Water-wise city

Surface water management in Jhenaidah, Bangladesh through regenerative urban design.

Mahmuda Alam
Department of Architecture, Chalmers University of Technology, Sweden
E-mail address: mahmuda@student.chalmers.se

Examiner: Catarina Östlund
Tutor: Emilio Brandao

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Contact: aritra_ahmed@hotmail.com

Final seminar: 2016-06-20 Examiner: Catarina Östlund Tutor: Emilio Brandão

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Gothenburg, Sweden

Telephone +46 (0) 31-7721000

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Abstract

Conventional urban water infrastructure is not only extremely energy consuming but also hides the urban water from the user. It is energy consuming in many aspects, for example, transferring water and treating it. Cities with resources from developed countries are somewhat being able to run this expensive system. However, cities with limited resources from developing countries have never reached the goal of providing water service to all their habitants and wastewater is released to various sources without treatment. Yet, these cities run behind the dream of being a 'piped one'.

The intention of this thesis is to find out the possible innovations through design for water management to increase water efficiency for future cities. Bringing out the water infrastructure in urban public spaces and thus enabling citizens to interact with water sources can create knowledge and awareness and unfold responsibilities for next generation water management.

This thesis discusses the specific case of a Bangladeshi municipality, Jhenaidah, to investigate the research question and relevance of implementing the learnings from WSUD (Water sensitive urban design) and DEWATS (Decentralised water treatment system) approaches in developing city.

A major part of the field visits and empirical study has focused on the institutional capacity of Jhenaidah for any kind of development implementation. The result of literature study is a set of technical tools derived from WSUD and DEWATS approaches, a discussion through idea sketches and a set of strategies to apply the tools in Bangladeshi urban context for conserving water and enhancing public space. The tool-set has also been applied to a neighbourhood waste water management system combining with communal playground as a design example. The focus of the design example lies on managing wastewater in community scale to improve the life of the inhabitants, especially women, who are the most vulnerable subjects to the situation.

Acknowledgement

Many have been part of this thesis, both in Sweden and Bangladesh. It has been a great pleasure to work with all of you and I would like to thank everyone. I am grateful to my family for the unconditional support. Thank you, Khondaker Hasibul kabir, Suhailey Farzana and POCAA for your guidance during the field visit. A special thanks to Emerald Baidya Upoma for retrieving the lost data and to Nazia Roushon for proofreading. Thanks to the forth year students of BRAC university, Masud Mehedi and Babul from the NGO ALIVE.

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Last but not least, I would like to thank my friends at studio, home and abroad as they became my support system until the final.

Preface

The thesis began with one simple curiosity; what if the water was not hidden under the hard surface of a city, since the beginning of urbanisation. Would it anyhow — have an influence on our behaviour around this limited natural resource?

I had decided to work with the context I was most familiar with, Bangladesh, where I was born and brought up and trained to be an architect through education and work.

In Bangladesh, the context of water sources and their usage is largely paradoxical in nature. Bangladesh has a significantly large number of water sources as rivers, lakes, ponds etc. and many other names in Bengali language that does not have proper synonyms in English. Moreover, a dominant monsoon season keeps these sources flowing for most of the time of the year. Yet, the irony is, not everyone has access to safe water - the trouble which will increase to great extents in the coming years with the growing population and unplanned urbanisation. Because of urban, agricultural and industrial residues, most of the water sources are too contaminated to be used. This paradox summarises the country's lack of sensitivity towards this abundant natural resource.

For me, the reason to work with this thesis was the responsibility I feel as a part of the society, to stop the process of turning a blessing into a curse. Water is a very vast issue; every profession, community or individual actually have something to contribute. In this thesis, I have tried to explore my role as an urban design/architect to address some of the issues related to water. The goal was to find the effects that space designing and process of designing can have on people's behaviour in regard to urban water. This is how, I can connect back to my initial curiosity (which, later, got more shaped according the context) and I hope, this booklet will unveil the findings, step by step, in a pedagogical manner.

The challenge is enormous, as the human settlements are changing very fast and so is their behaviour and life style. This means, new ways of contaminating the water sources are continuously generated. So, there has to be a continuous knowledge generating process that will not only identify the solutions about how to treat contaminated water, but which will also recognise and reveal the reasons/ways of the contamination, so that, the rate of contamination gets reduced from the very beginning.

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Water

: the clear liquid that has no colour, taste, or smell, that falls from clouds as rain, that forms streams, lakes, and seas, and that is used for drinking, washing, etc.

: an area of water (such as a lake, river, or ocean)

(Merriam-Webster's Advanced Learner's English Dictionary, 1999)

Introduction

Bangladesh, surrounded by India on three sides and the Bay of Bengal on the other side, is characterised as a delta. Almost 700 rivers run through Bangladesh, defining both the geography and people's way of life (Bangladesh Bureau of Statistics, 1999). This has always been considered as a blessing for the rural and agricultural economy base of Bangladesh. Because of the enormous, trans-boundary river bodies, the country faces regular visits of flooding. Years of efforts have been realised to adapt and mitigate the damages of flooding. However, the problem lies more in the contamination of water, with or without a flood. Lack of education and awareness about using contaminated water or underdeveloped sanitation system causes life threats more than the actual flooding does.

When it comes to the urban areas, the situation is a bit different from the rural areas. Urban areas are subject to rapid change and expansion. They are more rigid in structure. For the plain topographic characteristics of Bangladesh, channelling the excess water out of the urban system has been proven difficult. Unlike the rural areas where floods are natural and a regular occurrence, the reasons of flood occurring in urban areas are directly related to the approaches of urban design and planning and water management. Thoughtless construction activities, over-saturated settlements have made the wastewater management and quality water supply difficult for the administrations within the mega-cities. The smaller cities encounter the problem of insufficient resources and experts' attention. The ever growing urban population of the nation is able to focus very little on the 'sustainability' aspect of urban water system, when providing basic water to everyone has been an overwhelming problem for this country.

The aim of this thesis is-

- To focus on water treatment through wetland rather than just getting rid of water from urban setting like conventional water management system of Bangladesh.
- To provide for the relevant ecosystem so that it can co-exist with urban amenities.
- To educate and create awareness by changing the visibility status of water.
- To enhance the quality of public space by the presence of the element 'water'.
- To formulate strategy, based on the strength and challenges, mapped in the local context.

Reason to choose Jhenaidah

For investigation I chose a case of a city corporation in the western part of Bangladesh, named 'Jhenaidah'. Jhenaidah is a medium sized municipality of Bangladesh. Though the settlement dates back to fifth century, its establishment as an urban centre is quite new (dates back to 1958). (District town infrastructure development project (DTIDP), n.d.) More detail information about the municipality will be discussed later in ' The local context chapter' to provide a better perspective of the municipal's current situation about water and urban planning.

My personal connection with POCAA (Platform for community architects and activists) has helped me to choose the city for my thesis work. Since this organisation is working together with local government, NGO and low income communities in Jhenaidah, I knew that I could get critical perspective about involving different actors in community development. The organisation is mostly working with housing development. Water is not a separate issue in their discussion of community development. When I discussed my thesis idea to POCAA, they accepted it enthusiastically and were eager to see how the water element can be added to their present activity.

Women's perspective

As soon as I began research activities in the site, I realised that it was the women group of the communities who were most vulnerable to the issue. The women are most responsible for cooking, cleaning, washing dishes and clothes, collecting drinking waters. Without a proper wastewater disposal system, the burden falls on to women. Almost all the cases the women empty the wastewater ditch manually with buckets. This consumes a lot of time from their daily life. A proper wastewater disposal would give them time to develop their personal life. Also, they can use this time more in economic development by involving themselves into income generating jobs. Research activities and findings are described more in the later chapter.

Reading instruction:

The first chapter of the thesis gives an overall view of problems created by conventional 'piped' water infrastructure.

The second chapter presents the very complex situation of Bangladesh. It also discusses the context of Jhenaidah and the different urban planning aspects for near future from the analysis of the master plan (2015-2030) received from the Jhenaidah municipality.

The third chapter discusses the field researches. The field research is divided into three phase with focuses on three different scales. Each phase includes the activities done during the phase and the result/conclusion achieved from it. More detail of the activities (interview, workshop, discussion , etc.) can be found in the appendices. Each phase summarises This chapter ends with a list of possible design paths and requirements for the site.

The forth chapter derives a theoretical toolbox, possible application in urban planning, built environment and landscape and an urban planning and design strategy for Jhenaidah.

The contents (text, diagram, table , etc.) on the coloured background in chapter 1-4 are the conclusions derived from the discussions that respective chapter.

The fifth chapter shows some design ideas through drawings and sketches as an example for a specific site. It renders idea for how public space can become more water-efficient and how water can enhance the public space.

The final discussion, going forward with the thesis and my personal reflection is included in the concluding or sixth chapter.

Almost the whole country of Bangladesh is dependent on underground water for drinking. All types of used water are discharged to surface water bodies without treatment. A significant part of the population depends on this untreated surface water for daily activities, for example, washing cloths, utensils and bathing.

The development activities in the water sector of the country work mostly with short term solutions. One example is, providing hand pumped tube-wells to individual families to draw water from the underground. The absence of long term perspective can keep us in the same loop of problems. If the underground water level is not recharged and dropped down, where will we get the water to draw with these hand pumps? These facts have helped me to understand that if the issue of water treatment is not taken care of, we will always face the lack of safe water. From this understanding I have derived the research questions for the thesis.

Research Question

The investigation for the thesis is divided into the following parts:

Water management:

- What are the alternative researches or solutions being practiced for urban water (household grey water, runoff and surface waterbodies) management worldwide?

- How local communities and professionals (Local government, NGOs, academics, researchers, engineers, planners or architects) can organise, work and solve the problem of water safety locally?

Human behavioural science

- How can people shape their environment? Which characteristics of people, as individuals or groups of different sizes, are relevant to the shaping of particular environments(soil, water)?

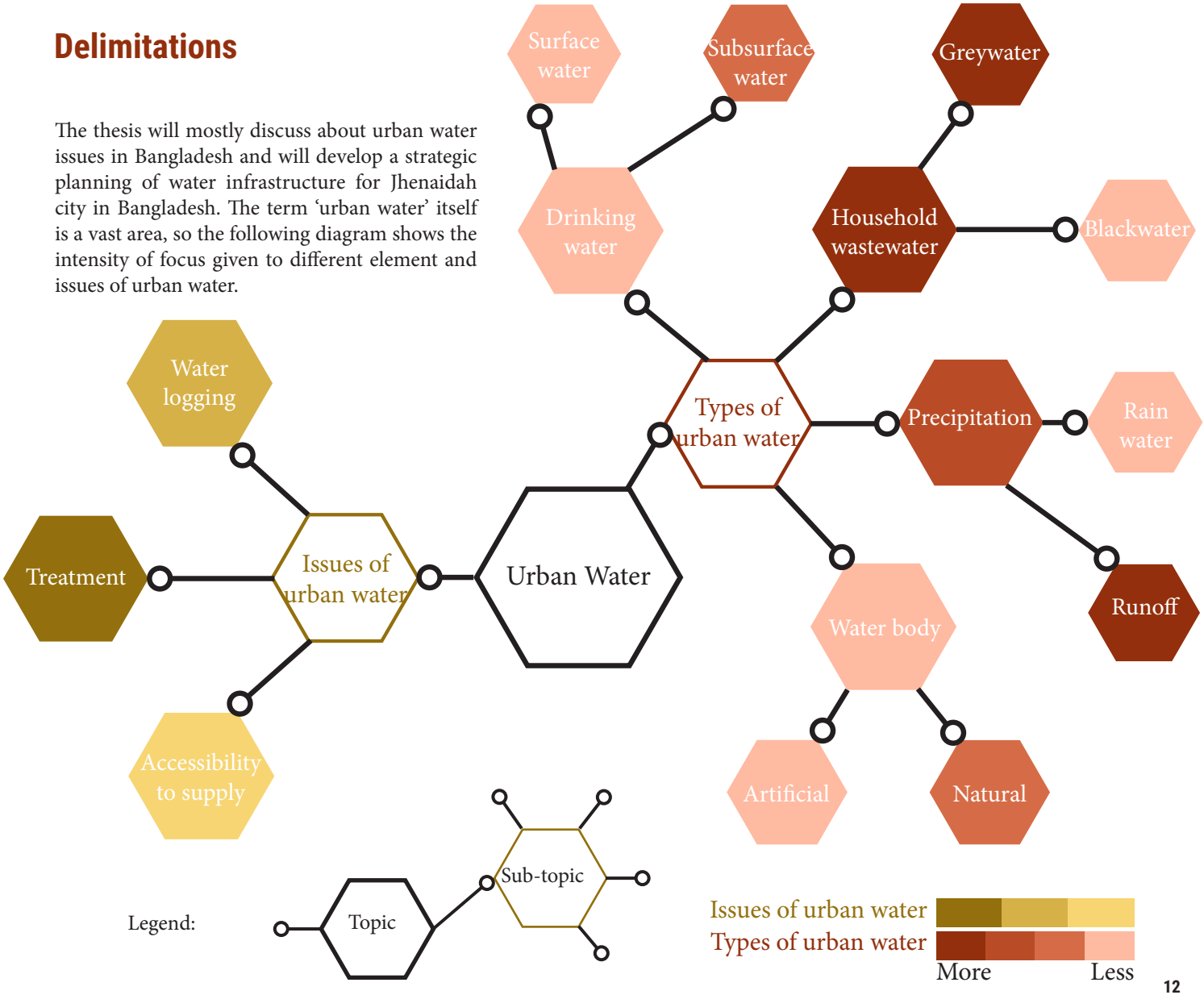
- How and to what extent can the physical environment affect people? How important is the designed environment and in which context?

The investigations have then directed to the final research question:

How to manage household grey water and surface water resources sustainably for present and future generations through urban design and planning in Jhenaidah, Bangladesh?

Delimitations

The thesis will mostly discuss about urban water issues in Bangladesh and will develop a strategic planning of water infrastructure for Jhenaidah city in Bangladesh. The term 'urban water' itself is a vast area, so the following diagram shows the intensity of focus given to different element and issues of urban water.



Methodology

The three major parts of this thesis are literature review, research stay and design development.

Literature review

Research about sustainable water management systems: An extensive literature study has been carried out in order to gain enough knowledge about researches being carried out world-wide to find sustainable ways of managing urban water.

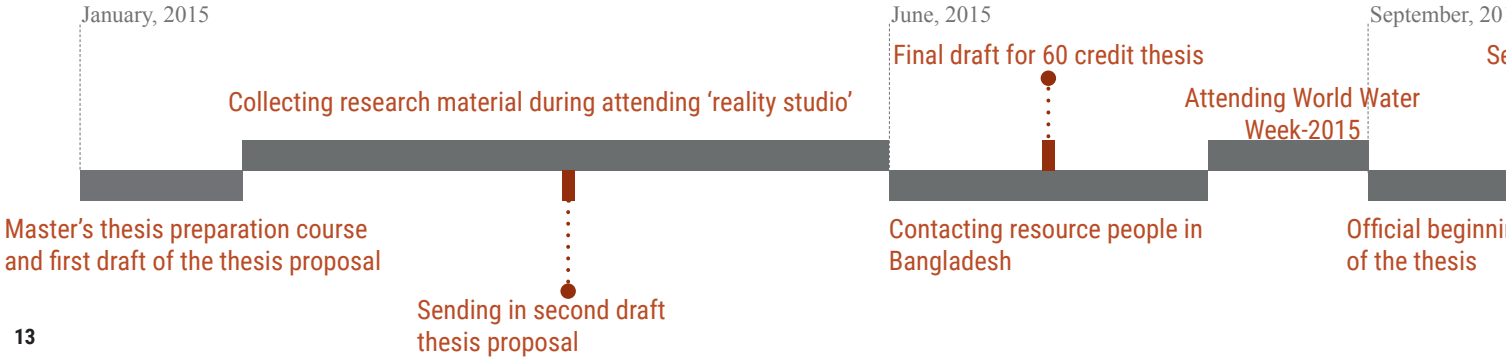
Case-study: Learning from implemented projects has been analysed.

Research Stay

I am naming the time spent at Jhenaidah city as 'research stay', during which I lived with a host family within the community I have worked with. Staying within the community has helped me to organise as many formal activities as it needed according to the community members' convenience. Moreover, living right in the research site also let me experience the current water problems first hand.

During the research stay, a number of activities had been carried out, starting from **Interviews** of architects, NGO personnels and community members. To plan the future activities and to inform about the findings of previous activities, meetings (with one or more professionals together) were held in regular basis.

Important dates of the thesis



Focused group discussions were done with different communities, in presence of community members (mostly women) regarding specific issues or topics.

