Planning for Sustainable Riverfront Development of Kham River in Chhatrapati Sambhajinagar (Aurangabad)

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS

CPCB	Central Pollution Control Board
CSR	Corporate Social Responsibility
FAR	Floor Area Ratio
LULC	Land use Land cover
MLD	Million Litres Per Day
MPCB	Maharashtra Pollution Control Board
MRTP	Maharashtra Regional and Town Planning Act, 1966
NIUA	National Institute of Urban Affairs
NMCG	National Mission for Clean Ganga
NGO	Non-governmental Organization
STP	Sewage Treatment Plant
UDCPR	Uniform Development Control and Promotion Regulations

Abstract

Urban "blue-green" space is the basic element of urban ecology. It plays a significant role in enhancing the quality, resiliency, sustainability and development of urban spaces. But rapid urbanization and allied anthropogenic activities has a negative consequences on these urban ecosystem. However, blue component (seasonal rivers) are often misinterpreted as drains (Nalas) and such rivers are lost in its own city. This phenomenon has led to the detachment of the city from the river. It is often regarded as less valuable and hence demand conservation.

River Kham in Chhatrapati Sambhajinagar (Aurangabad) a tributary of river Godavari, has similar story to exhibit. Historically, city effectively managed its water supply through visionary practices implemented by its rulers, regardless being located in low rainfall region. Once the source of drinking water and pride of city, now river serves no purpose other than carrying untreated sewage, solid waste and industrial discharge thus polluting the river. Due to its seasonal nature and narrow width it is often perceived as 'Nala' by most of its residents. The same polluted water is being used for irrigation purposes downstream and finally confluence to Godavari River, which is also the source of water supply for the city. Also other anthropogenic concerns such as encroachments, negligence to historical setting, degraded ecology, underutilised riparian space, lack of proper administrative control, and climate change impacts continue to threaten the value of the river.

A stretch of approx. 8 km of the Kham river passing through the municipal limits, originating from Harsul lake, Jatwada (Upstream) to Chawni Bridge (Downstream) is taken as study area. Much of the earlier research focus on assessing the water quality and ecology of the river stretch along the river, but no effective initiatives has been taken to study it from planning and urban design perspective. Today the Kham riverfront needs revival. So the question here is can we bring back the lost glory of the river? Yes, by reversing this trend and creating value for these features. Because what we value, we usually care. So, study focuses on devising a sustainable action plan for eco – restoration of the river and develop riverfront planning and design proposal that will aid in enhancing water quality, ecology, aesthetics and socio-economic value of the river.

Keywords: Urban ecology, Blue-Green, Kham River, Seasonal, Nala, Eco-restoration, Riverfront Planning and Design.

1. Introduction

1.1. Study Area

1.1.1. City Profile - Chhatrapati Sambhajinagar (Aurangabad)

Situated on the bank of river Kham and Sukhna, Chhatrapati Sambhajinagar (Aurangabad) is both district and administrative headquarter of Marathwada region in Maharashtra state. The city lies on the Deccan traps surrounded by hills of the Vindhya Ranges. City experiences hot and dry climate and with mean annual rainfall of 710 mm. The area of Aurangabad Municipal Corporation is approximately 175 sq.km. and current population is projected to around 17 lakhs. It is metropolitan class-1 city and 5th most urbanised area in the state. It is rich in historical, cultural and tourist, religious, and industrial importance. It is known by 'City of gates' for boasting 52 medieval era gates. Being a 'Tourism capital of Maharashtra' it is host to UNESCO world heritage sites such as the Ajanta and Ellora caves and other historical monuments. Recently, in 2019, under the country's flagship Smart Cities Mission, Aurangabad Industrial City (AURIC) became the 'First Greenfield Industrial Smart City of India'. Aurangabad was ranked 34th in terms of ease of living (EOL) index for cities having million plus population in 2020.

1.1.2. Delineation of Study Area – Kham River Stretch

Study area in focus is Kham River which is a tributary of river Godavari in Chhatrapati Sambhajinagar (Aurangabad) Maharashtra. It is seasonal river that carries fresh water only during monsoon season, rest of the year it receives waste water from the city drains. Despite being a seasonal river, it has unique hydrological characteristics (Table 1). It has varying shallow depths and its width ranges between 20 metres to 68 metres. An urban stretch of approximately 9 sq. km is taken for detail investigation which is further divided in to 3 zones as indicated based on the land use characteristics, natural and manmade edges and functions of that area. As seen river stretch is predominantly surrounded by residential, public and agriculture land use. Several sites of recreational, ecological and heritage importance lies in the vicinity of the river stretch (Figure 1).

Table 1: Unique hydro-physical characteristics of Kham River

Features	Data/Information
Nature of the River	Seasonal
Origin of the River	Jatwada hills(North)
Confluence Point	Godavari river (Nath sagar)
Rainfall	735.51 mm
Total Length of the River	60 Km
Source of Water	Rainfall, sewage inflow, fresh water springs
Length of The River considered under study	7.73 Km
Depth	Shallow 1- 3m
River Dimensions	Flood plain width - 80m; River width - Non uniform (8-68m)
Basis of delineation of study area	Depending on the physical features, land use characteristics & functions and transport boundary. Broadly divided into 3 zones – Upstream, midstream, and downstream

Source: (Ecosattva, December 2021)

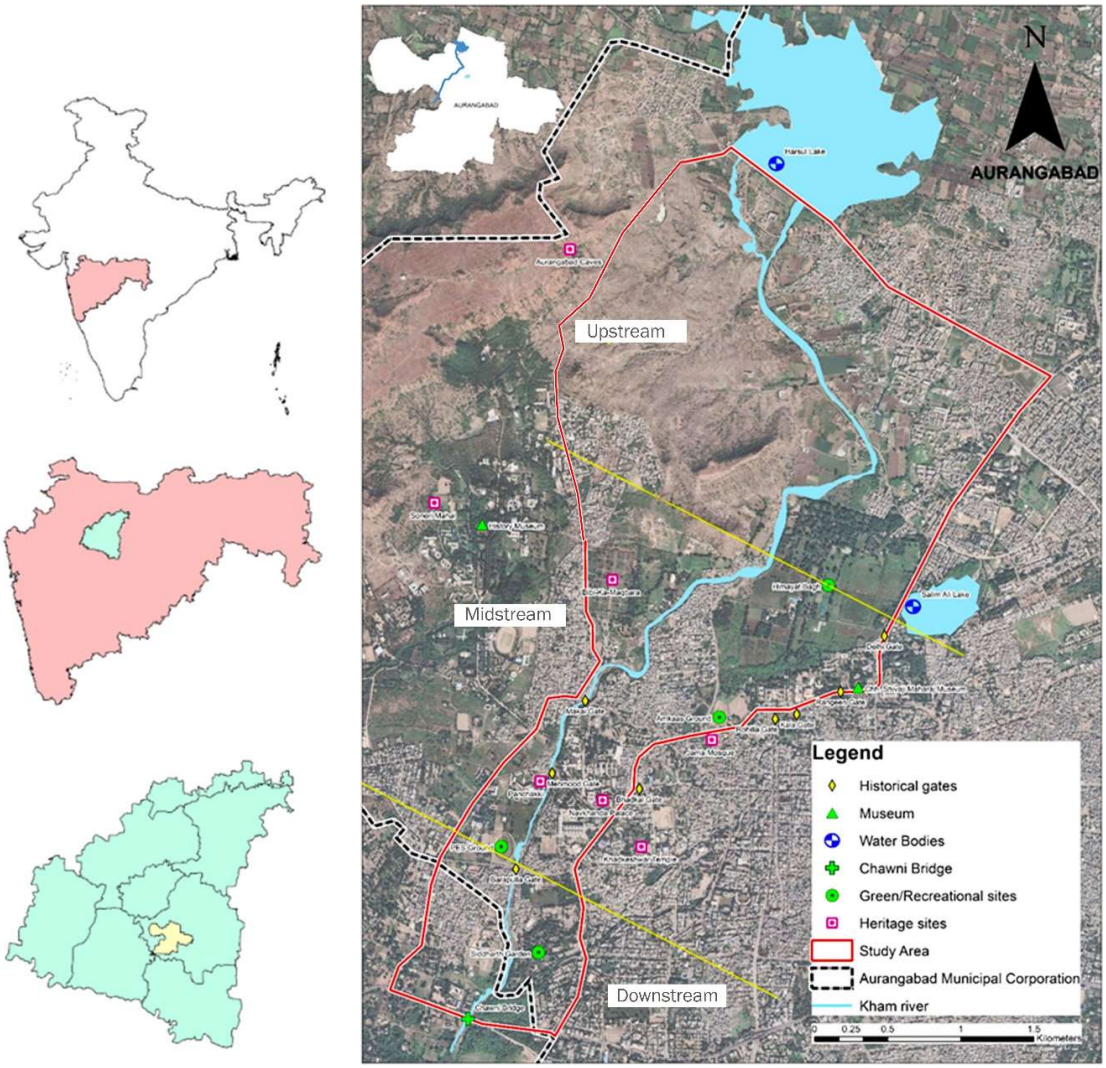


Figure 1: Delineated study area

Source: (Author)

1.2. Aim & Objectives

Need of Study

The need of study was determined by various issues and challenges of the river and area such as pollution, encroachments, negligence to the historical context, degraded ecology, underutilisation of vacant spaces, poor administrative control, and climate change impacts (Figure 2).

Figure 2: Issues and challenges

Source: (Primary Survey, 2022)

Aim

Kham River that is environmentally sensitive, climate adaptive and socially inclusive urban riverfront planning and development.

Objectives

a) To develop sustainable action plan for eco-restoration of river.
b) To create vibrant river zone that will enhance the recreational and tourism potential of the city.
c) To study the changes in land use and land cover features to understand urbanization and its impact on the river.
d) To analyze issues, challenges and priorities of riverfront development through primary and secondary data.
e) To reduce the impact of urbanization and anthropogenic activities - water quality, flood risk, and ecology.

1.3. Scope of the Study

a) River centric urban planning recommendations that addresses issues such as flash flood, encroachments, solid waste management, inaccessibility, depleting urban ecology etc.
b) Integration of existing heritage structures, socio-cultural, economic, and environmental activities with the riverfront development.
c) Recommend strategies to generate river based economy and engage citizens in river management activities.

1.4. Limitations

The limitations of the study include,

a) Study area of the river is confined to municipal limits of the city.
b) Information pertaining to some data points is outdated (E.g.: Census 2011, etc.).
c) The level of detail for the interventions restricted to the concept ideation and detailed modelling and calculations have not been taken up
d) Suggesting strategies towards balancing the environmental protection and recreational use of the river, aiming at long-term and sustainable practice

1.5. Methodology

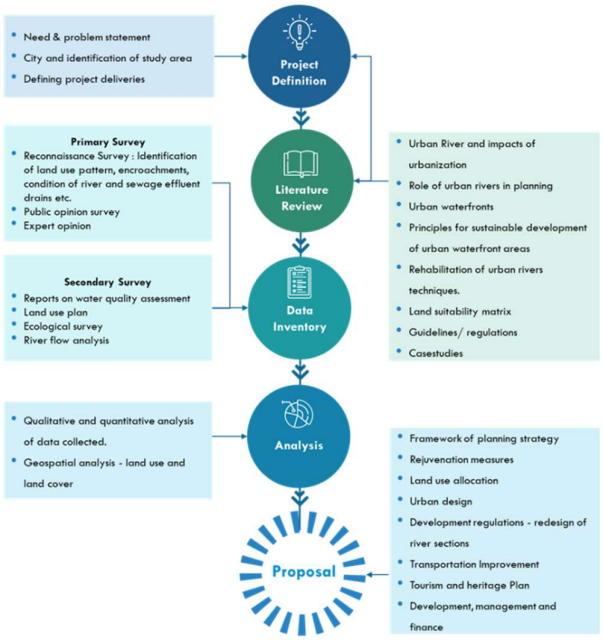


Figure 3: Methodology

Source: (Author)

2. Literature Overview

Various literature studies were referred to develop an understanding of the study area, review similar case studies, and gather tools and techniques for the analysis purposes. The following table enlists the various data types required for the accomplishment of the study.

