WATER PLANNING AND ECOSYSTEM SERVICES IN RIVER CATCHMENTS OF KAZAKHSTAN

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Abstract:

Water planning and ecosystem services in river catchments of Kazakhstan

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In arid Central Asia, Kazakhstan faces significant water resource challenges exacerbated by historical legacies, climate change, and human activities. Establishing the Ministry of Water Resources and Irrigation in 2023, with its specific roles and responsibilities in addressing these challenges and urban planning initiatives in Astana, underscores Kazakhstan's commitment to improving water accessibility and quality. However, these efforts still overlook environmental concerns, contributing to ongoing water scarcity and ecological degradation that need urgent attention.

This research aims to enhance water resource planning in Kazakhstan by assessing the ecosystem services of the country's river basins. From a macro perspective, this study examines the changes in Kazakhstan's water resource management across three significant periods: the first decade after independence in 1991, the next decade after the introduction of Integrated Water Resources Management (IWRM) in 2000, and the current situation in the 2020s. These periods are significant as they mark critical milestones in the evolution of water resource management in Kazakhstan. Also, over the last decade, there has been a mismanagement of water resources in the capital of Kazakhstan – Astana city, which entailed unsustainable water use practices that entail a high likelihood of water shortages during the summer season in the near future. The capital of Kazakhstan is encountering major challenges in the drinking water supply, which are related to insufficient quantity, exacerbated by rapid population growth, poor quality, and ecological degradation of the water basin.

In this regard, I conduct an Ecosystem Services Valuation (ESV) of the Astana reservoir to capture critical services in the main water reservoir that supplies the drinking water to the capital city. I further explore how ESV can improve water resources management and planning at a country level. For the ESV, I employ the System of Environmental-Economic Accounting for Ecosystem Services (SEEA-EA) methodology by adopting as a case study the Astana reservoir, which is the main drinking water supply in the capital.

To operationalize SEEA-EA, I applied different market valuation techniques such as cost-avoidance, opportunity, and travel costs to capture the economic value of critical ecosystem services in Astana related to water quantity, quality, erosion, and recreational activities. Further, I conducted semi-structured interviews with relevant water experts, policymakers, enterprise stakeholders, and water users and presented the results of the SEEA-EA of the Astana reservoir to interviewees. I found that most respondents had a positive attitude toward implementing ecosystem-based (ES) approaches in Kazakhstan's water resource planning. However, the interviewees highlighted challenges, including legalizing ES assessment methods, which involve navigating complex regulatory frameworks and ensuring the recognition of the ESV in policy decisions. Improving data transparency and enhancing cooperation among water resource management agencies were additional challenges that must be addressed for effective water resource management. In the final analysis, I provide policy recommendations to improve sustainable water resources management in Kazakhstan by prioritizing the integration of Integrated Water Resources Management (IWRM) and ESV to enhance efficiency and sustainability, ensuring a comprehensive consideration of both market and non-market values. Additionally, it is essential to strengthen legal and institutional frameworks to empower River Basin Commissions and Institutions, promote cross-border water resource cooperation, and increase funding for monitoring agencies. Public awareness campaigns should also be initiated to encourage community engagement in water conservation, addressing current water management challenges and achieving a balance between ecological and economic development.

This research offers valuable insights into water resource management in Kazakhstan. It fills a crucial gap in the literature and provides practical insights for regional stakeholders. It utilizes the SEEA-EA framework and interdisciplinary ESV tools to demonstrate the practical benefits of an ES-based approach, even for those without an environmental background. Additionally, ESV enhances decision-making by providing policymakers with critical insights into aquatic ecosystem issues and supporting informed policy formulation through analytical tools and stakeholder collaboration. This approach ensures that water resource management is based on credible evidence, contributing to restoring local ecosystems and improving overall practices.

Keywords: Water resource management, Water resource planning, IWRM, Ecosystem Services Valuation (ESV), SEEA-EA, EBPM, Kazakhstan.

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LIST OF ABBREVIATIONS

CWR	Committee for Water Resources of Kazakhstan
EBI	Esil Basin Inspector
EBPM	Evidence-Based Policy Making
ES	Ecosystem Service
ESV	Ecosystem Service Valuation
ESVD	Ecosystem Service Value Database
GWP	Global Water Partnership
IWRM	Integrated Water Resources Management
KZT	Kazakhstani Tenge
MCM	Million Cubic Meters
RBC	River Basin Councils
RBI	River Basin Inspector
RBO	River Basin Organization
RIOS	The Resource Investment Optimization System
ROSES	Reporting Standards for Systematic Evidence Syntheses
SEEA	System of Environment-Economic Accounting
SEEA-EA	System of Environment-Economic Accounting for Ecosystem Services

Chapter 1

Introduction

1 INTRODUCTION

1.1 BACKGROUND

In September 2023, Kazakhstan established a new Ministry of Water Resources and Irrigation. This institution aims to address critical issues related to water accessibility and quality, with a long-term goal of mitigating potential water shortages by 2040. Understanding the evolution of Kazakhstan's water resource management policies is essential for contextualizing the creation of the new institutional structure. These policies have undergone distinct phases: the first decade after independence in 1991, the next decade after the introduction of Integrated Water Resources Management (IWRM) in 2000, and the current trend of integrating environmental considerations into water resource management in the 2020s.

- **Water Resource Challenges in Kazakhstan**

Kazakhstan, located in the arid region of Central Asia, grapples with significant water resource challenges. Following the collapse of the Soviet Union in 1991, conflicts over water and energy distribution among the five Central Asian countries intensified, and the closure of essential monitoring stations exacerbated the management of these resources at the regional level (Unger-Shayesteh et al., 2013a).

These challenges are further compounded by climate change and human activities such as agriculture and hydropower development, leading to a rapid depletion of water resources. The shrinking Aral Sea is a prominent example of this depletion (Micklin, 2007). As water resources diminish, issues such as desertification and salinization become more pronounced, leading to ongoing environmental degradation.

Since 2010, there has been an increasing focus among Central Asian countries on integrating ecological factors into water resource planning. Heightened environmental awareness, international commitments, and regional cooperation have driven this shift, offering a glimmer of hope in the face of these challenges. Kazakhstan’s emphasis on environmental regulations reflects its commitment to adopting an ecosystem-based approach. However, the potential benefits of effective water resource planning remain limited due to financial constraints, lack of access to advanced technologies, and other challenges (Janusz-Pawletta & Gubaidullina, 2015; Ziganshina & Janusz-Pawletta, 2020; UNECE, 2017).

- **Importance of ES**

ES can represent the functions and processes of different biota, which directly or indirectly promote human well-being (Alcamo, 2003). The significance and role of ES in water resources management have been thoroughly discussed in the last three decades (Costanza et al., 1997). Sustainable water management fundamentally relies on the stability of ecosystems and the continuity of these services (Guo et al., 2020).

Environmental challenges related to ES, such as water quality deterioration, eutrophication, soil erosion, and habitat destruction, are increasingly recognized in many water basins in Kazakhstan (Chislock et al., 2013). In parallel, the rapid population growth in Kazakhstan's urban centers, coupled with poor planning and development, has further deteriorated water-related ES.

Therefore, effective water resource planning must prioritize environmental water use and require accurate assessments of ES to ensure improved management of water resources (Liquete et al., 2011; Korsgaard & Schou, 2010). The water resource ecosystems' condition is a significant indicator of their health. Healthy ecosystems play a crucial role in preserving water quality, regulating water flow, mitigating floods, and maintaining the resilience of biodiversity (Shaad et al., 2022).

However, in many post-Soviet nations, including Kazakhstan, water resource planning frequently relies on top-down bureaucratic administrative systems often operated by personnel with limited knowledge and expertise in specific areas (Baitursunov, 2020). Also, input from diverse stakeholders is frequently disregarded (Djanibekov et al., 2016). This limitation results in a lack of comprehensiveness and representativeness in the planning process. Historically, the opinions of scientific experts regarding environmental impacts have often been overlooked in large infrastructural projects, and this trend continues to affect stakeholder engagement today (Mostovenko, 2020).

- **Practical Application of ES in Water Management**

Various case studies underscore the significance of integrating ES into water management practices. For example, incorporating ES into river basin planning has shown promise (Zhang et al., 2021), as has valuing water-related services in Australia (Vardon, 2019). However, perhaps most importantly, utilizing frameworks to align policies with UN goals (Kumar & Martinez-Alier, 2011) invokes a sense of global responsibility. These examples highlight the essential role of ecosystem assessments in informing and guiding decision-making processes (Burkhard, 2014).

- **Integrated Water Resources Management (IWRM)**

The ES-based management concept and Integrated Water Resources Management (IWRM) approach have been widely implemented over the last three decades in an attempt to incorporate ES into improved water management (Komatina, 2011). IWRM is a coordinated approach that harmonizes water, land, and resource management to achieve sustainable socio-economic development while preserving ecosystems (Komatina, 2011; Romer, 2014). Integrating stakeholder needs, IWRM promotes more coordinated and sustainable water resource management.

However, its implementation faces challenges such as unclear legal frameworks, abstract definitions, and resistance to change (Ako et al., 2009). Incorporating the ES concept into IWRM enhances its effectiveness by fostering active stakeholder engagement and addressing its traditionally top-down approach, grounding decisions in practical, ES-based considerations (Vlachopoulou et al., 2014; Vörösmarty et al., 2018).

Adopting an ES-based approach within IWRM transforms water resource management from a theoretical framework into a practical model incorporating specific, quantifiable ecosystem values and services (Liu et al., 2013). This shift enables policymakers to consider diverse stakeholder inputs while prioritizing ecological functions. Consequently, such an approach aids in mitigating risks, optimizing resource allocation, and ensuring that conservation efforts align with human and economic needs, ultimately leading to more sustainable and equitable outcomes in water management.

1.2 PROBLEM STATEMENT AND RESEARCH QUESTION

Kazakhstan currently faces severe water resource challenges, including a water shortage of up to 50% in the southern and western regions (Table G.2), declining water quality in the central and eastern areas, a continuous drop in the water level of Lake Balkhash, and desertification in the Aral Sea region. These issues primarily stem from inefficient water resource management and planning (Almas et al., 2023). However, there is significant potential for improvement, particularly in addressing two significant shortcomings:

- **Lack of Transparency and Data Quality:** The methods for generating data on water balance and environmental flow lack transparency, leading to incomplete water resource assessments, especially in some river basins where ecological needs are often overlooked in water allocation (Adilet, 2016).
- **Implementation Challenges of Regulations:** Although Kazakhstan has established environmental regulations and water management plans, their actual implementation is limited due

to insufficient funding and difficulties in accessing technology (Janusz-Pawletta & Gubaidullina, 2015; Ziganshina & Janusz-Pawletta, 2020; Xenarios et al., 2022).

These challenges can be attributed to three interrelated factors: the weak transformation of the water resource management system (Medetov et al., 2018), the inadequate design and enhancement of water resource planning institutions (Zhupankhan et al., 2018), and the neglect of ecological issues (Alimbaev et al., 2021). Understanding the historical context is crucial to grasp Kazakhstan's water resource management complexities fully. Historically, Kazakhstan's water resource management has undergone multiple transformations (refer to Appendix F). During the Soviet era, water resources in Central Asia were centrally controlled, primarily focused on large-scale irrigation projects, which led to severe environmental degradation (Ahrorov et al., 2012). For instance, the diversion of the Amu Darya and Syr Darya rivers significantly disrupted the Aral Sea's ecological balance (Islam, 2024). After the disintegration of the Soviet Union in 1991, Kazakhstan continued to follow Soviet-era irrigation policies, emphasizing technological and economic needs, further exacerbating environmental issues. Since 2000, although Kazakhstan has attempted to introduce the IWRM concept, it has faced multiple challenges, including insufficient coordination and low public participation (Zhupankhan et al., 2018).

Moreover, there is a lack of effective coordination between different strategic planning documents in water resource planning. Third-level implementation documents (such as water use quotas) often conflict with higher-level strategic documents, leading to implementation difficulties. Local water management institutions frequently lack the capacity and authority to accurately collect and analyze comprehensive water body data (Ziganshina & Janusz-Pawletta, 2020). Neglecting ecological issues further exacerbates environmental degradation and the overexploitation of water resources in the country. Insufficient attention to ecological problems has led to ineffective ecological management measures, undermining the foundation for sustainable water resource utilization (Sarpong et al., 2020; Dhaouadi et al., 2022; Banaduc et al., 2022).

Consequently, addressing the dual challenges of water scarcity and environmental degradation in Kazakhstan urgently requires comprehensive water resource management tools that can provide adequate information to central water management authorities while ensuring the sustainability of water resources. This study encourages the implementation of an ES-based approach that emphasizes the integrated management of all ecosystem resources, aiming to maintain ecological integrity while promoting sustainable use of resources (Olander & Maltby, 2014; Moore et al., 2017). Implementing ES-based management strategies—such as prioritizing land use planning that safeguards ecosystems, investing in advanced wastewater treatment infrastructure, and adopting environmentally sensitive methods for water resource development—can significantly bolster resilience to climate change (Biggs et al., 2012; Hossain & Liam, 2024).

Although research on the relationship between ES and planning has gradually increased, particularly in urban and land-use contexts (Woodruff & BenDor, 2016; Cortinovis & Geneletti, 2018; Langemeyer et al., 2016), studies on the application of ES in water resource planning remain relatively limited and nearly non-existent in Kazakhstan. Most existing literature has focused on urban management and land use, leaving a gap in understanding how ES can effectively support water resource planning (Lautenbach et al., 2012). Current research lacks a mature theoretical framework explaining how ES can promote water resource management, with only a few case studies providing preliminary insights (Maynard et al., 2010; Saarikoski et al., 2018). Therefore, integrating ES into water resource planning is essential for fostering sustainable management practices and optimizing decision-making processes.

This research centers on the role of ESV in water resource planning within the ES-based approach based on the SEEA-EA valuation to selected techniques to assess critical ES in Kazakhstan's water systems. ESV functions as a methodological framework that quantifies the economic value of ecosystem services, emphasizing their essential contributions to human welfare and sustainable development. Additionally, it aids in informed decision-making for resource management (Li et al., 2018; Liu et al., 2010; Sannigrahi et al., 2019).

Building on this foundation, this study poses the following research question: How can ESV enhance water resource planning in Kazakhstan? This inquiry not only targets the specific application of ESV but also investigates its potential to improve the efficiency and sustainability of water resource management. By addressing this question, the research aims to provide insights into optimizing water resource strategies through the lens of ES and effectively improve the relevant policies.

To further clarify the direction of the research, this study proposes the following hypothesis: ESV approaches can serve as solid evidence for water resource planning, along with the support of institutional norms, capacities, and enabling decision-making bodies. This hypothesis is formulated based on the following theoretical frameworks:

- **Policy Cycle:** Langemeyer et al. (2016) investigate the role of ES in water resource planning decisions and propose a framework that illustrates the impact of ES within the policy cycle. Similarly, Moore et al. (2017) create a framework from the policy cycle perspective, clarifying

ES's role in natural resource management decisions. However, the applicability of these frameworks has limitations, as they do not fully address the specific needs and complexities of water resource management.

- **ES Based Decision Making (EBDM):** EBDM is a public policy decision-making framework that emphasizes using ES assessments as evidence in decision-making processes (Moore et al., 2017). EBDM integrates ecological knowledge and stakeholder participation across various stages, including agenda-setting, policy formulation, implementation, and evaluation as well, to facilitate effective dialogue between science and policy, thereby enhancing the legitimacy and effectiveness of policies (Chen et al., 2023; Laurans et al., 2013). Decision-makers must consider various factors, such as the decision environment, resources, and external influences, to ensure the adequate representation of ecological values and address inequalities (Turner, 2016; Mahaputra, 2022). EBDM aims to support sustainable development goals and enhance human well-being through interdisciplinary approaches and comprehensive valuation techniques.

By integrating these theoretical frameworks, this study explores how ES can effectively enhance the quality and effectiveness of water resource management decisions within a complex policy environment.

The primary contribution of this study lies in its comprehensive review of ESV methods in Kazakhstan, elucidating the challenges and opportunities faced by ES-oriented approaches. Additionally, the case study of the Astana Reservoir represents the first pilot study in Kazakhstan to apply integrated environmental and economic accounting methods, providing practical significance not only for the water resource planning of the Astana Reservoir but also offering a model for other developing countries. Third, the study offers some practical and actionable recommendations to improve Astana's currently unsustainable water practices by offering lessons for other cities and regions in the country facing similar challenges. Also, by combining ecosystem service assessment with water resource planning, this study aims to provide theoretical support and practical guidance for achieving more sustainable water resource management.

1.3 MATERIALS AND METHODS

This study followed an explanatory sequential research framework (Al-Mawali, 2016; Kandiero, 2022) to comprehensively assess the Astana Reservoir's ecosystem services and explore ESV's role in Kazakhstan's water resource planning. To achieve this objective, the study employed the System of Environmental-Economic Accounting (SEEA) methodology.

SEEA is a universal framework introduced by the United Nations for accounting for natural resources and ecosystem services. Since its introduction, SEEA has undergone pilot studies in multiple countries and several revisions, with an updated version released in 2021 (Tomas et al., 2017; CICES, 2011). SEEA includes multiple accounting accounts featuring a comprehensive central framework and particular sub-frameworks for different sectors, such as water and energy. Indicatively, the SEEA-EA (Ecosystem Accounting) sub-framework integrates biophysical information about ecosystems and measures the relationship between their services and human activities (SEEA-EA, 2021). The SEEA-EA enables systematic tracking of ecosystem changes and valuation of ecosystem services, rendering it widely applicable globally. Since its introduction, SEEA has undergone pilot studies in multiple countries and several revisions, with an updated version released in 2021 (Tomas et al., 2017; CICES, 2011).

This study has introduced SEEA-EA, which was incorporated into the wider ESV approach established by Turner et al. (2000) and was adjusted according to the characteristics of the case study. The ESV provides a systematic approach for analyzing the ES offered by the Astana reservoir and the contribution of critical ecosystem services to sustainable water resource management. The research is structured into five main phases, detailed as follows:

Phase One: Analysis of Current Water Planning in Astana

Phase 1 of the research involved a background analysis of Kazakhstan's water resource planning and management, focusing on Astana city. Using the ROSES framework for systematic reviews (Haddaway et al., 2018; Mengist et al., 2019), the study identified shortcomings in Kazakhstan's water resource planning and evaluated the impact of related policies and management strategies on the Astana Reservoir.

The investigation encompassed the overall state of water resource planning, the specific conditions in Astana, and the effectiveness of current measures. It tracked the water supply from the reservoir to various sectors since the city's establishment, taking into account factors such as population growth and hydrological, climatic, and economic influences.

A thorough literature search was conducted, filtering for recent and relevant studies while applying quality screening criteria to ensure the reliability of the sources. The key findings were synthesized through comparative analysis and presented in a structured review, highlighting the current state and critical water resource management insights in Kazakhstan and Astana. Although there were some limitations regarding data consistency and the availability of literature, the study prioritized recent, peer-reviewed sources and firsthand information to maintain relevance and accuracy.

Phase Two: Identification of Key Functions of Astana Reservoir

The second phase of the research identified the critical functions of the Astana Reservoir by analyzing its structure, characteristics, and biophysical processes (Turner et al., 2010). To evaluate the area's ecological health, a comprehensive assessment of land cover and ecosystem types was conducted, focusing on key attributes such as water quantity, quality, and soil composition. This analysis provided major insights into the reservoir's overall condition and capacity to deliver ecosystem services.

To further explore the ecological dynamics that influence the reservoir's functions, the study employed relevant hydrological and soil models to examine biophysical transformation processes. In terms of data collection, a combination of remote sensing technologies was utilized to gather information on land cover and ecosystem types, laying a solid foundation for subsequent analyses. Remote sensing offered extensive geographical data and enabled rapid acquisition of information, while field surveys were conducted to validate the accuracy of the remote sensing results.

However, the interpretation of remote sensing data could be affected by weather and environmental conditions, leading to potential sample selection bias (Bolliger et al., 2017). To address these challenges, this study incorporated multiple data sources, including remote sensing data and information provided by local water management and meteorological agencies, and conducted comparisons to ensure the reliability of the data.

Phase Three: Classification and Analysis of Ecosystem Services

In the third phase of the study, a comprehensive examination of the ecosystem services provided by the Astana Reservoir was undertaken. The research initially assessed the physical and chemical characteristics of the reservoir, including water quantity, soil erosion, and water quality parameters (such as pH, biochemical oxygen demand [BOD], and chemical oxygen demand [COD]) while also analyzing changes in ecological status from 2000 to 2019. Through the exploration of the reservoir's economic utilization and relevant ecosystem service classification standards, the study identified the types of ecosystem services offered by the reservoir. These services primarily include the provision of drinking water and fish products for Astana and surrounding areas, regulation services such as water storage, purification, flood control, and soil protection, as well as the recreation service (TEEB, 2010). The research employed a variety of indicators to systematically evaluate the health status and ecological functions of the reservoir, providing foundational data for understanding its importance in regional ecology and the economy.

The study analyzed physical indicators of water quantity (such as inflow and outflow rates) and chemical indicators of water quality to evaluate the reservoir's ecological health and service capacity thoroughly. The study assessed the reservoir's environmental health and service capacity by analyzing physical and chemical indicators and utilizing water quantity and quality measurements. However, it is essential to note that seasonal variations may have influenced these measurements, resulting in short-term data that might not accurately reflect long-term trends. By acknowledging this limitation, it is considered that even moderately deviated measurements can help estimate the relevant findings.

Phase Four: Economic Assessment of Ecosystem Services

The fourth phase of the study concentrated on the economic evaluation of the ecosystem services provided by the Astana Reservoir, a crucial step in justifying investments in protecting and restoring these ecosystems. Various assessment methods were employed, including direct market pricing for provisioning services like water supply, cost-avoidance, opportunity cost for regulating services related to water purification, and travel costs for recreational services. By utilizing these approaches, the research provides a comprehensive economic assessment of the ecosystem services offered by the Astana Reservoir. This assessment is intended to inform resource allocation and underscore these services' vital role in supporting healthy ecosystems for local communities (Davis & Slobodkin, 2004).

To carry out the assessment, the study analyzed relevant market data and local economic statistics to determine the economic value of different ecosystem services. While these economic assessment methods effectively convert ecosystem services into monetary values and offer a quantitative basis for policy-making and resource allocation, they may not fully capture non-market values, particularly cultural and ecological aspects.

Phase Five: Feedback Analysis of Integrating Ecosystem Approaches

In the final phase of the research, semi-structured interviews were conducted to gather stakeholders' perspectives on integrating ESV into water resource planning. A purposive sampling strategy was employed to ensure a diverse range of viewpoints from government departments, non-governmental organizations, local community members, and water resource management experts. The interviews were conducted either online or in person, with strict confidentiality maintained throughout the data collection and analysis processes. NVivo software was utilized for coding and analysis.

The qualitative analysis captured insights that might be overlooked by quantitative data and facilitated collaboration among stakeholders. Preliminary findings revealed several challenges in Kazakhstan's water resource management, including aging infrastructure, inadequate information sharing, neglect of ecosystems, and insufficient watershed monitoring. To address these issues, the research emphasized the need for comprehensive water resource accounting, improved data collection methods, and increased ecological awareness.

While the semi-structured interviews yielded valuable insights, they could have been influenced by participant biases, and the interview design might have limited data comparability. To mitigate these challenges, a standardized question framework was implemented to ensure consistency, and a thematic analysis was conducted after the interviews to extract key points and recommendations. Confidentiality was prioritized to encourage participants to share their honest perspectives.

Through a systematic investigation across these five phases, along with an analysis of the strengths and weaknesses of each phase's methods, this study provides a comprehensive and in-depth understanding of ecosystem service assessment for the Astana Reservoir. By implementing strategies derived from the literature review, the study ensured the accuracy and reliability of the data, thereby offering scientific evidence and recommendations for future water resource management policy formulation.

1.4 STRUCTURE OF THE DISSERTATION

This research provides strong theoretical support and empirical evidence for valuing ecosystem services in water resource management. Chapter 1 serves as the introduction, outlining the research background, clarifying the research questions and their significance, detailing the materials and methods employed, and laying out the structure of the dissertation.

Chapter 2 presents a literature review that explores the current state of water resource planning, including environmental considerations and economic benefits within a multi-dimensional decision-making framework. This chapter also analyzes decision-making theories in public policy, with a specific focus on evidence-based policy-making (EBPM), and discusses the evidence required to enhance water resource planning, emphasizing IWRM and its connection to ES.

Chapter 3 introduces the theoretical framework, which outlines essential elements for evidence analysis. It presents a decision-making framework based on ecosystem services to support scientific decision-making in water resource management.

Chapter 4 details the research methods used, including the application of the SEEA-EA framework, the Astana Reservoir as a case for data collection, and the stages of research design. This chapter describes the steps of systematic and rigorous analysis, progressing from background analysis to the economic valuation of ecosystem services.

Chapter 5 presents the results, highlighting key findings such as the mapping of water resource management and planning in Kazakhstan, the functional analysis of the Astana Reservoir, the classification and economic valuation of ecosystem services, and insights from semi-structured interviews regarding the integration of ecosystem service valuation into water resource management.

Chapter 6 discusses the current state of water management and planning in Kazakhstan, examines the status and economic valuation of ecosystem services in the Astana Reservoir, and addresses the application of the SEEA framework in Kazakhstan's water resource management, analyzing the challenges and opportunities encountered.

Finally, Chapter 7 concludes the study by summarizing the primary outcomes, proposing policy recommendations, and discussing the contributions to theory and methodology.

Chapter 2

Literature review

2 LITERATURE REVIEW

This chapter provides a comprehensive literature review covering critical points related to ecosystem services and water resource planning. Firstly, it starts with literature from environmental planning (EP) to delve into the vital role of water resource planning in environmental planning. Environmental planning is a rational decision-making process that integrates various factors, including land management, regulatory control, and interdisciplinary stakeholder interaction, to achieve sustainable development (Beathley, 1995). Water resource planning is an integral part of environmental planning, focusing on effectively managing water resources while considering economic, social, and environmental goals and actively promoting stakeholder involvement in the decision-making process (Matthew, 2017).

Secondly, in light of the transition in water resource planning from an economically driven approach to a multidimensional decision-making framework, this study conducts a literature review on public policy decision-making theory. It discusses several public policy decision-making models, including the rational incremental, comprehensive, bounded rationality, and garbage can and other models. It also explores the limitations and criticisms of these models in practical applications. Finally, the study advocates for an Evidence-Based Policy Making (EBPM) approach to facilitate effective decision-making in water resource planning, emphasizing that policymaking should be grounded in scientific evidence and rational analysis.

Subsequently, a detailed review of the compelling evidence for enhancing decision-making in water resource planning is provided, introducing two essential water management tools: Integrated Water Resources Management (IWRM) and Ecosystem Services (ES). IWRM is recognized globally as a water governance approach that emphasizes the coordinated development and management of water, land, and related resources; however, it faces challenges in implementation due to a lack of legal foundations and abstract definitions. The ecosystem-based approach complements IWRM by providing a more comprehensive resource management perspective through Ecosystem Services Valuation (ESV), fostering collaboration among decision-makers and stakeholders, and enhancing the efficiency and sustainability of water resource management.

Lastly, it thoroughly explores ecosystem services valuation, including their definition, classification, and sources. It elaborates on the crucial role of ecosystem services in water resource planning, emphasizing ecosystem-based water resource management methods. These methods utilize tools such as ecosystem services indicators, payment schemes, multi-criteria decision analysis, and environmental economic accounting to ensure the sustainable use of global water resources, which is crucial for the long-term sustainability of water resources. Valuation methods for ecosystem services include environmental accounting, international environmental accounting case studies, and monetary valuation methods. This review describes the evolution of environmental-economic accounting, the application of natural resource accounting in different countries, and various approaches to ecosystem services assessment, such as market assessment, revealed preference assessment, and stated preference assessment.

2.1 OVERVIEW OF WATER PLANNING

Water resource planning is a branch of environmental planning; thus, this section begins by providing an overview of various aspects of environmental planning, including its theoretical foundations, decision-making processes, strategic planning methods, and challenges in policy integration and institutionalization. It then outlines the crucial role of water resource planning in environmental protection and sustainable development. It emphasizes its core objectives of enhancing water resource utilization efficiency, improving well-being, and identifying various factors influencing water resource planning. Finally, it highlights the evolution of water resource planning from emphasizing economic benefits to a comprehensive decision-making process considering political, economic, environmental, and social dimensions to achieve sustainable development and environmental protection.

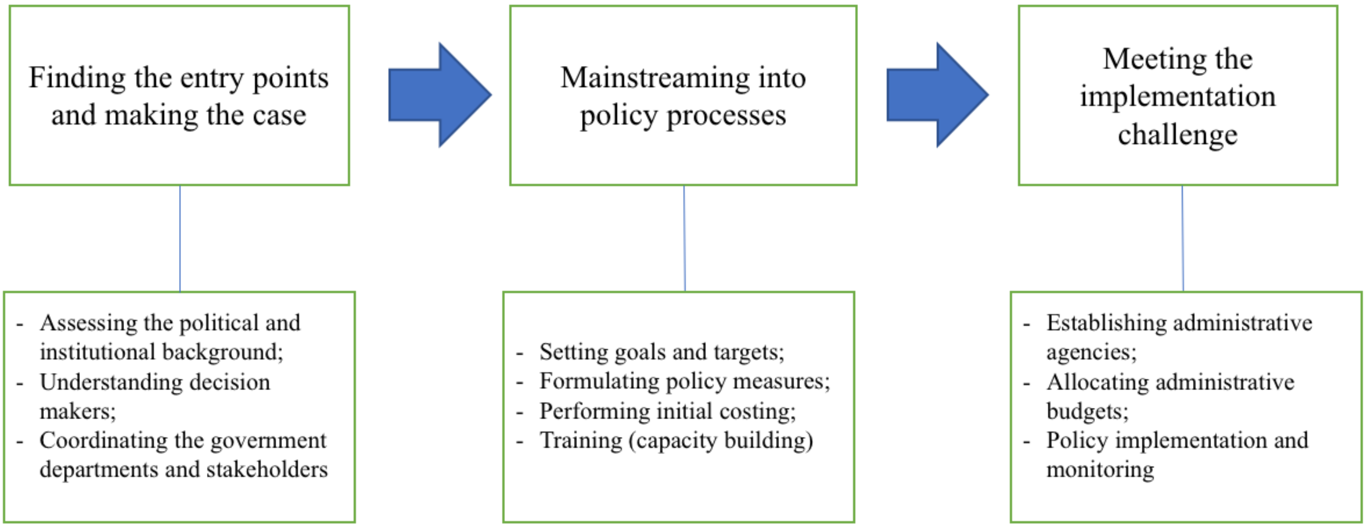
2.1.1 ENVIRONMENTAL PLANNING

Environmental planning (EP) is a rational decision-making process that aims to achieve sustainable development while considering political, social, and economic factors (Beathley, 1995). The narrow definition of EP focuses on several aspects, such as land management planning, legislative control, and economic incentives. EP also involves conceptualizing environmental issues, encouraging local public participation, and the integration of environmental governance through interdisciplinary and stakeholder interactions (Paul, 2002). However, the above definition of EP is either too general or only captures one aspect. Garry (2006) first defines the scope of the environment by using three colors - green for biodiversity, blue for water resources, and brown for human activities impact on the environment. He then proposes the following definition based on Daniels's (2009, p. 178) definition of environmental scope:

"Environmental planning is the theory and practice of making good, interrelated decisions about largely unmodified environments, environments exploited for resources, environments receiving human-produced wastes and toxins, and elements of the built environment that serve some environmental function. These decisions include immediate ones where development proposals have significant environmental implications and strategic plans and policies related to future development proposals."

Garry (2006), through an analysis of the relationship between environmental planning and environmental management, explains that EP includes strategic plans, management plans, and policies. The relationship between these three can be analyzed through the following literature. Hazemba and Halog (2021) summarized the main steps of EP through a review of the research on the "national environmental planning" of various countries (Figure 2.1). It begins with "finding the entry points and making the case," which involves assessing the national institutional and political background, understanding decision-makers, and coordinating between government departments and stakeholders (Hazemba & Halog, 2021, p. 4). Due to the complexity, variability, and transnational nature of environmental issues, the inclusion of "environmental issues" in the "National Development Plan" (or "environmental mainstream") is considered an essential starting point for achieving national sustainable development (OECD, 2012, p.89).

Figure 2.1 Main Steps of Environmental Planning



Source: adapted from Hazemba & Halog (2021).

The next step is incorporating environmental objectives into policy processes, such as national development plans or sectoral strategies. This stage also requires setting goals and specific targets for specific sectors, developing implementation plans, and using advocates within government institutions to persuade policy-makers of the benefits of mainstreaming the environment. For example, environmental policies such as the US Clean Air Act, Clean Water Act, or the EU's Environmental Action Plan contribute to establishing regulatory frameworks to address air and water pollution and promote clean technologies and energy use. Once environmental objectives are incorporated into policy processes, policy measures are formulated, and initial cost accounting is carried out. Capacity building, information sharing analysis, further training, and demonstration projects are all necessary in mainstreaming. Timing is critical because presenting evidence and reasons after government and departmental working groups have already decided on the subsequent development plan or strategy could be counterproductive (UNEP, 2009). Finally, "meeting the implementation challenge" refers to establishing administrative agencies or allocating administrative budgets, policy implementation, and monitoring (Hazemba & Halog, 2021, p. 5).

Taking the strategic environmental planning and green plans of OECD countries as an example, Janicke and Jorgens (2000) examined the green plans of OECD countries based on the three aspects of “the accuracy and relevance of environmental goals, the degree of integration of the planning process and the institutionalization of the plan” (Janicke & Jorgens, 2000, p. 619). They found that the goals of most countries' plans are qualitative and vague, mainly based on national obligations formulated by international agreements and laws, such as the percentage reduction of carbon emissions (the United Kingdom, Finland, Japan, Austria, etc.). A few countries have developed detailed plan completion time frames and quantitative indicators, such as Sweden and Canada, in the planning process, the primary lead department of these countries is the Ministry of the Environment (SEPA, 1997). Each country varies according to its departmental structure. For example, Switzerland has established an "inter-departmental committee", the Dutch government has designated four departments: "The Ministry of the Environment, the Ministry of Agriculture, the Ministry of Industry, and the Ministry of Transportation," to work together to formulate plans, and the United Kingdom has established a "Sustainable Development Roundtable" and a "Sustainable Development Government Group" (OECD, 1993). At the same time, all government departments in the United Kingdom must set up corresponding "green ministers" (Wilkinson, 1997b; Janicke & Jorgens, 2000, p. 623). Regarding the institutionalization of green planning, the inefficiency of long-term environmental planning has been caused by the contradiction between the time frame of the planning and the term of office of the government and the legislative period. The institutionalization here includes the legislative basis of the green plan, the establishment of corresponding administrative agencies, mandatory evaluation reports, and financing plans. However, even OECD countries have difficulty meeting the above-institutionalized conditions (OECD, 1995b).

2.1.2 WATER RESOURCE PLANNING: FROM ECONOMIC BENEFITS TO MULTI-DIMENSIONAL DECISION-MAKING

Water resource planning (WP) is crucial in environmental planning and cornerstone of national water resource management and sustainable development. To effectively manage water resources, it is essential to have a comprehensive understanding of the water resource system, including natural hydrological systems, human socio-economic activities, and water resource management and regulatory frameworks (Matthew, 2017).

The core objective of WP is to enhance water resource utilization efficiency, improve the nation's welfare, and prioritize environmental protection (UNSD, 2003; Jain & Singh, 2003). This objective involves rational planning, effective allocation, and optimized utilization, including water resource development (Mahima & Gurpreet, 2019). However, due to the profound impact of socio-economic activities on water resource systems, WP needs to comprehensively consider current and future water resource demands, especially from a sustainability perspective (Manawatu et al., 2021).

It is worth noting that water resource planning aims to uphold green development, balancing economic growth with ecological health. Therefore, the logic of WP integrates macroeconomic forecasting models and water resource system models for decision-making. Specifically, this includes water environment analysis reports, calculation of marginal costs for various types of water, and decision-making regarding investment allocation, water supply quotas, and environmental water usage, considering factors such as macro-industrial structure and income levels. Additionally, the WP process must involve stakeholders since their needs, consumption, and feedback are crucial information (Schramm, 1980).

The "Water Resource System Development Objectives" summarized by Hall and Dracup (1970) can provide guidance to achieve these objectives. They include ensuring the fair distribution of water resources between nations and regions at the macro level and achieving the first two objectives at the micro level through the most economical resource allocation (Hall & Dracup, 1970; UNSD, 2003).

Specifically, WP involves assessing, allocating, and balancing water resources under the guidance of water policies, tasks, and goals, considering their impacts on economic, social, and environmental factors (Zuo et al., 2014). Thus, WP is a complex and comprehensive process that aims to achieve efficient resource utilization, sustainable development, and environmental protection.

WP has evolved, reflecting changing priorities and societal values. Originating in the 19th century, it primarily focused on meeting human needs and maximizing economic benefits. However, in the 20th century, multiple uses of water resources were recognized, including fulfilling the needs of aquatic ecosystems (Maass et al., 1966).

By the 1960s, applying the "cost-benefit method" significantly shifted water resource planning approaches. This method involved designing various alternative schemes in line with water policy objectives and assessing their economic feasibility through systematic evaluations. However, this approach posed challenges as environmental costs and benefits were difficult to account comprehensively (Loucks et al., 1981).

As WP progressed, the involvement of stakeholders became increasingly important. Their active participation transformed water resource planning from a narrow focus on maximizing economic benefits to a comprehensive decision-making process covering political, economic, environmental, and social objectives (Matthew, 2017). This shift reflects changing societal values. For instance, in 1979, the United States Federal Water Resources Planning Act explicitly recognized the two primary objectives of water resource planning: "National Economic Development Goals" and "Environmental

Quality Goals" (Zuo et al., 2014), highlighting the growing importance of environmental quality in WP.

In conclusion, WP has undergone significant changes, evolving from economically driven efforts to a multidimensional decision-making process encompassing political, economic, environmental, and social objectives. Recognizing environmental quality as a critical element in contemporary water planning reflects the changing landscape of societal values and priorities.

2.2 DECISION-MAKING IN PUBLIC POLICY

The previous section elaborated on the historical changes in WP's goals, basic principles, and decision-making processes, illustrating the transition of WP from previous economic-oriented approaches to multidimensional decision-making. Therefore, from the perspective of public policy, this section will delve into various decision-making theories and principles of evidence-based policymaking (EBPM). This will provide a theoretical understanding of the complex process of formulating water resource plans.

In the realm of public policy, the decision-making process is integral to the broader policy-making framework, often referred to as "policy choice". During the policy formulation phase, this process entails a thorough analysis and discourse surrounding prevailing policy issues and potential solutions, culminating in the identification of multiple viable alternatives (Gary & Peter, 1983, p. 179; Howlett et al., 2020, p.182). Subsequently, in the decision-making stage, policymakers are tasked with evaluating these alternatives to determine their acceptance or rejection (Gültekin, 2014). As a result, scholars have formulated an array of policy decision-making models to illustrate the dynamics of this "policy choice" process (Howlett et al., 2020).

2.2.1 DECISION MAKING THEORIES IN PUBLIC POLICY

The more acknowledged decision-making models in public policy can be categorised into early rational incremental, comprehensive and bounded-rationality, incremental, mixed-scanning, garbage can, and decision accretion (Howlett et al., 2020, p.191). Firstly, based on "empiricism" and "rationalism," the comprehensive rationality model was introduced with the assumption of the "economic man". This model seeks to make decisions through a scientific policy-making process and complete information. Its implicit premise is that rational individuals can "maximize" and "scientifically" gather and understand comprehensive information about natural laws and social phenomena. However, the rational decision-making process is often troubled by poorly defined problems, conflicts among diverse values and goals, uncertainty, and sunk costs.

The American behavioral scientist Herbert Simon criticized the comprehensive rationality model, arguing that in the process of public decision-making, decisions are constrained by the individual capabilities of policymakers, making it challenging to achieve cost-effectiveness maximization. In the 1950s, Simon introduced the bounded rationality model, highlighting that in real-life scenarios, the "administrative man" possesses only "bounded rationality". Decisions are often influenced by psychological, diverse values, organizational, cost, and situational constraints (Simon, 1955).

Furthermore, policy analysts face significant challenges regarding time and energy when following the procedural requirements of rational decision-making. Therefore, bounded rationality reflects the human decision-making process based on their "satisfaction" criteria. The bounded rationality model is more practical than the comprehensive rationality model. However, its starting point remains managerial, overlooking the influence of political and institutional factors on public decision-making.

Specifically, rational decision-making models face criticism on two main fronts. First, the logical assumption of rational models is to establish consensus on goals and seek the best solutions based on those goals. However, reaching a consensus on goals in a political environment is challenging and may even be intentionally obscured (Birkland, 2001, p. 210). Second, rational decision-making models often rely on "cost-benefit analysis", but in a political environment policy effectiveness is difficult to measure with a single indicator (Dye, 1992, p.33). Ultimately, rational decision-making models overlook the political nature of policy formulation and neglect conflicts and coordination among actors and stakeholders in values, preferences, and goals.

Lindblom, approaching from the perspective of the practical political environment, introduced the incremental model. In contrast to the "root approach" advocated by the comprehensive-rationality model, which emphasizes scientific, systematic, comprehensive, and goal-oriented methods, the incremental model proposes a "branch method" that advocates improvements based on existing foundations, emphasizing a means-oriented approach (Lindblom, 1968; Guo et al., 2003, p. 41). The incremental model explains partial public policy decisions and accurately describes the reality of political life, indicating that many public policies are reached through negotiation and mutual compromise, reflecting an ongoing process of feedback and correction. However, criticisms of the incremental model include its difficulty in application to war or major innovative reforms. Additionally, the model's conservatism turns the policy-making process into a "circular and directionless" endeavor (Forester, 1984, p.23).

In response to criticisms of rational models and the incremental model, Etzioni (1967) combined the two to propose the mixed-scanning model. The mixed-scanning model consists of two stages. The first involves scanning all alternative solutions based on the decision-maker's experience and preference, using a political “heuristic" model (Howlett et al., 2020, p. 274). It aims to determine a rough policy direction within the established political environment by studying the preferences of political participants, predicting the outcomes of potential policy options, and considering historical cases and the decision-maker's experience. The second stage involves a "rational" analysis of the preselected policy options, applying limited rationality and a "satisficing" standard for decision-making. Criticisms of this model include its theoretical nature, making it challenging to implement in reality.

The garbage can model, proposed by Cohen, March, and Olson in 1972, criticizes the determinism and theoretical nature of rational and incremental models. It highlights phenomena such as "problematic preference", "unclear technology", and "fluid participation" in the actual policy decision-making process, where decisions are unknown and random. In this model, elements like "problem", "solution", "participant", and "opportunity" flow within the "policy agenda" garbage can, converging to create a policy window and leading to decision formation (Cohen et al., 1972). The garbage can model represents an initial exploration into organizational and institutional analysis, asserting that "organizations are complex" (Birkland, 2001). Furthermore, members of organizations may not have a clear understanding of the entire organizational vision, and even their own goals and preferences may sometimes be vague. The garbage can model, rooted in post-positivist epistemology, moves beyond the quantitative analysis of rational models, focusing on the "quality" of different policy choices from the perspectives of the organizational environment and institutional structure, exploring the "meaning" of policy choices through the "observations of participants" in various dimensions (Denzin & Lincoln, 1998, p. 25).

While the garbage can model of organizational decision-making has had a significant impact, it has faced criticism due to its uncertainty and metaphorical nature (Mucciaroni, 1992; Glynn et al., 2020). Critics argue that the model fails to provide a satisfactory explanation for agenda-setting in policy formulation (Mucciaroni, 1992). Researchers have suggested various improvements to address these limitations, such as modeling the arrival of problems, solutions, and participants as a queue, which offers more profound insights into organizational hierarchies and problem-solving approaches (Glynn et al., 2020). Applying this model in public sector management control has revealed how conflicting institutional arrangements can hinder fundamental change and lead to unexpected outcomes in customer-oriented work (Wiesel et al., 2011). Despite these criticisms, the garbage can model remains significant in organizational theory, policy-making, administrative reform, and institutional theory, with its core elements—problematic preferences, ambiguous technologies, and fluid participation—continuing to influence research (Jann, 2015).

The decision accretion model, proposed by Weiss (1980, p. 390), also examines complex decision-making from the organizational structure perspective, emphasizing that intricate decisions are made incrementally across various departments within an organization. In real-world public decision-making, even minor decisions often undergo scrutiny and approval from multiple government departments. This illustrates that public decisions emerge through cycles of involvement and feedback from different participants in various fields, whether administrative or political, all contributing to decision-making within the organizational framework. This model reflects the complexity of decision formation in public decision-making and decision-maker involvement.

The incremental, garbage can and accretion models discussed above provide a broader perspective on the decision-making process. However, their criticisms of rationalism contribute to heightened tension between researchers and policymakers (Guo et al., 2003, p. 43). This tension can be seen as a reflection of the relationship between scientific knowledge (analysis of policy) and practical policymaking (analysis of policy) (Howlett & Ramesh, 1995). To understand the relationship between the two, an analysis of the sources of policy advice is necessary. Decision-makers, when making policy choices, often receive policy advice from internal bureaucratic agencies, external think tanks, or research institutions (Craft & Howlett, 2014). The nature and timeliness of the advice can be classified into four types, as shown in the Table 2.1 (Howlett et al., 2020).

Water resource planning, as a substantive and long-term issue, tends to favor evidence-based policy making (EBPM). Decision-making in water governance is influenced by the background of using and understanding evidence, emphasizing the need to address the complexity of water governance through evidence-based approaches (Heikkila, 2016). However, the effectiveness of relying on scientific evidence to provide information for decision-making in regulating water resources and addressing socio-economic impacts has been questioned (Papas, 2016). Therefore, for complex water policy decisions, it cannot be said that a purely singular approach can determine the outcome. However, this study provides the most effective decision evidence by prioritizing ecosystems from the substantive perspective of water resource planning. Below is a detailed overview of EBPM (Table 2.1).

Table 2.1 Policy advice and advisors organized by policy content

	Short-Term/Reactive	Long-Term/Anticipatory
Procedural	***"Pure" Political and Policy Process Advice*** Political parties, parliaments and legislative committees; regulatory agencies As well as Internal as well as external political advisors, interest groups; lobbyists; mid-level public service policy analysts and policy managers; pollsters	***Medium to Long-term Policy Steering Advice*** Deputy ministers, central agencies/executives; royal commissions; judicial bodies As well as Agencies, boards and commissions; Crown corporations; international organizations (e.g., OECD, ILO, UN)
Substantive	***Short-Term Crisis and Firefighting Advice*** Political peers (e.g., cabinet); executive office political staffs As well as Expanded ministerial, legislative staffs; cabinet committees; external consultants; political strategists; pollsters; community organizations/NGOs; lobbyists, media	***Evidence-Based Policy-Making*** Statistical agencies; senior departmental policy advisors; strategic policy unit; royal commissions As well as Think tanks; scientific & academic advisors; open data citizen engagement driven policy initiatives/web 2.0; blue ribbon panels

Source: Howlett et al. (2020, p.185).

2.2.2 EVIDENCE-BASED POLICY MAKING (EBPM)

Even though EBPM can be traced back to the Enlightenment movement in the 17th century (Sanderson, 2003), marking the application of knowledge to political decision-making, it is in the 1960s that social science knowledge emerged as an institutionalized component of policy decision-making. Despite skepticism about the effectiveness of social science in decision-making in the 1970s-80s, the development of evidence-based medicine in the 1990s spurred rapid growth for EBPM (Davies & Nutley, 1999). In the United Kingdom, there was a growing emphasis on the "scientificity" of policies. With the Blair government's publication of the "Modernizing Government White Paper" and "Professional Policy-Making in the 21st Century," EBPM was officially adopted as a policy-making principle, extensively applied in areas such as healthcare, education, and crime prevention under a "government-led" approach (Wyatt, 2002).

The core of EBPM's definition lies in the evidence-based decision-making process, aiming to make government policy actions more rational and largely based on "wise evidence" (Sanderson, 2002). Tennant and Clayton (2002) detail the EBPM process, emphasizing rigorous methods (clear and transparent indicators) and rational analysis to ensure the provision of optimal policy options, achieving the most effective use of public resources. Davis (1999) views EBPM as an activity that is both strategic and operational, serving as evidence for policy formulation, monitoring, and evaluation, as well as a strategy for discourse and communication. In summary, EBPM is a process grounded in rationalism that applies the power of professional knowledge to provide effective evidence for policy formulation, decision-making, execution, and evaluation.

It is evident that the primary principle of EBPM is "strong evidence". The definition and types of evidence can vary (Table 2.2), but the rigor of evidence is mainly explained in two ways. The first emphasizes that evidence must strictly adhere to scientific rules, such as conducting randomized controlled trials (RCTs) to derive credible evidence through comparisons (Heinrich, 2007; Baron, 2018). For example, Sanderson and Pawson argue that "wise evidence" refers to research results with high quality and scientific rigor that can be effectively utilized by policymakers ("what works") (Sanderson, 2002; Pawson, 2002). The second interpretation includes both scientifically composed "hard evidence" and "soft evidence," such as "personal experience, consultation, expert opinions, political judgment, norms, and values" (Marston & Watts, 2003; Head, 2010).

Table 2.2 Types of Evidence for EBPM

Author/organization	**Types of evidence**
Pawson	1. Able to provide academic/research knowledge about "what works"; 2. Professional and institutional experience (techniques) on "what works" in actual decision-making, that is, the knowledge that government departments and agencies can better promote the development of management systems.
Head	1. Political knowledge and judgment. It primarily includes analysis of political actions such as adopting and adapting strategies or tactics, setting agendas, deciding priorities, persuading and advocating, communicating key messages and ideologies, shaping and responding to accountability issues, building support coalitions, and coordinating and compromising judgmental behavior; 2. Scientific (research-based) knowledge. Mainly refers to a series of disciplinary and interdisciplinary knowledge (economics, law, sociology, public management, evaluation, etc.) that can promote policy and project improvement. Among them, RCTs are regarded as the most rigorous methods in the policy field; 3. Practical implementation knowledge. Mainly refers to the experience of managers and experts in project management and execution.
Marston & Watts	"Hard evidence" includes: 1. First-hand quantitative data collected by researchers through experimental methods; 2. Secondary quantitative data collected by government agencies; 3. Interviews or social surveys based on questionnaires; "Soft evidence" includes: Qualitative data such as ethnographic and autobiographical material.
Suteliffe & Court	Evidence gathered through a systematic process: 1. Critical investigations and assessments; 2. Theory construction; 3. Data collection; 4. Analysis and compilation related to policy and practice developments; 5. Behavioral research.
Evidence-based policy-making practices of the UK Blair government	1. Expert knowledge; 2. Existing domestic and international research; 3. Existing data; 4. Stakeholder consultation; 5. Evaluation of past policies; 6. Appropriate new research; 7. Secondary information from the Internet; 8. Analysis of consultation conclusions; 9. Cost of policy options; 10. Results of economic or statistical models.
PART policy of the Bush administration in the United States	1. Randomized controlled experiments or quasi-experimental studies; 2. Long-term project evaluation; 3. Historical performance data; 4. Strategic plan for the Performance and Results Act; 5. Annual performance plan and report; 6. Financial statements; 7. Reports from prosecutors on program effectiveness.
Evidence-based decision-making practices of the Obama administration in the United States	It can be quantitative or qualitative and can come from a variety of sources, including: 1. Performance measurement; 2. Evaluation; 3. Statistical series; 4. Retrospective review; 5. Other data analysis and research.
Evidence-based decision-making practices of the Trump	Four main sources: 1. Policy analysis; 2. Project evaluation; 3. Basic factual conclusions;

administration in the United States	4. Performance measurement.

Source: Adapted from Wei & Zhang (2021).

However, EBPM also faces several criticisms, primarily focused on the credibility of evidence and the allocation of public resources. First, the RCTs advocated by EBPM have come under scrutiny regarding sample size, outcome measurement, and the scientific quality standards of research findings (Innvaer et al., 2002; Pawson, 2005). Additionally, differences in material selection and discourse systems between public managers and academic researchers often lead to disagreements about research outcomes (Wei & Zhang, 2021). More importantly, empirical research is typically time-consuming and resource-intensive, raising questions about its ability to meet the timely demands of public decision-making (Huw et al., 2000).

Secondly, compared to traditional public decision-making methods, EBPM may require a greater concentration of public resources during the policy formulation stage, potentially overshadowing expenditures in other stages of the policy cycle (Mulgan, 2003; Laforest & Orsini, 2005). Lastly, post-positivism critiques the instrumental rationality of EBPM, suggesting that "technocratic politics" may erode the normative foundation and practical applicability of public decision-making (Wang, 2009). Scholars argue that public decision-making should consider factors beyond evidence, such as constitutional powers or jurisdictional delineation (Davies, 2004; Radin & Boase, 2000; Young et al., 2002; Howlett et al., 2020). Policies based on EBPM are also often questioned regarding their "political feasibility and societal acceptance" during the implementation phase (Majone, 1989; Jackson, 2007). In summary, EBPM can be seen as an inheritance and development of bounded rationality.

The application of EBPM in water resource planning decisions is particularly important, especially in the face of uncertainties related to climate change and social values (Heikkila, 2017). Successful water policy reform requires evidence-based problem definitions, establishing coordinated governance structures, stakeholder participation, and adopting flexible implementation strategies (Gruère & Le Boëdec, 2019). Quantitative modeling of human responses to changes in water resource availability can provide valuable information for policy formulation, although current methods often lack effective integration with behavioral theory (Meijer et al., 2021). For instance, in developing countries like Nigeria, data-driven policy approaches are crucial for sustainable soil and water resource management (Doro et al., 2020). However, the complexity and interconnectedness of water systems, along with the lack of feasible evidence theories, pose significant challenges to applying EBPM in water policy (Cartwright et al., 2010; Head, 2010). To address these issues, researchers suggest developing decision support systems that integrate scientific data, stakeholder involvement, and adaptive management approaches (Serrat-Capdevila et al., 2011). Such systems can enhance the scientific rigor and flexibility of decision-making and strengthen effective communication among all parties, laying a solid foundation for the sustainable management of water resources.

2.3 WHAT EVIDENCE IS NEEDED TO IMPROVE WATER PLANNING

This section addresses the critical frameworks of Integrated Water Resource Management (IWRM) and Ecosystem Services (ES) in the context of water resource planning (WP). The primary challenges faced in WP include a lack of cooperation among water management agencies, insufficient transparency in planning tools, and the neglect of ecological considerations. In response to these issues, IWRM and ES are commonly employed as comprehensive tools focused on ecosystems, providing effective evidence for WP (Medema et al., 2008; Vollmer, 2022).

The section begins with an introduction to IWRM, highlighting its global recognition for promoting coordinated management of water, land, and related resources to maximize economic and social welfare while ensuring ecosystem sustainability. It examines the enabling environment, institutional roles, and management instruments that form the core of IWRM, as well as the successes and challenges encountered in its implementation. Following this, the limitations of IWRM are discussed, particularly in relation to its abstract definitions and the need for a legal framework. To complement IWRM, the section proposes an Ecosystem-based approach that emphasizes the role of ES—benefits derived from natural ecosystems crucial for human well-being and economic development. The integration of ES into water resource management enhances stakeholder engagement and informs decision-making processes. Finally, a review of ESVs is presented to illustrate how ecosystem-based approaches can influence decision-making, with a focus on SEEA. In conclusion, this overview highlights the interconnectedness of IWRM and ES, demonstrating their potential to address water resource planning challenges in Kazakhstan and promoting sustainable water management practices through evidence-based decision-making.

2.3.1 INTEGRATED WATER RESOURCE MANAGEMENT (IWRM)

Integrated Water Resource Management (IWRM) is widely recognized as a pivotal approach to water governance, rooted in the principles of Good Water Governance as established by the Global Water Partnership (GWP) (GWP, 2018). The concept of IWRM was formally proposed by GWP in 2000, defined as "*a process which promotes the coordinated development and management of water, land, and related resources, to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems and the environment*" (GWP, 2000, p. 22).

As an integrated management approach, IWRM effectively addresses the interactions between land and water, socio-economic groups, and the relationships between upstream and downstream stakeholders. It also incorporates local knowledge and institutional frameworks, thereby comprehensively considering the water needs of various stakeholders (Wang et al., 2015; Cheema & Kaur, 2018). IWRM is based on the principles of sustainable development, which necessitates the simultaneous advancement of social, economic, and environmental dimensions. It encourages a more coordinated and sustainable management of water resources among all users within a watershed or aquifer (Komatina, 2011; Romer, 2014).

As noted above, the general framework of IWRM comprises the three fundamental components of enabling environment, institutional roles, and management instruments. The enabling environment includes the basin state's water management policies, regulations, and agreements with neighboring countries. Institutional roles pertain to how the national system of a basin state influences its water resource administrative agencies and specific management mechanisms. Management instruments involve practical tools such as water accounting, allocation plans, and pricing strategies essential for effectively implementing water management policies.

Despite its global recognition, implementing IWRM presents both successes and challenges across different contexts, including developed and developing countries. For instance, countries that have adopted IWRM have made notable advancements in water resource planning, as exemplified by initiatives like the Water Framework Directive (WFD) in England and Wales (Fritsch & Benson, 2013).

In South Asian nations, IWRM has been applied to tackle interconnected issues of water, land, and food security (Kc et al., 2021; Elfithri et al., 2019).

However, the implementation of IWRM is not without its drawbacks and challenges. One significant issue is the often-limited legal framework supporting IWRM, which can hinder effective implementation (Mitchell, 2005). Additionally, the abstract nature of the IWRM definition can lead to ambiguities that complicate its application in practice (Ako et al., 2009). Moreover, implementing IWRM may clash with traditional practices, entrenched attitudes, and professional determinism within existing governance structures.

In summary, while IWRM offers a comprehensive framework for managing water resources sustainably, its implementation is fraught with challenges that must be critically assessed and addressed to realize its full potential. The next concept described is ES, which helps to address the challenges IWRM faces.

2.3.2 ECOSYSTEM SERVICES (ES)

ES can be defined as the diverse array of direct or indirect benefits offered by nature to humans. These benefits encompass climate regulation, water supply, disease control, and food production, among others. These services are generated through ecosystem functions, which are the natural processes and tasks performed by ecosystems, such as carbon cycling, maintaining the internal balance and biodiversity of ecosystems. ES is closely tied to the concept of natural capital, which comprises the stock of natural resources and environmental assets like water, soil, and biological species. These elements, linked by ecosystem processes, interact to produce ecosystem services that contribute to human well-being. These services are essential for human welfare and play a vital role in societal and economic development. Therefore, researching ES and understanding their connection to natural capital and ecosystem functions are crucial for effective resource management, environmental conservation, and sustainable development.

