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Article

An integrated urban water resources management approach for infrastructure and urban planning

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Abstract: Transportation projects are crucial for the overall success of major urban, metropolitan, regional, and national development according to their capacity by bringing significant changes in socio-economic and territorial aspects. In this context, sustaining and developing economic and social activities depend on having sufficient Water Resources Management. This research helps to manage transport project planning and construction phases to analyze the surface water flow, high-level streams, and wetland sites for the development of transportation infrastructure planning, implementation, maintenance, monitoring, and long-term evaluations to better face the challenges and solutions associated with effective management and enhancement to deal with Low, Medium, High levels of impact. A case study was carried out using the Arc Hydro extension within ArcGIS for processing and presenting the spatially referenced Stream Model. Geographical information systems have the potential to improve water resource planning and management. The study framework would be useful for solving water resource problems by enabling decision makers to collect qualitative data more effectively and gather it into the water management process through a systematic framework.

Keywords: integrated water resources management; urban water system integration; geographical information systems; hydro tool

1. Introduction

Theories and political frameworks for comprehending change in cities, the environment, policy, and infrastructure influence the form of study and activity. Integrated water management, sustainable water management, water-sensitive cities, and other formulations are often presented as the latest in a series of paradigms of water management [1]. A series of challenges has led to the continual evolution of the water management field. Practitioners and scholars have been promoting the need for a new "integrated" and "sustainable" water management paradigm. Such a paradigm is broadly defined to include many different objectives and methods. Integrated approaches, in different forms and identified by different names, have gradually become widespread in the field of water management over the past few decades [2].

The literature has a variety of terminologies that, when applied to urban water management, have definitions similar to IUWM. Integrated water cycle management, comprehensive water management, integrated urban water resource management, and integrated water cycle management are some of these terms. The IUWM idea is comparable to integrated water resource management (IWRM), which was first introduced by the UN in 1992. The application sector and spatial size are the main distinctions between IUWM and IWRM. The IUWM strategy focuses on managing water resources sustainably in urban environments, including stormwater, wastewater, and water supply. A multidisciplinary method for managing water and related resources, integrated water-resources management (IWRM) connects the multiple levels at which management occurs. The study commences with an examination of comprehensive methods for managing water resources at many scales, such as basin management, agricultural water management, watershed management, national policies and governance, and global decision-making [3].

The IWRM concept is separated by three levels of definition: (1) IWRM as a "principle" suggests balancing the social, economic, and environmental aspects of water resources. (2) The IWRM implementation's methodological components are referred to as a "framework" in this context. (3) IWRM as a "process," often called a "policy," that is predicated on a learning process [4].

The capacity to create plans and the authority to carry them out are prerequisites for spatial planning. Different planning agencies (national, regional, and local) are able to "establish visions and scenarios for the future, carry out urban projects, write policies, strategize to deal with emergent opportunities and problems, and design specific aspects in detail" thanks to the force of statutory decision-making powers. Spatial planning may control the kind, location, timing, and urban design of water-using activities in urban environments, as well as the corresponding infrastructure requirements [5].

Developments affecting water resources and efficient integrated water resources management (IWRM) are acknowledged as essential elements of environmentally sustainable development [6]. The following definition of IUWM has been approved by a number of prominent organizations, most notably the World Bank and the Global Water Partnership: A set of guidelines known as integrated urban water management (IUWM) supports more efficient, adaptable, and sustainable methods for managing resources. This approach takes into account water sources, water use sectors, water services, and water management scales. It seeks to protect, conserve, and use water at its source; it recognizes alternative water sources; it makes a distinction between the attributes and potential applications of those sources; it views the storage, distribution, treatment, recycling, and disposal of water as components of the same cycle of resource management; and it considers non-urban users who rely on the same source, harmonizes formal institutions (organizations, laws, and policies) with informal practices (norms and conventions) that govern water in and for cities, acknowledges the connections between water resources, land use, and energy, concurrently pursues economic efficiency, social equity, and environmental sustainability, and encourages participation by all stakeholders [2].

The water management performances are evaluated using the City Blueprint Framework. When it comes to comparing cities in terms of the sustainability evaluation of their IWRM, the City Blueprint is a useful and efficient tool. There are 24 performance metrics in the City Blueprint, which can be divided down into seven categories: (I) standard water utilities, (II) quality of the water, (III) water infrastructure, (IV) treatment of waste water, (V) solid waste, (VI) climate change mitigation, and (VII) plans and activities [7].

Analyzing the performance of the entire metropolitan water system across a variety of areas, including hydrological, ecological, engineering, social, economic, and environmental, is known as integrated systems analysis [3].

