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PCRWR

Guidelines for Science Policy Practice Interface (SPPI) for Achieving Water Security in Pakistan

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Pakistan Council of Research in Water Resources (PCRWR)

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2025

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Abbreviation and Acronyms

ADB	Asian Development Bank
BCS	Balochistan Conservation Strategy
CEWH	Commonwealth Environmental Water Holder
CRSS	Colorado River Simulation System
CCRA	Climate Change Risk Assessment
DCPs	Drought Contingency Plans
DIMP	Development Information Management Policy
EPA	Environmental Protection Agency
FFC	Federal Flood Commission
FAO	Food and Agriculture Organization
GIZ	German Agency for International Cooperation
GIS	Geographic Information Systems
GCF	Green Climate Fund
HAI	Hydro-Agro Informatic Center
ICPR	International Commission for the Protection of the Rhine
IRSA	Indus River System Authority
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IWMI	International Water Management Institute
ICIMOD	International Centre for Integrated Mountain Development
IPCC	Intergovernmental Panel on Climate Change
IWRM	Integrated Water Resource Management
MoWR	Ministry of Water Resources
MoCC	Ministry of Climate Change and Environmental Coordination
MoFSR	National Food Security and Research
MDBA	Murray-Darling Basin Authority
NUST	National University of Sciences & Technology
NDMA	National Disaster Management Authority
NWCC	National Water Coordination Council

NCCP	National Climate Change Policy
NWP	National Water Policy
NDCs	Nationally Determined Contributions
PCRWR	Pakistan Council of Research in Water Resources
PCAIR	Pakistan Council of Scientific & Industrial Research
PHED	Public Health Engineering Department
SPPI	Science Policy Practice Interface
SWRMD	Sindh Water Resources Management Department
SWP	Sindh Water Policy
SDGs	Sustainable Development Goals
UNESCO	United Nations Educational, Scientific and Cultural Organization
USAID	United States Agency for International Development
UNICEF	United Nations Children's Fund
UET	University of Engineering and Technology
UNDP	United Nations Development Programme
WFD	Water Framework Directive
WWF	World Wide Fund for Nature
WASA	Water and Sanitation Agency,
WAPDA	Water and Power Development Authority
WFD	Water Framework Directive

PREFACE

It is a great pleasure to present the *Guidelines for Strengthening the Science Policy Practice Interface (SPPI) for Achieving Water Security in Pakistan*, developed under the leadership of the Pakistan Council of Research in Water Resources (PCRWR) with the support of UNESCO. This document reflects the shared commitment of national institutions and UNESCO to advancing evidence-based, inclusive, and integrated water governance in the country.

The year 2025 holds particular significance as we celebrate the 50th anniversary of UNESCO's Intergovernmental Hydrological Programme (IHP) and 60 years of UNESCO's Water Sciences. Over the decades, UNESCO has played a leading role in strengthening hydrological research, capacity-building, and international cooperation. Today, under the IHP-IX framework *"Science for a Water Secure World in a Changing Environment,"* UNESCO places even greater emphasis on bridging the gaps between scientific knowledge, policy development, and practical implementation, an approach that lies at the heart of these SPPI Guidelines.

The Guidelines offer a structured framework for integrating scientific evidence into policy formulation and operational practice. They highlight the need for coordinated institutional mechanisms, transparent data-sharing, and adaptive management. Importantly, they promote participatory engagement by ensuring that scientists, policymakers, practitioners, and communities contribute to, and benefit from, more informed, equitable, and climate-resilient water governance.

UNESCO commends PCRWR and all partner institutions for their leadership and collaboration. The preparation of these Guidelines demonstrates Pakistan's strong commitment to integrated water resources management, institutional strengthening, and alignment with global frameworks such as Sustainable Development Goal 6 on clean water and sanitation.

As we mark these important milestones for UNESCO Water Sciences and the Intergovernmental Hydrological Programme, I am confident that these Guidelines will make a timely and meaningful contribution to enhancing national capacities, strengthening institutional linkages, and fostering a culture of knowledge-based and practice-oriented water governance in Pakistan.

Mr. Fuad Pashayev
Head of Office and UNESCO Representative to Pakistan
Islamabad, 2025

FOREWORD

Water is the foundation of Pakistan's social well-being, economic development, environmental sustainability, and national security, yet the country faces unprecedented challenges such as declining per capita water availability, deteriorating water quality, over-exploited groundwater, climate-induced extremes, and growing competition among domestic, agricultural, industrial, and environmental water demands. While the National Water Policy (2018) and subsequent provincial water policies and acts provide comprehensive frameworks for water management, persistent gaps exist between policy and practice; between data and decision-making, institutions and communities, and policy frameworks. These on-ground realities continue to undermine water security, resulting in fragmented responses, poorly targeted interventions, and limited local ownership.

The gaps identified above reflect systemic disconnects that require a structured approach to promote evidence-based decision-making, strengthen institutional coordination, foster inclusive stakeholder engagement, and support adaptive management. To address this, the Pakistan Council of Research in Water Resources (PCRWR), in collaboration with UNESCO and national partners, developed the Science Policy Practice Interface (SPPI) Guidelines through extensive policy reviews and consultations across multiple provinces. The guidelines adopt a systematic methodology encompassing policy analysis, multi-provincial consultations, stakeholder mapping, participatory dialogues, and expert validation to align scientific evidence, policy frameworks, and on-ground practices, ensuring they are coherent and mutually reinforcing.

At their core, the SPPI Guidelines establish key principles, a governance roadmap, priority actions, and a monitoring framework designed to integrate scientific knowledge with policy priorities and ground-level implementation, thereby strengthening water governance.

I am confident that these guidelines will support federal and provincial institutions, development partners, and civil society in fostering a culture of collaborative and informed water management. I commend the collective efforts of PCRWR, UNESCO Pakistan, water sector stakeholders, reviewers, experts and communities, and I particularly acknowledge the dedication and technical contributions of the PCRWR Water Management Research Team whose rigorous work made these guidelines possible. I hope this document serves as both a practical resource for action and a catalyst for long-term water security for the people of Pakistan.

Dr. Hifza Rasheed
Director General, PCRWR

MESSAGE

The development of these SPPI Guidelines represents a major milestone in modernizing and strengthening water governance in Pakistan. Effective management of our water resources requires informed decision-making, strong institutional coordination, and practical solutions grounded in scientific evidence. These guidelines offer a comprehensive framework that enables institutions to align research, policy mandates, and field-level realities in a coherent and collaborative manner. I am confident that the sincere implementation of these guidelines will significantly enhance the sustainable development, management, and use of water resources across the country. Beyond national relevance, this document also provides valuable guidance at regional and global levels, contributing meaningfully to efforts aimed at addressing growing water security challenges. I commend the authors and all stakeholders whose dedication and expertise have shaped this important and timely document.

Ghulam Zakir Hassan
Director, Irrigation Research Institute, IRI

Executive Summary

Pakistan's Water security is at risk due to rapid population growth, groundwater depletion, deteriorating water quality, inefficient water use, and accelerating climate change impacts. These factors have collectively pushed the country into a state of chronic water stress. The per capita water availability has fallen below the scarcity threshold, while rising temperatures, erratic rainfall, shrinking glaciers, floods, and droughts continue to reshape hydrological patterns. The 2022 floods demonstrated the country's high vulnerability to water-related disasters, causing vast economic losses and exposing significant institutional, infrastructural, and governance gaps. These challenges are most visible within the Indus Basin, the country's lifeline, where competing agricultural, domestic, industrial, and ecological demands are intensifying at an unprecedented pace. Poor coordinated planning, fragmented institutional mandates, and limited integration of scientific evidence into decision-making further complicate the national water landscape.

Keeping in view these challenges, the Science Policy Practice Interface (SPPI) Guidelines have been developed as a national framework to strengthen water governance in Pakistan through evidence-based, inclusive, and adaptive approaches. The guidelines are the outcome of extensive desk reviews of national and provincial water-related policies, multi-provincial consultations with federal and provincial institutions, academic experts, civil society, private sector representatives, and community-based organizations. The consultations conducted in Peshawar, Lahore, Karachi, Quetta, and Islamabad revealed consistent concerns regarding poor inter-institutional coordination, insufficient data sharing, duplication of efforts, limited capacity for implementing integrated water resource management, and the ineffective translation of scientific research into actionable policy and practice.

A comprehensive review of policies revealed significant gaps in alignment across levels of governance. Despite containing well-articulated policy aspirations, many documents lack effective implementation mechanisms, actionable institutional mandates, sustainable financing, or rigorous monitoring systems. The provinces often operate with differing priorities, and there is an absence of a unified, basin-wide approach necessary for coordinated management of the Indus system. The community participation also remains insufficient, and scientific research is rarely integrated into real-time decision-making. These gaps are compounded by the lack of a centralized national water data system, making it difficult to support evidence-based planning, forecasting, and policymaking.

To enrich the contextual understanding of SPPI, five international case studies were examined from the world. These cases highlight the importance of robust institutional architecture, legally mandated basin-wide governance, science-driven monitoring systems, transparent data platforms, well-financed environmental flow mechanisms, and sustained community participation. Their experiences illustrate that effective SPPI integration leads to improved water allocation, restoration of degraded ecosystems, strengthened climate resilience, and effective conflict resolution demonstrating clear pathways that Pakistan can adapt according to local context.

Drawing on these lessons, the SPPI Guidelines propose a forward-looking framework that places scientific evidence, institutional coordination, and community engagement at the center of Pakistan's water governance reforms. The recommendations emphasize the

establishment of a centralized national water data platform integrating surface water, groundwater, climate, agricultural, urban, and environmental datasets. This platform is envisioned as the backbone for real-time decision-making, forecasting, and policy formulation, strengthening institutional coordination is identified as another priority, with proposals for creating or revitalizing mechanisms that enable structured dialogue and joint planning between federal ministries, provincial departments, scientific institutions, and water users. The guidelines also promote climate-resilient infrastructure development ranging from nature-based solutions for flood and drought mitigation to modern irrigation technologies and groundwater recharge initiatives to enhance the resilience of both rural and urban communities.

The SPPI Guidelines further advocate for enhanced capacity building at all levels, ensuring that policymakers, managers, researchers, and practitioners possess the skills and tools required to adopt integrated and adaptive management approaches. The transfer of technology, public awareness campaigns, and community engagement are presented as key elements for improving local ownership and ensuring that water-related interventions are socially acceptable and practically implementable. Additionally, the guidelines introduce a monitoring, evaluation, and learning framework designed to track progress, promote transparency, and ensure policy responsiveness in a changing climate.

Overall, the SPPI Guidelines present a strategic pathway for the country to transition from fragmented, reactive water governance toward a more integrated, evidence-based, and climate-resilient approach. By institutionalizing strong linkages between science, policy, and practice, the guidelines aim to enhance water security, reduce vulnerability, promote equitable access, and support national development goals. They serve as a comprehensive national reference document to guide federal and provincial institutions, development partners, civil society organizations, and local communities in collectively shaping a secure and sustainable water future for Pakistan.

1 Introduction

1.1 Overview of Pakistan's Water Security Challenges

Pakistan's water security challenges are among the most pressing issues facing the country today, with far-reaching implications for its economic development, environmental sustainability, and social stability. With a population over 220 million, Pakistan is classified as water-scarce country, with annual per capita water availability plummeting from 5,260 cubic meters in 1951 to less than 1,000 cubic meters in 2023, far below the international threshold of 1,700 cubic meters that defines water stress (World Bank, 2021). This alarming decline is driven by a combination of natural, demographic, and anthropogenic factors, including rapid population growth, inefficient water management practices, and the overexploitation of groundwater and surface water resources. The situation is alarming particularly in the Indus Basin, which serves as the backbone of country's agricultural economy, contributing over 24% to the GDP and employing more than 40% of the workforce. However, the basin is under immense stress due to declining river flows, unsustainable groundwater extraction, and increasing salinity, which threaten food security and livelihoods for millions of people (Qureshi, 2020).

Climate change exacerbates further these challenges, introducing new layers of complexity and uncertainty to Pakistan's water security landscape. The country's water resources are heavily dependent on the Indus River system, which is fed by glaciers in the Himalayas. However, rising global temperatures are accelerating glacial melt, leading to increased river flows in the short term but posing a long-term threat of reduced water availability as glaciers shrink (IPCC, 2021). At the same time, erratic rainfall patterns and prolonged droughts are becoming more frequent, disrupting agricultural cycles and enhancing water scarcity. The devastating floods of 2022, which affected 33 million people and caused an estimated $30 billion in economic losses, underscore the vulnerability of Pakistan's water infrastructure and management systems to extreme weather events (UNDP, 2022). These climate-induced challenges are compounded by poor water governance, outdated infrastructure, and a lack of integrated planning, leaving the country less prepared to cope with the growing impacts of climate change and water security.

Water quality is another critical concern, with contamination from industrial discharge, agricultural runoff, and untreated sewage rendering many water sources unsafe for consumption. According to the Pakistan Council of Research in Water Resources (PCRWR), nearly 70% of water sources in urban areas are contaminated, with high levels of arsenic, fluoride, and other pollutants posing serious health risks to millions of people (PCRWR, 2021). In rural areas, where access to clean drinking water is already limited, the situation is even more awful, with waterborne diseases such as diarrhea, cholera, and typhoid contributing to high rates of morbidity and mortality. Additionally, inefficient irrigation practices have led to waterlogging and salinity in large parts of the Indus Basin, rendering fertile land unproductive and further reducing water availability for agriculture. These issues not only threaten public health but also undermine economic productivity, particularly in the agricultural sector, which remains the largest consumer of water, accounting for over 90% of total water use in the country.

Transboundary water issues also play a significant role in shaping Pakistan's water security landscape. The Indus Waters Treaty (1960) with India governs the sharing of the Indus River system and has generally been successful in preventing large-scale conflicts. However, tensions arise during periods of water scarcity, particularly over the construction of dams and hydroelectric projects by India, which Pakistan views as a threat to its water security (Briscoe & Qamar, 2009). Domestically, disputes between provinces over water allocation, further complicate water governance. These conflicts often arise from inequitable distribution and a lack of trust in water-sharing mechanisms, highlighting the need for more transparent and inclusive decision-making processes.

The absence of Institutional coordination and weak policy implementation further hinder efforts to address Pakistan's water security challenges. Despite the introduction of the National Water Policy (2018) and various provincial water acts, coordination among federal and provincial agencies remains poor, leading to overlapping responsibilities, inefficient resource allocation, and a lack of accountability. Moreover, the lack of integration between scientific research, policymaking, and on-ground practices limits the adoption of sustainable water management strategies. While scientific research provides critical insights into water availability, quality, and usage patterns, its translation into actionable policies and practices remains inadequate, creating a disconnect between knowledge and implementation. This gap is further exacerbated by limited public awareness about the importance of water conservation and sustainable water use, as well as a lack of capacity among water managers and practitioners to adopt modern technologies and best practices.

The absence of one basin approach in Pakistan is threatening the country's water security by fostering fragmented and inefficient water management practices. Currently, surface water, groundwater, and ecosystems within the Indus Basin are managed in isolation, leading to over-extraction, inequitable distribution, and environmental degradation. For instance, excessive groundwater pumping in one region can deplete aquifers that are hydrologically connected to surface water systems, reducing overall water availability. Additionally, the lack of coordinated management has intensified inter-provincial conflicts over water allocation, undermining trust and cooperation. Without a unified strategy, climate change impacts, such as erratic rainfall and glacial melt, are addressed in a fragmentary manner, leaving the basin vulnerable to floods, droughts, and long-term water scarcity. This isolated approach not only threatens food security, economic stability, and public health but also hinders the sustainable management of the Indus Basin, which is critical for Pakistan's survival.

Addressing these multifaceted challenges requires an integrated approach that links science, policy, and practice. The Science Policy Practice Interface (SPPI) Guidelines aim to bridge these gaps by fostering collaboration among researchers, policymakers, and practitioners by promoting evidence-based decision-making, stakeholder inclusivity, and adaptive management. The SPPI Guidelines seek to enhance water governance, build resilience to climate change, and ensure sustainable water management in Pakistan. This integrated approach is not only critical for addressing immediate water security challenges but also for achieving long-term goals such as the Sustainable Development Goals (SDGs), particularly SDG 6 (Clean Water and Sanitation), which emphasizes the implementation of integrated water resources management (IWRM) at all levels (United Nations, 2015).

1.2 Importance of an Integrated Approach linking Science, Policy, and Practice

The National Water Policy (NWP) 2018 and various provincial water policies and acts have laid the foundation for addressing water security challenges. However, the implementation of these policies has been hindered by fragmented institutional coordination, limited capacity, and a lack of integration between scientific research, policymaking, and on-ground practices. While scientific research provides critical insights into water availability, quality, and usage patterns, its translation into actionable policies and practices remains inadequate. Policymakers often operate in isolation from researchers and practitioners, leading to disjointed efforts that fail to address the root causes of water insecurity. Similarly, practitioners, including farmers, water managers, and local communities, often lack access to scientific tools and technologies that could enhance water use efficiency and sustainability. This disconnect underscores the urgent need for a robust Science Policy Practice Interface (SPPI) that bridges these gaps and fosters an integrated approach to water resource management.

The rationale for developing SPPI Guidelines is rooted in the recognition that sustainable water management cannot be achieved through isolated or siloed efforts. Water security is a complex and multifaceted challenge that requires a holistic and participatory approach, involving all relevant stakeholders. Science provides the evidence base for understanding water availability, quality, and usage patterns, while policy translates this knowledge into regulatory frameworks, strategic plans, and institutional reforms. On the other hand, practice ensures that these policies are effectively implemented on the ground, taking into account local contexts, cultural practices, and stakeholder needs by creating collaboration among researchers, policymakers, and practitioners, the SPPI aims to create a cohesive framework for sustainable water management in Pakistan, ensuring that scientific knowledge informs policy decisions and that policies are effectively translated into practice.

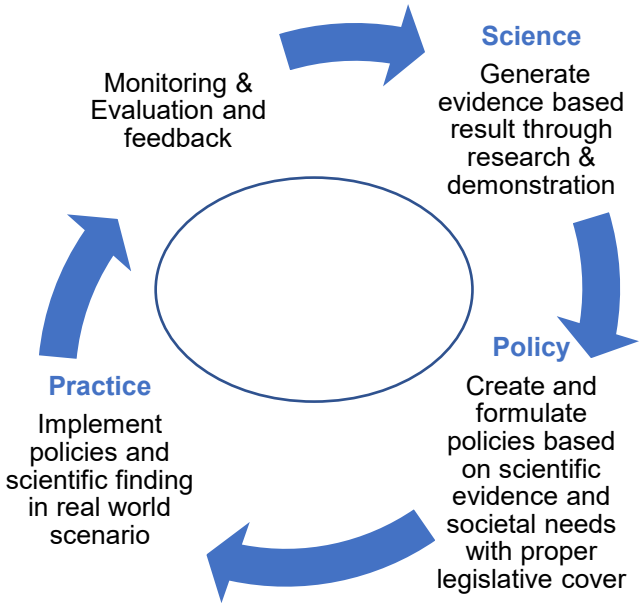

Figure 1: Conceptual Framework of SPPI

The importance of an integrated approach linking science, policy, and practice cannot be overlooked. For instance, the adoption of Integrated Water Resources Management (IWRM) principles, as outlined in the PCRWR-UNESCO IWRM Implementation Guidelines, highlights the need for holistic and participatory water governance (PCRWR, 2021). IWRM emphasizes the coordinated management of water, land, and related resources to maximize economic and social welfare without compromising the sustainability of vital ecosystems. However, the successful implementation of IWRM requires more than just technical solutions, it demands a paradigm shift in how water resources are managed, with a strong emphasis on stakeholder engagement, capacity building, and adaptive management. The SPPI seeks to operationalize this paradigm shift by providing a structured framework for aligning scientific research with policy priorities and practical interventions, ensuring that water management strategies are evidence-based, inclusive, and adaptive to changing conditions.

Moreover, the SPPI Guidelines are aligned with global commitments such as the Sustainable Development Goals (SDGs), particularly SDG 6 (Clean Water and Sanitation). Target 6.5 of the SDGs emphasizes the implementation of IWRM at all levels, while Target 6.a and 6.b focus on international cooperation and capacity-building support for developing countries (United Nations, 2015). The SPPI Guidelines also align with the UNESCO Intergovernmental Hydrological Programme (IHP-IX), which emphasizes the importance of social hydrology, adaptive pathways, and the dissemination of scientific knowledge to build resilience in water management systems (UNESCO, 2022). These global frameworks provide a strong foundation for the development and implementation of the SPPI Guidelines, ensuring that they are both context-specific and globally relevant.

