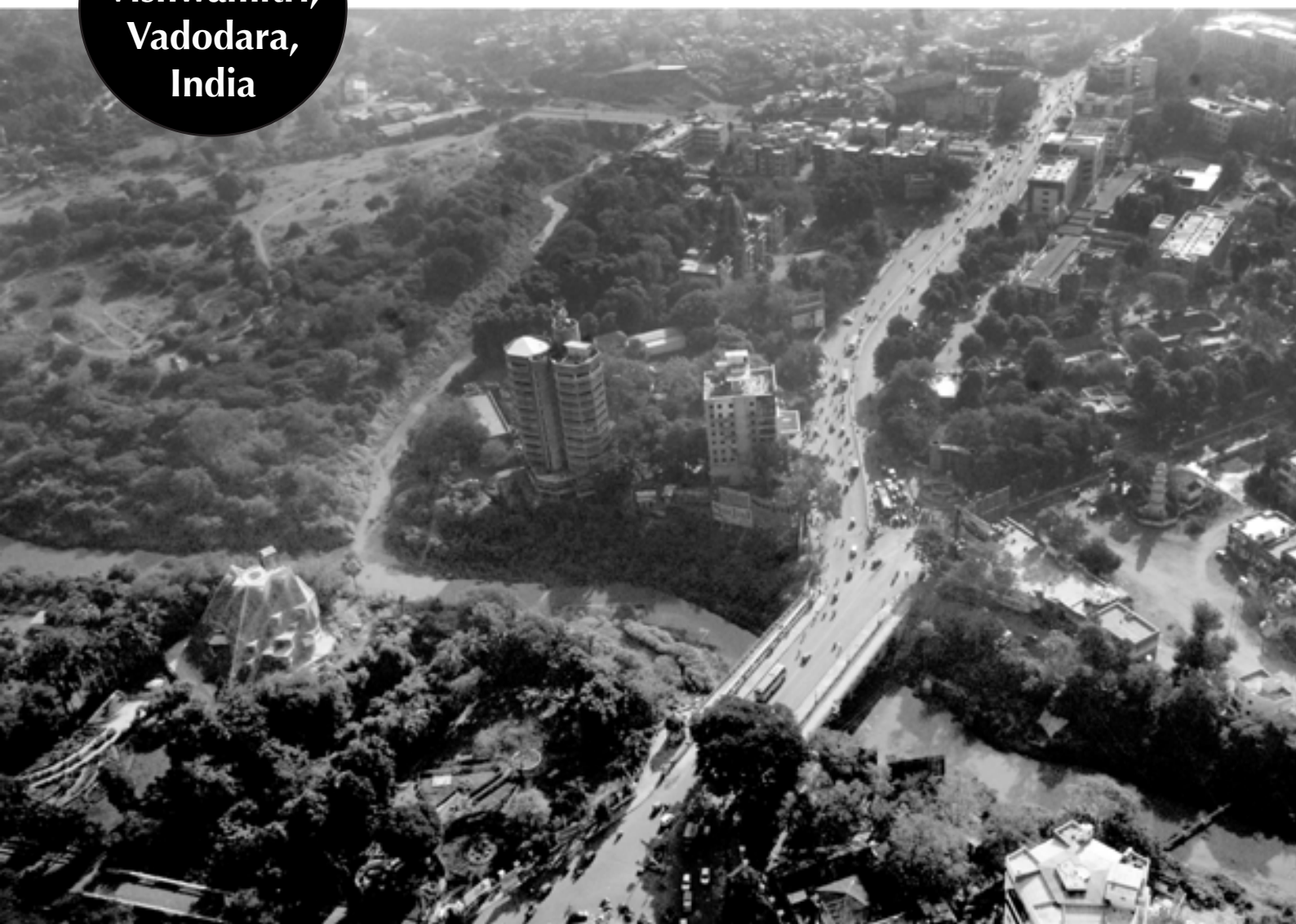
Crocodilia urbanis:
co-existing with urban wildlife

An MSc. Thesis in Landscape Architecture
Wageningen University and Research
Kareena Kochery



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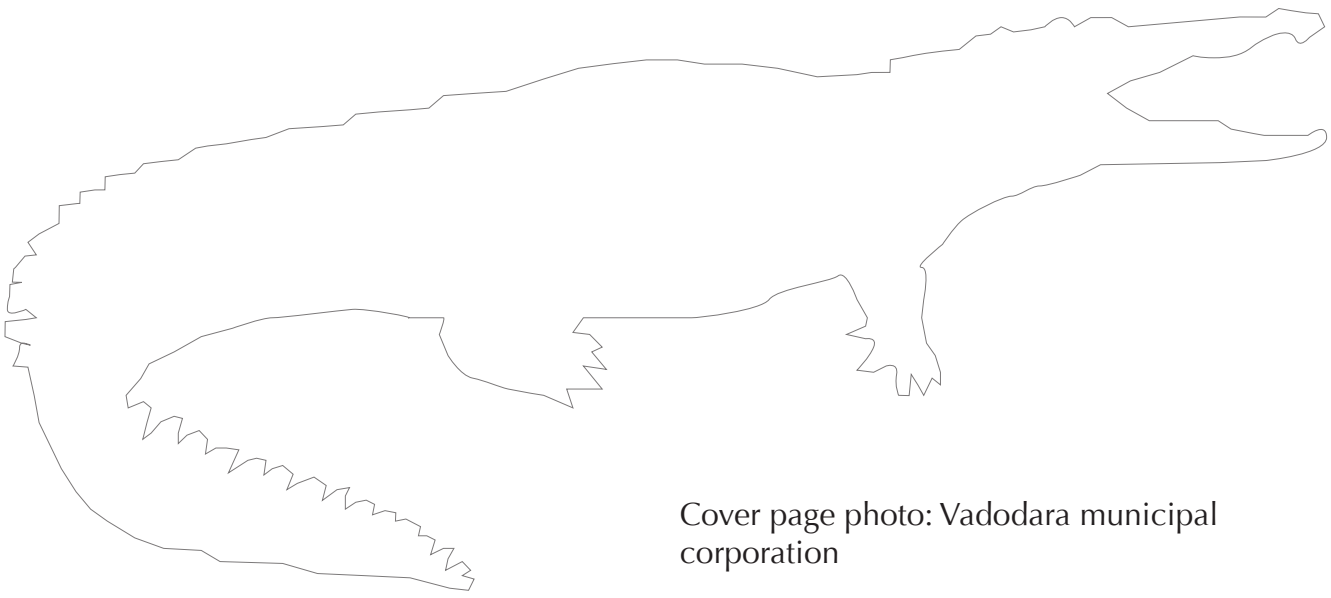

Cover page photo: Vadodara municipal corporation

In fulfillment of the requirements for the Master of Science degree in Landscape Archtecture at the Wageningen University, Landscape Architecture Group.

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Abstract

Animals have inhabited urban areas since the dawn of human settlements (Soulsbury and White,2015,). Urban areas are created by the urbanization of Nature (Barua and Sinha,2017) and in species rich countries like India, this entails the urbanization of wild animals. In some Indian cities, wildlife ranges from perceivably less threatening fauna to the presence of predator species. Vadodara, Gujarat India, is a city with a longstanding relation between hu-mans and reptiles. The river Vishwamitri passes through the city and this 25 km urban stretch of the river is home to over 250 Mugger crocodiles. The case of the river Vishwamitri presents a unique situation where crocodiles cohabit a city and are contained through the agency of the urban river landscape. However, the pressure of rapid urbanization is a looming threat to the continued cohabitation of humans and crocodiles in the city. New conflicts with human land-use arise and the pressure on urban wildlife habitat continuously increases. This research in landscape architecture reframes human-wildlife conflict to include effects of urbanization on crocodile habitat and explores how landscape design can enable human-crocodile interactions, in culturally and ecologically sensitive ways. Relevant perspectives from animal geography and applied ecology have been married in a framework for landscape architecture can design for the kinship and agency of animals in the formation of the urban (Wolch,2002). First, research for design (RfD) and includes field visits, data collection, analysis and synthesis. This was followed by research through designing (RtD), resulting in design guidelines for the city, that were tested on three sites. Site-specific design solutions being the final outcome. Ultimately, the thesis tries to answer “erstwhile calls for animating urban theory” (Barua and Sinha,2017:15) by showing ways forward for cohabitation.

Keywords: human-crocodile interactions, human-wildlife conflict, urbanization, landscape architecture, transspecies urban theory

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Introduction

1.0

Fig.1 Leopard in Mumbai, India

Photograph>Nikit Surve

1.1 Animals in the urban realm

Animals have inhabited urban areas since the dawn of human settlements (Soulsbury and White,2015,). It is the urbanization of Nature that gives rise to urban areas (Barua and Sinha,2017) and in species rich countries like India, this entails the urbanization of wild animals. Some populations now find themselves at the heart of major Indian cities. India is a country whose cities can boast of a wide range of undomesticated and domesticated animal life. It is not unusual to encounter Rhesus macaques, Grey langurs, domestic cows and water buffalo, elephants and stray dogs on urban streets in the country. Mammals apart, there are a large number of birds, insects and reptiles that inhabit urban areas as well

Facing the wave of urbanization also entails the modernization of urban spaces and this has meant the evacuation of many urban animals perceived as a nuisance. The rounding up and neutering of street dogs as part of the cleaning campaigns of Indian cities exemplifies the underlying modernist dimension of space that "systematically distorts our understanding of human animal relations (Kymlicka and Donaldson, 2011, p.68)".

In some Indian cities, animals range from the perceivably less threatening to predator species. In the Sanjay Gandhi National Park, live 22 Panthera pardus, or the Indian Leopard, surrounded by the cacophony of Mumbai city life (Fig.1) . Considering that in India and the developing world at large, most of the human population is projected to live

in urban settlements (Watson,2009) it is prudent to consider the effects of urbanization not only on humans but also on non-human species that cohabit urban spaces (Wolch,1996) and develop a new understanding for the design of urban landscapes for the non-human.

1.2 Crocodiles in the city

Vadodara, is the third biggest city in the state of Gujarat, India (Fig.2), with a population of around two million people. It is also a city with a longstanding relationship between humans and reptiles. The river Vishwamitri passes through the city for a transformational 25 Km journey and is home to over 250 Mugger crocodiles (Crocodylus palustris). The case of the river Vishwamitri presents a unique situation where crocodiles cohabit the city, contained through the agency of the urban river landscape.

The presence of a powerful reptile so close to human dominated areas has indeed lead to some conflict, with losses suffered by both species. Despite this residents are either indifferent or curiously tolerant of the crocodiles in the Vishwamitri (Ishore,2017). Wall art in the city, even suggests pride in sharing the city with crocodiles (Fig. 3). It is interesting to note that crocodiles have co-existed with humans in many parts of the world. However, persecution of crocodiles is deeply rooted in the European colonization of Asia (Bradshaw,2017).

Crocodiles in India have been traditionally associated with having divine agency (Borkar,2006). In Vadodara district, the crocodile has religio-cultural significance as the divine consort of a local deity (Fig.4). Historically there is great tolerance for the crocodile in the region (Vyas,2010). In Oct, 2011, cleaning activities on the Vishwamitri riverbank uncovered a sculpture of a Crocodile, dated to be 250 years old (Pandya.2011). However, the divine agency of the crocodile is a cultural projection that sits beside a present reality far from ideal. The river Vishwamitri, is highly polluted by the dumping of untreated sewage, garbage and construction debris along its banks (Fig.5) making it a contaminated environment by many standards (Mittal et al., 2016) .Yet, amazingly, this neglected and polluted habitat still supports multiple species including the Mugger crocodiles. Moreover, the croco dile is a Schedule I protected species of the Indian Wildlife Act (Vyas, 2012) making the animal and its habitat protected by law. Yet, the rate of urbanization in the city has rapidly increased to become a looming threat to the continued cohabitation of humans and crocodiles (Vyas,2012).

Through investigating the unique case of the crocodiles in the Vishwamitri, this thesis hopes to find ways of embracing the animal through urban landscape design. Furthermore, if the results of the thesis manage to successfully demonstrate how an urban predator species can continue to safely

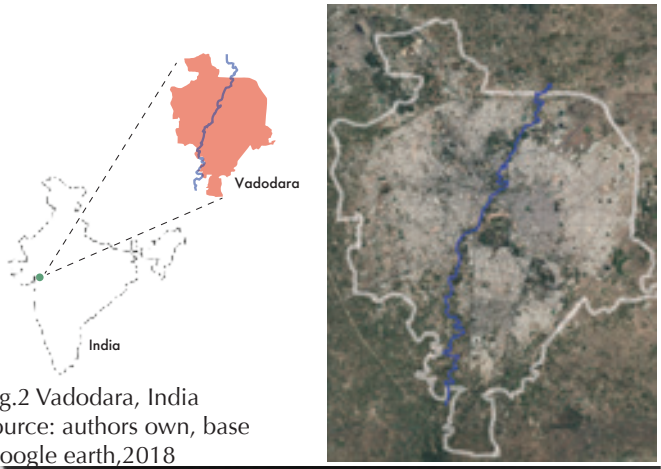


Fig.2 Vadodara, India
source: authors own, base Google earth,2018

Fig.3 Wall art with crocodile illustration
source: authors own

Fig.4 Khodiyar Maa - A local diety
image retrieved from:www.rudraksha-ratna.com

Fig.5 Untreated sewage being let out into the river
source: Sanjay Seth

co-exist with humans it strengthens the case for cohabitation with most other species found in the urban realm.

1.3 Knowledge Gap

Urban theories of the past few decades, despite having an ecocentric approach, hardly relate to wild animals when defining sustainability (Wolch,1995,p.747). Landscape architecture research and practice is largely focused on issues in North America and Western Europe. Considering that landscape architecture is defined as the interaction between the human and non-human (Roe,2013,p.401 from Bruns et al.,2016) the current focus of landscape architects is mainly on vegetation, topography and climate, largely ignoring other sentient beings. The interest in urban animals is growing (Barua and Sinha, 2017). Yet, this is restricted to small mammals, insects and birds, not predator species; certainly not predators in urban river landscapes. The approach taken by landscape architecture with regards to urban wildlife, is mostly based on landscape ecological studies about the impacts of fragmented habitat and the need for spatial cohesion through the ecological corridor (Opdam and Wascher, 2004). This further cultivates a tendency in landscape planning to separately allocate spaces for humans and wild animals, especially in urban areas. This ideological boundary between Nature and City is losing traction as studies in urban ecology indicate how animals adapt to new types of habitat offered by urban environments in amazing ways (Deliege,2018).
Although animal geographies of the developing world is a growing subject of interest, there has not yet been research carried out within landscape architecture that tries to arrive at design solutions combining an understanding of the ethology, ecology and geographies of animals living in the urban and urbanizing parts of the developing world.

Moreover, the Vadodara Municipal Corporation (VMC) proposed a Vishwamitri Riverfront Development Project (VRDP) with techno-engineered solutions like the channelization and concretization of the riverbed and banks. The VRDP also suggests the displacement of the crocodiles from the river, with a plan to confine them in a crocodile park instead (HCP, 2014). Presently, there is a stay order on the VRDP due to environmental clearance concerns and protests from eminent local scholars and environmental activists of the city (TNN, 2015).

I argue that the crocodiles in the Vishwamitri River (Fig.6) are no longer wild but through their interactions with humans have evolved with their urban environment. Furthermore, the crocodiles could be considered liminal animals and accorded denizenship (Donaldson and Kymlicka, 2011). There is now the time and space for alternative design strategies for the landscape of Vadodara city with its unprecedented urban wildlife.
The main design question this thesis will try to answer is:

Which urban landscape design interventions can facilitate denizenship for the crocodile in a culturally and ecologically sensitive way?

1.4 Thesis Outline:

The first part of the thesis tries to builds a theoretical framework derived from multiple disciplines and ultimately oriented to landscape architecture. Methods employed to conduct the research for design (RfD) are outlined, followed by a chapter which first describes crocodile ethology and the Vishwamitri river landscape. The results to the research questions follow. The last chapter of this part correlates the results with denizenship theory and evaluates proposed scenarios using theory as a basis of evaluation. A new scenario is proposed which the next part of the thesis is based upon.

The focus of the second part is research through design. Chapter 6 describes the development and application of design guidelines to test sites in the city. The following chapter describes and illustrates the site-specific designs. Chapter 8 covers methodological reflections. Chapter 9 discusses and elaborates on the societal relevance of the thesis and its contribution to landscape architecture, going on to reflect on one of the key design strategies, ending with reflections for further research. The ultimate chapter provides a conclusion to the study.

Fig.6 Mugger in Vishwamitri Photograph: Varun Vasava

Theoretical framework

2.0

The western nature-culture dualism is manifest as the dichotomy between city and nature. This is however impossible to delineate in the Indian context which perceives culture as an extension of Nature. In India Nature is thriving, abundant and not easy to control. The attempts by the British colonizers to separate Nature from human influence caused more damage than benefit to India's natural environment. This failure was partly due to the restrictions imposed on communities living with nature that still practice ancient traditions of reciprocity (Guha,2006). Presently, City/Nature formations (Massey, 2005) in some Indian cities are unlike any other places in the contemporary west and new trajectories must be traced.

The following chapter first briefly acknowledges the various associations with the crocodile in Indian tradition. It then reorients the understanding of the term human-wildlife conflict. Finally, relevant theories from the fields of animal geography, urban ecology, ethology and landscape architecture are woven into a framework that helps to produce urban landscapes apropos to their context.

2.1 The Crocodile in Indian culture

India has a rich intellectual tradition, within which the debate of nature-culture had evolved into an environmentally sensitive philosophy and way of life (Guha,2006). Traditional narratives were propelled by animal agency that formed a large part of folklore and myth (Ghosh,2016). The crocodile is known as 'Mugger' in many parts of the Indian subcontinent. The etymology of the word can be traced to the Sanskrit word Makara – a word used for "An ancient mythological symbol, the hybrid creature is formed from a number of animals such that collectively possess the nature of a crocodile. It has the lower jaw of a crocodile, the snout or trunk of an elephant, the tusks and ears of a wild boar, the darting eyes of a monkey, the scales and the flexible body of a fish, and the swirling tailing feathers of a peacock." (Beer,2003,p.77)

In Vedic astrology the Makara is the tenth sign of the zodiac equivalent to the sign of Capricorn (Fig.7). A winter solstice festival, Makara Sankranti, marks the erstwhile date of the suns movement into the zodiac of Makara, and is still widely celebrated all over India. In Vadodara, this day is celebrated with great enthusiasm in the form of a kite-flying festival. Presently, this date coincides with the start of the crocodile breeding season.

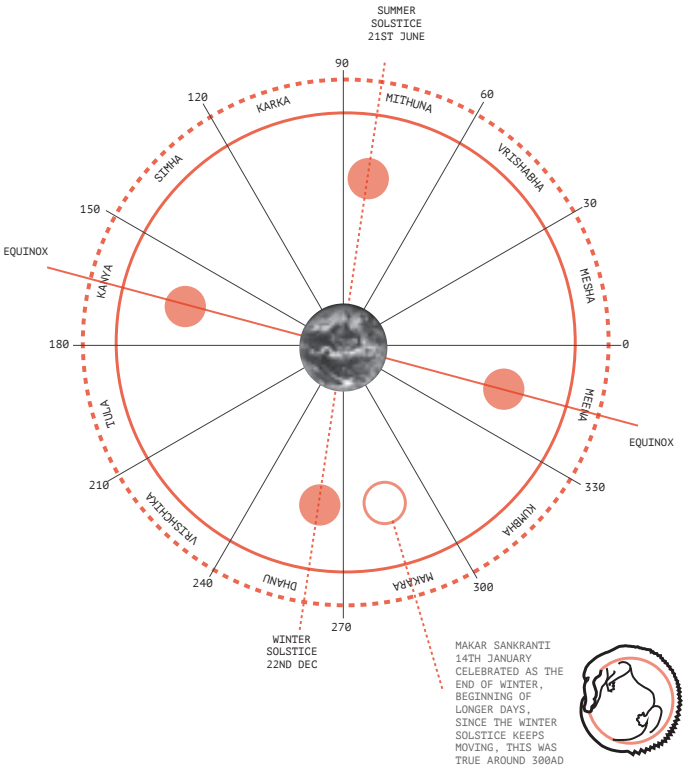


Fig.7 Indian astrological calendar with dates for Solstices and Makara Sankranti
source:authors own

The pantheon of Vedic Gods and Goddesses, features a large variety of animals as consorts. The Crocodile is the vehicle (Vahana) of the Goddess Ganga and the sea God Varuna (Srinivasan.1996:25) (Fig.8). It is also the symbol of Kamadeva (God of Love). Borkar (2006) has identified a "herpeto-eco-theological" tradition of Crocodile worship between certain indigenous communities and crocodiles in Goa, India. In Vadodara, the Crocodile or Makara is the divine consort for the local goddess, Khodiyar Maa and worshipped as 'Mogra Dev' (Crocodile God)(Vyas.2010) and could be the reason behind a long-standing history of tolerance for the Crocodile in the region (Vyas.2012). However, the contemporary Indian urbanscape presents a culture that worships animals at the same time desecrating the spaces they inhabit. These conditions have evolved from a long history of a "complex ecological, economic and spiritual triad (Robbins,1998:218)". Surviving in the intersections of this triad, animals have a remarkable presence in Indian urban life

Fig.8 Sea God Varuna with Makara
image retrieved from: https://collections.lacma.org/node/238301

2.2 Human-crocodile conflict

Growing human populations around the world, both in rural and urban areas, have resulted in competition between humans and wildlife for natural resources. This competition leads to dangerous encounters between humans and wildlife, termed 'Human-wildlife conflict' and defined as "any interaction between humans and wildlife that results in negative impacts on human social, economic or cultural life, on the conservation of wildlife populations, or on the environment" (WWF,2005. p.5). So what is in essence a competition for resources is termed as Human-wildlife conflict. In the past, Mugger populations were decimated due to hunting; timely action by the Indian Government resulted in the protection of the Mugger through the Wildlife Act of 1972. Successful captive breeding restocked the wild populations and presently the main concern is increasing human-crocodile interactions and how to manage these with minimal conflict.

A peak in human-crocodile conflict is observed during the monsoons, which begin in June and lasts until September every year (Vyas,2010). However, Peterson et al explain why 'Human-wildlife conflict' is not a realistic description as "This phrase is problematic because, given traditional definitions of conflict, it positions wildlife as conscious human antagonists"(Peterson et al, 2010). However, another less biased definition describes human-animal conflict as "characterized by the interactions that occur when an action by one has a negative effect on the other " (Torres et al 2017,p.421). I will look beyond the limited view of human-wildlife conflict and keep in mind the wide range of human-animal interactions in India, with a focus on the case of the crocodiles of Vadodara city and how to design for the sharing of habitat between species.

> "We are convinced that a transspecies urban theory is necessary-a position that is at once intellectual and spiritual, as well as theoretical and practical"
> Wolch et al,1995,p.736

2.3 Animal geography and the Urban

So how do animals negotiate and make urban environments their home? (Barua & Sinha,2017). Animals in urban areas can be broadly classified in "a matrix of animals who vary with respect to the extent of physical behavioral modification due to human intervention and types of interaction with people (Wolch,1998, p.123)". Donaldson and Kymlicka (2011), engage with the political status of animals and have developed a classification based on the degrees of animal interaction with human beings:

1) Sovereignty for wild animals

2) Denizenship for liminal animals
(These, unlike domesticated animals are animals living in human dominated landscapes but not entirely dependent on human interaction)

3) Citizenship for domesticated animals

The Denizenship status seems fitting for the crocodile population of Vadodara city, their status as wild animals can be questioned on the grounds of them inhabiting an urban environment alone.

Denizenship status ensures
a) Secure residency
b) Fair terms of reciprocity

Political ecologies create urban landscapes and herein lies the opportunity for its translation into landscape architecture. Animal geographers have tackled issues of the 'place' for wild animals in human dominated landscapes. Jennifer Wolch (2002) speaks of the anima urbis as the breath and life of the city and this seems fitting to remedy the paradoxical Indian urban realm. Both rural and urban Indian communities show a high tolerance towards most animals they share habitat with. However, the design of urban spaces for the inclusion of the non-human is yet to be given attention. Conceptions of cities as the sole realm of humans (Wolch, 1998), despite having a stronghold on urban imaginations, is evolving to recognize, retrieve and reimagine spaces for the multiple species that have coevolved with humans over millennia (Barua & Sinha,2017). Another urban theory of Wolchs' (1995), the transspecies urban theory, aims to create a framework built on an understanding of the effects of urbanization on the non-human in the urban. This can inform a transspecies urban design practice, motivated by feelings of kinship with the non-human (Wolch,1995).

Finally, crocodiles are powerful predators and are rightfully perceived as dangerous, however this essentialism can lead to unnecessary responses of fear and violence even when there is no actual threat. These conditioned responses largely spring from the lack of awareness regarding crocodilian behavior. Delving further into animal-human interactions, 'Animaling' (Birke,Bryld,&Lykke,2004) is a notion that allows us to transcend the essentialist perspective of animals to a profound knowing of the "material-semiotic performativity of human/animal relationships (Birke,Bryld,&Lykke,2004, p.169-170)". Moreover, understanding where both choreographies intersect can facilitate the inclusion of these non-human sentient agents in urban space (Instone and Sweeney, 2014).

2.4 Applied urban ecology

The discipline of urban ecology, has focused attention on the various tangible and intangible benefits of human-animal interactions (Soulsbury and White,2015,p.541). Human ontology, including kinship, is closely linked to our in¬teraction with animals. Influential Interactions that contribute to the development of human cognition, identity and consciousness (Shephard,1978 cited in Wolch,1996,p.28). Additionally, the tangible bene¬fit of the crocodile is that of a 'keystone species'-an ecosystem engineer that has evolved closely with the riverine ecosystem, important for ecosystem biodiversity and health (Thorbjarnarsen, 1992).

Another insight from the field of applied urban ecology, and crucial to the argument of this thesis, is the phenomenon of Synurbization in urban animals. Synurbization fuses synanthropization which "refers to the adaptation of animal populations to human created conditions in general (Luniak, 2004, p.50)" and urbanization which "refers to changes in landscape caused by urban development (Luniak, 2004, p.50)". It is an observation of how nature responds to urbanization and can help shed light on themes put forth by animal geographers. While the developing world will have most of its human population living in urbanized landscapes (Watson, 2009), synurbic wild populations suggest a chance "for some kind of co-existence between nature and expansion of urban civilization (Luniak, 2005, p.54)".

2.5 Ethology

Ethology is the study of animal behavior. The understanding of crocodile behavior is key to designing for them. The ethological perspective "involves in-depth engagements with specific animal populations or individuals and their lifeworlds (Buller, 2014 from Barua & Sinha,2017, p.2)". If the discipline of landscape architecture has to expand its list of clients and collaborators to include the non-human, ethology is the discipline that will be critical to this enterprise. This thesis thus chooses to rely on a basic ethological understanding of Crocodiles to interpret the results and formulate the corresponding design solutions.

2.6 Ecological Urbanism and Design

I choose ecological urbanism as a model of urbanization that combines the understanding of urban design and ecology (Spirn.2014). Ecological urbanism is competent to guide the creation of resilient city structures that also provide for human wellbeing and delight (Spirn.2014). There is great scope to extend the framework of ecological urbanism to include a transspecies urban planning and design practice. Conversely, the transspecies urban theory can be extended to "reimagine the role of 'nature' – including plants and eco-systems, as well as animals (Asikainen and Jokinen, 2009; Holmberg, 2015; Leino et al., 2015;Lulka, 2013 from Houston et al, 2017,p.12)".

Building on this marriage of transspecies urban planning and ecological urbanism, I adopt the paradigm of natural-novel ecosystems, which is an aes-thetically constructed landscape that highlights the role of design within modified urban areas (Sack, 2013). Concepts from animal geography and urban ecology, reinforce the theoretical and practical usefulness of framing the urban as an ecosystem. Or in other words, an Anthroposystem comprising the interactions over time between cultural and ecological systems (Alves et al.,2018).

In the case of Vadodara city, the anthroposystem can¬not be reversed back to the historical one. Having evolved into the present hybrid eco-system, it can, however, through further designed transformation, emerge as an urban natu-ral-novel ecosystem (Sack.2013 from Hallett et al.2013). (see table in appendix). 'Designed transforma tion' is thus the reversible threshold that pushes the hybrid eco-system to embody this novel ecosystem (Figure 3). It should be stated here that the novelty of the ecosystem is not the creation of an entirely new ecosystem but rather a novelty and innovativeness of designed solutions.

Finally, It is important to consider that designers and planners have two ways of influencing the dynamics of [hybrid] ecosystems (Adapted from Pulliam and Johnson, 2002).

1. By influencing the flows into and out of the system (Food)
2. By influencing the internal state of the system – (Habitat/Shelter)

In conclusion, the broad vision of ecological urbanism now inclusive of a transspecies urban theory, the paradigm of natural novel ecosystems for the production of urban landscapes, and finally the awareness of synurbization combined with the political ambition of denizenship (Fig.9) can steer landscape design that recognizes and celebrates the kinship and agency of animals in the narratives of urban place formation (Wolch,2002. Wolch,1996). To recall, the aim of this research is to create considerate design interventions that extend denizenship to the Muggers living in Vadodara's hybrid urban ecosystem.