The first step in deciding on goals is identifying an issue, which is then turned into a "problem statement." For considering the IUWM approach, Measures are required according to the IUWM objectives. From an economic point of view, examples of measures can include net present value, annualized capital value, infrastructure operation, maintenance, and replacement costs, as well as community benefits including returns on investment, externalities, and regional economic growth. From an environmental point of view, example measures can be listed as: urban streams and rivers' environmental flows; the quality of the contaminants' water levels in these waterways and rivers; changes to the local environment's biodiversity and habitats; energy consumption emissions of greenhouse gases Examples of social measures include the following: the quality of drinking water; the extent of flood mitigation and protection; hygiene; supply stability, accessibility, and fairness; the provision of drainage and wastewater services; the recreational and amenity features of green places and waterways; domestic gardening; Level of public involvement in the decision-making process [3].

As a case study of the Mediterranean region, Leeuwen [6] conducted a baseline evaluation of Istanbul's integrated water resources management (IWRM). Included in the European Innovation Partnership on Water of the European Commission, it is a component of the City Blueprint Action Group's water governance initiative. As a first step toward better understanding IWRM and the difficulties ahead, the City Blueprint indicator methodology and process have been adopted.

The concepts of Yellow and Blue Footprints were created as part of the "Blue Cities" project, "Blue for Smart Cities Footprint: A Method for Integrating the Water and Waste Sectors within the Framework of EIP Smart Cities and Communities." [8]. In the mentioned study, blue footprint and yellow footprint values were calculated for Istanbul province. Blue Footprint considers water quality, solid waste disposal, basic water services, wastewater treatment, infrastructure, climate change durability, and water management parameters, while Yellow Footprint considers parameters such as energy, transportation, information, and communication technologies. These are definitions that digitize through indicators for smart city applications.

Basic Water Services, Infrastructure and Water Management categories were selected from blue footprint findings, and transportation, information, and communication technologies were selected from yellow footprint findings for our study's initiative contents. The scores of the indicators calculated for Istanbul are shown in **Table 1**.

Table 1. Category-based indicators and points for Istanbul.

	Category	Number	Indicator	Point
Blue footprint	Basic Water Services	7	Access to drinking water	10
		8	Access to clean drinking water	10
		9	Drinking water quality	10
	Infrastructure	14	Average sewerage	8
		15	Operating cost recycling	3.6
		16	Water leaks	5
		17	Rainwater split systems	2.4

Table 1. (*Continued*).

	Category	Number	Indicator	Point
	Water Management	22	Management and implementation plans	4
		23	Public participation	2
		24	Measurement of water efficiency	4
		25	Attraction of water	7
Yellow footprint	Transportation	8	Commuting time	3.5
		9	Use of public transportation	0
		10	Bicycle network	0.3
		11	Transportation accidents	10
		12	Use of clean energy in transportation	6
		13	Pollution from transportation	10
		14	Transportation infrastructure investments	0
	Information and communication technologies	15	Access to information and communication technologies	5
		17	Use of information and communication technologies in the field of water services	8.3
		19	Use of Information and communication technologies in the field of transportation services	7.8
		22	Information and communication technologies infrastructure investments	7.2

2. Urban water systems integration

Urban water systems integration is defined as "the physical, social, and institutional interlinking of the urban water system with other urban systems." Urban water systems integration is distinguished by four types of geographical, physical, informational, and project-based systems integration, as shown in **Table 2**.

Table 2. Features of the various kinds of urban water system integration [9].

	Type of systems integration	Object of integration	Description	
1	Geographical	Space	Urban systems' spatial alignment in the same region	The goal of geographic systems integration is to prevent (undesired) interference between various urban infrastructure systems by arranging them spatially aligned.
2	Physical	Resources	Using a resource jointly for several purposes	When there is resource-based integration, the output– or product—of one system is necessary for the operation of another, or input.
		Infrastructures	Shared use of an infrastructure system	When two infrastructures are integrated based on their mutual use, each infrastructure performs its own role.
3	Informational	Data	Utilizing information from various urban systems to run such systems	Information systems integration, sometimes known as smart-city or digital-city efforts, is predicated on merging data from various urban systems.
4	Project-based	Planning	Plans for building and repair that are in line with several urban systems	The goal of project-based systems integration is to identify potential areas of overlap between the design and rehabilitation of urban infrastructure systems. This includes scheduling maintenance and replacement projects for various infrastructures such that they occur concurrently or right after one another, for example.

Recently, several nations have turned their attention to the management of water resources. The world's water and energy usage has grown over the past century. It is expected that this trend will persist in the ensuing decades. The unmanaged industrial operations that are destroying the environment in the name of a higher standard of living are one of the main causes.

