Changing perspectives from nalah to nadi: Landscape development of Kukrail nadi, Lucknow, Uttar Pradesh

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By
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CERTIFICATE

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Declaration

I **Abirbhav Sanyal**, Scholar No.:2017MLA005 hereby declare that the thesis entitled Changing perspectives from nalah to nadi: Landscape development of Kukrail nadi, Lucknow, Uttar Pradesh, submitted by me in partial fulfilment for the award of Master of Architecture (Landscape), in School of Planning and Architecture, Bhopal, India, is a record of bona fide work carried out by me. The matter embodied in this thesis has not been submitted to any other University or Institute for the award of any degree or diploma.

07th April 2019 Abirbhav Sanyal

Certificate

This is to certify that the declaration of Abirbhav Sanyal is true to the best of my knowledge and that the student has worked under the guidance of the following panel.

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I would like to give my fondest regards to my parents, who have always provided hope and encouragement to me during my moments of despair. They are the ones who imbued me with a sense of calm and spirit that made this thesis possible.

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Once again, a heartfelt thanks to the afore-mentioned people, who have nurtured and inspired me.

ABSTRACT

Urban streams, in today's world are one of natural resources that are threatened throughout the world. Despite carrying the most precious substance for life, they have been abused and ignored. This work traverses through the various aspects and layers of a stream to understand its structure and connections to understand the damage caused by insensitive urban developments. It also studies the associations and connections of urban streams with people to understand their behaviour towards the landscape resource. Cases of revival have been studied and the question is being put forward, "Can the perspective of the streams be restored to what once was considered sacred?" and "Can that perspective help preserve the sanctity of riverine landscapes?"

This thesis looks towards one such neglected stream in Lucknow and traces its history through its degradation just to find out ways to revive its physical, ecological and cultural importance in the city. Applying fresher perspective in a holistic fashion, it is an effort to redefine the urban experience of the stream and help rebuild connections with people in a landscape development approach.

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1. INTRODUCTION

1.1. Background

Water streams have been the origin of civilizations. Cities have thrived due their proximity to these water bodies since ages. Ever since man has learned to settle down, he has been altering the landscapes of this earth. Streams have been source of inspiration and life due to the various boons it provides to the settlements residing on its banks. Thousands of years of alterations have changed the face of earth from a natural canvas to human touched urban patterned scape. River basin is a 'geographical unit' enclosing an area drained by streams and channels that feed a river at a particular point. All the precipitation that falls on these slopes will either evaporate, used by plants and other living organisms, ground or end up in the river after various natural and man-made uses. Thus, it follows that river basin provides an important region to understand the implication of any particular form of human use of water. In many cases urban streams are the reminiscent of the natural drainage systems which still act as the arteries of the settlements.

In our urban development and land use planning concepts throughout the history, we have barely considered layers such as watershed contexts and ecological components. (Arnold C.L., 1996) it is the result of such endeavours that today's fast growing urbanization takes a heavy toll on water streams and its ecology. Urban stream degradation is now a worldwide phenomenon which quite challenging as its restoration is not instant, but takes time (J. Walsh, 2005). This universal issue has been taken into notice in many countries which are trying to restore these watersheds to their original form but, in developing countries like India a lot of research and remediation is still awaited.

1.2. Eco-system services

Urban water streams are one of the anchoring features of urban ecosystems which support all of the population, some directly and others indirectly. They also play a major role in providing ecosystem services.

Despite of obstructions in the catchments the urban streams continue to be a resource for the settlement. The given figure depicts the various services an urban stream provides. All of these services are owed to the uniqueness of geo-morphological features and

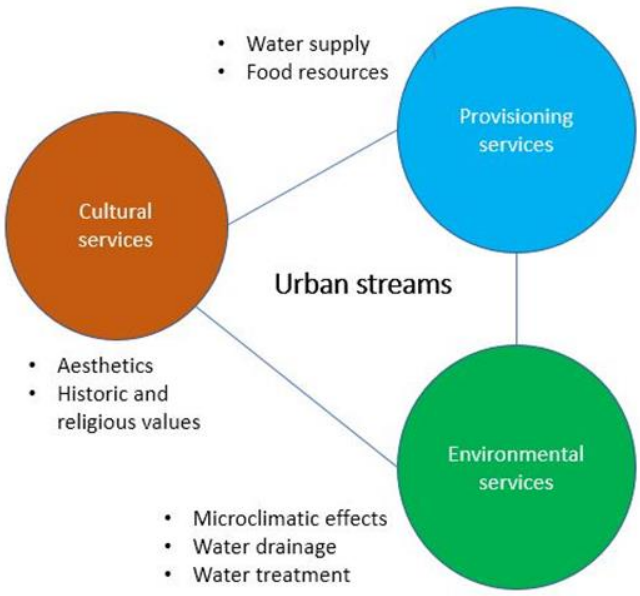

Figure 1-1Diagram depicting the services provided by streams

ecological character of the landscape of a stream. The potential and necessity of an urban stream in a city is enormous and usually an amalgamation of most of the mentioned boons as depicted. This is the very reason of urban settlements being formed around these streams, in order to harvest these resources. Drainage is the major service provide by these streams which play a vital role to sustain these settlements.

1.3. Perspective of a stream

In India, one may be a rare creature if they would have spent their childhood without at least hearing stories mentioning great and beautiful rivers. Since the beginning of our time as humans, we have been fascinated by the look and feel of these enormous vessels carrying our life substances. Sometimes fearsome and yet other times serene and chuckling; these streams have been our mother, our gods, our inspiration and our life. The light to us moths, these rivers have always been preference to early settlements which have grown into mighty civilisations, the remnants of which we still live in or know about.
This aesthetic and sensory quality of rivers led to connections to humans and thus inspired sacredness and love for such landscapes.
In today's date however, despite sacredness the value of this streams have been ignored.

1.4. Introduction to Site

1.4.1. Physical overview

It is one of the five tributaries of Gomti River, flowing in the middle of one of the densely populated areas of the city of Lucknow. A total stretch of 26km, the stream was a perennial stream is now seasonal. It was said to originate from Asti village in the north of Lucknow city, fed by groundwater springs in the reserve forest and through runoffs from neighbouring farmlands and urban settlements. In the present scenario the stream is visible from the forest, enters the urban area near Abrar Nagar. It meanders its way through Khurram Nagar, Sarvoday Nagar, Kukrail Pul and finally drains into the river at Jugauli. With a catchment of 87.5 km2 and a minimum of 30% of it with unplanned urbanization, the stream faces stress from these settlements in form of urban surface.
Runoff, storm water drainage and sewerage. The stream receives flow from three 3rd order streams which carry sewerage and urban effluents. The major flow in present consists of sewerage which has suffocated the landscape of this stream. The catchment also witnesses encroachment which leads to loss of riparian vegetation and edge degradation. Solid waste dumping is also a common visual character on the edges of the stream.

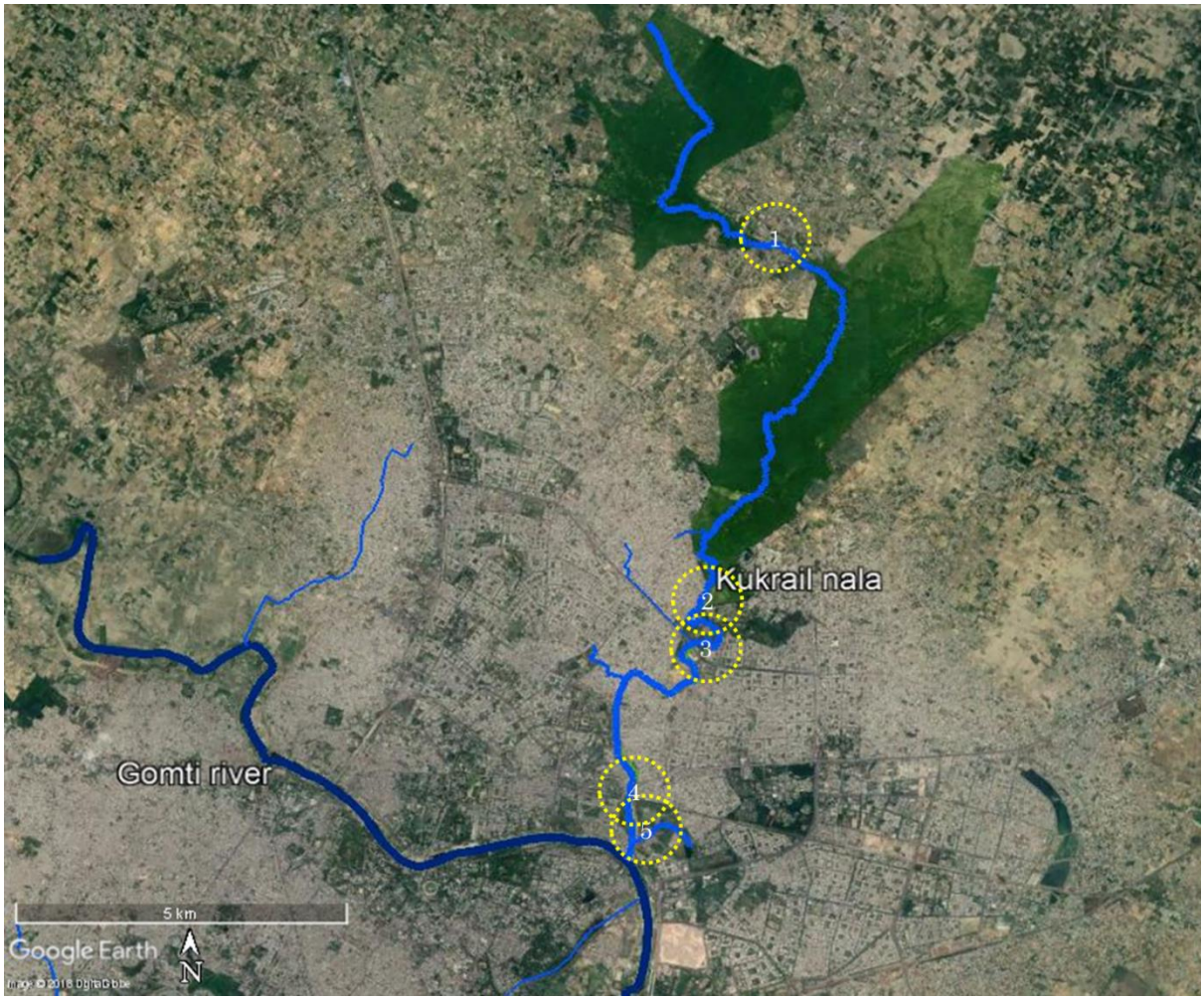

Figure 1-2The Kukrail stream and its peripherals

Figure 1-4 Kukrail stream near Khurram nagar @ 3

Figure 1-3 Kukrail stream @ 5

The leaching from these heaps of garbage adds to the contamination of the water. Loss of riparian vegetation can be linked to two factor a) Encroachments, b) water and soil contamination. Soil erosion is in form of runoff from fallow lands in the catchment and flood plain, and also from the barren edges of the stream. The health of the stream is in a steep decline which is evident to a mere look to any common viewer.

1.4.2. Cultural overview

Even though the human connection in today's date with Kukrail is that of drain carrying away waste; folklore suggests a belief of healing existed not more 50 years ago when the water was in its pristine condition. "Kukrail" gets its name from the local word "Kukur" meaning dog, which connects to a story of loyal dog belonging to a local saint. The river was believed to have originated from the grave of this dog, which was buried in a pond in Asti village. And hence, the sacredness of this stream was in the treatment of dog bites and hydrophobia.
This particular folkore has lost its knowhow in the new urban development and so have people lost their connection to the stream.

1.5. Aim:

To assess the case of Kukrail nadi, its current condition and reform the dynamics in and around it for the rejuvenation of its physical, ecological and social importance in Lucknow.

1.6. Objectives:

I. Understanding the landscape character and values of the Kurail urban stream, its importance in the Gomti basin.
II. Understanding the inter-relation between the city and the stream.
III. Assessing the condition of the stream and highlighting issues due to stresses from urban settlements to pinpoint source of origin.
IV. Identifying suitable programs for stream corridor design and management.

1.7. Methodology:

I. Studying the phenomenon of urban stream degradation through literature.
II. Identification of mal-practices which cause the phenomenon through literature and studying the ways used to cope with them through case studies.
III. Learning ways to analyse the landscape character and condition of urban streams and their surroundings through literature.
IV. Site study based on learnt assessment skills to understand current health of the landscape and issues related to it.
V. Data collection of various resources related and depended on the stream from administrative bodies.
VI. Analysis of site data to pinpoint source of the issues and to identify locations where design interventions could be applied.
VII. Policy formulation based on study of best management practices and site context as learnt from literature studies.
VIII. Design interventions of selected sites to detail out solutions of the issues identified.

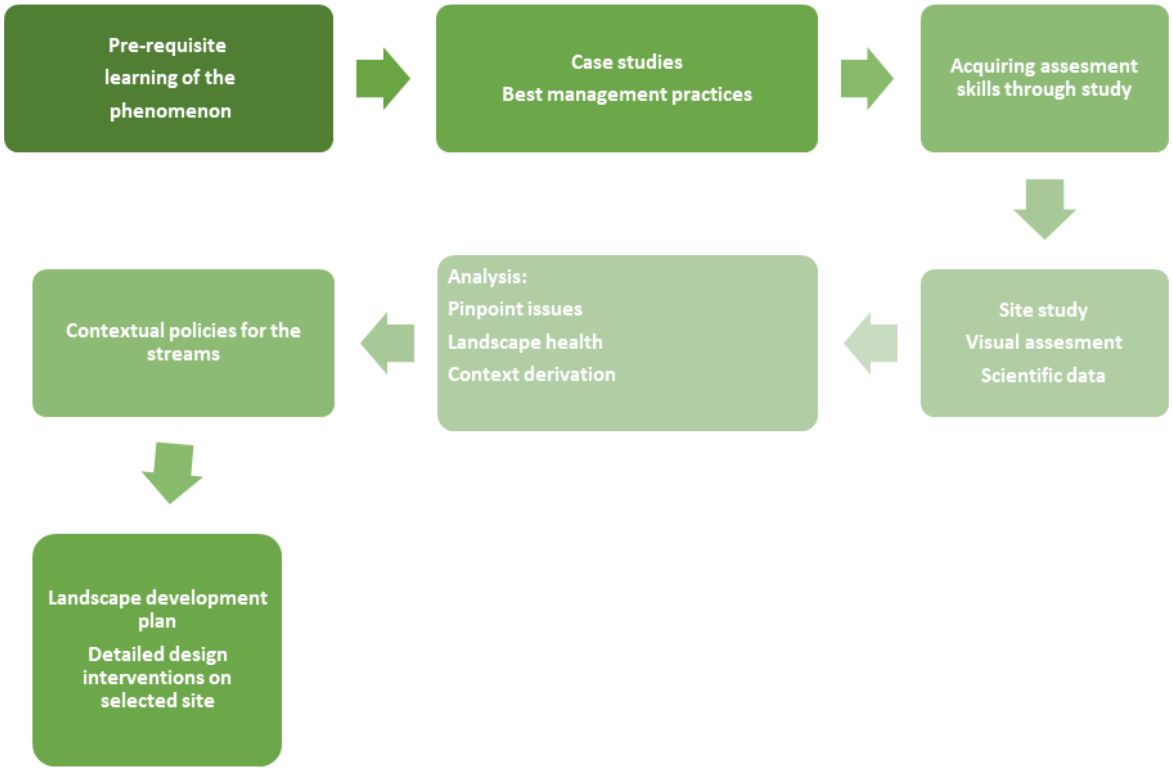

Figure 1-5 Methodology

2. LITERATURE REVIEW

2.1. Urban stream degradation

This term is used to sum up the downfall in the health of a stream due to stresses from surrounding urban settlements. It collectively describes the degradation in the physical, chemical and bio-logical health of an urban stream through finding comparisons to less-degraded relative streams (Allison Roy, 2016).

First and second order streams i.e. smallest part of a river which is furthest from the river's endpoint, are an important part in river system. They provide aquatic habitat, maintain water quality in downstream river and other water bodies and hence help in providing clean drinking water. These streams have an ecosystem of their own, as they contain wide range of species of fish, invertebrates and algae which are important in retaining and removing nitrogen and other nutrients. All these aspects are highly dependent on urbanization and watershed land use. Stream burial, a process where streams are channeled into culverts, pipes and other impervious surfaces, is one of the significant adverse impacts of urbanization on streams. Since these streams are small, it becomes economically feasible to bury them, destroying the largest fraction of natural stream length. This phenomenon is responsible for destruction of natural streams which results in deterioration of habitat in downstream river and water bodies, degradation of nutrient retention capacity and increased transportation of toxic contaminants. (Elmore & Kaushal, 2008)

In an urban area, where small streams are buried, larger streams and rivers are protected by riparian zones while in sub urban areas due to presence of less impervious surfaces, runoff filters through the ground contributing to ground water table.