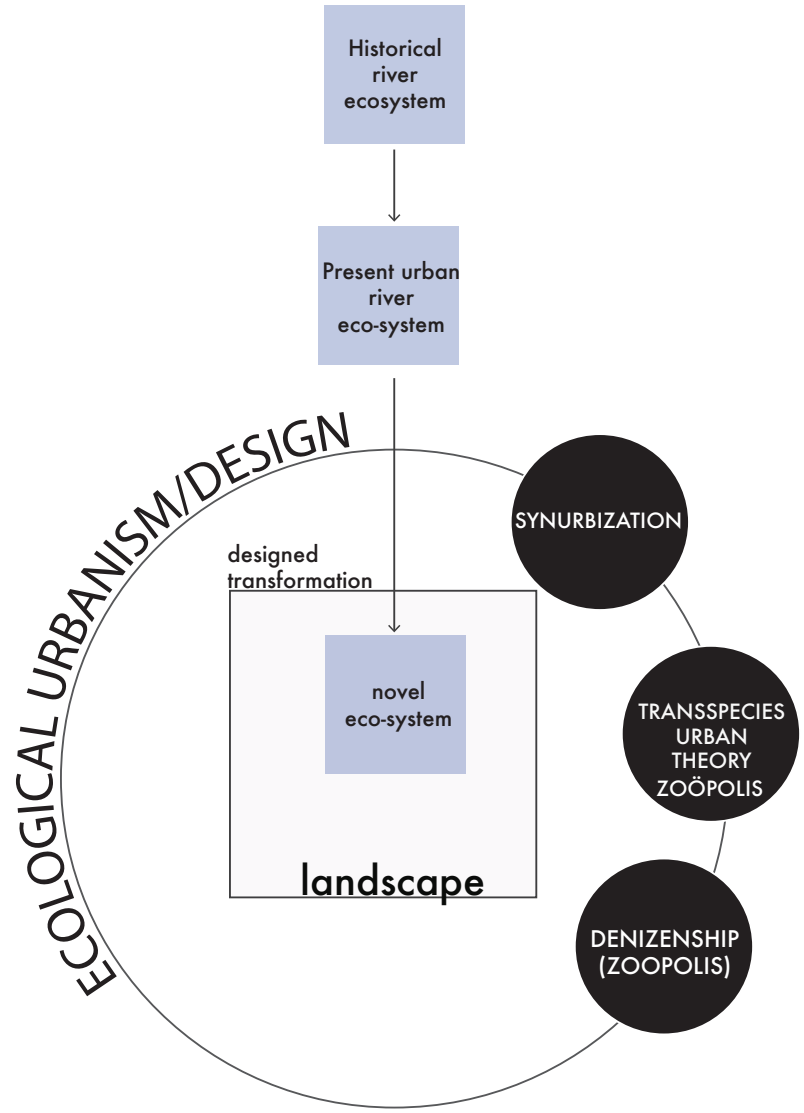
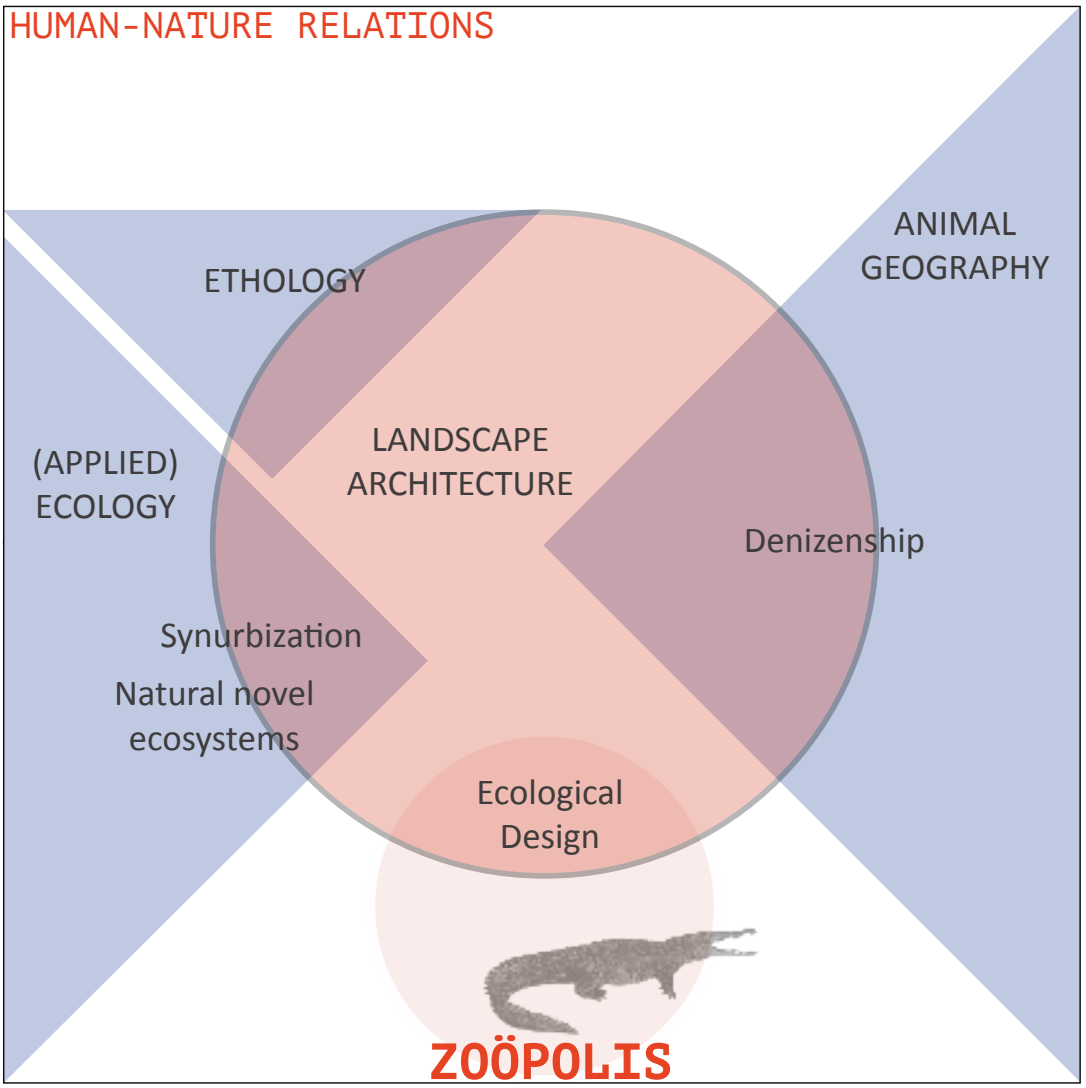


Fig.9 Landscape meets Zoopolis:Theoretical/Conceptual framework influencing physical dimension of the landscape
source: authors own


HUMAN-NATURE RELATIONS
ETHOLOGY
ANIMAL GEOGRAPHY
(APPLIED) ECOLOGY
LANDSCAPE ARCHITECTURE
Denizenship
Synurbization
Natural novel ecosystems
Ecological Design
ZOÖPOLIS

Methods

3.0

This chapter discusses methods used in Research for Design like interviews, on site observations and analysis of satellite images. These methods were selected based on their usefulness to answer the following design and research questions:

Design Question (DQ):
Which urban landscape design interventions can facilitate denizenship for the crocodile in a culturally and ecologically sensitive way?

In order to answer the design question I first ask the following three research questions :

Research Question 1 (RQ1)
What, if any, are the indications of synurbization in the urban Vishwamitri crocodile population?

Research Question 2 (RQ2)
In what ways does urbanization influence crocodile habitat in the Vishwamitri ecosystem?

Research Question 3 (RQ3)
What kinds of human-crocodile interactions are specific to Vadodara city?

This research in landscape architecture can be classified, as pragmatic research through designing, where an extreme case of crocodiles in Vadodara city provides the real world problematic that landscape architecture desires to solve. It is both constructivist and post-positivist (Deming and Swaffield, 2011) with a mode of enquiry that is quantitative and qualitative (Kumar, 2005). The results could contribute to a new approach for urban landscape architecture to be successfully inclusive of animals, elevating the thesis from its genesis in ethical and opportunistic grounds (Deming and Swaffield, 2011). The research questions were answered using mixed methods of enquiry.

3.1 Literature reviews

Google scholar was the search engine used to gather literature. The searches were conducted using keywords that varied for each question (See table.). Prior design proposals and theses on urban landscape design and planning for the river Vishwamitri in the past decade were scanned for relevant insights and data. These were obtained directly from the authors or promoters such as the Vadodara Municipal Corporation (VMC) website.

Limitations of the literature review:
Published papers on the Vishwamitri Muggers are numerous but limited in authorship to Dr. Raju Vyas, a recognized expert in the field of crocodile studies in India. Hence the expert interviews were a way of getting a balanced perspective.

3.2 Interviews

The particularly local nature of some parts of the enquiry meant that a literature review alone would not suffice. This is mainly because the subject is too specific to have enough published literature on it. Moreover, the academic culture in India does not stress upon publishing papers as criteria for teaching staff and this results in a low rate of both the production and publication of scientific literature (Reddy et al., 2016). Also, the Indian intellectual is more likely to communicate verbally than to write (Guha, 2006). Verbal dialogue forms a big part of the Indian intellectual tradition (Sen, 2005). Hence, in order to generate more grounded and relevant knowledge this thesis relies heavily on data from interviews with local experts. However, the reliance on interview data can also be seen as a limitation of the research design.

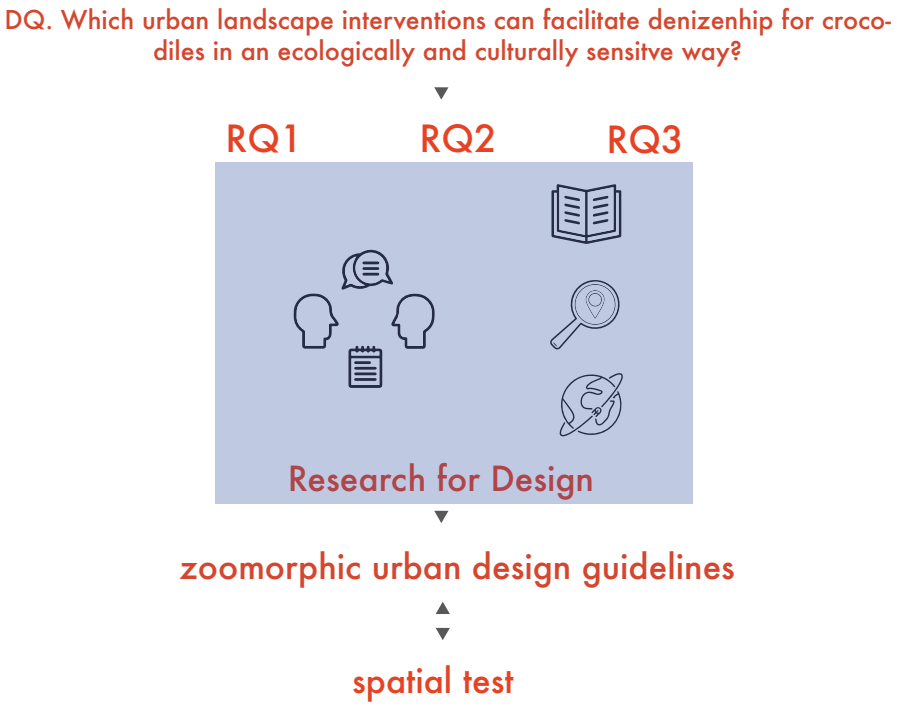


Fig.10 Research process source: authors own

The interviews asked research specific questions and were not conducted to measure attitudes of the interviewees. It is impossible to subtract the attitudes people have, it is however possible to avoid the influence of these attitudes by the coding of data.

Conducting the interviews:

The in depth semi-structured interview format is considered most suitable for exploratory research (Saldaña, 2015) and hence an appropriate tool of inquiry. The expert interviews can be broadly classified into local (9) and non-local (2), a total of 11 expert interviews were conducted. Most of the local experts were chosen by purposive sampling and were arranged using the network of Dr.Shishir R. Raval, a landscape architect who is known to the researcher. The rest were sampled by purposive snowballing.

Eight of the nine local experts were interviewed in person at a time and place of their choosing to enable their comfort. Some interviews were conducted in the homes or workplaces of the interviewees; others were conducted at locations along the Vishwamitri River. Due to his unavailability one local expert had to be interviewed by telephone. The interviews took between 30 to 90 minutes.

Local experts included;

1) Dr. Ranjitsinh Devkar – Assistant professor of Zoology, the Maharaja Sayajirao University of Baroda(Vadodara),
2) Dr. Deepa Gavali – Ecologist and Acting Director of the Gujarat Ecological Society (GES)
3) Vishal Thakur – local Wildlife (crocodile) expert and crocodile rescuer
4) Dr. Raju Vyas - Zoologist and former employee

of the Vadodara Municipal Corporation (VMC) in charge of Sayaji Zoo
5) Prateek Lakdawala - Director of an Animal rescue NGO
6) Rakesh Vadwana– Crocodile rescuer, Employee of the State forest department animal rescue Centre
7) Kartik Upadhyay - local Wildlife (crocodile) enthusiast and photographer
8) Dr. Shakti Bhatt – Water resource management expert.
9) Nilesh Shah – former Forest ranger with the Gujarat Department of Forests

The non-local expert interviews were conducted by telephone and used to triangulate data from local sources. Non-local experts were chosen through purposive sampling based on information gathered from scientific and news articles. They are listed below:

10) Dr. Pramod Salaskar – Zoologist, Mumbai, India.
11) Dr. Manoj Borkar- Natural Historian, Trained Environmental Biologist and Assistant Professor of Zoology, Goa, India.

Language and transcription:
Four of the nine local interviews were transcribed from audio recordings made with the prior consent of the interviewees; the remaining interviews were transcribed from field notes made by the researcher. One of the non-local expert interviews was recorded and then transcribed the other was transcribed based on the researchers notes.

Some of the interviews were conducted in Hindi and translated directly into an English transcription by the researcher. India speaks multiple languages and the local experts are from Gujarat where the language is Gujarati. If not educated in English then the preferred language could be either Gujarati or their native language if originally from another part of the country. Although I understand Gujarati, speaking it is barely possible. However the common language between the interviewer and interviewees was Hindi and if English was not an option Hindi became the second choice to conduct the interviews. One limitation of the study could be that for cultural reasons, non-native English speakers may see the researcher as an authority figure (Koulouriotis, 2011) and may not be as forth coming with their responses. Choosing to maintain a degree of caution with regards to the information they share.

Coding of interviews:
The local expert interviews were analyzed using first and second cycle coding methods (Saldaña,2009). This allowed for the thematic sorting of data into sub-categories and categories in which lay the answers to specific research questions (Appendix B). Coding enabled the researcher to transform the data from transcripts that had hints of subjectivity to objective information made ready to classify. The development of codes is largely based on the researchers interpretation and this makes it a qualitative process with a considerable influence on the results. By documenting the coding process, it is hoped that these limitations can be detected thus allowing for critical insights and discussion. The raw transcripts went through two cycles of coding (Saldaña, 2009).

First cycle coding:
The research question guided the first cycle of codes.
Crocodile Habitat Characteristics,
Behavior,
Locations,
Movements,
Human-animal interactions,
Impacts of Urbanization, and
differences in urban crocodiles compared to rural ones
Were sieved out as preliminary categories. Codes were developed based on these preliminary categories.

Second cycle coding:
The codes developed from the first cycle of coding, were systematically highlighted in all the transcripts. These were then further classified into sub-categories under the categories that were finally developed (Appendix A). The coding process demanded the reading and re-reading of the interview transcripts and this repetitive process allowed for deeper insights into the data which were missed the first few times. The answers to all the research questions were derived from the coded interview data albeit in different degrees.

3.3 Non-participant on-site observations

Non-participant on site observations were made at multiple locations along the river (Appendix B). The locations were chosen based on important crocodile habitat which in turn were finalized through data from interviews and literature. A local wildlife enthusiast, Sanjay Soni, accompanied me to spots where crocodiles can be observed at close range. In addition to his knowledge about these locations, all of which are not easily accessible or known to the wider public, the presence of Mr.Soni allowed me to safely venture into the riparian crocodile habitat. The choice of locations could have been made based on how the guide wanted to represent the crocodile, however a check on this was the literature and interview data which mentioned them as important crocodile habitat.

I was unaccompanied when visiting the other locations. I had initially planned to use walking as a method of experimental research (Schultz & Etteger.2016) and had wanted to conduct a continuous stop motion (CSM) walk along the banks of the Vishwamitri. However, this proved impossible as many parts were fenced in or inaccessible due to dense vegetation or landfills along the banks. The presence of crocodiles and my lack of knowledge on how to preempt and respond to crocodile behavior became an added concern for walking along the river. Hence I chose to move from one location to another by foot or public transport, sticking to established urban road networks. On-site observations at each location were documented through photographs and video footage made on a Panasonic Lumix digital camera.

3.4 Analysis of satellite imagery

Available Google earth images from the past decade were examined to triangulate results from the expert interviews. I studied the impact of urbanization on specific locations mentioned by the experts, within the larger crocodile habitat (Appendix B).

The outcomes of this investigation were distilled to provide answers to the research questions and are discussed in the following chapter.

Inventory and Results -Research for Design

4.0

The first part of this chapter contains relevant information about the Mugger crocodiles and the Vishwamitri River system. This data is presented first because it provides a basic knowledge of the species that is elementary to understanding the results presented in the next half of the chapter. This necessary pre-design data was obtained from interviews and literature reviews. The first section introduces the reader to the hydrological and geomorphological components of the Vishwamitri river landscape. The next section covers key information about the behavior and habitat requirements of Crocodylus palustris (Mugger crocodile) collected by a literature review and interviews. Both sections take note of what makes the Vishwamitri river system habitable for the crocodiles.

The second part of the chapter is result oriented, and systematically answers all three research for design questions. The results are derived mainly from the coding of interviews and triangulated by a literature review, analysis of satellite imagery and on-site observations.

Part 1

4.1 The Vishwamitri River system

The Vishwamitri begins its journey at Pavagadh Hill about 830 meters above sea level. Smaller tributaries empty into the Vishwamitri as she flows through agricultural alluvial plains before entering Vadodara city (Fig.11). Finally, merging with the Dhadhar River that ends its journey in the gulf of Khambat on the western coast of Gujarat.

The Gujarat alluvial plains are made of gravel, sand, silt and clay. Meandering is characteristic of these rivers; the Vishwamitri is no exception, displaying a " narrow, highly sinuous and deeply incised meandering channel (Raj et al, 2004. p1647)". The river is primarily rain-fed and the monsoon is a major player in these seasonal dynamics, transforming the parched river into a river that floods its banks.

Moreover, the meandering nature of the river makes it suitable Mugger habitat for two reasons. First, the flow is sluggish, ideal for Muggers that prefer still or slow moving water. Second, the meandering has led to the formation of numerous meander loops and ox-bow lakes. These lakes are crucial seasonal habitat for the crocodiles, especially in the rainy season.

The Vishwamitri river system has been urbanized over the last few decades (Fig.12) and it seems that the presence of the crocodiles could even be a result of urbanization. So when did the crocodiles start inhabiting the river system? Before or after the urbanization of the river system began? There is no conclusive evidence to answer this. Vyas (2010) strongly suggests that the crocodiles where introduced in the river after 1985, however other experts believe that there were crocodiles in the river and pond network historically as well, although their numbers were much less then.

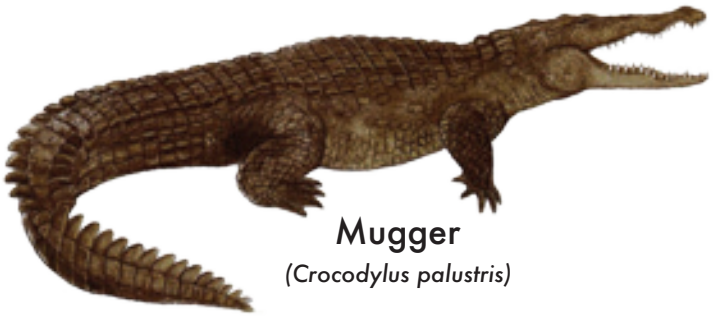
Fig.11 Vishwamitri watershed
adapted from: Mittal et al.,2017

Fig.12

Vishwamitri
before entering Vadodara
Photograph: Sanjay Seth

Vishwamitri
in Vadodara
Photograph: Sanjay Seth

Vishwamitri Landfill site
Photograph: Sanjay Seth



Mugger
(Crocodylus palustris)

4.2 Crocodile ethology

Crocodylus palustris, Marsh or Mugger crocodile, is widely distributed all over the Indian sub-continent. They are found in a diverse range of habitats both natural and man-made. Usually inhabiting wetlands, ponds, tanks, streams and rivers, irrigation channels and reservoirs (Whittaker and Whittaker,1989). A key to comprehend the habitat requirements/characteristics of the Mugger is ethology. Crocodile ethology although difficult to understand because of the "slow response times; amphibious/aquatic settings; and, complex social systems (Lang,1987, p.273)" can be grouped around the main life-supporting activities that take place through interactions with the landscape. Crocodiles engage with the terrestrial, aquatic and sub-terrestrial layers of the landscape.

Lang (1987) developed a Behavioral Inventory for the crocodilian, and this is a useful way of understanding crocodile ethology. I will adapt the classification of behaviors used by Lang and specify this for Crocodylus palustris. The three categories are;

1.Maintenance
2.Social interactions
3. Reproduction

I exclude social interactions between crocodilians, as investigating these behaviors in detail are not within the scope of this thesis.

1.Maintenance:

Crocodiles are Ectotherms; regulating their body temperature through environmental factors such as sunlight, water, soil and shade (Kaur, 2015). Changes in the environment on a daily and seasonal temporal scale result in corresponding changes in behavior (Lang,1987).

Basking – This is the primary temperature regulation activity. Crocodiles bask on sites along the banks, chosen based on slope and exposure to sunlight. These are known as basking platforms. Crocodiles bask on either the east or west bank based on the Suns position. The crocodiles clear

Fig.13
Crocodile basking platform cleared of vegetation, Vadodara
source: authors own


Fig.14 Crocodile basking, Vadodara
source: authors own

vegetation to make suitable basking platforms at many locations (Fig.13).Some wider stretches of the river do not need any modifications.

According to interviewee Nilesh Shah (Appendix A) another kind of basking observed in the crocodiles of Vadodara is surface basking. The crocodile exposes it's top surface length while staying afloat in the water. This form of basking is done if the climate is too warm in the summer months and entirely exposing themselves to sunlight can be counter-productive.

Aestivating –According to interviewee, Kartik Upadhyay, (Appendix A), in months of drought or harsh summer months, the crocodiles of the Vishwamitri have been known to aestivate in subterranean dens, which they make to regulate their body temperature and escape the extreme heat. It is the inverse of hibernating- done in winter months to minimize the impact of the cold. This behavior is a result of larger seasonal changes.

Seasonal habitat network includes the larger aquatic habitat of the pond network. These ponds are widely spread both within and outside the city limits (Vyas,2010). The function of these ponds became clear after an interview with Nilesh Shah (Appendix A) who explained that the crocodiles visit these ponds in the dry summer months or during the monsoon when the river is flooded making the banks unavailable for basking. They are known to walk for a few kilometers to these ponds. The study conducted by Vyas (2010) listed 18 ponds within the city limit still in use by the crocodiles (see fig.).

Feeding- Thermo-regulated metabolism results in a slower metabolic rate and this means that crocodiles do not need to feed on a daily basis. On average they feed once a week amounting to 48 times a year (Interview, Devkar, Appendix A). Muggers are also known to go for longer periods without food (Whittaker and Whittaker,1989). They store enough fat in their tails to tide them in these periods of fasting. The amount of food intake also varies with the seasons, with food intake rising in the warmer months and falling in winter. The Mugger is an indiscriminate master predator of its aquatic environment (Lang,1987. Whittaker and Whittaker,1989) and has a broad diet including livestock, birds, fish, insects and rats.

Hunting – It is a skilled predator and hunts animals that come close to the water's edge, in range for a sweeping hit from its powerful tail (Interview, Devkar, Appendix A). The Mugger stalks its prey and relies on the element of surprise in order to hunt. It moves in short bursts but tires easily (Lang,1987). Once swept into the water the Mugger locks the animal in its powerful jaws and kills it by drowning (Bradshaw, 2017). The prey is then swallowed whole. There is no conclusive evidence of Mugger crocodiles preying on humans, as attacks on humans could also be cases of accidental mispredation (Vyas,2010. Whittaker and Whittaker,1989).

Scavenging – Muggers are also scavengers and this makes for versatile feeding habits (Misra,1969. Bradshaw,2017). Their scavenging is beneficial to aquatic ecosystems as they help rid the water of carcasses and organic waste, contributing to cleaner waters.

Cannibalizing – Muggers are known to cannibalize each other but this is rare only occurring in extreme cases (Interview, Devkar, Gavali, Appendix A).

Locomotion- Perhaps the most obvious function of agency is that of locomotion. Crocodiles have five basic styles of locomotion.

Swimming - Crocodiles are expert swimmers, though usually found in freshwater habitats, some species like the salt-water crocodile are also comfortable swimming in the ocean.

Walking – Apart from moving over land with their bodies close to the ground -crawling, Muggers are also known to walk with their bodies raised a few feet above the ground called a high walk (Bradshaw,2017.Misra,1969) . They can walk for a few kilometers over land in order to search for food or seek shelter in seasonal habitats. This kind of high-walk is a unique feature of the Mugger compared to other crocodiles (Halliday and Adler,1989 from Mobaraki,2015). Juvenile crocodiles can even gallop or run (Bradshaw,2017).

Jumping- This is the near vertical motion involved when shooting out of the water to catch prey (Bradshaw,2017).

The crocodile's slow gliding movements have evolved with their preferred still water habitat and the sluggish waters of the Vishwamitri are ideal for them. Slow moving water is conducive to communicatory behavior between the Muggers. Displays include creating bubbles and ripples in the water, also head and tail slapping on the waters surface are part of communicatory behavior (Senter, 2008.Lang,1987).

Habitat Modification

Crocodiles modify their habitat due to changes in climate, water level and reproductive activity (Lang,1987).Nesting behavior of the Mugger in the Vishwamitri indicates four different kinds of nest architecture that are modified to serve different functions base on location and season (Bayani et al.,2011). Clearings, paths and earthen sills are made in order to restrict or provide access to dens (Bayani et al.,2011). Crocodiles inhabit terrestrial and aquatic habitats but their role as zoogeomorphic agents within the sub-terrestrial layers of the landscape are also significant (Butler,1995). They are burrowers, making tunnels as long as twenty meters ending in dens large enough to accommodate one or many crocodiles (Butler,1995). The Vishwamitri alluvial plains are made of gravel, sand, silt and clay a composition suitable for crocodile burrowing and aestivating in the hot summer months.

Habituation and learning

Recent studies about reptiles have helped to set aside the outdated image of reptiles as ancient, primitive and unintelligent (Bradshaw,2017). There is mounting evidence that reptiles (crocodiles) also have high emotional intelligence (Bradshaw,2017). The interview data is rich with anecdotes about the intelligence of the Vishwamitri crocodiles. Interviewee, Nilesh Shah (Appendix A) gives an account of crocodile behavior to outsmart human mal-intent.

"Crocs adapt their behavior around humans, a crocodile was once seen making a nest on the banks close to human settlement, it cleverly dug out six holes, and then came back at night laid the eggs in one of the holes and covered back all six holes so that no one could know for certain where it laid the eggs!"

Thus crocodiles have been observed to get habituated to human presence, adapting their behavior accordingly (Lang,1987). This adaptive capacity implies a learning tendency, evident in captive and wild crocodiles. Learning behavior is also socially facilitated (Lang,1987).

Site Fidelity
The mugger is territorial and roams within a defined home range. Site-fidelity, or adherence to chosen spots for basking and nesting, is characteristic (Lang,1987).

2. Procreation

The procreation cycle of Muggers in India seems to coincide with the monsoons. Hatchlings are born around the time of the first rains and the mating and nesting, which take around 2 months, are timed before this (Whittaker and Whittaker,1989).

Courtship and Mating - Mating season in Vadodara begins around the time of Makara Sankranti, in the month of January (Interview, Thakur, Shah, Upadhyay, Appendix A). This is the time when the crocodiles display aggressive and territorial mating behavior.

Nesting and Incubation - The Mugger is a hole-nesting species (Da Silva and Lenin,2010). The

female digs holes at about a height of 1-1.5 meters from the water level to lay her clutch of eggs. The gestation period is between 70-90 days (Mobaraki,2015). She usually guards her nest until the hatchlings are born, sometimes even going without food in order to be close to the nesting site (Whittaker and Whittaker,1989). Females tend to come back to the same nesting site year after year.

The Vishwamitri River, despite passing through densely populated parts of the city, still supports a healthy breeding population of Muggers (Bayani et al.,2011). It is crucial for the hole nesting species like the Mugger, to have the choice of nest sites and dens for various purposes. The banks of the Vishwamitri are conducive to nest building and four different kinds of nest architecture have been observed (Bayani et al.,2011).

Rearing - Crèche formation has been observed in Hatchlings from the same female. They are reared in these groups for up to two months (Lang,1987. Whittaker and Whittaker,1989)

Conclusion:

The data presented above helps to broaden our understanding of the Mugger crocodile, not only as a predator to be afraid of but also as an intelligent, sentient and social animal that actively shapes and reshapes the urban river landscape, while displaying an adaptive agency within the hybrid ecosystem.

Fig.15

Fig.16

Fig.15 Crocodile at the entrance to her den,Goa, India (Jim Manjooran)
retrieved from: https://carambolimwild.blogspot.com/2013/05/

Fig.15 Crocodile basking (Kamlesh Joshi)
retrieved from: https://twitter.com/KamleshJoshi82

"One question nobody can answer is why the Vishwamitri river has got so many crocodiles?"
-Interviewed expert

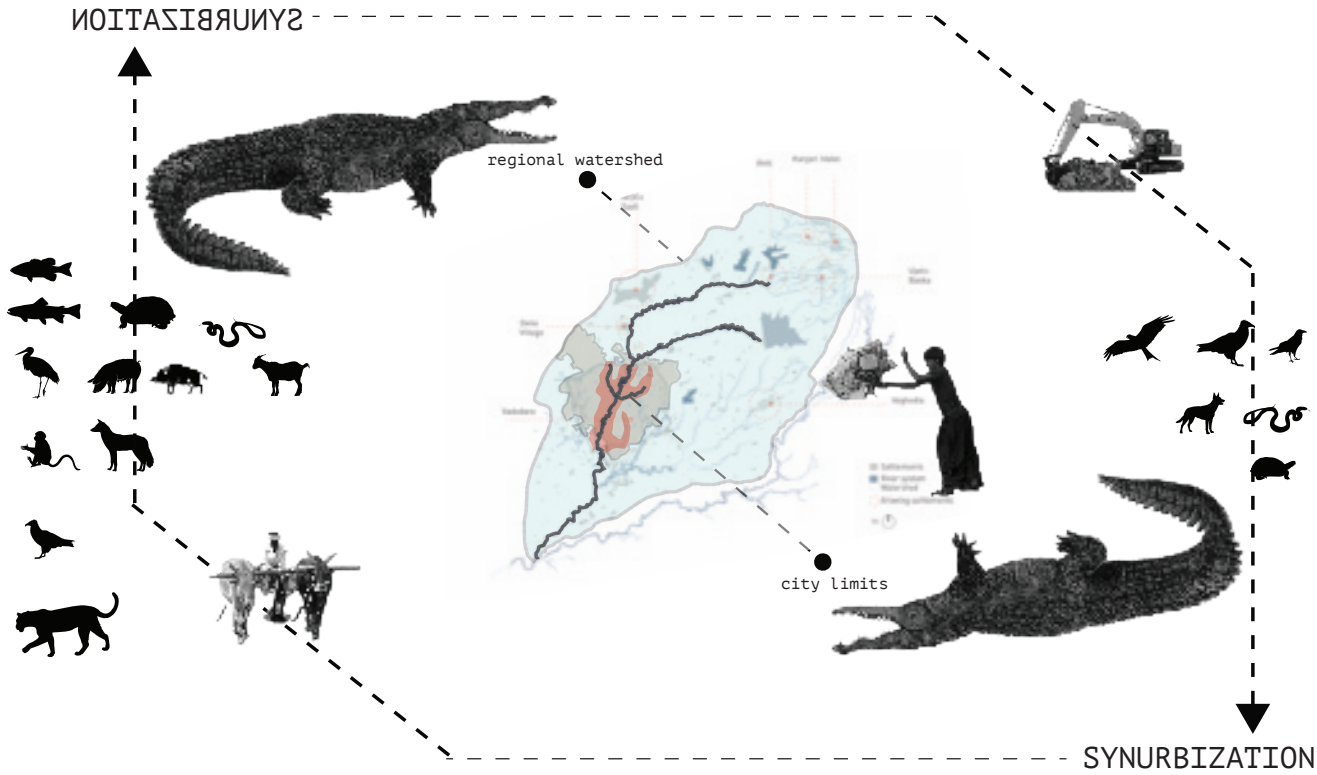


Fig.17
Reduced diet diversity between rural and synurbic crocodiles; in light blue-watershed, in orange-Vishwamitri urban stretch
source: authors own

Part 2

4.3 Results -Research for Design

RQ1 – What, if any, are the indications of synurbization in the urban Vishwamtri crocodile population?

The theoretical framework elaborates on a phenomenon called Synurbization i.e. the changes in animal behavior due to human influence specifically in urban areas (Luniak, 2004). Experts interviewed (Appendix A), were explicit about the difference between the urban crocodiles and their rural counterparts. The crocodiles display typical features of synurbic populations including (adapted from Luniak, 2004,p.50):

1) Changes in diet

The Vishwamitri ecosystem supports a large number of aquatic, avian, insect, reptilian and mammalian life. However, the urban stretch of the river, is highly polluted (Deshkar et al.,2014) with a reduced bio-diversity index, due to 1) Industrial effluents and sewage that is released untreated into the river, 2) loss of healthy riparian vegetation and 3) encroachment on the floodplains by both informal and formal settlements. What impacts the crocodilian diet the most are the low rates of dissolved oxygen that cannot sustain a breeding population of freshwater fish. Monkeys and wild boar were another source of food, however these animals are discouraged from inhabiting urban spaces. The contamination of the river system by organic waste (GERI, 2014) happens to be a food source to many animals including the crocodiles. Thus, the most significant interaction between

urban processes, individual actions and crocodiles is the dynamics of food. Urban crocodiles seem to have shifted away from a predominantly predatory lifestyle to one of scavenging on organic waste and even actively being fed. Local wildlife expert, Vishal Thakur, when interviewed (Appendix A) had to say the following - " the Vishwamitri river crocodiles get ready food, they are not as great hunters as the ones in the wild. . . all the butcher shops dump meat in the river which the crocs feed on. . ." The availability of ample food waste (Fig.18) also alters the crocodiles corporeal dispositions (Barua and Sinha,2017) as many of the crocodiles looked overweight.

By mapping the known feeding sites (Fig.19), a co-relation could be made between feeding and high populations of crocodiles in those areas. These areas also happen to be optimal habitat for undisturbed nesting, basking and burrowing (Ishore, 2017). On the other hand it can be argued that a highly visible number of crocodiles at those locations resulted in the dumping of meat waste there. Regardless of how the current situation came about, it does not diminish the relevance of this unique interaction.