Table 2: Table showing Data Sources and Takeaways from Literature Study and Case Studies

Sr. No.	Content	Takeaways/Inferences/Intentions
Literature Study		
1	Urban River and impacts of urbanisation	To understand the definition of urban river and its relationship with the city. Investigation on effect of urbanisation that results in physical changes to watersheds such as hydrology, morphology, water quality and biodiversity.
2	Role of urban rivers in planning	Urban rivers are a complex interplay of social-economic-ecological systems that serve cultural and religious beliefs, recreational demands, livelihood dependencies, and riverine ecosystem ecological functions.
3	Urban waterfronts	Comprehension of urban waterfronts on basis of its evolution, functions, importance, types, and regeneration approaches.
4	Principles for sustainable development of urban waterfront areas	Research indicates that each urban waterfront has a unique development focus, ranging from beautification and recreation to commercial exploitation of premium land use to cultural preservation and religious activities. Furthermore, experts advised that five essential concepts be taken into account while developing ideas for the sustainable development of urban waterfront area. These elements serve as the foundation for the future riverfront development guidelines: • Ensure the quality of water and the environment • Waterfront to be considered as an integrated component of the existing urban fabric

		• Collective heritage of water and city to be utilized • Mixed use to be prioritised • Public access is a pre-requisite
5	Techniques of river restoration	To understand various approaches involved in river conservation and assess the guidelines for river restoration success.
6	Planning for rehabilitation of urban rivers.	To understand the importance of rehabilitation planning through facts and challenges involved, broader human context and geo-social perspective.
7	Multi criteria analysis for land suitability	This tool was used to establish the appropriateness of a given tract of land for a certain purpose using land suitability matrix based on multi criteria analysis. In this matrix, each sub-zone is awarded a rating ranging from 1–4 based on its compatibility versus each factor within a certain land use category. As a result, each unoccupied plot of land is classified into four categories: Highly suitable, suitable, moderately suitable, and least suitable for each land use purpose.
Guidelines/Regulations		
1	Urban River Management plan Framework (URMP) - NIUA	To understand how the river cities should prepare river management plans and design holistic interventions so as to improve the liveability and efficiency of the cities. To understand regulations /zoning pertaining to prohibited, restricted, and regulated activities on river front development.
2	Guidance Note for Environmentally Sensitive, Climate Adaptive and Socially Inclusive Urban Riverfront Planning and Development - NMCG	
3	River Centric Urban Planning Guidelines(RCUP) - TCPO	
4	UDCPR Maharashtra	
Case studies		
1	**Sabarmati Riverfront Development, Ahmedabad, Gujrat** Urban design, urban renewal, and environmental improvement project that brought retention of surface water in river all year round, diversion of sewage, embankments, rehabilitation and resettlements of slums, organised space for informal activities and developments of promenades using hardscapes.	
2	**Patna Riverfront Development Project, Patna Bihar** Holistic development of the river edge, the proposal promotes a walkable city, creating larger usable open spaces and being sensitive to local context. Masterplan incorporates river management codes.	

3	**Ahar River, Udaipur, Rajasthan** Physico-chemical changes in the river water quality due to in-situ and cost-effective technology like Green Bridge – horizontal eco-filtration system were the reason for overall positive changes in the ecological health of Ahar River	
4	**Cheonggyecheon Stream Restoration, Seoul, South Korea** The restoration project was centred on revitalizing the Cheonggyecheon Stream that had been covered for decades by a highway overpass. The city of Seoul used its own resources to bring new life to the downtown by enhancing the urban environment. The restoration of Stream led to the revitalization of central Seoul, unleashing the potential for green public space.	
5	**San Antonio River Improvements Project, San Antonio, Texas, USA** Enhancements of the river through ecosystem restoration and flood damage reduction encouraged economic development, cultural connections, and provide space for people to enjoy recreational activities.	

Source: Analysed by (Author)

3. Survey and Data collection

A rapid baseline assessment was carried out to understand the ground reality of river issues and challenges faced by the city. The assessment was based on different sources such as secondary data, published reports, and project implementation by AMC. The baseline included information on planning provisions concerning river, pollution of river, encroachment in floodplain, latest status, encroachments in floodplain and ongoing projects in the city on rivers and drains. Stakeholder consultation were seek to input from different actors. Envisaged outcomes were correlated with types of surveys which were further classified as shown in the (Figure 4). For carrying out primary survey wards that lies within the study area were selected. For Public opinion survey a total household sample size of 378 (as per Cochran's formula) were surveyed using random sampling method. And expert opinion with different stakeholder were also conducted.

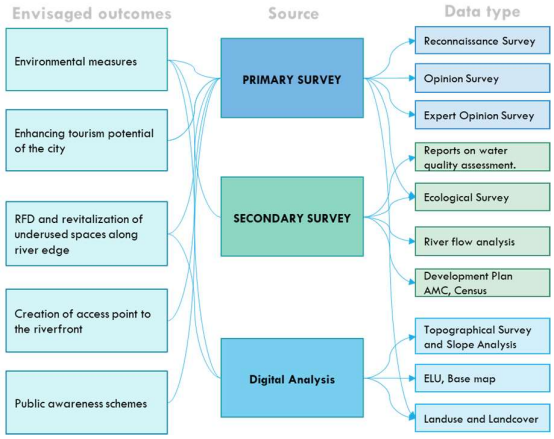


Figure 4: Data collection

Source: (Author)

The following (Table 3) list down the objectives and relevance of various types data types with method of data collection/ sources/ analysis toolkit adopted.

Table 3: Objectives of Data collection

Data Type	Relevance/ objectives	Method of collection/ Analysis tool/ Sources
PRIMARY SURVEY		
Reconnaissance survey	Understanding the existing use of land parcels, ongoing activities, connectivity, built characteristics, status of infrastructure, availability of vacant land and the river condition. Anthropogenic activities - encroachments, condition of river at different locations and sewage effluent points leading to Kham river.	Field visit
Household survey	To tap socio-economic status, condition of dwelling units and their willingness to rehabilitate and resettle.	Interaction with local people and Google form
General public opinion survey(POS)	Aspirations from riverfront development, perception of river, interaction and awareness about the river issues and city.	Google form
Expert opinion survey	To build consensus for the project (e.g.: issues, concerns and challenges) To investigate ongoing initiatives. To get conceptual understanding of various parameters for inclusive planning. To deliberate on solutions to develop riverfront areas.	Personal interview 1. Mail 2. Telephonic communication
SECONDARY DATA		
Reports on water quality assessment, flow and their impacts on ecology.	To understand physio-chemical properties of Kham river at different points To analyse flow of river stream at different points and their factors which would help in devising bioremediation proposals.	Published journal article
Ecological Survey	To map flora and fauna and identify vulnerable hotspots in the study area.	Published journal article + onsite visits.

Census Data	To understand demographic profile, socio-economic conditions and density distribution.	District census handbook - Aurangabad (2011)
Development plan and Land ownership Map.	For creation of base map, land use map, and potentials of proposals on land parcels.	Town planning department Aurangabad.
DATA ANALYSIS		
Land use and Landover changes	Potential analysis of - recreational opportunities, land use conversion, space integration and facilities replacement	ELU map ARCGIS + Landsat Supervised classification
Topographical Survey and Slope Analysis	Cross section study at different location and flood vulnerability assessment of encroachments.	ArcGIS, DEM, google earth, onsite visits and interaction

Source: (Author)

4. Data Analysis

4.1. Existing Land Use Pattern and Ownership

Existing land use distribution analysis for the study area reveals that riverside stretch is multi-functional (Figure 5). Approximately 23% of the overall area along the riverside is used exclusively for residential purposes. Majority of government buildings, educational and institutional buildings, heritage sites, and green/open areas are adjacent to the river stretch. Large chunk of land accounting to 15% lies vacant or underused and provides huge potential for proposing appropriate development that meets the need of the city. In land ownership, the considerable area of land is under private ownership which is a positive sign from an economic perspective on reasons of financing instrument like 'Value Captured Finance' which is based on the principle that if private buildings and lands are getting benefits due to the development, then the private owners of the buildings and lands have to pay for it.

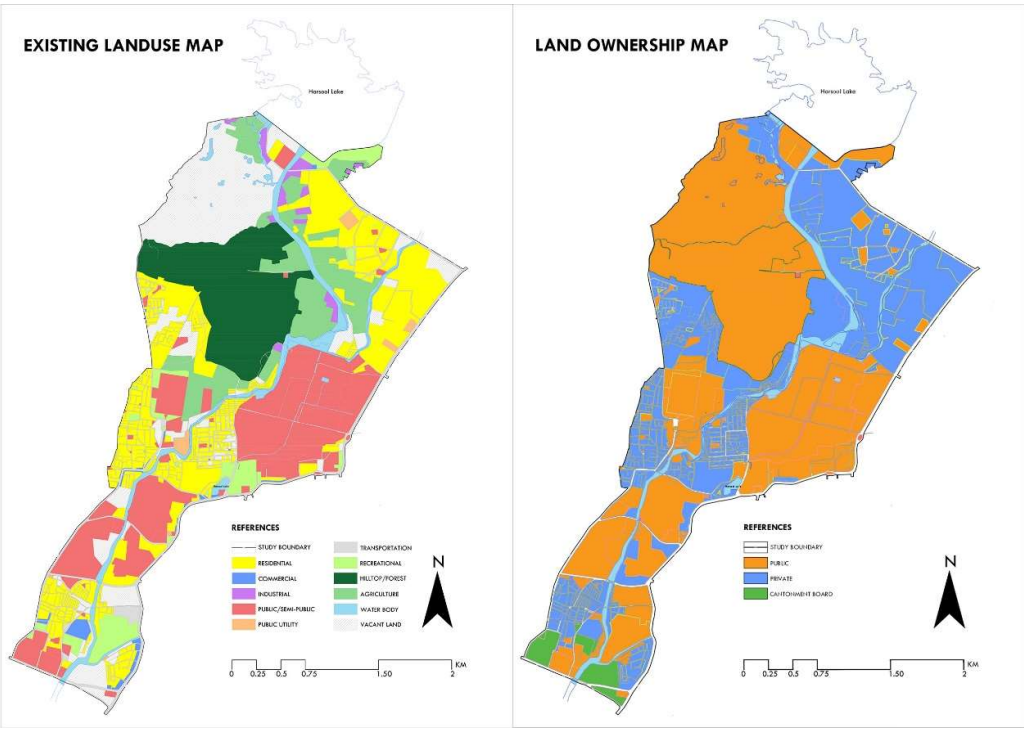


Figure 5: Existing land use and land ownership

Source: (Primary Survey, 2022); (Town planning dept)

4.2. Activities Observed along the River

Despite the fact that the riverside has a huge amount of undeveloped area, the activities witnessed along the river are limited. Primary activities such as agricultural and its allied components such as grazing of domesticated animals etc., sand mining, dhobi ghats (clothing washing, drying), river bed as playing field by children, and fishing, are among the most common activities seen near the river (Figure 6).

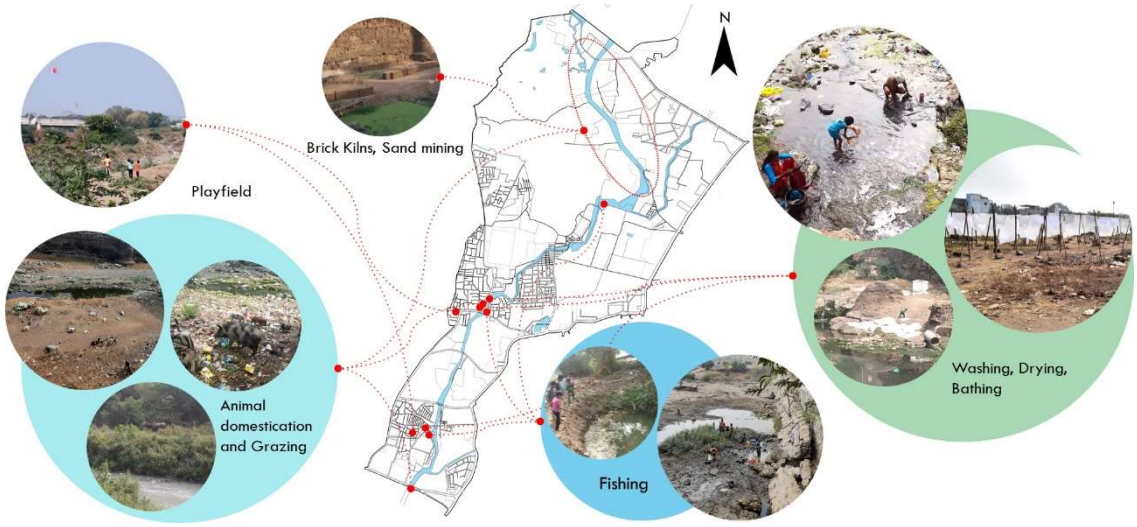


Figure 6: Locations of activities observed along the river stretch

Source: (Primary Survey, 2022)

4.3. Existing Transportation Network

The study area is delineated within two major arterial and sub-arterial roads. There are 5 major collector roads with bridges connecting 2 banks of the river. These roads intercepts the road running parallel to the river. The study area contain major transportation nodes through which maximum traffic movements take place (Figure 7). There is limited cross connectivity in the upstream zone of the study area. Makai and Panchakki bridge in the midstream zone faces heavy traffic issues due narrow width of bridge and encroachments. There is need of improvement in the existing transportation system to serve the riverfront development and activities along the river.