Figure 2-1 Ideal stream

Figure 2-2 Degraded Kukrail stream

2.1.1. Indicators of stream degradation

The symptoms of urban stream syndrome can indicate degrading health and stresses from urban settlements. These indicators can be used to assess urban streams and help find the source of problems in any given case (JUDY L. MEYER, Sep., 2005).

- *Unpredictable hydrograph:* The stream flow and amount of water if found inconsistent, indicates interruptions in catchment. The imperviousness of urban settlements is the cause of such behaviour of the stream and is an indicator of insensitive development in the catchment.
- *Elevation in nutrient and contaminant concentration:* The amount of nutrients found in the stream directly explains the type of activities that happen in its catchment.
- *Change in morphology and bank stability:* With erosion and silt deposition the shape and course of the stream changes. The edges clearly depict the state of degradation of a stream.
- *Loss in vegetation and biodiversity:* Non-vegetated edges and degraded riparian vegetation are clear markers of dilapidated health of the landscape. The bio-diversity is scarce as due to adverse conditions sensitive species die out or migrate and tolerant species take over.

The above-mentioned indicators can help understand the condition of a stream in an urban set up and provide clues for remediation. (Christopher J. Walsh, 2005)

2.1.2. Urban stressors

(JUDY L. MEYER, Sep., 2005)

- Reduced infiltration due to urban development in catchment areas.
- Storm water and surface run-off carrying effluents from different land-use.
- Sewerage from poorly planned urban settlements.
- Encroachments on non-serviced lands yield solid waste and effluents.
- Replacement of riparian vegetation with settlements.
- Reduced rates of nutrient usage due to degradation of ecosystem component.

2.1.3. Phenomenon of stream degradation

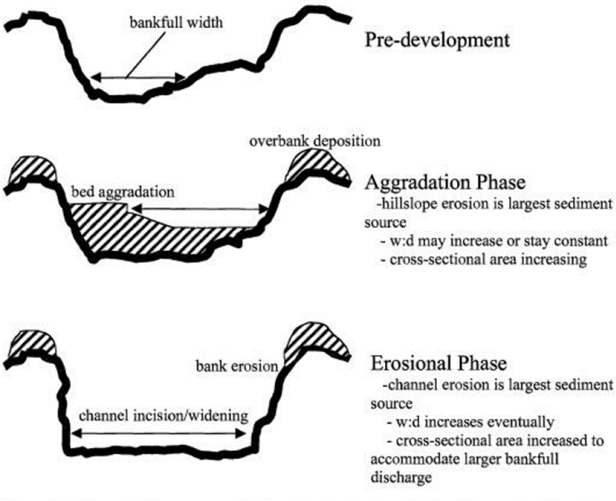

Figure 2-4 Changes in channel with urbanization.

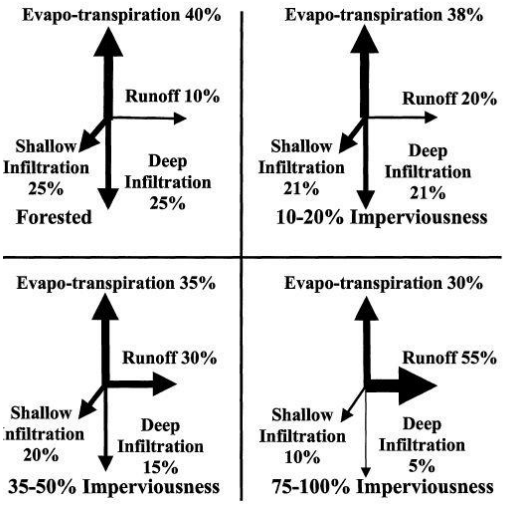

Figure 2-3 Changes in hydrological flows with increasing imperviousness (Arnold and Gibbons, 1996.)

The above figures depict morphological (Fig.2-4) and hydrological changes with increase in urban densities in catchment areas due to increase in imperviousness (Fig.2-3) (Michael L.Paul, 2001).

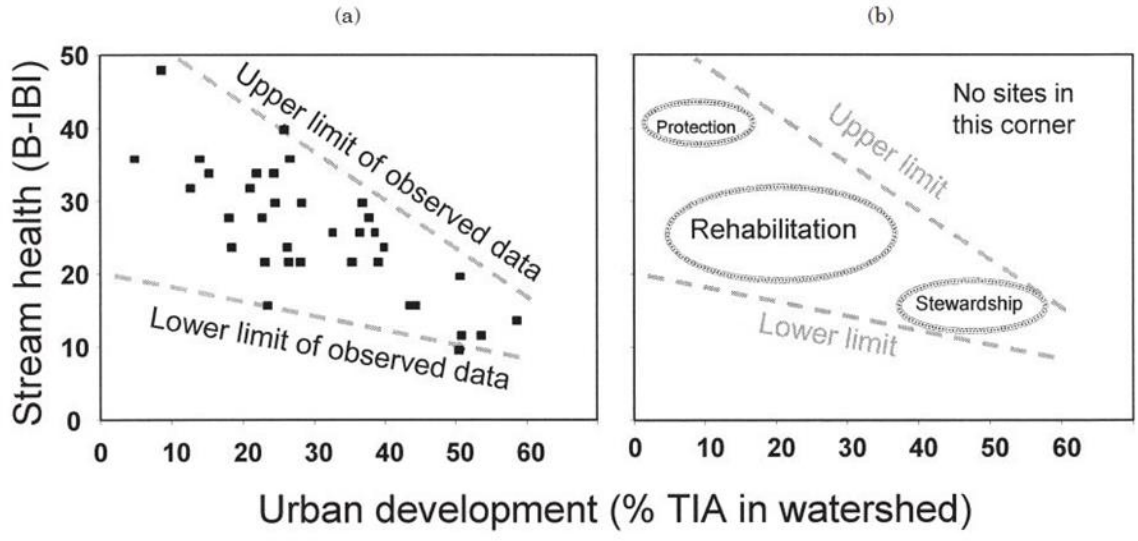

Figure 2-5 Plot of stream health v/s urban development (source: Derek B. Booth, 2004)

The stress from urban settlements has become so severe with growth that a direct relation can now be established between stream health and urban settlement (Fig.2-5). (Derek B. Booth, 2004)

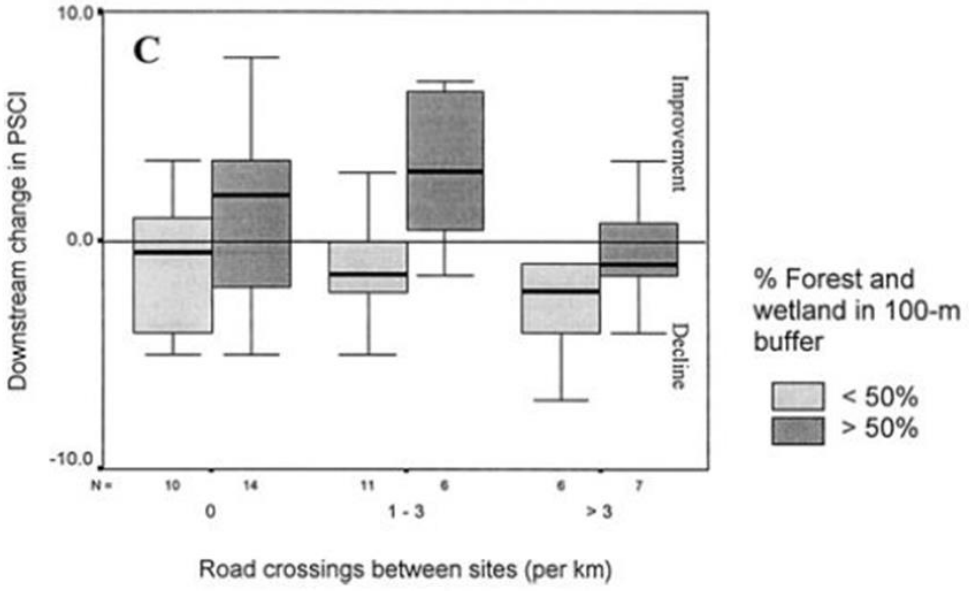

Figure 2-6 Plot of stream health change in relation to urban infrastructure

Urban infrastructure such as roads crossing over streams have negative effect on the physical condition of the stream, which worsens even more with reduced buffer width (Maeve McBride, 2005)

2.1.4. Assessment models

a. *Physical stream condition index (PSCI) or Index of stream condition (ISC) (Ladson, 1997) Field based data assessment*
   - Bank stability:
   - Bed condition
   - Density and origin of coarse woody debris (for floodplains reaches of streams only)
   - Width
   - Longitudinal continuity
   - Structural intactness
   - Proportion of cover which is indigenous
   - Condition of oxbow in floodplain

Observations to be rated as per ISC rating tables for all of the above parameters and cumulative indices to be generated. These indices shall highlight the areas which require interventions the most and individual scores shall indicate the particular issues to be tackled.

b. *Tropical rapid appraisal of riparian condition (TRARC) (Ian Dixon. Michael Douglas, 2006)-Field based assessment for vegetation*
   - Canopy cover, health, continuity
   - Tree sizes

- Large trees
- Vegetative regeneration
- Varied storey of vegetative layers and organic litter
- Weed community, canopy, cover
- Exposed soil
- Bank sediment size, slope
- Exposed roots
- Logs
- Gullies and undercuts
- Animal damage
- In stream structures
- Structures in the riparian area

The observations to be rated as per systems provided in the guideline to achieve scores for particular transects.

Both these analysis systems can also be used in reverse to achieve restorative guidelines in terms of designing the edges and riparian corridors for better scores.

2.2. Riparian buffer

Riparian buffers have been proven essential in maintaining the stream health. The width of the buffer has been the principal focus of most designers and regulators in recent times. Regulators and practitioners are following varying set of guidelines all over the globe. This is due multiple factors which owe to the complex structure of a stream. The stream is an intertwined system of physical, chemical and bio-logical mechanisms working in coherence with each other. Riparian buffer width has been determined through various formulae developed by experts based on their focus area. These focus areas determine the function as well as the width of the buffer as mentioned below (Tiwari, 2019).

Table 2-1 List of recommended buffer as per functions

	Function	Recommended buffer width	Author
1	Water quality improvisation	>30m	Lynch et al. (1985)
		>25m	Young et al. (1980)
2	Amphibian/ reptilian habitat	>30m	Rudolph and Dickson (1990)
3	Avian habitat	>40m	Hagar (1999)
		50-1600 m	Richardson and Miller (1997)
		>50 m	Whitaker and

			Montevecchi (1999)
4	Plant diversity	>30 m	Spackman and Hughes (1995)
5	Small mammal habitat	>50m	Dickson (1989)

2.3. Damage remediation

a) Phyto remediation techniques involve plant species that work on various nutrients and additives in the streamto improve water quality (Chhotu D. Jadia, 2009):
   - Phytoextraction (heavy metal sequestration): Species: Sunflower (H. annus), White mustard (Sinapis alba)
   - Phyto stabilization (soil stabilization): Species: Chara grass (Sorghum), Salix sp.
   - Rhizofiltration(water remediation):Species: Rye, Spinach, Corn, Paddy

b) Bio-remediation: Soil remediation techniques to eliminate excess organic contaminants through introduction of microbial elements.

The Natural Biological Systems or constructed wetland systems are on-site methods for simultaneous purification of soil and water. These complex and modular systems can be applied to urban/ sanitary, agricultural and industrial, lake and river rehabilitation etc. in varying environmental and climatic setups. It integrates sustainable and natural methods to process added constituents of pollution using plants, aggregates and hydraulic conditions. The living system is stabilized by the vast and varied surface area of carefully selected aggregates that are placed in the optimal arrangement for filtering, absorbing and interacting with pollutants. Together the combinations of the biological and physical components degrade, accumulate, extract, and volatilize contaminants of all kinds in water, soil and the air, resulting in clean and purified outflow. The technology makes use of a range of natural elements such as plants and biological supplements, aggregates with different physical and chemical properties and various hydraulic regimes.

Table 2-2 List of plant species used for phytoremediation

S.no	Scientific name	Media
1	Talinum fruiticosum	Hydrophonic system
2	Cyperus rotundus L.	soil and water
3	Echonrnnia crassipes	water
4	Spirodela polyrhiza	water
5	Pistia stratiotens	water
6	Alternanthera philoxeroids	river edge

7	Chrysopogon zizanioides	water edge and soil
8	Typha angustata	water edge and soil
9	Helianthus annuus	soil
10	Typha jatropha	soil
11	Cenchras ciliaris	soil
12	Arundo donax	soil
13	Typha elephantina	soil
14	Canna indica	soil

2.4. Effect of natural landscapes on urban environment

Kaplan's "Attention restoration theory" and "restorative capacity of natural textured environment"

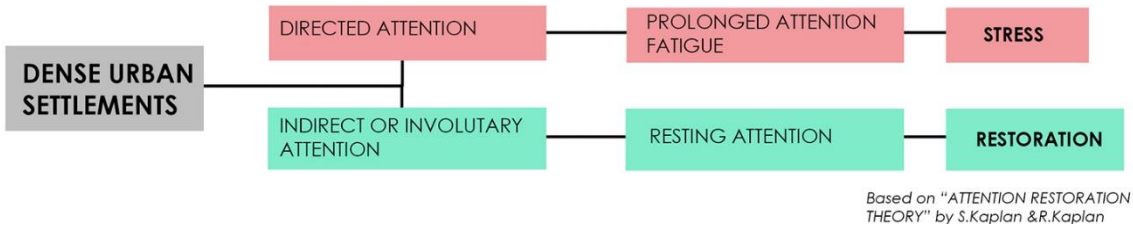

Figure 2-7 Illustration of Kaplan & Kaplan's "ART" theory

S.Kaplan & R.Kaplan give credit to the attention process and cognition for the overall physiological and psychological health in an urban area. The concept of attention states the process of reading and understanding the surrounding environment in terms of uninteresting, against the grain to fascinations and interests (James et al 1959). Reading and assessing against the interest require effort and thus in a prolonged sense causes fatigue. The texture of nature however, does not require forced attention and therefore, has the appeal of an escape from the fatigue.

Figure 2-8 R.Kaplan's theory of nearby nature and its components

In her work Rachael Kaplan explains the need of nature being close by, also termed as "nearby nature" or "nature at the doorstep" is a concept for urban settlements to have pockets of open green spaces amongst the dense built setup.

2.5. Case Studies

2.5.1. Chengochyang river landscape development, Seoul, South Korea

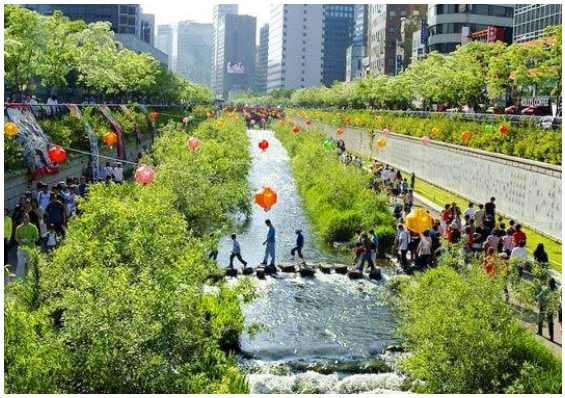

Figure 2-9 Stone crossing on the stream

Figure 2-10 Planting on the edge of the stream

The chengochyang river revival is one of the pioneer landscape restoration project in world. Its urban course stretches over 5.8 km in length and passes through the densely populated urban settlement. The area developed in the vicinity of the river along with the revival project sums up to 100 acres which includes public open spaces, walks, promenades and plazas both inside and outside the ROW of the river.

Post war migration and urbanization led to the deterioration and burial of the stream. High density of urban development demanded open spaces for the public and the site provided open spaces and room for breathing amongst the busy site flanked on both sides by busy roads. The dimension of bio-diversity was touched which responded positively adding to the quality and experience of the open space to home tranquillity as well as energy in the course of the stream.

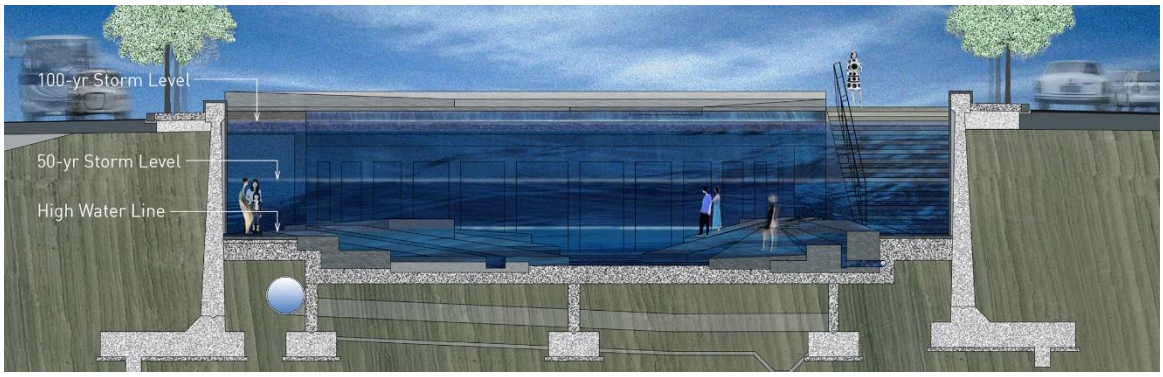

Figure 2-11 Designed for 100 years flood event surrounded by transport corridor

Key issues:

- Seasonal nature and urban discharge in the stream.
- Urban stream burial and its oblivious ecology.