Fig.18
Meat waste in river
source: Tanvi Choudhari

Fig.19 Known feeding sites correspond to urban stretch with high crocodile population density (indicated by dotted red line)
source:authors own

2) Higher density of population

The 25km urban stretch of the Vishwamitri has an unusually high number of crocodiles (Appendix B). The last official crocodile count in 2015 pegged the population at 250 (Interview, Nilesh Shah,Appendix A). The experts do not agree on a definite reason for this, some suggest that the loss of riparian vegetation and the subsequent decline of species that prey on crocodile eggs and hatchlings has allowed a higher survival rate (Interview.Devkar,Appendix A), others believe that the population is increasing due to the migration of rural crocodiles to the urban stretch since it offers safety and ample food (Interview, Vyas, Appendix A).

3) Changes in migratory behavior

"The talavs [lakes] in Sama, Harni and Lal bagh are all connected to the river especially during the monsoon floods…however these connections are fragmented by roads and made unsafe when the waters recede, . . . so when the crocodiles try to get back to the Vishwamitri they are run over or hit by traffic…" - Interview, Nilesh Shah (Appendix A). It is evident then that an increased fragmentation of road networks and human settlements block migratory routes to city ponds and are fatal for migrating crocodiles. These experiences have altered the crocodile's migratory routes forcing them to seek refuge in more safely accessible ponds, which could be further away from the river.

4) Changes in breeding ecology

Crocodile sex determination is temperature dependent – experts claim that there are a larger number of females than males in the urban stretch, causing the males to be less aggressive. Studies have shown that for Crocodylus palustris extreme temperatures result in an increase in female hatchlings (Lang and Andrews,1994). Temperatures in the city are on the rise (Mittal et al,2017) as a result of anthropogenic climate change and this could be an explanation for the skewed gender ratio of urban crocodiles.

5) Adaptive towards man

The crocodiles are both habituated and adaptive to human presence, as illustrated by the following excerpt from an interview-"Vishwamitri river crocodiles are shy and scared, . . . if we walk along the river and we see a croc it will quickly get into the water and move away . . . they are this way because they live in the middle of a human habitat "- Vishal Thakur (Appendix A). The interview data concludes that crocodiles in the urban stretch of the river are shy and less aggressive compared to their rural counterparts. An interview with Devkar (Appendix A) revealed that the Vishwamitri muggers have been known to shift both basking and nesting spots as a response to invasive human activities.

Ecosystem service provision

"The crocs are also helpful in cleaning the river… if not for the crocs the meat waste and other waste would have rotted and given off a foul odour and spread diseases . . . even if there was no waste being dumped…they would eat and scavenge the other dead aquatic animals like the turtle."- Interview, Nilesh Shah (Appendix A)

Experts believe that if not for the crocodiles, the river would have been more polluted. Their scavenging processes organic waste in the river. Additionally, Crocodiles are known to hunt and eat rats making them effective agents of urban pest control (Whittaker and Whittaker,1989). Apart from meat, crocodiles are known to consume fruits and legumes (Bradshaw,2017) and are agents of seed dispersal along the riparian habitat (Platt et al.,2013).

Conclusion:

Interviewed experts have observed that the urban crocodiles show behavioral and biological differences compared to their rural counterparts. The availability of food in the form of organic waste seems to have made them complacent as hunters, with an observed shift from predator mode to scavenger mode. The unexplainably high population density is akin to human populations that are concentrated in urban areas (Interview, Devkar, Appendix A). This questions the degree of commitment to a home range of the crocodiles in rural areas, as some experts claim that the increasing crocodile population is due to crocodiles migrating from rural parts. The increased number of females, due to environmental changes also has repercussions for the social lives of crocodiles, with males having to be less aggressive with each other in order to fight for a suitable mate. Consequently

this makes them less likely to get into conflict with humans. Most significantly, the crocodiles have a great capacity to adapt their behavior in human dominated areas. Some experts even label them as "shy" compared to their more aggressive rural counterparts. This adaptive capacity is a hallmark of synurbic populations and the basis on which coexistence in urban areas can be designed for.

RQ2- In what ways does urbanization influence crocodile habitat in the Vishwamitri ecosystem?

The Vishwamitri river system as described in the first part of the chapter outlines the characteristics of the natural system deliberately excluding the interactions with the urban that transform it into a hybrid ecosystem. The following section will expand on these interactions that manifest spatially and drive home the point that nature and the urban are not distinct but mutually constructed.

Below are some effects, both positive and negative, of urbanization on the river system and thereby on crocodile habitat.

1) Reclamation of riverine and riparian habitat
Including ravines, lakes and seasonal floodplains/ ponds are done to divert land for the enterprise of expanding human habitat. Encroachments on floodplains are common and happen with the knowledge of the state, both informally and formally. In 2009 work for a now hashed 'Riverfront project' by the Vadodara Municipal Seva Sadan, cleared, widened and flattened river banks resulting in the blocking of some burrows and the total loss of some. However within a few weeks the crocodiles remade or rescued their homes (Vyas,2010).

2) Invasive species
Experts are divided about the effects of Prosopis Juliflora - a dense shrub which was used by the Indian government to combat desertification but has now become a widespread nuisance - some are of the opinion that the scrubby bush has prevented human access to the river banks adding a layer of protection for the crocodiles (Interview, Gavali, Appendix A), others are of the view that the invasive plant turns into an impervious thicket blocking sunlight and taking over basking platforms, it is also responsible for putting huge demands on groundwater leading to a further loss of water in dry periods. It has a greater presence along urbanized stretches of the river but is slowly taking over undisturbed riparian vegetation.

3) Increasing temperatures due to the urban heat island effect
Being Ectothermic i.e. regulating body temperature from the external environment necessitates concern about increasing temperatures on crocodile basking and aestivating patterns (Interview, Thakur, Appendix A). The increasing temperatures can be attributed to anthropogenic climate change, specifically the urban heat island effect. Growing use of concrete in rapidly developing cities with little regard for green cover and permeable soil has contributed to this phenomenon.

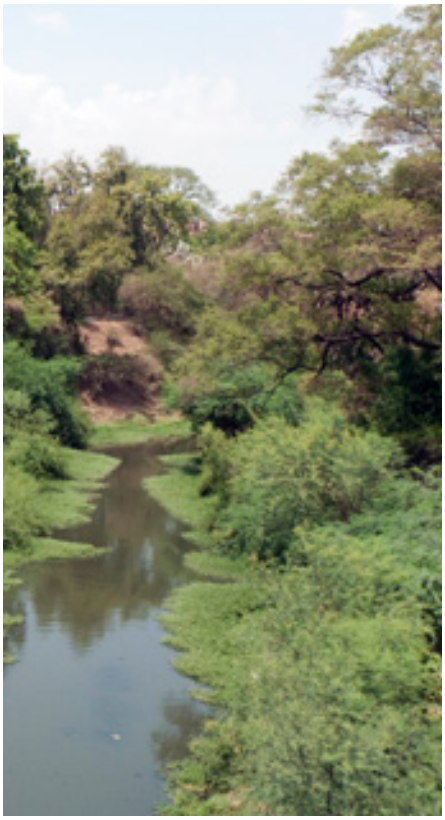
4) Water quality
Many studies have shown that the water quality of the urban Vishwamitri is dangerously toxic. About 78 Millions of Liters per day (MLD) of untreated sewage is discharged into the river, making Dissolved Oxygen (DO) levels too low to support a healthy fish population – a primary source of food for the Muggers upstream of Vadodara city. Crocodiles are robust animals and seem unaffected by the contaminated water, however no studies have been done on the effect of water pollution on crocodile health (Interview, Vyas, Appendix A). At present, a breeding population is an indicator of good health; this is not fool proof as growing populations are not necessarily indicators of excellent individual health.

5) Fragmentation of crocodile habitat network
As mentioned in the previous section, crocodiles live in a dynamic aquatic habitat network contingent on the monsoon season. Being able to traverse within this network is vital to surviving periods of harsher climate. Urbanization of the river system and adjacent land has led to a common problem faced by many wild animals – fragmentation of habitat. The remaining pond network that is still used by the crocodiles continues to become more inaccessible due to encroachment of human settlements and transport infrastructure of the city forcing the crocodiles to use them at great risk to their lives.

Fig.20 Urban Vishwamitri river banks

Building debris

Degraded and overrun with *Prosopis juliflora*



Better quality of vegetation along public gardens

Smoke from garbage being burnt along the river banks

Untreated piped outfall

Construction in floodplains

source: all images are the authors own except for the image titled “Building debris’ which was retrieved from https://counterview.org

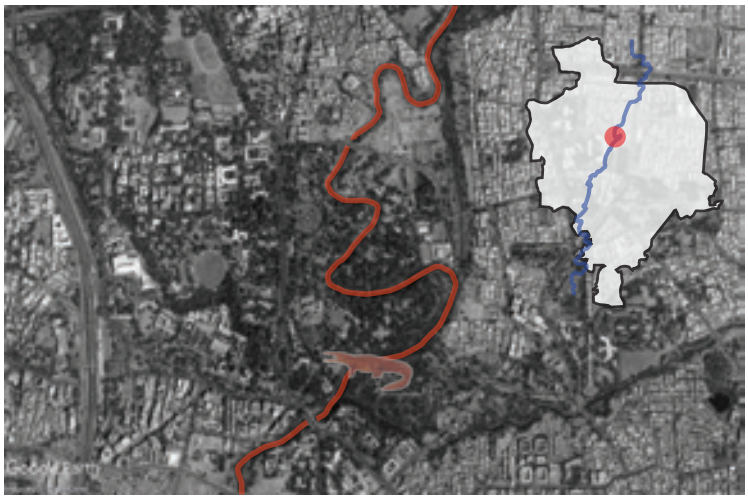
6) Exacerbated conflict due to urbanization of floodplains

With the intractable urbanization of the floodplains, a retention area for floodwaters is now inclusive of human settlements (Fig.21). This forces the crocodiles into the low-lying homes of people in the monsoon season when parts or the entire stretch of the river floods (Fig.22). This greatly exacerbates human-crocodile conflict, most calls to rescue centers being made in the peak of the monsoon season (Vyas, 2010).

However, urbanization does not only have negative impacts on the crocodile population the following excerpt from an interview with Raju Vyas (Appendix A) suggests that the crocodiles are safer in the urban areas than their rural counterparts - " Vishwamitri [river] provides a safe habitat for the crocs because of human neglect so the human dependency on the river water is not so much as compared to the more rural outskirts where they fish in lakes and crocs can get trapped in the nets, or they even actively hunt crocs. So it could be that the crocs are migrating to the urban stretch for a safer environment . . ."

Another interesting observation shows how crocodiles influence urbanization along the river. Satellite images of informal settlements along urban rivers in Indian cities like Mumbai and Surat; show how the riverfronts of these settlements vary from similar settlements in Vadodara city. While, informal settlements in the other cities are built right up to the waters edge despite the flooding of the rivers, this is not the case in Vadodara where there is an eight to fifteen meter vegetated buffer between the edge of settlements and the river's edge. This is how humans are adapting built form and behavior in the presence of a predator species such as the crocodile.

Fig.21 Dynamic crocodile habitat
source:authors own



non-monsoon ▲

▼ monsoon

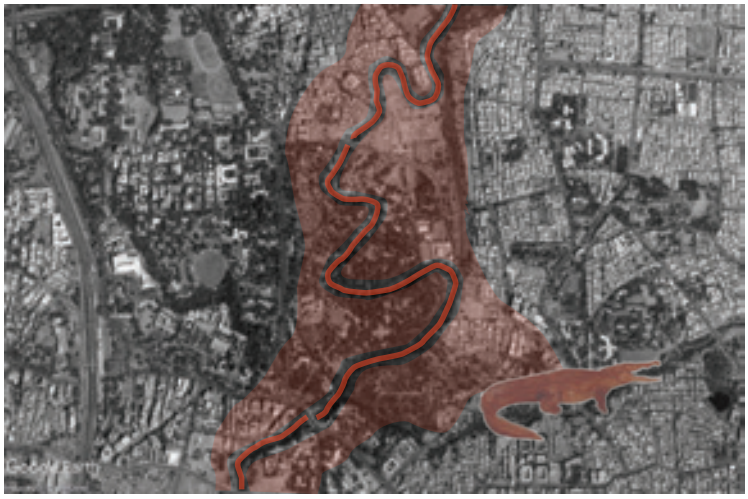


Fig.22 Crocodile carried into the city by flood waters
image retrieved from:www.barodarocks.com/

Conclusion:

Urbanization entails the despoliation of the river landscape. This is evident in the observed quality of the existing landscape (see fig) and the analysis of satellite images over the past decade (Appendix B). First, the dumping of construction debris, and the consequent construction of housing projects has reclaimed the ravines and ponds. This reduces the diversity of seasonal habitat available to the crocodiles. In addition to being greatly reduced in number the remaining pond network which forms crucial seasonal habitat for the crocodiles has become inaccessible thanks to fragmentation by transport networks of the city.

Second, when indiscriminate urbanization and monsoonal floods coincide, along with the water come the crocodiles. A reason why crocodiles are found in the city is their need to move inwards to find ponds and dry land for basking; a necessary maintenance behavior of crocodiles. Floods combined with the added danger of crocodiles trapped inside human settlements leads to a peak in urban human crocodile conflict, and this situation is specific to Vadodara city. Crocodiles also benefit from urbanization with their safety and food supply being insured. Finally, crocodiles influence urbanization patterns along the river, acting as a check on informal settlements taking over the riparian vegetation buffer.

RQ3- What kinds of human-crocodile interactions are specific to Vadodara city?

1) Feeding
Local butchers and fish vendors have taken to dumping offal into the river, some even incorporating the feeding of the crocodile as part of their daily routines. Suitable bridges across the river are the sites where the feeding unfolds (Figure 19). Stopping on their way home at night to feed the crocodiles, one meat vendor describes how the crocodiles have learnt to be there, jaws open, ready to receive their food.

2) Worship
Worshipped as Mogra Dev (Crocodile God), Khodiyaar Maa, A polio-stricken local deity whose companion is the Mugger crocodile, its slow gait on land making it an apt choice. Prayer offerings

Fig.23 Flowers as votive offerings to the river
source:authors own

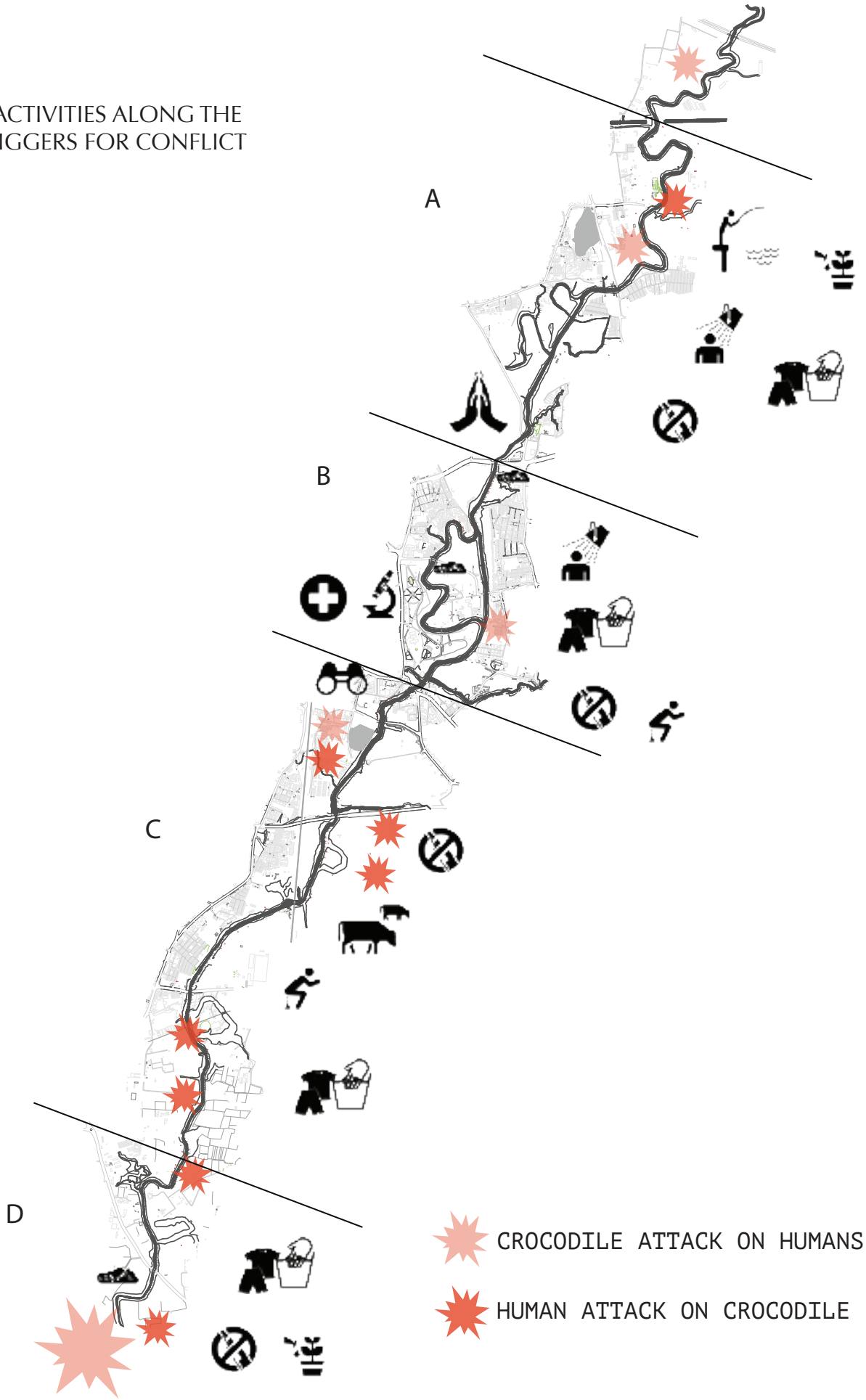
are made by the riverbanks to appease the crocodiles; flowers and diyas (floating oil lamps) are lit and set adrift as a part of this appeasement (Fig.23). These ancient rituals are still very much a part of the urban.

3) Crocodile spotting
"This place where we are at (Bhimnath bridge). Is a good place to spot the crocodiles. I sit here for hours and there are many people that come and go . . ." – Interview, Upadhyay (Appendix A).
Crocodile watching is a common pass time amongst locals and bridges across the river provide these spectators a place. Basking activities of the crocodiles are more or less unaffected by human observers (Kaur,2015).

4) Adapting to crocodile behavior
Locals, specifically ones living in informal settlements, are well aware of crocodile behavior throughout the seasons. This information has been passed down from generation to generation and is useful to the locals in avoiding conflict (Interview, Gavali, Appendix A)

5) Active concern and Rescue
Wildlife enthusiasts also actively engage with the river landscape. Wandering along the banks looking for crocodile nests, burrows to get a closer peek into crocodilian behavior. Some of them work with animal rescue agencies.The Vadodara Society for the Prevention of Cruelty to Animals (VSPCA) is one such outfit responsible for more than 50% of Crocodile rescues carried out in the city (Vyas,2010).

Fig.24
HUMAN ACTIVITIES ALONG THE
RIVER- TRIGGERS FOR CONFLICT



6) Scientific inquiry
Zoologists actively study the reptile with 23 publications on the Muggers of Vishwamitri up till the year 2010 (Vyas,2010).

7) Conflict
While the word conflict implicates conscious antagonism on behalf of the crocodile, in most cases this is not so. Situations are perceived as conflicts, depending on the attitude and tolerance of the people involved (Thekaekara,2017). The interviews and literature review showed that there was a balanced understanding of human-mugger conflict and most reported conflicts occurred due to a lack of awareness of crocodile behavior and mismanagement of overlapping habitat – fishing, crossing, washing clothes or defecating near the river (Fig.24).

Crocodile attacks on humans:
The quote from crocodile rescuer Rakesh Vadhwana (Appendix A) elaborates on reasons for crocodiles attacking humans -
"Attacks on humans have certain peculiarities . . . local slum dwellers, dwelling along the banks of the river are well aware about the movements, territory and behavior of the crocs and have never been attacked. It is the outsiders [migrant minimum wage workers] who go to dangerous spots and make themselves vulnerable to croc attacks . . Crocodiles have never eaten a human being."
There have been 19 reported crocodile attacks on humans in a time span of 15 years (1995-2009) (Vyas,2010). An interview with a former forest ranger, Nilesh Shah (Appendix A) sheds light on incidences of conflicts which have recently reduced to zero in 2017 after a successful, 'save the crocodile/safe from crocodile' awareness drive, focused on citizens living in close proximity to crocodile habitat.

Human attacks on crocodiles:
Crocodiles too have been victims of attacks. Vyas (2010) documents Mugger Killings, and Injuries brought upon by human contact. He also notes that most people call the local fire department or animal rescue centers, however in some cases people are so terrified that they brutally kill the animal and then burn the body to get rid of incriminating evidence, since the Mugger is a Schedule 1 protected species of the Indian Wildlife Act, 1972.

8) Miscellaneous activities
Informal settlers along the riverbanks with no sanitation facilities are forced to use the banks to defecate, wash clothes and bathe. Individuals also use the riverbanks to dump waste of all kinds, brewing of hooch or local alcohol – this is illegal as there is a statewide prohibition on alcohol in Gujarat. Moreover, it is home to 250 crocodiles that add a layer of security for the illegal activities to continue undisturbed as their presence ensures limited use of the riverbanks by the wider public. At the same time it is also a circumstance that can trigger human-crocodile conflict (Interview, Vyas, Appendix A).

Conclusion:
The dumping of meat waste into the river started as a necessity to individually manage urban meat waste - a common practice in many Indian cities with inadequate waste disposal infrastructure, however in Vadodara the presence of the crocodiles has transformed this interaction into a feeding ritual. Rituals involving the worship of the river and the crocodiles are also common practice in the city. Prayer offerings like clay oil lamps and flowers found in the river are evidence of these practices. Many curious residents gather at particular locations in the city to watch basking crocodiles as a part of their daily or weekly routines. Residents living in close proximity to the crocodiles have been there for generations and have developed an understanding of how to safely cohabit with the reptiles. Some local wildlife enthusiasts have specialized in crocodile ethology and rescue operations, it is safe to say that this interest in crocodiles and wildlife is a direct consequence of inhabiting a city with a resident crocodile population. However, inhabiting a city with a large crocodile population also gives rise to conflict with crocodiles attacking humans and vice-versa. Furthermore, interviewed experts suggest that further inquiries into these cases almost always implicate human lack of awareness or malice towards the reptiles.

According to Vyas (Appendix A) " There is a very thin line between tolerance of the urban populace towards the crocodile and an outright negativity or malice. This change in attitude can happen very easily. Overall people do not care ". It is important

for design to encourage wonder and awe amongst curious residents while also addressing the challenge of apathy among a growing population of local and migrant residents.

4.4 Expert prescriptions for future interactions

Below I present one of the results of coding (Code-Expert prescriptions, Appendix B) which helps with an overview of expert opinions for the future of the Vishwamitri and the crocodiles.

While unanimously acknowledging that the current urban river ecosystem is highly influenced by urban processes (hybrid ecosystem) and no longer an untouched natural habitat (historical ecosystem). Some warn of over-protection by way of creating a sanctuary in the city, arguing that this approach has almost always backfired within the socio-political context of the country, while others are for the commodification of human-crocodile interactions by promoting crocodile tourism in the city.

Opinions converge about minimum intervention in crocodile habitat and the conservation of habitat areas currently sustaining the crocodile population. Human intervention should be focused on preventing the dumping of waste, sewage and further encroachments on the floodplains. A Crocodile park in a small ox-bow lake of the river was floated as a solution for managing the crocodile population in the city, however, none of the experts believe this to be a sustainable solution.

With regards to ways forward, some experts believe that there should be no human use of the river and when cut off from anthropogenic influences the river would restore itself. One interviewee (Upadhyay, Appendix A) even suggested making a new river for human use. This expressed his negative opinion about negative human-nature interactions. Others are more optimistic, and think the Vishwamitri is ready and safe for human recreational use, even suggesting that it is the crocodiles that need protection from humans and not the other way around. To conclude, the uniqueness of the human-crocodile interaction in an urban setting is greatly valued. All the experts do believe that the crocodile should continue to co-habit the city, despite differences in opinion on how this can be achieved or to what degree.

Denizenship-Implications for design

5.0

This chapter reestablishes the relevance of Denizenship theory. It delves deeper into the meaning of denizenship, correlating it with the research results. The fundaments of denizenship; 1) secure residency and 2) fair terms of reciprocity are used to evaluate scenarios proposed by the city authorities and local planners. Finally a new scenario is proposed based on denizenship, thus using a political theory to provide direction to the next phase of the thesis – Research through Design (RtD).

For the non-human in Indian cities, the wave of urbanization means a slow death, due to growing pressures from anthropogenic activities or complete eradication through evacuation or displacement. Referring back to the theoretical framework (Chapter 2), Donaldson and Kymlicka, posit a political theory of animal rights that gives a place for animals in the governance of human dominated areas. They suggest different types of participation based on their interaction with humans. To recall, there could be 1) sovereign status for wild animals, 2) denizenship for liminal animals – these are wild animals that inhabit urban areas but are not completely dependent on human interaction and 3) citizenship for domesticated animals. The authors stress that recognizing the "rights of liminal animal denizens does not mean that humans must sit back and let them take over their cities and homes (Donaldson & Kymlicka, 2011.p.250)", instead we should recognize the legitimacy of their presence as part of the urban community and devise ways to co-exist (Donaldson & Kymlicka, 2011).

The indicators of synurbization of the crocodile population point clearly to the fact that the crocodiles can no longer be considered wild. The results of the research for design comply with the assumptions made in Zoopolis about liminal animals that;

a) Tend to avoid humans
b) Would prefer the risk of predation to confinement and other severe restrictions on liberty
c) Have considerable competence for negotiating the risks of their environment, a competence that requires liberty (and risk) to develop.

- Donaldson and Kymlicka,2011,p.242

The rights of a denizen include:

a) Secure residency

A fundamental feature of denizenship is the right of residency and to be treated as belonging to a place (Donaldson and Kymlicka,2011). What then could be the spatial dimension of these rights? It is safe to say that a secure resident denizen is one who has the option of safe habitat (food+ shelter) and the right to procreate. Experts have agreed on the conservation of existing habitat as critical for crocodile survival in the city. Landscape architecture can design to conserve and augment this habitat ensuring a secure residency for the crocodile population.

Additionally, food source is a crucial component of the river system. Design must address both the food and shelter components of habitat by understanding their current dynamics. This can ensure a robust design solution that not only addresses the physical characteristics of habitat but also the dynamics of food between the crocodiles and the city.

Evaluating ways forward: to feed or not to feed?

The research results have established that the crocodiles have ample food due to the dumping of

"fair sharing of risks would have significant implications for urban and suburban development"
-Donaldson and Kymlicka,2011, p.244

organic waste in the river. The question then arises – should we continue to indirectly feed them or not?

First, the feeding of the synurbic crocodiles as a result of unregulated meat waste is a significant interaction, and, if discontinued can have consequences for the area of crocodile habitat required at the city scale. The current hybrid ecosystem will have to somehow expand to provide the food needed to sustain 250 crocodiles.

Second, continuing to feed the crocodiles or withdrawing all food can also have behavioral implications. Discontinuing the feeding would result in a slow shift back to predation and consequently more aggressive behavior, as displayed by rural crocodiles, and expressed by this interviewed expert –" . . . most of the cases of human-crocodile conflict are there [Dhadhar river-which the Vishwamitri empties in to] the crocodiles in Dhadhar river are very aggressive and they actively hunt" – Vishal Thakur (Appendix A). Thus discontinuing a major source of food could result in an increase of human-crocodile conflict. These are both factors that can have a direct influence on urban landscape design.

b) Fair terms of reciprocity- a balancing of risks

The crocodile is a predator, and although " . . . inhabiting a human dominated place has made the crocs like this [shy and scared of human presence] they still possess the qualities of hunters" (Interview, Thakur, Appendix A). Although the crocodiles of Vadodara have modified their behavior in human presence, it is prudent to consider them as predators that could fatally attack humans. Furthermore, the crocodiles too are at risk of human attacks. In order to uphold denizenship of the crocodiles, liberty and autonomy must be balanced against safety of both species (Donaldson and Kymlicka, 2011). Denizenship allows the crocodile community liberty while reducing the responsibility of humans to give the crocodile the same degree of benefits and protection as a domestic pet. The design of the urban river landscape can be done with fairness in how mutual benefits and risks to both species are negotiated.

Scenarios were evaluated based on the fulfillment of the two criteria for denizenship – 1) Secure residency and 2) Fair terms of reciprocity.

5.1 Scenario 1- Crocodile Park

The Municipal authority of the city had proposed to evacuate the crocodiles from the river and contain them in a crocodile park of 0.063 sq.km, an area inadequate for 250 crocodiles (Fig.26). This would mean the conversion of synurbic liminal animals into an animal domesticated and transformed by captivity (Mullan and Marvin,1999). Apart from drastically reducing habitat diversity and area, this scenario also involves the total regulation of their food by humans. Experts also warn of genetic deprecation due to captivity as evidenced by the following excerpt " . . . let me clear the lesser it stays in its natural environment . . . you are inviting genetic decay . . . they have very little chance to spread their genetic material beyond that stock [in captivity] . . . so it is a kind of genetic dead-end . . . so keeping them in a small area of a croc park is actually working against natural selection . . . " - (Interview, Borkar, Appendix A).

On the one hand, there are obvious economic benefits of a pay to enter Crocodile Park and the evacuation of the crocodiles from the rest of the river. A move, that opens up riverside land to unobstructed human use promising even more economic benefits. On the other hand, the losses suffered by the crocodile population by way of habitat reduction, stress of capture and living in captivity, are too much to justify this economic gain. Moreover, the format of a crocodile park alters urban human-crocodile interactions from ones of encounter to commoditized interspecies interactions (Lorimer, 2015) greatly reducing the ontological and aesthetic benefit of spontaneously seeing a crocodile in the city.

Overall this scenario does not mutually benefit both species, with the resident crocodiles having to pay a greater price- their liberty. The captivity of the crocodile is also in direct violation of its Schedule 1 status, Indian Wildlife Act 1972. This scenario is discarded, as it does not uphold the fundamental rights of the liminal denizen crocodiles.

5.2 Scenario 2-Rewild

In response to the proposed crocodile park as part of the VRDP project, local architects, landscape architects and planners are valorizing the ecological restoration of the river environs. Although intuitively an obvious solution, these ecological restoration plans naively see the crocodiles as wild animals with no influence from their urban surroundings. The ecological restoration of the river would not accept the dumping of food waste and would force the rewilding of the now liminal crocodile population.

A rhetorical question posed by Zoologist, Ranjitsinh Devkar during the interview establishes the importance of the feeding interaction - "right now you're throwing garbage in there . . . you're throwing hospital waste . . . you're throwing animal refuse in there, crocs are feeding on that, but tomorrow if you stop that . . . and your plans [for ecosystem revival] are accepted . . . you start the ecosystem revival and nobody is throwing any animal stuff inside, what will they [the crocodiles] feed on?" (Interview, Devkar, Appendix A)

Ceasing to feed the crocodiles overnight, a consequence of restoring the ecosystem to a historic state would require 250 liminal crocodiles to suddenly find other sources of food. The replacement of meat waste by the natural food web, would take decades to reach a state, which supported more birds, wild boars, monkeys, and fish that were food for the Muggers. Each crocodile would also require more space than it presently occupies in order to hunt. Land adjacent to the river would have to be amassed and made available for the crocodiles (Fig.27), an unrealistic and unjustified objective in a burgeoning city like Vadodara, with immense pressure to house the growing urban population. Thus, restoring the ecosystem entails a large investment for the city both spatially and temporally.

