projected changes in dry season crop yield and income in the Upper and Lower Basins under current (baseline) and 3 plausible future Climate scenarios

CLIMATE SCENARIO	PERCENT OF MAXIMUM CROP YIELD		TOTAL INCOME (MILLION NPR)			
	UPPER BASIN	LOWER BASIN	UPPER BASIN	LOWER BASIN	BASIN TOTAL	% CHANGE FROM BASELINE
Baseline	82%	71%	170	746	916	
Warmer/ drier	82%	65%	170	682	852	-7%
Hotter/ wetter	82%	70%	164	730	894	-2%
Hotter/ drier	79%	66%	161	682	843	-8%

Exploratory scenarios

Four Exploratory scenarios were developed based on variations across 3 sets of driving forces: governance; sectoral focus of development; and agricultural knowledge and innovation systems (Table 4.7). The 4 scenarios are labelled: 1 '*Business as Usual*'; 2 '*Commercial smallholder agriculture*'; 3 '*Agribusiness*'; 4 '*Stagnant Agriculture*'. The key elements of these scenarios are shown in Table 4.7 for the year 2040. A set of storylines for each scenario is presented in Annex C.

Table 4.7 Exploratory scenarios framework

SCENARIO TITLE DOMAIN (BOLD) AND POTENTIAL OUTCOMES	1 BUSINESS AS USUAL	2 COMMERCIAL SMALLHOLDER AGRICULTURE	3 AGRIBUSINESS	4 STAGNANT AGRICULTURE
(1) Downward responsiveness of governance	Low to Moderate	High	Low to Moderate	Low
Devolution of resources and authority; capability of local, provincial, and federal agencies	Low to Moderate	Higher than Trend	Trend	Lower than Trend
Effectiveness of governance addressing landlessness	Lower than Trend	Higher than Trend	Lower than Trend	Lower than Trend
(2) Sectoral focus of development	Away from agriculture	Smallholder commercial agriculture	Commercial agriculture	Away from agriculture

SCENARIO TITLE DOMAIN (BOLD) AND POTENTIAL OUTCOMES	1 BUSINESS AS USUAL	2 COMMERCIAL SMALLHOLDER AGRICULTURE	3 AGRIBUSINESS	4 STAGNANT AGRICULTURE
Global development scenarios which contribute to realisation of Kamala scenario (Shared Socio-economic Pathway, 'SSP') /1	SSP 2 SSP 4	SSP 1 SSP 5	SSP 1 SSP 5	SSP 3 SSP 4
Economic growth and structural diversification of economy/2 (GDP/capita 2010-40 by SSP)	Medium 3.3% (SSP 2) 3.4% (SSP 4)	High 4.4% (SSP 1) 5.5% (SSP 5)	High 4.4% (SSP 1) 5.5% (SSP 5)	Low-Medium 2.3% (SSP 3) 3.4% (SSP 4)
Industrial water demand, average annual growth rate (2020–2040)	4.4%	5%	5%	3.9%
Urbanisation level in 2040 (2020 = 21%)/1	36% (SSP 2) 46% (SSP 4)	46% (SSP1, SSP 5)	46% (SSP1, SSP 5)	24% (SSP 3) 46% (SSP 4)
Level of inequality	Medium-High	Low	Medium-High	High
Agricultural workforce as % of workforce	High	Medium	Medium	High
(3) Agricultural knowledge & innovation systems				
Effectiveness of pro-poor, inclusive farmers organisations	Medium-Low	High	Medium	Low
Agricultural yields and returns from own-account agriculture/3	Medium-Low	Medium-High	High	Low
Use of conservation agriculture based sustainable intensification (CASI)/4	No	Yes	Yes	No
Agro-chemical inputs	Medium-Low	Medium	High	Low
Dominant cropping system (Upper Basin / Lower Basin)/5 (Baseline = Rice-Maize CT / Rice-Wheat CT)/6	Baseline	Rice-Maize CASI / Rice-Wheat-Mungbean CASI	Rice-Maize CASI / Rice-Wheat-Mungbean CASI	Baseline
Average cropping intensity (Baseline = 150%)	200%	300%	300%	200%
Gross cultivated area (Baseline = 72,400 ha)	65,800 ha	141,400 ha	176,400 ha	78,200 ha

Notes: (1) Annex A summarises SSPs; text below describes their use in this project. (2) Adapted from Dellink et al. (2017). Medium, high, and low descriptors in this row are relative to global rates. (3) Agricultural yields and returns from own-account agriculture: consistent with Gathala et al. (2020: Figures 4 & 5). (4) CASI is described in Chapter 7. (5) Upper Basin lies in Sindhuli and Udayapur districts; Lower Basin lies in Dhanusha and Siraha. (6) CT = conventional till.

Exploratory scenario definitions

Scenario definitions draw on the 'shared socio-economic pathways' (SSPs) (O'Neill et al. 2015) framework developed by the global change modelling community (associated with the Intergovernmental Panel on Climate Change). The five SSPs outline futures which are different in terms of rates of economic growth; openness to trade; rivalry and cooperation; inequality within and between countries; and urbanisation. Each SSP differs with respect to challenges for climate change adaptation, and mitigation. Table 4.7 notes which SSPs are likely to contribute to the realisation of each Exploratory scenario.

Nepal's urban population was approximately 20% of the total population in 2018 (cf. 35% in South Asia). To estimate Nepal's urbanisation levels under other scenarios, urbanisation levels for India modelled for the 5 SSPs (Jiang and O'Neill 2017) were used, adjusting for the average difference in urbanisation level between Nepal and India as of 2020 (-14%).

Projected changes in agricultural development for the Kamala Basin are described in Chapter 7.

The 4 scenario narratives (Annex C) start from a common socio-economic baseline context in 2020. Each narrative considers alternative ways in which the challenges of agricultural sector governance might be faced (successfully and unsuccessfully), and how opportunities associated with agricultural innovation might be captured and distributed.

The 4 Exploratory scenarios were used to estimate changes in water demand for households, livestock, industry and agriculture for 2040 based on the following assumptions:

Domestic (household) demand was based on United Nation's[20] medium variant population projections for Nepal (AAPR 0.75% 2019–40). The level of urbanisation estimates are based on assumptions in Table 4.8, and per capita daily urban and rural consumption are based on Saraswat et al. (2017) and WECS and CSIRO (2020) respectively.

Livestock demand. The baseline estimation of livestock water demand has been calculated based on the total number of livestock (cattle, buffalo, goat, sheep pig and others) in the 4 regions and the proportion of the area of the region that is in the Basin boundary plus the area of the KIP outside the Basin. The number of livestock was calculated based on CBS (2009) and reported in WECS and CSIRO (2020). The water consumption by livestock category was estimated based on FAO (2019).

Industrial water demand. During the period 2010–18, Nepal's industrial sectors (including construction) grew at an average rate of 4.24% p.a., slightly above its GDP/capita growth rate of 4% p.a. Industrial water estimation assumes the demand grows at a rate of GDP/capita + 1% p.a. for all scenarios where GDP/capita is greater than 3% p.a. (i.e. Exploratory scenarios 1 to 3; Table 4.8), otherwise at GDP/capita + 0.5% for Scenario 4. Estimates of GDP/capita by scenario are shown in Table 4.7.

Agricultural water demand. Agricultural water demand was modelled assuming changes in agricultural land, cropping intensity, and crop mix (Table 4.9 and Table 4.11). In Exploratory scenarios 2 and 3, mungbean was selected as a viable and profitable third crop, based on literature review (Islam et al. 2019, Gathala et al. 2020) and advice from agricultural scientists working with the SRFSI[21] project. Exploratory scenarios 1 and 4 have a lower total agricultural area but higher cropping intensity with increased irrigated agriculture, showing similarities between a business-as-usual scenario and retreat from agriculture. Investment in agricultural tools and technology (CASI) in Exploratory scenarios 2 and 4 are reflected in the potential growth of 3 crops and greater cropping intensity.

Table 4.8 Estimated agricultural areas (ha) for dry season crops comparing baseline with 4 Exploratory future scenarios

EXPLORATORY SCENARIO	CROP	SINDHULI FMIS	UDAYAPUR FMIS	TERAI FMIS	SIRAHA (EAST KIP)	DHANUSHA (WEST KIP)	BASIN
Baseline (1990–2009)	Wheat	-	-	300	6,600	12,500	19,400
	Maize	2,700	1,500	-	-	-	4,200
1 Business as Usual	Wheat	-	-	1,100	12,300	16,700	30,100
	Maize	1,800	1,000	-	-	-	2,800
2 Commercial smallholder agriculture	Wheat	-	-	1,600	18,100	24,700	44,400
	Maize	2,600	1,500	-	-	-	4,100
	Mungbean	-	-	1,600	18,100	24,700	44,400
3 Agribusiness	Wheat	-	-	2,000	22,600	30,800	55,400
	Maize	3,300	1,800	-	-	-	5,100
	Mungbean	-	-	2,000	22,600	30,800	55,400
	Wheat	-	-	1,300	14,600	19,900	35,700

[20] Produced by the UN Department of Economics and Social Affairs (DESA) https://www.un.org/development/desa/en/

[21]Sustainable and Resilient Farming System Intensification (SRFSI) project, funded by Australian Council for International Agricultural Research (ACIAR).

EXPLORATORY SCENARIO	CROP	SINDHULI FMIS	UDAYAPUR FMIS	TERAI FMIS	SIRAHA (EAST KIP)	DHANUSHA (WEST KIP)	BASIN
4 Stagnant Agriculture	Maize	2,200	1,200				3,400

Table 4.9 Estimated total irrigation command area (ha), gross cultivated area (ha) and cropping intensity (ha) comparing baseline with 4 Exploratory future scenarios. The area of rice is equal to the total irrigation command area

EXPLORATORY SCENARIO	AREA (HA)	SINDHULI FMIS	UDAYAPUR FMIS	TERAI FMIS	SIRAHA (EAST KIP)	DHANUSHA (WEST KIP)	BASIN	CROPPING INTENSITY
Baseline (1990-2009)	Total command	2,700	1,500	1,600	18,200	24,800	48,800	
	Gross cultivated	5,400	3,000	1,900	24,800	37,300	72,400	150%
1 Business as Usual	Total command	1,800	1,000	1,100	12,300	16,700	32,900	
	Gross cultivated	3,600	2,000	2,200	24,600	33,400	65,800	200%
2 Commercial smallholder agriculture	Total command	2,600	1,500	1,600	18,100	24,700	48,500	
	Gross cultivated	5,200	3,000	4,800	54,300	74,100	141,400	300%
3 Agribusiness	Total command	3,300	1,800	2,000	22,600	30,800	60,500	
	Gross cultivated	6,600	3,600	6,000	67,800	92,400	176,400	300%
4 Stagnant Agriculture	Total command	2,200	1,200	1,300	14,600	19,900	39,100	
	Gross cultivated	4,400	2,400	2,600	29,200	39,800	78,200	200%

Estimated future water demand is anticipated to increase significantly for each sector across all 4 Exploratory scenarios (ranging from 20% to 93%), primarily due to increases in agricultural water demand and respective agricultural area (Table 4.8). These increases assume no change in climate from baseline (1990–2009). The greatest increase is for Scenario 3 – *Agribusiness*, with the highest total command area and gross cultivated area. The variation between Exploratory scenarios is significant, highlighting the need for close alignment between water resources development and agricultural development plans.

The agricultural water demand is estimated based on a combination of hydrological model outputs and documented theoretical water requirements for rice (as described in Section 4.1). They include forecast irrigation requirements (surface and groundwater) as well as precipitation[22].

The greatest agricultural water demand is for rice, which is assumed to be primarily met by precipitation with limited (if any) need for irrigation. Whilst the 3 future Climate scenarios suggest that there is unlikely to be a reduction in monsoon precipitation (on average), potential reductions in precipitation cannot be ruled out given uncertainties in climate model projections (MoFE, 2019). Similarly, increases in monsoonal precipitation and associated flooding can also result in crop damage.

For dry season crops (wheat, maize and mungbean), water demand is estimated based on forecast irrigation requirements to maintain soil water levels to produce modelled crop yields which approximate observed District-scale values. Modelled dry season crop yields were calibrated to average observed values, and hence are lower than the estimated maximum potential yields (Annex A). Consequently, the baseline water demand is also lower than required to meet maximum potential yields.

[22] The total estimated baseline demand (510 MCM) is greater than the 183 MCM reported in the *State of the Kamala River Basin* (SoB, WECS and CSIRO 2020) as it includes precipitation use. In addition, the SoB value is based on estimated water supply along irrigation canals and groundwater extraction during the wet and dry season, rather than crop irrigation requirement.

Table 4.10 Estimated current (baseline) and future (2040) water demand (MCM) under the 4 Exploratory scenarios

SECTOR		SCENARIO				
		BASELINE	(1) BUSINESS AS USUAL	(2) COMMERCIAL SMALLHOLDER AGRICULTURE	(3) AGRIBUSINESS	(4) STAGNANT AGRICULTURE
Household		9.5	19.8	22.2	22.2	16.9
Livestock		3.2	6.7	7.5	7.5	5.7
Industry		1.0	2.4	2.7	2.7	2.2
Agriculture[1]	Entire year	510	390	680	850	470
	Dry season	70	100	240	300	120
Total		523.7	418.9	1012.4	712.4	494.8

Source: Estimated based on hydrological modelling and information from CSIRO and WECS (2020) and FAO (2019).
[1]Water demand for agriculture (Entire year) shows estimated theoretical demand for rice plus modelled demand (surface and groundwater) for dry season crops (wheat, maize and mungbean) comprising of forecast irrigation requirements to meet soil water demand plus precipitation. Demand for agriculture (Dry season) only includes the estimated irrigation plus precipitation water demand for dry season crops.

Excluding precipitation, estimated surface and groundwater irrigation water demand is shown in Table 4.11. Comparing these values with those in Table 4.10, precipitation comprises a small but important percentage of the estimated total water demand. The addition of a third crop (mungbean) in Exploratory scenarios 2 and 3 significantly increases the dry season water demand and would require the development of water resources options to make viable.

The water demand for maize in the Upper Basin is met between 0% and 25% of the time over the modelled period for all 4 scenarios, as opposed to 5% for the baseline[23]. There is insufficient water to meet the full requirement for wheat for all years and all Exploratory scenarios. Despite total water demands not being met in the majority of years, maximum yields are met 75–95% of the time for maize (80% for baseline); 40–60% for wheat (70% for baseline); and 30% for mungbean.

Water demand for rice was estimated using theoretical water requirements. On average, it is estimated that the water demand for rice is met from monsoon rainfall. Modelled rice yields reach 98–100% of maximum potential yields between for all scenarios.

Table 4.11 Estimated water demand (MCM) for dry season crops under baseline and the 4 Exploratory scenarios for the 5 modelled regions

EXPLORATORY SCENARIO	SINDHULI FMIS	UDAYAPUR FMIS	TERAI FMIS	SIRAHA (EAST KIP)	DHANUSHA (WEST KIP)	BASIN
Baseline	6	3	1	16	30	56
1 Business as Usual	4	2	3	30	40	79
2 Commercial smallholder agriculture	6	3	6	71	96	182
3 Agribusiness	8	4	8	88	120	228
4 Stagnant Agriculture	5	3	3	35	48	94

[23] This refers to the number of years where supply = demand. Should supply be lower than demand but not zero, crops will still grow but at a reduced overall yield.

4.3 Water resource development options

During the Development Pathways phase of the Strategy, participants identified a set of specific options for meeting their water resources development objectives (Chapter 3). These include 4 representative development options aimed at improving the availability and reliability of water for agriculture:

- Revitalisation of the Kamala Irrigation Project
- Sustainable utilisation of groundwater
- Construction of small to medium storages in the upper catchment
- Sunkoshi to Kamala inter-basin diversion scheme.

All 4 options endeavour to address the lack of dry season water availability in different parts of the Basin. Whilst they involve modifications to infrastructure, their intended outcomes rely on their appropriate and equitable management, use, and maintenance. These options were considered individually and combined in order to provide water across the Basin. The inadequate performance of the existing KIP system is demonstration of the challenge of aligning agricultural development aspirations with a naturally water-scarce region and insufficient system maintenance.

A summary of the 4 water supply development options is shown in Table 4.12 and is described further in the subsequent sections.

Table 4.12 Water supply development options

	DEVELOPMENT BASELINE	WATER SUPPLY DEVELOPMENT OPTIONS			
		1 REVITALISATION OF KAMALA IRRIGATION PROJECT	2 GROUNDWATER DEVELOPMENT	3 SMALL AND MEDIUM STORAGES	4 INTER-BASIN WATER TRANSFER
Infrastructure	High water leakage/ losses	Upgraded KIP with reduced water leakage	High water leakage/ losses	3 small storages of 16.4 MCM capacity	Sunkoshi Barrage and diversion pipeline, Kamala Dam at Timnai, increased capacity of KIP system
Operation	Alternating delivery to branches	Based on farmer orders	Alternating delivery to branches	Alternating delivery to branches	Based on farmer orders
Groundwater use (Lower Basin)	Assumed 40% of average dry season water use	Assumed 40% of average dry season water use	Assumed extraction based on average yearly recharge to groundwater	Assumed 40% of average dry season water use	Assumed 40% of average dry season water use
Exploratory Baseline	48,800	48,800	48,800	52,690[1]	48,800[2]
1 Business as Usual	32,900	32,900	32,900	36,790	32,900
2 Commercial smallholder agriculture	48,500	48,500	48,500	52,390	48,500
3 Agribusiness	60,500	60,500	60,500	64,390	60,500
4 Stagnant Agriculture	39,100	39,100	39,100	42,990	39,100

[1] The increased command areas (3890 ha) are supplied by the small storages. The water demand for dry season crops in the increased command areas is approximately 9 MCM, which is met from the small storage supply.

[2] It is the existing KIP command area resulting from the inter-basin transfer scheme for the purpose of comparing water supply between scenarios. More information of additional command areas under the scheme is provided in Annex B.6.

Revitalisation of Kamala Irrigation Project

The KIP is an aging surface irrigation scheme constructed in the 1970s, designed to irrigate 25,000 ha of agricultural land in Dhanusha and Siraha. As a result of limitations in design and construction (e.g. to regulate delivery of water to canals) as well as management and operation limitations and irregular maintenance, the actual area irrigated is estimated to be less than 20,000 ha based on available information (Annex B.2).

Investing in the existing KIP system could improve the efficient and equitable delivery of water to farmers. However, without increased storage or conjunctive groundwater use, there is still insufficient surface water during the dry season to fully supply the command area's irrigation water requirements. This option would benefit the existing command area only.

Reported issues with the KIP system include the accumulation of sediment within canals; lack of development of the tertiary and lower level canals with an absence of farm water level control structures (requiring farmers to flood irrigate and use an excess of water); deterioration of infrastructure due to lack of maintenance and inadequate payment models; unequal accessibility within the command area with significant variations across head-end and tail-end areas of the main canals and branch canals; and high losses (JICA 2016).

An improved KIP system could include:

- Monitoring – better understanding and quantification of available water, water use and water requirements and distribution and sedimentation
- Allocations – system of allocating water across branches and tertiary canals, between users and over time
- Infrastructure – revitalisation of infrastructure and construction of control structures at main canal
- Institutions – strengthen system for managing and allocating water including an appropriate payment structure and enforcement mechanism, repair and maintenance schedule
- Capacity - Improve technical assistance on irrigation systems and efficiency and crop requirements.

Chapter 5 discusses institutional reforms relevant to improving the performance of the KIP.

Groundwater development

Groundwater is a significant and important water source within the Kamala Basin, particularly to drinking water, and could be further developed to support dry season irrigation for agriculture. This is primarily restricted to the Terai, with some limited expansion possible for the Chure region. The focus of this option is the Terai plains south of the East–West Highway.

Increased groundwater use is anticipated to improve the equitable availability of water for agriculture throughout the Terai by providing more localised access, although will depend on affordability of installation, pumping, and maintenance. Installation of deep tube wells is costly (e.g. NPR6 million per well) and is subsidised up to 95% by the Government. Power-drilled shallow tube wells (STWs) cost between NPR300,000 and NPR500,000 and the hand-drilled tube wells cost up to NPR100,000. Failure of submersible pumps often render the tube wells useless. While Government agencies provide significant support in the installation of wells, maintenance and regular operation of the wells are done through farmers' collectives of or private players. The deeper the groundwater level, the harder it is to pump, especially for women and girls.

Usually individuals, often medium-large farmers, own STWs and pumps. Small farmers lack the capacity to invest in groundwater infrastructure and some are unable to access the subsidies to install STWs and purchase the pump due to procedural difficulties. Access to groundwater could be improved through collective ownership of STW and pumps, which has been observed working well in some parts of Nepal Terai or facilitating operation of groundwater pump rental market.

In addition to affordability, increased groundwater development relies on the establishment of the appropriate monitoring infrastructure, regulation, and institutions needed to ensure over-extraction does not occur.

Long-term groundwater level observations are not available for many monitoring bores within the KIP area. Minimum and maximum water level recorded at several monitoring bores were analysed to estimate annual average groundwater recharge in the West and East KIP areas. It is estimated that these areas have average replenishable recharge of 43 GL/year and 36 GL/year respectively (WECS and CSIRO 2020).

Small and medium storages

The construction of small or medium storage reservoirs has been identified by stakeholders as a possible option for flood control and water augmentation for year-round irrigation (Chapter 3). Stakeholders did not identify the location of these storages; however they did provide broad criteria for selecting locations based on maximising available water for agriculture, whilst minimising the impact in terms of displaced households and inundated roads and existing agricultural land. Criteria included:

- locations where dam wall size would be small, but dam capacity would be large
- enough volume to provide water for local crop requirements
- not have a large dam wall height (preferably < 20m high)
- not cross major roads (e.g. district roads, main roads)
- not inundate major built-up areas
- preferably not inundating existing agricultural land
- geological, seismic, construction issues would be required as part of pre-feasibility.

Based on these criteria, 3 sites were selected – Tawa Khola, Thakur Khola, and Chandaha Khola and Bhalu Khola confluence (Figure 4.5) – as potential storage sites for further analysis, noting that the focus of this analysis is on estimating increased water availability from surface storage schemes rather than detailed analysis of potential dam sites. The locations may therefore not be the most suitable sites based on a broader range of criteria and more detailed analysis is needed, however it should be indicative of the types of options and estimated dimensions. Further investigation would be needed to determine actual sites. Potential sites in the Gwang Khola were omitted because planned infrastructure is already being developed to support town water supply in the Sindhuli region.

The 3 small to medium storages were estimated to support an additional 3,890 ha of irrigation in the Katari, Sirthauli, Dudhouli, Bhimsthan and Belghari regions, benefiting approximately 21,000 people[24] (Annex A). The construction of these storages is estimated to result in the potential displacement of 550 people across Risku, Tribhuwan Ambote, Jinakhu, Arun Thakur, Sirthauli and Jarayotar, noting this is likely to be an underestimate of those affected.

[24] Estimates of impacts and beneficiaries are indicative only. However, the analysis is limited. A social-environmental impact assessment would be necessary to judge the accuracy of the data provided. Local consultation would also help identify secondary effects (e.g. impacts to those that fish, or benefits through better roads). There would also be advantage for those involved in construction of the facilities, which is not captured here.

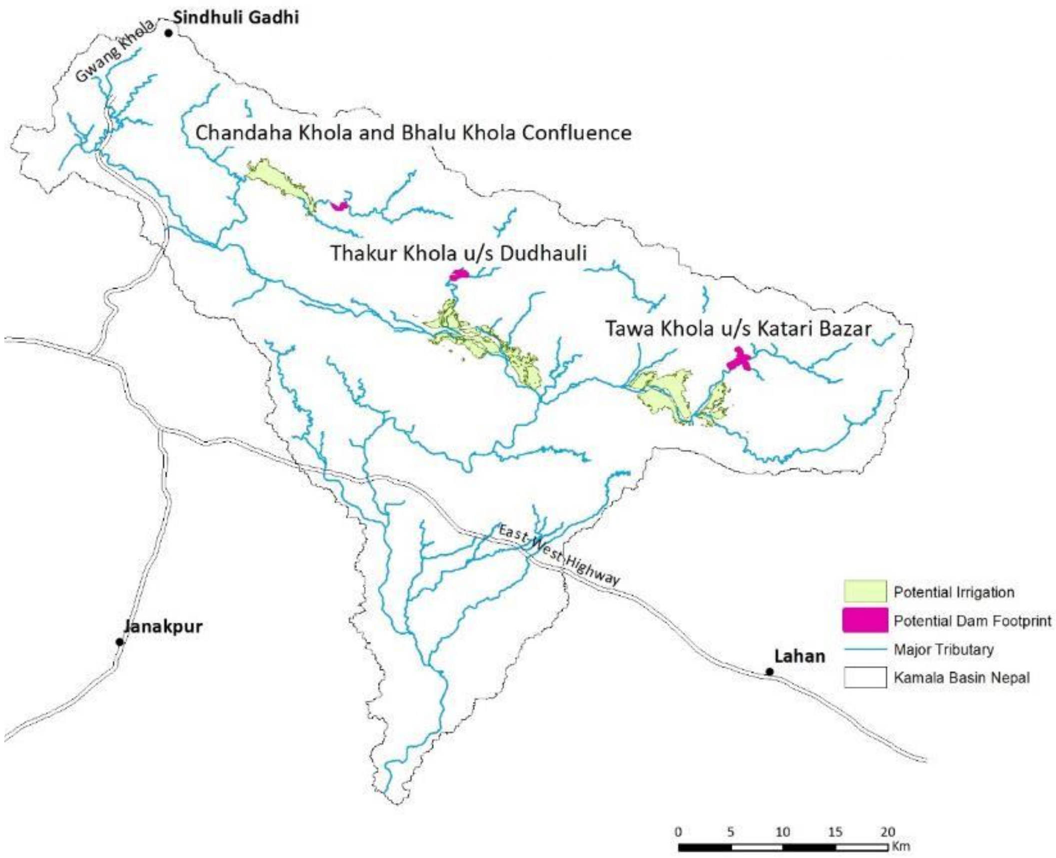

Figure 4.5 Location of possible small to medium storages, of which 3 have been assessed (Tawa Khola, Thakur Khola, and Chandaha Khola and Bhalu Khola confluence)

Inter-basin water transfer

The Sunkoshi to Kamala Diversion scheme was identified by stakeholders as a key option for consideration with the objective of providing reliable, year-round water for irrigation and other consumptive use. The scheme was initially proposed as part of a 1985 master plan developed by JICA (1985), which proposed a system of storages on Koshi River and a diversion to the Kamala River (Figure 4.6). The Sunkoshi to Kamala scheme is just one of multiple schemes proposed, each of which has potential impact on the other. The focus of this option is on the Kamala Basin scheme noting that the construction of other schemes such as the Sunkoshi to Marin scheme has the potential to impact its performance (NEA Engineering Company 2019).

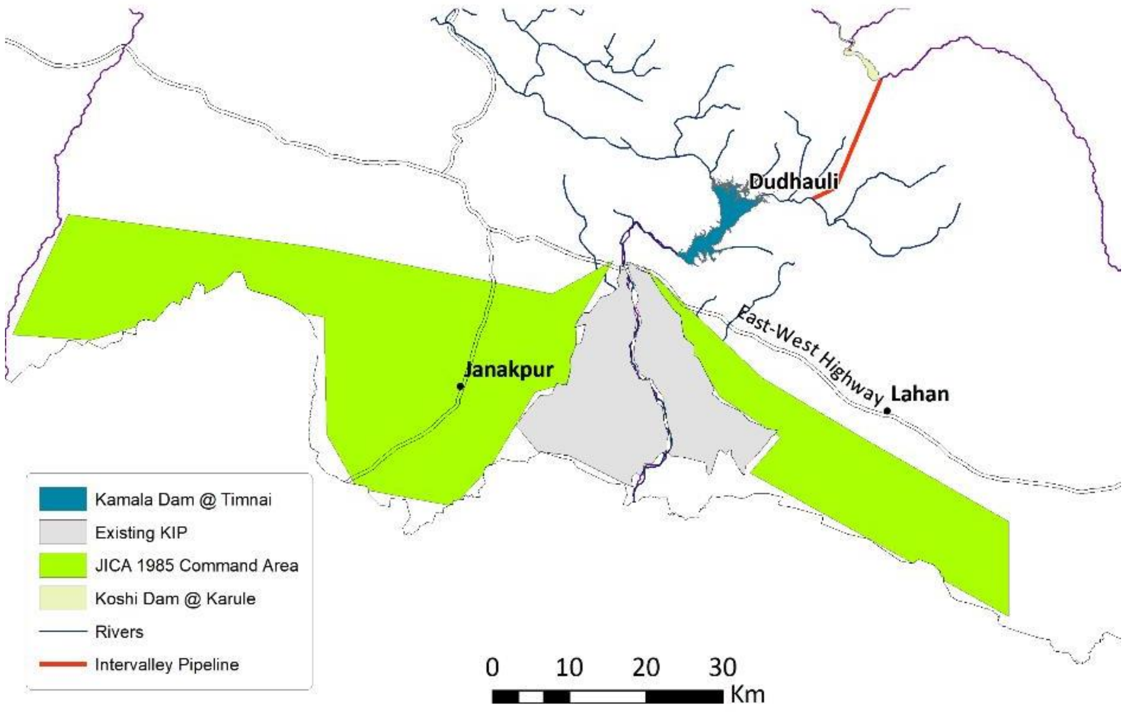

Figure 4.6 Approximation of Sunkoshi to Kamala Diversion scheme and associated command area

There are 4 main components to the scheme: (1) Sunkoshi Diversion Dam at Karule; (2) Kamala Dam at Timnai; (3) Diversion tunnel; and (4) Upgraded KIP infrastructure. The scheme is proposed to support an additional command area of 175,000 ha (Nepal-India Joint Project Office 2016), although the exact area is likely to vary.

Changes in water supply and agricultural production were estimated for the existing KIP command area resulting from the inter-basin transfer scheme for the purpose of comparing between scenarios. Within the hydrological model, we include both the existing and additional command areas under the scheme. More information describing representation of the scheme within the model is provided in Annex A.

4.4 Evaluation of WRD options across future scenarios

The 4 water resources development options are evaluated in terms of:

- water demand, supply, and shortage (Table 4.13 – Table 4.14)
- crop production (Table 4.15)
- impacts on ecologically important components of flow (Section 4.7)
- cost (Section 4.8)

The above assessments inform the recommendations presented in Chapter 5, regarding the institutional arrangements required to implement each of the 4 options.

Based on water availability alone, the diversion scheme almost eliminates the water shortage within the Basin across all 4 exploratory scenarios (Table 4.13 and Figure 4.7). Benefits are concentrated in the lower basin, although areas adjacent to the Tawa Khola in the upper basin may also benefit from increased flows resulting from the diversion.

Groundwater development has the second greatest overall reduction in water shortage across all 4 exploratory scenarios, followed by KIP revitalisation. The small–medium storages option has negligible reduction in water shortages (with a small increase compared with the baseline) with the benefits concentrated in the upper basin. This option also uses land to store water increasing the command areas. Hence despite shortages staying the same, the overall crop production and income is greater (by between 80 and 130% relative to the baseline) (Table 4.15). The small-medium storages option may have also socio-political benefits because it can reduce the migration of upper basin people to the southern Terai plains, and thus avoid population stress in the already densely population Terai region but on the other hand may create significant displacement depending on the location and size of the storages.

The modelling results show that differences in projected water shortage is greater between exploratory scenarios than between the development options, with the exception of the diversion scheme. With potential reduction in dry season flows due to a future climate, water shortages may further increase above those shown in Table 4.14.

Table 4.13 Projected water supply (MCM) and percentage of demand (%) that has been met for dry season crops under 4 WRD options for each Exploratory scenario in 2040

	BUSINESS AS USUAL (79 MCM DEMAND)			COMMERCIAL SMALLHOLDER AGRICULTURE (182 MCM DEMAND)			AGRIBUSINESS (228 MCM DEMAND)			STAGNANT AGRICULTURE (94 MCM DEMAND)		
	UPPER BASIN	LOWER BASIN	TOTAL	UPPER BASIN	LOWER BASIN	TOTAL	UPPER BASIN	LOWER BASIN	TOTAL	UPPER BASIN	LOWER BASIN	TOTAL
No Intervention	6	26	31 40%	7	29	36 20%	7	29	37 6%	6	26	32 34%
KIP Revitalisation	6	32	38 48%	7	38	44 24%	7	38	45 20%	6	32	38 41%
Groundwater	6	58	63 44%	7	71	78 43%	7	71	78 20%	6	60	67 41%
Small–medium storages[1]	13	26	39 44%	14	29	43 23%	15	29	44 18%	14	26	39 38%
Diversion Scheme	6	72	79 100%	8	173	181 99%	9	215	224 98%	7	86	93 99%

[1]The small-medium storages option supplies water to the irrigated area for each exploratory scenario but also approximately 7 MCM water to the increased command areas (3890 ha) in the upper basin.

Table 4.14 Projected water shortage (demand minus supply) (MCM) for dry season crops under 4 WRD options, for each Exploratory scenario in 2040

	BUSINESS AS USUAL (79 MCM DEMAND)			COMMERCIAL SMALLHOLDER AGRICULTURE (182 MCM DEMAND)			AGRIBUSINESS (228 MCM DEMAND)			STAGNANT AGRICULTURE (94 MCM DEMAND)		
	UPPER BASIN	LOWER BASIN	TOTAL	UPPER BASIN	LOWER BASIN	TOTAL	UPPER BASIN	LOWER BASIN	TOTAL	UPPER BASIN	LOWER BASIN	TOTAL
No Intervention	1	47	48	3	144	146	5	187	191	2	60	62
KIP Revitalisation	1	41	41	3	136	138	5	179	183	2	54	55
Groundwater	1	15	16	3	102	105	5	145	150	2	26	27
Small–medium storages	2	47	49	4	144	148	5	188	193	3	60	63
Diversion Scheme	0	0	0	2	0	2	3	1	4	1	0	1

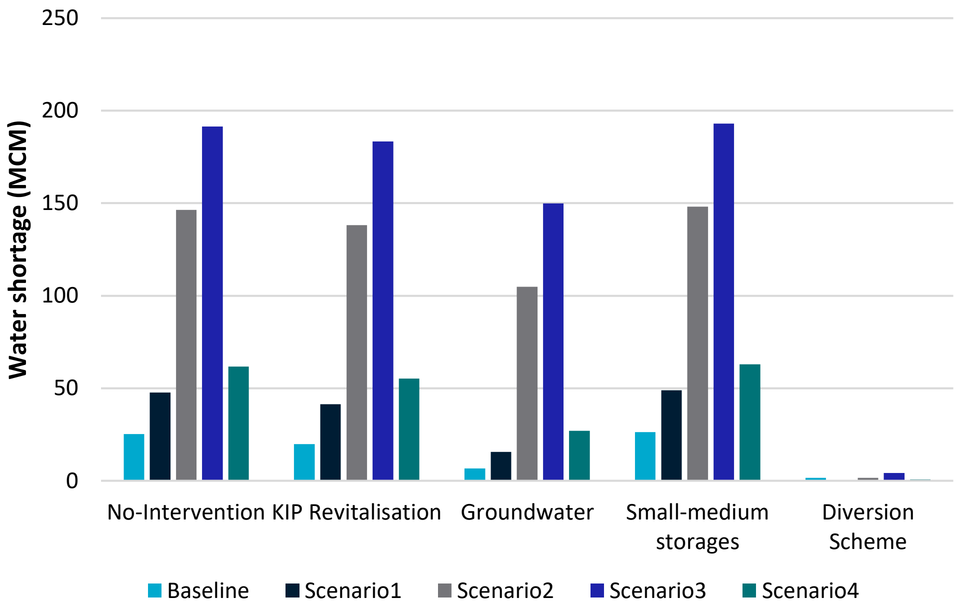

Figure 4.7 Modelled water shortage (MCM) for the 4 proposed WRD options under baseline conditions and the 4 Exploratory scenarios

Variations in water shortage between exploratory scenarios and water supply options are reflected in projected total crop income (Table 4.14). The diversion scheme has the highest income across all exploratory scenarios (averaged across the basin). The increase in income would be higher still when considering the extended command area beyond the Kamala Basin. As expected, for the upper basin the small storages option has the greatest benefit across all exploratory scenarios. Income is highest across options for the *Agribusiness* scenario, which has the greatest agricultural area. It also has the greatest water shortages.

The degree of effectiveness of each option relative to the baseline and relative to no intervention varies between exploratory scenarios. The small storage option has proportionally greater benefit for the two exploratory scenarios with the smallest areas (*Business as Usual* and *Stagnant Agriculture*) given the additional command area is proportionally higher. *Agribusiness* is the only scenario with additional command area in the upper basin, and hence the area associated with the small-medium storage construction has relatively lower impact (80% compared with 130% for *Business as Usual*). Despite being proportionally lower compared with no intervention, the total income remains highest for *Agribusiness*.

For the KIP revitalisation option, the increased income for *Commercial Small Agriculture* and *Agribusiness* is primarily through additional water supply during the wheat season and to some extent during the mungbean season (compared with no intervention). The KIP revitalisation provides a greater increase in income generated through mungbean compared with the groundwater water supply option, which has a higher benefit (relatively) for wheat production. Consequently, the proportional increase in income for the groundwater option is more consistent across the exploratory scenarios compared with the KIP revitalisation.

Table 4.15 Projected crop income (NPR million) and percentage change from baseline conditions under 4 proposed WRD options for the 4 Exploratory scenarios in 2040

WRD OPTION/ EXPLORATORY SCENARIO	BASE	BUSINESS AS USUAL			COMMERCIAL SMALLHOLDER AGRICULTURE			AGRIBUSINESS			STAGNANT AGRICULTURE		
	TOTAL (%[1])	UPPER BASIN	LOWER BASIN	TOTAL (%)	UPPER BASIN	LOWER BASIN	TOTAL (%)	UPPER BASIN	LOWER BASIN	TOTAL (%)	UPPER BASIN	LOWER BASIN	TOTAL (%)
No Intervention	3,720	290	2,710	2,990	400	4,520	4,920	480	5,520	6,010	330	3,130	3,460
KIP Revitalisation	3,830 (3%)	290 (0%)	2,840 (5%)	3,120 (4%)	400 (0%)	4,990 (10%)	5,390 (10%)	480 (0%)	6,100 (11%)	6,590 (10%)	330 (0%)	3,250 (4%)	3,580 (3%)
Groundwater	4,010 (8%)	290 (0%)	3,190 (18%)	3,480 (16%)	400 (0%)	5,300 (17%)	5,700 (16%)	480 (0%)	6,350 (15%)	6,840 (14%)	330 (0%)	3,700 (18%)	4,040 (17%)
Small-medium Storages	4,100 (10%)	680 (134%)	2,710 (0%)	3,380 (13%)	790 (98%)	4,520 (0%)	5,310 (8%)	870 (81%)	5,400 (-2%)	6,270 (4%)	720 (118%)	3,130 (0%)	3,850 (11%)
Diversion Scheme	4,110 (10%)	290 (0%)	3,480 (28%)	3,770 (26%)	420 (5%)	7,970 (76%)	8,380 (70%)	510 (6%)	9,960 (80%)	10,460 (74%)	340 (3%)	4,130 (32%)	4,480 (29%)

[1]Percentage change from the 'No Intervention' development scenario (not the baseline)

Despite greater crop incomes for the *Commercial Small Agriculture* and *Agribusiness* scenarios, as a proportion of agricultural area there is greater productivity for the business as usual and stagnant agricultural scenarios where water is limited. Under the diversion scheme option with greater water availability, there is an increased productivity across all Exploratory scenarios.

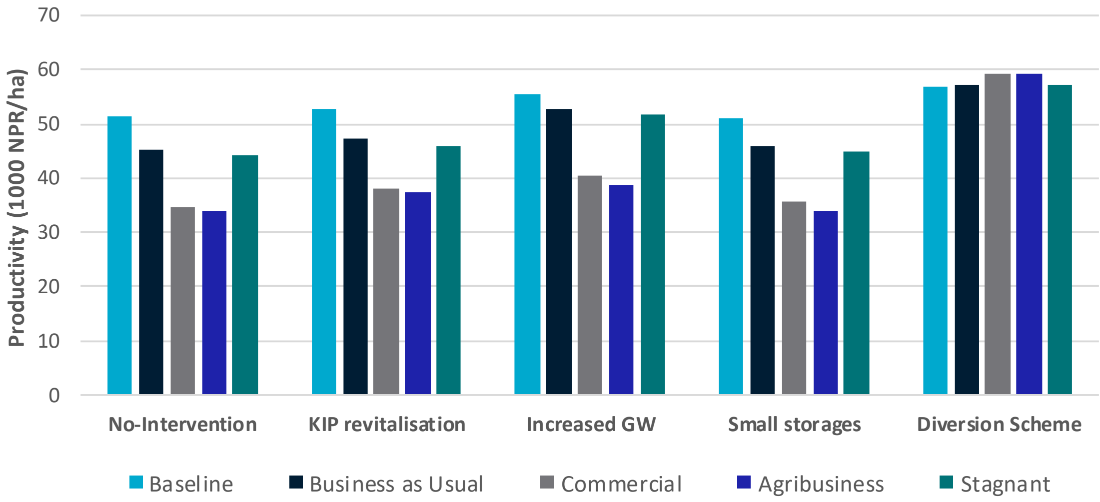

Figure 4.8 Crop income per hectare for the 4 proposed WRD options (x-axis) under baseline conditions and the 4 Exploratory scenarios

4.5 Combined water resources development options

The analysis of single water supply option provides a preliminary assessment of their effectiveness in reducing water shortages and increasing agricultural production. Portfolios of the options were also examined, given the single development options considered here vary in their target area, time to implement, cost, regulatory and institutional complexity, environmental and social impact, as well as robustness to different Exploratory scenarios.