The research on ES originated in 1981 when the ecological economist Robert Costanza first proposed the concept of ES (Costanza et al., 2017). Subsequently, Ehrlich, an ecologist at Stanford University, gave a systematic introduction to ES in "Extinction, substitution, and ecosystem services" (Ehrlich & Mooney, 1983). The emergence of ES as a prominent subject of inquiry gained momentum with the convening of the Annual Meeting of the PEW Fellows in Conservation and the Environment in 1995. The year 1997 marked a pivotal milestone in the evolution of ES research, notably underscored by the publication of the seminal work titled "Nature's Services". Illustrating the pivotal role of natural ecosystems in human survival and economic activities, Daily (1997) employed the case of species essential for lunar colonization as an example. In her exposition, she elucidated the service functions furnished by ecosystems, including those found in freshwater, grasslands, and oceans. In the same year, prompted by the initiative of 13 scientists, including Costanza, a quantitative assessment study of ES was initiated. Supported by the National Center for Ecological Analysis and Synthesis (NCEAS), the "Total Economic Value of the World's Ecosystem Services and Natural Capital" working group was established. They employed methods based on people's willingness to pay to calculate the value of ES for both global marine and terrestrial ecosystems (Costanza, 1997).

Ecologists, geographers, and ecological economists provide different classification standards for ES based on their disciplinary backgrounds. Currently, some authoritative scholars, including Costanza, Daily, De Groot, MA, TEEB, and Burkhard, are actively engaged in this field of study. Specific classifications of ES can be found in Table 2.3.

In the concept of "natural capital", Pearce's elaboration on the role of natural capital provides a basis for the functions of ES. Costanza et al. (1997) categorized the functions of ES into 17 types based on the different roles these functions play, and determined the ES value corresponding to 16 land use types. This represents the earliest classification system for ES. However, a major issue with Costanza's taxonomy is that some ES overlap, leading to double counting during the accounting phase. For example, the water supply function is also included in the moisture regulation function.

In the same year, Daily (1997) categorized ES into 14 types from the perspective of ecological processes. Although each category is described in great detail, the classification lacks comprehensiveness. De Groot et al. (2002) divided ES into four categories—production, regulation, information, and habitat—according to four directions: ecological processes, products, biodiversity, and cultural values, further subdividing into 23 subcategories. In 2005, the United Nations Millennium Ecosystem Assessment (MA) integrated previous studies and systematically classified ES into four main types comprising 23 categories, addressing both macro and micro levels. This classification is currently the most widely recognized and used.

The classification standards for the selected water resources ES include "The Economics of Ecosystems and Biodiversity (TEEB)", "Millennium Ecosystem Assessment (MA)" or "Common International Classification of Ecosystem Services (CICES) V5.1". For example, MA is classified according to the different benefits humans obtain from ecosystems. TEEB is similar to MA. CICES is further refined on the basis of TEEB and MA, but in order to avoid double counting, CICES does not calculate the supporting services of ecosystems, but focuses on the "final products" of ES (TEEB, 2010;

MEA, 2005; Burkhard & Maes, 2017; Vivagrass., 2022; Dushin et al., 2019). In order to better understand the types of ecosystem services, Table 2.4 provides the ecosystem service types and research purposes of aquatic ecosystems for reference.

Table 2.3 Classification of ES

Author	**Year**	**Classifications**
Costanza et al.	1997	1&2. Climate regulation: Carbon sequestration (NEP), Carbon storage; 3. Disturbance regulation/storm protection; 4. Water regulation/flood protection; 5. Water supply; 6. Sediment regulation/erosion control; 7. Soil formation; 8. Nutrient regulation; 9. Waste treatment; 10. Pollination; 11. Biological control; 12. Habitat/refugia; 13. Food production/non-timber forest products; 14. Raw materials; 15. Genetic resources; 16. Recreation potential; 17. Cultural/aesthetic.
Daily	1997	Purification of air and water, mitigation of droughts and floods, generation and preservation of soils and renewal of their fertility, detoxification and decomposition of wastes, pollination of crops and natural vegetation, dispersal of seeds, cycling and movement of nutrients, control of the vast majority of potential agricultural pests, maintenance of biodiversity, protection of coastal shores from erosion by waves, protection from the sun's harmful ultraviolet rays, partial stabilization of climate, moderation of weather extremes and their impacts, provision of aesthetic beauty and intellectual stimulation that lifts the human spirit.
De Groot et al.	2002	Regulation functions (gas regulation, climate regulation, disturbance prevention, water regulation, water supply, soil retention, nutrient regulation, waste treatment, pollination, biological control); Habitat functions(refugium function, nursery function); Production functions (food, raw material, genetic resources, medicinal resources, ornamental resources); Information functions (aesthetic information, recreation, cultural & artistic information, spiritual and historical information, science & education).
MA	2005	Provisioning services (food, fresh water, fuel, fiber, genetic resources, ornamental resources, biochemicals, natural medicines, etc.);

		Regulating services (air quality regulation, climate regulation, water regulation, erosion regulation, disease control, pest regulation, pollination); Support services (soil formation, photosynthesis, primary production, nutrient cycling, water cycling); Cultural services (spiritual and religious values, cultural diversity, aesthetic values, educational values, knowledge systems, recreation and ecotourism).
Wallace	2007	Food (for organism energy, structure, key chemical reactions), Oxygen, Water (potable), Energy (e.g., for cooking – warming component under physical and chemical environment), Dispersal aids (transport), Protection from predation, Protection from disease and parasites, Temperature (energy, includes the use of fire for warming), Moisture, Light, Chemical, Spiritual/philosophical contentment, A benign social group, including access to mates and being loved, Recreation/leisure, Meaningful occupation, Aesthetics, Opportunity values, capacity for cultural and biological evolution (Knowledge/education resources, Genetic resources).
TEEB	2010	1. Provisioning services (food, water, raw material, genetic resources, medical resources, ornamental resources); 2. Regulating services (air quality regulation, climate regulation, moderation of extreme events, regulation of water flows, waste treatment, erosion prevention, maintenance of soil fertility, pollination, biological control); 3. Habitat services (maintenance of life cycles of migratory species, maintenance of genetic diversity); 4. Cultural & amenity services (aesthetic information, opportunity for recreation & tourism, inspiration for culture, art and design, spiritual experience, information for cognitive development).
CICES	2011	Provisioning (nutrition, materials, energy), regulation and maintenance (regulation of wastes, flow regulation, regulation of the physical environment, regulation of biotic environment), cultural (symbolic, intellectual, and experiential).

Table 2.4 Cases of ecosystem services of river basins

Country	**Watersheds (rivers, wetlands)**	**Ecosystem service category**	**Detailed classification**	**Research purpose**	**Literature**
USA	Platte River Basin	Non-market ecosystem services	Dilution of water pollution, self-purification of water bodies, soil erosion control, animal habitat, leisure	Provide information for the public and policy-making	Loomis J. et al., 2000

Sweden	Scania River Basin	Intuitive ecosystem services	Precipitation, wild animals and plants, and beneficial birds prey on pests	Use non-academic classification to make it easier for the public to understand and recognize	Lewan & Soderqvist, 2002
		Non-intuitive ecosystem services	The contribution of plants to carbon, nitrogen fixation, and soil fertility		
		Ecosystem services based on human participation	A quiet environment that provides opportunities for hunting, fishing, and enjoying the views		
Sweden	Forests, wetlands, agricultural land	Pollution storage and reduction	Forest carbon dioxide fixation, wetland nutrition	Revise GDP	Gren & Isacs, 2009
Kenya	Yala and Nyando River Basin	Supply service	Cereals and cash crops, livestock, energy, construction materials	Provide a theoretical basis for rural planning, industrial investment, and watershed management	Swallow et al., 2009
		Regulating service	Soil and water conservation		
China	Taihu River Basin	Direct use value	Water supply, aquatic products, shipping, and tourism	Guide watershed zoning management	Wang, et al., 2011
		Indirect use value	Storage regulation, climate regulation, water purification, sand transportation, and land-making		
China	Jiulong River Basin, Fujian	Supply service	Water demand, agricultural production, shipbuilding industry, hydroelectric power generation	Assess the impact of hydropower stations on watershed ecosystem services	Wang et al., 2010
		Regulating service	Water regulation, river transportation, soil preservation, environmental purification		
		Provision service	Nutrient cycle		
		Cultural service	Aesthetics, tourism, education, scientific research		
China	Panyanghu River Basin	Supply service	Food crops, wood products, aquatic products	Assess the spatial distribution and dynamic changes of ecosystem services	Yu et al., 2010
		Provision service	Overwintering ground for rare birds, vegetation productivity, and carbon uptake capacity		
		Regulating service	Soil and water conservation, water		

			resource management, flood regulation		
		Cultural service	Wetland landscape, water bird landscape		
China	Manas River Basin	-	Climate regulation, water conservation, soil formation, waste disposal, biodiversity, food raw materials, recreational culture	Analyze the impact of land use changes on the value of ecosystem services	Feng et al., 2007

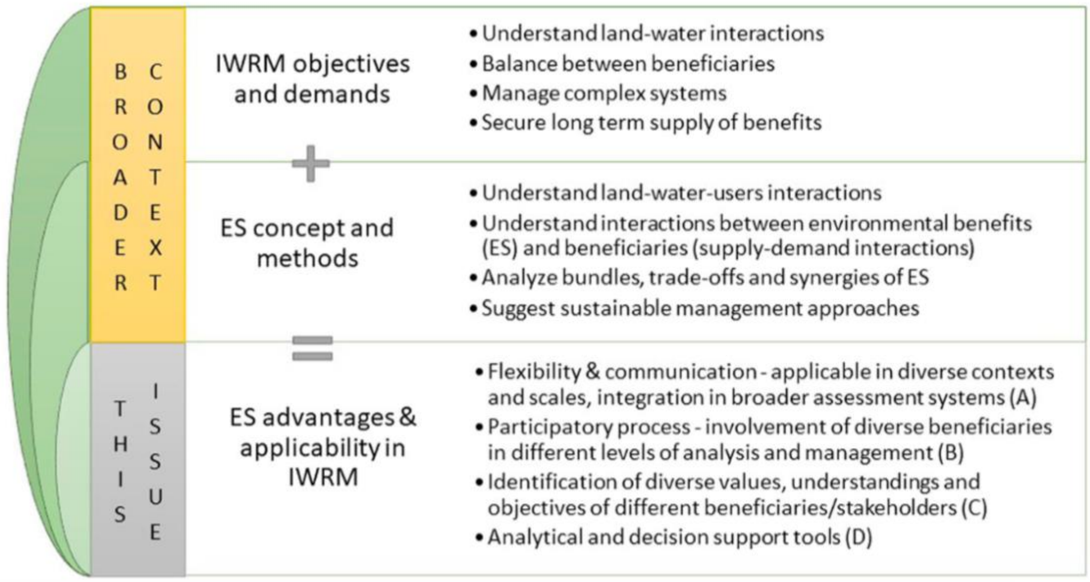
2.3.3 IWRM WITH ES

The similarity between IWRM and ES lies in their emphasis on the "coordinated development and management of water, land, and related resources" (GWP, 2000: 22). This highlights the complex relationship between humans and the environment, indicating that sustainable natural resource management can only be ensured through a balance of interests between humans and the environment. For instance, "applying the concept of water ecosystem services to water resources management" aligns well with the principles of IWRM, focusing on the human-environment relationship in the water management process (Cook & Spray, 2012; Vollmer et al., 2022). Although critics point out that both concepts face implementation challenges, particularly a gap between theory and practice (Cook & Spray, 2012), the ES concept has been widely applied in water resources management based on IWRM principles.

IWRM is a holistic water management approach requiring coordination across multiple sectors and stakeholders (Mitchell, 2005). While IWRM can be implemented at various scales, it is particularly effective when integrated into government planning processes. At the central level, IWRM can be incorporated into statutory frameworks and linked to land-use planning to enhance its credibility and implementation (Mitchell, 2005; Kidd & Shaw, 2007). The development of IWRM plans often involves participatory processes, engaging stakeholders from government agencies, local communities, and civil society (Goyal et al., 2020). These plans can address water management, land management, and livelihood issues, providing valuable input for district-level planning (Goyal et al., 2020). Integrating IWRM with spatial planning systems can further strengthen its effectiveness, potentially allowing IWRM to play a more central role in water resource management (Kidd & Shaw, 2007).

Vollmer et al. (2022) conducted a literature review of 12 papers on applying the concept of water ecosystem services to water resources management, emphasizing the importance of knowledge co-production by decision-makers and stakeholders. This demonstrates that the ES concept is a crucial tool for communication and collaboration between decision-makers and stakeholders, further explaining the role of ES in water resources management through ecosystem services assessment methods (Vollmer et al., 2022). ES provides a framework for assessing various stressors and outputs in river basins, facilitating stakeholder participation and trade-off analysis (Brauman et al., 2014). Additionally, applying the ES concept addresses some of the overly "idealistic, top-down" shortcomings of IWRM (Vlachopoulou et al., 2014; Vörösmarty et al., 2018). Vollmer et al. (2022) attempted to combine the goals and requirements of IWRM with the ES concepts and methods, highlighting ES's advantages and applicability in implementing IWRM (as shown in Figure 2.2).

Figure 2.2 The Integration of ES Concept with IWRM



Source: Vollmer et al. (2022)

Another example is the Global Water Partnership, which incorporates ES protection into the IWRM planning cycle designed by Cap-Net (Cap-Net, 2005). It shows that ecosystem-based management inputs are integrated into every stage of the IWRM planning process (GWP, 2016). For example, in the situation analysis phase, ecosystem-based management is crucial in promoting interdisciplinary approaches and enhancing the monitoring of service dynamics, flows, and land-use change impacts. In the strategic choice phase, including ecosystem supplies, values, and priorities facilitates clear discussions and enables stakeholders to adopt scenario planning for basin management. Incorporating ES into IWRM can support decision-making for water allocation reform (Liu et al., 2013) and enhance the resilience of river basins to human impacts (Wagner et al., 2009). Moreover, co-creating knowledge with stakeholders is essential for improving water resources management through ES integration (Vollmer et al., 2022).

During the implementation phase, incorporating ecosystem principles, such as using tools like payments for ecosystem services, enhances the willingness to pay to protect healthy ecosystems and their services. This demonstrates that despite limitations, economic evaluation methods still provide potential for payments for ecosystem services (Henkel, 2017). Finally, in the evaluation phase, ES are quantified and valued, serving as indicators for conservation efforts, prioritizing services, and overall assessments of social, economic, and environmental sustainability (GWP, 2016). Tools like participatory Bayesian network models (Xue et al., 2016) and Water Evaluation and Planning models (Yates et al., 2005) can assist in assessing ES within the IWRM framework.

Despite critics pointing out the challenges faced by these two concepts in implementation, particularly the gap between theory and practice (Cook & Spray, 2012), ES has been widely applied in water resource management based on IWRM principles. The following discussion will explore the specific applications of ES in water resource management and how enhancing the co-creation of knowledge between decision-makers and stakeholders can improve management effectiveness.

In the process of implementing IWRM, the ES concept not only complements the IWRM framework but also provides concrete methods for its implementation. For example, by employing ecosystem services assessments, decision-makers can better understand the multifunctionality of water systems and the economic value of ecological services, enabling more scientifically grounded and rational decisions in water resource allocation and management. Furthermore, through interaction and collaboration with various stakeholders, ES can enhance public participation and transparency, ensuring that management measures reflect the needs and priorities of local communities.

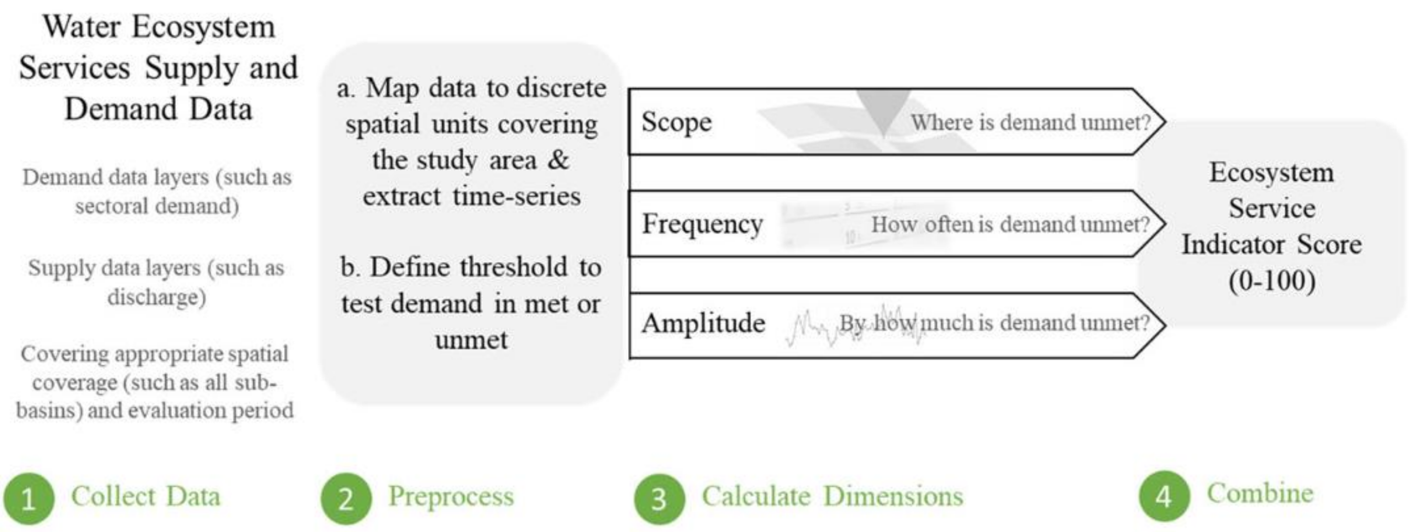
In summary, as a central-level planning tool, implementing IWRM requires comprehensive consideration of ecosystem services, with ES providing specific explanations and implementation strategies for this process. By effectively integrating IWRM with ES, sustainable water resource management can be achieved, and good cooperation among stakeholders can be fostered. This not only helps to overcome challenges encountered during the implementation process but also supports a more scientific and inclusive approach to water resource management.

2.3.4 ES AND WATER PLANNING

This section explores the significance of ES in water resource management, highlighting their role in assessing the long-term impacts of human activities on ecosystems, valuing natural capital through economic assessments, and fostering knowledge co-creation among stakeholders. Firstly, ES offer a comprehensive assessment of the impacts of water resource development and land use, helping to understand the long-term effects of human activities on ecosystems. For instance, evaluating the impacts of water quality changes and land use on ecosystem services can lead to better protection and management strategies. ES assessments can optimize investments in ecological conservation (Liang et al., 2017), evaluate the potential impacts of land use changes (Ling et al., 2019), and provide guidance for environmental flow management (Yang, 2011). Additionally, ES analyses enhance river basins' resilience to human impacts by developing more flexible water resource management strategies that ensure the long-term sustainable use of water resources.

Zhang et al. (2021) incorporated ecosystem services into water resource planning in the Júcar River basin in Spain using a water economic model, effectively allocating water resources among urban, agricultural, and environmental uses through quantified trade-offs. Burkhard et al. (2014) generated an ecosystem services potential map for a river basin in Germany, revealing that areas with high ecosystem service potential do not necessarily coincide with regions of highest biodiversity, thus underscoring the importance of ES assessments. Rozas et al. (2018) studied the impacts of integrating ecosystem services into spatial planning by analyzing texts from Chile's Strategic Environmental Assessment (SEA), finding that incorporating ES into SEA can strengthen local environmental strategy analysis. Krsnik et al. (2023) examined how Santiago and Barcelona utilize urban ecosystem service assessments to improve urban green space management and reduce environmental pollution. Hernández and Cameron (2023) demonstrated that including ecosystem service information in urban planning in Madrid, Spain, can enhance the quality of environmental assessment information. Finally, the ecosystem service indicator framework proposed by Shaad et al. (2022) assesses whether ecosystem services meet standards by comparing supply and demand data across three dimensions: scope, frequency, and magnitude (Figure 2.3).

Figure 2.3 The Framework of ES Indicators



Source: Shaad et al. (2022).

Secondly, the ES can be used for the valuation of natural capital through economic assessment methods, such as payments for ecosystem services (PES) which has been widely used on upstream and downstream water users in river basin systems. The PES approach can enhance awareness of the value of ecosystems among decision-makers and the public, thereby increasing the willingness to conserve them. By utilizing PES, Costanza et al. (2008) found that water supply and purification services hold significant economic value for local households in the Central Highlands of Victoria, Australia. Payments for ES, such as watershed service payments, water source protection plans, water reciprocity agreements, water funds, or ecological compensation, are typically used as incentives for rural areas, allowing downstream beneficiaries to address issues upstream communities face.

The RIOS (Resource Investment Optimization System) tool developed by NatCap integrates physical, social, and economic data to provide optimal support for decision-making (Gokool & Jewitt, 2019). Environmental economic accounting incorporates environmental factors into the national economic framework, addressing the shortcomings of traditional national accounts in representing the depletion of natural resources and environmental degradation (Bartelmus et al., 1991). This method facilitates the creation of revised economic indicators that effectively capture environmental costs and the depletion of natural assets (Bartelmus et al., 1991; Obst and Vardon, 2014). The System of Environmental-Economic Accounting (SEEA) offers a standardized approach for applying these accounting methods (Obst and Vardon, 2014; Pedersen and Haan, 2006).

Within this framework, the economic depreciation of environmental assets—encompassing both physical depreciation and actual capital gains or losses—is vital for accurately adjusting total income (Peskin, 1989). Physical flow accounting is a fundamental aspect of SEEA, as it enhances national accounts with physical data, enabling a combined analysis of environmental and economic policy matters (Pedersen and Haan, 2006). This integrated strategy supports a more thorough evaluation of sustainable economic growth and natural resource management. Pedro-Monzonis et al. (2016) explore the integration of ecosystem service data with socio-economic information within the SEEA, particularly through the use of water balance models to enhance SEEA water accounting. Such water accounting can assess how stakeholders' water management choices affect the economic value of water resources (Tilmant et al., 2015).

Thirdly, ES emphasizes knowledge co-creation by involving decision-makers, scientists, and stakeholders in the water resource management process, thereby enhancing collaboration and information sharing. Participatory assessment tools, such as Bayesian network models and Water Evaluation and Planning models, aid in evaluating ecosystem services within the IWRM framework, promoting broader stakeholder engagement and trade-off analysis. Kumar & Martinez-Alier (2011) developed a framework for assessing and managing the various ecosystem services provided by freshwater resources to support water management policies aligned with the United Nations Sustainable Development Goals. The ecosystem services framework proposed by Connolly et al. (2013) supports statutory water resource allocation planning in Australia, demonstrating the potential of ecosystem services to facilitate collaborative planning and stakeholder engagement and address information asymmetry and trade-offs. Prober and O'Connor (2011) emphasize that the ecosystem services approach can promote practical management alternatives in natural resource management, which is crucial for the sustainable use and management of water resources, especially in complex systems like rivers and riparian zones. Suárez-Torres et al. (2016) prioritized national ecosystem services and created a matrix to coordinate carbon and water resource management objectives to facilitate water conservation and climate change mitigation. Martunnen et al. (2021) reviewed case studies on using ES and Multi-Criteria Decision Analysis (MCDA) in water resource management, discovering that combining both approaches has benefits and drawbacks. While ES can help MCDA identify and fill gaps, inconsistent stakeholder understanding of the ES concept can lead to misleading subjective judgments.

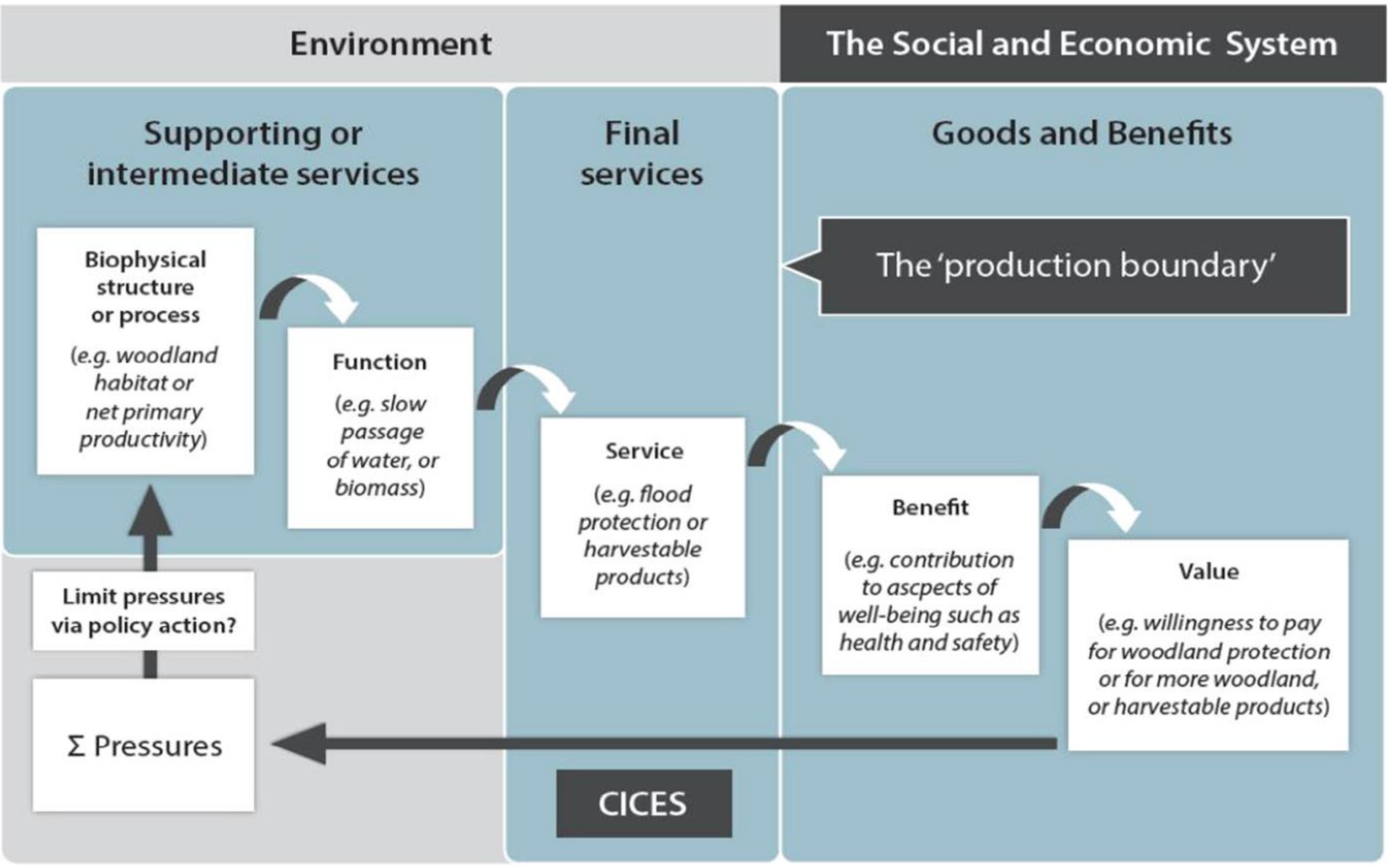
Applying ES-based approaches in water resource management provides scientific, economic, and collaborative evidence that fosters more informed, sustainable, and cooperative decision-making processes. These practices optimize ecological protection investments and management and enhance public and decision-maker awareness of ecosystem value, strengthening stakeholder cooperation to achieve the long-term sustainable use and management of water resources. After discussing the application of the concept of ecosystem services in water resources planning, the role of ESV in quantifying the value of ecosystem services is described in the following section.

2.4 ECOSYSTEM SERVICES VALUATION (ESV)

This section comprehensively examines ESV, highlighting its significance in quantifying ecosystem services' economic contributions and facilitating sustainable resource management. ESV is a methodological approach that assigns monetary values to ecosystem services, thereby underscoring their importance for human welfare and sustainable development. By enabling comparisons between natural, physical, and human capital, ESV informs decision-making and project evaluations related to ecosystem management.

ESV is a methodological approach that quantifies the economic value of ES, thereby highlighting their contributions to human welfare and sustainable development (Li et al., 2018; Liu et al., 2010). By assigning monetary values to ecosystem goods and services, ESV facilitates comparisons between natural, physical, and human capital (Sannigrahi et al., 2019). This valuation is crucial for monitoring natural capital over time, evaluating the impacts of projects on natural capital stocks, and informing ecosystem management and decision-making processes (Liu et al., 2010; Gattás et al., 2019; Laurans et al., 2013). The concept of ESV arises from the interaction between environmental systems and socio-economic factors. As illustrated in Figure 2.4, which depicts the relationship between ecosystem function, ecosystem service, benefit, and value, healthy ecosystems generate services that are valued based on human consumption and benefits.

Figure 2.4 The interaction of ecosystem function-ecosystem service-benefit-value



Source: Potschin and Haines-Young (2017).

The application of ESV is broad, encompassing the provisioning, regulating, supporting, and cultural services that ecosystems offer (Costanza et al., 1997; Hein et al., 2006). Additionally, integrating spatial data methods, such as remote sensing, has significantly advanced the accuracy and scope of ESV assessments (Sutton et al., 2002; Kienast et al., 2009). ESV is essential for addressing land use trade-offs, particularly in protected areas, and achieving goals related to efficient resource allocation, equitable distribution, and maintaining sustainable scales within whole systems (Chen, 2019; Costanza, 2020).

The research history of ESV spans over five decades, evolving from a single-service, monetized approach to a more integrated, transdisciplinary paradigm (Shuang Liu et al., 2010; Oleson et al., 2018). Early studies in the 1960s and 1970s recognized nature's benefits to human society, with research proliferating since the late 1990s (Lü et al., 2012; Ma et al., 2013). The field has progressed through "stages of enlightenment (1980-1997), exploration (1998-2004), and rapid development (2005-2012)" (Ma et al., 2013, p. 5963). Recent trends include incorporating landscape genetics (Li et al., 2023), addressing climate change impacts (Li et al., 2023), and moving towards system-scale valuation in island ecosystems (Oleson et al., 2018). Further research is suggested to focus on developing comprehensive ESV models, enhancing policy relevance, and improving ecosystem management practices (Bao et al., 2007; Hermann et al., 2011).

The ESV tools have emerged as crucial instruments for assessing nature's contributions to human well-being and informing decision-making processes (Liu et al., 2010). Specific ESV tools include

Ecosystem service indicators (Shaad et al., 2022), RIOS (Lüke & Hack, 2018), SEEA, InVEST, ARIES, and LUCI, and they can offer modeling capabilities for mapping and quantifying ecosystem services (Bartelmus et al., 1991; UN, 1993; Tallis & Polasky, 2009; Sharps et al., 2017). These tools can evaluate multiple services, including water supply, carbon storage, and nutrient retention, and assess trade-offs among management scenarios (Nelson & Daily, 2010). ESV methods encompass market-based approaches, existing market transactions, and non-market valuation techniques (Koetse et al., 2015). While these tools have advanced our understanding of ecosystem services, challenges remain in incorporating social data and designing effective policy mechanisms (Tallis & Polasky, 2009). The selection of appropriate tools depends on specific research questions, required outputs, and practical considerations such as expertise and data availability (Neugarten et al., 2018; Davies, 2014). Among them, SEEA consolidates research results in environmental and economic accounting, clarifying the objects and methods involved in the ESV process (Smith, 2007).

The ESV assess the economic value of nature's benefits to humans using approaches like direct and indirect market valuation, as well as stated preference methods (Legesse & Degefa, 2022). This typically employs the Total Economic Value (TEV) framework, which includes both use and non-use values.

Use value is categorized into direct use value, which includes market-traded ecosystem services (e.g., timber, fish, medicinal plants); indirect use value, derived from the Earth's life support functions (e.g., clean air and water), often acknowledged only when these services degrade; and option value, reflecting costs for potential future use (e.g., funding for national parks or endangered species). Non-use value encompasses values difficult to capture through markets, such as altruistic value, bequest value, and existence value, which highlights the intrinsic worth of ecosystems regardless of human utilization.

ESV is essential for comparing natural capital with physical and human capital, tracking natural capital over time, and evaluating projects impacting ecosystems (Liu et al., 2010). Mainstream economic assessment methods for ecosystem services include direct market assessment, revealed preference assessment, and stated preference assessment. Direct market assessment measures exchange value via market prices, using price-based, cost-based, and production-based methods, with the production function reflecting indirect use value. Revealed preference assessment deduces preferences from consumer behaviors, including hedonic pricing and travel cost methods. Stated preference methods, on the other hand, use surveys to determine willingness to pay for ecosystem services, assessing both use and non-use values (Table 2.5).

Table 2.5 Classification of ecosystem service valuation methods

Valuation methods			Economic values	ES valued	Benefits of approach	Limitation of approach
Market valuation	Direct market price		Direct and indirect value	Those that contribute to marketed products: timber, fish and etc.	Market data readily available and robust	Limited to those ES for which a market exists
	Cost-based methods	Avoided cost	Direct and indirect value	Depends on the existence of relevant markets for the ES in question. Examples include man-made defenses being used as proxy for value of water pollution damages.	Market data readily available and robust	Can potentially overestimate actual value
		Mitigation and restoration cost				
		Replacement cost				
	Factor income/production function		Indirect value	Environmental services that serve as input to market products, e.g. effects of air or water quality on agricultural production and forestry output	Market data readily available and robust	Data-intensive and data on changes in services and the impact in production often missing
Revealed preference valuation	Hedonic pricing		Direct and indirect value	ES that contribute to air quality, visual amenity, landscape, quiet.	Based on market data, so relatively robust figures	Very data-intensive and limited mainly to services related to property
	Travel cost		Direct and indirect value	All ES that contribute to recreational activities	Based on the observed behavior	Generally limited to recreational benefits. Difficulties arise when trips are made to multiple destinations.
Stated preference valuation	Contingent valuation		Use and nonuse value	All ES	Able to capture use and non-use values	Bias in responses, resource-intensive method, hypothetical nature of the market.
	Choice modeling			All ES	Able to capture use and non-use values	Similar to contingent valuation above

Source: Eftec (2006); DEFRA (2007); TEEB (2010).

GIS-based approaches can also classify, map, and evaluate ecosystem services (Baral et al., 2009). However, challenges in ESV include quantifying non-market services and addressing climate change impacts (Mehvar et al., 2018). A sequential decision support system can facilitate a more integrated approach to ESV (Morse-Jones et al., 2011). Additionally, ESV methods may vary across physical geographical zones (Yurak et al., 2021) and developing countries (Morando-Figueroa et al., 2022). According to De Groot et al. (2012), among the methods analyzed in the Ecosystem Service Value Database (ESVD), direct market pricing and contingent valuation are the most commonly used, followed by avoided cost and replacement cost methods. Successful valuation approaches should consider ecosystem service provision's economic, ecological, and social aspects (Sarvašová et al., 2014). Overall, these valuation approaches provide essential insights into the economic worth of ecosystem services, aiding policymakers and stakeholders in decision-making processes related to environmental conservation and resource management.

2.5 RESEARCH GAP

Based on the literature review, several gaps have been identified, specifically categorized into theoretical and contextual gaps.

Theoretical gaps:

Although studies have explored ES application in urban planning, land-use planning, and spatial planning (Woodruff & BenDor, 2016; Cortinovis & Geneletti, 2018; Lam & Conway, 2018; Cortinovis & Geneletti, 2020; Grunewald et al., 2021), there is a limied research on ES application in water resource planning. The integration of ES into water and land use planning faces significant challenges, creating a gap between research and practice (Qiu et al., 2022; Kagalou & Latinopoulos, 2020; Cook & Spray, 2012; Sitas et al., 2014; Bates, 2012; Wei & Zhan, 2023). This gap is evident in various contexts, including river basin management (Kagalou & Latinopoulos, 2020), spatial planning (Wei & Zhan, 2023), and development planning (Sitas et al., 2014). The disconnect between land use and water planning has been described as a "governance gap" (Bates, 2012). Despite progress in ES science, its application in planning remains below expectations (Wei & Zhan, 2023). Challenges include insufficient knowledge transfer to stakeholders (Vári et al., 2021), lack of explicit ES references in management documents (Sitas et al., 2014), and inadequate adaptation to climate change in water management plans (Colloff & Pittock, 2022). Bridging this gap requires improved integration of ES concepts into policy and practice and addressing power dynamics and political issues in planning processes (Wei & Zhan, 2023).

- **Insufficient theoretical support for ES in water resource planning from a policy perspective:**

While some studies suggest that ES can provide valuable information for water resource planning (Lautenbach et al., 2012), there remains a significant gap in the in-depth exploration of the theoretical mechanisms that underpin these services. This lack of theoretical grounding makes it difficult for policymakers to fully understand and leverage the potential of ES in their planning efforts.

Research has indicated that ES can be an effective tool in water resource management decision-making processes (Gleick, 2000; Vollmer et al., 2022). However, the overall role of ES within the broader framework of Integrated Water Resources Management (IWRM) has not been thoroughly examined. This oversight limits the ability to integrate ES into existing IWRM practices effectively, potentially undermining the benefits that could arise from such integration.

Frameworks for decision-making based on ES have been proposed, which include essential components like supply-demand assessments, stakeholder identification, and multi-dimensional trade-offs (Xu & Peng, 2022). These frameworks are crucial as they provide structured approaches for decision-makers to consider various factors and stakeholder interests in water resource management. Moreover, advanced methodologies such as Bayesian modeling and optimization approaches can support the integration of ES into watershed management (Bruen et al., 2022; Pascual et al., 2022). These tools offer sophisticated ways to analyze complex systems and make informed decisions based on the dynamics of ecosystem services.

Despite these advancements, several challenges persist. A lack of conceptual understanding among stakeholders can hinder the effective application of ES in decision-making. Additionally, the absence of regulatory mandates means that there is no formal obligation to incorporate ES into water resource planning processes. Furthermore, competition with overlapping approaches can create confusion and dilute the focus on ES, making it harder for decision-makers to navigate the landscape of water resource management (Kerr et al., 2021).

In summary, while there are promising frameworks and methodologies for integrating ES into water resource planning, the theoretical support and practical guidance needed to implement these ideas effectively remain insufficient. Addressing these gaps is crucial for enhancing the role of ES in policy-making and ensuring sustainable water resource management.

Context gaps:

Despite Kazakhstan's relatively abundant water resources, managing these resources entails numerous challenges. Issues such as aging infrastructure, inadequate urban water facilities, and improper management practices have resulted in inefficient and unsustainable water usage (Yessymkhanova et al., 2021; Amanbaeva et al., 2021). With assistance from the United Nations Development Programme (UNDP), the government has attempted to improve this situation through the implementation of IWRM, including the development of educational programs and a shift toward basin management approaches (Zinzani, 2014). However, challenges within the legislative and institutional frameworks persist, further leading to the unsustainable use of water resources (Medetov et al., 2018). In the context of irrigation management transfer and the implementation of water user associations, varying levels of government support have resulted in inconsistent outcomes (Sokolov, 2006; Wegerich, 2008; Zinzani, 2014).

To address these issues effectively, the introduction of an ES approach is particularly important. ES emphasizes the multiple functions of natural ecosystems in water resource management, such as water quality purification, flood regulation, and water source conservation (Brauman et al., 2007). This approach not only enhances the efficiency of water resource management but also promotes the sustainability of ecosystems, thereby providing a more stable supply of water for human use (Liu et al., 2016).

Despite the existence of case studies in southeastern Australia (Maynard et al., 2010), there is a shortage of cases from other regions. This results in a limited understanding of ES application effectiveness in water resource planning across different territories and environments.

This study bridges a significant gap in the existing literature through the exploration of the application of ecosystem services in water resource management within the specific context of Kazakhstan. Specifically, a systematic analysis and evaluation through the System of Environmental-Economic Accounting (SEEA) is conducted to provide a scientific basis for water management decision-making in Kazakhstan. This method can assist in identifying and quantifying the ecological value of water resources and evaluating the impacts of water management activities on ecosystem services, thus providing data support for formulating more targeted water management policies.

Furthermore, SEEA can facilitate collaboration and communication among different stakeholders, ensuring that ecological protection and socio-economic development are adequately balanced in water resource management. Through these measures, Kazakhstan will be able to develop more comprehensive and sustainable water management strategies, effectively improving water usage efficiency and ecosystem health while advancing the country's water management practices toward international standards.

In the specific context of Astana, however, several challenges to sustainable water use persist. Firstly, water resource management has failed to allocate water for environmental purposes, with all resources designated solely for human use, which could lead to further degradation of ecosystems (Adilet, 2016). Secondly, although the population is projected to double by 2035, the increase in water supply has not ensured the safety of water quality, particularly due to pollution in the Nura-Ishim River (Guney et al., 2020). Additionally, the Astana Reservoir has reached its maximum supply capacity from the studies reservoir, resulting in increased dependence on other water sources. At the same time, there is a lack of thorough assessments regarding the safety of these alternative sources (Tractebel Engineering, 2021).

The selection of the Astana Reservoir as a case study is particularly relevant, as it serves as the primary water source for the capital of Kazakhstan, which is experiencing rapid population and industrial growth without a corresponding increase in water resources. Moreover, the reservoir faces challenges such as aging infrastructure, sediment accumulation, and reduced rainfall due to climate change, further diminishing its available water supply. Therefore, investigating this reservoir's sustainability is paramount (Akiyanova et al., 2020). By applying the SEEA methodology to Astana's water resource management challenges, this study aims to provide scientific data support for addressing these issues and improving overall water management practices in the region.

Chapter 3

Theoretical framework

3 THEORETICAL FRAMEWORK

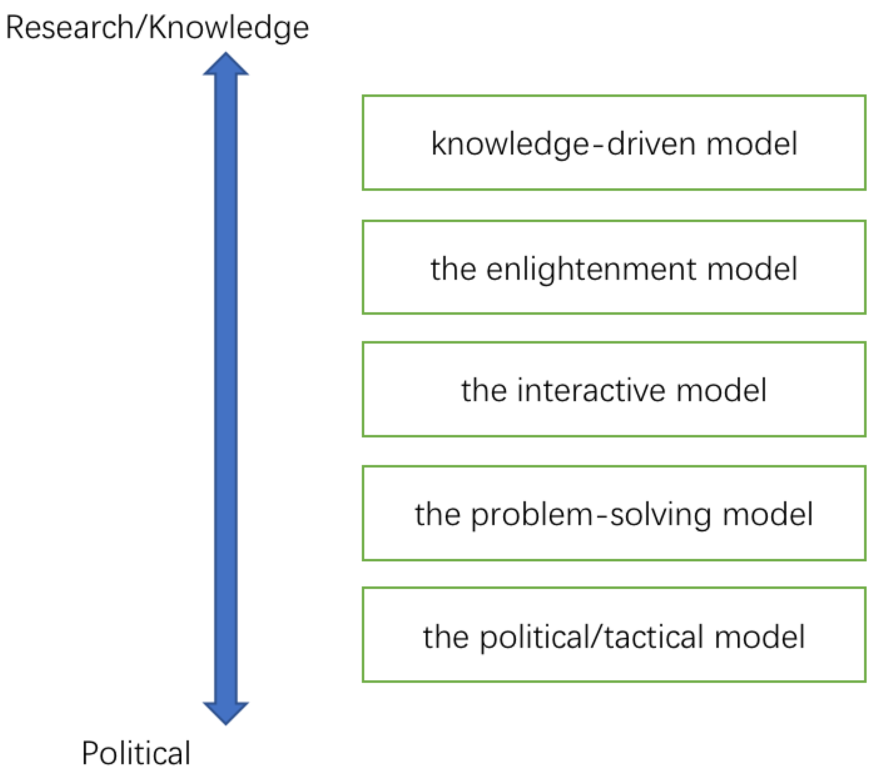
The role of the ES-based approach in public policy decision-making has been reviewed in the literature. By analyzing the scientific evidence generated through the ES-based approach, this research explores how it can serve as evidence in water resources planning policies, employing the Evidence-Based Policy Making (EBPM) theory and framework.

3.1 ELEMENTS OF EVIDENCE ANALYSIS

Evidence analysis plays a crucial role in formulating public policy, and its core elements can be summarized in several key areas. First, the factors influencing policy development primarily include systematic assessments, surveys, experiments, and expert opinions. These elements form the foundational data sources for policy-making, providing the scientific basis for decision-making. Second, the institutional norms within the decision-maker's environment and the resources, experiences, and values of the decision-makers themselves significantly impact the policy-making process. These internal and external factors collectively shape the context in which policies are formulated. Additionally, the influence of the lobbying system cannot be overlooked, including factors such as interest groups, think tanks, political parties, and media, all of which play critical roles in the policy formation process (Segone, 2008; Segone & Pron, 2008; Sutcliffe & Court, 2005).

The relationship between evidence and policy is complex and cannot be simplified into a linear rational connection. Young et al. (2002) summarize the relationship between policy and research/knowledge by proposing five models (Figure 3.1): the knowledge-driven model, the problem-solving model, the interactive model, the political/strategic model, and the enlightenment model. These models are ranked according to the relative importance of research/knowledge factors and political factors in public decision-making.

Figure 3.1 Research/Knowledge-based vs. Political-driven Public Decision-Making Models



Source: Drawn based on the Young et al. (2002).

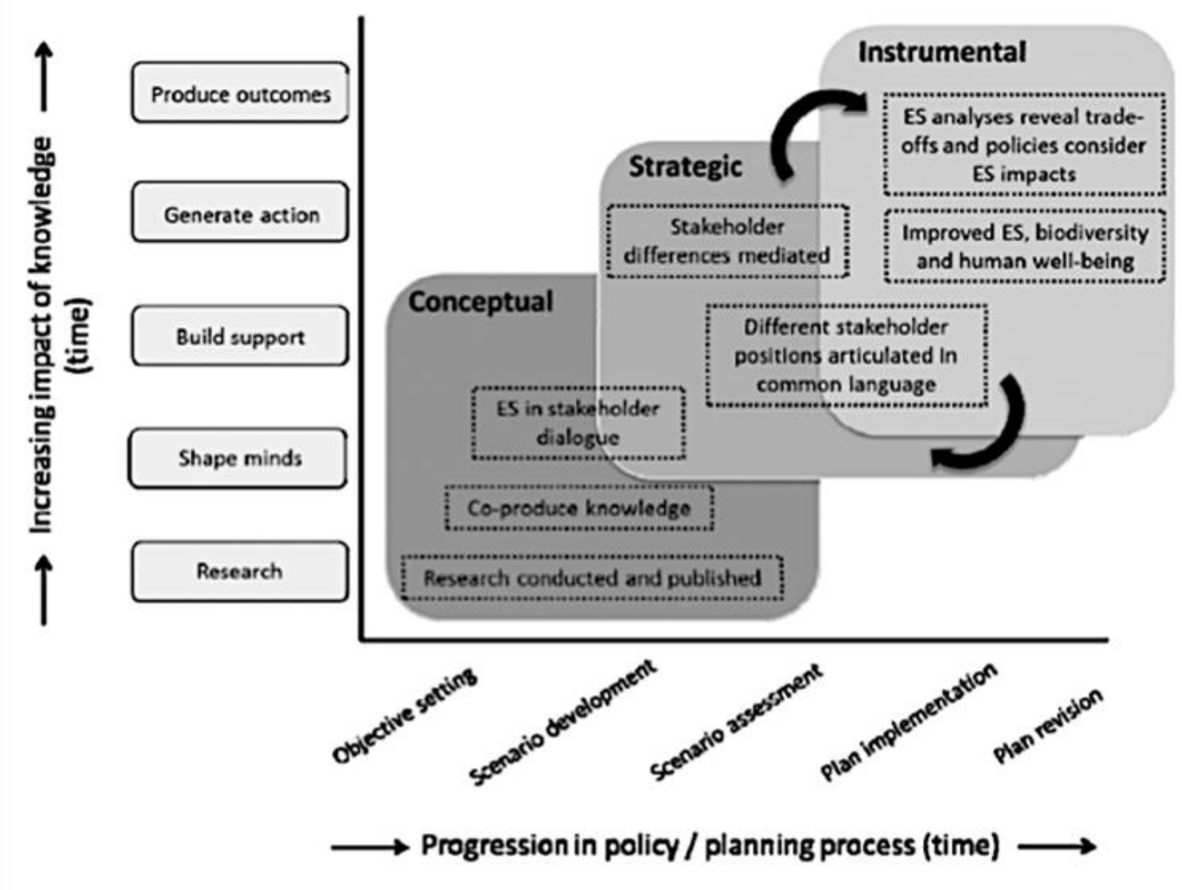
Among these models, the interactive model emphasizes that policy formulation is a collaborative effort among stakeholders to integrate research and political factors. In contrast, the problem-solving model focuses more on political factors than research. The enlightenment model, on the other hand, focuses on the decision-making context, analyzing various policy options and indirectly serving the decision-making process. Combining the interactive, problem-solving, and enlightenment models can be a significant evidence source in EBPM.

Evidence analysis involves several operational steps, including problem awareness, domain knowledge, data sources, and analytical techniques. Analysts must clearly define the problem, objectives, theories, and hypotheses. Next, they should design appropriate research plans and formulate testable hypotheses, operationalizing the fundamental concepts related to the problem and confirming suitable proxy variables. Subsequently, they must select appropriate methods for collecting primary or secondary data and undertake tasks such as error checking, data cleaning, and file merging. Finally, upon data analysis and interpretation, the results are presented to decision-makers as reports or as evidence for policy communication. These steps not only align with the requirements of the enlightenment model, the interactive model, and the problem-solving model but also reflect the fundamental function of EBPM, which is to act as a contributor to informed discourse rather than as a comprehensive, problem-solving scientific endeavor (Shulock, 1999, p. 241; Young et al., 2002). By systematically analyzing and integrating these elements, policy-making can more effectively reflect the interests and knowledge of various stakeholders, thereby promoting a more scientific decision-making process. Therefore, mastering the elements of evidence analysis is essential for enhancing public policy's effectiveness and scientific integrity.

3.2 ES BASED DECISION-MAKING FRAMEWORK

The following section further discusses the explicit position of EBPM in public policy decision-making through the practical application of the ES-based approach. McKenzie et al. (2014) and Posner et al. (2015) have vividly illustrated the impact of ecosystem service knowledge on public policy in a very intuitive manner (Figure 3.2). They demonstrate that at different stages of public policy process, from conceptualizing ecosystem services to formulating strategies and applying tools, the influence of ecosystem service knowledge continues to escalate. The impact of ecosystem service knowledge (ESK) on resource management and planning is not immediate. However, it evolves through continuous learning and reinforcement at each stage, deepening its influence on stakeholders and policymakers.

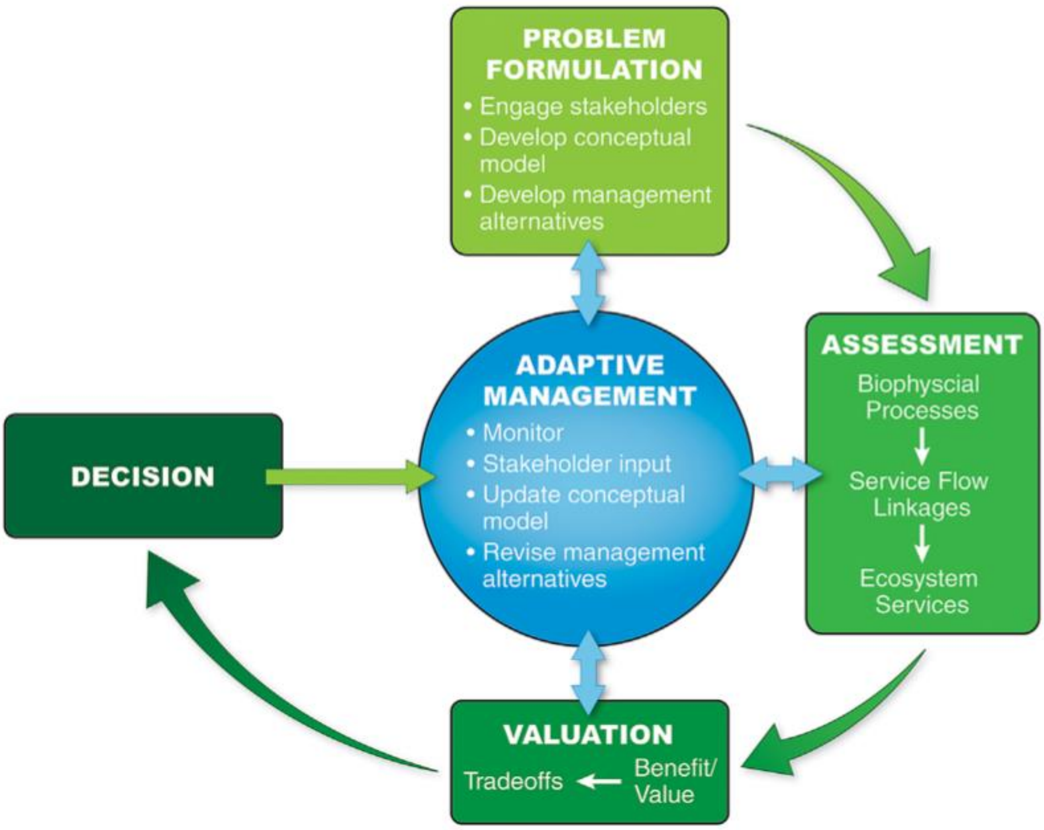
Figure 3.2 Iterative progression of conceptual, strategic, and instrumental use of ecosystem service knowledge (ESK) in the policy and planning cycle



Source: McKenzie et al. (2014).

Moore et al. (2017) also used the decision framework (Figure 3.3) to describe how to incorporate ecosystem services into natural resource management decision-making. This includes problem formulation based on the engagement of stakeholders, physical assessment of the selected ecosystem services, use of monetary and non-monetary valuation methods to value the ecosystem services, and decision-making. The following is a detailed description of each stage.

Figure 3.3 A decision framework for incorporating ecosystem services into natural resource management decision-making.



Source: Moore et al. (2017).

- **Problem Formulation Stage:**

Firstly, it is crucial to define the "decision context", including the issues to be addressed, the interests and roles of decision-makers, and the driving factors behind the decision. Emphasizing an understanding of the goals and procedures of natural resource management in this framework contributes to selecting indicators for ecosystem service assessment and determining the role of ecosystem services in decision-making. Additionally, understanding decision-maker's motivations and institutional constraints aids in choosing valuation methods for ecosystem services. Secondly, "stakeholder identification and involvement" involves recognizing individuals affected positively or negatively by resource management decisions. Stakeholder input helps decision-makers determine the valuation methods and prioritize ecosystem services. The third step is "conceptual model development", where a conceptual model provides systematic information for decision-makers and stakeholders, including historical data on research objectives, management factors, and socio-economic pressures (Moore et al., 2017).

- **Assessment Stage:**

During this stage, various biological and physical models are applied to assess the current status of ecosystem services. Specific indicators or variables are used, and established analytical models are chosen to assess changes in ecosystem services within the study area.

- **Valuation Stage:**

The literature provides a detailed review of this concept and different valuation methods. Policy evaluators can offer more intuitive results for policymakers and stakeholders by using monetary and non-monetary valuation.

Moore et al.'s model comprehensively illustrates the monitoring and management of knowledge/research related to ES in public policy formulation and application. However, this model only rationalizes applying ecosystem service valuation methods from a methodological perspective, overlooking stakeholders' and policymakers' understanding and acceptance of the ecosystem-based approach. Public decision-making is a complex process, and among numerous rational and irrational models, applicability varies based on actual circumstances. Therefore, the following section will enhance Moore et al.'s model from the perspective of public policy to illustrate how the ecosystem-based approach, as evidenced in public decision-making, will impact the policy process.

3.3 MODIFIED ES BASED DECISION-MAKING FRAMEWORK

In the literature review, a detailed examination of the types of evidence applied in EBPM was conducted, focusing on the sources and research methods of evidence. However, Sutcliffe and Court (2005) emphasize the systematic collection of evidence generated throughout the policy process, specifically highlighting the role of evidence at different stages of the policy cycle (Table 3.1). The utilization of evidence in various phases of policy development begins with identifying policy issues and extends to analyzing and confirming policy choices. During the implementation of pilot projects, professional knowledge and expert experiences are leveraged. In the final evaluation stage, evidence is essential for formulating monitoring mechanisms and exploring the next cycle of the policy (Sutcliffe & Court, 2005).

Table 3.1 Components of the policy process and different evidence issues

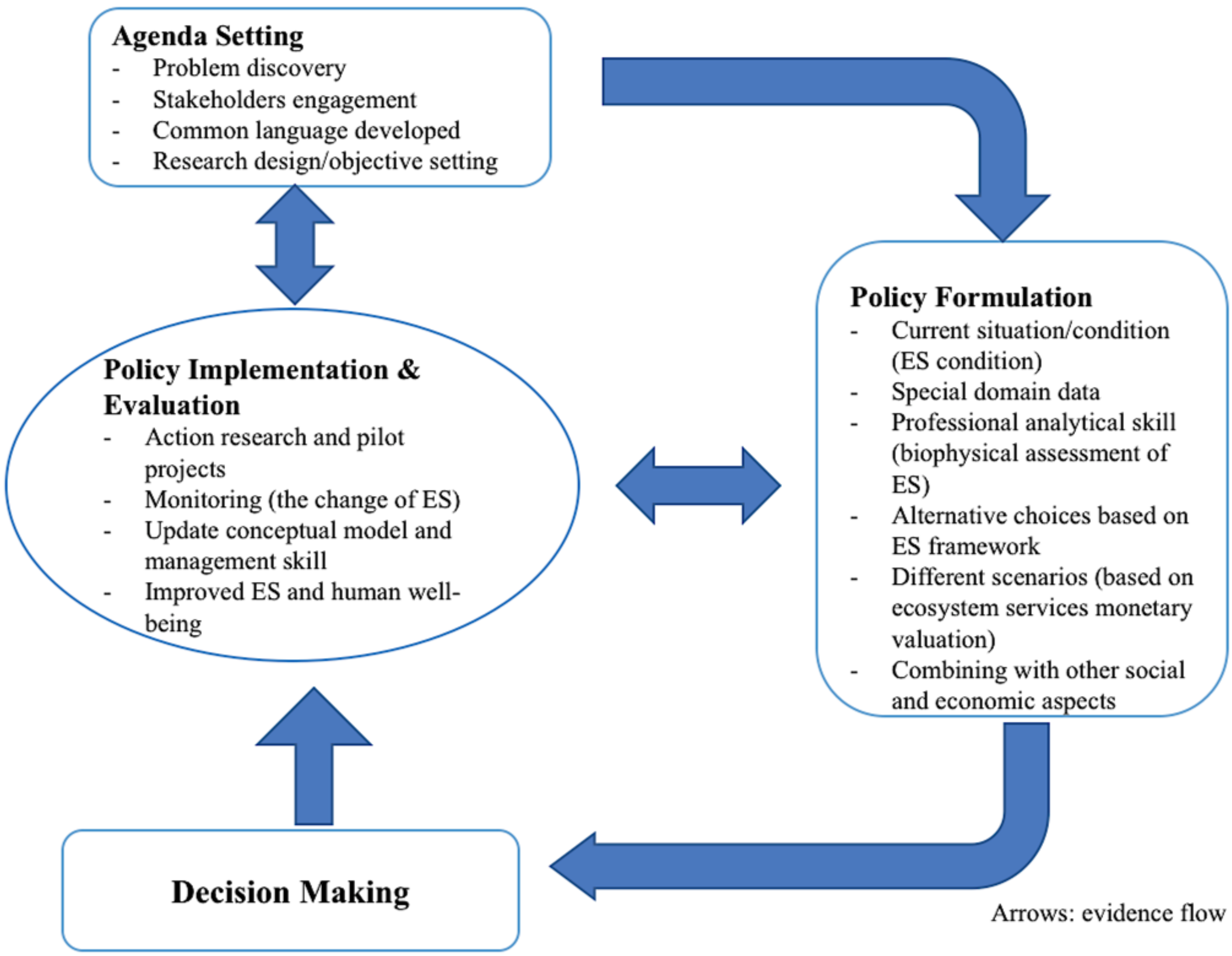
Stage of the policy progress	**Description**	**Different evidence issues**
Agenda setting	Awareness and priority given to an issue	The evidence needs here are in terms of identifying new problems or the buildup of evidence regarding the magnitude of a problem that the problem is indeed important. A key factor here is the credibility of evidence but also the way evidence is communicated.
Formulation	There are two key stages to the policy formulation process: determining the policy options and then selecting the preferred option (see Young and Quinn, 2002: 13-14).	For both stages, policymakers should ideally ensure that their understanding of the specific situation and the different options is as detailed and comprehensive as possible – only then can they make informed decision about which policy to go ahead and implement. This includes the instrumental links between an activity and an outcome as well as the expected cost and impact of

		intervention. The quantity and credibility of the evidence is important.
Implementation	Actual practical activities	Here the focus is on operational evidence to improve the effectiveness of initiatives. This can include analytic work as well as systematic learning around technical skills, expert knowledge and practical experience. Action research and pilot projects are often important. The key is that the evidence is practically relevant across different contexts.
Evaluation	Monitoring and assessing the process and impact or an intervention	The first goal here is to develop monitoring mechanisms. Thereafter, according to Young and Quinn (2002), "a comprehensive evaluation procedure is essential in determining the effectiveness of the implemented policy and in providing the basis for future decision-making". In the processes of monitoring and evaluation, it is important to ensure not only that the evidence is objective, thorough and relevant, but also that it is then communicated successfully into the continuing policy process.