In conclusion, the development of the SPPI Guidelines is a critical step toward addressing Pakistan’s water security challenges and achieving sustainable water management. The following sections of this document outline the principles, strategies, and implementation roadmap for achieving these objectives, with the ultimate goal of ensuring water security for present and future generations. The SPPI Guidelines are not just a technical document, it represents a vision for a more sustainable, equitable, and resilient water future for Pakistan.

1.3 Methodology

The development of science, policy, practice interface (SPPI) guidelines require a holistic approach by involving key organizations. Pakistan exists on the Indus River Basin System which is governed and managed by both federal and provincial organizations. Therefore, first critical component was to undertake stakeholder identification before initiating the process of consultation. Firstly, the documents available at federal and provincial levels were extensively reviewed and gaps and challenges were identified in the effective implementation of these policies and acts. Based on these gaps, different questions were formulated for the consultations to get the feedback from the stakeholders. As a second step, 5 consultations at Peshawar, Lahore, Karachi, Quetta and Islamabad were conducted. Based on the findings of the consultations and desk review of the existed policy/acts documents the draft guidelines have been prepared. These guidelines were shared with the stakeholders to get their views/inputs on the guidelines. Afterwards, these guidelines were reviewed by the experts from national and international organizations. The training cum consultation workshops were conducted to finalize the SPPI guidelines for water security in Pakistan. The schematic diagram of the methodology is as below;

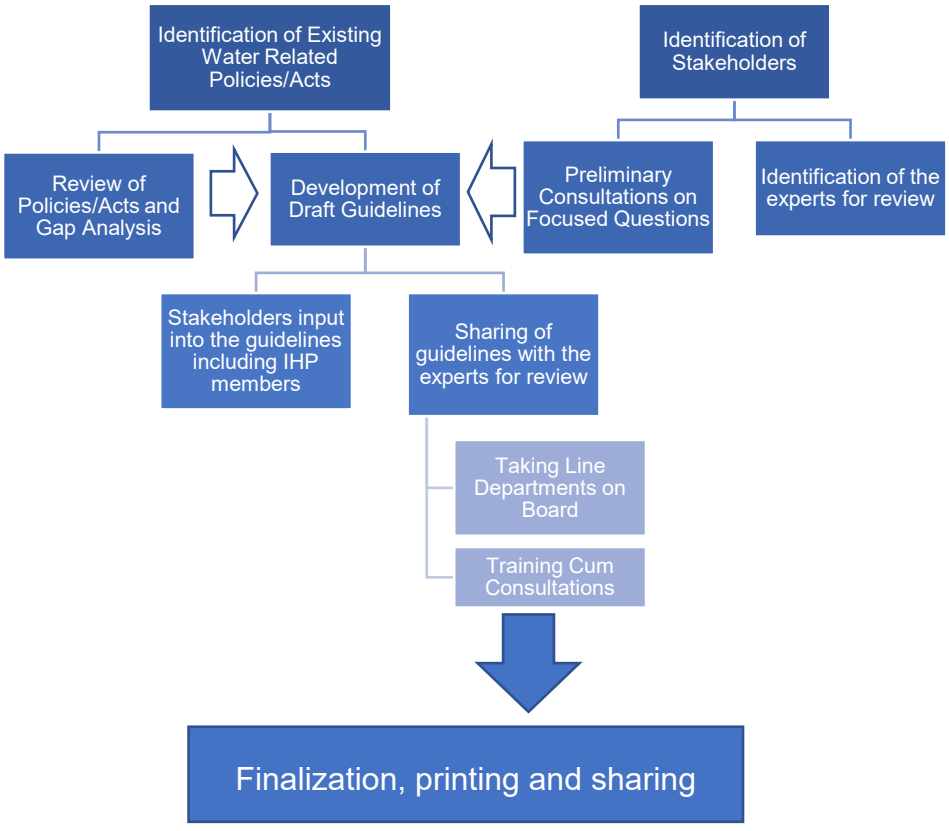

Figure 2: Methodological Framework of SPPI Guidelines Development for Water Security in Pakistan

1.4 Identification and Mapping of Stakeholder Organizations

Water security in Pakistan is a multi-dimensional challenge that requires integrating scientific research, policy-making, and practical implementation. The complexity of managing water resources sustainably is compounded by diverse ecological, socio-economic, and political factors across federal and provincial levels. The effectiveness of Science Policy Practice Interface (SPPI) demands the involvement of a wide range of stakeholders to ensure inclusive, evidence-based, and practical water governance solutions.

The stakeholder involvement is crucial for incorporating indigenous knowledge, translating the research into policies to bridge the gap between science and policy and providing the platform for the interaction of all actors who play pivotal role in the introduction and implementation of the policies at grass root level. The stakeholder mapping has been categorized into six main groups to ensure comprehensive participation in the SPPI consultation process.

1.4.1 Government Organizations/Departments

The key role of the government agencies is the Policy formulation, regulation, and enforcement of best management practices at federal and provincial levels. These agencies may be categorized into two categories like federal and provincial. The following organization were the part of SPPI consultations and discussions regarding water security of Pakistan. These organizations were involved to ensure alignment of water related policies at federal and provincial levels. These organizations include;

- Federal Ministry of Water Resources
- Pakistan Council of Research in Water Resources (PCRWR)
- Federal Flood Commission (FFC)
- Indus River System Authority (IRSA)
- Water and Power Development Authority (WAPDA)
- Federal Ministry of Climate Change
- Federal Ministry of National Food Security and Research
- National Disaster Management Authority (NDMA)
- Irrigation Departments (Punjab, Sindh, Khyber Pakhtunkhwa, Balochistan)
- Agriculture Departments (Punjab, Sindh, Khyber Pakhtunkhwa, Balochistan)
- Provincial Public Health Engineering Departments
- Provincial Environment Protection Agencies (EPAs)
- Water and Sanitation Agencies (WASAs)

1.4.2 Scientific and Research Institutions

These organizations are essential for evidence-based results and technical expertise for informed decision making and incorporating the research findings in the policies. These institutions may include;

- Pakistan Council of Scientific and Industrial Research (PCSIR)
- National Agricultural Research Centre (NARC)
- Universities and academic institutions with water research centers (e.g., UNESCO Chair in Knowledge Systems for IWRM at CIIT, Wah, USPCAS-W at Mehran University, NUST, UET Lahore).
- International research organizations (IWMI, ICIMOD etc.).

1.4.3 Non-Governmental Organizations (NGOs) and Civil Society

These organizations may be involved in the advocacy and capacity building of the masses at grassroot level. These organizations may include;

- WWF Pakistan.
- Hisaar Foundation.
- Pakistan Fisherfolk Forum.
- Local NGOs involved in water, sanitation, and hygiene (WASH) initiatives.

1.4.4 Private Sector and Industry

The private sector and industry may be involved to encourage sustainable water practices in industrial processes and promote investments in efficient water technologies. These may include;

- Industries with high water use (textile, sugar, and agro-based industries).
- Pakistan Business Council and Chambers of Commerce.
- Companies offering water treatment and management technologies.

1.4.5 Community-Based Organizations and Local Stakeholders

These organizations may be involved to ensure policies address local water needs and challenges. This may also facilitate the adoption of sustainable practices through local knowledge. These may include;

- Farmer associations (e.g., Farmer Organizations under PIDA).
- Water user associations (WUAs) managing irrigation systems.
- Karez management communities in Balochistan.
- Women's groups involved in water collection and management.

1.4.6 International Development Partners and Donors

These agencies may be involved to get access to international expertise and funding and to promote and track progress on international water security frameworks like SDG 6.0. These agencies may be;

- World Bank, Asian Development Bank (ADB).
- United Nations agencies (UNESCO, UNDP, UNICEF, FAO).
- Bilateral donors (USAID, GIZ, UKAID, AUS-AID)

2 Existing Policies and Acts & Case Studies for SPPI

The review is a process for assessing the potential of water related policies of Pakistan for addressing the issues of water in context of one basin approach keeping in view the challenges associated with climate change. There is a dire need to adapt the new scientific insights, changing environmental conditions, and emerging societal needs. Without a continuous process of review and refinement, there is a risk that policies will become outdated or disconnected from the realities which need to be addressed, ultimately failing to protect and manage one of Pakistan's resources shared among multiple stakeholders. Likewise, the assessment of policies with respect to SPPI principles is not just important, it is an imperative for securing long-term sustainability of Pakistan's natural resources with shared responsibilities.

Moreover, this comprehensive review was an essential step towards building a more robust and sustainable water management framework in Pakistan. It ensured that the policies in place are not only reactive to current challenges but also proactive in securing the country's water resources for future generations. This review was helpful in formulating the guidelines for the Science, Policy, Practice interface (SPPI) for Pakistan to enhance the effectiveness of policies and to build the capacity of the stakeholders on SPPI to cope water scarcity issues in the country. The review of existing policies/acts available at national and provincial levels was the first step towards guidelines development. Which enabled the stakeholders to understand the policy coherence and implementation gaps associated with SPPI in Pakistan.

2.1 Methodology for Policy Review and Gap Analysis

2.1.1 Document Selection and Scope Definition

2.1.1.1 Scope

The review was designed to encompass federal and provincial policies related to water resources, climate change, environmental protection, food security, and integrated water resource management (IWRM). This broad scope ensured that all relevant policy instruments and regulations were considered to provide a comprehensive understanding of the current landscape and its alignment with the Science Policy Practice Interface (SPPI).

2.1.1.2 Document Selection

The selection of documents was meticulously carried out to include a diverse range of national and provincial policies, acts, and relevant case studies from developed countries. The documents reviewed included;

- National Water Policy (NWP), 2018
- National Climate Change Policy (NCCP), 2021
- National Food Security Policy, 2018
- Integrated Water Resources Management (IWRM) Guideline for Pakistan
- Punjab Water Policy, 2018
- Punjab Water Act, 2019

- Khyber Pakhtunkhwa Climate Change Policy, 2022
- Khyber Pakhtunkhwa Water Act, 2020
- Integrated Water Resource Management (IWRM) Strategy Khyber Pakhtunkhwa, 2019
- The Balochistan Groundwater Rights Administration Ordinance, 1978
- The Balochistan Conservation Strategy (BCS)
- Sindh Water Policy (SWP), 2023
- Case Study of Murray-Darling Basin, Australia
- Case Study of Colorado River Basin, USA
- Case Study of Chesapeake Bay Restoration
- Case Study of Madagascar River Basins
- Case Study of Rhine River Basin

2.1.2 Review Criteria

2.1.2.1 Gap and Challenge Identification

Each policy and regulation were assessed to identify gaps and challenges in their integration with the Science Policy Practice Interface (SPPI). The review focused on key aspects such as policy coherence, implementation mechanisms, stakeholder engagement, and resource allocation. The aim was to understand how well these policies incorporated scientific research and practical applications into their frameworks.

2.1.2.2 International Best Practices

The review involved analyzing case studies from developed countries, specifically the Murray-Darling Basin in Australia, the Colorado River Basin, the Chesapeake Bay Restoration in the USA, Madagascar River Basins**,** South Africa and Rhine River Basin, Europe. These case studies were examined to understand the integration of SPPI and to identify best practices that could be adapted to the local context. The comparative analysis helped in drawing lessons and recommendations for improving local policies.

Evidence-Based Decision Making

The findings from the review were systematically identify the opportunities for evidence-based decision-making. This process helped in identifying actionable insights that could inform policy adjustments and improvements at both federal and provincial levels, ensuring that recommendations were grounded in thorough analysis.

2.1.3 Data Analysis

2.1.3.1 Content Analysis

The identified documents were analyzed to extract relevant information related to the Science Policy Practice Interface (SPPI). A detailed content analysis was conducted to identify specific provisions, goals, and implementation strategies within the policies. Gaps were identified by comparing these elements against SPPI goals and international best practices.

2.1.3.2 Comparative Analysis

A comparative analysis was performed between the reviewed national and provincial policies and international case studies. This analysis focused on understanding how SPPI was effectively integrated into water resource management and environmental conservation in developed countries. The goal was to draw lessons on successful strategies and identify how these could be adapted for local application.

2.1.4 Synthesis of Findings

2.1.4.1 Gap Identification

The review highlighted gaps in policy coherence, implementation frameworks, resource allocation, and stakeholder engagement across the reviewed documents. Specific challenges in effectively implementing SPPI were identified, particularly in aligning provincial policies with national goals. This synthesis aimed to pinpoint areas where policies fell short in integrating scientific research and practical applications.

2.1.4.2 Recommendations

Based on the identified gaps, recommendations were made to strengthen policy coherence, improve implementation mechanisms, and enhance stakeholder engagement. The review also suggests testing practices from international case studies to improve SPPI integration in local policies, ensuring a more robust and effective policy framework.

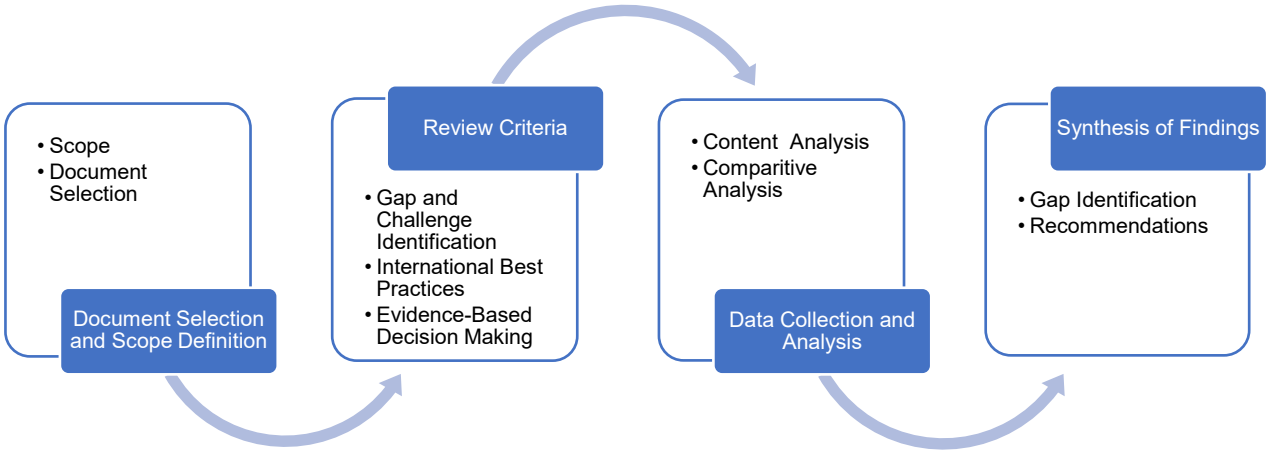

Figure 3: Conceptual Framework of Methodology of Review

2.2 Review of Policies/ Acts at National Level

2.2.1 National Water Policy 2018

The National Water Policy (NWP) 2018 is Pakistan's first comprehensive policy framework for water resources management, aiming to address water scarcity, improve governance, and ensure water security for energy, food, and domestic needs. The policy emphasizes science-based approaches and integrated water resources management (IWRM), advocating for the use of modern technologies, conservation practices, and sustainable development. It also highlights key initiatives that include enhancing water storage through projects like Diamer-Basha and Mohmand dams, promoting high-efficiency irrigation systems, and leveraging renewable energy. The policy also stresses the importance of a comprehensive regulatory framework and participatory decision-making, by the involvement of all stakeholders at every level to ensure informed decision making.

The institutional reforms are a central focus of the NWP 2018, with the establishment of the National Water Council and Ground Water Authority to oversee water management. The policy also envisions the creation of provincial water authorities to align with national objectives. The capacity building is also prioritized to equip water-related institutions with the skills needed to manage resources effectively, address climate change, and meet future demands. The policy underscores the need for a National Research Agenda to prioritize water-related research and ensure coordination between research institutions and policymakers. It also emphasizes the development of a comprehensive planning database to support evidence-based decision-making, including data on glacier melt and snowmelt.

The financial challenges are acknowledged, with the policy identifying underfunding as a major barrier to effective water management. It recommends increasing the water sector's share in the federal PSDP allocation from 10% in 2018-19 to 20% by 2030. The public awareness and education are also highlighted as critical components, with plans to promote behavioral change through media campaigns and the integration of water conservation lessons into school curriculum. It also emphasizes on the robust linkages between science, policy, and practice. The NWP 2018 aims to create a sustainable and resilient water management system for Pakistan.

2.2.2 National Climate Change Policy (NCCP) 2021

The National Climate Change Policy (NCCP) 2021 represents a robust integration of science, policy, and practice, addressing Pakistan's climate challenges through evidence-based strategies. It is grounded in scientific evidence, the policy highlights the impacts of climate change, such as increased frequency of extreme weather events, glacier melting, and rising sea levels. It aligns with international frameworks like the Paris Agreement, Sustainable Development Goals (SDGs), and the Sendai Framework for Disaster Risk Reduction, ensuring that Pakistan's climate actions are consistent with global scientific and policy standards. The policy emphasizes both adaptation and mitigation, focusing on water resource management, agricultural resilience, and disaster preparedness to address the projected adverse impacts of climate change.

The NCCP outlines specific implementation mechanisms, including the establishment of National and Provincial Climate Change Policy Implementation Committees to translate scientific recommendations into actionable plans. It emphasizes the need for capacity building and institutional strengthening, proposing the creation of climate change cells in federal and provincial ministries, a Climate Change Fund, and National and Provincial Implementing Entities (NIE & PIE). These measures aim to enhance coordination and ensure effective implementation of adaptation and mitigation projects. The policy also promotes public-private partnerships and encourages investment in sustainable projects through innovative financial instruments such as green bonds, blue bonds, and carbon credit trading.

The key aspect of the NCCP is its focus on public awareness and education, leveraging media, educational institutions, and community organizations to disseminate climate knowledge. The policy also highlights the importance of continuous monitoring through the Federal National Climate Change Implementation Committee, ensuring that climate actions are regularly evaluated and adjusted based on scientific data and practical outcomes.

2.2.3 National Food Security Policy, 2018

The National Food Security Policy 2018 of Pakistan demonstrates a comprehensive approach to integrating scientific research into policy and practice to enhance agricultural productivity and resilience. The policy emphasizes the importance of strengthening the National Agricultural Research Systems (NARS) to address modern research goals and improve coordination in research dissemination and technology adoption. It advocates for climate-smart agriculture by promoting soil and water conservation technologies, high-efficiency irrigation systems, and drought-resistant crop varieties, reflecting the translation of scientific research into actionable strategies. Additionally, the policy highlights the role of technological innovations and infrastructure development for post-harvest management and value addition, underscoring the need for a strong scientific and technological foundation.

It also stresses the importance of strategic partnerships involving provincial governments, researchers, entrepreneurs, academia, farmers, and civil society to foster a collaborative approach that bridges science, policy, and practice. The roles assigned to the Ministry of National Food Security and Research (MNFSR) and provincial governments in research, public investments, and continuous monitoring further illustrate the policy's commitment to evidence-based decision-making. This alignment of scientific knowledge with policy actions and practical implementation reflects a robust Science Policy Practice Interface (SPPI) aimed at achieving sustainable food security in Pakistan.

2.2.4 Integrated Water Resources Management, Implementation Guidelines for Pakistan

The document reviews existing policies such as the National Water Policy 2018, National Climate Change Policy 2012, and others, highlighting how scientific research informs policy development. This integration ensures that policies are grounded in scientific evidence and the current understanding of water resource management. It details provincial laws such as the Balochistan Groundwater Rights Administration Ordinance

1978 and Punjab Water Act 2019, showing how local regulations align with scientific recommendations for sustainable water use.

Being the first of its kind, this document has explained the process of IWRM, and the level of sectoral coordination required for planning and implementation of the IWRM process. The document outlines clear steps and conditions for IWRM implementation, including the need for river basin organizations, capacity building, and public awareness. This structured approach facilitates the translation of scientific concepts into actionable policies and practices.

The document clearly highlights the key driving factors behind the IWRM planning, governance, climate change, land use and land cover changes, population rise, economic situation, social conditions and technologies. The demographics of Pakistan and the hydrology of its river basins is dynamic and its highly volatile in the scenario of climate change. IWRM principles in fact establish the foundation of science, policy and practice interface by offering a holistic thinking approach. In these guidelines, sectoral perspectives are explained as well as short, medium and long-term initiatives are outlined.

2.3 Review of Provincial Policies/Acts

2.3.1 Punjab Water Policy 2018

The Punjab Water Policy 2018 is a comprehensive framework for managing water resources in Punjab, emphasizing the integration of scientific principles, policy directives, and practical applications. As the first provincial water policy following the 18th Constitutional Amendment in the constitution of Islamic republic of Pakistan, it addresses key challenges such as climate change, water scarcity, and sustainable water use. The policy highlights the importance of climate science, proposing adaptive measures like local climate models, enhanced groundwater and surface water storage, and techniques such as rainwater harvesting and artificial recharge to mitigate climate impacts. It underscores the need for sustainable water management by balancing productivity and conservation, ensuring equitable water allocation, and promoting efficient water use through high-efficiency irrigation systems like drip and sprinkler technologies.