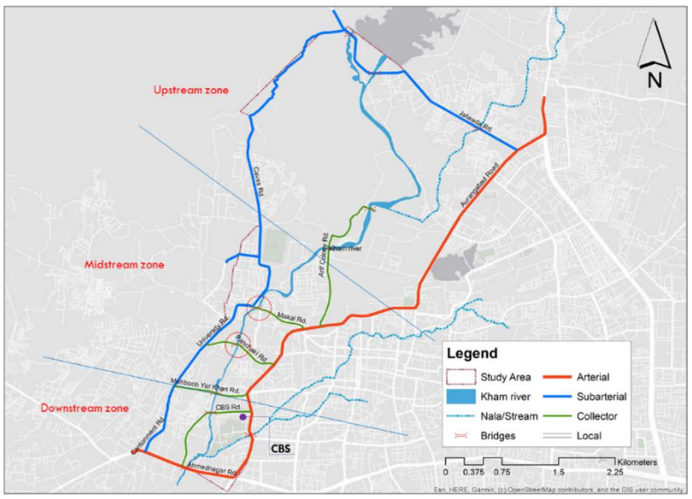


Figure 7: Existing transport connectivity

Source: Author

4.4. Tourism and Heritage

Aurangabad being a 'Tourism Capital of Maharashtra' and carrying historical importance has huge repository of sites and lesser known sightseeing destinations. The number of sites as indicated in map (Figure 8) carries historical, heritage, cultural, ecological and tourist value, and are located in and around study area. But as per Aurangabad tourism vision 2020, the staying period of tourists in the city is only 1.5 days and shows gap in awareness, tourist infrastructures, information signage and non-availability of modern tourist engagements.

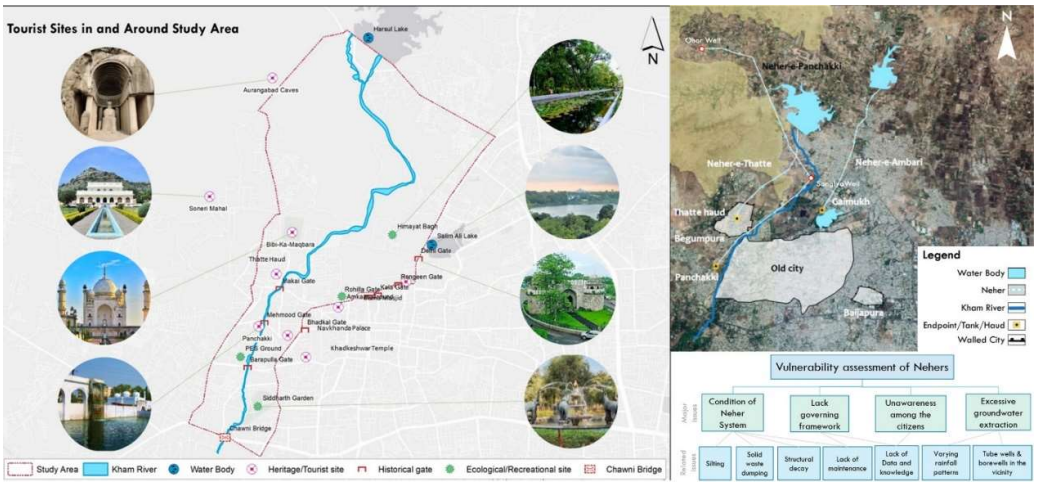


Figure 8: Tourist sites and vulnerability mapping of Nehers

Source: (Author); (Khadke & Mona, 2019)

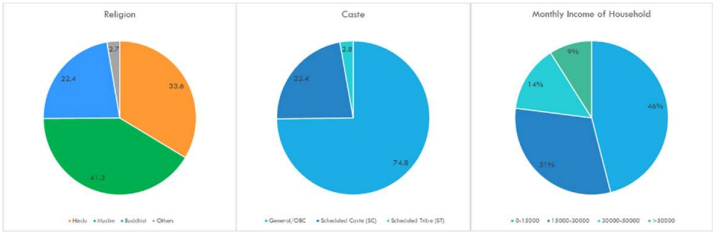
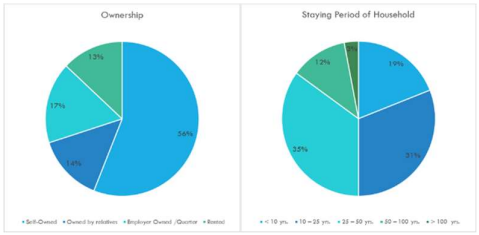
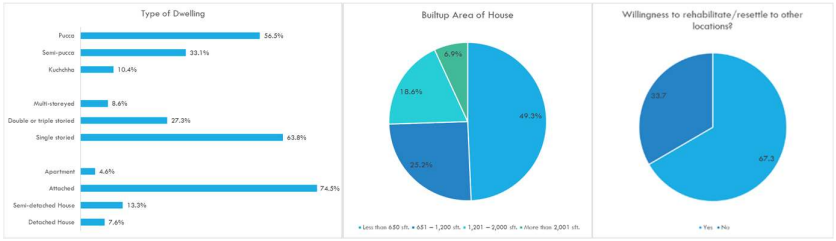
Another lotic water heritage along the river are Neher. Malik Ambar founder of the city, designed the historic engineering marvel - the city's water supply - There are 14 such Nehers in the city of which 3 nehers 'Neher-e-Ambari, Neher-e-Panchakki, Neher-e-Begumpura lie within the study area. This system carries socio-cultural and historical importance. With rapid population growth and the advent of pumping facilities, this system is now facing slow destruction. This is primarily due to poor upkeep of system, lack of governing framework, unawareness and excessive extraction of groundwater. As a result, these system have become paralysed and partially functional and calls for protection and conservation. Figure 8 also outlines the mapping of 'Neher' system along the river and its vulnerability assessment.

4.5. Household Survey

Household survey was conducted to tap the socio-economic status of encroached properties and their willingness to resettle, and the inference that we get from the analysis from table 4 is that,

a) The study area is mainly dominated by minorities accounting to 63.7%. Representation of SC and ST in the area is higher than city, which is about 22.4% and 2.8% respectively. It was observed that 91% of population living in the study area belong to EWS and LIG category.
b) 3/4 of the household ownership lies with either self-owned or owned by relatives. About 35% of households are 24-50 yrs. old and majorly located in the midstream zone of the study area.
c) More than 60% of dwellings of [Pucca + Single storied + Attached] typology observed. 43% of immediate riverside dwelling are of kuccha type and semi type. Up to 75% of dwellings have built-up area less than 1200 sq.ft. 2⁄3 of immediate riverside residents show positive attitude towards rehabilitation and resettlement plan.

Table 4: Household survey

	Question	Response
a	Social and economic structure.	
b	Ownership and Staying Period.	
c	Type of dwelling, built-up area of house, Willingness to relocate.	

Source: (Primary Survey, 2022)

4.6. Public Opinion Survey (POS)

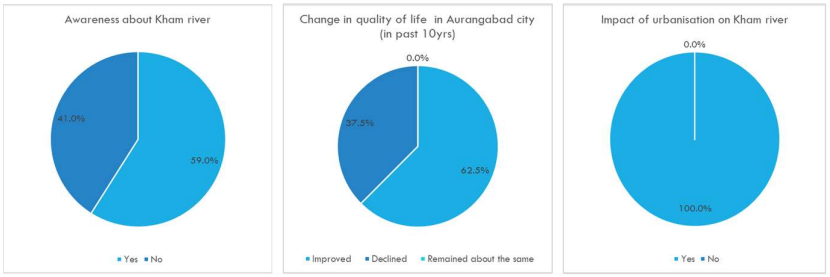
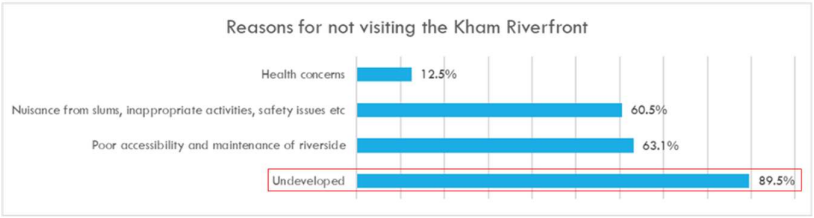
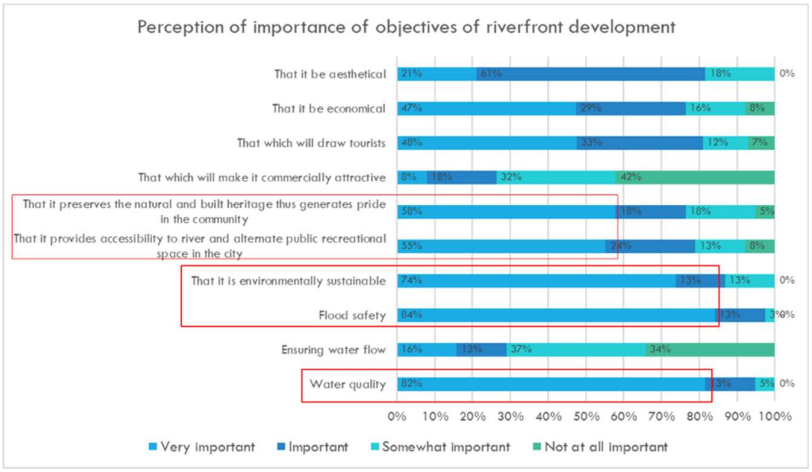
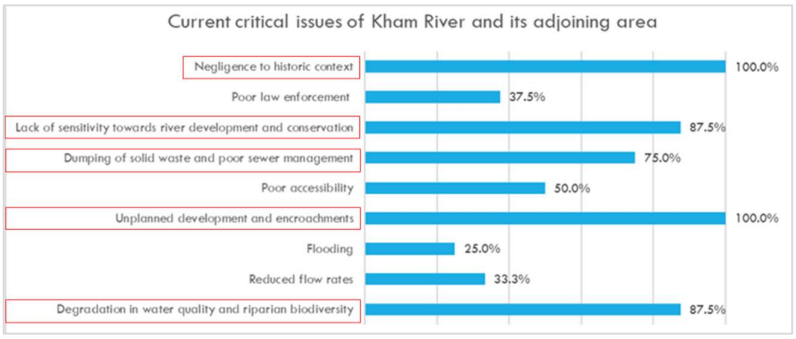
POS was meant to understand the aspirations of citizens from riverfront development, perception of river issues, awareness, appropriate development, reasons for not visiting the river etc. This included the opinion of all stakeholders – including immediate riverside residents, general public and experts to arrive at common consensus. The inference that we get from the analysis from table 5 is that,

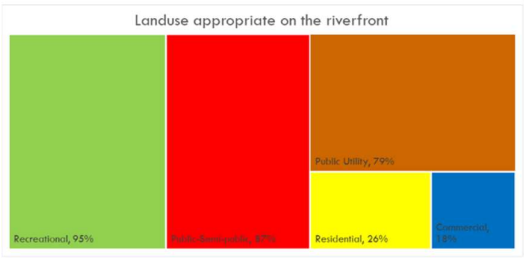
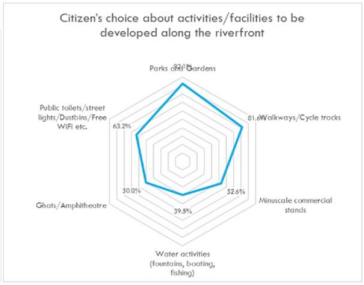
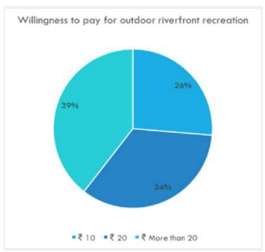
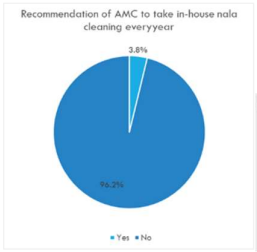
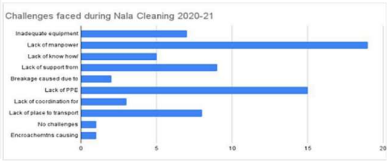
a. 60% of people were unware about the river in the city and thought the dirty nala was meant to carry sewage. Almost all respondents believed that Kham is negatively impacted due to current urbanisation trends in the city. About 63% people argued that while the quality of life in the city has improved but there has been very little attention towards creating green recreational opportunities and handling pollution.
b. Underdevelopment followed by inappropriate activities and poor accessibility are major reasons reported for no visit to riverfront area.
c. When asked about the perception on objectives of riverfront development, more than 75% of respondents mentioned that water quality, flood safety, environmental sustainability of project remains as forefront objectives, followed by recreational and heritage use.
d. More than 3⁄4 of the respondents reported - Negligence of historic context, degradation, lack of sensitivity, encroachments on river stretch as major issues.
e. Considering the appropriateness of land use development and activities on riverfront more than 50% respondents indicated recreational and public/semi-public use as suitable land use type. While activities such as developments of parks & gardens (92%), followed by walkways/cycle

tracks (82%) and public facilities. Development of ghats/amphitheatre and minuscule commercial also received considerable votes.

f. 73% of the respondents are ready to spend ≥ INR 20 per person per day for such outdoor riverfront recreation. Suggestion of issue of monthly/yearly passes would give better ease to visit the place frequently were received. Respondents also suggested AMC to take periodic nala cleaning and address the challenges of SWM services.

