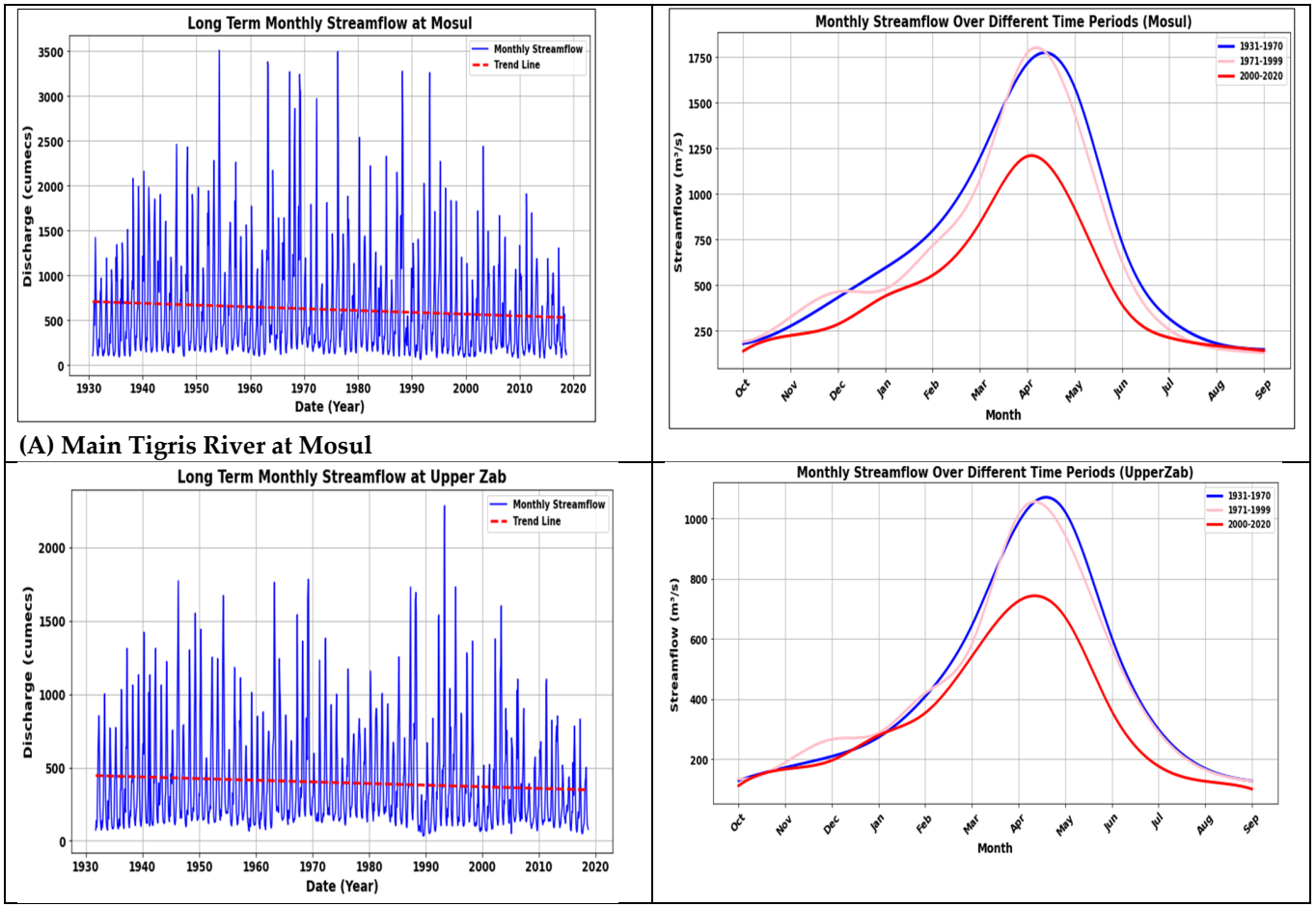
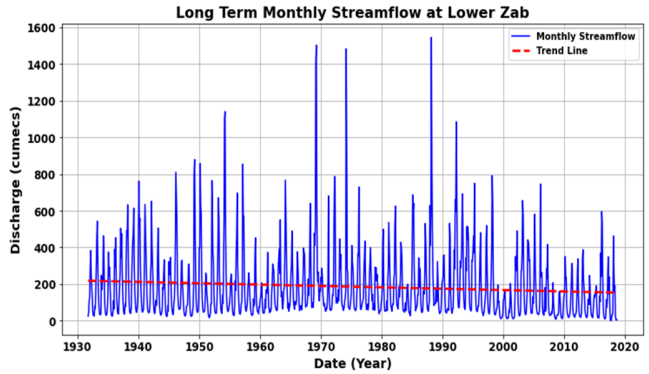
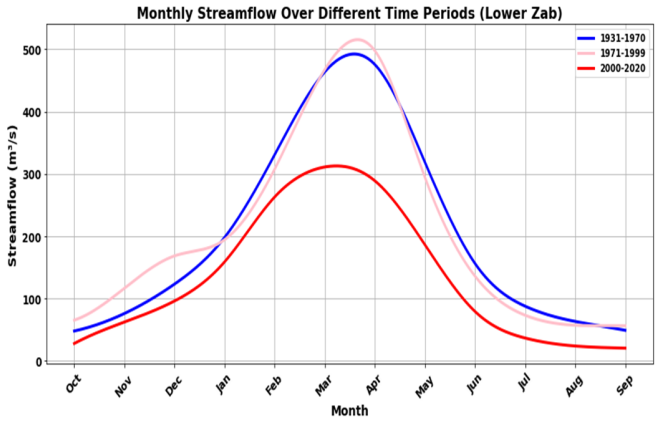
Supplementary Materials:

