

Climate-Sensitive and Data-Driven Hydrological Modeling for Transboundary Water Governance in the Tigris-Euphrates Basin

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Abstract

Transboundary water governance in the Tigris-Euphrates Basin represents one of the most hydro-politically volatile regional challenges globally. Shared among Turkey, Syria, Iraq, and Iran, the basin suffers from acute water scarcity, extreme hydrological variability, severe land degradation, and escalating ecological distress. While these vulnerabilities are drastically intensified by climate change, their primary driver stems from systemic deficits in political leadership, institutional governance, and transboundary water diplomacy. Upstream infrastructure development exemplified by Turkey's Southeastern Anatolia Project (GAP) has operated largely under unilateral state-centric models, resulting in reduced downstream river discharges, altered flow regimes, and severe socio-ecological disruptions in downstream Iraq. Conversely, downstream governance in Iraq has struggled with internal political fragmentation, outdated irrigation infrastructure, and reactive water management policy.

This paper presents a comprehensive synthesis of hydro-political dynamics, hydrological realities, and governance frameworks within the Tigris-Euphrates Basin. By integrating empirical streamflow data, remote sensing observations, spatial salinity modeling, climate sensitive hydrological modeling, and environmental impact assessments, this study evaluates how data-driven tools can serve as objective decision-support mechanisms for political leaders. Crucially, the paper highlights future climate change impacts on water availability across all riparians, emphasizing the unequal burden placed on downstream Iraq as the terminal receiver. Ultimately, this study formulates a strategic roadmap emphasizing legal institutional mechanisms, joint climate driven data sharing, adaptive damage-sharing provisions during drought years, integrated water resources management (IWRM), non-conventional water technologies, and trade-based benefit sharing to ensure long term regional stability and water security.

1. Introduction

Transboundary river basins are critical sites of geopolitical interaction, where ecological dependencies intersect with national sovereignty, economic development, and regional security ⁽¹⁾. The Tigris-Euphrates River Basin, shared primarily by Turkey, Syria, Iraq, and Iran, is widely recognized as one of the most hydro-politically complex and vulnerable river systems in the world (Fig. 1) ⁽²⁾. Originating in the high-altitude Anatolian headwaters, the Tigris and Euphrates rivers sustain over 60 million people across diverse ecological zones from the mountainous headwaters to the fertile Mesopotamian plains and the iconic Southern Marshes, terminating in the Shatt al-Arab delta and the Arabian Gulf (Fig. 1) ⁽³⁾.

Figure 1: *Tigris and Euphrates basin*

For decades, the basin has been characterized by hydro-political friction, unilateral water infrastructure construction, and periodic diplomatic crises ⁽⁴⁾. Iraq, situated at the lower end of the basin, faces an unprecedented and compounding water crisis ⁽⁵⁾. The primary drivers of water shortage in Iraq stem

from a combination of external hydro-hegemonic pressures, domestic governance failures, and climate induced environmental stressors:

- **Upstream Unilateral Infrastructure & Impoundments:** Upstream development programs—most notably Turkey's Southeastern Anatolia Project (GAP) have fundamentally altered historical flow dynamics through extensive dam building (such as the Atatürk and Ilisu dams), reservoir impoundments, and large-scale agricultural diversions ^(6, 7). Simultaneously, Iranian dam construction and water diversions on key Tigris tributaries (e.g., Sirwan, Karun, and Karkheh rivers) have cut vital inflows to eastern Iraqi provinces like Basrah and Diyala ⁽²⁾.
- **Absence of Binding Transboundary Treaties & Climate Adaptations:** Basin governance suffers from asymmetric power dynamics, a lack of a comprehensive basin-wide legal framework, and an absence of joint operational guidelines or damage-sharing mechanisms during climate-induced droughts, leaving Iraq vulnerable to unilateral upstream flow reductions ^(1, 8).
- **Domestic Governance & Infrastructure Deficits:** Decades of armed conflict, political instability, institutional fragmentation, and chronic underinvestment have severely weakened Iraq's internal water management capabilities ^(9,10).
- **Inefficient Agricultural & Conveyance Practices:** Iraq relies heavily on traditional, highly inefficient flood irrigation techniques and unlined open canal conveyance systems, resulting in massive water losses through evaporation and seepage ⁽¹¹⁾.
- **Severe Water Quality Degradation & Salinization:** Reduced River discharges lower self-purification capacity, leading to alarming increases in Total Dissolved Solids (TDS), industrial pollution, untreated municipal sewage, and catastrophic seawater intrusion in the Shatt al-Arab delta ^(12, 13).
- **Hydro-Climatic Stress & Aquifer Exhaustion:** Accelerating climate change, prolonged droughts, rising temperatures, and rapid population growth have intensified domestic water demand, forcing an unsustainable over-reliance on groundwater and causing rapid aquifer depletion ^(14, 15).
- **Localized Watershed Degradation:** High soil erosion rates and lack of soil conservation policies in internal sub-basins (such as the Al-Adhaim River Basin) cause severe dam siltation, drastically reducing storage capacity and available surface supply ⁽¹⁶⁾.

While the physical manifestations of water stress such as river flow reduction, soil salinization, groundwater depletion, and marshland desiccation are well-documented empirically, bridging climate-sensitive hydrological modeling with political and institutional governance frameworks remains essential for sustainable water planning and equitable burden-sharing ⁽¹⁷⁾.