Using the same time period of 2040s for the Exploratory scenarios, the evaluation here assumes multiple options have been implemented by this period. In practice, these options could be scheduled to enable adaptive management as water requirements and agricultural practices change into the future.

Alternatives of combined options are evaluated in terms of water supply (Table 4.16), water shortage (Table 4.17) and crop production. Water shortages under the groundwater option are reduced when KIP revitalisation is also implemented (Table 4.17). This reduction in water shortage varies between Exploratory scenarios from 5% (*Agribusiness*) and 30% (Business as Usual). These shortages are further reduced when small storages are also constructed in the upper Basin for 3 of the 4 Exploratory scenarios (the exception being Business as Usual).

Combining the groundwater option with the diversion scheme does not reduce the residual water shortage seen for the diversion scheme alone, other than a minor improvement for the *Agribusiness* scenario. This is due to the shortages being in the upper Basin, which is not benefitted by the groundwater option. The addition of small storages also does not reduce water shortages given the additional command area in the upper Basin, yet increases the total income (Table 4.17).

Table 4.16 Projected water supply (MCM) for dry season crops under baseline conditions and combined WRD options for the 4 Exploratory scenarios in 2040

	BASELINE	1. BUSINESS AS USUAL	2. COMMERCIAL SMALLHOLDER AGRICULTURE	3. AGRI-BUSINESS	4. STAGNANT AGRICULTURE
No Intervention	31	31	36	37	32
KIP Revitalisation + Groundwater	52	68	85	86	72
KIP Revitalisation + Groundwater + Small-medium storages	60	75	92	93	79
Diversion Scheme + Groundwater	55	79	181	225	93
Diversion Scheme + Small-medium storages	63	87	189	232	101

Note The amounts of water supply in the table are based on irrigation requirement to maintain soil water levels to meet the maximum potential yields of crops. They are not the maximum water availabilities under combined options. Diversion scheme is defined to include revitalisation of KIP (see Table 4.12).

Table 4.17 Projected water shortage (demand minus supply) (MCM) for dry season crops under baseline conditions and combined WRD options for the 4 Exploratory scenarios in 2040

	BASELINE	1. BUSINESS AS USUAL	2. COMMERCIAL SMALLHOLDER AGRICULTURE	3. AGRI-BUSINESS	4. STAGNANT AGRICULTURE
No Intervention	25	48	146	191	62
KIP Revitalisation + Groundwater	4	11	98	143	22
KIP Revitalisation + Groundwater + Small-medium storages	5	13	99	144	23
Diversion Scheme + Groundwater	2	0	2	3	1
Diversion Scheme + Small-medium storages	2	1	2	5	1

Note: Diversion scheme is defined to include revitalisation of KIP (see Table 4.12).

Crop income similarly increases for the combined groundwater plus KIP and groundwater plus KIP and small storage option compared with the groundwater scenario alone. The diversion scheme plus groundwater income remains unchanged compared with the diversion scheme scenario, whilst the addition of small-medium storages provides additional income to the upper Basin.

In terms of crop income per hectare of agricultural land (Figure 4.9), the addition of KIP revitalisation and small-medium storages provides only a minor increase (2-8%) to the groundwater scenario. There is no increase for the diversion scheme by adding the groundwater or small storage option.

Table 4.18 Projected crop income (NPR million) and percentage change from baseline under combined WRD options for the 4 Exploratory scenarios in 2040

WRD OPTIONS / EXPLORATORY SCENARIOS	BASELINE	1. BUSINESS AS USUAL	2. COMMERCIAL SMALLHOLDER AGRICULTURE	3. AGRI-BUSINESS	4. STAGNANT AGRICULTURE
No Intervention	3,720	2,990	4,920	6,010	3,460
KIP Revitalisation + Groundwater	4,060 (9%)	3,580 20%)	6,120 (24%)	7,160 (19%)	4,120 (19%)
KIP Revitalisation + Groundwater + Small storages	4,440 (19%)	3,970 (33%)	6,310 (28%)	7,310 (22%)	4,510 (30%)
Diversion Scheme + Groundwater	4,110 (10%)	3,770 (26%)	8,380 (70%)	10,460 (74%)	4,480 (29%)
Diversion Scheme + Small storages	4,500 (21%)	4,170 (39%)	8,780 78%)	10,860 (81%)	4,880 (41%)

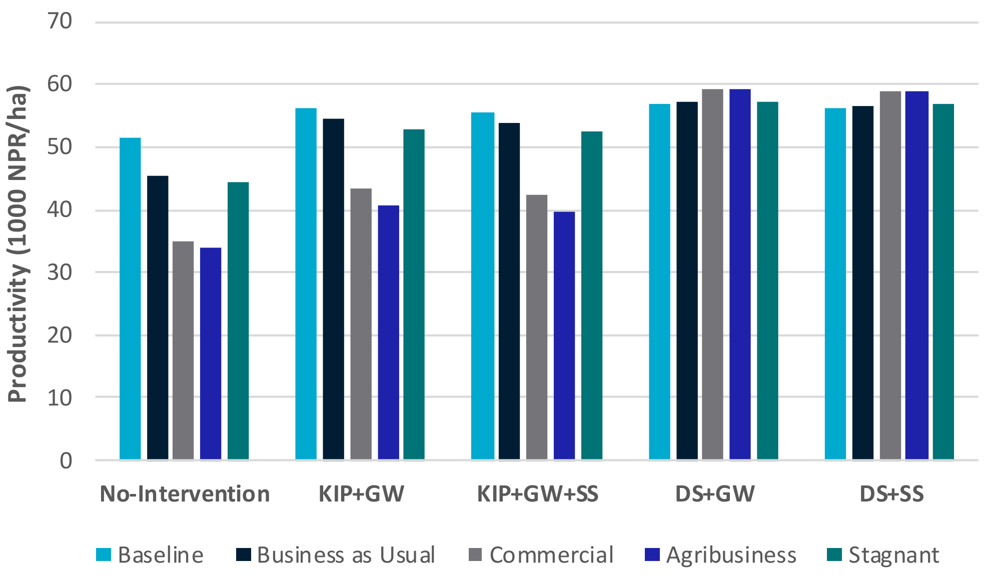

Figure 4.9 Crop income per hectare for combined WRD options under baseline conditions and the 4 Exploratory scenarios

KIP = KIP revitalisation, GW = groundwater, SS = small-medium storages, DS = diversion scheme

4.6 Formulating water resources development options

The 4 water resources development options represent a wider range of possible options. For example, for the purposes of this analysis it was decided to define the technology of the groundwater option as shallow tube wells, similar to those currently in operation, with use of solar energy for pumping. This definition does not exclude the use of diesel pumps or reticulated electricity, nor does it exclude consideration of more options such as deeper tube wells in advisable locations. Similarly, for the analysis of the small and medium storages option, candidate schemes were defined with detail sufficient to appreciate the level of technical complexities and costs likely to be incurred throughout the project cycles, as well as the beneficial outcomes anticipated.

It was noted in relation to the fourth option, that the Sunkoshi to Kamala Diversion and Multi-purpose Project (SKDMP) was one of many large-scale dams and diversion proposals which have been under consideration within the greater Koshi Basin over the last 4 decades and more. Early studies identified at least 4 potential major dam sites along the Sunkoshi mainstream, and several more on tributaries within the same Basin. At least one of these has an international dimension, and a joint (Nepal-India) project office was established. Studies and investigations for several proposed schemes have continued intermittently until the present. The stakeholders who nominated the SKDMP for consideration in this Strategy knew of at least some such proposals and identified the SKDMP as the only one of possible benefit to the Kamala Basin, and representative of the inter-basin transfer approach to augment water availability in the Kamala Basin.

For example, the Sunkoshi to Marin Diversion and Multi-purpose Project (SMDMP) has attracted sufficient interest among central government agencies to initiate further studies into the definition and feasibility assessment of the proposed scheme. Given that this scheme is located upstream of the SKDMP, and would likely interfere or overlap with elements of the SKDMP, a study was commissioned to compare the attributes of both proposed projects – the SMDMP and the SKDMP – to consider whether or which of the two should proceed (NEA Engineering Company 2019). This was undertaken as a desk study with supplementary field trips to confirm locations of proposed major infrastructure elements, and largely focused on technical and economic assessments. The study recommended that the SMDMP should commence implementation first, and that the SKDMP should also proceed, later and under supplementary conditions (NEA Engineering Company 2019). However, the findings are not fully conclusive as assessment of environmental, social, and political effects was not conducted for either scheme. Full implementation and operation of both diversion projects could mean a combined total transfer out of the Sunkoshi of up to 90% of mean monthly flows during the dry season, with implications for downstream water users and uses.

The comparative study has many points of contrast with this Strategy, in terms of objectives, range of options considered, approach and methodology.

This particular study highlights the likelihood that at any point in time there are many water resources development options in various stages of maturity which are vying for attention and consideration. This is particularly the case for proposals which are very large, complex and long term in scope, as decisions to proceed have very significant consequences and will be taken at the highest levels of government. For the purposes of this Strategy, 4 representative options for water resources development in the Kamala Basin were assessed using a participatory and interdisciplinary methodology (Section 1.5). Should additional options arise for consideration for the Kamala Basin in the future, the same approach, tools and methods can be applied to assess them as thoroughly. Likewise, the participatory approaches, with similar tools and methods to those demonstrated for this Strategy, could be applied to the assessment of options for other River Basins in Nepal.

4.7 Ecological analysis

Flow-based ecological metrics have been adopted to give a preliminary indication of the potential impact of future change on the river and floodplain environment. This approach could be improved in the future should more information become available to describe the water requirements of key indicator species in the Kamala Basin[25].

[25] The reader is referred to Doody et al (2016) which reports the current state of knowledge (quantitative and qualitative) of flow:ecology relationships in the Koshi Basin.

The flow-based approach uses a well-established set of 33 indicators (Indicators of Hydrologic Alteration), (Richter et al. 1996), which represent 5 ecologically important elements of instream flow: (1) flow magnitude; (2) duration of high and low flow events; (3) timing; (4) frequency of events; and (5) rate of change of flow. Each of the 33 indicators are assessed by comparing a baseline sequence of daily flows ('pre-impact') with an estimated future sequence incorporating the development scenario ('post-impact') (Richter et al. 1997). The comparison can also be used to compare existing development with an estimated 'natural' (without development) scenario.

For the Strategy, results for each of the 33 indicators have been categorised using 5 levels of change ranging from Low to Extremely High. The level of change for each indicator is then averaged into an overall level of change for each of the 5 ecologically important flow elements. The assessment is conducted downstream of the Kamala Irrigation Project at Inarwa.

The level of change categories are intended to give an indicative estimate of the degree of undesirable impact from existing and future water resources development options.

Table 4.19 Degree of discharge change categories

LEVEL OF CHANGE		RANGE IN PERCENTAGE OF CHANGE
[1]	Low	absolute % value < 33%
[2]	Moderate	33 < absolute % value <67%
[3]	High	67 $\leq$ absolute % value $\leq$ 100%
[4]	Very High	100% < absolute % value <200%
[5]	Extremely High	absolute % value ≥ 200%

First, a Without Development model scenario which removes all infrastructure and agricultural water requirements is compared with the Baseline model representing existing conditions (Table 4.20). The comparison suggests that construction of the KIP along with current agricultural abstractions has resulted in a large increase in flows from December to April during the dry season to support crop production, as well as an overall reduction in low flows. There are estimated to be fewer low-flow pulses, with the duration of pulses being longer. The rate of change of river levels has also been modified, with more gradual decreases in flows as well as more changes in water levels.

These changes are indicative of the moderate degree of impact already experienced in the lower Kamala Basin to support agricultural production. This existing level of impact is an important consideration when evaluating the implications of future development relative to current conditions. While the aggregate level of changes shown do not exceed the High category, individual indicators fall into the Very High, and in the case of water supply option, Extremely High categories.

Table 4.20 Estimated impact of current agricultural abstractions and the revitalisation scheme on ecologically important flow elements at Inarwa

	MONTHLY FLOW MAGNITUDE	EXTREMES	TIMING	PULSES	RATE OF CHANGE
Baseline	Moderate	Moderate	Low	Moderate	Moderate

The 4 WRD options are then compared against the baseline (as opposed to the Without Development scenario) (Table 4.21). No changes are observed for the groundwater and small storage scenarios at Inarwa given the evaluation is based on changes in surface water only, and the downstream flow impacts of the small storages is negligible, based on the model assessment.

For the revitalisation of the KIP, some changes in monthly flow magnitude is observed due to a shift from scheduled releases down each canal on a two-week basis to water being released based on crop demand. There is a moderate increase in low flows, with more water being delivered during the dry season. The yearly timing of low flows is also anticipated to shift to earlier in the year from April to March. There is expected to be a reduction in the number and duration of low-flow pulses, as well an impact on the rate of change of rise and fall of water levels.

For the diversion scheme option, the construction of storages and Sunkoshi diversion generates higher flows throughout the year, with increases in both extreme low and high flows. The timing of low flows occurs earlier in the year, and there is a reduction in the number of low-flow pulses. There is a significant impact on the rate of change of river levels.

The baseline (current development) scenario was also compared with the 4 Exploratory scenarios (Table 4.22). These plausible future changes (based primarily on changes in agricultural area and production) had observable but less impact on hydrological alteration compared with the 4 WRD options. The Exploratory scenarios primarily affected the number and duration of low and high-flow pulses as well as the rate of change of river levels.

Table 4.21 Estimated impact of WRD options on ecologically important flow elements at Inarwa

	MONTHLY FLOW MAGNITUDE	EXTREMES	TIMING	PULSES	RATE OF CHANGE
KIP Revitalisation	Low	Moderate	Moderate	Moderate	Moderate
Groundwater	None	None	None	None	None
Small-medium storages	None	None	None	None	None
Diversion scheme	High	Moderate	Moderate	Moderate	High

Table 4.22 Estimated impact of Exploratory scenarios on ecologically important flow elements at Inarwa

	MONTHLY FLOW MAGNITUDE	EXTREMES	TIMING	PULSES	RATE OF CHANGE
Business as Usual	None	None	None	Low	Low
Commercial smallholder agriculture	None	None	None	Low	None
Agribusiness	None	Low	None	Low	Low
Stagnant Agriculture	None	None	None	Low	Low

4.8 Cost analysis

Previous sections highlight the importance of additional irrigation water supply for agricultural income, whilst also exploring the potential ecological impacts of different supply schemes. This section estimates the cost of combinations (portfolios) of water supply options to meet future water demand.

Annual estimates of water demand by scenario were derived based on 2040 demand, and average annual growth rates of demand, for the period 2020–2040. Portfolios of supply were constructed and costed based on assumptions shown in Table 4.23.

Investment cost was defined as the sum of capacity cost and annualised management, operation, and maintenance (MOM) cost. Estimates of capacity cost by option were based on literature review and by interviewing experts in Nepal. For the Diversion Scheme and Small–Medium Storages WRD options, estimates of capacity cost include new canal and conveyance infrastructure. The capacity cost estimate for these 2 options includes adding 10% of the total cost of civil works, as a preliminary estimate of environmental and social costs.

The present value of investment cost to supply water in 2025, 2030, 2035, and 2040 was derived for all WRD options, except for the Diversion Scheme. For the Diversion Scheme (assumed 14-year lead time), the present value (PV) was derived for supply in 2035 and 2040. To derive the PV, the capacity cost was divided equally between each year of lead time, and discounted at an assumed public rate of 6%, or 10% for private groundwater.

Table 4.23 Assumptions for cost analysis of WRD options

OPTION	TOTAL INCREMENTAL CAPACITY (MCM)	LIFE-TIME (YR)	LEAD-TIME (YR)	OVERNIGHT CAPACITY COST (NPR/HA)	MAXIMUM AREA (HA)	CAPACITY COST, MAXIMUM AREA (MILLION NPR)	ANNUAL MOM COST	DISCOUNT RATE
KIP Revitalisation	12	40	4	353,466	53,400	18,875.08	5.0%	6%
Groundwater	44	10	2	92,490.27	55,400	5,126.44	10.2%	10%
Small–medium Storages	7	40	3	68,6902.26	3,890	2,672.20	5.0%	6%
Diversion Scheme	198	40	14	718,360.73	175,000	125,716.07	5.0%	6%

Note: (1). Maximum area for KIP, groundwater, and small–medium storages based on Kamala Basin study areas (Scenario 3, Table 'Estimated total command area, gross cultivated area and cropping intensity (ha) comparing baseline with 4 exploratory future scenarios'). For the Diversion Scheme, maximum area follows description in Section 4.3.

For groundwater, the assumed option was a private, 3 hp solar-pumped shallow tube well (STW), with no capital subsidy. The 10-year assumed lifetime meant that STW supplying water at the start of 2025 needed to be fully replaced by end of 2034. STW replacement costs were included in the estimated system cost.[26]

Figure 4.10 (top panel) shows irrigation water demand and supply for each of the 4 WRD options per decade up to the 2040s. The bottom panel shows cost of supplying water for each WRD option, from one or more options.

The 4 Exploratory scenarios consist of two 'low' water demand scenarios (S1, S4) and two 'high' water demand scenarios (S2 and S3).

For 3 out of 4 Scenarios (S1, S2, S4), water demand until 2025 is met by existing supply (31 MCM) and new groundwater. By 2030, groundwater meets demand in the low water demand Scenarios (S1, S4). Meeting 2030 demand for the two 'high' demand scenarios (S2, S3) will require a combination of KIP revitalisation, small–medium storages, and additional demand reduction options (which remain to be defined).

For the two 'low' demand scenarios, groundwater and KIP revitalisation are adequate to meet water demand in 2035 (and meet ≥93% of demand in 2040). For the two 'high' demand scenarios (S2 and S3), meeting water demand in 2035 and in 2040 requires construction of the Diversion Scheme.

[26] New STW supplying water at start of 2030 needed to be fully replaced by end of 2039. New STW delivery for start of 2035 were at 60% of lifetime by end of 2040. Hence for the 2035 cohort, 60% of system cost in 2040 were allocated as replacement cost.

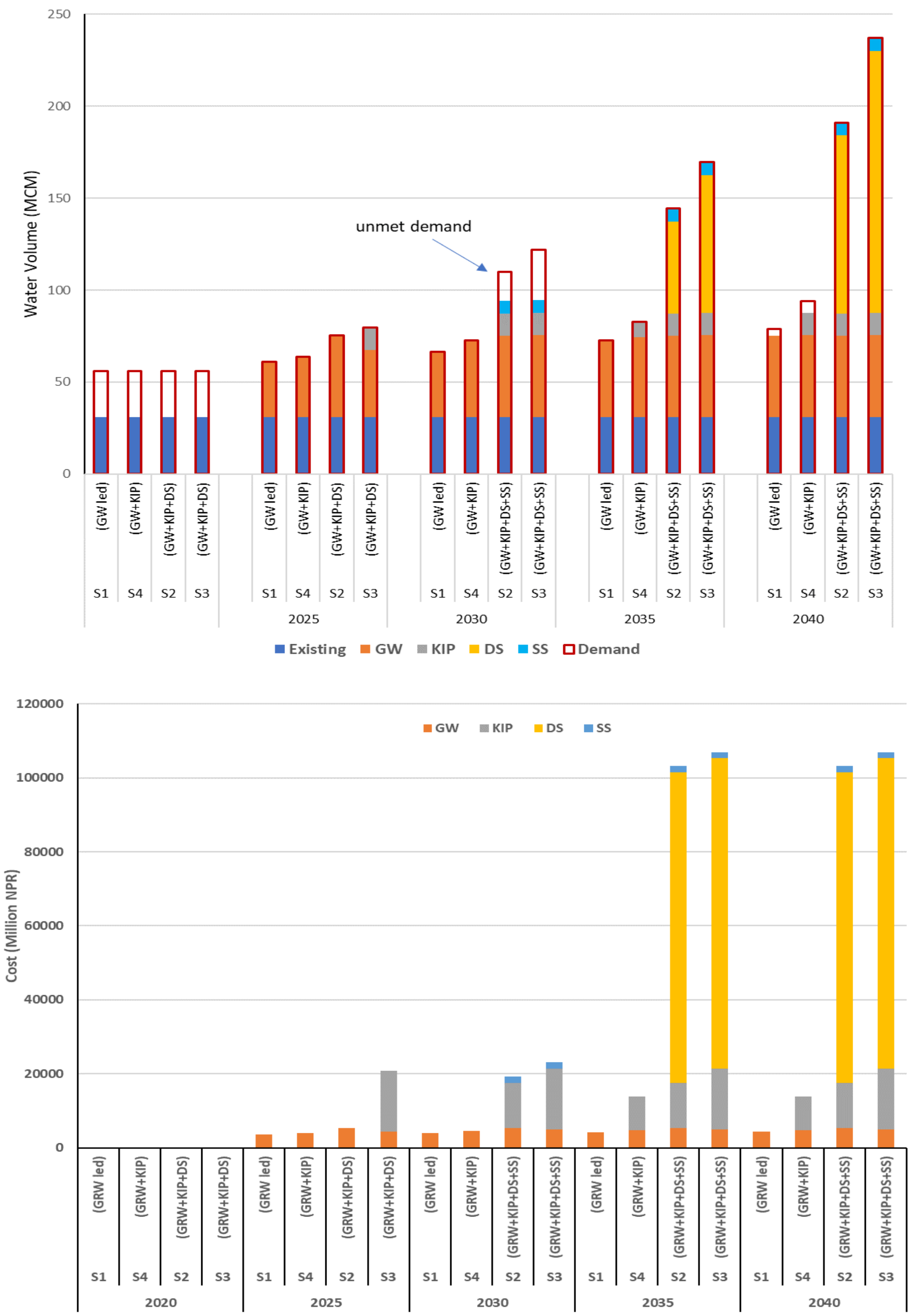

Figure 4.10 Irrigation water demand, supply, and cost of supply water for each combination of WRD Options for every 5 years from 2020 to 2040.

Note: S1, S2, S3 and S4 are model scenarios. 'DS' = Diversion Scheme. 'SS' = Small–medium storages.

The high investment cost of the Diversion Scheme results in a 468% increase in portfolio cost between 2030–2035 (NPR83.3 billion) to meet a 34% increase in demand (35 MCM) which means a very high marginal cost of supply.

Figure 4.11 shows the relation between crop income, and the present value of cost for different levels of water supply. Three portfolios are shown. Each represents the lowest cost technology option or combination of options to meet water demand, from the set of 4 technology options considered.[27] The addition of the KIP increases portfolio cost by 221% to improve water supply and crop income by 17% and 18% respectively.

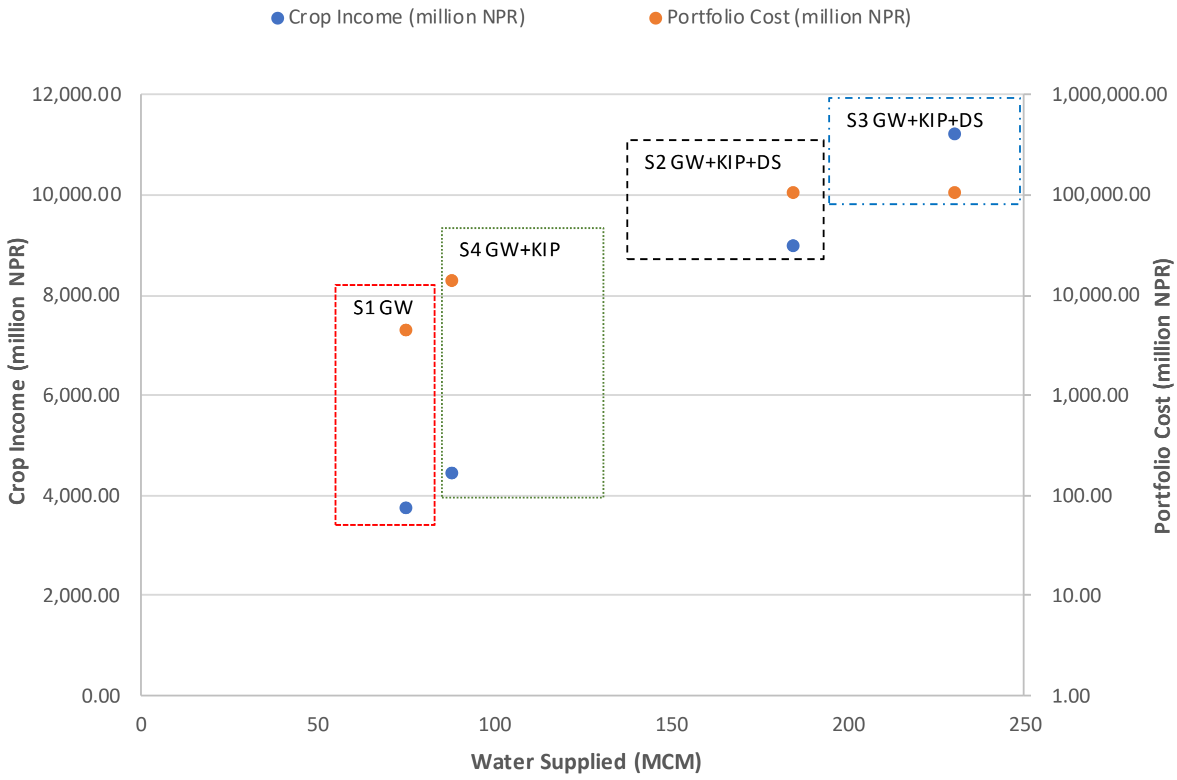

Figure 4.11 Water supply, crop income, and cost of supply

Note: Blue points show crop income, orange points show portfolio cost. From left to right, amounts of water supplied correspond to Scenarios 1, 4, 2, and 3. S1, S2, S3 and S4 are scenarios. GW= groundwater, KIP = KIP Revitalisation, DS = Diversion Scheme.

The results presented are sensitive to cost assumptions for each technology option. It should be noted however, that the differential in overnight cost between private STW and the surface water schemes is large, ranging from >380% to >760%. Comparing PV (year 2035) of investment cost/MCM, the Diversion Scheme is 895% higher than private STW.

The preliminary analysis of cost presented in this section reveals that portfolio costs can be lowered by postponing investment in the costliest infrastructure options. Early in the planning period, investments in groundwater are preferred, because they are scalable and low cost. Options beyond the 4 WRD options analysed here are worth consideration. Two such options include farm-level interventions, such as conservation agriculture based sustainable intensification (CASI) practices. CASI practices (see

[27] The small–medium size storages, with new command area of 3890 ha, was not included in this analysis. Although it provides water to the Upper Basin, the option sized at 3890 ha resulted in a net -2 MCM impact on basin water balance (net supply 7 MCM, net demand 9 MCM).

Section 7.3) can reduce irrigation water requirements by approximately 10% (Islam et al. 2019). Laser land levelling can increase water efficiency by more than 20% (M. Gathala, pers. comm. June 2020).

In addition, it will be necessary to explore the cost and benefits from revitalisation of existing FMIS schemes, which are important for water supply to the Upper Basin.

4.9 Conclusion

This Chapter considered 4 different WRD options and 4 plausible Exploratory scenarios for future water demand, each with important implications for future water requirement and crop income. Differences between these future scenarios have a greater impact on crop income than differences in water supply options.

Uncertainty in future development – both with respect to future scenarios, and ability to realise different options – is likely to have a greater influence on agriculture than future climate. However, climate impacts are potentially significant and are likely to exacerbate changes in development. These socio-economic and biophysical differences highlight the importance of adaptive management, and the need for close collaboration between the water resource sector and other broader development sectors.

The Diversion Scheme is the most effective in reducing water shortages and increasing crop income, although benefits are concentrated in the lower Basin. This WRD option has the highest complexity, longest period between the decision to implement and the first flow of benefits, highest total cost, highest cost per unit of water and greatest environmental implications. The next most effective option is private groundwater shallow tube wells. This technology has the greatest robustness across each of the Exploratory scenarios as it is assumed to support the staple crop of wheat the most during the dry season. Groundwater development however benefits only the lower Basin.

The 4 WRD options considered in this Chapter focus on the supply-side. As described in Section 4.8, as total demand rises beyond 75 MCM (the sum of existing supply and the limit of groundwater), the high-cost and/or large-scale nature of the surface water options result in very high marginal costs of supply. It is recommended that water resource planners consider demand-side, end-use water efficiency options, such as laser land levelling, and CASI practices (Chapter 7).

For potential outcomes described in this Chapter to be achieved, the construction or modification of infrastructure requires appropriate management, maintenance, and use. As such, effective governance frameworks are needed, which in turn will require reforms to existing institutional arrangements, both in the water sector (Chapter 5), and the agricultural sector (Chapter 7).

As with all modelling outputs, there is a substantive level of uncertainty in results, and hence the values presented here are intended to support collaborative decision making and guide more detailed assessment of specific option. Uncertainty is increased by limited existing data on key system characteristics such as streamflow in different part of the basin, agricultural systems, and location-specific crop water requirements. The variations between exploratory scenarios also demonstrate the impact of future uncertainty on both water resource and agricultural outcomes.

5 Strategies to develop water resources

5.1 Background

In 2018, participants in the Kamala Basin Initiative identified, as one of their primary development goals, 'reduced impact of water induced disasters, and improved availability, use, and allocation of water resources for livelihood generation, well-being and economic growth' (Goal 2; see Table 3.2). The KBI participants further identified the 'conservation, development, and management of existing and potential water resources for improving consumptive use, and water use efficiency' as a key objective (Goal 2, Objective 3).

To realise Goal 2.3, the stakeholders identified several major actions (Table 3.2). The project team re-formulated these actions as a set of 4 water resources development (WRD) options presented in Chapter 4:

- **WRD Option 1**: Revitalisation of the existing Kamala Irrigation Project
- **WRD Option 2**: Sustainable utilisation of groundwater
- **WRD Option 3**: Construction of small to medium water storages in the upper Basin
- **WRD Option 4**: Development of an inter-basin water transfer scheme (the Sunkoshi–Kamala diversion and multi-purpose project)

Chapter 4 quantified each of the above water supply options, in the context of water resources in the Kamala and Koshi Basins. The Chapter described the ability of each of the 4 WRD options to meet a range of future demand scenarios, with a focus on agricultural water demand. This Chapter provides strategic advice and alternatives on how to implement each of the 4 options in an effective and sustainable manner. The advice is based on an institutional and political economy analysis conducted by the project team, based on methods summarised below.

5.2 Methods

5.2.1 Concepts

To develop a given WRD option, a set of 'strategic actions' needs to be implemented. For example, in order to rehabilitate the Kamala Irrigation Project, it is recommended as the first strategic action, to 'prepare a comprehensive suite of plans for the future of the KIP' (Section 5.3.3).

Each strategic action can be defined as a sequence of essential 'governance functions', which need to be performed by capable actors. This Chapter proposes governance functions for each strategic action, then proposes which actors should lead and contribute to delivery of each of the governance functions, at different levels of governance (local, Kamala Basin, federal).

The analysis is based on the following concepts, which are drawn from Pahl-Wostl (2015) and from Hurlbert and Gupta (2018):

Institutions are defined as stable and collective patterns of dealing with basic social functions (such as managing and allocating natural resources). They may be 'formal' (e.g. officially recognised and resourced as a dedicated organisation) or 'informal' (e.g., self-organised and resourced, not always recognised by higher levels of governance). Institutions are not identical to organisations. They do not have a physical presence.

Actors are organisations and individuals. Actors may administer or deliver more than one institution (hence, prioritisation is important).

Governance functions are different types of action needed to govern (Pahl-Wostl 2015) (Table 5.1). Each function is a structured social interaction, intended to produce specific outcomes. Each function includes a set of actors assigned to specific roles.

Table 5.1 Governance functions

GOVERNANCE FUNCTION	CODE	DESCRIPTION
Policy framing	PF	Representing an issue as a particular type of policy problem. May include proposing a particular set of policy instruments as an appropriate response.
Resource or organisational mobilisation	RM	Securing political support and/or financial and human resources
Knowledge generation	KG	Producing relevant knowledge
Actor constitution	AC	Forming a new actor, especially one accepted by existing actors
Institution or rule making	IM	Establishing formal commitments on how to govern an issue
Conflict resolution	CR	Managing or resolving conflicts between actors
Monitoring and evaluation	ME	Includes setting specific targets or indicators against which outcomes of action can be evaluated; evaluation of outcomes; defining actions if targets not met

The quality of outcomes depends on having a range of roles adequate to delivering the outcome; the fit between actors and roles assigned to them; and on whether specific policy instruments used are suited to delivering the function. A detailed analysis of policy instruments is beyond the scope of this document. However, specific instruments proposed by experts interviewed are described.

5.2.2 Data collection

Necessary data was collected through literature review and key informant interviews. Literature review included a range of government documents as well as published literature. Key informant interviews were conducted with experts familiar about identified WRD actions. The key informants were selected based on their expertise on selected WRD actions. The interview started with a brief introduction to the objectives of the Kamala Basin Initiative, the WRD actions identified by the stakeholders (Chapter 3), and the strategic actions proposed for each WRD option by the project team. The experts were then requested to provide their views on key institutional arrangements at different levels. Twenty experts were interviewed for this purpose.[28]

[28] In accordance with CSIRO human research ethics protocols, the identity of persons interviewed has been kept confidential

5.3 WRD Option 1: Revitalisation of the existing Kamala Irrigation Project

5.3.1 Background

Designed to irrigate 25,000 ha of agricultural land in Dhanusha and Siraha, the Kamala Irrigation Project (KIP) was constructed in the 1970s. Although the KIP is able to provide water to its full command area during the monsoon season, it can serve less than 10,000 ha during the winter season. This is partly a result of lack of infrastructure to regulate delivery of water to canals, and partly a result of inadequate maintenance of existing infrastructure. The KIP experiences problems with sedimentation (scouring unlined canals); seepage from canals, and loss due to evaporation, which reduce its efficiency.

In absence of adequate funding for management, operation and maintenance, the system has not been functioning as expected. Scarcity and inefficient water delivery lead to inequitable sharing of water between different users in the system, leading to occasional conflict. The inadequate institutional capacity of the Water Users Group to measure the water delivered across the canals; schedule water; plan for asset management; and set and collect service fees, also contribute to the above problems with water delivery and allocation.

An additional challenge has been the association, in the minds of some stakeholders, of the KIP's future with a need to increase source water availability, via inter-basin transfer. This is a challenge to the extent that it diverts attention from focusing on the internal performance of the KIP.

5.3.2 Strategic Actions

A significant investment in management and institutional arrangements is needed in order to allocate resources to the most cost-effective actions to improve the KIP's performance. Three key strategic actions were identified to rehabilitate the KIP (Dyson et al. 2020):

- WRD1 Strategic Action 1: Prepare a comprehensive suite of plans for the future of the KIP
- WRD1 Strategic Action 2: Establish an effective statutory framework for management of KIP
- WRD1 Strategic Action 3: Capacity building.

For each of the 3 Strategic Actions, key governance functions at different levels are summarised in Figure 5.1.

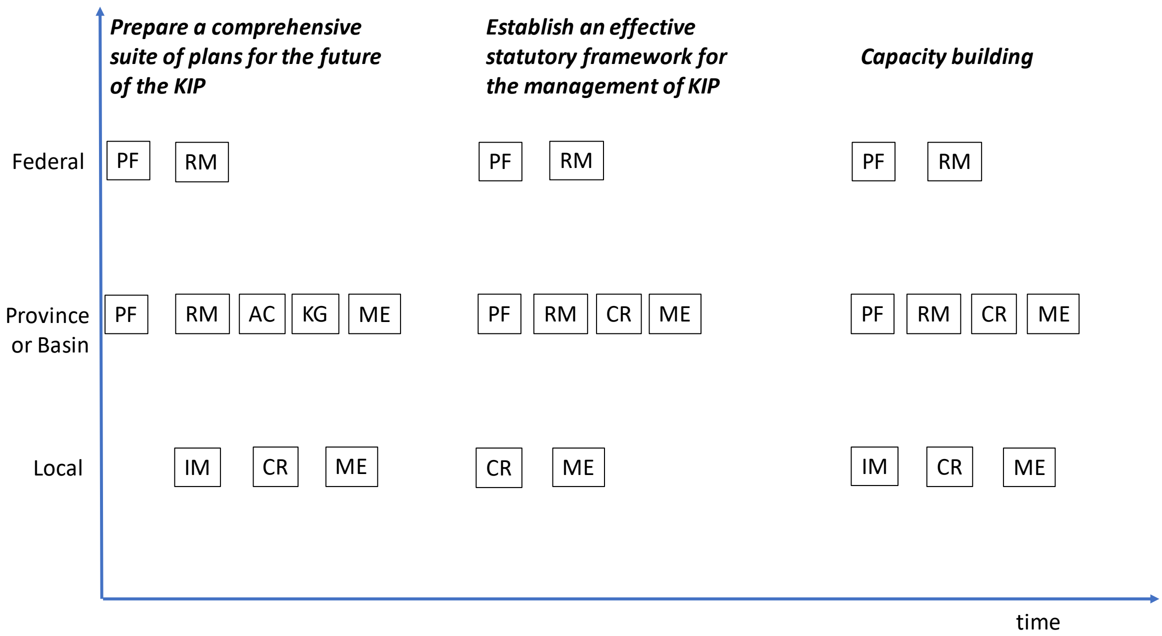

Figure 5.1 Strategic actions and governance functions for revitalisation of Kamala Irrigation Project

Note: Governance functions: PF = Policy framing; RM = Resource or organisational mobilisation; KG = Knowledge generation; AC = Actor constitution; IM = Institution or rule making; CR = Conflict resolution; and ME = Monitoring and evaluation

5.3.3 Strategic Action 1: Prepare a comprehensive suite of plans for the future of the KIP

Lead responsible actor. The federal Department of Water Resources and Irrigation (DoWRI) is a key responsible actor with respect to initiating this Strategic Action via policy framing and resource mobilisation DoWRI is an apex body with a mandate to plan, develop, maintain, operate, manage and monitor different modes of irrigation and drainage systems in Nepal. DoWRI and its regional offices focus on small- to large-scale surface systems, and individual- to community-scale groundwater schemes.

Knowledge generation. A comprehensive plan for the KIP's future requires knowledge generation: the identification and evaluation of alternative options for how to treat the KIP as an ageing infrastructure scheme with design limitations. Knowledge generation should provide a comprehensive set of alternatives, beginning with no- and low-regrets options. (Such options are characterised as requiring very low or low cost each year to obtain net benefits, without time lag.). A high upfront cost option is to augment water supply by diversion of water from Sunkoshi River to the Kamala River. It will be important to invest in participatory appraisal and trials of revitalisation of branch and minor canals, documenting impacts on farmers.

An opportunity exists to invest in agricultural knowledge and innovation systems to shift agricultural practices to more water productive crops (Chapter 7 Strategies to develop smallholder agriculture). Nepal Agriculture Research Council (NARC) and Agriculture Knowledge Centers (AKCs) within the Basin could develop appropriate technology and practices. Formulating a long-term strategic plan requires analysing possibilities and water demand implications of scaling out alternative agricultural practices. At the basin level, the KIP project office, and the AKCs could play a lead role in knowledge generation.

A strategic plan for the future of the KIP could be divided into an action plan (i.e. covering the kinds of actions presented above), a business or investment plan, and an asset management plan (Dyson et al. 2020).

Important roles for local level actors. Local level actors such as Water Users Associations (WUA) and municipalities have a crucial role to play in making local rules to facilitate water allocation (including for domestic use and livestock) and to facilitate operation and maintenance. These actors have crucial roles to play in monitoring and evaluation (ensuring that new plans and rules are implemented and enforced), and thus they appear to be key actors to lead on conflict resolution.

A WUA is a community-level organisation responsible for operation and management of irrigation systems. WUA possess good organisational skill including mobilisation of their members for collective actions but often lack technical competencies.

Linkages to other WRD Options. To reduce dependency on surface water during the dry season, emphasis should be placed on conjunctive use of groundwater and surface water (WRD Option 2). Groundwater pumping in dry season may supply water requirements, later replenished by surface water in wet season. Furthermore, building small and/or medium reservoirs upstream (linked to WRD 3) could contribute to regulating the flow in Kamala river and thus complement in stabilising water supply at KIP. Table 5.2 summarises the governance functions for this strategic action.

Table 5.2 Governance functions to implement comprehensive planning for KIP (WRD1–Strategic Action 1)

GOVERNANCE FUNCTIONS	OBJECTIVES	ACTOR INVOLVEMENT	ROLE AND LEADERSHIP
Policy framing (PF)	Necessary for placing this agenda at the interest of federal and provincial actors	• Federal: Department of Water Resources and Irrigation (DoWRI) • Province or Basin: Kamala Irrigation Project (KIP)	• DoWRI should take the overall lead (constitutional provision of managing large irrigation project)
Resource mobilisation (RM)	Mobilise resources for knowledge generation, rule making and conflict resolution	• Federal: DoWRI • Province or Basin: KIP	• DoWRI should take the overall lead – may require acquiring international funding to implement the long-term strategic plan
Knowledge generation (KG)	Understand better the ways to enhance the efficiency of operation of the KIP as well as agriculture knowledge and innovation systems	• Province or Basin: KIP, NARC and AKC	• KIP should take lead in providing necessary details to formulate long-term strategic plan • NARC/AKC should take lead on agricultural part
Rule or institution making (IM)	Develop new rules which refine existing practices, so as to improve operation, maintenance and management	• Local: WUA and Municipalities	• WUAs should take lead in managing the rules that suit to their respective branch or tertiary canals. • Municipalities could play facilitating role in this case
Conflict resolution (CR)	Improve the water allocation and operation and maintenance of the irrigation system	• Local: WUAs including Main Canal Committees for both Eastern and Western Main Canals, and Municipalities	• WUAs should take the lead as they are the ones working closely with the farmers, but Municipalities could play facilitating role.
Monitoring and evaluation (ME)	Required to ensure that new action plans are implemented and enforced.	• Province or Basin: KIP • Local: WUA and municipalities	• KIP could take lead but the role of WUAs is crucial at local level

5.3.4 Strategic Action 2: Establish an effective institutional framework for management of KIP

As noted above, the KIP's performance is inefficient, as a result of insufficient operation and maintenance, as well as poor enforcement mechanisms. The situation requires that any of the proposed institutional and policy responses are enabled and supported by an effective overarching institutional framework for the KIP. The framework should have statutory (legal) authority.