Figure S1: Long-Term Monthly Discharge at Key Stations for Various Historical Periods (1933–2022) in Iraq: (A) Mosul, (B) Upper Zab, (C) Lower Zab, (D) Diyala, (E) Baghdad, (F) Kut on the Tigris River and Its Tributaries, and (G) Hit- Haditha on the Euphrates River.

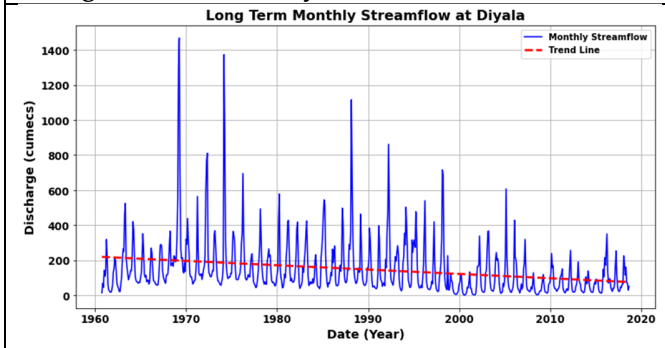


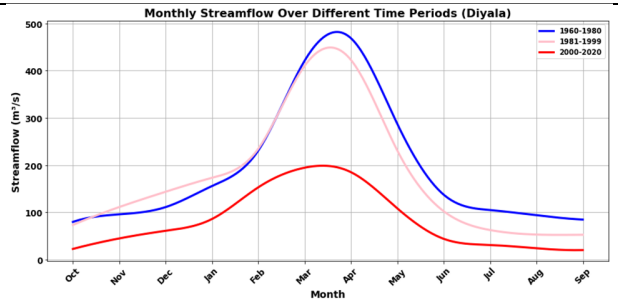
(B) Tigris River Tributary at Upper Zab River