Source: Sutcliffe & Court (2005, p.6).

Expanding to the example of ESV in water resource planning, the results of ESV are evidence throughout all stages of policy process for water planning and management. Examining the application of the ESV in public policy decision-making achieves a deeper understanding of the evidence-formation process in EBPM. The following framework can be established by integrating various frameworks and discussions mentioned above (Figure 3.4).

Figure 3.4 Modified ES-based decision-making framework



Source: Adapted Moore et al. (2017).

In the agenda-setting phase, ES knowledge aids policymakers in examining whether there are issues in the aquatic ecosystem and confirming the drivers and stakeholders behind these problems (Chen et al., 2023). At this stage, experts or researchers engage in advocacy and training for stakeholders and policymakers to establish an everyday discourse. Common policy goals are formulated through discussions among experts, stakeholders, and policymakers regarding real-world issues.

The policy formulation stage consists of two phases: determining and selecting policy options (Young & Quinn, 2002, pp. 13-14; Sutcliffe & Court, 2005, p.5). Specialized databases, secondary data, and empirical survey data are utilized in the determining policy options stage. Tools such as analytical tools, statistical analysis tools, and artificial intelligence tools are applied from the perspective of the specialized field. For example, the ESV may employ biophysical data processed through hydrological, physical, or ecological models or specialized data processing software such as InVEST and ARIES for ecosystem service assessment. In the selecting policy options stage, policy options are presented to policymakers in the form of policy briefs. This study's research question revolves around whether the ESV can provide compelling evidence for water resource planning. At this stage, economic methods are applied to convert the status of ecosystem services into monetary terms, facilitating a more precise understanding for decision-makers. Thus, within the framework employed in this study, this stage involves comparing various policy options.

In the public policy decision-making stage, ES-based policy options have proven superior to traditional approaches in water resource management decision-making. ES assessments provide comprehensive insights into the long-term impacts of human activities on ecosystems, facilitating better protection and management strategies (Liang et al., 2017; Ling et al., 2019). For instance, Zhang et al. (2021) effectively integrated ES into water resource planning in Spain, optimizing allocations through quantified trade-offs. Economic valuation methods like Payments for Ecosystem Services (PES) further enhance decision-makers awareness of ecosystem value (Costanza et al., 2008). Tools like RIOS and frameworks like the System of Environmental-Economic Accounting (SEEA) support informed decision-making by combining socio-economic and ES data (Pedro-Monzonis et al., 2016; Tilmant et al., 2015). Moreover, ES fosters stakeholder engagement and collaboration, which are vital for effective water resource management (Kumar & Martinez-Alier, 2011). By promoting sustainable practices and cooperation, ES-based approaches significantly enhance decision-making processes, ensuring the long-term sustainability of water resources.

However, ES methods are influenced by factors such as credibility, significance, and legitimacy (Laurans et al., 2013). Specifically, uncertainties and data limitations in ES assessments undermine their credibility, and a lack of targeted problem orientation may lead to a mismatch between knowledge and decision-making needs (Laurans et al., 2013; Longato et al., 2021; Martinez-Harms et al., 2012). Legitimacy is crucial for policy effectiveness, and broad stakeholder participation can enhance the legitimacy of policies (Posner et al., 2016). Moreover, insufficient cross-sector collaboration, as exemplified by the case study of Schleyer et al. (2015), may create barriers to the integration of ES due to industry policies and established interests (Chen et al., 2019). Furthermore, the co-production of ES knowledge and stakeholder involvement are critical to its practical application in public policy. It is argued that ES-related decision-making is inherently value-laden and requires integrating stakeholder knowledge and values through co-production models. However, power imbalances may marginalize specific stakeholders' voices, resulting in inequities (Spyra et al., 2018; Turkelboom et al., 2018).

During the policy implementation stage, ESV plays a key role by quantifying the benefits provided by ecosystems, promoting the integration of ecological considerations into economic frameworks (Daily et al., 2009). For example, SEEA accounts help “identify where management actions are needed or where the resources available will have the greatest impact” during the policy implementation phase (Chen et al., 2023, p. 208). That is, ESV guides resource allocation and funding by identifying priority ecosystems, and is also an indicator for monitoring policy effectiveness and adaptive management (Costanza et al., 2014).

In the evaluation stage, the ESV evidence is rigorously examined. This involves assessing whether the knowledge of ecosystem services has effectively enhanced water resource management and planning. In other words, after the implementation of water planning, the question arises as to whether the ESV has effectively contributed to the restoration of local ecosystems. Collaboration between researchers and public sector personnel is essential throughout the policy cycle. This collaboration ensures that expertise is effectively communicated while fostering dialogue between researchers and public officials. The analytical results from the first three stages will provide the foundation for policy implementation. A new iterative cycle will be initiated if technical issues or new challenges arise during the implementation process (Sutcliffe & Court, 2005).

The ES approach significantly promotes human well-being, supports sustainable development goals, guides decision-making frameworks, and enhances ecological functions (MA, 2005; IPBES, 2016; TEEB, 2010). With economic development, accelerated urbanization, and environmental degradation, policymakers increasingly recognize the importance of ecosystem-based public policy decision-making (Goldstein et al., 2012; Karimi et al., 2020). However, the ES approach faces multiple challenges in supporting policy decisions and conservation efforts.

Firstly, these challenges include the difficulties in quantifying non-market services, the complexities of valuing intangible services, and the issues of addressing climate change impacts (Mehvar et al., 2018). Secondly, existing economic assessment methods often overlook essential dimensions such as ecological and social values (Bautista-Rodríguez et al., 2020; Gunton et al., 2017), while spatial variability and non-linear benefit issues further complicate the assessment process (Turner et al., 2010; Morse-Jones et al., 2011). To enhance the effectiveness of ESV, it is essential to address structural uncertainties related to service selection, stakeholder interests, and parameter uncertainties (Boithias et al., 2016). Therefore, interdisciplinary approaches are recommended to integrate tools from various fields (Liu et al., 2010). Although valuation methods for ecological functions and services have strengths and weaknesses, service-oriented valuation methods are generally considered more practical (Ansink et al., 2008).

In this context, the development of ES must integrate multiple value dimensions and stakeholder perspectives to support decision-making and conservation efforts better (Liu et al., 2010; Gunton et al., 2017) while enhancing the relevance of research to policy development and the accuracy of valuations (Bao et al., 2007). The ES approach has adopted various strategies to address challenges related to institutional norms, capacities, and value beliefs. These strategies include employing interdisciplinary methods to integrate diverse stakeholder perspectives (Shuang Liu et al., 2010); utilizing comprehensive valuation methods to align institutional practices with broader values (Oleson et al., 2018); understanding complex social-ecological systems to formulate context-relevant policies (Oleson et al., 2018); addressing power dynamics to promote equitable decision-making (Hecken et al., 2015); improving the interface between science and policy to enhance the relevance of ES research findings (Kieslich & Salles, 2021); combining monetary valuation with deliberative techniques to facilitate participatory discussions (Kieslich & Salles, 2021); and focusing on the needs of rural communities to drive beneficial changes (Martin et al., 2010).

During policy formulation, decision-makers are influenced by the decision-making environment, resources, experience, and value beliefs (Turner, 2016; Mahaputra, 2022). External factors such as interest groups, think tanks, political parties, and the media can also impact policy development (Davies, 2004; Zhou et al., 2014; Averkyna & Skarbarchuk, 2024). The policy process involves complex interactions between decision-makers and their internal and external environments (Sami, 2023; Peters, 1992). Institutional analysis is crucial for understanding these interactions and restoring value considerations in policy interpretations (Peters, 1992). For instance, when assessing the value of ecosystem services, methods such as cost-benefit analysis, ecological compensation mechanisms, and social preference surveys are inevitably influenced by social and cultural contexts and stakeholder perspectives. Moreover, whether the effective integration of ecosystem services in land-use planning can be viewed as "strong support" depends on local governments' understanding and adoption of the ecosystem service concept and the effective communication and collaboration between policymakers and researchers.

In summary, the application of ES knowledge in the decision-making process has evolved from a conceptual to a strategic and instrumental approach (Mckenzie et al., 2014). Despite challenges such as knowledge gaps, indicator development, and the integration of cultural values (Greenhalgh & Hart, 2015; Turnpenny et al., 2014), ESV provides a structured approach to natural resource management (Hancock, 2010) and has been applied in various environmental standards, such as air quality (Rea et al., 2012).

Chapter 4

Methodology

4 METHODOLOGY AND DATA

This chapter introduces the System of Environmental-Economic Accounting (SEEA) and its framework and methods for ecosystem accounting (SEEA-EA). Since its inception by the United Nations in 2012, SEEA-EA has been the subject of numerous pilot studies in various countries and several rounds of revisions, leading to the release of a revised framework in 2021. SEEA-EA is designed to integrate biophysical information about ecosystems through a spatially-based comprehensive statistical framework, and its goal is to measure ecosystem services, monitor ecosystem changes, assess their value, and connect this information to economic and human activity indicators (SEEA-EA, 2021). The potential impact of SEEA-EA on ecosystem management is significant, making its adoption an urgent and essential task for all stakeholders.

This chapter elaborates on the five account typologies of SEEA-EA developed in the relevant literature (SEEA-EA, 2021). The five typologies include the ecosystem extent account, ecosystem condition account, ecosystem services supply and demand account, and monetary ecosystem asset account. By establishing these accounts, SEEA-EA can record changes in ecosystems under the influence of economic activities, thereby reflecting the supporting role of ecosystem services in human economic endeavors. The study also explores the classification criteria for ecosystem services and methods for assessing their economic value, emphasizing the importance of interdisciplinary collaboration among experts in evaluating ecosystem services.

This chapter also highlights the significance of different types of data, including survey, administrative, hydro-meteorological, and land cover data, regarding data collection. Using the Astana Reservoir in Kazakhstan as a case study, it details the methods for acquiring and analyzing relevant data. By assessing the ecosystem services of the Astana Reservoir, this research provides a scientific basis for local water resource management and policy-making, promoting sustainable water resource use.

Subsequently, it describes the steps involved in valuing the ecosystem services of the Astana Reservoir and illustrates how the case study results are utilized. It employed qualitative research methods for semi-structured interviews to review the implementation of ES-based approaches in Kazakhstan's water resources planning, focusing on the challenges and barriers encountered in integrating ES-based approaches into Kazakhstan's water resources planning.

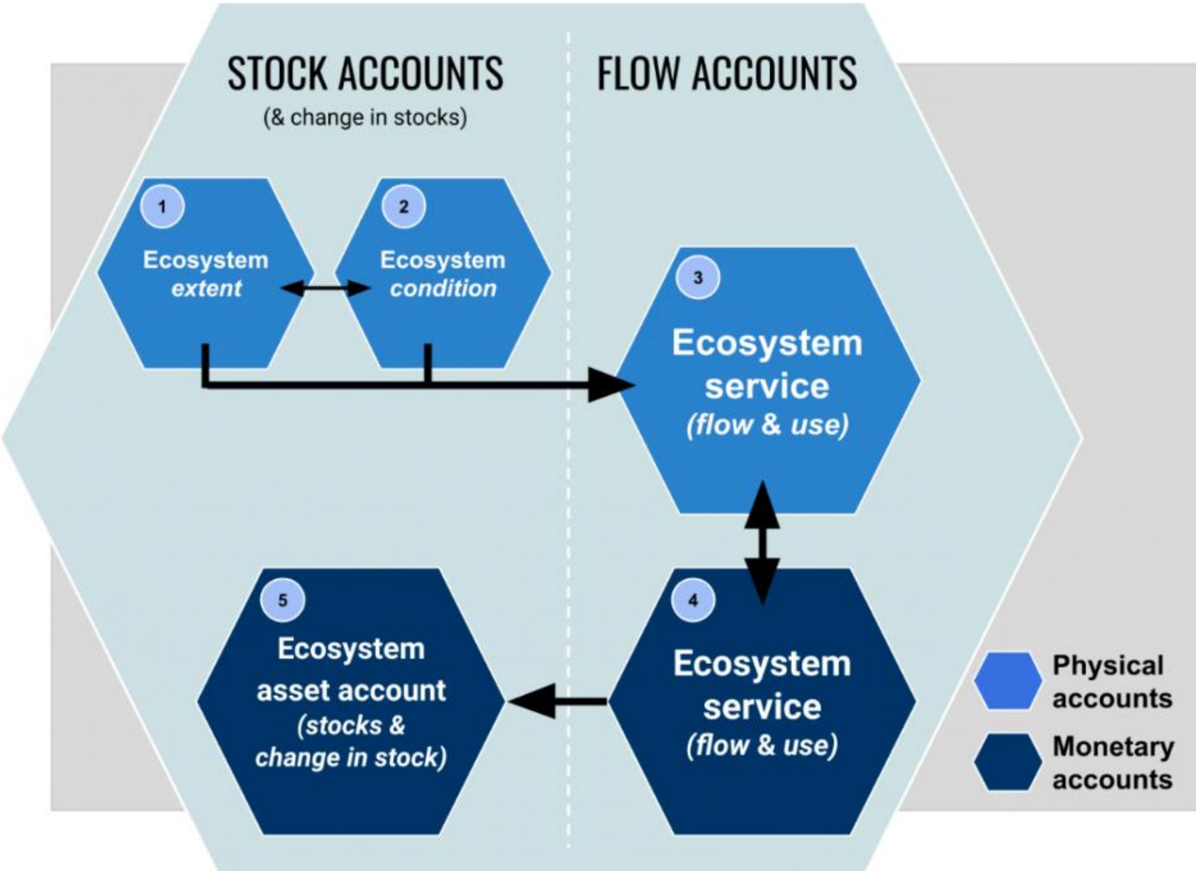
4.1 DESCRIPTION OF SEEA-EA

SEEA has several accounting accounts, as shown in Table C.2, including the comprehensive Central Framework (covering the accounting of all natural resources), specialized independent accounts for various natural resources such as water, energy, and agriculture, and supplementary accounts for ecosystem services (SEEA-EA). The following is a comprehensive explanation of the SEEA-EA concept as provided by the United Nations:

"SEEA-EA is a spatially-based, integrated statistical framework for organizing biophysical information about ecosystems, measuring ecosystem services, tracking changes in ecosystem extent and condition, valuing ecosystem services and assets, and linking this information to measures of economic and human activity" (SEEA-EA, 2021, p. 19).

SEEA-EA is a sub-framework of SEEA that aims to provide a systematic approach to recording and analyzing the relationship between ecosystems and economic activities. The SEEA-EA comprises five main accounts, categorized into physical and monetary (Figure 4.1).

Figure 4.1 Ecosystem accounts and its relationships



Source: SEEA-EA (2021).

Physical Accounts

In terms of physical accounts, SEEA-EA includes the following three accounts:

- **Ecosystem Extent Account:** This account is used to classify and define the scope of ecosystem services under study, typically delineated by administrative regions or watersheds. By clearly defining the scope, researchers can better understand the provision of ecosystem services in different areas.

- **Ecosystem Condition Account:** This account assesses changes in ecosystem services over time, recording key indicators such as ecosystem health, species diversity, and habitat quality. By monitoring these indicators, decision-makers can understand the trends in ecosystem changes and formulate more effective management policies.
- **Ecosystem Services Supply and Use Account:** This account records the supply and use of ecosystem services in economic activities and is classified as a flow account. This account helps decision-makers understand the extent to which ecosystem services support economic activities.

Monetary Accounts

In terms of monetary accounts, SEEA-EA includes the following two accounts:

- **Ecosystem Services Supply and Use Account:** As mentioned earlier, this account records the supply and use of ecosystem services in economic activities. It is categorized as a flow account, and it illustrates how ecosystem services are converted into economic value and circulate in the market.

- **Monetary Ecosystem Asset Account:** This account quantifies the changes in ecosystem service accounts, classified as a stock account, providing policymakers with an economic basis for managing and investing in ecosystem services.

Formation Process

The formation process of the five accounts begins with the relationship among biophysical environments, ecosystem services, and human benefits. The specific process is as follows:

- **Data Collection:** First, biophysical information about ecosystems, such as land use, vegetation cover, and water resource status, is collected. This information provides the foundation for subsequent account construction.
- **Establishment of Asset Accounts:** Assess the current state of ecosystems to form the Ecosystem Extent Account and Ecosystem Condition Account.
- **Definition of Ecosystem Flows:** Define "ecosystem flows", which refer to the ecosystem services produced by ecosystem assets during a specific accounting period (Tomas et al., 2017, p. 20). These flows reflect the dynamics of the generation and use of ecosystem services.

This study applies several classification standards (such as TEEB, MA, CICES, etc.) to analyze ecosystem services (Table 2.4) further. This study adopts the CICES V5.1 classification standards, categorizing ecosystem services into the following types: Provisioning Services (including freshwater, water products, wood products, food, water management, and energy generation, etc.), Regulating Services (climate regulation, water regulation, water filtration, flood regulation, and soil erosion control, etc.), and Cultural Services (tourism, shipping, landscape, and education, etc.) (CICES, 2011; MA, 2005; Swallow et al., 2009; Zhang et al., 2010).

Ultimately, economic valuation methods transform the ecosystem services that support human economic activities into monetary ecosystem assets. This involves calculating the benefits of ecosystem services in terms of their value to humans. Specific valuation methods include direct market valuation, revealed preference valuation, and stated preference valuation, as discussed in Appendix D.

During the implementation stage of SEEA-EA, the valuation process for different ecosystem services may require data and knowledge from different domains and disciplines related to ecology, hydrology, spatial analysis and economics. The specific process for generating ecosystem service valuation accounts includes the following steps:

Step 1: Identification of Ecosystem

After identifying the research subject, it is essential to determine the types and scope of the ecosystems to be studied. The first step is to identify the ecosystem functions, which involves collecting the most basic biophysical information to discern the structure and processes of ecosystems. For example, researchers may collect data on soil salinity, tidal influences, and biodiversity when studying mangrove ecosystems to understand their ecological functions (Alongi, 2012). Geographers, hydrologists, biologists, and other experts collaborate to analyze ecosystem functions and identify the types of ecosystems based on literature or legal standards (MEA, 2005). The output of this stage is an "Ecosystem Extent Account", which can typically be represented using land cover or land use of the research subject (Warnell et al., 2020, p.67). For instance, land use maps generated using remote sensing technology can illustrate the distribution of different ecosystems in the study area, such as forests, wetlands, and agricultural land (Lambin & Geist, 2006).

Step 2: Quantification of Ecosystem services

This crucial stage necessitates the integration of human economic activities in the research area. This integration is vital as it allows us to analyze the types and conditions of ecosystem services produced by the selected ecosystems over a specific period. The types of ecosystem services are classified based on the above criteria, while the condition of ecosystems involves examining their integrity (UNSD, 2021). For instance, in coastal ecosystems, services such as fisheries, tourism, and windbreaks can be classified as essential ecosystem services (Barbier, 2014). Ecosystem Condition refers to an ecosystem's "biotic and abiotic characteristics" that can be used to measure its integrity (Keith et al., 2020; UN, 2021). Ecosystem Condition is assessed by applying various indicators (biological, physical, and economic) to examine ecosystems' structure, processes, and functions (Heink & Kowarik, 2010; Potschin-Young et al., 2018). For instance, when assessing forest ecosystems, tree growth rates, and species diversity can be used as biological indicators, while soil quality and moisture content are physical indicators.

In the SEEA-EA condition account, "physical state characteristics" and "chemical state characteristics" are generally used to represent ecosystem conditions. "Physical state characteristics" include soil structure and water quantity, while "chemical state characteristics" reflect water quality, soil nutrient levels, and so on (Czúcz et al., 2021). For example, when evaluating agricultural ecosystems, soil nutrients (such as nitrogen and phosphorus concentrations) and irrigation water quality are critical chemical state characteristics (Guo et al., 2010). Table 4.1 provides an example of the ecosystem condition in freshwater systems, including various physical and chemical indicators and their measurements from the opening year to the closing year.

Table 4.1 Measures of ecosystem condition account for freshwater systems

SEEA Ecosystem Condition Typology Class	Variables	Indicators	Ecosystem type			
			Measurement unit	**Opening value (2000)**	**Closing value (2019)**	**Change, %**
Physical state	Water quantity	Water volume				
		Water level				
	Soil erosion	Soil erosion				
Chemical state	Water quality	BOD/COD				
		pH level				

Source: SEEA-EA (2021, Table 2.3, P.35).

Specifically, developing ecosystem characteristic indicators involves several vital aspects (UN, 2019, p.34). First, SEEA-EA describes various ecosystem characteristics and their related indicators, such as soil quality, vegetation cover, and water quality, which can comprehensively assess the health of ecosystems (FAO & UN, 2020). Typically, ecosystem condition assessments rely on 4 to 8 indicators; for example, in coral reef ecosystems, indicators such as the percentage of live coral, fish diversity, and water temperature variation can reflect overall health trends (Hughes et al., 2017). Data sources are diverse, with water quality monitoring achieved through water sample analysis, while biodiversity can be assessed using biological surveys and satellite data (Pérez-Harguindeguy et al., 2013). In South Africa, ecosystem condition assessment methods include selecting 4 to 6 indicators for each ecosystem type; for example, river ecosystems might choose "water flow velocity", "biodiversity index", and "pollutant concentration" (UN, 2019, p.55; Skelton, 2019). Although there is no universally applicable set of indicators, specific indicators (such as species richness) are shared across different ecosystems (Mace et al., 2011). All indicators should be evaluated against reference states to ensure the scientific rigor and validity of the assessment results.

Step 3: Develop the "Ecosystem Services Supply & Use Account" in Physical Account

This stage represents the process where ecology and economics interact to generate the value of ecosystem services. The "Ecosystem Services Supply & Use Account" includes inputs and outputs between ecosystems and sectors such as industries, households, and governments. This elucidates the production process of ecosystem services and demonstrates the value of ecosystem services in human economic activities. For example, in urban green spaces, ecosystem services (such as air purification, cooling, and biodiversity) can be quantified by analyzing the impacts of urban planning and related policies (Gómez-Baggethun & Barton, 2013). This stage will involve the application of numerous biophysical models to examine the changes in ecosystem services over a specific period. For example, ecological models are used to assess the impacts of deforestation on carbon storage and water quality (Houghton, 2003). Simultaneously, the pressure factors on the selected ecosystems will be analyzed, including population, land use, economic development, and climate change. Taking agricultural ecosystems as an example, studies have shown that agricultural expansion and increased fertilizer use can lead to the eutrophication of water bodies, affecting ecosystems' health (Carpenter et al., 1998). The output of this stage is an "Ecosystem Condition Account".

Step 4: Development of Monetary Accounts of ES

Subsequently, applying market valuation, revealing preference valuation and stated preference valuation methods generate an "ecosystem services monetary account" to express the quantitative values from the physical accounts in monetary terms. This process involves using economic indicators to represent the quantified indicators of ecosystem services, helping policymakers or other stakeholders who may not have a biophysical science background to understand these values. For example, in the study of wetland ecosystems, the market valuation method can be used to assess the water purification services provided by wetlands by calculating the water treatment costs in the area (Costanza et al., 1997). Additionally, the revealed preference valuation method can quantify the recreational value of wetlands by analyzing people's willingness to pay for wetland visits (Spencer, 2010). On the other hand, the stated preference valuation method can gather public perceptions of the value of wetland conservation through surveys, thus deriving corresponding economic values (Bateman et al., 2002). Combining these methods enables policymakers to understand the economic value of ecosystem services better, allowing them to consider the protection and management of these services in their decision-making.

Step 5: Development of Policy Recommendation

The four steps above have demonstrated the value of ecosystem services, and the results can be applied to various stages of the policy cycle. The four types of accounts mentioned above can be applied in the "policy formulation, decision making, policy implementation, and evaluation" stages of the policy cycle, as detailed in the theoretical framework (Figure 3.4).

In general, the results of ecosystem service valuation can be used to revise the national economic accounts, incorporating the economic value of ecosystem services into the national accounts, ensuring the sustainable growth of the national economy, i.e., economic growth without depleting natural resources. Secondly, the results of ecosystem service valuation can be used for ecosystem compensation, assessing and restoring polluted or damaged ecosystems. For example, in a region where water bodies have been damaged by industrial pollution, valuation results can help determine the amount of investment needed to restore water quality (Brouwer et al., 2009). Thirdly, the results of ecosystem service valuation can be used to develop new environmental protection policies, providing a basis and guidance for the sustainable use of local natural resources. Finally, the results of ecosystem service valuation can also be used to evaluate locally implemented policies by examining the condition of ecosystem services and generating monetary accounts to assess the effectiveness of policies. For example, after implementing an urban green space policy, the policy's success can be evaluated by comparing the changes in ecological service value before and after implementation (Liu & Russo, 2021).

4.2 OVERVIEW OF ASTANA RESERVOIR CASE STUDY AND DATA COLLECTION

This research focused on a case study of ESV for the Astana Reservoir. Generally, reservoirs provide numerous ecosystem services, including water supply, flood control, irrigation, carbon sequestration, and biodiversity conservation (Baral et al., 2016; Ghosh, 2021). The economic valuation of these services is crucial for informed decision-making and sustainable management (Korsgaard & Schou, 2010).

4.2.1 BACKGROUND SITUATION OF ASTANA RESERVOIR

In Kazakhstan, 309 reservoirs have been built, of which 83 are national and 191 are commercial (Wikipedia, 2009). Among the existing 653 hydraulic structures, 268 urgently need repair, of which 28 are significant. Many reservoirs in Kazakhstan have been in operation for more than half a century, such as the Shardara reservoir built in 1965, the Bukhtarma reservoir in 1960, the Kapshagai reservoir in 1970, the Sergeev reservoir in 1969, the Karatomar reservoir in 1965, the Samarkand reservoir in 1939, and Astana Reservoir in 1969. The latter is located on the upper ESIL river 65 km southwest of Astana city, 5 km from Arnasay village in the Arshaly region, and the right-side tributary of the Moiyldy River (Figure 4.2).

This research has adopted the Astana Reservoir (previously known as Vyacheslavsky Reservoir) as the case study. The Astana Reservoir was chosen because it currently serves as the primary water supply source for the capital city of Kazakhstan. Since Astana became the capital of Kazakhstan in 1997, the population has grown from 0.338 million in 1999 to 1.254 million in 2022, representing a 271% increase. However, the reservoir's available resources have not grown and cannot meet the rapid population growth and industrial expansion demands.

Furthermore, the reservoir faces long-term neglect, aging equipment, and issues related to sediment accumulation. Factors such as reduced rainfall and rising temperatures due to climate change have also decreased the reservoir's available volume (Akiyanova et al., 2020). Therefore, selecting the Astana Reservoir as a case study is highly relevant to ensuring Astana's sustainable water resource supply.

Figure 4.2 Location of the Astana reservoir. Landsat-8 satellite image, 26.05.2018.

Source: The Committee for Water Resources of the Ministry of Ecology, Geology and Natural Resources of the RK; Akiyanova et al. (2020).

The Astana Reservoir started operation in 1970. The data provided by the "Kazvodkhoz" (State Enterprise "Kazsushar") official website are shown in Table 4.2, and Akiyanova et al. (2020) provided unpublished data which was obtained by the "Kazhydromet" (National Hydrometeorological Service of Kazakhstan) with the “Lawrence echo sounder technic” in 2014 (Akiyanova et al., 2018, p.77). It shows that the water surface area of the reservoir is 47.3 square meters, and the water volume is 458.45

million m3. The total area of the reservoir spillway is 5,210 square kilometers, and the reservoir is fed by surface runoff formed during spring floods. According to the Astana Reservoir manual, the reservoir's maximum annual water supply capacity is 89 MCM (million cubic meters). Exceeding this limit could potentially impact the aquatic ecosystem of the reservoir (Kazvodkhoz, 2004).

Table 4.2 Parameters of Astana reservoir

Water source:	Esil River
Purpose:	For water supply of Astana city and irrigation
Location:	5 km southeast of the Arnasay village and 65 km of Astana
Throughput:	1910 m^3/s
Commissioning year:	1970
Water surface:	60.7 km^2
Dam height:	32 m
Dam length:	1.2 km
Average and maximum depth:	6.3 m and 25 m
Suspended irrigated area:	6.07 thousand

Source: Kazvodkhoz, from official website of RSE "Kazvodkhoz" Committee for Water Resources Ministry of Ecology, Geology and Natural Resources of the Republic of Kazakhstan (2020). Kazvodkhoz (https://qazsu.kz/en/).

The primary purpose of the Astana Reservoir is to provide drinking water, industrial water for Astana City, and agricultural irrigation water. It also fulfills the demand for agricultural irrigation of lands and water supply of populated areas of the Akmola region, as well as the restoration of the Esil riverbed. The primary water consumers of the Astana Reservoir are "Astana su arnasy" (State-owned

Enterprise), LLP "Kaysar" (Private Enterprise), irrigation water, industry water, domestic water, etc. The water distribution between water consumers is regulated by particular schedules for using reservoir water resources; the details are shown in Table 4.3.

Table 4.3 Main water consumers of Astana reservoir

Name of water consumers	**Length of water pipelines**, km	**Average annual water consumption**	
		m3/sec	million m3
SOE "Astana Su Arnasy"	66.7	1.98	62.68
Discharge into the downstream of the reservoir, sanitary permits, irrigation of collective orchards, and water intake of industrial water	-	2.44	77
Total		4.52	139.68

Source: Kazvodkhoz (2004).

4.2.2 IDENTIFYING THE BOUNDARY OF ASTANA RESERVOIR

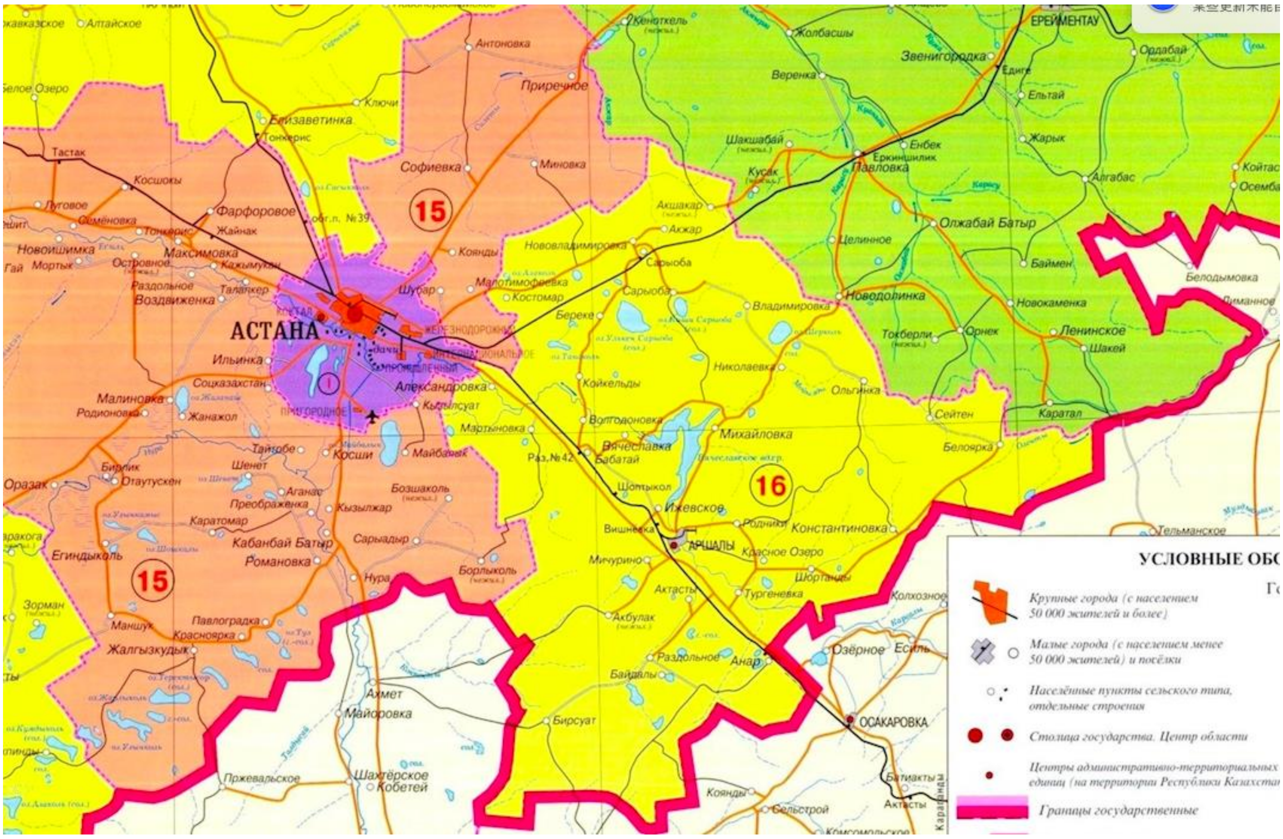
The Astana Reservoir is in the Akmola region, specifically within the Arshaly district. To provide a clear geographical context for this study, it is essential to clarify that the Arshaly district represents a broader administrative area (Figure 4.3). However, researching the entire Arshaly region would not align with the specific focus on the Astana Reservoir. The difference between the two maps is that administrative boundaries represent political boundaries, while watershed boundaries reflect natural water flows.

A specialized geographical dataset known as WWF hydroSHEDS (World Wildlife Fund hydroSHEDS, Lehner & Grill, 2013) was utilized to define the research boundary for the Astana Reservoir. This dataset helps delineate various watersheds and land areas where water collects and drains into a standard outlet, such as rivers or lakes. The hydroSHEDS dataset is a global dataset that categorizes watersheds into various hierarchical levels, ranging typically from Level 1 to Level 12. Each level represents a different scale of watershed delineation, with Level 1 being the most general and Level 12 being the most detailed. Choosing Level 10 for this research means focusing on relatively small, localized watersheds, which are helpful for specific ecological, environmental, or management studies. This level provided a more detailed breakdown of watershed boundaries, allowing for a focused analysis of the Astana Reservoir.

According to Figure 4.4, the Astana Reservoir was divided into five water areas based on this level 10 classification. Each of these areas had a unique identifier, or ID, which was listed in Table 4.4. These IDs enabled access to various hydrological (water-related), meteorological (weather-related), and soil data specific to each water area, facilitating detailed analyses relevant to the reservoir.

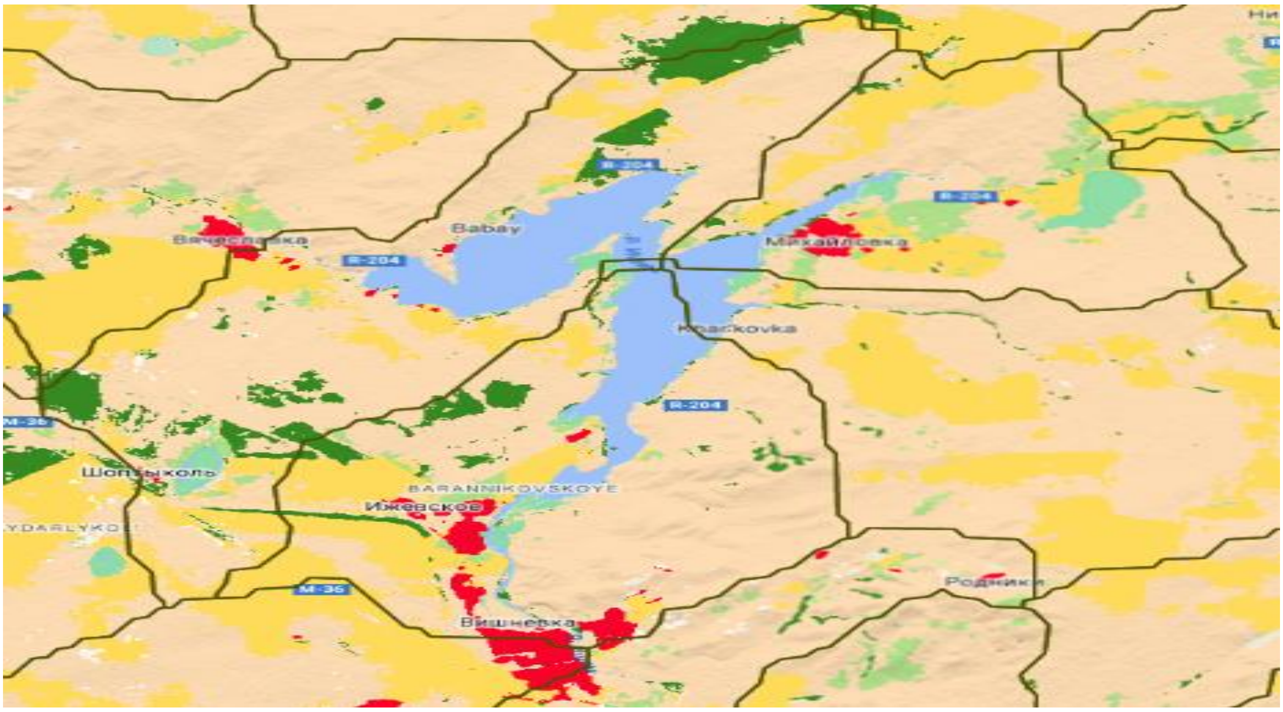
In summary, this research focused on a specific area—the Astana Reservoir—by defining its boundary using level 10 hydroSHEDS data, ensuring the study remained relevant and precise. This approach allowed for a clearer understanding of the hydrological dynamics at play within the reservoir, leading to more effective management and study of water resources in the region (Lehner & Grill, 2013).

Figure 4.3 Part of the administrative map of the Akmola region (Arshaly region - No. 16)



Source: Map of Akmola region with all populated areas. From Kokshetau. Online (2017). Kokshetau. Online (https://kokshetau.online/karta-akmolinskoj-oblasti-so-vsemi-naselennymi-punktami/).

Figure 4.4 Basin level 10 WWF hydroSHEDS



Source: Earth Map, by Google Earth Engine (n.d.), Google Earth Engine (https://earthmap.org/).

Table 4.4 Water Basin ID

No	Water basin ID
1	3100972150
2	3100665610
3	3100665750
4	3100665790
5	3100665740

Source: Earth Map, by Google Earth Engine, n.d., Google Earth Engine (https://earthmap.org/).

4.2.3 DATA COLLECTION

Typically, data collection for ESV encompasses "survey data, administrative data, hydrological/meteorological data, research data, and land cover data" (Vardon, 2014, p.5). Survey data is primarily utilized to analyze human consumption preferences for ecosystem services derived from economic activities and can be gathered through survey analysis. Administrative data includes relevant laws and regulations and demographic and industry data from urban areas. Hydrological/meteorological data pertains to the study area's specific hydrological and meteorological information, which can be obtained from local meteorological and water resource management agencies or various online GIS databases. When combined with soil information and hydrological/meteorological data, land cover data is used to assess ecosystem services' status and is typically sourced from GIS datasets. Research data encompasses literature and reports from local and global research institutions and relevant scholars.

In this study, the data collection includes hydrological data related to the Astana Reservoir (such as monthly and yearly inflow and outflow data, water levels, water volumes, evaporation rates, water temperatures, and water quality), meteorological data (including monthly and yearly rainfall and temperature), soil data, demographic statistics of Astana city, water consumption data from various industries, and references to existing policies like the Water Law of Kazakhstan, national water resource planning, Astana city water resource planning, and policies regarding the management of the Astana Reservoir. These policy-relevant materials consist of legislation, bylaws, and other pertinent documents.

The primary local data are provided by Astana City Water Supply Management Company (Astana Su Arnasay), Esil River Management Authority (Esil basin inspector), Reservoir Management Authority (Kazvodkhoz), and Meteorological and Hydrological Management Authority (Kazhydromet).

GIS (Geographic Information System) data was collected from various sources, including River catchment data from World Wildlife Fund-US, soil data from ISRIC (ISRIC soil data hub, 2024), and land cover data from the earth-map website (Google Earth Engine, n.d.). Precipitation and Evapotranspiration data are downloaded from TerraClimate (Abatzoglou et al., 2018) using the Google engine. Some GIS data can be downloaded directly based on the requirements of the data source and the desired year. However, other GIS data may require initial processing in ArcGIS software to segment and integrate river catchment data to obtain the boundaries of the study area. Subsequently, corresponding codes are applied to access other relevant hydrological and meteorological data on the

Google engine (https://earthengine.google.com/). Google engine is a data platform that stores vast amounts of data in cloud storage. All the related data collected for the Astana Reservoir are shown in Table 4.5.

Table 4.5 Data resources of Astana Reservoir

Local data				
Organization	**Data**	**Content**	**Time-frequency**	**Year**
Astana Su Arnasay	Water intake table	Approximate monthly water consumption in Astana	monthly	2015-2022
	Water intake report	Detailed Astana city water consumption and drainage breakdown	monthly	2016-2021
	Water quality report	Water quality report of Astana reservoir	yearly	2020-2022
	Astana Su Arnasay 2020 year general report	The pumping volume of each pumping station; Water consumption by four types of users from 2016 to 2019; Water price before tax.	yearly	2020
Esil basin inspector	Water balance	Astana reservoir water withdrawal details from the Esil River	monthly	2004-2021
Kazvodkhoz	Technical passport of Astana reservoir	1970-2004 water balance	monthly	2004
	Summary statement of the water balance of the Astana reservoir since 1970	Start and end of the flood; Absolute level mark, volume; Inflow during the flood period; Discharge to the downstream.	yearly	1970-2023
Kazhydromet	Water level	Turgen station; Moiyldy station.	monthly	1995-2020
	Water volume	07' Astana reservoir – Arnasay	monthly	2002-2020

		posts. Esil – post. Arshaly;		
	Water quality	07' Astana reservoir – Arnasay posts. Esil – post. Arshaly.	monthly	2002-2020
GIS data				
Organization	**Data**	**Content**	**Time-frequency**	**Year**
UCL-Geomatics	Land cover CCI	300 m spatial, the Land Cover CYLCCS (Harper et al., 2023)	yearly	1992-2020
World Wildlife Fund-US	hydroBASINS	River catchment (Asia, 1-12 level) (Lehner & Grill, 2013)	-	Real-time updates
University of Idaho	Precipitation	TerraClimate: Monthly Climate and Climatic Water Balance for Global Terrestrial Surfaces (Abatzoglou et al., 2018)	yearly	Real-time updates
University of Idaho	Evapotranspiration	TerraClimate: Monthly Climate and Climatic Water Balance for Global Terrestrial Surfaces (Abatzoglou et al., 2018)	yearly	Real-time updates
The ISRIC – World Soil Information Soil Data Hub	Soil erosion control	The ISRIC – World Soil Information Soil Data Hub ISRIC data hub, 2024); Kazakhstan Soil Microbiome Scientific Data (Yapiyev et al. 2018)	yearly	Real-time updates
Other data				
IBNET	Water consumption	IBNET, 2000-2016.	yearly	2000-2016

The local organization provides data covering monthly and annual statistics from 1970 to 2023. Comparing data from different sources can enhance the credibility of the research. Additionally, the IBNET website (International Benchmarking Network, IBNET, 2000-2016) offers data on Astana's water consumption from 2000 to 2016. Quantitative data is primarily collected through secondary data and official records, while qualitative data is obtained through semi-structured interviews.

Semi-structured interviews refer to an informal mode of communication conducted by researchers following a general interview outline (Zhao, 2021). Unlike highly controlled structured interviews, in semi-structured interviews, researchers pre-determine the questions to be explored but adopt a relatively open approach during the actual interview. This method does not enforce specific expressions or question sequences; instead, it revolves around engaging in a conversation about issues closely related to the research topic.

In semi-structured interviews, researchers can flexibly adjust the interview process and content based on the respondents' answers, building upon the designed questions. The flexibility of semi-structured interviews encourages respondents to express and reflect on their experiences openly. Researchers can gain in-depth insights into the respondents and often encounter unexpected findings contributing to the research. However, semi-structured interviews typically emphasize in-depth discussions, leading to extensive and detailed data collection, requiring specific recording tools such as audio and video recordings.

Table 4.6 outlines the steps involved in semi-structured interviews. Firstly, the research objectives and scope are determined based on the research questions, and a set of questions to be investigated is formulated (Dicicco et al., 2006). The questions to be used in the interview must undergo pre-testing to assess their effectiveness and control the time required (Kallio et al., 2016). Subsequently, an appropriate sampling strategy is chosen to select participants who can meet the research objectives. The number of participants depends on "information saturation, research goals, interview quality, and analysis strategy" (Hatch, 2023; Guest et al., 2006; Malterud et al., 2016).

During the interviews, a specific ethical review is conducted to ensure the confidentiality of participant information (Josselson, 2013, p.44). Additionally, preparations include obtaining informed consent, crafting participant recruitment materials for emails or calls, securing recording devices, and arranging interview locations (Edwards & Holland, 2013).

The next step involves the interview process, emphasizing the importance of interviewers exhibiting "empathy" toward participants (Josselson, 2013, p.45). Establishing a trusting relationship between the interviewer and participant directly impacts the quality of the interview. Interviewers must respect participants and encourage them to openly share their thoughts and experiences (Gary, 2006).

Table 4.6 Semi-structured interview steps

Steps	**Tasks**	**Explanation**
1	Determine the purpose and scope of the research	Defined the research objectives based on the questions posed.

2	Identify participants	Purposive sampling was used to select stakeholders who were knowledgeable in Water Resource Management.
3	Consider moral and ethical issues.	Ensured confidentiality and informed consent.
4	Materials preparation	Developed an interview guide and arranged logistics.
5	Build trust and rapport.	Established rapport with participants to enhance interview quality.
6	Taking interview	Engaged in one-on-one discussions, either in-person or via Zoom.
7	Record and reflect	Documented responses while maintaining participant anonymity.
8	Data analysis	Used NVivo for coding and analysis.
9	Demonstrate the credibility of the research.	Employed triangulation.
10	Present findings	Compiled results in reports or publications.

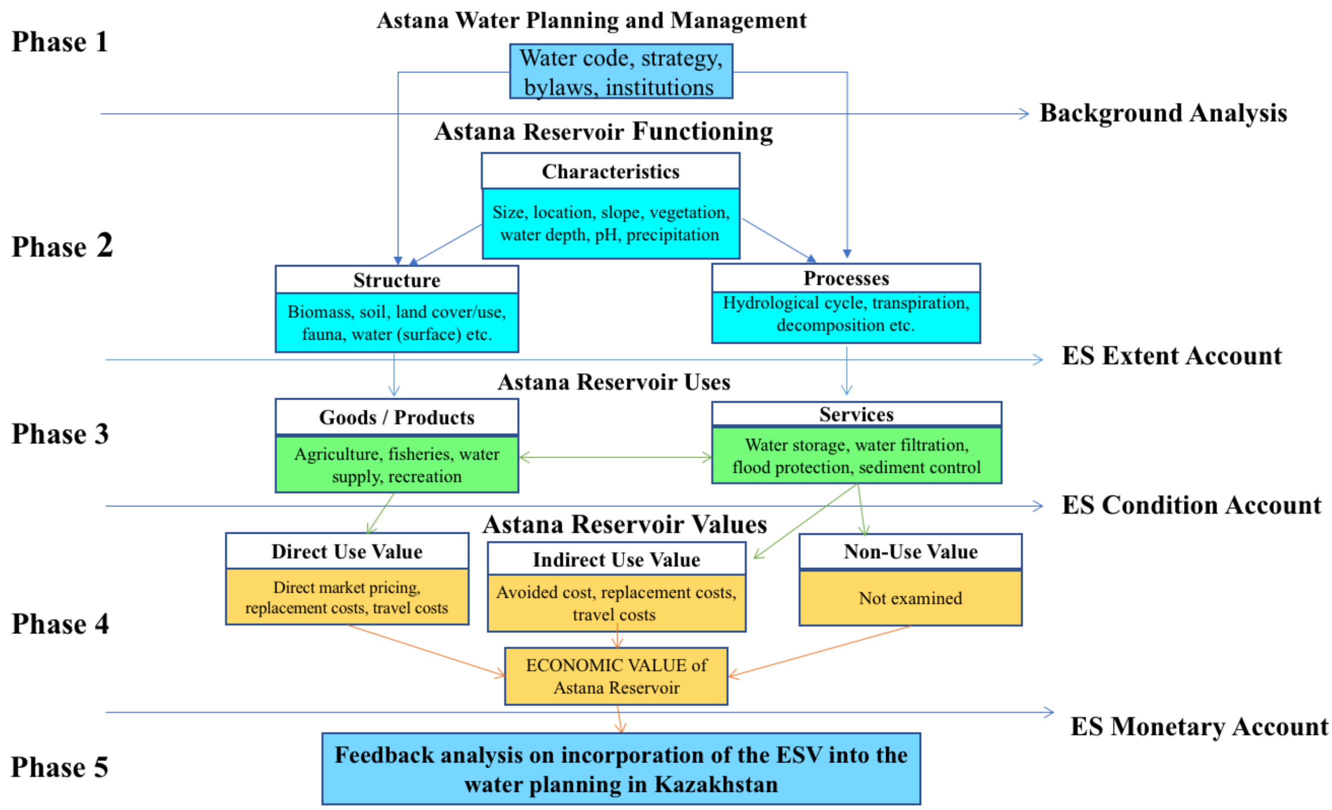
Source: De Jonckheere & Vaughn (2019).

4.3 SEEA-EA RESEARCH DESIGN IN ASTANA RESERVOIR CASE STUDY

This study employed an Explanatory Sequential Design (ESD), a mixed-method approach that integrates quantitative and qualitative data collection and analysis, typically divided into two consecutive phases (Ivankova et al., 2006; Toyon, 2021). This design usually starts with collecting quantitative data, followed by qualitative data to interpret preliminary results (Liem, 2018). Quantitative research can provide a wealth of information, helping researchers understand surface phenomena and their fundamental relationships related to the research question. In contrast, qualitative research delves deeper into the issues uncovered in the quantitative phase, exploring their underlying causes and motivations.

A comprehensive assessment of the Astana Reservoir's ecosystem services is conducted based on the framework established by Turner et al. (2000). This framework (Figure 4.5) offers a systematic method to analyze the ecosystem services provided by the reservoir and their impact on sustainable water resource management. The research followed five main phases to better reflect the methodological steps present in the previous sections. The first phase focused on analyzing the current water resource planning in Astana, exploring the effectiveness of Kazakhstan's water resource strategy through documentary research, and examining how policy and management factors influence the water supply from the Astana Reservoir, considering population growth and related hydrological, climatic, demographic, and economic factors. The second phase identified the critical functions of the Astana Reservoir, including its structure, characteristics, and biophysical transformation processes, and employed relevant models for assessment. The third phase examined the physical and chemical status of the Astana Reservoir's ecosystem and analyzed the types of ecosystem services it provides to ensure comprehensiveness in the research. The fourth phase converted physical and chemical parameters into economic parameters, using various valuation methods to assess the ecosystem services of the reservoir, such as water supply, water purification, and soil conservation. Finally, the fifth phase employed semi-structured interviews to analyze how to integrate an ecosystem-based approach into Kazakhstan's water resource planning and gain insights from stakeholders on its importance and potential impacts. The following sections provide a detailed explanation of the research methods for each phase, including the advantages and disadvantages of the methods, as well as validity and reliability.

Figure 4.5 The research design of the case study



Source: Author's development based on Turner et al. (2000).

4.3.1 PHASE 1 – BACKGROUND ANALYSIS OF ASTANA WATER PLANNING AND MANAGEMENT

This phase of the research employed ROSES (Reporting Standards for Systematic Evidence Syntheses), aimed at systematically exploring the current state of water resource planning in Kazakhstan, focusing on the planning and utilization of water resources in the Astana region. It investigated the reasons for the ineffectiveness of Kazakhstan's water resource planning and analyzed how the policies and management factors related to Astana's water resource planning impact the Astana Reservoir.

ROSES serve as the first guidance for transparent reporting of systematic reviews and maps in environmental management and conservation, offering versatility and flexibility to accommodate diverse methods and topics (Haddaway et al., 2018). Initially developed for environmental science, it has been adapted for interdisciplinary applications in fields such as cybersecurity (Khaw et al., 2024), conservation (Pullin & Stewart, 2006), and revenue management (Restuningdiah & Sidharta, 2023). The framework is valuable for formulating research questions, conducting systematic searches, assessing quality, and extracting data (Mengist et al., 2019; Rooney et al., 2014). ROSES have been used to analyze themes, identify gaps, and provide insights across various domains, including branding and farming practices (Sánchez et al., 2021). Its application demonstrates ROSES's multifunctionality and effectiveness, guiding systematic literature reviews beyond its initial environmental focus and offering a structured approach to synthesizing evidence for informed decision-making while facilitating transparent feedback and reducing submission-to-publication time.

For the background analysis of this study, the main research questions were clearly defined, including the overall state of water resource planning in Kazakhstan, the specific situation of water resource planning in Astana, and the effectiveness of existing policies and management measures. Additionally, the study tracked the water supply from the Astana Reservoir to various sectors since the city's establishment, considering population growth and related hydrological, climatic, demographic, and economic factors. Furthermore, the study assessed the impact of water use limits established for the Esil River under basin management and related reservoir management policies on the Astana Reservoir. During the literature search phase, using the ROSES framework, relevant keywords were formulated, such as "Kazakhstan water resource planning", "Astana water resource management", "water resource utilization in Kazakhstan and Astana", and "water resource policies", utilizing multiple academic databases (such as CNKI, Google Scholar, Web of Science, and Scopus) for the search. The literature was limited to studies published in the last ten years to ensure the timeliness and relevance of the information while also focusing on reports released by government departments and international organizations.

To ensure the quality of the research literature, screening criteria were established, including the fact that the literature content must directly relate to water resource management in Kazakhstan and Astana. Preference was given to articles published in peer-reviewed academic journals, reports from government or international institutions, and evaluations of the research methods and data reliability employed in the literature. All screening processes were meticulously documented to ensure traceability.

After completing the literature selection, in-depth readings of the chosen documents were conducted to extract key viewpoints, data, and conclusions. Comparative analysis was used to identify consensus and controversies within different pieces of literature, with a particular focus on issues related to policies and management measures and their effectiveness. Based on the analysis results, the current state of water resource planning in Kazakhstan and the specific situation in Astana were systematically organized and summarized, employing tables and charts to present important data and information where necessary.

Finally, a review was written and structured to include the research background, current situation analysis (summarizing the state of water resource planning in Kazakhstan and Astana), and main findings. Throughout the research process, efforts were made to ensure the diversity of literature sources to form a comprehensive perspective while maintaining critical thinking in analyzing the literature to assess the reliability and applicability of each study. All references were cited strictly per academic standards, with ongoing attention to newly published literature to ensure the research's relevance and timeliness. This methodology provided an in-depth theoretical and policy analysis of the current state of water resource planning and utilization in Kazakhstan and Astana.

However, this approach has limitations, such as potential delays in literature updates and inconsistencies in data that may affect the accuracy of the analysis. Additionally, the availability of relevant literature may impact the comprehensiveness of the research. To address these issues, the study prioritized the selection of the most recent peer-reviewed journal articles and policy documents, as well as interviews with local government and relevant institutions, to obtain first-hand information and ensure the timeliness and accuracy of the data.

4.3.2 PHASE 2 – IDENTIFICATION OF THE MOST IMPORTANT FUNCTIONS OF ASTANA RESERVOIR

After obtaining a basic understanding of the reservoir, the analysis examined the structure and functions pertinent to the Astana Reservoir. According to the framework provided by Turner et al. (2000), the analysis of the ecosystem functions focused on three key aspects: characteristics, structure, and biophysical transformation processes (see Appendix A for details on ecosystem functions). Specifically, this included:

Structure of the Reservoir: This encompassed land cover and ecosystem types. It was analyzed using land cover/land use data to derive the extent and account of the ecosystem of the Astana Reservoir. The structure also included the relationships between biotic and abiotic elements, such as vegetation types, soil types, and ecological networks (Turner et al., 2000). These indicators were essential for understanding the spatial distribution and composition of the reservoir's ecosystems, although they required extensive data collection and analysis.

Characteristics of the Reservoir: The reservoir's characteristics focus on critical parameters that describe its biological, chemical, and physical attributes. These included water volume, water quality (such as nutrient concentrations, pH, and dissolved oxygen), and physical features like the catchment area, water level, and storage capacity. The catchment area refers to the watershed area of the reservoir. During regular operation, the lowest allowable water level in the reservoir is known as the dead water level, and the storage below this level is termed the dead storage capacity. The space between the average and dead water levels constitutes the utilizable/standard storage capacity. During water supply periods such as irrigation, the water level in the reservoir needs to be maintained above the average storage capacity. These parameters were crucial for evaluating the reservoir's health and functionality, playing a pivotal role in monitoring environmental quality and resource availability, although continuous monitoring was necessary for accurate assessment. In each aspect of the assessment that requires examination, Table 4.7 lists the relevant indicators and the research purposes, advantages, and disadvantages associated with each indicator.

Biophysical Transformation Processes: Biophysical transformation processes refer to material and energy transformation dynamics within the reservoir. Relevant hydrological, soil, and flood regulation models assessed water flow, evaporation, nutrient cycling (e.g., nitrogen and phosphorus), and ecological interactions affecting ecosystem functions (Turner et al., 2000). These processes significantly impacted the reservoir's ecological balance and service provision. While they offered valuable insights into ecosystem dynamics and resource management, they often required complex modeling for precise data.

Additionally, Table 4.7 summarizes the indicators for the ecosystem and water condition of the Astana Reservoir, along with their advantages and disadvantages.