The framework should cover: establishing any new decision-making bodies specifying their powers and obligations (i.e. actor constitution); water sharing and distribution among users (rulemaking); management, operations and maintenance (rulemaking); resource mobilisation, and compliance and enforcement mechanisms (monitoring and evaluation; conflict resolution).

At present the KIP has 3 tiers of WUAs: minor canal committees at the lowest level; branch canal committees; and two main committees for eastern and western main canal. There is a lack of clarity about the responsibilities of these multiple committees. Most are currently defunct. Due to a non-functional institutional mechanism in recent years, collective action among the farmers has declined (Bastakoti 2019).

The new institutional framework could have the following organisation. A new, single apex body is constituted. The members of this apex body should include a small number of representatives from both main canals, with clear description roles and authorities. Such a new body could have a strong coordination function. This would improve the enforcement of operational rules, facilitate the functions of existing committees, and thereby improve the management of KIP.

Responsible actors. Federal agencies such as DoWRI should play key role in policy framing and resource mobilisation. Other governance functions (described above) include rule/institution making, conflict resolution as well as monitoring and evaluation. Local level actors should play a lead role on those governance functions. Table 5.3 summarises the governance functions for this strategic action.

Table 5.3 Governance functions to implement institutional framework for KIP (WRD1–Strategic Action 2)

GOVERNANCE FUNCTIONS	OBJECTIVES	ACTOR INVOLVEMENT	ROLE AND LEADERSHIP
Policy framing (PF)	Realise the need for organisational framework with legal authority to improve the operation and management of the KIP	• Federal: DoWRI • Basin/Province: KIP	• DoWRI should take lead in formulating any new provisions that are legally binding
Resource mobilisation (RM)	Mobilise resources for creating new legal provision, rule formation as well as conflict resolution mechanisms	• Federal: DoWRI • Basin/Province: KIP	• DoWRI should take overall lead
Actor constitution (AC)	Establish a new apex body	• Federal: DoWRI • Basin/Province: KIP • Local: WUA and Municipalities	• DoWRI
Rule or institution making (IM)	Create new set of rules and enforcement mechanisms	• Local: WUA and Municipalities	• WUAs should lead in making rules relevant to their branch or tertiary canals. Municipalities could play a facilitating role.
Conflict resolution (CR)	Enforcement of the water allocation and operation and maintenance rules	• Local: WUA including Main Canal Committees for both Eastern and Western Main Canals, and Municipalities	• WUAs should lead in coordination with Municipalities.
Monitoring and evaluation (ME)	Required to ensure that new rules are followed and enforced.	• Province or Basin: KIP • Local: WUA and municipalities	• KIP could lead, with support from WUAs to ensure enforcement at local level

5.3.5 Strategic Action 3: Capacity building

This strategic action focusses on policies and actions that are required in addition to the overarching, statutory institutional framework proposed above. Capacity building at different levels is crucial to support practical actions to improve governance. Drawing upon the Strategic Action 2, the capacity building should focus within the federal, provincial and local governments.

The new apex body should have strong coordination and policy formulation capacity. This includes the capacity to formulate action plans to be implemented at the main canal, branch canal and minor canal levels. At the branch and minor canal levels, the focus should be on improving the capacity of the WUAs to enhance their skills in water allocation, operation and maintenance, as well as conflict resolution. Furthermore, increased engagement with stakeholders at different levels is needed to make users aware of their rights and obligations regarding irrigation management, under revised rules or laws. Table 5.4 summarises the governance functions for this strategic action.

Table 5.4 Governance functions to implement capacity building (WRD1–Strategic Action 3)

GOVERNANCE FUNCTIONS	OBJECTIVES	ACTOR INVOLVEMENT	ROLE AND LEADERSHIP
Policy framing (PF)	• Formulate new policies and necessary actions to enhance the capacity and increased engagement of users	• Federal: DoWRI • Basin/Province: Provincial Ministries, KIP	• DoWRI should take lead in formulating any supporting policies
Resource mobilisation (RM)	• Mobilise resources for creating new supporting policies and actions	• Federal: DoWRI • Basin/Province: Provincial Ministries, KIP	• DoWRI should take the overall lead
Rule or institution making (IM)	• Create new set of mechanisms for capacity building and increased engagement	• Local: WUA and Municipalities	• WUAs should take lead in capacity building at local level, Municipalities could play facilitating role in this case.
Conflict resolution (CR)	• Facilitate engagement of actors in systems operation and management	• Local: WUA including Main Canal Committees for both Eastern and Western Main Canals, and Municipalities	• WUAs should take the lead in coordination with Municipalities
Monitoring and evaluation (ME)	• Required to ensure that new actions related to capacity building and engagement are implemented.	• Province or Basin: KIP • Local: WUA and municipalities	• KIP could lead • WUAs support is crucial to ensure implementation at local level

5.3.6 Summary

Revitalisation of the KIP will require comprehensive planning (Strategic Action 1). An institutional framework involving a new apex body (Strategic Action 2) could significantly improve the performance of the KIP through enhanced coordination across minors/branches and main canals.

A key requirement for the success of these main actions will be participatory irrigation management, that is, user involvement in all aspects of irrigation management (Playán et al. 2018). The active involvement of local institutions, particularly the WUAs, is crucial for improving the performance of the irrigation system (Bastakoti et al. 2010). Rules allowing WUAs to operate with increased autonomy may ensure better collective action in irrigation management (Bastakoti and Shivakoti 2012). WUAs have key responsibilities not only with respect to local level monitoring and evaluation, and conflict resolution, but also in formulating specific rules for the management of branch or tertiary canals.

Capacity of WUAs needs to be improved to enable farmers and their representatives to participate effectively (Strategic Action 3). Other areas such as access and utilisation are also equally important. For a given volume of available water, improving access and equitability between the head-end and tail-end of secondary branch canals is crucial. Such issues should be addressed with necessary infrastructure improvements (e.g. water control structures), as well as through addressing the problem of under-investment in operation and maintenance of secondary branch canals. Furthermore, there is a need to invest in agricultural knowledge and innovation systems to shift agricultural practices to more water productive crops through developing appropriate technology and practices.

5.4 WRD Option 4: Development of an inter-basin water transfer scheme

5.4.1 Background

The idea of diverting water from the Sunkoshi River to the Kamala River to increase water availability in the dry season was first proposed in the 1970s, and elaborated by JICA (JICA 1985) (Chapter 4). An inter-basin transfer (IBT) is a high up-front cost water resources development option, with multiple desirable and undesirable impacts. The option has high political, institutional, and technical complexity. Uncertainties about the degree and distribution of impacts add to that complexity. This section provides advice on the processes and structures required to take a decision on whether or not to proceed with developing an IBT.

The advice in this section shares key features in common with the advice presented for development of small or medium reservoirs (Section 5.6). It is recommended the development of a sustainability assessment framework (SAF) to guide knowledge production, as well as new structures (i.e., an interprovincial organisation or platform).

5.4.2 Strategic Actions and institutional arrangements

The following set of Strategic Actions are proposed to support well-governed decision-taking regarding whether or not to proceed with an IBT:

- WRD4 Strategic Action 1: Establish a sustainability assessment framework for approval of infrastructure
- WRD4 Strategic Action 2: Co-produce knowledge to inform decision making
- WRD4 Strategic Action 3: Establish mechanisms for intergovernmental cooperation.

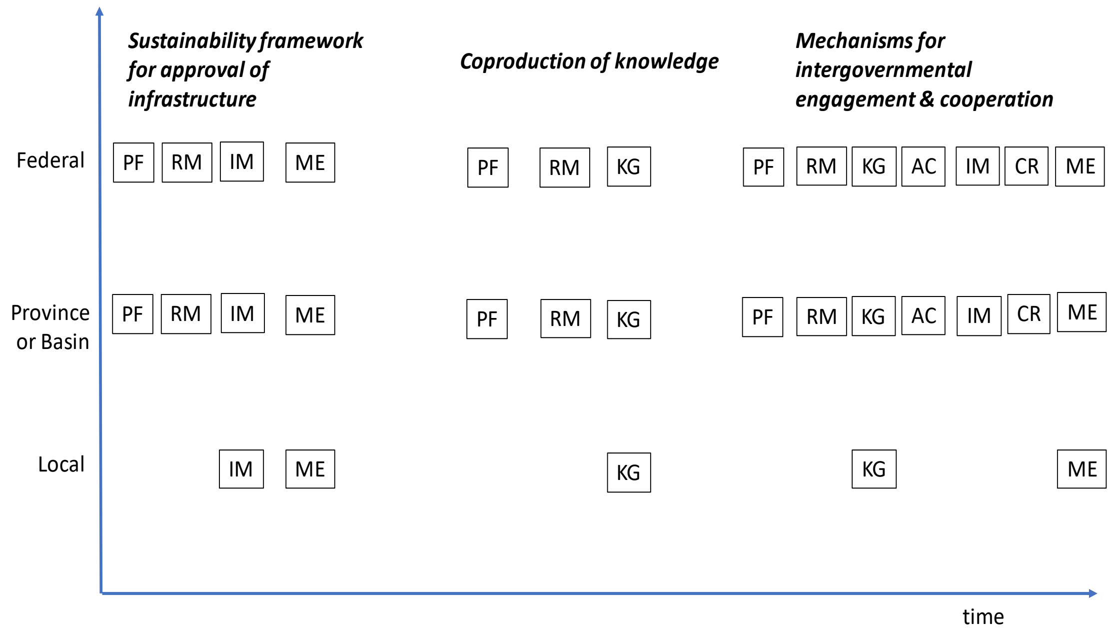

Figure 5.2 Strategic actions and governance functions for inter basin water transfer

Note: Governance functions: PF = Policy framing; RM = Resource or organisational mobilisation; KG = Knowledge generation; AC = Actor constitution; IM = Rule or institution making; CR = Conflict resolution; and ME = Monitoring and evaluation

5.4.3 Strategic Action 1: Establish a sustainability assessment framework for approval of infrastructure

In Nepal, large projects are currently examined on a case-by-case basis by government committees. The GoN may wish to consider the development of a consistent national sustainability assessment framework (SAF) for technical and policy assessment of major water supply infrastructure, including IBT, that could be applied to all proposed and potential future schemes. Incorporating a requirement for such a framework into legislation would encourage confidence of funders, investors and the community in the process. A statutory head power to create and apply such a framework could be provided in national legislation for assessment and approval of major development projects (Dyson et al., 2020). While a basis in law is recommended, a sustainability framework to assess the proposed Sunkoshi-Kamala IBT can be developed and applied without a statutory head power. If so, the SAF serves as an instrument of collaborative governance (Section 5.6.4).

This Strategic Action has comparable objectives and governance functions to the SAF proposed to guide decision-making around small–medium storages in the Kamala Basin (Table 5.12, Section 5.6.4). However, for an IBT, it is necessary for federal agencies to assume greater responsibility for leadership in policy framing and resource mobilisation. For knowledge production, it is recommended that provincial actors lead, with technical support from federal agencies. Compared to small–medium reservoir development (Table 5.13), actors such as the Koshi Basin Watershed Centre, and the Department of Electricity Development (DoED) have important contributions to make to framing, mobilisation, and knowledge generation.

The level of scrutiny attached to a framework adequate to assess an IBT will be high because of the complexity and risks discussed above. It is recommended that the World Commission on Dams (2000), Mekong River Commission Rapid Sustainability Assessment Tool (MRC et al. 2016) and the Hydropower Sustainability Assessment Protocol (International Hydropower Association 2010) be used as references for the design of the framework.

Importance of knowledge coproduction. Because of the risks and uncertainties associated with large infrastructure projects, stakeholders will expect studies produced to respond to their specific concerns and interests (i.e. be relevant); incorporate their perspectives and knowledge (be legitimate); and be scientifically credible.

One way to improve the relevance and legitimacy of studies produced is to use a co-productive mode of decision-making in planning. In this model, multiple state and non-state actors build knowledge together via processes they regard as credible, legitimate, relevant, leading in turn to outcomes they value – in this case, a series of findings which guide multi-stakeholder deliberation, leading to a recommendation or decision regarding the development of an IBT.[29] Deliberation refers to dialogue and reasoned argumentation, organised to generate advice on a set of alternative development strategies or options (Foran et al. 2019).

Table 5.5 summarises the governance functions for this strategic action.

Table 5.5 Governance functions to implement sustainability assessment framework (WRD4–Strategic Action 1)

GOVERNANCE FUNCTIONS	OBJECTIVES	ACTOR INVOLVEMENT	ROLE AND LEADERSHIP
Policy framing (PF)	• Create a conducive environment to formulate (design) the framework	• Federal: WECS, Department of Electricity Development (DoED), DoWRI • Province or Basin: Koshi Basin Watershed Centre, Provincial ministries, Soil and Watershed Management Offices	• Federal agencies could lead the process
Resource mobilisation (RM)	• Ensure availability of manpower and necessary resources to design the framework and participate in consultation	• As above	• As above
Knowledge generation (KG)	• See Strategic Action 2 (Section5.6.4)		
Rule or institution making (IM)	• Agree on how the framework and knowledge will inform decision-making	• As above	• As above
Monitoring and evaluation (ME)	• Ensure that local issues and local knowledge are integrated into design of framework • Evaluate the utility of the framework	• Local: Municipalities, Community Based Organisations and NRM groups	• Municipalities take lead on local knowledge integration • WECS lead on framework evaluation

5.4.4 Strategic Action 2: Co-produce knowledge to inform decision making

The SAF designed in Strategic Action 1 guides how knowledge will be used in decision-making. This Strategic Action implements processes of knowledge generation (i.e., the production of specific studies).

[29] By contrast, in a 'rational choice' mode of decision-making, a narrower group of high-level policy actors processes information provided by stakeholders and experts, and maximizes societal welfare on the basis of such inputs (Foran et al. 2019).

The topics relevant to decision-making about development of an IBT are wide-ranging. Section 5.6.4 lists some important ecosystem-related topics relevant to decision making.

Table 5.6 provides examples of additional cross-cutting topics. Discussion of such topics is provided in the following frameworks: WCD (2000), RSAT (Mekong River Commission et al. 2016), and HSAP (International Hydropower Association 2010).

Table 5.6 Cross-cutting topics to inform decision-making on major water infrastructure development

TOPIC	DESCRIPTION / EXAMPLE	REFERENCE
Comprehensive options assessment	Impartial consideration of range of demand- and supply-side options for meeting water demand ('integrated resource planning')	WCD RSAT HSAP
International transboundary issues	Prior framing of Sunkoshi – Kamala Diversion as one component of a joint Nepal-India water resources development plan Claims for transboundary benefit sharing	RSAT
Benefit sharing	Ability to reach agreement on type and level of benefits that should be shared with different categories of affected people, including women, marginalised groups and indigenous people	HSAP
Distribution of economic, social, and ecological impacts	Distribution of impacts, costs and benefits between basins; between people pursuing different livelihood strategies	HSAP RSAT
Water resource variability and change	Reliability of hydrological resource, including under climate change	
Financial viability	Ability of project to invest in programs to mitigate negative social and environmental impact Uncertainty in project investment cost	

The ability of an IBT to deliver net economic, social, and environmental benefits should be considered under a number of alternative scenarios (e.g. a drier climate; increased allocation of Sunkoshi water resources, or compensatory benefits to users or uses outside Kamala Basin; and underestimation of investment costs). In addition to sensitivity analysis, the use of exploratory scenario thinking is recommended, as demonstrated in Chapter 4.

Table 5.7 summarises the governance functions for this strategic action.

Table 5.7 Governance functions to implement knowledge production (WRD4–Strategic Action 2)

GOVERNANCE FUNCTIONS	OBJECTIVES	ACTOR INVOLVEMENT	ROLE AND LEADERSHIP
Policy framing (PF)	• Suggest the thematic studies and assessments	• National/Federal: WECS, DoED, DoWRI; Academics • Province or Basin: Koshi Basin Watershed Centre, Provincial ministries, Soil and Watershed Management Offices • Local: Municipalities, NGOs, CBOs	• Federal agencies could lead the process
Resource mobilisation (RM)	• Ensure key governments have adequate capacity to conduct studies • Ensure adequate participation of non-specialists in production of knowledge, building capacity where needed	• Federal: WECS, DoED • Province or Basin: Koshi Basin Watershed Centre, Provincial ministries, Soil and Watershed Management Offices	• Federal agencies could lead the process
Knowledge generation (KG)	• Thematic studies of impacts; informed by scenario thinking	• Province or Basin: Koshi Basin Watershed Centre, Provincial ministries, Soil and Watershed Management Offices • Local: Municipalities	• Provincial actors should lead

Importance of capacity building. The participation in knowledge production of people who are not technical specialists, as recommended in this section, requires adequate capacity building (Section 5.3.5). Such capacity building should be a joint responsibility of the lead federal and provincial agencies. The river basin multi-stakeholder platform (recommended in Section 5.6.4) is a structure that supports such capacity building.

5.4.5 Strategic Action 3: Establish mechanisms for intergovernmental cooperation

The Sunkoshi–Kamala IBT scheme will affect communities in 3 provinces. The federal government as well as governments in Provinces 1, 2 and 3, and numerous local governments, all have legitimate interests in all stages from deciding whether to proceed with the diversion scheme, design and construction, and the subsequent water sharing, operations and maintenance of the scheme.

This Strategic Action proposes that a Koshi RBO be established to support such decision-making, and to resolve conflicts that may arise between governments. This Action is similar in intent to our recommendation to establish a Kamala RBO to govern approval of small–medium projects within the Basin (Section 5.6.5).

Even if the IBT were to be assessed and approved entirely under Federal law, a mechanism for intergovernmental engagement and cooperation in the assessment phase is important (Dyson et al. 2020).

Since the proposed IBT is currently a part of larger Saptakoshi High Dam Multipurpose Project (Government of Nepal, Saptakoshi High Dam Multipurpose Project, Project Description), the decision to proceed with this project in its current form requires consultation with the Government of India. Therefore, one option could be to separate this project from the larger Saptakoshi project and proceed with a standalone project. In such a case, as expressed by one of the experts, assuming no objection from India, the IBT could be approved and funded by the federal government. As noted also in Section 4.6, this proposed development is one of several proposals for major dams, diversion works and multi-purpose projects in the Koshi Basin.

In order to manage the hydroelectricity component of this project, some experts interviewed for this section advised that the best idea would be to create a separate entity in the form of a Public Company including shares of federal, provincial and local governments, in addition to the public. Such an entity could be beneficial to all the tiers of government and helpful in ensuring intergovernmental cooperation. Experts advised that the irrigation component should be managed through the Department of Water Resource and Irrigation.

Table 5.8summarises the governance functions to implement intergovernmental structures.

Table 5.8 Governance functions to implement intergovernmental structures (WRD4–Strategic Action 3)

GOVERNANCE FUNCTIONS	OBJECTIVES	ACTOR INVOLVEMENT	ROLE AND LEADERSHIP
Policy framing (PF)	• Ensure governments from all levels show interest in intergovernmental structure (e.g. Koshi river basin organisation)	• Federal: WECS, DoED, DoWRI • Province or Basin: Koshi Basin Watershed Centre, Provincial ministries, Soil and Watershed Management Offices	• Federal agencies could lead the process
Resource mobilisation (RM)	• Ensure availability of resources to co-design intergovernmental engagement processes	• Federal: WECS, DoED, DoWRI • Province or Basin: Koshi Basin Watershed Centre, Provincial ministries, Soil and Watershed Management Offices	• As above
Knowledge generation (KG)	• Assess capacities and conditions required for cooperation among provincial governments	•	• As above
Actor constitution (AC)	• Establish organisation to support intergovernmental decision making • Deliberate on operation and management of hydroelectricity component of IBT	• Federal: WECS, DoWRI • Federal: WECS, DoED	• Federal: WECS, DoWRI • DoED
Rule or institution making (IM)	• Create rules and processes for cooperation	• Federal: WECS, DoED, DoWRI • Province or Basin: Koshi Basin Watershed Centre, Provincial ministries, Soil and Watershed Management Offices • Local: Municipalities, CBOs	• Federal actors lead
Conflict resolution (CR)	• Manage any potential tension in upstream-downstream areas	• Province or Basin: Koshi Basin Watershed Centre, Provincial ministries, Soil and Watershed Management Offices • Local: Municipalities, CBOs	• Provinces take lead
Monitoring and evaluation (ME)	• Ensure that local issues and local knowledge are integrated	• Federal: WECS, DoED, DoWRI • Local: Municipalities, CBOs	• Federal and municipalities jointly

5.4.6 Summary

An inter-basin transfer (IBT) is a high up-front cost water resources development option, with high political, institutional, and technical complexity. This section provided advice on the processes and structures required to take a decision on whether to proceed with developing an IBT.

Such a decision should be the outcome of a transparent and well-informed deliberative process, in which representatives of multiple interested parties participate. Such deliberation requires specific knowledge production and communication processes (Strategic Actions 1 and 2), as well as organisational structures capable of supporting engagement, collaboration, and conflict resolution among responsible authorities and non-state actors (Strategic Action 3). Investing in deliberative processes and supporting structures will allow governance of large projects to move from case-by-base decision making by government committees.

5.5 WRD Option 2: Sustainable utilisation of groundwater

5.5.1 Background

The downstream part of the Basin has potential to utilise groundwater resources sustainably for agricultural and non-agricultural uses. Availability and sustainable use are key concerns in the Terai given the importance of groundwater for multiple uses. In the Terai, groundwater is available in the near and medium term (e.g. it could support irrigation of 9,250 ha of land in the KIP; Section 2.2). However, if exploitation increases (in order to supplement monsoon rainfall, and increase dry season cropping) concerns may arise with localised depletion, possibly impacting on domestic water, and with long-term sustainability.

Affordable access to groundwater resources is another concern. Groundwater access via shallow tube wells (STW) is a rapidly deployable option, but not always affordable particularly for smallholder farmers. This is because of high costs of installation as well as energy costs (most STW pumps are powered by diesel or kerosene) as well as monopolistic rental markets (Bastakoti et al. 2017). There has also been some concern about groundwater quality, particularly water with high iron content is not suitable for drinking purpose, mainly in the areas close to the banks of the Kamala River (field interviews, May 2019). Arsenic contamination is also known to compromise water quality in Dhanusha district including in locations close to the river (WECS and CSIRO 2020; Section 2.9).

During the Development Pathways phase, participants proposed one Action, to '*promote conjunctive use of surface and groundwater*' (Table 3.2). The concept of '*conjunctive use*' refers to: '*the planned and coordinated management of surface and groundwater, so as to maximise the efficient use of total water resources*' (De Wrachien and Fasso 2002). It is considered a means to increase overall resilience of water supply in river basins with high seasonal variability in water supply, including in situations where surface or groundwater alone are inadequate to meet water demands (De Wrachien and Fasso 2002, Bertule et al. 2018). Section 4.5 analysed water availability from the combined use of groundwater from shallow tube wells during the dry season, and use of KIP surface water during the wet and dry seasons.

In this section, the described Strategic Actions are necessary components for the sustainable management of groundwater, which in turn provides the foundation for future elaboration of conjunctive use strategies. Infrastructural interventions to recharge aquifers (e.g. Khan et al. 2014) will require additional analysis and formulation of Strategic Actions beyond the scope of this document.

5.5.2 Strategic Actions

The following initial set of Strategic Actions are proposed for sustainable use of groundwater:

- WRD2 Strategic Action 1: Establish a registry of all groundwater wells and estimate current volume of use
- WRD2 Strategic Action 2: Establish a user-oriented groundwater monitoring system
- WRD2 Strategic Action 3: Develop rules to establish extraction limits in different parts of the Basin.

Strategic Action 1 and Strategic Action 2 are components of a water information system. Knowledge of usage and sustainable limits (contributed by Strategic Actions 1 and 2) is required to adapt rules over time.

Key governance functions to implement the Strategic Actions are summarised in Figure 5.3. The Figure shows how the development of formal rules to regulate levels of groundwater extraction at locations which are sensitive (ecologically, or with respect to water contamination) requires prior action to establish monitoring and evaluation systems at local and basin level.

In this document, 'basin level' refers to governance actions targeting multiple localities in the river basin, and referring to the river basin as a concept. It is not a formal level of governance.

Although Figure 5.3 shows a linear sequence, once all 3 Strategic Actions are initiated, they would interact closely, in a cyclic manner. For example, the user-oriented monitoring system (Strategic Action 2) is intended to empower users to monitor local use, and raise awareness among local actors of local use (Maheshwari et al. 2014). This should improve user compliance with extraction limits (Strategic Action 3).

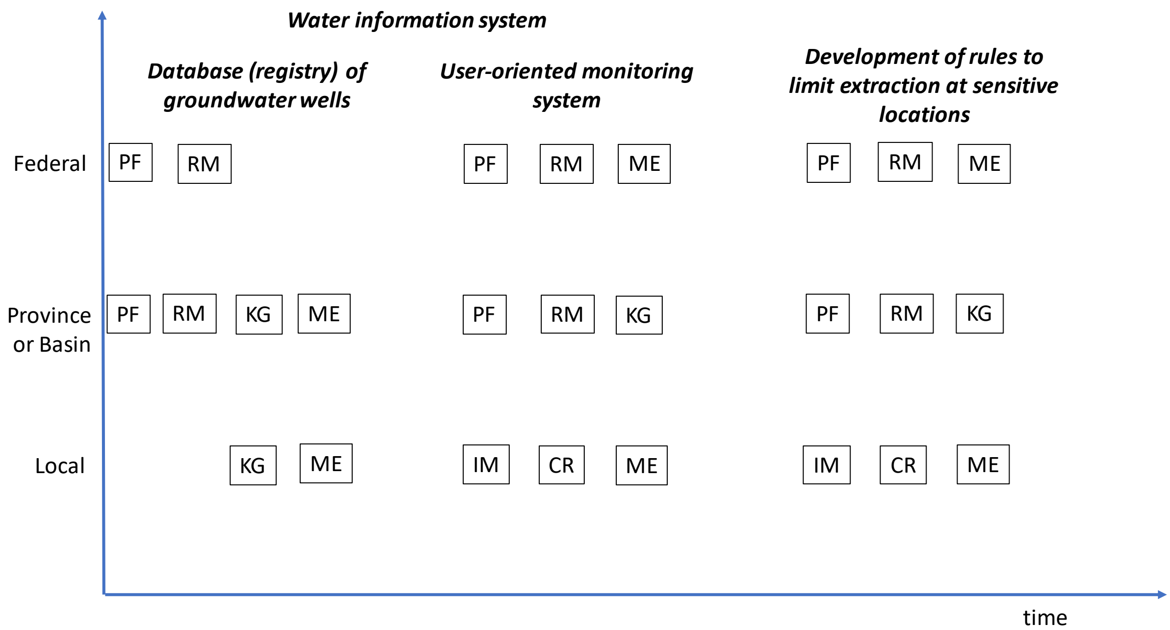

Figure 5.3 Strategic actions and governance functions for sustainable utilisation of groundwater

Note: Governance functions: PF = Policy framing; RM = Resource or organisational mobilisation; KG = Knowledge generation; AC = Actor constitution; IM = Institution or rule making; CR = Conflict resolution; and ME = Monitoring and evaluation

5.5.3 Strategic Action 1: Establish a database (registry) of groundwater wells

The *National Water Resource Policy 2020* (Government of Nepal, Ministry of Energy, Water Resource & Irrigation 2020). proposes that all persons, including a water user association, require a permit to drill a well. The Policy proposes that permits for deep wells (confined aquifer) can be granted by the province and permits for shallow wells (unconfined) can be granted by the local level.

These policy elements suggest a need to first establish a database of all groundwater wells in the basin. This database could be a component of a water information system. Over time, with the implementation of Strategic Actions 2 and 3, the database may include additional components such as operating hours of pumps, water extraction volume, water level, water quality and number of agricultural and non-agricultural users. Likewise, the database can evolve into a formal registry of licensed or permitted wells. Incentives for users to register wells (and supply usage information) will need to be carefully considered during policy framing.

The Groundwater Resources Development Board (GWRDB) is a key actor at the federal level. GWRDB has a well-equipped laboratory in its central office and has eight branches across the Terai, one in the Kamala basin. GWRDB is responsible for identification of Nepal's groundwater potential, as well as regular monitoring of water level fluctuations, groundwater reserves and water quality. However, its human resources are limited compared to its mandate. The federal DoWRI has a groundwater division responsible for facilitating use of groundwater for agriculture.

Table 5.9 summarises the governance functions for this strategic action. Federal level agencies are pivotal for policy framing and resource mobilisation. Knowledge generation requires collaboration between basin level and local level organisations. Basin level agencies should lead on methodology and technical analysis. Municipalities and water user groups should cooperate on information provision. Local level groundwater monitoring is described in Strategic Action 2 below.

Table 5.9 Governance functions to implement a groundwater database (WRD2–Strategic Action 1)

GOVERNANCE FUNCTIONS	OBJECTIVES	ACTOR INVOLVEMENT	ROLE AND LEADERSHIP
Policy framing (PF)	• Create a conducive environment to design the database (registry)	• Federal: Groundwater Resources Development Board (GWRDB) and DoWRI • Province or Basin: Provincial Ministries, GWRDB regional office	• GWRDB should lead this function
Resource mobilisation (RM)	• Ensure availability of manpower and necessary resources to design the database	• Federal: GWRDB and DoWRI • Province or Basin: Provincial Ministries, GWRDB regional office	• Agencies at both levels should contribute
Knowledge generation (KG)	• Supply information to database	• Local: Municipalities and tube well groups, individual users	•
Monitoring and evaluation (ME)	• Evaluate database (e.g. efficiency, effectiveness)	• Province or Basin: Provincial Ministries, GWRDB regional office • Local: Municipalities and tube well groups	• Provincial actors should take lead

5.5.4 Strategic Action 2: User-oriented groundwater monitoring system

This strategic action focuses on establishing a user-oriented groundwater monitoring system. The system would encourage local users to contribute data on local well and relevant surface water storages levels, and water quality. By doing so, it can raise awareness among local people of possible external impacts of over-use. Local actors would create rules to implement the monitoring. Improved knowledge among users and authorities of specific local use could contribute to conflict resolution.

The monitoring system is a quantitative way to establish limits of extraction aiming at sustainable use of the resource. Therefore, this strategic action is also a means to generate compliance with withdrawal limits (Strategic Action 3), as well as contribute knowledge required to establish any permit-based system to regulate existing and new wells. Table 5.10 summarises the governance functions for this strategic action.

Table 5.10 Governance functions to implement user-oriented groundwater monitoring (WRD2–Strategic Action 2)

GOVERNANCE FUNCTIONS	OBJECTIVES	ACTOR INVOLVEMENT	ROLE AND LEADERSHIP
Policy framing (PF)	• Raise awareness about importance of regular monitoring	• Federal: GWRDB and DoWRI • Province or Basin: Provincial Ministries, GWRDB regional office	• GWRDB should lead this function but with key contribution from provincial actors
Resource mobilisation (RM)	• Establish system for monitoring of groundwater at local level	• Federal: GWRDB and DoWRI • Province or Basin: Provincial Ministries, GWRDB regional office	• Agencies at both levels should contribute.
Knowledge generation (KG)	• Provide necessary techniques that can be used in regular monitoring to quantify groundwater resource and respective use	• Province or Basin: Provincial Ministries, GWRDB regional office	• Provincial actors should take lead
Rule or institution making (IM)	• Create specific local rules and procedures for monitoring	• Local: Municipalities and DTW/STW groups, individual users	• Municipalities could play key role
Conflict resolution (CR)	• Mitigate potential misunderstandings among the users	• Local: Municipalities and DTW/STW groups, individual users	• Municipalities could play key role
Monitoring and evaluation (ME)	• Ensure regular monitoring as specified in the protocol • Monitor	• Federal: GWRDB and DoWRI • Local: Municipalities and DTW/STW groups, individual users	• Local level should play key role, federal actors have minimal role in monitoring except create the monitoring mechanism

5.5.5 Strategic Action 3: Develop rules to establish extraction limits in different parts of the Basin

In the future, demand for groundwater may increase for both agricultural and non-agricultural uses. Consequently, it is necessary to establish rules to restrict volumes of water extracted for different locations, based on estimates of sustainable levels of groundwater use.

Such estimates would require an updated assessment of Terai groundwater resources. The assessment would be informed by the registry of wells (Strategic Action 1) and the local monitoring system (Strategic Action 2).

Federal actors could play key roles in policy framing and resource mobilisation, particularly to carry out the technical analysis (knowledge generation) needed to define rules. The role of basin and provincial level actors is also very important for such knowledge generation (Table 5.11).

Once the overall monitoring and evaluation system is designed (with leadership from GWRDB), local actors would play a leading role in managing the user-oriented monitoring and evaluation system (Strategic Action 2). Municipalities, user groups as well as individual users have a crucial role in ensuring that the groundwater withdrawal meets the restrictions agreed. Therefore, implementing this Strategic Action requires strong, cross-level cooperation among multiple actors. Table 5.11 summarises the governance functions for this strategic action.

Table 5.11 Governance functions to implement groundwater extraction limits (WRD2–Strategic Action 3)

GOVERNANCE FUNCTIONS	OBJECTIVES	ACTOR INVOLVEMENT	ROLE AND LEADERSHIP
Policy framing (PF)	• Raise awareness about the need of restrictions in withdrawal limit	• Federal: GWRDB and DoWRI • Province or Basin: Provincial Ministries, GWRDB regional office	• GWRDB should lead this function
Resource mobilisation (RM)	• Facilitate to establish conditions to restrict the groundwater withdrawal	• Federal: GWRDB and DoWRI • Province or Basin: Provincial Ministries, GWRDB regional office	• Agencies at both levels should contribute.
Knowledge generation (KG)	• Detailed mapping of groundwater storage/availability and sustainable yield at different locations • Generate other information required for setting the restrictions for withdrawal & regulation of drilling	• Province or Basin: Provincial Ministries, GWRDB regional office	• Provincial actors should take lead
Rule or institution making (IM)	• Create rules for withdrawal limit • Create rules for conditions to allow well drilling	• Local: Municipalities and DTW/STW groups, individual users • Province or Basin: Provincial Ministries, GWRDB regional office	• Municipalities could play key role
Conflict resolution (CR)	• Reduce tension among the users	• Local: Municipalities and DTW/STW groups, individual users	• Municipalities could play key role
Monitoring and evaluation (ME)	• Ensure that well drilling, and groundwater withdrawal meets the stipulated environmental and social restrictions	• Federal: GWRDB and DoWRI • Local: Municipalities and DTW/STW groups, individual users	• Local level should play key role, federal actors have minimal role in monitoring (except to create the monitoring mechanism)

With respect to rule making, 'distance rules' specifying the minimum distance from groundwater extraction to sensitive sites and ecosystems could be used to minimise local-scale impacts between nearby users and uses. Such rules should be established based on a technical analysis that maps the sensitive locations and estimates levels of sustainable groundwater extraction. Establishing management zones (i.e. areas where specific rules will apply) could be another option. Such rules could be designed as precautionary policy instruments informed by available knowledge and revised as knowledge of the groundwater resource at regional and local scale improves.

5.5.6 Summary

This section focussed on how to govern and regulate the use of groundwater within sustainable limits, thereby laying foundations for the future development of conjunctive use strategies. A set of 3 Strategic Actions was proposed, with key governance functions and responsible actors.

The 3 Actions are designed to interact and support each other over time. The water information system (i.e. the database in Strategic Action 1, and the user-oriented monitoring system in Strategic Action 2) contribute to the setting of rules (Strategic Action 3), in a manner that includes high user participation. Over time, such rules can be revised to include formal licensing or permitting. High levels of cooperation among multiple actors across different levels of governance will be necessary, as well as capacity building of local actors.

The sustainable use of groundwater will require the formulation of additional strategic actions to improve affordable access to groundwater.

5.6 WRD Option 3: development of small or medium storages

5.6.1 Background

The strategic actions in this section respond to challenges associated with sustainable development of small and medium storages in the upper Kamala Basin. Under the 2015 Constitution and subsequent legislation, elected local governments have authority to approve and construct small-scale water storage infrastructure. This has led in some instances to the rapid development of such infrastructure in the upper Basin, which was observed during the field visits. A central database for such projects does not exist.

The devolution to local government of funding and authority to implement such projects has the advantage of meeting local needs in a time-responsive manner. A notable feature of the projects observed was their low construction cost relative to estimates provided by a range of experts interviewed by the project team to inform a multi-criteria analysis capacity building workshop in May 2019 [30]. However, the cumulative impacts of such projects are not yet understood, particularly during low-flow periods. Given the Basin's high sediment generation and transport, additional concerns may arise with their operational sustainability, which would require actions to reduce sediment

[30] It should be noted that the actual construction cost may be much lower than cost estimates used for the MCA. Please refer to Chapter 4 for related analysis. Interviews conducted with local government officials in May 2019 revealed that small reservoirs under construction in Katari Municipality of Udaypur district could cost from ~NPR2.5 million (for a 50–60 m long dam with a dam height of ~13 m) to ~NPR4.5 million (80 m dam, dam height ~12 m)

transportation in the upper parts of the tributaries that contribute to the storages. An overall assessment framework to guide the approval of existing and new storages does not exist.

Constitutional provisions indicate that local governments have authorities to approve or reject small to medium reservoirs. However weak coordination of assessment and decision making could result in upstream–downstream conflicts, which requires intergovernmental cooperation (Strategic Action 3).

5.6.2 Strategic Actions

The following initial set of strategic actions are proposed for sustainable development of small and medium storages:

- WRD3 Strategic Action 1: Establish a database (registry) of existing and planned small and medium storages
- WRD3 Strategic Action 2: Establish a sustainability assessment framework for approval of new storages
- WRD3 Strategic Action 3: Establish mechanisms for intergovernmental engagement and cooperation.

Key governance functions to implement each strategic action are summarised in Figure 5.4.

The sustainability framework recommended in this section is also a recommended action for the development of an inter-basin transfer (Section 5.4).

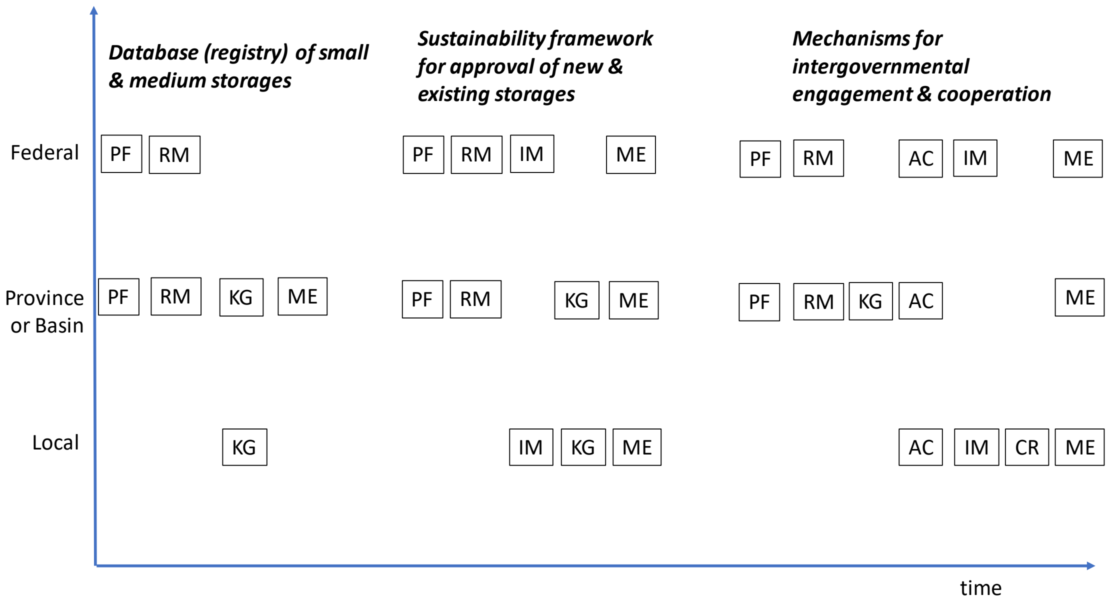

Figure 5.4 Strategic actions and governance functions for building small or medium reservoirs

Note: Governance functions: PF = Policy framing; RM = Resource or organisational mobilisation; KG = Knowledge generation; AC = Actor constitution; IM = Rule or institution making; CR = Conflict resolution; and ME = Monitoring and evaluation

5.6.3 Strategic Action 1: Establish a database (registry) of existing and planned small and medium storages

This strategic action involves establishing a database (registry) of all existing and planned small and medium storages, including key design parameters and operating rules. This database is a key element of an information system. The information system will support the further generation of knowledge which is required under the sustainability framework proposed in Strategic Action 2 below.

After federal and provincial agencies provide technical capacity building, local governments should lead contributions to the database. Technical agencies should evaluate the database (compare to WRD2–Strategic Action 1). The governance functions required to implement this action are similar to those required to establish a database of groundwater wells, except that the lead federal actor is DoWRI.