- Near extermination of bio-diversity associated with the river.
- Decline in community life in old Seoul downtown area.
- High pollution levels from the transport corridor.
- Rickety urban infrastructure and safety issues.

Key interventions:

- Diversion of sewage into sewer systems away from the stream.
- Designing 100 year flood protection through dug in retaining walls to hold peak discharge possibility.
- Maintaining water flow in lean period from Han River pump.
- Landscape design to accommodate interactive open green spaces.
- Design to support bio-diversity including both flora and fauna.
- Community upliftment by economic models from tourism planning on the stream.

Figure 2-12 Social spaces on the edge

Figure 2-13 Real estate boom along the stream

Inferences:

- Putting stream health in priority and seeing natural resources as potentials for betterment of urban experience.
- Adhering to the urban context and issues, solutions through involvement.
- Breaking room for breathing spaces for dense urban areas.
- Showcasing landscape as an asset and social space.
- Economic boost based on the experience landscape features bring based on the demand to be close to nature and its experience.

2.5.2. Barapullah landscape development proposal, New Delhi by Oasis design

The barapullah nala carries urban effluents and sewage from south and east Delhi into the Yamuna River near Sarai Kale Khan. The study here discusses the various aspects covered by team Oasis in their proposal for the development of a green corridor on the stream. Urban drainage is the paramount issue in all cities; and with heavy urbanization and migration Delhi faces challenge to carry and treat urban effluents.

Another challenge for a metropolitan is to provide for public open spaces to its populous. Delhi fortunately, has a multitude of spaces with varying themes and sizes. The vision here aims to create a connection for open green space network while also providing alternative transition corridors with better serial and spatial quality.

- *Ecological restoration:* This project initiative aims to reclaim almost 700 acres of open space in the South of Delhi to restore the ecological function of dirty storm water laden urban stream in order to change the stretch of 12.5 km long Barapullah drain into an ecological corridor.

Figure 2-14 NMV corridor and social spaces

Figure 2-15 Greenway in the riparian corridor

- *Green infrastructure for mobility:* The goal of this project is to create the first permanent car-free cycling and walking corridor in the city, providing critical connectivity to and from the metro and bus stations.Connecting five tourist destinations such as the Bahai Temple, Qutub Minar, Delhi Haat, the 5-Sense Garden, this park will also turn into the tourist spine in Delhi, enabling people to experience nearly 1000 years of the history of the city within about 10-15 kilometres.
  Heavy traffic issues always grip cities of such size and urban density. The alternative method can be to encourage non-motorised corridors which eases the load on the conventional traffic. In this case the Nizamuddin area has a railway station which witnesses a high traffic movement for obvious reasons. Adjoining is the ISBT at Sarai Kale Khan and the nearst metro station of Jungpura. The flow and transition amongst these three

nodes is very crucial and the close proximities allowed the porposal of an alternate route of travel which takes off the burden from the conventional traffic.

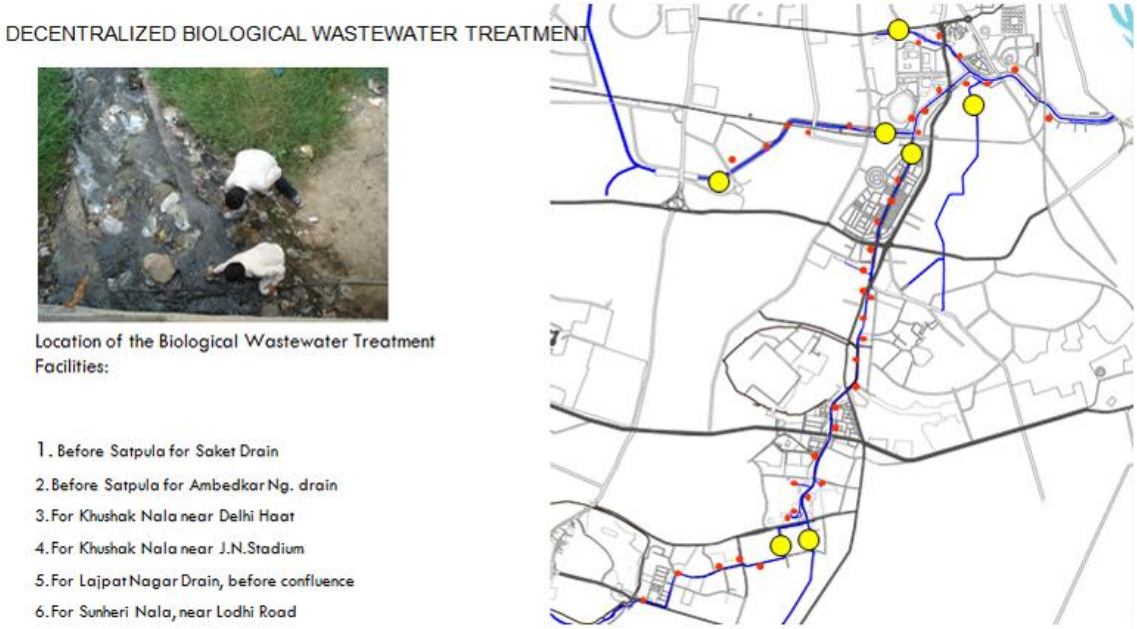

Figure 2-16 Urban waste water treatment strategy based on decentralized units

- *Urban waste water and storm water management:* The project South Delhi Greenway intends to highlight ecological solutions as well and to use a site-based approach to create a vibrant new public environment for the city, designed to address the problems of solid waste handling, waste water pollution and storm water management. The park shall use decentralized biological wastewater treatment systems to purify wastewater, which by specialized natural bio-remediation methods pollutes water from the water drain. The current dirty, odourless drain must be transformed in a green corridor in the city and the park shall utilize decentralized biological waste water processing systems to purify wastewater, which pollutes the drain, with the help of specialist natural bio-remediation technology.

Figure 2-17 Restoration of riparian edge of the stream

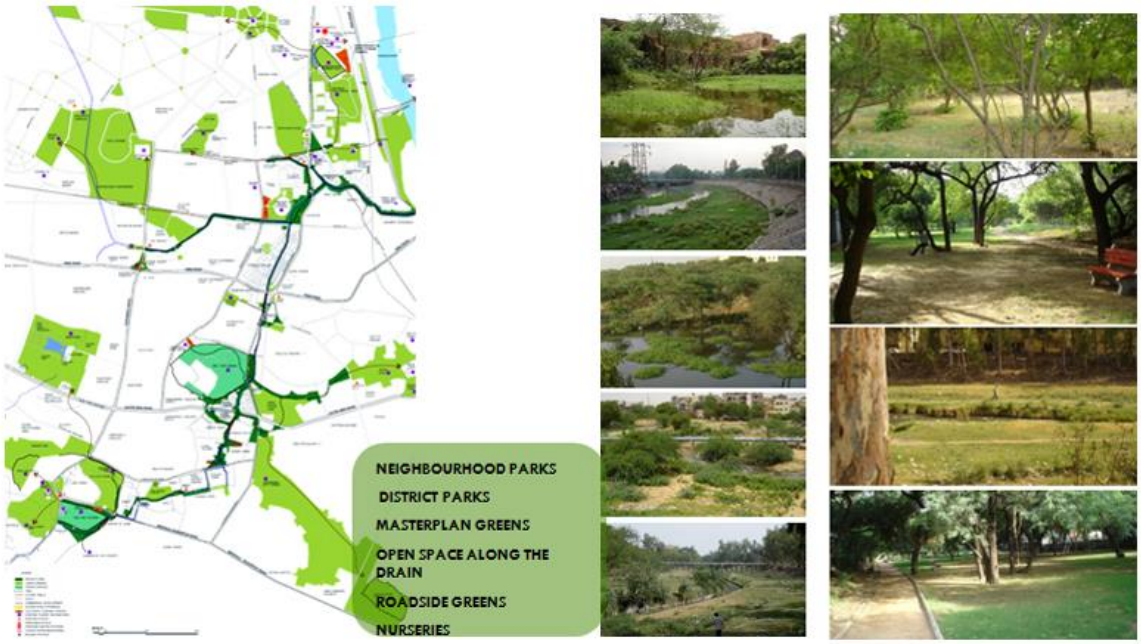

Figure 2-18 Networking of multiple open spaces across the city based on the linear corridor

- *Public open space:* The development of adjoining land parcels into breathing spaces and also connecting them to existing open spaces which, creates a network of spaces and invigorates the outdoor experience and gives tranquil spots for resting.

Inferences:

- Interception of sewage and storm water before reaching the main stream. Opportunities of providing alternative services.
- Walkable and cycle pathways help in reducing pollution, have health benefits which is rare in dense urban settings.

- Connection to the social network and nature through developing an open green space network.
- Economic support for lower income populous by providing a chance through NMV services.

2.5.3. San Antonio urban stream management, San Antonio, Texas

This particular case has been studied to understand the land use and land management practices in and urban setting. San Antonio is a good example of how keeping landscape features in perspective can help structure the urban experience better. The city has two streams flowing through its urban boundaries, namely San Antonio River and Salado creek. The salient features of the land management of the city are as follows:

- Integrated green open spaces connected with green ways on the course of the water.
- Protection of the streams in order to maintain the character in landscape to retain the quality of the space.
- Administration and bodies like San Antonio green alliance keep close watch to sustain these spaces.
- Adds to the social infrastructure and health of the residents of the city while retaining landscape character.

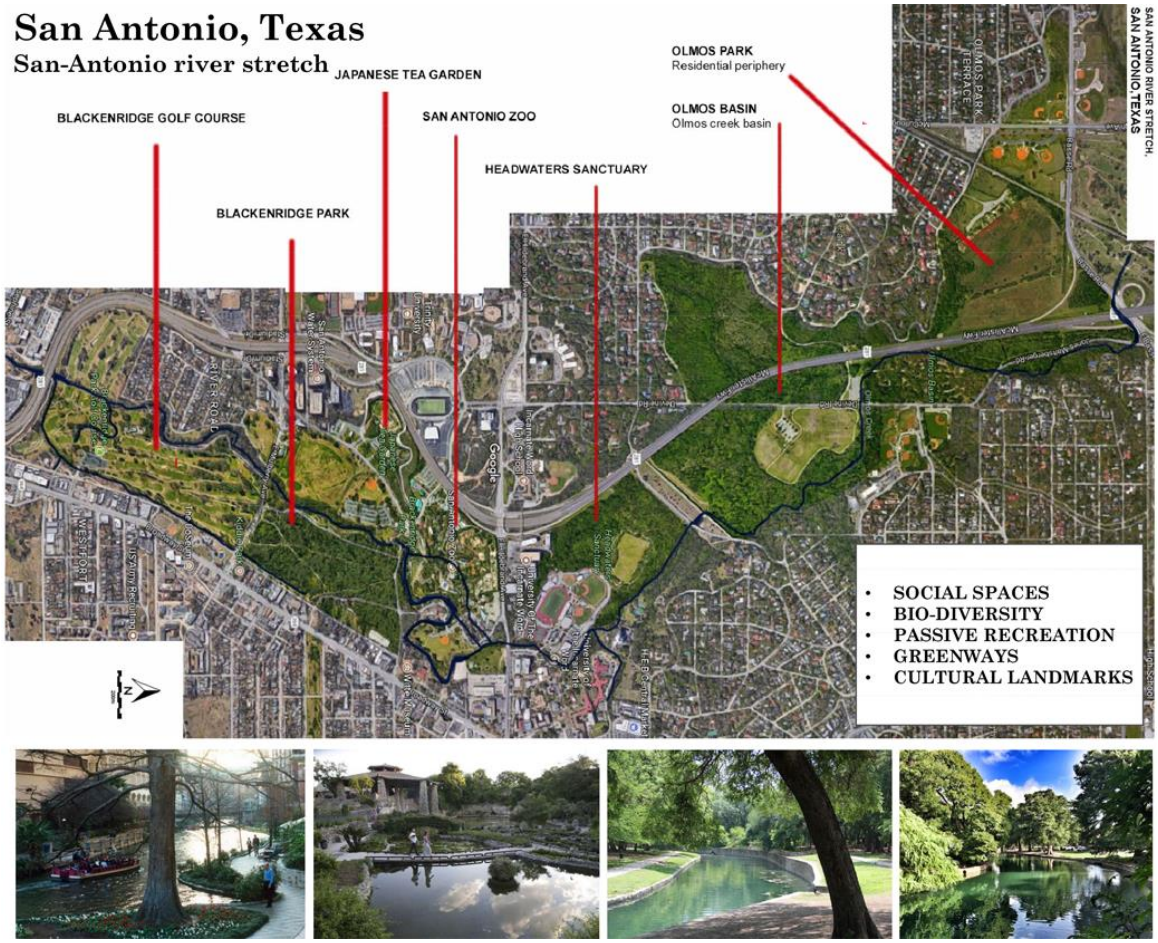

Figure 2-19 San Antonio river and its relation to the planned open spaces on its banks

Inferences:

- Land use based on the ecological footprint.
- Green open spaces and institutions with large campuses assigned in proximity to the stream.
- Development of Non-motorised corridors for transition.
- Connecting spaces in proximity of the streams and themselves to create continuous experience of the unique heritage of the city

3. SITE ANALYSIS

3.1. Physical and topographical Analysis

The total area under the Kukrail basin is 87.4 sq.km out of which 45% goes under urban settlements, 36% under farming and fallow lands, and 19% under forests.

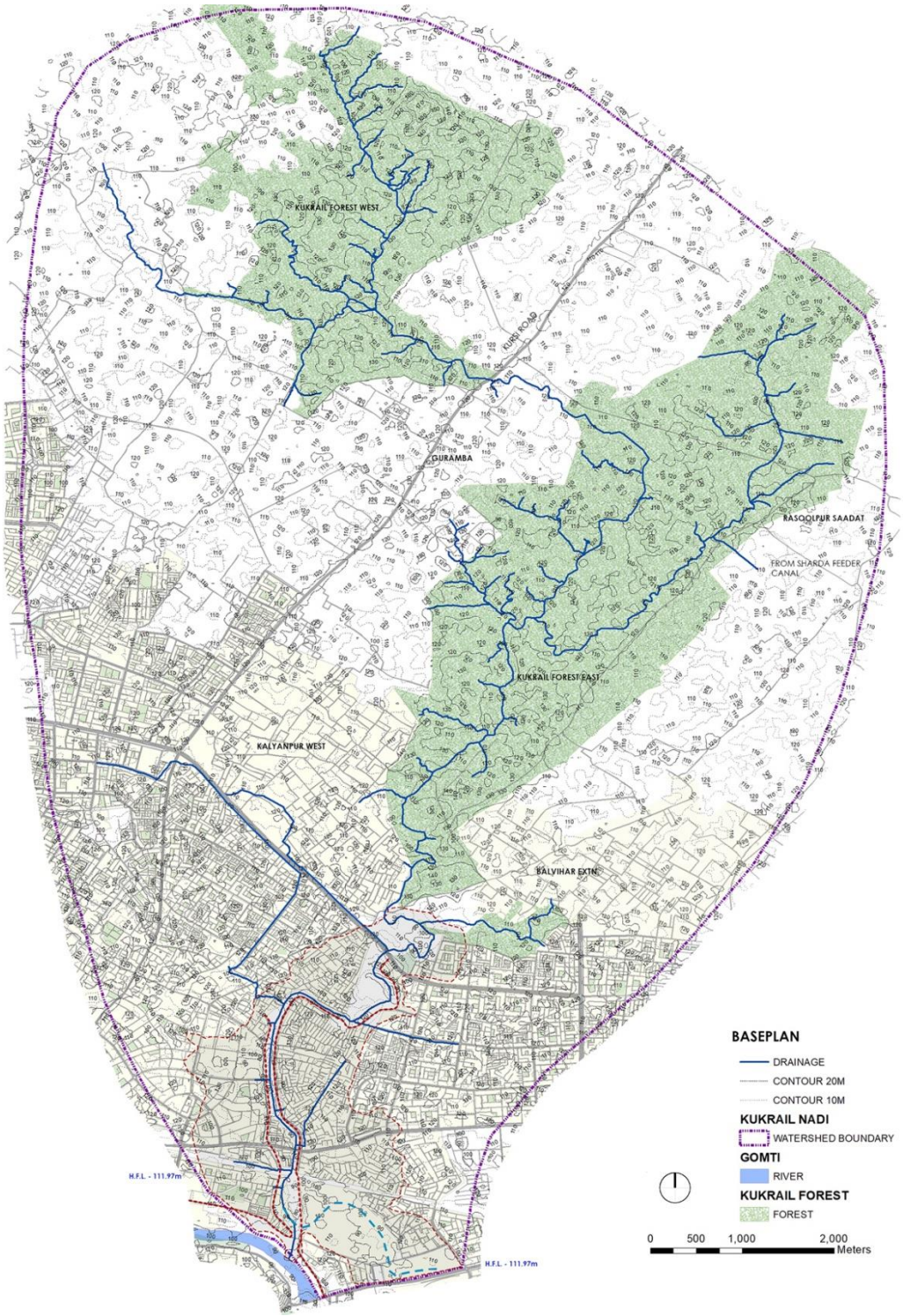

Figure 3-1 Kukrail basin map (based on USGS database, Arcmap GIS)