A way around this would be to gradually re-wild the synurbic crocodile population by reducing the inflow of food waste over time, allowing for the amassing of land and the efforts of ecological restoration in the highly polluted landscape to take effect. The morphology of City and Nature would

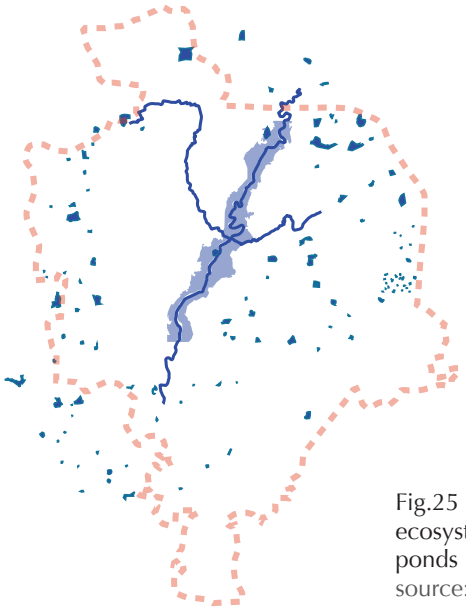


Fig.25 Historic aquatic ecosystem showing ponds
source:authors own

Fig.26 Area (in dark blue) of proposed crocodile park

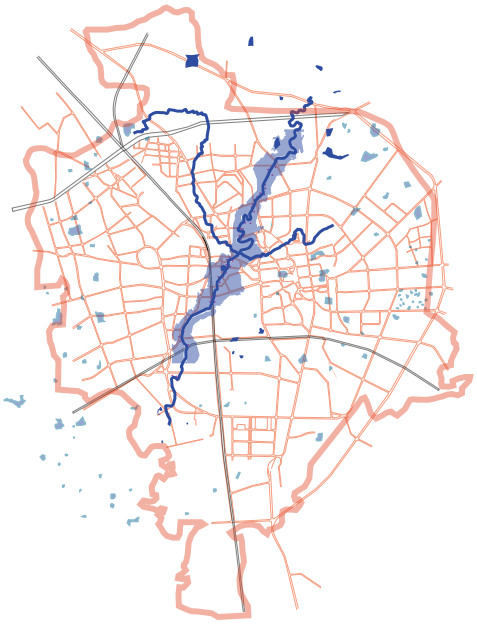


Fig.27 Historic aquatic ecosystem (in light blue) to be rewilded/reconnected to existing crocodile habitat (in dark blue)

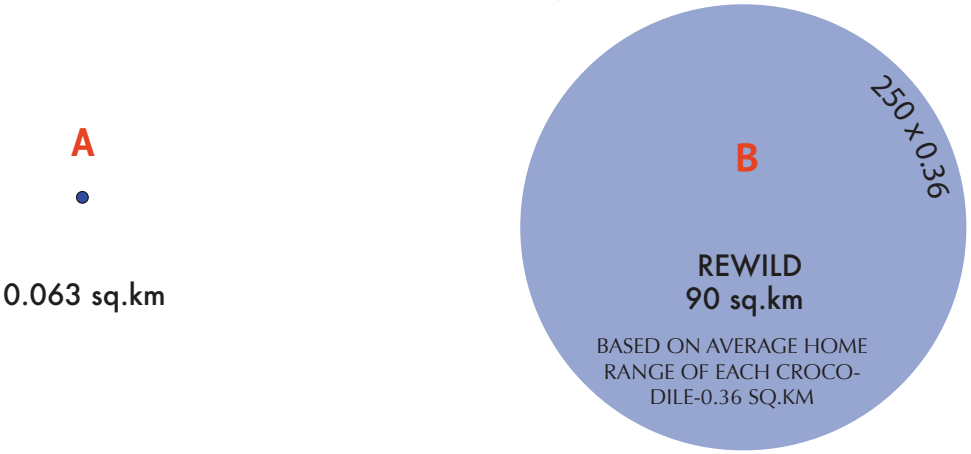


Fig.28 Comparison of area needed for crocodile park and rewilding
source:authors own

then coevolve into a delineated sanctuary for urban wilderness, sharply juxtaposed against the city. The development of a sanctuary in the middle of the city was a contentious topic amongst many experts as they claim that this approach has never worked in the socio-political context of India (See interview with Upadhyay, Appendix A). The strict boundary between human and animal habitat also disregards a longstanding culture of co-existence with the crocodile.

The rewilding of the habitat and the crocodile population in it, does not acknowledge that the ecosystem has evolved and so have the crocodiles, these are no longer wild animals and cannot be expected to automatically flourish if provided with a pristine habitat. This scenario is not convincing, as it overlooks the liminal denizen status of the crocodiles still choosing to see them as wild, and sovereign status for wild animals within city limits is unfeasible.

Both the scenarios considered so far fail to acknowledge the liminal, synurbic nature of the crocodile population and doing so could provide solutions for yet another alternative. I propose the development of a novel ecosystem, and as mentioned in Chapter 2, the novel ecosystem is conceived as the next stage of the present hybrid ecosystem. This stage can be achieved by designed transformation - strategic landscape design interventions that secure residency for the crocodile with mutual benefits for both species.

5.3 Scenario 3- Zoomorphic urbanization- Novel ecosystem:

I define zoomorphic urbanism as a form of urbanization that emerges by the designed inclusion of its resident animal life both spatially and politically.

A good starting point in order to formulate the novel ecosystem scenario is provided by Dr. Deepa Gavali " . . . the waste is being disposed off [by the crocodiles] otherwise they will have to dispose their waste to the municipality through the process of solid waste management. But here it is direct, after he closes the shop he will feed the crocodiles on his way and go away. This is also a mechanism of recycling the waste. Rather it going to the landfill, it can be food for the crocodiles." – (Appendix A)

This scenario considers that the synurbic crocodile population is neither truly wild nor fully domesticated. Scavenging for meat waste dumped on the riverbanks is a passive engagement with the urban dynamic, however the act of feeding transcends this passivity into a ritual that connects the urban and the animal in a more intimate bond. Currently the feeding is unregulated which has a direct impact on both crocodile population and health, evidenced by overweight crocodiles. It is possible to experiment with and regulate this to give the city some leverage in managing the growing population of crocodiles as well as recycling meat waste.

Landscape interventions can help mitigate the recurring conflict during the monsoon season and ensure safe coexistence without the need to drastically reduce or increase habitat for either. Sensitive zones, like nesting areas for crocodiles (Appendix B) can be protected from further despoliation and sensible urbanization can continue at suitable locations, all while working with the available land (Appendix B). The interventions can also allow for safe, spontaneous encounters with the crocodile as a benefit of city life. Safety in this case, relies on the willingness, awareness and adaptive capacities of both species to avoid risk.

I argue that it is of great relevance to recognize the liminal denizen status of Vadodara's synurbic crocodile population in order to formulate the novel ecosystem using landscape design strategies that enable further co-existence. The following chapter will elaborate on how the novel ecosystem can be achieved through the creation of design guidelines rooted in the terms of denizenship.

	CROCODILE PARK	REWILD	NOVEL ECOSYSTEM
SECURE RESIDENCY			
DIVERSE HABITAT	1. Greatly reduced habitat unhealthy popualtion density	1. -Habitat would expand enormously to accommodate 250 rewilded crocodiles. -Habitat would be restored to pristine quality and exclusively for the crocodiles. while habitat diversity will increase within the restored/recreated nature the interactions with the urban will be nil or limited.	1. -Work with available land -Prevent further despoilation of the urban river system
FOOD SOURCE	2. Diet in full control of humans	2. Food source is insufficient if food waste is abrubtly cut off. It would take time for the crocodiles to adapt to new food dynamics of the rewilded landscape	2. -Recognise the importance of food waste to the synurbic crocodiles diet -Integrate through the regulateddumping of food waste at chosen locations along the river
RIGHT TO PROCREATE	3. Captivity has consequences for the genetic pool, which will diminsh and this is regressive from an evolutonary point of view	3. Healthy procreation possible	3. Healthy procreation possible
FAIR TERMS OF RECIPROCITY			
TYPE OF INTERACTION	1. Transformation of a liminal animal into a domesticated one	1. Reconversion of liminal animals to wild ones	1. Recognise liminality of crocodiles and harness synurbic potential
BENEFIT/LOSS TO EITHER SPECIES	2. -Economic benefit due to the commoditization of human-animal interactions -River is without crocodiles and accessible for human use -Ontological and aesthetic benefit of spontaneously seeing a crocodile in the city is denied. -Crocodiles suffer great loss of habitat, stress of capture and living in captivity.	2. -Physical benefits to the environment of the city-dense green corridor. However not accessible to humans -Large areas of urban land diverted to sustain a rewilded crocodile population. This is a heavy price to pay for a developing country with immense pressures to house growing urban popualtions. -Sharp distinction of habitat into wilderness/urban disregards longstanding culture of coexistence between humans and crocodiles	2. -No need for evacuation of either species -Enhance the existing positive human-crocodile interactions, while minimising negative ones through strategic landscape design interventions that mutually benefit both species -Allow for spontaneous, safe encounters with the crocodile as a benefit of city life -Depend on awareness and adaptive tendencies of both species to avoid risk of conflict
RECIPROCAL INTERACTION?	3. Overall this scenario does not mutually benefit both species, with the resident crocodiles paying a greater price -their freedom	3. Overall rewilding is not a feasible option as it requires the human population to uproot itself and exacerbates social inequality of urban land use	3. Overall the creation of a novel ecosystem promotes a fair sharing of habitat and the risks involved. It is the only scenario that recognises the liminal crocodiles and hence in the position to spatialise denizenship status.

Table 1. Comparative evaluation of three scenarios
source:authors own

Towards Zoomorphic urban design guidelines

6.0

Zoomorphic urbanization can emerge from the designed inclusion of a cities' resident animal life through space and policy. The next step is to formulate zoomorphic design guidelines as spatial tools in order to produce the corresponding novel ecosystems. The translation of research results into design guidelines is key to reinforcing the link between research and design (Prominski, 2017). The resulting design guidelines are not generic but specific to certain conditions and have been formulated based on results from the interview data and a reading of the landscape. Designing for specific sites, presented in Chapter 7, spatially tested the design guidelines.

6.1 Design Objectives and Principles

The overarching design value is to promote positive human-crocodile interactions. Deriving from this value is the goal to devise landscape guidelines and specific interventions for positive urban human-crocodile interactions. The design objectives help meet this goal and include the following:

A. Design novel seasonal habitat for crocodiles and humans to reduce human crocodile conflict

B. Prevent further degradation and despoliation of existing crocodile habitat.

These values, goals and objectives helped to formulate the two main design principles:

1. Seasonal program to allow human and crocodile use of the novel urban landscape
The seasonal programming of shared habitat ensures the safe use of the urban habitat by both crocodiles and humans with minimum risk to both species. The seasons that distinctly affect crocodilian habitat include monsoon, summer and winter. Out of these, the monsoons have the most impact on the quality and quantity of available habitat to both species. By seasonally programming the shared urban habitat the city can avoid the use of segregation through barriers as the main way of dealing with shared habitat. The sharing of seasonal sharing of the landscape integrates with the objectives of reciprocity and balancing of risks than the violent division of space to exclude either humans or crocodiles.

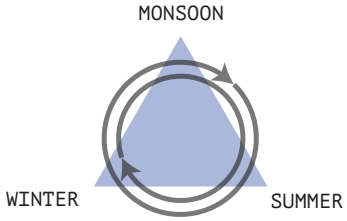
2. Integrate ecosystem services provided by/for the synurbic crocodiles with the outputs of urban metabolic cycles.

The urban system reflects the biological functions of the crocodiles, displaying a metabolism of its own. And, like any organism with metabolic functions, the city also consumes food and water, producing waste in the process. Unlike the crocodile, which shares reciprocity with the river ecosystem, the city contaminates it. The crocodiles are keeping the river cleaner than it would be without them. Can the city amplify this effect by taking the following steps?

Food - The food cycle includes the production and consumption of foods and more importantly the disposal of food unfit for human consumption. The research results indicate the regular dumping of offal or meat waste generated by local meat shops, directly into the Vishwamitri river system. This mode of habitat despoliation inadvertently becomes a complimentary food source for the crocodiles and designing for this interaction can integrate a major urban metabolic cycle.

Water – The city is dealing with high levels of contamination in the Vishwamitri River due to the diversion of untreated sewage (78MLD/day) and

GOAL	Denizenship status for synurbic crocodile population	
	A.secure residency	B.fair terms of reciprocity balancing of risks
OBJECTIVES	1. Regulate food to maintain population and habitat size	3. Harness ecosystem services provided by/for the synurbic crocodile population
	2. Minimize (seasonal) human-crocodile conflict	4. Provide Crocodile care and rescue services
DESIGN VALUE	human-crocodile reciprocities	
DESIGN GOAL	DEVISE Landscape interventions/guidelines for positive urban human-crocodile reciprocity	
DESIGN OBJECTIVES	A. Design novel seasonal habitats for crocodiles to reduce human crocodile conflict	B. Prevent further degradation & despoilation of existing crocodile habitat
DESIGN PRINCIPLES	1. SEASONAL PROGRAM TO ALLOW HUMAN & CROCODILE USE OF NOVEL LANDSCAPE	2. INTEGRATE ECOSYSTEM SERVICES PROVIDED BY/FOR SYNURBIC CROCODILES WITH OUTPUTS OF URBAN METABOLIC CYCLES



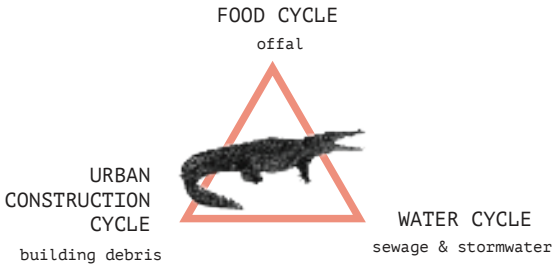


Table 2. From goals to principles
source:authors own

storm water into the river. The crocodiles, apart from having to live in these polluted waters, face a serious loss of pond habitat in the city. It is possible to combine these two concerns.

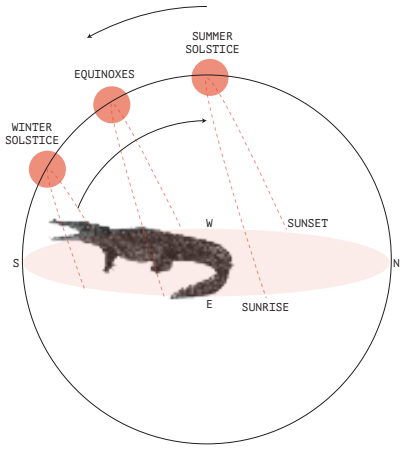
Urban construction- the construction industry in the city is rapidly growing. In order to construct anew existing infrastructure is destroyed, generating a huge amount of building debris. The debris then finds its way to ravines and low-lying areas along the river. The dumping of debris is also used as a strategy to reclaim riparian land. Instead of contributing to habitat degradation it could be possible to use this debris to construct the novel landscape.

6.2 Design concept

This thesis attempts to augment existing habitat with seasonal refuge in the riparian zone and floodplains, deliberately choosing not to intervene directly in the riverine zone; which the crocodiles expertly modify to suit their needs. The design concept for the novel urban ecosystem includes the strategic placement of four types of landscape design elements (Fig.29) that give formal value to the design principles. These are described below:

1. Feeding sites

The design of feeding sites embraces this dynamic and allows for it to continue in a regulated, safe and hygienic manner. These sites can be cleaned regularly and can contribute to the aesthetic value of the urban realm by reestablishing our material and spiritual (karmic) connection with the animal



ECTOTHERMICALLY
REGULATED METABOLISM

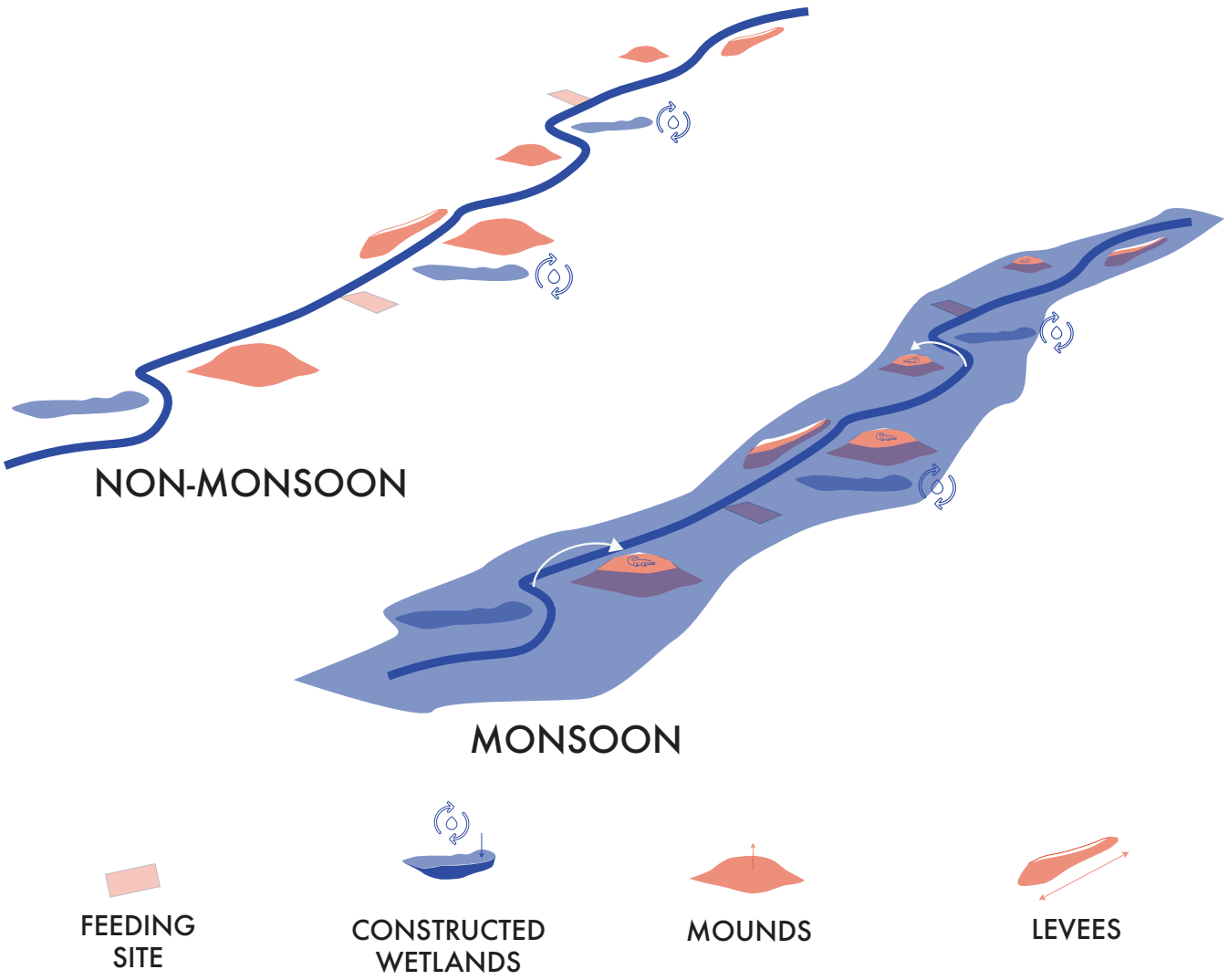


Fig.29 Design concept showing seasonal functioning of mounds and levees
source:authors own

world. The mutual benefit includes:
- A low cost meat waste disposal system for local vendors
- Reliable food source for the crocodiles

2. Constructed wetlands

The Vishwamitri river itself is just one part of the aquatic habitat of the crocodiles, their use of different types of water bodies implore us to see the river, ponds and lakes as an integrated system, an idea already gaining leverage (Sayer,2014). With the expansion of the urban infrastructure network, it is dangerous for crocodiles to access alternative habitat now surrounded by roads and buildings. Strategically placed constructed wetlands adjacent to the river can combine the aquatic habitat needs of both crocodiles and humans.
The wetlands can function as:
- A secondary pond network in close proximity to the river and safely accessible to the crocodiles for seasonal refuge. The proximity to the river is relevant as this means clear access routes for the crocodiles, unfragmented by roads and human settlements. During the rest of the year the constructed wetlands can also provide shelter for juvenile and sub-adult crocodiles pushed out of the main branch of the river due to territorial struggles with adult crocodiles.
-As part of a decentralized wastewater system to filter untreated sewage (78MLD) currently being dumped in the river. Constructed wetlands have great potential to manage wastewater in developing countries due to their decentralized functioning, low costs and ease of operation and maintenance (Kivaisi,2001). With advances in constructed wetland technologies it is now possible to optimize the space demands making them compact and thus viable for dense urban areas as well (Dou et al.,2017).
- As additional buffer areas that will expand to retain and store water in the rainy monsoon season.
-Human recreational use

3. Mounds

As mentioned earlier in this report, conflict between crocodiles and humans peaks in the monsoon season. This is mainly because the crocodiles are pushed further inland into human settlements by floodwaters. The crocodilian prefers still and stagnant aquatic habitat and the river in spate does not offer this. In addition, they require dry land to bask and flooded river banks minimize the opportunities for basking, these reasons in combination with the force of floodwaters compels the crocodiles to seek refuge in distant ponds at great risk to themselves and to the human population of the city. The placement of a series of high mounds along the river intends to:
- Secure safe dry spots that the crocodiles can access during the monsoons in order to bask
- Create viewing points accessible for human recreational use during the non-monsoon

4. Levees

The levees are elements that serve the following purposes:
- Protect low-lying human settlements from floods
- Prevent the transport of crocodiles into these settlements
- Provide safe multi-level basking platforms for crocodiles in both monsoon and non-monsoon seasons
- Human recreational use

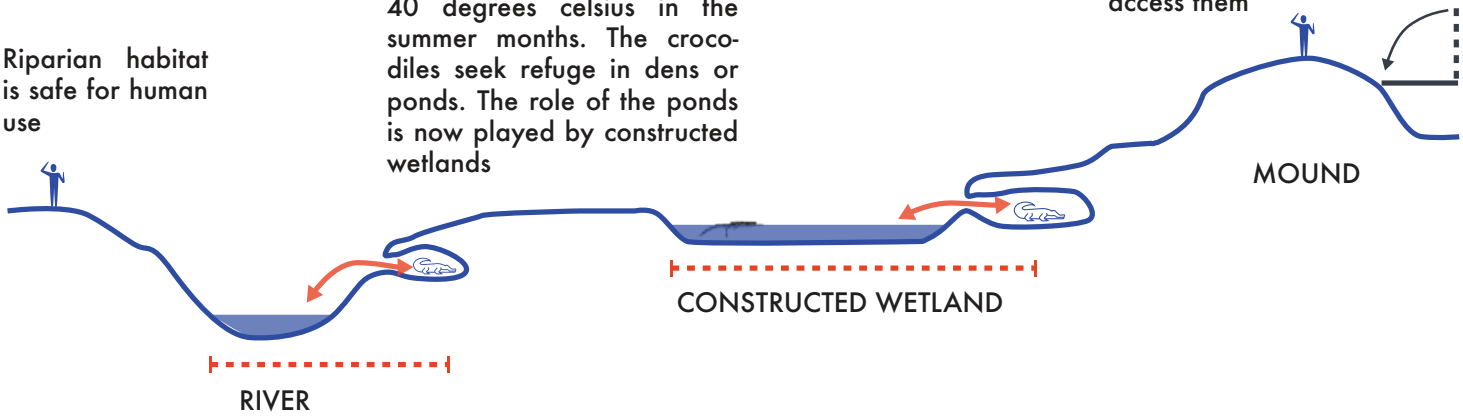
In conclusion, the ecosystem services provided by and for the synurbic crocodile population can be aligned with landscape designs and development plans for the city.

SUMMER (March-June)

Riparian habitat is safe for human use

With temperatures reaching 40 degrees celsius in the summer months. The crocodiles seek refuge in dens or ponds. The role of the ponds is now played by constructed wetlands

Top of mounds are now safe for human use with the crocodiles being unable to access them

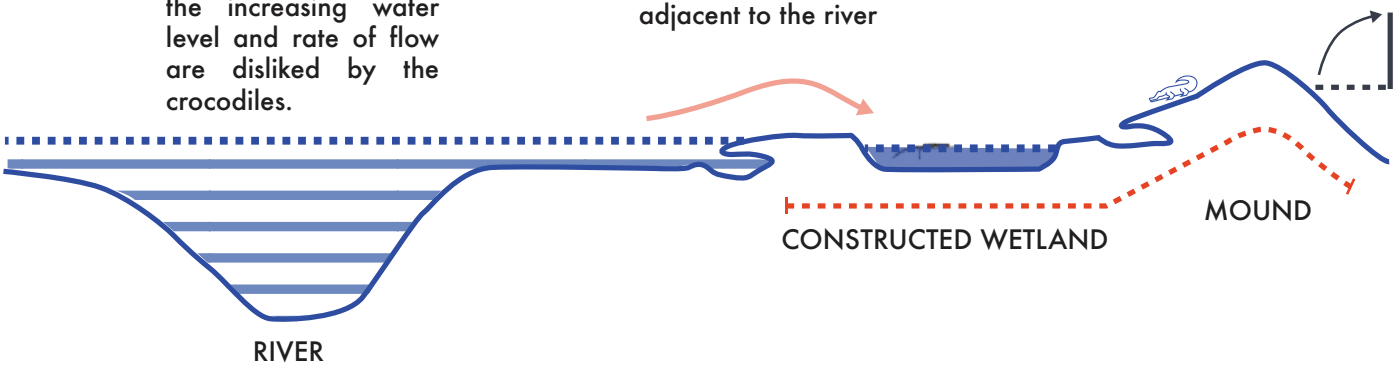


MONSOON (July-October)

Come the monsoons, the increasing water level and rate of flow are disliked by the crocodiles.

They usually move to ponds in the city. These are substituted by constructed wetlands adjacent to the river

Top of mounds are now used as refuge by the crocodiles. Access to humans is closed.



WINTER (November-February)

Winter is mating season and the crocodiles are most aggressive. Humans should avoid river and riparian zones

The constructed wetlands could also be dangerous for humans, however this will have to be determined after the design strategy is implemented

Top of mounds are now safe for human use with the crocodiles being unable to access them

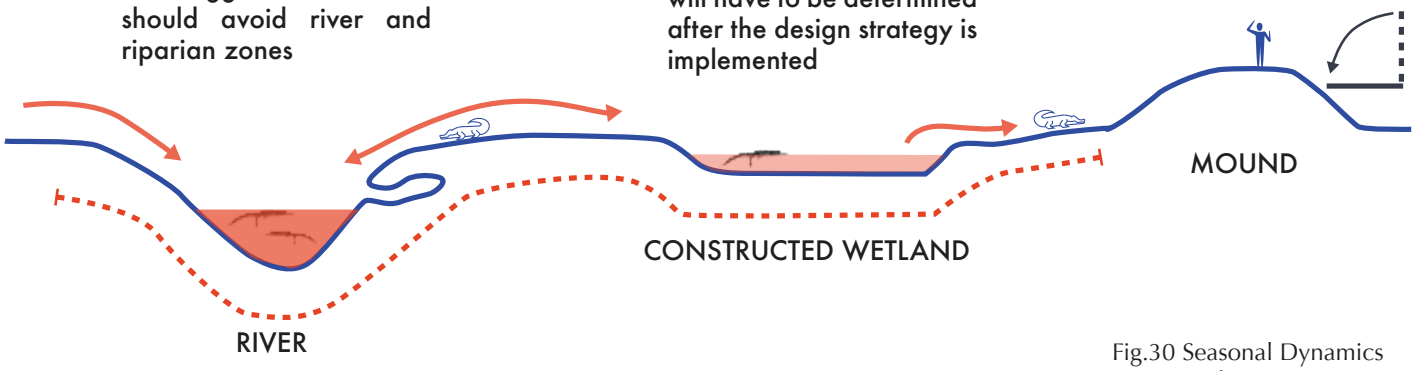


Fig.30 Seasonal Dynamics
source:authors own

MONSOON DYNAMICS

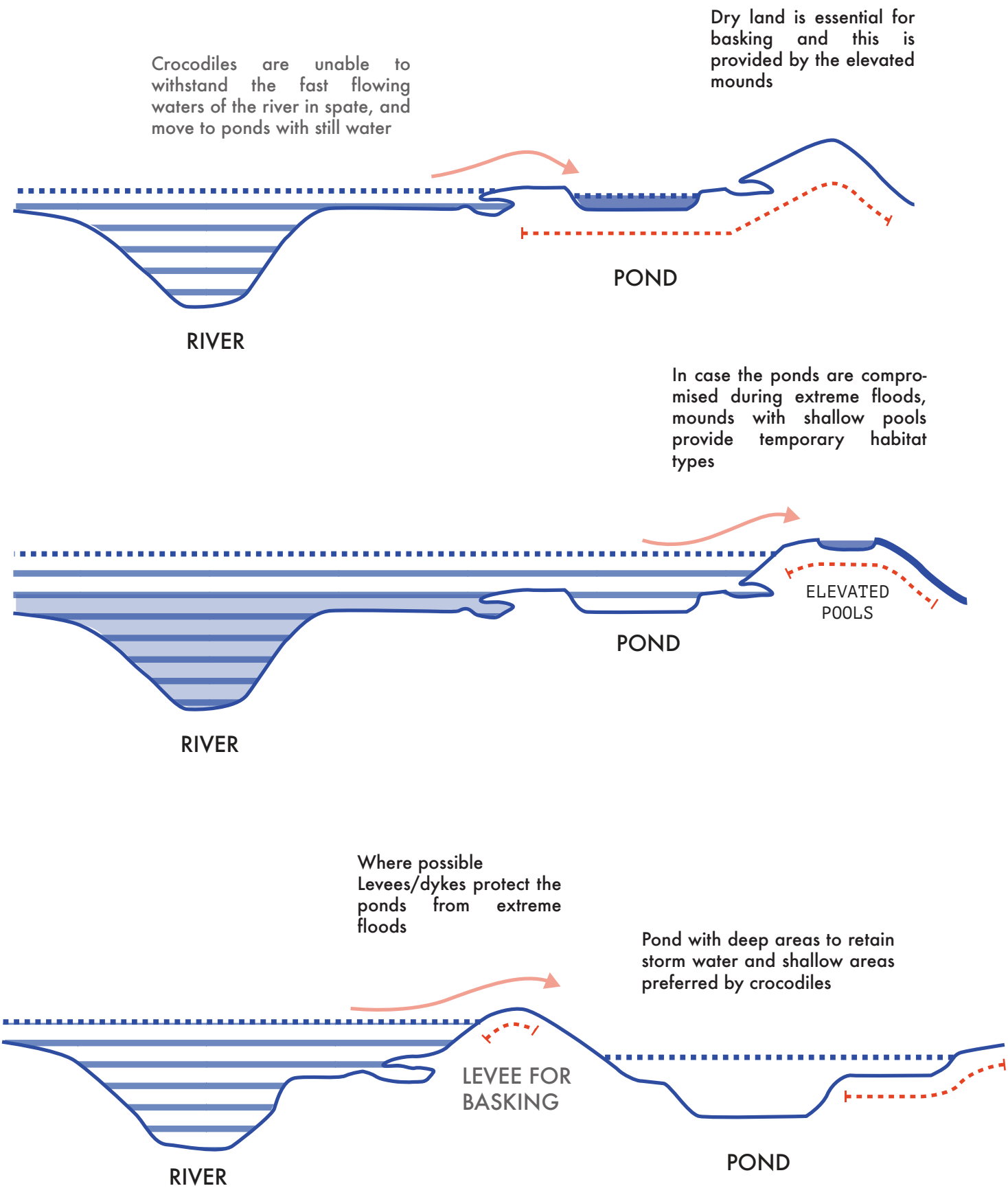
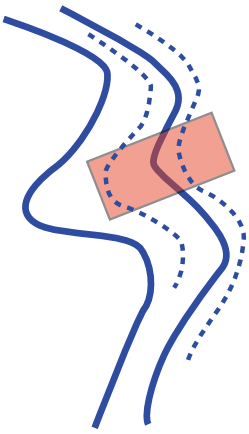


Fig.31
source:authors own

6.3 Zoomorphic design guidelines

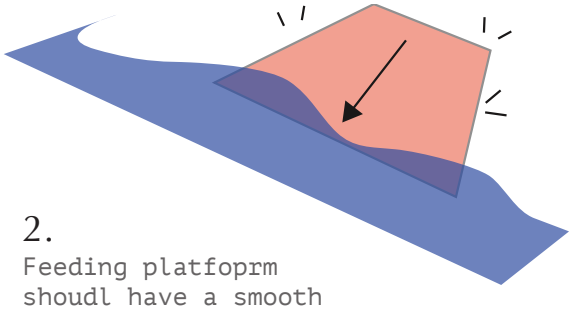
I then developed appropriate design guidelines for the practical realization of each of the four landscape interventions. These are illustrated in the following diagrams:

Fig.32 DESIGN GUIDELINES - FEEDING SITES



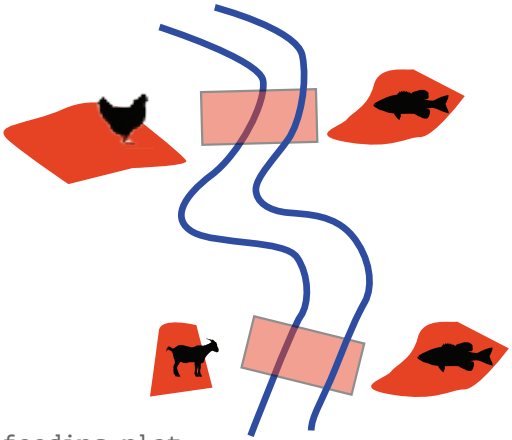
1.