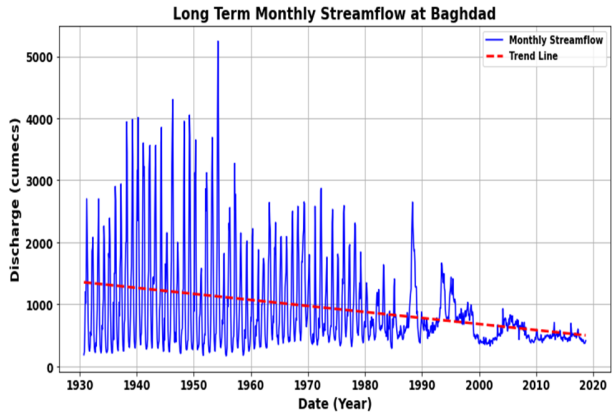


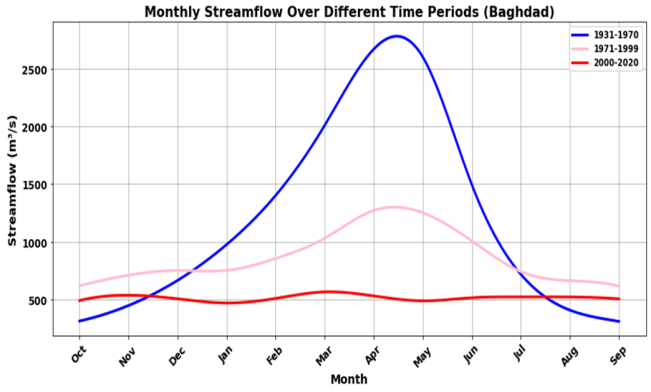
(C)Tigris River Tributary at Lower Zab River





(D) Tigris River Tributary at Upper Diyala River





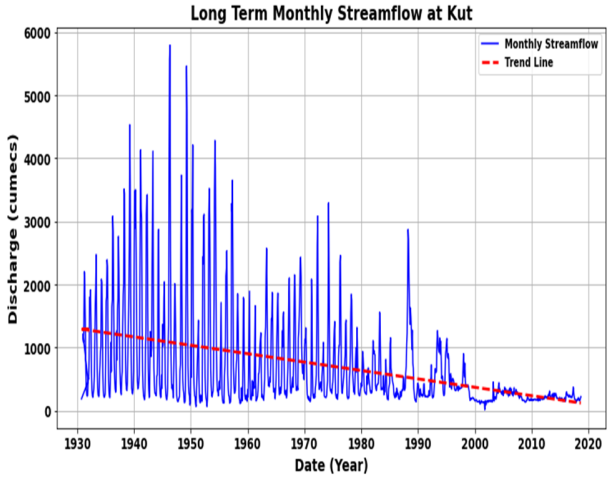
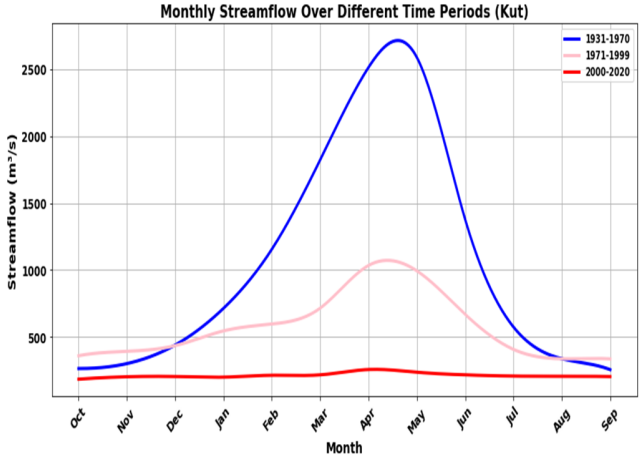
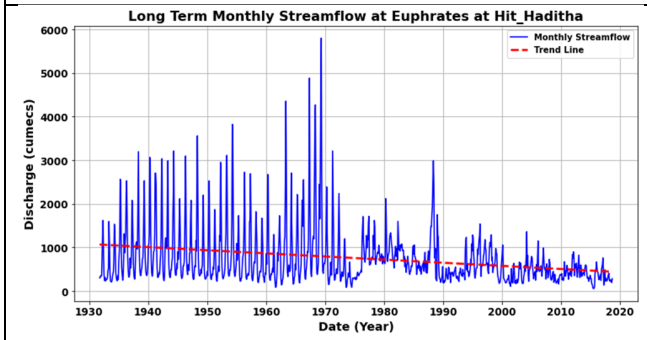
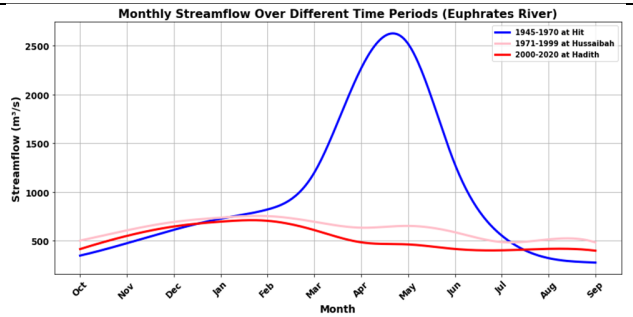
(E) Main Tigris River at Baghdad	
	