Table 5: Public opinion survey

	Question	Response
a	Perception, quality of life and impact of urbanization on Kham River	
b	Reasons for no visits	
c	Perception on objectives of riverfront development	
d	Critical issues of Kham River	

e	Appropriate land use development and activities on riverfront area	 
f	Willingness to pay, nala cleaning recommend-dation, challenges faced.	  

Source: (Primary Survey, 2022)

4.7. Expert Opinion Survey

The expert opinion survey was conducted with selected local government officials, private agencies and NGO's. The opinion were analysed in terms of different segments as shown in (Figure 9) get conceptual understanding of various parameters , to deliberate on solutions to develop riverfront areas etc..

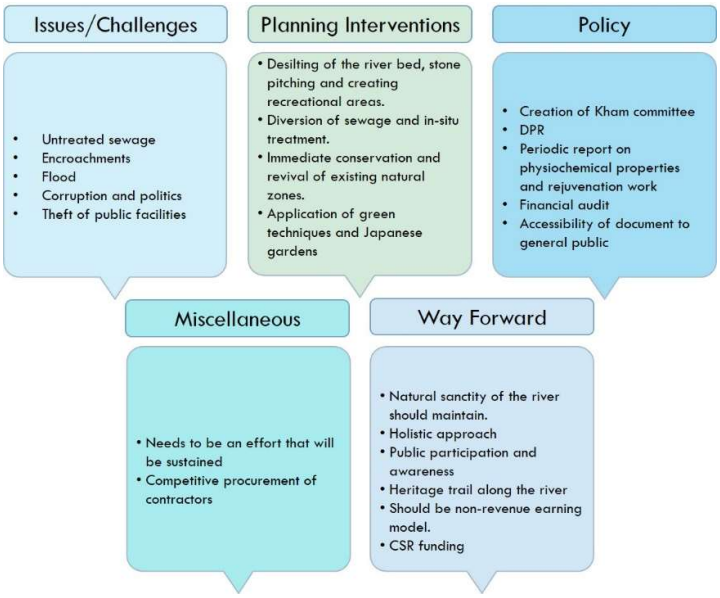


Figure 9: Expert opinion survey

Source: (Primary Survey, 2022)

4.8. Density Pattern

The study area shows great variation in density pattern. The population density varies from 65878.8 per/sq. km in the midstream zone to 1977.5 per/sq. km in outer zone. The upstream zone exhibits low density and sparse development due majority of land under agriculture and forest zone. Midstream area

being located in core and old part of city is characterised by high density and compact development. Downstream is more of combination of above two zones (Figure 10).

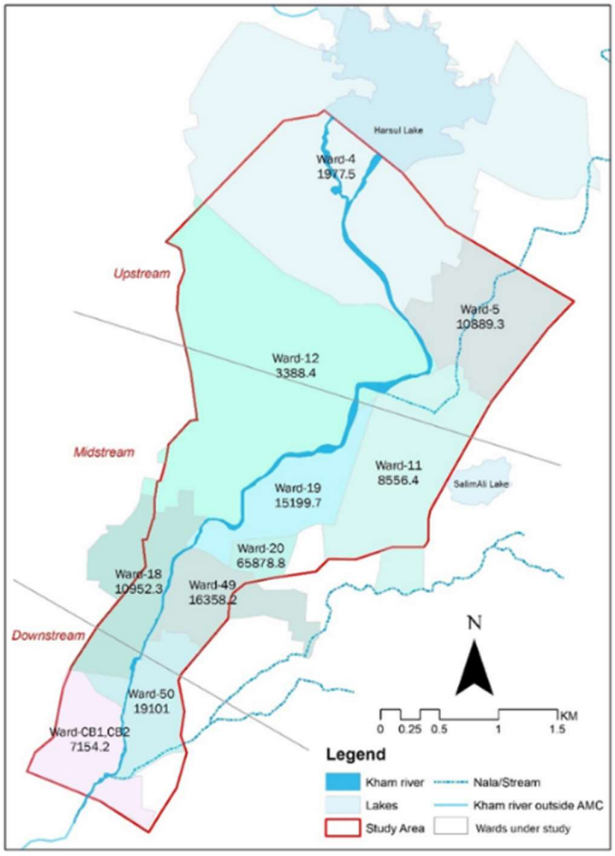


Figure 10: Density pattern of study Area

Source: (Census , 2011)

4.9. Water Quality Analysis

Secondary assessment of water quality of Kham river done on the basis of (Karhade, et al., 2020) study reveals that, there are diurnal and seasonal fluctuations in physiochemical properties of river. It revealed high levels of Chemical Oxygen Demand (COD), Total Dissolved Solids, and very low Dissolved Oxygen (DO) etc. It is found that water is less polluted in the upstream and pollution load increases as sewage drains (Nalas) gets intercepted to the river in the Midstream and downstream. There is also threat of contamination of ground water table in and around the river due to penetration of untreated sewage water. Hence, pollution control measures and frequent water quality monitoring becomes essential on river stretch.

4.10. Ecological Survey

Ecological survey was carried out by frequent visit to riverside and through secondary documentation. In this survey, flora and fauna in and along the river basin were noted and major potential and degraded hotspots were identified (Figure 11). The study revealed 86 species of aquatic, semiaquatic and terrestrial flora. Although water hyacinth and typha generally found in polluted water bodies were absent. Isolation of habitat and destruction of riparian habitat were observed. Hence immediate need for conservation and enhancement of the areas having good ecological quality and to revive the existing natural zones was understood.

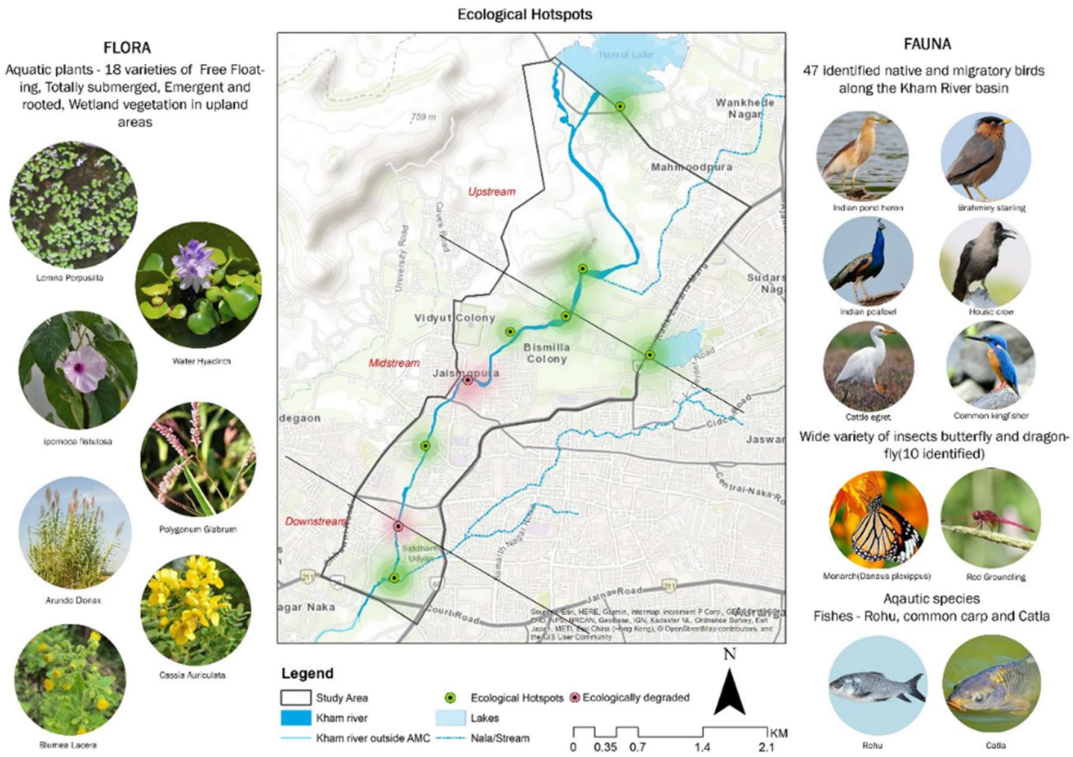


Figure 11: Ecological hotspots of flora and fauna

Source: (Primary Survey, 2022); (Karhade, et al., 2020)

4.11. Existing Liquid-Solid Disposal

There is huge gap in generation of sewage and its treatment in the city. As per the Maharashtra pollution control board (MPCB), total generation of sewage in the city is 110 MLD of which only 11.5 MLD of sewage is treated, the rest is disposed of into water bodies. Baseline survey conducted by CARPE | EcoSattva, a private organisation working on river restoration identified potential 30 vulnerable wards polluting the river with solid and liquid waste. 249 untreated sewage effluent points were also been reported that emptied into the river bed along with the 16 fresh water springs. Leakage from sewage systems has threat of degrading the ground water along the nala and river. Hence there is a need to connect disposal points to the underground sewerage system and install adequate STPs treatment at the earliest to maintain return flow in the river that meets the CPCB Standard.

4.12. Land Use Land Cover Change Detection

The geospatial analysis of land use land cover (LULC) reveals that city has undergone drastic LULC transformation in terms of reduction in blue-green spaces between the years 2001-2021. This has direct implications on the ecological and socioeconomic activities in the city. The water bodies including Kham River has reduced by 38%. Even green cover has reduced, wherein agriculture land and vegetation has changed by 48.55% in terms of area. These changes in land use are mainly due to urbanisation, increasing demand for housing and economic activities.

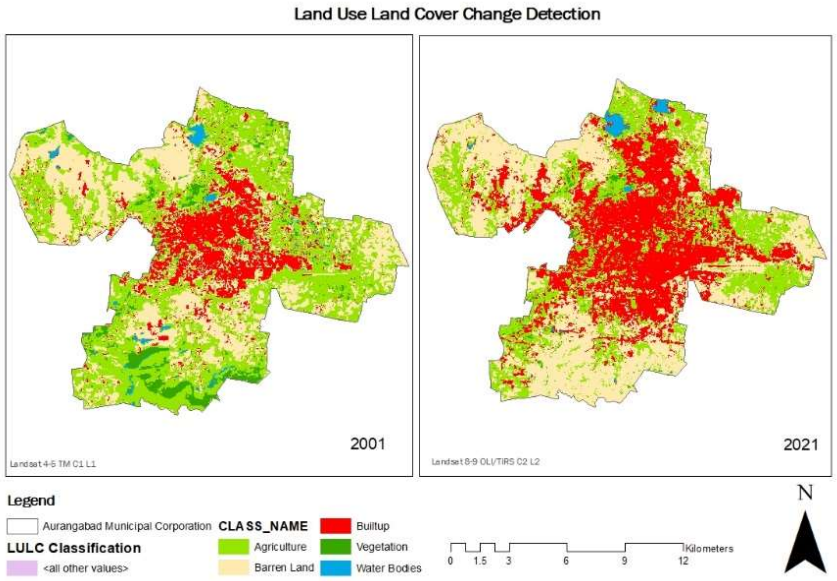


Figure 12: Land use and land cover change detection for Aurangabad city

Source: (Author)

4.13. Topographical Analysis

Since there is no information of blue and red flood line for flood plain area in the development plan, Flood plain of 80-90 m was determined by interacting with local residents. Flood plain, encroachments, condition mapping and river section were analysed as shown in (Figure 13).