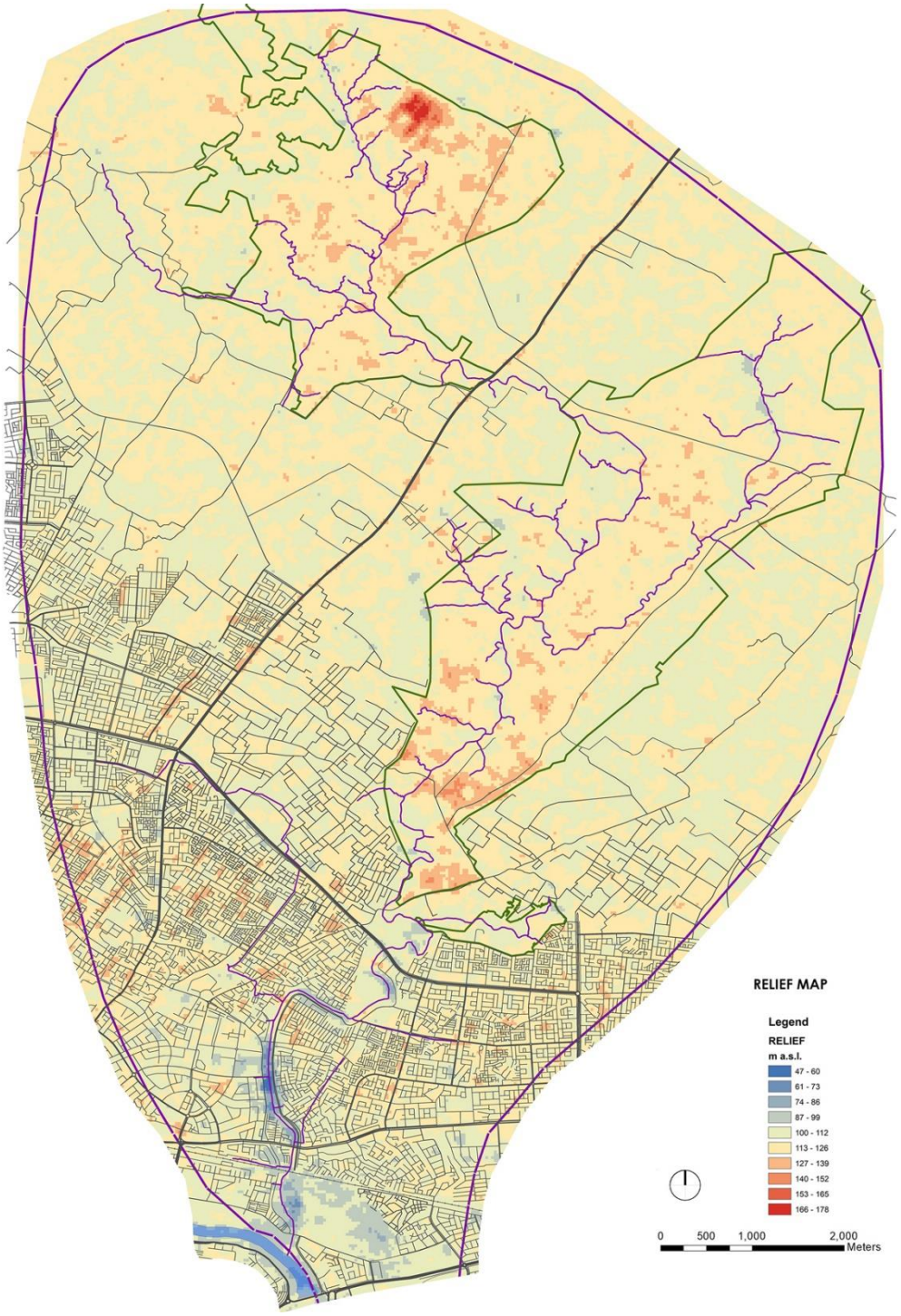

Figure 3-2 Relief map of the Kukrail basin (based on USGS database, Arcmap GIS)

The elevation in the Kukrail basin varies from as high as 178 m and as low as 47m above sea level. About 80% of the total area in the basin lies on an average elevation 90 to 110 m above mean sea level. The higher elevations found in the forest range and lower near the confluence of the stream with Gomati River. The terrain is majorly featureless as expected in the middle Gangetic plains of Awadh. Apart from the natural features urban areas have roads and dikes as miniature ridges which have effect on the overall drainage of the watershed.

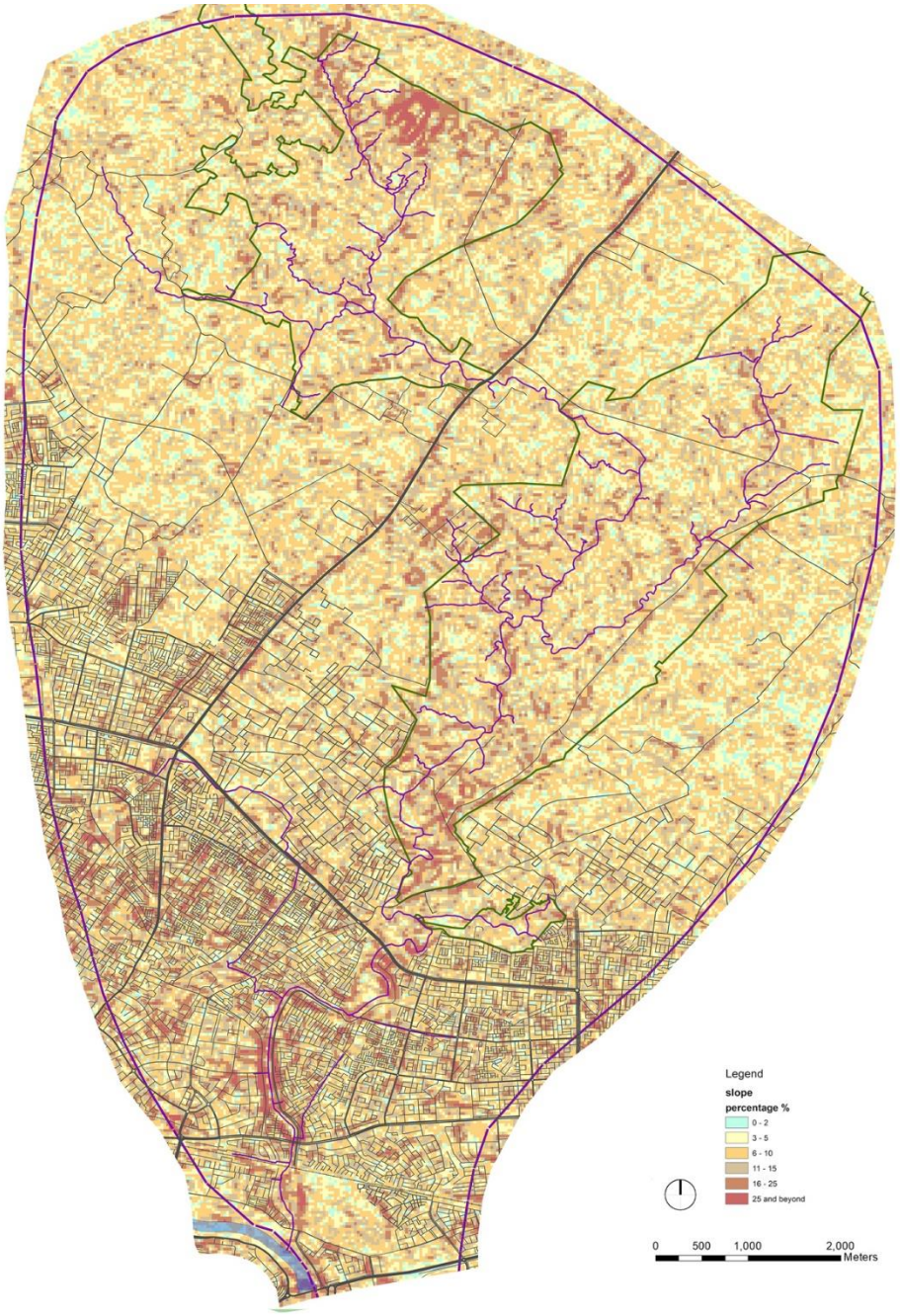

Figure 3-3 Slope map of the Kukrail basin (based on USGS database, Arcmap GIS)

The major slope dominancy in the landscape lies between 3-5% and 6-10% with higher slopes in the forest area and gullies. Also the dikes and road construction lead to higher slopes. Overall the slope in the landscape of Kukrail is gradual flowing towards the stream and even the headwaters of this streams flow at reduced speed.

3.2. Geo-morphological Analysis

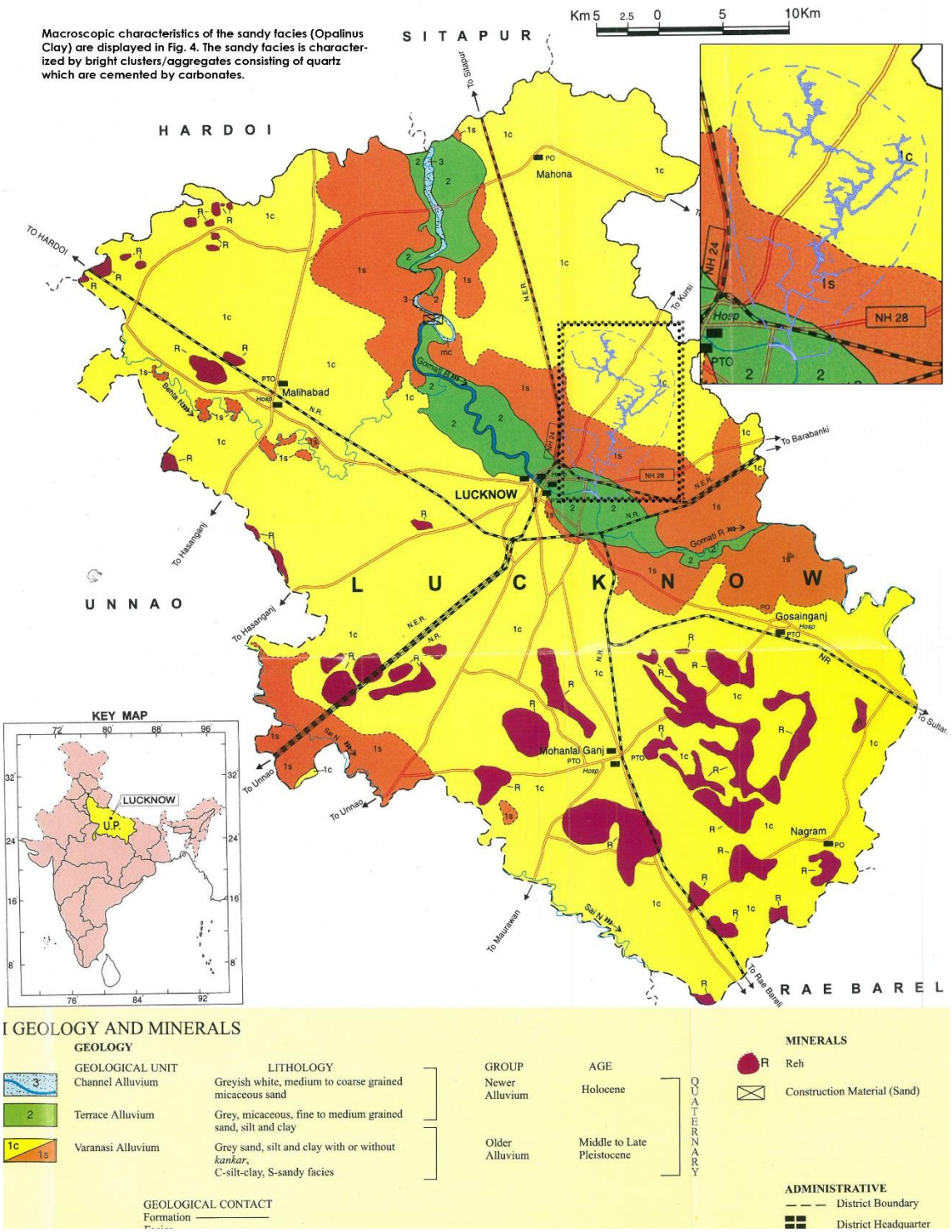

Figure 3-4 Geo-Morphological features of Lucknow district (source: GSI)

The basin has two major geo-logical features namely the older alluvium terrace and the newer alluvium terrace. The stretch from the origin to the half of the east forest is the part of older terrace and belongs to Pleistocene period. This stretch has a silt clay composition whereas the next stretch of the same terrace till half of the Sarvoday nagar has sand silt composition. The next newer alluvium terrace

consists of greyish white calcareous sand with silt. This soil is low on humus yet is highly fertile when irrigated and tended to. The newer alluvium terrace for Kukrail is currently under siege from urban construction thus, its fertility is unexplored. Also both the terraces have extremely high water percolation capacity which due to urban development have been buried and made impervious.

3.3. Climate

According to the Köppen Climate Classification, Lucknow lies under Cwa (Temperate-sub-tropical-Dry winter-Hot summer) .The average annual temperature in Lucknow is 25.7 °C. Precipitation here averages between 850-1000 mm. Precipitation is the lowest in November, with an average of 2 mm. Most precipitation falls in August, with an average of 305 mm.

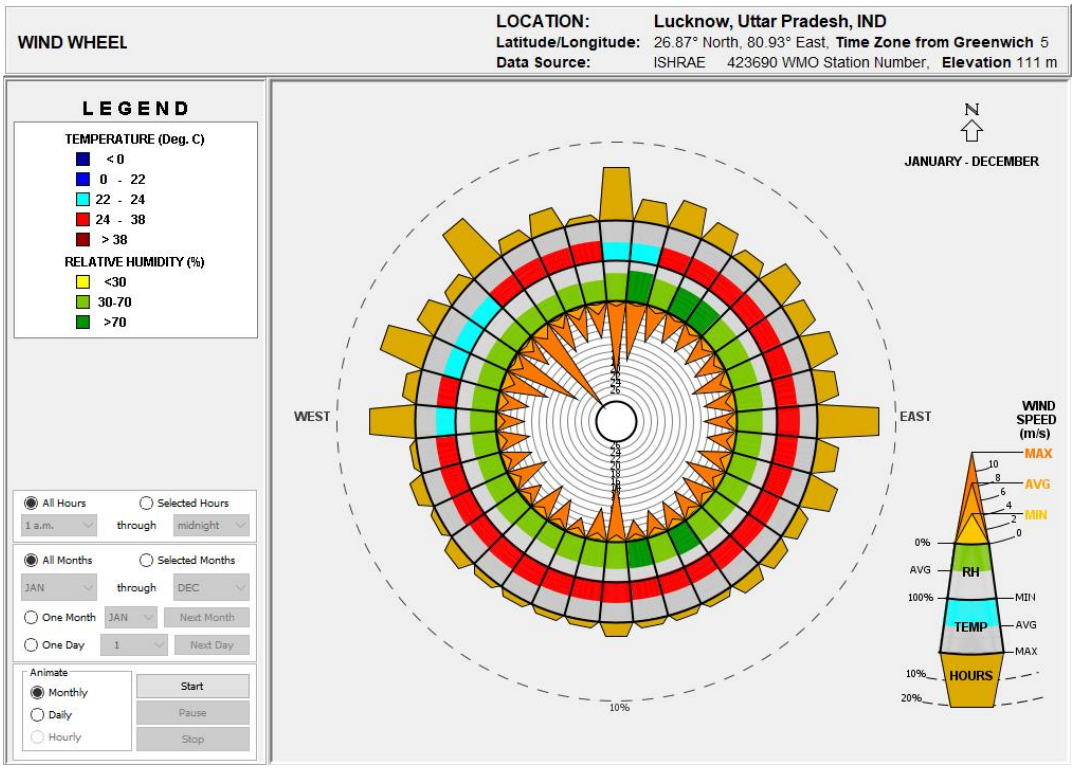

Figure 3-5 Wind Wheel

The region has hot summers with record of 48.5 degree Celsius and cold-dry winters with temperature as low as – 1 degree Celsius. This region is also subjected to both hot and cold winds speeding up to 28 m/s. The summer witnesses hot winds from the East and North West which is commonly known as loo. Whereas in winters the chilly winds are received from the North and North we