Table 4.7 Indicators for ecosystem and water condition of the Astana reservoir

Aspect of Assessment	**Indicators Used**	**Purpose/Explanation**	**Advantages**	**Disadvantages**

Structure of the Reservoir	Land cover, vegetation types, soil types	It helps assess the spatial distribution of ecosystems and the relationships between biotic and abiotic elements.	Understanding spatial distribution and composition facilitates effective management planning.	Requires extensive data collection and analysis
Characteristics of the Reservoir	Water volume, water quality (nutrient concentrations, pH, dissolved oxygen), catchment area, normal and dead water levels, storage capacity	Key for understanding biological, chemical, and physical attributes; essential for ensuring adequate water supply and quality.	Evaluate reservoir health and functionality and monitor environmental quality and resource availability.	Continuous monitoring is needed for accurate assessment
Biophysical Transformation Processes	Water flow, evaporation, sediment load	Assesses material and energy transformations affecting ecosystem functions.	Offers valuable insights into ecosystem dynamics and resource management.	Requires complex modeling for precise data

Applying hydrological and soil models was crucial for understanding the reservoir's water dynamics and conservation capabilities. These models offered a framework for assessing the reservoir’s role in water management and ecosystem service provision, thereby supporting informed decision-making in environmental and policy planning. The corresponding models are as follows:

Model for Understanding Water Dynamics

This model (Water Balance Model) helps us understand the flow and storage of water within reservoirs by calculating the balance between water entering and leaving the system (Plitkin & Gronskaya, 1981; Akiyanova et al., 2020). Analyzing this balance, we can determine changes in water storage over specific periods. This understanding is crucial for water resource management, as it highlights the reservoir's role in water supply and ecosystem services, aiding decision-makers in environmental and policy contexts (Song et al., 2022). The principle of the Water Balance Model involves subtracting the outflows from the inflows within a given region to determine ΔS, representing the change in water storage within the region over the study period (Song et al., 2022). The specific formula is shown in Equation 1 (Plitkin & Gronskaya, 1981; Akiyanova et al., 2020). By collecting data for each variable and manually calculating them, the reservoir's water balance can be verified.

$$(Q_i + P) - (Q_o + Q_{abs} + E) = \Delta S \qquad \text{(Equation 1)}$$

Qi - surface inflow from the river;

P - precipitation;

E - evaporation;

Qo - surface outflow;

Qabs - water abstraction;

ΔS - reservoir water storage change during the calculated time interval.

Model for Assessing Soil Conservation

The Sediment Regulation Model evaluates the role of vegetation in preventing soil erosion. It compares soil loss with and without vegetation cover, revealing how vegetation helps protect soil (Renard et al., 1997). This is vital for maintaining healthy ecosystems, as soil erosion can impact agricultural productivity and water quality. The model underscores the importance of vegetation and supports land management and environmental protection decisions (Burkhard et al., 2019; Boris & Stoyan, 2016; UN, 2021).

The Sediment Regulation Model is a tool based on the Revised Universal Soil Loss Equation (RUSLE) (Renard et al., 1997), which estimates soil loss and retention by vegetation in tons of sediment per hectare per year. By running RUSLE twice – first with existing land cover and then with all land cover changed to bare soil – the model determines the contribution of vegetation to soil retention, representing an ecosystem service.

The Sediment Regulation Model operates within the Artificial Intelligence for Environment & Sustainability (ARIES) platform, developed by the Basque Centre for Climate Change (BC3) in Spain, in collaboration with organizations like UN DESA and UNEP (UN, 2021). ARIES consists of k. Explorer and ARIES for SEEA Explorer interfaces, with k.LAB Modeler is the central coding hub—

this version of k.JAVA supports LAB Modeler (1.5.10) and offers various components like k.LAB Control Center and k.LAB Engine.

Within k.LAB Modeler provides comprehensive code definitions, data resources, and models covering agriculture, climate, demography, ecology, geography, hydrology, land cover, soil, and more (Kenneth et al., 2011). The Modeler facilitates ecosystem service valuation for research areas and provides table samples for SEEA accounts released by the UN (UN et al., 2021).

Soil erosion control is modeled as an ecosystem service by comparing erosion rates with and without vegetation cover, utilizing RUSLE methods (Burkhard et al., 2019; Boris & Stoyan, 2016). The calculation involves factors like LS, K, C, and P based on contributing area, soil characteristics, and land cover type (Equation 2). This modeling approach aids in understanding the role of vegetation in controlling soil erosion.

$$\mathbf{A = R * K * LS * C * P} \qquad \text{(Equation 2)}$$

A - soil loss;
R - rainfall-runoff erosivity;
K - soil erodibility;
LS - slope steepness and length;
C - cover management;
P - conservation practice.

Additionally, Evaluating flood regulation ecosystem services (ESFR) is a complex task that requires consideration of multiple factors, including vegetation biomass, forest cover, and available water space (Vári et al., 2022). These indicators directly affect the effectiveness of ecosystems in regulating floods, as higher biomass and extensive forest coverage can enhance water retention and groundwater recharge, thereby improving flood regulation capacity.

An effective assessment method involves using tools based on ArcSWAT outputs, which integrate hydrological modeling and geographic information system (GIS) technologies to conduct in-depth analyses of flood regulation capabilities (Nikolov & Nedkov, 2019). Through these technologies, researchers can create models to simulate future scenarios and evaluate the performance of ESFR under different management strategies. This approach not only aids in understanding ecosystem functions under various conditions but also provides valuable data to support land use and risk management decisions (Wübbelmann et al., 2021; Martínez-García et al., 2022).

In practice, various methods are employed to assess ESFR. For instance, damage avoidance methods, in combination with hydrological modeling and cadastral data, have been used to quantify the value of ESFR in agricultural ecosystems, indicating that irrigated woody crops excel in flood regulation (Martínez-García et al., 2022). Additionally, combining hydrological modeling tools (such as SWAT and HEC-RAS) with non-market monetary valuation methods for damage avoidance has been applied to basin management in forested mountainous areas (Gallay et al., 2021).

However, this study cannot comprehensively cover the assessment of ESFR due to the complexity of the process and the specialized knowledge required. Different ecosystems can provide ESFR, necessitating an in-depth examination of several key factors during mapping and modeling. The types and distribution of vegetation within floodplains significantly influence ESFR (Nagy et al., 2018), while water bodies' storage capacity (Acreman et al., 2003) and soil's water retention capability (Palmer & Smith, 2013) are equally important. Each type of water body (such as lakes and wetlands) and soil (such as clay and sandy soil) plays a unique role in flood regulation, and accurately assessing these factors necessitates extensive data collection and analysis involving specialized hydrological and geographic information technologies. In summary, assessing ESFR is a multidisciplinary process that involves knowledge across ecology, hydrology, and soil science and requires a substantial amount of high-quality data. Given this study's scope and resource limitations, it is evidently challenging to cover all these aspects comprehensively.

The output of this phase was the Ecosystem Extent Account, which recorded the total area of various ecosystems classified by type within different regions, such as countries, provinces, basins, and protected areas. Its purpose was to quantify changes in the extent of different ecosystem types over time. This account included total changes (increases and decreases) and net changes for individual ecosystem assets. These changes were categorized into managed expansion/reduction due to human activities like forest clearance and natural expansion/regression due to processes like forest succession (UN et al., 2021).

4.3.3 PHASE 3 – CLASSIFYING AND ANALYZING THE SELECTED ECOSYSTEM SERVICES IN ASTANA RESERVOIR

This step examined the status of the ecosystem studied in the Astana Reservoir, including an assessment of the "physical state characteristics" and "chemical state characteristics" of the aquatic ecosystem in the reservoir. Subsequently, by investigating the utilization of the reservoir for human economic activities and the commonly used classification standards for ecosystem services, specifically outlined in Table 2.4 (Classification of ES) in section 2.4, the types of ecosystem services provided by the Astana Reservoir were analyzed and determined.

The Ecosystem Condition Account for the Astana Reservoir systematically evaluates its physical and chemical characteristics from 2000 to 2019. This methodology outlines the indicators to be measured, providing a comprehensive rationale for each selection in the context of the reservoir's capacity and water supply conditions, in alignment with the ecosystem services assessment framework. Each selected indicator is supported by specific local data sources, detailing the frequency and scope of the data used.

Physical State Indicators

Water Quantity:

Assessing water quantity involves measuring inflow and outflow volumes and the reservoir's water level. Reservoir characteristics typically include the catchment area, water level, and storage capacity. The catchment area refers to the watershed associated with the reservoir, which is crucial in overall water quantity management. This includes the Volume at Dead Water Level (DWL), Volume at Normal Water Level (NWL), and Discharge Volume.

- Volume at Dead Water Level (DWL): Measured in meters (m), this indicator assesses the volume of water at the DWL. Data was sourced from the monthly water balance reports provided by Kazvodkhoz, covering the period from 2004 onward. This monthly frequency allows for a granular understanding of changes in storage capacity over time, enabling timely assessments of water availability. The lowest allowable water level during normal operation is known as the dead water/pool level, and the storage below this level is termed the Dead Storage Level (DSL)/Dead Water Level (DWL) (Majumdar, 1969).

- Volume at Normal Water Level (NWL): Also measured in meters (m), this indicator tracks changes in the reservoir's volume at the NWL. Monthly data from Kazhydromet's water volume reports (2002-2020) capture fluctuations and trends in overall water availability, informing water management strategies. The space between the NWL and the DWL constitutes the utilizable storage capacity.
- Discharge Volume: Measured in million cubic meters (million m^3), this indicator evaluates the total annual discharge from the reservoir. Monthly data from the Esil Basin Inspector on water withdrawals from 2004 to 2021 is used to assess water consumption trends and overall availability over time. During water supply periods, such as irrigation, it is essential to maintain the water level above the normal storage capacity to ensure effective utilization (Hesham et al., 2017).

Soil Erosion:

- Soil Erosion Metrics: Measured in tons, this indicator assesses the effectiveness of the reservoir in controlling soil erosion based on sediment regulation models. Changes in soil erosion can profoundly affect water quality and the integrity of aquatic habitats. Data was drawn from the

ISRIC – World Soil Information data hub, updated yearly. This annual frequency allows for a broader understanding of trends in soil erosion control, which is crucial for maintaining water quality and aquatic habitats.

Chemical State Indicators

The chemical characteristics of the reservoir are primarily evaluated through various water quality parameters:

- Water pH: This indicator measures the acidity or alkalinity of the water using a standardized pH scale (0-14). Maintaining a stable pH is critical for aquatic life, as extreme values can harm fish and other organisms. Monitoring pH levels helps assess the overall health of the reservoir and the effectiveness of its water purification functions, which are vital for ensuring safe drinking water and sustaining local biodiversity. The yearly water quality reports from Astana Su Arnasay (2020-2022) provided this data.
- Biochemical Oxygen Demand (BOD): BOD Measurement: BOD measures the dissolved oxygen microorganisms require to decompose organic matter in a water sample over five days, expressed in milligrams per liter (mg/L). Elevated BOD values indicate higher levels of organic pollution, suggesting that increased oxygen is necessary for the microbial breakdown of organic material

(Dodds et al., 2009). Monthly water quality data from Kazhydromet are used to evaluate organic pollution levels in the reservoir, which is critical for assessing water purification processes.

According to the Common International Classification of Ecosystem Services (CICES) V4.3 (CICES, 2011), ecosystem services are primarily categorized into three major types: provisioning, regulating, and cultural services. The Astana Reservoir is the primary water source for Astana and its surrounding villages, providing essential drinking water and fish products - Supply Services. In addition, the reservoir plays a crucial role in water storage, purification, flood control, and soil protection - Regulation Services. Lastly, the Astana Reservoir, known for its high tourism value and dedicated hunting grounds, attracts many visitors for fishing and relaxation, highlighting the increased value of recreation services due to improved environmental quality.

4.3.4 PHASE 4 – ECONOMIC VALUATION OF THE SELECTED ECOSYSTEM SERVICES IN THE ASTANA RESERVOIR

This step involves converting the physical and chemical parameters above into economic parameters, with valuation methods outlined in Table 4.8. The following provides a detailed explanation of each valued ecosystem service of the Astana Reservoir.

Table 4.8 ES valuation methods of Astana reservoir

Ecosystem services	**Function**	**Indicators**	**Methods**
Provisioning services	Water supply	Domestic (residential) water; Agricultural water; Industrial water; Environmental water.	Direct market price
Regulating services	Water purification	Chemical condition of freshwaters	Cost Avoidance; Opportunity Cost
	Erosion control	Average annual soil erosion control of the river	Avoided cost
Recreation services	Physical and intellectual interactions with biota, ecosystems, and land-/seascapes	Entertainment Aesthetic (Recreation)	Zonal Travel cost

Provisioning services

- **Water supply**

The water from the Astana City Water Supply Company supplies industries and households. Therefore, the final ecosystem service of water provisioning is reflected within the economic units of industries and households (Vardon et al., 2019). The water supply service of the Astana Reservoir was valued using the market pricing method.

The market pricing method is a commonly used economic valuation approach for assessing the value of water supply services. This method relies on existing water resource transactions and associated prices in the market for evaluation. Initially, it is necessary to identify market transactions related to water resources, such as water supplied by water supply companies to residents, businesses, or public institutions. Then, market data related to these water resource transactions must be collected, including prices, supply and demand quantities, transaction parties, and market structures. Based on this information, the market value of water resources can be calculated by determining the market price of water resources and multiplying it by the supply quantity. The calculation formula is shown in Equation 3 (Zhao & Wang, 2021):

$$\mathbf{V1=\sum(Q1i \times P1i)} \qquad \textbf{(Equation 3)}$$

V1: value for water supply (USD);
Q1i: the amount i of drinking water consumed (m^3);
P1i: the price of water for i purposes (USD /m^3).
Data needed: water consumption and prices of various types of water (agricultural, industrial, environmental, domestic).

Regulating services

- **Water purification**

A healthy aquatic ecosystem possesses self-purification capabilities, which are crucial for maintaining water quality. Higher levels of water pollution necessitate increased expenditures for treatment and restoration, resulting in significant financial burdens for municipalities and water supply companies. Conversely, improving water quality can lead to substantial reductions in the operational costs of water treatment plants, thereby exemplifying the concept of cost avoidance. This term refers to the savings achieved by preventing potential future costs, emphasizing that proactive measures in managing water quality can result in long-term financial benefits (Piper, 2003; Elsin et al., 2010; Montoya et al., 2011).

One effective method for evaluating the water purification services provided by the reservoir is the avoided-cost approach, which is widely recognized in environmental economics. This approach allows us to estimate the financial implications of maintaining or improving water quality by considering the costs incurred if such measures were not implemented. Specifically, when the Astana

City Water Supply Company abstracts water from the reservoir, the water requires treatment before distribution to consumers. Despite the treatment process, it is noteworthy that approximately 65% of residents prefer bottled water, indicating a lack of confidence in the tap water quality (Karaca et al., 2019).

Therefore, when assessing the value of the water purification service, it is essential to incorporate both the operational costs of the water treatment plants and the expenses associated with bottled water consumption by the population. This valuation approach underscores the economic options of investing in the health of aquatic ecosystems, as it not only enhances public health and safety but also contributes to significant cost savings for the city and its residents (Vardon & Onder, 2023).

The valuation formula for the Water purification service is Equation 4 (revised by Zan et al., 2020); this formula accounts for the costs of treating water from the reservoir and the additional costs incurred by the population choosing bottled water.

$$V2=\sum(Q2i \times P2i+C2) \qquad \textbf{(Equation 4)}$$

V2: purification value for the river (USD);

Q2i: the treatment capacity (t) of the river for category I;

P2i: the cost (USD/t) to process the i-type substance;

C2: = 62%*N*C.

(N is the population of Astana city, C is the per capita bottled water cost, and 62% stands for the percentage of the population consuming bottled water)

Required data: Statistical report on the pollutant treatment capacity of the reservoir/river for N element, the pollutant treatment capacity for COD (Chemical Oxygen Demand), and the pollutant treatment capacity for ammonia nitrogen.

- **Erosion control**

As defined by the MEA, the erosion regulation ecosystem service underscores the crucial role of vegetation cover in preventing soil erosion and preserving soil fertility (Burkhard et al., 2019). In Step 3, the Sediment Regulation Model was utilized to calculate the amount of soil lost from the Astana Reservoir between 2000 and 2019, with soil erosion leading to soil salinization. Therefore, the avoided cost method was applied, as it quantifies the losses incurred due to soil erosion, providing a value for the reservoir's soil erosion control. The avoided cost method estimates the costs that can be avoided by implementing measures to prevent or mitigate soil degradation (Panagos et al., 2024). This approach is crucial because it considers the current losses from soil erosion and assesses the potential economic losses that may arise if no action is taken in the future. By evaluating these potential expenses, stakeholders can better understand the economic benefits of erosion control practices (Mikhailova et al., 2019). This quantification helps stakeholders recognize the necessity and significance of investing in soil conservation measures, enhancing awareness and action towards protecting ecosystem services.

By quantifying the cost per unit reduction in soil erosion over a specific period, researchers can compare the efficiency of different conservation strategies (Wang et al., 2015; Kumar, 2010). This facilitates decision-makers in prioritizing interventions that yield the most significant soil conservation benefits relative to their costs. The principle is to multiply the cost of soil degradation in the study area by the amount of soil degradation in the study year; the calculation formula is as follows (Wang et al., 2015):

$$\mathbf{V3 = Q3 \times P3} \qquad \textbf{(Equation 5)}$$

V3: the river soil erosion control value (USD);

Q3: The average annual soil erosion control of the river (t);

P3: Land degradation costs (USD/t).

Recreation Services

The value of recreation services increases with the improvement of environmental quality and diversity. Its valuation typically involves the application and combination of various methods, with the most commonly used being the combination of hedonic pricing, Travel Cost Method (TCM), and Contingent Valuation Method (CVM) (Whitehead et al., 2000; Rolfe & Dyack, 2010).

The Zonal Travel Cost Approach explicitly provides several advantages, including simplicity, cost-effectiveness, and reliance on actual visitor behavior, which reveals valuable insights into economic value (Loomis & Walsh, 1997; Parsons, 2003). However, this method has limitations, such as potential data quality issues and the assumption that travel cost is the primary determinant of visitation, neglecting other influential variables like site quality (Ward & Beal, 2000; Cesario, 1976). To enhance the validity and reliability of the research design and its findings, it is essential to apply content and construct validity methods by consulting experts and comparing results with similar studies (Bateman et al., 2002). Reliability can be assessed through approaches including test-retest reliability, varying data periods, and inter-rater reliability involving multiple researchers (Freeman et al., 2014). Furthermore, sensitivity analysis and triangulation can be utilized to test the robustness of assumptions and cross-verify results using diverse methods (Hanley & Barbier, 2009). Together, these strategies establish the credibility and trustworthiness of the research.

In scenarios with limited data, researchers can further reinforce the validity and reliability of their study by engaging experts to evaluate the research design for relevance and credibility (Maxwell, 2013). Comparing findings with existing literature also aids in assessing consistency and plausibility (Yin, 2018). Using simulated sensitivity analysis data allows researchers to test result stability under varying assumptions (Pannell, 1997). Additionally, case studies involving similar contexts can validate the method's applicability and outcomes (Yin, 2018). Incorporating qualitative methods, such as interviews or focus groups, can provide complementary insights to bolster quantitative findings

(Creswell & Plano Clark, 2017). Collectively, these strategies enhance the study's robustness even in the face of data limitations. The specific steps of the Zonal Travel Cost Approach are shown in Table 4.9：

Table 4.9 The steps of the Zonal Travel Cost Approach

Steps		**Description**
1	Define Areas	Segment the region into different zones based on distance or geographic features to analyze visitor flow (Parsons, 2003).
2	Collect Visitor Data	Gather the number of visitors and their postal codes for each zone, summarizing the total visits over the past year (Ward & Beal, 2000).
3	Calculate Visit Rates	Compute the visitation rate per 1,000 people to standardize data for comparison across different zones (Freeman et al., 2014).
4	Calculate Travel Costs	Estimate each zone's average travel distance and time, calculating the total travel costs based on standard expenses.
5	Regression Analysis	Examine the relationships between visitation rates, travel costs, and other variables to identify influencing factors (Hanley & Barbier, 2009).
6	Develop Demand Function	Establish visitors’ demand functions based on regression results and estimate visitor numbers under different entry fees.
7	Estimate Economic Benefits	Assess the total economic benefits of the reservoir by calculating consumer surplus, providing an estimate of annual economic value (Bateman et al., 2002).

Source: Author (2024).

Below are the specific steps for estimating the recreational service value of Astana Reservoir using the Zonal Travel Cost approach. Data sources and detailed descriptions are incorporated to facilitate clarity and transparency.

Step 1 (ZTC): Research Area

To estimate Astana Reservoir's recreational service value, the administrative regions surrounding the reservoir in the Arshaly district were selected. This area serves as a short-distance travel base for Astana residents, with primary routes passing through Jibek Joly, Zhaltyrkol, and Arnasay villages. Key recreational destinations include Primevill, Beibarys, and Jansaya in Jibek Joly; The Lake House in Zhaltyrkol; and Otdykh Vyacheslavskoye Vodohranilishche in Arnasay.

Step 2 (ZTC): Collect Information

Telephone interviews were conducted to gather information on the travel zones identified in Step 1 concerning recreational trips to the study area. This information included the number of visits per year, the population of the villages, the distance from the travel zones to the city center of Astana, and cost-related details.

Step 3 (ZTC): Data Organization

In this step, the data collected in Step 2 was structured regarding the volume and frequency of visitors to the Arshaly region from Astana, with population figures based on the 2019 census. The visitation rates per 1,000 populations in each zone were calculated.

Step 4 (ZTC): Calculate Travel Costs

Using the geographical information of the five recreation centers mentioned, round-trip distances and travel times from the center of Astana to each center were obtained through geographic information systems (e.g., Google Maps). Additionally, the average travel cost was estimated to be $0.19 per kilometer based on data from Travelmath (Travelmath, 2024), which calculated fuel consumption costs. The average income in Kazakhstan from 2000 to 2023 was provided by CEIC (CEIC, 2024), translating to approximately $0.018 per minute of travel time cost. The average costs per person visiting the first three recreation centers were sourced from visitor reviews on the 2GIS software for 2024, and the fixed expenses for the last two centers included entry fees and estimated meal costs. The total cost of visiting each recreation center was calculated by summing transportation costs, travel time costs, and direct costs, excluding accommodation, as all centers are close to Astana.

Step 5 (ZTC): Regression Analysis

In this step, the total travel costs calculated for each zone in Step 4 were used along with the average number of visits per 1,000 people, as described in Table 4.9. A linear regression function was employed to analyze the relationship between total travel costs and average visitation rates for the Arshaly region, resulting in function parameters that provide a basis for further analysis.

Step 6 (ZTC): Develop the Demand Function

Based on the regression analysis results, this step involved deriving a hypothetical demand function for the Vyacheslavskoye recreation zone (Astana Reservoir). An increase of $2 in the entrance fee for each attraction in the Arshaly region was assumed to decrease total visits, as some recreational spots around Astana Reservoir require an entrance fee of approximately $2. Subsequent calculations determined how visitation would change under different fee scenarios. The demand function can be expressed as:

$$V4 = A4 - B4 * C4 \qquad \textbf{(Equation 6)}$$

V4: the visit volume (annual number of visitors);

C4: the total cost per trip (including travel and entry fees) (USD);

A and B are parameters estimated through regression, with A representing potential maximum visitation at zero cost and B representing the decrease in visitation as costs increase.

Step 7 (ZTC): Estimate Economic Benefits

Finally, the demand curve for the Vyacheslavskoye attraction (Astana Reservoir) was constructed using the data from the demand function. The X-axis represents the added cost, while the Y-axis indicates total visits. The area under the demand curve was utilized to estimate the total economic benefit provided to visitors over a year.

This research design systematically assesses recreational services' economic value at Astana Reservoir, providing quantitative data to inform related environmental and management decisions. The ZTC Method, due to its practicality and reliance on actual visitor behavior, offers valuable insights into the economic benefits of such recreational areas. Nonetheless, careful consideration must be given to data quality and the implications of various factors that influence visitation.

4.3.5 PHASE 5 – FEEDBACK ANALYSIS ON INCORPORATION OF THE ESV INTO THE WATER PLANNING IN KAZAKHSTAN

- **Semi-structured interview design and stakeholder selection**

The semi-structured interview questions were carefully crafted to examine stakeholders' perceptions, experiences, and opinions on integrating ESV into water planning in Kazakhstan. The goal was to assess how these methodologies could improve water resource management and enhance planning processes.

Purposive sampling was utilized to select participants, targeting key stakeholders with expertise in Kazakhstan's water management, environmental conservation, and policymaking. Purposive sampling was initially used to identify key stakeholders relevant to the ecosystem-based approach, followed by snowball sampling to facilitate additional interviews with those identified in the first round. This approach ensured that the selected individuals could offer valuable insights into the effective integration of ESV and SEEA in water planning initiatives. A total of 24 participants were included to achieve data saturation, providing a comprehensive understanding of stakeholder perspectives.

The participants in this study encompass a diverse array of stakeholders critical to water resource management (Table 4.10). They include central government authorities, represented by officials from ministries such as the Minister of Water and Irrigation and the Minister of Ecology and Natural Resources (coded as 1CG). Additionally, regional authorities at the basin, aquifer, and city levels, such as Kazvodkhoz and river basin inspectors, contribute to governance and oversight (coded as 2WO). The scientific and technological community is also represented, including water experts and researchers from institutions like Nazarbayev University and the Eurasian National University, who provide valuable insights into water management practices (coded as 3ST). Finally, water users, comprising industrial water suppliers and representatives from national and foreign oil companies, are integral to understanding water resource demand and usage patterns (coded as 4WU). Each stakeholder group is planned to include six participants, ensuring a comprehensive perspective on the multifaceted challenges and strategies in water resource management.

Interviews were conducted at the interviewee's workplace or a quiet public location in Astana, as per their preference, including within the Nazarbayev University campus. One-on-one interviews lasted approximately 30-45 minutes and required no additional equipment. For those unable to meet in person, interviews were conducted via Zoom, with meetings scheduled in advance according to the interviewee's availability. To maintain confidentiality, interviewees were asked to show their immediate surroundings during online sessions to ensure no third parties were present. Each interviewee was assigned a specific code to ensure anonymity, with the code key stored separately from the interview data.

Prior to conducting research, all relevant written documents related to the interview research were submitted to the Nazarbayev University Institutional Research Ethics Committee (NU IREC). These documents included the application, CITI training certificates for the interviewers and their supervisors, letters of recruitment for the interviewees, an information letter provided during the interview, confidentiality agreements, and written or verbal consent forms. After receiving approval and confirmation from IREC, the process of recruiting interviewees began.

Table 4.10 The information of interviewees

Type of stakeholder	Central government authorities	Basin, aquifer, protected area, and city-level	Scientific and technological community	Water users
Representatives	Committee of water resources/ministries responsible for water resources	RBIs, RBOs, Astana su arnasay, Kazhydromet, Kazvodkhoz	Water experts	Industry, agriculture sector
Planned Sample	6	6	6	6
Organizations	Minister of water and irrigation; Minister of ecology and natural resources; Water Resources Management Methodology Research Center.	Kazvodkhoz in Central and different regions; River basin inspector.	Nazarbayev University; Eurasian National University; Institute of Science Education.	Industrial water supplier company; National and foreign oil companies.
Codes of anonymous	1CG	2WO	3ST	4WU

The semi-structured interview questions were designed to explore the interviewee's background and their understanding of water resource management in Kazakhstan. They specifically addressed the history and significant changes in this field, as well as current issues and environmental challenges related to water resources. Additionally, the interviews sought to gather perspectives on ecosystem services valuation (ESV) in the Astana Reservoir, including the respondents' perceptions of the ESV results and their role in urban water resource planning in Astana. Finally, the questions examined the interviewees' views on integrating ESV into Kazakhstan's water resource management and planning, highlighting both potential implementation strategies and the challenges involved.

The coding frame of this study includes several main categories: background information, historical context, current issues, ecosystem services valuation (ESV), and the integration and management of ESV. The specific coding hierarchy is illustrated in Table 4.11, which encompasses the main topics and their subtopics. The main topics include understanding water resource management in Kazakhstan, with subtopics addressing history and significant changes, water resource management issues, and environmental challenges. Regarding the ESV of the Astana Reservoir, the subtopics focus on respondents' perceptions of ESV and its role in urban water resource planning in Astana. Finally, the views on integrating ESV into water resource management and planning feature subtopics that discuss perspectives on implementing ESV in Kazakhstan and the challenges involved in this implementation. This structure facilitates a systematic analysis of the data, allowing for a deeper understanding of various aspects. Detailed interview questions can be found in Appendix E.

Table 4.11 Main topics and subtopics of interview questions

Main topics	**Subtopics**
Understanding of Water Resource Management in Kazakhstan	History and major changes
	Water Resource Management Issues in Kazakhstan
	Environmental Challenges in Water Resources
Respondents' Views on ESV in the Astana Reservoir	The perception of the ESV of the Astana Reservoir

	The Role of ESV in Astana's Urban Water Resource Planning
Respondents' Views on Integrating ESV into Water Resource Management /Water Resource Planning	Views on Implementing ESV in Kazakhstan
	Challenges in Implementing ESV

- **Data analysis**

The analytical technique employs relational analysis to identify core themes and explore the interconnections between different concepts. Relational analysis is a social science method focused on the relationships between social entities (Kenney & Frontmatter, 2020; Cavasotto, 2015). This approach is particularly suitable for examining the interactions between ecosystem services and policy-making, revealing key factors influencing their relationship.

A coding framework is used to categorize the data into primary categories and subcategories to achieve effective analysis. This study's primary categories include the history and current state of water resource management, ecosystem service valuation (ESV), and related environmental challenges and opportunities. Specifically, the subcategories encompass the perspectives on the background, significant changes, current issues, and ecosystem service assessment related to water resource management in Kazakhstan (Zhao, 2021). This classification ensures the systematic and transparent nature of the analysis, allowing researchers to identify and understand the connections between various factors clearly.

The research team uses NVivo software to maintain analytical rigor for coding and organizing during the data analysis phase. NVivo effectively handles and analyzes large volumes of complex data obtained from semi-structured interviews (Dicicco et al., 2006; Kallio et al., 2016). This tool allows researchers to flexibly adjust the coding to suit the varying responses during the interview process, thereby gaining deeper insights into respondents' perspectives (Guest et al., 2006). NVivo also supports various recording and organizing functions, ensuring the systematic and traceable nature of the data. Additionally, detailed log records are maintained to enhance transparency and replicability, further bolstering the credibility of the research findings (Malterud et al., 2016). This systematic approach improves the efficiency of data analysis and provides a solid foundation for subsequent policy recommendations. Detailed interview questions and key themes can be referenced in Appendix E and Table 4.11.

- Validity and Reliability of the research design

The validity of this study is reflected in its integration of the System of Environmental-Economic Accounting (SEEA) and Ecosystem Service Valuation (ESV) methodologies, ensuring a comprehensive assessment of ecosystem services related to the Astana Reservoir. SEEA, as a global framework proposed by the United Nations and refined through multiple pilot studies, offers high applicability and reliability (Tomas et al., 2017; CICES, 2011). By combining SEEA with the ESV approach established by Turner et al. (2000), the research effectively captures the multidimensional characteristics of ecosystem services while ensuring a solid theoretical foundation for the findings. Furthermore, the phased approach—analyzing current water resource planning, identifying key functions, conducting economic assessments, and gathering feedback—facilitates clear causal relationships, thereby enhancing internal validity (Haddaway et al., 2018; Mengist et al., 2019). This systematic methodology allows for accurate evaluations of the ecological health of the reservoir and its role in water resource management, providing a scientific basis for policy formulation.

In terms of reliability, this study enhances the credibility of its findings through diverse data collection methods and strict quality control measures. The research employs a combination of remote sensing technologies, field surveys, market data analysis, and semi-structured interviews, ensuring diversity and accuracy in data sources (Bolliger et al., 2017). This methodological variety effectively mitigates potential biases associated with any single source. Additionally, a quality screening process was implemented during the literature review to include only peer-reviewed and relevant studies, thus improving data reliability. To address the impact of seasonal variations on physical and chemical measurements, the research utilizes long-term historical data (2000-2019), which enriches the understanding of long-term trends (Davis & Slobodkin, 2004). In the semi-structured interviews, a standardized question framework was employed, and NVivo software was utilized for coding and thematic analysis, ensuring the consistency and comparability of qualitative data. Through these measures, the study gains reliable data support and provides a solid foundation for future water resource management policies.

CHAPTER 5

RESULTS

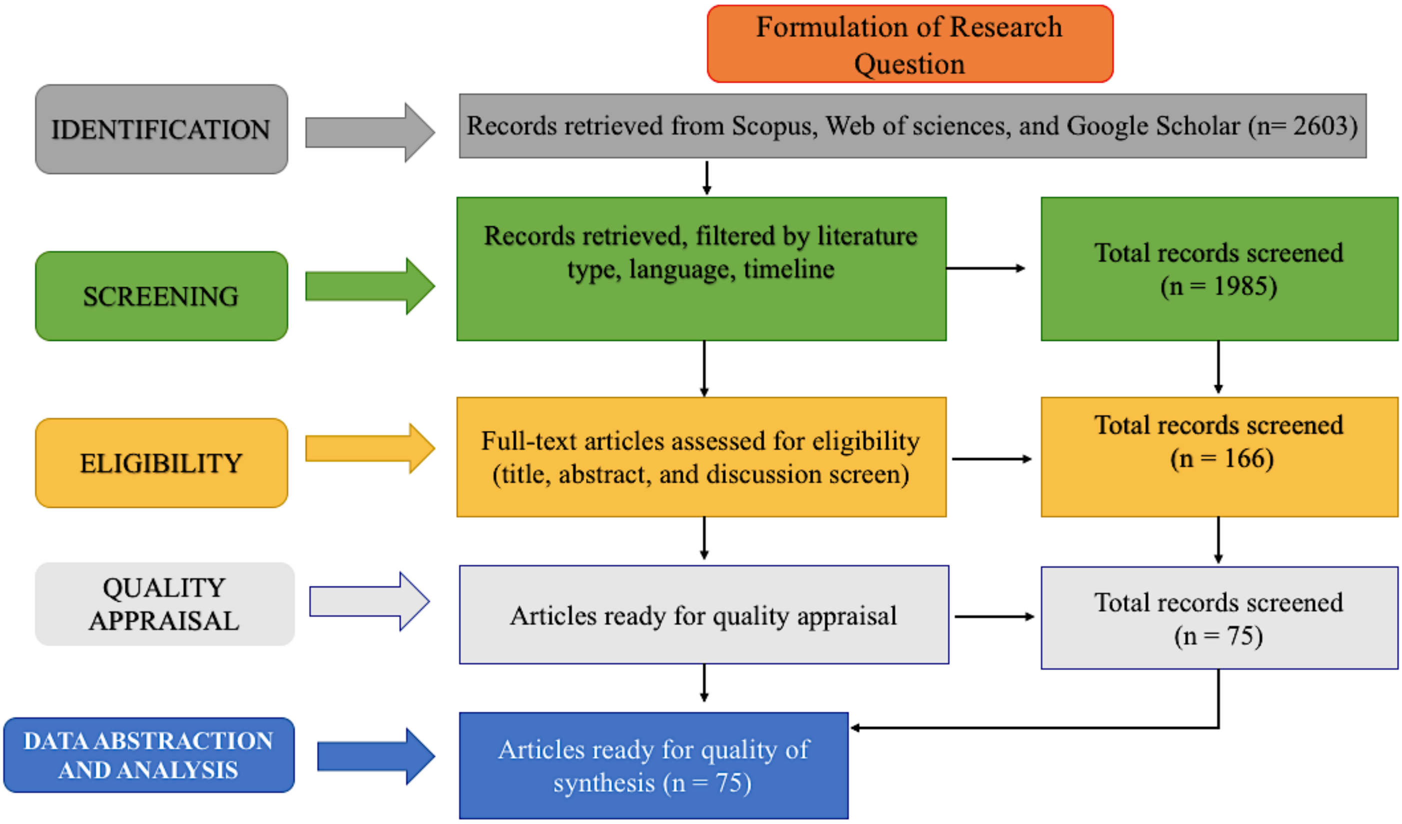
5 RESULTS

5.1 MAPPING OF WATER PLANNING AND MANAGEMENT IN KAZAKHSTAN (PHASE

5.1.1 SYSTEMATIC REVIEW ON WATER RESOURCE MANAGEMENT IN KAZAKHSTAN

The ROSES (Research on the Effectiveness of Systematic Reviews) process is a systematic review methodology encompassing four phases: Identification, Screening, Eligibility, and Quality Appraisal. This study focuses on water resource management in Kazakhstan, particularly in the Astana region, with particular attention to actual cases and policy analyses. The literature sources prioritized articles published in internationally renowned academic journals, official government reports, and publications from international organizations (such as the United Nations and the World Bank). The detailed flow diagram is shown in Figure 5.1:

Figure 5.1 The flow diagram of ROSES



Source: Author (2024).

1. Identification Phase

In this stage, relevant keywords were utilized to conduct literature searches across multiple databases. The Web of Science was selected as the primary source due to its reputation as one of the most comprehensive academic databases. It covers various disciplines and provides high-quality peer-reviewed papers that effectively support the research objectives.

The keywords employed for the search included "water resource management in Kazakhstan," "water planning in Kazakhstan/Astana/Nur-Sultan," "water regulations," and "water resource planning." Through these keyword searches, 2,603 literature sources were identified. To ensure the uniqueness and accuracy of the data, duplicate articles were removed during the literature processing, resulting in the removal of 618 articles.

Table 5.1 Keywords and Searching Information Strategy

Sources	**Keywords used**
Scopus	Water management in Kazakhstan
Web of sciences	Water management in Kazakhstan
Google Scholar	Water management in Kazakhstan, Water planning in Kazakhstan / Astana / Nur-Sultan
Adilet	Water code, Water plan

Focusing specifically on "water resource management in Kazakhstan," the search results in the Web of Science revealed 148 peer-reviewed papers. These papers were primarily distributed across several fields: Environmental Science (40%), Water Resources (21%), Green Sustainable Technology (13.5%), Environmental Research (12.5%), and Multidisciplinary Earth Sciences (9%). Notably, these studies began as early as 1996, with a significant increase in publications starting in 2012, particularly after 2017.

2. Screening Phase

The screening stage is the second step, where specific criteria are applied to evaluate the eligibility of the literature. This stage focused on retaining studies related to Kazakhstan, particularly those written in English. This approach ensures that the international academic community can widely understand and accept the literature, thereby enhancing the research's impact. The time frame set was from 2010 to 2024, while the legal literature span was from 2000 to 2024. As a result, 1,819 articles not meeting the criteria were removed from the initial pool of 2,603, leaving 784 articles for further analysis.

3. Eligibility Phase

The titles, abstracts, and literature results were carefully examined in the eligibility assessment stage to determine their alignment with the research objectives. The research scope was limited to "Environmental Science, Ecology, Water Resources, Business Economics, Social Sciences, and Public Administration." Of the 210 articles screened from the Web of Science, 38 were selected after further review. This review process included evaluating relevance by checking whether the literature directly pertains to water resource management in Kazakhstan, analyzing research methods to confirm that the employed methodologies meet scientific standards, and verifying data reliability to ensure that the data used in the studies are credible and valid. In the Scopus database, 84 articles were similarly assessed, resulting in the selection of 19 articles. This "careful reading" process encompassed thorough reading, where each article was read in full to understand the depth and breadth of the research; evaluating the validity of conclusions to analyze whether the findings were based on sufficient data and reasonable reasoning; comparing with existing literature to confirm the uniqueness and academic value of the studies.

4. Quality Appraisal Phase

In this phase, the quality of the selected literature was assessed, considering factors such as the rigor of research methods, data reliability, and the validity of research conclusions to ensure that the included literature meets high academic standards. Ultimately, 75 articles were retained for further examination.

As shown in Table 5.2, the literature screening process resulted in the retention of 75 articles for in-depth analysis. These articles cover various aspects of water resource management in Kazakhstan, including policy frameworks, management measures, and local case studies. Most of the literature consists of academic journal articles highlighting the significance of the academic community in this field. Additionally, reports from government and international organizations provide empirical support for policy analysis, aiding in the understanding of the effectiveness of actual management measures.

Table 5.2 Summary of the literature screening process

Databases	Identification	Screening	Eligibility	Quality appraisal
	Keywords	Literature type, language, timeline, countries	Title, abstract, and results: The article's content is by the criteria and research question.	Articles' methodology
Scopus	430	154	19	10
Web of Science	681	384	38	18
Google Scholar	1160	1130	54	27
Adilet	307	297	40	15
International Organization Reports	25	20	12	5
In total	2603	1985	166	75

Table 5.3 Topics and represented literature

Topics	Represented literature
Water Environment	Yerzhanova & Huszti, 2013; Aubakirova et al., 2017; Thevs et al., 2017; Karaca et al., 2019; Utepov et al., 2021; Seidakhmetova, et al., 2022; Salikova et al., 2024
Water quantity	Tussupova, et al., 2015; Thevs et al., 2017; Bissenbayeva et al., 2021
The impact of the climate crisis on water resources	Yegemova, et al., 2018; Bissenbayeva et al., 2021; Tursunova et al., 2022.
Sustainable water use	Dessalegn et al., 2018; Xenarios et al., 2019; Ospan et al., 2023; Radelyuk, et al., 2024
Water quality	Rzymski et al., 2019; Pangaliyev, et al., 2024
Water security	Assubayeva et al., 2022; Xenarios et al., 2018; Orynbayev, et al., 2024
Transboundary water cooperation	Zhupankhan et al., 2017; Boklan & Janusz-Pawletta, 2017; Ozenbayeva, et al., 2022; Xenarios et al., 2022

Technical Information and Data Management	Abdullaev & Rakhmatullaev, 2014

5.1.2 THE RESULT OF BACKGROUND ANALYSIS OF WATER PLANNING AND MANAGEMENT IN KAZAKHSTAN

Basic information regarding Kazakhstan's water resources, related laws, and water management institutions is detailed in Appendix G. The following is a background analysis based on the selected literature:

Firstly, government-established water resource management policies and plans, such as the "Kazakhstan 2030 Strategy" and the "Kazakhstan 2050 Strategy", were analyzed by reviewing relevant legal documents and international reports about Kazakhstan's water resource management and planning. These strategies emphasize protecting, effectively utilizing, and improving water quality. Additionally, issues in Kazakhstan's water resource management and planning were outlined based on peer-reviewed papers. Secondly, reports provided by international organizations present the current state of water resource management and planning in Astana. Most of the reports from international organizations were obtained from public websites and Nazarbayev University library resources.

5.1.2.1 WATER RESOURCE MANAGEMENT AND PLANNING IN KAZAKHSTAN

- **Water resource planning in Kazakhstan**

In terms of Kazakhstan's planning documents, as per Presidential Decree No. 827 of 2009, Kazakhstan's national development planning system comprises a three-tiered structure consisting of a "long-term vision for national development, regional/sectoral development strategies, and specific plans for the first two."

As finite natural resources, water resources must be planned with national strategies for sustainable development and environmental protection to ensure sustainable use. Therefore, the National Strategic documents on sustainable development are the primary documents for water planning. For example, both the "Kazakhstan 2030 Strategy" (Table G.1) and the "Kazakhstan 2050 Strategy" involve water resource planning. The NEAP-SD (National Environmental Action Plan for Sustainable Development) specifically highlights seven environmental issues that need significant attention within the framework of the national strategies. These include water scarcity, urban air pollution, pollution caused by oil fields, industrial and municipal solid waste, pastures and arable land degradation, scarcity of forests, and wastewater discharge (Municipal Water Services, 2001). Table G.3 lists the primary sustainable development strategic documents released by Kazakhstan. The

"Strategy Kazakhstan-2050" (2012) emphasized issues related to water supply for the population and irrigation, while the "Strategic Plan for Development until 2025" (2018) emphasized the protection of water resources. The "Concept of Transition to Green Economy" (2013) established the concept of integrating "Green Economy" into Kazakhstan's national strategy. Based on this concept, the "Green Bridge Partnership Program (GBPP) (2011), Memorandum of Understanding (MoU) between OECD and Kazakhstan (2015), and OECD's 2009 Declaration on Green Growth (2016)" were formulated (Table 5.4).

Table 5.4 2030 strategy: priorities and strategies for water resources

Priorities	**Strategies**
Protection of the water resources of Kazakhstan	Announcement of water resources as strategic public resources; Biological treatment of wastewater; Protection of small rivers, the establishment of water protection zones; Collection and treatment of surface water discharges (storm water); Treatment of drainage water filtrates from fields, water from melted snow, and their use in secondary and circulating water supply systems; Establishment of minimum environmental discharge standards for basins of main rivers and inland basins; Awareness campaign for effective use of drinking water; Signing of inter-state agreements regulating issues of everyday use of transboundary water resources.
Effective use of water resources	Increased recycling and reuse of industrial process water; Reduction of drinking water use for industrial purposes; Introduction of effective and highly technological ways of agricultural crop irrigation; Awareness campaign for water saving; The signing of international agreements regulating issues on the everyday use of transboundary water resources.
Water resource management	Elaboration of a National Program for water supply and development of the general scheme for water supply in Kazakhstan; Introduction of economic instruments for water resources management; Strengthening of R&D and design investigation works in the fields of water resources use and research; Establishment of a unified monitoring system over underground and surface waters.
Drinking water quality improvement	Improvement in quality of sources of drinking water; Modernization of technical processes for drinking water treatment; Use of highly efficient municipal wastewater treatment plants; Use of individual equipment and plants for drinking water after purification; Establishment of production lines for packaging (bottling) of environmentally clean surface and underground water.

Water supply to the South and West of Kazakhstan	Development of economic mechanism of discharge watershed for transboundary rivers in South and West of Kazakhstan; There is a possibility of additional water being provided in the south and west of Kazakhstan.

Source: Municipal Water Services, Kazakhstan Background Analysis for the Financing Strategy (2001).

Table 5.5 Kazakhstan's international activities in the green economy

Year	Strategy	Purpose and tasks
2011	Green Bridge Partnership Program (GBPP)	Provide leadership for green economic growth in Central Asia and other international cooperation, facilitating technology transfer, knowledge exchange, and financial support.
2015	Memorandum of Understanding (MoU) between OECD and Kazakhstan	Support policies and reforms in Kazakhstan's green economy.
2016	OECD’s 2009 Declaration on Green Growth	Kazakhstan joined the OECD’s 2009 Declaration on Green Growth.

Table 5.6 Strategic documents on sustainable development

Year	Strategy	Purpose and tasks
1997	Strategy Kazakhstan-2030	- Protection of the water resources of Kazakhstan - Effective use of water resources - Water resource management - Drinking water quality improvement - Water supply to the South and West of Kazakhstan
2012	Strategy Kazakhstan-2050	- Make Kazakhstan a global player in environmentally clean agricultural production - Become one of the 30 most developed countries by 2050 - Raise the share of alternative and renewable energy sources in total energy consumption to 50 percent by 2050 - Solve the problems with water supply to the population by 2020 and irrigation water by 2040
2013	Concept of Transition to Green Economy; Action Plan for the period 2013- 2020	- Introduced the applicability of the "Green Economy" concept to Kazakhstan and provided environmental protection goals and plans as a strategic document for the environmental sector. - Establishment of the Council on Transition to Green Economy in 2014 Tasks: - National water security - Resource efficiency and management - Construction and modernization of infrastructure - Propose methods of applying cost-benefit analysis to reduce environmental pressure
2015	Plan of the Nation 100 concrete steps	- Provides for several measures that had an impact on environmental regulation
2018	Strategic Plan for Development until 2025	- Achievement of the commitments under the Paris Agreement - Consideration of green finance and investments - Promotion of investments in green technologies - Decarburization of the economy - Increased efficiency in the use and protection of water resources - Development of RES and improvement of conventional energy sources - Conservation of biodiversity development in low-waste economy and waste management - Two indicators: energy intensity of GDP and share of RES

Source: Adilet (1996, 2011).

The National Water Resources Management develops the second-level document for the National Water Resources Plan based on the first-level national strategic document. These second-level documents are developed by the Ministry of Water Resources of Kazakhstan, as shown in Table 5.7. Each phase of the planning outlines detailed objectives and tasks.

Regarding the implementation of water resource planning outlined in Table G.4, the government has emphasized the importance of ensuring access to safe drinking water for Kazakhstani citizens and introduced two national plans. Despite negative feedback from citizens and experts regarding inefficiency, quality issues, and environmental degradation associated with the first plan, the "Drinking Water" plan from 2002 to 2010, the second plan, the "Ak-Bulak" plan from 2011 to 2020, provided drinking water to rural and urban residents through centralized water supply systems. However, despite the government's commitment that all citizens would have access to clean water by 2025 following the implementation of the "Nurly Zher" national plan, the reality is that the majority still rely on alternative water sources (Karaca et al., 2019, p.23). The 2021-2025 National Plan for Water Resources Management, introduced in 2020, aimed to launch a new water law in 2023. However, it was not until February 2024 that the newly appointed Minister of Water and Irrigation, under the Ministry of Water and Irrigation, established in 2023, presented the contents of the new water law at the "International

Water Technology and Resources" forum, with a focus on water conservation and protection of water infrastructure (Kemelova, 2024).

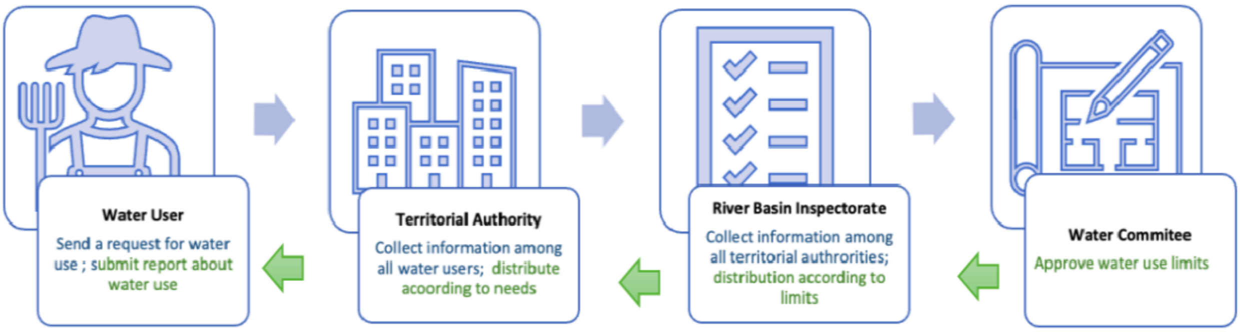
Table 5.7 National Water Plans of Kazakhstan

Year	Strategy	Purpose and tasks
2001	"Drinking water" for the years 2001-2030	Tasks: - Urban and rural water supply - Improve water quality - Revitalize the utilization of groundwater - Update and development of water equipment
2011	Program "Ak Bulak" for the period 2011-2020 (Expired in 2014)	Purpose: Increase water coverage Tasks: - Increase private sector participation in water management - Increase water metering - Research additional groundwater resources
2014	Regional Development Plan 2014-2020	Purpose: Effective and reasonable provision of drinking water and sanitation Tasks: - Increase urban central water supply coverage (from 80% in 2015 to 97% in 2019) - Increased rural centralized water supply coverage (from 11% in 2015 to 13% in 2019)
2014	National Water Management Plan for 2014-2020	Purpose: Ensure water availability for the population, environment, and economic sectors, increase water efficiency, and protect aquatic ecosystems. Tasks: - By 2020, water consumption per unit of GDP to be reduced by 33% compared with 2012
2020	Concept of the National Plan for Water Management 2020-2030	Purpose: Maintain a water balance of 100 cubic kilometers by 2030 by adding additional surface water resources: construction of 5-7 cubic kilometers of new reservoirs, water savings of up to 5 cubic kilometers, and use of groundwater up to 15 cubic kilometers Tasks: - Reduce the water consumption per unit of GDP from 91.2 cubic meters per thousand US dollars to 73 cubic meters, building 26 hydraulic structures, and renovating 182 and 300 public hydraulic structures - Increase the irrigated area from 1.7 to 3 million hectares and increase the length of covered trunk lines and distribution channels from 3,423 km to 19,000 km - The availability rate of materials and technical equipment for watershed inspections has reached 100%, and the watershed's forest coverage area has increased from 1 hectare to 200,000 hectares
2020	2021-2025 National Plan for Water Resources Management	Expected outcomes: 1) Take into account climate change and anthropogenic pressures to conduct surface water resource assessments - in the period 2021-2025 2) Update one and sign two agreements on the use and protection of transboundary rivers – by 2023 3) Potential directions for developing inter-basin routes for river runoff and groundwater transfer in 2024 4) A new water law in 2023 5) Establish a scientific center on water resources and water resource management issues in 2022 6) Create an information system for assessing river runoff resources using computer modeling techniques - 2025 7) Set new water restrictions - 2023

Sources: Adilet (2001), Kazakhstan Environmental Performance Reviews (2019), and the National Plan for Water Resources Management (2021)

The third-level document for water resource planning consists of detailed operational plans derived from the first and second-level documents. In water resource management, the water use limit is the third-level document. As the diagram shows (Figure 5.2), local water users initially provide the water management agency (Kazvodkhoz) with the water required for agricultural or industrial production. This information is then consolidated and submitted to the River Basin Inspector (RBI), who subsequently submits the water demand of water basin units to the CWR. The CWR, considering transboundary water volume and the directives of the first and second-level documents, formulates comprehensive water resource plans, resulting in the final annual water use limits (Figure G.2). RBI monitors water usage limits and penalizes for non-compliance (Assubayeva, 2021). Compared to secondary documents, the effective implementation of water use limits is ensured under the supervision of RBI and Kazvodkhoz. However, the fundamental issue lies in the design of water use limits, leading to damage to the local ecological environment, particularly by allocating a significant amount of water to economic production sectors due to economic demands while neglecting the water needs of the aquatic ecosystem (Adilet, 2016).

Figure 5.2 Process of issuing water use limits



Source: Assubayeva et al. (2021).

- **Challenges of water management and planning in Kazakhstan**

Kazakhstan's water resource management faces significant challenges, primarily climate change, geopolitical tensions, and increasing water demand (Orynbayev et al., 2024; Zhupankhan et al., 2018). Additionally, Kazakhstan's water resources heavily rely on neighboring countries, with approximately 44% of surface water sourced abroad (Zhupankhan et al., 2018). This dependency has led to competition for water resources, pollution issues, and potential conflicts with neighboring states (Zhiltsov et al., 2018). The lack of an adequate legal and institutional framework exacerbates the unsustainable use of water resources (Medetov et al., 2018; Ozenbayeva et al., 2022). In this context, transboundary water resource management issues are particularly pronounced, necessitating coordinated responses.

Moreover, aging infrastructure and low water prices hinder effective water resource management (Radelyuk et al., 2024). The inadequacies of policy and regulatory frameworks limit responses to the challenges posed by climate change (Orynbayev et al., 2024). Water quality pollution is also a severe issue, with studies indicating an urgent need for effective governance and management measures (Pangaliyev et al., 2024; Yegemova et al., 2018). Current water resource monitoring and management technologies are insufficient, lacking integration and innovation (Ospan et al., 2023), and the application of data management and information technology in data management and decision support remains inadequate (Abdullaev & Rakhmatullaev, 2014).

Since implementing IWRM principles in Kazakhstan in 2004, the country has begun to utilize watershed management strategies for water resource planning, supported by international organizations such as the United Nations Development Program (UNDP) and the Global Water Partnership (Adilet, 2016). However, the country continues to face challenges in coordinating traditional top-down water resource management methods with IWRM principles. Current water resource planning exhibits multiple issues that lead to unsustainable use of water resources, including a lack of transparency in methods for generating water balance and environmental flow data. Although international organizations such as the UNDP and the Asian Development Bank have provided evaluations and recommendations, the "Kazakhstan National Integrated Water Resource Management and Water Efficiency Plan" report has not received governmental approval (Adilet, 2016).

In Kazakhstan's third-level water resource planning, specific water use quotas are primarily based on user demands, often neglecting environmental considerations. Despite conducting watershed-level water resource analyses, disregarding environmental needs results in inadequate assessments. For instance, allocating specific river basins for environmental needs is zero (Adilet, 2016). The "2016-2025 Regional and Basin Water Quotas" approved by the Ministry of Agriculture reveals (Table G.6) that among 45 rivers and lakes across 14 regions, only 17 lakes and rivers allocate environmental water, reflecting a low level of attention to water quality and environmental issues.

Furthermore, Kazakhstan's water resource management plans primarily involve ecosystem measures, indicating a robust development of ecosystem-based approaches in the country (Janusz-Pawletta & Gubaidullina, 2015; Ziganshina & Janusz-Pawletta, 2020; UNECE, 2017). However, due to funding constraints and a lack of access to the latest technologies and information, the effectiveness of environmental regulations remains low. Facing environmental challenges inherited from the Soviet era, such as pollution, deforestation, and natural resource degradation, Kazakhstan did not fully recognize the importance of coordinating economic development with environmental sustainability until the late 1990s.

Kazakhstan has established River Basin Councils (RBCs) and National Policy Dialogues (NPDs) to engage local stakeholders in water resource planning based on IWRM principles. These platforms aim to promote the active involvement of local stakeholders in the decision-making process. However, challenges related to decentralization and funding persist, making it difficult for grassroots RBC perspectives and opinions to be effectively communicated to the central authorities responsible for water resource planning (Xenarios et al., 2022).

In summary, Kazakhstan's water resource management faces multiple challenges, including climate change, geopolitical dependency, inadequate legal frameworks, neglect of environmental issues, aging infrastructure, and insufficient public participation.

5.1.2.2 WATER RESOURCE MANAGEMENT AND PLANNING IN ASTANA

- **Water regulation and plans of Astana city**

Currently, water resource management in Astana mainly follows two types of documents: the first comprises laws and regulations, such as the Water Law of 2003 (latest amendment as of 2024). According to this law, Annex 1150 was approved on January 11, 2018, which stipulates general requirements for water users in Astana, including principles for water use, sanitation, and discharge (Adilet, 2018). These requirements are general for water users and do not specify specific water quotas. However, in the document "On approval of water use limits of Esil and Nura Rivers", based on Kazakhstan's river basin management, water resource quotas available for each administrative region, province, and city within the basin are specified, as shown in Table 5.8 (Region Akmola), the detailed water use limit for the whole region is in Table G. 1 of Appendix G. It can be observed that all water is allocated for human use, with zero allocation for the environment.

Table 5.8 Approval of water use limits by basins and regions (in million m3)

Region	River basin	Total, million cubic meters	Municipal, domestic, and industrial needs	Agriculture		Fisheries	Environmental needs and others
				Total	For irrigation		
Akmola, including Astana city	Esil river	115	82	32	11	1	0
	Nura river	19.5	0.3	19.2	1.8	0	0

Source: Adilet (2016).

The second category pertains to planning documents, such as those outlined in the Astana city planning developed by the "National 2030 Development Plan Outline". This planning was published in June 2001 and formulated by a Japanese JICA team called "The Master Plan for the Development of the City of Astana" (JICA, 2001; Koch, 2014). The JICA plan emphasizes the construction of an eco-friendly city. The city's plan, approved by decree number 884 on July 30, 2011, for the period up to 2030, still follows JICA's water resource management plan.

Within JICA's water resource plan, projections for the growth of Astana's water demand are estimated (see Appendix H.2). It anticipated that by 2010, the city's total drinking water and technical water needs would reach 63.9 million cubic meters (MCM), rising to 88.9 MCM by 2020, which closely aligns with actual water consumption, as shown in Table H.2. This plan suggests the development of new water sources for Astana, such as exploring other reservoirs in Akmola Province, establishing a pipeline for water transfer from the Irtysh-Karaganda Canal, and tapping into groundwater resources. The pipeline for water transfer from the Irtysh-Karaganda Canal has been completed. However, due to issues such as leakage in the pipeline, it has not yet been put into operation (Tractebel Engineering, 2021).