5.6.4 Strategic Action 2: Establish a sustainability assessment framework for approval of new storages

The operation of existing storages, and the approval of new storages, should be guided by an integrated framework for impact assessment, planning, and regulation. It is referred to this as a sustainability assessment framework (SAF).

A SAF is essentially an instrument to support collaborative governance, not a regulatory (i.e. statutory) instrument. The main existing regulatory instrument is the *2019 Environment Protection Act*. The Act specifies a need to prepare a proposal for any development work that could have potential environmental impacts. In the proposal it is necessary to include detail analysis of possible adverse effects and provide alternatives that could be adopted to mitigate any such effects. Such analysis should adhere to the standards and quality determined by the Government of Nepal. Further, the analysis should also include preparation of environmental management plan.

The intent of a SAF is to inform consultation and negotiation among governments at different tiers and locations of the Basin, aimed at reaching agreement about the operation of existing storages, or a proposed project. A SAF should therefore guide the production or review of specific assessments (thematic studies). The specific assessments should describe significant environmental, social and economic impacts of proposed reservoirs, including the state of knowledge regarding impacts.

The methods used in this Strategy to identify options and assess their initial economic, social, and environmental impacts (Chapter 4) produce knowledge required to conduct a sustainability assessment. Beyond the techniques used and results shown in Chapter 4 of this Strategy, the following issues require additional analysis:

- expected change to connectivity and flow regimes under different reservoir development scenarios (e.g. high numbers of small storages)
- practical actions to reduce sediment generation and transport under different development scenarios
- requirement of living aquatic resources, terrestrial biodiversity, and associated ecosystems for particular connectivity and flow regimes
- the ability of specific dam designs to manage sediments and deliver environmental flows[31]
- contribution of living aquatic resources to livelihoods (e.g. status and trends of capture and culture fisheries)
- impacts on agriculture- and aquatic resource-dependent livelihoods under different scenarios (e.g. numbers of storages, alternative rules for allocation of water).

31 Environmental flows are essentially specific quantities (and qualities) of water released in a particular pattern over time from built infrastructure, which are designed to meet environmental and social objectives that require a particular flow regime.

An improved understanding of such topics, gained through thematic studies, will be of interest to multiple government and non-governmental actors.

Stakeholders in the Kamala Basin can refer to a number of existing SAF. The best known is the WCD framework (World Commission on Dams 2000). Two additional frameworks – the Hydropower Sustainability Assessment Protocol (HSAP; International Hydropower Association 2010) and the Basin-wide Rapid Hydropower Sustainability Assessment Tool (RSAT; Mekong River Commission et al. 2016) – were developed in collaboration between development donors, hydropower industry, and environmental and social NGOs. These frameworks offer a structured approach to assess performance of one or more reservoir projects for the topics listed above, and multiple other topics of interest to stakeholders. To date, assessments using such tools have been voluntary. However, they could form part of a collaborative approach in the Kamala Basin, in which local, provincial, and federal actors agree on assessment topics, and use such tools to guide the assessment, with each actor contributing knowledge.

One source of knowledge relevant to sustainability assessment is a River Basin Plan. The *2020 National Water Resources Policy* calls for such Plans to be produced periodically (MoEWRI 2020).

Additional sources of relevant technical knowledge are the *2020 Irrigation Master Plan* (DWRI 2020) and the current River Basin Planning (RBP) projects, supported by GoN, ADB and World Bank respectively.

Table 5.12 summarises the governance functions for this strategic action. It will require coordination across 3 levels of government, with specific responsibilities for WECS, provincial ministries, and municipalities. It is proposed that WECS should lead municipalities in a process to formulate and agree on a sustainability assessment framework (SAF). Provincial agencies provide essential knowledge inputs (i.e. specific assessments). Local governments need to adopt ('own') the SAF because of their authority to approve small–medium scale infrastructure.

Table 5.12 Governance functions to implement a sustainability assessment framework (WRD3–Strategic Action 2)

GOVERNANCE FUNCTIONS	OBJECTIVES	ACTOR INVOLVEMENT	ROLE AND LEADERSHIP
Policy framing (PF)	• Create a conducive environment to formulate (design) the framework	• Federal: WECS, Forest and Watershed Division of Ministry of Forestry and Environment • Province or Basin: Provincial ministries, Soil and Watershed Management Offices	• WECS could lead the process
Resource mobilisation (RM)	• Ensure availability of manpower and necessary resources to design the framework and participate in consultation	• Federal: WECS, Forest and Watershed Division of Ministry of Forestry and Environment • Province or Basin: Provincial ministries, Soil and Watershed Management Offices	• WECS could lead the process
Rule or institution making (IM)	• Agree on how the framework and knowledge will inform decision-making	• Local: Municipalities, Community Based Organisations	• District Coordination Committee and WECS jointly lead (supported by WECS)
Knowledge generation (KG)	• Guided by the framework, produce specific	• Federal: President's Chure Conservation Program	• Provincial actors should lead

GOVERNANCE FUNCTIONS	OBJECTIVES	ACTOR INVOLVEMENT	ROLE AND LEADERSHIP
	knowledge (e.g. thematic studies)	• Province or Basin: Provincial ministries, Soil and Watershed Management Offices • Local: Municipalities, Community Based Organisations	
Monitoring and evaluation (ME)	• Ensure that local issues and local knowledge are integrated • Evaluate the utility of the framework	• Local: Municipalities, Community Based Organisations and NRM groups • Province or Basin: As above • Federal: As above	• Municipalities take lead on local knowledge integration • WECS lead on framework evaluation

The provincial government agencies contribute by producing assessments on specific topics, either through existing human resources and/or through deploying consultants as necessary. Municipalities and other local groups have an explicit monitoring role to ensure that such studies respond to local issues, and that they integrate local knowledge. People with expertise on local resources and river systems are vital knowledge providers.

A SAF for the Kamala Basin should be transparent, have a statutory basis, and be graduated (Dyson et al. 2020). Transparency in this context means that sustainability assessment is conducted in a manner accessible and inclusive to non-state groups. A graduated (or 'scalable') framework is one in which the rigor of assessment and decision-making increases in proportion to what is known about the risk posed by a reservoir project/s. The development of a legal requirement for an SAF should be guided by prior multi-stakeholder experience in working with a framework.

Multi-stakeholder platform. The dissemination and review of thematic studies, or an overall sustainability assessment[32], could occur via an annual Kamala Basin multi-stakeholder platform. This is a proposed annual gathering and interaction of knowledge providers (specialists), with representatives of local, provincial, and federal organisations (state and non-state). The platform is a means to support 'knowledge coproduction' – that is, a participatory, collaborative approach to knowledge production (Section 5.4.3).

A multi-stakeholder platform could address issues of concern to river basin governance, not limited to small–medium storages. Representatives should include:

- members of federal parliament and members of provincial assembly from the districts within the basin
- representatives from municipalities
- senior officials from government departments including both federal and provincial offices, representatives from educational institutes
- representatives from development partners working in the basin
- farmers' representatives.

The platform could meet once a year and could be convened for a duration of 3 days. The first day of parliament could focus on discussing local knowledge on key issues supplemented with presentations

[32] 'Overall sustainability assessment' here refers to a review, guided by the SAF, of the *quality* of relevant thematic studies or information systems. Also known as 'sustainability audit'.

from local governments. The second day could include presentations from provincial and federal representatives and other stakeholders. The final day could discuss rewards and sanctions to improve management of the river basin and ends with identifying key issues for future action.

5.6.5 Strategic Action 3: Establish structures for intergovernmental engagement and cooperation

The implementation of Strategic Action 2 requires joint local, provincial, and federal action. It results in the development and application of an agreed framework for decision-making about small–medium storages.

Strategic Action 3 proposes that organisational structures be established to support such decision-making, and to resolve conflicts that may arise between local governments. These conflicts may relate to distribution of impacts between upstream and downstream users, or between water uses.

Additional structures for cooperative decision-making and conflict resolution will need to be at more than one level. A District Coordination Committee (DCC) may be able to support inter-municipal decision-making and conflict resolution within the same province. Since the Basin traverses 3 provincial boundaries, a multi-level structure (river basin organisation, RBO) appears necessary. This RBO would be a formal intergovernmental organisation, designed to support local and provincial governments to engage in joint action guided by the sustainability assessment framework (Strategic Action 2), influencing and improving decisions around approval and management of storages. Under the collaborative model of governance described in Strategic Action 2, an RBO could provide process and technical support to DCCs.

A RBO could likewise convene the Kamala Basin multi-stakeholder platform – i.e., the platform to support collaborative decision making – proposed in Strategic Action 2 above.

It is recommended that Water and Energy Commission Secretariat as the federal apex agency should coordinate with provincial, districts and local actors to establish new or enhanced organisations whose structures enable Strategic Actions 1 and 2.

Table 5.13 summarises the governance functions for this strategic action.

Table 5.13 Governance functions to implement intergovernmental structures (WRD3–Strategic Action 3)

GOVERNANCE FUNCTIONS	OBJECTIVES	ACTOR INVOLVEMENT	ROLE AND LEADERSHIP
Policy framing (PF)	• Ensure governments from all levels show interest in intergovernmental structure (e.g. Kamala river basin organisation)	• Federal: WECS, Forest and Watershed Division of Ministry of Forestry and Environment • Province or Basin: Provincial ministries, Soil and Watershed Management Offices	• WECS could lead process
Resource mobilisation (RM)	• Ensure availability of resources to co-design RBO	• As above	• As above
Knowledge generation (KG)	• Assess capacities and conditions required for cooperation	• Province or Basin: Provincial ministries, Soil and Watershed Management Offices • Local: Municipalities and CBOs contribute to assessment	• Provincial actors should lead

GOVERNANCE FUNCTIONS	OBJECTIVES	ACTOR INVOLVEMENT	ROLE AND LEADERSHIP
Actor constitution (AC)	• Establish RBO to support intergovernmental decision making	• Federal: WECS, Forest and Watershed Division of Ministry of Forestry and Environment • Province or Basin: Provincial ministries, Soil and Watershed Management Offices • Local: District Coordination Committee	• WECS could lead process
Rule or institution making (IM)	• Create rules and processes for cooperation (to be implemented by RBO or DCC)	• Local: Municipalities, Community Based Organisations	• District Coordination Committee and WECS jointly lead
Conflict resolution (CR)	• Manage any potential tension in upstream-downstream areas	• Local: District Coordination Committee, Municipalities, Community Based Organisations	• District Coordination Committee could lead
Monitoring and evaluation (ME)	• Ensure that local issues and local knowledge are integrated • Evaluate performance of RBO and DCC to support intergovernmental cooperation	• Federal: WECS, Forest and Watershed Division of Ministry of Forestry and Environment • Local: Municipalities, CBOs and NRM groups	• Municipalities lead • WECS and municipalities lead on performance evaluation

5.6.6 Summary

Local municipalities have mandate and resources as well as strong local interest to build small or medium reservoirs. Conflicts may arise if a variety of upstream–downstream, or cumulative impacts are not considered while taking decisions. In response, this Section has proposed a linked set of 3 Strategic Actions. Strategic Actions 1 and 2 will improve the knowledge of stakeholders and authorities about the cumulative environmental, social, and economic impacts of small–medium reservoirs. New organisational structures for intergovernmental decision-making are proposed in Strategic Action 3. These structures include the formation of a Kamala river basin organisation.

Together, these Actions help achieve an integrated (cross-sectoral) and collaborative (cross-organisational) approach to managing and planning existing and proposed storages in the Kamala Basin. In order to realise these Strategic Actions, effective joint action between local, provincial, and federal government is required.

5.7 Summary of strategic advice

The strategic advice to implement 4 WRD options, in an effective and sustainable manner, was based on an institutional and political economy analysis conducted by the project team.

Revitalisation of the KIP (Section 5.3) will require comprehensive planning (Strategic Action 1). An institutional framework involving a new apex body (Strategic Action 2) could significantly improve the performance of the KIP through enhanced coordination across minors/branches and main canals. To enable farmers and their representatives to participate effectively, the capacity of water user associations (WUAs) needs to be improved (Strategic Action 3).

To govern the use of groundwater within sustainable limits, a set of 3 Strategic Actions was proposed (Section 5.5). High levels of cooperation across different levels of governance is necessary. The sustainable use of groundwater further requires additional strategic actions to improve affordable access to groundwater. Sustainable use of groundwater is a pre-requisite for future development of conjunctive use strategies.

The recommendations for development of small–medium reservoirs (Section 5.6) and for development of an inter-basin transfer (Section 5.4) were similar with respect to recommended Strategic Action. In each case, it is advised to develop a sustainability assessment framework (SAF), guided by international precedents (Sections 5.4.3 and 5.6.4); generate knowledge, guided by the SAF, using a co-productive mode of decision making (Section 5.4.4); and establish river basin organisations to support intergovernmental cooperation in the Kamala and Koshi Basins of Nepal.

A recurring theme in this Chapter is the need for joint action across levels of government. The devolution of authority to approve small–medium infrastructure to local government means that additional capacity is required at the local, and basin level to plan, approve, and implement such infrastructure sustainably. Actors at the local and basin level (e.g. new RBO, provincial ministries) who are planning infrastructure will need specialist support from federal agencies (notably WECS) in order to design sustainability assessment frameworks, commission thematic studies, and set up new organisations (Sections 5.4- 5.6).

An inter-basin transfer is a complex and long-term option. Prior to its approval or development, it will be necessary to implement options such as revitalisation of the KIP, sustainable groundwater governance, and basin-wide planning of small–medium storages. The prior implementation of these options will allow local, state, and federal actors to gain important experience establishing the processes and organisational structures necessary to develop an IBT in a sustainable manner.

6 Strategies to sustainably manage and conserve the Chure landscape

6.1 Background

In 2018, participants in the Kamala Basin Initiative identified the '*sustainable management of Chure and its natural resources for livelihood support and reduced vulnerability from water-induced disasters*' as one of their primary development goals (Goal 1; Section 3.1). The participants further identified several major on-ground actions to meet this goal, for example, improving conservation–livelihood linkages, and protecting gullies at the Chure head (Section 3.1).

To support the delivery of such on-ground action, the project team has formulated a set of 4 Strategic Actions:

- **Chure Strategic Action 1**: Develop a new policy framework and basin-level Strategy to guide watershed protection planning and investments
- **Chure Strategic Action 2**: Conduct annual planning, prioritisation and implementation of watershed conservation actions
- **Chure Strategic Action 3**: Improving conservation-livelihood linkages
- **Chure Strategic Action 4**: Regulation for sustainable riverbed extraction.

This Chapter provides advice on how to implement each of the 4 Strategic Actions in an effective and sustainable manner (Sections 6.4 to 6.7).

Each Chure Strategic Action is described as a series of 'governance functions', for which responsible actors are proposed. The advice is based on an institutional and political economy analysis conducted by the project team, based on methods and concepts described in Chapter 5. For detail on concepts and methods, the reader is referred to Section 5.2. For this Chapter, a total of 13 experts were interviewed.[33]

6.2 Geographic context

The sustainable conservation and management of the Chure carries immense significance for the livelihood and development aspirations of the Kamala Basin. The Chure or 'Siwalik' is a low mountain range that extends from the Indus River in Pakistan to the Bramhaputra River in India (Ghimire 2016). In Nepal, the range spans 800 km from the Mahakali River in the West to the Mechi River in the east.[34] The landscape accounts for 12.8% of Nepal's total area and hosts about 14% of its population. With

[33] In accordance with CSIRO human research ethics protocols, the identity of persons interviewed is confidential.

[34] It is located between the main boundary thrust situated at the south of the Mahabharat Range and the main frontal thrust situated at the northern of the Terai-Madhesh. Its elevation ranges from 120 to 1,972 m.

over 70% forest cover, the Chure supports diverse ecosystems and is a hotspot of biological diversity (DFRS 2014). Approximately 64% of the Kamala Basin falls in the Chure region (WECS and CSIRO 2020).

The geology of this region consists of sandstone, mudstone, and conglomerates, making it extremely fragile and erodible. Every monsoon, a large volume of sand, sediment, loose gravel, and boulder is deposited in nearby rivers and streams. Rivers in the Chure take away an estimated 780–20,000 tonnes/km^2 of debris annually. Consequently, riverbed aggradation remains a common phenomenon across all river systems in the Chure, often resulting in rising water levels and shifting of river courses (DFRS 2014).

New settlements in and around the Chure region expanded with the construction of the East–West Highway, and malaria eradication programs beginning in the 1950s. The increase in anthropogenic pressure has exacerbated the fragility of this landscape. Among Nepal's physiological regions, the Chure has the highest occurrence of forest disturbance. Factors such as unsustainable land use, deforestation, unsustainable quarrying of sand and stones, and open grazing are some of the key drivers of the biophysical degradation and vulnerability of the region (DFRS 2014, Ghimire 2017).

The impacts of degradation and depletion compromise the ability of hill and downstream populations to access food and water resources (Ghimire 2016, PCTMCDB 2016, Chaudhary and Subedi 2019). The Bhavar region along the Chure foothills is considered to be the primary recharge zone for groundwater in the Terai (Shrestha et al. 2018). Degradation of the Chure impacts on groundwater recharge (Rauniyar and Heyojoo 2019).

6.3 Actors and institutions

Following Nepal's transition to a federal system of governance, watershed conservation and management functions, including for Chure conservation, have been reorganised at the Federal and Provincial levels of government. Existing institutions have been reorganised with new scope and mandate.

Although Schedule 8 in the Constitution of Nepal (List of Local Level Power) recognises the role of local governments in watershed protection, the current restructuring of the forest and watershed administration in Nepal has not made any supportive deputation in this regard. Authority and resources for watershed protection and Chure flow from the federal and the provincial level.

Key actors and their defined role and mandate for the conservation and management of the Chure region in the Kamala Basin are introduced in Table 6.1, and described below.

Table 6.1 Key watershed and Chure conservation state actors in the Kamala Basin

<table>
<tr><th colspan="2">FEDERAL</th><th colspan="2">PROVINCIAL</th></tr>
<tr><td colspan="2">Ministry of Forest and Environment</td><td colspan="2">Ministry of Industry, Tourism, Forest and Environment</td></tr>
<tr><td colspan="2">Forest and Watershed Division</td><td colspan="2">Forest Management and Biodiversity Division</td></tr>
<tr><td>Department of Forest and Soil Conservation</td><td>President Chure-Terai Madhesh Conservation Development Board</td><td>Division Forest Offices
• P1 – Udaypur
• P2 – Siraha and Dhanusha</td><td>Soil and Watershed Management Office
• P1 – Okhaldhunga
• P2 – Lahan</td></tr>
</table>

FEDERAL				PROVINCIAL	
Forest Management Division	Watershed and Landslide Management Division	Large Watershed Management Office (Koshi)	Program Cluster Office (Dhanusha)	• P3 – Sindhuli	• P3 – Lalitpur

6.3.1 Federal Ministry of Forest and Environment

Ministry of Forest and Environment (MoFE) is the apex governing body on matters related to forest and the environment across the country. MoFE's Forest and Watershed Division has responsibility for assessing policy requirements and facilitating programs related to forest and watersheds. The division also facilitates the President Chure-Terai Madhesh Conservation Programme, established in 2010.

Federal programs and initiatives related to forest and environment are implemented through the various Departments and Development Committees of the Ministry. The Department of Forest and Soil Conservation and the President Chure-Terai Madhesh Conservation Development Board (PCTMCDB) are two key actors.

Department of Forest and Soil Conservation

The Department serves as the main functional arm of the Ministry for implementation and oversight over Federal programs related to Forestry and Watershed sectors. The Watershed and Landslide Management Division is one of the 3 divisions of the Department. The Division's programs are implemented at the basin level, through its recently constituted Large Watershed Management Offices, established for the Koshi, Gandak, Karnali, and Mahakali Basins.

The Large Watershed Management Offices have been established as a hub for basin-centric watershed planning and knowledge generation. They have been tasked with the mandate to:

- support all levels of government on watershed management planning and soil conservation
- innovate, test, and generate information for dissemination on landslide and erosion control through on-site demonstrations
- generate basin-level data and information on watershed conservation and erosion.

The jurisdiction of the Large Watershed Management Office (Koshi) (herein Koshi Watershed Management Office) encompasses 24 districts: 17 in the Koshi Basin, 4 in the Kamala, and 3 in the Bagmati Basin.

President Chure-Terai Madhesh Conservation Development Board

In 2014, 4 years after establishment of the President Chure-Terai Madhesh Conservation Programme, the Chure was notified as an Environmental Protection Area, and the Programme was listed as a GoN National Pride Project. In the same year a semi-autonomous PCTMCDB was constituted under MoFE. The Board was established to formulate, implement, and coordinate the conservation programme for the protection and management of the entire Chure region.

This initiative demonstrates the GoN's vision and commitment to sustainable management and conservation of the Chure landscape. More importantly, its strategic focus on an integrated Chure–Terai landscape builds relevance to the need for strengthening upstream-downstream linkage for sustainable conservation and management.

The Board has developed a comprehensive 20-year President Chure–Terai Madhesh Conservation and Management Master Plan. The key highlights of the Plan are:

- full restoration of encroached forest in the Chure hills, Bhavar, and Terai Madhesh regions
- habituate stall feeding practices among farmers who raise their cattle through open grazing
- transform agriculture lands with slope equal or greater than 19 degrees into plough free multi-year grass, fruit culture, and plan production lands
- improve and enhance silviculture-based forest management practices
- secured management of the settlements/houses within the areas highly susceptible to landslide, flood, and inundation
- mitigate forest fire risk in susceptible areas
- prepare and implement integrated river system resource management plan for 164 rivers in the Chure, including stabilisation of landslide susceptible areas in the upper watershed areas and management of river cutting and inundation in all 164 river systems
- enhance households' access to timber, wood, and other energy resources through outside forest plantations and clean technology (PCTMCDB 2017).

The Master Plan also proposes the establishment of coordination and technical committees at the Federal, Provincial, and 'River Systems' levels for effective coordination, facilitation, and oversight of the Program. It projects an investment requirement of NPR249.7 billion for the 20-year program. However, given sole financing from the GoN, yearly allocations remain nominal and insufficient. Given the investment constraints, the implementation prioritisation of the Plan is taking place at the river systems level (PCTMCDB 2017). For the fiscal year 2019–20, NPR1.74 billion has been allocated for the Program; key priorities include the construction of 113 runoff harvesting dams and multi-use storage ponds in the Chure region (MoFE 2019). The Plan is being implemented through the Board's 5 'cluster' offices across Nepal. The relevant office for Kamala Basin is the Dhanusha Cluster Office (herein PCTMCDB–Dhanusha).

Some elements of the 20-year plan draw on approaches which have been criticised as being protection-centric, to the detriment of people dependent on Chure landscape resources (Bishwokarma et al. 2016). Although consensus exists among key actors for the need for urgent action, their positions on the issue are guided by different understandings of the key drivers of degradation and its potential solutions (Bishwokarma et al. 2016, Bhattarai et al. 2018). Contestations over appropriate approaches continue to unfold within Nepal's current federal politico-administrative structure.

The Board is an important actor whose contributions are vital to implementation of the 4 Chure Strategic Actions proposed in this Chapter.

6.3.2 Provincial Ministry of Industry, Tourism, Forest and Environment

At the provincial level, Ministry of Industry, Tourism, Forest and Environment (MoITFE) is the apex governing body on matters related to forest and the environment. The Ministry, in concurrence with Federal law, has a mandate and authority to formulate policies to regulate relevant sector operations. Its Forest Management and Biodiversity Division coordinates matters related to forest, biodiversity, watershed, and soil conservation.

MoITFE have budgetary allocations for the forestry, soil conservation, and watershed management initiatives within a Province. They also receive supporting Federal allocations. For example, for Fiscal

Year 2019–20, provinces each received NPR30 million in federal funds to design and implement programs related to water source management and multiple use (run-off harvesting storages); gully and landslide protection; and bio-engineering (which includes horticulture) (MoFE 2019). Relevant programs and initiatives are implemented through the Soil and Watershed Management Office (SWMO) and the Division Forest Office (DFO).

Soil and Watershed Management Office (SWMO)

Key programs implemented by SWMO include soil conservation for hazard mitigation; watershed protection and productivity enhancement; and water conservation (including runoff retention infrastructure). Each Province has two Soil and Watershed Management Offices. Three provincial SWMOs have jurisdiction in the Kamala Basin.

Divisional Forest Office (DFO)

Under the Provincial MoITFE, the DFO holds the authority to regulate all national forest areas. DFO also hold the authority to maintain oversight of community forests, and facilitate community forest user groups in their divisions. Beyond their regulatory mandate, DFO supports extension initiatives for afforestation and scientific forest management. Four DFOs hold jurisdiction over the forest area in the Kamala Basin.

6.3.3 Municipal Government

Local governments hold the authority to regulate and manage the extraction of riverbed materials within Municipal boundaries. The volume of annual extraction is to be established through an Initial Environmental Examination (IEE) and approved by MoITFE. Based on this, Municipalities contract out the extraction sites and collect royalty revenues set by the provincial government.

Municipal governments do not receive direct funds from the Federal and Provincial governments for watershed management and flood control activities[35] Municipalities make their own determinations based on the nature and severity of their problems. For example, Dudhauli Municipality (Sindhuli) in collaboration with local Community Forest Users has been investing its resources for gully and torrent protection in parts of the Chure head. Similarly, the Municipality has invested over NPR10 million to prepare a Detailed Project Report for an ambitious (36 km) river training scheme on the Kamala River.

District Coordination Committee (DCC)

A District Coordination Committee is an elected local authority whose primary role is related to coordination, facilitation, and dispute resolution for the local government units in the district.[36]

DCC holds a mandate for monitoring riverbed extraction. Following a Ministry of Federal Affairs and General Administration (MoFAGA) directive, a monitoring and coordination Committee has been formed under the DCC to streamline riverbed extraction. The committee is comprised of the DCC Deputy Chief, Chief District Officer, District Police Chief, (provincial) District Forest Offices, the office of the Environment and Soil Conservation Monitoring Committee, engineers, and officials from the DCC in respective districts. This DCC-led Committee is responsible to maintain oversight to ensure all

[35] Approximately 75% of a local government's annual budget is met through federal allocations. Municipalities themselves raise 22% and the remainder comes from the provinces. Allocations from the federal and provincial governments are either conditional or unconditional grants.

[36] A DCC is elected by a District Assembly constituting Mayors and Deputy Mayors of all municipalities in the district.

riverbed extraction processes are legal and sustainable, including licensing; compliance with norms and volume of extraction; and revenue leakages among others. However, despite its mandate, the DCC does not have the resources, capacity, and regulatory powers to ensure compliance from Municipal governments.

Community-based or non-governmental organisations

Users Groups and Water and Sanitation Users Committees engage directly and indirectly in water conservation and source protection work. For example, Forest Users Groups spend a significant share of their earnings (e.g. from timber sales) for forest and community development works. These groups in the Kamala Basin have invested in their respective forest areas for erosion and flood protection works, and water conservation initiatives such as building storage ponds.

Similarly, the NGO Community Development and Advocacy Forum Nepal (CDAFN) have been working on small-scale community innovations on Chure watershed conservation, including in partnership with local governments. The successes of such work (in the Ratu River Basin, adjoining Kamala) have informed and inspired policymakers and practitioners at all levels.

6.3.4 Observations on institutional design and performance

At 3 levels of governance, organisations exist with responsibility for erosion control, watershed conservation, forest regulation, and riverbed mining in the Kamala Basin. As with all actors in the context of Nepal’s state restructuring, the organisations introduced above are still adapting to new roles and functions.

In addition to the organisations which were the focus of this Section, engagement and coordination with other state agencies is required. At the provincial level, these agencies include: the Policy and Planning Commission; Ministry of Economic Affairs and Planning; Ministry of Social Development; Ministry of Physical Infrastructure and Development; and Ministry of Land Management, Agriculture and Cooperative.

The current institutional arrangements reveal both challenges and opportunities. One of the key challenges is from the fact that these actors operate in jurisdictions which overlap, and/or are not mutually understood. For example, Koshi Watershed Management Office has the mandate to work at the basin level while the PCTMCP works at the ‘river-systems’ level. Organisations such as SWMOs and DFOs working within provincial boundaries. This issue is especially concerning for the current province-centric design and mandate of SWMOs. A failure to coordinate planning and actions between SWMOs in the Kamala Basin will limit the success of basin-level watershed conservation outcomes. More generally, coordination and cooperation between the different levels and types of actors and institutions will be key for any effective and result-oriented response for sustainable conservation and management of the Chure region.

A second challenge relates to reframing current local government development priorities, so as to increase their investment in watershed planning and sustainability (conservation) actions. Local governments are primarily interested in physical infrastructure development. Such investments are perceived as tangible achievements which create public and private value. Road and embankment construction are usually favoured over watershed conservation and erosion control. Furthermore, for many local governments, riverbed extraction is a key source of revenue generation, reducing incentives to regulate such activities more closely. Where interest exists in conservation, local governments have not been supported with the required capacity and resources to undertake conservation-oriented functions.

Important opportunities exist for coordination and cooperation. The goals and functions of existing organisations are complementary in design. For example, the Koshi Watershed Management Office is intended to function as a knowledge and information hub. It could support and guide other actors, especially Provincial SWMOs, who have the mandate to mobilise resources for actual watershed related initiatives. With overall resource allocation mostly insufficient to implement desired options, coordination and cooperation can be a key strategy to improve organisational efficiency and outcome effectiveness.

6.4 Chure Strategic Action 1: Policy framework and basin-level strategy for watershed protection

At present, more than one organisation is engaged in policy planning, prioritisation, and resource allocation related to analysis of erosion and landslide risks in the Kamala Basin. In the absence of coordination and cooperation in planning, these actors are operating in silos. As a result, limited available resources are spread sparsely and ineffectively.

The governance functions summarised in Figure 6.1 are proposed to improve interagency policy and planning coordination for efficiency and effectiveness of action. Table 6.2 details the proposed governance functions and responsible actors.

First, to guide local, state, and federal actors to engage in coordinated strategic planning, it is proposed that a new, whole-of-basin policy framework be developed with federal government leadership (Table 6.2, Functions 1–3).

Next, it is proposed that responsible actors cooperate to develop and exchange knowledge, leading to the formulation and adoption of a common basin-wide watershed conservation Strategy (Table 6.2, Functions 4–5).

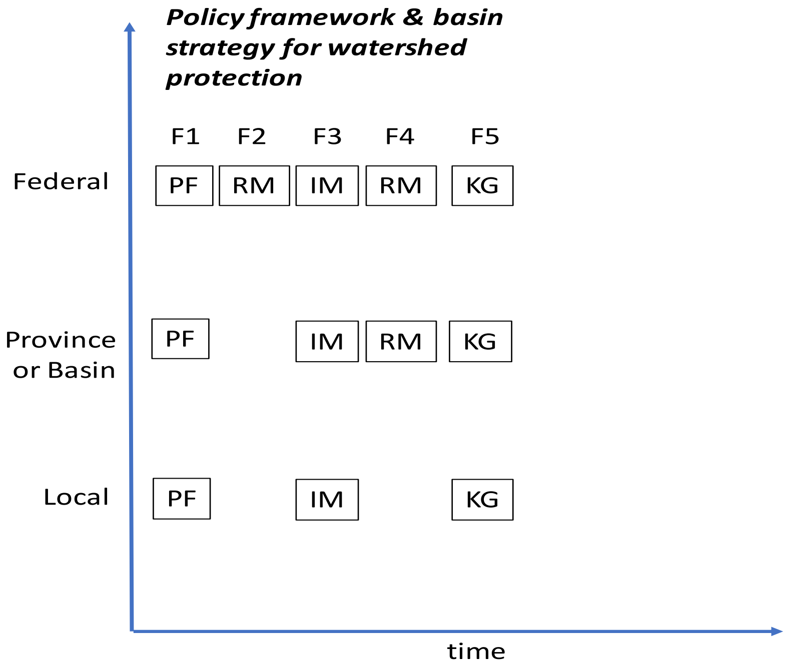

Figure 6.1 Governance functions for Chure Strategic Action 1

Note: PF = Policy framing; RM = Resource or organisational mobilisation; KG = Knowledge generation; AC = Actor constitution; IM = Institution or rule making; CR = Conflict resolution; and ME = Monitoring and evaluation

The Strategy should contain knowledge which supports action on the following areas:

- spatial profiling and prioritisation of areas vulnerable to landslide and erosion
- gully protection at Chure head for minimising erosion and debris flow
- improving conservation-livelihood linkages through reforestation, development of non-timber forest products, and sustainable management of cattle grazing.

The governance functions required to take on-ground action on topics 1 to 3 above are covered in Chure Strategic Actions 1 to 3. The watershed conservation strategy thus provides a knowledge base to inform decision making related to those actions.[37]

For example, the knowledge generated should identify locations in the Basin which are vulnerable to landslide and erosion and describe consequences of different levels of option. The Strategy should summarise key findings and include criteria to guide the prioritisation of specific watershed conservation actions, such as landslide and erosion risk reduction. It should outline specific options for action (i.e. by location, timeframe, and organisational model), and may include a proposed prioritisation. It is proposed that decisions about prioritisation are then taken in Chure Strategic Action 2, using dialogue and deliberative processes (Section 6.4).

[37] Knowledge to support regulation of riverbed extraction is covered in Chure Action 4.

Table 6.2 Governance functions to implement Chure Strategic Action 1

GOVERNANCE FUNCTION	OBJECTIVE	ACTOR INVOLVEMENT	ROLE AND LEADERSHIP
Function 1 Policy Framing (PF)	Agenda Setting. Each institution planning and implementing initiatives in silos is both undesirable and ineffective. Hence, to analyse problems across the landscape and prioritise actions, institutional arrangements and their roles must be clarified, and actors must cooperate	• Federal: MoFE, DoFSC, PCTMCDB • Provincial: MoITFE (Provinces 1–3)	• MoFE Forest and Watershed Division in coordination with DoFSC to formulate and circulate agendas.
Function 2 Resource Mobilisation (RM)	Convene relevant actors for dialogue and discussion on planning and implementation coordination arrangements	• Federal: MoFE, DoFSC, PCTMCDB • Basin: Koshi Watershed Management Office, PCTMCDB–Dhanusha • Provincial: MoITFE, SWMO, and DFO (Provinces 1–3)	• DoFSC to support necessary resource requirements
Function 3 Rule Making (IM)	Formalise discussion outcomes amongst relevant stakeholders by formulating a new, whole-of-basin policy framework that defines an approach to watershed conservation, including principles and processes to coordinate planning and implementation Based on the new policy framework, support sub-national governments in formulating relevant frameworks for sector governance within their respective jurisdictions	• Federal: MoFE Forest and Watershed Division • Provincial: MoITFE • Municipal: All	• MoFE Forest and Watershed Division in coordination with DoFSC: (i) draft the framework and circulate for comments and suggestions from sub-national governments (ii) legalise and adopt; and (iii)draft model framework/s for sub-national governments to adopt
Function 4 Resource Mobilisation (RM)	Mobilise resources for coordinated basin-level knowledge generation	• Federal: DoFSC and Koshi Watershed Management Office, PCTMCDB and Dhanusha Cluster office • Provincial: SWMO (Provinces 1–3)	• DoFSC/Koshi Watershed Management Office in coordination with the PCTMCDB to co-invest for basin-level knowledge generation for spatial profiling and investment prioritisation. • Note: The PCTMCDB, as part of its first fiver year engagement plan aims to take forward a detailed assessment of 64 river-systems for integrated planning and action, including the Kamala.

GOVERNANCE FUNCTION	OBJECTIVE	ACTOR INVOLVEMENT	ROLE AND LEADERSHIP
Function 5 Knowledge Generation (KG)	Develop and adopt a common basin-level Strategy which maps specific problems, and identifies technical options, and implementation models, for watershed conservation (including erosion control)	• Federal: DoFSC, PCTMCDB • Basin: Koshi Basin Watershed Office, PCTMCDB–Dhanusha • Provincial: SWMO (Provinces 1–3) • Municipal: All • CBOs: Forest User Groups and NGOs working on the issue in the basin	• DoFSC, Koshi Watershed Management Office, PCTMCDB: compiling and drafting • SWMOs, Municipal Governments, and CBOs: generating and compiling information from the field level

6.4.1 Considerations for successful implementation

New policy framework

The absence of inter-agency coordination has resulted in a status quo which is neither efficient nor effective. Spatial prioritisation of areas vulnerable to landslide and erosion in the Kamala Basin requires responsible actors to work together. The governance functions described above assume actors can be motivated to develop a new policy framework, that is, a set of formal commitments to guide coordinated basin-wide strategic planning and resource allocation, resulting in net benefits.

Processes and organisational structures

State restructuring in Nepal has led many observers to comment on challenges with vertical governmental coordination, cooperation, and collaboration (CCC). A full diagnosis of causes of limited CCC in the new federal state structure is beyond scope of the Strategy. However, this Strategy has proposed many actions – both strategic actions, and a series of linked 'governance functions' – which aim to strengthen CCC.

One key proposed action is to establish a new RBO. This would be an intergovernmental organisation whose purpose would be to support various governments to collaborate, along with non-state organisations (Section 5.5.5). It is not proposed as another regulatory agency.

Chapter 5 recommended the formation of a new RBO in the Kamala, for the purpose of guiding the planning and approval of small–medium storages, Chapter 5 recommended that WECS support the formation of this Kamala RBO, in collaboration with MoFE, SWMO, and DCCs. A new Kamala RBO could likewise guide the development of the Chure Actions. If an RBO assumed these functions, it could be supported by Large Watershed Management Center (Koshi).

It will be challenging to establish an RBO, and this Strategy does not elaborate on a detailed structure for the RBO. Instead, it is suggested that collaborative action to design a RBO would be a good way to get different actors to begin interacting, to address their 'CCC' issues (Table 5.13). It is recommended that WECS, MoFE, SWMO, and DCCs collaborate to design the RBO. Given the previous history of cooperation among these agencies, during the initial phases, the facilitation services of an independent party (third-party) may be useful.

The commitment to implement a basin-wide Strategy to prioritise vulnerability depends on its acceptance by those who must act (internal and external legitimacy). Such acceptance will depend in part on processes and institutional designs that build trust and mutual accountability among actors.

One process to support trust building, dialogue, and other intensive forms of communication among stakeholders is a multi-stakeholder platform. Chapter 5 proposed the formation of an annual multi-stakeholder platform to address specific sustainable development issues in the Kamala Basin. For Chure Action 1, the platform could develop the watershed conservation strategy. A key objective of the Kamala RBO would be to convene the multi-stakeholder platform.

Performance evaluation

With its basin-level mandate, Large Watershed Management Center (Koshi) appears best suited to anchor, monitor, and evaluate the performance of a basin-wide vulnerability reduction strategy.

One issue to consider when developing a new policy framework (Table 6.2, Function 3) is whether additional authority is required to direct government actors to allocate resources and act so as to implement the vulnerability reduction strategy. Such authority could be held by the Large Watershed Management Center (Koshi), or alternatively by a Kamala RBO.

6.4.2 Summary

In the context of a multi-jurisdictional river basin, the identification and prioritisation of areas requiring protection (e.g., vulnerable to erosion and landslide) is not solely a matter of technical analysis. The process of prioritisation will be influenced various options to mobilise financial and technical resources, including new options to invest more effectively through joint cross-organisational action. Those options require new rule making, supportive organisation structures, and effective communication processes. Accordingly, the proposed prior development of a new policy framework for watershed conservation and vulnerability reduction. The policy framework would provide basis for the development of a knowledge-based watershed protection and vulnerability reduction strategy. With respect to organisational structure, it is recommended an intergovernmental Kamala River Basin organisation supported by WECS and MoFE. An annual multi-stakeholder platform ('Kamala River Basin Platform') would enable more effective forms of communication.

6.5 Chure Strategic Action 2: Annual planning, prioritisation and implementation of conservation actions

This strategic action consists of annual planning, resource allocation, and on-ground implementation, guided by the watershed conservation strategy and policy framework developed in Chure Action 1.

The planning is conducted using a multi-stakeholder deliberative process, seeking a consensus on annual priorities, as well as mode of delivery.

The actors with proposed lead responsibility are PCTMCDB–Dhanusha and the 3 SWMOs of Provinces 1, 2, and 3, in consultation with Koshi Watershed Management Office. Governance functions are summarised in Figure 6.2 and detailed in Table 6.3.