2. Basin Profile and Hydrological Dynamics

2.1 Spatial and Topographical Setting

The spatial configuration of the Tigris-Euphrates Basin exhibits extreme elevation gradients, ranging from headwaters above 4,000 meters above sea level in eastern Anatolia to depression zones below sea level in the lower Mesopotamian delta (Figure 1) ⁽³⁾. The basin's runoff generation is concentrated in northern mountainous zones, making downstream arid plains heavily dependent on transboundary surface flows originating outside their national borders ⁽²⁾ (Al-Ansari, 2019).

2.2 Streamflow Variability and Historical Trends

Empirical streamflow records demonstrate a severe long-term secular decline in mean annual discharges across monitoring stations on both the Euphrates and Tigris rivers (Figure 2) ^(5,7). On the Euphrates River, gauge stations at Jarablus (Syria), Hussaybah, Hit, and Hindiyah (Iraq) display declining discharge trends spanning from 1940 to 2010 (Figure 2) ⁽⁸⁾. The onset of large-scale upstream dam fillings in the 1970s and 1990s sharply attenuated peak flood flows and reduced baseline stream flows (Figure 2) ⁽⁶⁾.

Figure 2: Mean annual discharge of rivers Tigris and Euphrates

Similarly, long-term gauge measurements along the Tigris River at Mosul and Kut demonstrate significant negative discharge slopes, as illustrated by the linear trend line for the Kut station (Figure 2) ⁽⁵⁾. The systematic reduction in instream volumetric discharge directly correlates with the expansion of upstream impoundments and escalating regional climatic drying trends (Figure 2) ^(7,18).

3. Political Leadership, Hydro-Hegemony, and Basin Governance

3.1 Upstream Hydro-Hegemony and Unilateral Infrastructure

The geopolitical dynamic of the Tigris-Euphrates Basin is defined by a pronounced spatial and structural asymmetry between upstream and downstream riparians ⁽²⁾. Turkey controls the headwaters of both rivers, contributing approximately 90% of the Euphrates' mean annual flow and 40% of the Tigris' annual discharge⁽¹⁾. Leveraging its geographic position, abundant hydrologic yield, and superior economic capacity, Turkey has historically operated as the basin's hydro-hegemon⁽⁴⁾.

The launch of the GAP project in the 1970s marked a structural shift in basin hydropolitics ⁽⁶⁾. Encompassing 22 major dams, 19 hydroelectric power plants, and extensive irrigation networks designed to water 1.8 million hectares of land, GAP aimed to catalyze economic development in Southeastern Anatolia (Bilgen, 2018). However, the unilateral filling and operation of mega-structures such as the Atatürk Dam on the Euphrates and the Ilisu Dam on the Tigris severely reduced seasonal flow volumes entering Syria and Iraq, altering historical spring flood pulses essential for deltaic replenishment and marshland flushing ⁽¹⁹⁾.

Similarly, dam construction along key Tigris tributaries originating in Iran (such as the Sirwan, Karun, and Karkheh rivers) has diverted substantial inflows that historically sustained Eastern Iraq, further exacerbating water deficits in cities like Basrah and Diyala ⁽²⁾. The absence of coordinated basin-wide reservoir operational guidelines demonstrates a persistent deficit in cooperative political leadership across all riparian states ⁽¹⁾.

3.2 Institutional Volatility and Legal Deficits

Transboundary water interactions in the basin have fluctuated between intense crisis and limited technical cooperation ⁽¹⁾. Historical diplomatic milestones provided localized stability but lacked comprehensive, adaptive management mechanisms ⁽⁵⁾. Attempts to institutionalize multilateral cooperation through the Joint Technical Committee (JTC) in the 1980s stalled repeatedly due to divergent legal interpretations and broader political-security disputes (Table 1) ^(1, 4).

Table 1
Key Transboundary Treaties, Initiatives, and Governance Deficits

Agreement / Institution	Key Riparians Involved	Primary Provisions & Objectives	Governance & Political Deficits
1987 Transboundary Protocol	Turkey – Syria	Guaranteed interim flow of 500 m³/s of Euphrates water at the border.	Bilateral only; excluded Iraq; fixed volumetric allocation lacking climate adaptation mechanisms (Kibaroğlu, 2015).
1990 Syrian-Iraqi Agreement	Syria – Iraq	Allocated 58% of Euphrates waters arriving at Syrian border to Iraq, 42% to Syria.	Dependent on upstream Turkish releases; failed to establish joint operational controls (Al-Ansari, 2019).
Joint Technical Committee (JTC)	Turkey, Syria, Iraq	Technical dialogue on flow monitoring, dam operations, and data exchange.	Stalled by political conflict, lack of binding mandate, and disagreements over river definitions (Kibaroğlu, 2015).
GAP & Ilisu Implementation	Turkey (Unilateral)	Integrated multi-sector regional development (hydropower, irrigation).	Unilateral impoundment altered seasonal flood pulses and degraded downstream water quality (Bilgen, 2018).

Table 1: Key Transboundary Treaties, Initiatives, and Governance Deficits

4. Hydro-Climatic Stress and Environmental Degradation

The failure of regional political leaders to establish joint environmental stewardship and climate-sensitive management has triggered widespread hydrological degradation throughout the basin ⁽¹⁸⁾. Downstream riparians face compounding challenges driven by physical reduction, severe water pollution, soil salinization, and land degradation (Table 2) ⁽¹⁰⁾.