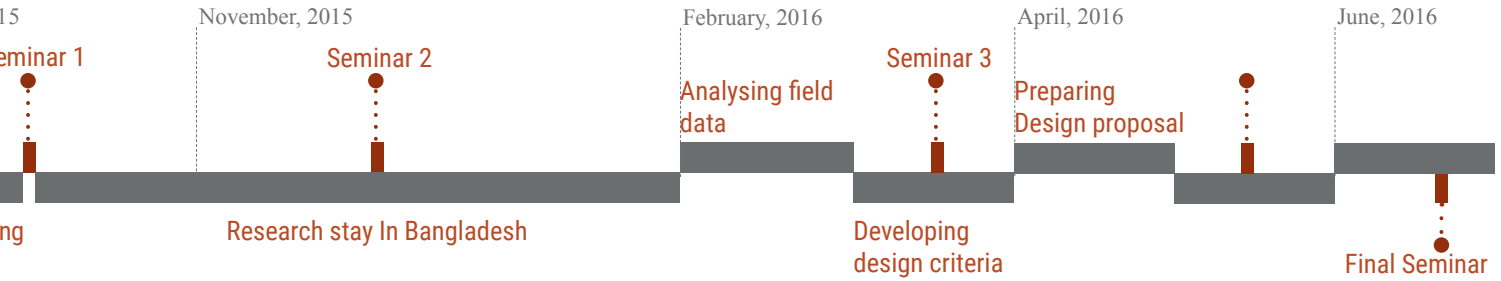
During the research stay, a lot of **informal discussions** with the community members took place, which gave me insights and **observations** that usually is unreachable through formal meetings or discussions.

Workshops can be called the most important part of the research stay for this thesis. Several workshops were organised to identify problems from different actors, to recognise the strengths and resources available in the local context and also to find design solutions of existing water problems.

Design development

This phase connects the relevance of research findings to the context of the site. WSUD and DEWATS focus on sustainable management of water that is closer to natural water cycle. Nature has its own elements to keep the resource flow in good health. The context shows that the water resources have to be managed with maximum efficiency with limited local resources. This is where the research meets the local need.

At the end of the thesis a compilation of possible design solutions and strategy is proposed with suggestions for implementation in reality.



Chapter one:
Defining the problem: Water issues in cities

Increasing problems

97.5% salt water
2.5 % fresh water

69.5% of the fresh water is locked in polar and glacier ice

29.5% of fresh water is located in the underground

Rest 1% makes the river and lakes etc.

(Shiklomanov, 1993)

We live in a world where the lands are surrounded by water, three quarters of total area are filled with water. Yet, water is one of the most valuable and shrinking resources as only 2.5% of this water is fresh water. Such a limited resource, is being exploited as we are 'developing' since the beginning; we want our economy to run faster. Throughout our constant consumption-based development, we pay almost no attention in keeping the water resources available and healthy for few more decades.

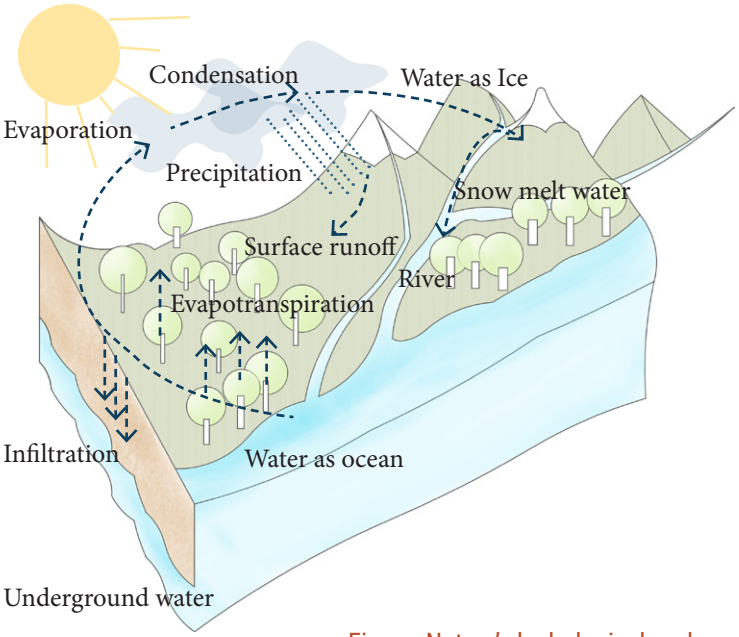


Figure: Nature's hydrological cycle

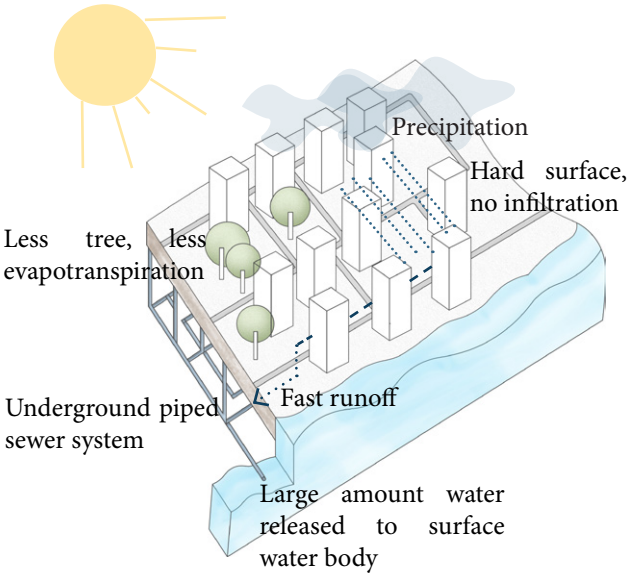


Figure: Urban hydrological cycle

As the world continues to urbanise, mass consumption and pollution are depleting natural resources and destroying natural ecosystems. Though the consumption of water is not equal for everyone in the world, a tiny part of the global urban population does get water from a water faucet. With a flush, it goes somewhere but no one wonders where it disappears to. On the other hand, there are areas without access to any sustainable water and sanitation systems. Further growth of the world's urban population (3 billion today, expected to reach 5 billion by 2030) (Reference), increases the demand for earth's resources and will lead to more inequity between those who have and those who does not have.

History of water drainage in urban areas

History of urban development shows that a rise of civilisation usually was located near water sources. However, we often forget that the declination of a civilisation was also highly related to the growing difference between supply and demand of the resources.

Pre-historic period

Humans learned not to only depend on water sources, but also started to create devices, such as water wells to store water around 6500 BC. (Ashkenazi, 2012). Being able to store water and dispose wastewater back to the water bodies had given the civilisations the chance to expand further from the water sources. In neolithic period, some mechanical tools such as pullies had been used to draw ground water for irrigation (Rashed, 1996).

A more sophisticated water management system can be traced back in the ancient Indus Valley civilisation of South Asia (current day Pakistan and Northwest India) (3300–1300 BC). The remains show that this civilisation had quite advanced hydraulic engineering, many of their water supply and sanitation devices were the first of their kind. The system of flush toilets existed in many homes, and were connected to a common sewerage network. The sewerage comprised of underground drains, built with precisely laid bricks. The urban areas of the Indus Valley civilisation provided public and private bath, and numerous reservoirs. Most houses also had private wells. City walls functioned as a barrier against floods (Khan, u.d.).

The ancient Greek civilisation of Crete used the first underground clay pipes for sanitation and water supply. The city was known for uses of toilets with flush, dating back to the 18th century BC. (Plumbing & Mechanical Magazine, 1989).

Figure above: An image of Indus Vally civilization showing the common sewer connected to households.(Kenoyer, n.d.)

Figure below: Roman aquaduct '*Pont du gard*' in south of France (yvesdequenne, 2009)

The Ancient Greeks of Athens and Asia Minor also had pressurised showers in houses (James & Thorpe, 1994). Pressurised piping had been used for fire fighting purposes in the City of Alexandria (Jeffe, 2006).

The Roman Empire had indoor plumbing, meaning a system of aqueducts and pipes that terminated in homes and at public wells and fountains for people to use. Rome and some other nations used lead pipes for plumbing purposes (CC, et al., 1987).

Traces of advanced plumbing can also be found in the Middle East and East Asia during the Qin and Han Dynasties (Chavalas, 2004).

Established network for wastewater collection can be mentioned as a breakthrough for human civilisations. In some cities, including Rome, and Istanbul, the ancient sewer systems are still functioning today. In the past, these sewer systems would release the wastewater in the nearby river or sea, while today, the pipes have been re-routed to modern sewer treatment facilities to retrofit with the present.

Early modern age

From then to the 17th and 18th centuries, very little progress was made in water management technologies. Also the knowledge was limited to the Romans and neglected throughout the

rest of the Europe. Medieval European cities used small natural waterways for carrying off. Eventually, they were covered and functioned as sewers. Open drains for waste water ran along the centre of some streets. These were known as "kennels" or canals, channels. The contents of the city's outhouses were collected every night by commissioned wagons and delivered to the nitrite beds where it was sown into the special soil beds to produce earth rich in mineral nitrates. In Paris, theses streets were known as "split streets," as it split the streets into two halves. The original purpose of designing and constructing a closed sewer for waste management was to get rid of the odour of waste water (Commair, 2009).

The use of human waste as fertiliser was especially important in China and Japan, where cattle manure was less available. However, most cities did not have a functioning sewer system before the Industrial era, relying instead on nearby rivers or occasional rain showers to wash away the sewage from the streets. In some places, waste water simply ran down the streets, which had stepping stones to keep pedestrians out of the muck, and eventually drained as runoff into the local watershed.

Modern age

The tremendous growth of cities during the Industrial Revolution quickly led to terribly over-polluted streets, which acted as a constant source for the outbreak of diseases. Flushing toilets and draining waste water to the public sewers were reserved to some extent for the rich people, as it also demonstrated political power. As cities grew, so did the concerns public health, (Staley & Pierson, 1899) and municipalities started to construct extensive sewer systems in many cities to help control outbreaks of diseases such as typhoid and cholera (Cutler & Miller, 2004).

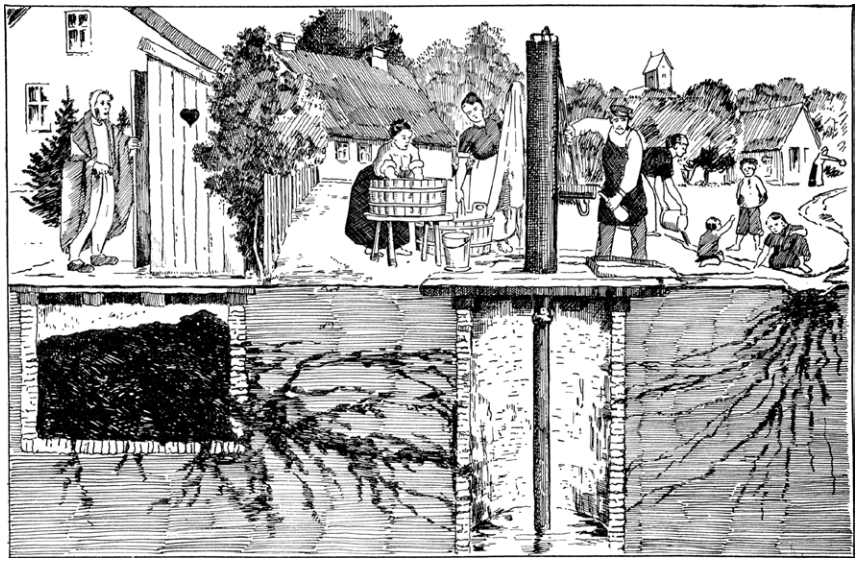


Figure: (An illustration showing various ways that a water well (centre) may become infected by typhoid fever bacteria., 1939)

Initially, these systems discharged sewage directly to surface waters without treatment. Later, cities attempted to treat the sewage before its discharge, in order to prevent water pollution and water-borne diseases. During the half-century around 1900, these public health interventions succeeded in drastically reducing the incidence of water-borne diseases among the urban population (Metcalf & Eddy, 1914).

Early techniques involved land application of sewage on agricultural land. In the late 19th century some cities began to add chemical treatment and sedimentation systems to their sewers.(Benidickson, 2011)

Figure above: Folsom lake, California in 2011 (Google Earth image of Folsom lake, n.d.)

Figure below: Folsom lake in 2014 (California Department of Water Resources, 2014

Scenario of the 21st century

Since the industrial boom all over the world, the urban water management is facing new challenges everyday. This is the time in human history when nature is not being able to reproduce the resources that the human societies consume. Same goes for the water system as well. Before, untreated release of water in to the water source was, to some extent, regenerated by nature's own system of soil properties or vegetation. But the rate of pollution introduced by the industrial era is way faster than the past.

A recent discussion has been circulated around California's water crisis. In the world of globalisation this kind of crisis does not only affect the locals but also translates to the rest of the world. The state produces large amount of world's total food production. Desperate measures have been taken to mitigate the crisis.

The effect of climate change is also much visible now on natural calamities and the failure of the present water management system. It invalidates the very first reason for the piped water system – draining of the water from surface to resume regular life. The flash flood in 2012 in Copenhagen has raised a lot of questions about the system's rigidity. Should we be trying to fit all the water from the city in some rigid network, or should we learn to live with water in a more flexible, productive and higher performance based system?

Problems of conventional water infrastructure

Unable to accommodate unexpected changes

A huge discussion for last few years has been the unexpected rainfall all over the world due to climate change; – either it is too much or too little. Developed cities, for example, Copenhagen, and Amsterdam have dealt with flood despite of having a well-organised drainage system. The previous drainage system is becoming obsolete for draining the unpredictable runoff. In such situations of unpredictable changes in the climate, the challenge is even more for developing cities.

Energy consumption

The problem with conventional urban water infrastructures (such as transportation and treatment of water) is that, it is energy consuming in many aspects. Cities from developed counties with resources are somewhat being able to run this expensive system. However, cities with limited resources from developing countries have never reached the goal of providing water service to all of their habitants, and wastewater is released to various sources without treatment. Still, these cities run behind the dream of being a 'piped one'.

Inadequate aquifer refill

Rapid urbanisation results into huge areas of hard surface that restricts water to go back to the aquifer and instead end up in the downstream. Thus, the underground water cycle is being reduced in an alarming rate.

Inadequate use of lower maintenance water resources

The conventional urban water management systems eliminate the possibilities of re-use of water with minimum energy use, for example capturing rainwater before it becomes runoff for the city and using it in agriculture or industry.

No interaction with the users

Another criticism of this system is that, it does not create any awareness about water use. From a tap, we get our water and with a flush, it goes somewhere – we do not wonder where it goes.

No waste (resource) revival

The household wastewater (black water) is full of nutrients. Most of the cases, the nutrient is thrown to the disposal. This nutrient can be regained to be used in agriculture.

Emerging pollutant

Urban habitats are introducing the use of new complex chemicals in their lives, which

eventually turn into refusals which mostly ends up in the water sources. An ever rising level of oestrogen hormones (from synthetic chemicals of household, industry, agriculture , etc.) in water has reduced the reproduction of aquatic habitats even after going through the wastewater treatment system.

Ecosystem collapse

In general, we discuss about the energy consumption of the conventional urban water system but we are still overlooking many dangerous issues brought by the system. The amount of nutrient and chemical pollutant released with the wastewater into waterbodies is altering the ecosystem completely.

Legend

A: Residential building
B: Industrial building
C: Commercial building
D: Water treatment centre
Supply water
Wastewater
E: Surface water
F: Rainwater
G: Ground water
H: Closed drain unable to accommodate weather behaviour, Result: flood.
I: More rain to come (Climate change/ unpredictable weather behaviour.
J: Distance travelled by supply water
K: Distance travelled by wastewater
L: Impermeable surface, Result: less aquifer recharge.
M: Emerging pollutant in water bodies, Result: Human-eco health disruption
N: No human interaction with water infrastructure.