Management, technology, green, and governance tools are suggested to organize solutions for floods and storms, lack of safe drinking water, ineffective drainage systems, absence of "green" infrastructure, and deficiency in the wastewater treatment system [10]. For instance, management tools are strategic management tools, foresight projects, scenario building, urban stormwater management systems, flood mitigation systems, and water resources management systems. Governance tools include things like comprehensive wastewater treatment programs with better policies (like effluent standards), frameworks for protecting ecological services at the local and city levels, recommendations for urban drainage, "hydrosocial" connections, standard language for communication, agendas and aspirations for citizen politics, and reasoning processes for making decisions.

In order to implement community goals for water management, an efficient governance model is required. The Victoria State Government proposed a development process prepared by the Department of Environment, Land, Water, and Planning, as shown in **Figure 1**. A cooperative planning strategy known as integrated water management unites organizations that have an impact on several aspects of the water cycle, such as stormwater management, wastewater treatment, alternate and drinkable water supply, water treatment, and waterways and bays.

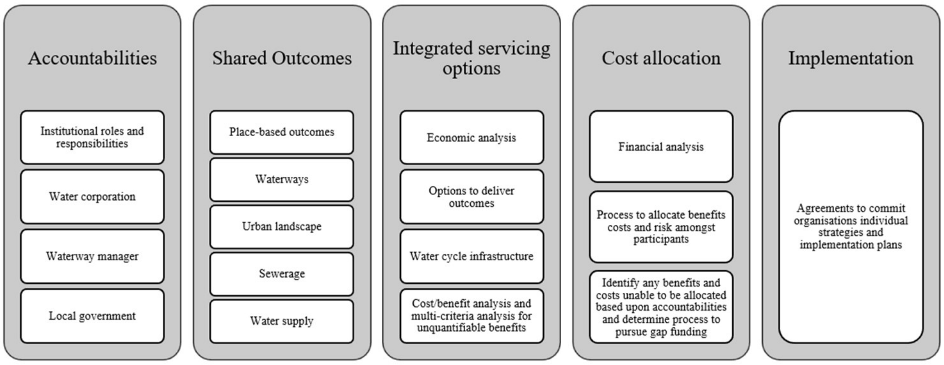

Figure 1. Integrated water management plan development process [11].

The lack of a good national and local database about water resources hinders the creation of management strategies that are effective in Turkey. Insufficient databases prevent monitoring activities. Above all other relevant institutions and organizations, the State Hydraulic Works (SHW) is the top authority in Turkey for the planning, management, development, and operation of water resources [12]. In Turkey, the institutional framework is divided into three levels: user (which includes both governmental and non-governmental organizations involved in project operation and maintenance) and executive (which includes governmental organizations under the ministries and the prime ministry, DPT, and ministries). Despite the existence of a conventional state planning method, the nation as a whole lacks a comprehensive strategy for sectoral and intersectoral water use and management [13].

3. Linking GIS and water resources management models

Systems of water resources can be represented spatially using Geographic information systems. An integrated global picture can be presented via a GIS, which can add spatial dimensions to the conventional water resource data base. This is achieved by merging different environmental, social, and economic aspects pertaining to the spatial components of a water resources issue and making them accessible for utilization in a decision-making procedure [14].

Geographic information systems (GIS) typically integrate hydrologic models together with the corresponding flooding, water pollution transportation, and water supply models for distributed hydrologic stimulations. For hydrological analysis and water resource management in GIS, it is crucial to extract the watershed's features, such as the stream network and catchment delineation. Watershed characteristics, or hydrologic and topographic parameters, can be obtained from digital elevation models (DEMs) and form the basis of these hydrologic models [15].

GIS is a useful tool to integrate with because of its data management, spatial analysis, and visual display capabilities, even if predictive modeling and GIS were not meant to be used together. Creating interfaces or connections between GIS and other watershed models, hydrologic software, and geographic datasets can help enhance the characterization and modeling of watersheds. As an illustration, flood modeling within a watershed can be accomplished by integrating hydraulic models and a GIS [16].

Planning is an essential tool to improve and support operational management and supplies an opportunity to analyze the current condition of the water bodies and the priorities over their use; prepare visions, set targets and goals, and orient the management; produce a structure for organizing law and policy, related research, and public participation; enhance the policy, public acceptance of water allocation, and water control, especially in times of stress; simplify the interaction and coordination among stakeholders and managers; and create a management plan [17].

4. Materials and methods

The following research topics are covered in this paper: (1) an analysis of integrated water resources management (IWRM) and the integration of geographical, physical, informational, and project-based urban water systems; (2) how to describe in a geographic information system (GIS) the data and functions of a model for managing water resources; (3) how to combine analytical operations, data manipulation, and problem definition in a GIS environment; (4) developing a modelbuilder flow for the construction of stream networks; and (5) how to use a geographic information system (GIS) to apply the Arc Hydro model.

4.1. Study area and data materials

Istanbul, which has a surface area of 5340 km^2, is the most populous city in Turkey. Fatih district was selected for a case study for applying the water management model. Fatih district covers an area of 15.62 km^2.