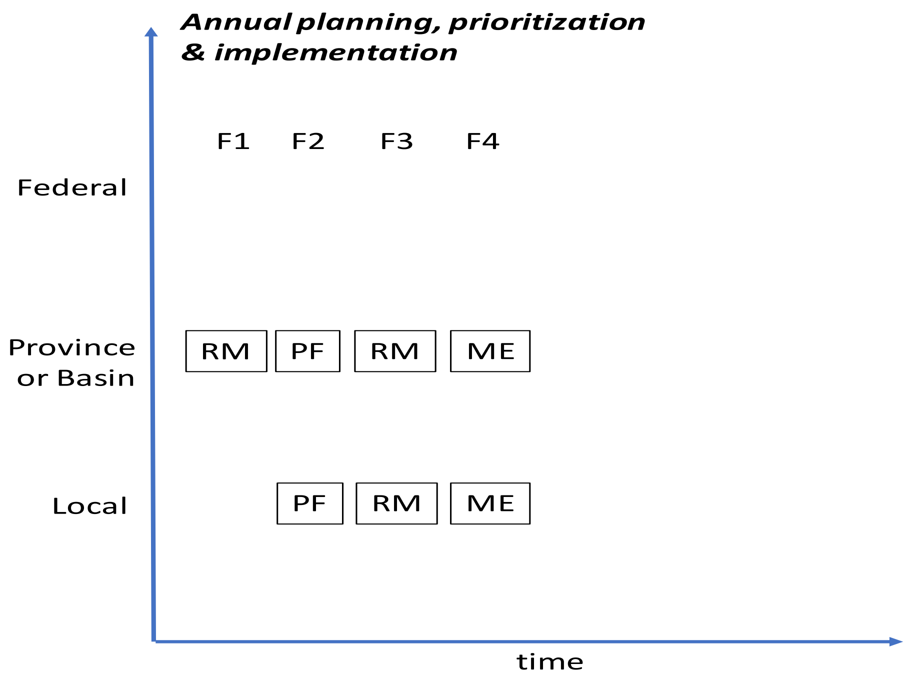

Figure 6.2 Governance functions for Chure Action 2

Note: PF = Policy framing; RM = Resource or organisational mobilisation; KG = Knowledge generation; AC = Actor constitution; IM = Institution or rule making; CR = Conflict resolution; and ME = Monitoring and evaluation

Table 6.3 Governance functions to implement Chure Action 2

GOVERNANCE FUNCTION	OBJECTIVE	ACTOR INVOLVEMENT	ROLE AND LEADERSHIP
Function 2 Resource Mobilisation (RM)	Convene relevant basin-level actors for dialogue and discussion (using Kamala River Basin Platform)	• Basin: Koshi Watershed Management Office, PCTMCDB–Dhanusha • *Provincial:* SWMO and DFO (Provinces 1–3) • Municipal: All • *CBOs:* Forest User Groups and NGOs working on the issue in the basin	• Koshi Watershed Management Office and PCTMCDB–Dhanusha to co-invest resources and facilitate
Function 3 Policy Framing (PF)	Consensus on prioritisation of annual investments and initiatives, and mode of delivery (partnership modality)	• Basin: Koshi Watershed Management Office, PCTMCDB–Dhanusha • Provincial: MoITFE (Provinces 1–3)	• PCTMCDB–Dhanusha and SWMO (Provinces 1–3) in consultation with Koshi Watershed Management Office: develop a joint annual investment plan
Function 4 Resource Mobilisation (RM)	Mobilise resources for watershed conservation as per set annual priorities	• Basin: Koshi Watershed Management Office, PCTMCDB–Dhanusha • Provincial: SWMO (Provinces 1–3) • Municipal / CBO: • Those interested in partnership and voluntary contributions	• PCTMCDB–Dhanusha and SWMOs: seek approval from respective line agencies for annual budget; finalise workplan • PCTMCDB–Dhanusha and SWMOs: explore co-investment modalities with municipalities interested to make voluntary allocations; design 'special collaborative projects'

GOVERNANCE FUNCTION	OBJECTIVE	ACTOR INVOLVEMENT	ROLE AND LEADERSHIP
Function 5 Monitoring and Evaluation (ME)	Build efficacy of investments on gully protection with effective oversight Generate knowledge on success and failures and standard methods for evaluation	• Basin: Koshi Watershed Management Office, PCTMCDB–Dhanusha • Provincial: MoITFE (Provinces 1–3) • Municipal: Those investing resources, individually or through co-investment schemes with PCTMCDB–Dhanusha and or SWMOs	• Koshi Watershed Management Office: Evaluate initiatives to assess investments and outputs at basin scale, for conformance with set priorities. Results inform regulatory actions for future prioritisation • PCTMCDB–Dhanusha, SWMOs, and Municipalities (where applicable): Monitor and evaluate to ensure actions adhere to time and quality requirements

6.5.1 Considerations for successful implementation

The key challenge faced by this strategic action is resource constraint. The scope of protection work is beyond current resource allocations. The possibility of delivering results under this action largely depends on the ability to pool resources to make agreed, prioritised investments.

Incentivising and sustaining collaboration with local governments and CBOs

Active participation of local governments and CBOs or NGOs remains key to ownership, monitoring, and sustainability of investments for erosion control and watershed conservation. The PCTMCDB and the SWMOs must explore the potential for collaboration with local governments, CBOs, and NGOs. This can be done either by co-investing in projects or bridging technical capacity gaps.

Furthermore, successful performance by local actors (as evaluated by PCTMCDB, the SWMOs, and the Koshi Watershed Management Office) should lead to additional resource incentives for their engagement on conservation-related activities. Local governments must also seek to incentivise and promote (in-cash or in-kind) successful conservation initiatives. For example, the Bardibas Municipality is promoting local conservation initiatives by providing areas for CBOs to test and implement their interventions.

Promoting the use of local and indigenous resources and techniques

The use of concrete – preferred by local governments and communities – to construct check dams and erosion control embankments faces resource limitations. Where possible, the use of local and indigenous resources and techniques for erosion control must be promoted and incentivised. Actors such as the Koshi Watershed Management Office have the mandate to innovate, test, and demonstrate locally adaptive methods for erosion control. The knowledge generated through such activities must inform erosion control initiatives at the local level. Similarly, NGOs such as the Community Development and Advocacy Forum Nepal (CDAFN) have pioneered relevant methods.

6.6 Chure Strategic Action 3: Improving conservation–livelihood linkages

The purpose of this Strategic Action is to mobilise resources for agreed actions to improve conservation–livelihood linkages. Its scope includes on-ground implementation followed by performance evaluation.

The Action is similar in form to Chure Action 2, except that it includes additional rulemaking to govern cattle grazing so that conflict with revegetation are minimised [38] With respect to responsible actors, it will be necessary to mobilise DFOs and community forest user groups (CFUGs).

Governance functions are summarised in and detailed in Figure 6.3 and Table 6.4.

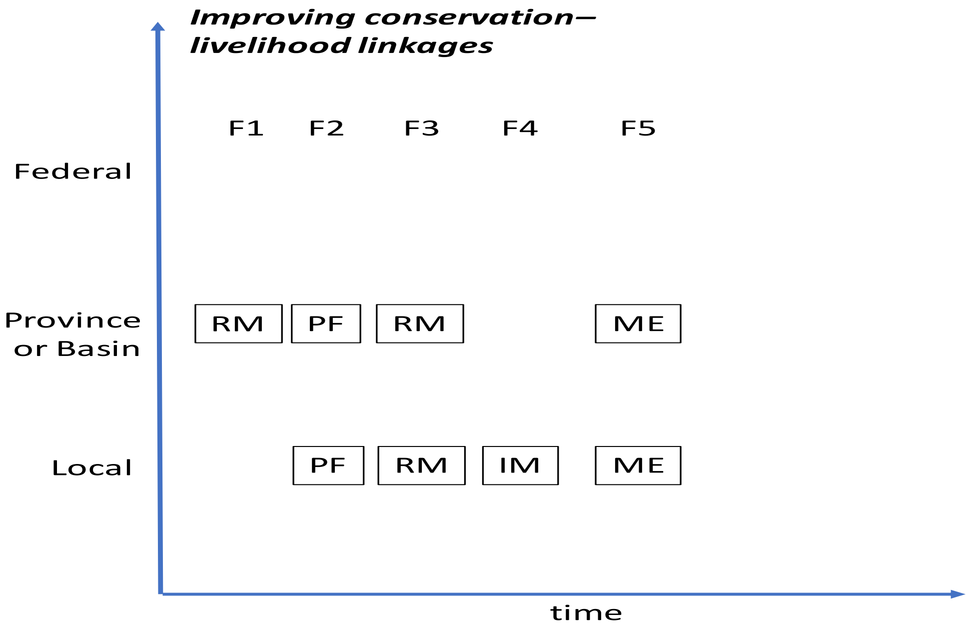

Figure 6.3 Governance functions for Chure Action 3

Note: PF = Policy framing; RM = Resource or organisational mobilisation; KG = Knowledge generation; AC = Actor constitution; IM = Institution or rule making; CR = Conflict resolution; and ME = Monitoring and evaluation

Table 6.4 Governance functions to implement Chure Action 3

GOVERNANCE FUNCTION	OBJECTIVE	ACTOR INVOLVEMENT	ROLE AND LEADERSHIP
Function 2 Resource Mobilisation (RM)	Convene relevant basin-level actors for dialogue and discussion (using Kamala River Basin Platform)	• Basin: Koshi Basin Watershed Management Center, PCTMCDB–Dhanusha • Provincial: SWMO and DFO (Provinces 1–3) • Municipal: All • *CBOs:* Forest User Groups and active NGOs	• Koshi Watershed Management Office and PCTMCDB–Dhanusha to co-invest resources and facilitate

[38] Detailed analysis of forest fire management falls outside the scope of this analysis. Given that it is related to livelihoods, it has been merged with Action 3.

GOVERNANCE FUNCTION	OBJECTIVE	ACTOR INVOLVEMENT	ROLE AND LEADERSHIP
Function 3 Policy Framing (PF)	Consensus on prioritisation of annual investments and initiatives, and mode of delivery (partnership modality)	• Basin: Koshi Watershed Management Office, PCTMCDB–Dhanusha • Provincial: SWMO and DFO (Provinces 1–3)	• PCTMCDB–Dhanusha, SWMO and DFO (Provinces 1–3) in consultation with Koshi Watershed Management Office: develop a joint annual investment plan
Function 4 Resource Mobilisation (RM)	Improve conservation-livelihood linkages through reforestation, and promotion and production of non-timber forest products, and sustainable management of cattle grazing as per set annual priorities	• Basin: Koshi Basin Watershed Management Center, PCTMCDB–Dhanusha • Provincial: SWMO and DFO (Provinces 1–3) • Municipal: Those interested in partnership and voluntary contributions • CBOs: Forest User Groups in the basin	• PCTMCDB–Dhanusha, SWMOs, and DFOs: seek approval from respective line agencies for annual budget; finalise workplan • DFOs: coordinate with & lead Forest Users Groups to make necessary investments and arrangements consistent with priorities • PCTMCDB–Dhanusha and SWMOs explore co-investment modalities with municipalities interested to make voluntary allocations; design 'special collaborative projects'
Function 5 Rule Making (IM)	Develop norms and enforceable rules to regulate open cattle grazing, and promote stall feeding at the local level	• Basin: PCTMCDB–Dhanusha • Provincial: MoITFE, SWMO, DFO (Provinces 1–3) • Municipalities: Those committed to act on the issue • CBOs: Forest User Groups in the basin	• DFOs in coordination with MoITFE: issue mandatory compliance directives to FUGs
Function 6 Monitoring and Evaluation (ME)	• Build efficacy of investments on conservation-livelihood linkages • Generate knowledge on success and failures and standard methods for evaluation • Maintain oversight on cattle grazing restrictions	• Basin: Koshi Basin Watershed Management Center, PCTMCDB–Dhanusha • Provincial: SWMO and DFO (Provinces 1–3) • Municipalities: Those committed to act on the issue • CBOs: Forest User Groups in the basin	• Koshi Watershed Management Office: Evaluate initiatives to assess investments and outputs at basin scale, for conformance with set priorities. Results inform regulatory actions for future prioritisation • PCTMCDB–Dhanusha, SWMOs, and Municipalities (where applicable): Monitor and evaluate projects/interventions at to ensure actions adhere to time and quality

With respect to specific governance functions, the joint investment plan (output of Policy Framing, Function 3), should include details about the selection and promotion of tree/fruit species for plantations; harvesting, and marketing.

The proposed design to manage cattle grazing (Function 4) is regulation by provincial government. However, the institutional design should also include encourage promotion (persuasion) and oversight roles for local governments.

6.6.1 Considerations for successful implementation

Provide services to add value and connect to markets

Often, community agroforestry or non-timber forest product (NTFP) programs are designed without adequate consideration to the abilities of communities to access markets, or to increase profit through value addition. The design of conservation–livelihood linkage programs in the basin should be informed by consideration of such ‘last mile’ services.

6.7 Chure Strategic Action 4: Regulation for sustainable riverbed extraction

The Chure region is a major source for the extraction of riverbed materials such as sand, gravel, and stone. It is estimated that about 6.5 million cubic meters of sand, gravel, and boulders are officially supplied annually from the Chure region to fulfill the demand for construction materials. The unofficial volume of supply is estimated to be twice as high (Ghimire, 2016). Despite the enactment of stronger regulatory norms, riverbed extraction is widespread across much of Chure, including in the Kamala Basin. After federalism, local governments in Nepal hold jurisdiction over riverbed extraction. Most local governments in the basin have a major interest in this industry. Existing processes of Initial Environmental Examination (IEE) and monitoring by DCCs have proven to be ineffective and insufficient to curb illegal and unsustainable extraction.

Sustainable riverbed extraction is an issue of major concern for Nepal. The governance functions proposed in this Section may also be relevant for improving institutional performance of the sector. However, any attempt to improve the state of sector governance may be vehemently challenged by those benefiting from the status quo. While reforms may be possible at the basin level, initiation of a national consultative and policy process including Federal, Provincial, and Local Governments is likely to deliver reforms for sector governance. Governance functions are summarised in Figure 6.4 and detailed in Table 6.5.

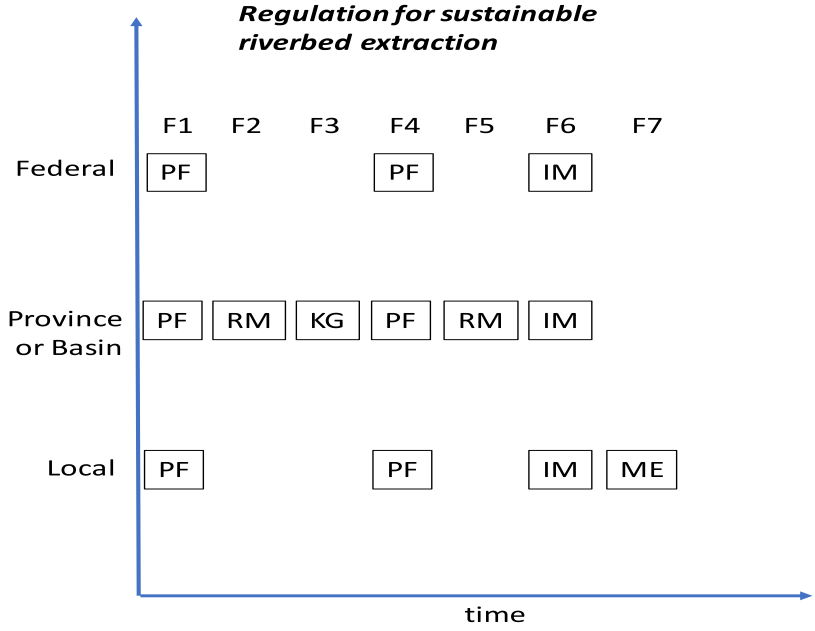

Figure 6.4 Governance functions for Chure Action 4

Note: PF = Policy framing; RM = Resource or organisational mobilisation; KG = Knowledge generation; AC = Actor constitution; IM = Institution or rule making; CR = Conflict resolution; and ME = Monitoring and evaluation

Table 6.5 Governance functions to implement Chure Action 4

GOVERNANCE FUNCTION	OBJECTIVE	ACTOR INVOLVEMENT	ROLE AND LEADERSHIP
Function 1 Policy Framing	Agenda Setting for national consultative process around examining policies and practices on sustainable riverbed extraction in the Kamala Basin	Federal: MoFE, MoEWRI, Ministry of Federal Affairs and Local Government, Ministry of Home Affairs, PCTMCDB Basin: Koshi Watershed Management Office, PCTMCDB–Dhanusha Provincial: MoITFE, SWMO, and DFO (Provinces 1–3) Municipal: All District: Chief District Officers (CDO), District Coordination Committees (DCCs) (Sindhuli, Dhanusha, Siraha, Udaypur)	MoFE: develop and circulate agenda in coordination with MoITEF
Function 2 Resource Mobilisation (RM)	Convene relevant federal and basin level actors for dialogue and discussion on sustainable extraction and improved sector governance		MoFE and MoITFEs to jointly invest resources, facilitate the event Function 3
Function 3 Knowledge Generation (KG)	Generate basin level knowledge and information on status of riverbed extraction, stock availability and replacement rates, key issues, challenges, and opportunities for scientific and sustainable extraction, quantify impact of the extraction on land instability and sedimentation downstream	Basin: Koshi Basin Watershed Management Center, PCTMCDB Dhanusha Cluster Office Provincial: MoITFEs Municipal: All	Koshi Watershed Management Office to lead a collaborative study
Function 4 Policy Framing (PF)	Agenda setting on options for policy and procedural reforms for sustainable and scientific extraction and monitoring at the basin level	Federal: MoFE, MoEWRI, Ministry of Federal Affairs and Local Government, Ministry of Home Affairs, PCTMCDB Basin: Koshi Watershed Management Office, PCTMCDB–Dhanusha Provincial: MoITFE, SWMO, and DFO (Provinces 1–3) Municipal: All District: Chief District Officers (CDO), DCCs	MoFE in to develop and circulate agenda in coordination with MoITEF
Function 5 Resource Mobilisation	Convene relevant federal and basin level actors for dialogue and discussion on sustainable extraction and improved sector governance		MoFE and MoITFEs to jointly invest resources and facilitate the event Directive to recommend and encourage voluntary promotion and oversight roles for local governments
Function 6 Rule Making (IM)	Develop national sustainability guidelines for river-bed extraction to make extraction scientific and sustainable Strengthen environmental clearance processes at the provincial level (based on basin-level data) Equip DCC with regulatory powers and financial resources to strengthen their role for effective monitoring of compliance by Municipal governments	Federal: MoFE, MoEWRI, Ministry of Federal Affairs and Local Government, Ministry of Home Affairs Provincial: MoITFEs Municipalities: All District: DCCs	*MoFE:* Draft national sustainability guidelines for riverbed extraction *MoITFE:* Devise mechanisms for strengthening environmental clearance processes at the provincial level MoITFE: Equip DCC with regulatory powers and financial resources to strengthen their compliance monitoring role

GOVERNANCE FUNCTION	OBJECTIVE	ACTOR INVOLVEMENT	ROLE AND LEADERSHIP
Function 7 Monitoring and Evaluation (ME)	Ensure all extraction is legal, scientifically sound, and sustainable over time	Provincial: DFOs District: DCCs, CDOs	DCCs, in coordination with other central agencies in the district

6.8 Summary of strategic advice

The Chure region covers almost two-thirds of the Kamala Basin. The region provides vital and essential ecosystem services such as food, fodder, and water for a majority of the population in the Chure–Terai belt, supporting livelihoods and human security. The Chure also provides resources such as sand, gravel, and stones which are vital for the construction industry, as well as providing revenue for Basin governments.

The ability to generate desired development outcomes identified in this Strategy require addressing longstanding challenges to sustainable management and conservation of the Chure.

The 4 strategic actions (Sections 6.4 to 6.7) enable on-ground resource conservation actions which have previously been prioritised by participants in the Kamala Basin Initiative (Chapter 3). These 4 actions are designed to improve governance and institutional performance, for the delivery of sustainable conservation and management outcomes.

The Kamala is a multi-jurisdictional river basin. As noted in Section 6.4, the identification and prioritisation of areas requiring attention is not simply a matter of technical analysis. Prioritisation will also be influenced by integrated financial and technical constraints on options. In a context of resource limitations, the Chapter recommended creating new options to invest more efficiently and effectively, through collaborative cross-organisational action.

To support such collaboration, new rule making, supportive organisation structures, and effective communication processes are required. Section 6.4 proposed the development of a new policy framework for watershed conservation. The policy framework would provide a formal basis for the development of a knowledge-based watershed protection strategy. The strategy would cover topics ranging from hillslope hazard and vulnerability reduction, to improving conservation–livelihood linkages.

With respect to organisational structure, it is recommended an intergovernmental RBO supported by WECS and MoFE. This would be an intergovernmental organisation whose purpose would be to support various governments to collaborate, along with non-state organisations. It is not proposed as another regulatory agency (Section 6.4.1). Convening a series of dialogues around the specific functions, and feasible structure, for an effective RBO, would be a practical way to get different actors to begin interacting, to address their coordination and cooperation issues (see Table 5.13). It is recommended that WECS, MoFE, SWMO, and DCCs engage in such cooperative design.

Regarding communication processes, an annual multi-stakeholder platform (‘Kamala River Basin Platform’) is proposed to support dialogue, deliberation, decision taking, and evaluation of workplans to implement the watershed protection strategy (Section 6.4). The annual Platform would support the work of RBO members, while offering opportunities for inclusive participation (Section 5.6.4).

The sustainable extraction of riverbed materials is a matter of national concern. Section 6.7 recommended the convening of an inter-agency dialogue with representatives of government agencies active at local, basin, provincial, and federal levels, led by MoFE and the MoITFEs of Provinces 1, 2, and 3, leading to the production of special studies to inform the preparation of new sustainability guidelines – that is a new governance framework – along with new rule making (specifically, to strengthen provincial environmental regulations and subsequent enforcement). Although Section 6.4 recommends that the sustainability guidelines be national in scope, it may be possible for Kamala Basin actors to initiate the development of a sustainability framework. For this purpose, the proposed RBO and Platform could provide supportive structure and communication processes. The development of a sustainability assessment framework – again supported by a Kamala RBO and Platform – was recommended for approval of new storages in the Basin (Chapter 5).

Riverbed extraction and approval of water supply infrastructure are different sectors. However, the proposals to improve their governance (Chapter 5 and this Chapter) share the development of capabilities for scientific assessment; and processes for collaborative planning and joint action. Thus, although riverbed extraction is a national concern, Kamala Basin actors could make progress on sustainability of this sector by taking complementary governance actions in the water supply sector.

The effective coordination and cooperation between existing responsible actors at the federal, basin, provincial, and local levels will be key for realising any positive outcome. With the watershed conservation sector challenged by weak resource allocation, collaboration between these actors in planning, prioritisation, and resource allocation will deliver improved results.

7 Strategies to develop smallholder agriculture

7.1 Background

In 2018, participants in the Kamala Basin Initiative identified, as one of their primary development goals, the '*commercial and scientific agriculture for local economic prosperity and livelihood security*' (Goal 3; Section 3.1). The participants further identified several actions to meet this goal, for example, technical support to improve productivity, and collective farming.

This Chapter offers strategic advice, based on literature review and 4 in-depth expert interviews, to address some cross-cutting challenges affecting smallholder agriculture in the Kamala Basin. The advice focusses on improving the performance of crop production systems, and supporting marginalised (land-poor) farmers:

- **Agricultural Development Strategic Action 1**: Support the sustainable intensification of crop production systems
- **Agricultural Development Strategic Action 2**: Support collective farming to improve access to land, water, and knowledge for marginalised farmers.

The two Strategic Actions comprise meaningful initial responses to the multiple challenges facing agricultural development. For each Strategic Action, the use of multi-stakeholder platforms is recommended as a process to support dialogue and deliberation.

7.2 Smallholder agriculture: challenges and responses

7.2.1 Livelihood security

Agricultural development in the Kamala Basin faces intertwined biophysical and socio-economic challenges, resulting in livelihood insecurity. Biophysical challenges include unbalanced water distribution across the Basin and shortage of water during the dry season, but also variable rainfall during the monsoon, resulting in either deficits for rainfed crops, or flash flooding (Islam et al. 2019). The upper catchment experiences hillslope erosion and landslide resulting in riverbed aggradation and localised hazards (Dahal 2019, WECS and CSIRO 2020).

As described in Chapter 2, agricultural systems in the Basin are characterised by small farm sizes, low levels of physical assets, and household labour constraints. Although increases in net rural population have resulted in the total expansion of area of cultivated land, average farm sizes have not increased, and it is one of the main economic limiting factors. Ownership of land is highly valued. Land is tightly held, despite the fact that 80% of holdings in Nepal are <1 hectare (Brown et al. 2017, Dahal 2019). Household agricultural assets are also limited. These factors, combined with limitations in agricultural knowledge and innovation systems, contribute to difficulty competing against India in rice, wheat and other irrigated crop production (Brown et al. 2017).

Land ownership

In the Kamala Basin, the proportion of farmers defined as landless, or owning less than 0.5 hectare of land, ranges from 45% to 60% (Jalsrot Vikas Sanstha and Policy Entrepreneurs Inc. 2018). Low levels of land ownership are a persistent major factor contributing to rural livelihood insecurity. Marginal farming households engage in wage labour, and they may also rent land.

Although tenancy is a common means of accessing land, tenancies can be insecure and economically oppressive. For example, under *bataiya* sharecropping agreements, tenants bear the cost of inputs, and deliver 50% of the harvest to landlords (Sudgen 2018). Such agreements discourage tenants from intensifying output. Tenants with sharecropping agreements often invest less in inputs and thus result in lower outputs. Landlords have been criticised for not reinvesting rents in improving productivity (Sugden et al. 2014). At the same time, public agricultural extension is limited in extent and quality, contributing to low yields for major crops.

Economic returns per unit of land are affected by the crop productivity and value, the cost of inputs and the cost of land rents. Gross margins per hectare can be very low. For marginal households, agriculture contributes to household consumption and nutritional security, but little to monetary incomes. This is aggravated by the risk of production losses caused by environmental stressors such as flood, drought, pest and diseases.

Migration and feminisation of agriculture

The insecurity of agricultural livelihoods in the Basin is a driver of long-term out-migration, predominately of men, in search of wage income. Male out-migration causes an increase in farm labour burden for women (Sugden et al. 2014). Whether out-migration leads to increased control by women of their household's agricultural strategy, or increased control of product, depends on specific gender, caste, and class relations. Women spend considerable time on household reproductive tasks: fuel and water provision, cooking, childcare, and other domestic tasks. Even prior to male out-migration, women already performed the most time-consuming agricultural work, such as transplanting, weeding, and harvesting. Women, in many cases, have been responsible for raising livestock. Women thus have multiple demands on their time, and such demands can be acute for women-headed households (Lahiri-Dutt 2014). Women have weaker control over land and water, and less power relative to men in joint decision-making.

Agricultural development actions designed to benefit women farmers need to meet two conditions. First, new agricultural development programs must anticipate and manage tensions resulting from changes to intra-household and intra-community social relations. Unmanaged community tensions (e.g. over contributions of labour to collective farming; Section 7.4) can lead to discouragement of participation in such programs. Male family members need to support women so that they can engage in new and innovative agricultural practices. Men typically mediate access to water, machinery such as pumps and tractors, and engagements with government agencies. However, in some cases, they have helped women learn to operate machinery independently (Lahiri-Dutt 2014, Leder et al. 2019). A similar point applies to male support for greater female control of agricultural production and use of income from sale of produce.

Second, agricultural interventions have the potential to benefit women with access to land, if the interventions result in labour- and/or time-saving benefits. For example, sustainable intensification of rice-wheat, rice-maize, and rice-wheat-mungbean cropping systems, can reduce average person-days required per ha by >40% (A. Laing, personal communication, May 2020) (Section 7.3; see also Gathala et al. (2020)). A second example is multiple-use water systems (MUS). MUS systems are designed to serve domestic and productive uses, and have been used successfully in Nepal's hilly rainfed farming systems (Clement et al. 2019).

7.2.2 Agricultural diversification

Agricultural diversification can be defined as a change from a low-value commodity mix of crops and livestock to a higher value and specialised mix of crops and livestock. Diversification can be defined based on the number of crops cultivated by a household (Shively and Sununtnasuk 2015). The ability to diversify may result in viable alternatives to current, longstanding production systems.

The main crops cultivated in the Basin are rice, wheat and maize. Despite this fact, there is increasing interest in high-value crops as a form of increasing income and improve livelihood of the small farmers (Barghouti et al. 2004). Diversifying to high-value crops is considered as alternative for declining trend of agricultural growth (Rosegrant and Hazell 2000, Thapa et al. 2017). Households that diversify from traditional crops, mainly farmers with land size <2 ha, are less poor (Birthal et al. 2015). Diversification towards high-value vegetable crops improves employment opportunities, including for girls and women.

High-value crops may allow farms to increase income per cultivated area, improve water use efficiency, increase flexibility in time to develop activities, adapt to crops more resistant to drought or resilient to pests and diseases.

Potential impediments or pitfalls need to be considered. Scaling out diversification can be limited by several factors. One of the most common is the lack of knowledge or experience applying suitable or best practice, which can cause loss of potential productivity due to incorrect management. The prevalence and quality of improved seeds may be limited, and knowledge of how to control pests and diseases is required. Factors such as distance to markets, storage infrastructure, and fluctuations in market price, are critical for perishable products.

Thapa et al. (2017) provide a comparison of value shares of crops between 1995, 2004 and 2010 for the Mountain, Hill and Terai zones of Nepal. There is a clear trend to increase high-value crops from 9% to 18% in the Terai and Mountain zones, and from 14% to 23% in the Hill regions. Cereals predominate, but their value share (percent) decreases from 79% in 1995 to 63% in 2010 in the Mountain and Terai zones, and from 75% to 62% in the Hill zone. The main differences were observed in farmers with larger areas. The most common high-value crops are vegetables, potatoes, and fruits.

In the Basin the incentive and expansion of the adoption of high-value farming, as a strategy for developing a more commercial and competitive agricultural sector, depends on water availability during the dry season, and access to irrigation systems. Expansion of gross cultivated area may influence water demand, depending on crop water requirements and adopted irrigation practices. It is expected that providing better distribution of water across the Basin throughout the year will stimulate farmers to diversify. Farmers in proximity to urban areas have incentives to grow market vegetables.[39]

[39] Between 1989 and 2016, the development of urban or built-up areas in the Terai occurred in a dispersed manner. Growth occurred along roads, in small settlements, as well as existing towns. Janakpur in Dhanusha district, Lahan in Siraha district, and the East-West Highway experienced notable growth (Rimal et al. 2018).

7.2.3 Agricultural sector governance

Nepal's recent rates of economic growth appear to provide adequate resources for public and private investment and innovation in agriculture.[40] Agriculture received 10.6% of total government outlays in 2017 (up from 4.3% in 2007) (FAO 2020a). Notwithstanding the impact of COVID-19 on Nepal's economy, insufficient public revenue may not be the primary obstacle to innovation.

Rather, the degree to which Nepal develops more sustainable forms of agriculture depends on governance – broadly speaking, on what structures and processes its agriculture sector actors develop, in response to demands from society for agricultural investment and system innovation.

A situation assessment of agricultural sector governance in Province 2 revealed several challenges as of 2019 (Dahal 2019). Recurring challenges, which apply elsewhere in Nepal, include:

- the inadequate capability of many actors. Multiple organisations have approved but unfilled positions, with frequent changes to staffing; capability is also limited in private sector; some new actors have unclear purpose (e.g. Agricultural Knowledge Centres)
- a lack of effective strategic planning. While Province 2 has identified several products in which it has competitive advantage, there exists a 'lack of joint planning and common targets' between various actors who need to act in coordination
- weaknesses in accountability, resulting in unbalanced allocation of government budgets (i.e. overallocation of resources to a single program, leaving other programs under-resourced)
- allegations of financial impropriety in the administration of agricultural subsidies (Dahal 2019: section 3.3.8).

Recommendations for the comprehensive reform of public administration of agricultural development are beyond the scope of this document. Nonetheless, the multi-stakeholder communicative processes proposed in Section 7.5 can focus the attention of multiple actors on specific agricultural development solutions, and specific institutional and administrative barriers to action.

7.2.4 Summary: challenges and recommended responses

Table 7.1 summarises the intertwined challenges facing smallholder agriculture in the Kamala Basin, showing how the two Strategic Actions each constitute a relevant response. These Actions are described in Sections 7.3–7.4, followed by advice on how to initiate action, using multi-stakeholder platforms (Section 7.6).

Table 7.1 Summary of agricultural development challenges and potential responses

CHALLENGE	RESPONSE
Low-asset smallholder systems. Low levels of asset endowments (land, water, machinery, human capital) result in low levels of productivity and profit. This discourages farmer innovation and discourages a range of private sector investment (e.g. in supplying inputs). High numbers of farmers relative to government resources make it difficult to provide extension services to all who need it. This is expected to be less critical with the adoption of ICT using available connectivity, internet,	Sustainable intensification of crop systems (Agricultural Development Strategic Action 1) Collective farming to improving access to land, water, and knowledge for marginalised farmers (Agricultural Development Strategic Action 2)

[40] For example, the average rate of GDP/capita growth was ~4% p.a. during 2015–19. The estimate for 2020–2021 is 2.4% (PPP, constant prices) (International Monetary Fund 2020)

CHALLENGE	RESPONSE
YouTube and informal extension networks (Brown et al. 2017, Dahal 2019)	
Weaknesses in governance of agricultural development are hampering the ability to deliver a range of vital functions. State restructuring appears to have weakened capability of actors (organisations) through delayed staff recruitment, lack of strategic planning, and ineffective resource allocation (Dahal 2019)	Multi-stakeholder platforms, focussed on identifying structures and processes for collaborative action (Agricultural Development Strategic Actions 1 and 2)

7.3 Strategic Action 1: Sustainable intensification of crop systems

During the decade ending in 2017, Nepal experienced yield improvements of 9% for wheat, 18% for maize, and 21% for rice (FAO 2020b). By comparison, during the same period, India's respective yield improvements were 15%, 29%, and 18%. However, Nepal's modest yield increases during the above period were achieved through significant (>225%) increases in chemical fertiliser input (compared to <10% increases in equivalent use in India), raising concerns with financial viability and agroecological sustainability. Yield improvements over the decade should also be attributed to constantly increasing availability of improved and hybrid seeds developed either internally or through importation from outside.

Beginning in 2015, 85 farmers in Dhanusha and Sunsari districts were directly supported to adopt conservation agriculture based sustainable intensification (CASI) practices (Islam et al. 2019, Gathala et al. 2020). On-farm trials of CASI practices were organised through the Sustainable and Resilient Farming System Intensification (SRFSI) project.[41] Key CASI practices and technologies include:

- the use of specialised reduced or zero tillage machinery for crop establishment (e.g. zero-till planting of rice, wheat, maize, and lentils), reducing human labour, fuel, and other inputs
- retention of crop residue from the rainfed rice crop for the winter rabi crop (which increases soil moisture, reducing the volume of irrigation water required for the rabi crop)
- precise management of fertilisers and agrochemicals.

The CASI practices included different treatments which varied according to crop establishment, for example, whether rice was conventionally tilled and manually transplanted; mechanically transplanted without prior tillage; or directly seeded without prior tillage (Islam et al. 2019).

Trials of CASI practices were organised in a bottom-up manner, with in-village farmers organisations playing a role as hubs connecting researchers, private sector input suppliers, and government (detailed in Section 7.5.2).

Use of CASI practices resulted in the following productivity improvements compared to conventional till (CT) practices (Gathala et al. 2020):

- increased grain yield per unit water used (5% to 8% increase in grain yield across treatments)
- increased yield per energy input (8% to 18% increase)
- reduced labour requirement (14% to 42% increase)
- improved economic returns (14% to 25% increase, in gross margins).

[41] Through the Sustainable and Resilient Farming System Intensification (SRFSI) project, funded by Australian Council for International Agricultural Research (ACIAR)

7.4 Strategic Action 2: Collective farming to improve access to land, water and knowledge

Collective farming refers to approaches that involve action taken by groups of farmers to access and to manage vital resources – such as knowledge, labour, land, inputs, and water – for the purpose of achieving more secure livelihood outcomes and to improve access to the market and product prices and commercialisation. Various models of collective farming have been demonstrated in the eastern Gangetic plains, including in the Nepal Terai, the Indian states of Bihar and West Bengal, and northern Bangladesh, in 2016–17.

In Nepal, a project supporting collective farming focussed on villages in Saptari district with a high proportion of marginal households. [42] As noted in Section 7.2.2, the proportion of marginal farmers in the 4 districts comprising the Kamala Basin ranges from 45% to 60%.

NGOs with prior experience in the region engaged in social mobilisation and invited households to join the groups on a voluntary basis. Participants came from Tharu, Dhanuk/Mandal, Dalit, and Muslim backgrounds, and groups ranged in size from 5–16 individuals. The NGOs involved were a local community-based organisation, and iDE Nepal (an international organisation). The Department of Irrigation provided technical irrigation support. Groups accessed land from landlords willing to lease it out for a fixed rent, instead of leaving it fallow. [43]

This arrangement is preferred over sharecropping, because it allows for any improvement in outputs or profit to be retained by farmers.

Table shows 4 models of collective farming that evolved during the course of the above project. All models involved group cooperation for training, crop planning, land preparation, and irrigation. The models differ according to whether households contributed their labour to a group effort, or whether they cultivated individual household plots.

Farming groups adapted labour arrangements to meet their needs. For example, some groups pooled labour during the dry season, but farmed individual plots during the wet season. Other groups reserved some of the land for pooled labour, and some for individual farming.

Table 7.2 Models of collective farming

COLLECTIVE MODEL / LOCATION	DEGREE OF COOPERATION	LABOUR ARRANGEMENT	LAND ARRANGEMENT	TARGET GROUP
Model 1 (Saptari District and Madhubani [Bihar])	High	Pooled labour within group	Collective leasing of single contiguous area	Landless /Tenants
Model 2 (West Bengal)	High	Pooled labour within group	Voluntary consolidation of single contiguous area	Small owner cultivators
Model 3 (Saptari District and Madhubani [Bihar])	Medium	Household labour on own land	Collective leasing of single contiguous area, but maintaining individual plots, cooperation for land preparation, inputs and irrigation	Landless/Tenants

[42] Supported by Australian Council for International Agricultural Research, project *Improving water use for dry season agriculture by marginal and tenant farmers in the Eastern Gangetic Plains* (ACIAR LWR/2012/079).

[43] ACIAR project *Improving water use for dry season agriculture by marginal and tenant farmers in the Eastern Gangetic Plains* (LWR/2012/079).

COLLECTIVE MODEL / LOCATION	DEGREE OF COOPERATION	LABOUR ARRANGEMENT	LAND ARRANGEMENT	TARGET GROUP
Model 4 (West Bengal)	Medium	Household labour on own land	Maintenance of individual plots within single contiguous area, cooperation for land preparation, inputs and irrigation	Small owner cultivators

Source: Authors, adapted from (Sudgen 2018)

7.4.1 Collective farming: benefits and challenges

Water access

Collective farming offers important opportunities to access irrigation water more affordably. This is for several reasons. First, private groundwater rental markets are common but can be monopolistic. Collectives shared ownership or access to groundwater pumps under terms which are explicitly equitable. Second, farming on larger plots of land makes irrigation more feasible and can improve water use efficiency (Bastakoti et al. 2017).

Access to land and knowledge

Groups allow for collective bargaining, improving the terms on which land is accessed, as well as other inputs (including groundwater supplied by larger farmers, if needed). Participants in the above demonstration project received multiple trainings (e.g. on agronomic practices, disease and pest management, on-farm water management, group functioning, and gender and social inclusion). All collective farming groups included group monthly savings activities. These were used to pay for agricultural inputs, as well as serving as a platform to accumulate savings. For some groups, this could lead to potential gains in productivity and/or profitability.

In the collective farming experiments, cropping intensity increased from 110% to 200% (2016–17), with high gross margins for potato, mungbean, and a variety of vegetables.[44] In Saptari district, the average gross margins reported for collective farming equalled or exceeded NPR50,000/ha for the following crops: wheat, radish, bitter gourd, zucchini, onion, potato, and tomato. However, groups also experienced variation between sites, which can be attributed to lack of experience, weather, and market conditions.

Challenges

Collective farming requires strong intra-group communication, cooperation, reciprocity, and trust. An ongoing challenge faced by groups was to secure adequate and timely labour contributions from all members. Group members who were also engaged in individual farming, or domestic labour, were not available during critical periods with high labour demand.

In addition, collective farming requires many tasks to be performed competently and in a trustworthy manner on behalf of the group, e.g. activity scheduling, tractor hire, input purchases, and maintaining productive landlord relations. In the ACIAR demonstration project, these management services were provided by the group chairperson. Leadership appears to be crucial for adoption of diverse crops and intensification.

[44] R. C. Bastakoti, personal communication, September 2018.

7.5 Initiating action

7.5.1 Multi-stakeholder platforms

A multi-stakeholder platform (MSP) is a process designed to support state and non-state actors to communicate for the purpose of exploring a public policy issue. Ideally, an MSP is socially inclusive, supporting participants to consider diverse perspectives, and to engage in sincere and reasoned argument. Multi-stakeholder communication may explore the potential for collaborative approaches to addressing the policy issue. Collaborative approaches are those where actors work together to address problems whose complexities exceed the ability of any one actor to resolve alone. That complexity may take the form of social and ecological systems complexity, organisational interdependence, as well as uncertainty about how best to define the problem.

Effective MSPs are those that support collaboration. This means that they help build trust between participants; generate mutual understanding between organisations with different interests and capabilities; support the discovery of common objectives, as well as (possibly) agreement on strategies to achieve those objectives (Emerson et al. 2012). These communicative processes are demanding, for example they require a willingness from participants to detach from prior relations of hierarchy.

MSPs were recommended in Chapter 5 (focussed on water resources development) and Chapter 6 (focussed on the Chure) as processes to support a range of intensive communication and planning activities which require contributions from multiple state and non-state organisations.

MSPs in the agriculture sector often take the form of 'innovation platforms'.[45] An innovation platform can be defined as a network of key actors including farmers, who have been selected for their expertise, interest, and relevance to a particular agricultural development challenge (Foran et al. 2014). Typically, an innovation platform addresses a specific challenge such as to how to add commercial value to a crop (as opposed to reforming an agricultural extension system). These platforms typically begin as temporary networks, although in some cases they have led to development of businesses providing new agricultural services (Section 7.5.2) (Brown and Darbas 2018, Brown et al. n.d.).

The justification for this form of MSP is that new technology alone is insufficient to improve agricultural development. In addition to technology, it is necessary to focus on specific constraints, or opportunities, present in the system in which smallholders produce. Knowledge of constraints and opportunities is held by multiple local actors (farmers, traders, input suppliers, knowledge brokers).