3.4. Hydrological Analysis

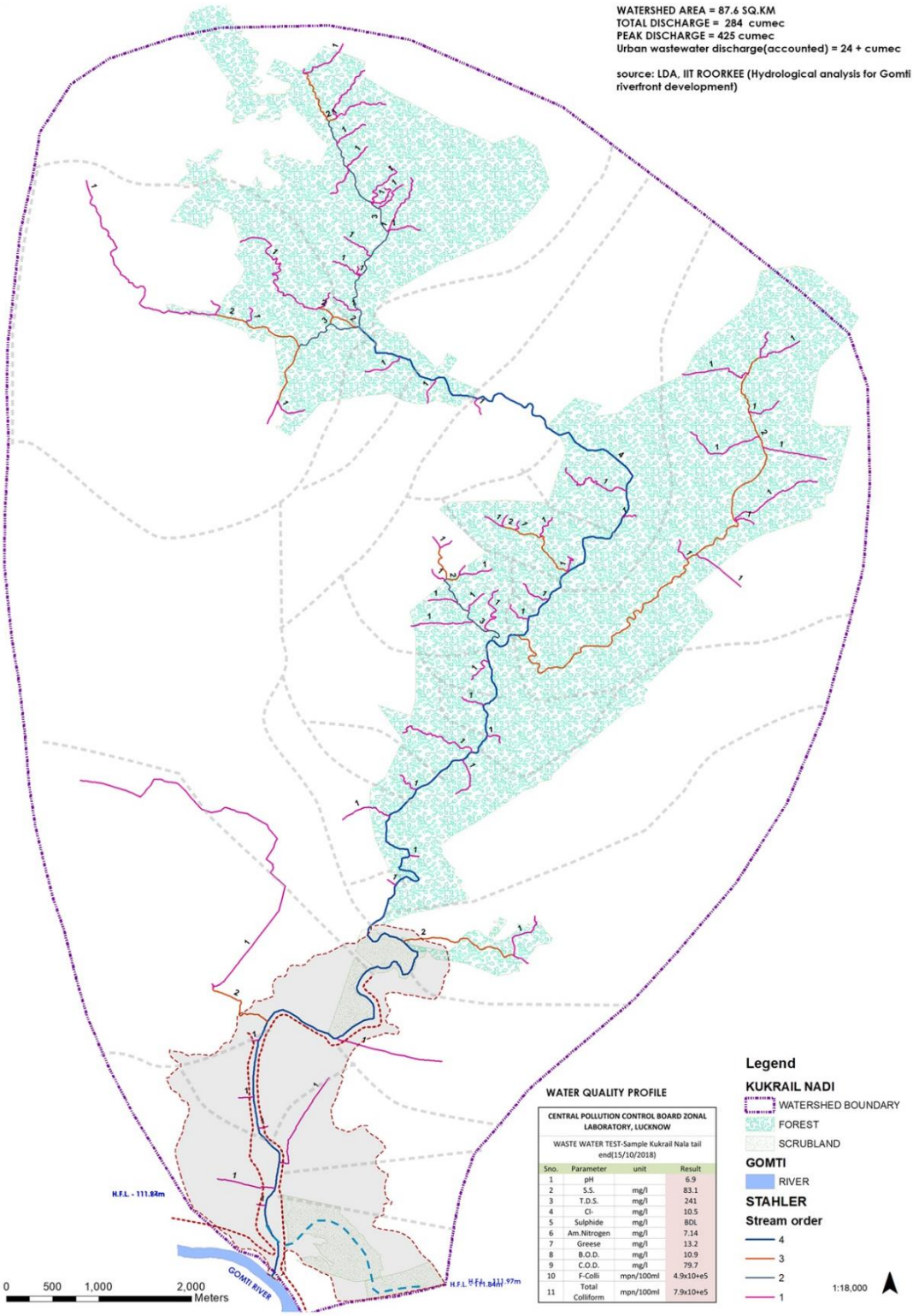

Figure 3-6 Hydrological map of Kukrail basin

Covering an area of 87.4 sq.km, the Kukrail stream basin is a reduced form of its previous size. Calculating from the starting point of its origin, the stream travels a course of 26 kms. Through the analysis of the current physical condition of the stream the following facts come to light:

Floodplain and events: As discussed above in geo-morphology and in the hydrological map, the urban stretch of the stream lies in the 100 year floodplain as shown in the map. There have been two notable flood events in 1960 and 1985 which had caused flooding in the adjoining areas of Mahanagar and Indira Nagar. The highest flood level recorded was nearing 112m a.s.l. (Commission, 2017). In response of the event a dike was constructed on the banks of Gomati and continuing into the kukrail urban stretch.

Course and volume of the stream: The current course of the Kukrail has been underway transformation due to multiple causes. Primarily a perennial stream, the Kukrail now has become a seasonal one but, still flows due to a support by pass channel from Sharda canal which feeds it inside the Kukrail east forest in order to conserve the habitats of crocodiles and turtles found in it. The reason for this drying up is change in land use, agricultural practices which obstruct its feeder drainage and extensive extraction of sub-surface water flows through boring. The smaller streams which feed the Kukrail stream have been compromised due to encroachments, their riparian corridors afforested and their catchments obstructed. Another phenomenon, is observed in the urban stretch where it meets the Gomati River. The flood prevention dike constructed in the 80's strangled it by cutting its course short.

Stream order and discharge: Kukrail stream is a fourth order stream in accordance to the Stahler's model of stream classification. It has a discharge of 284 mld out of which 180 mld accounts for the urban sewerage.

Water quality:
The quality of water is that of a mildly polluted stream apart from its microbial content of e-colliform which is at dangerous levels and in par with major rivers.

Table 3-1 Water Quality Report

CENTRAL POLLUTION CONTROL BOARD ZONAL LABORATORY, LUCKNOW			
WASTE WATER TEST-Sample Kukrail Nala tail end(15/10/2018)			
Sno.	Parameter	unit	Result
1	pH		6.9
2	S.S.	mg/l	83.1
3	T.D.S.	mg/l	241
4	Cl-	mg/l	10.5

5	Sulphide	mg/l	BDL
6	Am.Nitrogen	mg/l	7.14
7	Greese	mg/l	13.2
8	B.O.D.	mg/l	10.9
9	C.O.D.	mg/l	79.7
10	F-Colli	mpn/100ml	4.9x10+e5
11	Total Colliform	mpn/100ml	7.9x10+e5

Urban Micro-watersheds:

	Urban Micro-watersheds	**Area (sq.km)**	**Total water cap.(mgl)**
1	Sagara nala catchment	4.5	3621
2	Khurram nagar nala catchment	7.4	6357
3	Shisham bagh nala catchment	4.09	3181
4	Mahanagar drain catchment	1.9	1513
5	Railway colony drain catchment	0.15	110
6	Babaji ka purwa nala catchment	0.34	245
7	Ravindrapalli drain catchment	1.22	1012
8	Indira Nagar catchment	3.4	2696
	Total		**16039**

Table 3-2 Urban micro-watershed capacity

The above table depicts the total storm water from the urban catchment of the stream.

3.5. Flora and fauna

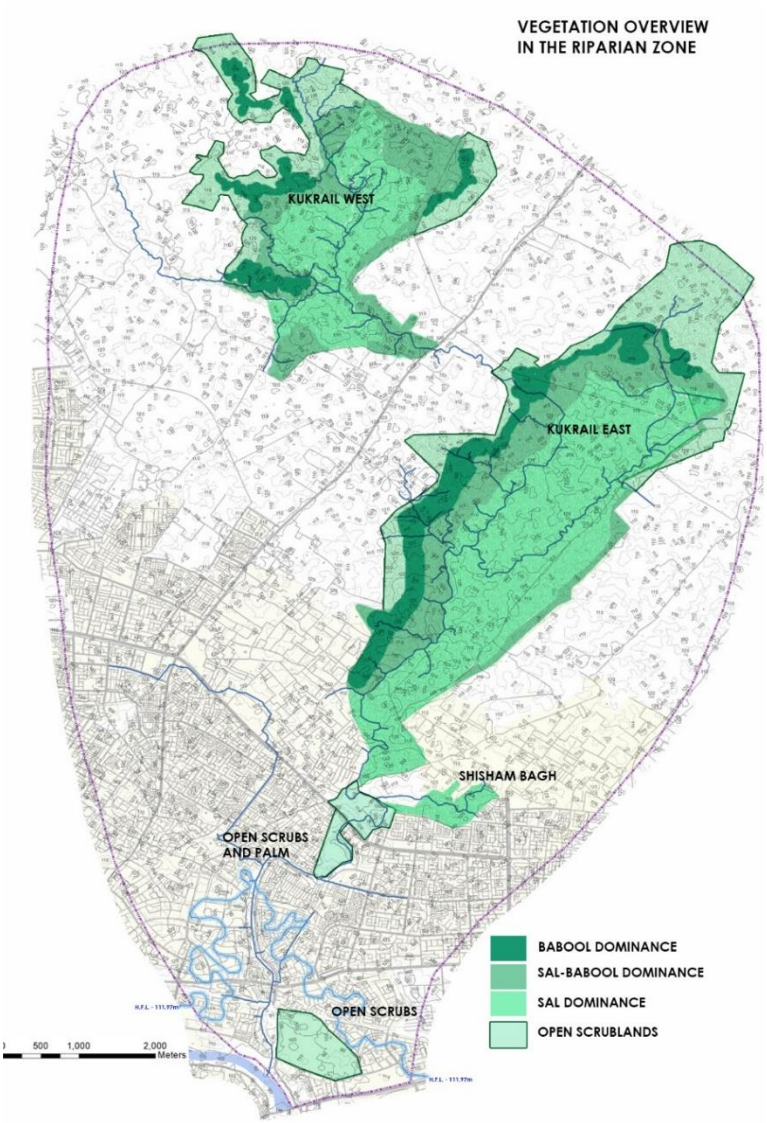

Figure 3-7 Mapping of forest sub-types in the Kukrail basin

3.5.1. Forest and flora

The forest type found in this part of the Indo-Gangetic region is tropical mixed deciduous forest (dry and moist). Forest sub-types found are:
a. Northern dry/mixed decidous
b. Dry babool forest
c. Date palm forest

The figure depicts the kukrail forest on the banks of the Kukrail stream. The dominant species found in the range is Sal (Shorea robusta). The mapping of these forest types has been done based on the soil study and related flora species. (Prachi Gangwar, 2018) (Monika Kumari, 2016)

The Awadh plains has a rich phyto-diversity which has been listed below.

Figure 3-8 Kukrail reserve forest- east

Table 3-3 Native flora species of Awadh floodplains

(Source: Awadh Forest department, Kukrail range)

No.	Common Name	Scientific Name
GRASSES		
1	Anjan	Cenchras ciliaris
2	Usari	Sporobolus marginatus
3	Kans	Saccharum spontaneum
4	Kush	Chrysopogan fulvus
5	Kala Lappa	Hetereopogan contortus
6	Khas	Vetivaria zizanioides
7	Bluestern grass	Andropogon pumilus
8	Guner	Themeda quadrivalvis
9	Chakwa/Guria	Chrysopogan montanus
10	Phuleria	Bothriloclоa pertusa
11	Jenva	Dichanthium annulatum
12	Daab	Desmostachya bipinnata
13	Doob	Cynodon dactylon
14	Narsal	Arundo donax
15	Vindra	Setaria glauca
16	Bagai/Bawad	Eulaliopsis binata
17	Bhanjuri/Phuleka	Apluda mutica
18	Moonj	Saccharum munja
19	Murjhana	Eremopogan foviolatus
20	Musail	Iseilema laxum
21	Gandhabel/lemon grass	Cymbopogan martinii
22	Safed Lappa	Aristida depressa
23	Siru	Imperata cylindrica
24	Sen/Seta	Sehima nervosum
25	Finger grass	Chloris dolichostachya
46	Baans	Dendrocalamus strictus
47	Kath Baans	Bambusa arundinacea
56	Patera	Typha elephantina
Climbers		
1	Amar bel/Aakash bel	Cuscuta reflexa
2	Aal	Mimosa himalayana
3	Kakora	Capparis sepiaria
4	Indrayan	Trichosanthes bracteata
5	Kaali bel	Combretum decandrum
6	Kyohi/Haria	Ventilago calyculata
7	Kuchi/Aaila	Acacia pinnata
8	Kundru	Coccinea indica
Shrubs and Herbs		
1	Ased/juhir	Solanum verbascifolium
2	Aak/Madaar	Calotropis procera
3	Arhar	Cajanus cajan

4	Kansha	Adhatoda vasica
5	Inni	Clerodendron phlomoidis
6	Uth Katar	Echinops echinatus
7	Katayya	Flacourtia indica
8	Kareel	Capparis decidua
9	Karonda	Carissa spinarum
10	Kairi	Dichrostachys cinerea
11	Kuri	Lantana camara
12	Kathmaar	Ficus cunea
13	Kankohar/Menpal	Randia dumetorum
14	Kakad	Abutilon indicum
15	Kharber/Kaata ber	Zizyphus nummularia
16	Khariyal/Piluwa	Salvadora persica
17	Gandhela/Kathneem	Murraya koenigii
18	Gudshakri	Grewia hirsuta
19	Chakunda	Cassia occidentalis
20	Chakvad	Cassia tora
21	Gurgava	Grewia flavescens
22	Chinari	Grewia tenax
23	Jungli pyaz/Indian squill	Urginea indica
24	Javasa	Alhagi camelorum
25	Jharveri	Zizyphus mauritiana
26	Jhau	Tamarix dioica
27	Dhota/Dhavai	Woodfordia fruticosa
28	Neel/Basanta	Indigofera hirsuta
29	Vransi	Crotalaria medicaginea
30	Bhaang	Cannabis sativa
31	Bhaat	Clerodendron viscosum
32	Bhatkacheua	Solanum Xanthocarpum
33	Mola/Manju/Shivari	Vitex negundo
34	Raam Baans	Agave americana
35	Sarfonk	Tephrosia purpurea
36	Harsingaar/Siharu	Nyctanthes arbortristris
37	Hingot	Balanites aegyptiaca
38	Hins	Capparis zeylanica
39	Konch	Mucuna prurita
40	Gonj	Millettia auriculata
41	Gureech	Tinospora malabarica
42	Mulathi/Ratti	Abrus precatorius
43	Chawak Chari	Cryptostagia grandiflora
44	Chharendi	Cocculus hirsutus
45	Darhari bel/Tameraan	Maerua arenaria
46	Dudhia	Ichnocarpus frutesoens
47	Dudhi	Cryptolepsis buchanani
48	Dudhi bel	Vallaris solanacea
49	Paani Bel	Vitis repanda

50	Parwal	Trichosanthes dioica
51	Puraina/Harjuri	Cissampelos pareira
52	Badhasin	Butea superba
53	Vanda	Deudrophthoe falcata
54	Maurien	Bauhinia vahlii
55	Makoh	Zizyphus oenoplia
56	Malkangini	Celastrus paniculatus
57	Ramdatun	Smilax prolifera
58	Satavar	Asparagus racemosus
Trees		
1	Ankol	Alangium salvifolium
2	Augusti	Sesbania grandiflora
3	Arjuna	Terminalia arjuna
4	Amrud	Psidium guajava
5	Amaltas	Cassia fistula
6	Akash neem	Ailanthus excelsa
7	Ashoka	Polyalthia longifolia
8	Asna	Terminalia alata
9	Aam/Mango	Magnifera indica
10	Aadu	Prunus persica
11	Aal	Morinda tinctoria
12	Aaloo Bukhara	Prunus communis
13	Amla	Emblica officinalis
14	Anjan	Hardwickia binata
15	Anjeer	Ficus carica
16	Imli	Tamarindus indica
17	Kachnar	Bauhinia variegata
18	Kaim	Mitragyna parvifolia
19	Kadamba	Anthocephalus indicus cadamba
20	Kardha	Anogeissus pendula
21	Kanji	Pongamia pinnata
22	Kathal/Jackfruit	Artocarpus heterophyllus
23	Katsagon	Haplophragma adenophyllum
24	Kanak champa	Pterospermum acerifolium
25	Khaja	Bridelia retusa
26	Kari/Gopali	Miliusa tomentosa
27	Kamrakh	Averrhoa carambola
28	Cassia	Cassia siamea
29	Ketha	Feronia limonia
30	Kumhar	Callicarpa arborea
31	Keruwa/Tamaal	Diospyros cordifolia
32	Kala Siras	Albizia lebbeck
33	Karar	Sterculia urens
34	Kusum	Schleichera trijuga
35	Kumbi/Kumbhi	Careya arborea
36	Kaner - Red	Nerium indicum