The demographics, average household size, average income, average length of education, average socio-demography, and average socio-economic status indicator points for the Fatih study region are displayed in **Table 3**.

Table 3. Study area population, socio-economic and socio-demographic characteristics.

District name	Population (2019)	Average income ($)	Average household size	Average education time (year)	Socio-demography indicator point	Socio-economy indicator point	Average socio-economic status point
FATIH	443,090	300.55	3.59	8.37	51.30	52.08	45.93

^ 1$ = 8.36 TL.

^ Source: Social vulnerability research report (2018) [18] and Turkish Statistical Institute Data Portal (2019) [19].

Digital elevation models

A crucial dataset for watershed modeling and characterization is elevation or topography data. A raster DEM, a TIN, or vector contour lines are a few examples of the data structures that can be used to describe topographic data. A DEM is conceivably the most widely utilized elevation data model for managing and studying watersheds [16]. The computer depiction of natural topographic characteristics is known as a digital elevation model (DEM). DEMs have been widely used for resource management, earth sciences, environmental evaluations, urban planning, transportation planning, and Geographic Information System (GIS) applications during the past few decades. The hydrologic community is also entering a new phase of leveraging GIS technology for spatially explicit eco-hydrological and hydraulic modeling, where the major and necessary input is the DEM of the area of interest [20].

Digital topographical maps (Contour Lines) obtained from Istanbul Metropolitan Municipality, The Directorate of Geographic Information Systems [21]. The following steps were taken for conversions.

Step: TIN model was created from contour lines shown in **Figure 2**. (Arc Toolbox—3D Analyst—Data Management—TIN—Create TIN)

Step: Raster map was created from TIN model (**Figure 2**). (Arc Toolbox—3D Analyst—Conversion—From TIN—TIN to Raster)

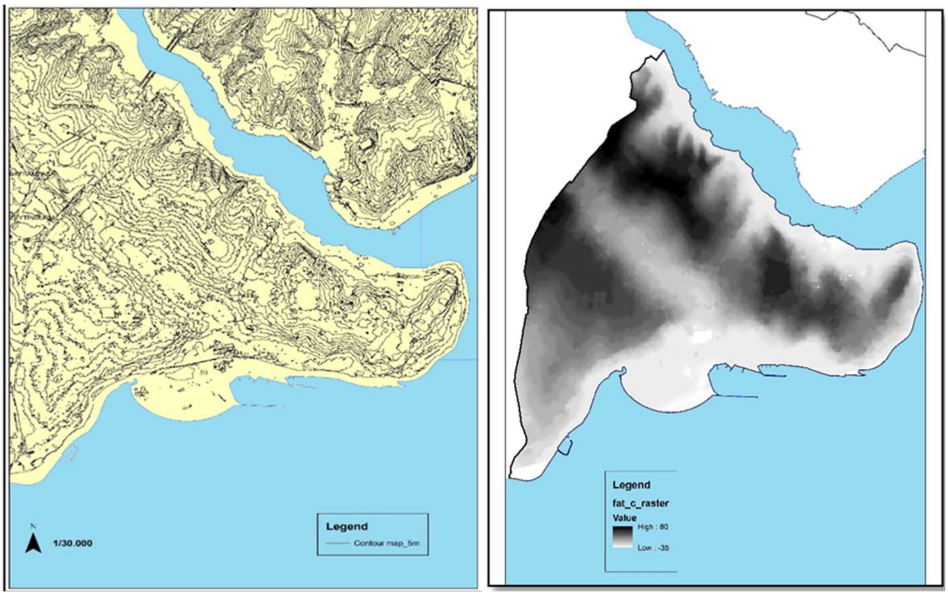

Figure 2. Contour map-raster map for Fatih district.

4.2. ArcGIS Hydro data model

The automated delineation of drainage zones based on a land-surface topographical model is made easier by the Arc Hydro Data Model Toolset. A triangulated irregular network (TIN) or a digital elevation model (DEM) can be used as the model. Arc Hydro is an ArcGIS-based spatial and temporal data model for water resources. Information regarding the network of rivers, watersheds, waterbodies, and monitoring stations is stored in the Arc Hydro framework. It is predicated on notions and ideas that are flexible enough to be developed and tailored to specific uses [22].

The Arc Hydro framework offers a straightforward, compact information structure for storing the most crucial geographic data that characterizes a water resources system. Basic models and studies on water resources can be supported by this framework. A collection of feature classes for water resources (such as watersheds, monitoring points, and classes having point, multipoint, polyline, polygon, annotation, or network features) are defined by Arc Hydro in ArcGIS along with the relationships between these classes, and the data is stored in a geodatabase. A geodatabase is a specialized type of relational database that holds GIS layer spatial coordinate data in a single field within a relational data table. Five categories—network, drainage, channel, hydrography, and time series—are used in the whole model to separate the various components of water resources [23].