Table 2
Ecological, Climate, and Socio-Economic Impacts Across Basin Zones

Basin Zone	Primary Hydrological & Climate Stressors	Observed Ecological / Socio-Economic Impacts	Key Scientific References
Upper Basin (Turkey)	Reservoir evaporation, irrigation runoff, dam impoundments, rising temperatures, shifting precipitation, and reduced snowpack runoff.	Altered seasonal regimes, trapped sediments, ecosystem fragmentation, shifting seasonality of peak flows, lower headwater yield during droughts.	Bilgen, 2018; Guzey & Önöz, 2023
Middle Basin (Syria / N. Iraq)	Flow reduction, agricultural return flows, climate droughts, elevated evapotranspiration, erratic rainfall distribution.	Decreased hydropower yield, crop failures, regional displacement, drop in agricultural yield, elevated groundwater extraction.	Adamo & Al-Ansari, 2018; Adamo et al., 2022
Lower Basin (S. Iraq & Delta)	Extreme flow deficits, severe saline intrusion, marsh desiccation, compounded upstream drought retention, hyper-saline tidal intrusion, temperature extremes.	Loss of biodiversity, agricultural land loss, drinking water crises, disproportionate absorption of basin-wide climate shocks, severe marshland degradation.	Al-Ansari, 2018; Lateef et al., 2020; Al-Ansari, 2020

Table 2: Ecological, Climate, and Socio-Economic Impacts Across Basin Zones

4.1 Subsurface Groundwater Exhaustion

As surface water supplies have diminished, dependence on groundwater resources has increased exponentially ⁽¹⁴⁾. Satellite observations from the GRACE (Gravity Recovery and Climate Experiment) mission reveal alarming rates of aquifer depletion across the Tigris-Euphrates Basin representing one of the fastest rates of groundwater loss on Earth ⁽¹⁴⁾. Unregulated pumping for domestic and agricultural usage has lowered water tables, diminished baseflow to river channels, and caused localized land subsidence ⁽¹⁴⁾.

4.2 Downstream Water Quality Degradation and Salinization

Water quality exhibits severe spatial degradation along the length of both rivers, reaching critical levels in southern Iraq (Fig. 3, Table 3) ^(5, 20). Longitudinal monitoring along the Tigris River demonstrates a continuous linear rise in Total Dissolved Solids (TDS) from below 300 mg/L near the Syrian Iraqi border to over 800 mg/L near Qurnah (Fig. 3) ⁽⁵⁾.

Table 3
Spatial Salinity Trends Along Mainstream River Reaches

Location / Reach	Parameter Measured	Observed Values	Primary Causes & Implications
Upper Euphrates (Border)	TDS (mg/L)	400–600 mg/L	Relatively low salinity; suitable for multi-sector domestic and agricultural use.
Middle Euphrates (Central Iraq)	TDS (mg/L)	1,200–1,800 mg/L	Agricultural drainage discharge, reduced dilution capacity (Al-Ansari, 2018).
Lower Tigris / Shatt al-Arab	TDS (mg/L) / Electrical Conductivity	2,800 – >10,000 mg/L	Severe marine tidal intrusion, heavy urban run-off, collapse of municipal supply (Abdul-Hameed & Hatem, 2021).

Figure 3: Variation of salinity along Tigris and Euphrates Rivers

While the measurements were published by ESCWA in 2013⁽²¹⁾ an even steeper exponential increase in TDS is observed along the Euphrates River at the present, where salinity increases from under 300 mg/L downstream of the Atatürk Dam to over 3,000 mg/L in Samawah and Nasiriyah ⁽⁸⁾. Now, the salinity in Nasiriyah approaches 4000 mg/l and it is about 1850 mg/l in Amarah (Fig. 3). In Shatt al-Arab delta, decreased instream freshwater discharge permits severe seawater tidal intrusion from the Arabian Gulf, pushing TDS levels past 10,000 mg/L during low-flow periods and triggering public health emergencies in Basrah (Fig. 4, Table 3) ^(13, 22). Salinity in the Tigris River has risen sharply over the decades, increasing from under 600 ppm (parts per million) historically to over 1000 ppm in downstream areas by the mid-1980s and continuing to worsen significantly into 2025.

Figure 4: Variation of salinity along Shatt al-Arab River

Table 3: Spatial Salinity Trends Along Mainstream

4.3 Climate Change Impacts and Transboundary Burden-Sharing

Regional climate change modeling studies indicate rising mean temperatures, declining snowpack accumulation in the high-altitude Anatolian headwaters, and an increased frequency of prolonged droughts across the Tigris-Euphrates Basin ^(15, 18). These hydro-climatic shifts significantly reduce overall surface water availability for all riparian states ⁽²³⁾. However, under rigid or non-existent allocation regimes, downstream Iraq disproportionately absorbs these impacts as the terminal basin recipient ⁽²⁴⁾.

When upstream reservoirs retain water during multi-year droughts to meet domestic quotas, downstream inflows drop below ecological and municipal survival thresholds ⁽⁵⁾. Sustainable governance requires transitioning from fixed volumetric allocations to climate-sensitive hydrological modeling that operationalizes mutual risk and damage sharing ⁽¹⁵⁾. Incorporating dynamic, percentage-

based allocation rules during drought years ensures that climate-induced water deficits are distributed equitably across all basin countries rather than shifting the full burden of scarcity onto downstream populations ⁽¹¹⁾.