37	Kaner - Yellow	Thevetia neriifolia
39	Kagazi Nimbu	Citrus aurantifolia
40	Khajur	Phoenix sylvestris
41	Kharhar	Gardenia turgida
42	Kharpat	Garuga pinnata
43	Khirni	Manilkara hexandra
44	Khair	Acacia Catechu
45	Khataria	Wrightia tinctoria
46	Gamhar	Gmelina arborea
47	Gavdi	Cochlospermum religiosum
48	Goolar	Ficus glomerata
49	Tumdi	Trewia nudiflora
50	Gulmohar	Delonix regia
51	Gondni	Cordia rothii
52	Parijaat	Adansonia digitata
53	Banpalas	Schrebera swietenioides
54	Ghont/Van ber	Zizyphus xylopyra
55	Chamror	Ehretia laevis
56	Chakotra	Citrus maxima
57	Chandan	Santalum album
58	Chilla	Casearia tomentosa
59	Chhenkur	Prosopis cineraria
60	Chhitvan	Alstonia scholaris
61	Jarul	Lagerstroemia flos reginae
62	Jungle Jalebi	Pithecolobium dulce
63	Jacaranda	Jacaranda mimosifolia
64	Jamrasi/Mamri	Elaeodendron glaucum
65	Jalmalha/Virla	Salix tetrasperma
66	Jamun	Syzygium cumini
67	Jhhingan	Lannea coromandelica
68	Palash	Butea monosperma
69	Taarchwi	Sapium sebiferum
70	Taad	Borassus flabellifer
71	Toon	Toona ciliata
72	Tendu	Diospyros melanoxylon
73		Holarrhena antidysenterica
74	Dhameena	Grewia tiliifolia
75	Dho/Bakli	Anogeissus latifolia
76	Nashpaati	Pyrus communis
77	Nimbu	Citrus medica
78	Nimbu meetha	Citrus limetta
79	Neem	Azadirachta indica
80	Neem chameli	Millingtonia hortensis
81	Paapra	Gardenia latifolia
82	Pakad	Ficus lacor
83	Chilvil/Paapdi	Holoptelea integrifolia

84	Paralia	Ficus rumphii
85	Peepal	Ficus religiosa
86	Paaiel	Stereospermum suaveolens
87	Pindaar	Randia uliginosa
88	Peelu/Pilua	Salvadora oleoides
89	Papita	Carica papaya
90	Pula	Kydia calycina
91	Putranjiva	Putranjiva roxburghii
92	Paper mulberry	Broussonetia papyrifera
93	Farash	Tamarix aphylla
94	Farai	Erythrine suberosa
95	Falsa	Grewia subinaequalis
96	Babool	Acacia arabica
97	Bargad	Ficus benghalensis
98	Baheda	Terminalia bellerica
99	Vijayasara/Indian Kino	Pterocarpus marsupium
100	Bakain	Melia azedarach
101	Badahar	Artocarpus lakoocha
102	Bel	Aegle marmelos
103	Ber	Zizyphus mauritiana
104	Barna/Banna	Crataeva odora
105	Black Siris/Banta	Albizia odoratissima
106	Baikal	Gymnosporia spinosa
107	Bhurkut/Bhurkul	Hymenodictyon excelsum
108	Mahua	Madhuca indica
109	Mahuli	Bauhinia racemosa
110	Maalta	Citrus sinensis
111	Mutammi	Citrus aurantium
112	Maulsari	Mimusops elengi
113	Eucalyptus	Eucalyptus hybrid
114	Reetha	Sapindus emarginatus
115	Riyonj	Acacia leucophloea
116	Rohini	Mallotus philippinensis
117	Indian cherry	Cordia dichotoma
118	Lichi	Nephelium litchi
119	Lukaat	Eriobotrya japonica
120	Vilayti kikad	Prosopis juliflora
121	Shareefa	Anonas squamosa
122	Sheesham	Dalbergia sissoo
123	Shehtoot	Morus alba
124	Saagwan	Tectona grandis
125	Sandan	Ougeinia oojeinensis
126	Safed Siras	Albizia procera
127	Sihor/Sihori	Streblus asper
128	Dhaura	Lagerstroemia parviflora
129	Semal	Bombax ceiba

130	Sehjan	Moringa oleifera
131	Hingot (Foreign)	Hesperethusa crenulata
132	Silver Oak	Grevillea robusta
133	Saal	Shorea robusta
134	Sawni	Lagerstroemia indica
135	Harad	Terminalia chebula
136	Haldu	Adina cordifolia
Exotic Species		
1	Subabul	Leucaena leucocephala
2		Cassie auriculata
3		Khaya senegalensis
4		Kigelia pinnata
5	Australian Babool	Acacia auriculiformis
6		Populus spp.
7		Peltophorum ferrugineum
8	Parkinsonia	Parkinsonia aculeata
Saline remediation		
1	luni/ nuna	Suaeda fruticosa

3.5.2. Vegetative cover

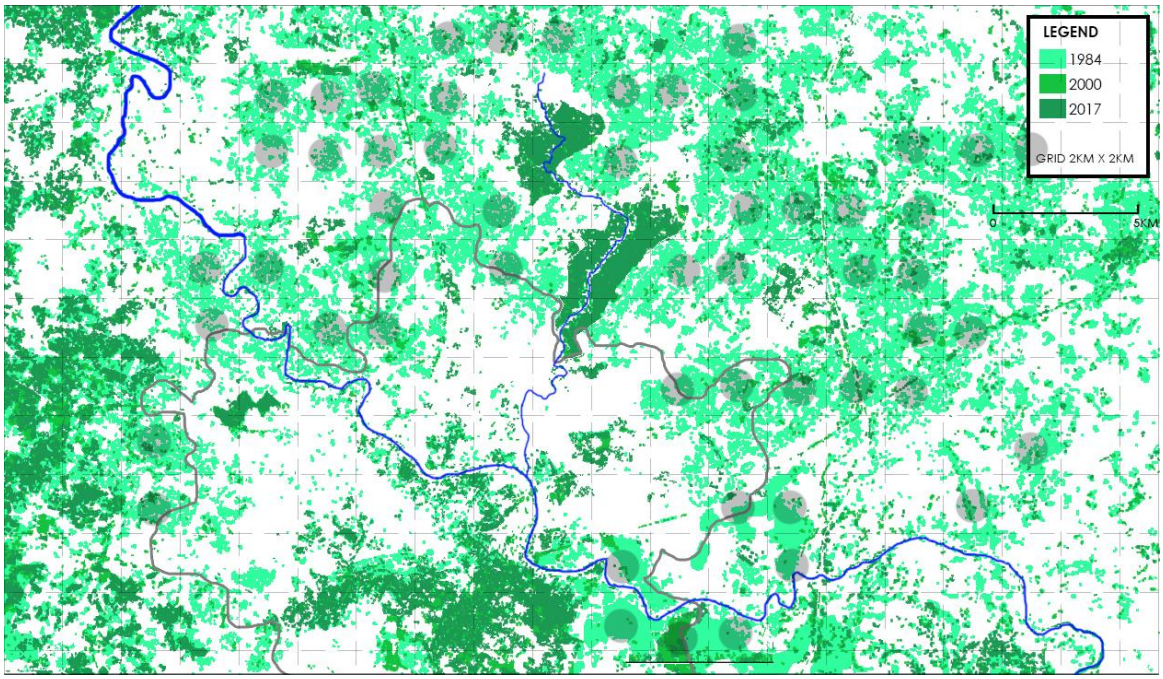

Figure 3-9 Green cover map of Lucknow North with Kukrail stream

The given map has been developed from three distinct satellite imageries from 1984, 2000 and 2017; which gives us an outlook on the change in the vegetative cover in the northern urban and peri-urban fringe of Lucknow. The lightest color tone depicts the vegetative/tree cover in 1984 and extinct today. On a grid based

evaluation, over 250 sq.km of tree cover has been lost since 1984 which has led to the decline of bio-diversity in the zone.

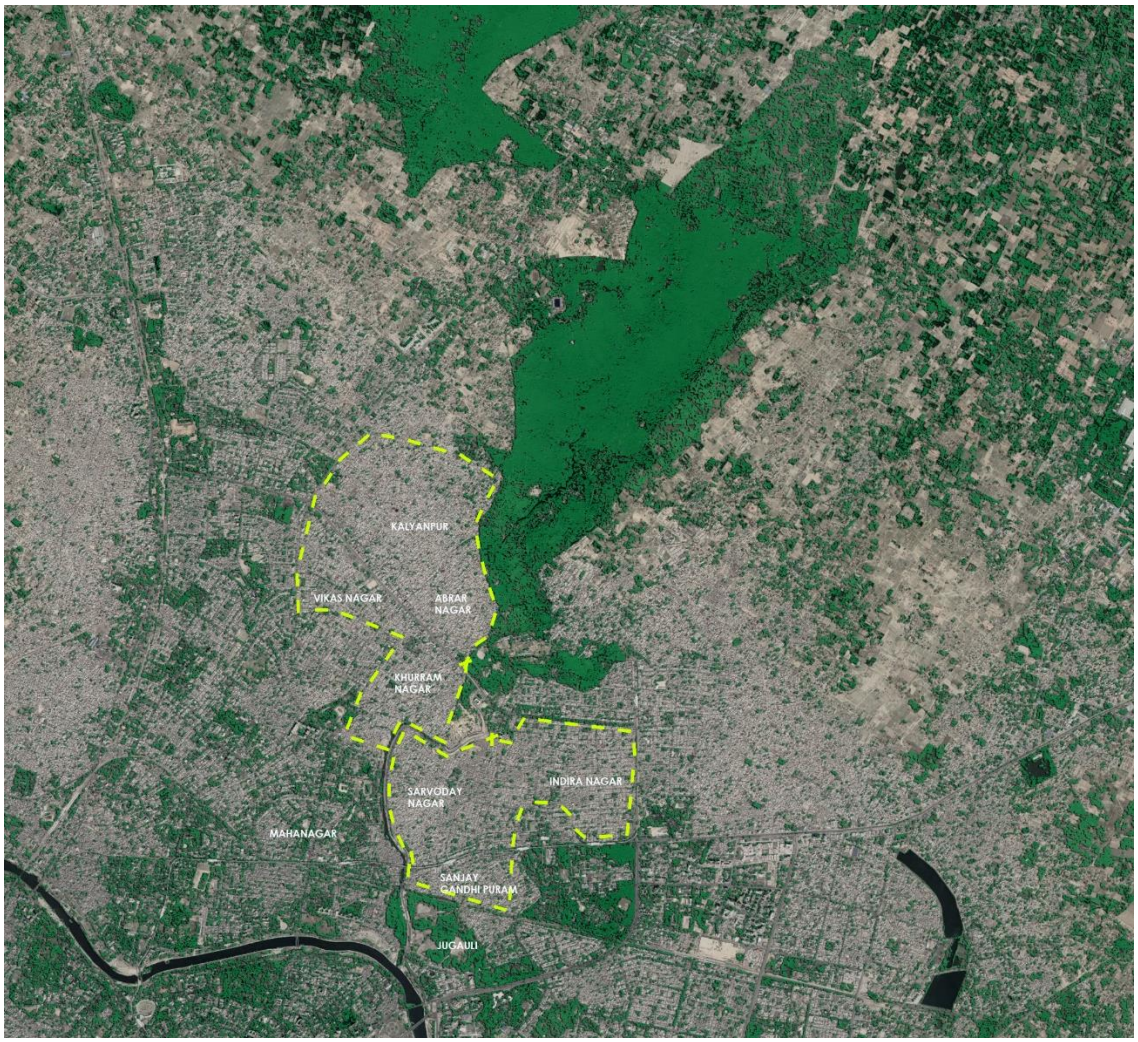

Figure 3-10 Vegetation cover map of the urban stretch of Kukrail stream

In the urban context, the course of Kukrail finds itself scarcely covered with vegetation. The dense urban development in nearby areas have devoured any land for vegetative growth and thus, creating a hardscaped and impervious surface which absorbs solar radiation and adds to the heat of the city. There is dire need of tree cover in this part of the city.

3.5.3. Invasive species and forest degradation

This phenomenon of takeover by foreign species have been observed on the stream banks in the urban area. The riparian buffer of the stream as well as the edge of the reserve forest are also facing degradation due to human stresses and are dying out only to let these invasive species take over. A particular species of *Prosopis juliflora* is the major threatening species due to its behaviour of disallowing other flora species to grow in its vicinity and its forming open scrublands throughout the stretch.

3.5.4. Fauna

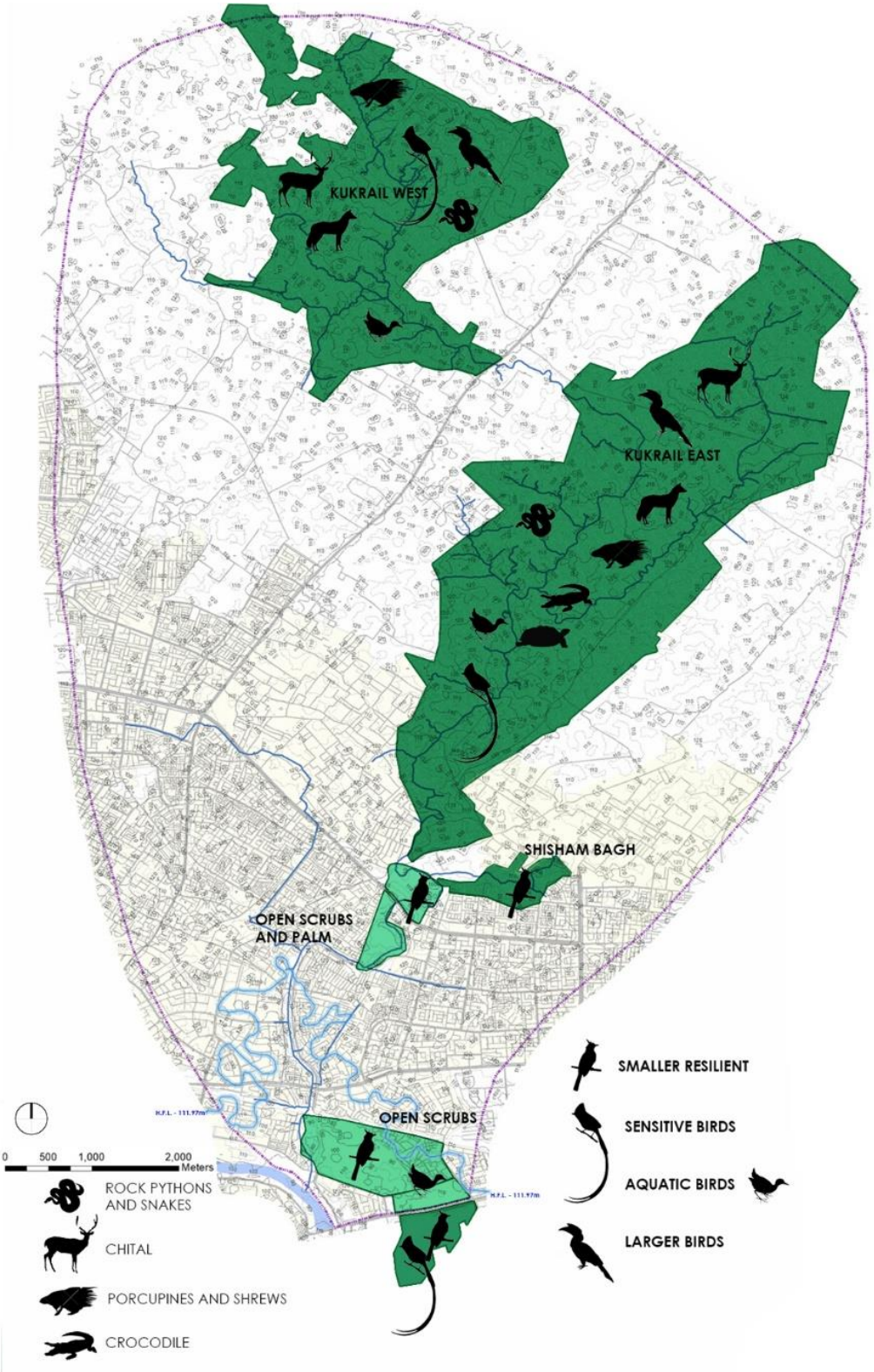

Figure 3-11 Map depicting locations of habitats of various fauna species

The Kukrail forest has a rich Bio-diversity, but with rapid urbanization in Lucknow, the stress has taken its toll on their lives. Many species have been found to migrated or disappeared from their habitats due to threats from human activities. The Kukrail forest was under threat of encroachment in the 1950's due to which it

was declared as a reserve forest in 1958. But, by the time this step was implemented the forest had already seen degradation, afforestation and fragmentation. The kursi road cutting through the forest was one of the major causes of fragmentation and division into east and west part. This fragmentation affected the routes of many species. The gap in the forest at Guramba is due to settlements and creates a divide in the riparian forest of the stream. Also in the urban stretch there is no riparian buffer maintained to accommodate fauna.