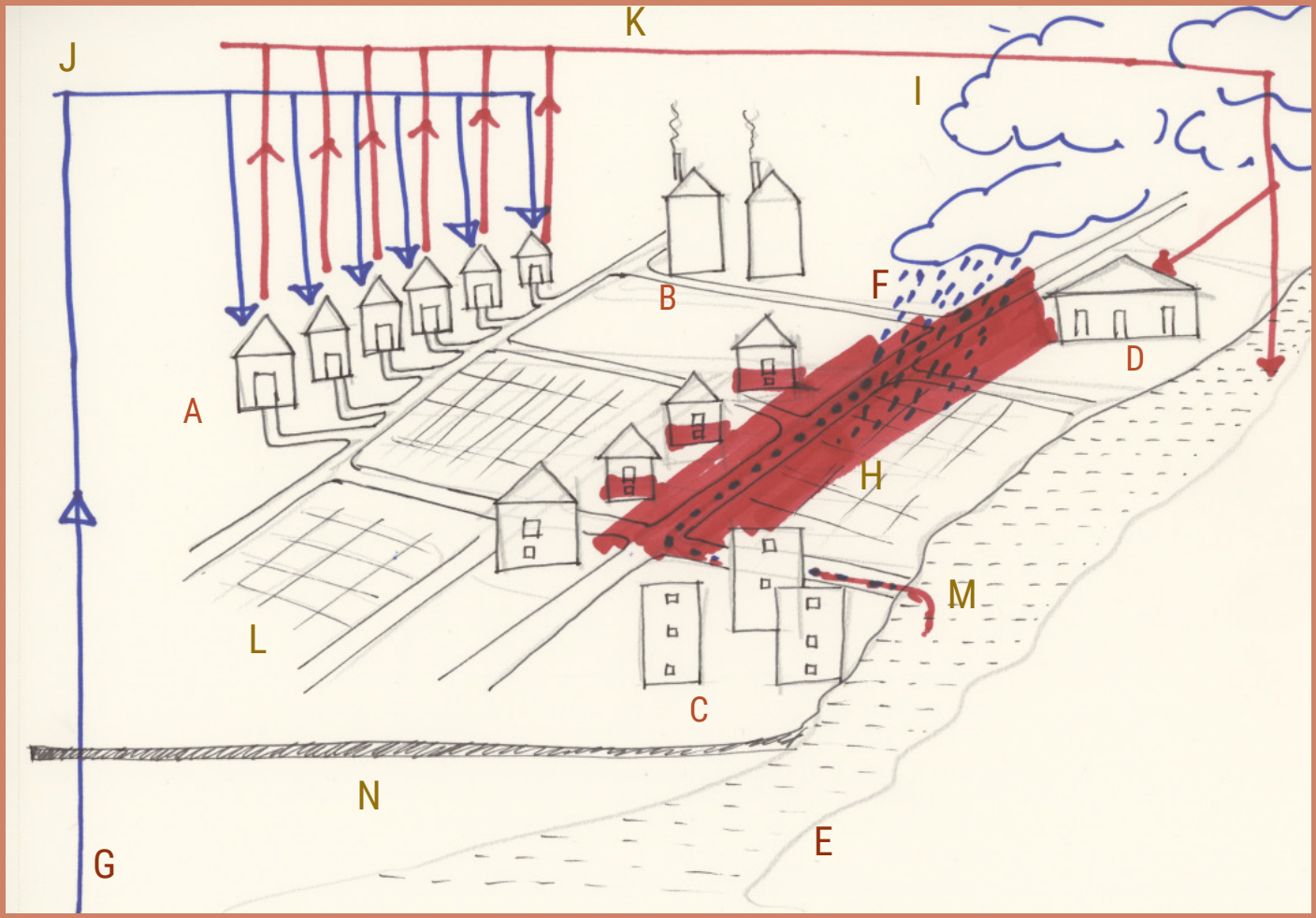


Figure: Illustration of the problems generated from conventional piped water management system

Chapter two:
The local context

Introduction to Bangladesh

Figure: Bangladesh, in the world map

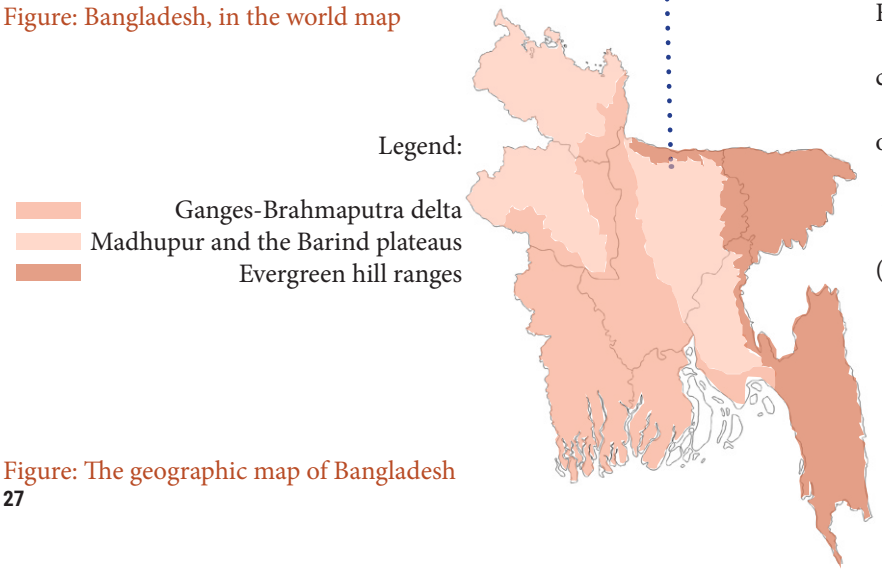


Figure: The geographic map of Bangladesh

Fast facts about Bangladesh

Capital:	Dhaka
Area: Total	147,570 km2/ 56,977 sq mi (92th in the world)
Forest	17%
Hilly area	12%
Population:	168,957,745 (8th in the world)
Density:	1,033.5/km2 2,676.8/sq mi (7th in the world)
Official language:	Bengali
Ethnic groups:	98% Bengali 2% other
Religion:	86.6% Islam (state religion) 12.1% Hinduism 0.6% Buddhism 0.4% Christianity 0.3% Others

Formation:

- Separated as East-Bengal from British colonization on 14 August 1947
- Declared independence from Pakistan on 26 March 1971
- Recognized on 16 December 1971

Currency: Taka (BDT)

(CIA, 2016)

Topography:

Geographically, Bangladesh is divided into three regions. Most of the country is dominated by the fertile Ganges-Brahmaputra delta. The Ganges delta is formed by the confluence of the Ganges (locally known as Padma), Brahmaputra (locally known as Jamuna), and Meghna rivers and their respective tributaries. The Ganges unites with the Jamuna and later joins the Meghna, finally flows into the Bay of Bengal. The alluvial soil deposited by the rivers when they overflow their banks has created one of the most fertile plains in the world. The northwest and central parts of the country are formed by the Madhupur and the Barind plateaus. The northeast and southeast parts are home to evergreen hill ranges. (Suvedī, 2005)

Bangladesh has a low-lying flat plain, almost all over the country, except for the eastern hilly region. Most parts of Bangladesh are less than 12 m above sea level. (Ali, 1996)

Climate:

Sitting on the Tropic of Cancer, Bangladesh's climate is tropical with a mild winter from October to February. A hot and humid summer runs through the rest of the year with a monsoon season lasting from June to August and supplies most of the country's rainfall.

Average Temperature:

Figure: Topographic map of Bangladesh (Lambert Conformal Conic projection, 2010).

Figure above: Tanguar haor, Bangladesh (Sumon, 2015)

Figure below: Image of fast urbanisation, Dhaka, Bangladesh (Karail slum, Dhaka, n.d.)

Winter 11° C - 20° C (October - February)
Summer 21° C - 38° C (March - September)
Rainfall : 1,100 mm to 3,400 mm (June - August)
Humidity:
Highest 99% (July)
Lowest 36% (December & January) (CIA, 2016)

Water- too Much but too little :

Bangladesh has 57 trans-boundary rivers, making water issues politically complicated to resolve – in most cases as the lower receipant state to India. (Suvedī, 2005)

In September 1998, Bangladesh saw the most severe flooding in modern history. There were several reasons for the severity of the flooding. Firstly, there were unusually high monsoon rains. Secondly, the amount of melted water from the Himalaya was also unexpectedly high in that year. Thirdly, a continuous process of deforestation to allow country's evergrowing need of development led to lack of trees that can sustain the land from flood. (Haggett, 2002)

Bangladesh is now widely recognised as one of most threatened the countries from climate change. It is estimated that about 10% of the land would be flooded if the sea level were to rise by 1 m (3.28 ft) (Ali, 1996)

The main source of drinking water for 97% of the rural population and a significant share

of the urban population is the ground water. (Bangladesh Demographic and Health Survey, 2004)

Economy

Bangladesh is a developing country, with a market-based mixed economy and is listed as one of the emerging markets of 21st century. After first few years of socialist policies since independence, in 1991, the country launched a range of liberal reforms. The Bangladeshi private sector has since rapidly expanded. Major industries include textiles, pharmaceuticals, shipbuilding, steel, electronics, energy, construction materials, chemicals, ceramics, food processing, and leather goods. The predominant export earnings of Bangladesh come from its garments sector, which is the largest manufacturing sector. The country also has a vibrant social enterprise sector. Foreign remittance from unskilled labour in different countries all over the world is another huge foreign currency earning for the country. (World bank, 2006)

Agriculture is the largest producing sector of the economy since it comprises about 18.6% of the country's GDP and employs around 45% of the total labour force. (CIA, 2016) The performance of this sector has an overwhelming impact on major macroeconomic objectives like employment generation, poverty alleviation, human resources development and food security. The country ranks among the top producers of rice (4th), fish (5th), jute (2nd), tea (10th) and tropical fruits (5th) (Golub & Varma, 2014)

Urbanization:

Urbanization in Bangladesh is moving at a rapid pace. Between 1961 to 1981, the average urban growth rate was 8%. The present average growth rate is about 4.5%. According to the population census of 2001, the share of urban population was about 23.29% and at present it is approximately 37%. The importance of urban development is emphasized in terms of its role in the national economy. More than 60% of the national GDP is derived from the non-agricultural sectors that are mainly based in urban areas. Again, the most foreign exchange earning sectors, like, garment and knitwear enterprises are agglomerated in urban areas. These sectors earn over 70% of the foreign exchange. Remittance is also a major sector of foreign exchange earning and a large share of the remittance goes into the purchase of urban land. Surplus remittance is invested in business and manufacturing located in urban areas. These phenomena indicate the increasing role of urban areas being played in the national economy. The expansion of urban economy leads to the growth of urban population and concomitant haphazard urban spatial growth without planning. (District town infrastructure development project (DTIDP), 2015)

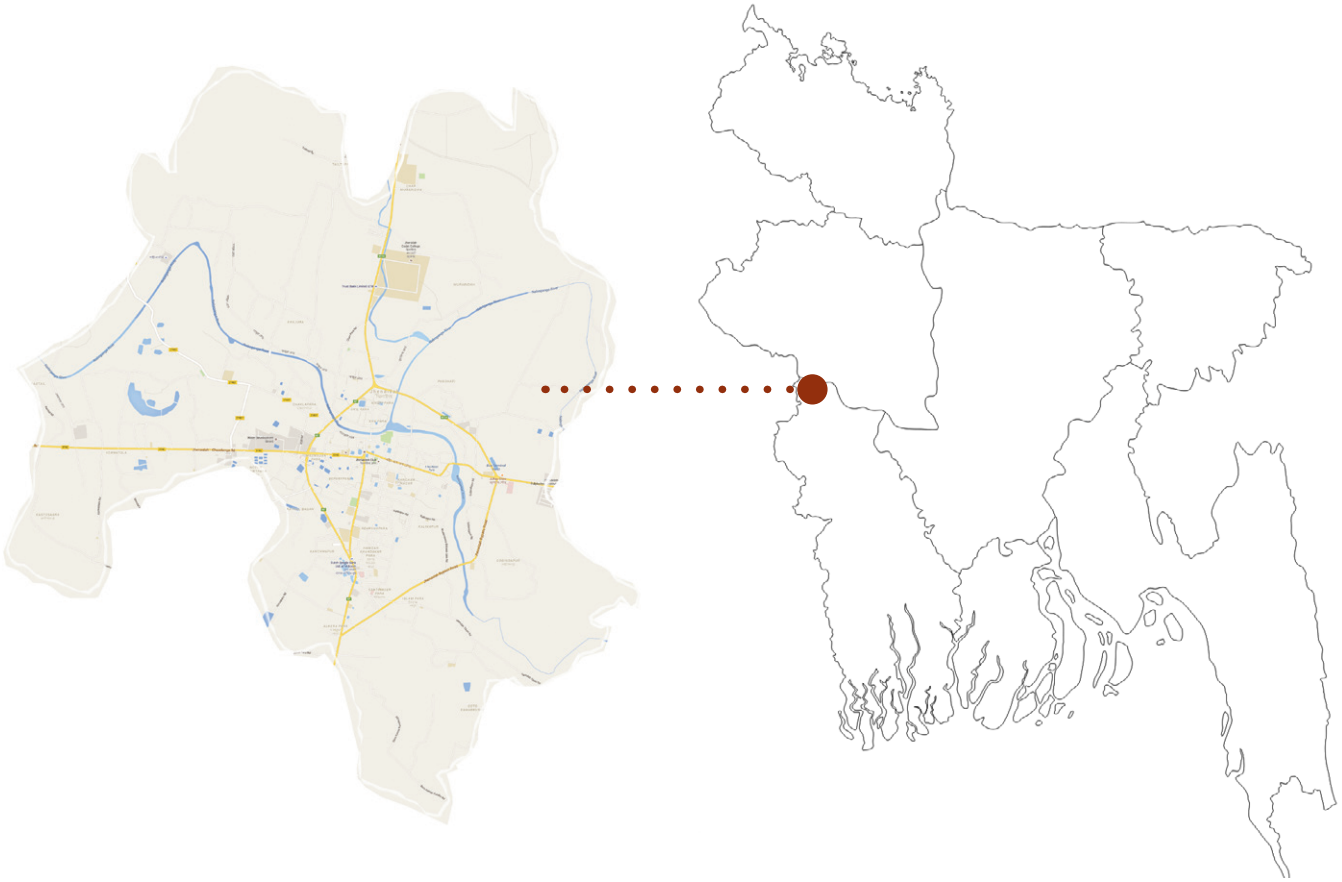


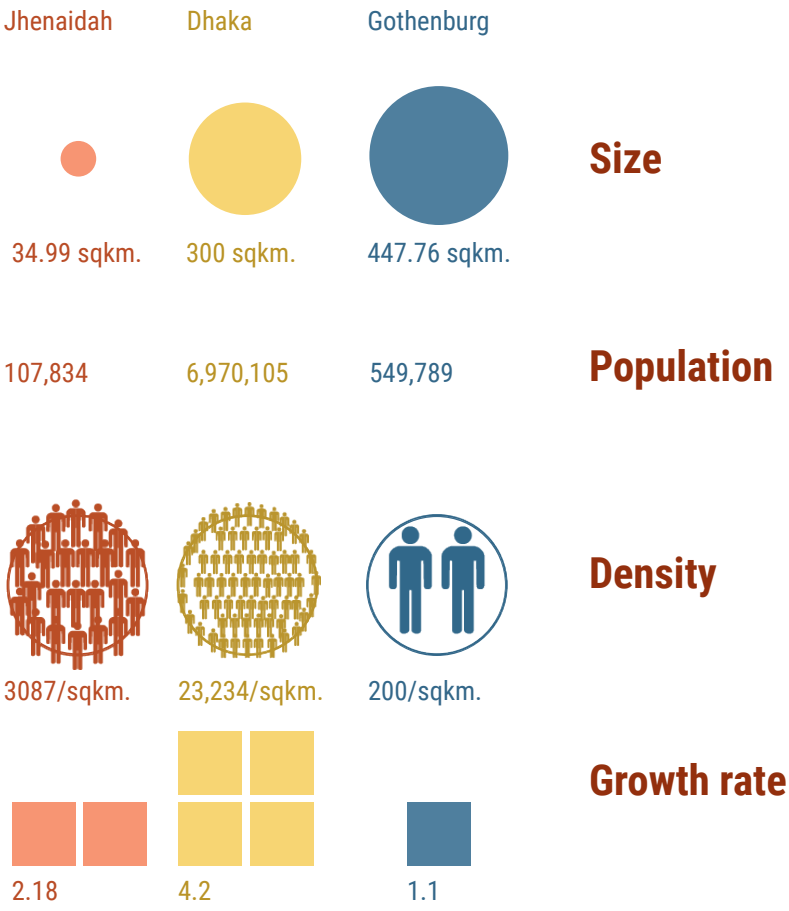
Figure: Jhenaidah, in the map of Bangladesh (Google map, 2016)

Introduction to Jhenaidah

Jhenaidah Municipality stands on the bank of the Noboganga River. Located on 210 km west to the capital city(Dhaka) Bangladesh. Jhenaidah Municipality was established in 1958. This is a class "A" municipality. The municipality consists of 9 wards and 33 *mahallas* (neighbourhoods).

"A beautiful and productive river (Noboganga) with clear water, meandering through the heart of Jhenaidah city, is a common nostalgia of the people. Middle-aged people would be relishing their memories from past, how they coexisted with this river, how "sacred" it was to them, how they taught their children to respect its water. Every house would be facing the river while the toilets are placed in the back. Continuous earthen walkways were there along the river, which are now disconnected by open toilets and garbage dump. This negative change happened within one generation. But 30-40 years back they were much concern before dumping anything in the river as the water was used for daily chores, cleaning, cooking, ablution, etc. The river was never a "back" for them; it was deliberately a wonderful "face" to their life and living" -Architect Suhailey Farzana

Comparison: Jhenaidah, Dhaka of Bangladesh and Gothenburg of Sweden



(CIA, 2016)

Historical background

Different concepts can be found for the name Jhenaidah. Jhenaidah was introduced from "Jhinuk" and "Dahon". Jhinuk means oyster in Bangla and Dahon means to burn. Once oyster used to be collected from Nabaganga River, and were burnt to prepare "Chun" that is Calcium Chloride. So Jhenaidah comes from "Jhinuk" + "Dahan" = Jhenukdah, and finally Jhenaidah. Some other concepts are also found but another acceptable concept is "Jhinuk" + "Daho" = Jhinukdaho. According to this concept "Daho" means village or big ditch. So this was the big ditch or village of oyster , according to this concepts. Both the concepts link the settlement's relationship to its river Noboganga and the habitat of oyster that was once found here..

The trace of established settlement in Jhenaidah dates back to fifth century. At that time, the area was included under Bongo Empire, sixth century under Gupta kingdom; seventh century Jhenaidah was ruled by Sasanka king of Goar. After that the area was subjected to frequent war and was under the rule of few different reigns of short periods. In the middle of the eighth century, Jhenaidah came under Pal kingdom. The conquer of Pal kingdom by Bormon Empire took place in 1080 and Bormon Kings ruled this area till 1150. After the conquer of Bormon kingdom by king Sen, Sen kingdom came into the ruling.