The convenors of an MSP should have adequate status to bring together representatives of existing farmers' groups, government and NGO agricultural experts, finance organisations, and local political leaders.

It is recommended that 2 MSPs be convened to focus on each of the Agricultural Development Strategic Actions proposed in Sections 7.3 and 7.4. The key responsible actors appear to be the provincial Ministry of Agriculture, Land Management and Cooperative (MOALMAC), and local governments. Local governments are responsible for providing agricultural extension services, while MOALMAC may be the structure under which Nepal's Agricultural Knowledge Centres (AKC) will be placed. It is understood

[45] 'Innovation' refers to the processes by which activities new to a particular social group are acquired by that group and put into use, resulting in novel outcomes (World Bank 2012).

that MOALMAC's budget (prior to the impacts of COVID-19) was adequate to convene and facilitate MSPs, and follow-on actions.

Given the importance of women in agriculture, and their central role in household nutrition, women are central to forms of agriculture which deliver improved nutrition and health outcomes (directly or indirectly) (Kadiyala et al. 2014). It is important for MSPs to include representatives with experience in designing, supporting and evaluating gender- and nutritionally-sensitive agricultural interventions (Rao and Raju 2019).

7.5.2 MSP to support sustainable intensification of crop production systems

CASI practices make it possible to lower the energy (human labour and fuel) and irrigation water use of crop production systems, while increasing gross margins (Gathala et al. 2020). However, sustainable intensification requires access to specialised equipment and training in specific applications of fertilisers and agrochemicals.

An MSP can explore and deliberate on alternative options to mobilise resources and create the set of required capabilities across multiple organisations. In West Bengal, agricultural service providers used MSP to develop new business models supporting CASI for rice- and wheat-based systems. The services provided included sale of improved varieties and agro-chemicals; farm equipment hire; advice on small livestock production; and improved linkages to government agricultural programs (Brown et al. n.d.). The organisations able to develop such new services were for-profit or non-profit organisations with an established profile or demonstrated capability (Brown and Darbas 2018, Brown et al. n.d.).

In Nepal, MSPs were used in Dhanusha and Sunsari districts to focus attention on the challenges of implementing CASI practices, through the SRFSI project (see Section 7.2.3). With the support of District Agricultural Development Office (DADO), 10 village-level innovation platforms were created as new farmers clubs in Dhanusha and Sunsari districts. One district-level platform was also formed in each of these 2 districts. Additional support was provided by Nepal Agricultural Research Council (NARC).[46]

The support provided generally consisted of training to establish an innovation platform. Training included developing capabilities of actors serving as convenors and facilitators. Additional support included exchanges across project sites, and support for monitoring, evaluation, and learning.

The innovation platforms focussed on problems such as limited availability and timing of inputs, and limited technical knowledge related to CASI. Some village-level platforms reported notable improvements in accessing agricultural inputs and subsidies, adoption of CASI practices, and marketing of produce (Brown et al. n.d.). As of 2019, the village-level platforms in Nepal were 'partially active' (Brown et al. n.d.).

Nepal's post-2015 restructuring dissolved DADO, leaving the above platforms with a gap in budgetary and human resources support. Coordination between DADO and NARC was limited (Brown et al. n.d.). After federal restructuring, weak linkages are further reported between NARC and local government, which has assumed responsibility (from DADO) for agricultural extension. This has resulted in a lack of coordination and insufficiently developed agricultural development strategies and program implementation, observed in Province 2 (Dahal 2019).

The above experiences imply that the emergence of new agricultural service providers (whether for-profit or non-profit) requires initial access to innovative technology and knowledge, and that it takes

[46] SRFSI supported a total of 37 village-level irrigation projects and five district-level IPs in Nepal, Bihar, West Bengal, and Bangladesh

time to develop viable organisational models. These considerations justify initial public sector leadership.

A follow-on project to SRFSI, operating in Provinces 1 and 2, is the Roadmaps project led by CIMMYT (International Maize and Wheat Improvement Centre). This project is using multi-stakeholder platforms to develop strategies for agricultural mechanisation in support of sustainable intensification (Shrestha 2019). One organisational model that may be relevant is collective ownership of specialised agricultural machinery (e.g. as tractor attachments), combined with rental access to tractors.

7.5.3 MSP to improve access to land, water, and knowledge for marginalised farmers

As noted in Table 7.1, high numbers of farmers relative to government resources make it difficult to provide extension services to all who need it (Brown et al. 2017, Dahal 2019).

In the past, development projects focussed on collective farming have helped farmers groups representing marginal farmers access agronomic advice leading to increased production of dry season vegetables (Section 7.4). The scaling out of collective farming approaches requires delivery of specific technical skills, such as management of collective farming groups. More generally, it requires a coherent and effective system of agricultural extension.

The needs of marginalised farmers extend beyond agronomic advice and group formation. This MSP may also consider the policy and institutional dimensions of the following issues:

- transparency, equity, and efficiency in access to land via rental markets
- pro-poor regulation of private groundwater markets.

The improved performance of agricultural extension requires effective linkages between local government (which holds responsibility for extension); knowledge brokers at provincial level (i.e. Agricultural Knowledge Centres) and at federal level (NARC); large farmer organisations, which are key intermediaries; and influential individual farmers.

Organised MSP should therefore consider how to improve delivery of agricultural extension by enhancing the internal capabilities of state actors; enhancing their ability to take joint action across levels of governance; and enhancing their ability to work with existing farmer organisations.

7.6 Summary of strategic advice

Based on recent experience in Dhanusha District and elsewhere in the Eastern Gangetic Plains, it is recommended that agricultural development agencies in the Kamala Basin support CASI (conservation agriculture based sustainable intensification) practices to improve the profitability, energy-efficiency, and water-efficiency of rice- and wheat-based cropping systems (Section 7.3). Agricultural development agencies should support collective farming programs, which improve access to land, water, and knowledge for farmers who own less than 0.5 ha of land. As reported in Section 7.4, collective farming can lead to higher-value dry season vegetable production.

Women are central to linking household agricultural strategies to nutrition and health outcomes. Their agency is critical to realising synergies between resource-efficient agriculture, and human development outcomes, and hence to realising synergies between the SDGs. Agricultural development actions - whether focussed on CASI practices, collective farming, or combinations thereof – can be designed to further women's potential agency. Programs designed to empower women farmers require support not only from male family members, but an enabling local social environment. Women's diverse experience with collective farming and CASI projects should be critically reviewed by program designers so as to avoid the unintentional reproduction of inequitable gender relations in agriculture (Leder et al. 2019).

The use of MSPs, supporting collaboration between state and non-state organisations, can help address problems requiring high levels of coordination (Section 7.5). The advice focussed on establishing 2 MSPs: one to support sustainable intensification of crop systems, and the other to improve access to assets and skills for marginal farmers. It is recommended that the Ministries of Agriculture, Land Management and Cooperative (MOALMAC) for Provinces 1, 2, and 3 explore the joint sponsorship of these 2 MSPs, linking to recent or current development assistance projects operating in the Kamala Basin and Terai, which also use multi-stakeholder platforms.

8 Strategies to manage water-induced disasters

8.1 Objectives

Actions to prevent or mitigate water induced disasters are particularly important in the water management of the Basin, because severe water induced disaster events have occurred with loss of lives and mostly irrecoverable infrastructure damage. Impacts on lives and livelihoods are becoming even more significant – this is mainly because people are now living in areas prone to floods and landslides due to rapid population growth, and also because the magnitude of such events are increasing due to land degradation and climate change. Hence, the Strategy considers safety and security to prevent loss of lives and properties through proper water-induced disaster management as a part of overall river basin management (as components of Goals 1 and 2; Chapter 3). The specific objective is to mitigate the impacts of water-induced events.

8.2 Kamala Basin context

8.2.1 Flood issues

In Nepal, flood problems are mainly of two types - (i) river bank erosion, and (ii) inundation. Almost all over the basin there are problems of river bank erosion, whereas inundation problems are limited to southern areas of the basin, mainly on the two sides of the Kamala River, in the lowland plains of the Basin. River bank erosion is frequently compounded with overbank flow with high velocity eroding top soil, standing crops and vegetation and even structures on the banks. Such problems are more prevalent in the valleys within the Chure range and also in the Kamala river stretch immediately downstream from the East-West Highway.

In the past, inundation problems, which were limited to the areas along Nepal-India border, were not given that much attention, because mostly the problems would last only a few days due to adequate terrain slope leading to high drainage. However, as continuous flood dikes were constructed along the rivers and also more road and embankments were constructed transverse to the direction of overbank flows to the Indian side, flood problem has increased on the Nepal side of the border. Such problem cropped up almost everywhere along the Nepal-India border in varying degrees, which necessitated establishment of a joint institutional mechanism called Standing Committee on Inundation Problems along Nepal India Border between the two countries in 1985. There were issues on the Indian side also, which were raised on account of some interventions on the Nepal side. The same joint institutional mechanism dealt with the issues on both sides, and has still been functioning with a different name- Joint Committee on Inundation and Flood Management to resolve the flood problems along the border on the both sides.

8.2.2 Kamala River Training Project

In the bilateral institutional mechanism between Nepal and India, it was agreed to extend the flood protection works, which existed on the Indian side, further upstream to the high grounds on Nepal side in order to reduce the problem in both countries. As a result, a flood protection and river channelisation master plan was prepared for the Kamala River covering a nearly 32 km stretch from the East-West highway to the points the continuous dikes could be connected to the similar structures across the border. The plan also consisted of several series of spurs and other bank erosion protection structures. The implementation of the plan commenced in 2009/2010 and completed in 2017/2018 at a cost of NPR2.8 billion under Indian bilateral assistance. Approximately NPR50 million has now been allocated for a fiscal year for the upkeep of the structures.

Thus it has been seen that flood control works in the Kamala River's downstream reach (from East-West Highway to Nepal-India border) have mainly been guided by the necessity of compatibility with those activities on the Indian side. However, in rivers with high sediment load, continuous dikes on both sides of the river will create an unending problem as a cycle of riverbed aggradation and dike height raising. However, in successive years, it is necessary a combination of bio-engineering with revegetation of riparian zones to contribute to stabilise the riverbank. There are several other flood control measures with appropriate sediment management, which can be applied along with the non-structural measures in the form of legislation, emergency flood fighting mechanism. Many of these measures are to be considered at the planning and design stage of flood control and management works, hence, not discussed in detail here.

8.2.3 Flood control works in the upstream reach

In the upstream reaches of the Kamala river, i.e. upstream from the East-West highway and beyond, and its tributaries, the flood control works, which are essentially anti erosion infrastructures, have been implemented along the river, depending on the priority, risk of flooding and public fund available. Based on field visits and discussions with the local communities it is observed that some of these infrastructures have limited effectiveness and sometimes counterproductive for the following reasons:

- they are not implemented with proper investigation and design
- inappropriate orientation of structures has sometimes led further erosion
- the sediment yielding process and river behaviour in and around Chure region is less understood, and empirical equations developed elsewhere for sand-bed rivers and applied in the Kamala river system, particularly in the upstream reach, have proved to be inaccurate
- estimation of sediment yield, transportation and deposition on a riverbed can be unprecise, and hence, riverbed sediments extraction, if necessary, should be based on actual observations of annual changes in the field
- rampant and haphazard riverbed sediment extraction has disturbed the river regime completely leaving no use of the constructed river training works.

Extraction of riverbed materials to supply construction projects in different parts of Nepal and even export to India have caused serious problems in the upstream reaches. Although, some institutional mechanism has been established as described in Section 6.3.3 to address the uncontrolled extraction of riverbed material, positive result is not yet seen on the ground, primarily because of high financial return.

8.2.4 Agency support and local participation

Until the establishment of the Department of Water Induced Disaster Prevention (DWIDP) in February 2000, river training and flood control works were taken care of by the Department of Irrigation and its district level offices. Such institutional arrangement in the context of flood control works was mainly geared towards the protection of irrigation infrastructure and irrigated agricultural land. DWIDP was later renamed to Department of Water Induced Disaster Management (DWIDM). DWIDP/DWIDM remained functional for nearly two decades till 2019 with its division offices all over the country. DWIDM has again been merged with the erstwhile Department of Irrigation, with a combined new name Department of Water Resources and Irrigation. Although there have been some changes in the institutional arrangement after the country embraced a federal system of governance, hardly any difference is noted in the functioning of the institutional arrangement. In order to mitigate the flood problems, structural measures are still being resorted to on as and when necessary basis with the limited public fund available.

A very serious shortcoming noted in the Kamala Basin and also elsewhere in Nepal is that there is virtually no mobilisation and participation of flood affected people in preparedness and also emergency flood fighting. Nor has the related agency attempted to introduce local participation in emergency preparedness, and flood fighting, evacuation.

8.3 Relevant policy

Until 2006, Nepal did not have any water induced disaster management/prevention specific policy, except that irrigation related policies used to have a few provisions for the protection of agricultural lands (Irrigation Policy 1992). The first water-induced disaster management policy was formulated in 2006, mainly to facilitate private sector investment in reclamation and utilisation of flood-eroded lands. However, such reclamation could not be carried out due to legal complexities. A more comprehensive new water-induced disaster policy was introduced in 2016. Some of the main features of that policy are:

- water induced disaster management to be done following master plans at national as well as local levels
- users participation in water-induced disaster management
- large river training and landslide works to be carried out following IWRM principles
- introduction of early warning system(s)
- flood and landslide prone areas to be zoned in 3 categories depending on risk and vulnerability
- reclamation of flood eroded areas with mandatory requirement of GoN permits.

Since the policy was formulated for a unitary system of governance, it needs to be amended to make it compatible with the current federal system. Water resources management in general and water-induced disaster management in particular are the concurrent subjects in the country's Constitution requiring agencies at all 3 levels to have authorities as well as responsibilities in these matters. In absence of a federal legislation defining such rights and responsibilities, the agencies' mandates, responsibilities and domain are not clear. To address these issues, a National Water Resources Policy has been approved by the federal government on 13 July 2020. A federal Water Resources Legislation is on the anvil now to give effect to the approved policy and thus to bring clarity on the above stated matter. State level legislations need to be formulated at various States (State No. 1, State No. 2 and

Bagmati State in case of Kamala Basin) to address water induced disaster issues and water resources issues in general by making the provisions of such State level legislations consistent with that of the federal Water Resources Legislation.

8.4 Existing institutional arrangements

In a process of transforming unitary system of governance to a federal one, the following institutional arrangements have been made, however, they appear to be an interim arrangements without backing of federal legislation:

- At the central level, the former Department of Water Induced Disaster Management, along with its activities, has been merged into the Department of Irrigation. The new department is now called Department of Water Resources and Irrigation
- Six field offices across the country have been established directly under the above stated federal department to implement programs called *Janatako Tatbandha* (people's river training works). Each field office would take care of specific rivers
- There are 9 federal large river training and flood control projects. The Kamala River Project is one of these. The project is currently under maintenance phase
- Almost every district has a water-induced disaster management division. These divisions will be under the State Governments. Thus, each of the 4 districts in the Kamala Basin has a provincial level water-induced disaster management division.

8.5 Summary of strategic advice

The following strategies have been identified to mitigate water induced disasters:

- Install a flood forecasting and early warning system
  - DHM at the federal level in coordination with the concerned ministries at State Governments along with their district divisions will be involved in establishment and operation
- Prepare and periodically refine planning and design standards for flood and landslide control infrastructure
  - Responsible actor is a central government agency, most likely WECS
  - WECS, as a non-executing agency, prepares such standards with the support and involvement of Department of Water Resources and Irrigation, Department of Hydrology and Meteorology, and academic institutions
  - Standards and guidelines should be applicable country-wide
- Prepare hazard classification maps, based on disaster risks
  - Responsible actor is the provincial Ministry concerned with water resources needs.
  - Based on the maps, formulate land use plans
  - Carry out flood and landslide management accordingly
- Classify areas in the vicinity of the river to protect the river and address the escalating problem of encroachment upon the right of way of rivers
- Enhance the capacity of at-risk or flood-affected communities to fight floods and conduct emergency operations.

- In hazard-prone areas, conduct awareness raising and confidence building programs to enhance awareness and confidence that communities have sufficient resources and capacity to confront flood disasters in the form of emergency measures
- Booklets with illustrated pictures and written in simple language on emergency river training measures (such as dumping boulders and sandbags, and driving bamboo piles and porcupines) should be prepared and distributed by Federal and State governments agencies responsible for flood control
- Conduct training and drill programs, utilising maps and emergency materials on how to prevent river erosion and damage to property and life
- Make provision for the stocking of construction materials required for emergency operations to prevent river erosion and inundation

• Preparation should be made to mitigate the impact of floods and landslides by stocking construction materials, equipment, relief and rescue materials at appropriate locations, and including:
  - elaboration of hazard classification maps
  - establishment of emergency disaster management centres in each province for the management of disasters including flood and landslide
  - in such centres, stock the necessary quantity of rescue and relief materials and equipment; make legal provisions to mobilise private sector equipment or other materials in an emergency, on condition of subsequently providing compensation
  - Allocate personnel trained in flood and landslide management to staff the centres in required numbers

• Land eroded or inundated by flood and subject to such risks should be utilised judiciously through reclamation and protection. Recommended actions under this Strategy are:
  - Put public land eroded and inundated by flood to commercial use, by leasing it to the private sector for reclaiming, protecting and use, for a definite number of years
  - Develop necessary laws and guidelines for the implementation of the reclamation and utilisation strategy

9 Strategies to secure drinking water supply

9.1 Introduction

In 2018, participants in the Kamala Basin Initiative identified, as one of their major development actions, the need to '*secure and develop water resources for current and future drinking water requirements*.[47] The participants further identified several specific actions to meet this goal, for example, development of storage and distribution systems, and source conservation.

This Chapter offers strategic advice, based on literature review and recent experience in Nepal, to address some cross-cutting challenges affecting sustainable development of the WASH sector in the Kamala Basin. The advice focusses on the need for all local governments to prepare integrated WASH plans addressing multiple themes, ranging from affordable access, to long-term sustainability (Section 9.13). Accordingly, the Chapter identifies a need for short-term capacity development of local governments to engage in such planning (Sections 9.11).

In addition, the Chapter describes a need for independent regulation of service delivery (Section 9.3). It further identifies a need to promptly clarify and formalise relations between service providers such as WUSCs (water use and sanitation committees) and local governments (Section 9.11).

The Constitution of Nepal has recognised access to safe water supply and sanitation as a fundamental right of Nepalese citizens. Government programs are focused on realising this right by implementing the 'leaving no one behind' approach (NPC 2020). This approach accords with commitments expressed in the United Nations Sustainable Development Goals (SDGs). SDG 6 includes targets to achieve:

- universal and equitable access to safe and affordable drinking water for all by 2030 (target 6.1);
- access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations (target 6.2).

SDG 6 is interlinked with other SDGs, which aim to achieve a broader sustainable development by providing access to nutrition, education, health, ending inequality, caring for the environment, and building resilient cities.

Drinking water has been accorded the highest priority, amongst all competing uses, in Nepal's *Water Resource Act (1992)* and associated regulations. This has enabled rapid expansion of water supply coverage across the country. The *Rural Water Supply and Sanitation Policy 2004* and *Urban Water Supply and Sanitation Policy 2009* have guided the WASH (water, sanitation and hygiene) sector. These policies guided action to meet Millennium Development Goals[48], where Nepal surpassed its target. The policies are now being updated to align with new development and constitutional provisions. A newly drafted *Water Supply and Sanitation Bill* has been tabled to the parliament. When approved by the Ministry of Water Supply, the legislation, along with the above policies and the Sector Development Plan, will define new provisions, including targets and indicators for monitoring the sector's progress.

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[47] Goal 2, Objective 3, Action 1. See Section 3.1

[48] The United Nation's Millennium Development Goals set goals to be reached by the year 2015. They were the forerunner of SDGs which set targets for 2030.

These new policies also focus on sustainability and quality of services, moving from nominal to effective coverage in the sector, which will be achieved by service standards as indicated in Table 9.1.

Table 9.1 Level of services and indicators as per Urban Water Supply and Sanitation

LEVEL OF SERVICE	INDICATORS
Basic	At least 45 Litres per capita per day (LPCD), public tap within 30 mins of fetching and waiting time, at least 4 hours of service a day
Medium	45–100 LPCD, 24 hours service, yard connection, at National Drinking Water Quality Standard
High	More than 100 LPCD, 24 hours service, fully plumbed, within the house, meeting World Health Organisation (WHO) standard

Source: (GoN 2009)

The draft *WASH Sector Development Plan* has included robustness and resilience as the indicator of service which takes emergency services and ability to handle shock loads as parameters to measure the level of services.

Similarly, a Joint Monitoring Program (JMP) between United Nation Children Fund (UNICEF) and WHO provides internationally recognised indicators of service level (Table 9.2).

Table 9.2 Globally agreed WASH service level indicators on SDG 6

LEVEL OF SERVICE	INDICATORS
Safely managed	Improved sources located on premises, available when needed and free from faecal and priority chemical contaminants
Basic	Improved source within 30 minutes of fetching and waiting time
Limited	Improved source over 30 minutes of fetching and waiting time
Unimproved	Water from unimproved sources
No service	Surface water

Source: (UN-Water 2016)

In Nepal the measurement of quality in delivery of WASH services, for basic levels of water supply and sanitation, and hygiene provisions, is done by reporting against nationally adopted indicators, which closely align with the JMP indicators.

9.2 Long-term plans in WASH services

The Government of Nepal has adapted the SDG targets to suit the country's situation. Performance indicators are proposed in an approach paper developed by the National Planning Commission (NPC), for the fifteenth *Five-Year Plan and Long-Term Development Plan 2043*. National indicators are shown in Table 9.3.

Table 9.3 Nepal's SDG WASH performance indicators

COMPONENTS	2015 (%)	2030 (%)
Basic water supply coverage	87%	100%
Piped water supply	49.5%	90%
Using safe drinking water	15%	90%
Households with E-Coli	82.2%	1%

COMPONENTS	2015 (%)	2030 (%)
Basic sanitation	82%	100%
Improved sanitation facility (not shared)	60%	95%
Urban toilets connected to sewer system	30%	90%

Source: (DWSS 2019)

Table 9.3 shows that the country target is to achieve 100% basic water supply coverage and about 90% safe drinking water in the 15th periodic plan (2020–24). This is in line with the SDG6 target of 94% of basic water supply services and 20% of safely managed sanitation services (includes faecal sludge management and urban sewerage waste water treatment plant) and 37% of medium level of water supply services (if Table 9.1 is compared with Table 9.3 medium level water supply services almost fulfils the performance criteria).

It is critical that the Ministry of Water Supply ensure that the development of Management information systems (MIS) used in the WASH sector are in line with sectoral goals to measure the performance. In the past, basic water supply coverage was measured by system coverage. However, the MIS should shift towards level of service, as the basic water supply level approaches 100%.

The sector needs to be certain that all people are getting water for daily needs within 30 minutes without any barriers (social exclusion, gender exclusion or due to limited mobilities). Similarly, to attain Nepal's 2030 safe drinking water level of 90%, daily recording of water quality by service operators, and integration with MIS is necessary. This will help to track the reduction of E-coli as well. Similarly, MIS should record effluent quality to ensure safely managed sanitation services.

9.3 Institutional arrangements

Responsibilities for water supply, sanitation and hygiene are defined as matters of concurrent rights of the federal, provincial and local governments in Schedules 5 to 9 of the 2015 Constitution. The *Local Government Operations Act 2017* entrusts this as a primary responsibility of municipalities. Attempts have been made through a cabinet order to further classify the concurrent function responsibility provided for by the Constitution. According to this classification, water supply projects serving more than 1,000 people in mountain districts, 5,000 in hill districts, and 15,000 in Terai districts, as well as projects with technical complexities, fall within the responsibility for federal implementation.

Federal agencies implementing WASH programs are mainly the Ministry of Water Supply (MoWS) and Ministry of Urban Development (MoUD). Provincial governments build and manage WASH programs through their respective Ministries of Physical Planning and Infrastructure Development (MoPID). Many programs, although administered under federal and provincial governments, are implemented in close consultation and partnership with local governments or the respective WUSCs. Local governments directly manage projects with relatively small service populations, which are technically simple to construct, operate and maintain.

Water supply systems are in general managed and operated by locally formed Water Users and Sanitation Committees (WUSCs), which operate under the provisions of the *Water Resource Act (1992)*.[49]

Currently, services in Kamala Basin are being provided either by WUSC or (for larger urban centres) by Nepal Water Service Corporation (NWSC). However, with Municipalities now leading public service delivery, the role of WUSC and of NWSC must be reviewed and realigned to match changed governance requirements.

With a large-scale splitting of federal functions into several local government responsibilities, the need for an independent service regulator is increasing. Figure 9.1 shows the current institutional arrangements at the National level.

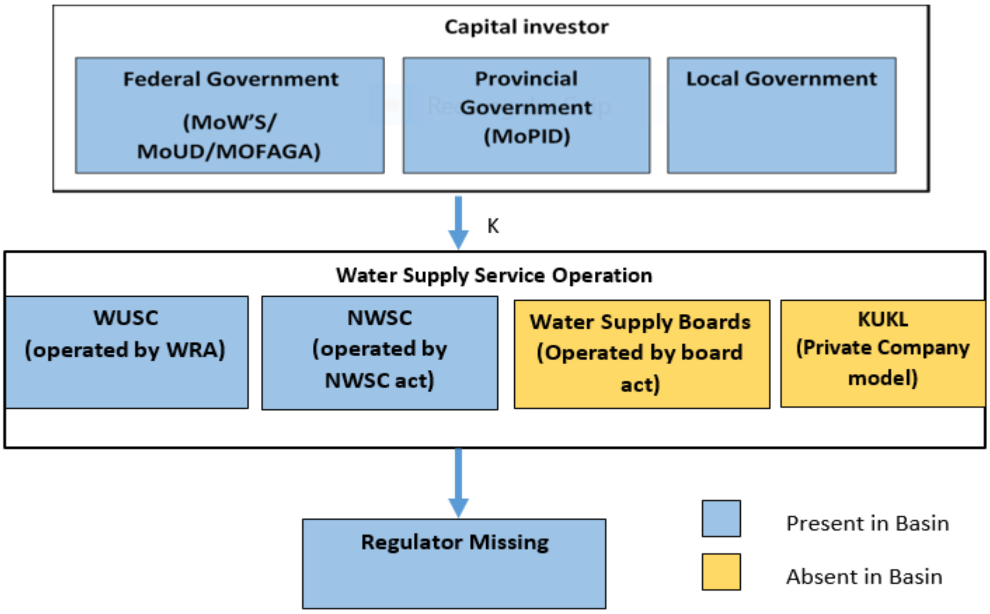

Figure 9.1 National level institutional arrangement of water supply services

9.4 Water supply status and challenges in Kamala Basin

Department of Water Supply and Sewerage Management (DWSSM) has classified[50] households with access to piped water, tube well, covered wells, and rainwater harvesting (RWH), as having access to 'improved' sources, while household with access to surface water or unimproved sources have been classified as having 'no service' (Table 9.2).

The overall water supply coverage of Kamala Basin with respect to the source of supply is shown in Figure 9.2. The overall coverage (84%) is approximately 5% lower than the national average. The Terai

[49] The Nepal Water Supply Corporation (NWSC) operates about 23 water supply utilities across Nepal, for relatively large urban centres. Water Supply Management Boards manage water supply and sanitation services in Bharatpur, Hetauda, Dharan, Kavre Valley, and in Kathmandu Valley

[50] Under its National Management of Information Project

districts (Siraha and Dhanusha) have higher water use of shallow tube wells as water supply services where as Udayapur and Sindhuli has higher piped coverage.

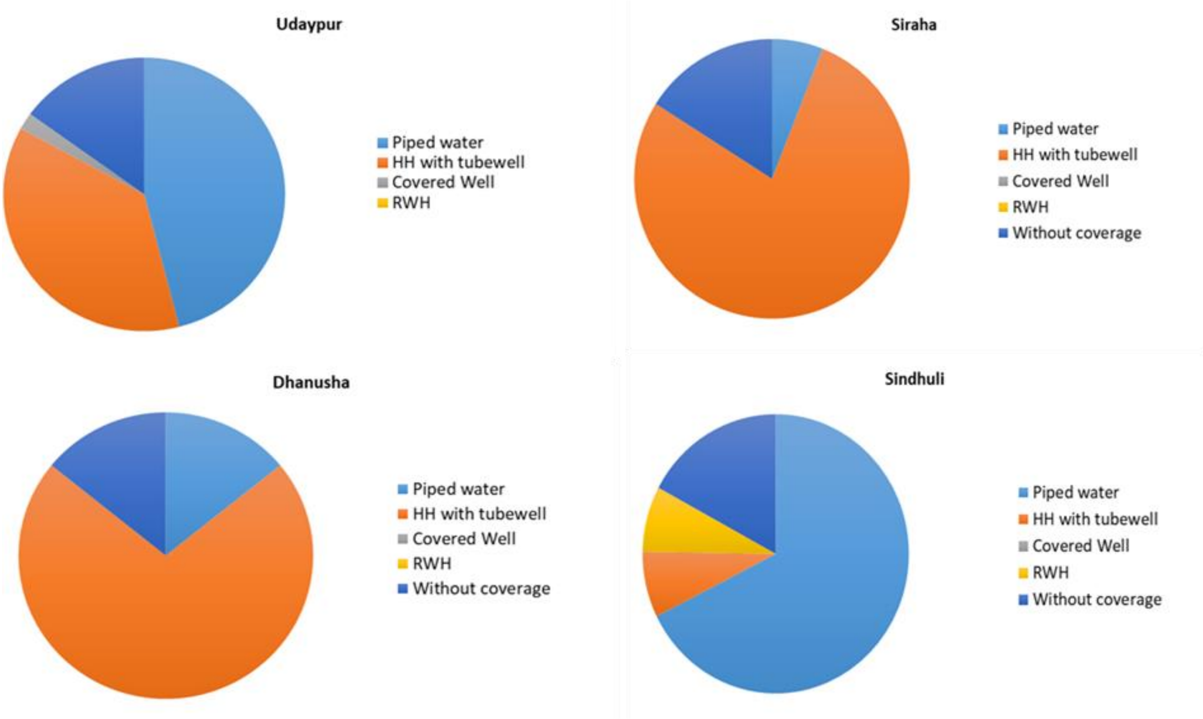

Figure 9.2 Overall water supply status for drinking water in Kamala Basin

Figure 9.2 is based on available government data, structured according to the pre-2015 administrative classification of district, VDC and urban municipality. It is difficult to transfer this data to the post-2015 administrative boundaries, as the boundaries of the old and the new systems are not free from overlapping (e.g. some sections of a particular VDC might have been merged with more than one municipality in the current classification). The monitoring of progress towards SDG targets will require specific data sets structured by current administrative boundaries.

The current levels of coverage, and the mode used to access water in the Basin, are two cross-cutting issues which are introduced below, and discussed further in Sections 9.4.1 and Section 9.4.2.

9.4.1 Leaving no one behind

Approximately 16% of the Kamala Basin's population lack basic water supply coverage (slightly higher than the national average). Sindhuli District has the highest proportion of unserved population (18%).

The unserved population in any area can be difficult to identify because such population is comprised of households which are distributed within served communities. Several methods are being discussed to identify these households in order to provide them with improved levels of water supply, sanitation and hygiene facilities. Local governments and respective water utility systems are best placed to identify these households, supported by MIS. MIS can also support estimation of investment required.

9.4.2 Mode of access

As noted above, the dominant mode of access to drinking water is tube well for the Terai districts (Siraha and Dhanusha), and piped system for the Upper Basin districts of Udayapur and Sindhuli. The capital investment to provide safe water services by 2030 is approximately NPR6 billion (NPR950 million in Udayapur; NPR1.9 billion in Siraha; NPR2.3 billion in Dhanusha; NPR850 million in Sindhuli).

Although Nepal has a national target of 90% piped water supply by 2030 (Table 9.3), 75% percent of the population in the 4 districts of the Kamala Basin (>1.5 million people) do not have access to piped water.[51]

In terms of the Joint Monitoring Program level of service (Table 9.2), most tube wells meet the 'safely managed' level with respect to proximity and availability when needed.

The performance of this mode of access can be improved by informed site selection (for new systems), and investment in water quality treatment to remove faecal contamination and arsenic (a priority chemical contaminant). Small community schemes with modular treatment units can treat coliform, Arsenic, Iron, Manganese. Where groundwater is available, the cost of providing treated drinking water from tube wells needs can be explored as an alternative to piped water.

National level stakeholders are providing technical and financial support to local governments to formulate integrated municipal WASH plans, which can also be adopted for Kamala Basin (Section 9.12).

9.5 Piped water supply schemes in terms of maintenance needs

The overall asset value of piped water systems in the Kamala Basin is shown in Table 9.4.

Table 9.4 Overall asset value of piped water supply schemes in 4 districts of Kamala Basin

DISTRICTS	ASSET VALUE (000 NPR)
Udayapur	636,160
Siraha	99,690
Dhanusha	281,370
Sindhuli	862,160
Total	1,879,380

Source: Department of Water Supply and Sewerage Management (DWSS 2019)

According to DWSSM, data on the functionality of piped water schemes indicates that approximately one-third are in a well-functioning status (~346 schemes; Figure 9.3 below), while one-third require minor repairs (~381 schemes). The remaining one-third of piped water schemes (~365 schemes) either require major repair (e.g. critical structures such as intake or reservoir are destroyed, affecting water service); revitalisation (e.g. project requires extension in the service area) or reconstruction (project has already crossed design periods and affecting the service level).

DWSSM policy and guidelines for rural water supply and sanitation state that minor repairs are generally the service providers' responsibility. Such minor maintenance should generally be derived as part of their tariff determination, and implemented in a timely manner, to reduce the need for major

[51] Achieving a target to deliver piped water nationally would require >NPR45 billion

repairs. In the Kamala Basin, WUSCs and NWSC would be among the agencies responsible for minor maintenance.

Intervention and support from all local, provincial and federal governments, will be necessary to maintain services at intended levels, and further improve them.

District wise disaggregation of data is presented in Figure 9.3.

The thresholds of these interventions must be however, set out for support by these 3 tiers of governments.

The number of piped schemes in Siraha and Dhanusha is much lower than that in Udayapur and Sindhuli districts, as a result of availability of groundwater in these districts. In these 2 Terai districts, meeting a piped water supply coverage target of 90% requires approximately NPR1.1 billion, compared to a requirement of NPR230 million for Udayapur and Sindhuli combined. As the target is the national target agreed by National Planning commission (NPC) the local governments are also responsible is achieving so. The Federal and provincial governments technical and financial support to local government is necessary to meet the target.

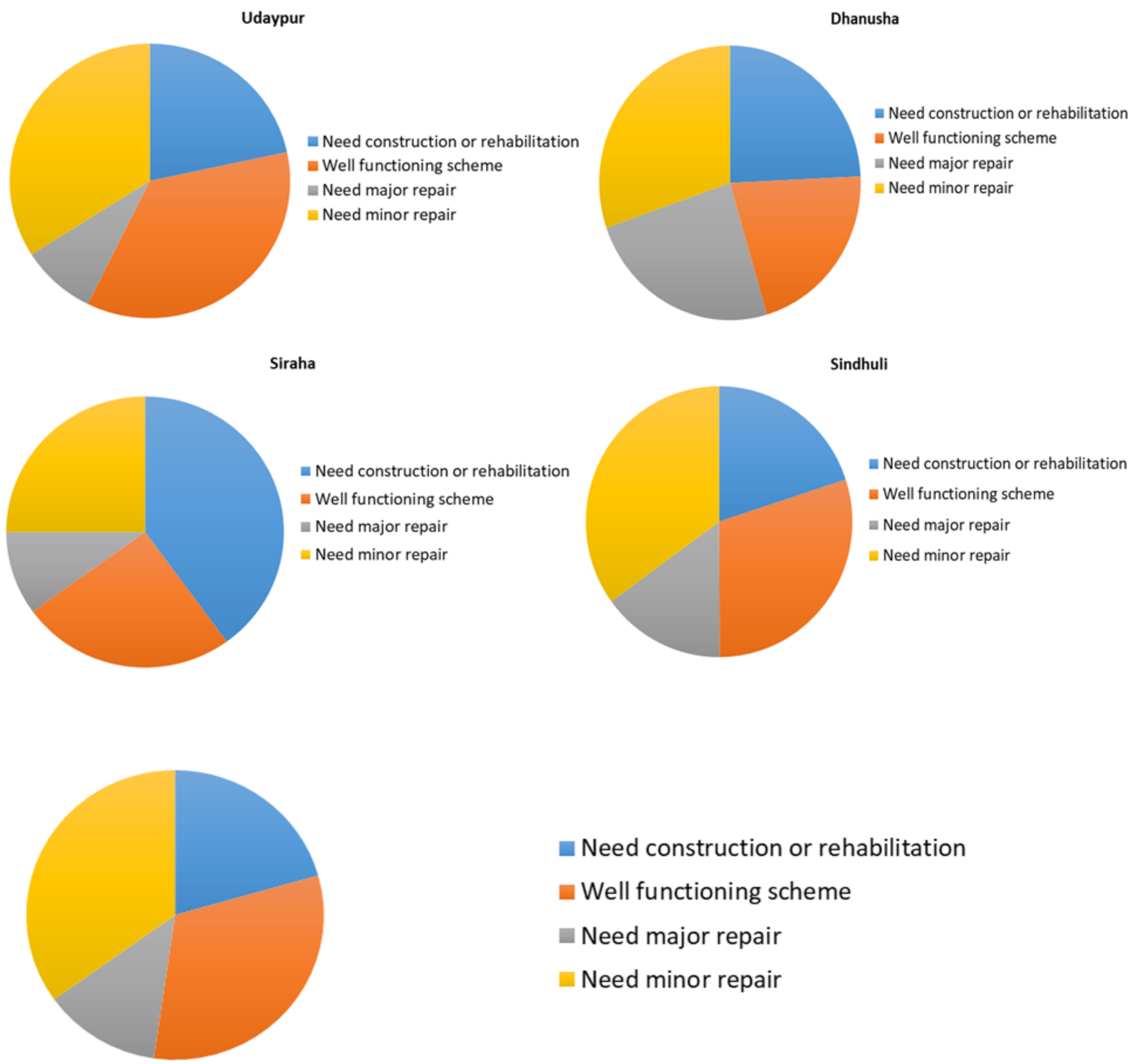

Figure 9.3 Condition of Water Supply Schemes in Kamala Basin

Based on national estimates that 3–5% of capital investment cost is required for one-time maintenance costs, approximately Rs 600 million will be required to achieve such maintenance requirements for systems in districts of the Kamala Basin.

9.6 Water supply service levels

It is not sufficient to have piped schemes installed to ensure basic water supply services to people and satisfy their daily consumer needs. Service levels must be improved and aligned with the 'one house, one tap connection policy' of the GoN. This will require additional investments beyond those shown above: the above estimates were derived based on a public stand post water service, which has thus far been widely and commonly practiced for counting coverage.

Data presented in Figure 9.3 are for schemes at the 'basic' service level (i.e. within 30 minutes of fetching and waiting time). Figure 9.3 suggests minor repair, major repair, revitalisation and reconstruction needs of any schemes are likely to fall in limited category because that might change the fetching time or reduce the water availability.

Additional financial and technical resources are required to ensure that the water supply is safe from contamination, and safe for consumption at all times. This will be in accordance to meet the requirements of providing safely managed water for all by 2030.

It is estimated that approximately NPR750 million (beyond capital investment costs) will be required to ensure safe water quality, and to support good management practices. This estimate covers laboratory facilities (to ensure safe water quality), capacity building for efficient management, and customer service delivery.

These figures are derived based on estimated cost requirements of 1.5% of capital cost for capacity building, suggested in the draft WASH Sector Development Plan, under approval by the MoWS (MoWSS 2020b).

9.7 Water quality

Water supply services can be considered safely managed for meeting SDG targets, only when contaminants (mainly faecal contamination and priority chemical contaminants) are removed from drinking water.

The *National Drinking Water Quality Standards 2020,* under development by MoWS with support from WHO (MoWSS 2020a), has categorised guidelines for water quality parameters into:

- non health-based parameters (contaminants do not affect health)
- health-based parameters (contaminants have adverse health effects).

Major issues for drinking water quality in Kamala Basin are shown in Table 9.5.

Table 9.5 Water quality issues in Kamala Basin

WATER QUALITY PARAMETER	TYPE OF PARAMETER	AFFECTED AREAS
Arsenic	Health-based	Dhanusha and Siraha districts are classified as having moderate vulnerability to arsenic pollution (NHRC, 2006) Siraha and Saptari have shown arsenic concentrations more than recommended value of NDWQS (50 parts per billion) (Jay Krishna Thakur 2011) Long term exposure can create adverse health impacts such as skin cancer
Faecal contamination	Health-based	Water schemes not following proper chlorination or with high leakages are contaminated by faecal matter/1
Iron and manganese	Non-health-based	Concentration greater than guidelines values may cause unpleasant taste, appearance by colour, and have effect of staining of teeth, clothes, bathroom fittings and other materials (Yellow colour indicates iron, black indicates manganese contamination)
Calcination	Non-health-based	May cause blockage in pipes Generally, results in hardwater, which prevents forming soap lather Chure region with high calcium in geology is vulnerable to calcination

Note: A multi-indicator cluster survey showed more than 80% of water sources are contaminated from faecal contamination (CBS 2015)

The water quality issues summarised in Table 9.5 require management interventions: major types of interventions are described below.