The concept and methodology described in this paper are applicable to connecting GIS with models in hydrology fields that have a spatial dimension, and hence GIS can provide a useful data structure as a collection of spatial features and thematic maps. The main watershed features for the Fatih District's catchment area are built using the ArcGIS Geoprocessing model. The ArcHydro tool in ArcGIS was used to produce this model for the Fatih District. Stream Model Flowchart. Geoprocessing and GIS analysis of information-derived data play a crucial role in organizing the GIS as a whole. A mechanism for structuring transactions is provided by the model builder, which uses geoprocessing procedures to create mixed interactive GIS. The Arctool box tool operates within the ArcGIS geoprocessing utility package. Model builder, designed for applications that require more than one operation by changing and updating the input data used in the models [24].

The following steps were needed to convert the elevation data into flow direction and accumulation data, and finally into streams and watersheds.

(1) step Filling Tool: This method fills sinks in a grid. If cells of higher elevation surround a cell, the water becomes trapped and cannot flow. The fill sink function alters the elevation value to eliminate these issues [25]. Considering the basic fact that water flows downhill, grids with a higher value will flow to grids with a lower value [26].

(2) step Flow Direction: The drainage network cannot be created without flow direction. In this stage, a 3 × 3 grid is created around each cell to determine the direction it travels in. The direction of flow is determined by the lowest value surrounding the cell. The cell is subsequently given a numerical value according to the direction of flow. This number is solely utilized since the raster data in ArcGIS software needs to have numerical values; it has no other relevance beyond the flow direction [26].

(3) step Flow Accumulation: The next stage of the procedure is to create the flow accumulation layer. The Flow Accumulation tool determines the number of upstream cells that pass through each cell by using the flow direction raster. A value equal to the total number of upstream cells is assigned to each cell [26]. Each cell with higher flow accumulation values should be designated in areas of low elevation, such as valleys [25].

(4) step Stream Order: Linkages in a stream network can be numerically arranged using a technique called stream ordering. Using this arrangement, streams can be identified and categorized according to the quantity of their tributaries. Knowing a stream's sequence alone can reveal some of its properties. First-order streams are characterized by concentrated upstream flow, or overland water flow.

(5) step Stream to feature: Flow to vector is the process of converting river beds in raster format into vector data format. The resulting map is a linear map in vector format converted from raster format (**Figure 3**).

(6) step Watershed creation: The functions of Watershed Processing aid in the delineation of the watershed. The input data required was the definition of the stream, the catchment, the adjoint catchment, and the flow direction that was obtained during the terrain preprocessing. The Watershed Point feature class and the Watershed feature class were the outcomes.

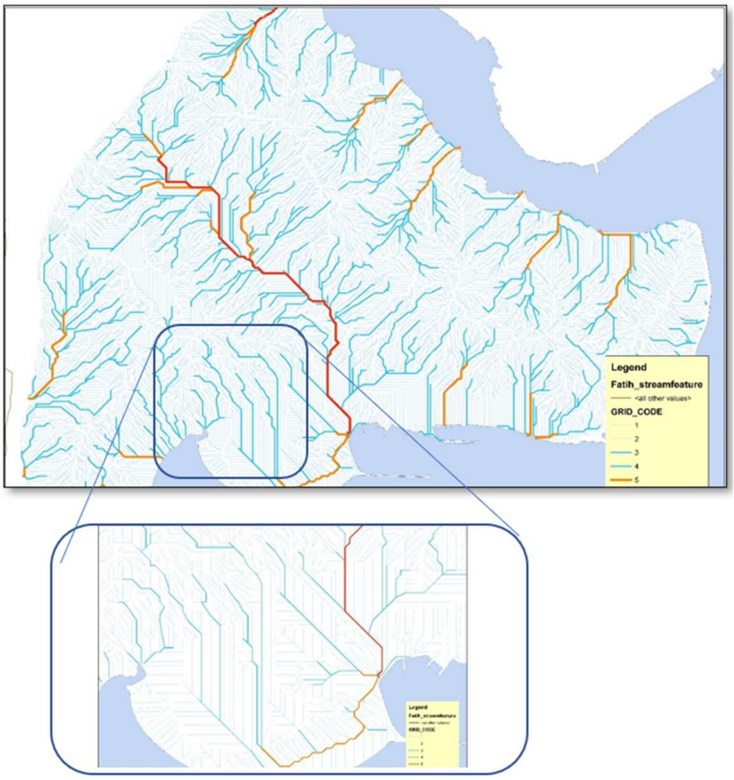

Figure 3. Fatih area-stream features.

"Stream model" is automated by using Arc GIS-Arc Hydro tools; a spatially linked database encompassing geographic and hydrographic data, including basin and stream networks, was generated for the study region (**Figure 4**).