A central focus of the policy is the integration of scientific knowledge into decision-making. It advocates for the development of a knowledge database and water informatics, including GIS-based systems, water balance models, and real-time data acquisition tools to support evidence-based planning. The policy also emphasizes stakeholder participation, ensuring that water management decisions are inclusive and consider the interests of farmers, communities, and other stakeholders. This participatory approach is reinforced through awareness campaigns, educational programs, and capacity building initiatives aimed at fostering public involvement in water conservation efforts.

The Punjab Water Policy 2018 also prioritizes institutional reforms and capacity building to strengthen water governance. It calls for the adoption of Integrated Water Resources Management (IWRM) principles, improved infrastructure development, and the enforcement of water quality standards to protect resources from contamination. The policy stresses the integration of scientific research, policy frameworks, and practical measures to resolve water related issues. The policy aims to achieve sustainable water

management in Punjab, addressing challenges related to climate change, agricultural efficiency, and public awareness.

2.3.2 Punjab Water Act, 2019

The Punjab Water Act 2019 establishes a robust framework for the management and regulation of water resources in Punjab. It emphasizes the integration of scientific principles into policy and practice. The Act mandates the creation of two key institutions, the Punjab Water Resources Commission and the Punjab Water Services Regulatory Authority. The Commission, composed of government officials and experts. The commission is responsible for the conservation, redistribution, and augmentation of water resources, ensuring that water management policies are guided by scientific principles. The Regulatory Authority oversees water and sewerage services by ensuring compliance with regulatory standards and applying scientific and economic principles to water pricing and service delivery.

A significant aspect of the Act is its inclusion of experts in water, environmental science, and public health within both institutions, bridging the gap between scientific research and practical implementation. This ensures that policies are informed by the latest scientific understanding and are effectively translated into actionable practices. The Act also adopts a holistic approach to water management, emphasizing the interconnection of ecosystems by addressing the maintenance and development of water resources, wildlife, fisheries, flora and fauna. This reflects the application of ecological science in policy decisions.

The Act provides mechanisms for enforcement and compliance by ensuring that scientific and regulatory standards are not only theoretical but are practically enforced through clear penalties for non-compliance. This ensures that policies are effectively implemented on the ground.

2.3.3 Khyber Pakhtunkhwa Climate Change Policy 2022

The Khyber Pakhtunkhwa Climate Change Policy 2022 demonstrates a strong integration of scientific knowledge, policy frameworks, and practical measures to address climate change challenges in the province. The policy emphasizes the use of scientific evidence to assess climate risks, such as riverine floods, glacier bursts, heatwaves, and droughts, and incorporates these insights into adaptation and mitigation strategies. It aligns with the National Climate Change Policy 2021 and the updated Nationally Determined Contributions (NDCs) 2021. It ensures that provincial actions contribute to national and international climate commitments. The policy promotes Integrated Water Resources Management (IWRM) by advocating for sustainable water resource management practices that reduce vulnerability to climate-induced water-related disasters.

The establishment of a Climate Change Cell within the Environmental Protection Agency (EPA) and the creation of a Provincial Climate Change Policy Implementation Committee illustrate the commitment to effective policy implementation based on scientific research. Additionally, the policy highlights the importance of stakeholder engagement, involving government departments, academia, civil society, and international agencies in decision-making processes. The focus on capacity building and awareness programs is intended to equip stakeholders with the knowledge and skills required to implement climate actions

effectively. The continuous monitoring and evaluation mechanisms are embedded in the policy to ensure that practices are updated based on scientific feedback and emerging insights. This comprehensive approach reflects a robust Science Policy Practice Interface (SPPI) aimed at enhancing climate resilience and sustainable water management in Khyber Pakhtunkhwa.

2.3.4 Khyber Pakhtunkhwa Water Act, 2020

The Khyber Pakhtunkhwa Water Act, 2020, follows the National Water Policy 2018 and creates important bodies like the Khyber Pakhtunkhwa Water Resources Commission and the Khyber Pakhtunkhwa Water Resources Regulatory Authority. These groups include ministers, secretaries, and experts in water management, the environment, public health, and industry, ensuring that decisions about water policies are based on scientific knowledge. The Regulatory Authority is responsible for ensuring that service providers follow the law, approves pricing for services, and holds public hearings to collect input from the community.

The Act highlights the importance of using scientific information to make decisions about water quality and availability. It sets clear standards for safe drinking water and requires actions to prevent contamination and waste. Additionally, the Commission is tasked with protecting and improving aquatic life, like wildlife and fish, indicating a focus on science-based management of ecosystems. The Act also allows for the hiring of technical experts to assess water resources, ensuring decisions are based on solid data and scientific analysis.

A key feature of the Act is the creation of advisory committees made up of experts from different fields. These committees provide diverse insights on water resources, wildlife, fisheries, aquaculture, and environmental issues, ensuring a well-rounded approach to policymaking. The Regulatory Authority's role in organizing public hearings and gathering community feedback further enhances its commitment to inclusive decision-making.

2.3.5 Integrated Water Resource Management (IWRM) Strategy Khyber Pakhtunkhwa, 2019

The Integrated Water Resource Management (IWRM) Strategy for Khyber Pakhtunkhwa presents a comprehensive approach by integrating science, policy, and practice for sustainable water management. The strategy aligns with the National Water Policy 2018 by advocating a shift from sectoral to integrated water management approaches that consider the interests of all stakeholders, including upstream and downstream communities. It emphasizes the use of scientific knowledge for watershed protection, water conservation, and pollution control, ensuring that water management practices are both evidence-based and sustainable. The strategy also incorporates elements of the National Climate Change Policy 2012 and the National Food Security Policy 2018 by addressing groundwater depletion, urbanization, and climate-induced water risks through science-based adaptation measures.

Additionally, the IWRM Strategy promotes public-private partnerships under the Khyber Pakhtunkhwa Public Private Partnership Act 2014 to enhance water infrastructure and service delivery. It highlights the need for data-driven decision-making, particularly concerning private sector water use and contamination levels, to foster transparency and

build trust between public and private entities. Its alignment with existing provincial policies, such as the Economic Growth Strategy 2015 and the Drinking Water Policy 2015, reinforces the integration of scientific research into policy frameworks and practical actions.

It focuses on empowering the Khyber Pakhtunkhwa Environmental Protection Agency (EPA) to regulate water pollution, the strategy strengthens the science-policy-practice interface (SPPI) by ensuring that water management practices adhere to environmental standards. The focus on institutional capacity building and stakeholder participation reflects a commitment to translating scientific insights into actionable policies and practices. Overall, the IWRM Strategy for Khyber Pakhtunkhwa serves as a robust model for integrating scientific knowledge with policy frameworks and practical implementation to achieve sustainable and equitable water resource management.

2.3.6 The Balochistan Groundwater Rights Administration Ordinance, 1978

The Balochistan Groundwater Rights Administration Ordinance 1978 is a foundational piece of legislation aimed at regulating groundwater use in Balochistan, Pakistan. The act enacted to address growing concerns over groundwater depletion due to increasing agricultural activities and population pressures, the ordinance established a framework for managing groundwater resources through a licensing system. It focuses on regulating the drilling of wells and controlling over-extraction by issuing permits for groundwater use. The ordinance also established a Water Board/Committee responsible for monitoring groundwater withdrawal, registering wells and karezes, and resolving disputes related to groundwater extraction.

While the ordinance reflects an early recognition of the need for sustainable groundwater management, its alignment with modern scientific understanding is limited. It does not fully account for the complexities of aquifer systems, local hydrogeological conditions, or seasonal variations in recharge rates. Over the years, the ordinance has been amended to include provisions such as the installation of water meters to monitor groundwater flow, reflecting some progress toward integrating scientific tools into groundwater management. However, the effectiveness of these measures is often hindered by a lack of technical capacity, resources, and coordination among stakeholders.

The ordinance represents an important step in bridging the Science Policy Practice Interface (SPPI) by establishing a regulatory framework for groundwater management. However, to fully align with contemporary scientific knowledge and practices, the ordinance requires updates to incorporate advanced hydrological research, improved monitoring mechanisms, and greater community involvement.

2.3.7 The Balochistan Conservation Strategy (BCS)

The Balochistan Conservation Strategy (BCS) aims to integrate science, policy, and practice to address environmental and developmental challenges. The BCS emphasizes the importance of cross-sectoral analysis, ecosystem evaluation, and demand assessment to balance economic needs and sustainable use of resources. This reflects the integration of scientific understanding into policy-making and practical applications. The strategy highlights the role of public participation and community-based management

in sustainable development. This involves educating and engaging communities, which is essential for effective implementation of environmental policies.

The development of a Development Information Management Policy (DIMP) is crucial for making accurate and timely information available for decision-making. This policy ensures that scientific data and indicators are used to monitor progress towards sustainability and inform policy decisions. The BCS outlines the need for strengthening institutions to better manage natural resources. This includes creating and operationalizing environmental protection agencies and councils, which bridge the gap between scientific research and policy implementation. One of the BCS's primary aims is to integrate environmental considerations into daily economic, social, and physical decisions. This demonstrates the application of scientific knowledge in policymaking to achieve sustainable development goals. The document acknowledges challenges in policy implementation, such as the lack of transparency and political instability. It suggests that the civil society and NGOs play a crucial role in mobilizing support for environmental accountability and policy enforcement.

2.3.8 Sindh Water Policy (SWP) 2023

The Sindh Water Policy (SWP) 2023 demonstrates a strong integration of scientific knowledge, policy frameworks, and practical measures for sustainable water management by explicitly adopting the principles of Integrated Water Resources Management (IWRM). The policy emphasizes a holistic approach to managing all sources of water, including surface water, groundwater, and wastewater, across various sectors such as domestic, agriculture, fisheries, industrial, and environmental uses. This integrated approach aims to balance social, economic, and environmental needs, ensuring that water management practices are grounded in scientific evidence and sustainability principles.

To facilitate effective implementation, the policy establishes the Sindh Water Resources Council (SWRC) and the Sindh Water Policy Implementation Committee to oversee and monitor progress. The creation of the Sindh Water Resources Management Department (SWRMD) and the Hydro-Agro Informatic Center (HAI) is a significant step towards enhancing governance and data-driven decision-making. These institutions are designed to bridge the gap between science, policy, and practice by promoting collaboration among scientists, policymakers, and practitioners. The focus on proactive information sharing through the Hydro-Agro Informatic Center supports evidence-based policymaking and ensures that scientific insights are effectively translated into practical water management actions.

The policy also highlights the importance of updating legal frameworks to replace outdated regulations, aiming to strengthen water quality management, groundwater regulation, and the governance of water supply and sanitation. By advocating for new unified legislation, the policy seeks to enforce science-based standards and practices more effectively. Additionally, the SWP underscores the need for adaptive management strategies that can accommodate advancements in scientific knowledge, changing community values, and emerging water management challenges.

The effective participation of stakeholder is a central element of the policy, involving agriculture, municipalities, industries, and environmental groups in the planning, operation, and maintenance of water resources. This inclusive approach ensures that

diverse perspectives are integrated into water management practices, enhancing the science policy practice interface. The policy's alignment with sustainable development objectives further reinforces its commitment to long-term water security, resilience to climate-related risks, and maximizing economic benefits while maintaining ecological balance. Overall, the Sindh Water Policy 2023 reflects a comprehensive and integrated framework for managing water resources effectively by bridging the gap between science, policy, and practice.

2.4 Gap Analysis

Through a detailed examination of policy and act documents related to water resource management and climate action, several pervasive and significant gaps and challenges were identified. These issues are evident at both national and provincial levels, exposing critical shortcomings in the implementation and effectiveness of current policies. Furthermore, the analysis reveals notable deficiencies in integrating the Science-Policy-Practice Interface (SPPI), highlighting the need for improved alignment between scientific research, policy development, and practical application. The following outlines the major gaps and challenges identified through this review.

2.4.1 Sectoral Focus and Top-Down Approach

Many policies, including the National Water Policy and provincial policies, exhibit a sectoral focus with a top-down approach. One such example is the completely isolated governance mechanism of national policies for food security and water resources despite their intimate linkage. Such isolated approaches often lead to a misalignment between national objectives and provincial implementations. There is a need for a more integrated approach that coordinates efforts across different levels of government and includes input from scientists, users, and policymakers.

2.4.2 Legal Implementation Support

Policies such as the National Environmental Policy and the National Climate Change Policy (NCCP) 2021 incorporate scientific principles but struggle with translating these principles into actionable steps. This gap is particularly pronounced at the provincial level, where practical implementation is hindered by inadequate resources and coordination. Policies are to be driven by a policy objective, if for instance, policies are being introduced to ensure the corrective measures or anticipate a drastic behavior change, policies need to be legally implemented. In the case of national water policy, provincial water acts and Balochistan's groundwater administration regulations are good examples of such regulations. However, in the context of science-policy and practice interface, there is a need to understand whether these canons are supported by a strong technical wing or not. Additionally, in order to ensure the legal implementation of policy directions and science recommendations, there is no mechanism for the improvement enforcements. If there is major water theft or damage to an early warning system, no policy offers channels of legal actions against the wrong doers.

2.4.3 Financial Constraints

The gap between proposed funding and actual financial disbursements is a significant barrier. For instance, the National Water Policy 2018 acknowledges the need for increased funding but faces challenges in mobilizing and effectively utilizing these funds. Similarly, the NCCP 2021 highlights the need for a dedicated climate fund, which remains underdeveloped, affecting the execution of climate initiatives. Similar to the legal support to the legislative mechanism, no policy ensure straight forward and quick financial arrangements to enable smooth financing for international funding agencies. Climate Change is a subject that is equally affecting water, agriculture, disaster risk and the environmental sector but policy itself does not reflect the joint priorities of these sectors.

2.4.4 Institutional Mechanisms and Coordination

The reviewed policies often emphasize the role of policymakers and institutions but neglect the involvement of scientists, researchers, and end-users. This lack of integration among key stakeholders hampers effective policy implementation. The creation of new institutions is proposed, but these often suffer from inadequate expertise and resources, leading to overlapping mandates and inefficiencies. In National Water Council composition proposed within the National Water Policy 2018, there is no representation from the Ministry of Food Security. Sharing knowledge resources is one key method to ensure coordination and integrated application of different polices, however, none of the policies, acts or regulations clearly mentions the need for a centralized database related to the natural resources of the nation. This is a major gap with the capacity to compromise any plan for science policy practice interface approach in a single basin unit.

2.4.5 Stakeholder Engagement and Community Awareness

Despite stressing participatory decision-making, policies such as the Sindh Water Policy 2023 and Punjab Water Act 2019 do not effectively address the issue of local communities and scientists. The emphasis on stakeholder engagement is often insufficient, particularly regarding community awareness. Policies advocate for community mobilization and awareness campaigns, but actual implementation is inconsistent. Limited outreach and engagement in rural and vulnerable communities result in resistance to policy measures and inadequate local support. Effective engagement must include comprehensive awareness programs that educate and involve communities in decision-making processes to ensure broader support and successful implementation.

2.4.6 Monitoring and Evaluation Systems

The absence of robust monitoring and evaluation systems leads to a disconnect between policy objectives and actual outcomes. Policies often lack transparency and accountability in how implementation progress is tracked, affecting the ability to adapt and improve strategies based on real-world feedback.

In summary, aligning provincial policies with national goals requires overcoming these challenges by enhancing coordination, improving resource allocation, involving a broader range of stakeholders, and establishing effective monitoring and evaluation mechanisms. The emphasize on community awareness and engagement is also crucial to ensure that SPPI is effectively integrated and implemented across all levels of government.

2.5 Case Studies

2.5.1 Murray-Darling Basin, Australia

The Murray–Darling Basin is Australia's largest river basin, with a catchment of greater than 1 million km^2. The basin's hydrology is highly variable and unpredictable, exacerbated by the fact that Australia has the lowest continental run-off in the world (excluding Antarctica), with an average basin-wide runoff of 31,600 gigalitres (GL) year^{-1}, ranging from 6,700 GL year^{-1} in the driest years to 117,900 GL year^{-1} in the wettest. This river system has been extensively developed since the late 19th Century for shipping passage, flood management, and irrigation. From the 1930s to the 1990s, water diversion and use approximately tripled to almost 11,500 GL year^{-1}. Because of these diversions, many environmental problems have emerged in the Murray–Darling Basin, including increased salinity and nutrients, lake acidification in the lower part of the system, declining condition of floodplain forests, and reduced populations of some native fish, invertebrates, waterbirds, and amphibians (MDBA,2020).

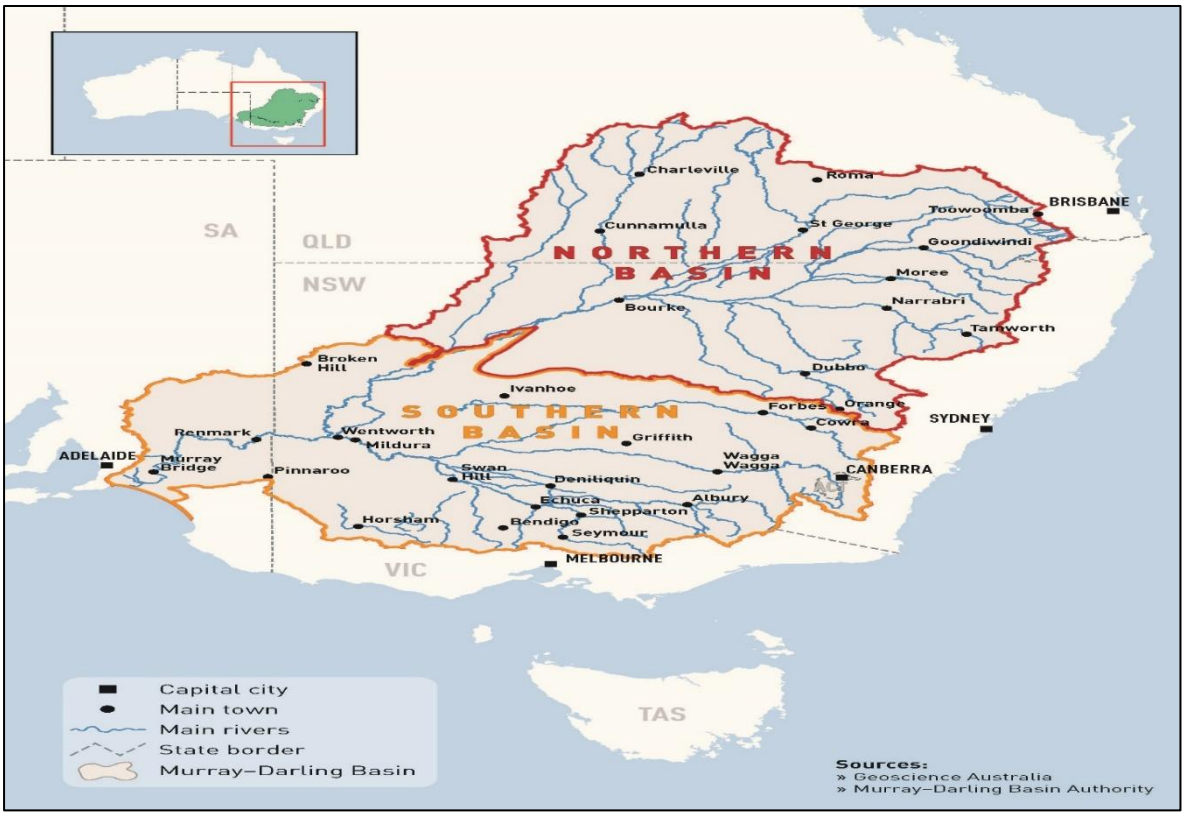

Figure 4: Map of Murray- Darling Basin Australia
(Source: mdba.gov.au)

2.5.1.1 Governance Structure of the Murray–Darling Basin

To manage the issue robust governance structure including different authorities was introduced, details have been given below;

- Murray-Darling Basin Authority (MDBA) was established by the Australian Government in 2007 to oversee water management across the basin. It is

responsible for implementing the Basin Plan, monitoring compliance, and coordinating water sharing between states.
- Commonwealth Environmental Water Holder (CEWH) manages water recovered for the environment, ensuring that it is used effectively to sustain river health and biodiversity.
- Water Market and Trading System allows participants to buy, sell, and transfer tradeable water rights to manage water use efficiently across different sectors and regions.
- State and Territory Governments collaborate with federal agencies to implement water management strategies and ensure compliance with the Basin Plan.