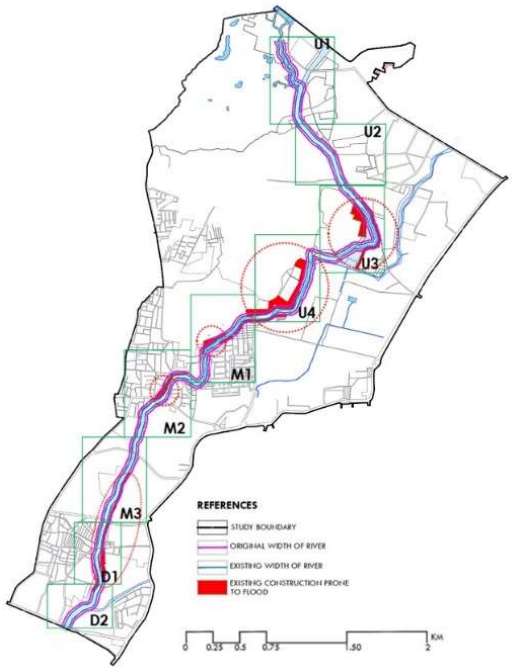


Figure 13: Existing encroachments/construction prone to flood situations

Source: (Primary Survey, 2022)

The 3 sections of river from each zone is selected for detailed investigation which would also form sites for proposal/intervention. The river section has varying profile with 0-3 m depth. It is shallow in the upstream and goes deeper in midstream and again gets shallower in the downstream. The river's width also keeps on varying between 8-68m. The river bed in the upstream is mostly dry in non-monsoon season and only receives waste water. While in case of midstream and downstream sewage drains and fresh water springs are major water sources. (Figure 14).

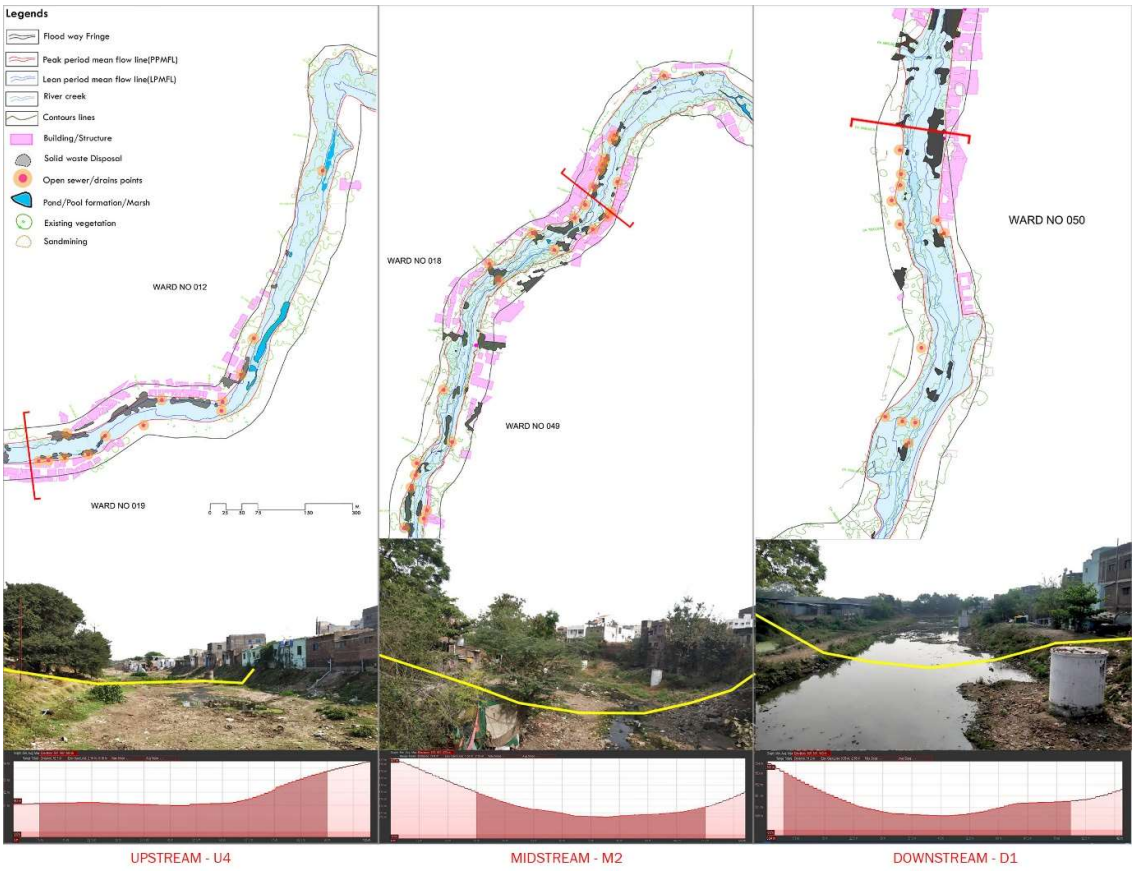


Figure 14: Kham river cross section indicating various attributes

Source: (Primary Survey, 2022); (Geo-Resource Mapping Pvt. Ltd., 2021); Google Earth

5. Proposals and Recommendations

5.1. Planning approach, vision, framework for spatial planning, range of measures

5.1.1. Planning approach

Urban river management is very crucial while attaining sustainable developmental goals. Based on the surveys conducted and analysis, unique selling propositions are devised which are low cost & low maintenance, high performance and at the same time sustainable in nature.

5.1.2. Vision

The vision for planning strategies is based on three pillars of sustainability i.e. Environment, Society and Economy. Based on these objectives three perspectives of development are formulated: River restoration, integration with the city, improving the river-people connect. The details of this are presented in figure 15.

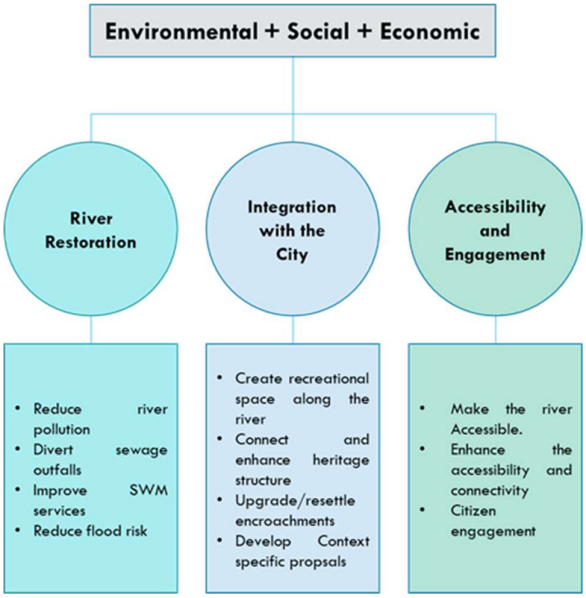


Figure 15: Vision for Riverfront development

Source: (Author)

In achieving this vision, a strategic and three-dimensional approach consisting of time scale, spatial scale and range of measures has been adopted to tackle specific issues and problems with a constant view of the long-term vision. Figure 16 describes each dimension in detail.

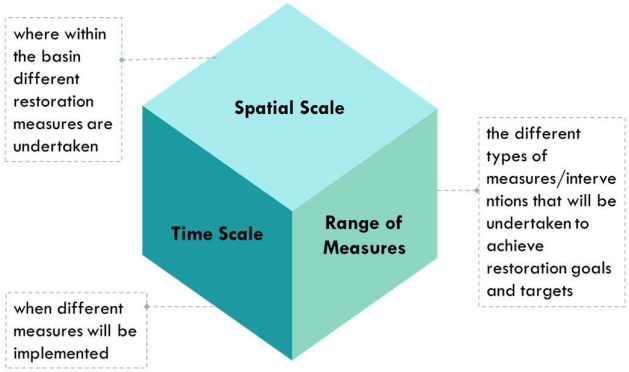


Figure 16: 3D approach

Source: (Author)

5.1.3. Framework for spatial planning

The spatial scale of planning for Kham River becomes important for various reasons such as eco-hydrological issues at different scales. Restoration plan, vision, and overall key issues are assessed at the basin scale. However, based on this, priorities were set at a City stretch level and interventions are proposed accordingly as shown in figure 17. Planning interventions for restoration is done on the basis of division of stretch - Comprehensive watershed management is proposed in the upstream; Better management of solid and liquid waste, ecological restoration and removal of encroachments, etc. is proposed in the midstream. It is understood that the condition at the downstream will improve due to the efforts taken in above stretches.

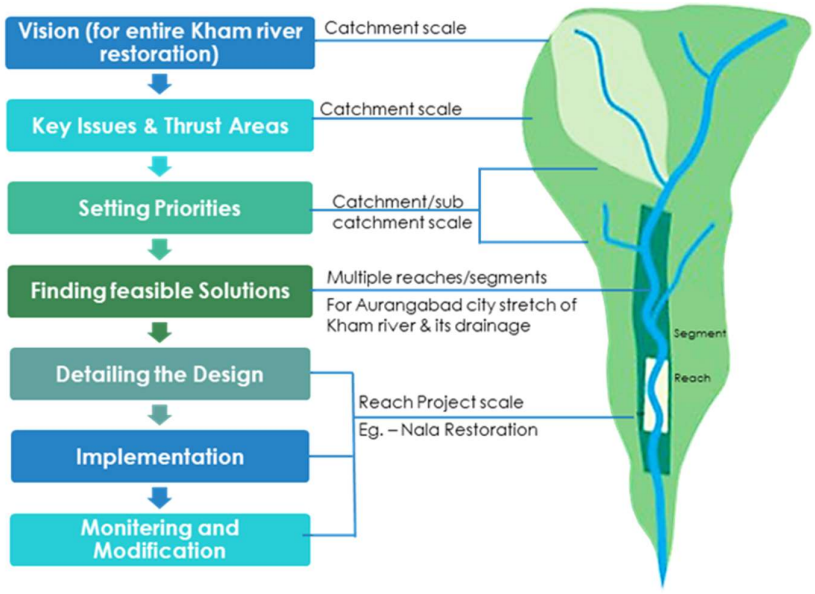


Figure 17: Framework for spatial planning of Kham river restoration

Source: Modified from Rutherfurd et al., 2000.

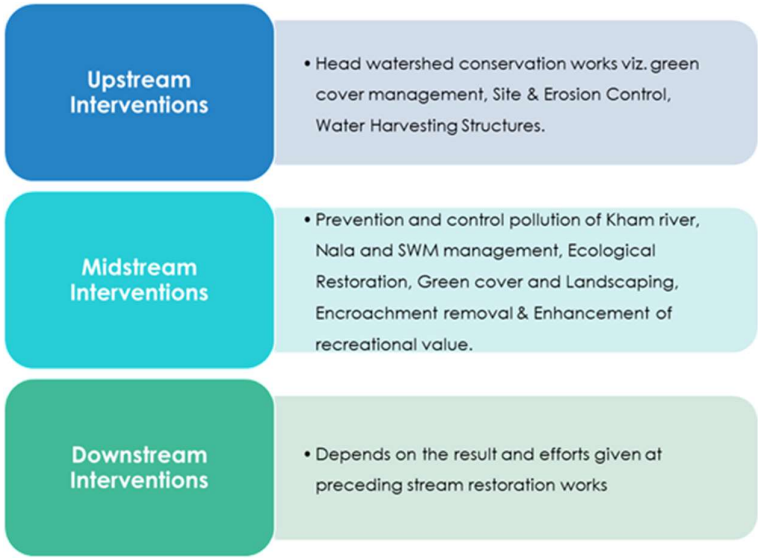


Figure 18: Planning interventions for Kham riverside restoration

Source: (Author)

Therefore proposals are focused on pollution control, land use planning, flood control and development measures, accessibility, tourism, and lastly spatial interventions. Following sub-sections detail out each of these interventions.

5.2. Pollution Control and Rejuvenation Measures

The first important step towards river rejuvenation is pollution control. For this In-situ bio remediation-horizontal filtration system -Green Bridge system (developed by SERI Pune) of 40MLD is proposed for treatment of sewage. The map (Figure 19) shows the locations for setting up of the 3 Green Bridges on river. The advantage of applying this system is that, it is cost effective as compared to the conventional methods of using STPs and, involves one time investment and requires no skill labour.

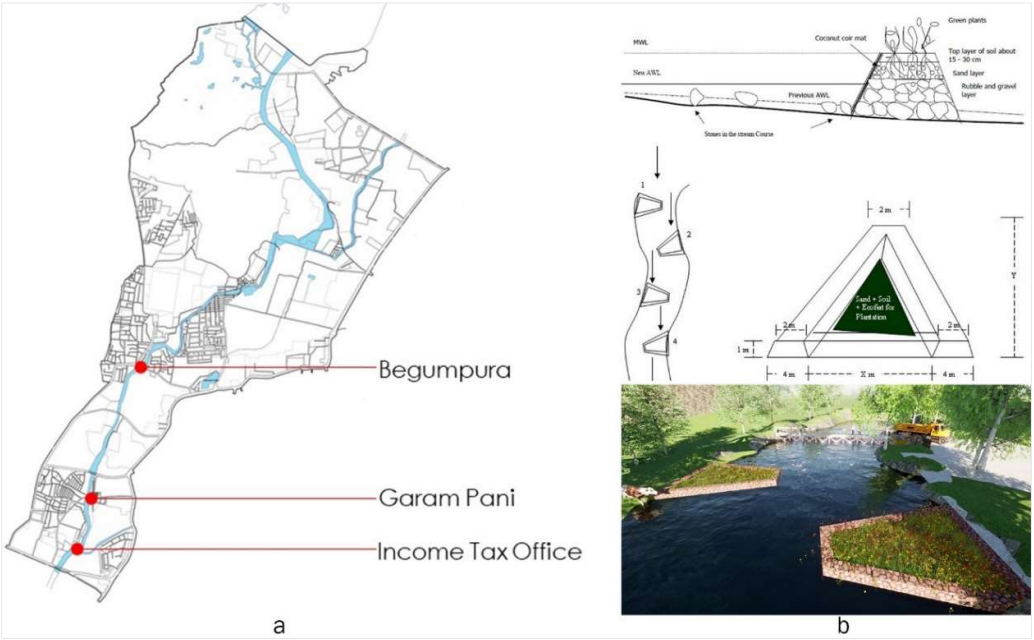


Figure 19: (a) Location and (b) schematic of installation of green bridge system

Source: (Author); (Kodarkar & Joshi, 2010), developed by SERI Pune,

Along with this it is proposed that green lakes shall be developed between the 2 green bridges and a landscaped lagoon will be set up for further purification.