Crocodiles feed on the edge of the water, design should accommodate the seasonally varying edge of water and land



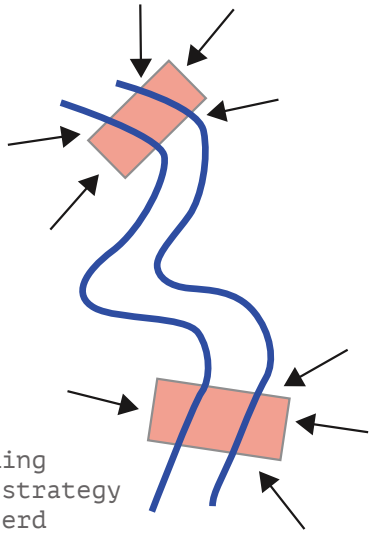
2.

Feeding platfoprm shoudl have a smooth and sloped surface for ease of cleaning



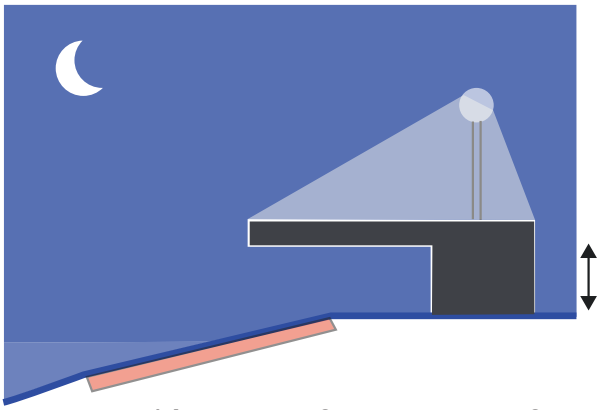
3.

Connect feeding platforms to meat/fish vending districts

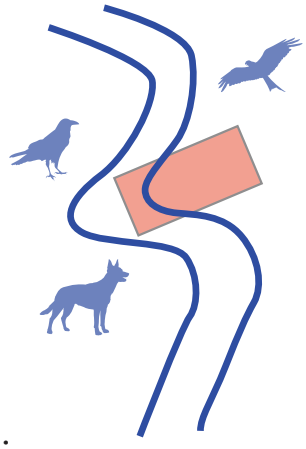


4.

Distribute feeding platforms as a strategy to attract or herd crocodiles to desirable locations along the river



5. Adequate safety measures for person in charge of feeding through elevated platforms, since crocodiles feed at night lighting should be adequate for human safety yet not interfere with crocodilian behaviour

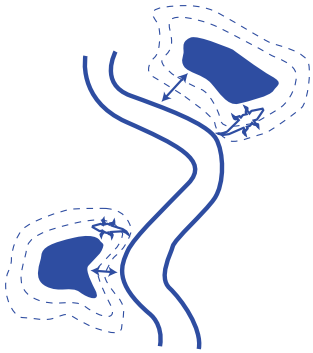


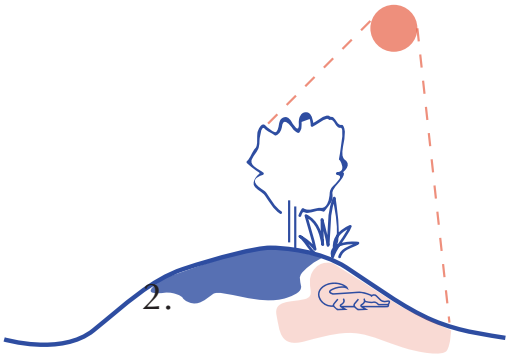
6. Feeding platforms can also accommodate other liminal species

Fig.33 DESIGN GUIDELINES -CONSTRUCTED WETLANDS

1.

Place ponds in low lying areas in close proximity to the river ensuring Accessibility to Crocodiles



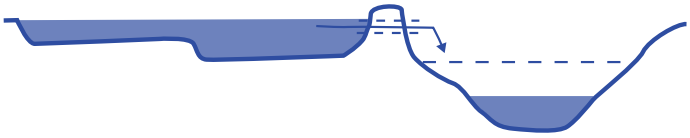


2.

Modulate sun & shade through planting pattern of vegeta-tion, ensuring range of opportunities for thermoregulation

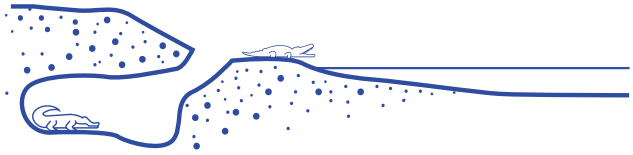
3.

Ponds with shallow edge areas (max. 1metre) for croco-diles and deeper areas to retain excess discharge during the monsoon



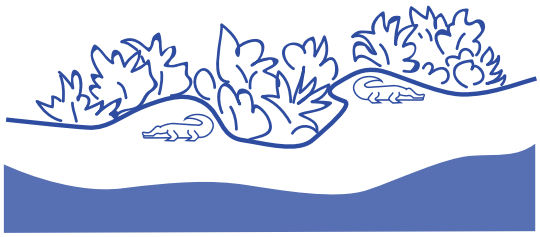
4.

Treated water outlet should empty into the river and should be placed higher than the known high flood level



5.

Soft, sandy bank edges to allow for basking and burrowing



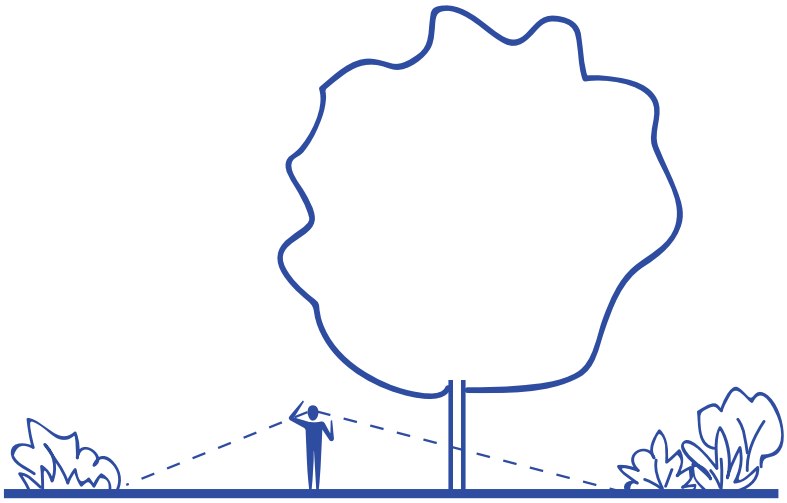
6.

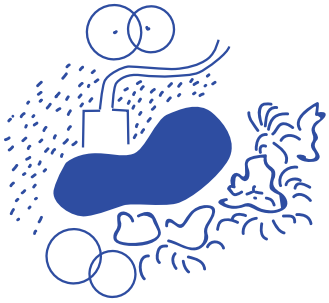
Densely plant ground cover, alternating with open spaces, this creates visual & physical barriers that reduces aggression between crocs

7.

Fine, ornate plants for juvenile crocodiles

Palms, woody plants, tall sturdy grasses for adult crocodiles

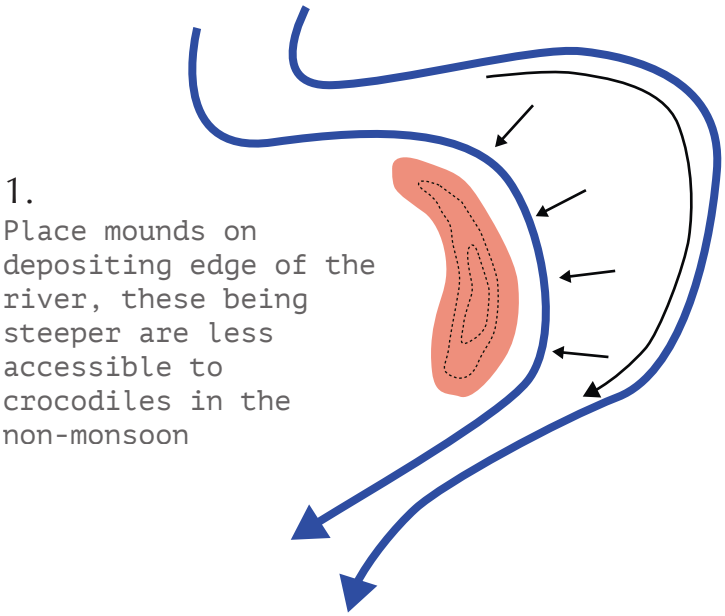




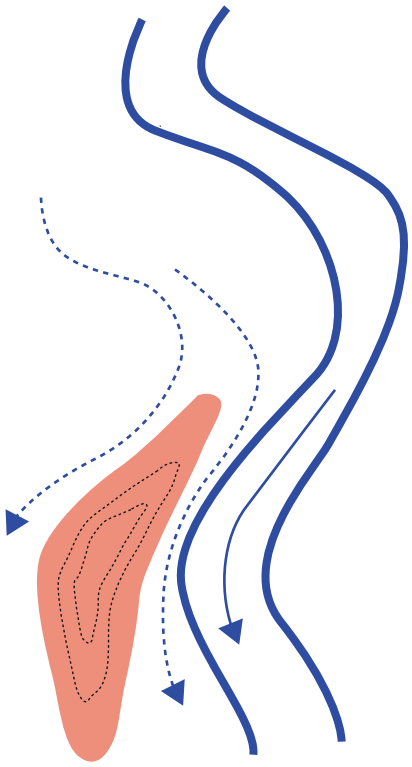
8.

Only tall trees, no or low ground cover in zones visited by humans
-ensures the ability to spot a crocodile
-this clear unobstructed visual range must be enough to allow time to retreat in case a crocoidle is spotted

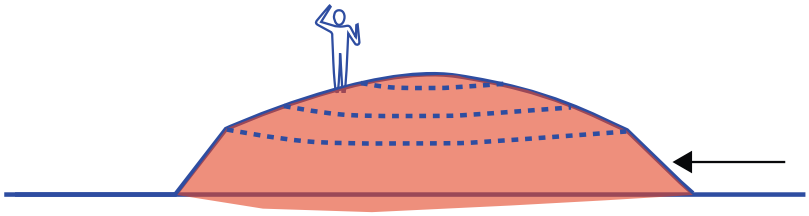
Fig. 34 DESIGN GUIDELINES -CONSTRUCTED MOUNDS



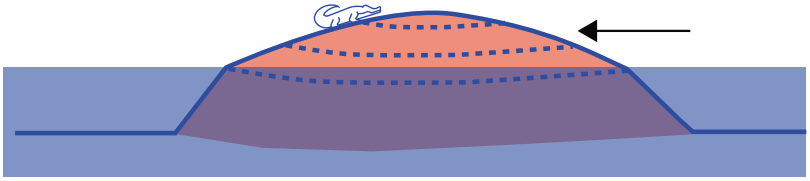
1.
Place mounds on depositing edge of the river, these being steeper are less accessible to crocodiles in the non-monsoon



2.
Hydrodynamically shape mounds so as not to obstruct flow of river in spate

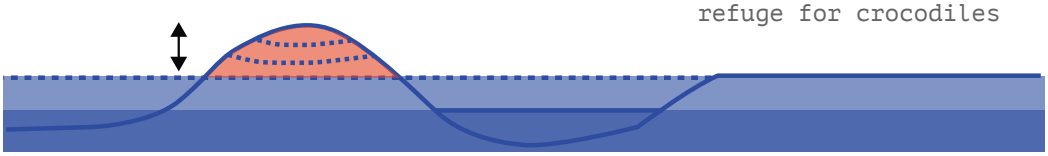


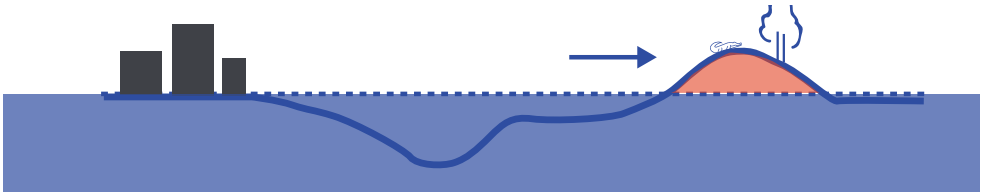
3.
Mounds should have a double slope. The bottom half should be prohibitively steep for crocodiles in the non-monsoon.



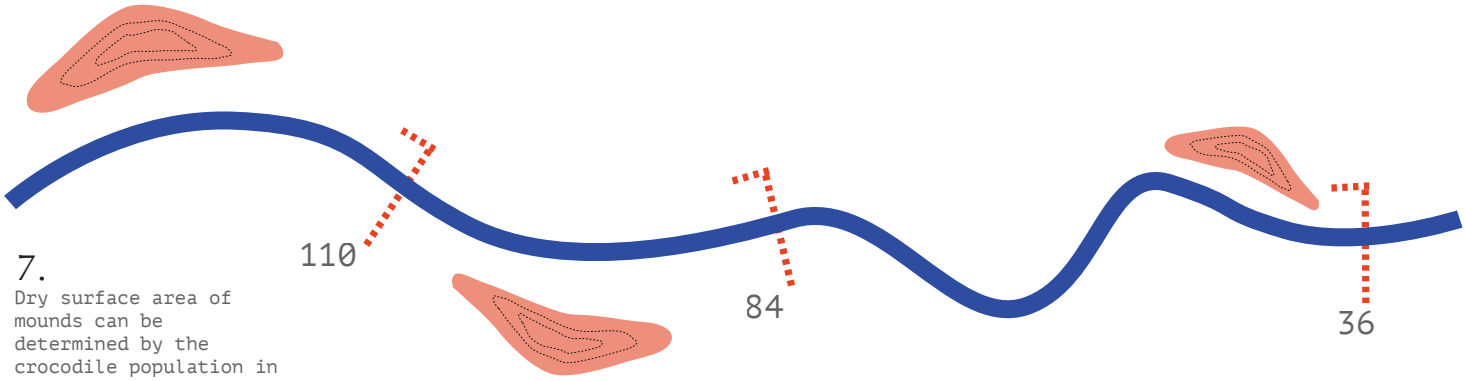
4.
uring floods the dry top half should have a gentle slope making it accesible to crocodiles.

5.
Mounds should be higher than the known high flood level to provide refuge for crocodiles

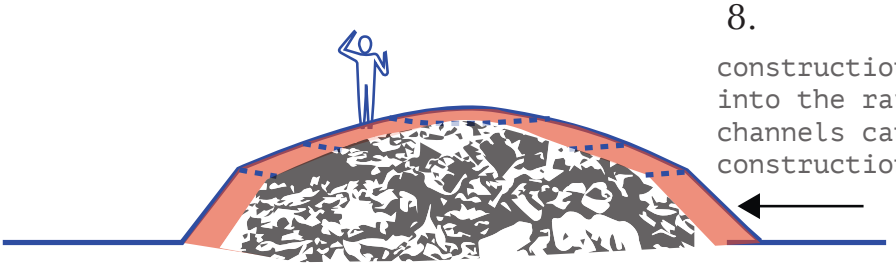




6.
place mounds strategically to draw crocodiles away from human Settlements

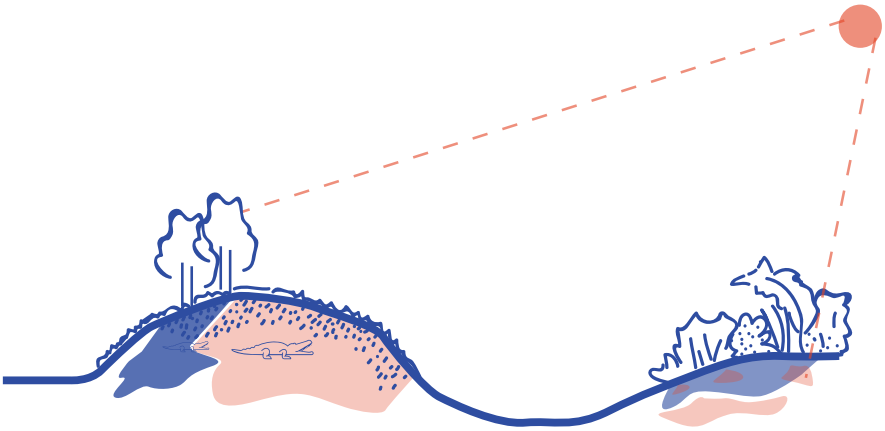


7.
Dry surface area of mounds can be determined by the crocodile population in the river segment



8.

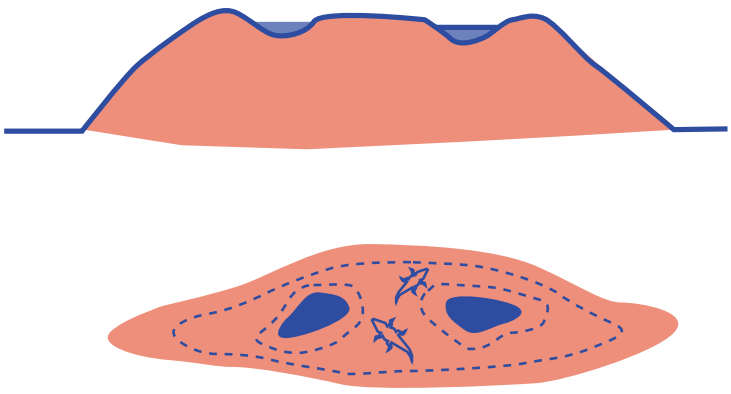
construction debris that gets dumped into the ravines and small tributary channels can be diverted for mound construction



9.

mounds should have vegetation to provide both sun & shade for crocodiles

vegetation should comprise of lowgroundcover and clusters of 2-3 sturdy shade giving trees



10.

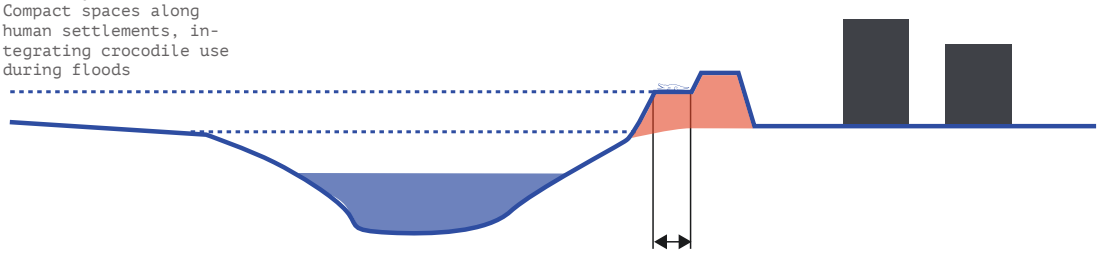
some mounds can have seasonal rainwater fed pools at the top to provide habitat diversity incase of extreme floods that make it difficult for the crocodiles to leave the mound

Fig. 35 DESIGN GUIDELINES - DYKES

Dykes along human Settlements
-protection from flood
-prevention of crocodiles
-temporary refuge for stranded crocodiles during floods

1.

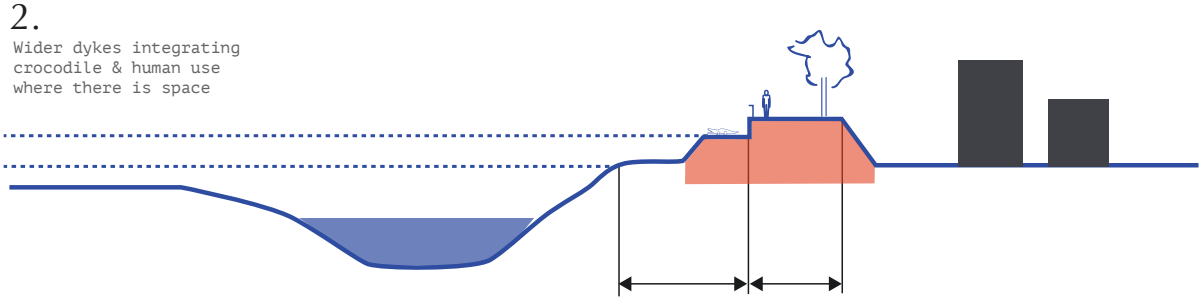
Narrow dykes for Compact spaces along human settlements, integrating crocodile use during floods



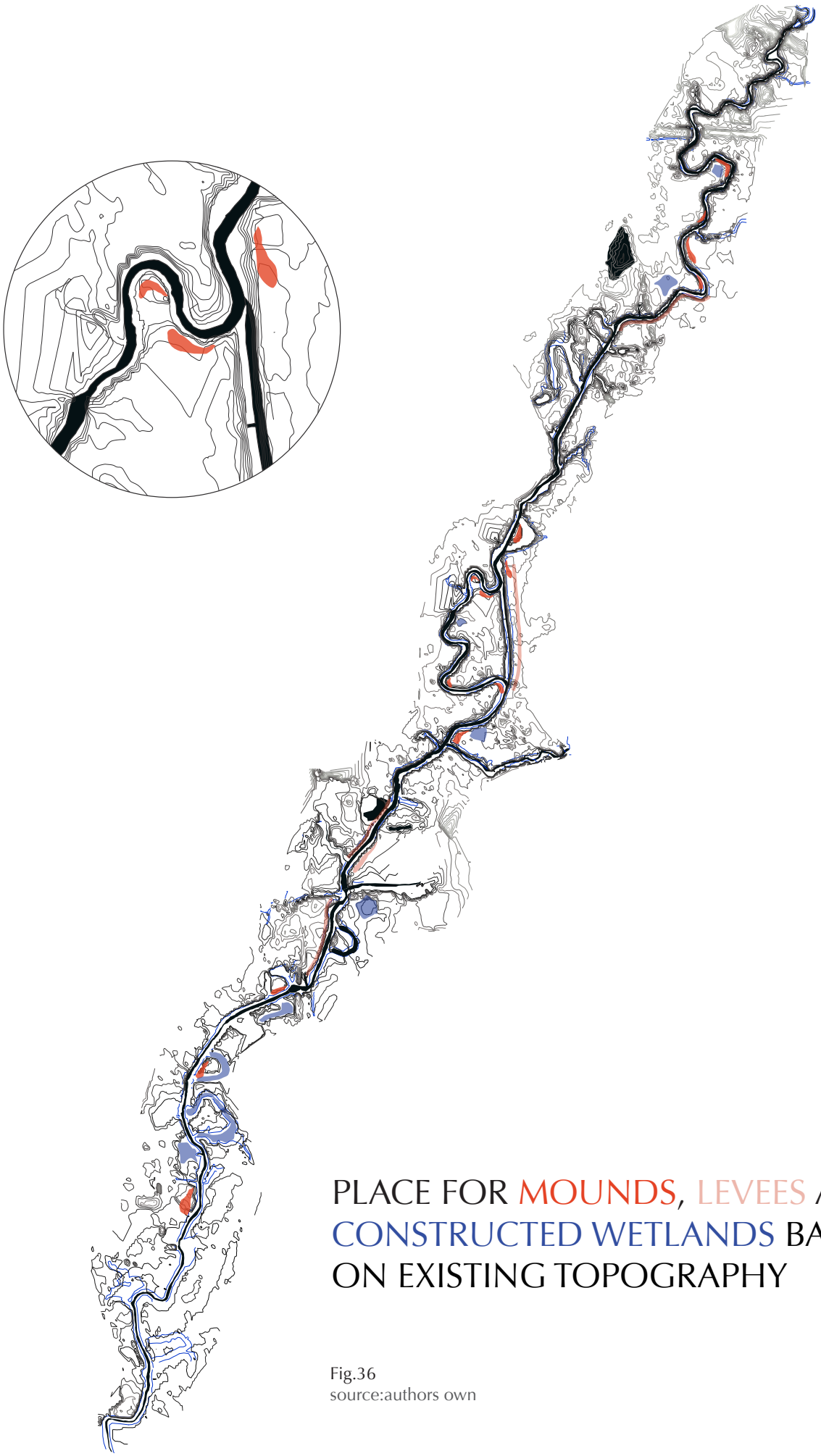
BASKING PLATFORM INTEGRATED WITH DYKE

2.

Wider dykes integrating crocodile & human use where there is space



MULTILEVEL TERRACE



PLACE FOR MOUNDS, LEVEES AND CONSTRUCTED WETLANDS BASED ON EXISTING TOPOGRAPHY

Fig.36
source:authors own

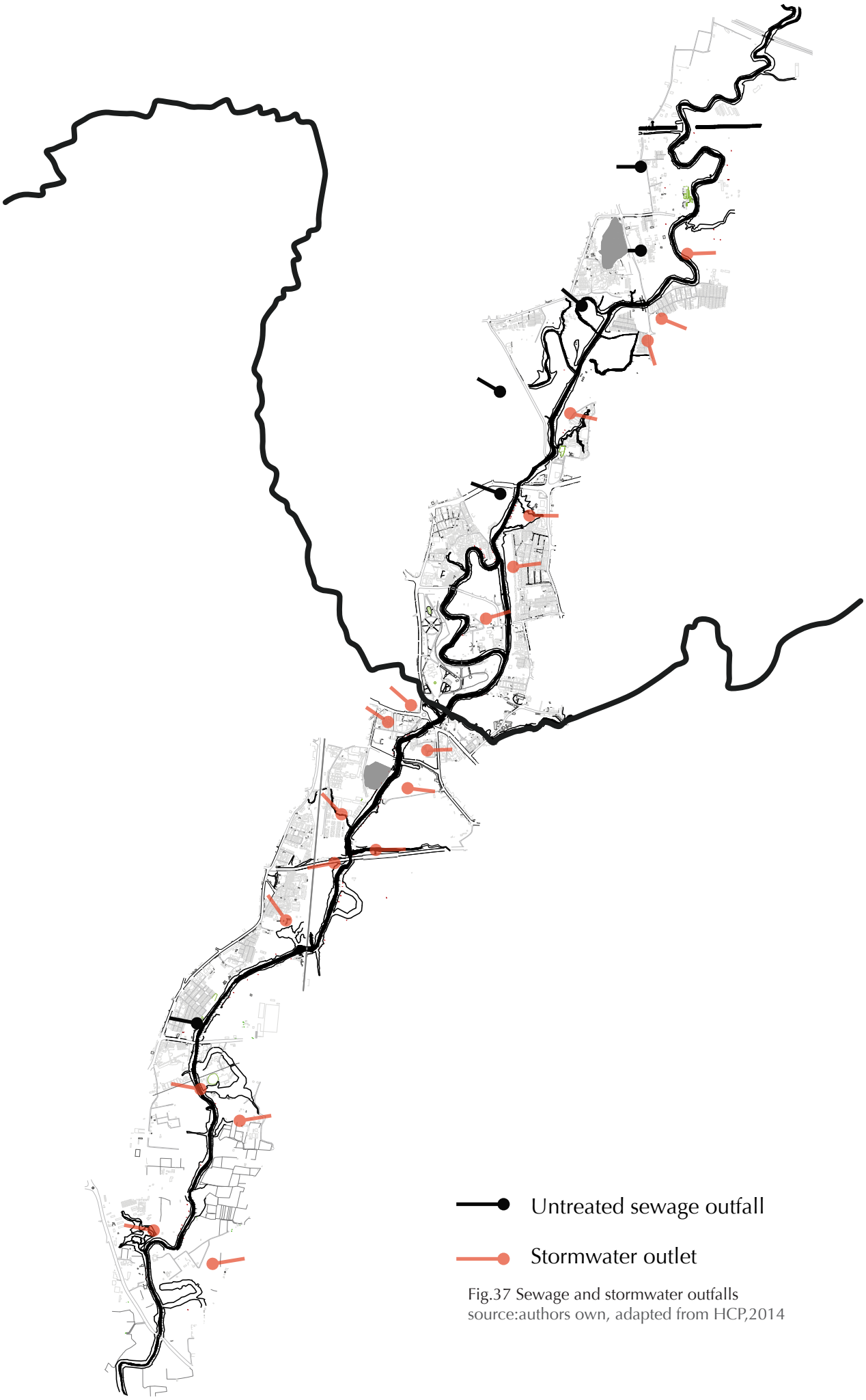


Fig.37 Sewage and stormwater outfalls
source:authors own, adapted from HCP,2014

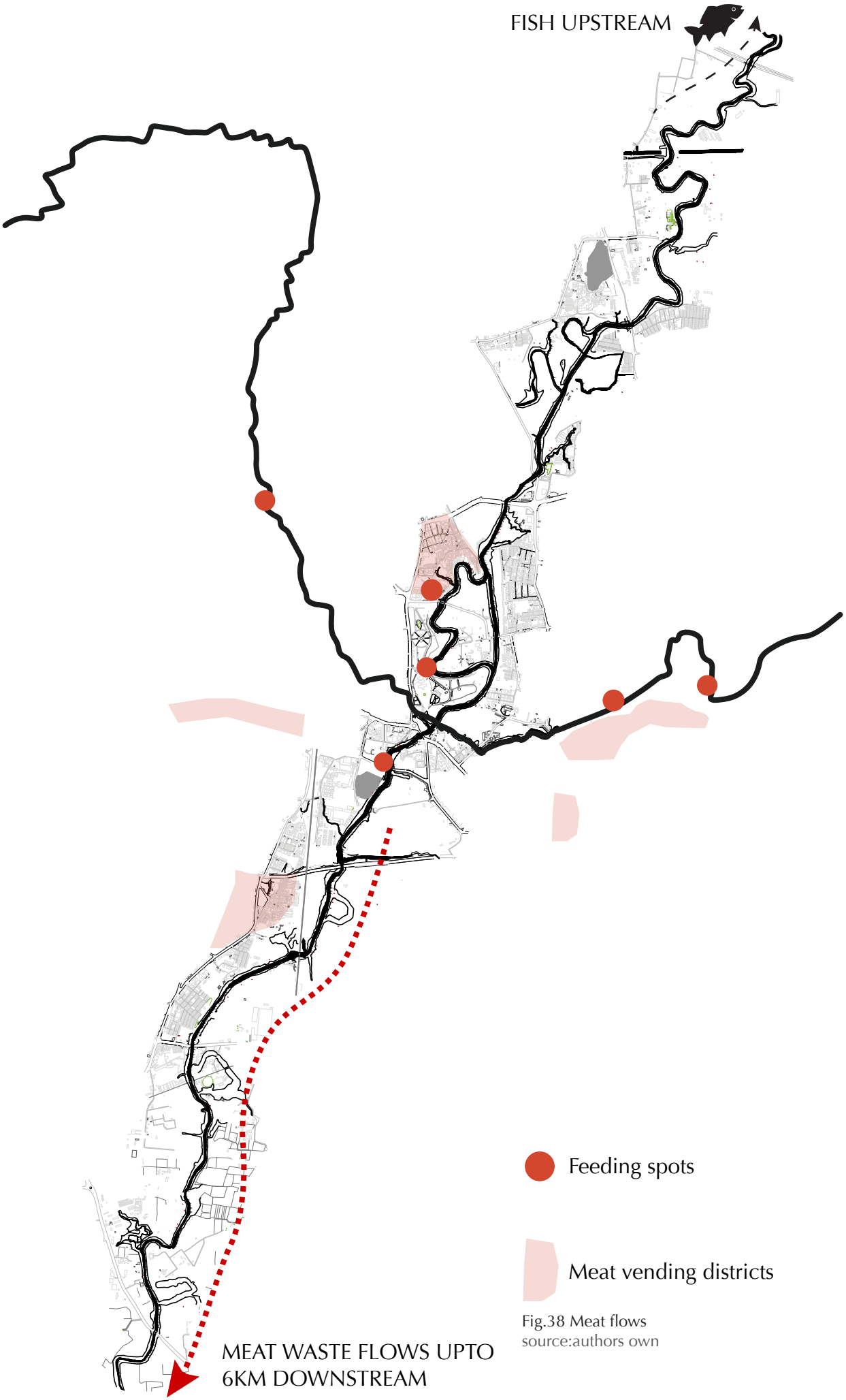


Fig.38 Meat flows
source:authors own

Zoomorphic Design for a synurbic crocodile population

7.0

This chapter will first introduce the selection criteria for the sites on which the design guidelines are applied and spatally tested. The next section describes each site with a brief analysis first and then the corresponding landscape design. Below is a scheme showing the steps prior to design.