2.5.1.2 Problems of the Murray–Darling Basin

- Extensive water diversion for agriculture significantly reduced river flows, impacting aquatic ecosystems.
- Excessive water extraction led to higher salinity levels, nutrient pollution, and lake acidification, particularly in the lower parts of the basin.
- Declining populations of native fish, invertebrates, waterbirds, and amphibians due to altered river flows and degraded habitats.
- The implementation of water reforms created winners and losers, causing polarization among communities, farmers, and other stakeholders.
- Prolonged droughts exacerbated water scarcity and stressed existing governance and management frameworks.

2.5.1.3 Solutions Implemented

- Introduction of a Water Cap (1995) to establish limits on water entitlements to prevent further over-extraction.
- Murray-Darling Basin Plan (2012) set a sustainable diversion limit, reducing consumptive use by 2,750 GL per year to ensure sufficient water for environmental flows.
- Investment in Infrastructure by allocating AU$9 billion to modernize irrigation systems and improve water use efficiency.
- Water Market Reforms facilitated tradeable water rights to promote efficient water use and allow flexibility for farmers.
- Environmental Water Management by allocating water specifically for maintaining wetlands, floodplains, and aquatic ecosystems through the Commonwealth Environmental Water Holder.
- Science-Based Monitoring and Evaluation by Implementing robust programs to track environmental health, water usage, and socio-economic impacts, informing ongoing policy adjustments.
- Ensured that local communities, indigenous groups, and various stakeholders were included in decision-making processes.

2.5.1.4 Key Success Factors

- Integration of Scientific Research by Using hydrological, ecological, and socio-economic data to inform water management policies and adapt them based on monitoring outcomes.

- The Basin Plan provided a comprehensive and legally supported robust policy structure for managing water sustainably.
- Successfully translated scientific insights into actionable strategies, such as sustainable diversion limits and infrastructure upgrades.
- Effective coordination among federal, state, and local governments, alongside stakeholder involvement, ensured smoother policy implementation and collaborative governance.
- Ongoing adjustments to water allocations and policies based on scientific monitoring allowed for flexibility in managing uncertainties.
- Established water trading systems promoted efficient water use and adaptation to variable water availability.
- Dedicated environmental water allocations safeguarded riverine ecosystems and biodiversity.

2.5.2 Colorado River Basin, USA/Mexico

The Colorado River is one of the most critical water sources in the United States, supplying water to over 30 million people, irrigating nearly 4 million acres of cropland, and generating over 10 billion kilowatt-hours of hydropower annually. It also supports recreation, ecosystems, and biodiversity across seven U.S. states (Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming) and Mexico. However, the river faces significant challenges due to overallocation, prolonged droughts, climate change, and growing water demands. The integration of the Science Policy and Practice has been central to managing the Colorado River Basin, ensuring sustainable water use and addressing complex challenges.

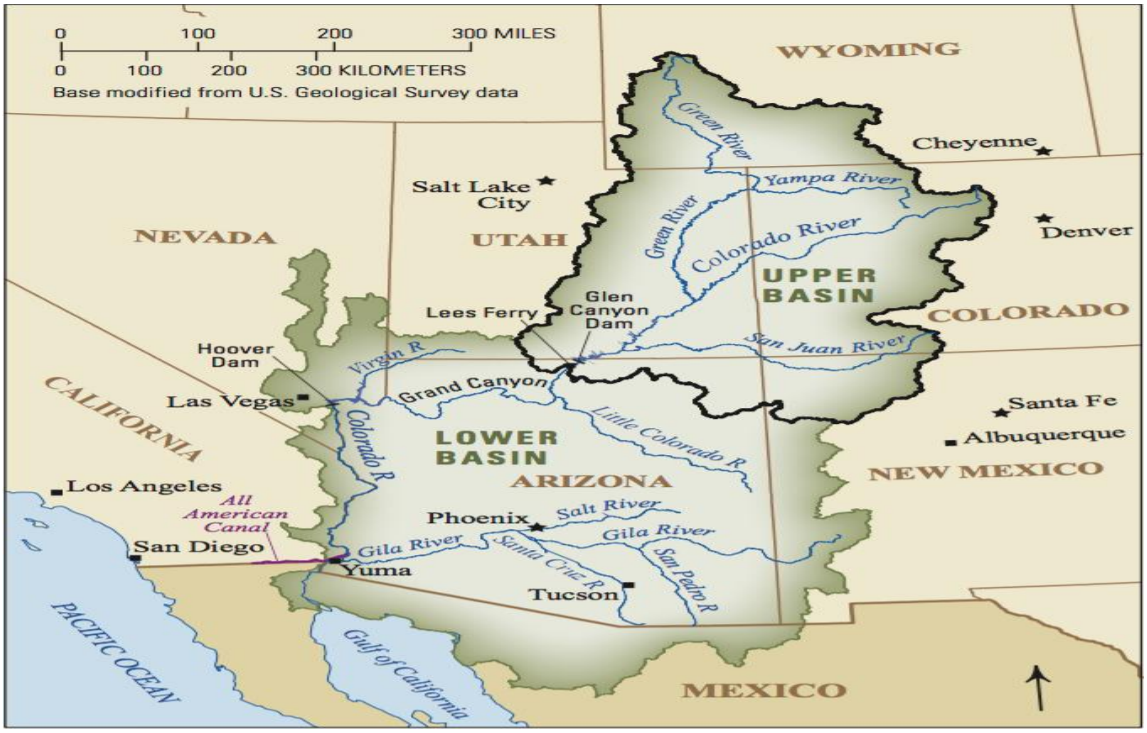

Figure 5: Map of Colorado River Basin, USA/Mexico
(Source: usgs.gov)

2.5.2.1 Governance Structure of the Colorado River Basin

- Colorado River Compact (1922) allocates water between the Upper Basin (Colorado, Wyoming, Utah, New Mexico) and the Lower Basin (Arizona, California, Nevada).
- U.S. Bureau of Reclamation manages water storage, delivery, and hydropower generation in the basin.
- Upper Colorado River Commission oversees water allocation and management in the Upper Basin states.
- International Boundary and Water Commission (IBWC) manages water-sharing agreements between the U.S. and Mexico, including the 1944 U.S.-Mexico Water Treaty.
- State and Local Agencies implement water management policies and conservation programs within their jurisdictions.
- Tribal Nations are indigenous communities that play a critical role in water rights and management decisions.

2.5.2.2 Problems of the Colorado River Basin

- The water is over-allocated, with demand exceeding supply, especially during droughts.
- Persistent drought conditions have reduced river flows and reservoir levels, threatening water availability.
- Changing Climate patterns like rising temperatures, reduced snowpack, and altered precipitation patterns exacerbate water scarcity.
- Declining water levels and habitat loss threaten fish and wildlife, including endangered species.
- Increasing population and agricultural needs strain the river's resources.
- Coordinating water management between the U.S. and Mexico adds complexity to governance.

2.5.2.3 Solutions to Address the Problems

- Balancing water supply, demand, and environmental needs through collaborative governance and Integrated Water Resources Management (IWRM).
- Agreements among states to reduce water use during shortages and stabilize reservoir levels by introducing Drought Contingency Plans (DCPs).
- Climate Adaptation Strategies by using scientific models like the Colorado River Simulation System (CRSS) to predict water availability and plan for climate impacts.
- Environmental Restoration by introducing Initiatives like the Minute 319 Agreement (2012) restore flows to the Colorado River Delta, benefiting ecosystems.
- Water Conservation Programs initiated to Promote efficient water use in agriculture, urban areas, and industries.
- Upgrading dams, reservoirs, and irrigation systems to improve water storage and delivery.
- Involving tribes, local communities, and NGOs in decision-making processes.

2.5.2.4 Key Success Factors

- Scientific research on climate change, hydrology, and ecosystems informs policy decisions, which are implemented through collaborative practices.
- Multi-stakeholder partnerships, including federal, state, tribal, and international entities, ensure coordinated management.
- Continuous monitoring and adjustment of water management strategies based on new data and changing conditions.
- Engaging communities and stakeholders in water conservation and restoration efforts builds support and ensures inclusivity.
- Introduced policies to promote sustainable water use while protecting ecosystems and supporting economic growth.
- Agreements like the U.S.-Mexico Water Treaty and associated minutes (e.g., Minute 319) facilitate Transboundary water management of the river.
- Scenario planning and adaptive strategies prepare the basin for future challenges, including climate change and population growth.

2.5.3 Chesapeake Bay Restoration

The Chesapeake Bay is the largest bay in the United States, covering a watershed of over 64,000 square miles across parts of Delaware, Maryland, New York, Pennsylvania, Virginia, West Virginia, and the District of Columbia. Home to more than 18 million people and a diverse range of species, the Bay has historically suffered from significant environmental degradation due to land-use changes, nutrient pollution, overfishing, invasive species, and toxic contaminants. This degradation led to reductions in economically vital fisheries, loss of underwater vegetation, and annual dead zones caused by nutrient-driven algal blooms. In response, the U.S. Congress initiated efforts to restore the Bay as early as 1965, leading to the establishment of the Chesapeake Bay Program (CBP) in 1983. The CBP implements the Chesapeake Bay Agreement, a cooperative and non-binding accord among federal agencies, watershed states, and local governments, with the latest version signed in 2014, aiming for substantial restoration progress by 2025.

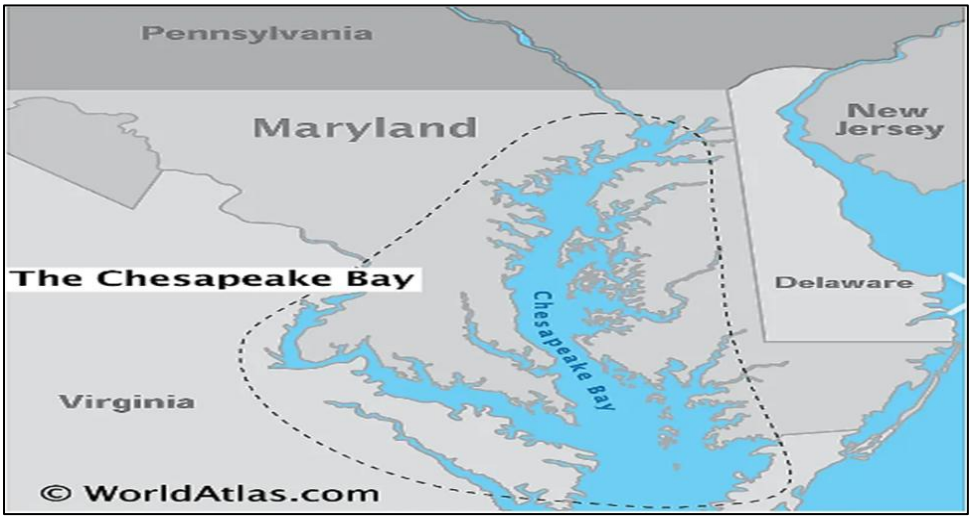

Figure 6: Map of Chesapeake Bay
(Source: WorldAtlas)

2.5.3.1 Governance Structure of the Chesapeake Bay

- Chesapeake Bay Program (CBP) was established in 1983, it is a regional partnership led by the U.S. Environmental Protection Agency (EPA) and includes state governments, local municipalities, academic institutions, and non-governmental organizations.
- Chesapeake Bay Watershed Agreement (2014) was a collaborative agreement among the Bay states and federal agencies to set goals for restoration, including water quality improvement, habitat restoration, and sustainable fisheries.
- Each state within the Bay watershed has its own agencies responsible for implementing restoration projects and enforcing environmental regulations.
- Citizen Advisory Committees are in place to engage local communities and stakeholders in decision-making processes.
- The EPA provides funding, technical assistance, and oversight to ensure compliance with the Clean Water Act and Total Maximum Daily Load (TMDL) requirements.

2.5.3.2 Problems of Chesapeake Bay

- Excessive nitrogen and phosphorus from agricultural runoff, wastewater treatment plants, and urban stormwater cause algal blooms and dead zones.
- Soil erosion from deforestation, construction, and agricultural practices leads to sedimentation, which smothers aquatic habitats.
- Rapid urbanization and land-use changes have destroyed wetlands, forests, and underwater grasses critical for wildlife.
- Unsustainable fishing practices have depleted key species like oysters and blue crabs, disrupting the Bay's food web.
- Climate anomalies like rising sea levels, warmer temperatures, and increased storm intensity threaten the Bay's ecosystems and coastal communities.
- Coordinating efforts across six states and multiple jurisdictions is challenging, leading to uneven progress and fragmented governance.

2.5.3.3 Solutions to Address the Problems

- A science-based framework was introduced to limit nutrient and sediment pollution entering the Bay, for the calculation of Total Maximum Daily Load (TMDL) enforced by the EPA.
- Implementing agricultural best management practices (BMPS) like cover crops, buffer strips, and nutrient management plans to reduce runoff.
- Rehabilitation of wetlands and planting trees to improve water filtration and habitat quality.
- Rebuilt oyster populations to enhance water quality and support fisheries.
- Upgraded urban stormwater systems to reduce pollution and improve water retention.
- Encouraged citizen involvement through volunteer programs, education, and advocacy.
- Developed strategies to adapt to sea-level rise, increased flooding, and other climate-related challenges.

2.5.3.4 Key Success Factors

- Scientific research on nutrient pollution, habitat restoration, and climate impacts informs policy decisions, which are implemented through collaborative practices.
- The Chesapeake Bay Program fosters cooperation among federal, state, and local entities, ensuring a unified approach to restoration.
- Engaging communities and stakeholders in restoration efforts builds support and ensures inclusive decision-making.
- Continuous monitoring and evaluation of restoration projects allow for adjustments based on new data and changing conditions.
- Policies promote sustainable agriculture, fisheries, and urban development while protecting the Bay's ecosystems.
- Federal Leadership and Funding through EPA's oversight and financial support provide the necessary resources and accountability for achieving restoration goals.
- The Chesapeake Bay Restoration effort demonstrates the importance of sustained investment and collaboration over decades to achieve meaningful results.

2.5.4 Madagascar River Basins as Japanese Basin Management Model

Madagascar, the fourth-largest island in the world, is home to diverse river basins that play a critical role in supporting its ecosystems, agriculture, and human settlements. The island's six primary river basins are further divided into 533 sub-basins and 32 macro-basins, spread across 22 regions. These basins are vital for water supply, irrigation, hydropower, and biodiversity. However, Madagascar faces significant challenges due to climate change, deforestation, and unsustainable water use, which threaten the sustainability of its water resources.

2.5.4.1 Governance Structure of Madagascar River Basins

- National Water Code (1998) was introduced to provide the legal framework for Integrated Water Resources Management (IWRM) in Madagascar.
- Ministry of Water, Sanitation, and Hygiene is responsible for water resource management and sanitation policies.
- National Climate Change Coordination Office was established in 2010, it coordinates climate change adaptation and mitigation efforts.
- Regional and Local Authorities are responsible to implement water management policies at the sub-basin and community levels.
- Collaboration with organizations like the World Bank and the Southern African Development Community (SADC) to support IWRM and climate resilience initiatives.

2.5.4.2 Problems of Madagascar River Basins

- Water Scarcity leads to uneven distribution of water resources and seasonal variability exacerbate water stress, particularly in the south and west.
- Increased frequency of droughts, cyclones, and floods disrupt water availability and quality.

- Practices like slash and burn agriculture (Tavy) lead to sedimentation and reduced water retention in basins.
- Agricultural runoff, industrial discharge, and untreated wastewater degrade water quality.
- Limited investment in water storage, distribution, and sanitation infrastructure hinders effective water management.
- Some basins extend beyond Madagascar's borders, requiring regional cooperation for sustainable management.

2.5.4.3 Solutions to Address the Problems

- Adopted a holistic approach like Integrated Water Resources Management (IWRM) to balance water supply, demand, and environmental conservation.
- Implemented various programs to reduce deforestation and soil erosion, such as sustainable land management practices.
- Developed early warning systems, flood management plans, and drought-resistant crops to tackle climate change impacts.
- Enhanced governance by enforcing regulations to reduce agricultural and industrial pollution, and improving wastewater treatment.
- Invested in water storage, irrigation systems, and sanitation facilities to enhance water security.
- Promoted public participation and community-based water management initiatives.
- Collaborated with neighboring countries for transboundary basin management.

2.5.4.4 Key Success Factors

- Scientific research on climate change and water resources informs policy decisions, which are implemented through community-based practices.
- Empowering of local authorities and communities to manage water resources at the sub-basin level.
- Engaging local communities in decision-making processes to ensure inclusive and sustainable water management.
- Continuous monitoring and evaluation of water management strategies to address emerging challenges.
- Promoting economic growth while integrating environmental protection and sustainable water use.
- Strengthening institutional and technical capacities for effective water resource management.
- Leveraging partnerships with global organizations to access funding, technology, and expertise.

2.5.5 Rhine River Basin

The Rhine River, spanning 1,320 km with 880 km navigable, is one of Europe's most vital waterways. Originating in Switzerland, it flows through France, Germany, and the Netherlands before emptying into the North Sea. Its catchment area also includes parts of Italy, Belgium, Luxembourg, and Austria. The Rhine serves as a critical trade route,

supports industries, generates hydroelectric power, and sustains diverse ecosystems. However, its transboundary nature and multiple uses have led to conflicts and challenges, necessitating robust governance and integrated management approaches. The Science Policy Practice Interface (SPPI) has played a pivotal role in addressing these issues, making the Rhine River a success story in transboundary water management.

2.5.5.1 The Governance Structure

- International Commission for the Protection of the Rhine (ICPR) was established in 1950, it coordinates protection and management among Switzerland, France, Germany, Luxembourg, and the Netherlands.
- The Water Framework Directive (WFD) by European Union and Floods Directive provide regulatory frameworks for water management and flood risk reduction.
- Regional and National Agencies collaborate on flood forecasting, early warning systems, and floodplain management.
- Local and Regional Authorities implement policies and manage water resources at a localized level.

2.5.5.2 Issues of Rhine River Basin

- Water Pollution increased due to industrial discharge and agricultural runoff degrade water quality, harming ecosystems and human health.
- Flood Management Conflicts raised because of Urban development in flood-prone areas exacerbates flood risks, requiring careful planning.
- The balance between habitat protection with shipping, agriculture, and tourism was challenging.
- Difference in national policies and priorities complicate integrated management of transboundary water.
- Climate Change impacts in the form of altered precipitation patterns and extreme weather events intensify flooding and water scarcity.

2.5.5.3 Solutions to Address the Problems

- Integrated Water Resources Management (IWRM) approach was adopted to balance water quality, flood control, and ecosystem health.
- EU directives like the Nitrates Directive and Urban Waste Water Treatment Directive were implemented to counter water pollution.
- Enhanced Transboundary Cooperation and Strengthening collaboration through organizations within and with the countries.
- Stakeholders were engaged through consultations, educational programs, and volunteer activities.
- Developed scenario planning and informed decision-making to address climate change impacts.
- Utilizing diplomacy, mediation, arbitration, and legal frameworks to resolve disputes.

2.5.5.4 Key to Success Factors

- Scientific research strengthens policy decisions, which are effectively implemented through stakeholder collaboration.
- Transboundary governance structures like the ICPR ensure cohesive management across countries.
- Active participation of local communities and stakeholders enhances acceptance and effectiveness of water management strategies.
- Continuous monitoring and enforcement ensure resilience to climate change and evolving challenges.
- Policies promote industrial growth while integrating pollution control and conservation technologies.
- Scenario planning and evidence-based decision-making support sustainable management practices to counter the adverse impacts of climate change.

2.6 Comparative Analysis of Case Studies with National and Provincial Policies

The comparative analysis examines key aspects of water management policies and practices, focusing on integration of scientific research, policy coherence, implementation frameworks, stakeholder engagement, resource allocation, and monitoring and evaluation. The comparison of water related policies, such as the National Water Policy (2018) and various provincial acts, with successful international case studies from the Murray-Darling Basin in Australia, the Colorado River Basin in the United States, and the Chesapeake Bay Restoration and other case studies, aims to uncover critical gaps and challenges in Pakistan's approach. The insights gained from these case studies highlight effective strategies and best practices that can provide valuable guidance for enhancing Pakistan's water management policies and practices, ultimately aiming to improve their efficacy and sustainability. The comparative analysis was done on different aspect of policies and case studies and is presented in table below;

Table 1: Comparative Analysis of National and Provincial Policies with Case Studies

Aspect	**Pakistan's Policies/Acts**	**International Case Studies**	**Comparative Insights**
Integrated Water Resources Management (IWRM)	Emphasized in the National Water Policy 2018 and IWRM Guidelines for Pakistan, focusing on river basin management and stakeholder participation.	Murray-Darling Basin (Australia) and Colorado River Basin (USA/Mexico) use basin-level management with clear legal frameworks.	Pakistan's IWRM lacks enforcement mechanisms and financial resources compared to well-funded international examples.