The introduction of Muslim reign started after the conquest of Bongo (Bangla used to be referred as "Bongo" back then) by Ikhtiar-uddin Mohammad bin Bokhtiar Khilji. In the middle of thirteenth century, Sultun Mugish Uddin Tughrol included Jhenaidah under Muslim reign (Lakkhanaboti). In 1342, Sultan Shams Uddin Ilias Shah declared Lakkhanaboti as an independent state (Saltanat) and accumulated all Bongo under one administrative structure.

After the introduction of Mughal reign in India Jhenaidah was included under the Mughal kingdom, when "Raja" King Propaditta was defeated by Mughal General Islam Kha.

The last independent Nabab Siraj-ud-Doula was defeated by East India Company in 1757 and so started the period of East India Company (although Jhenaidah came directly under English in 1781). During the English period they introduced 'Nil' (Indigo) cultivation in this area. Administrative center 'Mahakuma' was established in Jhenaidah in 1861. During the Pakistan period and before 1984 Jhenaidah Mahakuma was the administrative center. In 1984 Jhenaidah Mahakuma was upgrade to District. (DTIDP), n.d.)

Figure, left: Jhenaidah city centre (Hasib, 2014); right: Main business street of Jhenaidah (Baidya, 2016)

Figure, left: Newly developed weekend market (Jhenaidah municipality, 2016); right: Noboganga river (Khondaker, 2016)

Master plan (2015-2030)

Water Supply

In Jhenaidah Municipality, there are 928 permitted tubewells and 14 water pump houses. The pump house present in the Municipality is used for piped water supply.

Water production:

1200 thousand litres
Backlog 17000 thousand litres.
By 2030 the backlog will be, 28000 thousand litres.

Sewerage System

There is no proper sewerage system in the Municipality. The Municipality authority does not have any record of sanitation condition. However, according to the socio-economic survey done before proposing the master plan, about 64.21% households have Pucca (permanent) sanitary latrine and 1.78% have pit latrine facilities. The town lacks sewerage system and people use to dispose off household sewer to the surface drains/ surface water bodies. Most of the outlets of the drains are discharged in to the river Noboganga without any treatment measures. Inadequate maintenance of human, domestic and market wastes, open and poor drainage system, water logging etc. create environmental degradation within the Municipality area. Drains are mostly clogged that can not drain out water during heavy rains and natural drainage systems have either been filled up or occupied by land grabbers creating water logging during monsoon.

Drain:

Primary drain: Nobogonga river
Secondary drain: built (closed or open) drain, 943 ponds and ditches
Tertiary drain: connections from households to secondary drains.

Solid Waste Disposal

Jhenaidah Municipality generates a massive quantity of solid waste everyday from various sources. There are a few dustbins/locations for dustbins, claimed by the Municipality, among which five of them could be identified as a physical feature during the survey for the master plan. However , this (claimed) number is not sufficient for the city dwellers. Among the five dustbins/locations for dustbins, two in each wards 5 and 6 (core areas) have two each and one in another ward has been identified. In the absence of any specific rules and criteria for placing the dustbins, most of the households do not use the dustbins properly. As a result, they dispose off their waste on the roads, drain sides, low-lying areas or individual's backyards. The Municipality does not have any dumping site of its own. All wastes are being dumped in a low-lying suburban area. (District town infrastructure development project (DTIDP), n.d.)

Figure, left: Zoomed into the site; drainage proposal from the masterplan of Jhenaidah (2015-2030 (District town infrastructure development project (DTIDP), 2013)

Figure above: Disposal of household solid waste everywhere in the city.

Figure below: Disposal of household waste water directly to the river.

Climate:

The climatic condition of Jhenaidah Municipality is dominated by the monsoon and can be categorised into four seasons: (i) winter (ii) summer (iii) monsoon and (iv) post monsoon season. The winter season starts in November. During winter the daily maximum and minimum temperature ranges from 29.4°C to 11.00°C. During summer the daily maximum and minimum temperature ranges from 35.7°C to 17.8°C.

River pollution

There is no station in Jhenaidah; according to meteorological department of Bangladesh the nearest Jessore station is the station of Jhenaidah and information about the temperature and rainfall will be same. The highest annual rainfall was recorded in 2004 (2444 mm) with highest monthly rainfall of 917 mm. In this time period the lowest rainfall was recorded in 2001 (1457 mm).

The area of Jhenaidah Municipality is not subject to annual flooding. This Municipality did not get affected during the major floods of 1988 and 1998 or 2004. 'High water level' with respect to the mean sea level in latest as well maximum level in the record, shows that the level ranges

from 2.65 meters (in February) to maximum 4.86 meters (in September). However, the survey point (benchmark data) near Jhenaidah Municipality just beside the river - approximate 6 meters (above the maximum high water level) provides the justification of flood free Jhenaidah. On the contrary, tides in the Noboganga river ranges from 0.5 meter to 1.0 meter during the dry season and 1 meter to 1.5 meter during the wet season. Although Jhenaidah Municipality is free from floods, it is subject to water logging. Water logging is happening due to drainage congestion of surface water specially during the rainy season. Water logging is a common problem in this area.

Existing manpower and equipments

There is an acute shortage of manpower in each section of the Municipality. The Municipality has only 96 officials against 135 allocated in the Municipality organogram. In the Administration Division, there should be 50 officials but there are only 35 officials working in that division. In the Health and Family Planning Division, 16 are working against the post of 28 and in the Engineering Division, 45 are working against the available post of 57. In the Municipality, two important posts of Chief Executive Officer and Health Officer are also vacant. 28.89% posts of this Municipality are vacant. It can therefore be easily said that there is a huge lack of staff in this Municipality and it needs more manpower to run its functions efficiently.

There is also a huge lack of equipments in the Municipality. It lacks 2 road rollers and 1 trucks which are very necessary for development activities. There are 8 computers which minimised the lack of type writer machine and also increased the efficiency of the officials. (District town infrastructure development project (DTIDP), n.d.)

Proposed urban services

Legend:

- Bench Mark (BM)
- District Headquarter (DC Office)
- Upazila Headquarter
- Pourashava Office
- Union Parishad Office
- Khas land
- Kindergaten
- Primary School
- Madrasha
- High School
- College
- Hospital/Clinic
- Health Centre
- Mosque/ Mazar
- Temple/Church/Pagoda
- Eidgah
- Graveyard
- Crematorium
- Museum
- Monument/Shahid Miner
- Cinema Hall/Auditorium/Theater
- Historic Sites
- Park
- Playground
- Open space
- Railway Bridge
- Railway Over Bridge
- Sluice Gate
- Refueling Station
- Power Plant/Electric Sub-Station
- Fire Service
- Gas Transmission
- Police Box
- Police Station
- Traffic Signal Post
- Boat Ghat
- Ferry Ghat/Landing/Launch Terminal
- Railway Station
- Helipad
- High-Volt Electric Tower
- Tele-Communication Tower
- Radio/TV Tower
- Post Office/Post Box
- Water Pump House
- Overhead Tank/Water Reservoir
- Town Centre
- Neighborhood Centre Complex
- Renewable Energy Centre
- Central Park & Motel
- High Income Housing
- Low Income Housing
- Resettlement Area
- General Industrial Zone
- Noxious Industrial Zone
- Central Graveyard
- Solid Waste Disposal Site
- Surface Water Treatment Plant
- Sewerage Water Treatment Plant
- Medical College
- University
- Polytechnic Institute
- Veterinary Hospital
- Bus Terminal Complex
- Truck Terminal Complex

Figure: Proposed urban services for Jhenaidah Municipality (District town infrastructure development project (DTIDP), 2013)

Structural map

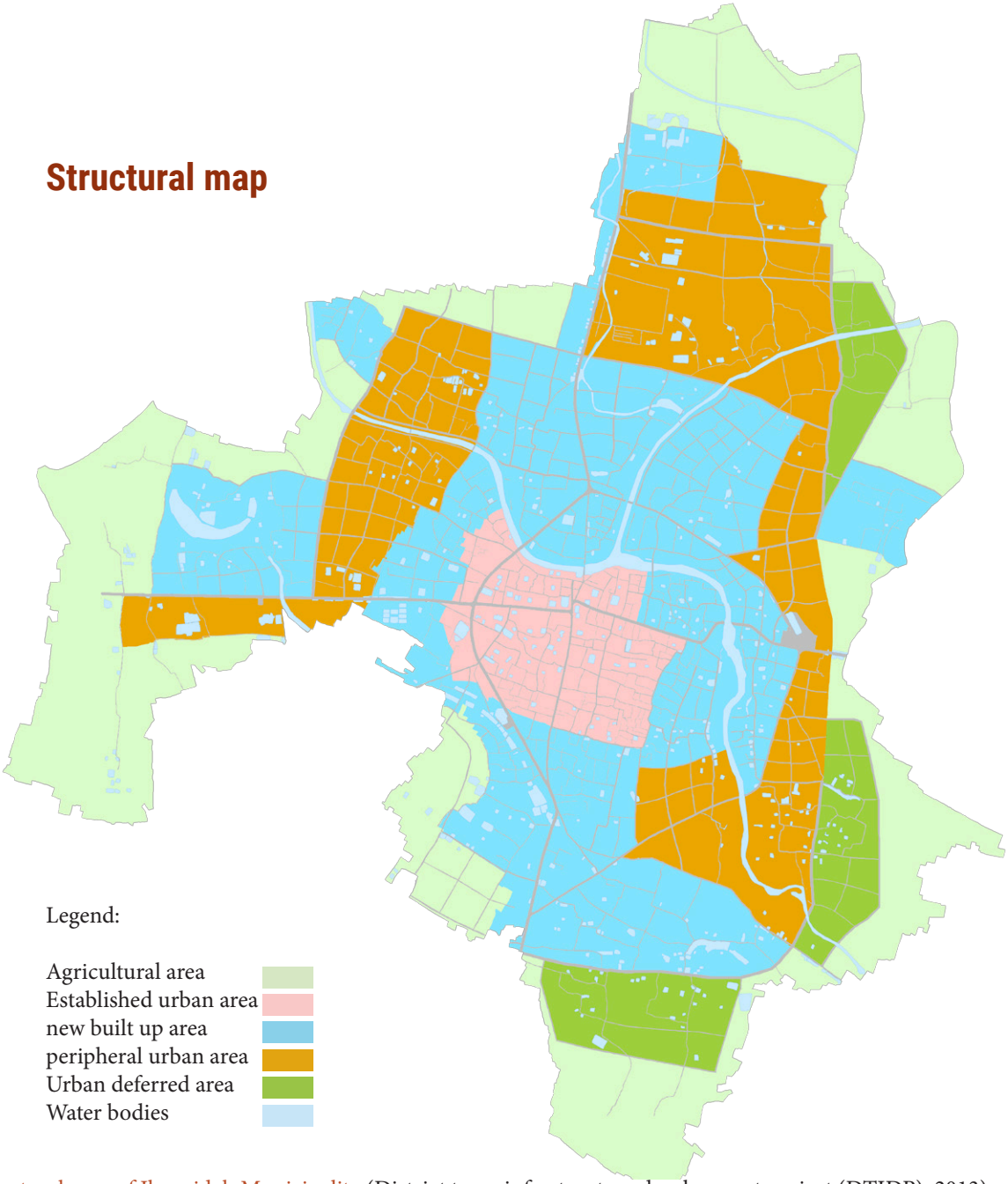
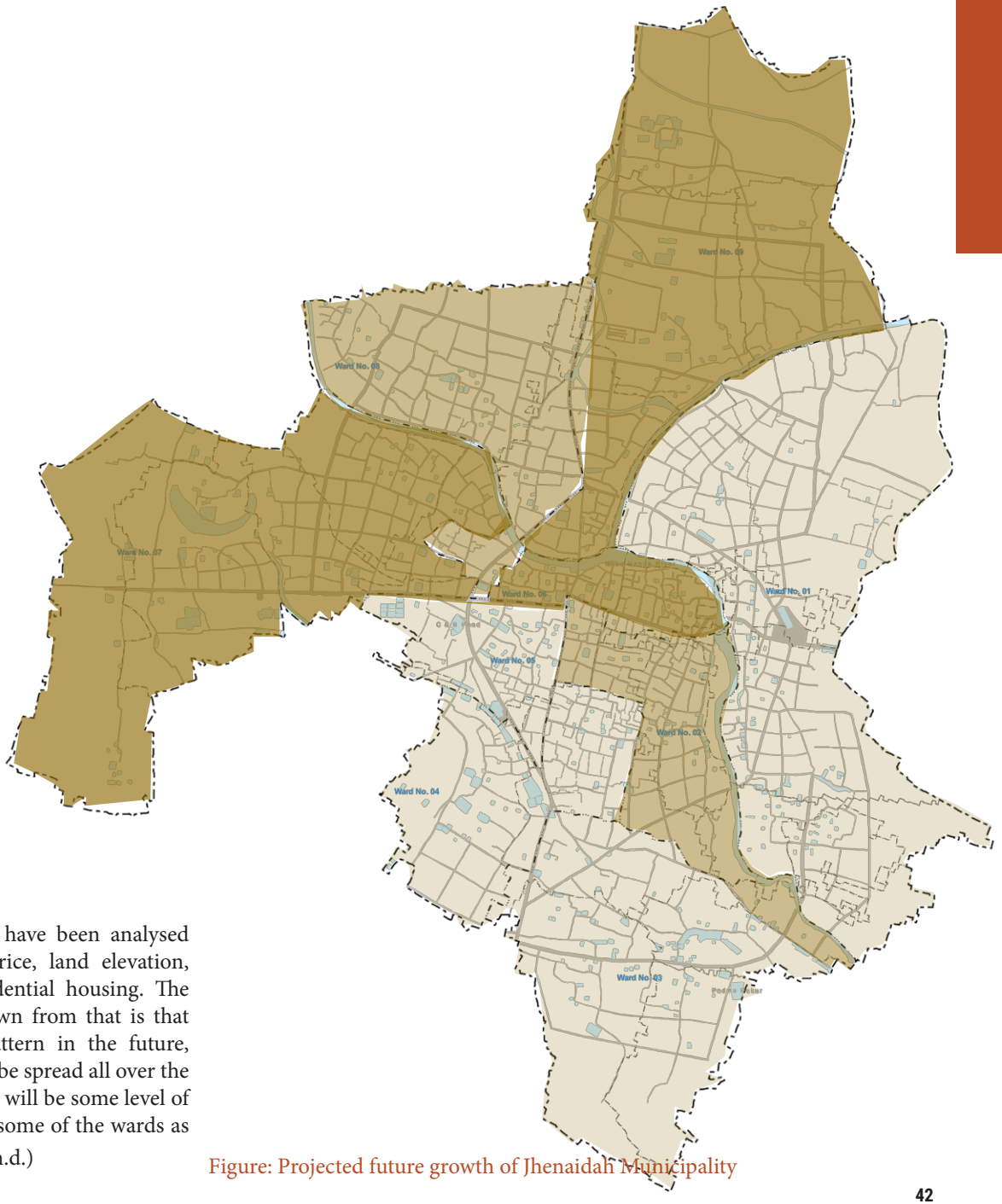


Figure: Structural map of Jhenaidah Municipality (District town infrastructure development project (DTIDP), 2013)

Future growth



Legend:

Highest growth
Medium growth
Lower growth

Four major spatial aspects have been analysed in the masterplan: land price, land elevation, road accessibility and residential housing. The conclusion that can be drawn from that is that growth will take linear pattern in the future, along the road. Growth will be spread all over the Municipality area, and there will be some level of concentration of growth in some of the wards as show in the map (DTIDP), n.d.)