Development of laboratory facilities

The GoN is considering establishing laboratory facilities in each province to allow testing of water samples towards ensuring water quality. Mobile water quality testing laboratories (caravans fitted with laboratory facility) are already in operation, one of which is providing services through the federal water supply office located in Dhanusha. Portable water quality testing kits to facilitate onsite testing of eater samples are also provided. However, these interventions are very limited compared to the testing requirements. Laboratories and testing facilities must be expanded to allow testing for faecal and priority chemical contaminants and providing adequate certification.

Water Safety Plan

A Water Safety Plan is a preventive tool to minimise water quality related risks and vulnerabilities by ensuring proper monitoring and frequent testing. It should be developed and implemented to minimise risk of system contamination.

Procedures and capacity building for operators

Operators should be clearly instructed and guided on how to operate the treatment units. Development of treatment unit-specific standard operating procedures is necessary to manage treatment units sustainably.

Operators capacity needs to increase. A draft Urban Water Supply and Sanitation Policy (GoN 2009) has mentioned benchmarking the performance of utilities to assess operator capacity based upon the performance against pre-defined indicators. Similarly, *Water Services Providers Operational Guidelines 2012* has also reinforced the need to build such capacity in system operators (MoWSS 2014).

The above policies need to be reviewed and updated post-federalisation together with development of standard procedures for water testing facilities.

Relevant technical personnel of the operators must be trained with adequate skills to identify and mitigate contamination as well as implement Water Safety Plan, operate water treatment facilities, and maintain water quality in distribution, including carrying out disinfection.

9.8 Safely managed sanitation services

People in the Kamala Basin who are dependent upon groundwater and river water, are prone to being affected by upstream discharges of wastewater effluent, both treated and untreated. Such discharges can affect groundwater and river water quality and the health of people using contaminated water for drinking, washing, bathing or recreation.

Major sanitation issues inside the Basin include:

- lack of knowledge about the actual functional performance of sanitation systems against the JMP indicator of 'safely managed sanitation services.' A safely managed level of performance requires faecal sludge management and wastewater management services
- need for proper management of latrines. Single pit latrines are generally regarded as unsafe. Risk of contamination can be reduced with proper emptying schedules. In hilly areas, double pit latrines are generally considered safe with proper use and maintenance. In the Terai, pits run the risk of being filled with groundwater during the monsoon: they must be elevated and protected against such failures
- safely managed sanitation further includes attributes such as: continuous and reliable availability of water and soap for hygienic practices.

These are potential areas for local governments to immediately engage to protect public health and safety.

In addition, safe handwashing facilities in schools, health centres, and public places, coupled with promotion of hygienic behaviour and menstrual hygiene is critical. An adequate number of such facilities, which are safe, reliable and accessible to all people at all times, must be provided and closely monitored for their continued functional delivery.

9.9 Technical considerations

Water supply systems have multiple components: water source, with intake and transmission facilities to transfer water to communities; treatment units; storage reservoirs; and properly laid distribution mains to minimise leakage, as well as for maintaining water quality up to the consumer tap.

All facilities and structures need to be properly designed keeping the geography, water demand, population pattern and ease of access and use in mind. The systems must also be designed for climate and disaster resilience. Major technical considerations are summarised in Table 9.6.

Table 9.6 Technical considerations

AREAS	CONSIDERATIONS
Water sources	• Source should be reliable; climate vulnerability should be assessed properly as small sources are more vulnerable to climate change

AREAS	CONSIDERATIONS
	• Some local governments have initiated protection of small sources by digging recharge pits upstream • Development works such as road construction can have adverse effect on the small spring sources, which are liable to drying • Increasing use of pesticides for agricultural purpose can degrade quality of source water • Groundwater recharge is important aspect in Kamala Basin as large part of the population is dependent upon groundwater: recharge mechanisms should be adopted • Proper distance from toilet to shallow tube well should be maintained to achieve the desired water quality. Different countries have different regulation on the safe distance ranging from 3 meters to 30 meters with average of 25 meters (Parker and Carlier 2009) • Some chemical contaminants require advanced methods for removal. If concentrations of arsenic, iron, or calcium carbonate are too high and costly, alternative sources may need to be found.
Reservoir tanks	Following the COVID-19 pandemic, focus on WASH services has shifted towards promoting good hygiene practices specifically for hand hygiene. Water supply designs of 45 litre per capita per day (LPCD) are likely inadequate for frequent handwashing and promotion of hygienic behaviour. Reservoir tanks should be considered as an alternative to meet the growing hygienic need, as well as increasing temperatures from climate change
Transmission and distribution lines	Following needs generally exist: • for proper burial with top cover to protect pipelines • for appropriate sizing, considering reasonable future demand • for mechanisms to monitor discharge and pressure through assigning district metering areas (DMA), where the inflow and outflow of water can be measured in a grid system of supply
Water treatment units	• Cheap and affordable technologies can be selected (e.g. slow sand filter requires approximately 20 times more sand than rapid sand filters required hence the value of sand would plays a critical role in selecting the choice of filtration technology. • The selection of treatment technology should be to the level that can be supported by respective operator, usually the WUSCs • Advanced methods of treatment generally fail in the absence of local capacity to operate. • Household-level technologies such as bio sand filters, point-of-use, or small-scale community technologies can be promoted.
Demand management	• Water demand tends to rise with increase in socio economic status: e.g. increased use of flushed toilets and modern toilet fixtures, change in hygiene practices

Note: Supports reduction in non-revenue water (NRW), equitable distribution of water.

Many technical considerations discussed above have economic, policy or institutional ramifications. For instance, financing upstream source conservation work through water tariffs, or local government taxes may be appropriate. Economic policy instruments as payment for ecosystem services (PES), although new to Nepal, could form part of a structure of incentives to reduce the water quality impacts of change development practices in upstream areas.

9.10 Economic considerations

Portions of the Kamala Basin with lower socio-economic status[52] may struggle to meet a GoN policy for increased financial contribution from beneficiaries.[53] The GoN policy is to source 20% of capital investment from users in Hill or inner Terai-Madhesh districts (i.e. Sindhuli and Udayapur), and 10% in

[52] Siraha falls in the lowest quartile of human development index among other districts in Nepal

[53] Rural Water Supply and Sanitation Policy (GoN 2004) has advocated contribution requirements in projects

Terai-Madhesh districts (i.e. Dhanusha and Siraha). WUSCs generally contribute through earthworks for distribution lines.

In Sindhuli and Udayapur districts, as the local effects of climate change are becoming more pronounced, inadequately protected water sources have started to dry up. This is putting pressure on finances as communities have to resort to costly pumping solutions to get their supply of water. Calcination may increase maintenance requirements.

In Siraha and Dhanusha districts, groundwater is relatively accessible, which enables people to quickly install a shallow tube well to draw their daily supplies. In such circumstances, people are hesitant to contribute to water utility projects, which appear more supply driven rather than demand driven. Increased awareness of the health benefit of piped water supply over shallow tube wells may help motivate people to contribute to mandatory requirements. In poorer areas, additional policy instruments may be required to mobilise financial resources required to provide piped water (Table 9.7).

Table 9.7 Economic considerations

AREAS	CONSIDERATIONS
Leaving no one behind (consideration for marginalised communities)	• Projects like small town water supply, have come up with Output-Based Aid mechanism (OBA) to facilitate marginalised communities for availing household connections and constructing toilet facilities. The OBA mechanism supports this process by making payments to service utilities after such connections have been provided. • Cross subsidies can be one of the mechanisms such as hotels and other profit-making organisations can be charged higher to subsidise rates for marginalised communities • Similarly, through good technologies and better management water at WHO standard could be produced and sold to replace bottled water/ revenue can cross subsidise marginalised communities
Capital maintenance	• Maintenance costs can be reduced by good asset management practices: regular monitoring & maintenance schedules; standard operating procedures (Section 9.7) and barcoding assets • WUSCs and other water utilities can initiate manual asset management systems then transition to online asset management • System insurance can be a good tool to address climate vulnerabilities[2]
Business plan of water utilities	• The business plan of any water utility should describe its approach to minimise operational expenditure and maximise revenue generation, through means such as: o non-revenue water reduction o system automation for efficient management o outsourcing of work such as billing[3]

Notes Once piloted by NWSC for cross subsidies.

[2] Trialled in Lekhnath water supply project (Kaski), and a few rural water supply projects

[3] Many WUSCs have initiated e-billing mechanisms, increasing the collection ratio and reducing the staff to connection ratio as well

9.11 Institutional considerations

Institutions in water supply and sanitation are fragmented with many agencies having overlapping roles. Water supply systems are being operated by WUSCs, NWSC, or local boards, depending upon the historical practices, relative size and complexity of the utility. With so many different agencies, with almost every system having its own WUSC, service management is becoming unwieldy. A suitable solution for more robust distribution agency must be found, under local government ownership.

A need for a technical and tariff regulator is also emerging, to facilitate and harmonise water supply and sanitation systems. After the enactment of the federalisation process, responsibility for operations now rests with local government. However, no formal linkages exist between the WUSC and the local municipality, which has resulted in some conflicts, in other parts of the country. An effective policy solution is promptly required (Table 9.8).

Table 9.8 Institutional considerations

AREAS	CONSIDERATIONS
Legal linkages	• Legal linkages between the service operator and local governments with respect to asset ownership, management handover and continuous service improvement appears necessary • Similarly, groundwater source ownership and local government jurisdiction also need to be examined in detail. Source licensing for all water sources pursuant to *Water Resource Act (1992)* has been difficult to implement for groundwater • Conflict resolution mechanisms for transboundary issue, water allocation mechanisms, prioritisation and revenue sharing after resource sharing needs to be guided legally (see Chapter 5)
Accountability	• Service regulations can make water utilities accountable towards regulating agencies. There is no mechanism to regulate large number of WUSCs, who are independently operating systems. • Draft WASH Sector Development Plan has proposed establishing regulating agencies differentiated by type of system. • Continuous monitoring mechanism also should be established under the local governing bodies to ensure the level of service. Recently, establishment of integrated MIS of WASH in federal level has been initiated. The principle user of the MIS would be local government. Provincial government would also use the same MIS platform It is expected that local government can use that channel to properly monitor the WASH systems within its jurisdiction
MIS & Decision Support Systems	• Motivation, capacity strengthening and backstopping from federal and provincial sides are needed for use of MIS or Decision Support Systems at local government level

Notes Some administrative regulation of NWSC and water boards is provided by MoWS

9.11.1 Capacity development

Functionality of water supply and sanitation systems depends upon technical, economic and managerial strengths of the service provider. Assessment of capacity should be indicator-centric (see Example Capacity Development Program below).[54]

Capacity building can be carried out through different initiatives (e.g. recording meeting minutes, public consultation, account keeping, store keeping, simple plumbing trainings). However, as the service level of a utility increases, new capacity development packages are required for continuous service level improvement. These areas can also be built in MIS.

Ongoing capacity development in different themes such as climate and disaster resilience, new technologies, on-revenue water, and smart water management (the management of water through technology such as SCADA) is relevant to system designers, tariff setters, and managers. Capacities once developed need to be monitored closely for efficient service delivery.

Capacity development needs to be addressed by all 3 levels of government. The National Water Supply and Sanitation Training Center (a dedicated capacity development organisation) might be insufficient. Activities can be developed through partnerships between service providers (previously trialled at Lekhnath Water Users Committee (Kaski) to reduce non-revenue water). Best performing organisations

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[54] Nepal has recently used national indicators, and SDG indicators from JMP

after benchmarking could be selected as the WASH service centres to build the capacity of other organisations in the form of networking.

Example capacity development program

One example of a capacity development program is the Water Supply Management Improvement Program (WaSMIP)[55] aimed to improve the key performance indicators (KPIs) such as quantity of water per population; meter connection ratio (ratio between metered tap to total tap); operation ratio (ratio between operation cost to revenue generated); and non-revenue water (ratio of non-billed water to total water produced). This was done through capacity building and technical backstopping from the government.

The program has shown promising progress in improving the efficiency of service. Examples include Mangadh Water Supply Project of Biratnagar and Lekhnath Water Supply Project of Kaski. Such backstopping is recommended for systems within Kamala Basin.

9.12 Sustainability of water supply services

Attaining sustainability is a long-term process that involves making informed and legitimate decisions regarding which type of WASH system to develop (Section 9.4.2). It further involves sustainable physical design, and effective organisational management. Some of these aspects have been touched upon in previous sections, and are summarised in Table 9.9.

Table 9.9 Factors affecting sustainability of water supply services

FACTORS AFFECTING DRINKING WATER SUPPLY SUSTAINABILITY	CONSIDERATIONS
Choice of system of service provision (mode of access)	• In districts like Siraha and Dhanusha, existing decentralised tube well systems compete with piped water utility models. Financial sustainability requires user fees to be set in an affordable manner and collected • An informed and legitimate decision regarding which system is best for a given municipality or set of municipalities is recommended • A sectoral decision support tool can help prioritise projects, identify investment options and design management models
Design aspects	• Site specific designs are necessary as the Kamala Basin has varied geological formulations. Previous designs have not considered resilience to flood and landslide, resulting in structures susceptible to such hazards. Quantity and intensity of rainfall need to be considered when designing systems for the Chure
Management improvement	• Benchmarking reports from Sector Efficiency Improvement Unit (SEIU) of Ministry of Water Supply (MoWS) suggest that adequate management of the established infrastructure has impact on the sustainable use of water (SEIU 2016);(SEIU 2013)and (SEIU 2012) • Service providers need to perform technical, managerial, and financial functions efficiently and effectively (Section 9.11) • Service operators should anticipate climate induced disaster and develop strategies to improve resilience

[55] Supported by Japanese International Corporation Agency (JICA) through DWSSM, Rural Water Supply and Sanitation Improvement Project (RWSSIP) Component 2

9.12.1 WASH planning for sustainable development

Water resource utilisation decisions could be based on core economic indicators like cost to benefit ratio for any activity or a project. In general water and sanitation projects also provide multiple social and human development benefits. These benefits are not always manifested in the short term, and they cannot always be easily quantified. Water supply projects are required to be implemented to meet the overriding commitment of universal access, guaranteed by the constitution. Thus, water and sanitation services cannot be judged solely by short-term benefit to cost indicators.

A careful accounting of social and economic benefits and costs must therefore be carried out for rational and informed decision making for water and sanitation projects. Alternative systems must be explored and presented with different options and cost models. When planning improved service levels and/or higher uses, the economic value of water must be costed properly.

Integrated WASH planning and decision taking can be supported using a participatory multi-criteria analysis (MCA). Socio-technical alternatives can be assessed by criteria which describe health, and economic & financial impacts. For example, small-scale treatment units for shallow tube wells can be assessed against piped water supply services in Siraha and Dhanusha.

Institutional arrangements and organisational models to implement alternatives most favoured by stakeholders can be developed through institutional analysis, as presented in Chapters 5 and 6.

9.13 Summary of strategic advice

Proposed strategic actions and time frames are tabulated Table 9.10. Time frames are classified as short term (< 2 years); medium term (2–5 years); and long term (> 5 years).

Table 9.10 Proposed actions and time frames

PROPOSED ACTION	TIME FRAME	REMARKS
Preparation of integrated WASH plan for all local governments	Short term	Initiated by Department of Water Supply and Sewerage Management Main responsibilities of federal government are to provide process and analytic framework for WASH plans; facilitating local governments to establish goals in harmony with national and SDGs Local governments after consultation with various actors will identify their investment options, set priorities, and plan accordingly
Prioritisation of investment	Short term	Integrated WASH plan to cover themes such as: leaving no one behind (Section 9.4.1); service level improvement (Section 9.4.2); WASH in institutions; building climate resilience; incorporating gender equity and social inclusion in projects Resource planning for above themes should cover: capital expenditure; management, operation, and maintenance expenditure; and direct support
Identify the water allocation for WASH against total water resource	Medium term	Basin-scale organisation can gather the data and determine the allocation Allocation must be supplied regularly without any hinderance and conflict (basic human right in Constitution)
Generating new investment options	Long term	Includes development of public–private partnership models; development of climate-change related financing
Water efficiency and demand management	Long term	Includes introduction of water efficient technology
Water recharge, wastewater reuse	Long term	As water stress increases, adaptive options such as recharge and reuse of wastewater deserve to be developed

With respect to new investment options: government alone will not be able to invest in WASH services adequate to achieve the SDGs (Table 9.3). Private sector resources can be mobilised through subsidies, redemption in taxes, local concessions for mineral water production or agricultural compost production, as well as international climate financing for sanitation.

In the short-term, capacity development of local governments is required for the recommended local and municipal WASH plans. To achieve this, DWSSM should lead a process by which adequate frameworks, tools, and trainings are offered to local governments. Integrated WASH planning requires coordination of multiple local level plans with sub-basin and basin resources. It is an iterative and communication intensive process (see Chapter 5).

The above capacity development and multi-level planning processes require adequate institutional basis. It is recommended that such institutional arrangements be backed by new policy and legislated regulations. Similarly, the establishment of effective relations between WUSCs and local governments (Section 9.11), and independent regulation of service delivery (Section 9.3), require formal institutional arrangements.

10 Implementing the Kamala River Basin Strategy: next steps

The planning of water resources development for any basin or catchment is an ongoing process. At the conclusion of any part of that journey, the documentation – i.e. this Strategy document – presents the progress and outcomes achieved at that point in time, and highlights steps for the continuation of the journey. This document presents the end point of the current phase of water resources development planning for the Kamala Basin, the aim of which is to define a Strategy for ongoing efforts, leading to a range of agreed improvements and their implementation. The processes, analysis and findings to date are set out in detail in the preceding Chapters, particularly Chapters 4 to 9. These are brought together in summary form in this final Chapter, which also highlights common themes and key messages for the next steps and implementation process.

Traditional approaches to basin planning in the past and present have been relatively closed, top-down processes conducted by one expert or a team of experienced, technically qualified specialists, using available stored data and methods and tools accessible to specialists. The documentation produced for decision-making was similarly not widely shared, and as the whole process lacked transparency, the outcomes were not well understood by those most likely to be most impacted. If the analysis and decision-making were sound, as the plans were implemented, they resulted in net positive development of the water resources in the basin, with more winners than losers. In other cases, as decisions and their likely impacts became known, social acceptance and participation was low, with both short-term and long-term impacts on development outcomes.

The top-down approach described has a long history in many developed countries and most developing countries worldwide. With minor variations, it was the model used since the 1950s for developing countries by multilateral and bilateral international development assistance agencies, whose principal partners were the national governments, particularly when loan funding was extended. Nepal was no exception. Lessons were learned from decades of mixed experiences, and incremental adjustments were made to account for aspects affecting the sustainability of outcomes. These improvements occurred at different speeds in different locations and sectors, and were eventually acknowledged in a global sense in the UN Millennium Development Goals, and subsequently in the Sustainable Development Goals.

The water sector generally, and household water supply and sanitation in particular, had experienced an earlier period of special attention, under a United Nations International Water Supply and Sanitation Decade (1981 to 1991) which started with very ambitious aims of near-universal access, but fell well short of expectations. This gave rise to much introspection and distillation of lessons, recognising that real sustainability of development outcomes was achievable, but required quite different approaches with attention being focused much more on end users of water services, including decentralisation of decision-making. The deliberations recognised that the major use of water resources worldwide is for irrigation, and this sub-sector also featured in the final recommendations, their very public declarations in several international forums[56], and practical application of sustainable (water-related) development

[56] Dublin Principles, 1991, Rio Declaration 1992, subsequent application facilitated by UN agencies, Development Banks, bilateral development assistance agencies and others.

principles. However, financial lending arrangements remained exclusively with national governments and were much slower to accommodate changes to the structure of development assistance.

With the declaration of the new Constitution in 2015, the GoN started the general decentralisation of governance structures, moving to 3 formal levels of government, with further representation of communities in decision-making within Districts and Municipalities. This provided opportunities for undertaking water resources development planning with a more bottom-up approach, incorporating representative participation of water users, in accordance with the sustainability principles derived from decades of international experience. The current Strategy for the development of water resources in the Kamala Basin is the first application in Nepal of such a collaborative, bottom-up approach to development planning in the water sector.

There are considerable advantages of this new approach, not least of which is the overall increase in assurance of successful outcomes. The extensive research on past international experience since the early 1990s confirmed that the involvement of stakeholders in decision-making at the lowest practical level, i.e. water users, individually and collectively, is essential to the long-term sustainability of water resources development initiatives. Indeed, the institutional and social aspects of sustainability are now recognised as being of equal importance to the technical, economic / financial and environmental aspects. Real sustainability depends upon simultaneously addressing the contributions of all five components. Clearly, there are up-front challenges in applying these principles for the first time, mostly arising from the processes of devolving responsibilities, and empowering local stakeholders with the knowledge, tools and opportunities for their contributions to be most effective. Being the first attempt in Nepal, this Strategy has assessed in detail and recommended tools and methods which are most likely to overcome these up-front challenges, and provide the basis for ongoing improvements to sustainability.

The previous Chapters 4 to 9 of this Strategy describe in considerable detail the findings of the investigations and analyses in support of the agreed Development Pathways described in Chapter 3. It is worth recalling that the agreed statements of Goals, Sub-Goals, Actions and how they might be achieved, were derived from a series of facilitated consultations, firstly at local level within the basin, then at central government level, and again at local level with a roaming workshop. The process was focused on consensus-building, and the statements of agreed outcomes included areas of overlap, even internal inconsistencies and ambiguities, all of relatively minor importance to the level of agreement reached. These drafting oversights were more thoroughly scrutinised, clarified and corrected through the subsequent processes of consultation and analysis. Particularly through detailed analysis it was possible to more carefully structure the aggregation and wording of Sub-Goals and Actions, which allowed the consolidation of the details of the Development Pathways, while retaining the original Goal statements, the structure of the pathways and the intentions and expectations conveyed in the initial agreements.

The outcomes of the processes described are summarised in the following Table 10.1. The table has a similar structure to the initial tables of Development Pathways in Chapter 3, however this final version provides more definitive detail regarding how to achieve the Goals. The pathways summarised here as Sub-Goals, Actions and corresponding responsible actors, are derived from assessments and multiple analyses, as described in considerable detail in Chapters 4 to 9. The extent of the analyses was also able to identify key attributes and constraints for additional attention in the continuation of the process towards decision-making for implementation; the highlights are included in the final column of this Table 10.1.

Table 10.1 Kamala Basin Development Pathways as modified through analysis and strategy development (Chapters 4 to 9)

GOALS	SUB-GOALS	ACTIONS	HOW CAN IT BE DONE?	WHO NEEDS TO ACT?	KEY CONSTRAINTS
Goal 1: Sustainable management of Chure and its natural resources for livelihood support and reduced vulnerability to water induced disasters	Sub-goal 1: Watershed conservation and improvement	Action 1: Develop a new policy framework and basin-level strategy to guide watershed protection planning and investments	Formulate whole-of-basin policy framework with federal leadership Collaboratively agree on common basin-wide watershed conservation strategy, including identifying and prioritising areas requiring protection Support sub-national governments to set sector governance frameworks within their jurisdictions Resource mobilisation Monitoring and evaluation Recommend establishment and use of a Kamala River Basin Organisation (RBO), with annual Multi-Stakeholder Platform (MSP)	**Federal** Ministry of Forest and Environment (MoFE), Forest and Watershed Division Department of Forest and Soil Conservation, Divisions: Forest Management, Watershed and Landslide Management, and Large Watershed Management Office (Koshi) [Lead Agency] President Chure-Terai Madesh Conservation Development Board, Cluster Office (Dhanusha) **Provincial** Ministry of Industry, Tourism, Forest and Environment (MoITFE), Forest Management and Biodiversity Division, with 3 each of local Divisional Forest Offices (DFOs), and Soil and Watershed Management Offices (SWMOs) **District** District Coordination Committee (DCC) with sub-committees Municipal Governments, NGOs, Community Groups	Resolution of overlapping responsibilities, clarification of new institutional arrangements and mechanisms for whole-of-basin cooperation and coordination Community engagement, and active participation Sourcing and allocation of adequate funding, possible pooling of funds

GOALS	SUB-GOALS	ACTIONS	HOW CAN IT BE DONE?	WHO NEEDS TO ACT?	KEY CONSTRAINTS
		Action 2: Conduct annual planning, prioritisation and implementation of watershed conservation options	Convene basin-level actors for annual dialogue and intermediate reviews, prioritising annual investments and initiatives, resource mobilisation, delivery favouring partnerships, generating knowledge from monitoring and evaluation.	As above, local leading by Provincial Watershed Management Offices, Soil Conservation Offices, President Chure Terai-Madesh Conservation Development Board Relevant Local Governments, and Community Forest Users Groups. Possible role for Kamala RBO and use of MSP, including for conflict management and monitoring	Engagement between technical specialists and local indigenous people Ensuring resource allocations also for continuing operation and maintenance for sustainability Effective monitoring and evaluation with feedback Basin-level coordination
			Building check dams: Larger scale engineered public works, Medium and small-scale (where relevant and possible, by using and promoting indigenous technologies and locally sourced materials to make structural interventions affordable and sustainable) Non-structural measures, incl. Bio-engineering and improved vegetation	Soil Conservation Offices, relevant Local Governments, Community Forest Users Groups, Forest Offices	
	Sub-goal 2: Sustainable management and utilisation of natural resources	Action 1: Improve conservation-livelihood linkages (through reforestation, and promotion and production of non-timber forest products)	Similar to previous, with additional focus on cattle grazing rules, especially in revegetation areas, alternative energy sources	As above, including basin-level, provincial, municipal and local organisations	Regulation on illegal harvesting of timber and non-timber forest products Mobilisation of youth groups in the conservation and monitoring Improving access to markets
			Identify, develop and promote plantation of varieties suitable for the Chure region, and supporting livelihood requirements. Multi-year nurseries to ensure saplings can adapt to local conditions for regeneration		
		Action 2: Regulation and sustainable riverbed mining/ extraction	Initiate a national consultative process for all 3 levels of government to ratify policies and practices for sustainable extraction and improved sector	As above, with lead agencies at municipal and district levels, with confirmed legal authorities, supported at provincial and national levels,	National concern with major conflicts of interest especially with Municipal governments

GOALS	SUB-GOALS	ACTIONS	HOW CAN IT BE DONE?	WHO NEEDS TO ACT?	KEY CONSTRAINTS
			governance Establish coordinated oversight at district and provincial levels (DCCs) Generate specialist basin-level knowledge and capabilities Plan river channelisation and implement the necessary works, Allow extraction within estimated sustainable limits Identify, map and classify areas with high susceptibility of erosion and sedimentation transport, establish and implement a plan of erosion control and reduce the risk Routinely monitor and adjust	including Ministry of Federal Affairs and Local Government, Ministry of Home Affairs	As a dynamic process; bed sediment extraction needs to be regulated and unstable areas be protected and reclaimed according to scientific dynamic plans
Goal 2: Improved availability, use, allocation of water resources for livelihood generation, well-being, economic growth	Sub-goal 1: Reliable measurement of water cycle for effective management	Action 1: Measure and maintain reliable hydro-meteorology data on the basin for evidence-based water resources management	Install rainfall stream flow and sediment gauging stations at selected locations (upper and lower catchment, main river, tributaries, canal systems) to document spatial and temporal variations at regular intervals Mapping vulnerable zones and quantify soil lost and sedimentation processes	Department of Hydrology and Meteorology (DHM) in coordination with Kamala Irrigation project and other relevant agencies	Installation of quality equipment Training of operators for record keeping, monitoring, maintenance of equipment
	Sub-goal 2: Reduced vulnerability from water induced disasters and control of bank erosion	Action 1: Provide an early warning system and preparedness to mitigate impacts of flood and landslide events	Design and install an early warning system to national standards based on observations, assessment and excellent communications systems from basin-level to household level Identify hazardous areas for priority interventions Prepare for each settlement response/ evacuation plans, communication materials and training of all community members in implementation, supplemented with support expertise and materials as	Recent changes made but not fully effective at all levels DHM and Department of Irrigation and Water Resources (incorporating former DWIDM) and their district-level divisions District Administration Offices, Local Governments, Civil Society and communities Assign rights and responsibilities of landslide and flood control and management to the governments at	Responsibilities and legal authorities of key institutions require legislative effect. Also adequate resourcing. Currently no warning systems nor preparedness or mobilisation plans Installed equipment needs proper training to operate and maintain in coordination with civil society and local media groups

GOALS	SUB-GOALS	ACTIONS	HOW CAN IT BE DONE?	WHO NEEDS TO ACT?	KEY CONSTRAINTS
			required Longer-term plans to include permanent disaster management centres, with appropriate skills and materials, at District level Design and implement sediment studies, testing options to reduce sedimentation in different parts of the basin	all 3 tiers by federal policy and legislation	Concerned agencies need to work in continuous engagement with all stakeholders, integrating indigenous knowledge Strengthen capabilities in the design, construction and maintenance of structural measures No history of community preparation for emergencies response; initial facilitation requirements likely to be significant.
		Action 2: Minimise impacts of water-induced disaster events with structural and non-structural measures	Prioritise the mitigation works, especially the structural measures according to the sensitivity and seriousness of the problems Implement mitigation measures, both structural and non-structural, according to the priority and assigned rights and responsibilities Encourage and train the affected people to participate as much as possible at all stages of flood and landslide control and management process Increase protection of vulnerable areas impacted by erosion and sedimentation	As above Department of Water Resources and Irrigation is widely represented in the basin, and has been responsible for all the structural measures to date, including cooperative works with the Government of India Also linked to actions arising under Goal 1	
	Sub-goal 3: Conservation, development, and management of existing and potential water	Action 1: Secure and develop water supply, sanitation and hygiene (WASH) services and facilities for current and future	Assessment of current and future drinking water needs	Local Governments	Inclusion of women and marginalised communities in assessment, planning and their training for conservation of drinking water source
			Locate water source and develop necessary infrastructure (storage and distribution)	Department of Water Supply and Sewerage, Water Supply and Sewerage Division Offices, Provincial Governments and Local Governments	

GOALS	SUB-GOALS	ACTIONS	HOW CAN IT BE DONE?	WHO NEEDS TO ACT?	KEY CONSTRAINTS
	resources for improving all consumptive uses, and water use efficiency	household requirements	Protection/conservation of drinking water source	Local governments, Drinking Water Users Groups, Community Forest Users Groups, Communities	
		Action 2: Quantitatively assess existing basin water resources, water supplies and likely future demands for irrigation, and scope for improvements	Using a hydrological model and existing data, quantify whole-of-basin hydrology and major flows, both natural watercourses and constructed for irrigation. Estimate current and future 40 yr demands for range of scenarios Estimate projected surpluses and deficits by location and season Consider suggestions arising from consultations for suitable supply augmentation options	**Federal:** WECS, Department of Water Resources and Irrigation (DoWRI), Department of Hydrology and Meteorology (DHM), Agriculture, other data sources **Provincial**, District and Municipal: multiple line agencies, including District Coordination Committees (DCCs), engagement with NGOs, water users and community groups	Limitations of existing data Handover and continuity of constructed models, as useful tools for next steps and longer term Access to modelling support services
		Action 3: Identify and assess 4 major water supply improvement options as follows:	Based on analysis above, collect available additional data for candidate options Quantify possible contributions to estimated water deficits above and key attributes Confirm selection of options for continuing detailed multi-factor analysis	As above Specialist organisations with detailed knowledge of current systems and practices, e.g. KIP, groundwater, local structures	Shared understanding of necessary assumptions and consequent confidence limits of quantity estimates Additional options, not identified now, may emerge over time
		1) revitalisation of existing Kamala Irrigation Project (KIP)	Prepare specific plans for the future of the KIP Establish an effective statutory framework for management of the KIP Capacity building Proceed with design and implementation of large works Consider linkages to Option 2 – groundwater, especially for winter season, for conjunctive use Resolve longer-term operation and	Large projects under Federal Ministry of Water Resources and Irrigation (MoWRI), through regional offices, though O&M record on existing KIP is mixed Local Water Users Associations (WUAs), local governments	Institutional responsibilities, policies and legalities to be resolved, including roles for water users (WUAs) Heavy annual maintenance requirements – may be lessened by initiatives under Goal 1 New participatory O&M arrangements must be sustainable

GOALS	SUB-GOALS	ACTIONS	HOW CAN IT BE DONE?	WHO NEEDS TO ACT?	KEY CONSTRAINTS
			maintenance constraints, including user charges and sedimentation		
		2) groundwater and conjunctive use with surface water	Establish and maintain a registry of all g/w wells with estimates of current volume of use Establish a user-oriented g/w monitoring system Develop rules to limit extraction at sensitive locations in the basin Monitoring, recording and adjustments cyclically	**Federal** Groundwater Resources Development Board (GRDB), DoWRI G/W Division with regional offices Projects and schemes under all levels of government, Farmers (self-investment)	User affordability Coordination of small farmers with co-operatives, local governments for the installation of wells Training water users in monitoring, operation and maintenance
		3) small and medium water storages upstream	Establish and maintain a registry of existing and planned small and medium storages Establish a sustainability assessment framework for approval of new storages Establish mechanisms for inter-governmental engagement and cooperation	**Federal:** WECS, also similar agencies as for Goal 1 for watershed management in coordination with Provincial and Local Governments agencies, DCCs, Community-Based Organisations and NRM groups Recommend use of Kamala Basin RBO and Multi-Stakeholder Forum	Structural integrity and sustainability of existing and planned constructed works, dealing with high sediment loads Equitable allocation and use of stored water
		4) Sunkoshi Kamala inter-basin transfer scheme	Establish a sustainability assessment framework (SAF) for approval of infrastructure Co-produce knowledge to inform decision-making Establish mechanisms for inter-governmental cooperation	Federal Government assesses large projects case-by-case, could apply national SAF WECS, DoED, DoWRI in consultation with multiple Provincial and local governments in both basins, water users and community groups Also recommend use of Multi-Stakeholder Forum	Major project in all dimensions including impacts, many long-term **All** stakeholders, including water users in both basins expect concerns to be considered Complexity of knowledge sharing, consultation and decision-making

GOALS	SUB-GOALS	ACTIONS	HOW CAN IT BE DONE?	WHO NEEDS TO ACT?	KEY CONSTRAINTS
		Action 4: Improve efficiency of existing water use in irrigation	Basin-wide needs for efficiency improvements, physical and non-physical Consider complementary actions, e.g. conjunctive use of surface and groundwater, scheduling of inputs, incremental changes	Projects and schemes under all levels of government, Farmers (self-investment)	Cost-effectiveness of proposed improvements
Goal 3: Commercial and scientific agriculture for local economic prosperity and livelihood security	Sub-goal 1: Improve farming practice and productivity	Action 1: Support the sustainable intensification of crop production systems	Improve knowledge base on scientific farming through regular and effective extension service on seeds, fertilisers, pesticides, farming techniques and diversification options. Promote farmers to adopt suitable higher-value crops, mixed farming, conservation agriculture based sustainable intensification (CASI) Identify and capitalise on emerging opportunities, including organic farming	Agriculture Knowledge Centres in coordination in participation with various agriculture extension officers, NGOs, local farmers and collectives See Goal 2 for water-related matters. Recommended use of Multi-Stakeholder Platforms for collaborative approaches, knowledge sharing, innovation	Weak sector governance and strategic planning Reliability and access to water in dry season Scientific testing facilities to support selection of options Access to information and practical advice/ demonstrations at district level to farm level
	Sub-goal 2: Support marginalised (land-poor) farmers	Action 1: Support collective farming to improve access to land, water, knowledge and resources for marginalised farmers	Collect and disseminate information of experience with similar practices (4 models) in the Terai region in Nepal and India Facilitate shared learning at sub-basin and local levels Maintain communication with and support services to marginal farmers, individually and collectively, whichever their chosen model	As above Recommended use of Multi-Stakeholder Platforms for collaborative approaches and targeting support	Livelihood security, with low-asset smallholdings as tenants, unreliable access to water, out-migration, constrained resources Coordination of timing of inputs

There are two supplementary considerations which are not able to be appropriately conveyed in this tabular summary: combinations and timing. Particular reference is made to the identification of the 4 possible water supply improvements, though the considerations also apply more generally to the whole Strategy. The 4 proposed options were initially assessed individually, each as a stand-alone initiative, and subsequently considered in various combinations. The results of the analysis of such combinations are not able to be fully appreciated in the Table, so it needs to be highlighted that it is indeed possible to undertake two or more initiatives simultaneously, with complementary outcomes. Perhaps the best example is the combination of Options 1 and 2 – the revitalisation of the Kamala Irrigation Project (KIP), together with groundwater development, allowing the conjunctive use of surface and groundwater. Supplementary access to groundwater within the command area of the KIP, particularly during the winter season when surface water supplies are limited, could improve irrigated agricultural outputs considerably, though the extent of net benefits is pending more detailed analysis.

The second supplementary consideration is timing or scheduling of commitments and implementation of initiatives. Using the same 4 water supply improvement options as examples, they clearly have very different characteristics, not least in the magnitude and extent of times required for implementation, from commitment to completion and productive use. The inter-basin transfer option represents by far the largest commitment and will take many years to complete construction and commission into full operation (though making such a commitment does not exclude the possibility of proceeding with other water supply improvement options in the basin in the meantime). In contrast, groundwater development may be undertaken incrementally, with relatively little time from commitment to drill a well to having it operational and productive. At the stage of compiling an authoritative Basin Plan and considering implications of priorities, the possible scheduling of commitments, individually and in combination, will contribute to the clarification of feasible options over the extent of the planning horizon.

Upon reviewing all the findings of the assessments and analyses in the preceding chapters (Table 10.1), 4 main themes emerge as common threads between and within the development pathways for each Goal. The recurrence of these 4 related themes throughout the Strategy formulation in Chapters 4 to 9 is detailed in the following Table 10.2, and further discussed below.

Table 10.2 Recurring themes in strategic advice contained in this document

THEMES IN STRATEGIC ADVICE	MEETING AGRICULTURAL WATER DEMAND CHAPTERS 4 AND 5	SUSTAINABLE CHURE LANDSCAPE CHAPTER 6	AGRICULTURAL DEVELOPMENT CHAPTER 7	WATER-INDUCED DISASTER CHAPTER 8	DRINKING WATER SUPPLY AND SANITATION CHAPTER 9
Institutional reform	Sustainability assessment framework (SAF) for infrastructure planning	New policy framework for watershed conservation New sustainability guidelines for riverbed extraction (national issue)		Legal authority to define and enforce land use zoning measures for purpose of flood risk reduction	Clarify and formalise linkages between local government and service providers Analytic framework and normative principles for IWRM-based WASH planning New public-private partnership models to mobilise resources

THEMES IN STRATEGIC ADVICE	MEETING AGRICULTURAL WATER DEMAND CHAPTERS 4 AND 5	SUSTAINABLE CHURE LANDSCAPE CHAPTER 6	AGRICULTURAL DEVELOPMENT CHAPTER 7	WATER-INDUCED DISASTER CHAPTER 8	DRINKING WATER SUPPLY AND SANITATION CHAPTER 9
New organisations	RBO to support intergovernmental cooperation (supported by WECS and MoFE)				Independent regulator
	New apex body for Kamala Irrigation Project				
Specific policy or planning processes	Comprehensive assessment of demand- and supply-side options (key component of SAF) Assess existing and proposed infrastructure or conservation actions using SAF	Assess existing and proposed conservation actions using watershed protection strategy	Two multi-stakeholder processes: sustainable agricultural intensification; improving access to assets and skills for marginal farmers	Land use planning for risk reduction	Integrated WASH planning Use of PES
	Convene annual multi-stakeholder forum ('Kamala River Basin Forum') to support intensive communication				
Vertical and horizontal coordination	Need for joint action across levels of government: Devolution of authority to approve small-medium infrastructure to local government means that additional capacity is required at local and basin levels to plan and implement infrastructure sustainably Actors at local and basin level need specialist support from federal agencies (notably WECS)	Need for joint action across levels of government: limited resource allocation requires collaborative planning and resourcing	MOALMAC of Provinces 1, 2, 3 Local governments	Capacity building of local governments and civil society organisations: enabling them to train community members for flood emergency response	Capacity development of local government for WASH planning and effective utility management (supported by DWSSM)

The first recurring theme – the need for formal **institutional reform** – is an overarching one, which to some extent includes elements which the other 3 themes make more explicit. The fact that it is identified as a constraint to progress of the majority of the recommended strategic actions is confirmation of its importance to realising all 3 Goals. Indeed, it is such a consistent recommendation, it might be considered a pre-condition for proceeding with further planning efforts, being such an essential ingredient for the sustainability of the outcomes initially achieved in implementation.

For example, the Kamala Irrigation Project has been operational since its original construction was completed in the late 1970s. There has been ample time for all managers, operators and water users to identify the shortcomings of existing arrangements, and many have consistently supported the creation of a new statutory framework, a new institution responsible not only for revitalisation works but also with the authority to determine and manage ongoing operations and maintenance in all respects. In addition, existing organisational arrangements would require adjustments to allow the new institution to function effectively. In further examples, there have been significant changes arising from implementation of the new 2015 Constitution, some resulting in overlapping and unclear lines of authority, others being left in temporary arrangements, and all requiring resolution, including the delegation of sufficient authority to effectively fill the required role. Often this means the creation of a new organisation with decision-making authority at the basin level and below. Again, this is entirely consistent with the national and international lessons learned to build sustainability from the lowest possible level, where the water is being used.

The second recurring theme – the need for **increased collaboration across organisational boundaries** – is also a universal one, but which has been identified as a specific need to achieve outcomes within the Basin. Governments, government agencies and non-state actors naturally tend to be insular within their organisations, and more so in dealing with others. Even coordination of mutually beneficial activities does not happen spontaneously; the opportunities need to be noticed and encouraged. Forming more collaborative arrangements and lasting partnerships requires greater efforts, especially from the leading organisations in the sector, where leadership may include mandated inclusionary policies. Goal 3 specifically identifies collective approaches, in this case at the farm level, as most likely to provide long-term sustainable benefits, but to achieve this in the short-term requires supplementary external enablement and support measures.