Aspect	Pakistan's Policies/Acts	International Case Studies	Comparative Insights
Science-Policy Integration	Policies integrate scientific research but lack effective mechanisms for implementation and feedback loops.	Chesapeake Bay (USA) uses scientific monitoring to inform policy adjustments and adaptive management.	International cases show stronger science-policy linkages with real-time monitoring and adaptive frameworks.
Institutional Framework	Fragmented between federal and provincial levels with limited technical capacity (e.g., Punjab Water Act 2019).	Murray-Darling Basin Authority and Colorado River Compact provide centralized governance with clear roles and responsibilities.	A unified institutional approach is needed in Pakistan to avoid overlap and improve coordination.
Stakeholder Engagement	Emphasized but weakly implemented; limited local community involvement (e.g., Sindh Water Policy 2023).	Chesapeake Bay restoration involves diverse stakeholders, including NGOs, local governments, and communities.	Pakistan requires stronger local stakeholder participation and transparent decision-making processes.
Financial Mechanisms	Financial constraints are a significant challenge; reliance on international funding (e.g., National Water Policy 2018).	Murray-Darling Basin has robust funding through federal allocations and water markets; Colorado River uses state and federal funding mechanisms.	Pakistan's policies need dedicated funding sources and financial sustainability plans.
Climate Change Adaptation	Integrated into NCCP 2021 and provincial policies with a focus on water management and agriculture.	Madagascar's IWRM strategy integrates climate resilience with water management using Japanese models.	Pakistan's policies align well but lack implementation capacity and effective monitoring.
Legal and Regulatory Framework	Existing regulations are outdated and lack strict enforcement (e.g., Balochistan Groundwater Ordinance 1978).	Colorado River Basin has a strong legal framework with binding agreements and compliance mechanisms.	Pakistan needs to update legal frameworks with enforceable provisions and compliance mechanisms.

Aspect	Pakistan's Policies/Acts	International Case Studies	Comparative Insights
Monitoring and Evaluation (M&E)	Limited M&E mechanisms across policies; lack of real-time data sharing and centralized databases.	Chesapeake Bay uses continuous monitoring and adaptive management practices based on scientific data.	Strengthening M&E systems with real-time data integration is essential for Pakistan's water policies.
Public Awareness and Capacity Building	Highlighted in policies but weakly implemented (e.g., Punjab Water Policy 2018 focuses on education).	Chesapeake Bay restoration includes public education campaigns and community-based management.	Pakistan needs to enhance public awareness and invest in capacity-building initiatives at grassroots levels.
Water-Energy-Food Nexus	Addressed in the National Water Policy 2018 but lacks actionable strategies and cross-sectoral coordination.	Murray-Darling Basin's water management incorporates agriculture and energy considerations through integrated planning.	Pakistan requires a more integrated approach linking water, energy, and food policies effectively.

3 Stakeholders Consultation and Strengthening the Science Policy Practice Interface (SPPI) in Pakistan

The Science Policy Practice Interface (SPPI) is a critical mechanism that connects scientific research with policy-making and practical implementation. Globally, several platforms exemplify how science, policy, and practice converge for solving complex issues. The major examples include Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES) which facilitates the provision of scientific knowledge to policymakers to promote sustainable biodiversity management. It functions as an interface between the scientific community and policy sectors. The other notable example is Intergovernmental Panel on Climate Change (IPCC), it serves as the foremost global body for assessing climate science and translating it into actionable policies for governments worldwide. Its success lies in its structured approach, where scientific findings are synthesized and then presented to inform global climate policies. Both IPBES and IPCC demonstrate that robust interfaces between science, policy, and practice are vital for tackling global environmental and water challenges.

The aspect of SPPI has been examined in the available policy instruments at national and provincial level. After the detailed review the key issues identified were lack of policy integration as Pakistan has a rich body of scientific research, the findings often do not influence policy decisions effectively. This leads to a mismatch between the realities on the ground. The lack of policy coherence was other gap identified as Pakistan has developed several water-related policies, including the National Water Policy (2018) and National Climate Change Policy 2012 and revised NCCP 2021. However, these policies often lack coherence and are implemented in silos, leading to fragmented water resource management. Unlike global examples such as IPCC, there are no permanent platforms in Pakistan where scientists, policymakers, and practitioners can regularly engage. This results in disjointed efforts that lack coordination and often do not reflect the latest scientific knowledge.

Based on the identified gaps, the research questions were developed to guide stakeholder consultations held in Islamabad and Pakistan's provincial headquarters i.e., Lahore, Peshawar, Karachi, and Quetta. These consultations provided a platform for diverse voices to highlight challenges and propose solutions for integrating science-based approaches into water resource management practices, in synchronization of policies.

3.1 Findings of the Consultations

The consultations conducted across Pakistan’s four provinces and Islamabad revealed several critical insights into the challenges and opportunities for improving water security through the Science Policy Practice Interface (SPPI). The discussions highlighted the need for better coordination, evidence-based decision-making, and coherent policy frameworks to address Pakistan’s growing water challenges. The stakeholders emphasized that scientific research must be aligned with pressing societal and policy challenges to ensure its relevance and impact. The research should focus on real-world problems such as water scarcity, climate change, food security, and urbanization. However, the lack of coordination among scientists, policymakers, and practitioners often leads to fragmented research efforts. The financial constraints and limited research

facilities further hinder progress. To address these issues, research should be guided by national priorities, involve local stakeholders, and be problem-driven rather than theoretical. The strong collaboration between academia, industry, and think tanks is essential to ensure that research is both policy-relevant and practically implementable.

A recurring theme across the consultations was the lack of effective communication and collaboration among scientists, policymakers, and practitioners. While workshops and seminars provide some opportunities for engagement, there is no formal, sustained platform for regular interaction. This gap limits the impact of research and hinders the integration of scientific evidence into policy-making. The stakeholders recommended the establishment of structured platforms, such as steering committees or national-level water sector platforms, to facilitate continuous dialogue and data-sharing among all stakeholders. The enhanced collaboration would ensure that research findings are effectively translated into actionable policies and practices.

The consultations revealed that decision-making in the water sector is often not based on robust scientific evidence. The policies are rarely revisited or updated to reflect new research findings, leading to outdated and ineffective strategies. The realistic data availability and reliability are major concerns, with many decisions being made on adhoc basis or influenced by political considerations rather than technical evidence. To improve this, stakeholders suggested regular policy reviews, the establishment of comprehensive databases, and the use of emerging technologies like artificial intelligence to support evidence-based decision-making. These policies should be revisited every 5-10 years to incorporate new scientific evidence and address emerging challenges.

The implementation of Integrated Water Resources Management (IWRM) at the basin level in Pakistan is largely absent. The provinces manage water resources independently, with little coordination at the national level. This lack of a unified "one-basin" approach hampers effective water management, particularly for shared resources like groundwater. The need for a cohesive national framework was highlighted that integrates surface and groundwater management and addresses issues such as salinity, over-pumping, and transboundary water conflicts. The strengthening of institutions like the Indus River System Authority (IRSA) and the Ministry of Water Resources (MoWR) is crucial for improving basin-level coordination and governance.

There is a significant lack of coherence between national and provincial water policies in Pakistan. The national policies are often developed without fully considering regional challenges, leading to misalignment and inefficiencies in water management. Each province has its own priorities, which further complicates coordination. The stakeholders recommended better alignment between federal and provincial policies, with a focus on tailoring policies to local conditions. A more inclusive, bottom-up approach to policy development, involving local stakeholders and communities, would help address regional needs and improve policy coherence. Water is not effectively managed as a shared resource across different sectors such as agriculture, industry, and domestic use. The existing policies often operate in silos, leading to conflicts and inefficiencies in water allocation. The stakeholders emphasized the need for integrated policies that balance the competing demands of different sectors and promote equitable distribution. The transparent water allocations and better coordination among sectors are essential to ensure sustainable water management.

The successful implementation of water policies is hindered by several factors, including resource constraints, weak legal frameworks, and poor coordination among stakeholders. Political instability, cultural resistance, and insufficient research-based policies further obstruct progress. The stakeholders identified the need for capacity-building, stronger enforcement mechanisms, and better stakeholder engagement to address these gaps. The key recommendations from the participants were the establishment of formal platforms for regular interaction among scientists, policymakers, and practitioners to ensure continuous dialogue and data-sharing. They also stressed on the regularly updating the policies based on new scientific evidence and establish comprehensive databases to support informed decision-making. It was also suggested to develop a cohesive national framework for IWRM that integrates surface and groundwater management and promotes coordination across provinces. The Improved alignment between national and provincial policies by adopting a more inclusive, bottom-up approach that addresses regional needs can ensure the water security. There is a dire need to invest in capacity-building initiatives to strengthen institutions and improve the technical and managerial skills of stakeholders and increase public awareness and engagement to promote sustainable water management practices and reduce cultural resistance to policy changes.

The consultations highlighted the urgent need for a structured and collaborative approach to address Pakistan's water security challenges. The alignment of research with policy priorities, improving communication and collaboration among stakeholders, and ensuring evidence-based decision-making, Pakistan can develop more effective and sustainable solutions for water management. The recommendations from these consultations provide a roadmap for bridging the gaps between science, policy, and practice, ultimately leading to better water security for the country.

Findings of the Consultations on SPPI for Water Security in Pakistan

Characteristic	Scientists	Policymakers	Practitioners
Coordination	Fragmented efforts	Lack of national-level coordination	Poor stakeholder engagement
Communication	Lack of sustained platforms	Policies rarely revisited	Siloed sectoral policies
Decision-Making	Research not policy-driven	Ad-hoc decisions	Resource constraints
Policy Frameworks	Theoretical research	Lack of policy coherence	Political instability

Figure 7: Overall Findings of Consultations

3.2 Strengthening the Science Policy Practice Interface (SPPI) in Pakistan

To strengthen the Science Policy Practice Interface (SPPI) in Pakistan, it is essential to address the identified gaps and challenges through a comprehensive and integrated approach. Firstly, there is a need to shift from sectoral and top-down approaches to more holistic and collaborative frameworks. The policies should be designed to reflect the interconnected nature of water, food security, and climate change, ensuring that national objectives align with provincial implementations. This requires fostering collaboration between academia, industry, and policymakers to create localized, problem-driven research that addresses real-world issues such as water availability, quality, and climate change impacts. The creation of formal platforms for regular meetings and data-sharing can facilitate this collaboration, ensuring that research is relevant and actionable.

Secondly, the enhancement of legal implementation support is crucial. The policies must be backed by strong technical expertise and enforceable mechanisms to ensure that scientific recommendations and policy directions are effectively translated into practice. This includes creating clear channels for legal actions against violations, such as water theft or damage to critical infrastructure like early warning systems. Additionally, financial constraints must be addressed by ensuring consistent and adequate funding for policy implementation. The development of dedicated climate funds and improving the mobilization and utilization of resources will enable smoother execution of climate and water-related initiatives.

The institutional mechanisms and coordination also need significant improvement. The policies should emphasize the involvement of scientists, researchers, and end-users in the decision-making process. The centralized databases for natural resources and sharing knowledge resources across sectors can enhance coordination and integrated application of policies. Strengthening institutional capacity and expertise will help avoid overlapping mandates and inefficiencies, ensuring that new institutions are well-equipped to fulfill their roles.

The stakeholder engagement and community awareness are vital for the successful implementation of SPPI. The policies must go beyond advocating for participatory decision-making and actively involve local communities and scientists. The comprehensive awareness programs and outreach initiatives, especially in rural and vulnerable areas, can educate and engage communities, fostering broader support for policy measures. This will help mitigate resistance and ensure that policies are more inclusive and effective.

Finally, robust monitoring and evaluation systems are essential to track the progress of policy implementation and adapt strategies based on real-world feedback. The transparent and accountable mechanisms will help bridge the gap between policy objectives and actual outcomes, enabling continuous improvement.

3.3 Key Principles for SPPI

3.3.1 Evidence-Based Decision-Making

Evidence-based decision-making is a foundational principle of the Science Policy Practice Interface (SPPI). It emphasizes the use of robust scientific research and data to inform policy development and practical implementation. This principle ensures that policies are grounded in credible evidence, reducing the risk of ineffective or counterproductive interventions. According to Cairney (2016), evidence-based policymaking involves systematically integrating scientific knowledge with political and practical considerations to address complex societal challenges. This approach requires transparent communication of research findings, accessible data-sharing platforms, and mechanisms to translate scientific insights into actionable policy recommendations. For example, in water resource management, evidence-based decision-making can involve using hydrological models and climate data to design policies that address water scarcity and flood risks. By prioritizing evidence, policymakers can enhance the legitimacy, effectiveness, and sustainability of their decisions.

3.3.2 Stakeholder Inclusivity and Participatory Governance

Stakeholder inclusivity and participatory governance are central to the SPPI framework, ensuring that diverse voices are heard and considered in decision-making processes. This principle recognizes that sustainable solutions require the active involvement of all relevant stakeholders, including scientists, policymakers, practitioners, local communities, and marginalized groups. Reed et al. (2014) highlighted those participatory approaches foster trust, shared understanding, and collective ownership of policies, leading to more equitable and socially just outcomes. In practice, this can involve creating platforms for stakeholder engagement, such as community consultations, workshops, and collaborative planning sessions. For instance, in climate adaptation projects, involving local communities in the design and implementation of policies ensures that interventions are culturally appropriate and address local needs. By promoting inclusivity, SPPI enhances the legitimacy and effectiveness of policies while empowering communities to take an active role in shaping their future.

3.3.3 Adaptive Management and Resilience-Building

Adaptive management and resilience-building are critical principles of SPPI, particularly in the context of dynamic and uncertain environments such as those affected by climate change. Adaptive management involves a flexible, iterative approach to policymaking, where strategies are continuously monitored, evaluated, and adjusted based on new information and changing conditions. Williams (2011) describes adaptive management as a process that embraces uncertainty and uses feedback loops to improve decision-making over time. This principle is especially relevant for addressing complex challenges like water scarcity, where climate variability and population growth create unpredictable conditions. on the other hand, resilience-building focuses on enhancing the capacity of systems and communities to withstand and recover from shocks and stresses. For example, integrating climate-resilient infrastructure and ecosystem-based approaches into water management policies can help communities adapt to extreme weather events.

By prioritizing adaptability and resilience, SPPI ensures that policies remain effective and sustainable in the face of uncertainty.

3.3.4 Bridging the Science-Policy Gap

3.3.4.1 Establishment of Knowledge Exchange Platforms

The establishment of knowledge exchange platforms is a critical strategy for bridging the science-policy gap within the Science Policy Practice Interface (SPPI). These platforms serve as intermediaries that facilitate the flow of information between scientists, policymakers, and practitioners, ensuring that scientific knowledge is accessible and actionable for decision-makers. According to van Kerkhoff and Lebel (2006), knowledge exchange platforms can take various forms, such as workshops, conferences, online portals, and collaborative networks. These platforms enable stakeholders to share data, discuss research findings, and co-develop solutions to complex problems. For example, in water resource management, knowledge exchange platforms can bring together hydrologists, policymakers, and local communities to address issues like water scarcity and pollution. By fostering dialogue and collaboration, these platforms enhance the relevance and applicability of scientific research, ensuring that it informs policy development and practical implementation.

3.3.4.2 Strengthening Research Translation into Policy Actions

Strengthening the translation of research into policy actions is essential for ensuring that scientific knowledge leads to tangible outcomes. This principle involves creating mechanisms that bridge the gap between scientific findings and their application in policy and practice. Cash et al. (2003) emphasize the importance of research organizations and intermediaries that can translate complex scientific information into formats that are understandable and useful for policymakers. This process includes synthesizing research findings, developing policy briefs, and providing evidence-based recommendations. For instance, in climate change adaptation, translating climate models and vulnerability assessments into actionable policies can help communities prepare for extreme weather events. Strengthening research translation also requires building the capacity of policymakers to interpret and use scientific evidence effectively. By enhancing the connection between research and policy, SPPI ensures that scientific knowledge drives informed and effective decision-making.

3.3.5 Enhancing Science-Practice Integration

3.3.5.1 Capacity Building for Practitioners on Scientific Tools and Approaches

Capacity building for practitioners is a vital component of enhancing the integration of science into practice within the Science Policy Practice Interface (SPPI). This principle focuses on equipping practitioners with the knowledge and skills needed to effectively use scientific tools and approaches in their work. According to Fazey et al. (2018), capacity building involves training programs, workshops, and educational initiatives that enable practitioners to understand and apply scientific methods, data, and technologies. For example, in water resource management, practitioners can be trained to use hydrological models, geographic information systems (GIS), and remote sensing tools to

monitor water quality and availability. The enhancement of technical capabilities of practitioners, capacity building ensures that scientific insights are effectively translated into practical solutions. This approach not only improves the quality of implementation but also fosters a culture of evidence-based practice, where decisions are informed by robust scientific knowledge.

3.3.5.2 Technology Transfer for Improved Water Management

Technology transfer is another key principle for enhancing science-practice integration, particularly in the context of water management. This principle involves the dissemination and adoption of innovative technologies that can improve the efficiency, sustainability, and resilience of water systems. As highlighted by Rogers (2003), technology transfer requires effective communication channels, demonstration projects, and partnerships between researchers, industry, and practitioners. For instance, the adoption of advanced irrigation technologies, such as drip irrigation and soil moisture sensors, can significantly enhance water use efficiency in agriculture. Similarly, the implementation of real-time water quality monitoring systems can help detect and address pollution issues promptly. Technology transfer also involves adapting technologies to local contexts and ensuring that practitioners are trained to use them effectively. The adoption of cutting-edge technologies, SPPI enhances the capacity of water management systems to address current and future challenges.

4 Guidelines for SPPI in Pakistan for Achieving Water Security

4.1 Institutional Framework for Water Governance in Pakistan

The institutional framework for water governance in Pakistan involves a range of key government agencies and regulatory bodies at both federal and provincial levels, each institution plays a crucial role in managing water resources sustainably. The federal and provincial departments in Pakistan play distinct but complementary roles in water governance, ensuring both national-level policy direction and effective local-level implementation. This multi-tiered approach is essential for managing the country's water resources sustainably, given its diverse geographic and administrative challenges. With the devolution of water management responsibilities under the 18th Amendment to the Constitution of Pakistan, provincial departments have a crucial role in implementing water policies, managing local resources, and addressing regional challenges.

To sum up, the federal departments provide the strategic vision, funding, and regulatory frameworks necessary for managing Pakistan's water resources, while the provincial departments are responsible for local implementation, operational management, and ensuring that national policies are adapted to regional contexts. The effective coordination between these levels is crucial for addressing Pakistan's complex water challenges, from managing water resources to ensuring equitable distribution and sustainable use at the local level. The details of the institutions/agencies along with their role has been presented in table below;

Table 2: Role of Organizations/Departments in Water Governance in Pakistan

Sr. No.	Institution	Role
1.	Ministry of Water Resources	It formulates national water policies, oversees inter-provincial coordination, and manages water resources at the federal level.
2.	Pakistan Council of Research in Water Resources (PCRWR)	It conducts research on water resources, quality, and management practices and provides evidence-based recommendations for policy-making.
3.	Water and Power Development Authority (WAPDA)	It develops and manages water storage infrastructures, hydropower infrastructure, and flood control projects.
4.	Indus River System Authority (IRSA)	It regulates inter-provincial water distribution in the Indus Basin as per water apportionment accord 1991 and resolves disputes over water allocation among the provinces.
5.	Federal Flood Commission (FFC)	It plans and coordinates flood control measures and develops national flood protection plans.

Sr. No.	Institution	Role
6.	Ministry of Climate Change	It is responsible to integrates climate resilience into water management policies; addresses climate impacts on water resources.
7.	National Disaster Management Authority (NDMA)	It coordinates disaster response related to floods and water-related emergencies. It also implements risk reduction strategies.
8.	Ministry of National Food Security and Research (MNFSR)	It develops policies for sustainable agriculture and water use. It also promotes climate-smart agriculture and efficient irrigation practices.
9.	Provincial Agriculture Departments	They manage irrigation for agriculture, promote water-efficient farming practices, and implement policies for sustainable water use.
10.	Provincial Irrigation Departments	They manage irrigation systems, water distribution for agriculture, and maintenance of canal infrastructure at the provincial level. They are responsible for managing both surface and groundwater resources at provincial level.
11.	Provincial Public Health Engineering Departments	They Ensures access to clean drinking water and sanitation services in rural and urban areas of the provinces.
12.	Provincial Environment Protection Agencies (EPAs)	These authorities are responsible to regulate water quality standards, monitors industrial discharge, and enforces environmental compliance.
13.	Water and Sanitation Agencies (WASAs) and TMAs	They manage urban water supply, wastewater treatment, and stormwater drainage in major metropolitan cities.
14.	Provincial Planning and Development Departments	These departments coordinate water-related projects, secure funding, and ensure alignment with national policies.