Figure: Projected future growth of Jhenaidah Municipality

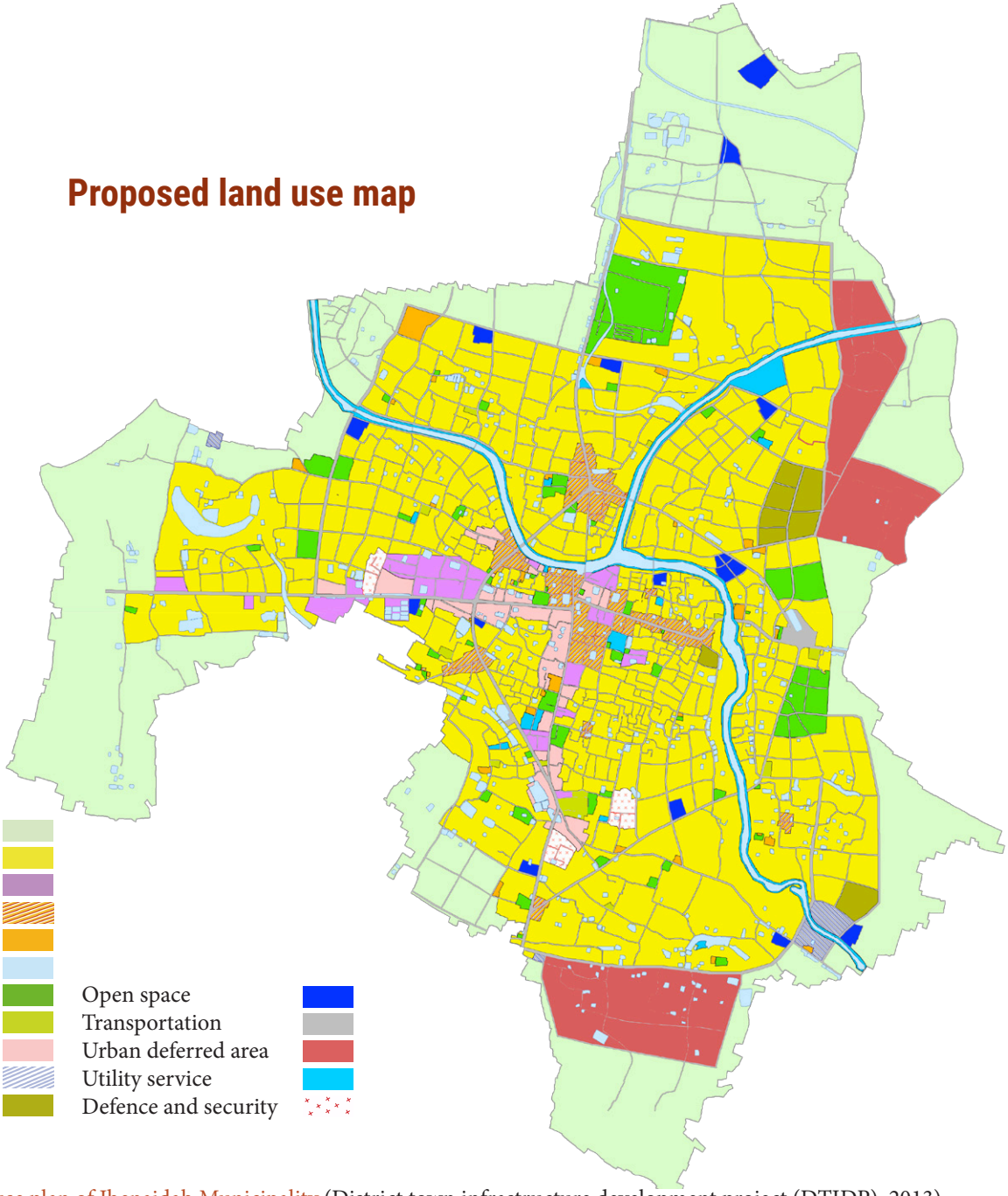


Figure: Proposed land use plan of Jhenaidah Municipality (District town infrastructure development project (DTIDP), 2013)

Conclusion: Understanding Jhenaidah as an informally grown city

As I have discussed previously, the municipality is in a huge shortage in terms of man-power and equipments. According to the suggested organogram, the engineering department should have 6 engineers of all fields, while it has 5 engineers. There is only one planner for the whole municipality. The post of 'slum upgrading officer' is vacant. There are no architects/landscape architects or other design professionals working for the municipality.

My point for elaborating this organogram is to focus on the impossible scenario for this structure to provide planning service for the whole municipality. This is exactly what is happening in Jhenaidah and many municipalities in Bangladesh. The citizens are moving much faster than the city can provide for them. The citizen has to discard waste or wastewater whether there is any waste collection/draining system or not.

The national focus on economic development has taken the country a long way, even with some complex problems (overpopulation or natural hazards). In a short period of time, Bangladesh is on the verge of becoming 'middle income country' from 'developing country'. The economic development of the cities are driving people to come to the city for work, and Jhenaidah is no exception. So, when new people are coming to the city everyday, the need of housing is increasing. The people start to built, not only houses, but also additional infrastructure, even if it is a bare minimum. Since the enforcement of the law is not strong enough to make people build according to the proposed master plan, the city keeps growing informally and the master plan with all its good intention stays only on paper.

In such a situation the municipality has to have more realistic approaches for a better and sustainable development of the city. When there is not enough people to design the city in the top, the 'top-down design process' cannot work. Since the citizen are active in building the city, the best idea for the municipality is to acknowledge and encourage people's initiatives with as much technical support as possible, flexible financing system and sensible policy for people to use all the available resources. The municipality should aim at strengthening their structure in order to assist these initiatives, not to run after an unachievable goal of 'provide for all'.

A danger that both the municipality and people's initiatives have, is the example of most developed megacities of Bangladesh. Dhaka (the capital) or Chittagong (the port city) can be called successful in economic prospects. Since economic development is the priority for any municipality, running way forward than environmental or social development, being another Dhaka or Chittagong seems to be the aim. This is not considered good in long run, since Dhaka has lost almost all of its water bodies and green spaces to 'development'.

Chapter Three:
Field research and participatory work

Introduction

The field trip carries important insights for this thesis work. It is important to be introduced with various actors, contribution from them through interview, discussion or workshop to understand the relevance of them to the thesis work. Moreover, the time when the event took place is also very important to understand the sequence of analysis each event brought to the thesis. In next occasions, I will go in detail of the each events, before that, the following list shows how the site activities are documented in this booklet.

Contributors' background

Introduction to the organizations who cooperated. These groups are active in development works in Jhenaidah municipality, so they have great knowledge about the real situation.

Site Inventory

The complex relationship of different elements is illustrated, so that the discussion later can include the influences and roles of each of them during the activities.

Time-line

Time-line includes list of site activities according to the date of execution. The whole field trip can be divided into three parts depending on their focuses. All of them had interviews, workshops, focused group discussions etc.

First phase

Analysing the strength of communities and city-wide network through different activities.

Second phase

Activities to find problem, strength, resource etc. of the chosen community.

Third phase

Possible design solution and feedback.

Contributors' background

Platform of Community Architects And Activists (POCAA)

POCAA is a platform for group of architects who introduce themselves as 'community architect'. POCAA began its journey with an intention to work for disadvantaged communities (though not limited) by housing and community development. To their belief, mapping is a tool that can bring the communities strengths, conflicts, mutual interests, threats, opportunities together.

The platform is currently active in Jhenaidah municipality together with the Department of Architecture, Brac University of Dhaka, Bangladesh. POCAA is working in Jhenaidah with two external funding, received from ACCA (Asian coalition for community action) and Perween Rahman Fellowship. The ACCA funding is for two kinds of projects. The bigger budget is a seed fund to start a revolving loan system for housing development. There is also smaller fund for small-scale intervention that community can decide to spend on any kind of infrastructure development.

In the beginning of my thesis work, I have conducted an interview with one of the architect. Later, when I visited the site, I was accompanied by POCAA several times for my workshops, focus group discussions, interviews, filming, and different site visits as well as I participated in the meetings called by POCAA. The processes, contents and reflects from these activities will come up in this booklet according to relevance. This collaboration has turned to be crucial both for my thesis and POCAA.

POCAA has close connection to Brac University, one of the leading Universities of Bangladesh with Architecture department. I was invited as a guest tutor and encouraged to use this connection to conduct a workshop with students of this university.

Alive

Alive is a local NGO, active in Jhenaidah and some other cities of Bangladesh. They have collaborated with POCAA for housing development project at Mohishakundu Shordarpara community. They are responsible for mobilising, skill developing in other communities. Together with POCAA, they are now working to establish a city-wide network of low- income communities in Jhenaidah municipality.

Alive has projects running about medical waste management, water quality measuring in other cities. Currently, they are preparing to launch a project of community-led solid waste, wastewater management and urban food production.

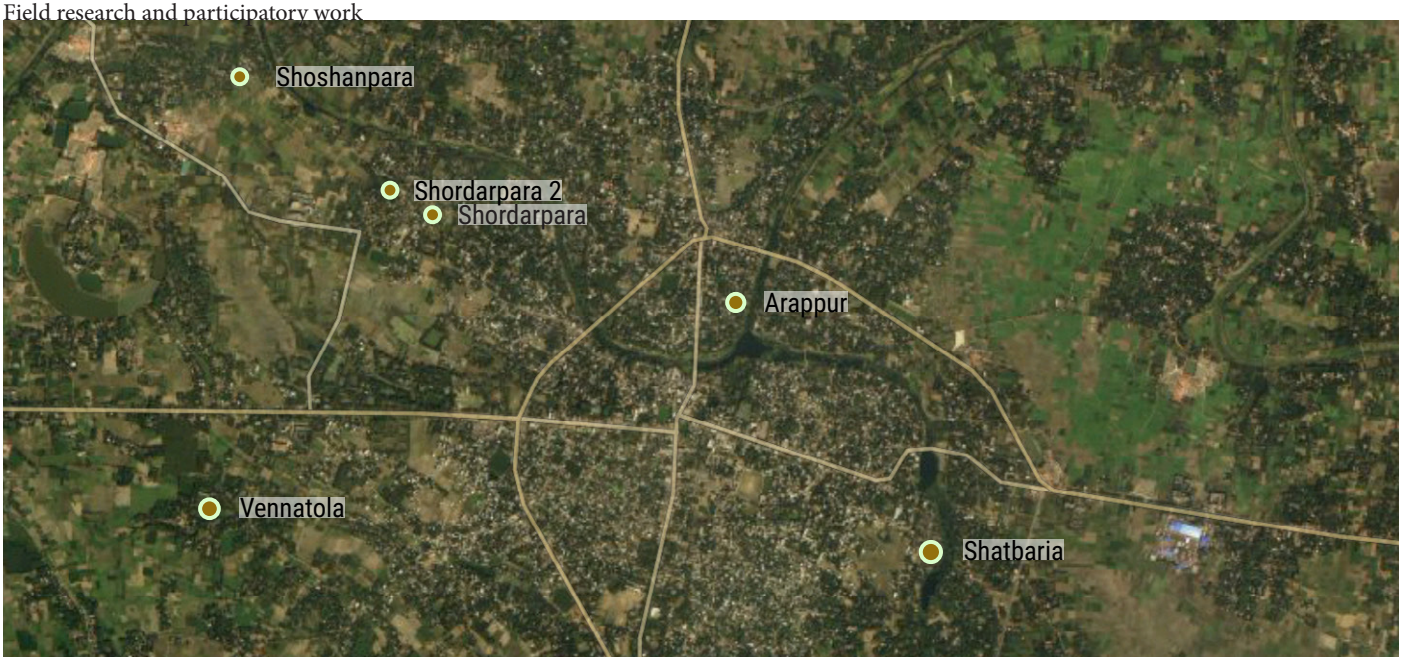


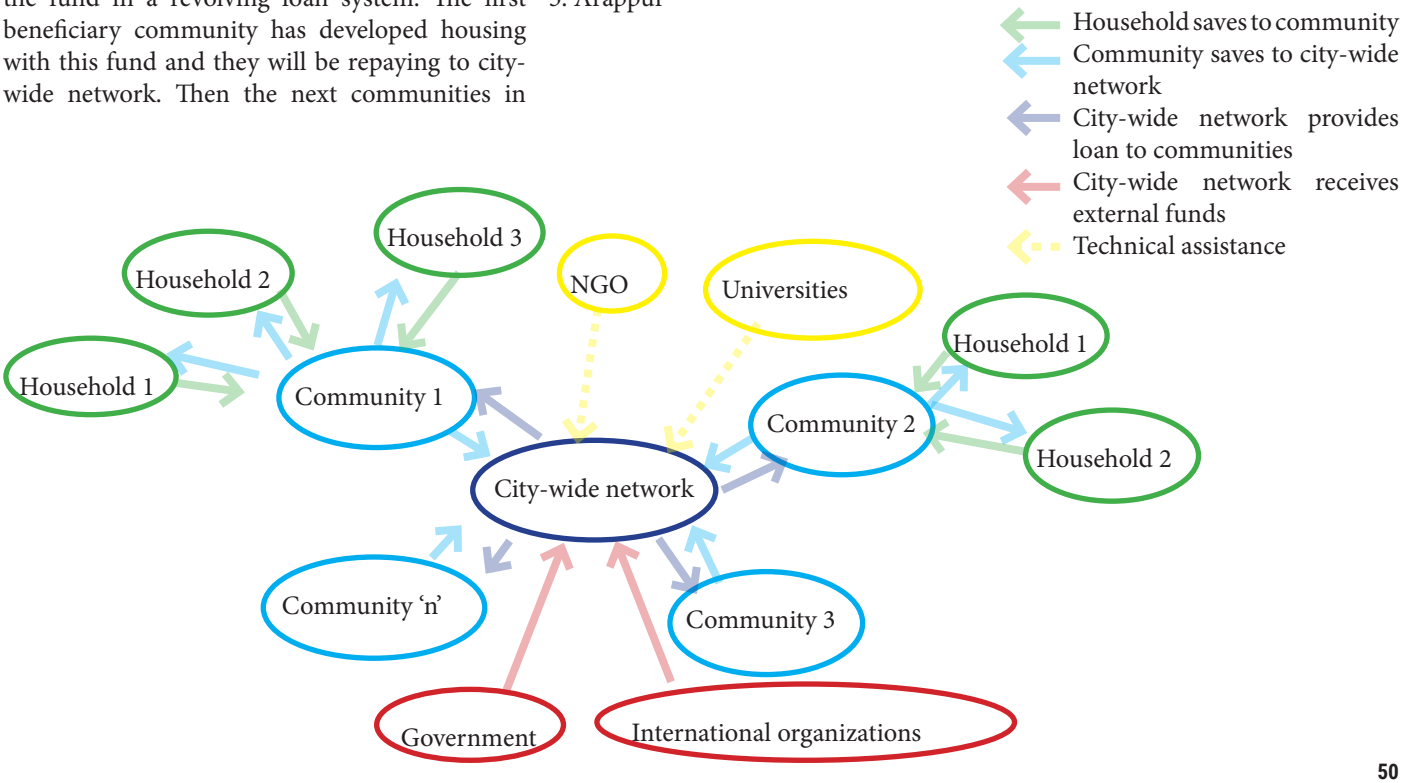
Figure above: Positions of the communities of city-wide network on google image (Google Earth, 2015)

Figure below: A day of sharing skill through city-wide networking (Farzana, 2015)