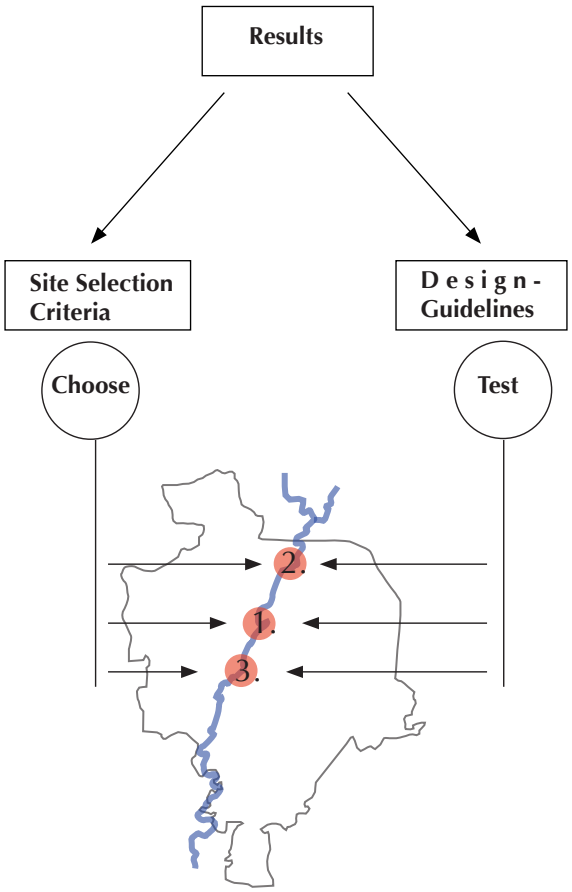


Fig.39 Steps between results to site design
source:authors own

7.1 Site selection for the spatial testing of design guidelines

The test sites are selected based on the results of the research for design. First, a mounting concern, shared by all the experts, is the threat to existing good quality crocodile habitat and the need to preserve it in order to sustain the crocodile population. Second, the most prominent instance of human-crocodile conflict is during the monsoon, it is thus prudent to test the design guidelines on affected sites. Finally, it is crucial to generate awareness amongst residents about the crocodiles in the city and this can be done by allowing for safe, spontaneous human crocodile interaction as part of city life.

In summary the three sites were selected based on the opportunities they presented to address the following concerns:

1. Facilitate conservation of preferred crocodile habitat and urbanization
2. Seasonal conflict resolution through landscape design
3. Promote positive interactions through urban landscape encounters

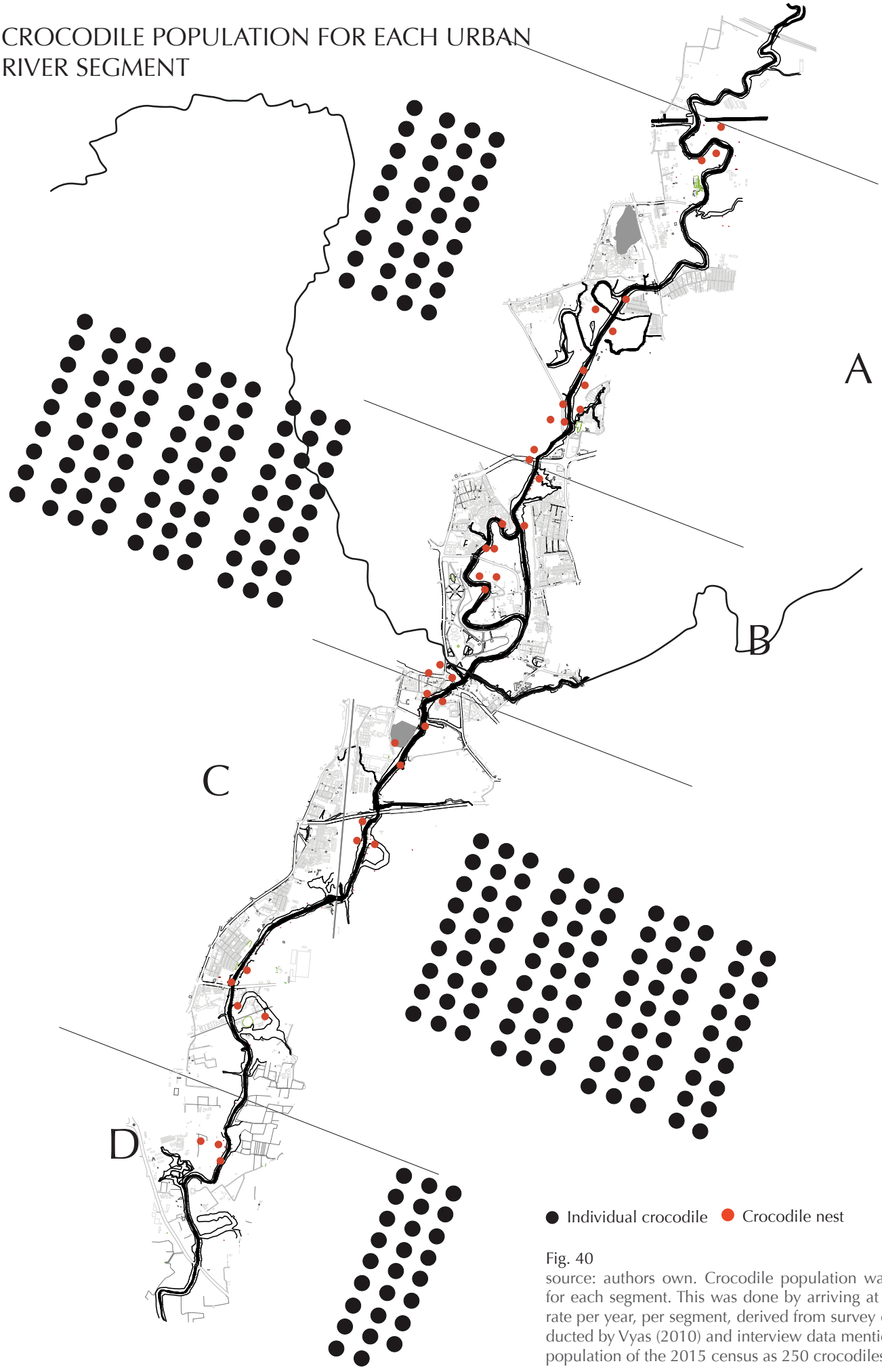


Fig. 40
source: authors own. Crocodile population was plotted for each segment. This was done by arriving at a growth rate per year, per segment, derived from survey data conducted by Vyas (2010) and interview data mentioning the population of the 2015 census as 250 crocodiles

Test Site 1- Habitat conservation and sustainable urbanization

The selection and design of this site is crucial since crocodile preference and habitat suitability studies identify this stretch of the river (Fig.40, B) as sensitive and preferred crocodile habitat (Ishore,2017) vulnerable to land use changes, making it the most important habitat to conserve for the continued habitation of the crocodiles in the urban river system. It is no surprise that this stretch of the river also supports one of the highest population densities of crocodiles in the urban stretch.

Fig. 41 View over informal (recently raised to the ground) and formal settlements
Photograph: Sanjay Seth

Test Site 2 – Mitigating seasonal conflict in low-lying human settlements

This site is notorious for human-crocodile conflict in the monsoon season (Vyas, 2010) with interviewed experts regularly mentioning this site (Fig. 40, A). The low-lying housing next to the Vishwamitri is prone to flooding and with the floodwaters come crocodiles, thus making the cause and the solutions directly related to river landscape dynamics. It is optimum for the testing of the design guidelines, especially the mounds and levees that are by far the most innovative parts of the design concept and thus in need of testing. It also demands a special focus on storm water retention and retardation of flow into the main branch of the river.

Test Site 3 – Promoting positive crocodile human interactions at the city scale

This site is part of the Palace complex of the city (Fig.40, C) and was selected as suitable land by the city authorities to develop into a crocodile park (HCP,2014). Although, this thesis will not follow the same approach as the crocodile park, it will try to provide alternative design solutions for the city that promote positive interactions keeping in mind the objectives of denizenship.

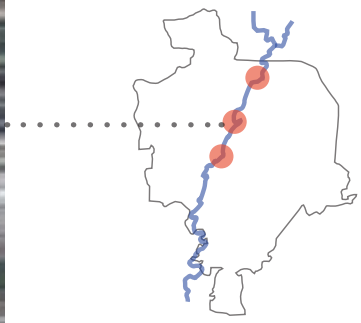


Fig. 44 Site 1
source: Google Earth,2018

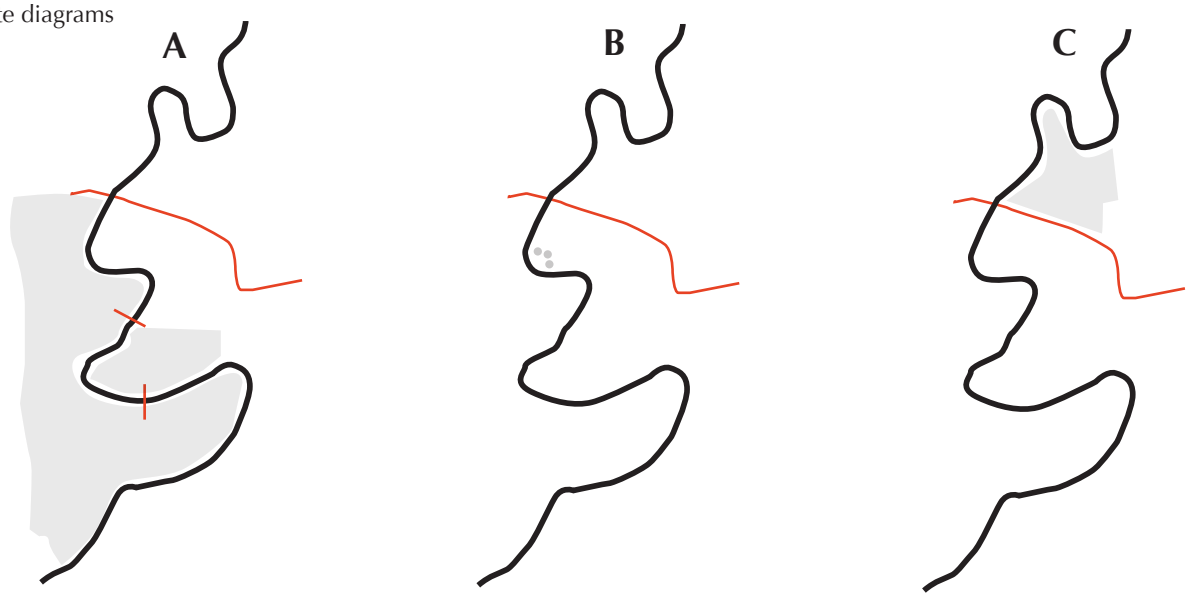
7.2 Site 1– Kamati gardens

Kamati gardens (Fig 45.A), built in the late 19th century, is on the banks of the Vishwamitri. However this reality is barely acknowledged through the design of the park, the only opportunity is while on the two pedestrian bridges that cross the river.

The site also includes the Kamanath Mahadev temple complex (Fig.45.B), built for the worship of Kamadev (whose consort happens to be the crocodile), this site has great cultural value and should be conserved.

More recently, a large portion of land along the river was cleared of informal settlements and slated for the development of urban housing (Fig.45.C,D), additionally there is a sewage treatment plant (Fig.45.E) and flood diversion canal (Fig.45.F) located adjacent to this plot allowing for the possibility of integrating decentralized waste water management with the multiple functions of constructed wetlands.

Fig. 45 Site diagrams



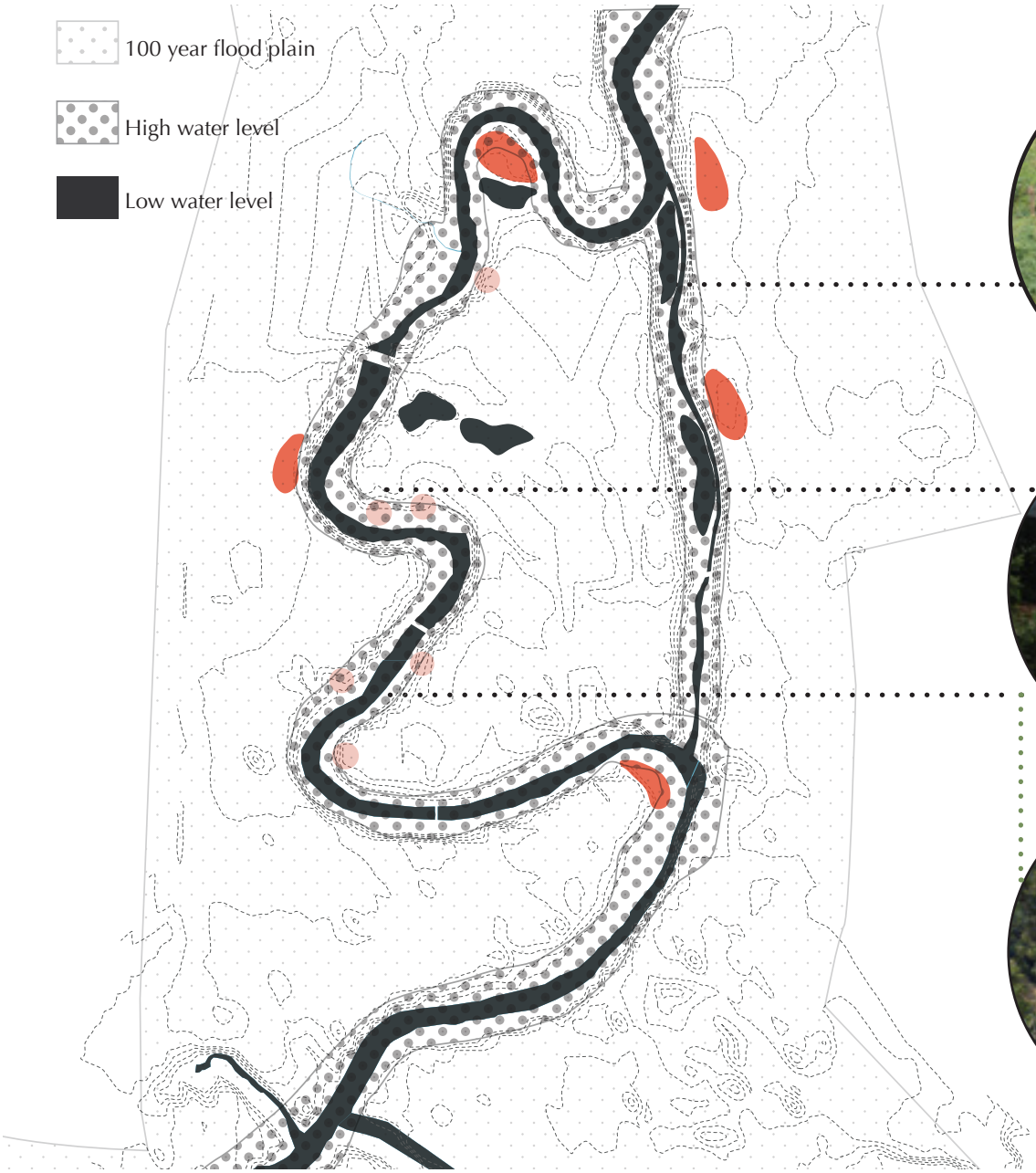


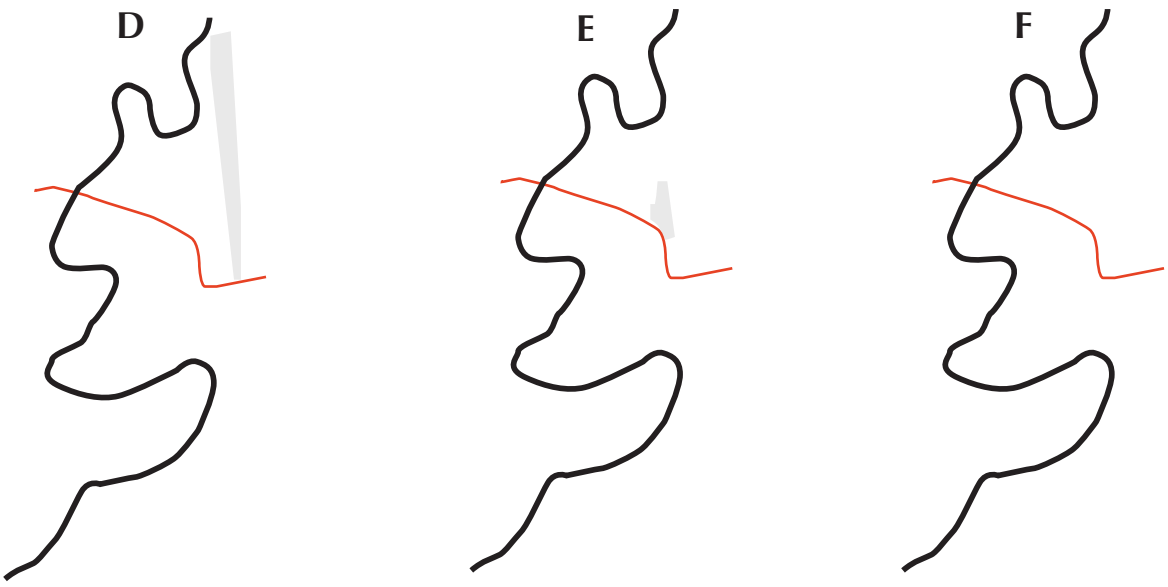
Fig. 47

Fig. 48

Fig. 49

Fig.46 The map shows the locations for the mounds (on naturally raised areas) and the constructed wetlands (on naturally low-lying areas) along the river. The circles indicate known crocodile nesting locations

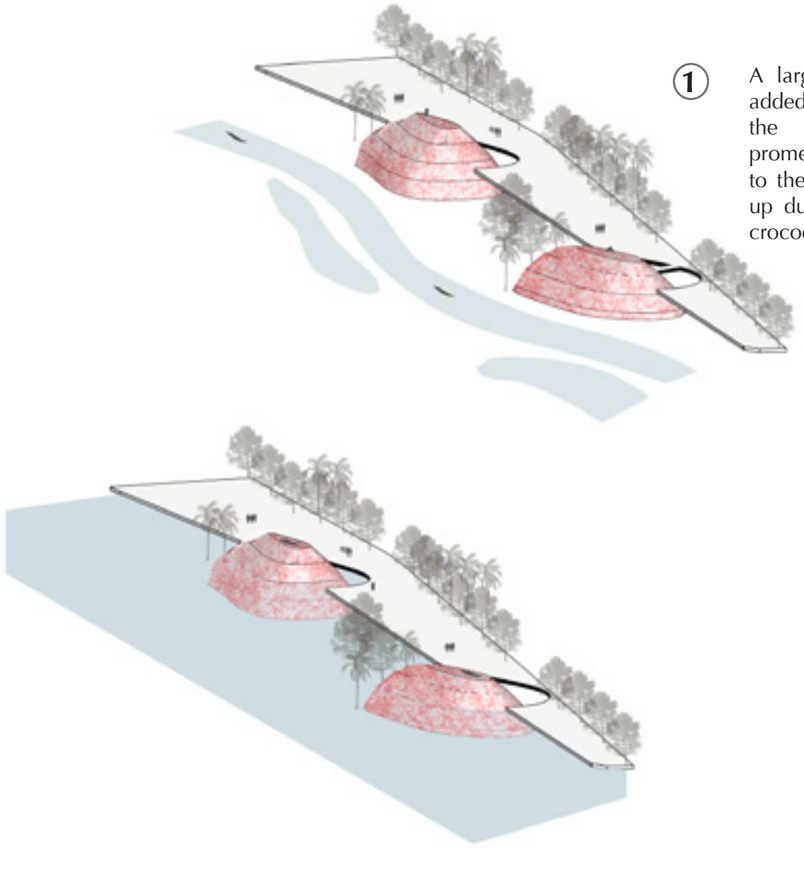
Fig. 47,48,49
source:authors own



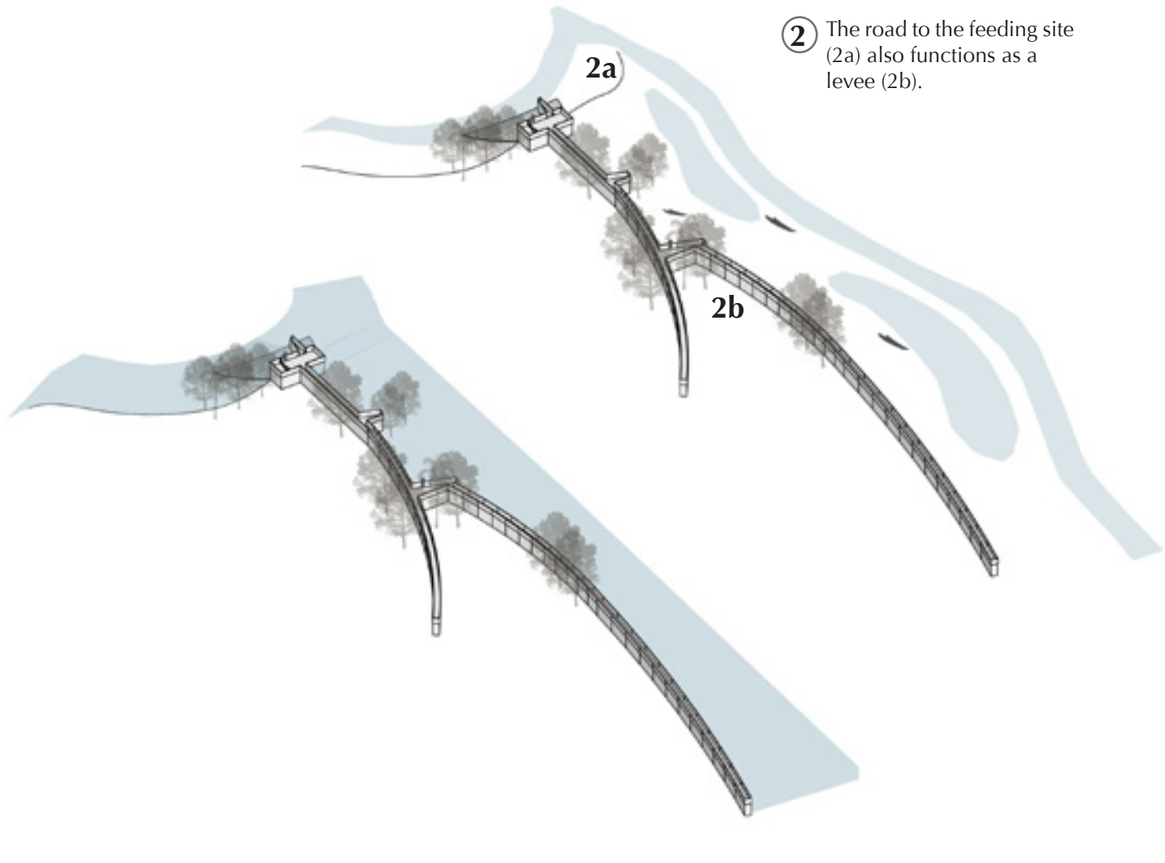
Design

The design tries to replace the form of the flood diversion canal (5) with the multiple functions of the constructed wetlands. A feeding site (2) is clubbed next to an existing sewage treatment plant (6) and this in turn is integrated with the constructed wetlands. The design creates a place for urban housing(7) adjacent to the river. It proposes a future for the Kamanath Mahadev temples (3) - The integration of crocodile habitat (8) around the temples will help protect them from human encroachment. Finally the design tries to reinvigorate the connection of Kamati bagh, Vishwamitri and the crocodiles through the careful insertion of a recreational pathway (9) along the riparian edge of the park.

Fig. 50 Site Plan

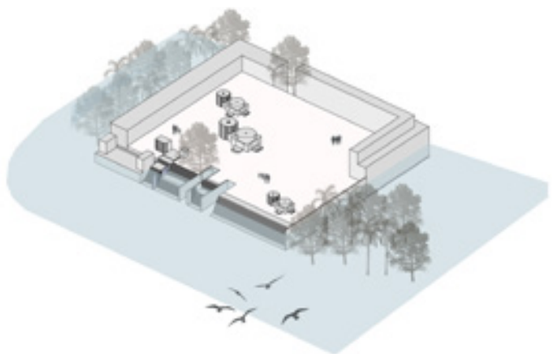


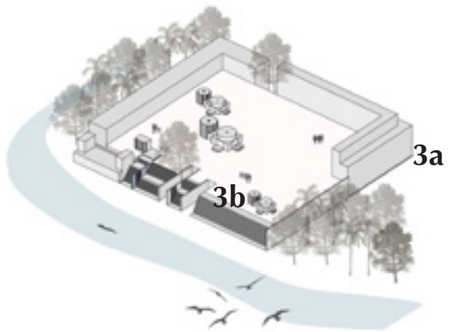
① A large raised promenade has an added function as a dyke protecting the existing settlements. The promenade has drawbridges leading to the mounds that can be pulled up during the monsoon, when the crocodiles can access it.



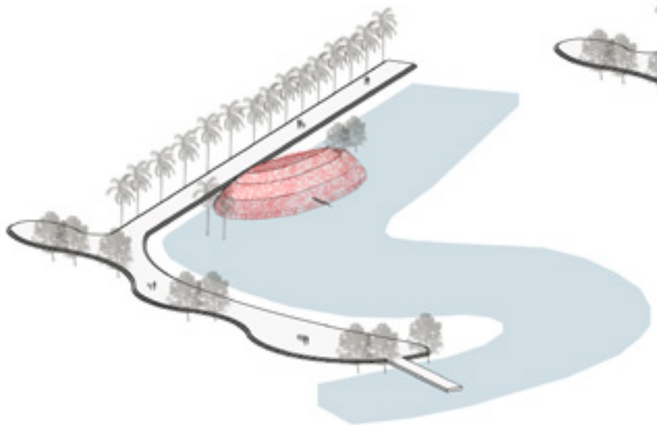
② The road to the feeding site (2a) also functions as a levee (2b).

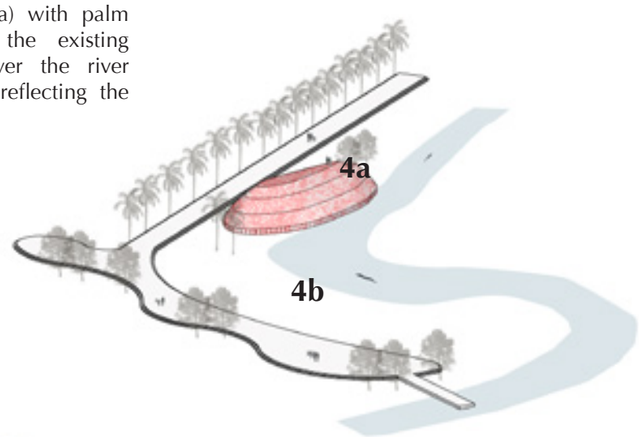
③ A ring dyke (3a) integrated with inhabitable spaces, protects the temples from floods and encroachments.
Additional steps (3b) leading to the river are added to the already existing *ghats* (steps).





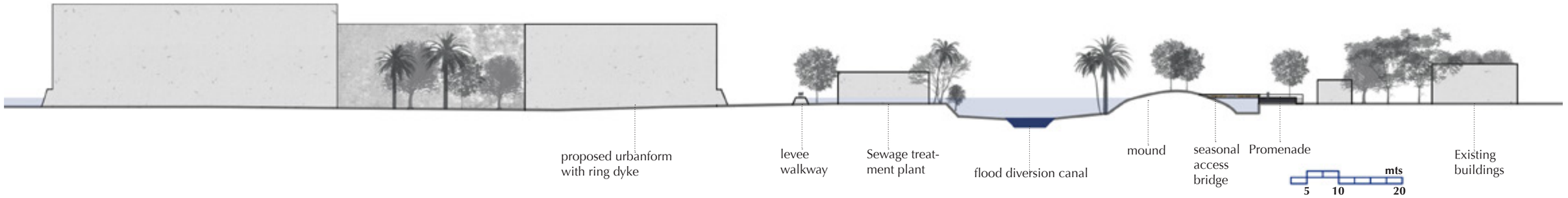
④ A new boulevard (4a) with palm trees, connects to the existing pedestrian bridge over the river through a plaza(4b) reflecting the riparian edge.



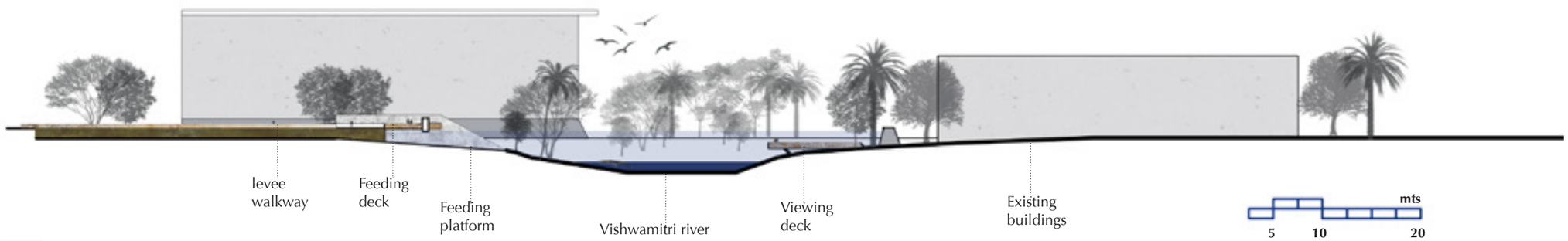


turn

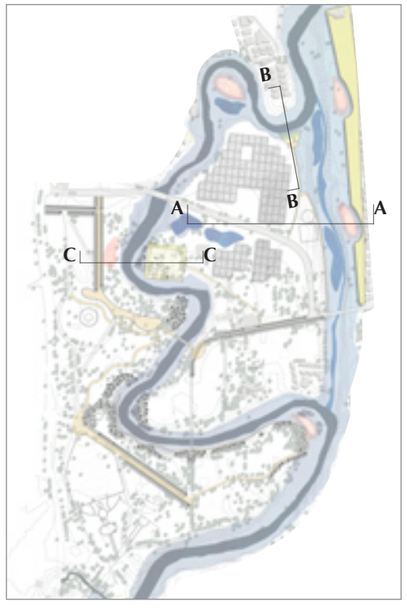
Fig. 51 Site Sections



Section AA

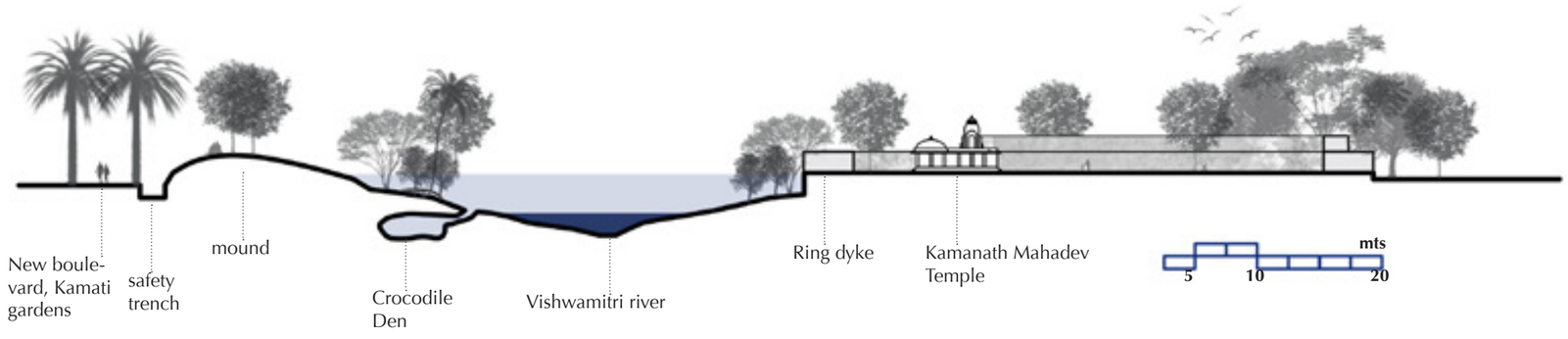


Section BB



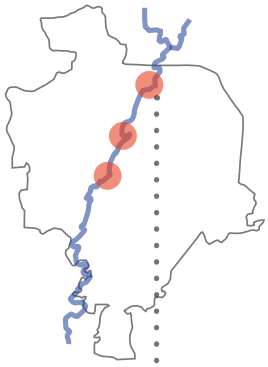
Flood level

Non-flood level



Section CC

Fig.52 Visualisation of SIte 1 - Feeding platform as seen from the viewing deck on the opposite bank



7.3 Site 2- Sama

The Sama lake (diag.A) was accessed by crocodiles in the monsoon, due to increasing human use of the lake and fragmented access, it is uncertain how much longer the crocodiles can approach the lake safely. Realtors built houses along the river (diag.B) despite the low-lying nature of the site, resulting in the regular flooding. The flooding of people's homes is far worse if those flood waters bring along crocodiles. A highway cuts through the residential site and leads out of the city as it passes by the Sama lake (diag.C). The area is rapidly urbanizing and if the landscape dynamics are ignored, the seasonal conflict will escalate in the years to come.