The latest comprehensive plan for Astana city until 2035 was issued by Decree No. 33 on January 25, 2024, emphasizing the importance of conserving water through technological advancements in water-saving systems and promoting rational water resource utilization through economic incentives (Adilet, 2024). Considering the projected doubling of the city's population to 2.3 million people by

2035 due to the expansion of Astana, measures have been outlined to ensure an adequate water supply for the urban population.

To meet the water needs of the growing population, a fourth filtration station with a daily processing capacity of 210,000 cubic meters will be added to the Astana Reservoir water source (Adilet, 2024). Additionally, the pipeline for water transfer from the Irtysh-Karaganda Canal will be activated. Furthermore, the production capacity of the Telman Pumping Station in the southern part of the city, which draws water from the Nura-Ishim River, will be increased to 160,000 cubic meters per day, three times the current extraction rate (Adilet, 2024).

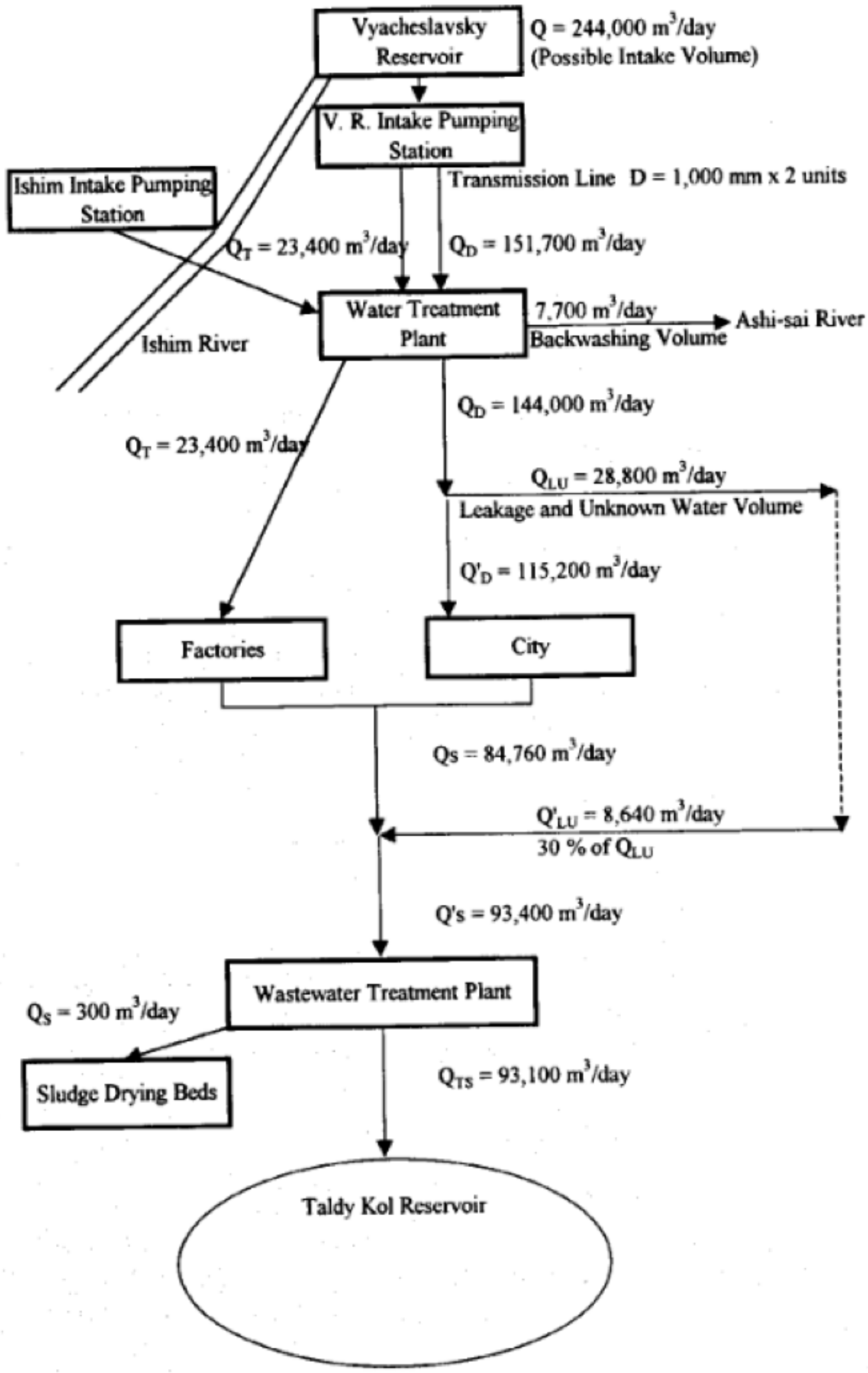
The Water Committee is responsible for implementing the planning documents above. Based on river basin management principles, the Esil Basin Inspector oversees the allocation and management of Astana city's water use quotas. Astana Su Arnasay sells city water and maintains water supply pipelines. In contrast, Kazvodkhoz manages the operation and maintenance of the Astana Reservoir.

- **Water consumption of Astana city**

According to the JICA Plan, the water supply map of Astana City is shown in Figure 5.3. The water supply capacity of the Astana (Vyacheslavsky) Reservoir is 244,000 cubic meters per day or 89 million cubic meters (MCM) per year.

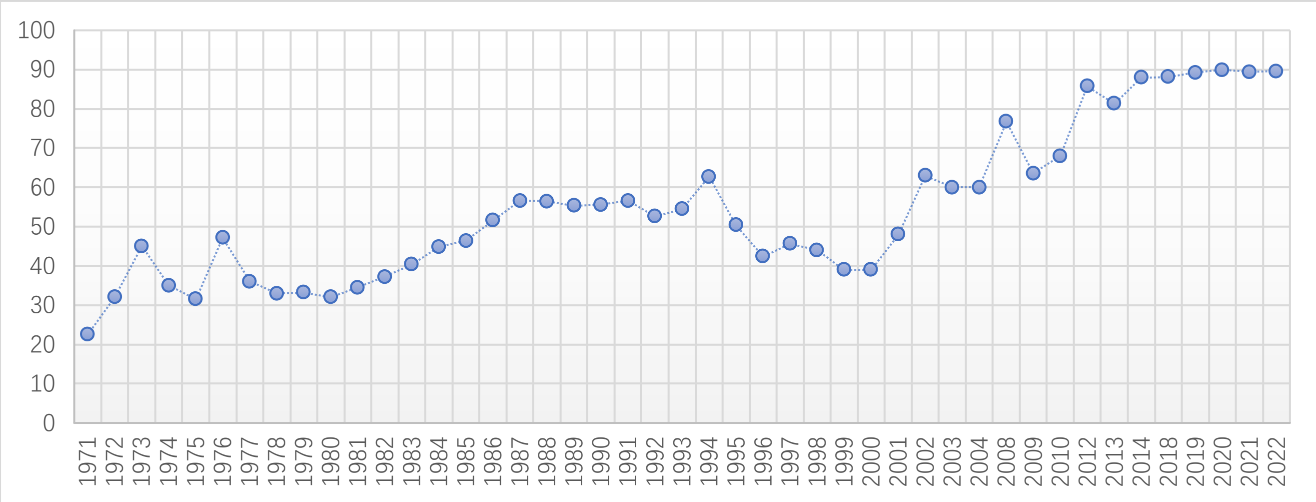
Astana's urban water consumption increases yearly, as shown in Figure 5.4, growing linearly from 2000 to 2014. As the demand for water supply grows, new Pumping Stations and Bulk water supply lines have been built. The V.R. (Vyacheslavsky Reservoir) Pumping Station delivers raw water to the water treatment plant through two pipelines. The designed daily processing capacity of the water treatment plant is 175,100 cubic meters per day. Of this total, 144,000 cubic meters per day are allocated for urban and commercial water use, while 23,400 cubic meters are designated for technical water use in factories. Ultimately, 93,400 cubic meters per day of water are discharged into the Taldy Kol reservoir after treatment at the wastewater treatment plant. Detailed parameters of the water supply equipment capacity for Astana city are outlined in Table H.2.

Figure 5.3 Water supply design of Astana City



Source: JICA (2001).

Figure 5.4 Water intake from the reservoir by the city water utility (in million m3)



Source: Kazvodkhoz (1971-2022).

As the population of Astana city continues to grow, its water consumption gradually increases. Analysis of data from Kazvodkhoz spanning from 1971 to 2022 reveals that water consumption has risen from 22.5 million cubic meters (MCM) per year in 1971 to 89.56 MCM per year in 2022, marking a growth rate of 398% (Figure 5.4). Specific data collected in Table 5.9 allows for further analysis, including the population figures for Astana city from 2016 to 2021, the volume of water extracted from different water sources, and water usage across various sectors. The average urban population growth rate in Astana is 5.2%. Since 2017, six wells have been developed within the city in response to water scarcity issues.

In 2016, the water supply from the Astana Reservoir exceeded its maximum annual capacity of 89 MCM. Therefore, starting in 2018, the village of Telman began drawing water from the Nura-Ishim River, with the volume of water extraction increasing steadily each year. Judging from the water consumption situation of various industries, user water consumption is increasing with the growth of the population, and other industries are relatively stable. However, the water consumption of group (2-4) users in 2021 doubled compared with 2020. The specific reasons still need to be investigated.

Table 5.9 Water use facts for different sectors of Astana city (million cubic meters per year (MCM))

<table>
<tr><th></th><th>2016</th><th>2017</th><th>2018</th><th>2019</th><th>2020</th><th>2021</th></tr>
<tr><td>The population of Astana (person)</td><td>949 000</td><td>1 007 000</td><td>1 068 000</td><td>1 118 000</td><td>1 166 000</td><td>1 212 000</td></tr>
<tr><td>Total water use (MCM)</td><td>95.2</td><td>97.3</td><td>98.1</td><td>102.1</td><td>105.7</td><td>110.5</td></tr>
<tr><td>Water intake from Astana reservoir (MCM)</td><td>95.2</td><td>97.1</td><td>88.1</td><td>90.3</td><td>89.9</td><td>89.3</td></tr>
<tr><td>Water intake from other sources (MCM)</td><td>0</td><td>0.216</td><td>10</td><td>11.8</td><td>15.8</td><td>21.2</td></tr>
<tr><td>Drinking water (MCM)</td><td>62.5</td><td>61.3</td><td>67.6</td><td>70.0</td><td>68.8</td><td>90.8</td></tr>
<tr><td>Group 1 domestic (MCM)</td><td>44.1</td><td>43.2</td><td>49.3</td><td>51.5</td><td>53.9</td><td>59.5</td></tr>
<tr><td>Group 2: Enterprises for the production and distribution of heat energy (MCM)</td><td>1.7</td><td>0.5</td><td>0.8</td><td>1.0</td><td rowspan="3">14.9</td><td rowspan="3">31.3</td></tr>
<tr><td>Group 3: Budgetary organizations (MCM)</td><td>3.7</td><td>3.8</td><td>3.8</td><td>3.7</td></tr>
<tr><td>Group 4: Legal entities and others (MCM)</td><td>12.9</td><td>13.8</td><td>13.7</td><td>13.8</td></tr>
<tr><td>Technical water (MCM)</td><td>12.2</td><td>13.0</td><td>11.6</td><td>12.1</td><td>16.2</td><td>22.8</td></tr>
<tr><td>Water loss during transportation, %</td><td>22</td><td>23.4</td><td>19.6</td><td>19.5</td><td>18.8</td><td>16.9</td></tr>
</table>

Source: Kazvodkhoz (1971-2022); Tractebel Engineering (2021); Astana, Kazakhstan metro area population (1950-2023).

Based on the data analysis above, the current water situation in Astana city can be summarized as follows: The Astana Reservoir has reached its supply limit. In contrast, the water source for Telman originates from the Nura-Ishim River, which experienced mercury (Hg) pollution in the latter half of the 20th century. Although projects are dedicated to cleaning mercury-contaminated soil, insufficient data does not allow proper evaluation of its safety (Guney et al., 2020). Consequently, Astana faces issues in terms of both water quantity and quality. Additionally, the over-supply from the Astana Reservoir has led to ecological damage.

5.2 FUNCTIONS OF ASTANA RESERVOIR (PHASE 2)

The functions of the reservoir ecosystem are diverse. Firstly, the Astana Reservoir provides water resources for downstream drinking, technical water, irrigation, greenery, landscaping, and miscellaneous uses. Besides, the Astana Reservoir is included in the list of crucial local fishery reservoirs in the Akmola region (DNRERAR, 2021). However, because the Astana Reservoir is used to supply drinking water to the city of Astana, the government has banned commercial fishing in the reservoir (Sputnik, 2017). There are crucian carp, carp, bream, tuna, marinka, perch, osman, roach, zander, grayling, pike, ide, ruff, etc. (Rybalku. ru).

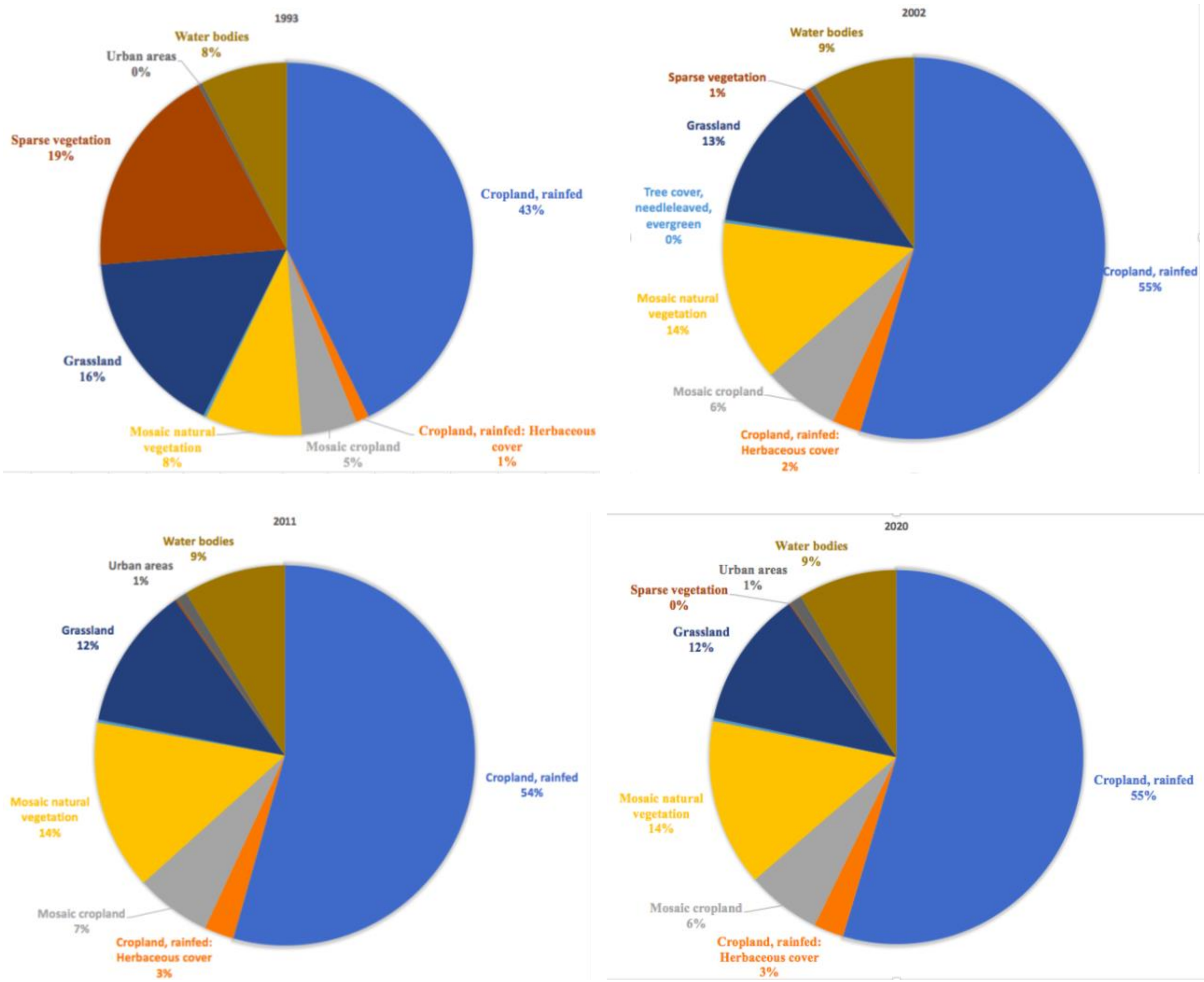
Secondly, the reservoir serves a regulatory function in hydrological cycles, effectively mitigating the impacts of floods and droughts. The storage capacity of the reservoir helps address water scarcity issues during droughts. At the same time, its flood control function reduces damage to downstream land for agricultural and other economic activities by containing excess river water during spring runoff. Thirdly, the reservoir ecosystem contributes to water purification. Specifically, aquatic plants within the reservoir efficiently decompose nutrients such as nitrogen and phosphorus and collaborate with other organisms in the reservoir for biological purification. A more complete reservoir ecosystem provides enhanced water purification and soil conservation functions. Finally, the scenic beauty of the reservoir area serves recreational and tourism purposes. The reservoir attracts a large number of visitors who engage in activities such as fishing, hunting, and sightseeing. Although commercial fishing is prohibited, tourists can still engage in personal fishing activities, making it a popular destination for leisure and tourism for residents of Astana and the surrounding areas.

The following analysis will utilize various parameters to examine the structure, characteristics, and biophysical transformation processes of the Astana Reservoir.

5.2.1 STRUCTURES OF RESERVOIR

The reservoir structure is the type of reservoir ecosystem, and the Ecosystem Extent Account expresses the proportion and changes of the reservoir ecosystem. Firstly, based on the watershed areas mentioned above, land cover information can be obtained on the Earth Map from 1993 to 2020. Information on land cover is gathered from all five watersheds, as shown in Annex 3.3. Land cover CCI (Climate Change Initiative) is a 300-meter resolution land cover produced from ENVISAT MERIS data, with 23 types of land cover maps. Furthermore, the European Space Agency has created the ESA/CCI Land Cover Viewer to allow users to view this map online (http://maps.elie.ucl.ac.be/CCI/viewer/index.php) (Harper et al., 2023). According to the CCI classification in Aspen, Astana Reservoir has 11 land cover types. From the degree of land cover change from 1993 to 2020 (Figure 5.5), rained cropland has the highest degree of growth, nearly 12%, while sparse vegetation has almost reduced to 0%. Based on the complete data from 1993 to 2020, the most apparent year of change was from 1996 to 1999, when the proportion of cropland increased from 43% in 1996 to 53% in 1999.

Figure 5.5 Percentage of land cover distributions in the years 1993 and 2020 in Astana Reservoir



Source: Land cover CCI (1993-2020), (Harper et al., 2023).

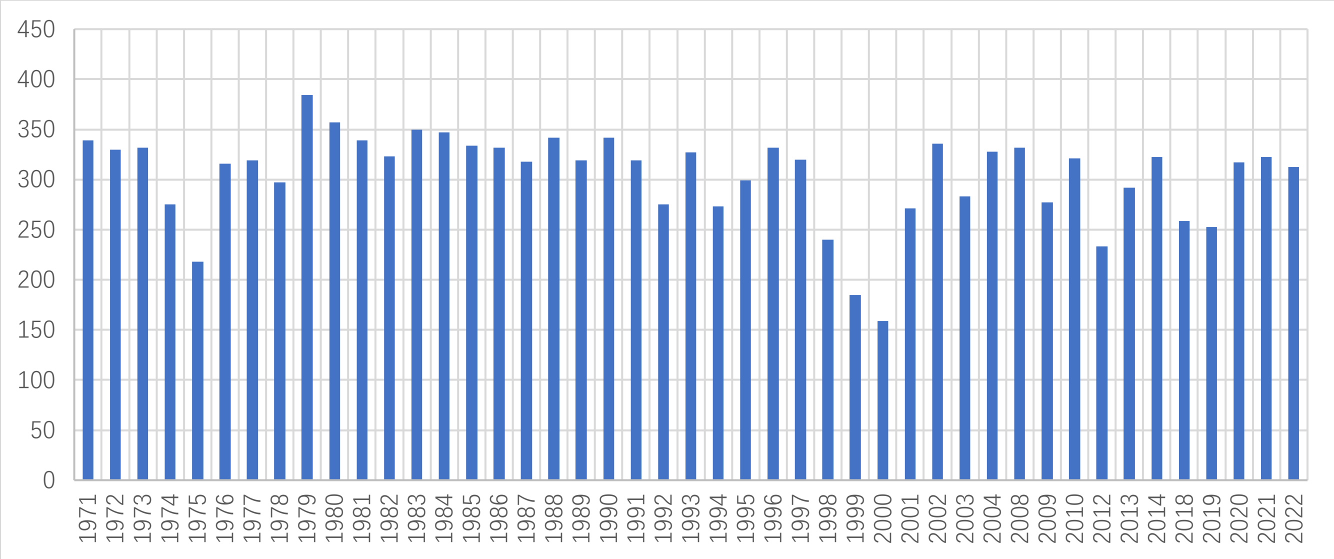
Then, an analysis of the changes in ecosystem types for 2000 and 2019 was conducted according to the IUCN Global Ecosystem Typology 2.0 classification standards. The ARIES platform was also utilized to generate The Ecosystem Extent Account of Astana Reservoir (Table 5.10).

Table 5.10 The Ecosystem Extent Account of Astana Reservoir (in km²)

	Aquatic	**Boreal temperate montane forest woodland**	**Cool temperate heathland**	**Cropland**	**Rocky pavement lava flow screen**	**Urban industrial ecosystem**	**Total**
start of 2000	45.48	1.57	78.26	458.60	8.20	2.24	594.34
end of 2019	51.45	1.72	71.40	463.00	0.47	6.31	594.34
Net change	5.97%	0.15%	-6.86%	4.40%	-7.73%	4.07	-

The reservoir's physical and chemical characteristics are judged by its physical state, which includes water volume and total annual discharge. Based on the water volume data provided by Kazvodkhoz from 1971 to 2022, the reservoir capacity is decreasing, and the average storage capacity from 1990 to 2022 decreased by 8.23% compared with the previous two decades (Figure 5.6).

Figure 5.6 Reservoir water volume 1971-2022 (in cubic meters)



Source: Kazvodkhoz (1971-2022).

In the parameters of water volume, the volume of the available water at primary regulatory levels, such as Normal Water Level (NWL) and Dead Water Level (DWL), determines the regime and management of the reservoir's water resources. The volume at DWL has undergone significant changes compared to other levels. From the moment of commissioning till 2023, no work was done to clean the bottom of the reservoir. As a result, in this half-century period, the volume of water at the Normal Pressure Level has decreased from 403 million m3 to 367.2 million m3 due to sedimentation (Akiyanova et al., 2020).

Regarding chemical state, the two variables, pH level and BOD, are applied, and the changes in BOD, COD, and OD values from 2000 to 2021 are shown in Table 5.11. According to Kazhydromet's test report, the MPC of heavy metal group substances was exceeded in the Astana reservoir (copper—1.5 MPC, zinc—3.2 MPC).

Table 5.11 Water quality of Astana reservoir

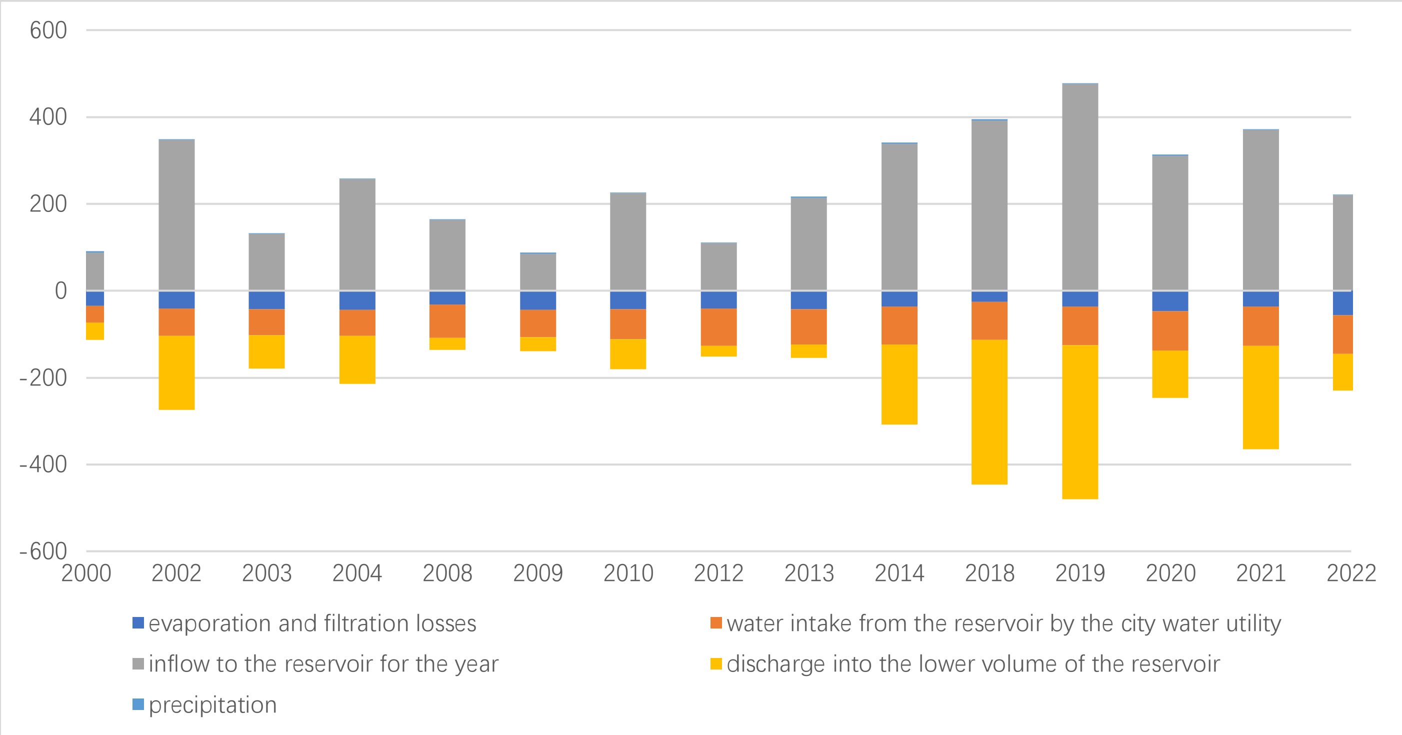
	2000	2002	2003	2017	2018	2019	2020	2021	standard
BOD	2.4/2.1	2.4/1.6	1.8/2.2	0.68/3.59	0.56/2.42	0.57/1.78	0.86	0.85/3.35	<1.0
COD	31/24	46.9/38.4	32/26.4						Third category ≤20
OD				8.42/15.5	15.2/8.01	8.25/12.5	7.76	4.3/7.92	

Source: Kazhydromet (2000-2020); Astana Su Arnasay (2020-2022).

5.2.2 WATER BALANCE OF ASTANA RESERVOIR

According to the settings of Equation 1, it is necessary to combine the inflow and outflow values of the reservoir at the upstream Turgen and downstream Volgodonovka observation stations, as well as the data of evaporation, filtration losses, and the water intake by the city water utilities. The inflow of the reservoir changes with downstream water demand, precipitation, and snowmelt is visible. The water balance of the Astana Reservoir is shown in Figure 5.7. The income item includes the upper inflow to the reservoir and precipitation, while the expenditure item includes the lower surface outflow, evaporation, and water intake for the city utilities. The change in reservoir capacity can be obtained by subtracting the expenditure item from the income item. The average change in the Astana Reservoir capacity is between 0-70 MCM.

Figure 5.7 Water balance of Astana Reservoir from 1971-2020



Source: Kazvodkhoz (1971-2022).

5.2.3 SEDIMENT REGULATION MODEL

Soil erosion control change (Table 5.12) can be obtained through the Sediment Regulation Model's RUSLE methods (Equation 2) in software ARIES. Table 5.12 shows that 1785.33 tons of soil have been lost around the Astana Reservoir compared with 2000.

Table 5.12 Soil erosion control change of Astana Reservoir (in tons)

	Aquatic	**Boreal temperate montane forest woodland**	**Cool temperate heathland**	**Cropland**	**Rocky pavement lava flow screen**	**Urban industrial ecosystem**	**Total**
Start of 2000	0	83.16	4797.37	9911.34	306.51	0	15098.37
End of 2019	0	83.43	4219.46	8948.87	61.29	0	13313.04
Net change	0	0.26	-577.91	-962.47	-245.22	0	-1785.33

5.3 CLASSIFYING ECOSYSTEM SERVICES IN ASTANA RESERVOIR (PHASE 3)

After determining the extent of the reservoir, it is necessary to analyze the water supply condition of the reservoir. Collecting all the above information in the ecosystem service condition account, as shown in Table 5.13, there has been a decrease in reservoir capacity from 2000 to 2019. The volume at DWL has undergone significant changes compared to other levels. The most considerable change in water consumption is for reservoirs, with a growth rate of 128.7%, and has exceeded the upper limit of the reservoir's water supply capacity.

Table 5.13 ES Condition Account of Astana Reservoir

SEEA Ecosystem Condition Typology Class	Variables	Ecosystem type			
	Descriptor	**Measurement unit**	**Opening value (2000)**	**Closing value (2019)**	**Change, %**
Physical state	Volume at NWL (403.0 m) = DWL+FL	m	389.802	367.2	-5.8
	Volume at DWL	m	30.97	23.29	-24.8
	Soil erosion control	ton	15098.37	13313.04	-11.65
	The total annual discharge of the reservoir	million m3	39	89.2	128.7
Chemical state	pH level (water quality)	-	8.5	8.1	-4.7
	BOD (water quality)	-	2.4/2.1	0.86	-61.7

Source: Kazvodkhoz (2004), Kazhydromet (2000-2020), Astana Su Arnasay (2020).

According to the classification standards of CICES V4.3 (CICES, 2011), the Astana Reservoir performs functions such as water storage, water purification, flood control, and soil conservation. Based on the data collected, this study valued four ecosystem services of the Astana Reservoir, including water supply, water filtration, sediment control, and recreation (Table 5.14).

Table 5.14 The classification of ecosystem services of Astana Reservoir

Ecosystem services	Function	Indicators	Code in CICES	Assessed
Provisioning services	Water supply	Domestic water Agricultural water Industrial water Environmental water	1.1.2.1 1.2.2.1	Y
	Aquatic products	Fish species	1.2.1.1	N
Regulating services	Water storage	River surface water resources, groundwater resources, and reservoir water storage	2.1.2.1	N
	Water purification	Chemical condition of freshwaters	2.3.4.1	Y
	Flood protection	Flood regulation and storage	2.2.2.2	N
	Erosion control	Soil erosion control	-	Y
Recreation services	Physical and intellectual interactions with biota, ecosystems, and land-/seascapes	The physical use of land-/seascapes in different environmental settings	3.1.1.2	N
		Entertainment Aesthetic (Recreation)	3.1.2.4 3.1.2.5	Y

Note: N= Data is not available to support the assessment.

Due to data availability limitations, this study only assessed four ecosystem services. Other services, such as aquatic products, water storage, flood regulation, and cultural services, could not be evaluated. A lack of detailed data on fish populations and species limited the assessment of aquatic products. Water storage required comprehensive data on river and groundwater resources, which were not readily available, for flood regulation, one of the most essential ecosystem services provided by the Astana Reservoir. Minimizing flood impacts in surrounding areas and protecting lives and property is critical (Martínez-García et al., 2022; Van der Ploeg et al., 2010). However, assessing flood regulation was challenging in this study. The complexity arises from the need for detailed knowledge of vegetation, water body storage capacities, and soil properties, requiring extensive data and specialized expertise beyond the scope of this study (Nagy et al., 2018; Acreman et al., 2003; Palmer & Smith, 2013).

5.4 ECONOMIC VALUATION OF SELECTED ECOSYSTEM SERVICES IN ASTANA RESERVOIR (PHASE 4)

5.4.1 PROVISIONING SERVICES

5.4.1.1 WATER SUPPLY SERVICE

Among provisioning services, the most crucial function of the Astana Reservoir is water supply. Since 2017, the capacity of the Astana Reservoir has reached its water supply limit. According to data published (Astana Su Arnasay, 2020), in 2019, the supply from the Astana Reservoir accounted for 88.44% of the urban water supply in Astana. This must be considered when calculating the water supply service value of the reservoir.

The calculation of the reservoir's water supply service value uses the direct market value method (Equation 3). The data used in this study comes from the water tariffs and consumption of different types of water in Astana city for 2019 (Table 5.15). The Astana Water Company (Astana Su Arnasay) and Tractebel Engineering provide this information. Data from 2019 is used to substitute the water supply amounts and prices into the formula to perform the calculations. Below is the detailed calculation process (see Table 5.16).

Water Supply Amounts (in million m^3/a):

Domestic Water (Group 1): 51.3

Enterprises (Group 2): 1

Budgetary Organizations (Group 3): 3.7

Legal Entities and Others (Group 4): 13.7

Technical Water: 12.1

Unit Prices (in KZT/m³):

Domestic Water: 56

Enterprises: 141

Budgetary Organizations: 195

Legal Entities and Others: 195

Technical Water: 30

Calculate Exchange Values (in million KZT):

Domestic Water: $51.3 \times 56 = 2872.8$

Enterprises: $1 \times 141 = 141$

Budgetary Organizations: $3.7 \times 195 = 721.5$

Legal Entities and Others: $13.7 \times 195 = 2671.5$

Technical Water: 12.1×30=363

Calculate Net Present Values (in million KZT):

Domestic Water: 2872.8×0.8844=2540.70432

Enterprises: 141×0.8844=124.7004

Budgetary Organizations: 721.5×0.8844=638.0946

Legal Entities and Others: 2671.5×0.8844=2362.6746

Technical Water: 363×0.8844=321.0372

Total Net Present Value: 5987.21112

Water Supply Service Value Range: Based on the comparison of water price increase rates from literature across various countries, the average increase rate is approximately 4% (Anselin et al., 2008; Kinfe et al., 2009; Liu & Shen, 2011; Vásquez, 2013). However, due to the annual occurrence of unpaid user fees in Kazakhstan, this research has set the contingency rate at 10% for this study. As a result, the value of water supply services ranges from 5,388 to 6,386 million KZT, which is 14.07 – 16.67 million USD.

Table 5.15 The water tariff and consumption of different groups in Astana city in 2019

Group	Tariff	Consumption
	KZT/m3	Million m3/a
Group 1 domestic		

< 3 m3	37	
> 3 m3	45	
Unmetered sales	56	51.3
Group 2: Enterprises for the production and distribution of heat energy	141	1
Group 3: Budgetary organizations	195	3.7
Group 4: Legal entities and others	195	13.7
Technical water	30	12.1
Overall water supply tariff, weighed by deliveries	74	

Source: Astana Su Arnasay (2019); Tractebel Engineering (2021).

Table 5.16 Monetary account of water supply service of the reservoir in 2019

Variable	**Ecosystem service**	**Unit**	**Value**
ES quantity supplied	water supply in Group 1	Million m3/a	51.3
	water supply in Group 2	Million m3/a	1
	water supply in Group 3	Million m3/a	3.7
	water supply in Group 4	Million m3/a	13.7
	water supply in technical water	Million m3/a	12.1
Unit price	water supply in Group 1	KZT/m3	56
	water supply in Group 2	KZT/m3	141
	water supply in Group 3	KZT/m3	195
	water supply in Group 4	KZT/m3	195
	water supply in technical water	KZT/m3	30
Exchange value	water supply in Group 1	Million KZT	2872.8
	water supply in Group 2	Million KZT	141
	water supply in Group 3	Million KZT	721.5
	water supply in Group 4	Million KZT	2671.5
	water supply in technical water	Million KZT	363
Water use percentage of Astana Reservoir			0.8844
Net present value	water supply in Group 1	Million KZT	2540.70432
	water supply in Group 2	Million KZT	124.7004
	water supply in Group 3	Million KZT	638.0946
	water supply in Group 4	Million KZT	2362.6746
	water supply in technical water	Million KZT	321.0372
	Total EAA	Million KZT	5987.21112

5.4.2 REGULATING SERVICES

5.4.2.1 WATER PURIFICATION SERVICE

The cost-based method must be used to calculate the valuation of the Astana Reservoir water purification services. However, considering data availability and to ensure the study's credibility, two cost estimations were utilized: water treatment cost and bottled water.

1) Water treatment cost:

First, using cost-avoidance techniques to value the water treatment costs for the water company to meet national standards. This study draws on data from IBNET, established in 1997, to conduct comprehensive assessments to monitor and improve water sector performance by collecting data from more than 4,000 utilities in 130 countries (Danilenko et al., 2014; Berg & Danilenko, 2010). According to the indicator "11.3 - Unit Operational Cost – Water only (US$/m3 sold)" provided by the International Benchmarking Network (IBNET, 2000-2016), this operating cost includes material costs, equipment costs, labor costs, and other cost components (Appendix H.4). Taking the average value from 2010 to 2016 as 0.29 US$/m3 and the total urban water consumption in 2019 as 81.8 million m3, based on Equation 4, the valuation of the Astana Reservoir water condition service in 2019 is:

81.8 million m3 × 0.29 US$/m3 = 23,722,000 USD.

2) Cost of bottled water:

Secondly, the opportunity costs of bottled water consumption in Astana, as opposed to drinking tap water provided by the network, were considered. According to a survey conducted by Karaca et al. (2019) on the drinking water practices of Astana residents, approximately 62% of the participants avoided using tap water from the network (Figure 5.8). Tap water was perceived to have a sour taste (44%), turbidity (25%), odor (20%), and health concerns (16%), leading people to use bottled water. There is also a considerable amount of residents (18%) using both water sources (bottled and tap water).

Figure 5.8 Survey of drinking water consumption in Astana city

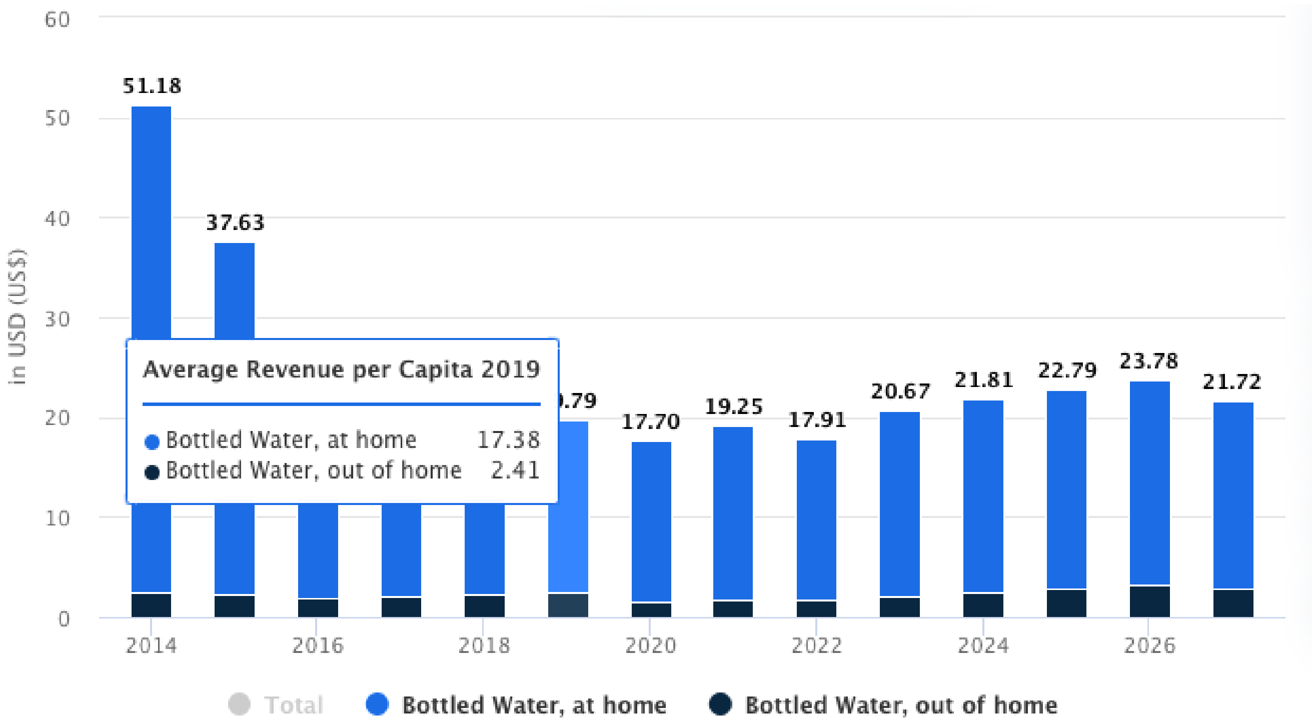
	Always tap water	*Only bottled water*	*Mostly tap water*	*Mostly bottled water*	*Both*
Do you usually drink water from the tap or bottled water?	6%	35%	12%	27%	18%

Source: Karaca et al. (2019).

Also, the per capita consumption of bottled water in Astana in 2019 was estimated at 19.79 USD of cost equivalence (Figure 5.9), while the population of Astana in 2019 was 1,350,228 people.

Therefore, we approximate the value of bottled water for the Astana residents using this source by also considering a range for those using both bottled and tap water, as mentioned above.

Figure 5.9 Average revenue per capita for bottled water in Astana city in 2019



Source: Statista (2024).

Based on the above assumptions, the opportunity costs of the water quality ecosystem services in 2019 by using bottled water as a proxy are estimated as below:

19.79 USD × 1,350,228 people × (62% ±18%) = 11,757,245 USD – 21,376,810 USD.

Each number in the final formula can be clearly explained as follows:

19.79 USD: This is the estimated per capita cost of bottled water in Astana in 2019, derived from data by Statista (2024).

1,350,228 people: This is the total population of Astana in 2019, used to calculate bottled water consumption.

62%: This percentage represents the finding from the survey conducted by Karaca et al. (2019), where approximately 62% of participants reported avoiding tap water in favor of bottled water.

±18%: This range indicates the proportion of residents using bottled and tap water. Since 18% of residents use both sources, the range implies that those relying on bottled water could be as low as 44% (62% - 18%) or as high as 80% (62% + 18%).

In summary, the logic behind the formula is as follows: calculating the number of residents using bottled water by multiplying 19.79 USD (cost per person for bottled water) by 1,350,228 people (total population) and then by (62% ± 18%) (the range of the proportion using bottled water), resulting in:

Lower bound: 19.79 USD × 1,350,228 people × 0.44 = 11,757,245 USD

Upper bound: 19.79 USD × 1,350,228 people × 0.80 = 21,376,810 USD

Therefore, the opportunity cost of bottled water for Astana residents in 2019 is estimated to range between 11,757,245 USD and 21,376,810 USD.

The value of water purification services is derived from the sum of the costs of purified water and bottled water consumption, as outlined in Equation 4 of section 4.3.4. When comparing the calculation methods for these two costs, it becomes apparent that each has its own limitations and controversial assumptions, which may affect the accuracy of the methods. This study identifies that the limitations primarily arise from Astana's scarcity of data and water consumption patterns' low reliability. Therefore, two cost estimates have been proposed using different methods and data sources, enhancing the credibility of this research. Ultimately, in 2019, the total value of water purification services from the reservoir was:

23,722,000 USD + 11,757,245 USD / 21,376,810 USD = 35,479,245 USD / 45,098,810 USD

5.4.2.2 SOIL EROSION CONTROL SERVICE

The value of the soil erosion control service is obtained by applying the river's average annual soil erosion control multiplied by the land degradation cost according to Equation 5 (Section 4.3.4). In the previous section, the reservoir's average annual soil erosion control was calculated to be 13,313.04 tons of land equivalence on an annual basis (Table 5.12) through the sediment regulation model.

Mirzabaev et al. (2016) used the MODIS LUCC and TEEB database from 2001 to 2009 to estimate that the annual cost of land degradation in Kazakhstan in 2009 was 3.06 billion USD, while the land area of Kazakhstan was 2.725 million km². On a unitary basis and assuming a homogeneity of land degradation across the country, the annual cost of land degradation per km² in Kazakhstan can be approximated at 1122.94 USD per annum. According to different soil densities, the soil erosion control value of each type of land can be obtained for the case study in the Astana reservoir.

Table 5.17 lists the soil erosion control amounts (measured in tons) for different land types at the beginning 2000 and the end of 2019, along with the net changes. Specifically, the soil erosion control amount for aquatic ecosystems consistently remains at zero, indicating that this ecosystem fails to provide effective soil erosion control services.

In 2000, the soil erosion control amount for temperate coniferous forests was 83 tons, which slightly increased to 83.3 tons by the end of 2019, resulting in a net change of 0.3 tons, showing that the soil protection function of this ecosystem remained relatively stable. In contrast, the soil erosion control amount for cold temperate shrublands decreased from 4,797 tons to 4,219 tons, with a net decline of 578 tons, indicating a weakening effectiveness in soil protection capacity within this ecosystem.

Crop ecosystems also exhibited a downward trend, with the soil erosion control amount decreasing from 9,911 tons to 8,949 tons, resulting in a net change of -962 tons, suggesting that agricultural activities may negatively impact soil protection capacity. The soil erosion control amount for rock-paved lava flow screens also decreased from 307 tons to 61 tons, with a net change of -245 tons, indicating a significant reduction in soil protection function for this ecological category. The urban industrial ecosystem did not provide soil erosion control services in either case, thus displaying zero in this table.

Regarding soil density, the range for various ecosystems spans from 0 (such as aquatic and urban industrial ecosystems) to varying types of forests, farmland, and rocky lands, with soil densities of 400-1,105 kg/m^3, 993-1,506 kg/m^3, 497-1,137 kg/m^3, and 897-1,474 kg/m^3, respectively. These soil density data are crucial for subsequent calculations of soil erosion control value.

In terms of soil erosion control value, based on the soil erosion control amounts and soil densities of various land types, economic values have been estimated. The estimated soil erosion control value for temperate coniferous forests ranges from 37,475 USD to 103,524 USD, while the value for cold temperate shrub lands ranges from 4,705,033 USD to 7,135,730 USD. The soil erosion control value for farmland ranges from 4,994,375 USD to 11,425,763 USD, and the value for rock-paved lava flow screens is estimated between 61,736 USD and 101,448 USD. In total, the estimated economic value of soil erosion control services in the Astana Reservoir ranges from 9,798,620 USD to 18,766,466 USD. This data not only provides a quantitative basis for the economic value of soil and water loss control services but also offers important references for formulating relevant ecological protection policies.

Table 5.17 Soil erosion control service physical supply change summary

	Aquatic	**Boreal temperate montane forest woodland**	**Cool temperate heathland**	**Cropland**	**Rocky pavement lava flow screen**	**Urban industrial ecosystem**	**Total**
Start of 2000 (ton)	0	83	4,797	9,911	307	0	15,098
End of 2019(ton)	0	83	4,219	8,949	61	0	13,313
Net change (ton)	0	0.3	-578	-962	-245	0	-1,785
Soil density (kg/m³)	0	400-1,105	993-1,506	497-1,137	897-1,474	0	
Soil erosion control value (USD)	0	37,475-103,524	4,705,033-7,135,730	4,994,375-11,425,763	61,736-101,448	0	9,798,620 - 18,766,466

5.4.3 RECREATION SERVICES

Step 1: Research Area

In this section, in order to calculate the recreational service value of the Astana Reservoir, the travel cost equivalence of Astana residents visiting areas for recreational purposes adjacent to Astana Reservoir was estimated. In particular, the administrative regions centered around the reservoir in the Arshaly district were selected. The Arshaly region serves as a short-distance travel base for residents of Astana, with the main routes passing through the villages of Jibek Joly, Zhaltyrkol, and Arnasay. Key tourist destinations include Primevill, Beibarys, and Jansaya in Jibek Joly; The Lake House in Zhaltyrkol; and Otdykh Vyacheslavskoye Vodohranilishche in Arnasay. The main recreational destinations adjacent to the study area are presented in Table 5.18; by identifying these leisure destinations, the study was able to understand tourists' visitation patterns better and provide context for subsequent analysis.

Table 5.18 Main recreational destinations adjacent to the study area

Village	**Recreation center**
Jibek Joly	Primevill
	Beibarys
	Jansaya

Zhaltyrkol	The lake house
Arnasay	Otdykh Vyacheslavskoye Vodohranilishche

Step 2: Collect Information

This step collects information about the travel areas mentioned in the first step through telephone interviews, including the number of visits per year, village population, distance between the travel area and the center of Astana, and cost-related information. This information provides the necessary data basis for subsequent analysis and helps to understand tourists' behavior and preferences.

Step 3: Data Organization

The collected data in step 2 was organized to clarify the amount and frequency of visitors from Astana to the Arshaly region. Utilizing the 2019 population census data, visitation rates per 1,000 people for each area were calculated. During this process, Table 5.19 displays the visitation information for various villages and their associated recreation centers, including total annual visits, village population, and visits per 1,000 people. This data facilitates the standardization of visitor information across different regions, allowing for comparison and analysis of recreational participation rates.

Table 5.19 Visitation rates per 1000 population in each zone

Village	Recreation center	Total visits/year	Zone population	Visits/1000
Jibek Joly	Primevill	15000	1078384	14
	Beibarys	18250	1078384	17
	Jansaya	17500	1078384	16
Zhaltyrkol	The lake house	6000	1078384	6
Arnasay	Otdykh Vyacheslavskoye Vodohranilishche	4000	1078384	4
	Total visits	60750	-	57

The results show that the Beibarys recreation center in the Jibek Joly region has the highest total annual visits, at 18,250, with a visitation rate of 17 per 1,000 people, indicating a strong appeal to tourists. Primevill and Jansaya also have relatively high visitation numbers, 15,000 and 17,500, respectively, reflecting their popularity among visitors. In contrast, Zhaltyrkol's The Lake House and Arnasay's Otdykh Vyacheslavskoye Vodohranilishche have lower visit numbers, at 6,000 and 4,000, respectively.

Step 4:

In this step, the total travel costs for each of the five recreation centers were calculated based on various factors, including transportation costs, travel time costs, and direct expenses.

Transportation Costs:

The round-trip distances and travel times from Astana's center to each recreation center were obtained using spatial analysis tools, specifically Google Maps. This application provides precise distance and time estimates, which are critical for understanding travel logistics.

The average cost of driving in Kazakhstan, specifically the fuel consumption cost for a trip from Almaty to Astana, was calculated using data from the Travelmath trip calculator. This source indicated that the average fuel cost is approximately $0.19 per kilometer for visiting the recreational areas. This figure calculates the total transportation costs based on the distances obtained in the first point.

Travel Time Costs:

Based on data from CEIC (2024), the average monthly earnings in Kazakhstan from 2000 to 2023 are reported to be approximately $782 (as of May 4, 2024). This translates to an opportunity cost of labor income of approximately $0.018 per minute. This figure represents the potential income that is foregone while traveling, thus it is used to calculate the travel time cost for each recreation center. Understanding travel time as a cost is crucial as it reflects the value of time spent on traveling rather than engaging in productive work.

Direct Cost:

For the first three recreation centers, average costs per person (including any applicable fees) were derived from visitor reviews available on the 2GIS software for 2024. This information helps ascertain how much visitors typically spend when visiting these centers. This data is compared against historical exchange rates for the Kazakhstani KTZ and the U.S. dollar for 2019 and 2023 to ensure consistency and accuacy in financial calculations.

Fixed Expense:

For the last two recreation centers, fixed expenses are considered. These consist of an entrance fee of 2,000 KZT and estimated meal costs of about $6.03 per day per person, based on data from "Budget Your Trip" (Kazakhstan Travel Cost, 2024). These costs reflect typical visitor spending behaviors and are crucial for understanding the overall financial burden of visiting these recreational facilities.

Total Cost Calculation:

The total cost of visiting each recreation center is computed by summing the transportation costs, travel time costs, and direct costs (as outlined in Zhou et al., 2021). This comprehensive calculation provides a holistic view of the economic impact on visitors. Notably, since all recreation centers are located close to Astana, the costs related to accommodation are excluded from this assessment, simplifying the cost estimation for day trips. The specific results are shown in Table 5.20:

Table 5.20 Average round-trip travel distance and travel time to each zone

Recreation center	**Round trip travel distance**	**Round trip travel time**	**Transport cost (Cost/kilometer) ($ 0.19)**	**Travel time cost (Cost/minutes) ($ 0.018)**	**Direct cost**	**Total travel cost/trip**
Jansaya	60 km	98 min	$ 11.4	$ 1.76	$ 63.34	$ 76.5
Primevill	62 km	98 min	$ 11.78	$ 1.76	$ 63.34	$ 76.88
Beibarys	62 km	94 min	$ 11.78	$ 1.69	$ 52.78	$ 66.25
The lake house	84 km	122 min	$ 15.96	$ 2.2	$ 11.25	$ 29.41
Otdykh Vyacheslavskoye Vodohranilishche	174 km	168 min	$ 33.06	$ 3	$ 11.25	$ 47.31

The average exchange rate in 2019 was 383.0425 KTZ.

The travel costs for the five recreation centers revealed significant differences influenced by distance, travel time, and spending patterns. Jansaya and Primevill present higher total travel costs of approximately $76.5 and $76.88, respectively, due to their proximity to Astana and associated amenities. In contrast, Beibarys offers a slightly lower total cost of $66.25 but maintains a similar travel distance. The lake house stands out as a more economical option, with a total cost of $29.41. In contrast, Otdykh Vyacheslavskoye Vodohranilishche, despite its greater distance resulting in a total cost of $47.31, remains attractive for visitors seeking budget-friendly recreation.

Step 5:

In this step, the total travel costs calculated for each region in step four and the average visit frequency per 1,000 people described in Table 5.20 were used. The regression function, which was widely used in travel cost methods (Table 5.21), was employed between the total travel costs in the Arshaly region and the average visit frequency per 1,000 people. In this function, x represented the average visit frequency per 1,000 people, and y represented the total travel costs.

Table 5.21 Linear Regression between total travel cost and average number of visits per 1000 in each zone

Function type	**Function expression**	R^2
Linear function	y = 0.252·x – 3.511	36.21
Cubic curve regression	y = - 0.0009·x3 + 0.148·x2 – 7.442·x + 119.6	5.16

Step 6:

This step involved deriving an assumptive demand function for the Vyacheslavskoye recreation zone (Astana Reservoir) based on the results of regression analysis. First, assume that the total number of visits is expected to change if the entrance fee to each attraction in the Arshaly region increases by

$2. The table shows the visit data for a $2 increase in travel costs. The effect of different entrance fees on tourist behavior can be further inferred by plugging the average visit frequency per 1,000 people and the total travel costs into the Cubic curve regression equation derived in step 5. As shown in Table 5.22, the total number of visits decreases to 51,762 per year.

Table 5.22 Total visits in Arshaly area (when travel cost increases by $2)

	Travel cost plus $ 2	**Visits/1000**	**Population**	**Total visits**
Jansaya	$78.50	12	1078384	12940
Primevill	$78.88	12	1078384	12940
Beibarys	$68.25	15	1078384	16176
The lake house	$31.41	4	1078384	4314
Otdykh Vyacheslavskoye Vodohranilishche	$49.31	5	1078384	5392
	Total visits	48		51762

Next, it was possible to calculate the entrance fee increase for each attraction in the Arshaly region until total visits decreased to zero, as shown in Table 5.23:

Table 5.23: Change in total visits with the increase in entrance fees for attractions in Arshaly

Added entry fee	**Total visits**
$ 0	52841
$ 2	51762
$ 4	47449

$ 6	42057
$ 8	36665
$ 10	29116
$ 12	18333
$ 14	8627
$ 15	2157
$ 15.5	0

The table shows the trend of total visits as the entrance fees increase. The cumulative data in Table 5.23 demonstrates that as the entrance fee increases, there is a steady decline in total visits, illustrating a clear inverse relationship between cost and demand. For instance, visits plummet from 52,841 at no additional fee to 2,157 at a fee of $15, signifying that higher entry costs dramatically deter potential visitors.

Finally, the same method was used to calculate the change in the total number of visits to the Astana Reservoir recreation zone (Otdykh Vyacheslavskoye Vodohranilishche) when the entrance fee increases (Table 5.24).

Table 5.24 Change in total visits with the increase in entrance fees for attractions in Astana Reservoir

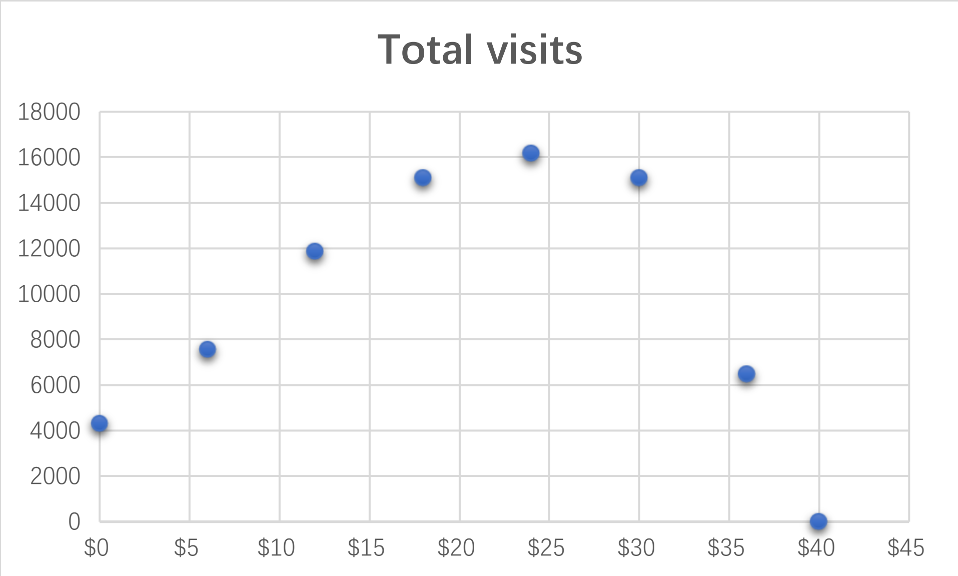
Added entry fee in Otdykh Vyacheslavskoye Vodohranilishche	**Total visits**
$ 0	4314

$ 6	7549
$ 12	11862
$ 18	15097
$ 24	16176
$ 30	15097
$ 36	6470
$ 40	0

Step 7:

The final step involved deriving the demand curve for the Vyacheslavskoye attraction (Astana Reservoir) based on the data from Table 5.23 (Figure 5.10). The *X*-axis represents the added cost, while the *Y*-axis represents total visits. The area under the demand curve can be used to estimate the total economic benefit the attraction provides to visitors over a year. The consumer surplus is calculated as follows: 16×12176/2+24×12176/2+4000×24= 339520. Based on the above assumptions, the economic value of the recreational services in the Arshaly region through the TCZ method is estimated at $339,520 per year.

Figure 5.10 The demand curve for the Astana Reservoir recreation zone



In conclusion, this study evaluated the recreational service value of the Astana reservoir using the zonal travel cost and provided quantitative support for management and environmental decision-making in the region using multiple data sources and calculation methods. The above results lay a solid foundation for further strategy formulation and environmental protection measures.

Summarizing the above four ESV results and converting all results into US dollars using the average exchange rate for 2019 (383.0425 KZT), the ESV results of the Astana Reservoir for the assessed ES are presented in Table 5.24. The total value of the four selected services of the Astana Reservoir ecosystem amounts to approximately 59.69 – 80.88 million USD/year, with water supply service accounting for 21.87%, water purification service for 57.32%, soil erosion control for 20.32%, and recreation service for 0.5%.