4.2 SWOT Analysis of Exiting Setup

Pakistan's water governance institutions possess significant strengths, including a comprehensive institutional framework and expertise in various aspects of water management. However, addressing weaknesses such as coordination challenges, funding constraints, and implementation gaps is essential. By leveraging opportunities for international cooperation, public-private partnerships, and policy reforms, Pakistan can improve its water management practices. Simultaneously, mitigating threats related to climate change, water conflicts, and resource depletion will be crucial for ensuring sustainable water governance in the country.

4.2.1 Strengths

Pakistan's water governance framework benefits from a comprehensive institutional setup that covers a wide range of functions from policy-making and research to disaster management and urban water supply. The presence of specialized institutions like the Ministry of Water Resources, WAPDA, IRSA, and PCRWR allows for a focused approach to managing the country's water resources. For instance, the Ministry of Water Resources plays a crucial role in formulating national water policies, while WAPDA's expertise in water storage and hydropower infrastructure strengthens Pakistan's capacity to manage its water resources effectively. Additionally, IRSA's mandate to regulate inter-provincial water distribution ensures a structured mechanism to address water-sharing conflicts among provinces.

Moreover, the integration of climate resilience into water policies by the Ministry of Climate Change is a significant strength, aligning national efforts with global sustainability standards. The institutions like the National Disaster Management Authority (NDMA) and the Federal Flood Commission (FFC) enhance Pakistan's ability to respond to water-related disasters through well-coordinated disaster management strategies. In urban areas, Water and Sanitation Agencies (WASAs) are instrumental in managing water supply and wastewater treatment, providing a targeted approach to urban water governance. The expertise of Provincial Irrigation Departments in managing extensive irrigation networks also underscores the institutional strength in addressing water needs for agriculture, which consumes the majority of Pakistan's water resources.

4.2.2 Weaknesses

Despite a well-defined institutional framework, water governance in Pakistan suffers from significant coordination challenges among federal, provincial, and local agencies. The overlapping of responsibilities and bureaucratic approach often hinder effective implementation of water policies. For instance, the roles of the Ministry of Water Resources, IRSA, and Provincial Irrigation Departments frequently intersect, causing delays and inefficiencies in decision-making. The financial constraints further aggravate these challenges, particularly for provincial institutions, limiting their ability to maintain and upgrade critical water infrastructure.

A major weakness is the gap between policy formulation and implementation. While the Ministry of Water Resources has developed comprehensive policies, their execution at the ground level remains inadequate due to limited technical capacity and resources. Similarly, the research insights provided by PCRWR are not always effectively integrated into policy-making or utilized by other institutions. Provincial Environment Protection Agencies (EPAs) also face significant challenges in enforcing water quality standards due to limited authority and resources, leading to unchecked industrial discharge and water pollution. In the agriculture sector, traditional farming practices and a lack of awareness impede the adoption of efficient irrigation methods promoted by the Provincial Agriculture Departments.

4.2.3 Opportunities

There are substantial opportunities for enhancing water governance in Pakistan through international cooperation, technology adoption, and institutional reforms. The

international funding and expertise can play a pivotal role in financing large-scale water infrastructure projects and climate adaptation initiatives. The strong partnerships with international organizations could also facilitate access to advanced water management technologies such as GIS, remote sensing, and IoT, enabling better monitoring and efficient distribution of water resources.

Public-Private Partnerships (PPPs) present a viable opportunity to bridge the resource gap, particularly in urban water supply and wastewater management. The use of private sector expertise could enhance service delivery by WASAs and other local bodies. Additionally, the growing awareness of climate change impacts offers a platform for expanding climate-smart water management practices in collaboration with the Ministry of Climate Change. The effective community participation in water management can also improve conservation practices at the local level, particularly in rural areas.

Legal and policy reforms offer another significant opportunity. Revisiting outdated water laws and enhancing the enforcement capabilities of regulatory bodies like the EPAs can improve compliance with water quality standards. The Provincial Planning and Development Departments can play a crucial role by securing funding for water-related projects and ensuring alignment with national water policies. The improved coordination mechanisms among water-related institutions could address existing gaps and make governance more effective.

4.2.4 Threats

The most pressing threat to Pakistan's water governance is climate change, which is causing an increase in the frequency and intensity of floods, droughts, and glacial melt. These changes pose severe risks to both the availability and quality of water resources. The Indus River System, which supports most of Pakistan's agriculture, is particularly vulnerable to shifts in glacial melt patterns and rainfall variability. Moreover, inter-provincial water conflicts over the allocation of Indus waters, especially between Punjab and Sindh, could escalate if not managed effectively by IRSA and other federal bodies.

The rapid population growth and urbanization are further straining water resources and the capacities of institutions like WASAs and Provincial Public Health Engineering Departments. As cities expand, ensuring access to clean drinking water and adequate sanitation becomes increasingly challenging. The depletion of groundwater resources due to over-extraction, particularly in Punjab and Sindh, represents another significant threat. The lack of effective regulation and monitoring of groundwater use further complicate this issue.

The institutional instability can also undermine long-term water management efforts. Frequent changes in leadership and shifting priorities at both the federal and provincial levels disrupt the continuity of water policies and projects. Additionally, the limited enforcement capacity of Provincial EPAs to regulate industrial pollution poses a severe threat to both surface and groundwater quality, making it imperative to strengthen regulatory frameworks and compliance mechanisms.

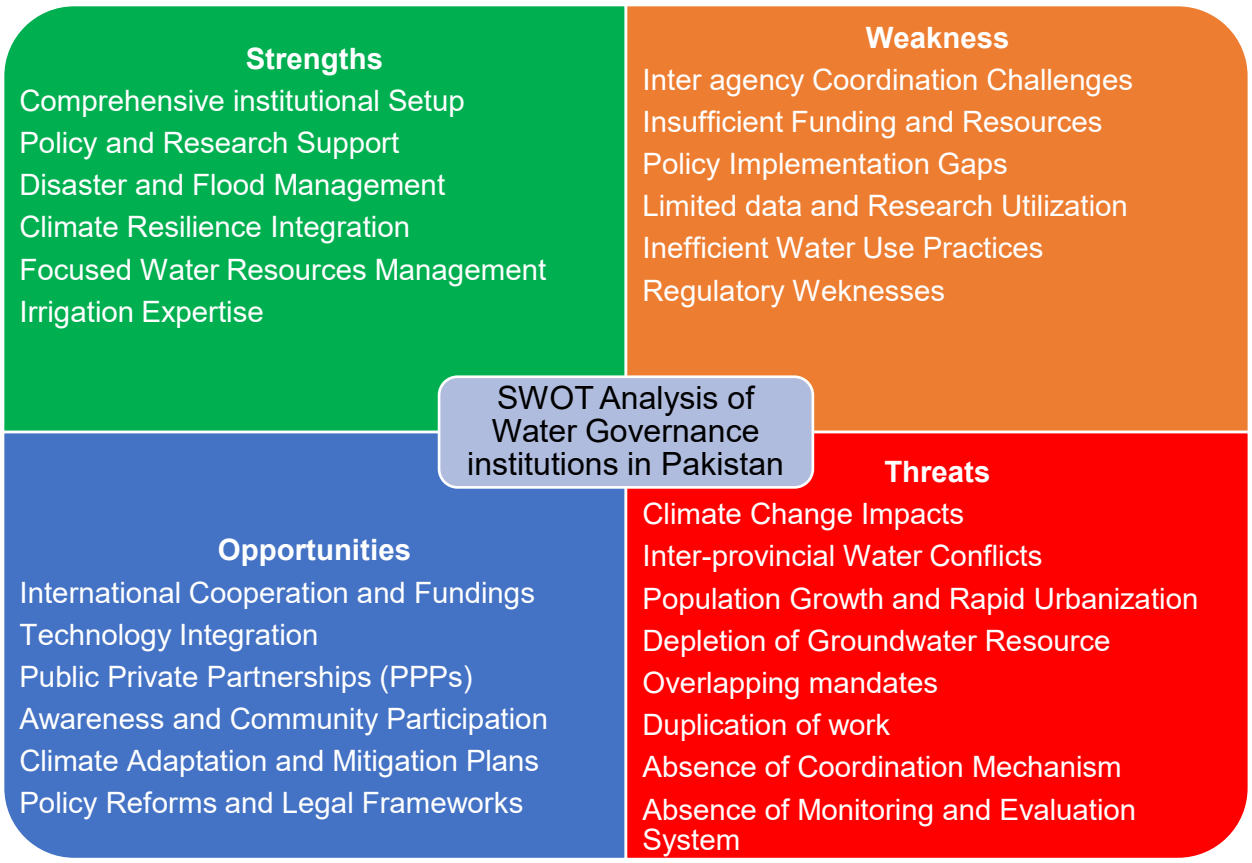

Figure 8: SWOT Analysis of Water Governing Institutions of Pakistan

4.3 Suggesting Role as per Feedback from Stakeholders

The consultations on the Science Policy Practice Interface (SPPI) for water security in Pakistan have highlighted the need for significant modifications in the roles of various institutions to address challenges such as fragmented policies, lack of coordination, and insufficient data-driven decision-making. These changes aim to create a more integrated, resilient, and efficient water governance framework capable of responding to the growing pressures of climate change and increasing water demand.

The **Ministry of Water Resources** should expand its role beyond formulating national policies to actively coordinate with provincial bodies, ensuring policy coherence and alignment across all levels of governance. By facilitating platforms for continuous dialogue and data sharing between federal and provincial institutions, the Ministry can ensure that decisions are informed by real time data and research outcomes. This approach will enhance the integration of national and provincial water management strategies, fostering a unified approach to water governance.

The **Pakistan Council of Research in Water Resources (PCRWR)** needs to shift its focus towards localized, problem-driven research that addresses critical issues such as water availability, quality, and climate impacts. The robust collaborations with academia, industry, and policymakers, can ensure that research outcomes are translated into

actionable policies. The establishment of data sharing platforms will further enhance the relevance and applicability of scientific research in addressing real world water challenges.

The **Water and Power Development Authority (WAPDA)** should incorporate data analytics into its water storage and hydropower management practices. This shift will enable WAPDA to optimize resource utilization and better address the impacts of climate change. The adoption of climate resilient infrastructure strategies, WAPDA can enhance its capacity to manage water resources sustainably and efficiently.

The **Indus River System Authority (IRSA)** must adopt Integrated Water Resources Management (IWRM) principles to manage water distribution across provinces comprehensively. Enhancing IRSA's role with real-time data-sharing capabilities will improve transparency and efficiency in water allocation, helping to resolve inter-provincial disputes more effectively. This approach will ensure equitable access to water resources and promote basin-level planning.

The **Federal Flood Commission (FFC)** should update its flood management strategies to integrate climate projections, ensuring resilience against extreme weather events. The strong collaboration with the **Ministry of Climate Change** will enable the FFC to develop more accurate and proactive flood control measures. The Ministry of Climate Change, in turn, needs to expand its mandate to ensure that climate resilience is integrated into all levels of water management policies, coordinating closely with both national and provincial institutions to address climate-induced water challenges.

The **National Disaster Management Authority (NDMA)** should enhance its role by building institutional capacity at provincial levels for disaster preparedness, particularly concerning floods and water-related emergencies. The enhancement of technical training and resource allocation for provincial bodies will ensure more effective implementation of risk reduction strategies. Similarly, the **Ministry of National Food Security and Research (MNFSR)** must align its policies with national water management strategies, promoting climate-smart agriculture and efficient irrigation practices that consider water scarcity and sustainability.

The provincial institutions also need to adapt their roles to address emerging challenges. **Provincial Agriculture Departments** should shift from isolated management of irrigation practices to a collaborative approach that reflects basin level planning. With the enhancement of their role to coordinate with IRSA and WAPDA can improve water use efficiency and reduce inter provincial conflicts. **Provincial Irrigation Departments** should focus on integrating both surface and groundwater management with comprehensive data driven approaches, strengthening their capabilities for real time water distribution monitoring.

Provincial Public Health Engineering Departments should expand their focus to include climate-resilient water infrastructure, ensuring sustainable access to clean drinking water amid increasing climate variability. **Provincial Environment Protection Agencies (EPAs)** must align their regulatory frameworks with national standards, emphasizing the enforcement of water quality compliance and management of industrial discharges more effectively.

Water and Sanitation Agencies (WASAs) should enhance urban water supply management by adopting smart metering and data analytics to minimize water losses and ensure equitable distribution. The expansion of their infrastructure to include climate resilient technologies will help in addressing urban water challenges more effectively. Lastly, **Provincial Planning and Development Departments** must prioritize securing sustainable funding for water projects, focusing on climate-resilient infrastructure and ensuring alignment with both national priorities and IWRM principles.

The following table summarizes the previous roles of these institutions and the proposed modifications based on the SPPI consultations;

Table 3: Modified Roles of the Organization/Departments for Effective Water Governance in Pakistan

Sr. No.	Institution	Previous Role	Modified Role
1	Ministry of Water Resources	Formulates national policies, oversees inter-provincial coordination.	Enhance data-sharing, facilitate dialogue between federal and provincial bodies, ensures policy coherence.
2	PCRWR	Conducts research on water resources and management.	Focus on localized, problem-driven research, enhance collaboration with academia, industry, and policymakers.
3	WAPDA	Manages water storage, hydropower, and flood control projects.	Integrate data analytics for resource optimization, adopt climate-resilient infrastructure strategies.
4	IRSA	Regulates inter-provincial water distribution in the Indus Basin.	Adopt IWRM principles, enhance real-time data sharing for transparent water allocation.
5	Federal Flood Commission (FFC)	Plans and coordinates flood control measures.	Integrate climate projections into flood management strategies, collaborate with the Ministry of Climate Change.
6	Ministry of Climate Change	Integrates climate resilience into water management policies.	Expand role to coordinate climate-resilient strategies across institutions, address emerging climate-induced water challenges.
7	NDMA	Coordinates disaster response for floods and water emergencies.	Build institutional capacity at provincial levels, enhance technical training and resource allocation.
8	MNFSR	Develops policies for sustainable agriculture and water use.	Align agricultural policies with national water strategies, promote climate-smart agriculture and efficient irrigation.

Sr. No.	Institution	Previous Role	Modified Role
9	Provincial Agriculture Departments	Manage irrigation and promote water-efficient farming.	Adopt collaborative approach with IRSA and WAPDA, focus on basin-level water management.
10	Provincial Irrigation Departments	Manage irrigation systems and water distribution.	Integrate surface and groundwater management with data-driven approaches, enhance real-time monitoring.
11	Provincial Public Health Engineering Departments	Ensure access to clean drinking water and sanitation.	Focus on climate-resilient water infrastructure to address variability and sustainability.
12	Provincial Environment Protection Agencies (EPAs)	Regulate water quality standards and enforce compliance.	Align regulatory frameworks with national standards, strengthen enforcement of water quality compliance.
13	WASAs	Manage urban water supply and wastewater treatment.	Adopt smart metering, expands climate-resilient urban water infrastructure, minimize water losses.
14	Provincial Planning and Development Departments	Coordinate water-related projects and secure funding.	Focus on sustainable funding for climate-resilient projects, ensure alignment with national policies and IWRM principles.

4.4 Key Actions to Improve Existing Setup for Effective SPPI

To enhance Pakistan's water governance framework in line with the revised institutional roles, a comprehensive and strategic approach is essential. This approach must focus on improving coordination, leveraging data-driven decision-making, building institutional capacity, and fostering innovation to address the multifaceted challenges of water security.

4.4.1 Establish a Centralized Water Data Platform

A unified and centralized water data platform is critical for effective water governance. This platform should integrate real time data on water availability, quality, and usage from institutions such as the Pakistan Council of Research in Water Resources (PCRWR), Water and Power Development Authority (WAPDA), Indus River System Authority (IRSA), and provincial bodies. By consolidating data, the platform will enable evidence-based decision making, improve transparency in water allocation, and provide a reliable foundation for policy formulation. The platform should also incorporate advanced technologies such as Geographic Information Systems (GIS) and remote sensing to enhance data accuracy and accessibility.

4.4.2 Strengthen Inter-Institutional Coordination

To address the fragmentation in water governance, a National Water Coordination Council should be established under the leadership of the Ministry of Water Resources. This council would include representatives from federal and provincial institutions, ensuring harmonized policies and coordinated implementation of Integrated Water Resources Management (IWRM) principles. The National Water Coordination Council (NWCC) can play a pivotal role in establishing and strengthening the Science-Policy-Practice Interface (SPPI) in Pakistan by acting as a central hub for inter-institutional coordination and collaboration, by bringing together policymakers, researchers, practitioners, and stakeholders from various sectors, NWCC can ensure that water governance is evidence based, inclusive, and adaptive to the country's evolving challenges. This centralized repository would not only enhance data accessibility and reliability but also support informed decision-making, enabling more effective water resource management and policy formulation.

4.4.3 Adopt Integrated Water Resources Management (IWRM)

IRSA should take the lead in adopting IWRM practices, which emphasize the holistic management of water resources. This includes integrating surface and groundwater management, considering basin-level planning, and balancing the water needs of agriculture, industry, and domestic users. By coordinating with provincial irrigation and agriculture departments, IRSA can ensure equitable water distribution and sustainable resource utilization. IWRM will also help mitigate inter-provincial conflicts and promote long-term water security.

Integrated Water Resources Management (IWRM) can also transform water governance in Pakistan by strengthening the Science Policy Practice Interface (SPPI) and enhancing institutional capacity. By integrating scientific knowledge, policy development, and practical implementation, IWRM ensures evidence-based, inclusive, and sustainable decision-making. It bridges the gap between science, policy, and practice through knowledge exchange, pilot projects, and innovative solutions, facilitating collaboration among government agencies, research institutions, civil society, and local communities. With a focus on sustainability and resilience, IWRM addresses water scarcity, climate change, and disaster risks, making it a crucial tool for long-term water security and institutional strengthening in Pakistan.

4.4.4 Enhance Research and Innovation

PCRWR should expand its mandate to focus on localized, problem-driven research addressing critical issues such as salinity, waterlogging, and climate impacts. Collaborations with universities, research institutions, and international partners should be encouraged to introduce advanced water management technologies and innovative solutions. Research outcomes must be translated into actionable policies and practices, ensuring that scientific knowledge directly contributes to solving real-world water challenges.

4.4.5 Promote Climate-Resilient Infrastructure

WAPDA and the Federal Flood Commission (FFC) should prioritize the development of climate-resilient infrastructure, including water storage, hydropower, and flood control systems. Climate projections must be integrated into planning and management processes to enhance the resilience of water infrastructure against extreme weather events. This will involve upgrading existing facilities, investing in new technologies, and adopting adaptive management practices to address the uncertainties posed by climate change.

4.4.6 Strengthen Regulatory and Compliance Frameworks

Provincial Environment Protection Agencies (EPAs) must be empowered to enforce stringent water quality standards and monitor industrial discharges effectively. Clear guidelines and penalties for non-compliance should be established to safeguard water resources. Strengthening regulatory frameworks will ensure that industries adhere to environmental standards, reducing pollution and protecting aquatic ecosystems.

4.4.7 Align Agricultural Policies with Water Management

The Ministry of National Food Security and Research (MNFSR) and provincial agriculture departments should work together to promote efficient irrigation techniques, such as drip and sprinkler systems, and climate-smart agricultural practices. These measures will reduce water consumption, enhance agricultural productivity, and ensure sustainable water use. Aligning agricultural policies with national water management strategies is essential for addressing water scarcity and achieving food security.

4.4.8 Enhance Institutional Capacity and Training

Capacity-building programs should be implemented for provincial irrigation, agriculture, and public health engineering departments. These programs should focus on technical training, modern water management practices, and the use of data analytics for efficient water distribution. Strengthening institutional capacity will improve the implementation of water policies and ensure that institutions are equipped to address emerging challenges.

4.4.9 Implement Smart Urban Water Management

Water and Sanitation Agencies (WASAs) should adopt smart metering systems to monitor urban water supply and reduce losses. Investments in wastewater treatment and recycling facilities are essential to address urban water challenges sustainably. Smart urban water management will improve service delivery, enhance water efficiency, and ensure equitable access to clean water in urban areas.