Fig.53 Site 2- source: Google Earth,2018

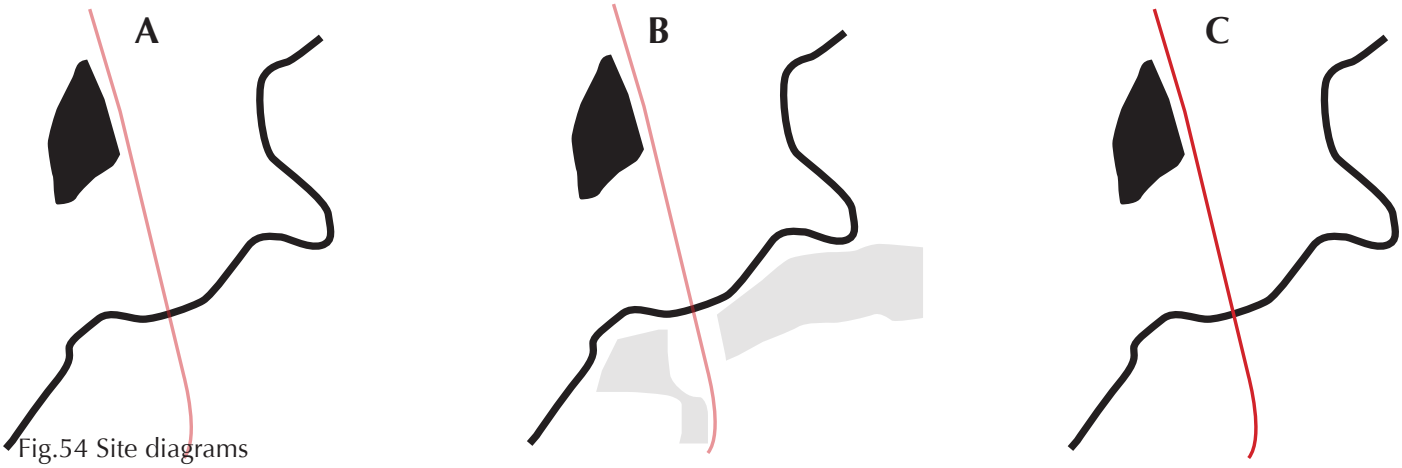


Fig.54 Site diagrams

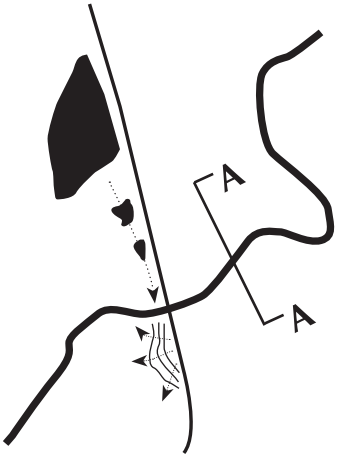
Fig. 55 The map below shows the locations for the mounds (on naturally raised areas) and the constructed wetlands (on naturally low-lying areas) along the river. The green dots indicate known crocodile nesting locations

Fig.56
Image source: Siddarth Prabhu
retrieved from: https://plus.google.com/photos

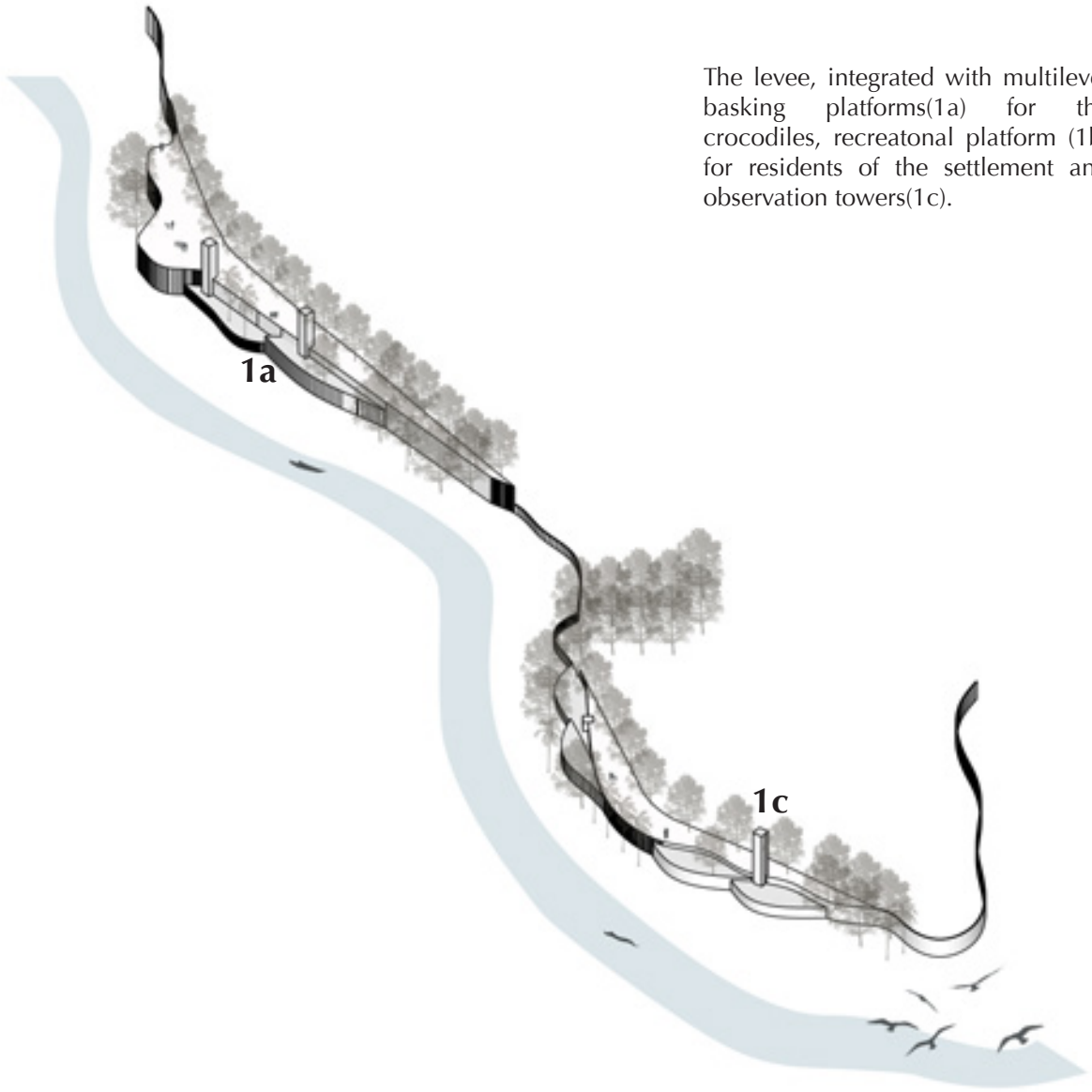
Design

The design protects low-lying settlements by employing multiple solutions. The first is being the levee (1) as a defensive strategy, second the checkdams (2)and vegetated swales (3) which retard the flow of water into the river. The design includes constructed wetlands (4) to store water while also providing seasonal refuge for the crocodiles. Finally, the mounds (5) are placed to attract crocodiles away from the settlements as spots of refuge during extreme floods. The levees also provide additional basking platforms at multiple levels. At this site there was enough room to integrate the levee with human

Fig.57 Site Plan - Sama



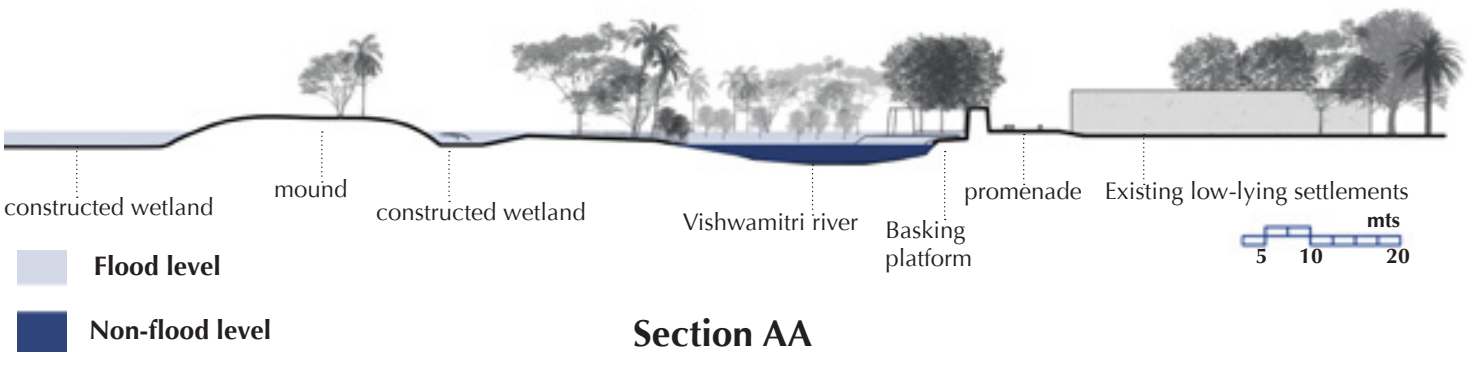
Checkdams and swales as an offensive strategy



The levee, integrated with multilevel basking platforms(1a) for the crocodiles, recreatonal platform (1b) for residents of the settlement and observation towers(1c).

2

Fig.58 Site sections



Section AA

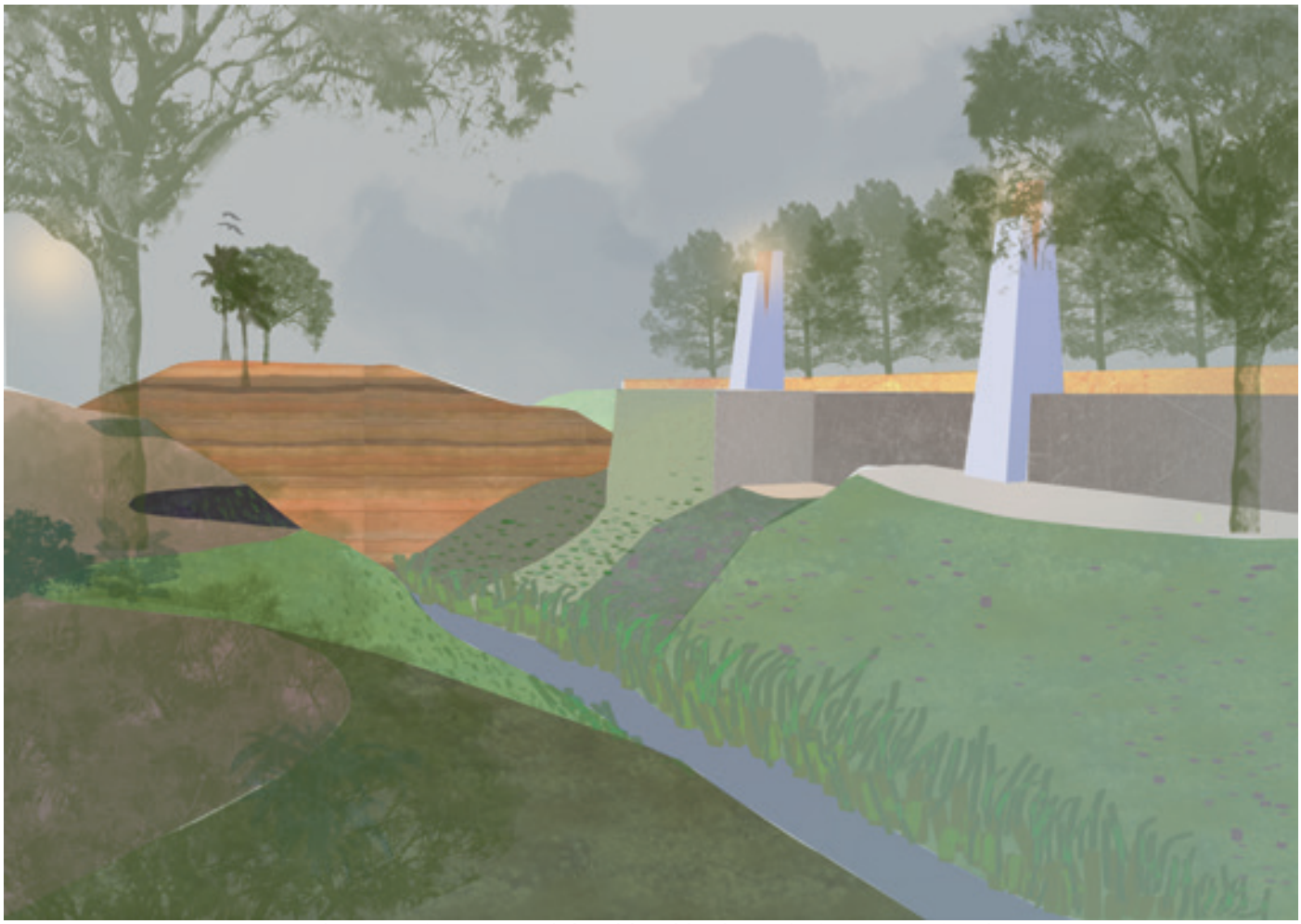


Fig.59 Visualisation of Site 2 - Multilevel level basking platforms (non-flood situation)

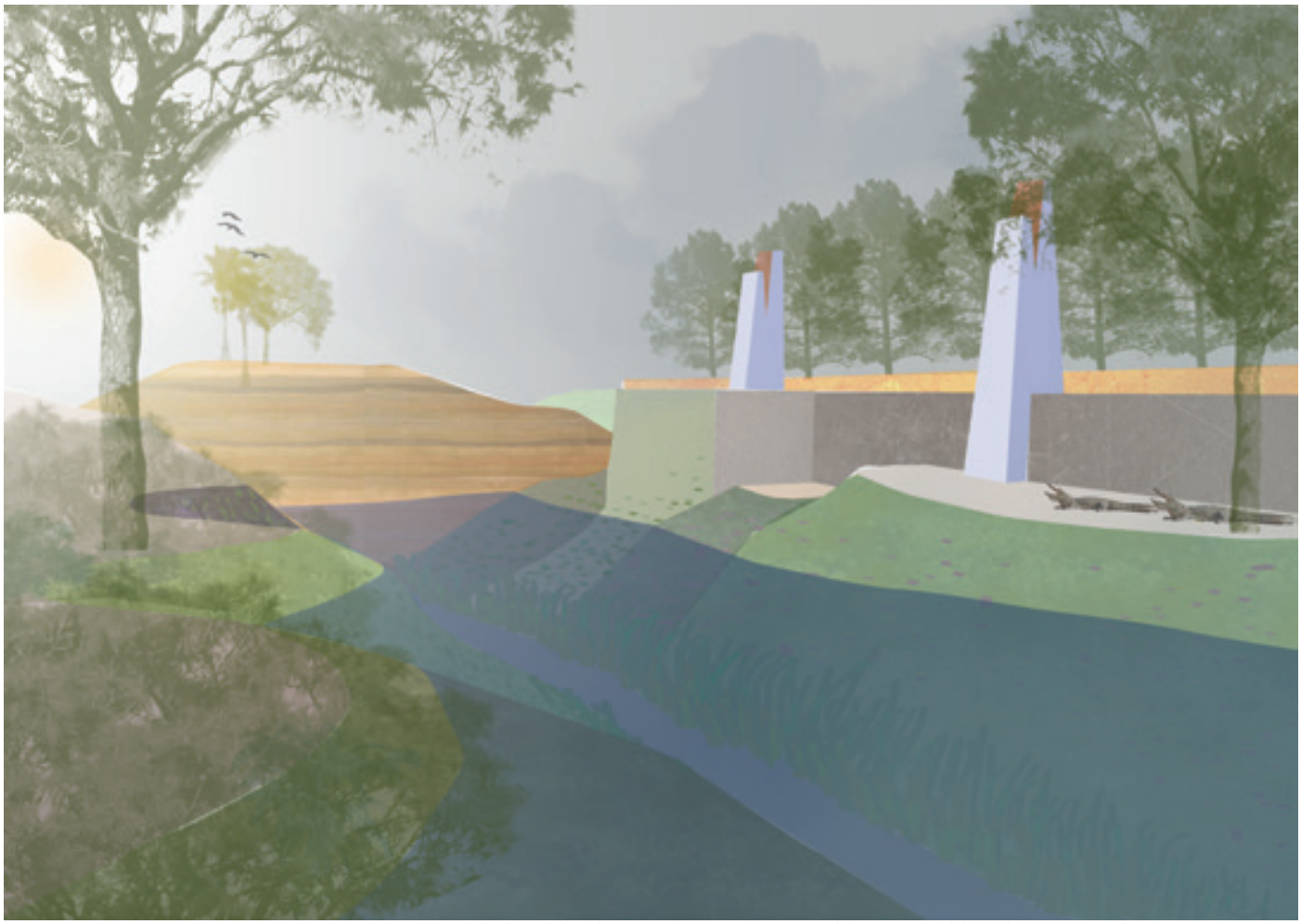
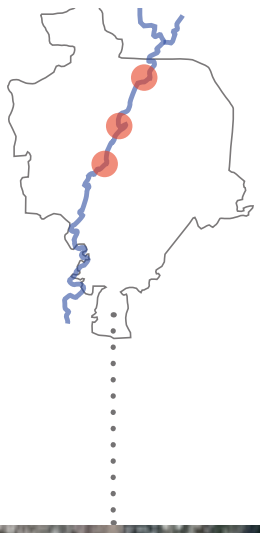


Fig.60 Visualisation Site 2 - Multilevel basking platform accessed by crocodiles during floods



7.4 Site 3– Palace complex

Informal settlements along the river are slated for in-situ redevelopment (diag.A).The Laxmivilas Palace and gardens (diag.B), still inhabited by the royal family, is also a part of the area.

The landscape opportunities on this site include, the presence of an ox-bow lake, low lying areas, wide open spaces untouched by buildings (diag.C), and high crocodile populations. This makes it an optimum location for the creation of crocodile habitat. Lastly, the location is along a recently built major road (diag.D)connecting the old fortified part of the city with the new centers of development on the other side of the Vishwamitri. There is potential and incentive to develop a parallel pedestrian link that can overlap with crocodile habitat.

Fig.61 Site 3 - source: Google Earth,2018

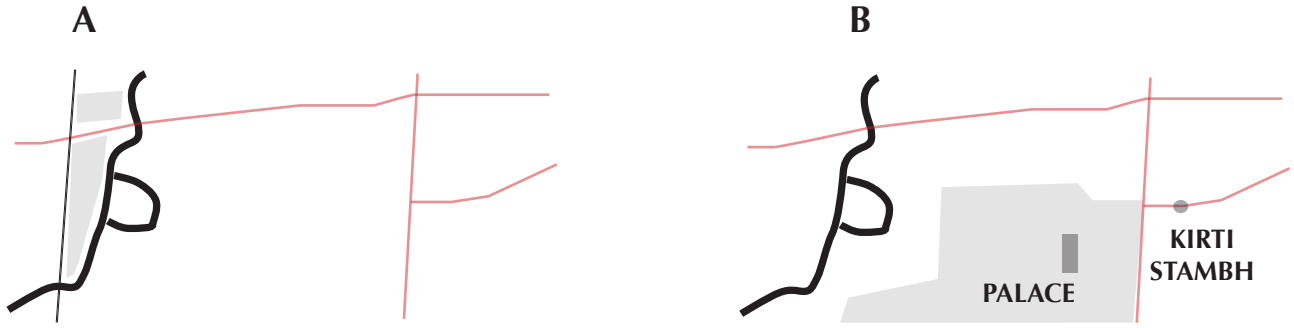


Fig.62 Site diagrams

Fig.63 The map below shows the locations for the mounds (on naturally raised areas) and the constructed wetlands (on naturally low-lying areas) along the river. The green dots indicate known crocodile nesting locations

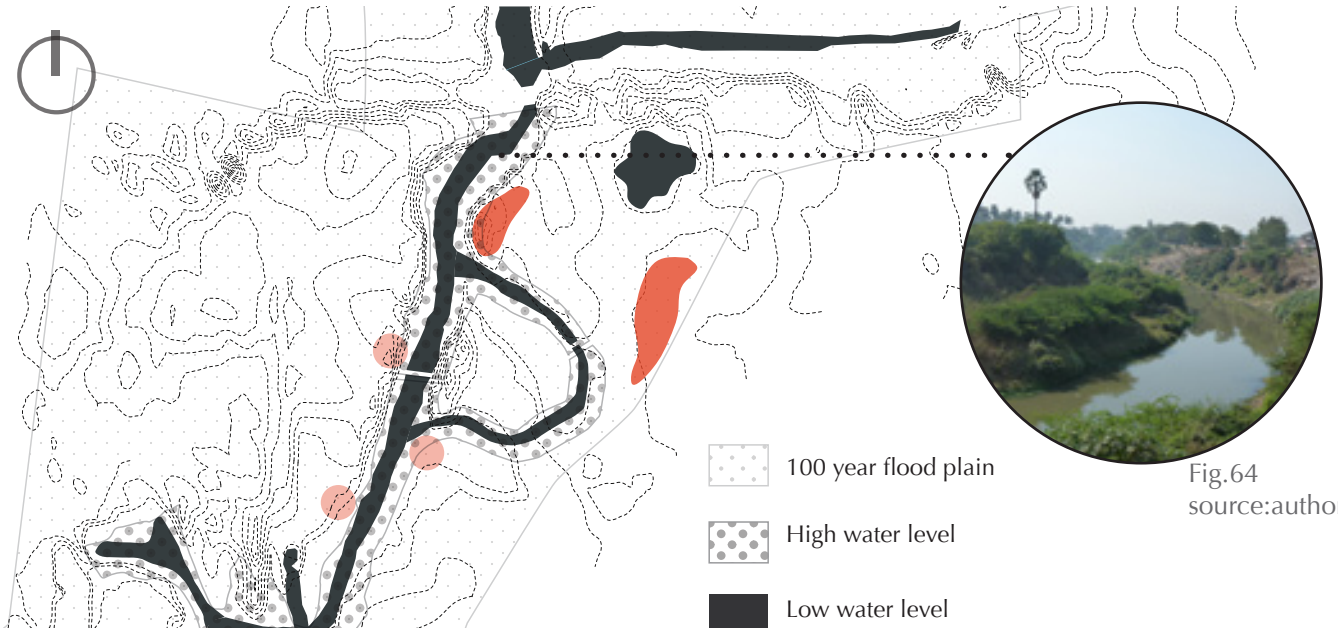


Fig.64
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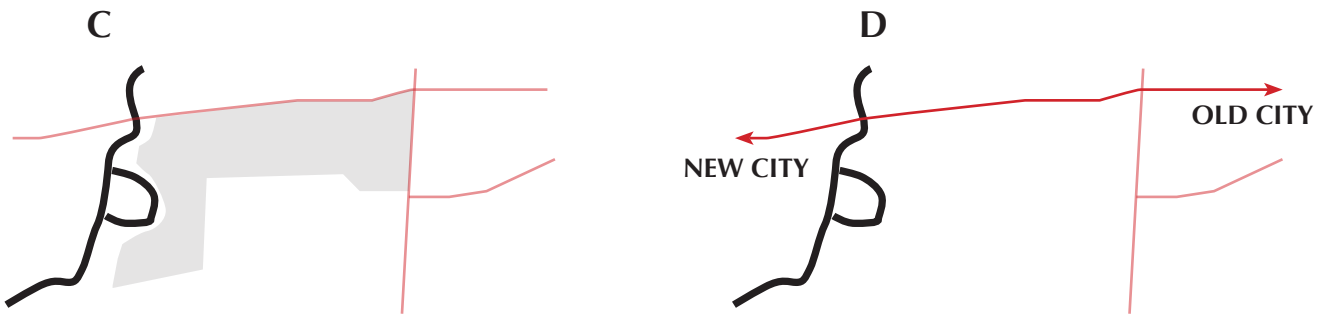
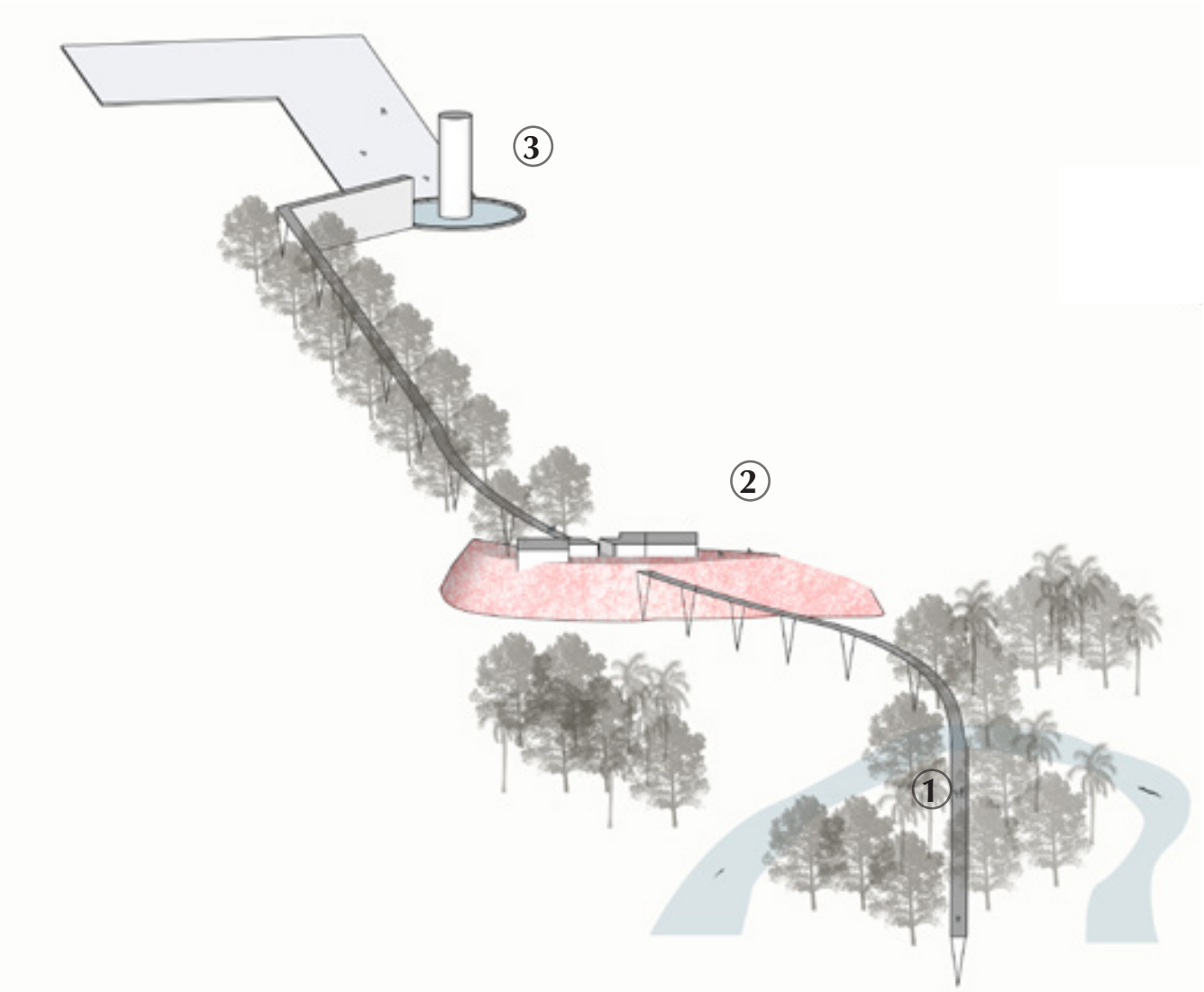


Design

As mentioned earlier, this site was zeroed on by city authorities for the creation of a crocodile park, Instead of creating a park, I propose to encourage crocodile presence on the site by preserving the habitat, establishing a feeding site and place for crocodile interpretation and rescue center. The juxtaposition of an important pedestrian link between the new and old parts of the city allows for the chance of spotting a crocodile while commuting in the city at a pace to observe ones surroundings. Thus the juxtaposition of an important pedestrian link with good quality crocodile habitat, promotes safe encounters between humans and crocodile. The animal rescue centers in the city play an important role in remediating human-crocodile conflict and this is given a more prominent place in the urban fabric.

Fig.65 Site Plan - Palace grounds


High water level
Low water level
mts
15
45
105
3



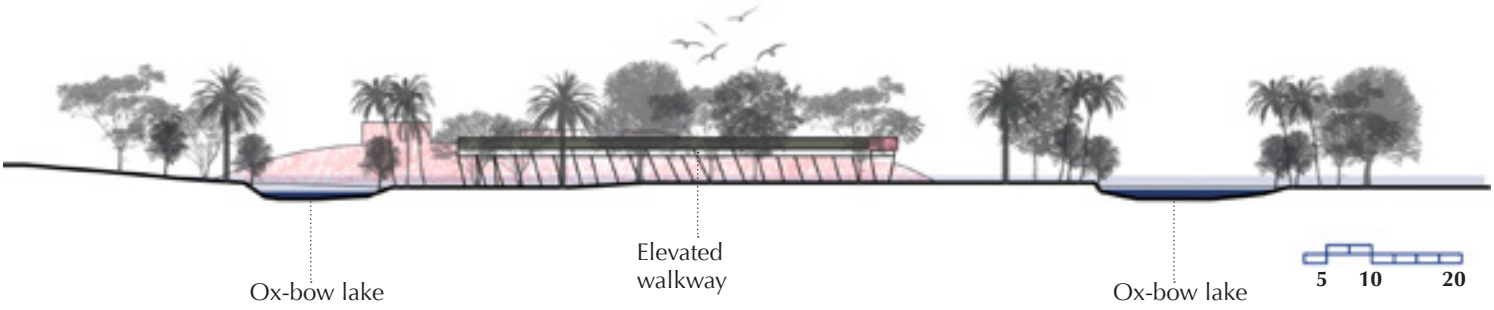
1 The main element of the design is the pedestrian link. It is elevated to:
1) Maintain a safe distance between crocodile habitat
2)avoid people wandering into the private property of the Palace
3)offer views over the open landscape and palace grounds
4)cross the railway line

2 The mound has two functions:
1) It provides high ground for a crocodile interpretation center. The access is located where the mound and pedestrian link intersect, encouraging people to visit
2)Safe, raised platform for people to observe crocodiles
3)seasonal refuge for crocodiles

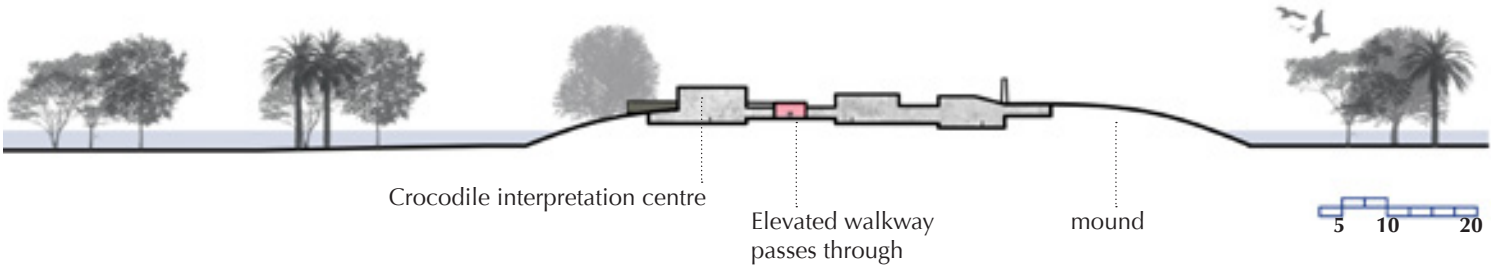
3 The pedestrian link descends onto a holding space/plaza. I propose the creation of a new landmark here for the city in alignment with the palace tower and reflecting Kirti Stambh.

4 An elevated pathway connects the crocodile interpretation center to another mound with a viewing platform (4a) overlooking a feeding site (4b) on the opposite bank.