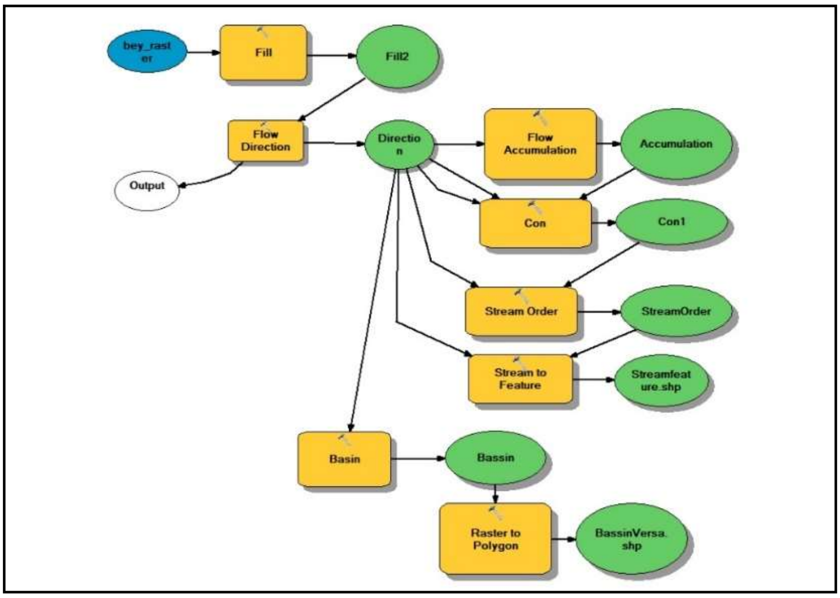

Figure 4. Stream model builder.

5. Results and discussion

In our study, the number of cells with code 1 was 8105, the number of cells with code 2 was 3358, the number of cells with code 3 was 1558, the number of cells with code 4 was 637, the number of cells with code 5 was 227, and the number of cells with code 6 was obtained as 98. Those with cell codes 5 and 6 represent the densest river beds. **Figure 5** shows the graphical distribution of grid codes by shape lengths and the grid code value frequency distribution.

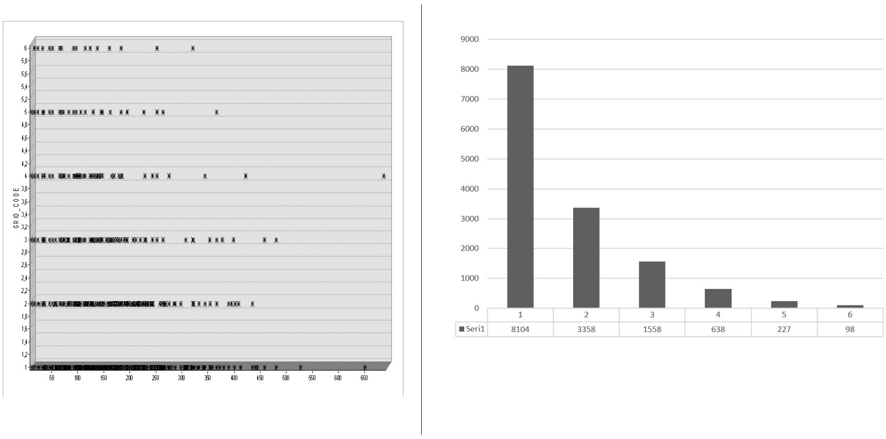

Figure 5. Study area grid codes and frequency distribution.

The results of our research provide a workflow to build a stream model and how to derive a suitability map according to stream levels. Transportation projects establish, develop, incorporate, and deliver effectively by selecting the best location for reducing construction, maintenance costs, and cost-effective solutions for drainage, landslides, and flood control.

Major infrastructure projects alter the natural landscape by creating sloped, impermeable surfaces and embankments, which are intended to facilitate transportation and prevent surface water accumulation, respectively. Examples of these projects include the construction of rail and road networks [27]. Roads are an essential component of the infrastructure for the planning and design process, especially highway crossings that pass-through streams and rivers. Roads will therefore inevitably have an influence on how stream corridor's function. Stream corridors are impacted by roads in hydrological, geomorphological, chemical, and ultimately ecological ways. However, these impacts can be lessened or eliminated by the location, construction, and maintenance of roadways [28]. To avoid flooding and increasing water tables during storm events, roadways in flat areas are frequently raised or realigned, resulting in an artificial gradient and subsequent runoff channel. The road-building regulations regulate the input of crossfalls, also known as cambers. The carriageway design incorporates an angle, typically 3% for paved roads, to facilitate water mobilization from the road surface by the shortest path, thereby changing the terrain [27]. An appropriate landform not only saves money on construction and maintenance, but it also decreases environmental risks like erosion and flooding. Steeper slopes normally incur higher expenditures, although too-small slopes may cause drainage problems [29].