4.4.10 Secure Sustainable Funding for Water Projects

Provincial Planning and Development Departments should facilitate funding mechanisms for climate-resilient water infrastructure projects. Public-private partnerships and international grants should be explored to support large-scale water management initiatives. Sustainable funding will ensure the timely implementation of critical projects and enhance the resilience of water systems.

4.4.11 Strengthen Disaster Preparedness and Response

The National Disaster Management Authority (NDMA) should expand its role to include comprehensive risk assessments and early warning systems for floods and droughts. Building local-level disaster response capabilities and integrating them with provincial and national plans will improve preparedness and reduce the impact of water-related disasters.

4.4.12 Periodic Review and Policy Update

A mechanism for regular review of water policies should be established to adapt to emerging challenges. Institutions must update their strategies based on data analytics, research findings, and stakeholder feedback. Periodic reviews will ensure that policies remain relevant and effective in addressing evolving water security issues.

4.4.13 Public Awareness and Stakeholder Engagement

Awareness campaigns on water conservation and management should target communities, farmers, and industries. Participatory water management practices should be encouraged by involving local stakeholders in decision-making processes. Public engagement will foster a sense of ownership and responsibility, ensuring broader support for water management initiatives.

4.4.14 Legal and Institutional Reforms

Legal frameworks governing water management should be reviewed and updated to clarify roles, reduce overlaps, and streamline regulatory functions. Clear mandates for conflict resolution, especially between provinces, should be introduced to address disputes effectively. Institutional reforms will enhance governance efficiency and ensure accountability.

Pakistan's water governance framework can become more resilient, efficient, and capable of addressing the complex challenges of water security in a sustainable manner by following these steps. This integrated approach will ensure that water resources are managed effectively, equitably, and in alignment with national and global sustainability goals.

4.5 Three Priority Actions to Improve Pakistan’s Institutional Setup for Water Governance

The Improvement in Pakistan’s water governance framework requires targeted actions that address institutional fragmentation, data management, and climate resilience. The prioritization of these three actions is based on the urgent need to address key institutional, data, and climate-related challenges in Pakistan’s water governance framework. These actions align with the National Water Policy (NWP) 2018 and respond to critical gaps that have been identified through policy analysis and scholarly literature.

4.5.1 Action 1: Establish a Centralized Water Data Platform

A major challenge in Pakistan’s water governance is the fragmentation of water-related data across multiple institutions, including the Pakistan Council of Research in Water

Resources (PCRWR), Water and Power Development Authority (WAPDA), Indus River System Authority (IRSA), and various provincial bodies. The lack of a unified data management system leads to inconsistencies, duplication of efforts, and inefficient decision-making. Effective water governance requires a comprehensive and integrated data system that can provide accurate, real-time information on water availability, quality, and usage.

To address these challenges, the establishment of a Centralized Water Data Platform is essential. This platform should act as a National Water Data Center, consolidating data from all relevant institutions. It should feature standardized data collection protocols to ensure consistency and reliability by Integrating advanced technologies such as Geographic Information Systems (GIS), remote sensing, and Internet of Things (IoT) devices would enhance the accuracy and accessibility of data. The platform should also have user-friendly interfaces to support policymakers, researchers, and local water managers in making data-driven decisions.

Such a centralized system would improve transparency in water allocation, facilitate efficient resource management, and minimize disputes among provinces by providing a reliable basis for decision-making. The emphasis on a centralized data platform is also supported by the *(Section 6.1)*, which calls for enhancing data-driven governance. Mustafa and Wrathall (2011) argue that a centralized data management system is crucial for resolving transboundary water conflicts and ensuring equitable distribution in federal systems.

A Centralized Water Data Platform in Pakistan can also significantly strengthen the integration of science, policy, and practice by providing a unified, accessible, and reliable source of water-related data. The consolidated information from diverse sources including rainfall patterns, river flows, groundwater levels, and water consumption, this platform would enable policymakers, researchers, and practitioners to make informed, evidence-based decisions. It would enhance water resource management, improve forecasting for droughts and floods, and support the formulation of sustainable water policies. Moreover, the platform would foster collaboration among stakeholders, ensuring that scientific insights are effectively translated into actionable strategies, ultimately leading to more efficient and equitable water management in Pakistan.

4.5.2 Action 2: Strengthen Inter-Institutional Coordination

Pakistan's water governance suffers from a lack of coordination and overlapping mandates among federal and provincial institutions. This institutional fragmentation leads to conflicting policies, inefficient resource management, and frequent inter-provincial disputes over water allocation. For instance, disagreements between provinces over the distribution of the Indus River water have been a long-standing issue. The National Water Policy 2018 *(Section 4.2)* highlights the need for institutional reforms to streamline governance and resolve such conflicts effectively.

To address these issues, establishing a National Water Coordination Council under the Ministry of Water Resources is proposed. This council should include representatives from federal, provincial, and local institutions and serve as a platform for coordinating water policies, resolving disputes, and ensuring consistent implementation of Integrated Water Resources Management (IWRM) principles. The council's responsibilities should include;

- Harmonizing policies across federal and provincial levels.
- Coordinating the implementation of IWRM practices.
- Facilitating dialogue among stakeholders to build consensus on critical water issues.

The frequent meetings, transparent decision-making processes, and a clearly defined mandate would help the council function effectively. This approach aligns with international best practices for managing shared water resources and would reduce conflicts and enhance cooperation among provinces. Mirza et al. (2015) emphasize the importance of inter-institutional coordination in federations, arguing that integrated councils can promote sustainable water management and reduce conflicts.

Moreover, NWCC can also bridge the gap between science and practice by facilitating knowledge exchange, promoting pilot projects, and implementing capacity-building programs for stakeholders at all levels. To further strengthen the SPPI, NWCC can promote cross-sector partnerships, engage local communities through public awareness campaigns, and advocate for sustainable water management practices. The introduction of cohesive framework for collaboration, NWCC can ensure that diverse institutions ranging from government agencies and academic institutions to NGOs and private sector entities work in synergy to address Pakistan's water challenges. This inclusive and coordinated approach will not only improve water governance but also contribute to long term water security and climate resilience in the country.

4.5.3 Action 3: Promote Climate-Resilient Infrastructure

Pakistan is highly vulnerable to climate-induced water risks such as floods, droughts, and glacial melt, which threaten water security and the livelihoods of millions. The National Water Policy 2018 *(Sections 7.1 and 7.2)* emphasizes the need to enhance climate resilience in water infrastructure. However, current infrastructure systems managed by WAPDA and the Federal Flood Commission (FFC) are outdated and lack the capability to cope with extreme climate events. The promotion of climate-resilient infrastructure requires a comprehensive strategy that includes:

- Upgrading and modernizing dams, canals, and flood control systems to withstand extreme weather.
- Incorporating climate risk assessments and future climate projections into planning and management processes.
- Adopting nature-based solutions such as wetland restoration and reforestation to act as natural buffers against floods.
- Encouraging water-smart agricultural practices like efficient irrigation and drought-resistant crops to reduce water demand.

A National Climate-Resilient Water Infrastructure Fund could be established to mobilize resources, including public-private partnerships (PPPs) and international grants, for these upgrades. Additionally, integrating disaster risk management with infrastructure planning would improve preparedness and reduce the impacts of water-related disasters. Qureshi (2020) highlights those investments in climate-resilient infrastructure can significantly reduce vulnerability to climate extremes and ensure sustainable water management in South Asia.

Climate-resilient infrastructure strengthens the Science Policy Practice Interface (SPPI) by providing a sustainable and adaptive foundation for water governance. It is designed to withstand climate-induced stresses, such infrastructure ensures water service continuity and reduces vulnerabilities. The integration of scientific research and climate data into planning, policymakers can make evidence-based decisions aligned with long term adaptation goals. For practitioners, solutions like resilient irrigation, flood barriers, and rainwater harvesting enhance water management under changing climate conditions. Additionally, climate-resilient infrastructure fosters collaboration among scientists, policymakers, and practitioners, integrating local knowledge with scientific insights. This holistic approach enhances water security, strengthens institutions, and promotes adaptive, sustainable water management in Pakistan.

4.6 Strategies to Promote the Proposed Actions and Potential Benefits

4.6.1 Establish a Centralized Water Data Platform

4.6.1.1 Strategy 1: Develop a National Water Data Framework

A standardized framework for data collection, storage, and sharing is essential to ensure consistency and reliability across institutions. This framework should include protocols for data formats, quality standards, and metadata requirements.
This will be implemented by developing uniform data collection protocols for all water-related institutions, including PCRWR, WAPDA, IRSA, and provincial bodies. This will ensure that the platform is compatible with existing systems used by different agencies, enabling seamless data integration by including data on water availability (surface and groundwater), quality, usage (agricultural, industrial, domestic), climate variables, and infrastructure status. This will be helpful in enacting legislation mandating all relevant institutions to contribute data to the centralized platform, ensuring compliance and transparency. Australia established the National Water Account (NWA) to provide a comprehensive and standardized dataset on water resources. The NWA integrates data from multiple sources, including government agencies, research institutions, and private entities, to provide a unified view of water availability, use, and management. The potential benefits of this strategy for Pakistan will be;

- This will eliminate data silos and ensures consistency across institutions.
- This will facilitate evidence-based decision-making by providing accurate and comprehensive data.
- This will enhance transparency and accountability in water governance.

4.6.1.2 Strategy 2: Leverage Advanced Technologies

The technological integration such as Geographic Information Systems (GIS), remote sensing, and Internet of Things (IoT) devices can enhance the accuracy and accessibility of water data by using satellite imagery and GIS mapping to monitor water resources, track changes in water bodies, and assess land use patterns. this will be done by deploying IoT-enabled sensors in rivers, canals, and reservoirs to collect real-time data on water levels, flow rates, and quality. This will utilize cloud-based platforms for data storage and processing to ensure scalability, accessibility, and security by developing user-friendly dashboards and visualization tools to make data accessible to policymakers,

researchers, and the public. India's National Hydrology Project (NHP) uses advanced technologies such as GIS, remote sensing, and IoT devices to monitor water resources. The project has established a centralized data platform that provides real-time information on water availability, quality, and usage. Potential benefits for Pakistan will be;

- This will provide real-time data on water availability, quality, and usage.
- This will enhance the ability to monitor and predict water-related risks, such as floods and droughts.
- This will support policymakers with actionable insights for water management and will be helpful in evidence-based decision making.

4.6.1.3 Strategy 3: Build Institutional Capacity

The dedicated training programs for staff at federal and provincial agencies are necessary to ensure effective data collection, analysis, and interpretation. This may be implemented by conducting workshops and training programs on data management, analysis, and interpretation for staff at PCRWR, WAPDA, IRSA, and provincial bodies. This will promote data literacy among policymakers and practitioners to ensure they can effectively use the platform for decision-making. This will also establish a knowledge-sharing network to disseminate best practices and lessons learned to the stakeholders. South Africa's Water Research Commission (WRC) has implemented capacity-building programs to train water professionals in data collection, analysis, and interpretation. The WRC also collaborates with universities and research institutions to build local expertise in water data management. The potential benefits may be;

- This will empower institutions to effectively utilize the centralized data platform.
- This will ensure that policymakers and practitioners can interpret and apply data for decision-making.
- This will also promote a culture of data-driven governance.

4.6.2 Strengthen Inter-Institutional Coordination

4.6.2.1 Strategy 1: Establish a National Water Coordination Council

A National Water Coordination Council (NWCC) under the Ministry of Water Resources should be established to harmonize policies and resolve disputes among federal and provincial institutions. The European Union's Water Framework Directive (WFD) established river basin management plans that require coordination among member states. The WFD created a platform for dialogue and consensus-building on water issues, reducing conflicts and ensuring consistent implementation of water management policies. This will be implemented by including representatives from federal, provincial, and local institutions, as well as civil society and academia by defining the mandates of each stakeholder, including policy harmonization, dispute resolution, and IWRM implementation. The regular meetings to discuss water-related issues, review progress, and make decisions will enhance the tracking of progress in implementation. This will also ensure transparency in decision-making by publishing meeting minutes and decisions. The benefits associated with this strategy are;

- This will provide a platform for dialogue and consensus-building on water issues.
- This will reduce conflicts and overlapping mandates among institutions.

- This will ensure consistent implementation of Integrated Water Resources Management (IWRM) principles.

4.6.2.2 Strategy 2: Develop Clear Mandates and Responsibilities

The clarity of the roles and responsibilities of each institution involved in water governance is critical to avoid duplication of efforts and ensure accountability.
For this purpose, clearly define the roles and responsibilities of federal, provincial, and local institutions in water governance. This will definitely ensure that federal and provincial water policies are aligned and mutually supportive. This will establish mechanisms to hold institutions accountable for their roles and responsibilities. The United States' Clean Water Act (CWA) clearly defines the roles and responsibilities of federal, state, and local institutions in water governance. The CWA has been instrumental in reducing water pollution and improving water quality through coordinated efforts. This will help in

- Reducing institutional fragmentation and overlapping mandates.
- This will ensure that each institution contributes effectively to water governance.
- This will enhance transparency and accountability in decision-making.

4.6.2.3 Strategy 3: Promote Stakeholder Engagement

The effective engagement of stakeholders, including farmers, industries, and local communities at all levels, in water governance processes is essential for building consensus and ensuring inclusivity. For this purpose, Conduction of workshops and consultations with stakeholders to gather input and build consensus on water management plans is crucial. This will empower local communities to participate in water management decisions, particularly in rural areas where agriculture is the primary water user. This will also create formal mechanisms for resolving disputes over water allocation and usage. The Netherlands' Delta Programme engages stakeholders, including farmers, industries, and local communities, in water governance processes. The programme has successfully built consensus on water management plans, ensuring that they reflect the needs and priorities of all users. The benefits of this strategy will be;

- This will build trust and cooperation among stakeholders.
- This will ensure that water policies reflect the needs and priorities of all users.
- This will enhance the legitimacy and acceptance of water governance decisions.

4.6.3 Promote Climate-Resilient Infrastructure

4.6.3.1 Strategy 1: Conduct Climate Risk Assessments

Climate risk assessments should be integrated into the planning and design of water infrastructure projects. This may be helpful in identifying the most vulnerable areas to climate change impacts, such as floods, droughts, and glacial melt. The use of climate models to project future scenarios and assess their potential impact on water infrastructure will be helpful in informed decision making. This will also incorporate climate resilience into the design of new infrastructure projects, ensuring they can withstand extreme weather events. IPCC (2021) emphasizes the importance of climate risk assessments in building resilience to climate change impacts. The United Kingdom's Climate Change Risk Assessment (CCRA) evaluates the vulnerability of water

infrastructure to climate change impacts. The CCRA has informed the design of climate-resilient infrastructure, ensuring that it can withstand extreme weather events. This will be helpful in;

- Identifying vulnerabilities and informs the design of climate-resilient infrastructure.
- This will ensure that infrastructure can withstand extreme weather events.
- This will reduce the long-term costs of disaster recovery and reconstruction.

4.6.3.2 Strategy 2: Upgrade and Modernize Existing Infrastructure

The existing water infrastructure, such as dams, canals, and flood control systems, should be retrofitted to improve its resilience to climate change. The Strengthening of existing dams, canals, and flood control systems to improve their resilience to extreme weather events is paramount. This will enhance flood protection measures, such as levees, embankments, and early warning systems. China's Sponge Cities Initiative upgrades urban water infrastructure to improve its resilience to climate change. The initiative includes retrofitting existing infrastructure and incorporating nature-based solutions, such as green roofs and permeable pavements. This initiative can be act as model to adopt to counter the flooding hazards, this will enhance the durability and functionality of water infrastructure by reducing the risk of infrastructure failure during extreme weather events. This will also ensure a reliable water supply during periods of scarcity.

4.6.3.3 Strategy 3: Mobilize Resources through a National Climate-Resilient Water Infrastructure Fund

A dedicated fund should be established to finance climate-resilient water infrastructure projects. This may be done by securing funding from public budgets, international grants, and private sector investments. There should be policies to encourage private sector participation in climate-resilient infrastructure projects through PPPs. This will allow transparent and equitable allocation of funds to priority projects. The Green Climate Fund (GCF) may be another opportunity which provides financial resources for climate-resilient infrastructure projects in developing countries. The GCF has supported projects that upgrade water infrastructure and enhance climate resilience. The potential benefits associated with this strategy may be;

- This will provide financial resources for upgrading and modernizing water infrastructure.
- This will encourage private sector investment in climate-resilient projects.
- This will ensure the sustainability of water infrastructure investments.

4.6.3.4 Strategy 4: Adopt Nature-Based Solutions

Nature-based solutions, such as wetland restoration, reforestation, and rainwater harvesting, should be integrated into water infrastructure planning.

This will be helpful in incorporating the indigenous knowledge in water resources management. This action may be restoring wetlands to act as natural buffers against floods and droughts. This will promote reforestation in catchment areas to reduce soil erosion and improve water retention. This will also encourage the adoption of rainwater harvesting systems at the community and household levels. Internationally, New York

City's Green Infrastructure Plan is the best example which incorporates nature-based solutions, such as wetland restoration and green roofs, to enhance climate resilience. The plan has reduced the city's vulnerability to floods and improved water quality. The associated benefits will be;

- This will Reduce the impact of climate-induced water risks.
- This will Promote sustainable water management practices.
- This will Enhances ecosystem health and biodiversity.

4.7 Implementation Roadmap

The Science Policy Practice Interface (SPPI) is a critical framework for bridging the gap between scientific research, policy formulation, and on-ground implementation. For Pakistan, the integration of SPPI into water governance is essential to address the challenges of data fragmentation, institutional coordination, and climate resilience. The proposed implementation plan is divided into short-term (1-2 years), medium-term (3-5 years), and long-term (6+ years) actions, each with clear Key Performance Indicators (KPIs) and timelines. This roadmap ensures a structured and phased approach to achieving the goals outlined in the National Water Policy (NWP) 2018 and aligns with international best practices. The plan is given in below table;

Table 4: Implementation Roadmap of SPPI in Pakistan

Phase	Actions	Key Performance Indicators (KPIs)	Timeline
Short-Term (1-2 years)			
Mapping of existing policies and research gaps.	Conduct a comprehensive review of existing water policies, research studies, and institutional frameworks.	• Report on policy and research gaps published. • Stakeholder feedback incorporated.	Months 1-6
Initial consultations and stakeholder engagement.	Organize workshops and consultations with federal, provincial, and local stakeholders, including academia, NGOs, and communities.	• Stakeholder consultation reports finalized. • Consensus on priority areas for SPPI integration.	Months 6-12
Establish a task force for SPPI implementation.	Form a task force comprising representatives from federal and provincial water institutions, research organizations, and civil society.	• Task force established and operational. • Terms of reference and work plan finalized.	Months 12-18

Phase	Actions	Key Performance Indicators (KPIs)	Timeline
Pilot projects for data integration.	Launch pilot projects to integrate water data from key institutions (e.g., PCRWR, WAPDA, IRSA) into a centralized platform.	• Pilot projects completed. • Lessons learned documented for scaling up.	Months 18-24
Medium-Term (3-5 years)			
Development of SPPI institutional mechanisms.	Establish a National Water Coordination Council (NWCC) to oversee SPPI integration and resolve inter-institutional conflicts.	• NWCC established and operational. • Regular meetings and decision-making processes in place.	Years 3-4
Capacity-building programs for decision-makers and practitioners.	Conduct training programs on data-driven decision-making, IWRM, and climate-resilient infrastructure for policymakers and practitioners.	• Number of trained professionals (target: 500+). • Training modules and materials developed.	Years 3-5
Launch a centralized water data platform.	Develop and operationalize a centralized water data platform integrating real-time data from federal and provincial institutions.	• Platform launched and operational. • Data from key institutions integrated.	Years 4-5
Implement IWRM principles in pilot basins.	Apply Integrated Water Resources Management (IWRM) principles in selected river basins (e.g., Indus Basin).	• IWRM plans developed for pilot basins. • Stakeholder feedback incorporated.	Years 4-5
Long-Term (6+ years)			
Full operationalization of SPPI frameworks.	Scale up SPPI frameworks across all provinces and river basins, ensuring full integration of science, policy, and practice.	• SPPI frameworks operational in all provinces. • Annual progress reports published.	Years 6-8
Continuous monitoring, evaluation, and policy adaptation.	Establish a monitoring and evaluation (M&E) system to track progress and adapt policies based on feedback and changing conditions.	• M&E system operational. • Policy adaptation reports published annually.	Years 6+

Phase	Actions	Key Performance Indicators (KPIs)	Timeline
Promote climate-resilient infrastructure nationwide.	Upgrade and modernize water infrastructure across the country, incorporating climate risk assessments and nature-based solutions.	• Percentage of climate-resilient infrastructure increased (target: 50%+). • Flood and drought resilience improved.	Years 6+
Strengthen international collaboration.	Partner with international organizations (e.g., World Bank, UNDP, GCF) to secure funding and technical expertise for SPPI initiatives.	• Number of international partnerships established (target: 5+). • Funding secured for key projects.	Years 6+

5 Monitoring and Evaluation Framework

The Science Policy Practice Interface (SPPI) serves as a bridge between scientific research, policy formulation, and practical implementation in water governance. Effective SPPI integration ensures that water management strategies are grounded in the latest scientific evidence, align with policy objectives, and address on-the-ground challenges effectively. However, for SPPI to deliver meaningful results, a robust Monitoring and Evaluation (M&E) system is essential. M&E provides a systematic approach to assess progress, identify gaps, and ensure accountability, enabling continuous improvement in water governance practices.