Fig.66 Site sections



Section AA



Section BB

Flood level

Non-flood level

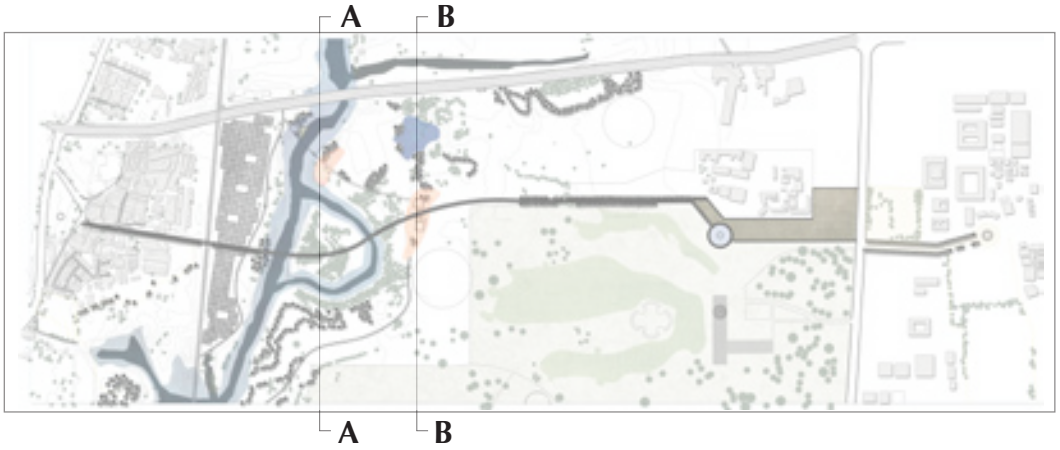


Fig.67 Visualisation Site 3 - Elevated pedestrian link to the old city (non-flood situation)

Fig.68 Visualisation Site 3 - Elevated pedestrain link to the old city (flood situation)

7.5 Conclusion:

The zoomorphic design guidelines, which were tested and applied to the different sites in the city, provided answers to the design question and helped to generate design solutions apropos to the individual sites. The designs try to engage with the crocodilian presence reinvigorating the experience of the river landscape and encouraging human-crocodile co-existence by managing the degrees and types of interaction. Landscape interventions, including designed feeding sites, wetlands and mounds are limited to the floodplains – the zone of intersection of crocodile and human habitat. Minimal intervention in the riverine habitat ensures respect for the crocodile's own agency and perspectival world (Sharpless, 2016).

Methodological reflection

8.0

It is interesting to note that the phenomenon of Synurbization was discovered after the initial data gathering process and became one of the cornerstones on which the arguments of this thesis were built. Extensive searches on 'urban wildlife' did not yield the term synurbization. After analyzing the interview data one of the sub-categories that emerged was 'Crocodile adaptive strategies to humans' this included codes that described modifications in crocodile behavior in response to human presence or activities. The search for studies on urban animal adaptations lead to the discovery of 'Synurbization' a term first published in the 1978 in a study on rodent communities living in urban areas (Andrzejewski et al.,1978). However, the search for literature with the search term synurbization yielded limited results. This could be because there is a lack of studies conducted on urban animals with this lens. Animals in cities are termed 'urban wildlife' and the use of the word wildlife polarizes the interaction between city and nature. The term urban wildlife amplifies the dualistic thinking of city vs. nature (Plumwood,1993).

8.1 Reliability/Dependability

The nature of research in landscape architecture spans both quantitative and qualitative methods. The reliability can be ensured to a higher degree in quantitative research compared to qualitative research, where the concept of dependability replaces reliability. Both the reliability and dependability of this research is maximized by keeping a record of the steps taken while gathering data, maintaining a record of keywords and sources for all literature cited as well as for maps and images. Interview data was recorded to enable a better understanding of the tone of the interviewee in order to cross check and eliminate the researchers own perception.

The research through design on the other hand is harder to replicate. Design is never solely the outcome of rational, logical choices but also involves the intuition and aesthetic experiences of the designer. I have maintained a journal and all the progression of design drawings that came before the final design, so that I can offer a glimpse into the creative process.

8.2 Internal Validity/Credibility

The internal validity or credibility of this research can be assured by showing the design to some of the experts that were interviewed in Vadodara city. The response from them will confirm and validate the design outcome. Unfortunately this could not be done yet due to limitations in time and distance. It is a possibility to follow up once back in India. Content validity is achieved by employing various supporting questions and methods to cover the range of the issue that was researched. Research questions were answered by mixed methods thus triangulating the results. Since there is no consensus on a definite approach for landscape architecture research it is difficult to internally validate the design method. Secondly, the particular case of the crocodiles in an urban setting is unique and has never been designed for before. Some of the design approaches like the development and application of design guidelines and particularly, ecological design are tried and tested and these can be relied upon for credibility. Third, since this research involves a synurbic crocodile population that has its own agency, it is difficult to predict the response to the design because this would need input from studies in crocodile ethology that would require a lot more time to conduct.

8.3 External Validity/Transferability

Vadodara city is a fine example of the accelerated urbanization processes prevailing in most parts of the global south. The presence of crocodiles in the city adds another layer of complexity to the urban landscape, and being a predator species gives it an almost equal footing with humans compared to most other animals. The research demonstrates how the crocodiles can cohabit with humans in Vadodara city. The extreme nature of this case makes it possible to generalize to other sites in urban India inhabited by liminal animals and even to other parts of the world. However, with the design approach itself it is difficult to fully establish transferability as the approach depends on the particularities of each site and the perspective of the individual designer.

Discussion

9.0

The seeds of this inquiry in landscape architecture were sown with the announcement of the Vishwamitri Riverfront Development Project (VRDP). According to the VRDP, the danger associated with crocodiles became a check on the frequency and types of land-use along the river. With crocodiles policing the possibilities of land-use, it became imperative to remove them in order to open up land for the growing real estate market. Hence, amongst ideas to straighten, channelize and concretize the riverbed and banks, the VRDP proposed the evacuation of the crocodiles from the river enabling uninhibited access to the riverfront. Soon after the announcement and commencement of the VRDP, eminent scholars and environmental activists in the city began to question the relevance of the design solutions leading to jurisdiction that prohibited any further construction.

The city authorities are now open to alternative design solutions for the river. The societal relevance of this thesis was thus a big motivation for me to focus on urban human-animal interactions. While keeping in mind the pitfall of merely reducing the non-human to a poster child of urban political struggle (Metzger,2014b; Byrne,2011 from Houston et al,2017,p.9)- the design demonstrates how the crocodile's presence in Vadodara city can be the guiding force for the creation of the urban landscape, a re-enchanted landscape in which people and animals are integrated (Wolch,1996).

The academic relevance of this thesis is twofold:

1) Translating a political theory into spatial design

The urbanization of Nature, seemingly a techno-engineering project is a result of politics just as any other social process (Swyngedouw,2006). It is important to recognize the political meaning of nature if "sustainability is to be combined with a just and empowering urban development; an urban environment that returns the city and its environs to its citizens (and denizens) (Swyngedouw,2006)" both human and non-human. Landscape architecture is a practice and research based discipline dealing first hand with the urbanization of nature in cities and actively shaping the urban.

The ecological visions that landscape architecture produces are thus also political visions or vice versa (Swyngedouw,2006). While being an established instrument of spatial change, landscape architecture is also capable of affecting political change, and it is this link between political theory and the production of urban space that the thesis builds on. By finding a spatial resolution for a political theory of animal rights, the design shows alternatives for the city to move forward without the captivity of its resident crocodile population, demonstrating the effect of political theory on urban space. More specifically, the thesis has attempted to envision how Denizenship as a political theory of animal rights can manifest spatially by creating design guidelines and site-specific landscape design solutions. This has not been attempted before and takes a step towards building a bridge between disciplines to form urban landscapes inclusive of the animal.

2) A step to developing a human-animal focused framework for landscape architecture

Landscape architecture is a medium through which humans engage with and alter ecosystems. If landscape architecture has to design in a post-wild world (Marris,2011) the need to become aware of the various non-human agents that actively shape the ecosystems we inhabit, can no longer be ignored. Furthermore, while designers will benefit from knowing how to design with

non-human animal agents, knowing when to have minimal design interventions or not design at all is equally important to ensure that human activities do not completely disrupt the habitability of the spaces we share with the non-human.

Landscape architecture now finds itself in the critical position to design for shared habitat and coexistence between multiple species. Designing not only for animals or humans alone, but choreographing the space and place for both is a contribution that landscape architecture can make to our evolving relationship with the natural world. By positioning itself as less concerned with Nature in cities but more so with the Urbanization of Nature (Barua and Sinha,2017.Swyngedouw,2006), the research into the crocodiles of the city was tuned to discover the effects of urbanization on crocodile habitat and habits. One of the most significant results of the research for design was the recognition of the crocodile population as synurbic. The most surprising result was the shift from predation to scavenging on waste being dumped into the river. This provided another reason, apart from the fact that they live in a human dominated landscape, to no longer consider the crocodiles as wild but to recognize them as liminal animals, thus making the case for denizenship even stronger.

9.1 Feeding as public ritual- Reflections from an Indian context

While the apparent paradox within a culture that worships animals at the same time desecrating the spaces they inhabit has evolved from a long history of a “complex ecological, economic and spiritual triad” (Robbins,1998,p.218), It is the very desecration of these spaces through the dumping of waste that inadvertently ensures a reliable food supply not only for the Muggers but a host of other animals like cows, dogs, crows, kites and vultures. Balancing the synurbization of crocodiles with the zoomorphic urbanization of Vadodara city, the design considers the feeding of crocodiles to be a remarkable urban human-animal interaction and sets the stage for this interaction to continue.

Traditionally, feeding animals is a part of the Indian cultural landscape and is thought to be a virtuous deed bringing good karma. In urban areas, the feeding of pigeons and other birds is a common sight. There are places in the urban realm dedicated for this, called Kabutar Khanas (Pigeon foodhouses). A diverse range of animals, including animals usually considered as pests or vermin are accorded divine agency in the Indian pantheon of Gods and Goddesses. In rural

Rajasthan there is even a temple dedicated to Rats. However, the feeding of animals as part of temple ritual entails that the food must be vegetarian. More so if the animals fed are carnivorous. There is great pride in converting carnivorous animals to vegetarianism. Exemplifying this ritual conversion to vegetarianism are the Jackals of Kala Dongar. These wild jackals have been fed vegetarian food cooked daily by the temple priests for the last 400 years. Another example, more closely related to the topic of this thesis is the case of the crocodile called Babia, who inhabits a temple tank in Kerala. Babia, is fed a vegetarian meal everyday by the temple priests that are then blessed by his snout (picture!).

The question then is how would people respond to feeding meat? – The proposed design strategy will bring to the forefront the meat industry, a stigmatized trade that the Indian government is ambivalent about. The Gujarati community, for whom vegetarianism is a superior moral and ethical choice, demographically dominates Vadodara city. Meat eating communities are ghettoized and these ghettos are the only places where butcher shops are to be found. The institutionalized, public ritual feeding of crocodiles could antagonize the sensitivities of the vegetarian Gujarati majority.

Regardless of how people perceive eating habits, it is important to be aware that unlike other urban animals, the crocodile is a predator, highly capable of hunting humans for food and compelling us to re-evaluate our relation with the crocodile (Plumwood,2012). Despite adapting to the urban environment and displaying less aggressive behavior towards humans, we must ensure that the crocodile is given the 'place' it is due in the larger scheme of the food web and as humans we are humbled by the realization that we too can be food (Plumwood,2012). Hence, regulated feeding as a tactic for urban waste management and crocodile population control is an interaction whose mutuality and codependence (Sharpless,2016) cannot be over emphasized.

9.2 Reflecting for further research

First, While the literature review (one report by Raju Vyas) touches on the fact that the crocodiles are flourishing not in 'natural habitat' but in modified/ altered habitat (Vyas,2010). There is no research that looks at the crocodile population from the lens of Synurbization. Although the indications of synurbization are evident in the interview data, these are not scientifically verified but based on observations made by experts. Hence, further research into this is recommended.

Second, a question about the design decision to continue feeding would be that if the interactions between human and non-human are malleable and adaptive then can the synurbic crocodile population be herded to less densely populated parts of the river? By shifting feeding sites and creating favorable conditions this could indeed be possible. To explore this would require a much deeper investigation into the human-crocodile interaction at the city-scale. Crocodiles being territorial with complex social structures would require an in-depth study of the synurbic populations' social dynamics to know if herding them elsewhere is even possible. This would require a multidisciplinary study across an extended period of time, making it a data hungry design beyond the scope of this thesis but can however, be a topic of further research.

Third, Anthropogenic climate change means significant consequences for the synurbic crocodile population. It would be interesting to study the effects of climate change on crocodile breeding ecology and behavior, and use these as a starting point to design climate proof urban habitat.

Finally, Zoomorphic urbanization can consider other animals as well. Ultimately the decision to focus on the crocodile can be seen as too narrow for the paradigm of transspecies urban theory/ Zoopolis. It is however a case in need of attention and thus a good starting point. The crocodile is a keystone species and the design relies on its ecological significance, assuming that other animals will also benefit along with the crocodile. The case of Mumbai's Leopard population is also in need of attention and this could be the focus of further research in landscape architecture.

Conclusions

10.0

This thesis argues that there is a growing need for landscape architecture to consider and design for animals in the urban realm. The urbanization of wild animals is proceeding along with the rapid urbanization of Nature. The western world chooses to make a distinction between wilderness and city, but this does not hold up for the Indian context where wildlife habitat and city are shared. This thesis attempts to find ways in which landscape architecture can design for unprecedented urban wildlife by transforming a political theory into an approach to design for urban animals. Through this thesis I have contributed to the expansion of landscape architectures' approach to designing urban spaces inclusive of the non-human. The case I chose to demonstrate this approach is that of the crocodiles in Vadodara city, India.

10.1 The inquiry

In order to proceed, I first asked relevant research questions and answered them through fieldwork in the city involving expert interviews and on site observations. Desk studies included a literature review and analysis of satellite imagery. This comprised the research for design phase and enabled a deeper understanding of how the city and crocodiles have co-evolved. These questions along with the research results are listed below.

RQ1 - What, if any, are the indications of synurbization in the urban Vishwamitri crocodile population?

The research for design component of the thesis yielded fascinating results about the urban crocodile population of Vadodara city. The results of the first research question confirmed the hypothesis that the crocodiles are synurbic and hence liminal animals no longer prudent to still consider wild. The interview data strongly points to the synurbization of Vadodara's crocodiles, which satisfy all known characteristics of synurbic populations. The two characteristics with direct implications for the design include the adaptive capacity of the crocodiles to urban influences and the integration of food waste in their diet.

RQ2- In what ways does urbanization influence crocodile habitat in the Vishwamitri ecosystem?

The answers to the second research question shed light on how urbanization influences crocodile habitat. It was interesting to understand how this modifies crocodile behavior in order to be able to design for them. The seasonal flooding of the river in combination with low-lying human settlements in the floodplains impacts the crocodiles in two ways. First, they are transported by floodwaters only to find themselves trapped in human settlements. Two, they need to seek out dry land for basking when the river is in spate, they prefer dry land around ponds which allows them to also be in the water. These ponds are now surrounded by urban developments making them difficult and dangerous to access. This situation is ripe for human-crocodile conflict and was a major concern to be addressed by the design. Urbanized river habitat also had benefits like providing safety and ample food for the crocodiles. Finally crocodiles even influence urbanization along the river edge, preventing informal settlers from removing riparian vegetation to build too close to the water out of fear. It is almost as if the crocodiles perform the function of policing the urban green-blue infrastructure, ensuring its preservation.

RQ3- What kinds of human-crocodile interactions are specific to Vadodara city?

The final question asked about the specific human-crocodile interactions in Vadodara city. The results ranged from worshipping the reptile to out rightly attacking the animal out of fear or malice, although these extreme cases were recorded towards the outskirts of the city. The dumping of meat waste into the river, which started as a necessity to individually manage urban meat waste, is transformed into a feeding ritual due to the presence of the quick learning crocodiles. The city has produced experts in the field of crocodile studies and rescue, a testament to the effect of growing up close to these fascinating creatures. Despite the sporadic cases of human triggered conflict, it is safe to say that the residents are tolerant and even proud to share their city with these ancient reptiles.

10.2 The Strategy

The next step of this thesis involved the evaluation of proposed scenarios based on how well they upheld the denizenship status of the liminal, synurbic crocodile population. One scenario considered the evacuation and captivity of the crocodile in a crocodile park, which drastically reduces and alters habitat in an unnatural way and pace. This was ruled out due to the fundamental transformation of the freely roaming liminal animals into domesticated captive ones. The second scenario, is based on design solutions for the urban river ecosystem being valorized by city environmentalists and architects – ecological restoration and the inadvertent rewilding of the crocodiles. Rewilding would demand much more land and inevitably draw a strict boundary between crocodile and human habitat with a disconnected conceptual juxtaposition of urban life and wilderness. The ecological restoration of the river Vishwamitri fails to recognize two important realities, one that the crocodiles of the Vishwamitri are no longer wild animals and two, there is immense pressure for housing the growing urban populations in the developing world and diverting land for the rewilded crocodiles to be able to hunt is unjustified. The synurbic crocodiles now depend on external urban food sources, and naively cutting ties between humans and crocodiles could be dangerous, careful designed changes to the landscape are crucial in the transition to successful cohabitation.

After concluding that the two proposed scenarios are not convincing, the next step was to propose a new scenario that is geared to mutually benefit both the liminal denizen crocodiles and the human population of the city. This novel landscape chooses to recognize the fact that first, the crocodiles depend on meat waste, as a source of food, making this a truly remarkable urban human–crocodile interaction. The crocodiles inadvertently offering an ecosystem service of processing meat waste. Second, apart from the riverine zone the crocodile also actively engages with the larger pond network of the city. These ponds are crucial refuge for the crocodiles in the monsoon. With most of this pond network being lost there was a need to address this concern.

10.3 The Design

Design concepts, guidelines and subsequent designs for the extreme case of the crocodiles of Vadodara city were developed. The overarching political theory of denizenship along with the results from the research for design component provided the basis on which design objectives and principles were formulated.

The design objectives were as follows;

A. Design novel seasonal habitat for crocodiles and humans to reduce human crocodile conflict

B. Prevent further degradation and despoliation of existing crocodile habitat

The design concept strategically addresses these objectives and integrates research findings to produce four landscape design elements. Each of these elements serves the needs of both the human and the crocodile community while also alleviating seasonal conflict.

To achieve the first objective;
1) Mounds- Raised topography strategically placed along the river which help to achieve the first objective provide high safe dry land for crocodiles to bask during monsoon floods, in

the non-monsoon season these can be accessed by humans and function as recreational viewing points.

2) Levees – the main function of the levees is to protect low-lying human settlements from floods and the consequent entry of crocodiles. They also double up to provide basking platforms for the crocodiles in the monsoon.

The next two interventions contribute to achieving both the objectives in the following ways;

3) Constructed wetlands- The design solution includes the creation of a parallel network of constructed wetlands that have a threefold function- safely accessible seasonal habitat for crocodiles, decentralized sewage treatment for the untreated sewage currently being dumped in the river and retention areas for the storage of storm water.

4) Feeding sites – These are sites where feeding of the crocodiles can continue in a safe way. Instead of meat waste being dumped into the river, it can now be deposited at these sites. These feeding sites are strategically located and designed to also allow for the viewing of this interaction by interested residents. The feeding sites themselves do not contribute to the reduction of conflict however the design strategy to continue the feeding ensures that the crocodiles have ample food, making them less aggressive and thereby reducing chances of conflict.

These conceptual interventions were then made applicable by the formulation of design guidelines for each one. Furthermore, these guidelines were spatially tested on three sites in the city, and produced site-specific designs to show how crocodiles and humans can safely cohabit. The resulting landscape designs rely on the learning and adaptive capacity of the crocodiles to be able to negotiate the spaces of the designed novel landscape. The research through design exercise thus resulted in designs for the synurbic crocodile population to co-exist in a novel ecosystem. I can thus conclude that it is possible to design for the continued cohabitation of both species.

While the design should help mitigate seasonal monsoon conflict and promote positive interactions, ultimately it is also the design of policy that will need to be considered for the benefit of both residents living close to crocodile habitat and the crocodiles. Hunting had decimated the crocodile population in India, resulting in the crocodile receiving Schedule 1 status of the Wildlife protection act of 1972, this technically means that there can be no external influence in its habitat. However in reality, crocodile populations have been successfully retrieved and a growing concern is human-crocodile conflict (Interview, Borkar, Appendix A). This research confirms that the Schedule 1 status needs to be reviewed within areas with growing human populations, allocating them denizenship status instead; a policy revision that can legitimize the continued feeding of urban crocodiles and the construction of novel landscape interventions in crocodile habitat.

The evidence of synurbization in the crocodiles of Vadodara city and the corresponding designs, are a hopeful indicator for other urban sites with animals, especially with predator species. First, as evidenced by the influence of the crocodiles on patterns of urbanization, predator species can play a role in the protection of the green-blue infrastructure of cities. Second, it is essential to reframe urban wildlife as not wild but synurbic liminal animals. These urban animals interact with the Anthroposystem, thus evolving and adapting their habits and habitat accordingly. Third, it is important to understand the food dynamics of resident animal populations, which can then become a starting point for the designed inclusion of animals as part of the urban metabolic. Finally, political reciprocity with animals backed by ecological science can steer the design of City/ Nature formations of the future.

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Note: Appendix A containing the transcripts of the interviews are available at the Landscape Architecture Chair Group, Wageningen University and Research, Netherlands

Appendix

B

Note: Appendix A containing the transcripts of the interviews are available at the Landscape Architecture Chair Group, Wageningen University and Research, Netherlands

Codes & Categories

Category:
Effects of urbanization on crocodile habitat

1

Code: development
Code: habitat loss
Code: construction
Code: building
Code: safety
Code: population

Sub-category: Transport infrastructure

1a

Code: roads
Code:railways
Code: bridges
Code: fragmentation

Sub-Category:
Direct Human interaction with croc- Habitat

1b

Code: dumping of debris/ garbage
Code: dumping of waste (meat)
Code: neglect
Code: illegal activities
Code: defecating
Code: fishing
Code: washing

Category:
Crocodile Habitat Characteristics

2

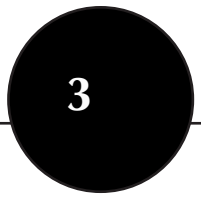
Code: location names
Code: Vegetation
Code: temperature
Code: ViRi
Code: wildlife (other species)
Code: ecosystem
Code: riparian
Code: population

Sub -category: Seasonal Habitats

2a

Code: seasons (winter, summer, monsoon)
Code: floods
Code: lakes(talavs)
Code: floodplains
Code: Ravines

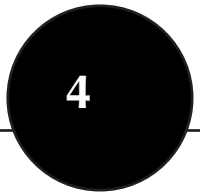
Category:
Crocodile Ethology



Code: feeding – scavenging, hunting, cannabalising
Code: basking
Code: mating
Code: nesting
Code: migrating
Code: territorial

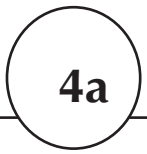
"Process coding uses gerunds ("-ing" words) exclusively to connote action in the data. Simple observable activity and more general conceptual action (struggling,-adapting, surviving) "p.77

Category:
Human-croc interactions



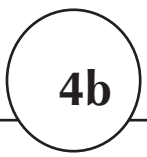
Code: croc-spotting
Code: co-existence
Code: rescue
Code: ecosystem services
Code: conflict
Code: stone throwing
Code: attack
Code: killed
Code: dumping of waste (meat)

Sub-category:
Croc adaptive strategies in human-dominated areas(urban)



Code: Shy
Code: Move away
Code: close to urban built area
Code: safety
Code: migrating to city
Code: Adapt
Code: sensitive

Sub-Category: underlying attitudes towards the crocodile



Code: Awareness
Code: local knowledge
Code: worship
Code: myth
Code: religious significance
Code: Curiosity/Interest

Values coding-"reflect a participants(?) values,attitudes, and beliefs". p89

Category:
Expert prescriptions for the future - urban river landscape

5

Code: landscape
Code: revival
Code: conservation
Code: design
Code: new river

Sub-category:
Urban river landscape in the past

5a

Code: mentions earlier time periods ex. 50's, 60's
Code: past

Fig.1
source : Mittal et al, 2017

Bhimnath Lake- urbanizing landscape

28-11-2003

15-12-2005

20-02-2010

23-10-2015

27-02-2016

27-05-2017

Fig.2
source : Google Earth, 2018

Sama Lake - urbanizing landscape

29-10-2002

15-12-2005

20-03-2010

11-12-2012

27-05-2016

27-05-2017

Fig.3
source : Google Earth, 2018

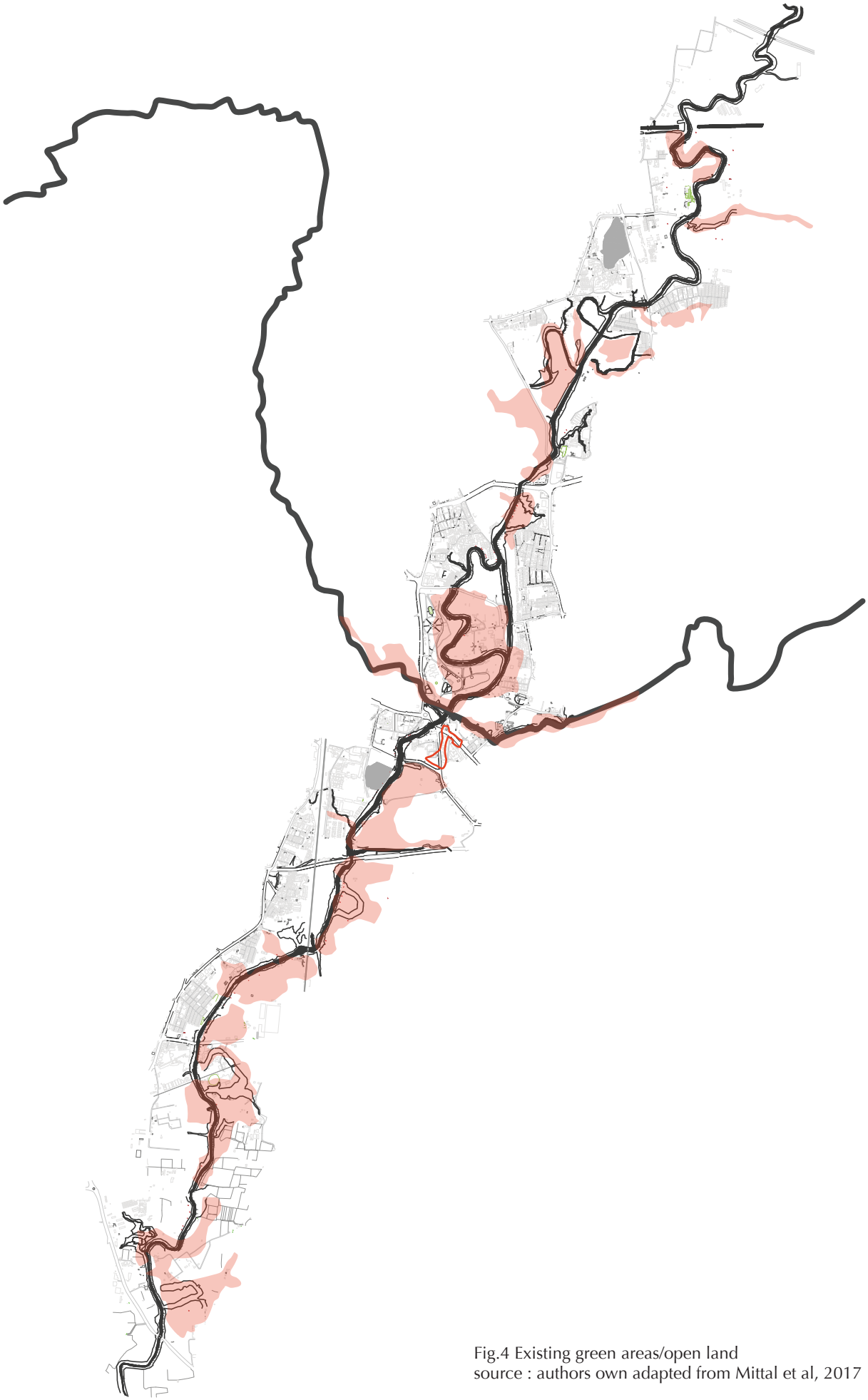


Fig.4 Existing green areas/open land
source : authors own adapted from Mittal et al, 2017

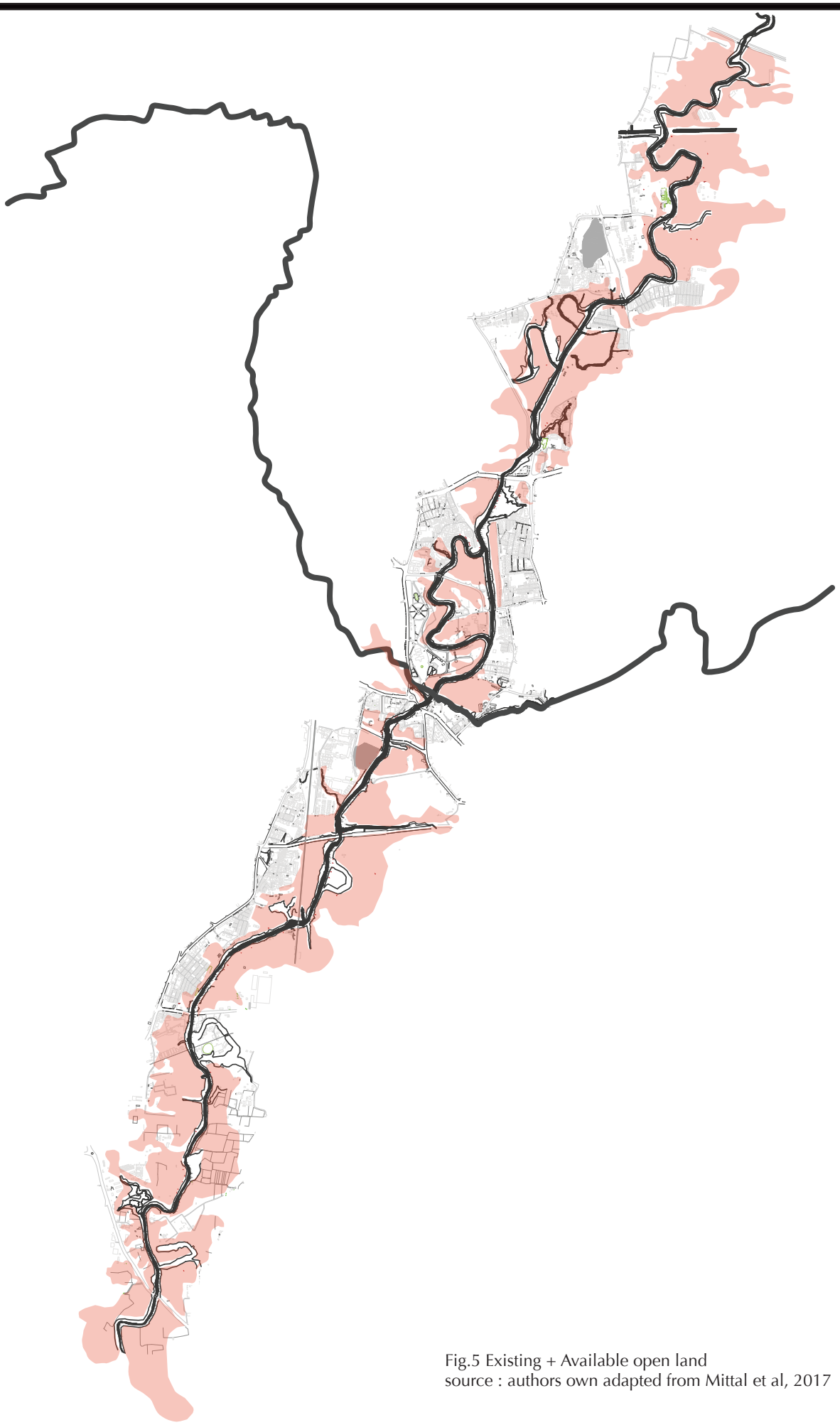
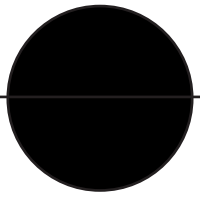


Fig.5 Existing + Available open land
source : authors own adapted from Mittal et al, 2017



Wageningen 2018