Roads, pipelines, levees, streambank protection, and storm-water infrastructure are examples of streamside infrastructure, whereas stream crossing infrastructure includes bridges and culverts, pipelines, grade control structures, dams, reservoirs, and surface water diversion structures [28]. Impacts of construction on highways include runoff pollution from pavements and rights-of-way and excessive sediment yield during construction. For instance, stream channel instability brought on by hydrologic changes brought on by site preparation, grading, increased imperviousness, and landscape maintenance may result in habitat loss and stream bank erosion. Furthermore, deicing compound-containing runoff is poisonous to plants, fish, and other wildlife. Tracer metals, oil and grease, pesticides, and fertilizers are some of the other dangerous pollutants found in roadway runoff. It has been discovered that some petroleum hydrocarbons cause cancer. Additionally, aquatic fauna's ability to travel could be hampered by highway culverts near stream crossings [30].

6. Conclusion

This review begins with a definition and principles of integrated urban water management as a combination of policy and technical proposals. Within the growing paradigm of integrated urban water resource management, there are several approaches to identifying the nature of the problems to be addressed, viable solutions, and how to implement them. The City Blueprint indicator method is addressed as the first step toward a deeper understanding of IWRM and the problems that lie ahead. Four forms of urban water system integration—geographical, physical, informational, and project-based—are used to demonstrate the characteristics of the various types.

The study's workflow demonstrates how a scientific approach can be applied to the investigation of water resources with GIS as a tool, simplifying and improving decision-making. This paper explores the potential of Arc Hydro modeling techniques by utilizing the spatial capabilities of a GIS, specifically: (1) how to use a GIS to represent the spatial and thematic characteristics of the information and capabilities of a model for managing water resources; (2) the way to combine the problem formulation, data processing, and analytical features in a geographic information system setting; and (3) the model's implementation and analysis of the outcomes. According to model findings, streamside and stream crossing infrastructure construction and maintenance priority areas can be determined for short-, medium-, and long-term investment and allocation of future development. For future research, this study can be extended to determine and prevent possible damage to sensitive areas, floodplain areas, and vulnerable zones supported by field investigations.

In summary, the research aims to address the following questions, which we present below for determining infrastructure and urban planning concerns related to urban water management:

- How can qualitative data collection more effectively gather existing situations and adjust this into a water management process?
- How can planners and managers create "technical" solutions to water disputes that are appropriate, practical, and fiscally sound while also utilizing innovative workflows and modeling techniques?
- Which techniques can procure integrated water resource management?
- Is geographical information system analysis sufficient to resolve water conflicts?
- How can designers, engineers manage infrastructure projects in the stream environment?

Conflict of interest: The author declares no conflict of interest.

References

1. Bell SJ. Frameworks for urban water sustainability. WIREs Water. 2020; 7(2). doi: 10.1002/wat2.1411
2. Furlong C, Dobbie M, Morison P, et al. Infrastructure and Urban Planning Context for Achieving the Visions of Integrated Urban Water Management and Water Sensitive Urban Design. Approaches to Water Sensitive Urban Design. Published online 2019: 329–350. doi: 10.1016/b978-0-12-812843-5.00016-2
3. Maheepala S, Blackmore J, Diaper C, et al. Towards the Adoption of Integrated Urban Water Management Approach for Planning. Proceedings of the Water Environment Federation. 2010; 2010(9): 6734–6753. doi: 10.2175/193864710798207017
4. Ben-Daoud M, Mahrad BE, Elhassnaoui I, et al. Integrated water resources management: An indicator framework for water management system assessment in the R'Dom Sub-basin, Morocco. Environmental Challenges. 2021; 3: 100062. doi: 10.1016/j.envc.2021.100062
5. Hurlimann A, Wilson E. Sustainable Urban Water Management under a Changing Climate: The Role of Spatial Planning. Water. 2018; 10(5): 546. doi: 10.3390/w10050546
6. Leeuwen Kv, Sjerps R. Istanbul: the challenges of integrated water resources management in Europa's megacity. Environment, Development and Sustainability. 2015; 18(1): 1–17. doi: 10.1007/s10668-015-9636-z
7. Koop SHA, Grison C, Eisenreich SJ, et al. Integrated water resources management in cities in the world: Global solutions. Sustainable Cities and Society. 2022; 86: 104137. doi: 10.1016/j.scs.2022.104137
8. Alhan K CM, Gülbaz S. Blue cities: European Smart City with Water and Waste Integration of Strategy: Blue and Yellow Footprint Application of Concepts for Istanbul. DÜMF Engineering Journal. Available online: https://dergipark.org.tr/tr/download/article-file/453957 (accessed on 17 January 2024).
9. Nieuwenhuis E, Cuppen E, Langeveld J. The role of integration for future urban water systems: Identifying Dutch urban water practitioners' perspectives using Q methodology. Cities. 2022; 126: 103659. doi: 10.1016/j.cities.2022.103659