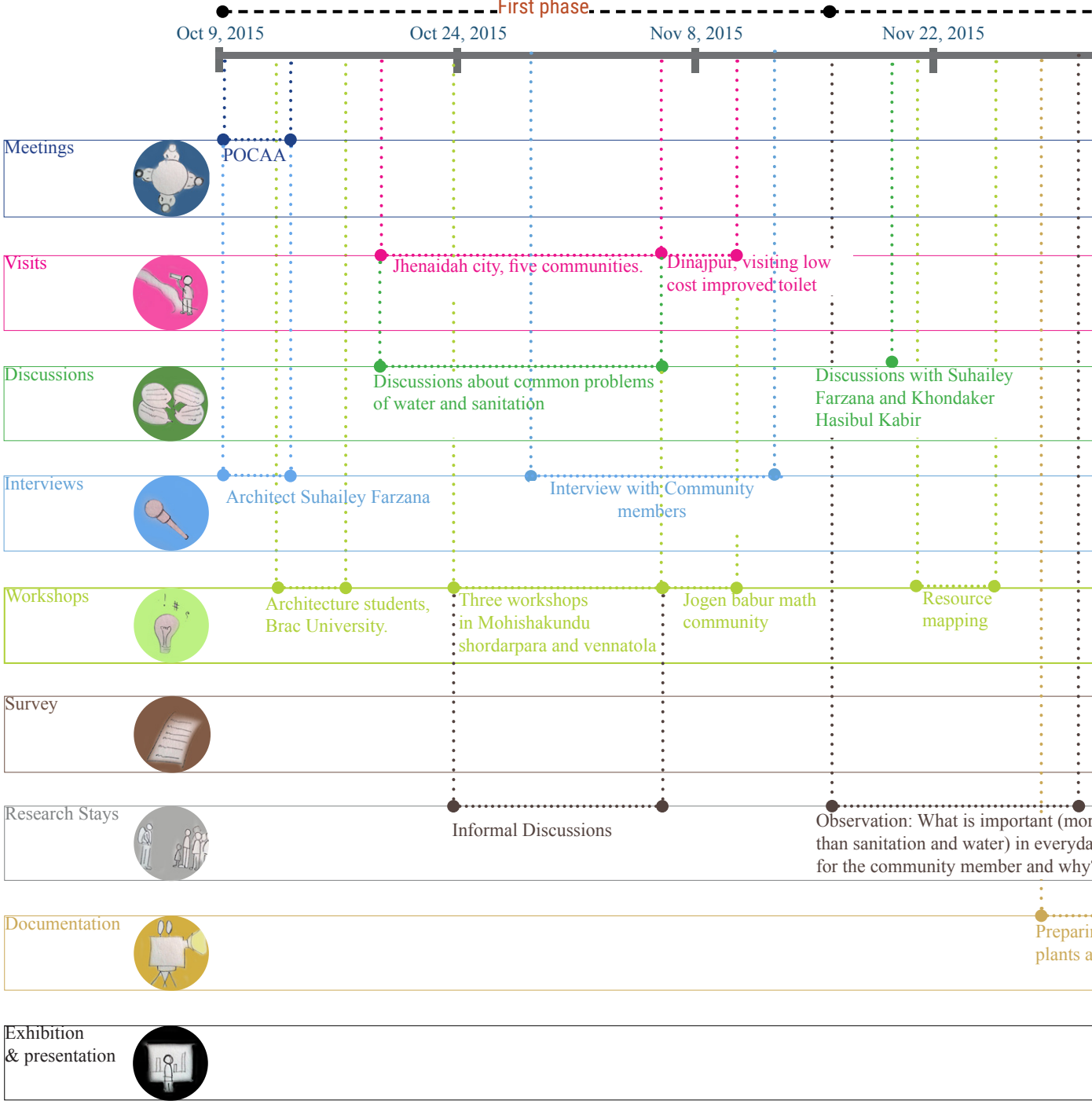
City-wide network, Jhenaidah

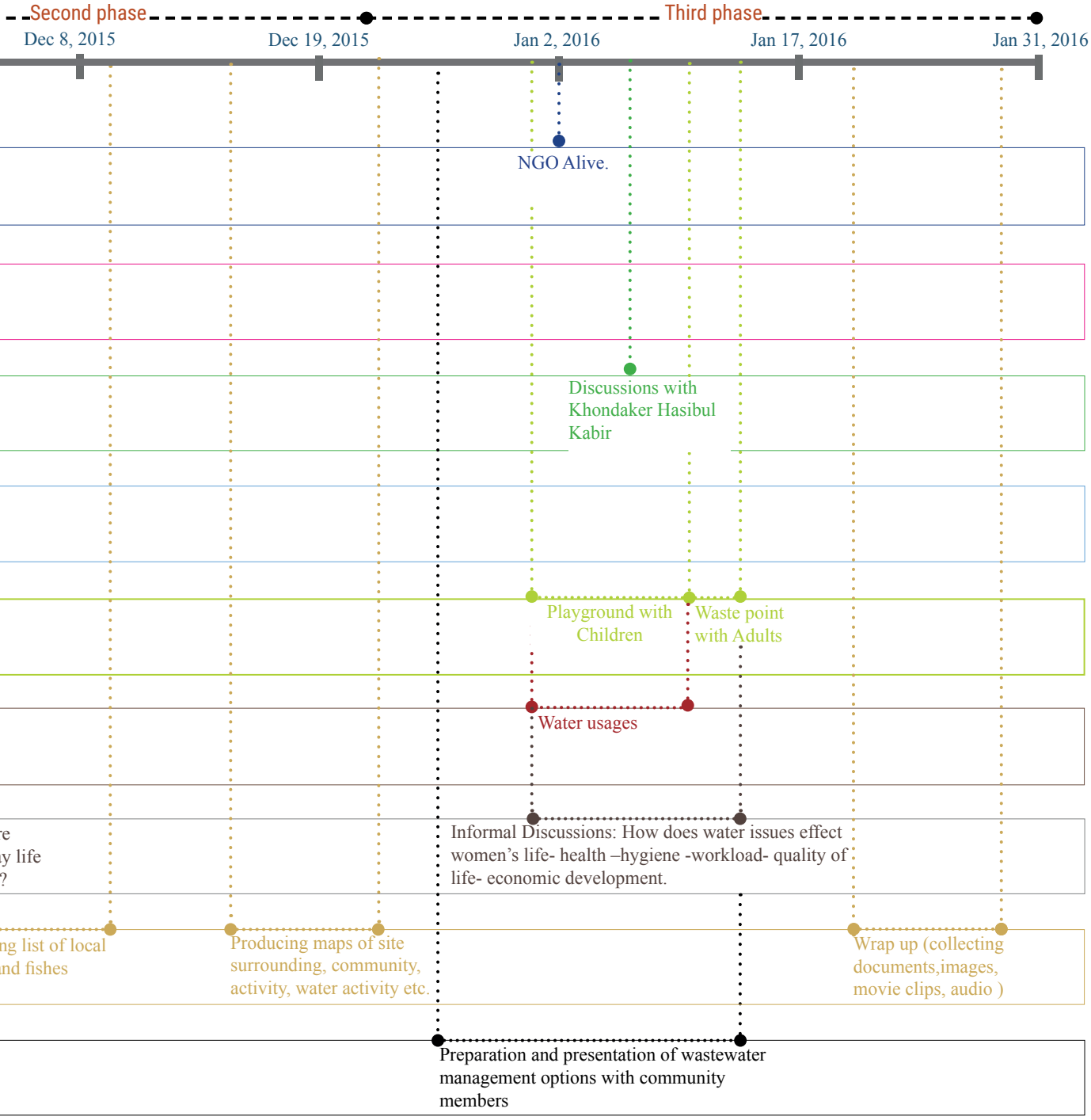
The low-income communities are trying to form a city-wide network. Currently, this network has 5 communities as members and few more as interested. The basis of creating a network is to start saving group within community. The member communities have been saving for last one year. City-wide network has received one funding from ACHR (Asian Coalition for housing development. The idea is to include the fund in a revolving loan system. The first beneficiary community has developed housing with this fund and they will be repaying to city-wide network. Then the next communities in pipeline will receive the fund. The network aims to expand the fund from their own savings along with the external funds. The name of the existing five communities of city-wide network are:

1. Mohishakundu Shordarpara
2. Mohishakundu 2
3. Shoshanpara
4. Vennatola
5. Arappur



Timeline of field research




Second phase
Third phase
Dec 8, 2015
Dec 19, 2015
Jan 2, 2016
Jan 17, 2016
Jan 31, 2016
NGO Alive.
Discussions with Khondaker Hasibul Kabir
Playground with Children
Waste point with Adults
Water usages
Informal Discussions: How does water issues effect women's life- health –hygiene -workload- quality of life- economic development.
ng list of local
nd fishes
Producing maps of site surrounding, community, activity, water activity etc.
Wrap up (collecting documents,images, movie clips, audio)
Preparation and presentation of wastewater management options with community members

Phase one: Mapping the 'strength' in the city

The first phase of field research was dedicated to learn about the municipality overall, learning about its strength and weaknesses, communicating (through interview and workshop) with the design professionals and NGO-s who have been working on ground. An important step was to locate the community base organisation and to learn (by walking the city with them, mapping workshop, focused groups discussion, etc.) how they organise their activities from the first hand.

Discussed topics

Interview with POCAA

Date: 12.10.2015

Place: Brac University, Dhaka, Bangladesh

During the interview, architect Suhailey Farzana, who is responsible for POCAA's Jhenaidah project explained the scope of my thesis work in the city.

Reflection from the interview

- Community needs mobilisation.
- Possible business around the river.
- Small scale intervention fund might be available.
- Land grabbing is a big problem.
- All wastewater go directly to the river.
- Water-front small scale development is possible
- The city has no public places to celebrate the festivals or holidays.

Field stay activity planned

Together with Suhailey, we planned the visit to Jhenaidah and possible activities for first visit. Since it was important for me to get recognised as a master's student to different actors (community member, city-wide network, NGO and municipality) I decided to join the regular meetings of POCAA with different communities. Apart from that we planned for three workshops.

Where?	Agenda
Mohishakundu Shordarpara	Water
Mohishakundu Shordarpara	Sanitation
Vennatola	Community strength

The agenda of POCAA was to keep regular contact with the community where they had worked, to find out next possible community for continuing the housing development activity and to find out other need of the communities than housing, such as community health development or community space/garden development.

Workshop with student of architecture,Brac University

Date: 16.10.2015

Place: Brac University, Dhaka, Bangladesh

Participants:

The forth year architecture students (26 nos),

Background:

As this group of students has been working for Jhenaidah city through close participation with different communities, they have updated information, opinion about holistic, sustainable development through local knowledge and technology and most importantly, feedback on critical issue, as housing, drainage, waste management, toilet, water, etc. Hence, I organised a workshop with the group of students, considering them a group of resource people.

Discussed topics

Figure: Workshop at Brac University

Visit to Jhenaidah

The first visit to the city involved series of introductory meeting with active NGO-s, discussions, 'walking in the city'- activity , other than the previously planned workshops, in different communities. These communities are, by any means, deprived from municipal services (water, waste management, sanitation, sewerage, etc.) As water is not a separate issue, the discussion topics varied depending on the communities' necessity. A significant amount of time was spent with Mohishakundu shordarpara community. In the other communities, focused group discussion was held about income generation and benefits of saving group.

Figure : New houses at Mohishakundu Shordarpara community

Mohishakundu Shordarpara community

Among the five communities of city-wide network, the Mohishakundu Shordarpara community is in the process of upgrading their houses with the help of platform of community architects and activists (POCAA) and NGO Alive. There is still need of improvement in terms of water, toilet, and drainage for a healthy living condition. First, the community has learned how to make map. Then the measured their houses, kitchens, toilets, tube well, religious spaces, shops, roads, etc. and produced the map of their own community. After that, through a 'dream house' workshop, the designed their houses with the assistance of POCAA's architects. During the construction of the houses a committee was formed by the community member to purchase material for everyone. Each family has supervised and provided some labour to minimise the cost.

Figure: Women from Mohishakundu suggesting on how to write a saving account book to women from another community

Figure: Discussion about saving group and mapping at Vennatola

Figure: City-walk with the women of Mohishakundu and Shoshanpara

Figure: Mapping workshop at Vennatola community

Figure: Community visit at Arappur

Three workshops in the city

A series of three workshop was conducted during this time. Two of them were with Mohishakundu Shordar para. Feedback and design suggestions came from the community people on municipal toilet. The community also expressed their learning from a knowledge exchange visit to Dinajpur, a city located north of Bangladesh, with years of experience of community involvement in water and sanitation. A mapping exercise was done for laying out drain that would draw the wastewater from the households. The third workshop happened at Vennatola community, where the women from Mohishakundu Shordar para community shared their experience about managing saving groups. Also a map of vennatola was produced by this two communities.

Figure above: Mohishakundu community teaching Vennatola community about how to map

Figure below: Mental map, produced with Vennatola community

Summery of first phase: Overall reality of the city

Resource limitation of the municipality

The municipality lacks both monetary and human resources to provide basic water supply and drainage. The resource limitation has bound the municipality to have any kind of innovative problem soling. As a result, despite of the intention, the goals of master plan is falling back from the targeted achievement. Also, the decision making process is very much top-down, which could be different by delegating more responsibility to citizen and establishing partnership with community organizations.

Women's position in the context

Women in these communities stand far behind than their male counterparts. With a male presence, the women groups are quiet and shy. But when they discuss with women from different communities, they share their problems , challenges and ways to solve them. At household level, women suffer the most for water related issues since responsibility of collecting and managing wastewater are solely upon them. The amount of time they spent in managing wastewater could have been spent for economic and personal development if the problem was taken care of.

Power of networking

Though the journey of city-wide network is very recent, form the interviews and meetings it was clear that the communities recognise the benefits of uniting under one network based in the administrative boundary. They talk about the negotiation power they could achieve against the top-down process by uniting themselves for common causes like housing, community space, water and sanitation.

Power of saving

Creating saving group within the community has been the entry point to the city-wide network. The saving is being used as small loans within the community. Micro-credit is a well-known concept in these communities, since many NGO-s are active with micro-credit loans in the area. The communities have realised that they would not need a NGO to provide them with loans, if they can loan themselves with their own savings. Thus, they can avoid getting in any NGO-s interest rate, increase their own saving by keeping the interest within the community and develop a central fund. This fund will help them to improve their settlement of their own without much of external aid.

'Mapping' as a tool of communication

From the previous mapping activities, the communities was able to point out mapping as a tool to discuss different issues, even conflicts.

Phase two: Site selection and mapping activities

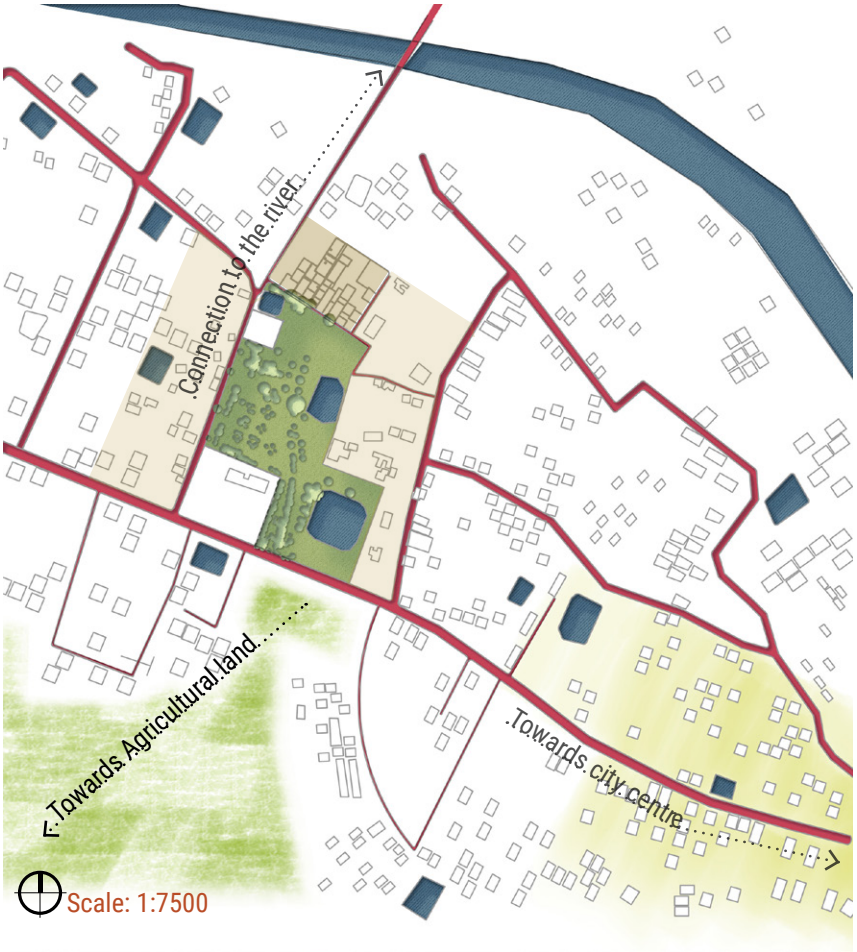


Figure below: The site, in relation with the neighbouring areas

Site Analysis

To the south of Mohishakundu Shordar para, there is a unoccupied land owned by Jhenaidah municipality. This is the most logical site if wastewater from Mohishakundu Shordar para gets treated closer to the generating point. There are two ditches and two ponds. The land is being used for multiple reasons mostly by neighbouring communities. According to the city's masterplan, this site is proposed to develop a neighbourhood playground. At the present, the site includes different types of trees that provides shade. There are a few sitting arrangement available, so the site , to some extent, turns into gathering place in the afternoon. Other than that, the area is mostly used as a bypass for pedestrian or bicycle/ motorbike riders.

Legend:

Selected site
Mohishakundu shordarpara community (Low income community)
Middle income community
Water
Road

Tree resource mapping

Before proposing any intervention for the site, it was important to document the different types of trees. This mapping was done by a fun workshop 'Know the tree' with the children of neighbouring areas. There are total 173 trees of 16 different kinds.

Figure Left: The tree mapping team

Figure right: The 'tree' resource map of the site

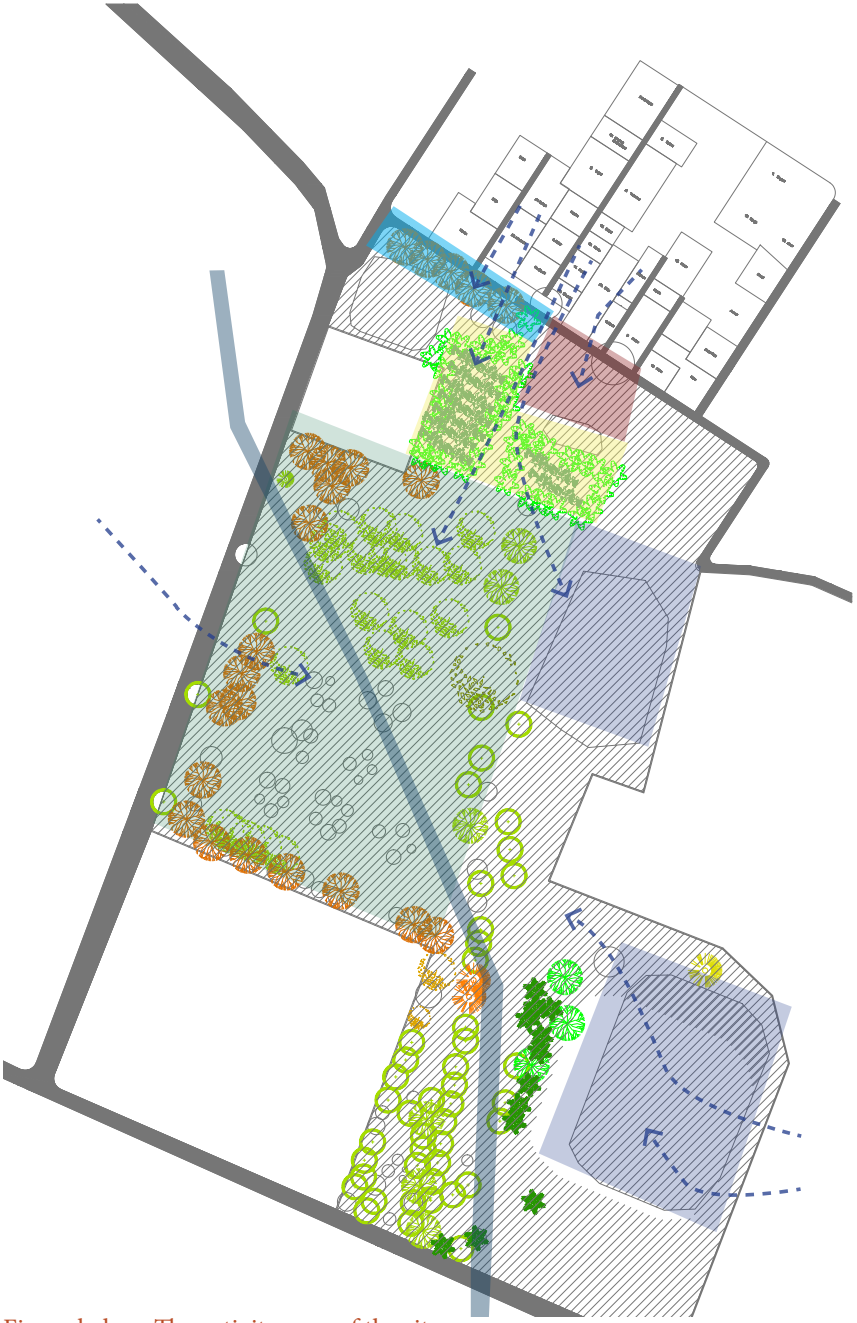


Figure below: The activity map of the site

Activity mapping

Activity map explains the neighbourhoods need of different types of spaces in relation to their lifestyle, economic activities and leisure or recreational activities. The space is kept almost without anything planned and the communities around are creating definition to the space.