5. Local Sub-Systems and Watershed Management

5.1 Mesopotamian Marshlands Ecological Security

The Mesopotamian Marshlands (Central, Hammar, and Hawizeh marshes) represent a crucial ecological and socio-cultural sub-system within the lower basin (Fig. 1) ⁽¹⁸⁾. Following severe anthropogenic drainage in the 1990s, re-flooding efforts initiated after 2003 achieved partial ecological recovery ⁽¹⁸⁾. However, sustained restoration remains highly vulnerable to upstream flow regulation, climate variability, and internal water allocation decisions ^(15, 18). Political leadership in Iraq must establish guaranteed baseline environmental flow allocations (e-flows) derived from climate-sensitive hydrological modeling to maintain marsh biodiversity, sustain indigenous Marsh Arab livelihoods, and prevent catastrophic ecosystem collapse ⁽¹⁸⁾.

5.2 Internal Watershed Conservation: Al-Adhaim Tributary

Internal watershed management is equally critical for mitigating water scarcity ⁽¹⁶⁾. The Al-Adhaim River Basin a key left-bank tributary of the Tigris located entirely within Iraq demonstrates the severe consequences of land degradation and lack of localized soil conservation policies ⁽¹⁶⁾. High rates of soil erosion, driven by sparse vegetation cover and intense convective rainfall, lead to severe reservoir siltation at the Al-Adhaim Dam, reducing its active storage capacity and compounding regional water supply stress ⁽¹⁶⁾. Addressing these internal ecological crises requires proactive domestic leadership and data-driven watershed management strategies ⁽¹⁷⁾.

6. Strategic Framework: Data-Driven Leadership and Water Diplomacy

To reverse environmental degradation and mitigate conflict risk, political leaders across the Tigris-Euphrates Basin must transition from reactive crisis management to proactive, institutionalized water diplomacy anchored in climate-sensitive data ^(1, 2). A comprehensive governance strategy must encompass legal, technical, and economic interventions (Table 4) ⁽¹⁷⁾.

Table 4
Strategic Leadership Domains and Operational Governance Benefits

Domain	Specific Leadership Action	Expected Water & Governance Benefit	Key References
Transboundary Diplomacy	Establish permanent, binding Basin Treaty with joint real-time data sharing.	Guarantees equitable allocations, reduces geopolitical friction, and standardizes dam operational rules.	Kibaroğlu, 2015; Al-Ansari, 2019
Climate Burden-Sharing & Scarcity Governance	Adopt dynamic, percentage-based reservoir release mechanisms linked to climate-sensitive hydrological indices during low-flow years.	Distributes climate-induced water deficits equitably across all riparians, preventing downstream water collapse in Iraq during droughts.	Adamo & Al-Ansari, 2018; Al-Ansari, 2025
Domestic Irrigation	Convert flood irrigation to drip/sprinkler networks; canal lining. apply DSS for optimal water management.	Reduces agricultural water demand by 30–50%, increasing instream flows.	Adamo, 2015; Al-Ansari & Adamo, 2024;AL-Hudaib ,Adamo, Bene, Ray &Al-Ansari ,2025
Economic Integration	Adopt Virtual Water Trade frameworks; joint energy-water markets.	Optimizes regional resource allocation and builds economic interdependencies.	Adamo et al., 2023
Technology & Supply	Deploy solar-powered desalination and municipal wastewater reuse.	Diversifies supply, secures coastal drinking water, and restores downstream flow regimes.	Akshay, 2023; Al-Ansari et al., 2023

6.1 Modernizing Domestic Water Governance (IWRM)

Downstream states, particularly Iraq, cannot effectively negotiate transboundary allocations without first reforming domestic water usage through data-driven IWRM practices ^(9, 11):

- **Infrastructure Rehabilitation:** Transitioning from traditional surface flood irrigation to modern pressurized systems (drip and sprinkler) to drastically increase water-use efficiency ⁽¹¹⁾.
- **Conveyance Modernization:** Lining open irrigation canals and enclosing water conveyance conducts to reduce high evaporative and seepage losses ⁽⁹⁾.
- **Regulatory Enforcement:** Enforcing strict anti-pollution laws to prevent raw municipal sewage and industrial effluent from entering main river channels ⁽²⁰⁾.
- **Water Management:** Developing and applying modern water management procedures by installing and using Decision Support Systems (DSS) for optimal allocation of water reducing water waste

6.2 Trade-Based Benefit Sharing and Virtual Water

Political leadership should leverage economic mechanisms to reframe transboundary water management from a zero-sum territorial dispute into a win-win economic opportunity⁽²⁵⁾. Implementing Virtual Water Trade strategies where water-scarce downstream riparians import water-intensive agricultural crops (e.g., rice, wheat) while exporting high-value goods or energy services can dramatically reduce domestic agricultural water demands ⁽²⁵⁾. Collaborative economic integration between Turkey, Syria, Iraq, and Iran provides the structural foundation for sustainable transboundary peacebuilding ⁽²⁵⁾.

6.3 Non-Conventional Water Augmentation

Mitigating structural supply deficits requires expanding non-conventional water resources ^(25, 26). Large scale investments in solar powered seawater desalination along the Gulf coast can secure drinking water supplies for Basrah and southern urban centers, relieving pressure on upstream freshwater releases (26). Additionally, expanding municipal wastewater treatment and recycling systems can supply industrial and agricultural sectors with reliable alternative water streams⁽²⁵⁾.