A well-designed M&E system can help track whether scientific knowledge is being translated effectively into policies and practices, whether institutional coordination is improving, and whether water governance outcomes align with national and international standards. Without such a framework, it becomes difficult to determine if SPPI initiatives are achieving tangible benefits like enhanced water security, reduced conflicts, and greater climate resilience.

Moreover, M&E systems enable adaptive management by establishing feedback loops that allow policymakers to refine strategies based on real-time data and stakeholder input. For instance, if data from a centralized water platform is not being used effectively, M&E can pinpoint barriers and suggest corrective actions. Similarly, if infrastructure projects fail to deliver expected results, M&E can identify design flaws or funding gaps that need to be addressed.

In Pakistan, where water governance is challenged by institutional fragmentation, data limitations, and climate vulnerabilities, a comprehensive M&E framework is critical. Such a framework can help align SPPI initiatives with the National Water Policy (NWP) 2018 and ensure sustainable water management. By using clear and measurable indicators, Pakistan can monitor progress, ensure accountability, and adapt policies to evolving challenges effectively. The possible indicators with their description have been represented in below Table;

Table 5: Key indicators for SPPI Monitoring and Evaluation

Sr. No.	Indicator	Description	Measurement
1.	Policy Coherence and Alignment	Measures the extent to which water policies are aligned with scientific evidence and practical challenges. Evaluates whether policies are informed by research and tailored to address real-world water management issues.	• Conduct policy reviews to assess alignment with scientific evidence. • Track the number of policies revised or developed based on research. • Conduct stakeholder feedback surveys to gauge satisfaction with policy coherence.

Sr. No.	Indicator	Description	Measurement
2.	Data Integration and Utilization	Assesses the extent to which water-related data is integrated into decision-making processes. Evaluates the functionality of a centralized water data platform and its utilization by policymakers and practitioners.	• Track the percentage of institutions contributing data to the centralized platform. • Monitor the frequency of data usage in policy formulation and implementation. • Conduct user satisfaction surveys to gather feedback on the platform's effectiveness.
3.	Institutional Coordination and Collaboration	Measures the effectiveness of institutional coordination mechanisms, such as the National Water Coordination Council (NWCC), in fostering collaboration among federal, provincial, and local institutions.	• Track the number of inter-institutional meetings held annually. • Monitor the reduction in inter-provincial water disputes. • Conduct stakeholder perception surveys to assess improvements in coordination.
4.	Capacity Building and Knowledge Transfer	Evaluates the effectiveness of capacity-building programs in enhancing the skills and knowledge of decision-makers and practitioners. Measures the extent to which scientific knowledge is transferred to stakeholders.	• Track the number of professionals trained in data-driven decision-making, IWRM, and climate resilience. • Assess the percentage of trained professionals applying their knowledge in practice. • Gather stakeholder feedback on the relevance and effectiveness of training programs.

Sr. No.	Indicator	Description	Measurement
5.	Implementation of IWRM Principles	Assesses the extent to which Integrated Water Resources Management (IWRM) principles are implemented in water governance. Evaluates the adoption of holistic and basin-level approaches to water management.	• Track the number of river basins with IWRM plans developed and implemented. • Monitor the reduction in water use conflicts within pilot basins. • Assess improvements in water use efficiency through metrics such as water productivity.
6.	Climate Resilience of Water Infrastructure	Measures the extent to which water infrastructure is upgraded to withstand climate-induced risks, such as floods, droughts, and glacial melt. Evaluates the adoption of climate-resilient designs and nature-based solutions.	• Track the percentage of water infrastructure upgraded to meet climate resilience standards. • Monitor the reduction in damage to water infrastructure during extreme weather events. • Conduct stakeholder perception surveys to assess improvements in climate resilience.
7.	Stakeholder Engagement and Participation	Evaluates the extent to which stakeholders, including farmers, industries, and local communities, are engaged in water governance processes. Measures the inclusivity and effectiveness of stakeholder participation.	• Track the number of stakeholder consultations and workshops conducted annually. • Assess the percentage of stakeholders reporting satisfaction with participation processes. • Evaluate the inclusion of stakeholder feedback in policy formulation and implementation.
8.	M&E System Functionality	Assesses the effectiveness of the Monitoring and Evaluation (M&E) system in tracking progress, identifying challenges, and adapting policies based on feedback and changing conditions.	• Track the frequency of M&E reports published. • Assess the percentage of recommendations from M&E reports implemented. • Conduct stakeholder perception surveys to evaluate the effectiveness of the M&E system.

Sr. No.	Indicator	Description	Measurement
9.	Economic and Social Benefits	Measures the economic and social benefits resulting from SPPI integration, such as improved water security, increased agricultural productivity, and enhanced livelihoods.	• Track increases in agricultural productivity through metrics such as crop yields. • Monitor reductions in water-related conflicts and disputes. • Assess improvements in community livelihoods through income levels and access to water.
10.	Environmental Sustainability	Evaluates the extent to which SPPI integration contributes to environmental sustainability, such as maintaining minimum environmental flows and reducing water pollution.	• Track the percentage of rivers and streams with maintained environmental flows. • Monitor reductions in water pollution levels through water quality indices. • Assess improvements in ecosystem health through biodiversity metrics.

5.1 Potential Benefits of an Effective M&E System

5.1.1 Informed Decision-Making

An effective M&E system provides policymakers with accurate and real time data, enabling them to make well-informed decisions that are based on evidence rather than assumptions. By tracking key indicators and assessing the impacts of various policies and practices, M&E helps in identifying successful strategies that can be scaled up and recognizing ineffective approaches that need modification. This leads to more strategic planning and targeted interventions in water governance, ultimately contributing to more sustainable and resilient water management practices.

5.1.2 Transparency and Accountability

A comprehensive M&E framework promotes transparency by making information about policy performance and implementation outcomes publicly accessible. Regular publication of M&E reports allows stakeholders, including civil society, media, and local communities, to hold decision-makers accountable for their actions. Transparent monitoring processes also help build trust between different stakeholders, reducing skepticism and resistance to policy initiatives. This openness is essential in water governance, where diverse interests must be balanced fairly.

5.1.3 Efficient Resource Allocation

By identifying which programs deliver the most significant benefits relative to their costs, M&E systems support efficient allocation of financial and technical resources. For instance, if a specific intervention, such as upgrading irrigation systems, is shown to substantially improve water-use efficiency, resources can be prioritized for similar projects. Efficient resource allocation not only enhances the effectiveness of water governance but also prevents wastage of limited financial and human resources.

5.1.4 Conflict Resolution

In regions like Pakistan, where water resources are often contested between provinces and sectors, a data-driven M&E system can play a crucial role in conflict resolution. By providing objective evidence on water availability, usage, and compliance with agreements, M&E helps in mediating disputes more transparently and fairly. For example, monitoring inter-provincial water flows can prevent conflicts by ensuring equitable distribution based on verified data rather than perceptions or political pressures.

5.1.5 Climate Resilience

M&E systems that include climate resilience indicators enable proactive adaptation strategies by tracking vulnerabilities in water infrastructure and management practices. By assessing the resilience of infrastructure to floods, droughts, and other climate risks, M&E provides actionable insights for upgrading and designing more robust systems. This reduces the long-term risks and costs associated with climate impacts, ensuring that water governance frameworks can withstand and adapt to changing environmental conditions.

5.1.6 Continuous Improvement and Adaptive Management

One of the most significant benefits of an M&E system is its ability to facilitate adaptive management. By creating feedback loops that provide continuous information on policy performance, M&E enables decision-makers to adjust strategies promptly in response to emerging challenges or opportunities. For instance, if monitoring reveals that certain policies are failing to reduce water pollution effectively, adjustments can be made in real-time, rather than waiting for comprehensive policy reviews. This adaptability is particularly valuable in dynamic environments where water challenges are complex and evolving rapidly.

5.1.7 Strengthening Institutional Capacity

Regular monitoring and evaluation processes enhance institutional learning and capacity by identifying gaps in skills, knowledge, and resources. Training personnel in M&E methods not only improves their technical capabilities but also fosters a culture of accountability and results-oriented management within water governance institutions. Over time, this institutional strengthening contributes to more competent and effective water governance systems that can handle complex challenges.

5.1.8 Enhanced Stakeholder Participation and Ownership

Inclusive M&E systems that involve diverse stakeholders in monitoring processes help build a sense of ownership and commitment to water governance initiatives. By integrating feedback from local communities, farmers, and other water users, M&E systems ensure that policies reflect the realities on the ground and address actual needs. This inclusive approach not only improves the relevance and effectiveness of policies but also encourages stakeholders to actively support and comply with water management regulations.

5.1.9 Promotion of Integrated Water Resources Management (IWRM)

An effective M&E system aligns with the principles of Integrated Water Resources Management (IWRM) by assessing cross-sectoral impacts of water policies and ensuring that environmental, social, and economic dimensions are considered holistically. By monitoring indicators related to environmental flows, water quality, and equitable access, M&E supports the implementation of IWRM principles in a systematic and measurable way. This leads to more balanced and sustainable water management outcomes that benefit all sectors and regions.

5.1.10 International Cooperation and Funding

A robust M&E system with transparent indicators and outcomes can attract international funding and support by demonstrating accountability and effective governance. Development partners and international organizations are more likely to invest in water governance programs that have clear M&E frameworks, as these ensure that resources will be utilized effectively. Moreover, by aligning M&E indicators with global standards and reporting frameworks, Pakistan can enhance its credibility and collaboration with international bodies working on transboundary water management and climate resilience.

5.2 Regular Policy Reviews and Adaptations

An effective Science-Policy-Practice Interface (SPPI) system plays a vital role in enabling regular policy reviews and adaptations by ensuring that water governance policies are continuously informed by the latest scientific findings, real-time data, and practical ground-level insights. In the context of Pakistan's water security, where challenges like climate variability, water scarcity, and inter-provincial disputes are prevalent, a robust SPPI can help policymakers assess the effectiveness of existing policies and adapt them proactively to emerging threats and needs. By integrating scientific research, continuous Monitoring and Evaluation (M&E), and real-time data into the policy cycle, SPPI facilitates a dynamic feedback loop that allows for the timely identification of gaps, inefficiencies, and unintended consequences in water management policies. M&E mechanisms enable policymakers to systematically track the progress of SPPI initiatives against key performance indicators, assess the effectiveness of policy interventions, and make data-driven decisions for policy adaptations. This approach aligns with the National Water Policy (NWP) 2018, which emphasizes the need for evidence-based policymaking and adaptive management strategies to address evolving water challenges (Government of Pakistan, 2018).

Internationally, the Murray-Darling Basin Plan in Australia serves as a compelling example of how an effective SPPI system combined with robust M&E mechanisms can facilitate regular policy reviews and adaptations. The plan integrates scientific research, comprehensive monitoring programs, and stakeholder consultations to manage water resources across multiple states effectively. Through a well-established SPPI and M&E framework, policymakers could adapt water allocations based on hydrological models, climate predictions, and stakeholder needs, ensuring equitable distribution of water resources while protecting environmental flows (Connell & Grafton, 2011). The M&E component played a critical role in identifying areas where policy adjustments were necessary, such as optimizing water trading rules and addressing environmental flow requirements. This adaptive management approach significantly reduced conflicts among states and enhanced the resilience of water systems to droughts and other climate risks.

Similarly, in the European Union, the Water Framework Directive (WFD) mandates member states to review and update river basin management plans every six years, guided by scientific assessments, continuous monitoring, and stakeholder input. The SPPI system under the WFD, reinforced by a robust M&E framework, enables policymakers to adjust pollution control measures, water use regulations, and conservation strategies based on the latest environmental data and monitoring results (European Commission, 2015). The M&E mechanisms under the WFD include regular reporting, performance indicators, and compliance checks, which have been instrumental in achieving measurable improvements in water quality and ecosystem health across several EU member states.

For Pakistan, adopting a similar SPPI-driven approach for policy reviews, supported by a comprehensive M&E system, could bring multiple benefits. Firstly, it would ensure that water policies remain relevant and responsive to challenges such as glacier melt, changing monsoon patterns, and urban water demands. The M&E system would provide continuous feedback on the effectiveness of policies, enabling timely adjustments to enhance outcomes. Secondly, it would enhance transparency and stakeholder trust by basing policy adaptations on transparent data, evidence-based evaluations, and inclusive consultations. Lastly, a well-functioning SPPI and M&E system would improve the efficiency of resource allocation, reduce the risks of policy failures, and strengthen Pakistan's overall water security framework by ensuring that policy adaptations are both timely and effective.

5.3 Feedback Mechanism for Stakeholders

An effective feedback mechanism for stakeholders is a crucial component of the Science-Policy-Practice Interface (SPPI) in water governance, facilitating two-way communication between policymakers, scientists, and on-ground practitioners. In the context of Pakistan’s water security, a structured feedback system can significantly enhance policy responsiveness, transparency, and inclusivity. By enabling local communities, farmers, industries, and civil society organizations to voice their concerns, share practical insights, and evaluate the effectiveness of water management policies, the feedback mechanism ensures that policies are grounded in reality and adapt to emerging challenges. The National Water Policy (NWP) 2018 emphasizes participatory water governance and stakeholder engagement as key principles, advocating for inclusive decision-making

processes where stakeholder feedback informs policy adaptations and implementation strategies (Government of Pakistan, 2018).

In the SPPI framework, the feedback mechanism functions through a continuous cycle of consultation, assessment, and adaptation. Scientific findings inform policy decisions, which are then implemented on the ground. Stakeholders provide feedback on these implementations based on their experiences and observed outcomes. This feedback is systematically collected, analyzed, and communicated to policymakers and researchers, who adjust policies and practices accordingly. Such a mechanism not only bridges the gap between science and practice but also ensures that policies remain dynamic and context-specific. For instance, farmers facing challenges due to inefficient irrigation practices or water scarcity can provide feedback that can lead to the adoption of more effective water conservation techniques, thereby enhancing agricultural productivity and sustainability.

Internationally, the European Union's Water Framework Directive (WFD) offers an exemplary model of stakeholder feedback integration within the SPPI system. The WFD mandates public participation in water management through structured consultations, surveys, and advisory committees, ensuring that feedback from local stakeholders influences river basin management plans. Feedback collected from stakeholders on issues like water quality, pollution control, and usage rights is systematically incorporated into the planning and review processes, enabling continuous improvement of water management policies (European Commission, 2015). This approach has been instrumental in achieving significant improvements in water quality and ecosystem health across EU member states by aligning policies with ground realities and stakeholder priorities.

For Pakistan, establishing a comprehensive feedback mechanism within the SPPI framework can deliver multiple benefits for water security. Firstly, it would enhance policy legitimacy and public trust by ensuring that policies reflect the needs and challenges faced by local communities and sectors dependent on water resources. Secondly, it would enable adaptive management by providing real-time insights into the effectiveness of policies, thus allowing timely adjustments to address issues like inter-provincial water disputes, groundwater depletion, and climate-induced water risks. Thirdly, a robust feedback system would strengthen accountability by making policymakers answerable to the concerns and inputs of stakeholders, thus reducing the risks of policy failure and misallocation of resources.

To operationalize this mechanism, it is essential to establish multiple channels for collecting stakeholder feedback, such as digital platforms, community forums, and periodic surveys. Feedback should be analyzed systematically using data analytics tools and then communicated to relevant institutions, including the Ministry of Water Resources, Indus River System Authority (IRSA), and provincial water management authorities. Institutional mechanisms, such as a National Water Coordination Council with a dedicated feedback review committee, can further streamline this process by ensuring that feedback informs policy revisions and resource allocation decisions effectively.

A well-designed feedback mechanism is indispensable for effective SPPI integration in Pakistan's water governance. By institutionalizing stakeholder feedback through structured processes of collection, analysis, communication, and policy adaptation,

Pakistan can ensure that its water management strategies are inclusive, evidence-based, and resilient to emerging challenges. The integration of continuous Monitoring and Evaluation (M&E) into this mechanism further ensures that policies remain adaptable and outcome-oriented, enhancing the overall water security framework of the country.

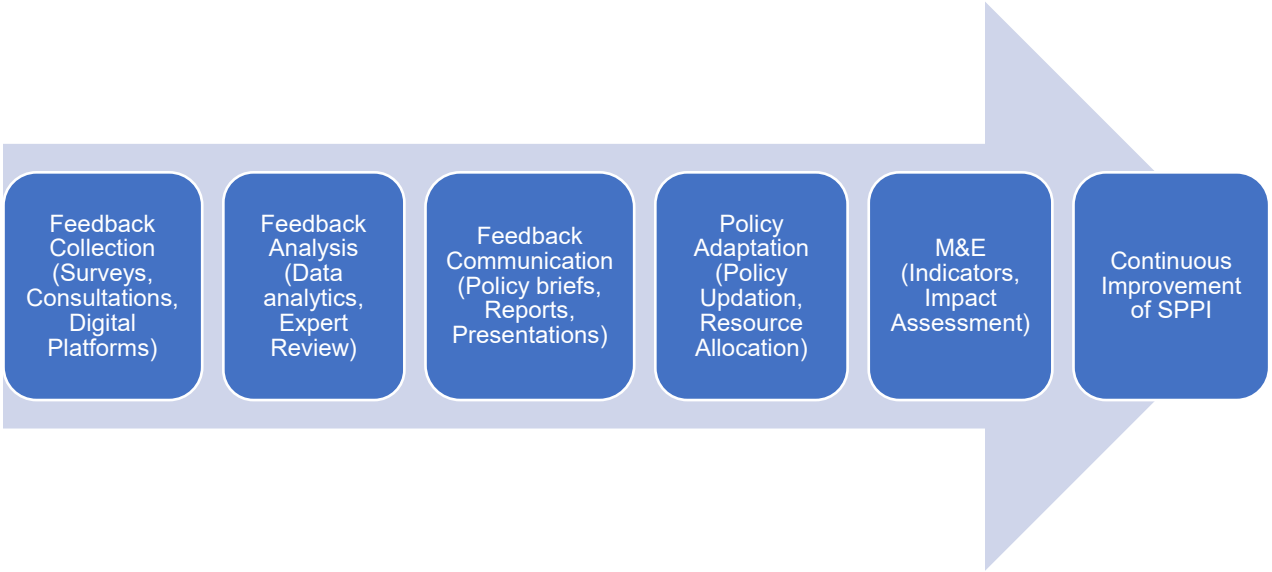

Figure 9: SPPI Feedback Mechanism for Water Security

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About PCRWR

PCRWR is an apex body of the Ministry of Water Resources and is mandated to conduct, organize, coordinate and promote research on all aspects of water resources including irrigation (surface and groundwater), drainage, soil reclamation, drinking water and wastewater. It has eight regional offices located at different agro-ecological zones and each centre conducts research on water-related issues of the respective zones. These Regional Offices are located at Lahore, Bahawalpur, Tandojam, Quetta, Peshawar, Karachi, Gilgit and Muzaffarabad. Besides these eight Regional Offices, PCRWR has a setup of 24 water quality testing and research laboratories in major cities of the country. This includes ISO-17025 accredited National Water Quality Laboratory having its own Laboratory Information Management System (LIMS). PCRWR has all types of infrastructure such as soil and water testing laboratories, groundwater assessment equipment, research farms to conduct and disseminate the research. It is the only organization in Pakistan that owns drainage type lysimeters in Lahore, Tandojam, Quetta and Peshawar. PCRWR has done considerable work on crop water requirements, tile drainage, soil reclamation, on-farm water management technologies, rainwater harvesting, artificial recharge, groundwater assessment and management, skimming wells, drinking water, and indigenous development of water testing and treatment tools, salinity and moisture sensors. To help in developing the capacity of in-service professionals and fresh graduates, PCRWR has also a well-equipped National Capacity Building Institute in Islamabad to provide short and long term trainings on all aspects of water.

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