(F) Main Tigris River at Kut	
	
(G) Euphrates River at (Hit and Haditha)	

Table S1: Multi-Hazard Matrix with DSS-DPSIR Integration, Iraq.

No.	Hazard	Likelihood (1–5)	Impact (1–5)	DSS Response Measures	Risk Score (Severity)	DSS Link / DPSIR Element	Strategic Risks if Unaddressed	Required Response Measures
1	The Delay to implement the national water strategy investment plan (2025–2050)	4	5	Integrate project tracking dashboards, investment alerts, and implementation timelines into the DSS; monitor sector compliance and performance across all ministries.	20 (Extreme)	Driving Force / Response: Represents overarching institutional and governance challenges that hinder strategic implementation, highlighting the need for coordinated policy responses, multi-sectoral integration, and investment planning mechanisms.	Institutional fragmentation, delayed policy reforms, misalignment among water-using sectors, suboptimal resource utilization, and an increasing disparity between water supply and demand.	Ensure committed financial allocations for strategy implementation; mandate all water-using sectors to align with the development plan; enforce national water laws; empower the Iraqi Federal Water and Environment Council (IFWEC) to lead coordination, oversight, and DSS integration for evidence-based planning and monitoring.
2	Reduced inflow from Transboundary Riparian Countries (no binding agreements)	5	5	Incorporate transboundary inflow monitoring and predictive modeling into the DSS to simulate upstream water scenarios and support negotiation frameworks.	25 (Extreme)	Pressure – Represents external water withdrawals or flow alterations beyond Iraq's control, exerting significant stress on national water availability.	Long-term reduction in strategic water availability	Negotiate binding international water treaties; align water-sharing discussions with broader security, energy, and economic cooperation; activate the Iraqi Supreme Water Council (ISWC) to lead diplomacy; leverage DSS outputs

								to support technical claims, assess vulnerability, and guide long-term cooperation mechanisms.
3	Recurrent seasonal droughts and summer water scarcity	5	4	Integrate seasonal drought forecasts, real-time monitoring, and early warning modules into DSS; support drought contingency planning and water allocation modeling.	20 (Extreme)	Pressure / State: Seasonal droughts function as recurring climatic pressures that significantly alter the hydrological state of river basins, reducing flow reliability, water availability, and system resilienc	Increased frequency of water crises, growing rural-to-urban migration, reduced agricultural productivity.	Develop a national drought strategy with early warning systems, seasonal water allocation priorities, multi-objective reservoir operations, and DSS-based demand forecasting.
4	Groundwater over-extraction without regulation	5	5	Integrate groundwater abstraction monitoring, aquifer depletion indicators, and recharge planning modules within DSS.	25 (Extreme)	State / Pressure: Over-extraction excessive pressure on the system and directly alters groundwater status (state).	Depletion of aquifers, land subsidence	Establish a legal and regulatory framework for groundwater abstraction; enforce licensing and monitoring; incorporate aquifer behavior into DSS for sustainable management.
5	Lack of flood risk preparedness and control infrastructure	4	5	Use hydrologic/hydraulic modeling to design flood mitigation plans	20 (Extreme)	State / Impact: Utilize hydrologic and hydraulic modeling within DSS to identify flood-	DSS supports flood planning by modeling flood risks, informing mitigation strategies, and enhancing preparedness and response coordination.	Develop and implement a national flood risk management plan; construct multipurpose flood control infrastructure; use DSS to simulate