Table 4: **Strategic Leadership Domains and Operational Governance Benefits**

7. Strategic Roadmap for Regional Governance

Achieving sustainable transboundary water security requires a phased execution plan that links political leadership commitments with technical hydrological milestones over immediate, medium-term, and long-term horizons (Table 5) ⁽¹⁷⁾.

Table 5
Phased Implementation Roadmap for Peacebuilding and Governance

Phase / Horizon	Key Leadership & Technical Objectives	Target Outcomes & Institutional Deliverables
Immediate Phase (1–3 Years)	• Establish real-time hydrologic and climate data exchange protocols between riparians (Kibaroğlu, 2015). • Finalize emergency interim flow agreements and define shared drought thresholds (Al-Ansari, 2019). • Enforce strict domestic anti-pollution regulations in all basin reaches (Al-Ansari et al., 2019b).	Restores basic diplomatic trust; establishes an immediate interim protocol for proportional release reductions during drought years; mitigates acute urban water crises in Basrah.
Medium-Term Phase (3–7 Years)	• Modernize downstream agricultural infrastructure (drip irrigation, canal lining) (Adamo, 2015). Initiate procedures for the application of DSS and automation • Construct large-scale solar-powered desalination plants in southern Iraq (Akshay, 2023). • Integrate basin-wide climate change forecasting models into shared dam operational plans (Adamo et al., 2022). • Implement joint sediment management plans in sub-basins (e.g., Al-Adhaim) (Al-Ansari et al., 2025).	Saves significant agricultural freshwater volume; secures coastal domestic drinking water; operationalizes joint drought-response management among riparians; reduces dam siltation.
Long-Term Phase (7–15 Years)	• Negotiate and ratify a binding, multilateral Transboundary Basin Treaty with equitable climate-damage sharing provisions (Kibaroğlu, 2015; Al-Ansari, 2025). • Establish a permanent, empowered Tigris-Euphrates River Basin Commission (Al-Ansari, 2019). • Institutionalize regional Virtual Water Trade and joint energy-water markets (Adamo et al., 2023).	Ensures equitable and reasonable water allocation; institutionalizes climate-adaptive allocation formulas so Iraq does not bear the sole brunt of drought; secures long-term ecological e-flows; locks in regional hydro-peace.

Table 5: Phased Implementation Roadmap for Peacebuilding and Governance

8. Conclusion

The Tigris-Euphrates River Basin stands at a critical juncture. The historical paradigm of unilateral water infrastructure development, hydro hegemonic dominance, and reactive crisis management is no longer sustainable under compounding hydro-climatic stress and regional demographic growth. The physical degradation of the basin manifested in declining river flows, severe salinization, aquifer exhaustion, and wetland loss ultimately a symptom of political and institutional failure.

Transforming transboundary water conflict into cooperation demands courageous, visionary political leadership across Turkey, Syria, Iraq, and Iran. By integrating climate-sensitive hydrological modeling and data-driven decision-making into governance, political leaders can shift from zero-sum hydro-nationalism to joint basin management. Crucially, future regional agreements must explicitly address climate change impacts on available surface water, incorporating provisions for shared damage during dry years so that downstream Iraq as the end receiver is not forced to absorb the entirety of climate-induced scarcity alone. The strategic roadmap outlined in this paper provides an actionable pathway for decision makers to transform shared water vulnerabilities into a catalyst for sustainable development and transboundary hydro-peace.

Declarations

Competing interests

No relevant financial or non-financial interests to disclose.

Ethical Approval

The manuscript is original work except where indicated and does not infringe on third-party copyrights.

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Author Contribution

Conceptualization, Nadhir Al-Ansari, Nasrat Adamo and Salwan Ali Abed methodology, Nadhir Al-Ansari, Nasrat Adamo validation, Nadhir Al-Ansari, Nasrat Adamo and Salwan Ali Abed investigation, Nadhir Al-Ansari, Nasrat Adamo and Salwan Ali Abed data curation, Nadhir Al-Ansari, Nasrat Adamo writing—original draft preparation, Nadhir Al-Ansari, Nasrat Adamo and Salwan Ali Abed visualization, Nadhir Al-Ansari, Nasrat Adamo and Salwan Ali Abed project administration, Nadhir Al-Ansari All authors have read and agreed to the published version of the manuscript