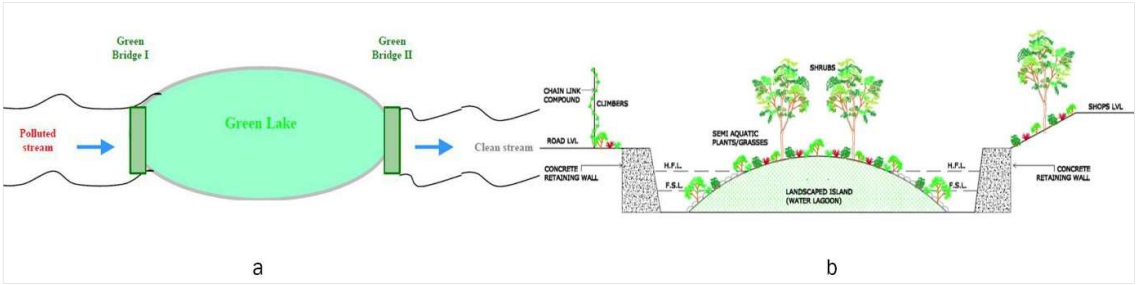


Figure 20: (a) Formation of Green Lakes; (b) Constructions of landscaped water Lagoons with Semi aquatic species

Source: (Kodarkar & Joshi, 2010); Author

Along with these, Installation of net traps, Connecting drains to underground sewage system, and augmentation of SWM services and Nala cleaning is proposed for better management of solid and liquid waste. Furthermore, creation of dashboard in the Smart City Command and Control Centre for river

quality data is recommended. This data to be made available for decision makers as well as general public.

Figure 21: (a) Solid waste management priority wards; (b) Net traps installation

Source: (Author); (Storm Water Systems, Inc., n.d.)

5.3. Proposal for Land-Use Allocation

While preparing proposed land use plan, a land suitability matrix was created for each of the five principal land uses identified in an earlier literature analysis, as well as its practical value for riverside land use. They were recreational, semi-public, residential, commercial, and public utility.

Table 4, shows the land suitability matrix for recreational land use as an example here. Vacant lands having maximum scores were identified as most suitable for that particular land use (as highlighted in yellow rows here). The figure 22 shows the existing vacant and redevelopable land parcels considered for allocation of land use. The same procedure was repeated for all other appropriate land uses and thus the proposed land use map was prepared. In proposed land use map, land immediately abutting the river is kept under recreational land use as a riparian buffer/ green spaces followed by public and semi-public land use. The agricultural land upstream is kept untouched for promoting urban farming (Figure 22).

Table 6: Land suitability matrix for recreational land use

Land suitability matrix for recreational land use										
Land	**Slope**	**Elevation**	**Accessibility by transport**	**Erosion Potential**	**Parking facilities**	**Topographic/ Scenic/ Vegetation Interest**	**Eco sensitive Interest**	**Visual connectivity with the river**	**Compatibility with surrounding land use**	**Total**
V1	2	1	4	1	1	4	4	3	4	24
V2+A1+E1	4	3	4	1	4	4	4	4	4	32
A2+A3+A4+E2	1	4	1	2	1	1	2	3	1	16
E1+E3+E4+E5+E6	4	3	1	1	2	4	4	4	2	25
V17 +V9+V10	3	2	2	1	3	4	4	4	4	27
V3	3	3	4	2	4	1	1	1	2	21
V4	3	3	4	2	3	1	1	1	2	20
V5+V6+V7	3	3	4	1	3	1	1	1	2	19
V8	3	3	4	1	3	1	1	1	2	19
V11	3	3	4	1	4	2	1	1	2	21
V12	3	2	2	1	3	2	2	4	1	20
V13	3	2	2	1	4	2	2	4	1	21
V14	3	2	1	1	3	2	2	4	1	19
V15	3	2	4	1	3	2	2	4	2	23
V18	3	2	3	2	3	1	2	4	1	21
V20	3	2	2	1	3	2	2	4	1	20
V16+V21+V22	3	2	2	1	3	2	2	1	1	17
V23	4	3	2	4	3	2	2	2	1	23
V24	4	3	2	4	3	2	2	1	1	22

Source: (Author)

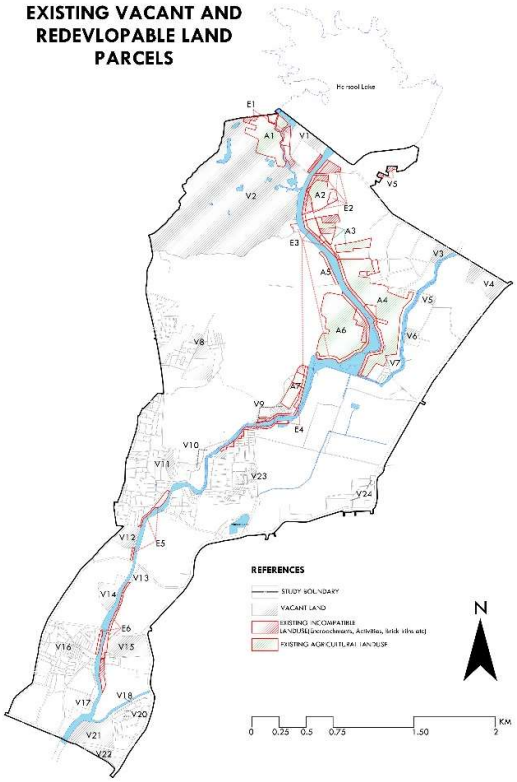


Figure 22: Existing vacant and redevelopable land parcels

Source: (Author)

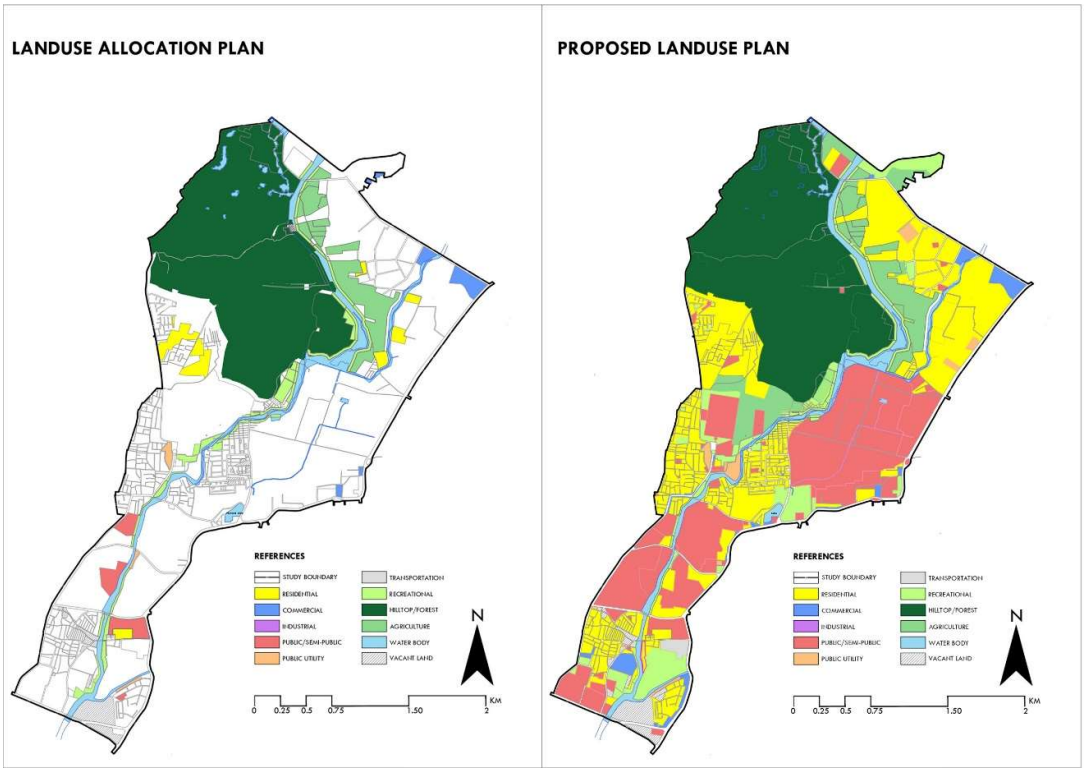


Figure 23: Proposed land use

Source: (Author)

5.4. Proposal for Transportation Improvement

Given limited cross connectivity in the upstream zone, proposal focuses on laying network of roads alongside river which further connects with the main arterial roads. While in the midstretch parallel roads to the river are proposed which would allow efficient movement and access to riverfront activities. While to decongest the roads on city gates two lane two way are proposed by laying additional road adjacent to the gate.(Figure 24).

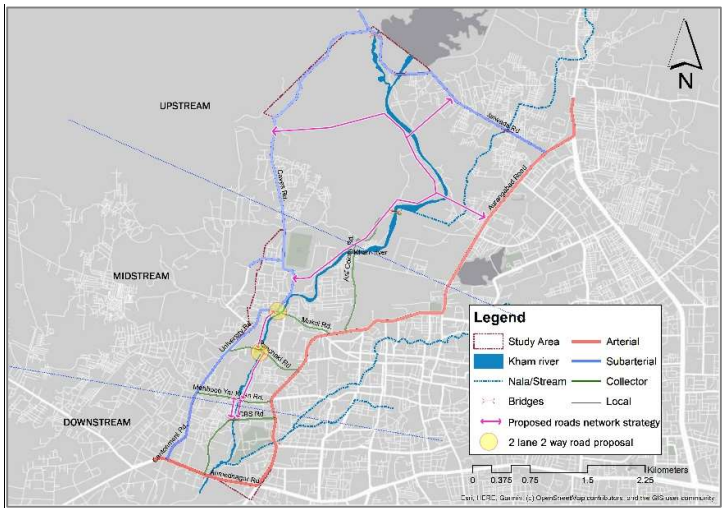


Figure 24: Proposed transportation improvement plan

Source: (Author)

5.5. Regulation of Activities in Floodplain

a) Riparian buffer:

Channelization of the river to uniform mean width of 35m and 24m offset on either side as floodplain/riparian buffer shall be demarcated for flood protection. A typical section showing the zonation of the riparian buffer indicating the stream side zone and outer zone shall be followed. Each zone shall be specified by the activities permitted and restricted as Uniform Development Control and Promotion Regulation (UDCPR). Species that degrade the riparian region are recommended to be restored with native flora and fauna species. Tree planting and Reforestation along the banks of the river is recommended for rich biodiversity enhancement for environments (Figure 25).

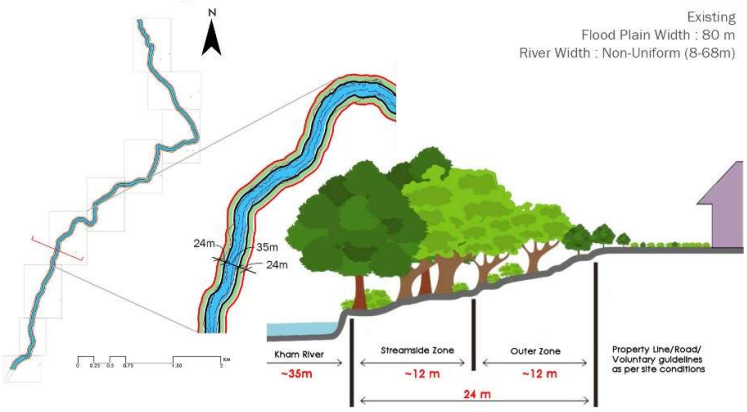


Figure 25: Typical riparian zonation for Kham River

Source: Adapted from (URMP by NIUA, 2020)

b) Re-Sectioning of the river:

For improving the carrying capacity and protection against flood, bank stabilization measures (majorly 3km in Upstream) using stone pitching shall be done. Other technical corrections such as deepening and widening at required locations, construction of bunds in series for water retention should be undertaken.

c) Demarcation of red and blue flood lines in masterplan:

Since there is no data available on red and blue in the development plan of Aurangabad, a demarcation of Blue and red flood line is suggested indicating the prohibitive and restrictive zones and activities permitted therein. The plinth of structures shall be kept 600mm above red flood line level

d) Upgradation and relocation of slums:

Built spaces highly susceptible to flood situations should either be retrofitted as per aforesaid recommendation or relocated under comprehensive development plan as per section 32 of Maharashtra Regional and Town Planning Act, 1966 (MRTP, 1966).

e) Control of Architectural features

a) Structures abutting the river shall follow architectural standards which will give brand identity to the Kham River in terms of elevation and frontage towards river side.
b) Avoid bold colours.
c) Walls to be painted with Murals, information, slogans on river protection.