						plan and innundation areas, design mitigation strategies, and support emergency planning.		flood response and optimize mitigation investments.
6	Deterioration of Restored Marshlands and Wetlands and Shatt Al-Arab Saltwater Intrusions	4	5	Monitor marshland extent and progress of restoration using satellite data and remote sensing; assess ecological flow requirements through DSS-integrated tools.	20 (Extreme)	Impact: Captures ecosystem degradation from reduced freshwater inflows and saline intrusion, affecting environmental and human systems.	Loss of biodiversity, collapse of ecosystem services, degradation of water quality, displacement of local communities, and deterioration of internationally protected sites.	Reintroduce and regulate environmental flows to maintain wetland balance; implement restoration and conservation programs for marshlands; mitigate Shatt Al-Arab saltwater intrusion through upstream flow regulation and salinity monitoring; and protect Ramsar-listed wetlands using DSS-informed ecological planning and flow modeling.
7	Pollution from Untreated Wastewater and Agricultural Return Flows (including the Main Outfall Drain)	4	4	Expand wastewater treatment infrastructure; link discharge monitoring to DSS for real-time tracking and compliance assessment.	16 (Very High)	Pressure / State: Expand wastewater treatment infrastructure; link discharge monitoring to DSS for real-time tracking and compliance assessment.	Worsening surface and groundwater quality, increased public health risks, contamination of irrigation water, and environmental degradation.	Enforce effluent treatment for all sectors; monitor discharges—including from the MOD—via DSS-linked water quality sensors; reuse treated water for green belts around cities to support environmental resilience.

8	Degraded Irrigation Systems and Reclamation Project	3	4	Utilize DSS to assess irrigation system performance, identify efficiency gaps, and prioritize rehabilitation areas; support phased investment planning within a national irrigation strategy.	12 (High)	State: Reflects the deteriorated condition of infrastructure impacting water use efficiency and agricultural productivity.	Continued water losses, low irrigation efficiency, reduced agricultural yields, and mounting maintenance costs.	Formulate a national strategy for the rehabilitation, improvement, and reclamation of irrigation projects; allocate dedicated financial resources; adopt smart technologies (e.g., sensors and automation); and link planning, monitoring, and investment decisions with DSS outputs
9	Reduced Reservoir Efficiency and Underutilization of Rainwater Harvesting and Groundwater Recharge Opportunities	4	4	Use DSS to assess reservoir storage efficiency, simulate sedimentation and evaporation losses, and optimize multi-reservoir operations and recharge planning.	16 (Very High)	State: Use DSS to assess live reservoir storage performance, evaluate sedimentation and evaporation impacts, simulate multi-reservoir operation strategies, and identify recharge and harvesting potential.	Declining reservoir performance, reduced water security for downstream users, inefficient dam operations, and loss of long-term storage capacity.	Implement dam rehabilitation and improvement programs; adopt evaporation control and sediment management measures; assess rainwater harvesting potential through small and medium dam projects; enhance managed aquifer recharge to reduce unsustainable groundwater abstraction; and use DSS to guide investment and operational decisions.
10	Institutional, Legal, and Economic Gaps in Water Governance	4	3	Use DSS platforms to coordinate cross-sectoral planning,	12 (High)	Response: Highlights the institutional,	Ongoing governance fragmentation, conflicting sectoral policies,	Establish a unified national water governance body;

	and Water Productivity			ensure transparency in water allocation, support cost-effectiveness analyses, and improve water productivity metrics.		legal, and economic reforms needed to strengthen integrated water management in Iraq.	inefficient resource allocation, low return per unit of water, and delayed reforms.	enact and enforce updated water legislation; mainstream economic valuation of water resources; promote equitable cost recovery; and adopt water productivity indicators to enhance decision-making. Integrate all planning and monitoring efforts through DSS to support transparent, evidence-based, and participatory water governance.