Data Availability

Data will be available on request

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Figures

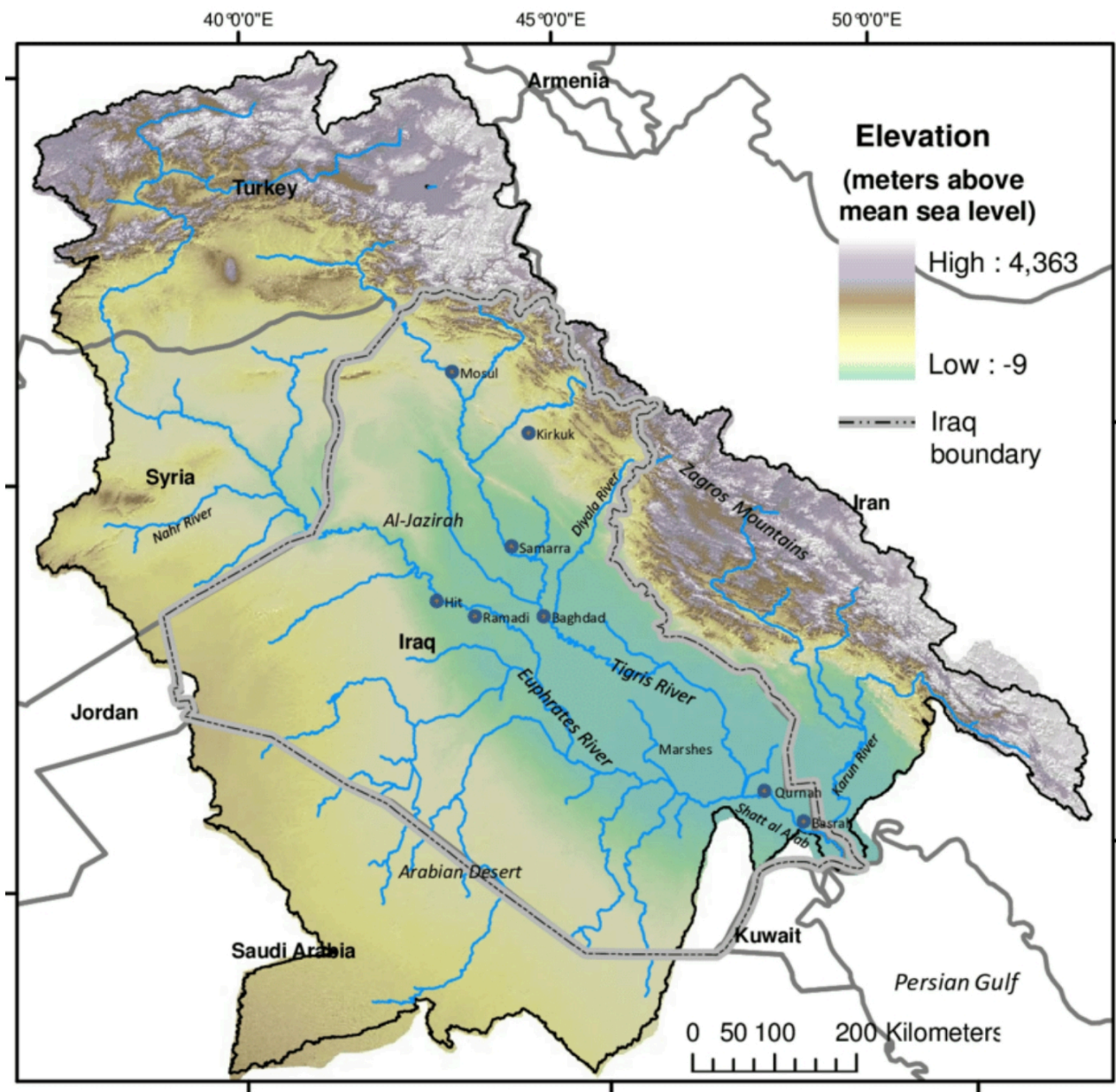


Figure 1

Tigris and Euphrates basin

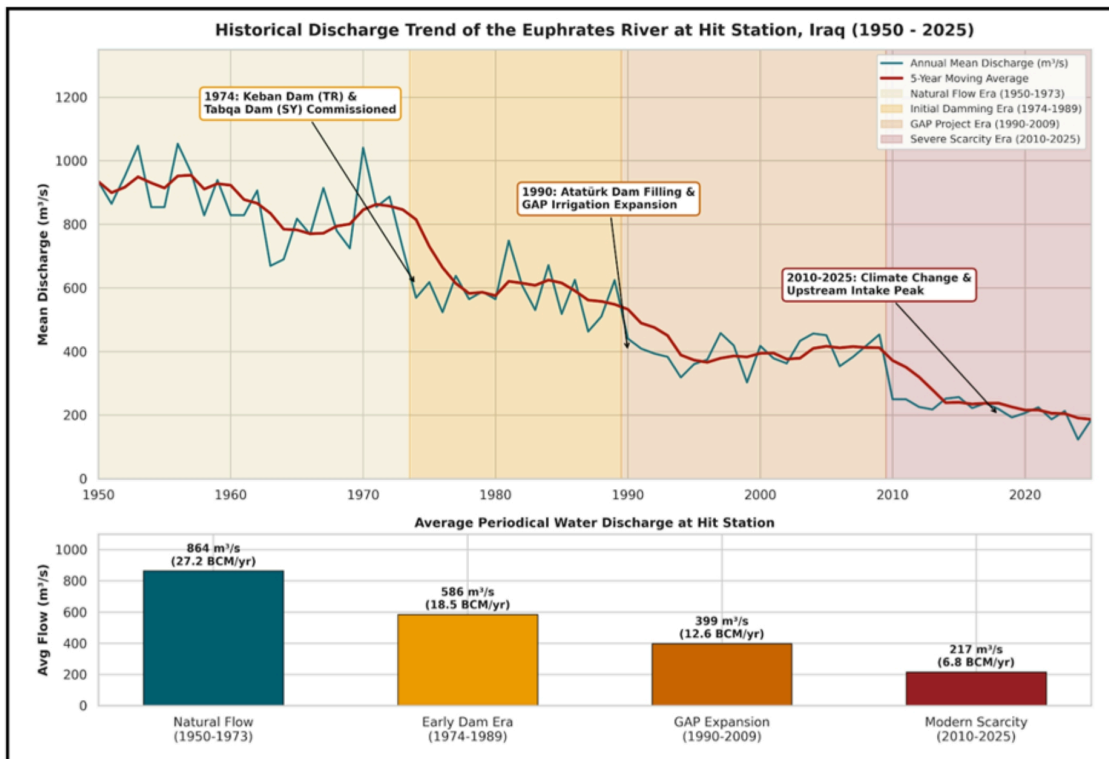
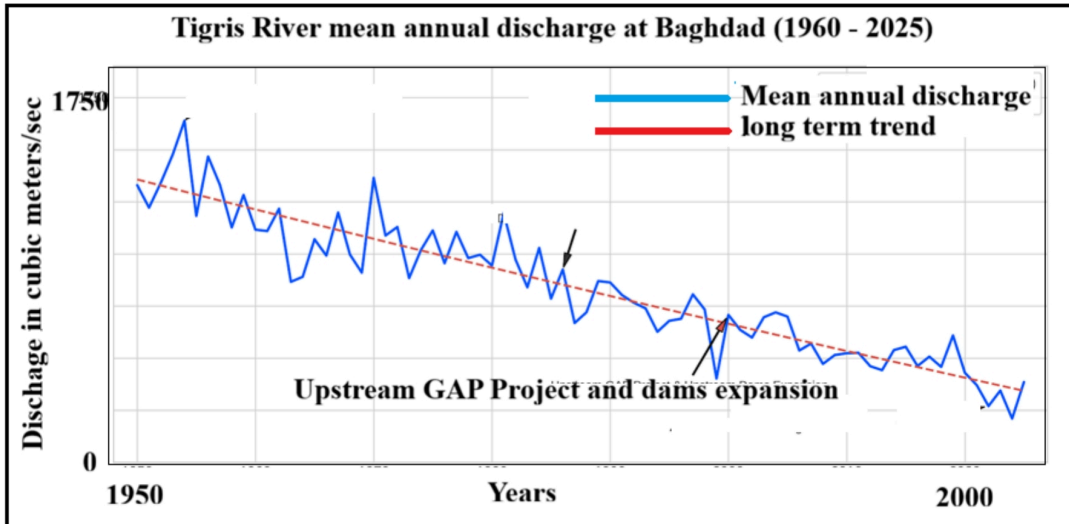