Activities in the playground:

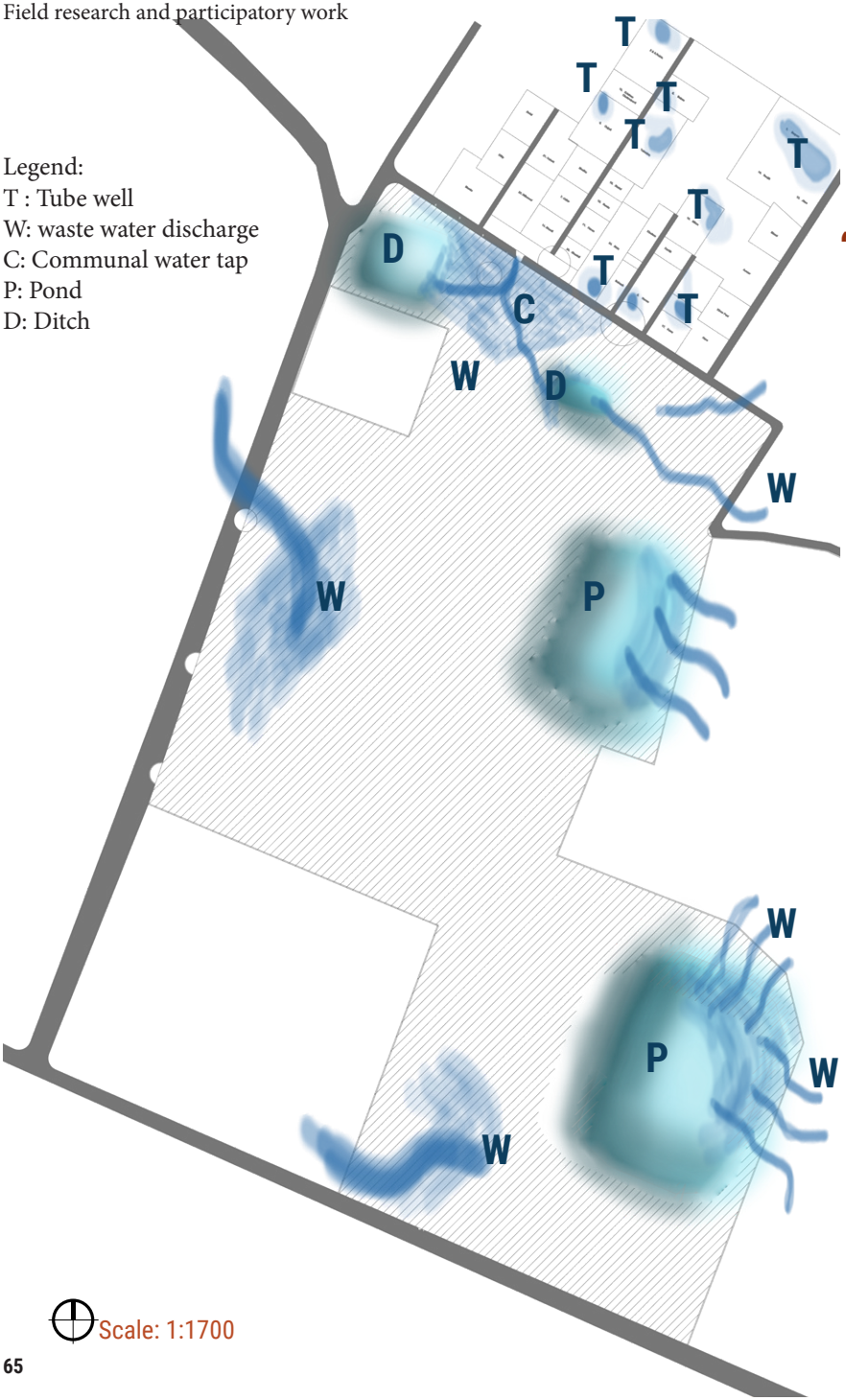
- Livestock (Cow, Goat) grazing.
- Collecting And preparing food for livestocks (Banana tree, grass).
- Preparing/drying biofuel from cow-dung
- Evening walk (Families).
- Playing (Children).
- Gathering (Young people).

Activities around the temple/ temple yard:

- Morning prayer and rituals
- Preparing food, except for cooking (cutting and washing vegetables etc.)
- Drying washed clothes
- Weekly meeting, saving collection by the execute committee of the community
- Hanging out in the afternoon and evening (both men and women)
- Playing (Children)

Figure, above: meeting in the temple yard; below: Children gathering around the temple

Legend:
T : Tube well
W: waste water discharge
C: Communal water tap
P: Pond
D: Ditch



Scale: 1:1700

‘Mapping’ of water in daily life

The daily use of water includes preparing food and cooking, washing dishes and cloths, bathing and raising domestic animals and poultry. The use of water is very minimal in this community, not because of the scarcity of water, but because of unavailable infrastructure to dispose the used water. Household tube-well and communal water taps are mainly used for potable water requirements. The existing ponds are very much used for daily use of water by Mohishakundu Shordarpara community.

Household hand-pumped tube-well:

30% of the households have tube-wells for water. The tube-well water is used only for cooking and washing utensils. The more they use the water, the more will be the amount of wastewater. As each household owns a very small piece of land, it is considered as a luxury if the wastewater occupies too much of the land.

Ponds

It is notable in the community that almost no one uses tube-well or community taps for washing cloths or taking a bath. Men, women and children take their baths in the ponds, as making a large amount of wastewater closer to the community is not a viable option for them. The ponds are also taken under lease and are being used as fish ponds.

Waste water discharges:

Since the municipal drain network is not completed in this area, everyone, regardless of low-income or affluent households, have to release their wastewater in this chunk of space. Mohishakundu releases water with only food scraps (as they do not use chemicals for washing utensils). However, the affluent households have to release both grey and black water without any treatment.

Communal Water taps

In the community, water taps are the main sources to collect drinking and cooking water, and water for washing utensils for those who do not have a tube-well. The taps have water supply twice a day, in the morning and in the evening. During these two times, there is usually a queue near the taps.

Ditches

Ditches mainly collect some of the waste-water discharged from the surrounding houses. Some of the community people grow fish in the ditches. Poultries, owned by the community are also kept around these ditches. Children play with the water and catch fish as a part of their playing time.

Mapping interrelation between physical spaces

Legend:

Flow (waste, water, resource etc.)

Interrelation

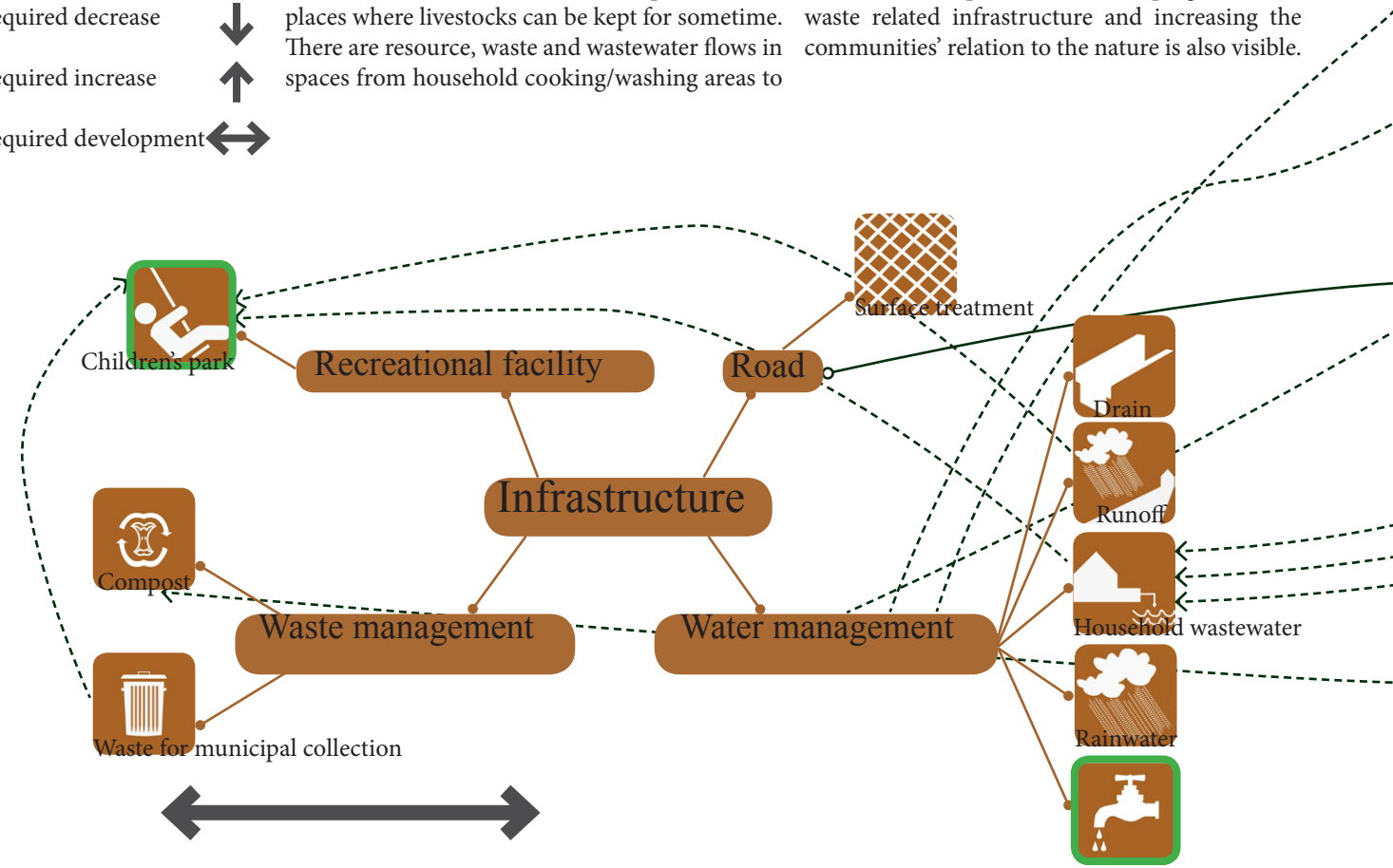
Required decrease

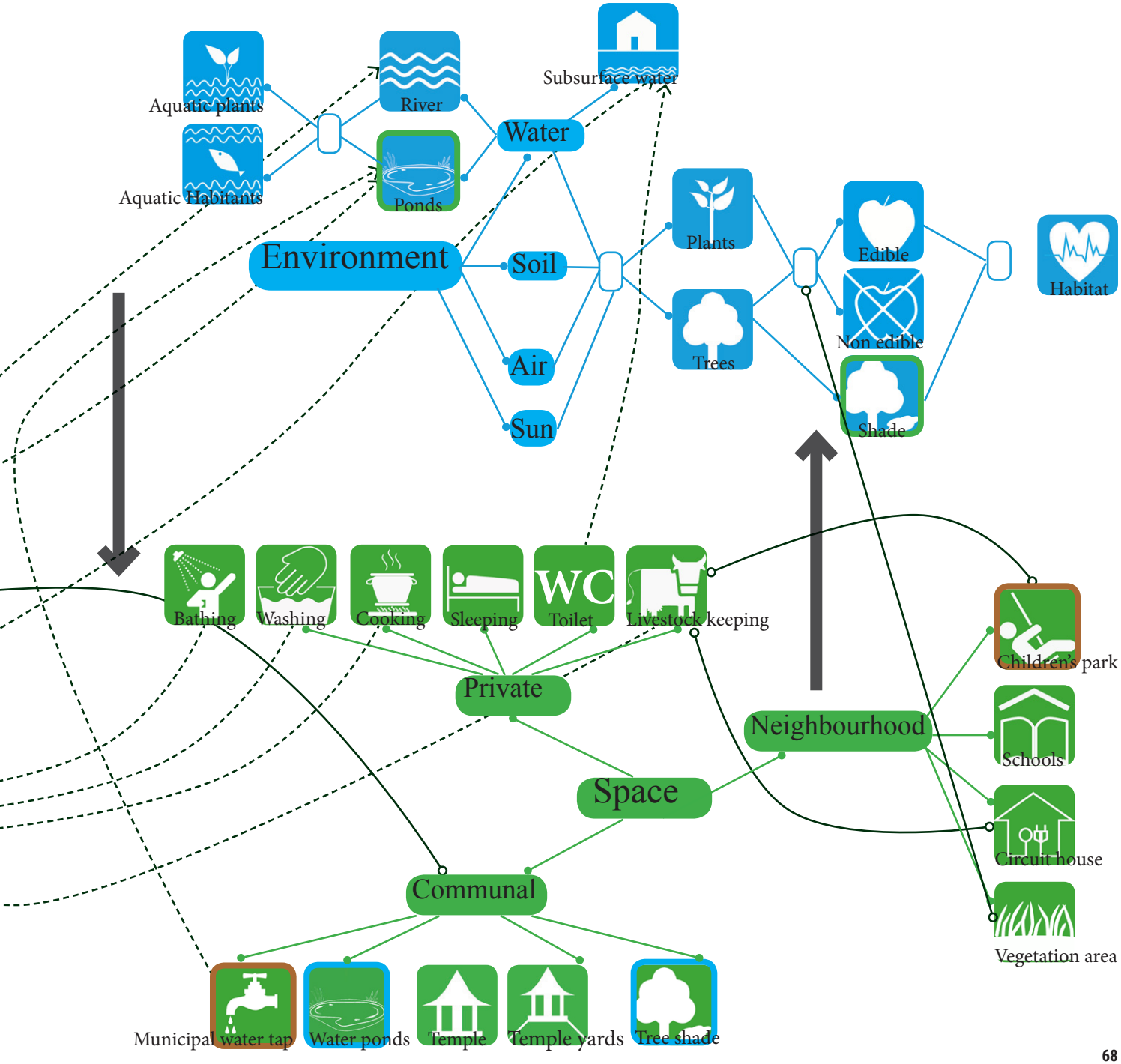
Required increase

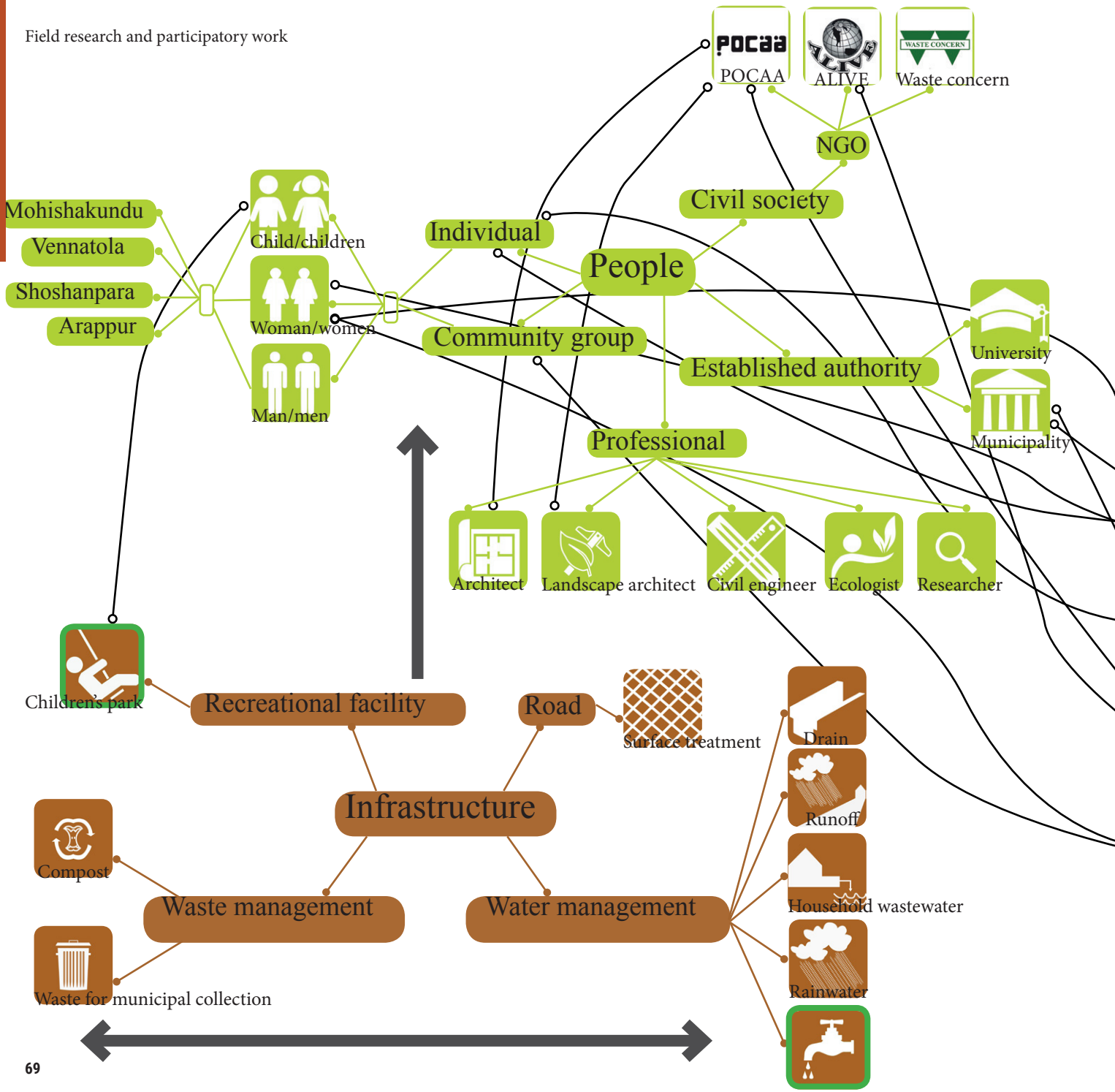
Required development

The diagram shows the relation among infrastructure, environment, private, communal and neighbour spaces. For example, the roads become communal space from time to time. Or, the circuit house and the children's park become places where livestocks can be kept for sometime. There are resource, waste and wastewater flows in spaces from household cooking/washing areas to communal /recreational areas.