Table 3-4 List of fauna (Source: Awadh Forest department, Kukrail range)

Mammals	***Avifauna***	***Reptiles***
Rhesus monkey	Paradise flycatcher	Monitor lizard
Grey langur	Grey hornbill	Rock python
Jackal	Green bee-eater	Kraits
Porcupine	Golden oriole	Russels viper
Chital deer	Egrets	Indian marsh crocodile
Nigai	Herons	Indian cobra
Jungle cat	Kites	
Mongoose	Shikras	
Shrew	Alexandrine parakeet (NT IUCN)	
Wild boar	Waterhen	
	Great tit	
	Coppersmith barbet	
	Mallard duck	
	Black drongo	
	Ruffus tree pie	
	Cuckoos	
	Blue flycatcher	
	Sun birds	
	Blue flycatcher	
	Jungle owlet	

Though many terrestrial species will remain in the reserve forest area, the prospect of a full length riparian forest corridor can be promising for small mammal and reptiles. Avi-fauna diversity can multiply by the presence of habitats, food and perching points.

3.6. Urban fabric and dynamics

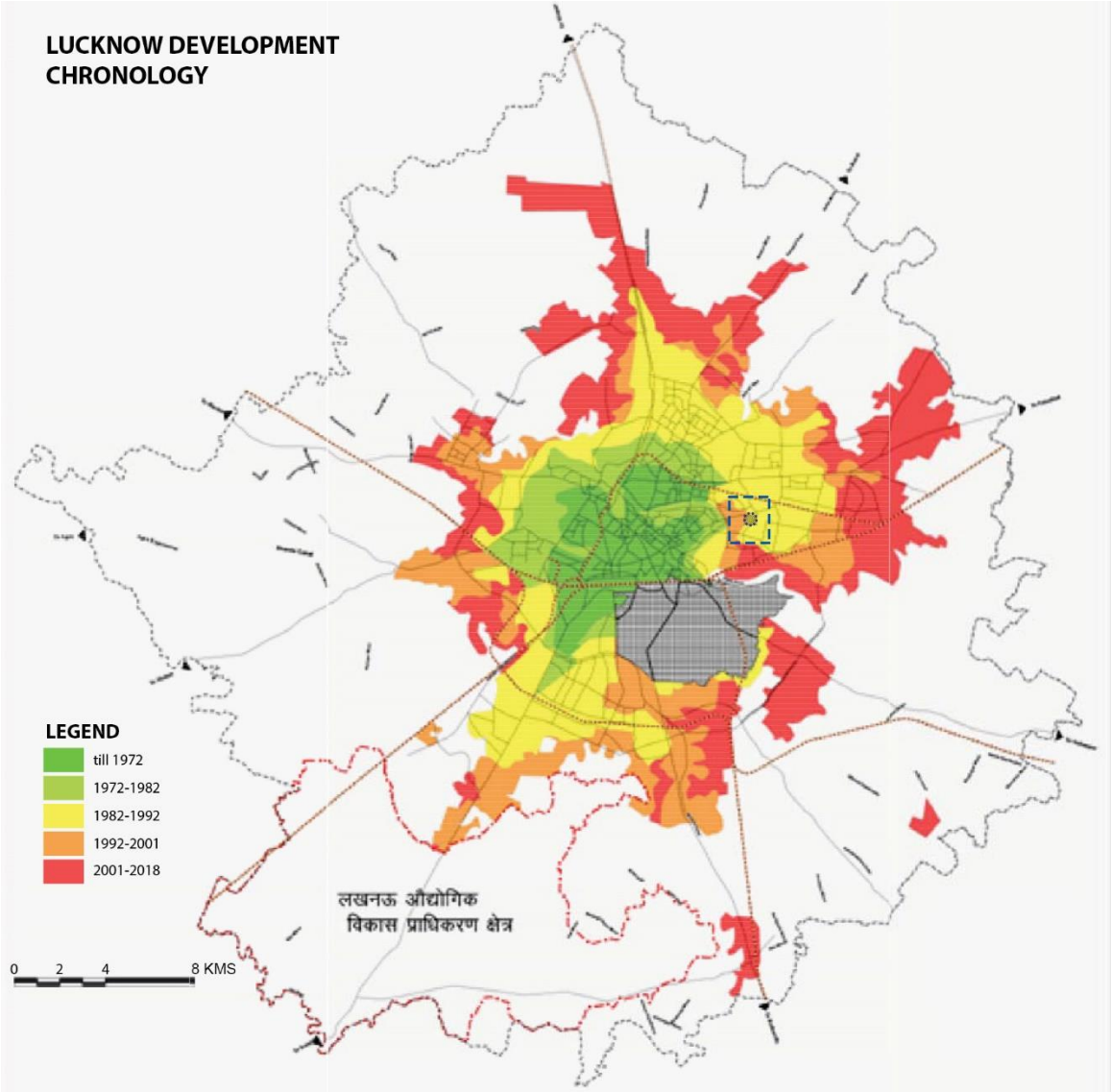

Figure 3-12 Lucknow Development Chronology

The Kukrail basin was put into development phase only after the 1960s. Before this period the area was a part of the floodplain as evident by the two flood events which caused the construction of flood protection structures. Before the dikes there was a considerable offset between the stream and the newer planned settlements, which faced minor flooding. But sadly, there wasn't any consideration of riparian zone for the construction of dikes which were built just after the stream width. This also gave rise to the unplanned settlements just neat to dike on un-serviced lands. These two factors contributed majorly to the decline of urban stream health. Moreover, the waste water from these settlements and others surrounding it were insensitively poured into the stream which made it into

a filthy undesirable body of water. The current urban fabric texture can be seen in the base map 3-11.

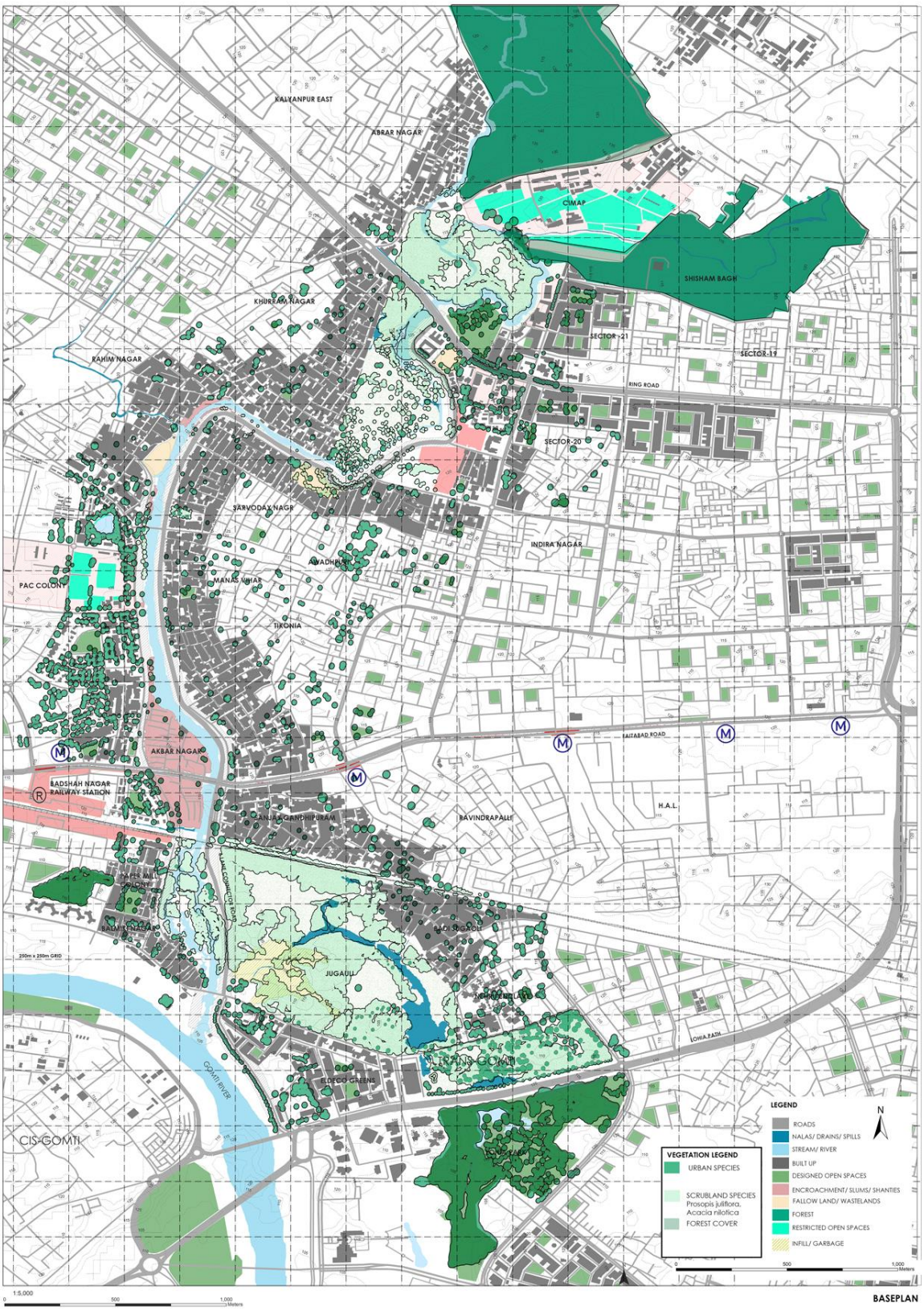

Figure 3-13 Map depicting the Urban stretch of Kukrail with its urban features

The map depicts a dense settlement pattern with barely any room for green open spaces in the settlements near the stream. The vegetative cover in these unplanned areas is scanty owing to the encroachments and ignorance of the authorities. The stark difference in layouts and open spaces is evident between the planned and unplanned areas. Apart from these areas there are encroachments on the dike as well as inside the stream at locations of Akbar nagar, Rahim nagar and Abrar nagar.

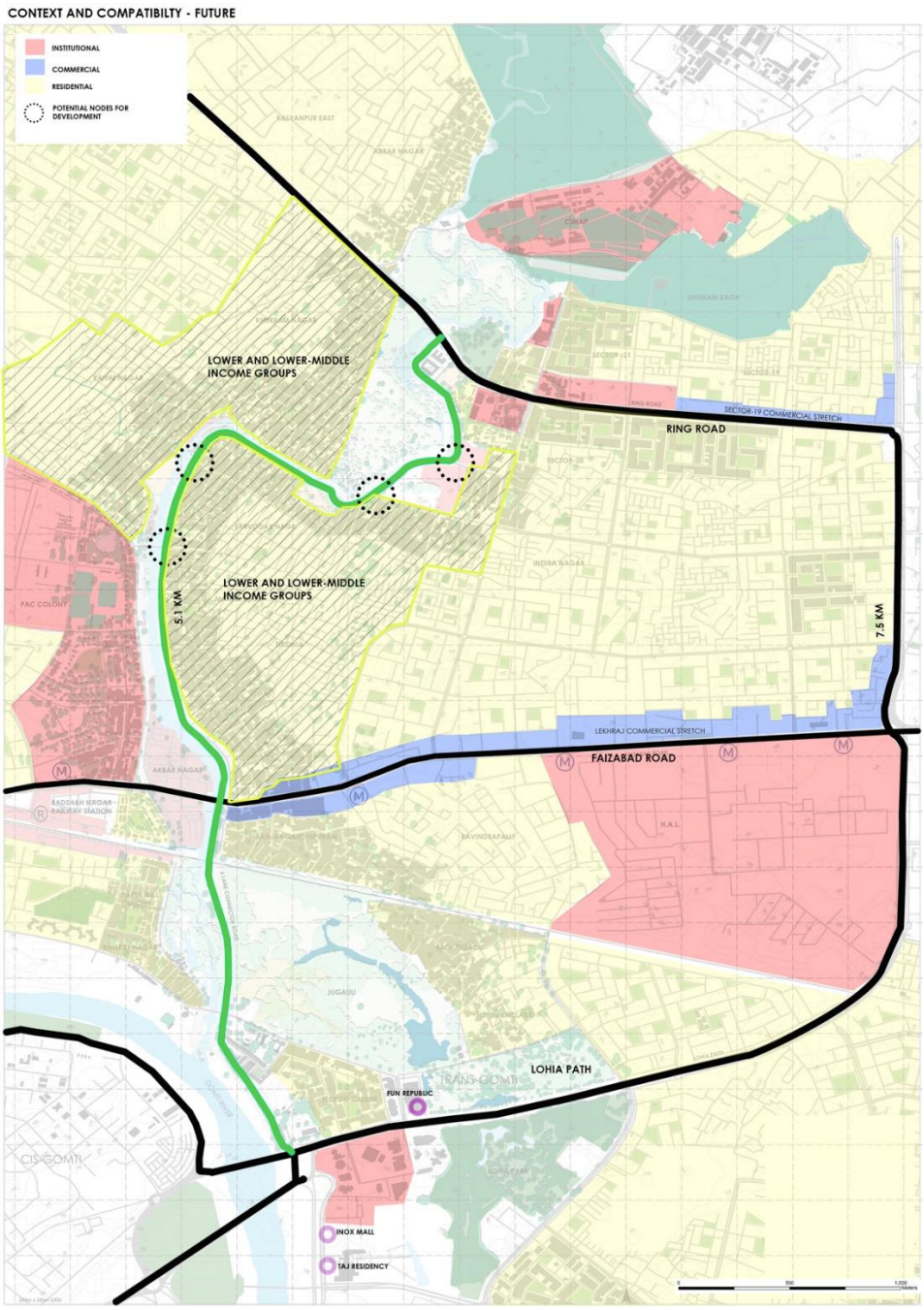

Figure 3-14 Land use map of urban Kukrail stretch with upcoming road

The above composite map shows the land-use pattern which is mostly residential on both sides of the stream and also, the areas of sarvodaya nagar and Khurram

nagar being resided by lower income groups. Another feature is the new six lane road cutting across the ring road and providing a 2km shorter route from the cis to the trans side of the Gomati river.

Judging by past growth of commercial buildings on major ring road and faizabad road, the commercial overtake in parts of Sarvodaya nagar is strongly likely to happen. This generates a certain potential for the redevelopment of the dense Sarvoday Nagar area which can be boosted in terms of real eastate through landscape development of the stream. The increment in the experiential quality of the stream landscape can make this area more desirable and highly likely for investments.

The pros of the six lane are inevitable and so are the cons, which include air and noise pollution due to the traffic. Also aspects of vehicular effluents flowing into the stream with storm water is something to be expected which can be all accommodated through landscape oriented interventions.

3.7. Activity Mapping

This mapping included observations on activities in and nearby the stream which came out to be mostly harmful or threatening for both the urban fabric and the stream.

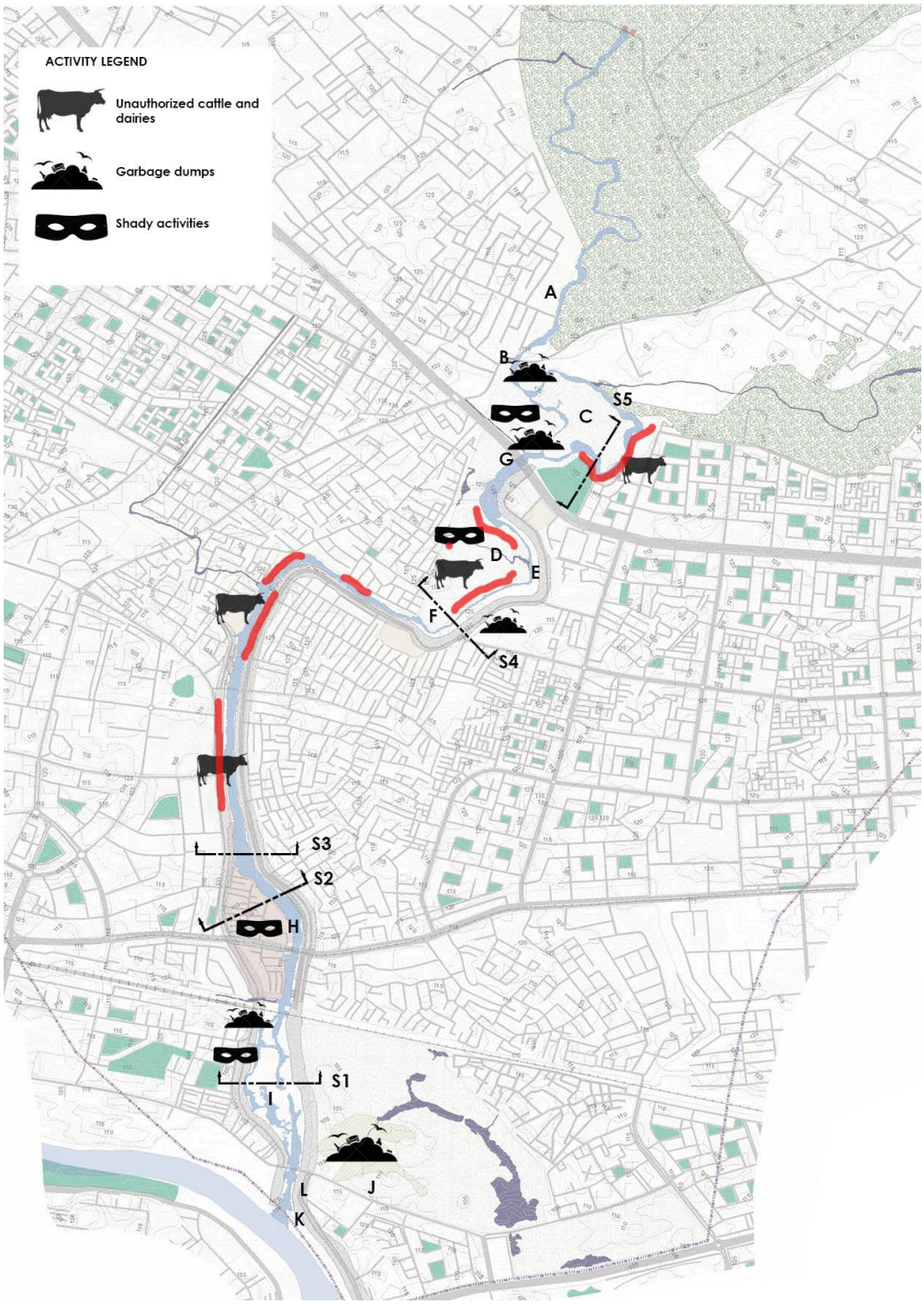

Figure 3-15 Activity map of Kukrail urban stretch

Unauthorised activities, solid waste dumping and shady activities were the three major categories of association with the stream. The stream edge was found to be dotted with cattle sheds and garbage piles. Stream buffer was used for illegal activities due to its undesirability by common folk.