No organisation can be fully effective by implementing actions on its own: multiple state and non-state organisations need to work together. The collaboration, which is required may be vertical, for example when local governments require technical guidance from national specialists. It is also horizontal, for example when different federal or provincial government agencies improve the effectiveness of their actions by clarifying responsibilities, avoiding duplication, and bridging gaps in service delivery. This document has identified many issues which require close collaboration. Prominent examples include: an important opportunity for new major watershed offices recently established under MoFE to collaborate with the proposed new basin offices under WECS; another opportunity to integrate planning of water infrastructure for agriculture and for WASH; and multiple collaborations for the sustainable governance of groundwater.

The third recurring theme – **enhanced policy processes** – is a corollary of the first two themes. It is a precondition for making other reforms effective. It is very clear from the assessment and analysis of the existing institutional structures and arrangements, and examination of possible solutions, that corrective measures will only be possible by first addressing legal and policy constraints, and ensuring that responsibilities can be discharged to best effect, as detailed in the companion report on policy and legal instruments (Dyson et al. 2020). While national government actions are essential, these matters cannot be resolved by any one party acting unilaterally, as noted above. The analysis suggests specific approaches and tools for addressing the recommended wider perspectives including use of a Sustainability Assessment Framework (SAF) and participatory Multi-Stakeholder Processes (MSPs).

A recommended approach to enable productive MSPs is to use a co-productive model of decision making. In this model, state and non-state actors build knowledge together via processes they regard as credible, legitimate and relevant, leading in turn to desired public outcomes. A co-productive model was specifically recommended to guide decision making over the approval of water augmentation Option 4 – the inter-basin transfer. It is also relevant to deciding how to regulate human settlement in floodplains, balancing demand for land against flood risk, and which type of drinking water system should be developed in specific locations of the Kamala Basin, balancing water quality against affordability.

Indeed, such a co-productive approach was applied in the processes of this Strategy. First, a set of water supply augmentation options were identified by participants in several iterations of framing the Goals and Development Pathways. Next, the performance of those options was quantified and analysed technically and environmentally by the project team. This phase of the analysis included a participatory MCA workshop (2019). Later, the project team analysed the performance of the 4 options using hydrological modelling and exploratory scenario thinking. The findings of such analyses led to recommendations about the need to consider additional options, which are more rapidly deployable and/or more robust to future uncertainty in the agricultural economy.

The fourth recurring theme – **supportive organisational structures** – could be regarded as a specific component or application of the previous themes. It arises as a recommendation from several analyses showing that no one existing organisation appears appropriate to fill the identified need, and a significant component of the need is to provide a consultative, collaborative mechanism, as well as the authority to oversee the implementation of agreed measures. For example, the creation of a formal River Basin Organisation (RBO) appears as a recommendation under all 3 Goals, to enable the resolution of both top-down and bottom-up perspectives on whole-of-basin matters (especially those reflecting upstream-downstream differences) and having the authority to ensure that balanced responses are implemented, with appropriate support to those most disadvantaged. The proposed RBO would be an intergovernmental organisation whose purpose is to support various governments to collaborate, along with non-state organisations. It is not proposed as another regulatory agency (Section 6.4.1).

An acceptable structure for a Kamala Basin RBO is a matter for multi-stakeholder deliberation. This Strategy has not proposed any specific structure. Instead, it is suggested that dialogue around the specific functions, and best structure for an RBO would be a practical way to get different actors to begin interacting, to address their coordination and cooperation issues (Table 5.13). It is recommended that WECS, MoFE, SWMO, DCCs, and other relevant institutions engage in such cooperative design. Given the previous history of coordination and cooperation among these agencies, during the initial phases, the facilitation services of an independent party (third-party) may be useful.

Two important areas where the RBO could support collaboration are: to facilitate coordination and cooperation to develop a new policy framework for watershed management, as well as a new watershed management strategy for the basin (i.e. Chure Action 1; Section 6.4). In addition, the RBO could support development of a sustainability assessment framework, which local and provincial governments could use to guide the planning and approval of new water storage infrastructure (Chapter 5).

Specific strategic advice is provided throughout the previous Chapters 4 to 9, arising from the detailed analyses of each component of the agreed Development Pathways. The summary in Table 10.1 captures a selection of those findings and suggestions; the interested reader, and those involved in the continuing phases of the planning process, are invited to refer to the individual item analyses for much more detail. The remainder of this Chapter focuses on the next steps to enable key decisions to be made for proceeding to implementation of the agreed development of Kamala Basin water resources.

It is acknowledged that this Strategy is not the only activity being undertaken and/or considered in the water resources sector in Nepal, nor specifically in the planning phase for future development. Where relevant activities were being undertaken concurrently, a degree of knowledge-sharing occurred in the course of this work. As this was the first basin strategy being undertaken applying bottom-up participatory processes in Nepal, it may serve as a demonstration of such processes for consideration and application in current and future basin planning activities. There are additional dimensions to be considered by the GoN, within the water sector and in the wider national development context; all of them are acknowledged as the setting for looking ahead to the next phases of work on development of the water resources of the Kamala Basin.

Once actions to address the priority list of challenges are well under way, attention can be focused on what needs to be done to arrive at the next stage of decision-making, sufficiently well-informed about the alternatives along the development path to make sound decisions. Usually that destination is a 'Basin Plan.' A Basin Plan would describe the development options in more detail, based on a solid understanding of environmental, social and institutional matters. A Plan would need to ensure that practical issues are fully identified; solutions and remedial actions are feasible; and resource inputs and corresponding financial costs estimated to reasonable accuracy. This next phase of continuing assessment and analysis is to refine but not reduce the range of options for decision-making, providing the best possible information on each element of the development pathway to enable better decisions.

The Strategy in many respects has already illuminated a wide 'pathway' ahead, identifying the additional requirements and actions to fill in the existing gaps to complete the next step analyses, and also the boundaries of possibilities including the major obstacles and constraints (the priority list discussed above, and more). It will be clear to decision-makers that they need this additional level of detail to be more confident that their decisions will not entail significant risks of surprises. It is of course accepted that there will be unknowns; the underlying objective of investing additional effort in each level of investigation and analysis is to reduce the dimensions and risks of uncertainties, and thus their possible impacts on development outcomes. This is a recommended worthwhile investment.

The implicit recommendation arising from the whole experience of undertaking this Strategy, and the results achieved, is that the next phases of effort should continue to be based on inclusive, participatory approaches, effectively engaging all stakeholders to contribute to sustainable outcomes. Specific tools and methods for doing so are recommended. Their application will build on the raised awareness and willingness of water users, organisations and government agencies at all levels to participate, cooperate, co-ordinate and increasingly to collaborate on shared objectives. Once experienced, such approaches tend to be relatively self-sustaining, especially as they are continued into long-term operation, maintenance, and ongoing improvements of the developments initiated in this way.

It is also acknowledged that the finally selected development pathway to proceed to implementation may not follow the direct alignment suggested by a Basin Plan, for many reasons not known nor understood nor even contemplated in the Basin Plan. As noted earlier in this Chapter, this is but one of many important basins, and water is one of many sectors competing for priority investment in development in Nepal. It is presently unclear the national priorities which are likely to be applied to water sector development, or to the region of the Kamala River Basin, and thus the planning horizon for possible implementation. Notwithstanding, the completion of this Strategy, using these participatory methods, is an important milestone for sustainable water resources development. It provides direction and impetus to continue the planning process to sound decision-making, and onward to implementation of agreed development actions. The process may also serve as an example for others.

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Annex A Shared socioeconomic pathways

Table A1 Simplified version of assumptions for key elements of the Shared Socioeconomic Pathways (SSPs)

SSP Element	SSP 1 ('Sustainability – Taking the green road')			SSP 2 ('Middle of the road')			SSP 3 ('Regional rivalry – a rocky road')			SSP 4 ('A divided road')			SSP 5 ('Fossil fuel development – taking the highway')		
	Country Income Groupings														
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Storyline elements (applicable to Nepal)	Rapid urbanisation. Gradual shift to sustainable development: broad-based growth, reductions in inequality; policy support to reduce resource intensity; rapid diffusion of best agricultural practices.			Rapid urbanisation (at historical trends), including in vulnerable locations. Progress towards universal education. Slow improvement in access to safe water, health care, and sanitation. Slow liberalisation of agricultural markets. Limited social cohesion.			Slow urbanisation as a result of slow economic growth. However, rural-to-urban migration driven by distress expands informal settlements. Poor urban planning makes areas vulnerable to natural hazards. Very limited transfer of agricultural and other technologies. Tensions between Nepal and larger neighbours as economic stagnation pushes poor migrants into Nepal to engage in agriculture and forestry?			Highly uneven economic growth and uneven urban development (driven by a few technology sectors, with limited opportunity for unskilled labour) High urbanisation & youth out-migration rates (driven by economic growth in large urban areas). Large peri-urban slums.			Strong investments in health, education, and social inclusion Global integration Rapid technological progress High labour mobility Rapid economic growth Strong reliance on fossil fuels Lack of concern with global environmental change		
Population	Relatively low			Med			High		Low	Relatively high		Low	Relatively low		
Urbanisation	Rapid			Central			Slow			Rapid	Rapid	Central	Rapid		
Education	High			Med			Low			V. Low/ unequal	Low/ unequal	Med/ unequal	High		
Economy Growth	High	High	Med	Med, uneven			Slow			Low	Med	Med	High		
Inequality	Reduced across and within countries			Uneven moderate reductions across and within countries			High, especially across countries			High, especially within countries			Strongly reduced, especially across countries		

SSP Element	SSP 1 ('Sustainability – Taking the green road')			SSP 2 ('Middle of the road')			SSP 3 ('Regional rivalry – a rocky road')			SSP 4 ('A divided road')			SSP 5 ('Fossil fuel development – taking the highway')		
	Country Income Groupings														
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Policy Orientation	Toward sustainable development, moderately open to exchange			Weak focus on sustainability, moderately open to exchange			Oriented toward security, relatively closed to exchange			Toward the benefit of the political and business elite. Relatively closed to exchange			Toward development, free markets, human capital		
Institutions	Effective at national and international levels			Uneven, modest effectiveness			Weak global institutions/national gov. dominate societal decision-making			Effective for political and business elite, not for the rest of society			Increasingly effective, oriented toward fostering competitive markets		
Technology Development	Rapid			Medium, uneven			Slow			Rapid in high-tech economies and sectors; slow in others			Rapid		
Environment & Natural Resources	Improving conditions over time			Continued degradation			Serious degradation			Highly managed and improved near high/middle-income living areas, degraded otherwise			Highly engineered approaches, successful management of local issues		

Source: adapted from Jiang and O'Neill (2017), and O'Neill et al. (2015)

Annex B Hydrological modelling

The following provides an overview of the hydrological modelling used to estimate available water supply, agricultural water demand, and crop production for different scenarios. Additional information is provided for (1) Surface water availability; (2) Agricultural production; (3) the KIP revitalisation scenario; (4) Groundwater scenario; (5) Small storage scenario; and (6) Diversion scheme scenario.

B.1 Surface water availability

The Kamala model was calibrated to observed streamflow at Chisapani gauge (observed data available from 2000–03), as well as observed average district crop yields. The baseline period was defined as 1990 to 2009, providing a 20-year time slice covering both inter and intra-annual variability. The total water availability upstream of the agricultural areas during the crop growing seasons is shown in Figure B.1. However, the actual water used for irrigation is constrained by the canal capacity for both FMIS and KIP command areas.

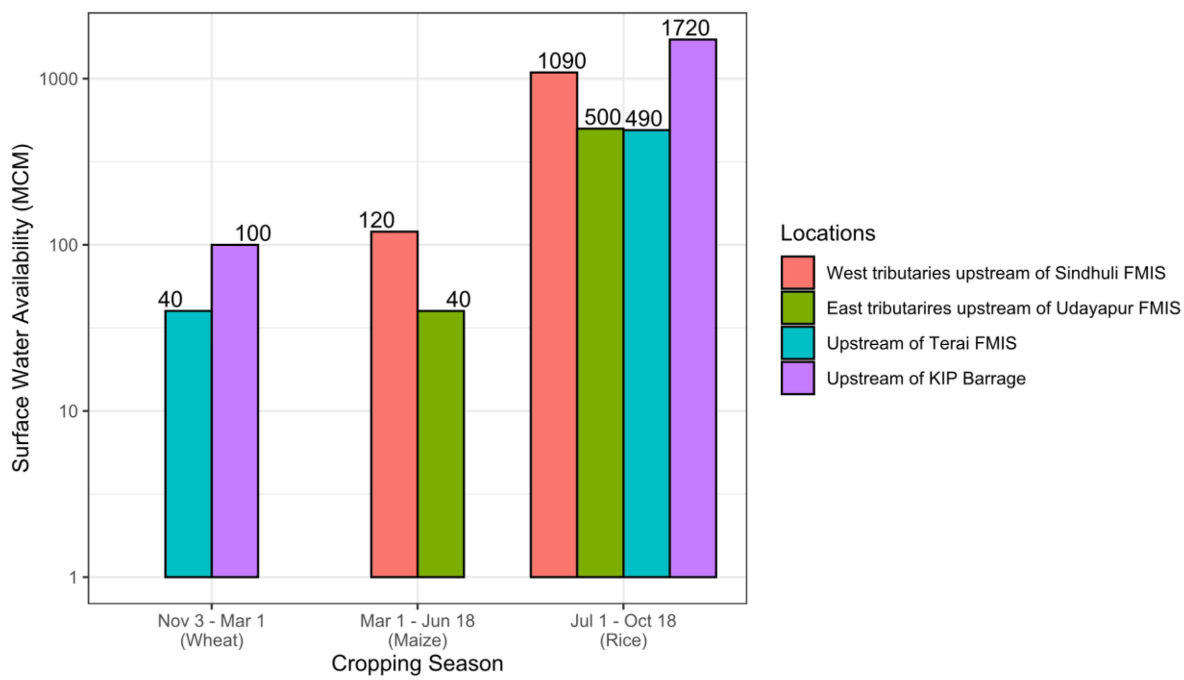

Figure B.1 Total surface water availability during cropping seasons, averaged over the twenty-year simulation

B.2 Agricultural production

Irrigated agricultural production was modelled for 5 main areas within the Basin: FMIS in Sindhuli and Udayapur districts as well as in the Terai region; and the East and West canals of command areas of the KIP. The 2 main crops grown in the Terai are paddy rice and wheat (ICIMOD 2012), whilst in the hilly areas are rice and maize. Areas under rice, wheat and maize were estimated using a combination of remote sensing and secondary data. Areas were found to vary between different sources of information, hence the values adopted are approximate only. Exact areas are also likely to vary between years as farmers respond to different climatic conditions or factors such as access to finance and labour. Assumptions used in estimating values are provided in Table B.1.

Table B.1 Irrigated agricultural areas (ha)

	MAXIMUM IRRIGATED AREA (HA) BY DISTRICT AND IRRIGATION SCHEME				
CROP	SINDHULI FMIS	UDAYAPUR FMIS	TERAI FMIS	SIRAHA (EAST KIP)	DHANUSHA (WEST KIP)
Rice	2,700[1]	1,500[1]	1,600[1]	18,200[2]	24,800[2]
Wheat	-	-	300[3]	6,600[4]	12,500[4]
Maize	2,700[1]	1,500[1]	-	-	-
Total irrigated area	2,700	1,500	1,600	18,200	24,800

[1]FMIS area based on data from JVS and PEI (2018) Table 23. It was assumed that the entire area is used for both maize/wheat and rice, noting that maize production will be most impacted by water availability

[2]Estimated agricultural area based on land cover raster for the Kamala Basin

[3]Assumed to be 20% of the total FMIS area, based on the proportion of wheat in Sindhuli and Udayapur FMIS

[4]Area based on remote sensing in February 2009 for wheat, minus the area reported as under FMIS in JVS and PEI (2018)

Crop parameters were used as inputs to the model to calculate water requirements and crop production (Table B.2). The expected usage is for reference only and is not used within model calculations. Maximum crop yields are the estimated yields assuming no water shortages based on average observed data.[57] Modelled actual yields are therefore always equal to or lower than these maximum yields depending on water availability. All of these values are estimated based on the best available information at the time of writing, and can influence the model results in terms of both water use and crop production.

Table B.2 Crop parameters applied in the Kamala model

	RICE	WHEAT	MAIZE	MUNGBEAN[7]
Plant Date Harvest Date	1 July 18 October[1]	3 November 1 March[1]	1 March 18 June[1]	7 March 10 May
Maximum crop yield (t/ha)	Sindhuli: 2.3[2] Udayapur: 2.4 West KIP: 2.4 East KIP: 2.3	Sindhuli: 2.5[2] Udayapur: 2.4 West KIP: 2.3 East KIP: 2.5	Sindhuli: 2.3 Udayapur: 2.3	West KIP: 1.6 East KIP: 1.6
Expected Usage (mm)	900	600	650[3]	300
Crop income (NPR/tonne)	24,375[4]	24,372[4]	21,000[5]	40,000

[1]Table 29 in JVS and PEI (2018). For rice, the season is capped at 18 October to total 110 growing days, consistent with the FAO crop coefficient growing days

[2]Maximum yield based on observed data from 1990 to 2009. Maximum yields were used given that wheat and maize will be water limited, hence actual yields from the model should then more closely match observed average yields

[3]From FAO Crop Information at http://www.fao.org/land-water/databases-and-software/crop-information/maize/en/ . Coefficients based on values for Spain and California. Some assumptions made where values missing. Root depth assumed to be

[57] Average yield based on observed data from 1990 to 2009. Average yields were used for rice given it is assumed rice is not under water stress.

maximum depth. Depletion assumed to be the depletion coefficient at late stage growth. Expected usage taken as average of range 500-800mm

[4]Taken as the average of price data from 1999/2000 to 2011/2012 assuming coarse rice and wheat flour (in the absence of further information)

[5]Price of maize was not reported in the agricultural statistics. Instead, a report in the Himalayan Times was used, showing a value of 21,000 Rs/tonne in the year 2000 (which increased to 35,000 in the year 2016)

[6]Crop parameters from: Allen and Pereira, 1998; Chadha, 2010; Gathala et al., 2020; Grains Research & Development Corporation, 2014 & 2017; Subedi and Yadav, 2013

B.3 KIP revitalisation

An improved KIP system was represented within the Source river model by changing the operational schedule, canal capacity, and reducing the conveyance loss (Table B.3).

Table B.3 Hydrological model representation of a revitalised KIP

MODEL REPRESENTATION	BASELINE	REVITALISED KIP
Operational schedule	Alternating East and West delivery	Delivered on demand based on crop irrigation requirements
Conveyance loss	52%	36% [1]
Canal capacity	14 m^3/s	14 m^3/s [2]

[1]Source: NEA Engineering Co. ppt on Comparative study (slide 62). It is 1 – (0.8*0.8) where 0.8 are fractions of water received that reaches end of main and distribution canals

[2]An increased canal capacity was tested but did not increase crop production in the model

B.4 Groundwater development

Field visit and local survey data from 2 areas in West KIP command area indicates groundwater usage varies from around 10–80% of total water use for irrigation, and that households use either surface water or groundwater but typically not both. It has been assumed 40% of households use groundwater for irrigation during the dry season, with precipitation and surface water providing all water during the monsoon.

Groundwater is represented in the model as a monthly pattern, with availability based on the assumption that groundwater provides 40% of the total water supply during the dry season (Table B.4). To define the groundwater development option, increased groundwater use was represented by increasing the total availability to the estimated maximum sustainable limit. The same monthly pattern was applied with increased volumes. Note that these values are model inputs, not the volume of water used.

Table B.4 Groundwater (GW) extraction limits for increasing groundwater use

	SCENARIO	TOTAL GW AVAILABLE (MCM)	GROUNDWATER EXTRACTION LIMIT (ML/D) (MCM/MONTH)			
			JAN	FEB	NOV	DEC
West KIP	Baseline	9	110 (3)	90 (3)	10 (0.1)	90 (3)
	Groundwater development	43	530 (16)	450 (13)	20 (1)	430 (13)
East KIP	Baseline	7	90 (3)	70 (2)	10 (0.2)	70 (2)
	Groundwater Development	36	440 (14)	360 (10)	40 (1)	360 (11)

B.5 Small storages

Three small storages at Tawa Khola, Thakur Khola, and Chadaha Khola were modelled in Source using the following characteristics (Table B.5). Their capacity and design were based on a combination of GIS analysis and observations of two small storages currently being constructed in Udayapur, hence being closest to Tawa Khola.

Table B.5 Modelled small storage characteristics

	TAWA KHOLA	THAKUR KHOLA	CHADAHA KHOLA
Storage size (height, m)	39	26	18
Command area[1] (ha)	1500	1600	790
Beneficiaries	8,800	8,600	4,000
Displaced	260	230	70
Valve parameters[2]	Diameter = 4m Discharge coefficient = 0.6	Diameter = 3m Discharge coefficient = 0.6	Diameter = 2m Discharge coefficient = 0.6
Crops	Assumed to be maize and rice. Crop parameters the same as for the FMIS in the district: Udayapur FMIS (Tawa Khola), and Sindhuli FMIS (Thakur and Chadaha Khola).		

[1] Estimates between 1,500 and 2,600 ha in Tawa Khola, 1600 and 2500 ha in Thakur Khola, and 790 ha in Chadaha Khola. Conservative assumption used here

[2] Outlets were represented using an ungated spillway and valve outlet. Spillways were configured assuming an unlimited release once the water level exceeds the full supply level (the approach used in the Ayeyarwady model developed by eWater). This is considered reasonable in the absence of any design data. Under baseline conditions the maximum modelled flow entering these 3 storages are approximately: 130 m^3/s (Tawa Khola); 150 m^3/s (Thakur Khola); and 450 m^3/s (Chandaha Khola). Actual spillway design needs to consider maximum inflows to the storages

B.6 Diversion scheme

Changes to the modelling configuration to represent the diversion scheme is shown in Figure B.2. The Koshi system is included to enable future examination of the impacts of the diversion to be assessed, yet has no impact on the Kamala Basin assuming the proposed diversion of 72 m^3/s is met. Modelling assumptions are shown in Table B.6.

JICA (1985) reports a design KIP height of 3 m under the diversion scheme with a right bank (west command area) discharge of 135m^3/s and left bank (east command area) discharge of 84 m^3/s. Given the 3m height is below the current assumed full supply level of 4.6m, the storage dimensions of the KIP were not changed for the diversion scheme scenario. However, the west and east canal capacities were increased such that the design discharge could be met at a height of 3 m. Discharge relationships have been estimated using an ogee crested weir equation to achieve these design discharges at 3m. Values are entirely hypothetical, assuming a 13 m length weir to the west and 8 m length weir to the east.

Based on these assumptions, it is important to note that the 72 m^3/s diversion is met throughout the simulation after 30/6/1987 (6 months), whilst the Sunkoshi storage is filling (in reality it would take much longer to fill the dam to minimise downstream impacts).

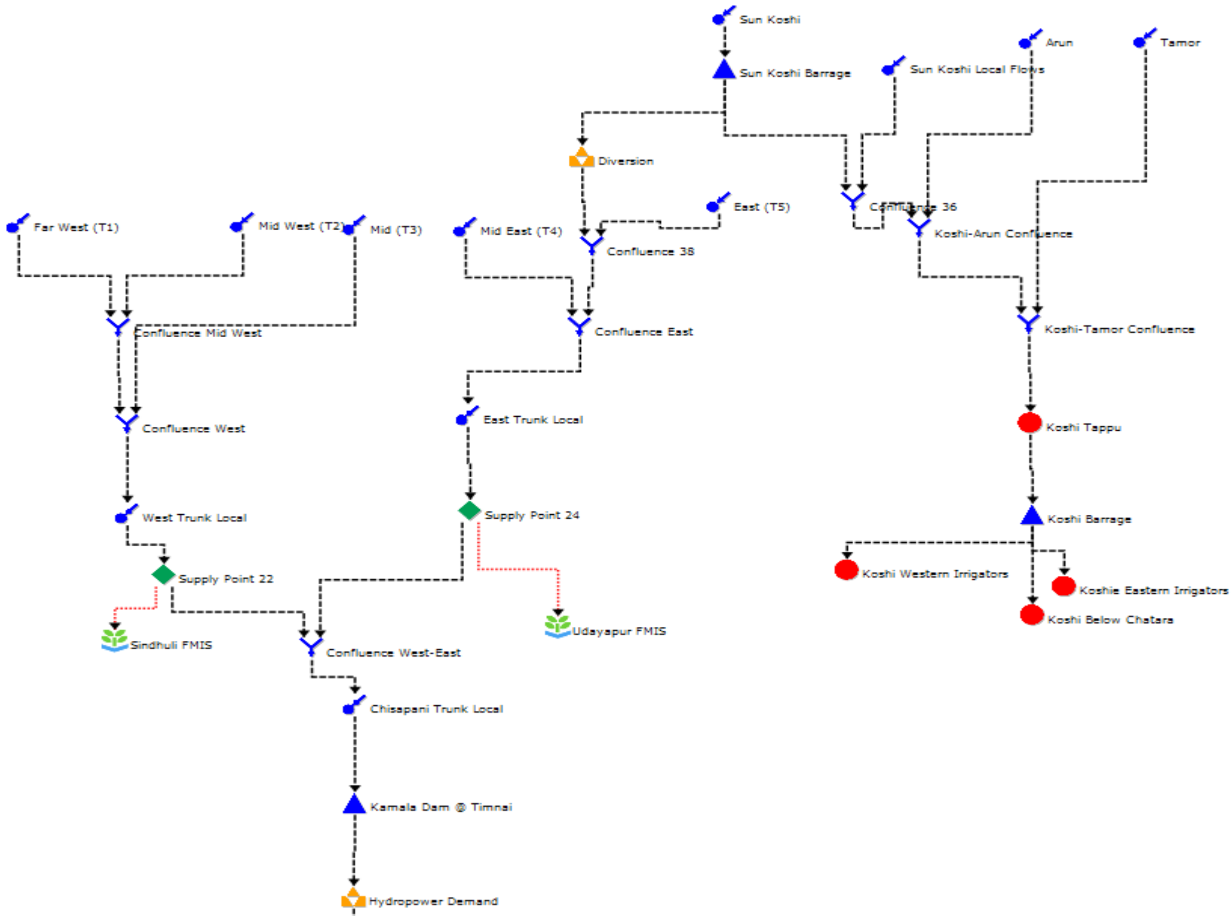

Figure B.2 Model representation of the Sunkoshi to Kamala Diversion Scheme above the KIP

Table B.6 Modelled diversion scheme characteristics

	SUNKOSHI BARRAGE	KAMALA DAM	KIP[6]
Storage size (height, m)	49[1]	51[1]	4.6
Volume (GL)[2]	217	404	2.2
Displaced[3]	1,500	6,000 to 10,000	
Outlets	Gated Spillway[4] Hydropower: Turbine efficiency 80% Head difference 100m[5] Maximum discharge 72 m^3/s Diversion: 72 m^3/s[1]	Spillway[4] Hydropower: Turbine efficiency 80% Head difference 0m[5] Discharge at Full Supply Level 270 m^3/s[6]	Gated and Ungated Spillway Western Canal Outlet Maximum discharge 135 m^3/s Eastern Canal Outlet Maximum discharge 84 m^3/s
Command area	175,000 ha in addition to existing command area, assumed split of 70% in the West (122,500 ha), 30% in the East (52,500 ha)[7]. Total command area is 147,300 ha West and 70,700 East (inclusive of existing area). Main crops assumed to be rice and wheat. Rice was assumed to cover the entire command area, yet there was insufficient water to supply maximum wheat yield. Irrigated areas were therefore reduced to 51,600 ha West KIP and 28,300 ha East KIP, the greatest area at which maximum yield was produced. At the assumed yields, this gives a maximum potential production of wheat 338,790 tonnes in the west, and 176,750 tonnes in the east.			

[1] Nepal – India Joint Project Office (2016) proposed hydropower for Sunkoshi Barrage is 61 MW, and for Kamala Dam is 32 MW– also gives some information on dimensions for the Kamala Dam and Sunkoshi Barrage

[2] Dam capacities and dimensions were estimated using DEM data combined with reported dam heights and locations. Dam wall locations were identified using open street map, using Indian Government's reported planned reservoir sites with GPS coordinates. A DEM was used to estimate volume-height relationships, as well as hydropower generation. ADB (2016) reports a proposed volume of 713 Mm^3 gross storage and 493 Mm^3 active storage, which is similar to the volume estimated using GIS

[3] See text below for estimations on number of displaced people

[4] It is assumed that all water over the spillway is immediately discharged in the absence of further information. This is considered reasonable given the model is not examining the impacts of flooding. For the gated spillway in the Sunkoshi, releases can be made as soon as there is water in the dam (from 1m), and spills once it reaches full supply level. Values are otherwise arbitrary

[5] Head difference refers to the difference in height between the inlet and outlet for hydropower. It is assumed that there is no head difference for the Kamala Dam, whilst the outlet for the Sunkoshi drops 100m below the dam into the Kamala river

[6] Hydropower discharge through a valve was estimated as $Q = AK\sqrt{2ghH}$ where Q is the discharge, A is the valve area (assumed here to have two outlets with a radius of 1.5m each in the absence of any information), g is gravity, H is the head (difference between the water level and height of the valve), and K is a coefficient based on the shape of the orifice, estimated to be 0.6

[7] The Nepal-India Joint Project Office (2016) reports 175,000 ha command area. It is unclear if this includes or is in addition to the existing command area, although on p3 there is the suggestion that it is in addition to existing areas. Other reports give widely varying values for gross and net command areas. For example, ADB (2016) reports a lower area of 51,000 ha major and 151,000 ha total command area for the Kamala Irrigation Project with the Diversion Scheme. Tractebel (2019 - Irrigation Master Plan) suggests a command area of approximately 129,000 ha, although also refers to a total suitable area of 81,400 ha in Siraha; 76,900 ha in Dhanusha; and 68,500 ha in Mahottari. Yadav (2001) refers to an Irrigation Master Plan Study indicating a command area of 67,200 ha in Siraha and Saptri and 107,900 ha to the East across Dhanusha, Mahottari and Sarlahi but with a total net command area of 138,000 ha based on a current diversion of 72 m^3/s. A GIS was used to map the approximate new command area based on available maps of the proposed diversion scheme, and estimated a rough split of 70% of the new area to be in the West, and 30% in the East. This is in the absence of further information. The mapping also confirms that the 175,000 ha could be in addition to the existing area

[8] The existing KIP system is modelled using dimensions reported in the KIP project office, Nepal, combined with estimates from satellite imagery (CSIRO, 2017). The existing height is estimated to be 4.6m based on the difference between the maximum high flood level of 108.6m ASL and the upstream bed level of 104m ASL.

It was assumed that the diversion scheme would include the development of irrigation infrastructure in Udayapur, enabling existing areas to have adequate water availability. The extraction rate was increased by 125% for the Udayapur FMIS in the model. The area under irrigation was the same from the baseline.

People would be likely displaced by the storages. For Sunkoshi barrage, the Sunkoshi storage dam at Karule covers an area of around 600 ha. The footprint of the storage covers the localities of Lekhani and Sorung in Udayapur and Dikuwa and Bahunidanda in Khotang. The population density across all land uses is between 72 and 103 people per km^2. Given the population is concentrated in the non-forest areas, the population density is assumed to be 250 people per km^2 (60% of the area is forest or barren). Therefore, the total number of people displaced by the project would be of the order of 600 ha x 2.50 people per ha = 1,500 people. For Kamala Dam, the Kamala Dam at Timnai would have a footprint of around 3300 ha. The storage site would displace people living in the main township of Dudhauli and cover the Tribeni Ghat meeting place. The dam would cover 6 localities and displace around 6,000-10,000 people depending on the final dimensions of the storage based on numbers in CBS (2011).

Annex C Exploratory scenarios

Three main themes (i.e. policy domains) were used to define exploratory scenarios for the Kamala Basin. All are relevant to the future of agriculture, the dominant use of water in the Basin:

- governance, resources, and the capability of local, provincial, and federal level agencies to address challenges facing agriculture.
- the sectoral focus of development in the Basin (agriculture vs. other sectors). This theme impacts on the relative security of non-farm versus farm-based livelihood strategies. It is influenced by (i) assumptions of national (and global) economic growth and structural diversification; and (ii) the prioritisation agriculture receives in public policy. Higher rates of growth and economic diversification lead to more non-farm livelihood opportunities. However, if agriculture is prioritised, a strong and diverse economy generates more resources (public and private) for investment in agriculture.
- agricultural knowledge and innovation systems (AKIS). AKIS considers actors and institutional arrangements which deliver services (e.g., advice, new technologies, water, credit, collective bargaining, marketing) and products (e.g. improved varieties, diversification to high value products) which farmers require in order to improve their productivity in a sustainable manner. Effective knowledge and innovation systems result in higher yields per unit of water or energy input (including human labour) and thus higher returns to farmers, in a manner that can be sustained over time. The chapter on agricultural development describes particular innovations further.

C.1 Scenario 1: Business-as-Usual

Compared to the situation as of 2020, Nepal's 3 levels of governance develop more effective arrangements for agricultural extension and innovation. In part this is because of moderate improvements in downward accountability.

However, improvements in sector governance amount to keeping afloat: they are not sufficient to transform smallholder productivity. Smallholder agriculture is financed by remittances from household members working in cities and outside the farm economy. Clusters of innovation exist, supported by research institutes, private firms, NGOs, and donor projects. These innovative clusters are typically oriented to supporting commercial commodity agriculture. However, a minority of them focus on products based on Nepal's agrobiodiversity.

Overall, conventional farming and water management practices dominate. The dominant crop systems are conventional: rice-maize in the Upper Basin, and rice-wheat in the Lower Basin. Yields improve consistent with historic trends, with the exception of wheat, which is constrained by a short winter growing season (Figure C.1). Although yields increase, so too does the cost of energy, water, and chemical inputs, resulting in the perpetuation of subsistence-oriented agriculture for the majority of farmers. In 2040, the Basin's cropping intensity is assumed to be 200% (cf. 141% at present). Figure C.1 shows plausible increases in crop yields and reductions in Rice-Maize irrigation water requirement. Estimates of water demand and crop production in Chapter 4 however do not use these assumptions, meaning that additional yield and irrigation water efficiencies may be possible (beyond those explored in Chapter 4).

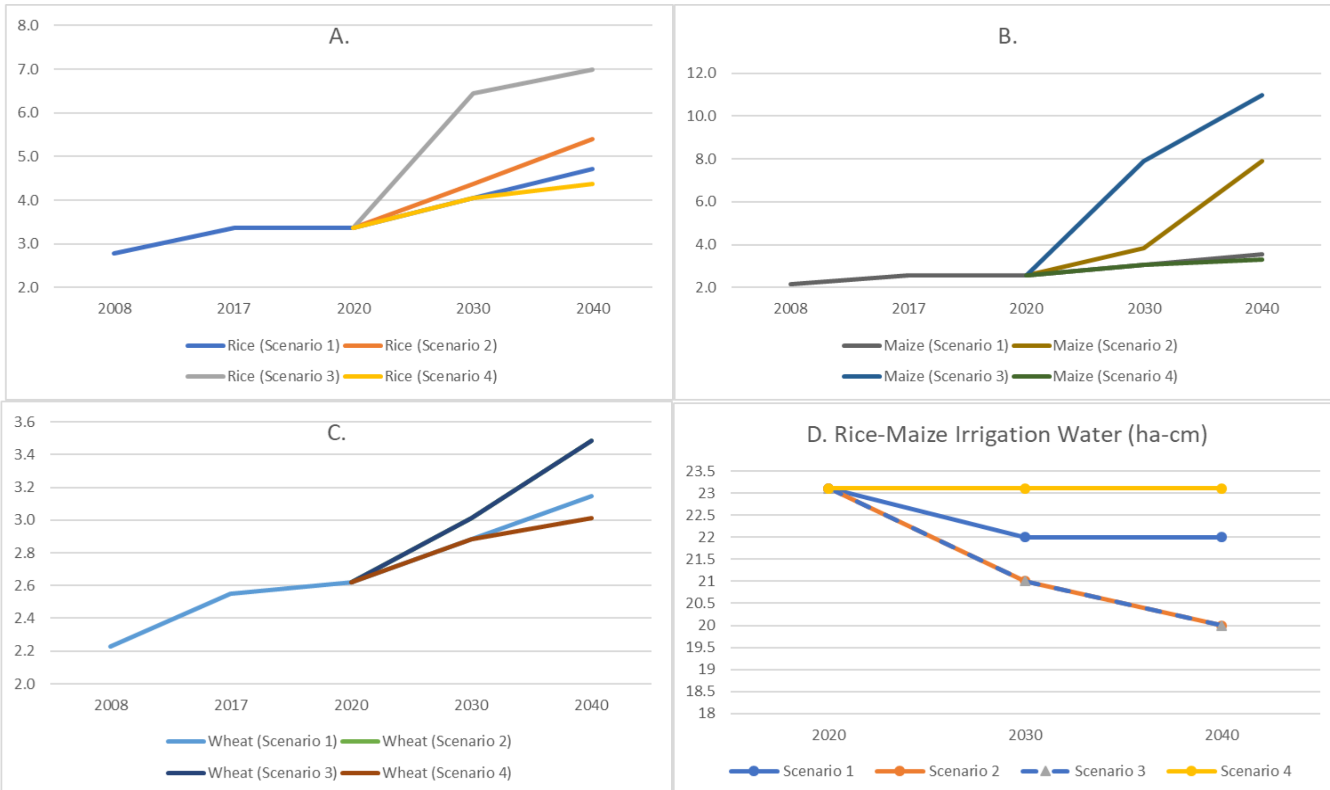

Figure C.1 Plausible changes to crop yield (A-C) (mt/ha) and rice-maize irrigation water requirement (D) (ha-cm) by Kamala Scenario

Source: based on FAOStat (FAO 2020) and Islam et al. (2019). Note: Climate change effects not included

C.2 Scenario 2: *Commercial smallholder agriculture*

In this scenario, higher rates of national economic growth, more effective sector governance, and the prioritisation of agriculture, leads to the highest number of smallholder commercial farmers. Governance is considered more devolved (decentralised) than in 2020, while at the same time, mechanisms evolve that support the 3 levels of government to coordinate their actions.

Consequently, CASI practices have been scaled out broadly in the Terai. Similarly, innovations in horticulture and agroforestry are developed and have been disseminated in the Basin.

Farmers' organisations and networks played a key role in the above scaling out of innovation, connecting farmers with private sector providers of seeds, fertiliser, and herbicides, as well as financing organisations, extension agencies, and policy makers (Gathala et al. 2020).

The dominant cropping system is rice-wheat-mungbean, using reduced tillage (CASI) technologies. By 2040, the adoption of CASI practices among capable farmers leads to yield increases of 33% (wheat) to 30% (maize), and improvements in gross margins of 25% (Gathala et al. 2020).

Intensification allows smallholder farmers who might otherwise exit agriculture, the opportunity to continue farming, thus diversifying their household livelihood portfolio. However, many such farmers increasingly find that the highest returns are to be made from high value horticulture and pisciculture culture, and that is where the greatest demand lies for innovation. In 2040, the Basin's cropping intensity is 292% (200% in Upper Basin; 300% in Lower Basin).

In Scenario 2, as well as in Scenario 3 below, incentives to maximise water productivity are strong. This is because during the part of the period to 2040, irrigation is supplied by groundwater (increasingly, by solar groundwater). In the event the Sunkoshi-Kamala scheme, or other inter-basin transfer scheme was approved, water would not be available until close to 2040 because of complexity of the scheme, and the delay in getting agreement from all interested parties.

C.3 Scenario 3: *Agribusiness*

In this scenario, commodity agriculture is more viable for large enterprises than for small farmers. Agribusiness firms dominate the production of cereal grains and other commodities. Because of competition from Indian agriculture, profit margins are low, and to compensate, farms expand their area and invest in mechanisation. Nepal has become a destination for major Agribusiness, attracting investment from countries seeking to advance their geopolitical interests.

Scenario 3 assumes that differences in political power between agribusiness and small farmers allows the former to expand farm holding and maximise economies of scale. Cropping intensities are equivalent to Scenario 2, but the gross cultivated area is 25% greater in this scenario than in Scenario 2. Marginal farmers who cannot compete with the corporate operations either find work as agricultural labour on agribusiness farms or exit agriculture.

C.4 Scenario 4: *Stagnant Agriculture*

This scenario imagines a failure to develop agriculture in the Kamala basin compared to Scenario 1. Between 2020–30, yields increase at the same rate as Scenario 1, however in the second decade, weaknesses in sectoral governance constrain the productivity increases.

These governance weaknesses, combined with severe regional rivalries and conflicts, make the economy grow at sluggish pace. Consequently, the urbanisation level is the lowest of the 4 scenarios, meaning that this Scenario has the greatest number of people who remain in agriculture, under difficult circumstances.

Compared to Scenario 1, policy makers have reduced investment in most agricultural innovation programs, leaving such programs to the market, but the private sector - aside from a few horticultural products - withdraws from Nepal, in favour of investment elsewhere (e.g. West Bengal). The dominant crop systems are the same as Scenario 1.

For most households, agriculture, even more so than Scenario 1, becomes a matter of production for own consumption. It is carried out by an older cohort of farmers, some of whom are women heads of households. As with Scenario 1, agriculture is subsidised by remittances non-agricultural household members, however remittances are lower than in Scenario 1 (which assumes a more prosperous economy). The Basin's gross cultivated area is 13% higher than the current level.

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