Figure 2

Mean annual discharge of rivers Tigris and Euphrates

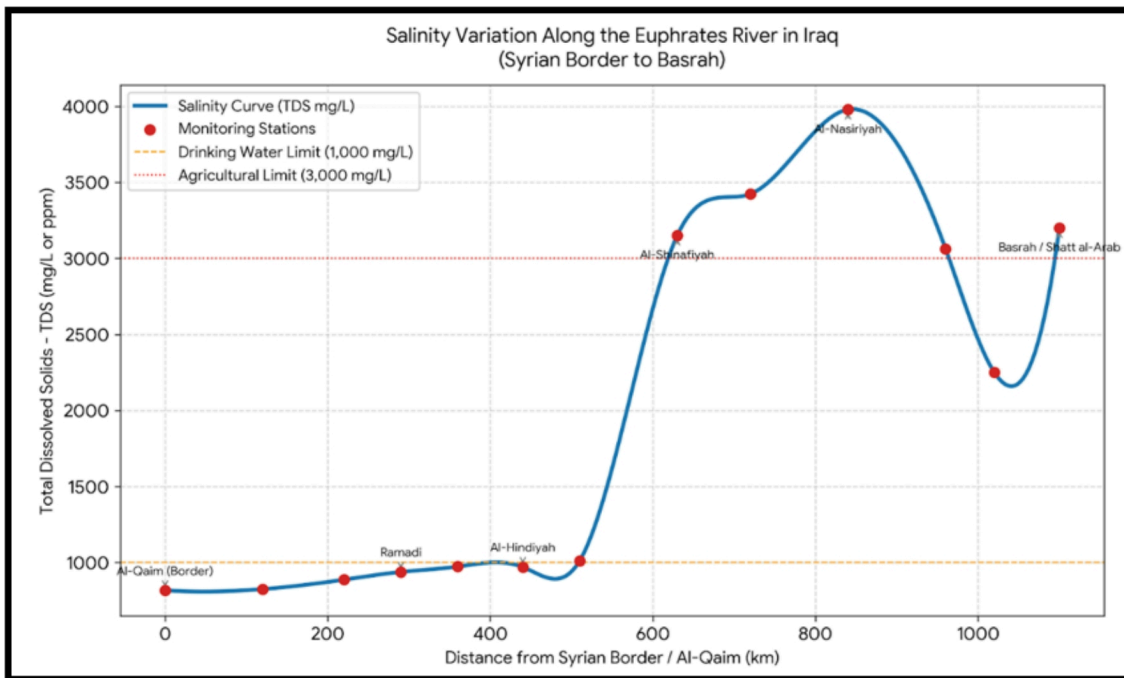
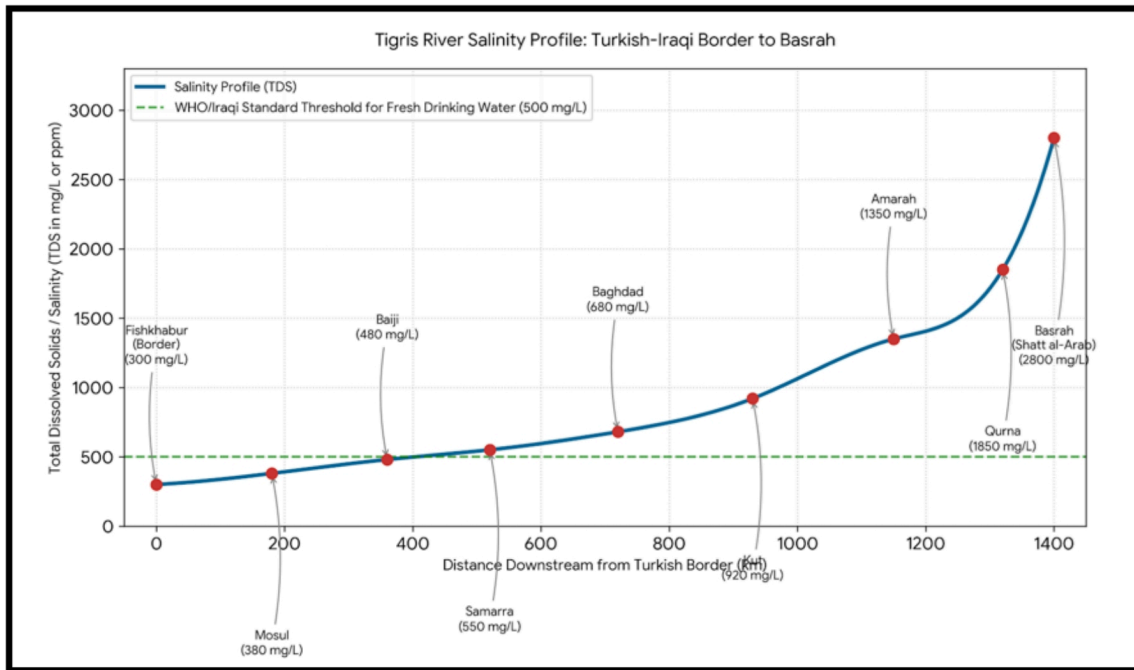