Table 5.25 Monetary Valuation of Astana Reservoir ES

Ecosystem service		Indicators	Value	Percentage
Provisioning services	Water supply	Domestic water	14.07 – 16.67 million USD	21.87%
		Industrial water		
Regulating services	Water purification	Chemical condition of freshwaters	35.48 – 45.1 million USD	57.32%
		Opportunity cost		
	Soil erosion control		9.80 -18.77 million USD	20.32%
Recreational services	Physical and intellectual interactions with biota, ecosystems, and land-/seascapes	Recreation	339,520 USD	0.5%
TOTAL			59.69 – 80.88 million USD / year	

The average exchange rate in 2019 was 383.0425 KTZ.

5.5 FINDINGS FROM THE SEMI-STRUCTURED INTERVIEWS ON INTEGRATING ESV INTO WATER PLANNING IN KAZAKHSTAN (PHASE 5)

5.5.1 BACKGROUND OF INTERVIEWEES

A total of 28 interview applications were distributed, and 21 potential interviewees responded and agreed to participate in the interviews, resulting in a participation rate of 75% among potential interviewees. The gender ratio was 2:1, with more male participants. The research planned to recruit interviewees from the following four categories: Central government authorities (such as the committee of water resources and relevant ministries), basin and city-level water management organizations (River Basin Organizations, Kazhydromet, Kazvodkhoz), the scientific and technological community (water experts, scholars), and water users (mainly include representatives of large water users in manufacturing and agricultural enterprises in Astana city, as well as representatives of individual water users engaged in farming or fishing in villages surrounding the Astana Reservoir. Table 5.26 presents the recruited interviewee information. Except for the water user's category, which slightly fell below the anticipated sampling amount (4 out of 5), the other categories met the initial targets. Due to confidentiality principles, interviewee personal information will be treated anonymously, and anonymous codes are coded in Table 5.26 for identification.

Table 5.26 Basic information of respondents

Type of stakeholder	**Central government authorities**	**Basin, aquifer, protected area, and city-level**	**Scientific and technological community**	**Water users**
Representatives	Committee of water resources/ministries responsible for water resources	RBIs, RBOs, Astana su arnasay, Kazhydromet, Kazvodkhoz	Water experts	Industry, agriculture sector
Planned Sample	6	6	6	6
Actual Sample	6	5	6	4
Gender	Male - 5 Female - 1	Male - 4 Female - 1	Male - 3 Female - 3	Male - 2 Female - 2
Organizations	Ministry of Water and Irrigation; Ministry of Ecology and Natural Resources; Water Resources Management Methodology Research Center.	Kazvodkhoz in central and peripheral regions; River basin inspector.	Nazarbayev University; Eurasian National University; Institute of Science Education.	Industrial water supplier company; National and foreign oil companies.
Interview type	Zoom - 1 In-person - 4 Written response - 1	Zoom - 3 In-person - 2	Zoom - 2 In-person - 4	Zoom - 2 In-person - 2
Codes of anonymous	1CG	2WO	3ST	4WU

Among the planned categories of interviewees, central government authorities include representatives from the Ministry of Water and Irrigation, Ministry of Ecology and Natural Resources, Water Committee, and Water Resources Management Methodology Research Center. Local-level water management authorities primarily come from the Kazvodkhoz branches in Astana, Taraz region, and Almaty region, as well as the Esil basin inspector. The scientific and technical community comprises professors and researchers from Nazarbayev University, Eurasian National University, and the Institute of Science Education. Water users are drawn from enterprises that extensively use water or engage in water treatment, including industrial water supplier companies and national and foreign oil companies.

Interviews were conducted mainly through face-to-face meetings and Zoom conferences, with each interviewee allocated 45-60 minutes. The age distribution of interviewees is as follows: 19% (4 individuals) aged 25-35, 48% (10 individuals) aged 36-45, 28% (6 individuals) aged 46-55, and 5% (1 individual) aged 56 and above. The interviewees possess 8-20 years of experience in water resources management and research.

In addition to basic information, this study prepared three categories of questions for the interviewees, including their understanding of water resource management in Kazakhstan, their perspectives on the application of ESV in water resource planning, and their thoughts on the results obtained from the ESV of the Astana Reservoir in the case study. The following sections present the interview results one by one.

5.5.2 INTERVIEWEES' UNDERSTANDING OF WATER RESOURCE MANAGEMENT IN KAZAKHSTAN

- History and significant changes

The history and significant changes in Kazakhstan's water resource management and planning can be traced back to the period before and after its independence. Respondents commonly highlighted significant shifts during this process.

They mentioned that from 1991 to 1996, Kazakhstan conducted relatively comprehensive water resource planning. This period's planning was based on 20 years of hydrological and meteorological data, scientifically formulating schemes for water resource utilization. However, from 1996 to 2010, water resource management decisions in some regions relied more on short-term data, particularly 1-2 years' data from local reservoirs.

After 2010, the Kazakhstani government began to enhance its focus on water resource planning, with various water resource management departments actively collecting and analyzing data. Simultaneously, the role of environmental factors in water resource management began to receive attention. Around 2013, IWRM was incorporated into water law, introducing the concept of environmental flow.

Some respondents noted a gradual shift in Kazakhstan's water resource management concept from the Soviet Era’s Integrated Use of Water Resources (Комплексное использование водных ресурсов, КИВР. European Environment Agency, 2020) to IWRM. However, some water experts still have some ambiguity in their understanding of these two concepts.

Since 2010, Kazakhstan has begun to prioritize water resource planning. The previous pattern of water resource allocation primarily based on demand has gradually shifted towards providing water consumption recommendations to water users based on water supply volume. For instance, for agricultural cultivators, the government suggested crop types suitable for local water resources to ensure their rational use. Directives issued by governors and the central government require permits for crop cultivation, ensuring alignment with overall water resource planning.

"*It can be said that the era of water planning is back*". *(3WO2).*

Simultaneously, many regions are researching water-saving irrigation technologies and techniques for desalination, such as the application of patented technologies like drip irrigation and activated carbon purification of irrigation water to reduce evaporation.

Regarding specific water resource planning, many managers point out that about 70% of Kazakhstan's water resources are used for agriculture, especially irrigation. Local water management departments compare and analyze specific water requirements for different crops in terms of demand and supply. Annually, Kazhydromet provides forecast data, based on which water management departments formulate water supply plans for reservoirs and rivers. Basin inspectors are responsible for verifying and confirming this data, and local water management departments operate on the principle of "water limit" to ensure water resource allocation does not exceed the quotas set by the central government.

In terms of water resource management setup, respondents raised the following points:

“*Agricultural irrigation accounts for a significant proportion of our country's water resource demand; the Water Committee has historically fallen under the jurisdiction of the Ministry of Agriculture. However, as awareness of ecological factors has increased, it became evident that solely linking water resource management with agriculture was inappropriate. Consequently, the Water Committee was transferred to the Ministry of Ecology to more comprehensively consider the relationship between water resource management and ecological protection. However, this arrangement still has certain limitations. In recent years, the emphasis on water security has increased, leading to the establishment of an independent Ministry of Water and Irrigation. However, the functions and work distribution of this new ministry are currently not sufficiently clear and need further clarification and improvement”. (1CG2)*

Around 2010, River Basin management institutions (RBC, RBO) were introduced. This reform shifted the functions of RBI from primarily planning and management to predominantly inspection functions. Additionally, some provisions in water laws were adjusted to accommodate economic development needs. For example, the requirement for purification before drainage was canceled, reflecting a trend in water resource management to consider economic and environmental factors comprehensively.

- **Water resource management issues in Kazakhstan**

Water resource management faces challenges, particularly in arid regions like Kazakhstan. Exacerbated droughts and irregular rainfall patterns pose challenges to water resource management. Respondents have identified numerous issues within Kazakhstan's water resource management, primarily manifested in aged water infrastructure, insufficient information sharing, outdated data collection methods, neglect of ecological water use, and inadequate basin monitoring. These problems result in difficulties in allocating and managing water resources, necessitating comprehensive water resource accounting and reassessments.

Firstly, Kazakhstan lacks comprehensive water accounting in its water resource management. Management institutions often focus solely on allocating water without effectively managing water resources. This results in blind water allocation rather than rational management based on comprehensive water resource accounting. For example, water resources from Kyrgyzstan fail to adequately supply certain areas of Kazakhstan, particularly evident in the shortage of transboundary water resources in the Shu Talas region of Zhambyl Province, highlighting the adverse effects of mismanagement. Existing management methods prioritize profitability and lack consideration for environmental and social aspects.

"*We are not managing water; we are simply allocating it to those who need it. It depends on the water use. However, water management requires comprehensive water accounting, where we can understand how to manage effectively*". *(3ST3)*

"*The primary issue at present is water security. The task assigned by the President is to conduct a comprehensive water analysis. A specialized Ministry of Water and Irrigation has also been established due to the water security concerns. The Ministry is currently focused on revising water laws, upon which all water resource management will be based. The main drafting principles of the current water law focus on water conservation, the application of new technologies, and the promotion of water recycling and purification. However, the existing water laws do not align with current conditions, hence the need for revision. Once the water law is drafted, the country will enact corresponding water resource management strategic documents. Subsequently, specific methodologies will be formulated according to laws and regulations*". *(1CG4)*

Secondly, outdated hydrological and meteorological data collection methods fail to provide accurate and real-time data support. This incomplete understanding of water resource conditions hampers the scientific basis for water resource planning and management, making it difficult to address challenges such as future climate change.

"*It is necessary to reassess water resources in local basins, including reviewing available water quantities and water quality, adjusting prescribed water use limits, and distinguishing between agricultural, industrial, and domestic water supplies. This requires comprehensive water resource audits to ensure the rational allocation and management of resources". (3WO1)*

“*The central Water Resources Committee is responsible for national water resource planning. Generally, they collect data from local entities such as Kazvodhoz and basin inspectors. However, there is a lack of comprehensive assessment of ecological environments. Kazvodhoz, Kazhydromet, Astana Su Arnasay, and others collect their data independently, without a dedicated department for integrating and analyzing it comprehensively*”. *(1CG4)*

Neglecting ecological water use is also a significant challenge in Kazakhstan's water resource management.

“*In the balance between development and environmental protection, the government favors development, overlooking the importance of protecting ecosystems and ecological water use. This leads to environmental ecosystem degradation, exacerbating water resource tensions and posing risks to future sustainable development”. (2WO1)*

Additionally, the lack of information sharing and collaboration among water resource management institutions leads to delays in addressing water resource issues. Different departments (such as the Ministry of Ecology, Ministry of Agriculture, etc.) manage various aspects of water resources, but their interaction is limited, lacking effective coordination mechanisms. This increases the complexity of addressing cross-sectoral water resource issues and impedes comprehensive problem-solving.

“*There is a lack of interaction among various institutions. For instance, some departments are responsible for research, while others handle planning. Although information is shared between departments, the final planning is not done collaboratively. For example, several factories discharge wastewater into the Nura River, but each applies for discharge separately. We review and grant permits based on their data. However, there is no calculation or analysis of total discharge or* *comprehensive assessment. While individual discharges may not exceed standards, the combined discharge from 5-6 factories can lead to exceeding limits*". *(3ST2)*

In short, Kazakhstan faces numerous challenges in water resource management, including the rationality of management methods, the credibility of data, and collaboration among water resource management institutions.

- **Current environmental challenges in water resources**

Kazakhstan faces severe water resource management and ecological and environmental issues, notably concerning transboundary rivers like the Chu River basin. Specifically, respondents highlighted several cases.

Chu River Basin Changes: The Chu River originates in Kyrgyzstan and extends to South Kazakhstan's Sudakun County. Over the past few decades, due to the construction of reservoirs in Kyrgyzstan and Kazakhstan's Tassotekli Reservoir, the water volume of the Chu River has significantly decreased to the extent that it cannot reach the Moiyrka area. Despite the Tassotekli Reservoir having a capacity of 500 cubic meters, it has not released any ecological water for ten years, leading to severe land salinization issues in the region. Since 2008, attention has been focused on ecological issues, with efforts to rectify the situation by releasing ecological water.

Ecological Issues in the Talas and Asau Basins: The Talas Basin used to terminate at the Kilyefka Reservoir but now flows near Sarysu. Meanwhile, the Asau Basin flows to Akkol, and insufficient winter discharge causes droughts in downstream areas. These ecological issues have only recently garnered attention. Since 2012, the central government has encouraged local water management agencies to implement ecological drainage and provided corresponding incentives, indicating a growing awareness of and response to these issues.

Pollution in the Zhaiyk River, a transboundary river: The Zhaiyk River is highly polluted, mainly due to pesticide and industrial wastewater contamination from Russia. This pollution affects Kazakhstan's domestic water resources and exacerbates international environmental issues.

Several other basins, including the Balkhash, Aral Sea, Zaisan, and Belaya basins, also face severe water resource ecological problems. These problems primarily stem from poor human management, which exacerbates the ecological crisis of water resources.

In summary, Kazakhstan's water resource management issues include transboundary water resource allocation, ecological water release, land salinization, water pollution, and more.

5.5.3 INTERVIEWEES' PERSPECTIVES ON THE VALUATION OF ECOSYSTEM SERVICES OF ASTANA RESERVOIR

Interviewees are well aware of the situation regarding the reservoir:

"*With the decreasing water levels in the Astana Reservoir, the population in surrounding villages will decrease, as will the number of tourists. Additionally, fish production will decline, and the land around the reservoir will become saline-alkaline*". *(4WU1)*

Perception of the ESV of the Astana Reservoir:

Most of the respondents agree with the approach of expressing the value of water through the SEEA:

"*The first time I saw this methodology, I mentioned it many times to water economists. You need to calculate the productivity of water, not just manage the costs of water, but the true value of water". (2WO3)*

"*We need to link these issues to our economy, such as tourism, citizen life, social and economic systems, etc. Water economics is an important part of the Astana economic system. We can conduct research in this area later, but it needs to be comprehensive, not just individual indicators. We need to know the water consumption of all factories and products, the steam generation and reuse of the power system, etc.*". *(1CG3)*

This methodology emphasizes the assessment of the true value of water resources rather than merely managing the costs of water resources. By valuing the ecological system services of the reservoir, we can better understand the complexity of water resource management and consider the impacts of water resource inflows and outflows on ES. For bodies of water like the Astana Reservoir, their value lies not only in providing water for domestic and industrial use but also in maintaining ecological balance, supporting agricultural irrigation, and promoting tourism development. This approach enables decision-makers to have a more comprehensive understanding of the importance of water resources, thereby formulating more effective and sustainable management strategies.

For example, a water expert mentioned:

"*The Astana Reservoir was established in 1968 when there were only 300,000 people. When Astana became the capital in 1997, water experts suggested addressing water source issues before relocation, but politicians did not heed expert advice. We, water experts, always make predictions, forecasting 10-20 years ahead*". *(3ST2)*

In the case of Astana, respondents repeatedly mentioned the history behind reservoir construction and the challenges of water resource management. They pointed out that while reservoir construction can provide water resources, it also impacts the surrounding ecological environment. By valuing the ecological system services of the reservoir, the benefits and costs of reservoir construction can be better weighed, thus avoiding irreversible damage to the ecological environment caused by excessive development.

Furthermore, valuing the ES of the reservoir can provide guidance for water resource planning and management. Experts mentioned using multi-year analysis and water balance calculations to assess river flow and sustainability. This analysis provides decision-makers with data support, enabling them to better set quotas for population and industrial water use and make corresponding recommendations. For instance, they pointed out:

"*You need to conduct a multi-year analysis to see if this river can be used for multi-year applications. You need to calculate the water balance of the Esil River*". They also mentioned: "*Water resource management departments can adjust water resource allocation schemes based on the valuation of ecosystem services, promoting the rational utilization and protection of water resources".* *(2WO1)*

- **Role of ESV in Astana's Urban Water Resource Planning:**

Firstly, most respondents believe that valuing the ES of the reservoir can provide comprehensive data support for Astana's water resource planning. Through the assessment of ES of the reservoir, decision-makers can better understand the supply and demand situation of water resources, the health of the ecological environment, and the economic impacts of water resource utilization, thereby formulating more scientific and sustainable water resource planning schemes.

"*I think it is essential to incorporate this ecosystem-based approach into the water planning process. Because we need to know what benefits we can obtain when allocating water, through economic analysis, we can anticipate the results of decisions made*". *(1CG1)*

Secondly, valuing the ES of the reservoir can guide water resource management in Astana. Respondents mentioned various suggestions such as digital management, promoting water recycling, and updating water facilities, all of which can be supported by valuing ES. For example, they proposed:

"*A comprehensive water analysis is needed. The Ministry of Water and Irrigation is currently mainly revising water laws, and all water resource management is based on this water law*". *(1CG1)*

Lastly, respondents also suggested that valuing the reservoir's ES can promote conservation awareness among Astana citizens. By conducting ecological education courses and promoting water-saving technologies, citizens can pay more attention to the importance of water resources, develop water-saving habits, and further promote the sustainable utilization and management of water resources.

Valuing the reservoir's ES can also support Astana's economic development. Eco-tourism, aquaculture, and urban greening rely on good water resources and ecological environments. Therefore, by properly valuating the reservoir's ES, a better balance between economic development and environmental protection can be achieved, promoting sustainable development.

In brief, respondents believe valuing the reservoir's ESV is crucial for Astana's urban water resource planning. It provides decision-makers with scientific data support and management guidance, promotes citizens' awareness of water conservation, drives sustainable utilization and protection of water resources, and balances economic development with environmental protection.

5.5.4 INTERVIEWEES' PERSPECTIVE ON INTEGRATING THE ESV INTO WATER RESOURCE PLANNING AND MANAGEMENT

- Views on Implementing an ESV in Kazakhstan

For Kazakhstan, implementing the ES-based approach is of significant importance. Firstly, this approach can help Kazakhstan gain a more comprehensive understanding of water resources' value and the importance of the ecological environment. By valuing the ES of water resources, the contribution value can be quantified clearly, thus raising awareness and promoting protection among decision-makers. For instance, an expert mentioned:

"*Kazakh people only see water as a resource and raw material. We always think about how much profit we can make from water, but our people do not know the value of water and always think water is free*". *(3ST1)*

In the past, water resources were considered inexhaustible, and their value was often overlooked. However, with a deeper understanding of ecosystems, people are beginning to realize water resources' scarcity and ecological value. Implementing the ESV method can challenge this traditional view and make people aware of the actual value of water resources. Additionally, respondents compared IWRM with ES, stating:

"IWRM is not practical; it is just conceptual. At the same time, the ecosystem services method is more realistic and can guide people on how to do it. The goal of IWRM is sustainable development and more policy-oriented. Kazakhstan needs a more practical method; whichever method is most useful should be used. Moreover, it is difficult to define the effectiveness of the IWRM application". *(3ST3)*

Secondly, respondents believe implementing the ESV method can provide a scientific basis and decision support for water resource management in Kazakhstan. For example, an expert mentioned：

"*If we adopt digitalization, water users and we can see the supply situation in real-time. Our water supply department may report false numbers in the current situation, but with digitalization, water users will also feel more reassured*". *(4WU1)*

Digitalized ESV methods can enhance the transparency and efficiency of water resource management. They provide data support for the rational allocation and management of water resources, making more scientific and accurate decisions.

Regarding successful cases and priority issues, respondents mentioned that Kazakhstan has already begun introducing the concept of environmental flow. They cited the case of the Small Aral Sea, which has begun to recover its surrounding ecology after water filling, marking progress in water resource management.

- Challenges in Implementing an ES-based approach

Implementing the ESV method in Kazakhstan faces several challenges. Firstly, since the Soviet era, the government has prioritized economic development, a perspective reflected in many policy decisions. However, despite the crucial importance of economic growth for national development, the worsening ecological environment has become an urgent issue. Therefore, promoting the implementation of the ESV method requires overcoming the contradictions between economic interests and ecological protection and formulating and enforcing relevant policies and regulations.

Secondly, the formulation and enforcement of laws and regulations pose another difficulty. Although the ES-based approach is theoretically considered an effective method for managing water resources, its practical implementation in practice requires its incorporation into the legal framework of national water resource management. Only in this way can the ES-based approach be effectively applied to promote sustainable water resource management. However, Kazakhstan's current legal framework may be imperfect and requires revision and improvement to meet the application requirements of the new ESV method.

"*To introduce this ES-based approach, you must first legalize it. The complete methodology and workflow need to be incorporated into the law so that it can be truly implemented. Otherwise, it is not* *easy to enforce in reality. Because that is how public sector employees work, just within their scope of responsibilities, following the prescribed methodology*". *(1CG2)*

Furthermore, promoting the application of the ESV method also requires strengthening technical support and capacity building. As Kazakhstan's water resource management still relies on traditional manual methods, a digitized water resource management system can more accurately measure and monitor water resource usage.

"*To implement this method specifically, a common information center must be implemented. For example, when working on the Balkhash project, I could open and access the required data. Of course, when I work on this project, I need to use this data for analysis, but then I have to ask the central government for it, which involves a lot of procedures, time, and effort*". *(1CG2)*

Since this method involves multidisciplinary expertise and technical skills, professional teams and technical support are needed to ensure its accuracy and feasibility. Additionally, training and education for relevant personnel are necessary to enhance their understanding and application capabilities of the ESV method.

"*When introducing this method, you need to define the responsibilities of specialized public sector employees; otherwise, it will be difficult to implement. That is, from local government departments to central government departments, the responsibilities of public sector employees need to be defined*". *(2WO1)*

In conclusion, despite facing challenges, the potential value and significance of implementing the ESV method in Kazakhstan cannot be ignored. By overcoming economic, legal, and technical difficulties and implementing measures such as strengthening the legal framework, promoting digitized water resource management, and introducing ecosystem protection policies, the implementation of the ESV method can provide more scientific and practical support for water resource management and ecological protection in Kazakhstan.

Chapter 6

Discussion

6 DISCUSSION

The study adopted the Astana Reservoir as a case study, which is the city's primary source of water supply, by assessing critical ecosystem services that support the city's water systems. The valuation of the reservoir's ecosystem services and the insights gathered from in-depth interviews with professionals indicate the substantial role of ecosystem services on ESV in water resources management planning at the city and country levels. The results highlight a critical requirement for integrating ESV into water resource management. This integration is essential for addressing inefficiencies and enhancing decision-making processes.

6.1 WATER MANAGEMENT AND PLANNING IN KAZAKHSTAN

First, this study analyzed the research background of water resource management in Kazakhstan, employing the ROSES framework that yielded 75 articles. The results indicate that research in this area began in 1996, with a noticeable increase starting in 2012 and a significant surge from 2017 onward. This finding corroborates studies on the transitions in Kazakhstan's water resource management regime (Abdullaev & Rakhmatullaev, 2015; Rakhmatullaev et al., 2017; Zhupankhan et al., 2018; Assubayeva et al., 2022), which suggest that during the 1990s, following the dissolution of the Soviet Union, water management issues were primarily viewed as technical problems. However, as economic development intensified the demand for water resources, these issues evolved into economic and political concerns (Abdullaev & Rakhmatullaev, 2015). With the concurrent challenges of competition for water resources among the five Central Asian countries, climate change, and worsening water environments, water resource issues transformed into security concerns post-2015 (Rakhmatullaev et al., 2017). A detailed discussion of the transitions in Kazakhstan's water resource management regimes can be found in Appendix F.

From the content of the selected articles, it is evident that they are predominantly distributed across the fields of environmental sciences (40%), water resources (21%), green sustainable technology (13.5%), environmental studies (12.5%), and geosciences multidisciplinary (9%). Specifically, research on Kazakhstan's water resource management primarily focuses on the water environment, water quality, water quantity, the impact of climate crises on water resources, sustainable water resource utilization, water security, transboundary water disputes, and technological information and data management. Notably, there is a significant upward trend in research related to the water environment, water quantity, sustainable water resource utilization, and the impact of climate crises on water resources. This is primarily due to the anticipated exacerbation of water shortages resulting from climate change, with water demand expected to rise significantly by 2050 (Saimova et al., 2020). Agriculture is the primary source of water use in the region, leading to land degradation and salinization and further damaging ecosystems (Hamidov et al., 2016; Mueller et al., 2014). This situation creates a vicious cycle, intertwining water scarcity with environmental degradation.

Additionally, research on water security and transboundary water resource management has gained importance, mainly due to the competition among the five Central Asian countries for transboundary water resources. Issues such as water quality problems in the Syr Darya and Ili rivers, as well as demand competition between upstream and downstream countries (Yegemova et al., 2018; Thevs et al., 2017), and environmental disasters like the drying of the Aral Sea (Micklin & Caucasian Prospects, 2000) have been highlighted. To address these challenges, researchers advocate for implementing integrated water resource management approaches, improved irrigation efficiency, and enhanced international cooperation (Karthe et al., 2017; Zhupankhan et al., 2018).

A further summary of the challenges in Kazakhstan's water resource management and planning reveals critical issues, including inadequate legal frameworks, neglect of environmental concerns, aging infrastructure, and insufficient public participation. This is evident from the analysis of legal documents and international reports related to Kazakhstan's water resource management and planning, which indicate that sustainable water resource utilization is a core element of national strategy. For instance, the "Kazakhstan 2030 Strategy" and the "Kazakhstan 2050 Strategy" emphasize protecting the water environment, effectively utilizing water resources, and improving water quality (Table 6.1). This focus is primarily influenced by various international environmental agreements, such as the United Nations Framework Convention on Climate Change, the Convention on Biological Diversity (Philippines, 2017), the United Nations Sustainable Development Goals (SDGs), and the Paris Agreement, which aim to enhance environmental awareness to promote sustainable development, attract international investment, and elevate the country's 'great power' image (Poberezhskaya & Bychkova, 2021). Additionally, geopolitical considerations necessitate cooperation among Central

Asian countries in transboundary water resource management, which requires incorporating environmental impacts into joint water projects.

Table 6.1 Kazakhstan strategies

Document Name	**Year Released**	**Main Objectives**
"Kazakhstan 2030 Strategy"	1997	Protect water resources, ensure effective use, and improve drinking water quality.
"Kazakhstan 2050 Strategy"	2012	Address population water supply issues by 2020 and irrigation water issues by 2040
"Concept of Transition to Green Economy"	2013	Promote a green economy, emphasizing sustainable water management and protection
"2021-2025 National Water Resources Management Plan"	2020	Implement new water legislation and ensure sustainable use considering climate change impacts

Source: Kazakhstan Environmental Performance Review (2019).

However, in Kazakhstan's third-tier water resource planning, specific water use quotas are still based on user demands, often neglecting environmental considerations. This oversight can be attributed to the government's reduction in the number of environmental protection strategic documents since 2010, leading to many documents related to environmental issues becoming outdated, which in turn affects the resolution of specific environmental problems and the allocation of funding (Kazakhstan Environmental Performance Review, 2019). Additionally, some strategic documents may be constrained by insufficient funding during implementation. In some instances, the environmental goals outlined in these documents may lack feasibility or be challenging to achieve in practice.

Although monitoring and reporting on the implementation of strategic documents are mandated, accessing relevant reports on government websites can be challenging, significantly impacting public awareness of policy implementation (Russell et al., 2018).

Next, examining the issues in water resource management and planning in Astana, the city faces significant challenges related to water resources, including increasing demand and water quality issues. Data on water usage indicates that demand has increased from 22.5 million cubic meters (MCM) in 1971 to 89.56 million cubic meters in 2022, representing a growth rate of 398%. The existing problems and challenges include:

1) Water scarcity: Astana's water consumption is nearing the supply limits of its reservoirs (Kazvodkhoz, 1971-2022).

2) Water quality pollution: Some sources, such as the Nura-Ishim River, are contaminated with heavy metals, affecting drinking water safety (Guney et al., 2020).

3) Ecological impacts: Overuse of water resources has led to ecological degradation, harming local ecosystems.

The city plans to implement the following measures to address water shortages and quality issues:

1) Increase water sources by enhancing supply through the Irtysh-Karaganda Canal pipeline.

2) Upgrade infrastructure by constructing new filtration stations to improve water treatment capacity.

3) Strengthen water resource management by advancing watershed management to ensure equitable distribution and utilization of water resources.

The analysis reveals that the government's response policies to the water resource issues in Astana are unsustainable. Merely increasing water supply sources can only temporarily relieve the current water scarcity problem and fails to address the fundamental underlying supply issues. Furthermore, the degradation of the water ecological environment indicates ineffective implementation of water resource planning in Astana. Indicatively, the Japan International Cooperation Agency (JICA), which had supported the water supply system in Astana, emphasized the development of eco-friendly urban environments and stipulated ecological water quotas (JICA, 2001), proposing corresponding solutions to the water scarcity faced by Astana. However, water quotas are still determined based on consumer demand, leading to ecological deterioration and negatively impacting water quality. The transition from the Soviet management structure to a market-oriented water resource management model has been ambiguous, hindering efficient water use and adaptation to water resource pressures (Barrett et al., 2017).

Kazakhstan's water resource management system has been implementing IWRM for nearly 20 years in response to environmental degradation and water scarcity (Zhupankhan et al., 2018). This initiative has been primarily advocated by international organizations and projects such as the Global Water Partnership (GWP) (Molle, 2008; Mukhtarov & Gerlak, 2013). However, despite expectations that introducing River Basin Organizations (RBOs) would promote bottom-up water management, the actual management model remains predominantly top-down, lacking effective participatory mechanisms (Barrow, 1998).

In practice, RBOs play a crucial role in implementing water policies, responsible for issuing water licenses, monitoring, and protecting water resources (Assubayeva et al., 2022). However, although River Basin Committees (RBCs) exist in all river basins as dialogue platforms for water users and stakeholders, their recommendations lack legally binding force (IWRM Data Portal, 2021). This reflects a fragmented water governance phenomenon, where, despite some communication among national institutions regarding data sharing, there remains a lack of practical cooperation and inter-departmental coordination in planning and implementation (Karatayev et al., 2017; Thevs et al., 2017; Zhupankhan et al., 2018).

Moreover, the legal framework for water resource management in Kazakhstan is complex, comprising multiple laws, international treaties, and government decrees, which results in an intricate policy and regulatory framework (Medetov et al., 2018; Ozenbayeva et al., 2022). This complexity increases management difficulties and poses challenges to policy implementation (IWRM Data Portal, 2021). Additionally, current water resource monitoring and management technologies are inadequate, lacking integration and innovation (Ospan et al., 2023), and the application of data management and information technology in decision support remains insufficient (Abdullaev & Rakhmatullaev, 2014). While Kazakhstan has made some progress in implementing IWRM, challenges such as centralized management, fragmented governance, and a complex legal framework persist, necessitating the development of more effective bottom-up participatory mechanisms to enhance water security and governance efficiency.

It is important to note that this study has certain limitations, as it primarily focuses on the context of water resource management and planning in Kazakhstan. Consequently, the literature review concentrated mainly on Kazakhstan without delving into a broader range of Central Asian water resource management literature. However, Appendix F provides a detailed description of the evolution of water resource management regimes in Central Asia and lists the transboundary water cooperation agreements signed among the five Central Asian countries (Table F.4). Future research could focus on the valuation of transboundary water resources between Kazakhstan and its neighboring countries, conducting valuation studies that emphasize these shared resources.

6.2 ECOSYSTEM SERVICES IN ASTANA RESERVOIR AND SIGNIFICANCE TO ECONOMIC WELFARE

The study of the Astana Reservoir emphasizes its multifaceted role and the critical challenges it faces, particularly in providing essential ecosystem services for surrounding communities and the environment. The reservoir is crucial for water supply, flood control, water purification, and recreational activities, while its physical and chemical characteristics can undergo significant changes over time.

As the study findings on the economic valuation indicate, water supply service accounts for 21.87%, water purification for 57.32%, soil erosion control for 20.32%, and recreation only contributes 0.5%. of the overall valuation results It is noted however that this study examined only four ES of the reservoir, which represents a fraction of its total ecosystem services and does not account for the entirety of the services provided by the reservoir. Studies have estimated the total economic value of reservoirs ranging from $30 to $3,000 per hectare per year in developing countries (Korsgaard & Schou, 2010), with specific examples like $45,623 per hectare per year for a Brazilian reservoir (Periotto & Tundisi, 2013) and £123-215 million annually for Rutland Water in the UK (Gaterell et al., 1995). Valuation methods include market price, cost-based, and revealed preference approaches (Korsgaard & Schou, 2010). Challenges in reservoir management include sedimentation (Sude et al., 2011; Hansen & Hellerstein, 2007), water level fluctuations, and eutrophication (Gunkel et al., 2015). Sustainable management focuses on maintaining water quality, balancing multiple uses, and preserving ecosystem services for local communities and future generations (Baral et al., 2016; Ghosh, 2021). However, the valuation results of reservoir ES vary depending on the size, condition and economic and social factors of the research object, the valuation results of the ES of the Astana Reservoir are discussed below:

6.2.1 WATER SUPPLY SERVICES OF ASTANA RESERVOIR

- **Major Findings**

The Astana Reservoir supplied approximately 88.44% of the city's water needs in 2019, with an estimated economic value ranging between 14 to 16 million USD. This finding not only underscores the reservoir's key role in meeting urban basic drinking water requirements and supporting local economic activities but also highlights its importance for the overall health of the urban ecosystem. Furthermore, the reservoir effectively mitigates flood risk and addresses drought conditions through its storage capacity, playing a critical role in regional water resource management, akin to the function of the Hoover Dam (Johnson, 2019). It also regulates the hydrological cycle, alleviating flooding during spring runoff. However, the Dead Water Level (DWL) has decreased from 30.97 meters to

23.29 meters, a decline of 24.8%, indicating a reduced capacity for flood management and the need for proactive water resource management strategies (Kazvodkhoz, 1971-2022).

- **Primary Reasons**

The economic valuation of the water supply services is influenced by several factors, with the most significant being the ongoing increase in water demand. According to DNRERAR (2021), the annual discharge of the Astana Reservoir rose from 39 million cubic meters in 2000 to 89.2 million cubic meters in 2019, marking an increase of 128.7%. This trend reflects the growing demand driven by urban expansion and agricultural development in the Akmola region. Moreover, the government's decision to prohibit commercial fishing to protect water quality emphasizes the importance of balancing human needs with ecological health (Sputnik, 2017). This policy demonstrates how regulatory measures can profoundly impact water resource utilization and management.

- **Comparison with Other Literature or Case Results**

The findings of this study align with existing literature. For instance, Mulyana et al. (2020) highlight the crucial role of freshwater ecosystems in urban water supply assessments, emphasizing the intrinsic ecological value of water resources. Unlike many studies that only focus on economic outputs, this research stresses the importance of recognizing and assessing the comprehensive value of ecosystem services, a perspective often overlooked in traditional evaluations. Additionally, the situation in Almaty, where water sources primarily come from the Big Almaty Lake, mirrors the economic pressures and challenges related to the water supply faced in Astana. By drawing parallels to other critical reservoirs, such as the Toktogul Reservoir, which has experienced low water levels leading to energy crises (Juraev, 2009), the relevance of the findings in this study is reinforced. Furthermore, the study emphasizes the role of the Astana Reservoir in regulating the regional hydrological cycle and its capacity for flood management, reinforcing the argument made by Johnson (2019) about the importance of large reservoirs in water resource evaluation.

- **Research Challenges**

The valuation process faces several challenges. One major issue is that a fixed water pricing structure may lead to a mismatch between pricing and actual market conditions, restricting commercial water use and distorting price signals. Research indicates that changes in water pricing may cause overestimation or underestimation of actual resource consumption, often linked to unpaid bills or seasonal demand fluctuations. This study has accounted for a margin of error of ±10%; however, it also highlights the limitations of the direct market pricing method in providing comprehensive valuation (Zhao & Wang, 2021). Moreover, the social and economic impacts of water pricing must be considered carefully, especially in water-scarce regions where fixed prices might disproportionately burden low-income households (Tussupbekova et al., 2021).

- **Future Research Directions**

To deepen the understanding of water resource valuation, future research should explore how different water pricing structures impact various user groups, ensuring equity considerations are integrated into water resource management policies. Incorporating perspectives from different regions of Kazakhstan could offer a more nuanced view of these dynamics. Given that this research is based on data from 2019, subsequent changes in environmental conditions, water resource management policies, or urban growth could significantly alter the valuation. Therefore, conducting longitudinal studies to track changes in water resource management and their impacts on the value of ecosystem services will be essential for understanding the evolution of these relationships over time (Fisher et al., 2009).

Moreover, a multi-faceted ecosystem service valuation approach combining quantitative and qualitative methods is recommended to address existing limitations. A mixed-methods approach can enrich economic analysis and provide deeper insights into community values and preferences (Sullivan et al., 2017). Furthermore, investigating the impacts of climate change on water availability and quality is crucial for establishing adaptive management strategies that ensure the sustainability of the Astana Reservoir and its ecosystem services.

Finally, innovative water pricing mechanisms that reflect real-time supply and demand conditions can enhance the resilience of urban water supply systems. As emphasized by the World Bank (2016), adaptive pricing strategies promote efficient use of resources and better support vulnerable populations by ensuring fair access. Implementing such mechanisms could effectively mitigate the economic burdens on low-income households while improving overall water management efficiency and sustainability.

In conclusion, the valuation of the Astana Reservoir's water supply services underscores its critical role in economic sustainability and ecological health, necessitating proactive management strategies to address growing environmental challenges and ensure equitable resource distribution. Further research is essential for enhancing our understanding of water resource dynamics and informing effective policy decisions.

6.2.2 WATER PURIFICATION SERVICES OF ASTANA RESERVOIR

- **Major Findings**

Evaluating water purification services at the Astana Reservoir reveals trends regarding water quality. Although biochemical oxygen demand (BOD) levels have significantly improved, decreasing by 61.7%, the concentrations of heavy metals exceed permissible limits, posing serious risks to aquatic life and human health. Specifically, copper levels are 1.5 times the maximum permissible concentration (MPC), while zinc levels are 3.2 times the MPC. This indicates that the levels of copper and zinc present in the water body are far above safety standards, potentially leading to water pollution and ecosystem degradation, further affecting the safety and availability of water resources (Kazhydromet, 2021).

Despite the Astana Water Supply Company providing high-quality pure water, residents often choose bottled water due to concerns about taste, odor, and potential contamination arising from aging infrastructure (Karaca et al., 2019). In 2019, the operational cost of water purification was approximately 23.7 million USD, while expenditures on bottled water ranged from 11 to 21 million USD.

This study employed two primary cost-based methods to assess the value of water purification services: the cost avoidance method through the water treatment assumption and the opportunity cost method through the bottled water use assumption. Based on the evaluations from these methods, the total value of water purification services at the Astana Reservoir is estimated to range from 35 million USD to 45 million USD in 2019. This range highlights the significant impact of water quality and consumption patterns on economic valuation. These findings emphasize the broader context of water quality challenges faced in Kazakhstan, illustrating the effects of industrial pollution, inadequate infrastructure, and climate change on ecosystem health and community well-being (World Bank, 2020).

- Reasons

The valuation of water purification services is framed within a complex landscape of water quality issues in Kazakhstan. Significant water quality problems persist from natural and anthropogenic factors, exacerbated by industrial activities and insufficient regulatory frameworks. These challenges threaten the integrity of vital water ecosystems, resulting in public health concerns. The operational cost-based approach used in this study estimates the value of water purification services at approximately 23.72 million USD, reflecting an operational cost of $0.29 per cubic meter in 2019 and total consumption of 81.8 million cubic meters. However, this reliance on operational costs may overstate the actual economic value of purification services, as such costs do not incorporate qualitative factors influencing consumer perceptions of water quality. Thus, while this method yields a significant figure, it cannot capture the complete economic reality of water purification.

- **Literature Comparison**

When compared with existing literature, the results of this study align with the research of Oates et al. (2019) and Mulyana et al. (2020), both of which emphasize the impact of consumer perceptions of water quality and the challenges posed by the lack of effective data for water resource management. Notably, the evaluation methods used in these studies primarily focus on either water treatment costs or bottled water consumption. In contrast, this study integrates both methods, enhancing the comprehensiveness and reliability of the results. Furthermore, Brander et al. (2012) have pointed out that data based on operational costs can often be overestimated; however, this study mitigates that possibility by combining different data sources and methodologies, thereby providing a more robust estimate of the value of water purification services. This multidimensional assessment approach strengthens the scientific rigor of the research and provides empirical evidence for future water resource management policies.

- **Research Challenges**

The bottled water cost method relies extensively on survey data, potentially introducing biases or inaccuracies related to consumer preferences and consumption habits. Factors such as socioeconomic status, access to information, and cultural attitudes toward water consumption are inadequately explored, which could skew the results.

- Future Research Directions

Future research should incorporate a broader range of valuation methods, including contingent valuation and choice modeling, to assess non-market benefits related to water quality. Longitudinal studies could provide insights into how public perception and water quality changes influence consumer behavior and economic valuation. Additionally, qualitative research to explore the underlying reasons for consumer preferences and concerns about tap water quality could enrich the analysis. Investigating the specific impacts of water quality improvements on public health and economic outcomes would offer a more comprehensive perspective on the benefits of adequate water purification services. Furthermore, enhancing data collection efforts related to local water treatment costs and expanding consumer surveys to encompass various demographic factors will strengthen the validity of future valuations. Collaborating with local stakeholders and water management authorities could also facilitate a more thorough understanding of community needs and priorities regarding water quality.

6.2.3 SOIL EROSION CONTROL SERVICES IN ASTANA RESERVOIR

- Main Findings

Analysis from 1993 to 2020 shows that rain-fed agricultural land has increased by 12%, while sparse vegetation has decreased. This change is crucial because it may increase sediment and nutrient loss, adversely affecting water quality and ecosystem health. Furthermore, ecosystem accounts indicate that the area of water bodies has increased by 5.97%, which, while enhancing water quality purification capacity, has simultaneously reduced habitat diversity—this pattern is similar to changes observed in the Mekong Delta (Nguyen et al., 2021; Xenarios et al., 2021). Regarding the economic valuation of soil erosion control, this study used the ARIES tool to estimate soil loss from 2000 to 2019 at 1,785 tons, translating to approximately 2 million USD in losses (Mirzabaev et al., 2016). The estimated annual soil erosion control amount is 13,313 tons, with a monetary value ranging from 9.8 million USD to 18.7 million USD. This result emphasizes the importance of effective erosion management. This finding particularly resonates with Kazakhstan's soil degradation and erosion issues, highlighting soil erosion control services' economic and ecological significance.

- Reasons for Findings

The observed trends are mainly attributed to several factors, particularly urbanization and agricultural expansion in the Akmola region, which increased water demand and altered land use. Additionally, pollution from industrial discharges and agricultural runoff has significantly impacted water quality and ecosystem health. Another factor is the inadequate maintenance of reservoirs, especially the lack of dredging operations, which has exacerbated sediment accumulation issues, leading to reduced reservoir capacity and operational efficiency. Therefore, these interrelated issues underscore the multifaceted challenges the Astana Reservoir faces.

- **Literature Comparison**

In comparing the findings of this study with existing literature, the monetary valuation results of soil erosion control services (SECS) for the Astana Reservoir exhibit both significant similarities and differences with other cases. For instance, this study estimates the annual monetary value of SECS for the Astana Reservoir to range between 9.8 million USD and 18.7 million USD, highlighting its economic and ecological importance amid Kazakhstan's challenges with soil degradation and erosion. In contrast, a study conducted in southern Spain estimated the off-site benefits of soil erosion control at €42 to €72 per hectare per year (Colombo et al., 2003), providing a reference for understanding the monetization of localized ecological benefits.

Furthermore, in Nigeria, it was found that soil erosion control measures increased agricultural land values by approximately 26% (Chakraborty et al., 2023), demonstrating a similar economic enhancement. In the Yellow River Basin of China, a study quantified on-site erosion prevention and sediment delivery mitigation, finding the monetized value of SECS to be 910.13 × 10^4 CNY for a 54.2 km² watershed (Liu et al., 2020). This evidence further reinforces the economic value of SECS.

In the UK, while cost-effective erosion control measures, such as tramline management, mulching, buffer strips, high-density planting, and sediment traps, have potential benefits, many of these approaches lead to negative financial returns for farmers (Posthumus et al., 2015). These findings highlight the critical importance of SECS and the need for targeted investments in sustainable agriculture. The comparative analysis provides a broader context for understanding the economic value of soil erosion control services in the Astana Reservoir, illustrating how effective management and investment can enhance soil resource sustainability across different regions.

- Research Challenges

Firstly, data constraints have restricted the assessment to only four types of ecosystem services, suggesting that future research could greatly benefit from a more comprehensive evaluation that includes a broader range of services. Additionally, the focus on the time frame from 2000 to 2019 may overlook significant long-term trends related to climate change, meaning the implications of those changes might not be fully understood. Moreover, the reliance on complex sediment and water balance models introduces uncertainties, necessitating careful validation against empirical data to strengthen the findings. Lastly, it is important to recognize that the results of this study are tied explicitly to the Astana Reservoir and may only apply to other reservoirs if they are analyzed within their unique ecological and socio-economic contexts.

- Research Directions

To enhance our understanding of the Astana Reservoir and similar ecosystems in Kazakhstan, future research should prioritize several key areas. First, there is an urgent need to implement real-time monitoring systems to track water quality and sediment changes, utilizing methodologies similar to those in successful large-scale projects like the Chesapeake Bay Program (Baker et al., 2020). Such systems will facilitate timely data collection and analysis, allowing for adaptive management strategies that respond to emerging soil erosion and water quality degradation challenges. Furthermore, comparative analyses across different ecological zones can provide valuable insights into the specific drivers of soil erosion in various regions. Case studies from areas like the Balkash region, which faces severe soil degradation issues, will enable researchers to assess existing conservation practices and their socio-economic impacts on local communities. By incorporating advanced modeling techniques that consider the interplay between climate change, land use, and socio-economic variables, we can enrich our understanding of soil erosion dynamics, ultimately contributing to informed policy-making and sustainable land management practices in Kazakhstan.

6.2.4 RECREATIONAL SERVICES IN ASTANA RESERVOIR

- **Major Findings:**

The comprehensive evaluation of recreational services at the Astana Reservoir, utilizing the Zonal Travel Cost (ZTC) method, revealed an annual economic benefit of approximately $339,520. This value underscores the importance of these services to the local economy, although it reflects an underutilized potential due to current limitations in tourism resources and infrastructure (Vallecillo et al., 2019). Despite these challenges, visitation data indicate that certain recreational centers, such as Beibarys, have significant appeal, attracting a substantial number of visitors and demonstrating growth opportunities.

- **Reasons for the Findings:**

Several factors contribute to the findings observed in this study. Primarily, visitor preferences were evident in the varying visitation rates at different recreation centers, with Beibarys recording 18,250 visits per year, highlighting its strong local appeal. In contrast, centers such as Otdykh

Vyacheslavskoye Vodohranilishche only drew 4,000 visits, indicating a disparity in recreational offerings that may affect overall attraction. Additionally, the analysis demonstrated that travel costs play a critical role in determining visitor numbers, as higher expenses correlated with lower anticipated visits (Juhasz & Matrai, 2024), reflecting the sensitivity of recreational demand to economic factors.

- **Literature Comparison:**

The findings from this study align well with existing literature that emphasizes the significance of environmental quality and infrastructure in attracting visitors to recreational sites. In this study, comparative analysis with different regions of Kazakhstan, such as the Almaty region, provided context for external validity. Existing studies have extensively explored the recreational potential of river basins in Kazakhstan, including the Nura River Basin (Ramazanova et al., 2020), river basins in the Aktobe region (Omirzakova et al., 2024), the Sharjin River Basin (Kerimbay et al., 2021), and Alakol Lake (Agybetova et al., 2023; Gumilyov, 2023). These studies have highlighted the importance of natural resources, climate comfort, and infrastructure for tourism development. However, challenges include inadequate infrastructure, poor road networks, and environmental issues (Omirzakova et al., 2024; Agybetova et al., 2023). Although the number of visitors to the Astana

Reservoir may be lower than in other regions, its recreational value is still significant and worthy of attention.

- **Research Challenges:**

Throughout the study, several challenges were noted that may impact the results and their interpretation. Firstly, the reliance on data gathered through telephone interviews presents an inherent limitation, potentially failing to encapsulate demographic diversity and could introduce bias, thus affecting understanding of visitor behavior (Juhasz & Matrai, 2024). Furthermore, the choice of a cubic regression model for analyzing visitation trends revealed complexities that simpler models could not address, indicating a need for more nuanced modeling techniques. Lastly, the unique geographic and socioeconomic aspects surrounding the Astana Reservoir pose challenges for generalizability, necessitating cautious application of findings to other regions.

- **Future Research Directions:**

To enhance the robustness of future studies, several directions could be pursued. Firstly, adopting a mixed-methods approach that integrates qualitative data—such as visitor feedback and satisfaction surveys—alongside quantitative analyses could yield a richer understanding of recreational demands and preferences. Additionally, broadening the geographical focus to include various recreational sites across Kazakhstan would facilitate a more comprehensive analysis of regional differences in visitor behavior (Agybetova et al., 2023; Gumilyov, 2023). Finally, undertaking detailed sensitivity analyses regarding travel and entry cost variations can provide deeper insights into visitor response dynamics, which may inform targeted marketing strategies and infrastructure investments aimed at optimizing the recreational potential of the Astana Reservoir and similar locations.

In conclusion, the comprehensive valuation of ecosystem services (ESV) in the Astana Reservoir reveals its significant role in water resource management. Firstly, the valuation of ecosystem services shows that water supply accounts for 22.87%, water purification for 57.32%, soil erosion control for 20.32%, and recreational activities a mere 0.5% (demonstrating the multifaceted nature of the services provided by the reservoir). In terms of water supply services, the Astana Reservoir met approximately 88.44% of the city's water needs in 2019, with an estimated economic value ranging from $14 million to $16 million (Johnson, 2019), underscoring its crucial importance for urban drinking water and local economic activities. Additionally, the reservoir effectively mitigates flood risks and drought conditions through its storage capacity, serving as a key component in regional water resource management. Regarding water purification services, while biochemical oxygen demand (BOD) levels significantly improved in 2019, concentrations of heavy metals exceeded safety standards, with copper and zinc levels at 1.5 times and 3.2 times the maximum permissible concentration, respectively, indicating severe water quality challenges (Kazhydromet, 2021). The estimated economic value of water purification services is between $35 million and $45 million (World Bank, 2020), reflecting the critical impact of water quality issues on public health and ecosystem health. Furthermore, the economic value of soil erosion control services is estimated at between $9.8 million and $18.7 million (Mirzabaev et al., 2016), highlighting the importance of effective management, especially against the backdrop of urbanization and agricultural expansion exacerbating soil erosion. Finally, an evaluation based on the Zonal Travel Cost Approach (ZTCA) indicates that the recreational services of the reservoir generate an economic benefit of approximately $339,520 per year (Vallecillo et al., 2019), suggesting that the reservoir's tourism potential has yet to be fully realized. Collectively, these data not only highlight the critical role of the Astana Reservoir in economic sustainability and ecological health but also provide effective evidence for policymakers in water resource management.

Building upon this, policymakers can leverage these precise data and in-depth analyses to fully recognize the significance of ecosystem services in water resource management. First, the quantitative assessment of ecosystem services offers clear objectives for policy formulation, such as identifying the specific economic benefits of improving water quality and enhancing water supply capacity, thereby promoting the development of targeted policy measures to address water-related issues. Second, faced with the economic valuation of water purification services and the severe challenges of water pollution, policymakers should reinforce monitoring and remediation efforts to ensure the safety and sustainability of water, thereby protecting public health and the integrity of ecosystems. Furthermore, by integrating the economic assessments of different ecosystem services, policymakers can more effectively allocate resources and manage them, particularly by driving greater investment into soil conservation and optimized water resource utilization, ultimately achieving dual benefits of economic and ecological improvements. The implementation of dynamic pricing mechanisms can also enhance the efficiency of water resource usage and ensure fair distribution, especially concerning water access for low-income households (World Bank, 2016). In summary, these research findings and policy recommendations provide scientific evidence and a practical pathway for managing the Astana Reservoir and other water resources, emphasizing the importance of informed decision-making in achieving sustainable development goals.

6.3 STAKEHOLDERS' PERSPECTIVES ON THE ESV

In implementing ESV and SEEA, the perspectives of different stakeholders reflect their respective concerns and interests, which are particularly important in Kazakhstan. Water management professionals emphasize the importance of legal compliance, which stems from the regulatory pressure they face when implementing policies. Kazakhstan's water management system is highly complex and involves multiple interests and regulations (Kharin et al., 2020). Therefore, their concerns about compliance are extreme.

The perspectives of the respondents effectively validate the content of the literature review. For instance, concerning institutional norms, the literature points out that ESV adopts a transdisciplinary approach, integrating insights from various fields to ensure the participation of diverse stakeholders (Liu et al., 2010). This point is reflected in the interviews conducted in Kazakhstan, where the regulatory pressure and compliance concerns faced by water management professionals illustrate the significant influence of institutional norms within the complex water management system (Kharin et al., 2020). The legal compliance needs of these stakeholders promote the adjustment of ESV strategies to align more closely with existing institutional frameworks. Thus, institutional norms can be seen as constraints and critical foundations for enhancing ecological sustainability through reasonable response strategies.

Private enterprises are particularly concerned about potential financial impacts, especially regarding water shortages. They worry that implementing ESV may lead to higher operating costs, such as additional taxes or compliance costs, which could affect their market competitiveness (World Bank, 2019). This concern reflects the contradiction between economic interests and ecological protection. On the other hand, state-owned enterprises see the value of ESV in terms of long-term sustainability, particularly in the context of the government's increasing emphasis on sustainable development (Kazakhstan Government, 2021). Nevertheless, they also have reservations about potential tax increases, emphasizing the need to consider different stakeholders' economic affordability and risk appetite when promoting the implementation of ESV and SEEA.

These diverse perspectives and concerns highlight the need to acknowledge all parties' different needs and expectations when promoting the implementation of ESV and SEEA. However, there are some limitations in the research process, especially the lack of stakeholder participation. There are several reasons for this.

First, the failure to involve stakeholders in the application design of ESV in the early stages of the research stems from the researchers' consideration of potential conflicts of interest and time constraints. In the early stages of the research, the selection of participants was often based on accessibility and information availability. The researchers relied more on the water management experts interviewed and ignored the opinions of a wide range of stakeholders, including community representatives and water users. This selection bias led to insufficient diversity in stakeholder participation and limited the reflection and applicability of the research results.

Second, in order to ensure the smooth progress of the interviews, the researchers chose to conduct highly structured interviews, which, to some extent, limited the opportunities for stakeholders to express their unique insights and concerns. In particular, among the water user group, the number of interview participants was slightly lower than expected (see Table 5.26), which means that the information collected from the perspective of water users is not comprehensive. This lack prevented the research from fully capturing water users' specific needs and interests in resource management and water value assessment.

Despite these limitations, all participants agreed on people's perception of the value of water resources and their ecological and environmental importance. They generally agreed that implementing ESV methods could help Kazakhstan gain a more comprehensive understanding of the value of its water resources and the importance of the ecological environment. By clarifying the contribution value of water resources, decision-maker's conservation awareness can be enhanced (TEEB, 2010). One expert noted that "Kazakh people typically view water merely as a resource and raw material, lacking an adequate understanding of its true ecological value." Changing this traditional perspective is essential for implementing ESV (Mäler et al., 2003). This aligns with the role of ecosystem service methodologies in promoting human well-being and supporting sustainable development goals (MA, 2005; IPBES, 2016).

It was also commonly accepted that implementing ESV methods can provide a scientific basis and decision support for water resource management. Respondents indicated that digital management could enhance the transparency and efficiency of water resource management. By monitoring water resource supply in real-time, decision-makers can allocate resources more scientifically and accurately (Kumar et al., 2014). This process corresponds with the literature that discusses the difficulties in quantifying non-market services and the complexities of valuing intangible services in supporting policy decisions and conservation efforts (Mehvar et al., 2018).

Further, most respondents mentioned that Kazakhstan has begun introducing the concept of environmental flow, particularly in the Small Aral Sea restoration case, demonstrating progress in water resource management. Future planning should focus on ecological protection and restoration, enhancing the participation of local governments and communities (Davis et al., 2016). This multi-stakeholder engagement aligns with the literature's emphasis on integrating multiple value dimensions and stakeholder perspectives (Liu et al., 2010; Gunton et al., 2017).

In summary, while there are diverse viewpoints and concerns, the understanding and worries of different stakeholders emphasize the necessity of implementing ESV and SEEA to achieve a balance between economic, ecological, and social aspects. By drawing lessons from successful cases in countries like Australia (Vardon et al., 2019), Kazakhstan can establish more effective communication and cooperation mechanisms that facilitate sustainable water resource management.

These diverse perspectives collectively underscore the importance of effective communication and collaboration among stakeholders in promoting ESV and SEEA implementation. When considering legal compliance and financial implications, it is equally crucial to deeply understand the roles and expectations of various stakeholders in resource management. Only by comprehensively integrating the opinions of all parties and adequately addressing these interests in the policy framework can the effectiveness and sustainability of water resource management strategies be ensured.

Future research should particularly focus on how to build inclusive decision-making mechanisms that ensure broad participation from stakeholders. This includes engaging local governments, communities, academia, and the private sector to facilitate mutual understanding and integration of diverse needs. Additionally, the application of modern technological solutions, such as digital water resource management systems, should be incorporated into the research framework to enhance the scientific and transparent nature of decision-making.

In conclusion, Kazakhstan must foster effective communication and collaboration among stakeholders when implementing ESV and SEEA. By better understanding and integrating the needs of different parties and enhancing the legal framework's adaptability and flexibility, Kazakhstan can achieve more sustainable water resource management and ecological protection goals in the future. This integrative approach will contribute to the preservation of Kazakhstan's natural resources and promote social equity and economic development, ensuring a holistic advancement toward sustainability.

As Kazakhstan navigates its path forward in ESV and SEEA implementation, learning from global best practices and adapting them to local contexts will be essential. By establishing collaborative frameworks that consider the complexities of stakeholder interactions and interdependencies, Kazakhstan can create an inclusive environment that embraces diverse perspectives and drives effective ecological governance. Thus, the ongoing evolution of stakeholder engagement strategies will play a critical role in enhancing the resilience and sustainability of Kazakhstan's water management practices, ultimately serving as a model for other nations grappling with similar challenges.

6.4 APPLICATION OF ESV IN THE CONTEXT OF KAZAKHSTAN

6.4.1 SEEA: CHALLENGES AND OPPORTUNITIES

This study emphasizes the importance of the System of Environmental-Economic Accounting (SEEA) in the policy planning stage of water resource management. It significantly influences the decision-making process and integrates ecological and economic considerations. First, in the context analysis of local water resource management, a clear identification of the historical background and current challenges of Kazakhstan's water management institutions lays the foundation for understanding the current state of water resource planning and provides the necessary context for identifying ecosystems that require further research (MEA, 2005). Once this context is established, the next crucial step is the identification and quantification of ecosystem services. This stage combines ecological assessments with human economic activities, allowing decision-makers to better understand the environment's contributions to society (UNSD, 2021). By adopting biological, physical, and economic indicators, policymakers can assess the integrity of ecosystems and the distribution of various services, such as water supply, flood control, and recreational opportunities (Warnell et al., 2020). The integration of data not only helps identify key ecosystems that need protection and provides a comprehensive perspective on ecological health for policy formulation. The ability to quantify these services enhances awareness of the necessity for balancing resource utilization and conservation (Keith et al., 2020).