10. Pavlova D, Milshina Y. Sustainable water management in megacities of the future. Urban Ecology. Published online 2020: 201–219. doi: 10.1016/b978-0-12-820730-7.00012-4
11. Victoria State Government, Environment, Land, Water and Planning. Integrated Water Management Framework for Victoria. Available online: https://www.water.vic.gov.au/__data/assets/pdf_file/0031/663556/integrated-water-management-framework-for-victoria-an-iwm-approach-to-urban-water-planning-and-shared-decision-making-throughout-victoria.pdf (accessed on 17 January 2024).
12. Altay E. The Integrated Lake Basin Management Planning: A Study on the Beyşehir Lake Basin [Master’s thesis]. Middle East Technical University; 2012.
13. Buyukcangaz H, Korukcu A. Integrated approach for water resources and irrigation management in Turkey. Water International. 2007; 32(sup1): 710–719. doi: 10.1080/02508060.2007.9671992
14. McKinney DC, Cai X. Linking GIS and water resources management models: an object-oriented method. Environmental Modelling & Software, 2002; 17(5). doi: 10.1016/S1364-8152(02)00015-4
15. Li Z. Watershed modeling using arc hydro based on DEMs: a case study in Jackpine watershed. Environmental Systems Research. 2014; 3(1): 11. doi: 10.1186/2193-2697-3-11
16. Colby DJ. GIS for Watershed Characterization and Modeling. Available online: http://www.appstate.edu/~perrylb/Courses/5000/Readings/Faculty/Colby%202020.pdf (accessed on 18 January 2024).
17. Pouya S. (2021) Relationship Between Watershed Management and Spatial Planning in Terms of Sustainable Development [PhD thesis]. Istanbul Technical University; 2021.
18. Istanbul Metropolitan Municipality’s Directorate of Earthquake and Ground Research. Understanding Social Vulnerability Against Disasters Survey Results in Istanbul; 2018.
19. Turkish Statistical Institute Data Portal. Available online: https://www.tuik.gov.tr/ (accessed on 15 May 2019).
20. Mohammed Adam MH. The Use of Remote Sensing and GIS Techniques With Special Emphasis on The Use of Arc Hydro Data Model in Characterizing Atbara River Watershed [Master’s thesis]. Available online: https://inis.iaea.org/collection/NCLCollectionStore/_Public/44/003/44003637.pdf (accessed on 17 January 2024).
21. Istanbul Metropolitan Municipality. The Directorate of Geographic Information Systems, Digital topographical maps (Contour Lines). 2020.
22. Maidment DR. Arc Hydro: GIS for Water Resources. ESRI Press; 2002.
23. Patil PR., Thorat SB, Pande SR. Hydrological Information System using Archydro Data Model. https://www.ijcstjournal.org/volume-5/issue-2/IJCST-V5I2P4.pdf (accessed on 18 January 2024).
24. Bostancı A. ArcGIS Model Builder Application in Basin Database Management Tekirdağ Central District Case (Turkish) [Master’s thesis]. Namık Kemal University; 2013.
25. Kaviya B, Kumar O, Verma RC, et al. Watershed Delineation Using GIS in Selaiyur Area. Available online: https://acadpubl.eu/jsi/2017-116-13-22/articles/13/65.pdf (accessed on 17 January 2024).
26. Watson RP. Martha Washington. A Companion to First Ladies. Published online April 29, 2016: 6-19. doi: 10.1002/9781118732250.ch1
27. McGrane SJ. Impacts of urbanisation on hydrological and water quality dynamics, and urban water management: a review. Hydrological Sciences Journal. 2016; 61(13): 2295-2311. doi: 10.1080/02626667.2015.1128084
28. Sholtes JS, Ubing C, Randle TJ, et al. Managing Infrastructure in the Stream Environment. JAWRA Journal of the American Water Resources Association. 2018; 54(6): 1172-1184. doi: 10.1111/1752-1688.12692
29. Chen W-B, Guldmann J-M. Optimal Allocation of Stormwater Pollution Control Technologies in a Watershed. Available online: https://www.researchgate.net/publication/272505086_Optimal_Allocation_of_Stormwater_Pollution_Control_Technologies_in_a_Watershed (accessed on 17 January 2024).
30. Yu LS, Stanford RL, Zhen JX, et al. Water management for eco-friendly urban and highway construction. Available online: https://wwwwec.ntut.edu.tw/var/file/95/1095/img/3010/Watermanagementforeco-friendlyurbanandhighwayconstruction.pdf (accessed on 2 January 2024).