Figure 3

Variation of salinity along Tigris and Euphrates Rivers

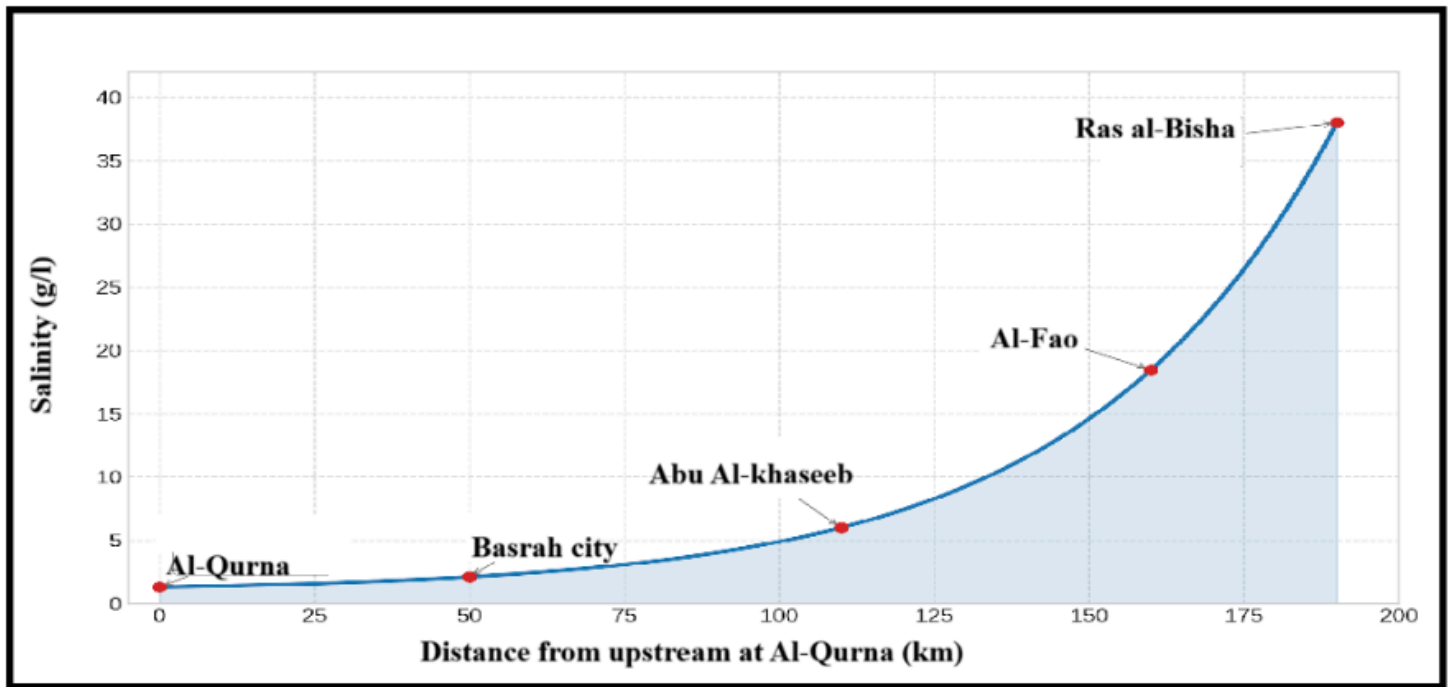


Figure 4

Variation of salinity along Shatt al-Arab River