On this basis, categorizing these services according to international standards can effectively support conservation efforts to balance ecological integrity with societal needs. This categorization helps clarify action priorities, ensures the sustainable use of resources, and further strengthens the interdependence between economic development and environmental protection (Alongi, 2012). At the same time, the economic valuation of ecosystem services is indispensable in the decision-making process. By converting ecological assessments into economic terms through market pricing and cost avoidance methods, policymakers can base ecological health investments on quantified benefits (Vardon et al., 2019). This clear economic basis enhances support for sustainable practices and improves the effectiveness of budget allocation. These economic assessments hold significant importance in guiding policy, highlighting the long-term financial benefits of maintaining and improving ecosystem services and revealing the direct links between environmental management and economic stability (Piper, 2003). Finally, feedback from stakeholders collected through semi-structured interviews is closely linked to the above steps, further enhancing the overall policy framework. Interactions with various stakeholders, such as government officials and local water users, provide rich perspectives that reflect the practical challenges and expectations in water management. This collaborative approach ensures that policy decisions are not isolated but rooted in real experiences and community needs (Hanley & Barbier, 2009).

Overall, the various steps within the SEEA framework reinforce each other, enhancing the effectiveness of water resource planning and promoting a comprehensive understanding of ecosystem services and their economic impacts. This interconnected approach increases the regularity of policy analysis and fosters a more sustainable relationship between human activities and natural resource management. By relying on robust ecological and economic data and stakeholder participation, SEEA significantly enriches the decision-making process, paving the way for resilient and adaptive water management strategies. Although applying SEEA in water resource management brings notable advantages, its effectiveness depends on the specific implementation environment. Consistency with Integrated Water Resources Management (IWRM) principles can enhance its applicability in sustainable water resource management; however, coordination between theoretical frameworks and practical applications remains a challenge, which is also a common criticism of SEEA and IWRM (Cook & Spray, 2012). Developing countries face numerous obstacles when implementing these frameworks, primarily including the availability and quality of data, the lack of funding and human resources, and limitations in information and communication technology infrastructure (Pirmana et al., 2019; Sylla et al., 2021; Qian et al., 2021). Additionally, cultural resistance and insufficient content development hinder progress (Hassibian, 2013; Meiyanti et al., 2018). For instance, many developing countries suffer from data and technical infrastructure shortages, severely impacting the effective implementation of SEEA. Furthermore, the lack of necessary institutional capacity and expertise also limits the practical application of the SEEA approach.

Despite these challenges, SEEA remains crucial for monitoring sustainable development goals and integrating environmental information into national accounts (Laykam et al., 2022; Serageldin & Steer, 1994). The SEEA-EA provides a framework that combines with national accounts to quantify and assess the value of ecosystem services (Brander et al., 2022; Edens et al., 2022). Its objective is to integrate environmental and economic information, moving beyond the confines of traditional financial accounting (La Notte et al., 2019; Obst et al., 2013). Implementing capacity-building projects like the World Bank's WAVES is crucial for successfully applying SEEA (Pirmana et al., 2019). Researchers point out that appropriately addressing challenges related to regulatory, political, cultural, and socio-economic contexts is critical (Qian et al., 2021). Therefore, developing countries must prioritize infrastructure development, address management issues, and enhance digital culture

(Meiyanti et al., 2018). Considering these factors comprehensively, combining SEEA and IWRM can provide practical solutions for achieving sustainable water resource management.

Future research should focus on how to effectively integrate SEEA with IWRM to better adapt to and respond to global environmental changes and their impacts on water resource supply. By employing the systematic approach provided by SEEA, policymakers can more clearly identify the economic value of water resources while promoting the synergy between ecological protection and economic development. Through ongoing stakeholder engagement and feedback, policies can achieve greater transparency and inclusiveness, thereby better-serving communities and gaining support from various parties, thus enhancing the effectiveness of policy implementation.

Ultimately, the effective integration of SEEA and IWRM will benefit more scientific management of water resources and provide critical support for global efforts to address climate change and achieve sustainable development goals. This framework can offer substantial technical support for countries in formulating water resource management policies, ensuring a positive interaction between ecological health and socio-economic development. Moreover, to achieve long-term sustainability, cooperation between countries and regions is also essential; countries should work together to establish shared knowledge platforms to promote good practices and experience sharing, thereby accelerating innovation and progress in water resource management worldwide.

6.4.2 THE WAY FORWARD OF ESV AND WATER PLANNING IN KAZAKHSTAN

Although the implementation of ecosystem service assessment methods has excellent value in Kazakhstan, it also faces many challenges:

- Economic-ecological contradiction:

Since the Soviet era, the government has prioritized economic development, and this concept still exists in many policy decisions. However, the worsening ecological and environmental problems require more reasonable resource management strategies (Oleson et al., 2018). In the process of promoting ESV, it is necessary to overcome the contradiction between economic interests and ecological protection, which is consistent with the challenge mentioned in the literature that existing economic assessment methods ignore environmental and social values (Bautista-Rodríguez et al., 2020; Gunton et al., 2017).

- Improvement of the legal framework:

The current legal framework in Kazakhstan needs to be revised to effectively apply ecological-based methods (Kieslich & Salles, 2021). Therefore, relevant laws need to be revised and improved to support the implementation of ecosystem service assessment. The literature points out that challenges related to institutional norms, capacity, and value beliefs must be addressed to improve the effectiveness of ecosystem services (Boithias et al., 2016).

- Technical support and capacity building:

Kazakhstan's water resources management still relies on traditional means, and promoting digital management systems is critical to improving management efficiency (Martin et al., 2010). In addition, it is also crucial to train relevant personnel to enhance their understanding and application of ecosystem service assessment methods. This is consistent with the strategy mentioned in the literature to improve the interface between science and policy (Kieslich & Salles, 2021).

Despite multiple challenges, the potential value of implementing ecosystem service assessment methods in Kazakhstan must be addressed. By overcoming economic, legal, and technical difficulties, promoting the improvement of the legal framework, implementing digital water resources management, and introducing ecological protection policies, more scientific and practical support can be provided for Kazakhstan's water resources management and environmental environment protection. This will not only help achieve the Sustainable Development Goals but also offer an experience that can be learned from other countries, echoing the critical role of the ecosystem service approach in promoting human well-being and supporting the Sustainable Development Goals (MA, 2005; IPBES, 2016; TEEB, 2010).

Kazakhstan urgently needs to address water scarcity and environmental degradation, especially in arid regions, and the synergy of ecosystem service assessment frameworks through the SEEA lens is essential. Interviews with stakeholders indicate a growing recognition of the importance of these frameworks in promoting sustainable management practices. However, they also acknowledge that there are significant barriers to their implementation. Therefore, Kazakhstan has the potential to achieve more sustainable water management through an integrated approach and learning from experience.

Chapter 7

Conclusion

7 CONCLUSION

7.1 SYNTHESIS

This research investigates the application of ESV to enhance water resource management in Kazakhstan, mainly focusing on the Astana Reservoir. It highlights the critical ecosystem services that sustain urban water systems and emphasizes integrating ESV into management practices to improve decision-making and address systemic inefficiencies. The study ultimately demonstrates success in answering the research question: How can the ESV enhance water resource planning in Kazakhstan? Furthermore, it provides evidence to validate the research hypothesis that Ecosystem Service Valuation approaches can serve as "strong evidence" for water resource planning, supported by institutional norms, capacities, and enabling decision-making bodies.

- **Overview of Kazakhstan's Water Management Landscape**

The study provides a comprehensive analysis of Kazakhstan's water management, revealing a historical evolution since the 1990s from a purely technical approach to a more integrated method that accounts for economic and political factors. Despite frameworks like the "Kazakhstan 2030 Strategy," the study highlights the fragmentation of legal and institutional structures that often neglect environmental concerns and public engagement. Key findings indicate significant challenges the

Astana water management system faces, such as rising demand, deteriorating water quality, and ecological impacts from unsustainable practices. These issues underscore the necessity for high-resolution data in ecosystem assessments, along with critiques of existing sediment regulation models for their inadequacies in varied landscapes.

- **Ecosystem Services Valuation in Astana Reservoir**

The systematic ESV reveals the economic value of the reservoir's ecosystem services. Water purification services account for 57.32% of the total value, with water supply and soil erosion control contributing 21.87% and 20.32%, respectively. Recreational services represent only 0.5%, highlighting the need for balanced management strategies. Furthermore, integrating ESV into water management practices presents challenges and opportunities. For instance, legitimizing the ecosystem services valuation methodology is critical for its acceptance among stakeholders. Data transparency and addressing capacity issues within water planning institutions are also vital. Despite these challenges, the feasibility of conducting pilot studies remains promising. Such studies can raise awareness about environmental protection and push for higher demands for water-related data from management institutions, thereby increasing public participation in decision-making processes.

In analyzing soil erosion control, the study uses the ARIES model to evaluate the reservoir's function. It reveals a decrease of 1,785 tons from 2000 to 2019, equating to a loss of $2 million. This underscores the economic and ecological importance of effective erosion management in Kazakhstan, where annual costs of land degradation are estimated at approximately $3.06 billion. Targeted interventions in high-risk areas could mitigate soil erosion and enhance ecosystem resilience.

In the case study, the Astana Reservoir's recreational value is the lowest among the services analyzed, primarily due to underdeveloped tourism resources and inadequate infrastructure. Investment and promotion from local governments are essential for realizing the economic benefits of recreation. Notably, integrating an ES-based approach into water laws can facilitate the establishment of ecosystem payment systems, enhancing corporate awareness of environmental conservation.

- **Improved Water Management and Stakeholder Perspectives**

The potential for digitization of water services to enhance transparency and efficiency is prioritized by stakeholders, among other options for improving water management in the country. Real-time monitoring allows for scientifically grounded resource allocation, addressing the complexities of quantifying non-market services highlighted in the literature. Successful cases, such as the environmental flow concept in restoring the Small Aral Sea, demonstrate Kazakhstan's promise to advance water resource management while emphasizing the need for increased stakeholder participation.

Different stakeholder perspectives reveal the complexities of implementing ecosystem service assessments and SEEA in Kazakhstan. Water management professionals stress the importance of legal compliance amid regulatory pressures, while private enterprises express concerns about potential financial implications, such as increased operational costs or taxation. State-owned enterprises recognize the long-term sustainability value of ecosystem service assessments but remain cautious about possible tax increases. These diverse viewpoints underscore the need to consider multiple stakeholder interests when advancing ecosystem service assessments and SEEA implementation.

- **Limitations and Future Research Directions**

While the study provides valuable insights, it acknowledges limitations in its methodologies. The reliance on market pricing excludes non-market values, such as cultural and recreational benefits. Future research should adopt a multi-faceted approach to ESV that captures both market and non-market values, enhancing the overall understanding of ecosystem services. Additionally, longitudinal studies are essential for tracking changes over time, and exploring innovative water pricing mechanisms could further enhance urban water systems' resilience.

Integrating ESV into water management practices presents challenges and opportunities. Legitimizing the ESV methodology is crucial for stakeholder acceptance, and enhancing data transparency alongside addressing institutional capacity issues is vital for effective implementation. The study successfully answers the research question and validates the hypothesis, demonstrating that ESV can provide strong evidence for water resource planning when supported by institutional norms and decision-making bodies. This approach not only aids in achieving sustainable development goals but also sets a precedent for other countries facing similar challenges, emphasizing the importance of ecosystem services in promoting human well-being and sustainable development. The gradual recognition of the SEEA framework marks a transformative shift in Kazakhstan's sustainable water resource management, especially in addressing water scarcity and environmental degradation in arid regions. While the implementation of ESV in Kazakhstan holds significant promise, challenges remain. Key measures include overcoming the historical precedence of economic development over ecological concerns, refining legal frameworks, and promoting technical support and capacity building. By strengthening legal structures and implementing digital water management systems, Kazakhstan can provide more scientifically grounded and practical support for water resource management and ecological conservation.

7.2 CONTRIBUTIONS TO THEORIES AND METHODOLOGY

This study focuses on integrating ESV into national water resource planning, utilizing the SEEA-EA framework to analyze how the interactions between society and ecosystems effectively influence water resource management decisions. Despite the limited research on the valuation of water resource ecosystem services in Kazakhstan and the lack of in-depth analyses from a public policy perspective (Niels et al., 2016), this topic has garnered significant interest from water resource managers and policymakers, particularly in light of the growing emphasis on sustainable development globally.

In Central Asia, the issue of ecosystem services assessment is especially urgent. Although Kyrgyzstan has incorporated the protection of ecosystem services into its legal framework and conducted pilot accounting studies (Sabyrbekov et al., 2020), Kazakhstan remains relatively behind in this area. The country faces significant deterioration of its water ecosystem services due to rapid economic growth and increasing population, leading to worsening water quality and quantity issues. It wasn't until 2015, with the assistance of the United Nations Development Program, that Kazakhstan began to focus on assessing ecosystem services related to water resources, highlighting inadequate attention at the national policy level toward ecological protection and water resource management.

Developing countries face substantial challenges in implementing the System of Environmental-Economic Accounting (SEEA), including limitations in data availability and quality, as well as constraints in funding and human resources (Pirmana et al., 2019). These challenges are particularly prominent in ecosystem accounting, where methodological issues arise in defining benefits, delineating ecosystem service flows, and addressing global services such as carbon sequestration in local contexts (Sylla et al., 2021). Nevertheless, the application of SEEA, such as in the accounting of protected areas, can provide valuable information for decision-making and sustainable development planning (King et al., 2023). Addressing these data and technical challenges will thus provide crucial support for strengthening water resource management in Kazakhstan.

As the concept of sustainable development becomes more deeply ingrained and the impacts of climate change intensify, the application of ecological assessment tools across various disciplines is likely to increase. However, for policymakers lacking a background in environmental research, the available tools and methods are still quite limited. To bridge this gap, this study employs interdisciplinary approaches and advanced tools (such as ARIES) for ecosystem services assessment, aiming to offer new research and practical pathways for scholars and policymakers without environmental backgrounds. This not only promotes the understanding and quantification of ecosystem services but also fosters a closer integration of science and practice in the public policy-making process.

The contributions of this study lie in providing empirical support for water resource managers, policymakers, and researchers in ecosystem services, emphasizing the importance of integrating ecosystem services assessment with water resource planning. Assessment of ecosystem service values in Central Asia indicates significant spatiotemporal variations influenced by land use/land cover changes and climatic factors, particularly highlighting water quantity, soil conservation, and net primary productivity as notably important within this context (Fu et al., 2015; Yan & Li, 2022). Identifying the substantial impacts of land use changes—especially agricultural expansion and urbanization—on ecosystem service values (Li et al., 2019) can drive policy innovation and practical advancements in water resource management in Kazakhstan, thereby addressing global sustainable development needs. Ultimately, this will lay a solid foundation for ensuring a sustainable relationship between water ecosystems' health and human well-being, encouraging effective dialogue and collaboration among stakeholders to achieve more scientific and equitable water resource management strategies.

7.3 POLICY IMPLICATIONS

This research entails critical policy implications for improving water resource management in Kazakhstan, particularly concerning the Astana Reservoir and broader ecosystem service assessments. The implications focus on several key areas that address the pressing challenges in water management.

1. Promoting Integrated Water Resources Management (IWRM)

Kazakhstan faces significant water resource management challenges, including transboundary water issues and water scarcity (Zhupankhan et al., 2018; Medetov et al., 2018). To address these challenges, the country is actively promoting the implementation of Integrated Water Resource Management (IWRM) strategies (Myrzahmetov et al., 2019). For policymakers, developing a water resource monitoring system is a priority, as it will help enhance data integration and decision support systems. Effective regional cooperation and adherence to international water law are crucial for achieving sustainable water resource management in Central Asia (Zhupankhan et al., 2018; Kostianoy et al., 2020). As water resource pressures increase, it is essential to respond effectively to water scarcity and competition through scientific management and inter-country collaboration. Therefore, developing monitoring systems and complying with international standards will provide a more reliable water resource management foundation, promoting sustainable development across the entire region. Additionally, adopting integrated planning methods that prioritize ecological sustainability alongside economic development is necessary to balance both quantity and quality in water resource management.

2. Integration of Ecosystem Services Valuation (ESV)

Policymakers should prioritize integrating ESV into water resource management frameworks, recognizing both market and non-market values of ecosystem services. This holistic understanding is vital for promoting urban sustainability and community well-being.

3. Strengthening Legal and Institutional Frameworks

Policymakers should strengthen legal and institutional frameworks to facilitate the integration of ESV into water management. This includes revising laws to enhance the roles and functions of River Basin Commissions (RBCs) and River Basin Institutions (RBIs), which cannot currently act effectively (Molle, 2009; Mukhtarov & Gerlak, 2013). Clear compliance guidelines and increased funding are essential to empower these institutions to fulfill their mandates. Encouraging cooperation among government agencies, non-governmental organizations, and local communities can foster a more integrated approach to water resource management.

4. Enhancement of Data Management and Technological Innovation

Investment in technological innovation and data management is essential for effective water resource management (Abdullaev & Rakhmatullaev, 2014). Strengthening the application of information technology can improve data management capabilities and decision-support systems, ensuring adequate water resource allocation (Ospan et al., 2023). Implementing advanced data collection and monitoring systems is vital to providing real-time information on water resources and usage. Promoting infrastructure investments and applying circular economy principles can reduce water wastage and pollution (Radelyuk et al., 2024). Integrating ecosystem service assessments into urban and regional planning supports sustainable development (Utepov et al., 2021). However, current capacities need to be improved; for example, some monitoring organizations may have only one vehicle to cover an entire basin. This lack of resources hampers their ability to monitor effectively. Policymakers should implement advanced data collection and monitoring systems to ensure timely access to water resource information.

5. Stakeholder Engagement and Capacity Building

Effective stakeholder participation is crucial for successful ecosystem service assessments. Policymakers should create platforms for dialogue among water management professionals, private enterprises, state-owned enterprises, and local communities to balance economic, ecological, and social needs. Enhancing the roles and functions of River Basin Commissions (RBCs) and River Basin Institutions (RBIs) is essential for improving water resource management efficiency (Molle, 2009; Mukhtarov & Gerlak, 2013). Increased funding and support for these institutions can bolster their capacity and effectiveness. The current limitations in monitoring capabilities must be addressed to ensure that agencies can act on the information they gather. Moreover, public awareness campaigns are needed to educate citizens about the importance of water conservation and engage communities in sustainable practices.

6. Cross-Border Cooperation and Legal Frameworks

Establishing effective legal mechanisms is necessary for improving transboundary water resource management. Policymakers should focus on creating robust legal frameworks that facilitate the integration of cross-border water resources (Zhupankhan et al., 2018). In ecological and agricultural management, modeling tools and strategic interventions, particularly in the Ili-Balkhash basin, can improve water resource management (Yerzhanova & Huszti, 2013; Seidakhmetova et al., 2022).

7. Promotion of Clean Energy and Environmental Awareness

Policy efforts should promote information and training on environmental quality and its links to welfare and available technologies to bridge the information gap regarding public awareness of clean energy benefits. Public awareness campaigns to educate citizens about the importance of water conservation can further enhance community engagement in sustainable practices. Supporting the mass deployment of clean energy technologies at the national level must be complemented by policies that incentivize infrastructure upgrades and investments in transmission systems.

Addressing Astana's pressing water management challenges, driven by increasing demand, ecological degradation, and policy shortcomings, necessitates immediate and concerted actions. By implementing these strategies, Kazakhstan can enhance its water resource management practices, promote environmental sustainability, and improve community well-being. These efforts can position Kazakhstan as a leader in sustainable water management in the region.

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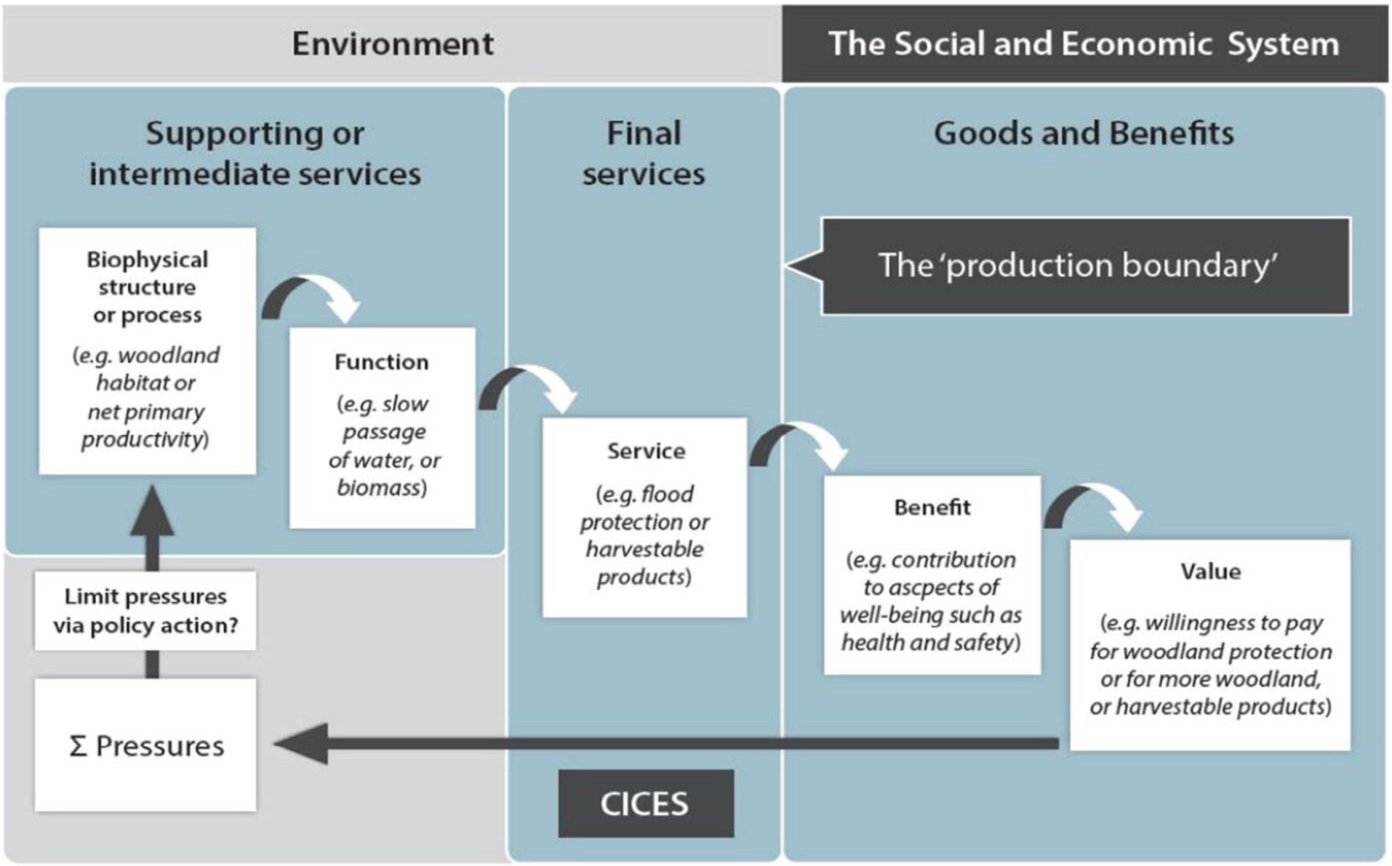
APPENDICES

APPENDIX A - ECOSYSTEM FUNCTION

Firstly, the most commonly used definition of ecosystem services is: "Ecosystem services (ES) are the ecological features, functions, or processes that directly or indirectly promote human well-being: the benefits people obtain from well-functioning ecosystems" (Costanza et al., 1997; Daily, 1997; Millennium Ecosystem Assessment (MEA), 2005; Wallace, 2008; The Economics of Ecosystems and Biodiversity (TEEB), 2010; Common International Classification of Ecosystem Services (CICES), 2011; Burkhard et al., 2012b). Regarding the generation of ecosystem services, Potschin and Haines-Young (2017) believe that there is such a cascade process of marketization of ecosystem services: "ecosystem function-ecosystem service-benefit-value" (Figure 2.10), emphasizes the ecological Contribution of system services to the benefit of humanity. MAES (2013, p.17) also offers similar ideas, illustrating the relationship between ecosystems and socioeconomics, and they both emphasize the importance of ecosystem functioning. Therefore, to comprehend nature's ecological functions, we first need to approach it from an ecological perspective.

Figure A. 1 The interaction of ecosystem function-ecosystem service-benefit-value



Source: Potschin and Haines-Young (2017).

For the first time, ecologist George Marsh (1965) recorded the service function of the ecosystem in "Man and Nature," pointing out that soil erosion caused by the disappearance of forests, the barrenness of grassland, and the drying up of rivers due to the lack of water resources, and also proposed the function of the ecosystem to decompose the corpses of animals and plants. Ecologists such as Fairfield Osborn and Vogt began to study the role of ecosystems in social and economic development. In particular, Vogt explained that the development of human society and economy depends on the depletion of natural resources through the concept of natural capital (Osborn, 1948; Vogt, 1948). Ecosystems have their functions. Generally, energy flows and material cycles. Specific functions include carbon dioxide fixation, productivity, soil and water conservation, buffer disturbance, and atmospheric regulation. In 1970, the United Nations University put forward the concept of ecosystem service function in the "Report on the Impact of Human Beings on the Global Environment." Since the 1970s, ecosystem service function has gradually developed into a branch of ecology and ecological economics (SCEP, 1970). Specifically, Ecosystem service functions refer to the natural environment conditions and utility formed and maintained by ecosystems and ecological processes for human survival. (Daily, 1997).

Ecological economist Costanza (1997) clarified that specific ecosystem services include: "gas regulation, climate regulation, disturbance regulation, water regulation, water supply, erosion control and sediment retention, soil formation, nutrient cycling, waste treatment, pollination, biological control, refugia, food production, raw materials, genetic resources, recreation, and culture." Combined with the analysis of other ecologists, geographers, and other scholars, it can be summarized explicitly as the following functions:

1) Ecosystem products: The ecosystem provides primary products for humans, such as grains and vegetables, meat, wood, medicine, and other products, and when combined with human production and processing, it produces organic matter and energy products (Hall et al., 1993).

2) The production and maintenance functions of biodiversity. The diversity of ecosystems ensures the diversity of biological populations because different organisms have different adaptations to different ecosystems, resulting in different populations, reducing the probability of species extinction, and ensuring rich genetic information (Holdren & Ehrlich, 1974).

3) Regulate the climate. Ecosystems mitigate the "greenhouse effect" by purifying carbon dioxide from the air, and evaporation from soil and transpiration from forests lead to rainfall that regulates local temperatures. (Holdren & Ehrlich, 1974) The function of regulating climate is often referred to as the human life support function of the environment (Freeman et al., 1973).

4) Reduce flooding and drought disasters. Ecosystem services play a crucial role in flood control, particularly through flood regulation ecosystem services (ESFR), which help mitigate flood disasters by operating through two mechanisms: watershed flood prevention and river flood attenuation (Wübbelmann et al., 2021; Vári et al., 2022). Agricultural ecosystems, especially irrigated woody

crops, can provide substantial ESFR comparable to that of natural ecosystems, with values estimated at €22.51 per hectare per year in certain study areas (Martínez-García et al., 2022). However, their regulatory capacity may be limited during extreme weather events. Vegetation on the surface plays an essential role by absorbing precipitation, retaining water, and facilitating groundwater recharge, thereby aiding in the prevention of both floods and droughts. Ecosystems such as wetlands and forests serve as natural flood buffers (Pimentel et al., 1989).

5) The service function of the soil ecosystem. Since ancient times, the country has developed due to soil productivity. The soil maintains the nutrient cycle. The soil supports the life cycle of plants, providing them with nutrients and maintaining nutrients. For example, the rich activities of fungi, bacteria, protozoa, and other organisms in the soil ensure its nutrition. For example, bacteria can convert atmospheric nitrogen into the soil, and earthworms can process organic matter. Earthworms in 1hm^2 land decompose more than 10 tons of organic matter every year. (Lee, 1985) Soil also has a key role in the degradation of organic matter, such as organic matter in fertilizers, oils and acids in industrial waste, etc. By reducing complex organic matter to simple inorganic substances, harmful substances are converted into soil nutrient elements - N, C, and S (Schlesinger W. 1991).

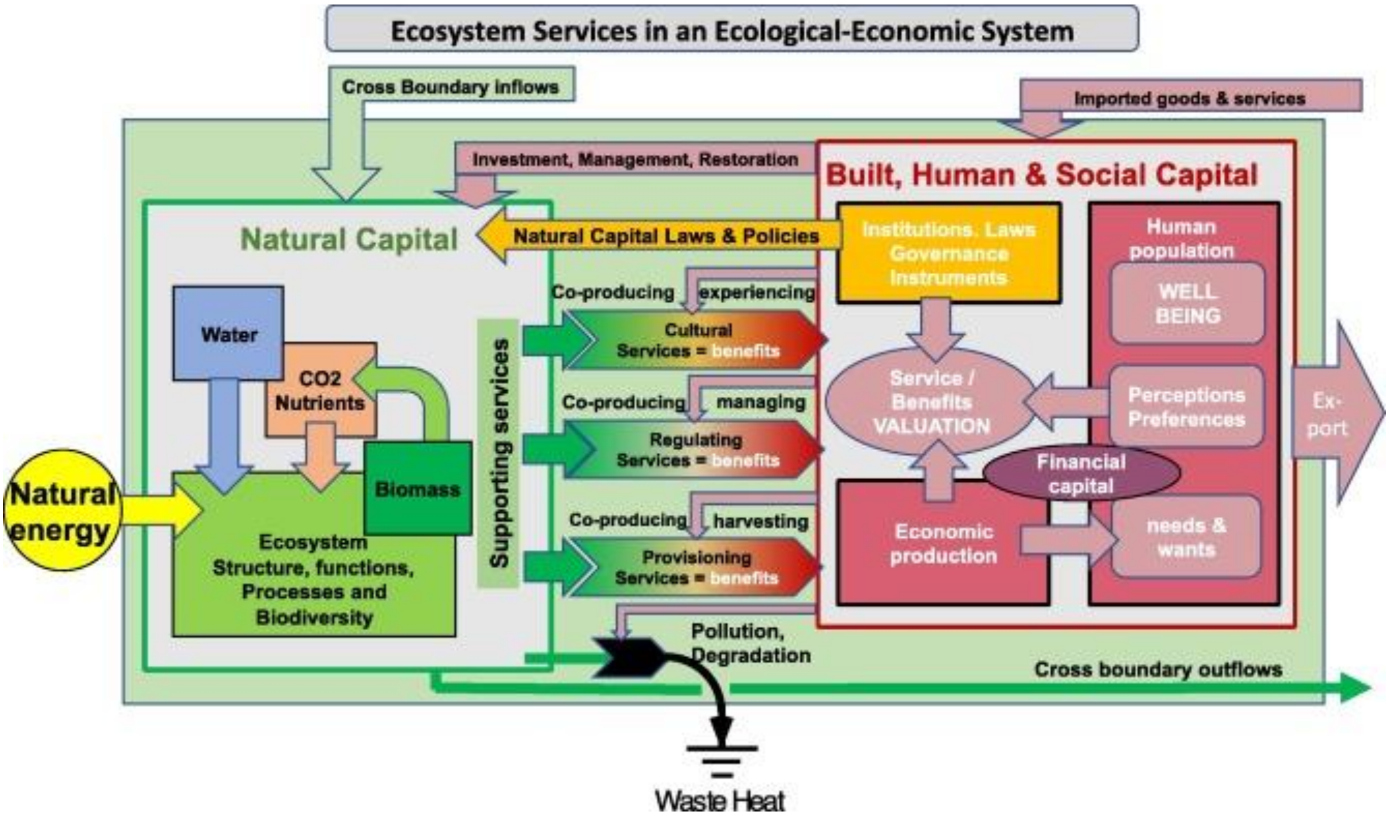
6) Pollination and seed dispersal. Animals and plants are interdependent, and it has been recorded that 80% of the world's flowering plants require the help of animals to pollinate them, including insects and birds (Buchmann & Nabhan, 1996). It can be seen that biological diversity also ensures the reproduction of plants.

7) Environmental purification. Environmental pollution mainly exists in the atmosphere and soil, and the purification of the environment by the ecosystem mainly includes the purification of the atmosphere by plants and the purification of the soil by the soil-plant ecosystem. Plants purify the atmosphere mainly by absorbing carbon dioxide, as well as harmful gases such as nitrides, halogens, and sulfides. At the same time, plants also have blocking, filtering, and adsorption effects on dust. It is also called the “waste receiver function" of the environment. ”(Kneese et al., 1970; Freeman et al., 1973).

8) Cultural and educational functions. It can be seen that the atmosphere, soil, water, plants, and animals are interdependent in the ecosystem. The ecosystem provides human beings with raw materials and products for life and production and provides human life support systems, hydrological cycles, and atmospheric cycles, purifying the environment and maintaining biological genetic diversity.

Sangha et al. (2022) believed that the cascade of Potschin and Haines-Young (2017) ignored the dynamism of ecosystem services and failed to reflect the ecosystem services generated by the interaction between natural capital and other capitals. The concept of ecosystem services is closely linked to the concept of “natural capital,” which is a "flow asset" from an economic point of view (Schröter et al., 2014). Starting from the concept of capital, Costanza stated that capital is "the stock of material or information at a certain point of event" (Costanza & Daly, 1992). Ecosystem service flows are also referred to as "natural income" (Costanza & Daly, 1992), while "natural capital" is the corresponding "stock asset" (Schröter et al., 2014). Many scholars agree that ecosystem services originate from natural capital, that is, each type of capital (which also includes natural capital) can produce a series of service flows that act on human well-being.” (Costanza & Daly, 1992; Hinterberger et al., 1997; Costanza et al., 1997; Ekins et al., 2003; Farley & Daly, 2006; Van et al., 2015; Smith et al., 2017; Mancini et al., 2017). Natural capital and ecosystem services are connected by ecosystem processes, which include complex processes such as soil-biological-atmospheric water circulation and nutrient circulation (Maseyk, 2017).

Figure A. 2 Ecosystem Services in an ecological-economic system



Source: Sangha et al. (2022).

In the field of environmental economics, research on natural capital mainly includes the relationship between natural capital and manufactured capital, the accounting of natural capital, key natural capital, and the investment of natural capital, among other issues. The concept of natural capital was proposed in the 19th century, but the definition of it has always been vague. Until the 20th century, the concept of natural capital gradually became clear as capital theory developed. In 1948, ecologist Vogt (1948) first proposed the concept of "natural capital" by considering natural resources as a form of capital that can generate wealth and bring value to human well-being. Daly H. E. (1996) summarized the definition of "natural capital" from an ecological perspective in 1996: "It refers to the stock of natural resources and environmental assets that can provide a flow of useful products or services in the present or in the future." Here, “stocks” represent elements such as water, soil, air, and biological species, etc. (Mace et al., 2015). Robinson et al. (2013) take the soil ecosystem as an example to illustrate that soil stock is the natural capital in the ”ecosystem service supply chain”; that is, soil stock is a necessary condition for providing soil ecosystem services.

Pierce first proposed the concept of “natural capital” from the perspective of “environmental economics” in 1988, indicating that in the past, “capital” in economics only involved “man-made capital,” ignoring “natural capital.” Pearce defines natural capital as follows: "Natural capital is the natural environment that regards the natural environment as a natural asset that serves economic functions." Here, Pearce (1988) provides an economic foundation for the natural environment and illustrates the role of natural capital, including providing raw materials for economic production, disposing of waste from economic production, supporting Earth's living systems, and providing natural landscapes.

APPENDIX B - THE ECONOMIC THEORIES OF ECOSYSTEM SERVICES VALUATION

The economic theories of ESV mainly focus on the necessity of valuing ES. The necessity of valuing ecosystem services has been a topic of debate among scholars from various disciplines. Environmentalists argue that a "people-oriented" evaluation is unethical, and some scholars even contend that evaluating natural assets can be misleading. Blanco & Costanza (2018) highlight that ecosystem services, being flows generated by the stock of natural assets, may lead to a narrow focus on monetized economic benefits, neglecting non-marketable values. This could result in the destruction of natural ecosystems, emphasizing the risk of ignoring their intrinsic value (Bekessy, 2018).

Liu & Dai conducted a literature review of natural capital and found that economists tend to emphasize the "exchange value" of natural capital, while ecologists prioritize the "use value" (Liu & Dai, 2021). From the perspective of motivating ecosystem service valuation, James Boyd outlines three aspects: 1) Ecosystem service valuation provides adequate decision-making information; 2) It contributes to the sustainable development of society based on the principle of maximizing social welfare; 3) The valuation process fosters connections between experts, stakeholders, and communities

(Boyd, 2012). The following analysis will apply environmental economics, welfare economics, and sustainable development theories.

First, according to the concept of ecosystem services' value, Costanza et al. (2006) divided the value of nature into "instrumental value" and "intrinsic value." Among them, "intrinsic value" expresses the right to exist of natural resources and expresses a "purpose" to protect nature, which is "biologically oriented," so it is difficult to measure. In contrast, "instrumental value" quantifies contributions to human well-being, being human-centric. Most "natural capital" possesses characteristics of public goods, making market failures likely, necessitating government intervention for management. However, maintaining it effectively requires estimating both natural costs and benefits, as decisions on natural capital preservation inherently involve valuation. Neglecting natural capital can be viewed as neglecting its overall value (Costanza et al., 2006). People often start valuing ecosystem services only after ecosystems are damaged. For example, forests' soil and water conservation functions become apparent only after forest clear-cutting causes flooding, or the soil and water conservation functions of grasslands are recognized during dust storms. Similarly, the vital regulatory role of natural ecosystems becomes evident when excessive use of science and technology occurs, highlighting the need to protect what we value (Daily, 1997).

Second, from the perspective of welfare economics using the Bergson-Samuelson social welfare function (SWF), SWF intends to evaluate the allocation of various goods and resources quantitatively from a utilitarian standpoint (Bergson, 1938). Although Arrow demonstrated the non-existence of SWF by analyzing two assumptions (1. People make truthful choices; 2. Human preferences are relatively fixed and observable), efficiency-wise, welfare maximization means maximizing resource allocation efficiency under limited resources. Social welfare depends on maximizing consumer surplus.

From an efficiency perspective, Pareto improvement shows that there is a system that can make at least one person's welfare better without making anyone's welfare worse (Hammond, 2001). From the perspective of fairness, Kaldor and Hicks also proposed the "compensation principle"; that is, the benefits of policy decisions are large enough to compensate those who suffer losses, and there is a surplus, which means that social welfare has increased (Johansson, 1991). However, the "compensation principle" has been criticized by Little, Samuelson, and others due to income distribution issues (Little, 1951; Schmitz & Zerbe, 2008; Bruce & Harris, 1982).

In short, the issue of fairness in social welfare returns to the issue of efficiency, that is, valuing based on the preferences of market goods defined by property rights. Generally, consumer surplus is calculated for pricing through cost-efficiency analysis, cost-utility analysis, and cost-benefit analysis methods (Brent, 1996). However, demand does not only arise from commodities that are already tradable in the market. People often also have great demands for objects where there is no market or whose property rights are unclear or even undefined, such as pollution emissions, biodiversity, landscapes, ecosystem services, etc (Corbera & Martínez, 2007; Lant et al., 2008).

Furthermore, Freeman (1993) argues that ecosystem service valuation cannot fully represent their value. Economic valuation methods, rooted in the mainstream concept of marginalism, rely on market exchange, where prices and values are determined by the interaction of supply and demand, emphasizing the importance of price information. Without market prices, ecosystem service valuation is an information source for cost-benefit analysis of environmental protection (Chen, 2019; Cao & Lu, 2016). For instance, setting pollution control levels relies on the intersection of "marginal benefits" and "marginal costs," yielding different marginal benefits or values under various marginal cost standards. In essence, policy choices determine value based on the input of marginal costs. The more information policymakers have, the better their choices, making ecosystem service valuation a valuable source of information (Fisher et al., 2008; Ferraro et al., 2012; Forster et al., 2019).

Third, from the perspective of human sustainable development, the balance between socio-economic and ecological systems is crucial. If the development of the socio-economic system harms the ecological system, it can ultimately damage human welfare. Both systems contribute to human welfare, with the socio-economic system providing products and services through economic activities and the ecological system supporting human survival and development through ecosystem services. Currently, the socio-economic system's function is measured by Gross Domestic Product (GDP), based on assumptions from labor theory of value, where "human activities create value, and value is the social average labor time embodied in products and services." (Xie et al., 2015, p. 1741). Another GDP measurement standard is transaction-based, assessing economic activities based on market transactions. Early economics focused on measuring value through land, labor, and capital. For instance, François Quesnay and the Physiocrats emphasized the role of land, while from Adam Smith to Karl Marx, labor's role in value was underscored in these views, value determined price. Thus, GDP reflects the value of human labor in socio-economic output but fails to consider the full value of ecosystem services provided to society. Ignoring ecological costs misguides human development when GDP rises due to resource exploitation, increased carbon emissions, or overfishing, as it overlooks the ecological costs (Boyd, 2012). Sustainable development requires both sufficient economic output and ecosystem service output in a region, emphasizing the necessity of valuing ecosystem services in the absence of market mechanisms.

APPENDIX C - SYSTEM OF ENVIRONMENTAL-ECONOMIC ACCOUNTING (SEEA)

Among SEV methods, SEEA serves as a framework for linking environmental and economic data, enabling comprehensive accounting of ecosystem services and natural resources. This section outlines the development of SEEA, emphasizing its role in providing descriptive statistics that reveal the interactions between economic activities and environmental conditions. Various accounts within SEEA, such as environmental asset accounts and monetary accounts related to environmental transactions, help monitor and evaluate the impact of human activities on ecosystems.

Environmental accounting refers to “statistics, verification and measurement of the total amount and structural changes of natural resources in a certain time and space, based on reasonable valuation, in terms of physical objects, value and quality, and reflects their balance" (UN & UNEP, 2000, p. 158) Generally, since the publication of Rachel Carson's "Silent Spring" by an American oceanographer in 1962, many scholars and research institutions have begun to study the environmental, economic accounting system. For example, in 1971, the Massachusetts Institute of Technology first proposed the "Ecological Demand Indicator" (ERI), trying to use this indicator to quantitatively measure and reflect the corresponding relationship between economic growth and resource and environmental pressure. In the 1970s, Tobin and Nordhaus (2018) focused on studying the negative impacts of reduced leisure time, urbanization, resource depletion, and increased pollution on quality of life, leading to the development of the Net Economic Welfare (NEW) indicator. 1989 Repetoo et al. (1989) proposed the net domestic product index (net domestic product, NDP). Taking Indonesia as a research object, they focused on the relationship between natural resource depletion and economic growth. They argue that oil depletion from economic development activities, reductions in timber volumes, and soil loss from timber logging should all be deducted from GDP. Calculated according to the indicators they designed, from 1971 to 1984, although the GDP growth rate of Indonesia was 7.1%, after deducting the above factors, the actual growth rate was only 4.8%. Subsequently, the World Bank senior economists Daly and Cobb (1989) proposed the Index of Sustainable Economic Welfare. This indicator includes a broader range of social factors, such as the inequitable distribution of wealth, unemployment, and the harm that crime rates bring to society.

In recent years, many scholars have devoted themselves to environmental and economic accounting research and have made some new progress. The research results of Simon & Proops's (2000) "Greening the Accounts" comprehensively reflect the latest progress in green national accounting research, including the history of national accounts, green national accounting methods and models, and the construction and analysis of green national accounting accounts. Hartwick (2000) systematically studies the incorporation of environmental capital into the national economic accounting system from a macroeconomic perspective in his research results "National Accounting and Capital." In 1998, Wackernagel et al. (1998) proposed the “ecological footprint," mainly used to calculate the production area necessary to maintain resource consumption and waste absorption under specific population and economic scale conditions.

Many governments and research institutions worldwide are also committed to environmental and economic accounting research. For example, in the mid-1970s, the National Bureau of Economic Analysis (BEA) tried to build a national account framework for pollution reduction and control, which gave the prototype of comprehensive accounting of the environment and the economy in satellite accounts. Subsequently, the United Nations Environment Program (UNEP) issued guidelines for establishing environmental accounts in 1982. In 1989, a comprehensive international cooperative research project participated by the United Nations Statistics Agency (UNSD), UNEP, WB, the Organization for Economic Cooperation and Development (OECD), the Economic Commission for Europe (ECE), and the International Monetary Fund (IMF) jointly discussed the issue of comprehensive environmental and economic accounting. In 1993, the United Nations launched the System of National Accounts (SNA, 1993) and "Satellite System for Integrated Environmental and

Economic Accounting" (SEEA) to guide the comprehensive environmental and economic accounting of countries around the world. Under the basic principles of the SEEA of the United Nations, combined with the characteristics of the European Union and the existing theories and practices of various countries, the EU has researched and formulated the National Accounting Matrix Including Environmental Accounts (NAMEA), and has practiced in Germany, the Netherlands, Sweden, France, and other countries.

SEEA was first proposed by Bartelmus et al. (1991) and then formally summarized as a complete framework by the United Nations Statistical Commission in 1993 (Bartelmus et al., 1991; UN, 1993). Cavalletti & Corsi (2022) conducted a detailed literature review of the development of various versions of SEEA, stating that the purpose of each version of SEEA is to maintain consistency with the SNA account, and the specific development of SEEA-EEA is shown in Table 2.4. In 2001, the Expert Working Group of the United Nations Commission on Sustainable Development (CSD) issued the "Regulations and Principles for Environmental Management Accounting" for the first time (Jasch, 2001). Based on summarizing the practical experience of various countries, the United Nations Statistical Commission issued SEEA-2003 (Walker & Pearson, 2007). This accounting manual consists of 4 groups of accounts and discusses specific accounting methods separately. It brings together the research results in environmental and economic accounting over the years and further clarifies the accounting objects and methods involved in the accounting process (Smith, 2007). Since the late 1990s, with the promotion of ecosystem services research and the value of ecosystem services, and the promotion of ecological economists Daily, as well as research institutions such as MA and TEEB, the United Nations Statistics Office officially released the revised edition of SNA and the 2012 Environment System of Economic Accounting: A Central Framework (SEEA-2012) (Table C.1), which is the first international statistical standard for the System of Environmental-Economic Accounting (Daily, 1997). In this standard, the United Nations Statistical Commission recognized the increasing importance of measuring ecosystems, ecosystem degradation, and flows of ecosystem services. It therefore supported the development of the System of Environmental-Economic Accounting 2012: Experimental Ecosystem Accounting. SEEA-EEA can organize biophysical data, measure ecosystem services, track changes in ecosystem assets, and link this information to economic and other human activities (UN, 2014).

Table C. 1 Timeline of the development of SEEA-EEA

1970s-80s	Integrating natural capital and national accounts becomes part of the research agenda (Ahmad, El Serafy, and Lutz 1989; Bartelmus 1987)
1981	Ecosystem services appear for the first time in the scientific literature
1991	Bartelmus *et al.* publish an framework for environmental-economic accounting
1992	The UN Conference in Rio de Janeiro calls for a global initiative to integrate the environment in national accounts
1993	The UN Statistical Commission publishes SEEA 1993
1994	The London Group of Experts in Environmental Accounting is established
1997	Daily *et al.* publish a conceptual framework in which the value of nature is interpreted in terms of ecosystem services
2003	The Millennium Ecosystem Assessment endorses the concept of ecosystem services
2003	The UN publishes SEEA 2003
2008	The UN issues a revised edition of SNA
2010	The Economics of Ecosystems and Biodiversity study (TEEB)
2011	UK National Ecosystem Assessment
2012	IHDP/UNU-UNEP Inclusive Wealth Report
2012	The UN publishes SEEA 2012
2017	The UN Statistical Commission and the Committee of Experts on Environmental-Economic Accounting recommend a revision of SEEA-EEA
2018	The UN publishes the final note on the revision issues to form the baseline of the revision process
2021	The revised framework is finalized for submission to the UN Statistical Commission

Source: Cavalletti & Corsi (2022).

The function of SEEA is to conduct descriptive statistics on the relationship between the environment and the economy in the form of indicators and to examine and supervise the impact between human economic activities and environmental conditions using specific indicators. SEEA specifically includes a main SEEA-CF (Central Framework) account and SEEA-Water, Energy, Agriculture Forestry and Fisheries, Ecosystem Accounting, and other branch accounts (Table C.2).

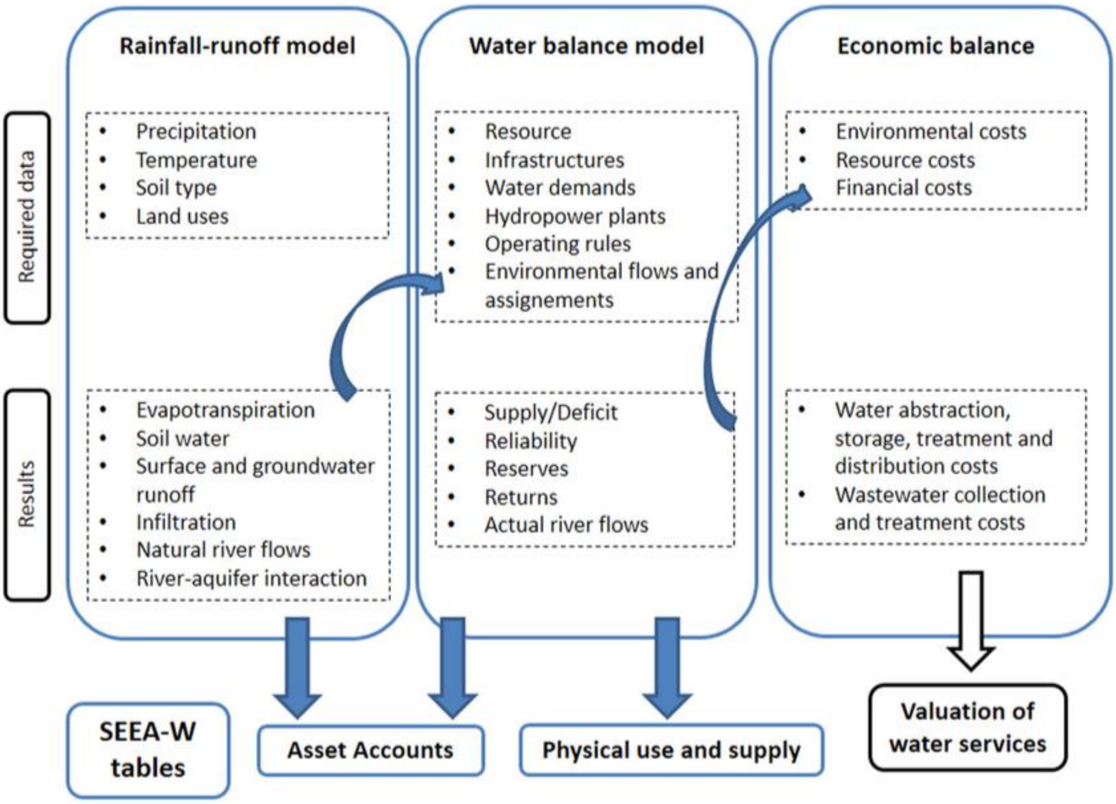
Table C. 2 The classification of SEEA

SEEA-CF (Central Framework)	• **Assets** • **Physical flows** • **Monetary flows**	• Minerals & Energy, Land, Timber, Soil, Water, Aquatic, Other Biological • Materials, Energy, Water, Emissions, Effluents, Wastes • Protection expenditures, taxes & subsidies
SEEA Water; SEEA Energy; SEEA Agriculture, Forestry and Fisheries	Add sector detail	As above for • Water • Energy • Agricultural, Forestry and Fisheries
SEEA-EEA (Experimental Ecosystem Accounting)	Adds spatial detail and ecosystem perspective	Extent, Condition, Ecosystem Services, Thematic: Carbon, Water, Biodiversity

Source: Edens (2019).

SEEA, as a subsidiary account of SNA, uses SNA's accounting standards, which mainly include physical accounts and monetary accounts. Specifically, there are four types of accounts in total: The first type is the "environmental asset account," which shows the changes in various natural resources at the beginning and end of the accounting period, as well as the stock valuation. For example, changes in land, animal, and plant populations or changes and losses in the value of natural capital. During the process of water resource environmental quality assessment, an integrated dynamic assessment of water quantity, water quality, and ecological environment in the basin is required. Because the services and products provided by the ecosystem are the benefits that the natural environment provides to humans, the assessment of ecosystem services can convey ecosystem status information to humans. For a river basin, the water cycle is an important control factor for the river basin ecosystem, and human activities have changed the water cycle process in various aspects (Figure C.1).

Figure C. 1 Application of hydrological information and economic activity information in SEEA-Water.



Source: Pedro-Monzonis et al. (2016).

The second category is mixed physical and economic flow accounts, which represent the consumption and impact of resources in the economic production process, as shown below in Table C.3 - Physical supply and use tables (PSUT); the third category is monetary accounts related to environmental transactions, that is, expenditures by governments, businesses, and households to protect the environment. Such accounts can be used to monitor the costs of human beings to reduce environmental impacts, such as environmental taxes and subsidies, etc.; the fourth category is to obtain the economic impact on the environment based on the above-mentioned types of accounts, and adjust the original SNA accounts based on this result (SEEA implementation guide, 2013).

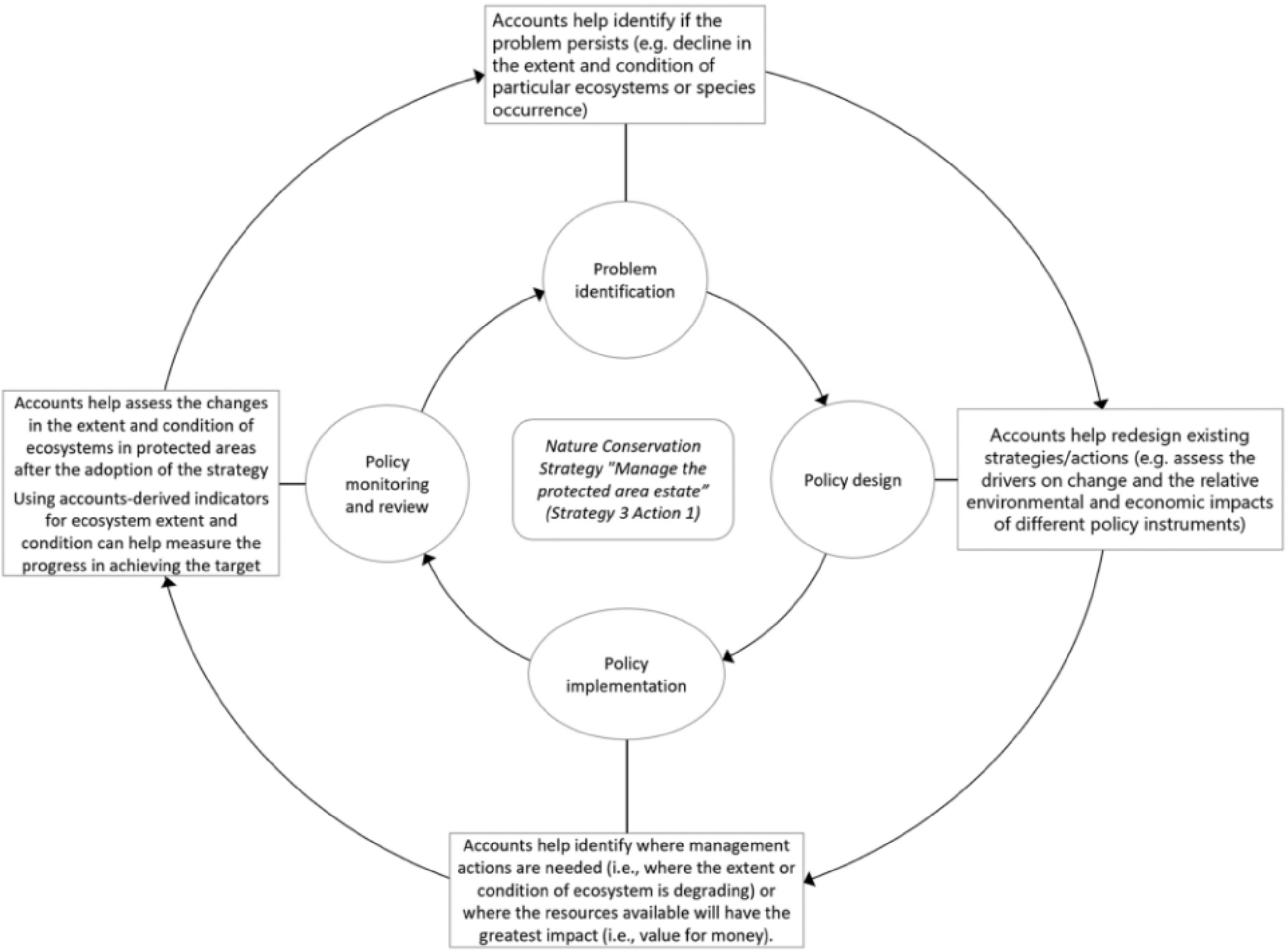
Table C. 3 Physical supply and use tables (PSUT)

	Industries	Households	Accumulation	Rest of the world	Environment	Total
Supply table						
Natural inputs					Flows from the environment	Total supply of natural inputs
Products	Output			Imports		Total supply of products
Residuals	Residuals generated by industry	Residuals generated by final household consumption	Residuals from scrapping and demolition of produced assets			Total supply of residuals
Use table						
Natural inputs	Extraction of natural inputs					Total use of natural inputs
Products	Intermediate consumption	Household final consumption	Gross capital formation	Exports		Total use of products
Residuals	Collection & treatment of waste and other residuals		Accumulation of waste in controlled landfill sites		Residual flows direct to environment	Total use of residuals

Source: SEEA implementation guide (2013).

Chen et al. (2023) utilize the Nature Conservation Strategy to illustrate the role of SEEA accounts (Figure C.2). According to the ES Condition account, policy issues needing to be addressed can be identified; through the Physical supply and use account, the relationship between ecosystems and human economic activities can be assessed to minimize the driver factors damaging the ecosystem; and monetary valuation accounts can provide a basis for ecosystem payment methods such as ES payment. Lastly, SEEA-ES accounts can be used to monitor the supply status of ecosystem services in real time.

Figure C. 2 The function of SEEA accounts in the policy cycle



Source: Chen et al. (2023).

The evolution of environmental-economic accounting, initiated by Norway in 1987, has seen widespread adoption globally, with countries like Germany, Finland, and the United States implementing their frameworks and methodologies to address resource management and economic sustainability. The application of natural resource accounting began in Norway in 1987 when the Norwegian National Statistics Office and the Energy Board published the "Norway Natural Resources Accounting" report (Alfsen & Greaker, 2007). Following Norway's lead, the Finnish government established a framework for natural resource accounting, encompassing forest resource accounting, environmental protection expenditure statistics, and air emission surveys (Kermana & Peltola, 2012). Moreover, various countries worldwide have engaged in environmental-economic accounting tailored to their specific environmental themes and accounting methodologies. Notable cases include the United States, Germany, Norway, Finland, and Mexico.

In Germany, environmental and economic accounting initiatives began in the 1980s under the German Bureau of Statistics, initially focusing on environmental protection expenditure and energy accounting (Statistisches Bundesamt, 2015). Over time, the scope expanded to include environmental pressure, state, and response, utilizing the System of Environmental-Economic Accounting (SEEA) framework (Schaltegger & Burritt, 2015). Physical flow accounting, particularly comprehensive in Germany, describes material flows between economic activities and the environment, with specific emphasis on land and forest resource accounting (Statistisches Bundesamt, 2015).