5.6. Ecofriendly Reverine Projects

Considering the context, appropriateness, and at same time addressing the issues and the need, four key locations were identified for development of eco-friendly riverfront spaces which keeps minimal carbon footprint and focusses on restoring the ecology and at the same time remains a public asset. These are:

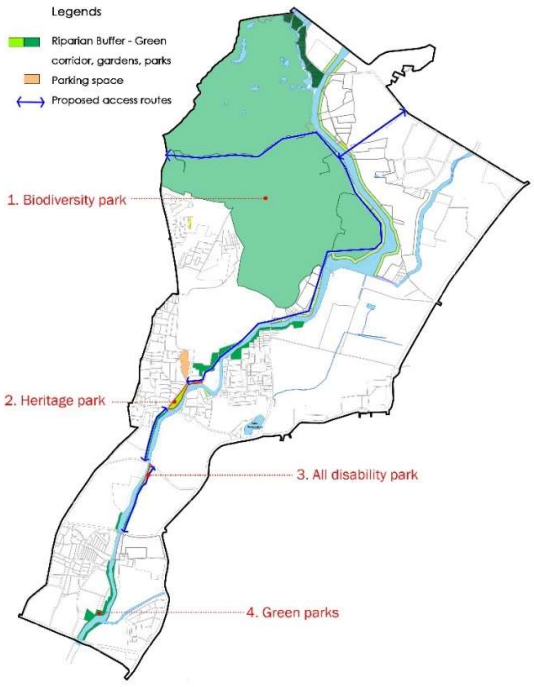


Figure 26: Locations of specific riverfront interventions

Source: (Author)

a) Bio Diversity Park

Biodiversity Park is proposed over 300 ha of land in the upstream section of the river which forms part of the catchment area of the river. Currently land is barren and needs high eco-conservational measures promoting afforestation which would also help in watershed management and flood prevention in upstream. This will also help in imbibing visitors about environmental education. The schematic plan shows the different components of parks under the Nature conservation zone and the visitor zone.

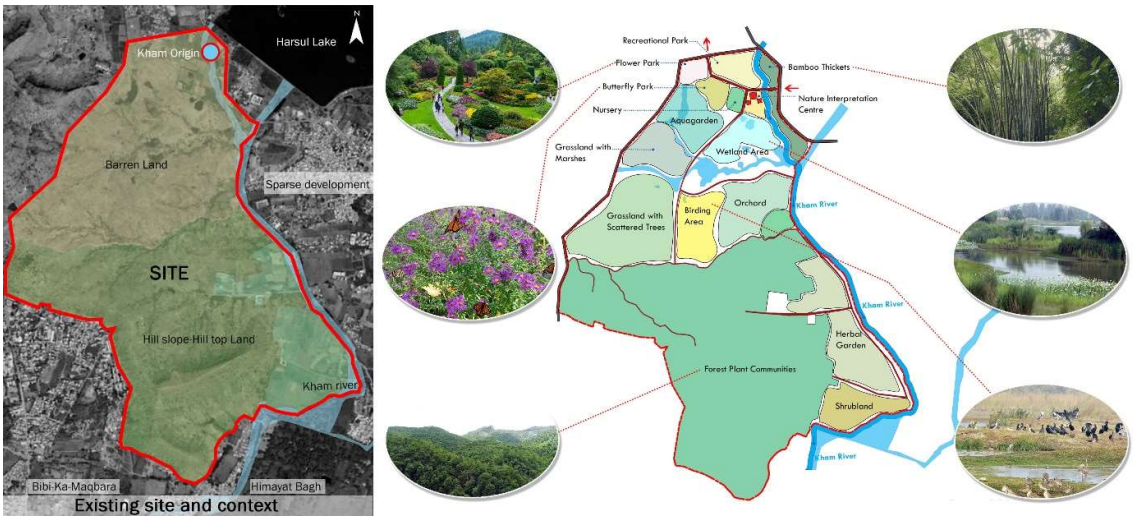


Figure 27: Conceptual layout for Biodiversity Park

Source: (Author)

b) Heritage Park

Heritage Park is proposed in the midstream section near Bibi-Ka-Maqbara with multidimensional objectives of urban river landscape promoting local art forms stalls (paithani, bidri, himroo work stalls) and recreational opportunities. Lying directly on the tourist circulation route will help to attract the tourist and also nearby residents for recreational purposes.

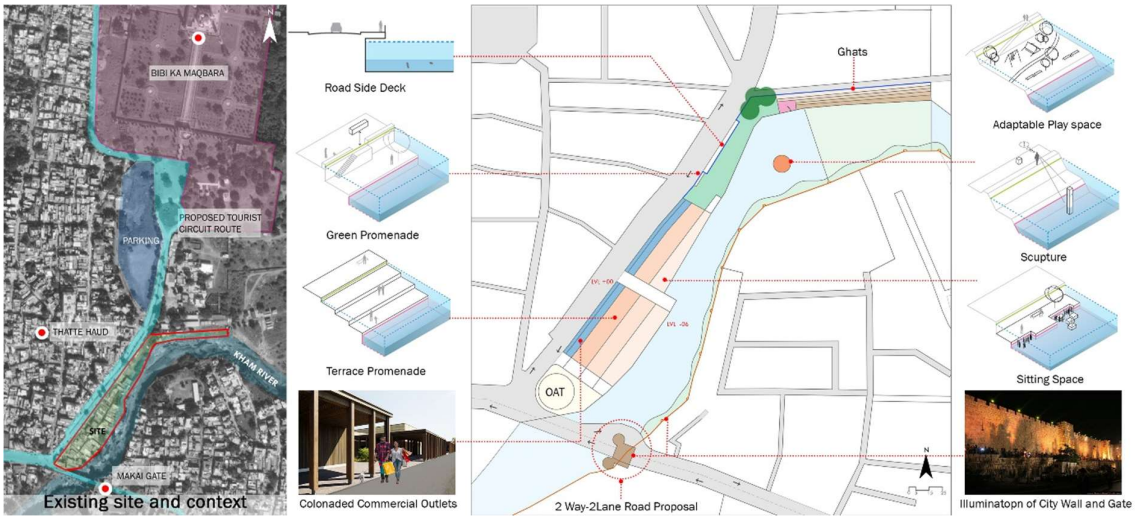


Figure 28: Conceptual layout for Heritage Park

Source: (Author)

c) All disability Park:

To provide a dedicated facility for the especially abled with indoor and outdoor activities an all disability park is near Panchakki which may attract tourist. This will be a pioneer park in the city and promote inclusivity and equality.

Figure 29: Conceptual layout of 'All Disability Park'

Source: (Author)

d) Green Parks

Green Parks are proposed in the downstream with variety of public gardens/urban forestry, walkways and parks including opening rear portion of Siddharth Garden along the river promoting recreational, ecological function and non-motorised urban mobility. Transport routes proposed in transportation plan shown in blue to enhance the accessibility to the riverfront activities.

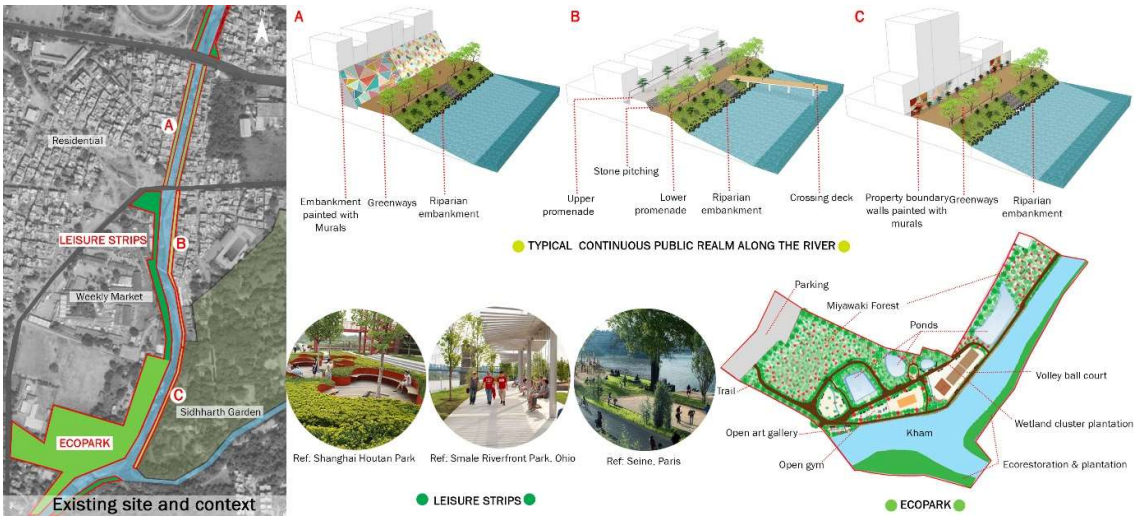


Figure 30: Conceptual plan for Green Parks

Source: (Author)

5.7. Heritage and Tourist Circuit Plan

A possible tourist circuit plan is proposed, that integrates existing sites of tourist importance with newly proposed riverfront sites (Figure 31). Heritage Conservation Plan for 'Nehers' and Heritage Structure

along River is also suggested. Various conservation measures such as structural restoration, illumination and fountains are proposed for conservation, and promotion of heritage assets and 'Nehers' in the study area (Table 7) and (Figure 32) .

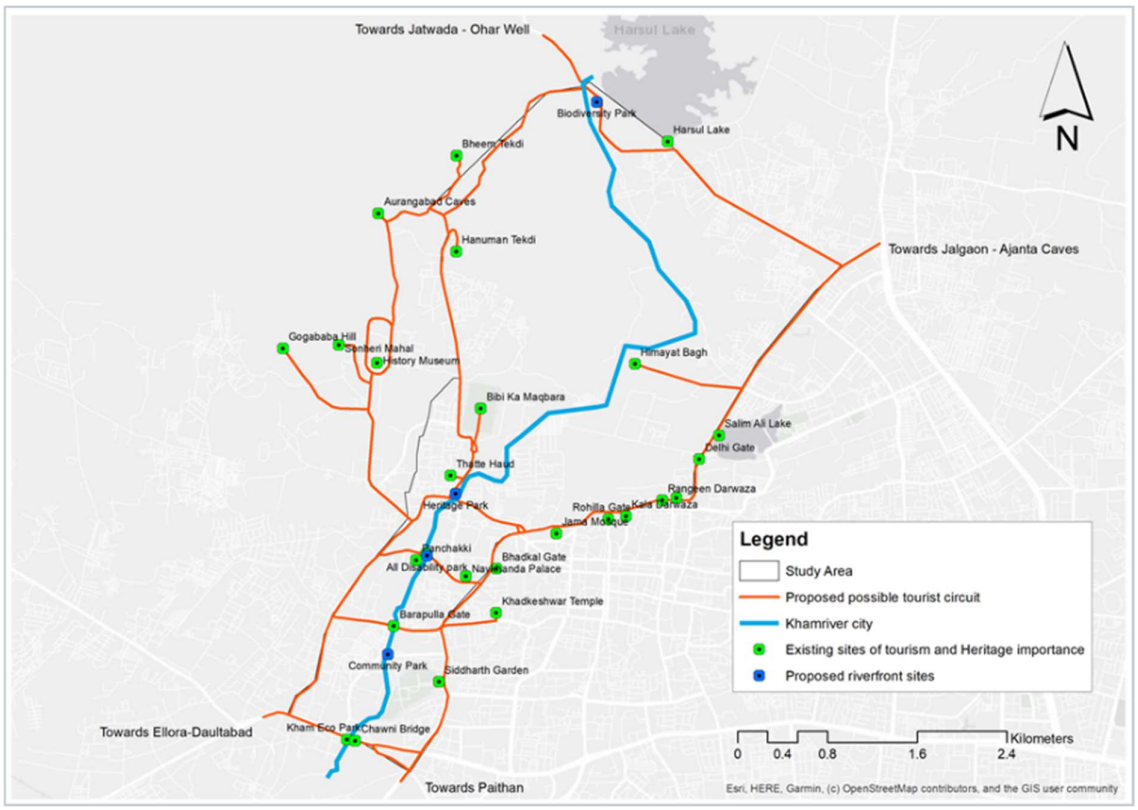


Figure 31: Possible tourist circuit plan

Source: (Author)