3.8. Experiential Mapping

The experiential mapping is based on Kaplan's theories and depicts the quality of sensory experiences throughout the urban stretch of the stream.

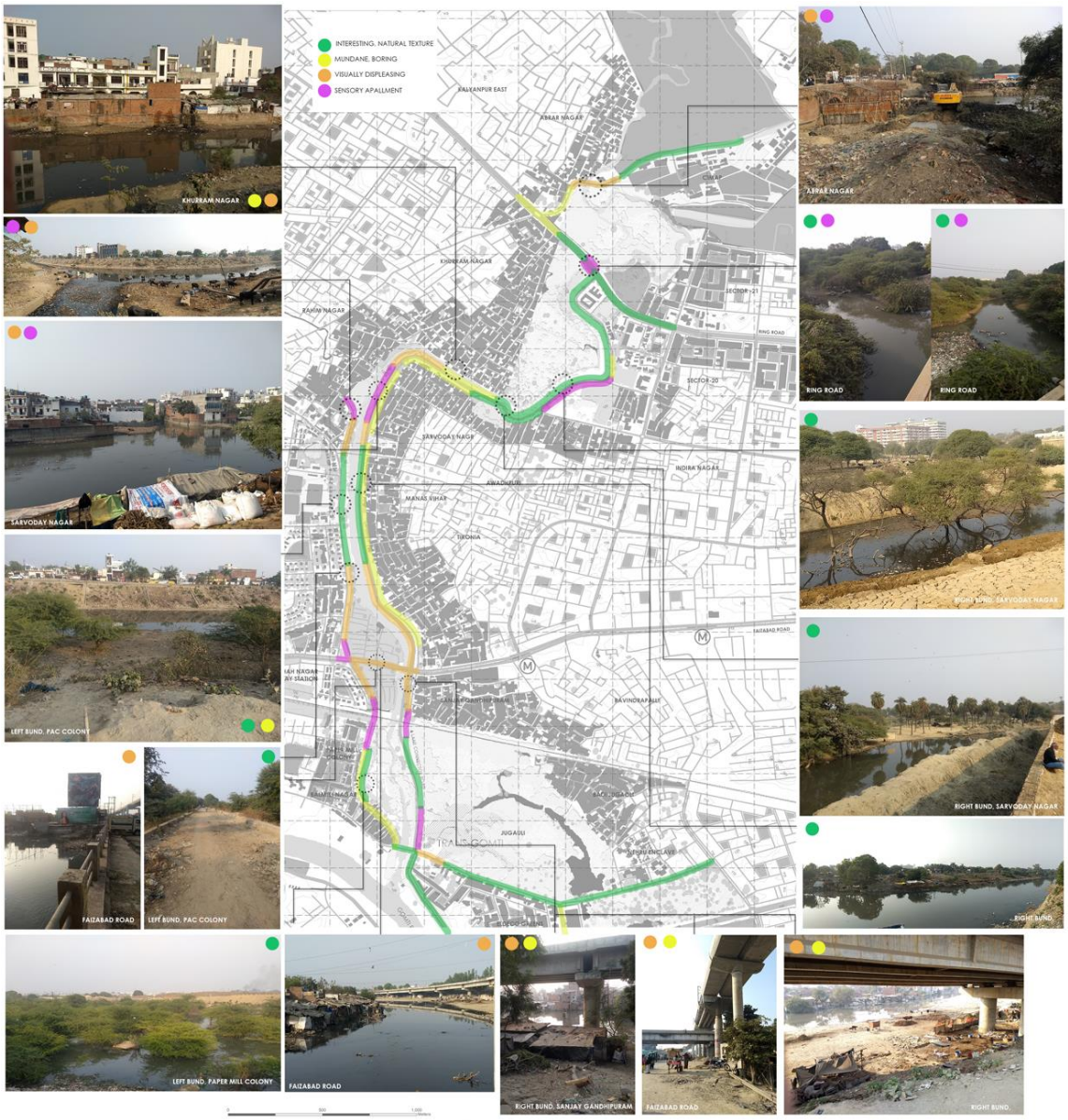

Figure 3-16 Experiential map of Kukrail urban stretch

The experience has been divided into four categories out of which the top experience being the sense of nature and the last being an appalling experience which causes detest towards the stream. This map gives us potential areas to be developed for public open spaces and other areas to be intervened into to change the hate perspective of the urban population.

Areas with reminiscent riparian vegetation still provide a fascinating experience such as the area near Jugauli and Khurram nagar. These areas can be

developed into successful green open spaces to allow people to indulge in the riverine landscape of Kukrail stream.

4. Issue and Site Identification

4.1. Issues and Problems

The identified issues with current condition of the stream are as follows:

- Physical condition of the stream and periphery: The stream banks and the riparian forest are vulnerable due to encroachments. The stream banks in the urban stretch are devoid of vegetative cover and under severe erosion due to water flow and air. Formation of gullies and ravines have been observed due to lack of vegetation.
- Vegetation and bio-diversity: Firstly the fragmentation of the riparian corridor is a major issue to the stream health and bio-diversity. Secondly, the scanty vegetation in the urban stretch of the stream causes harm to the stream health and also creates an unwanted experience of the urban environment as it fails to remedy the stresses such as pollution, heat etc. Thirdly, the takeover of invasive species is destroying the local bio-diversity.
- Urban fabric: Despite the enormous potential of having a landscape feature, the urban settlement pattern has no cohesion with the stream and rather, is bent on destroying it. Encroachments and abuse of the stream regime is a major issue in the urban area. Moreover, the dense urban settlements on these un-serviced lands provide no open spaces as required by the people living in them. The scarcity of open spaces degrades the urban experience.
- Water and waste management: In the current scenario, the urban storm water, its waste water and dry waste, all are subjected to burden the kukrail stream and tend to pollute it.
- Urban policies: The measures taken in the master plan to protect natural resources in superficial as the buffer is a passive land use and the authority too ignorant to check on it. Only an active use may help recover the stream from being abused.

4.2. Delineation of Site

As for interventions the entire Kukrail basin requires certain changes for which guideline shall be provided. But, for detailed intervention, the land parcel of *Khurram nagar* downstream from the ring road bridge is appropriate. It is so due mentioned factors:

- The 60 acre land parcel has been recently put into public open space category and is surrounded by dense urban settlements who are deficient of open spaces.

- Its location and connection to a prime road gives it a potential.
- Its size is good enough to help restore the health of the stream.
- It is a degraded and open scrubland, with patches of ravenous formation which require protection from erosion.

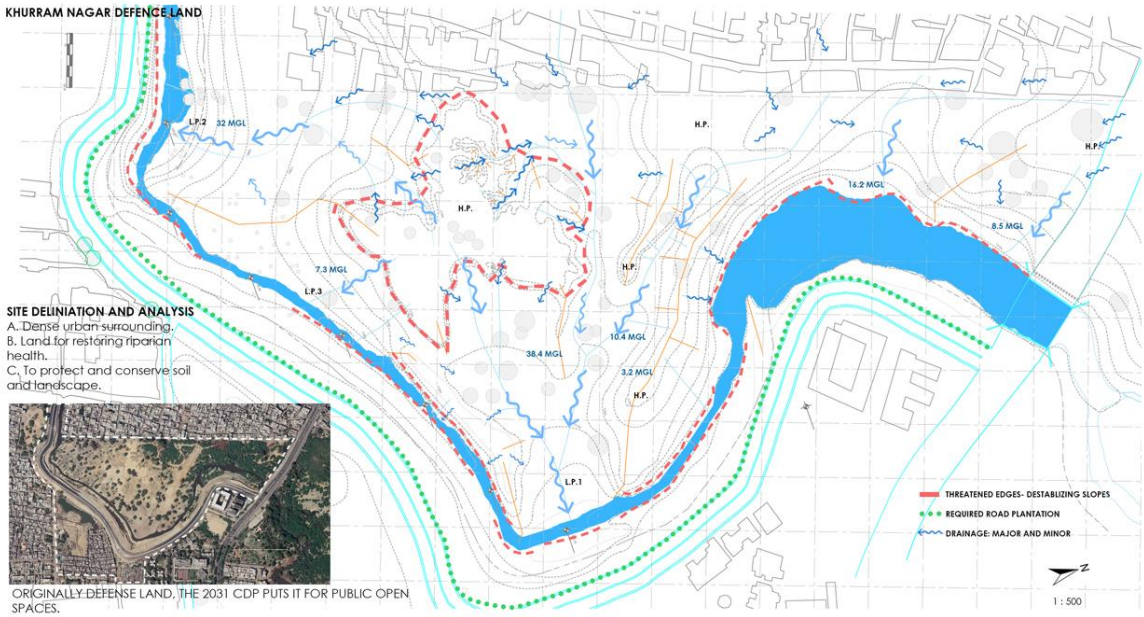

Figure 4-1 Khurram Nagar Defence Land

- The vegetation is very scanty and declining. Also, under attack from invasive plant species which are taking over the land.
- It has been abused by encroachers as a dry waste dumping yard and unauthorised cattle yard which needs to stopped by assigning an active use to the space.

4.3. Programme Development

The first step to restore the health of the stream is to make people believe in the potential of a landscape feature to improve their everyday life. Therefore, providing spaces to connect with the stream and its landscape in a positive fashion will trigger a change in the use of the stream from being an embodiment of disgust and neglect to a haven of tranquillity and sublime experience.

- The preliminary action is to analyse the waste water and solid waste management system and change to an auxiliary method such as composting and decentralised-biological waste water treatment system in order to prevent polluted effluents and solids from entering the hydrological regime of the stream.
- After the water quality is brought to non-toxic, the next step is to protect the stream banks and ravineous lands and stabilise them through vegetation.

- A storm water management plan has to be put into place in order to look after the vegetation even in the lean period so as to avoid the degradation of landscape.

Table 4-1 Sewage treatment capacity on existing nalas

S.no.	Drain	Length (km)	wetland width	singly loaded	doubly loaded	Area of wetland(acres)	**Treatment capacity (MLD) @ 1.21 mld/ acre**
1	Sagara nala	4.3	mixed (6m ,3m, 12 m)	yes	yes	8.7	10.6
2	Khurram nagar nala	2.1	mixed (6m,3m)	yes	yes	4.2	5.2
3	Railway colony drain	0.98	3m	yes		0.72	0.89
4	Babaji ka purwa nala	0.48	6m		yes	1.42	1.72
5	Ravindrapalli drain	0.72	6m	yes		1.07	1.35
6	Begum purwa nala	1.12	6m		yes	1.65	2.01
	Total						**21.77**

- Identifying the riparian corridor as green infrastructure and putting it to use for movement and as a network of spaces for passive recreation will put to motion the acceptance of the project.
- Encroachments and unauthorised use of riparian lands can be reverted underway the corridor development as it should include the participation of the locals. The corridor itself will improve the urban experience and thus will make the adjacent properties more desirable. This model as studied in the case study works as the encroachers and neighbouring people are generally lower income to middle income groups who can benefit from the proposal.
- The effort to connect the vegetative riparian patches will also boost the bio-diversity which will bring in new experiences in and around the corridor, which in turn will enhance the urban experience with the restoration of an urban riparian corridor.

5. DESIGN PROPOSAL AND RECOMMENDATIONS

5.1. Comprehensive Landscape Development Plan

The comprehensive landscape development plan encompasses the following layers and interventions into them:

a. Bio-diversity and stream ecology revival through vegetation.
b. Reversing the degradation of land and its fertility.
c. Reconnecting fragmented riparian forest patches.
d. Urban waste water management to stop polluted inflow into the stream. Also, acquiring water to maintain the landscapes and to maintain a steady flow in the stream through hybridised biological treatment close to the point of origin.
e. Enhancing urban experience through provisions of road side buffers and green open spaces.
f. Connectivity through alternative non-motorised means on the course of the stream, connecting open spaces and important junctions through a stimulating journey instead of stressful experience of travel.
g. Affecting the climate of the city through developing landscape sinks that absorb heat and pollution and create milder micro-climates.

5.2. Concept

The proposal is based on the idea of cohesiveness between urban settlements and natural health. It has a holistic approach to bring to balance a multitude of disequilibrium and trigger harmony in the landscape. The proposal sits on the belief that

“Healing urban stream landscape results into healing stressed human urban environment as well and even more, humanises the population into reforming bonds with their far ancestral habitats”

5.3. Guidelines

Below mentioned are the guidelines for the landscape development of the Kukrail stream basin:

5.3.1. Land use change:

a. 100m right of way from the centre on both sides for the stream, no construction to be allowed in the zone. Any unauthorised structure and building within the zone to be demolished and removed.
b. In case of existing dike, any built up between the stream and the dike to be removed. Built up after the dikes maybe retained given all other guidelines are followed.

5.3.2. Vegetative buffers:

a. 50m dense vegetative buffer on the both stream banks near Guramba, connecting the east and west forest patches. An overhead forest pass for terrestrial fauna movement from both the forest patches over the Kursi road.
b. 15m vegetative buffer for all first order streams draining into the stream. Obstructions to these smaller streams to be removed.
c. Complete vegetative cover over the dikes in the urban areas.
d. 6m road buffer on the new six lane road on the right dike.

5.3.3. Storm water management

a. Storm drains to be converted to soft based swales to allow infiltration of water.
b. Rain water harvesting at neighbourhood level in open spaces and government campuses to be mandatory in the basin.
c. RWH tanks to be encouraged in individual houses through programmes.

5.3.4. Wastewater management:

a. No direct waste water in lets into the stream or any of its tributaries.
b. All wastewater to be led either into de-centralised biological treatment systems or into the trunk sewer lines.
c. Only the outlets from Dewatts systems through constructed wetland corridor to be allowed to drain into the Kukrail stream.

5.3.5. Solid waste management

a. On source segregation of solid waste in the city zone; with organic matters committed to composting on secured pits in open spaces. Toxic and non-biodegradable waste to be carried away from the basin for disposal.
b. Single use plastic and polyethene bags to be banned in the city to avoid choking of the drainage and eventually the Gomati River itself.

5.3.6. Vegetation management

a. Given the case, the species *Prosopis juliflora* to be exterminated through uprooting and using for construction and other required purposes.

5.4. Salient features of design

a. Streamside Park

- Jogging track
- MUGA court (multi-utility games arena)
- Open gym
- Open air theatre
- Yoga and meditation spaces
- Seasonal and herbal garden

- Lawns
- Plazas
- Thematic play areas
- Plant nursery
- Water body and lily pond
- Dewatts plant and constructed wetlands for waste water reclamation

b. Kukrail bio-diversity corridor

- 30m undisturbed riparian forest corridor
- 20m walkable forest corridor
- Perennial streams
- Constructed marshland
- Glades
- Sensitive amphibious, avian and insect habitat
- Bird refuge structures
- Bee farm
- Bird watching towers
- Walking trails
- Bio-diversity information centre
- Exhibition gallery
- Public amenities
- Parking space

c. Earthen dike and non-motorable vehicular pathway

- Planted dike
- 100 year flood event protection
- NMV pathway

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