Norway distinguishes natural resources into material resources (e.g., fishery, minerals, forests) and environmental resources (e.g., air, water, soil), constructing an extensive environmental accounting system (Statistics Norway, 2018). The system encompasses land use, water, fisheries, and forest accounting. Similarly, Finland, renowned for its abundant forest resources, primarily focuses on forest resource accounting, addressing physical quantity, quality indicators, and value assessment (Natural Resources Institute Finland, 2021). Additionally, Finland conducts environmental expenditure statistics and air emission surveys.

In the United States, the Bureau of Economic Analysis developed the Integrated Economic and Environmental Satellite Account (IEESA) in 1992 (U.S. Bureau of Economic Analysis, 2020). IEESA employs a satellite framework, emphasizing the economy-environment interaction tied to market activities. It features asset and production accounts, categorizing non-financial assets into man-made, developed natural, and environmental assets. The production account highlights natural resources and environmental services utilized in production and tracks resource depletion and degradation.

The SEEA faces significant challenges in developing countries, including data availability and quality, funding constraints, and limited human resources (Pirmana et al., 2019). Implementing SEEA requires addressing methodological issues such as defining benefits for own consumption and delineating ecosystem service flows in data-scarce contexts (Sylla et al., 2021). Social and environmental accounting research in developing countries is limited, with a focus on social rather than environmental challenges (Qian et al., 2021). Despite these obstacles, SEEA is crucial for monitoring Sustainable Development Goals and informing environmental policies (Laykam et al., 2022). Capacity development and international support, like the World Bank's WAVES program, are essential for successful SEEA implementation (Pirmana et al., 2019). Advancing ecosystem accounting requires addressing implementation issues, improving methodologies, and enhancing data collection techniques (Comte et al., 2022). Overcoming these challenges is vital for developing countries to move towards sustainable resource management and energy policies (Falcone, 2023; Hein et al., 2020).

Overall, these diverse initiatives showcase the evolution and implementation of environmental-economic accounting worldwide, underpinning sustainable resource management and economic development.

APPENDIX D - ECONOMIC VALUATION APPROACHES OF ECOSYSTEM SERVICES

As described in Appendix C, the System of Environmental-Economic Accounting (SEEA) includes both physical and monetary accounts. Physical accounts are used to record the supply and demand situation of ecosystem services, generally expressed using biophysical indicators. Monetary accounts apply economic valuation methods to convert this biophysical information into economic information, specifically calculating the economic value of ecosystem services resulting from the interaction between human economic activities and ecosystems.

The economic valuation of ecosystem services typically adopts the Total Economic Value (TEV) framework, comprising of use value and non-use value. Specifically, use value includes direct use, indirect use, and option value. Direct use value refers to the value of ecosystem services directly traded on the market, such as timber, fish, medicinal plants, etc. Indirect use value refers to the value of ecosystem services not directly obtained on the market but derived from the Earth's life support functions, most of which are only perceived when these services are impaired, such as clean air and water resources, soil conservation, waste decomposition, etc. Option value refers to the cost paid for potential future use value, such as sponsorship for national parks or endangered species. Although the specific functions of these biological species are not yet clear, biodiversity can ensure the integrity and health of ecosystems, serving as a form of insurance value.

Non-use value refers to the value that is difficult to obtain through markets or other valuation methods, including altruistic value, bequest value, and existence value. Altruism and bequest values represent the value of ecosystem resources to current and future generations, while existence value is the value of ecosystems simply existing, even if not utilized by humans in reality.

Currently, mainstream economic assessment methods for ecosystem services include direct market assessment, revealed preference assessment, and stated preference assessment. Direct market assessment measures the exchange value of ecosystem services based on their market-priced positioning, including price-based, cost-based, and production-based methods. TEEB classifies the production function method as a separate market assessment method, where the market prices obtained through the production function method require corresponding production models, reflecting the indirect use value of ecosystem services. Revealed preference assessment infers preferences through consumer purchasing behavior, including hedonic pricing and travel cost methods. Stated preference valuation involves using surveys to allow consumers to assess the value of ecosystem services, which can evaluate both ecosystem services and non-use values (Table 2.5-Classification of ecosystem service valuation methods).

The selection of methods for valuing ecosystem services varies depending on the research objectives and data availability, for instance, by analyzing the ecosystem service valuations of 665 cases in the Ecosystem Service Value Database (ESVD) (De Groot et al., 2012). The most commonly used methods are direct market pricing and contingent valuation, followed by avoided cost, replacement cost, and factor income/production function method. The advantages of these methods lie in their relatively simple and reliable data availability, while the disadvantage is that they may not apply to valuing all ecosystem services.

On the other hand, the remaining methods either have high data requirements or may result in biased valuation outcomes. The valuation of ecosystem services can be approached through various methods, each offering insights into the economic worth of these services. These methods include:

1) Market Valuation Approach:

- Direct Market Price: This method assesses the exchange value of ecosystem services in fundamental markets, focusing on their provision, regulatory, and cultural functions. It quantitatively evaluates the impact of ecosystem services and then determines their economic value based on prevailing market prices (Chee, 2004; Daily et al., 2000).

- Cost-based Approach:

Avoided Cost: Based on Ridker's research, this approach reflects the expenses incurred to prevent environmental damage. It assesses the impact of ecological destruction on both market and non-market products and services. This method, commonly applied to evaluate environmental pollution, estimates costs at various levels, from national to household levels (Ridker, 1966; Gerking & Stanley, 1986; Murdoch & Thayer, 1990; Abdalla et al., 1992; Abrahams et al., 2000).

Replacement/Restoration Cost: Used widely in Europe, this method measures the costs of restoring or replacing assets affected by environmental degradation. For instance, it evaluates the expenses required to restore a polluted lake to its original quality. Case studies have shown its effectiveness in valuing environmental services (Kuttunen & Brink, 2006).

2) Revealed Preference Valuation Approach:

- Hedonic Price Methods: These methods estimate ecosystem values based on market transactions, such as house prices, to understand preferences related to clean air, scenic beauty, and other environmental attributes. Researchers utilize data analysis to gauge consumer preferences and willingness to pay for these services (Ridker & Henning, 1967; Harrison & Rubinfeld, 1978; Powe, 1995; Ready et al., 1997; Koirala & Bohara, 2014).

- Travel Cost Method: By analyzing travel expenses to visit tourist destinations, this method determines the economic value of these sites. Researchers derive demand curves to assess consumer surplus, providing insights into the value of various landscapes (Smith & Kopp, 1980; McKean et al., 1995; Poor & Smith, 2004).

3) Stated Preference Valuation Approach:

- Contingent Valuation: Individuals express their willingness to pay for specific environmental services through surveys, allowing researchers to estimate society's valuation of these services. Despite its widespread use, this method faces challenges related to respondents' subjective judgments (Wackernagel & Rees, 1996; A.Markandya & R.A.Ortiz, 2011; Christie et al., 2006).
- Choice Modeling: This method involves presenting individuals with choices to elicit value judgments about environmental attributes. Researchers analyze these choices to understand preferences and willingness to pay for different aspects of environmental items (Adamowicz et al., 1994).

These valuation approaches offer valuable insights into the economic worth of ecosystem services, aiding policymakers and stakeholders in decision-making processes related to environmental conservation and resource management.

APPENDIX E – SEMI-STRUCTURED INTERVIEW QUESTIONNAIRE

Thank you for participating in this semi-structured interview. This interview aims to gather insights into the current state of water resource planning and management in Kazakhstan, with a particular focus on integrating the ecosystem service-based approach. Your expertise and experiences are valuable for understanding the challenges and opportunities in sustainable water management. The interview will take approximately [estimated time] to complete. All information provided will be kept confidential and used for research purposes only.

Table E. 1 Semi-Structured Interview Questionnaire

	Main question	Supplementary question/Probing questions
1	Background Information	1. Age ____ 2. Education background____ 3. Which of the following best describes your organization or your work? a. Government authority b. Basin and city-level water management organization c. Scientific and technology community d. Water users 4. Could you please describe how your responsibilities/work relate to water resource planning and management?
2	Could you please describe your understanding of Water Resource Management in Kazakhstan?	1. Can you please describe the history of water resource planning and management in Kazakhstan? What were the significant changes in different periods? 2. Has any shift in the water planning and management strategies since 2010 in Kazakhstan? If yes, what are the main factors contributing to this change?

		3. In your opinion, what are the significant environmental challenges and issues related to water management in Kazakhstan today?
3	What do you think is the importance of integrating the ecosystem based approach into water resource planning and management?	1. Are you familiar with the application of ecosystem-based approaches in the field of water resources management? 2. How relevant is the ecosystem service-based approach to enhancing water resource planning and management in Kazakhstan? 3. Do you see any benefits of adopting an ecosystem service-based approach in water management, and how does it contribute to achieving sustainable development goals? 4. Are you aware of specific water projects or policies where the ecosystem based approach has been applied successfully or faced challenges in Kazakhstan?
4	We are developing an ecosystem-based approach for the Astana reservoir, which supplies the city with drinking water. What are your thoughts on the process and outcomes of ecosystem service valuation for the Astana Reservoir?	1. What challenges and potential benefits do you see in applying the ecosystem-based approach to water resource planning in Astana? 2. In your opinion, does this approach of valuing aquatic ecosystem services influence water resource planning and management in Astana? Why? 3. How do you think it could be improved?
5	Conclusion	1. What do you believe should be the top priorities or action points for Kazakhstan in improving its water resource planning and management in the coming years? 2. From your perspective, what critical roles can governmental and non-governmental organizations play in advancing sustainable water resource planning and management in the country?

		3. How can Kazakhstan improve cooperation with other Central Asian countries on water management, particularly in addressing environmental problems in transboundary rivers? 4. Is there anything else you would like to add or share regarding water resource planning and management in Kazakhstan and the importance of incorporating the ecosystem service-based approach?

Thank you for your valuable insights and time. Your contributions will significantly shape sustainable water management practices in Kazakhstan and the broader Central Asian region. If you have any additional comments or would like to share further information, please feel free to do so.

APPENDIX F - THE HISTORY OF WATER RESOURCE MANAGEMENT REGIMES IN KAZAKHSTAN

From Central Asia's perspective of water resources, there are 15 major rivers, with the two largest transboundary river basins being the Syr Darya and Amu Darya. The distribution and utilization of freshwater resources in the five Central Asian countries can be found in Table F.1. Over different periods, the five Central Asian countries have adopted different water resource management paradigms, as shown in Table F.1. The transformation of water resource management in the five Central Asian countries can be found in Table F.3, and the detail content is as follow:

Table F. 1 Transboundary water distribution in Central Asia

Country	Total renewable freshwater resources (km3/year)	Renewable freshwater resources per capita (m3/person/year)	Domestic use ratio (%)	Industrial use ratio (%)	Agricultural use ratio (%)	Dependence on external water resources (%)	Syr Darya Quota (%)	Amu quota (%)
Kazakhstan	21.10	1339	4	30	66	31	38.1	0
Uzbekistan	56.00	2015	7	3	90	77	51.7	43
Tajikistan	11.50	1625	6	4	91	-	9.2	13.6
Turkmenistan	28.00	5409	3	3	94	-	0	43
Kyrgyzstan	8.00	1441	3	4	93	-	1.0	0.4

Source: Bedford (1996).

Table F. 2 Water Resources Management Regimes in Central Asia

Paradigms/Period	Main transformation and development features
Until the 1860s	Small-scale, community-based water management, nomadic irrigation schemes, individual farming
1860-1920s	Decentralized and small-scale cotton production, simple irrigation schemes, and small-scale basin transfer projects
1920-1940s	Collectivization and nationalization, development of new irrigation projects, state influence on water sector

1940-1990s	Hydraulic mission with mega construction of hydraulic infrastructures, inter-basin transfer projects, centralized economy, mechanization of agricultural production
1990-2016	Sovereignty, market-oriented economy, decentralization of water and agriculture systems, IWRM, river basin management, transboundary water management

Source: Abdullaev & Rakhmatullaev (2015).

Table F. 3 The transformation of water resource management

Periods	**Water issue**	**Principles**	**Water-related strategies in Kazakhstan**
Before the collapse of the Soviet Union	Water is a technical issue	Soviet water allocation principles	-
1990s–2000s	Water is a technical issue	Prolongation of Soviet water allocation principles	"Strategy of Kazakhstan 2030"
2000's – 2015's	Water economic and political issues	Integrated Water Resource Management (IWRM)	"National Plan for Integrated Water Resources Management (IWRM) and Water Efficiency in Kazakhstan," River Basin Councils (RBCs) and National Policy Dialogues (NPDs)
Since 2015 - future	Water is a security issue	Water-Energy-Food-Ecosystems Nexus (WEFE)	"Water Strategy for 2020", "Green Economy"

Source: Rakhmatullaev et al. (2017).

- **Before the collapse of the Soviet Union**

Starting from the 6th and 7th centuries, Central Asia witnessed the early development of water resource management due to the construction of large-scale irrigation infrastructure. Management committees, consisting of khakis (collective farms) and beks (state farms) appointed by the khan, were established from the 13th to the 20th centuries (Abdullaev et al., 2009b). Despite the relatively small scale of irrigation, community-based water management methods were implemented. Since 1918, with increased Soviet investments and technological inputs in Central Asian irrigation projects, large-scale irrigation was carried out under collective and state-owned farms. Under the unified management of the Soviet Union, the upstream countries of the Syr Darya and Amu Darya river basins provided water resources. In contrast, the downstream countries provided coal and oil resources (Abdullaev & Rakhmatullaev, 2015); however, despite these efforts significantly increasing the region's cotton production, neglect of environmental issues led to ecological degradation.

- **1990s – 2000s**

The Soviet-era water resource management system has become a challenge for contemporary Central Asian countries in transboundary water resource allocation. Specifically, in the early post-Soviet period, while water resource management focused more on hydraulic technical issues, changes occurred in Central Asian water resource management at the national, agricultural, and interstate levels, involving efforts by various stakeholders to control water resources.

Firstly, the collapse of political, social, and economic systems at the national level led to multifaceted reforms. With the transition from a planned economy to a market economy, water resource management's scope shifted from administrative to hydrological boundaries, replaced by non-governmental organizations such as water user associations instead of the collective agriculture system. Economic crises and limited national budgets reduced funding for water resource sectors, weakening their influence on national development.

Secondly, agricultural structures transformed, with individual farming replacing collective farms, and abandoned agricultural irrigation infrastructure exacerbated competition for water resources. Finally, at the interstate level, Central Asian countries established intergovernmental water coordination committees. However, different countries began to incorporate their national interests into discussions, leading to conflicts between the energy interests of upstream countries and the irrigation water needs of downstream countries.

Although a series of contracts have been signed between the five Central Asian countries on allocating transboundary water resources (Table F.4), the results have been less than satisfactory. For example, the Almaty Agreement stipulated that downstream countries receive a larger share of water due to their higher level of development. However, upstream countries desired agricultural development, leading to conflicts in water usage between upstream and downstream, such as the 40-year dispute over the Rogun hydroelectric power plant between Uzbekistan and Tajikistan. Meanwhile, ethnic conflicts in border regions between Kyrgyzstan and Tajikistan exacerbated cross-border water resource utilization issues (Abdullaev & Atabaeva, 2012).

Table F. 4 Agreement of transboundary water resources of Central Asia

Year	countries	agreements
1988	Turkmenistan, Iran	«Agreement on construction of Doosti Dam and Dolat-abad diversion dam and equal utilization of the dam»
1992	Russia, Kazakhstan	«Russia-Kazakhstan Agreement on Joint Utilization and Protection of Transboundary Water Resources»
1996	Russia, Kazakhstan	«Ural River Basin Water Resources Management Coordination and Transboundary Water Joint Utilization and Protection Agreement», «Tobol River Basin Water Resources Management Coordination and Transboundary Water Joint Utilization and Protection Agreement,»
1996	Turkmenistan, Uzbekistan	«Urban-Turkish Cooperation Agreement on Water Resources Management»
2000	Kazakhstan, Kyrgyzstan	«Kazakhstan and Kyrgyzstan Inter-Governmental Agreement on Utilization of Water Conservancy Facilities of Chu and Talas Rivers Crossing the River»
2001	China, Kazakhstan	«China-Kazakhstan Cooperation Agreement on Utilization and Protection of Transboundary Rivers»

Source: Yegor (2011).

The five Central Asian countries attempted to address existing water resource allocation issues through transboundary water management. The Interstate Commission for Water Coordination (ICWC) was established in 1992, followed by the Interstate Commission for the Aral Sea Basin (ICAS) in 1993, and the International Fund for Saving the Aral Sea (IFSA) in 1997 through the integration of ICWC and ICAS. However, multilateral management in Central Asia proved ineffective due to the lack of procedures and legal frameworks (Pawletta, 2014).

Xenarios et al. (2018) summarized the roots of CA's water conflicts: the lack of decentralization led to weak management agency capabilities and ineffective allocation mechanisms, manifested in poor implementation and supervision of water agreements. The fundamental reason is that after the collapse of the Soviet Union, the water management departments of the five Central Asian countries still followed the top-down technical approach of the Soviet era, with most water departments focusing only on water supply and distribution.

After the collapse of the Soviet Union, Kazakhstan faced the challenge of transitioning from the Soviet era's focus solely on agricultural production to meeting the demands of international organizations for addressing unequal water resource distribution and inefficient supply. The Kazakhstani government introduced the "Kazakhstan 2030 Strategy" in 1997 to address these challenges. This strategy aimed to tackle water-related issues by focusing on water resource conservation, promoting efficient water usage, implementing scientific water management practices, and addressing concerns regarding drinking water quality. Additionally, it emphasized resolving water supply issues in regions facing scarcity, notably in western and southern Kazakhstan. However, environmental protection aspects were not initially integrated into this plan. It was not until the release of the "Development Strategy Plan until 2020" in 2010 that specific objectives for environmental conservation were formally introduced.

- **2000s to 2015**

During this period, Integrated Water Resources Management (IWRM) was introduced in Central Asia, aiming to strengthen water cooperation among Central Asian countries through comprehensive water resource management. Many collaborative organizations were established, including the Interstate Commission for Water Coordination (ICWC) in 1992, the Interstate Commission for the Aral Sea Basin (ICAS) in 1993, and the International Fund for Saving the Aral Sea (IFSA) in 1997, formed by integrating ICWC and ICAS. However, despite these efforts, multilateral management in Central Asia proved ineffective due to the lack of procedures and legal frameworks (Rakhmatullaev et al., 2017).

Critics of Integrated Water Resources Management argue that while it introduced watershed management principles and established River Basin Councils (RBCs) to facilitate stakeholder communication, it did not fundamentally address water scarcity issues. Despite decentralizing water resource management to local governments, these entities' fiscal and administrative capacities remained weak (Abdolvand et al., 2013). Moreover, the effective participation of the private sector and other stakeholders in water resource management has been lacking, making it challenging to convey grassroots RBCs' views to central departments responsible for water resource management (Abdullaev & Atabaeva, 2012; Abdolvand et al., 2013; Xenarios et al., 2022).

Kazakhstan pioneered the implementation of integrated water resources management, enacting the "Kazakhstan National Plan for Integrated Water Resources Management and Water Efficiency" in 2004 (Zhupankhan et al., 2018). However, this posed challenges as it attempted to reconcile traditional top-down water resource management methods with IWRM principles. Despite assessments and recommendations provided by international organizations like the UNDP and the Asian Development Bank, transparency was lacking in generating water balance and environmental flow data. The UNDP also produced a comprehensive report titled "Kazakhstan National Integrated Water Resources Management and Water Efficiency Plan" but did not receive government approval (European Union, 2010). In efforts to engage local stakeholders, Kazakhstan established River Basin Committees (RBCs) and National Police Department-led Cold Dialogues based on IWRM principles. However, they encountered hurdles in decentralization and fiscal constraints similar to those of other Central Asian countries during implementation (Xenarios et al., 2022).

- **From 2015 – Future**

After 2015, the policy focus of Central Asian countries shifted towards the "Water-Energy-Food-Ecosystem Nexus," marking a fundamental change in addressing water environmental degradation and water scarcity issues. Concepts such as "green economy" and "green infrastructure" were introduced. In 2017, the Central Asian Regional Environmental Center (CAREC) was established to incorporate environmental issues into water resource management (United Nations Development Programme, 2015). According to the "WEFE approach in the UN Syr Darya Initiative," Central Asian countries were urged to adopt this approach to address transboundary water cooperation issues. However, the implementation effect was insignificant (UNECE, 2017; Karatayev et al., 2017). This is due to factors such as weak willingness to share water resources between upstream and downstream countries, political instability, and differences in the importance attached to ecosystems by each country (Chenoweth & Feitelson, 2001; Zinzani & Menga, 2017; Xie & Ibrahim, 2021).

In 2013, Kazakhstan enacted the "Water Strategy 2020," incorporating the "green economy" concept and elevating environmental protection goals to the national strategic level. In transitioning to a "green" economy, water resources are crucial in Kazakhstan's agricultural and industrial production growth. Econometric models are used to analyze and predict economic processes at various levels, aiming to demonstrate the water resource situation and its utilization in Kazakhstan's water strategy, growth, and development (Saparova & Saginova, 2022).

APPENDIX G - THE OVERVIEW OF WATER RESOURCES AND WATER GOVERNANCE IN KAZAKHSTAN

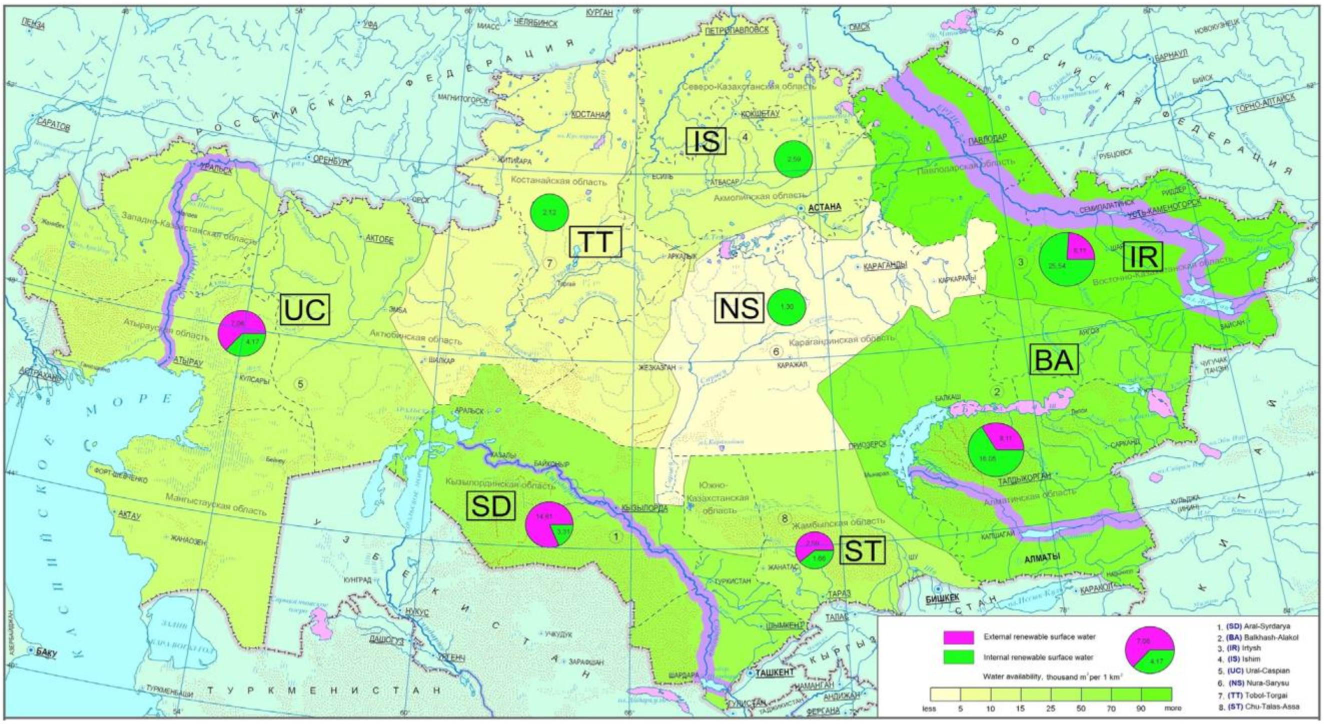
Kazakhstan is divided into eight main river basins based on hydrological boundaries. These include the Ishim Basin (IS), Tobol-Torgai Basin (TT), and Nura-Sarysu Basin (NS) in the northern region. The Syr Darya Basin and Shu-Talas-Assa Basin (ST) are in the southern part. The western region encompasses the Ural-Caspian Basin (UC), while the eastern region consists of the Irtysh Basin (IR) and Balkhash-Alakol Basin (BA) (Table G.2). Kazakhstan's available water resources amount to 144.5 km3, with 44.64 km3 originating from neighboring countries such as China, Russia, Kyrgyzstan, and Tajikistan (Ryabtsev, 2010). For detailed information on specific rivers, refer to Table G.1.

Table G. 1 Main Features of the River Basins in Kazakhstan

River Basins	BA	IR	SD	UC	ST	IS	NS	TT
Area* (km^2)	353,000	316,500	345,000	415,000	64,300	245,000	139,700	214,000
Population (1.02.2019)**	4,039,757	2,132,147	3,793,564	2,158,185	980,000*	2,375,107	1,000000*	1,050,000*
Main rivers*	Ili	Irtysh	Syr Darya	Ural	Shu, Talas, Assa	Ishim	Nura and Sarysu	Tobol, Torgai and Irgiz
Other water bodies* (L=Lakes, R=Reservoir)	Balkhash, Alakol (L) Kapchagai reservoir (R)	Zaisan, Bukhtarma, Oskemen and Shulba (R)	Aral Sea (L) Shardar (R)	Caspian Sea			Tengiz and Karasor (L) Telekol (R)	Kushmurun, Sarykopa, Aksuat, Sarymoyin (L)
Countries in the drainage basin*	Kazakhstan, China	Kazakhstan, China, Mongolia, Russia	Kazakhsta n, Kyrgyzstan, Tajikistan, Uzbekistan	Kazakhstan, Russia	Kazakhst an Kyrgyzstan	Kazakhstan, Russia	Kazakhsta n	Kazakhstan
Outflow*	Lake Balkhash	Ob River	Aral Sea	Caspian Sea	Lake Aydyn	Irtysh River	-	Depression Shalkarteniz
Groundwater resources (km^3/yr)*****	6.9	2.3	1.6	1.2	1.6	0.2	0.8	0.4
Formed outside the Kazakhstan* (km^3)**	9.75	4.48	18.93	8.26	2.91	0	0	0.31
Formed in the Kazakhstan* (km^3)**	15.43	25.92	3.36	4.13	1.33	2.77	1.37	1.63
Water potential** (km^3)**	25.18	30.41	22.29	12.39	4.24	2.77	1.37	1.94
Surface water flow (km^3/yr)***	29.16	35.7	17.34	21.5	4.8	6.48	3.69	3.39
Multiyear average surface water flow* (km^3/yr)**	28	36.4	17.5	16	4.71	2.52	1.3	2.11
Inflow from adjacent countries* (km^3 yr)**	11.8	9.5	15.3	10.5	3.47	-	82 from IR Basin	0.34
Surface flow formed within the basin* (km^3/yr)**	16.2	26.9	2.14	5.47	124	2.52	1.3	1.78
Water consumption for municipal needs (km^3)*****	0.27	0.13	0.1	0.12	0.03	0.12	0.09	0.04
water per one capita * (ths m^3/yr)**	-	16.7	-	4.7	3.9	1.4	11	21
Water consumption for industry (km^3)*****	0.29	2.31	0.04	1.32	0.04	0.21	1.03	0.03
Water consumption for agriculture (km^3)*****	3.48	1.41	8.7	0.1	2.83	0.02	0.08	0.02
Water loss during transportation (km^3)*****	0.83	0.10	1.78	0.14	0.82	0.03	0.04	0.008

Source: Karatayev et al. 2017 * UNDP 2008 ** NSA 2019 *** MoA RK 2018 **** Xenarios et al. 2022 ***** Kazakhstan National Report, 2018 ****** Ryabtsev,2010.

Figure G. 1 Main river basins of Kazakhstan



Source: Kazakhstan Research Institute of Geography (KRIG) (2013).

Regarding the distribution of rivers, as shown in Table G.2, most water resources are concentrated in Kazakhstan's eastern, southern, and southeastern parts. At the same time, the central and northern regions face severe water shortages. In addition, Kazakhstan has a predominantly arid and continental climate with hot summers and cold winters, limited precipitation, and uneven water distribution. This climate significantly affects agriculture, livestock farming, and natural resource development, leading to water availability and management challenges due to frequent droughts and extended dry periods.

Table G. 2 Distribution of water resources in Kazakhstan

Regional	East	Southeast	South	West	Northern	Central
Oblasts	East Kazakhstan, Pavlodar	Almaty	Zhambyl, South-Kazakhstan, Kyzylorda	West-Kazakhstan, Atyrau, Aktobe, and Mangystau	Kostanai, North Kazakhstan, and Akmola	Karaganda
Distribution ratio	34.5%	24.1%	21.2%	13.4%	4.2%	2.6%

Source: Shibutov (2017).

Kazakhstan heavily relies on freshwater and groundwater for its agricultural activities. In particular, the BA, SD, and ST rivers in the southern and southeastern regions of the country provide 90% of the national agricultural water supply. However, irrigation efficiency is relatively low due to outdated infrastructure, leakages, and high evaporation rates (Xenarios et al., 2022). Despite these challenges, these river basins supply drinking water to densely populated areas. For example, the Balkhash-Alakol (BA) basin is a source of drinking and agricultural water for approximately 4 million residents in the Almaty metropolitan area (NSA, 2019). The Aral-Syrdarya (SD) basin supports around 21% of the country's total population and flows through neighboring countries such as Kyrgyzstan, Tajikistan, and Uzbekistan. Additionally, the smaller Shu Talas (ST) basin, shared with Kyrgyzstan, contributes to the agricultural water supply in Kazakhstan and is regarded as a successful model of cooperation among Central Asian countries.

The Irtysh River (IR) in the northern region originates from the Altay region in China. Approximately 59% of its water is used for industrial purposes, while 36% is allocated for agriculture (MoA RK, 2018). However, the basin faces challenges such as reduced inflows and pollution due to intensified agriculture and industry in China's easternmost areas. Kazakhstan also experiences water scarcity issues in the Nura-Sarysu (NS) and Tobol-Torgai (TT) basins. To address this, inter-basin transfers from the Irtysh River and increased utilization of groundwater reserves are being implemented. The Ishim basin (IS), the primary water source for the capital city with a population of 1.2 million, originates in Kazakhstan's Karaganda Oblast. However, only 30% of the river flows within the country. Currently, the water supply from the Ishim River is insufficient to meet the water demand of the capital (Population of Astana, 2023).

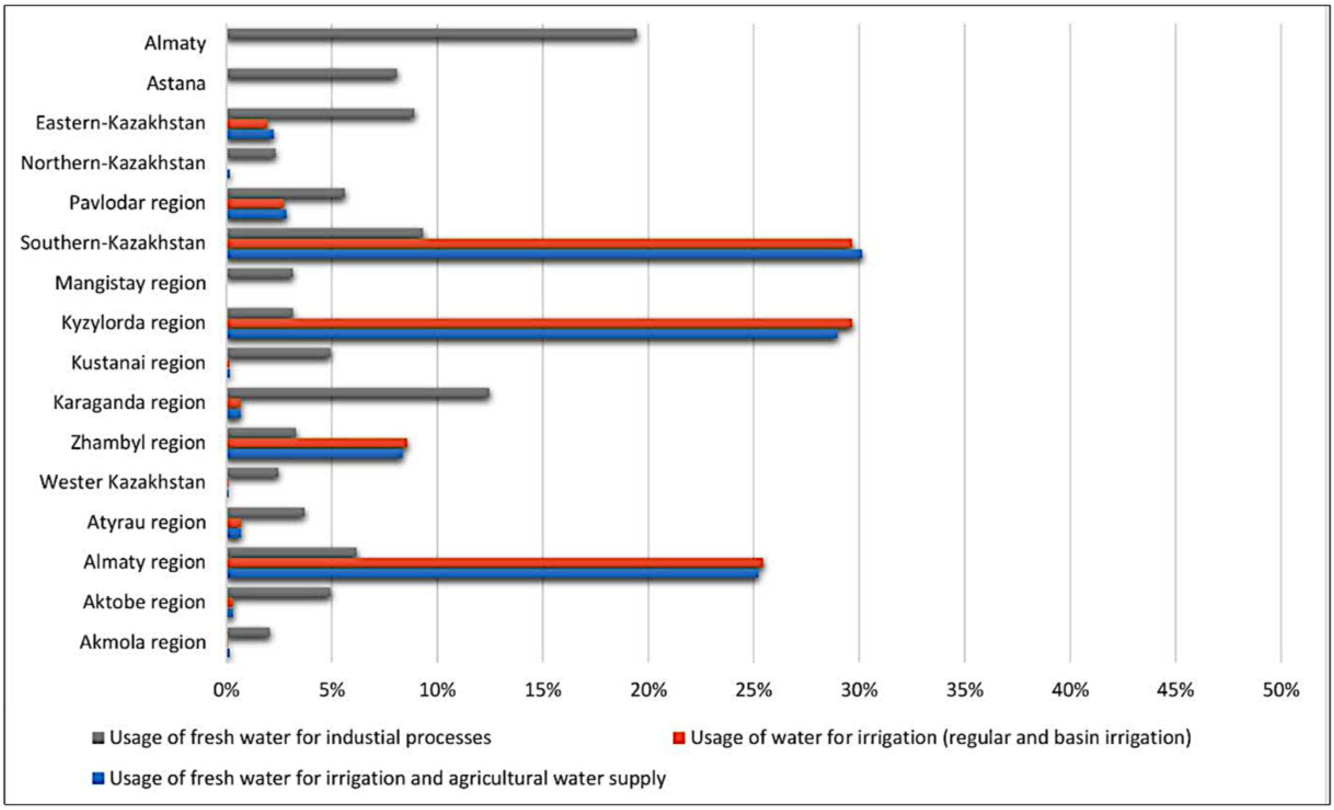
Table G.3 provides data on water reserves and water consumption by users in Kazakhstan from 2007 to 2016. According to the water consumption in different sectors, 65.7% of water is used for agricultural purposes, 29.9% for industrial activities, and 4.5% for household use (Kazakhstan Environmental Performance Reviews, 2019).

Table G. 3 Information on water resources in Kazakhstan (2007-2016)

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Renewable freshwater resources (million m3/year)	19331	17852	19031	21173	18750	18457	19680	20286	19171	19309
Gross freshwater abstracted (million m3/year)	22814	20474	21538	23812	21948	21389	22530	23078	21661	22771
Share of water losses in total water abstraction (%)	12.7	13.1	10.6	12.4	12.4	14	10.9	12.3	10.9	10.2
Total water use by sectors (million m3)										
agricultural	11512	10002	10932	11703	9373	9141	9774	12147	13582	12414.4
households	709	735	742	751	790	724	711	732	730	715
industry	4489	4577	4371	4853	5173	5240	5477	5592	5263	5230
Household water use per capita (l/capita/day)	82.1	79.4	80.8	83.8	80.4	86	82	80.6	79.7	78.6

Source: Kazakhstan Environmental Performance Reviews (2019).

Figure G. 2 Regional water usage: Industry and agricultural (2015)



Source: Nugumanova et al. (2017).

The river ecosystems in Kazakhstan have suffered severe damage, particularly in the Nura-Sarysu basin in the central region (Alimbaev et al., 2021). These areas are affected by industrial sectors such as aluminum, cadmium, coal, non-ferrous metals, metallurgy, and chemical industries, leading to the pollution of surface water and groundwater by industrial wastewater. This phenomenon is closely related to rapid urbanization and agricultural expansion in the central region of Kazakhstan. The ecological problems in the northern part of Lake Balkhash are also significant, with pollution from non-ferrous metal metallurgy, open-pit coal mines, and light industry enterprises, all of which have exceeded pollution standards (International Ecological Forum on the problems of Lake Balkhash, 2015). Pollution in the Ulbi River, a branch of the Eastern Irtysh River, is mainly attributed to local mining activities (Adryshev, 2008). The ecology of the western Caspian Sea region is primarily threatened by chemical substances such as sulfur compounds, hydrocarbons, and tar found in petroleum products, which have detrimental effects on the marine, soil, and biological communities (Yegorov et al., 2003). Oil extraction, production, discharge, and transportation all harm the surrounding marine ecosystems.

The aforementioned industrial activities have destroyed aquatic ecosystems. Water pollution has decreased water purification capacity, reduced soil fertility, diminished habitat availability, and decreased biodiversity. Furthermore, water infrastructure such as dams and irrigation projects alter the natural hydrodynamics of rivers, reducing their ability to absorb and retain excess water during heavy rain or snowmelt. Industrial activities along the rivers, such as mining and manufacturing, contribute to pollutant emissions and excessive sedimentation, severely impairing the rivers' ability to transport essential nutrients and sediments downstream.

- The "Water Code" of Kazakhstan

The "Water Code" in Kazakhstan, signed on July 9, 2003, regulates the management of water resources with the objective of environmentally safe and economically efficient utilization of water, protection of water resources, provision of water supply and wastewater treatment services, and improvement of living conditions for the population and the environment. This legislation resulted from water reform in Kazakhstan and was influenced by the United Kingdom's Department for International Development and international experiences in water resource management. The concepts of water management related to basins were strengthened by establishing the 2003 water code. The roles and purposes of basin water departments, previously outlined by the Committee for Water Resources, are now incorporated into the water code. However, the 2003 water code in Kazakhstan has faced criticism for being hastily developed and not fitting well with local conditions, especially regarding the Western idea of empowering stakeholders. This concept, which involves giving more authority to different groups, has been hard to apply in Kazakhstan. One example is the introduction of new ideas like "water user associations" (WUAs), which traditional water experts in Kazakhstan were not familiar with (Wegerich, 2008). Therefore, further research is needed to determine whether the water code generated through these reforms has genuinely achieved its intended objectives or represents old wine in new bottles (Genina, 2007; Mukhtarov, 2013).

The use of groundwater in Kazakhstan is primarily regulated by the "On Subsoil and Subsoil Use" (No. 291-IV, June 24, 2010). Regulations concerning water facilities are reflected in the "Land Law." In contrast, the rights and responsibilities of water users are primarily outlined in other administrative regulations, such as the "Law on Rural Water Consumer Cooperatives" (2001). In terms of water accounting and monitoring, the Ministry of Agriculture has issued the "Rules of maintaining state records of water and their use, the state water cadaster, and state monitoring of water bodies" (Order of the Ministry of Agriculture of the Republic of Kazakhstan, No. 19-1/718, July 31, 2015) and the "Rules of primary water accounting" (Order of the Ministry of Agriculture of the Republic of Kazakhstan, No. 19/1-274, March 30, 2015) (Tractebel Engineering, 2021; UNECE, 2018).

Faced with environmental challenges stemming from the legacy of Soviet-era pollution, deforestation, and natural resource degradation, Kazakhstan only realized the importance of economic development in harmony with environmental sustainability in the late 1990s. These changes were also influenced by the introduction of several international environmental agreements, such as the United Nations Framework Convention on Climate Change, the Convention on Biological Diversity, the United Nations' Sustainable Development Goals (SDGs), and the Paris Agreement. Kazakhstan was "keen on promoting sustainable development to attract international investments and enhance its 'strong nation' image" (Poberezhskaya & Bychkova, 2021, p. 894). A third reason relates to Kazakhstan's geopolitical situation, as transboundary water management issues necessitated collaboration among Central Asian countries, leading to the consideration of environmental impacts in joint water projects.

Regarding legislation, the "Environmental Protection Law" (No. 400-IV, January 2, 2021) in Kazakhstan is the cornerstone for environmental protection, encompassing legal, social, and economic aspects. The provisions related to water in this environmental law primarily focus on environmental requirements for using freshwater and groundwater, water reserves, wastewater discharge, and environmental assessments within the water licensing system. The detailed state programs for the environmental conservation of Kazakhstan are in Table G.4. Since 2007, Kazakhstan has made significant progress in compiling environmental laws, covering various domains such as environmental impact assessment (EIA) (2008), greenhouse gas regulation (2011), environmental responsibility of enterprises (2015), public participation (2016), environmental permits (2012), land degradation (2017), and natural conservation. These developments have laid the foundation for enhanced environmental protection in the country.

Table G. 2 State programs for environmental conservation in Kazakhstan

Year	Program
1999	1999 National Strategy and Action Plan on Conservation and Sustainable Development of Biodiversity
2000	Concept of Development and Management of Specially Protected Natural Areas until 2030
2004	Programme Environmental Protection in the Republic of Kazakhstan for 2005-2007
2004	Programme Forests of Kazakhstan for the period 2004-2006
2005	Programme to Combat Desertification for 2005-2015
2005	Programme zhasyl el (forests and tree planting) for the period 2005-2007
2005	Program for Conservation and Restoration of Rare and Endangered Species of Ungulates and Saigas for the period 2005-2007
2007	Programme zhasyl el for the period 2008-2010
2010	Programme zhasyl Damu (Green Development) for the period 2010-2014

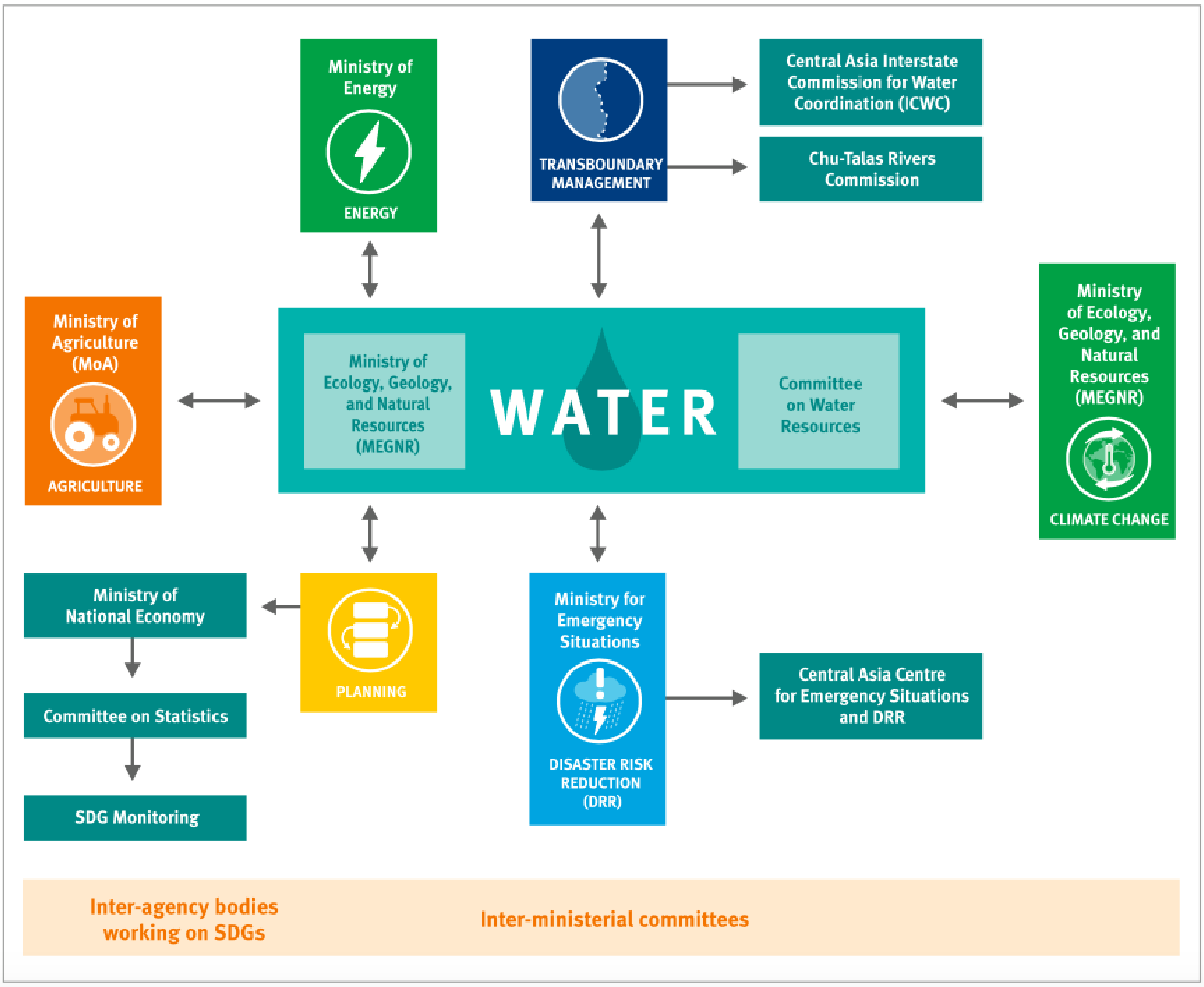
From the perspective of river basin management, Kazakhstan has also begun to utilize river basin management based on the concept of river basins as natural units, following the introduction of the Integrated Water Resources Management (IWRM) concept, which plays a vital role in IWRM (Cai et al., 2003). The concept of river basin management has been a fundamental tool in countries like England and Wales, where it is now being reinforced through directives like the Water Framework Directive (Logan, 2001). Implementing laws and directives such as the European Water Framework Directive is crucial in formulating river basin management plans and ensuring compliance with environmental standards (Logan & Furse, 2002; Rault & Jeffrey, 2008).

- The water management institutions of Kazakhstan

Water resources management is a complex process involving the management of various institutions. The Global Water Partnership (GWP) has summarized the water management institutions in Kazakhstan (Figure G.3) (Clifford-Holmes, 2021). Based on other sources, the adapted water management institutions in Kazakhstan are presented in Table 2.6. Kazakhstan's leading water policy actor is the Committee on Water Resources of the Ministry of Ecology, Geology, and Natural Resources of the Republic of Kazakhstan (CWR), established in 1995. The committee's responsibilities include granting special water permits, participating in the approval of integrated water resources management plans, overseeing compliance with water resource regulations, identifying water-saving measures, setting water quality standards, supervising water resource management facility projects, approving joint water use, managing fish farming and conservation efforts, issuing water permits, and implementing water resource management investment projects. The committee is also responsible for cooperating with relevant domestic and international organizations to promote international water resource cooperation and transboundary water resource management (Shibutov, 2017). To ensure comprehensive management of Kazakhstan's natural and water resources, the CWR was transferred from the Ministry of Agriculture to the Ministry of Ecology, Geology, and Natural Resources (Clifford-Holmes, 2021). With the deepening concern over water resource issues, which are regarded as equally important as oil, metals, and other resources, a dedicated Ministry of Water

Resources and Irrigation was established on September 1, 2023, to carry out the responsibilities previously undertaken by the Central Water Resources (CWR).

Figure G. 3 Water Management Institutions of Kazakhstan



Source: Clifford-Holmes (2021).

The Committee of Ecological Regulation is responsible for issuing environmental permits and protecting water-related environments by environmental laws. The Ministry of Agriculture is responsible for water-related land management, while water equipment falls under the jurisdiction of the Ministry of National Economy. State-owned enterprise - KazVodkhoz is responsible for maintaining and operating water management systems and equipment. The Ministry of National Economy is also involved in water accounting and reviewing water plans, while the Ministry for Emergency Situations focuses on disaster risk reduction. At the provincial administration level, governors/mayors (Akims) can authorize economic development plans, manage water facilities, and subsidize the cost of services. The River Basin Inspector (RBI) is subordinate to the Central Water Resources (CWR) and, based on its directives, determines the rights of water users in various parts of the basin, manages urban water supply and sewage, oversees reservoir operation, conducts groundwater assessments, and operates flood release systems. River Basin Councils (RBC) serve as basin-level advisory groups that collectively address water usage issues and the protection and implementation of basin agreements. However, Mukhtarov (2013) and others have pointed out that the political and financial dependency of the RBC on the Ministry hampers its administrative capacity.

The water companies (Vodokanals) affiliated with each regional municipality mainly manage urban water supply. Most of these companies have been privatized and are primarily responsible for providing drinking water, industrial water, and wastewater treatment and constructing and maintaining relevant infrastructure (Municipal Water Services, 2001).

Table G. 3 Water Management Institutions of Kazakhstan

Institutions	**Responsibilities**
Ministry of Water Resources and Irrigation	Water resource management policy formulation, development and utilization planning, water resource monitoring and evaluation, water quality protection, water disaster prevention and control, etc.
Committee for Water Resources of the Ministry of Ecology, Geology and Natural Resources	
Committee of Ecological Regulation of the Ministry of Ecology, Geology and Natural Resources	Organization, coordination, regulation of emissions, implementation of the issuance of environmental permits, and implementation of state environmental control. (https://www.gov.kz/memleket/entities/cerc/about?lang=en)
Ministry of Agriculture	Responsible for agricultural research, land reclamation, soil quality monitoring, drainage, and salinity.
Committee for Construction, Housing and Communal Services Land Management of the Ministry of National Economy	Development of rules of technical operation and use of water supply systems and sanitation in settlements.
Committee on Statistics of the Ministry of National Economy	SDG monitoring, water accounting
Ministry for Emergency Situations	Manages the prevention and elimination of natural and artificial emergencies. (for example, Central Asia Centre for Emergency Situations and Disaster Risk Reduction)
Provincial level administration	The heads of local government, known as Governors/Mayors (akims), are appointed by the president. They have the power to authorize economic development plans, manage water facilities, and subsidize the cost of services.

River Basin Inspector	Regulatory tasks: The agency determines water restrictions for different water users, establishes rules for operating reservoirs, determines urban water allocations, the location and quality of sewage discharges, and flood release systems. It issues, extends, and renews water licenses and prevents unauthorized use of water bodies or encroachment on designated buffer zones around water bodies. Directly involved in water resources management: overseeing reservoir operations, registering dam safety declarations, controlling flooding, waterlogging, and shore damage, and assessing groundwater reserves. Coordination: Liaise with local implementing agencies and branches in other municipalities to coordinate the activities of various stakeholders, including the preparation and implementation of basin agreements, and submit recommendations to relevant national agencies and water users.
River Basin Councils	Protection of water, resources, water supply, and sanitation: As a consulting agency, it reviews financing proposals from various sources and provides recommendations on priority projects. However, its authority is limited. It does not coordinate activities or make final decisions among stakeholders but advises and recommends basin strategic plans.
Interstate Commission on Water Coordination	Conducts water allocation between all five Central Asia countries every year. (for example, Chu-Talas River Commission)

Source: adapted from UNECE (2008); Mukhtarov (2013); Tractebel Engineering (2021); Clifford-Holmes (2021).

Table G. 4 The approval of water use limits in the context of basins and regions (cities of republican significance, the capital) for 2016-2025 (Million cubic meters)

No	**Regions**	**River basin**	**Million cubic meters**	**Municipal and industrial needs**	**Agriculture**		**Fisheries**	**Environmental needs and others**
					total	**Regular irrigation**		
1	Akmola, Nursultan city	Esil river	115	82	32	11	1	0
		Mesopotamia Esil-Ertis	41	33	6	2	2	0
		Chaglinka river	29	21	7	3	1	0
		Nura river	19.5	0.3	19.2	1.8	0	0
		total	204.5	136.3	64.2	17.8	4	0
2	Aktobe	The basin of Zhaiyk river	325	60	50	30	5	210

		Rivers Wil, Sagiz, Emba, Priaralya	75	45	30	10	0	0
		Turgai river	13.2	0.7	12.5	0	0	0
		total	413.2	105.7	92.5	40	5	210
3	Almaty region, Almaty city	Ile river	3051.6	385.2	2622	2578.4	34.4	10
		rivers of the Eastern and Northern Balkash	1189.1	67.2	1121.9	1094.6	0	0
		lakes Alakol, Sasykkol	241	4.5	236.5	230	0	0
		total	4481.7	456.9	3980.4	34.4	10	220
4	Atyrau	Jayik river	302.3	151.8	76.5	27	4.2	69.8
		Volga river	48.3	39.6	4.5	1.2	0	4.2
		River Will, Sagiz, Emba	24.9	0.9	24	0	0	0
		Caspian sea	7.5	7.5	0	0	0	0
		total	383	199.8	105	28.2	4.2	74
5	West Kazakhstan	Rivers Big and Small Uzen, Chizha, Ashachy, Uzek Zhanibek irrigation and watering system	109	1	5	2	0	103
		Jayik river	669	39	30	13	0	600
		total	778	40	35	15	0	703
6	Zhambyl	Shu river	1540	24.2	1292.8	1227	23	200
		Talas river	808	40	698	678	0	70
		Asa river	455	30	345	309	0	80
		Lake Balkash basin	3	2	1	0	0	0
		Ile river	2.5	1	1.5	0	0	0
		Total	2808.5	97.2	2338.3	2214	23	350
7	Karaganda	Nura river	1411.4	1322.9	88.5	88.5	0	0
		Sarysu river	238.2	229.8	8.4	8.4	0	0
		Lake Balkash	175.5	175.5	0	0	0	0
		Yertis (canal named of Kanysha Satpaeva)	153.3	101.8	8.3	8.3	1.2	42
		Cumola river	0.1	0.1	0	0	0	0
		total	1978.5	1830.1	105.2	105.2	1.2	42
8	Kostanay	Tobol river	114.4	82.1	24.4	21.9	1.1	6.8
		Torgai river	5.3	4.7	0.6	0.5	0	0
		total	119.7	86.8	25	22.4	1.1	6.8
9	Kyzylorda	Syr darya river	5429.9	45	4174.9	4159.9	10	1200
		total	5429.9	45	4174.9	4159.9	10	1200
10	Mangistau	Caspian sea	1464.9	1464.7	0.2	0.1	0	0
		Aral sea, Volga river	23.4	22.9	0.5	0.2	0	0
		total	1488.3	1487.6	0.7	0.3	0	0
11	Turkestan, Shymkent city	Syr darya river	2418.5	11	2233	2215.2	11	163.5
		Arys river	2087.7	127	1703	1616.1	9	248.7
		Chirchik river	1250	9	1022.2	990.5	0	218.8
		Rivers of the Northern slope of the Karatau mountains	66.9	4	59.9	51.1	0	2
		Total	5822.1	151	5018.1	4872.9	20	633
12	Pavlodar	Ertis river	3569	2399.7	969.3	70	1	199
		Shiderty river	6	0.1	5.9	0	0	0
		Olenty river	2	0.1	1.9	0	0	0
		Aschisu river, Tundyk, Espe	23	0.1	22.9	0	0	0
		total	3600	2400	1000	70	1	199
13	North Kazakhstan	Esil river	72.5	55	15.5	3	2	0
		Mesopotamia Eeil-Ertis	5.5	1.5	4	0.5	0	0

		Chaglinka river	7	1	6	0.5	0	0
		Total	85	57.5	25.5	4	2	0
14	East Kazakhstan	Ertis river	916	395	491	270	30	0
		Lake Balkash	40	5	35	10	0	0
		Lakes Alakol and Sasykkol	49.5	2.5	47	40	0	0
		total	1005.5	402.5	573	270	30	0
Total for Kazakhstan			28597.9	7496.4	17537.8	15772.7	135.9	3427.8

Source: Order of the Deputy Prime Minister of the Republic of Kazakhstan (2016).

APPENDIX H – WATER CONSUMPTION DATA IN ASTANA CITY

Table H. 1 Forecast of urban water consumption in Astana city (in million m3)

Item	1999	2010	2020	2030
Drinking	50.4	55.4	79.2	96.6
Technical water	6.5	8.5	9.7	11.2
Irrigation	2.7	20.7	25.2	30.8
Greenery	0.1	0.3	0.4	0.5
Sanitary flow	5.0	5.0	5.0	5.0
Landscaping and miscellaneous use	-	3.0	3.0	3.0
Water loss (evaporation + infiltration)	-	12.0	12.5	13.1
Total	64.7	104.9	135.0	160.2

Source: JICA (2001).

Table H. 2 Water supply infrastructure in Astana

Section	Component	Characteristics	Value	Unit
Raw water source	Astana (Vyacheslav) reservoir	Storage volume:	410	million m³
		Availability	67.2	milliom m³/a
Intake Station	1st Lift Pumping Station old	Design capacity	200000	m³/d
	1st Lift Pumping Station new	Design capacity	210000	m³/d
Bulk water supply line	DN 1400	Length	52	km
	DN 1000	Length	52	km
	DN 1000	Length	52	km
	Old line	Design capacity	200000	m³/d

Water Treatment Plant	New line	Design capacity	105000	m^3/d
	Drinking Water Storage	Volume	60000	m^3
	Technical Water Storage	Volume	20000	m^3
	2nd Lift Pumping Station - Drinking Water	Pump set 1+2		
	2nd Lift Pumping Station - Technical Water	Eight pumps		
Drinking Water Supply Network	Network	Network length	1412	km
	3rd Lift Pumping Station	No. Stations	7	pcs
		No. Stations	91	pcs

Source: Tractebel Engineering (2021, p. 97).

Class	1993	1996	1999	2002	2005	2008	2011	2014	2017	2020	Change percentage
Cropland, rainfed	25291	25989.2	31733.9	32273.29	32171.01	32171.01	32171.01	32153.96	32148.27	32312.42	11.87%
Cropland, rainfed: Herbaceous cover	682.16	733.3	1264.47	1434.87	1423.51	1451.88	1490.14	1583.12	1577.43	1536.36	1.44%
Mosaic cropland (>50%) / natural vegetation (tree, shrub, herbaceous cover) (<50%)	2837.41	2899.92	3641	3840.47	3806.36	3806.36	3806.36	3806.36	3806.36	3802.32	1.63%
Mosaic natural vegetation (tree, shrub, herbaceous cover) (>50%) / cropland (<50%)	4975.23	5009.23	6858.07	8079.76	8068.4	8363.42	8536.81	8567.13	8567.13	8546.05	6.04%
Tree cover, needle-leaved, evergreen, closed to open (>15%)	130.45	130.45	130.45	130.45	130.45	130.45	130.45	141.82	141.82	141.82	0%
Tree cover, mixed leaf type (broadleaved and needleleaved)	17	17	17	17	17	17	17	17	17	17	0%
Grassland	9646.24	9475.8	8300.43	7624.43	7522.15	7391.54	7208.31	7086.88	7058.44	7041.56	-4.40%
Sparse vegetation (tree, shrub, herbaceous cover) (<15%)	10914.39	10159.6	2463.49	322.24	322.24	123.76	95.33	82.1	70.74	70.74	-18.33%
Urban areas	216.99	216.99	222.66	301.73	551.75	557.45	557.45	574.5	625.67	629.63	0.70%
Water bodies	4442.56	4521.94	4521.94	5129.2	5140.56	5140.56	5140.56	5134.87	5134.87	5049.84	1.03%
Shrubland	0	0	0	0	0	0	0	5.68	5.68	5.68	0%

Table H. 3 Land cover in 1993-2020 of Astana Reservoir

Source: Land cover CCI (1992-2020).

Table H. 4 Unit Operational Cost for water supply of Astana city in 2000-2016

Indicator	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
11.3- Unit Operational Cost – Water only (US$/m3 sold)	0.09	0.1	0.11	0.12	0.12	0.14	0.16	0.17	0.18	0.23	0.13	0.25	0.31	0.34	0.35	0.36	0.27

Source: IBNet (2000-2016).