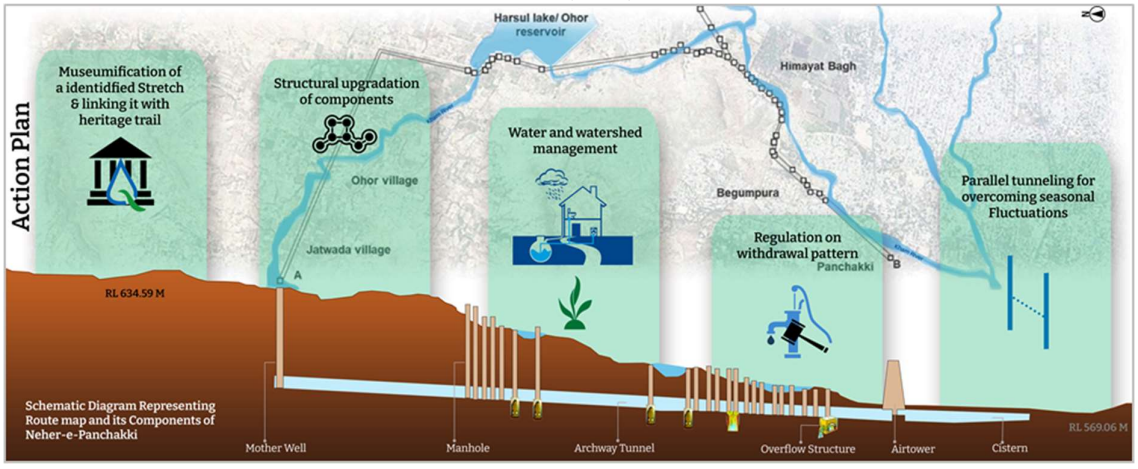


Figure 32: Action plan for conservation of Nehers

Source: (Khadke & Mona, 2019); (Author)

5.8. Recommendations for Engagement and Sensitization of Citizens in River Activities

Currently, there are number of avenues used by the city to raise awareness and engage citizens on the value of rivers, and the need to protect them. For e.g. CARPE | Eco sattva a private organisation in collaboration with various instruments organises various programmes on different occasions, wall

paintings along river, clean-up drives, conducting educational tours for school children on biodiversity along river etc. Particularly celebration of 'Kham River Restoration Day' - 25th January on annual basis from 2023 is worth unique. While these have had some effect, there is good room for improvement in terms of behavioural change. This can be done using innovative approaches like as follows:

- Organising Competition for school Children;
- Conducting heritage walk every month.
- Live Performances by youth, local artists;
- Hoardings, digital displays

On similar lines, interventions such as engaging citizens in water quality monitoring and organizing clean-drive on regular basis can be looked up.

5.9. Development, Management and Finance

5.9.1. Creation of Kham Committee

Currently, there is no independent committee formed which will manage and developed the river stretch. So Creation of Kham committee or similar kind of statutory body in consultation with all the stakeholders is proposed. This body should exclusively deal with the matters related to rejuvenation, development, maintenance and management of waterbodies, 'Nehers', and environment in the city.

Figure 33: Kham committee responsibilities and functions

Source: (Author)

5.9.2. Phasing

The implementation of the project is divided into 3 phases (Figure 29) on the basis of division of stretch of the river with long-term timeline of 10 years and hence will start from the upstream section of the river. The proposal needs to be executed in a strategic and careful manner on the basis of annual monitoring, evaluation, and implementation of key lessons learnt.

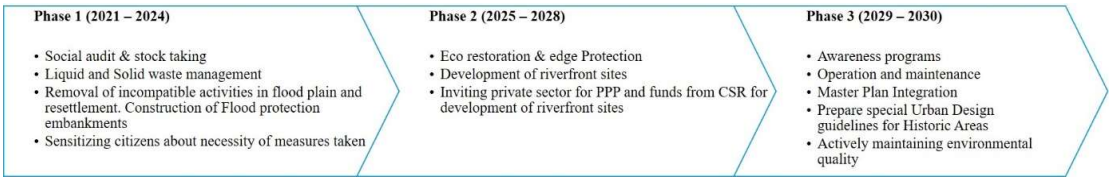


Figure 34: Phases of riverfront development

Source: (Author)

5.9.3. Budgeting and Fund Flow Mechanism

Various funding sources and scheme have been worked out for the implementation of the specific proposal of the project, for instance Biodiversity Park could be developed with the help from CAMPA fund, recreational parks under CSR and so on as mentioned in (Table 8)

For revenue generation from the riverfront activities to the local body, a visiting fee of 20 rupee shall be collected at riverfront sites that could be used towards development and maintenance of sites. The budget allocation for the overall project may be prepared upon further discussion with the State and AMC. Further means of fund flow may also incorporate such as CSR, crowdsourced funding etc. A fee of ₹ 20 may be charge for developed spots from the visitors and be use be for maintenance and development.

Table 7: Schemes identified for implementation for proposal

Sector	Interventions	Scheme/Funding source
Riverfront spatial intervention	Biodiversity Park	CAMPA, Forest department
	Heritage Park, Ecopark, Gardens, walkways	CSR
	All disability park	CSR, SMART Cities, Self-funding
	Tourism promotion, Heritage restoration	MTDC, AMC, ASI
Engineering measures	Eco restoration, Pollution control	Jal Jeevan mission, SBM, Smart City Mission, Self-funding
Solid waste management services	Nala cleaning, Desilting of river	Swatchh Bharat Mission, Mazi Vasundhara programme(State)
Citizens engagement programmes	Water quality monitoring, Clean up drives	Smart city, SBM, Jal Jeevan Mission
Operation and maintenance		A visiting fee of 20 INR can collected at proposed riverfront sites

Source: Adapted from (URMP by NIUA, 2020)

5.10. Impacts and Benefits

Through this project, the deteriorated urban river – Kham and its adjoining area can be successfully transformed into a high-performance and low maintenance front yard, which will have positive impact on environmental, social and economic attributes of the river. River will find safe passage through the city, at the same time provide public access to high quality open space, restore native habitats for biodiversity, and attracts residents and tourists. This waterfront can act as a catalyst in connecting the community to their context and sensitising them to become aware of the great potential this has for their future development, also stimulating a positive change towards the immediate environment.

6. Conclusion and way forward

This project tries to deal with some of the most common issues and problems associated with urban rivers and its adjacent area. It tries to address the issues of seasonal river that is often considered 'nala'. For compact city like Aurangabad situated in drought prone area with paucity of open spaces, it is imperative to leverage the Kham River that passes through the city and take opportunity to develop into eco-friendly riverfront area. The proposal is low-maintenance, ecologically functional, and active. It will not only provide a recreational place for the communities but also rebuild ecological health leading to the recovery of biodiversity and native habitat around it, as it become an attraction for the whole city of Aurangabad. Rejuvenation of stream and its adjacent area takes into account of social, environmental, and economic aspects that will facilitate connecting the community to their context and sensitising them towards blue green environment.

The proposed development should be included in future masterplans of the city. Intervention and development akin to the proposals for Kham should be done for Sukhna river in the city and other relevant water bodies. Case of illegal settlements should be settled at the earliest and resettlement options should be deliberated upon.

7. Acknowledgments

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8. Conflict of Interest

Authors has no conflict of interest to declare.

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10. References

Ahmedabad Municipal Corporation. (2018). *Sabarmati Riverfront Development Project.* Retrieved from https://smartnet.niua.org/content/ab02acfb-48d4-4c8d-8b16-7ef7d3fc22f8

Boralkar, D. (2014). *Project Proposal on Bioremediation of sewage Disposal in the Kham river, at Aurangabad (Maharashtra).*

Census . (2011).

Development asia. (2016). *Revitalizing a City by Reviving a Stream* . Retrieved from https://development.asia/case-study/revitalizing-city-reviving-stream

Ecosattva. (December 2021). *Kham River Restoration Project: Summary Report* . Aurangbad.

Environment and Climate Change Department, Government of Maharashtra. (2021). *Majhi Vasundhara Abhiyan*. Retrieved from https://majhivasundhara.in/en/majhi-vasundhara-abhiyan

Geo-Resource Mapping Pvt. Ltd. (2021). *Detail plane- table & contour survey using drone Kham river at : Aurangabad.*

Global Designing Cities Initiative. (n.d.). *Case Study: Cheonggyecheon; Seoul, Korea*. Retrieved from https://globaldesigningcities.org/publication/global-street-design-guide/streets/special-conditions/elevated-structure-removal/case-study-cheonggyecheon-seoul-korea/

Hathway, E., & Sahrples, S. (2012). The interaction of rivers and urban form in mitigating the Urban Heat Island Effect: A UK case study. *Elsevier*.

Jagdish. (2014). *SRDP, Ahmedabad.* Retrieved from http://urbanmobilityindia.in/Upload/Conference/b84df2be-cebe-4e83-a741-c6eb4c97f5c9.pdf

Karhade, V., Kamble, A., Vangujare, S., Wadgaonkar, P., Gadekar, G., & Godihal, J. (2020). Environmental Impact Assessment of Anthropogenic Activities and Conceptual Restoration Strategy for Kham River in Aurangabad, India. *Current world environment*.

Khadke, S., & Mona, I. (2019). *'Nehers' of Aurangabad: Medieval Water Planning, Current Use and Challenges.*

Kodarkar, M., & Joshi, S. (2010). *ILBM Impact Story.*

Lall, N. (2016). Creating a Civic Realm Ganga Riverfront Revitalisation, Patna. *Tekton*, p. Vol. 3.

Li , X. (2016). *Planning Integrated Approach in Riverbased Regions towards Low-carbon development.*

Lombardi, A. (2014). *https://www.witpress.com/.* Retrieved from Ecosystem under restoration : a sustainable future for the cultural landscape of San Antonio River, Texas : https://www.witpress.com/Secure/elibrary/papers/SC14/SC14096FU2.pdf

MPCB. (2015). *CEPI Presentation on Action Plan for Aurangabad.*

MPCB. (n.d.). *Proposed Action Plan dor Industrial Cluster at Aurangabad.*

MTDC. (2010). *Vision tourism 2020.*

NilA Architecture and Urban Design. (2020, July 24). *Patna Riverfront Development and Revitalization*. Retrieved from Architecture Live: https://architecturelive.in/patna-riverfront-revitalization-by-nilaa-architecture-and-urban-design/

NIUA & Namami Gange. (2020). *Urban River Management Plan (URMP).*

NIUA. (2020). *Mainstreaming Urban River Management into Master Plans.*

NMCG. (2020). *Guidance note for environmentally sensitive,climate adaptive and socially inclusive Riverfront Planning and Development . .*

Rathore, A., & Jadon, S. (2019). A sustainable approach for urban riverfront development. *IRJET*.

San Antonio River Authority. (2022). *The San Antonio River Improvements Project*. Retrieved from https://www.sariverauthority.org/: https://www.sariverauthority.org/about/history/san-antonio-river-improvements-project

Seoul Metropolitan Government. (n.d.). *Stream Restoration Project.*

Seoul Solution. (2017). *Seoul Urban Regeneration: Cheonggyecheon Restoration and Downtown Revitalization*. Retrieved from https://www.seoulsolution.kr/en/content/seoul-urban-regeneration-cheonggyecheon-restoration-and-downtown-revitalization

Shinde, S., Patil, K., & Sadgir, P. (2016). Assessment of river and groundwater quality and its suitability for domestic uses in Aurangabad, Maharashtra, India. *Current World Environment*.

Sinde, S.D.; Patil, K.A.; Sadgir, P.A.;. (2016). *Assessment of River and Groundwater Quality and its Suitability for domestic Uses in Aurangabad, Maharashtra, India.*

SRFDCL. (2021). *Sabarmati Riverfront*. Retrieved from https://sabarmatiriverfront.com/srfdcl-master-plan/

TCPO. (2020). *River Centric Urban planning Guidelines.*

Timur , U. P. (2013). *Urban waterfront regenerations.*

Urban Development & Housing Department, Government of Bihar. (2016). *Patna Masterplan 2031.*

Urban Sustainability Exchange. (n.d.). *Seoul Urban Renewal: Cheonggyecheon Stream Restoration*. Retrieved from https://use.metropolis.org/case-studies/seoul-urban-renewal-cheonggyecheon-stream-restoration#casestudydetail