The diagram shows the necessity of cutting the direct connection between wastewater and natural waterbodies. Importance of developing water and waste related infrastructure and increasing the communities' relation to the nature is also visible.




Aquatic plants
River
Subsurface water
Aquatic Habitants
Ponds
Water
Environment
Soil
Air
Sun
Plants
Trees
Edible
Non edible
Shade
Habitat
Bathing
Washing
Cooking
Sleeping
WC
Toilet
Livestock keeping
Private
Neighbourhood
Space
Communal
Children's park
Schools
Circuit house
Vegetation area
Municipal water tap
Water ponds
Temple
Temple yards
Tree shade


POCAA
ALIVE
Waste concern
NGO
Civil society
Mohishakundu
Vennatola
Shoshanpara
Arappur
Child/children
Woman/women
Man/men
Individual
People
Community group
Established authority
University
Municipality
Professional
Architect
Landscape architect
Civil engineer
Ecologist
Researcher
Children's park
Recreational facility
Road
Surface treatment
Drain
Runoff
Household wastewater
Rainwater
Infrastructure
Compost
Waste management
Water management
Waste for municipal collection

Mapping interaction between people and space

This diagram with the current relation between people and spaces shows that the user group has hardly any access to the waste or water related infrastructure. Among the private spaces, washing, cooking and livestock keeping areas are mostly used by the women of community. While municipal service is expected to be highest, the only municipal services the community receive are communal tap water and toilets.

Among NGO and similar organisations, POCAA and Alive, are active in designing/developing private space, including houses but excluding cooking, washing areas, toilets etc.

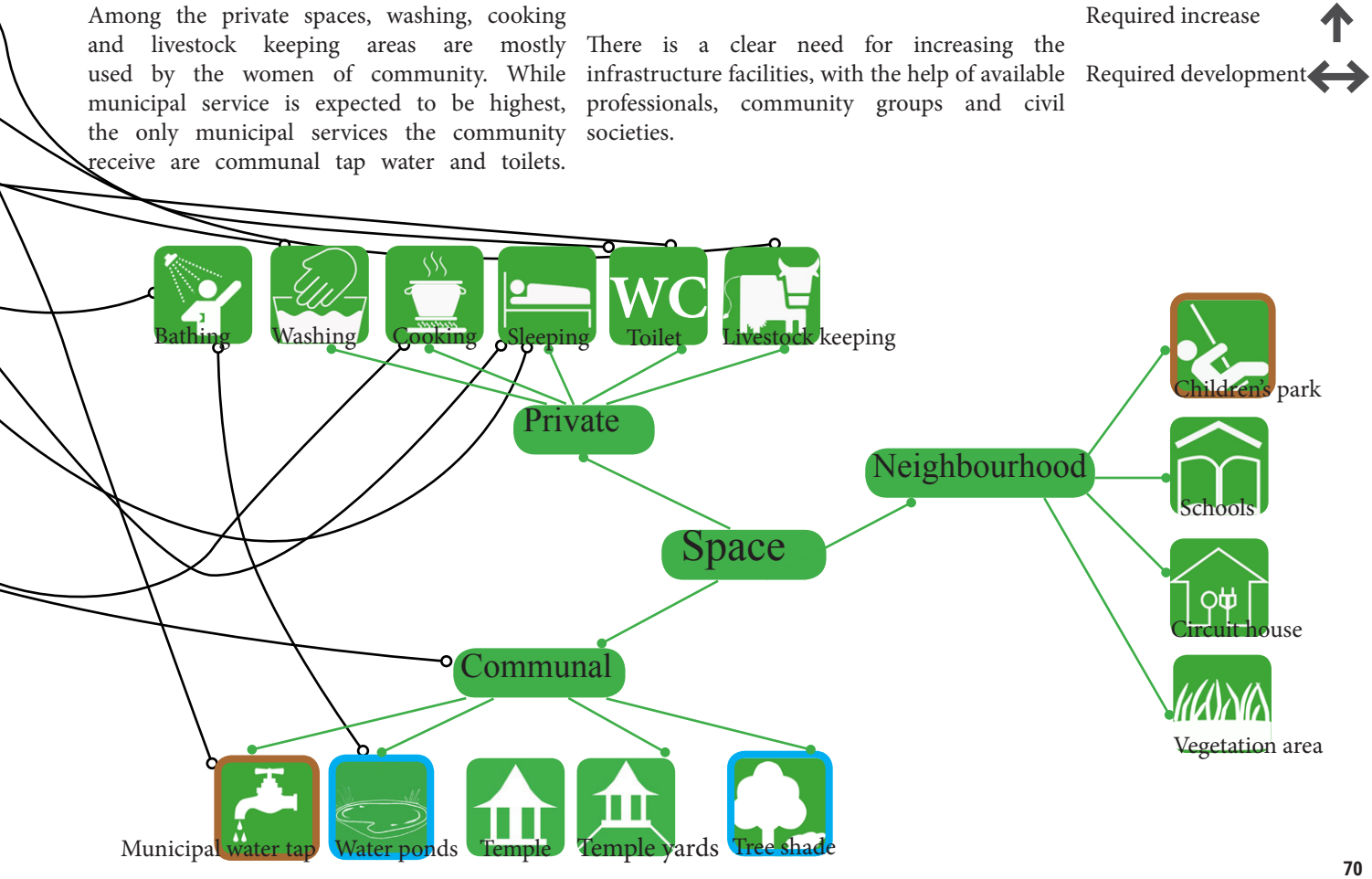
There is a clear need for increasing the infrastructure facilities, with the help of available professionals, community groups and civil societies.

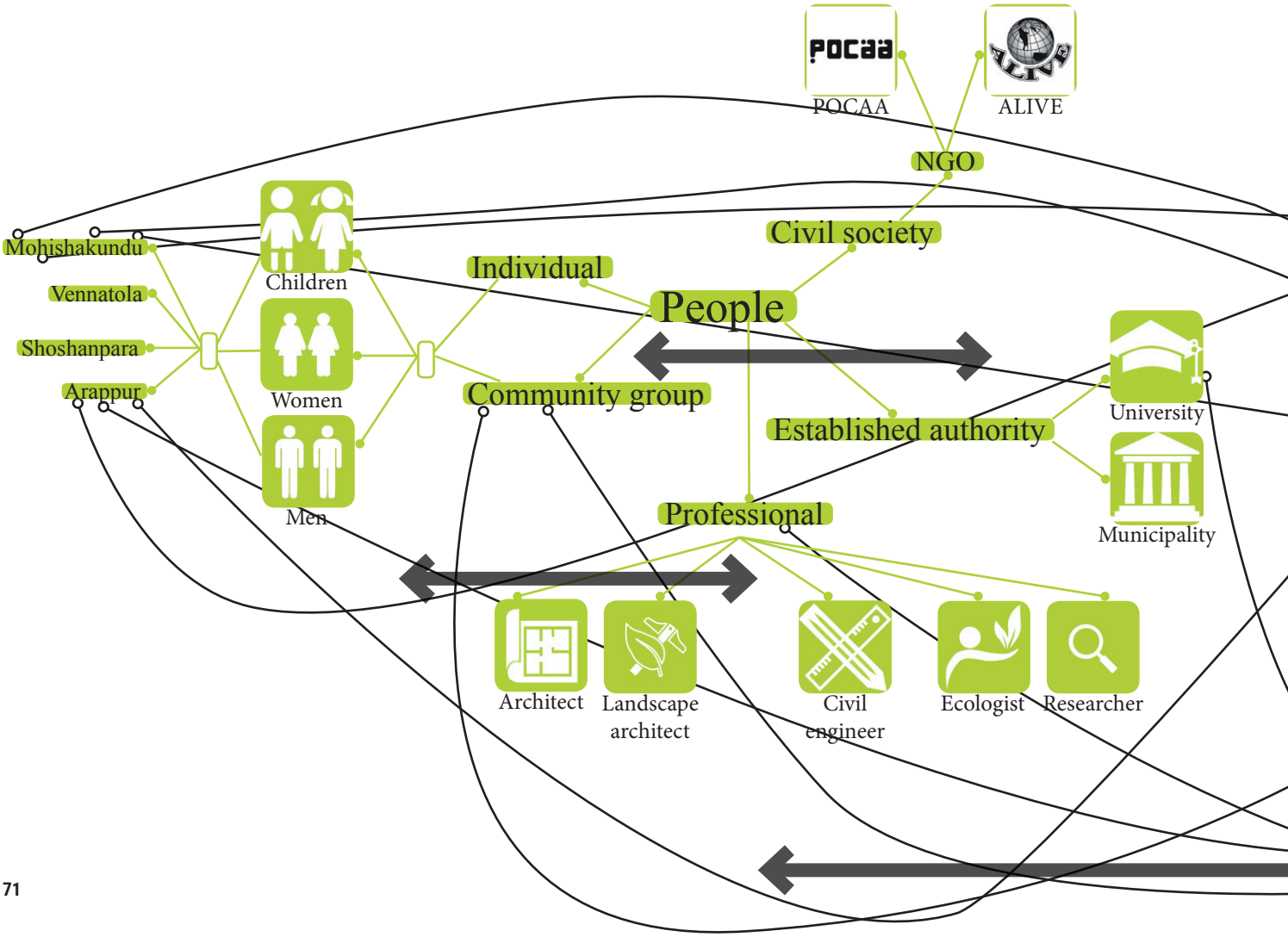
Legend:

Interrelation

Required increase

Required development




POCAA
ALIVE
NGO
Civil society
Mohishakundu
Vennatola
Shoshanpara
Arappur
Children
Women
Men
Individual
People
Community group
University
Established authority
Municipality
Professional
Architect
Landscape architect
Civil engineer
Ecologist
Researcher

Mapping interrelation between people and intangibles

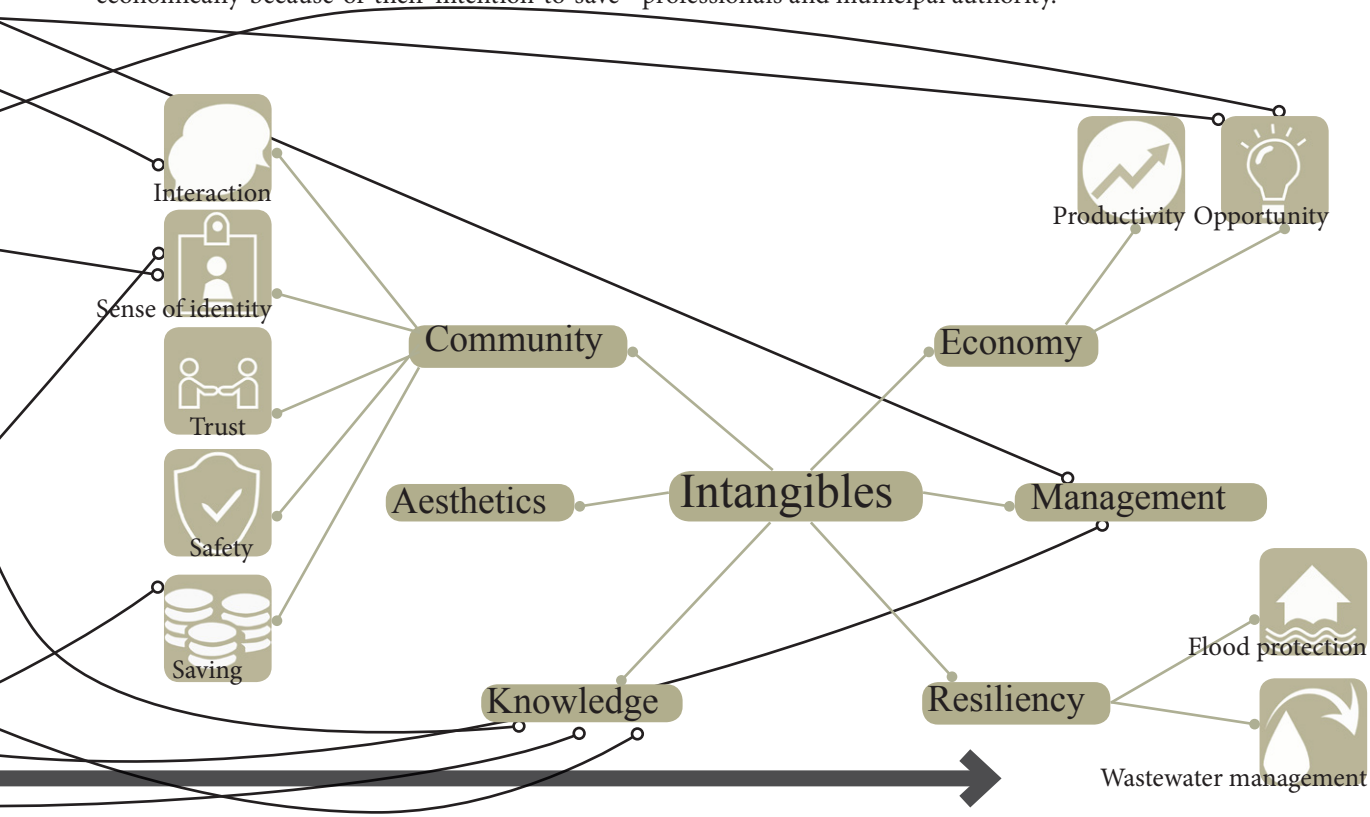
This diagram shows that among the communities in the city-wide network, Jhenaidah, has their saving groups.

Mohishakundu and Arappur community has more communal values than other communities. For example, interaction, sense of identity, management and opportunities to develop economically because of their intention to save up more. The students of Brac University, and the architects of POCAA are knowledge resources for these communities. Not to mention, the community groups themselves have a lot of skills and knowledge. Resilience for the municipality should be developed with the help of these local professionals. It is also important to develop relationship among community groups, professionals and municipal authority.

Legend:

Interrelation

Required development



Meeting with NGO alive

After working with NGO Alive and the City-wide network, Jhenaidah for a couple of months, NGO Alive showed interest in implementing the outcomes from this research. From the discussion, we decided to frame a social business model of community-led food and compost production on trial basis. The summary of the meeting is illustrated below:

Background:

There are no available options for women to improve their economic status. Growing food and manufacturing compost nearby can be an income generating option for them. Since there is land available for taking under lease, this can be a viable option for the women group. If Mohishakundu Shordarpara women group can start it as a business model, they can be the pioneer to train other women groups through the city-wide network.

Target groups:

The women groups of city-wide network: Mohishakundu shordarpara, Mohishakundu 2, Shoshanpara, Vennatola, Arappur.

Target product/service:

- Food production with vulnerable women saving groups
- Turning household food waste to compost
- Delivery service of compost to the customers
- Assistance with training, management, marketing.

Result

- Increase of family income
- Contributing to community's nutrient demand
- Improving community's health
- Strengthening the community organisation

Threats

- Handling the complexity of leasing the required piece of land
- Conflict within the group might surface during the operation

First course of action:

- Test-run of the idea within community's own land and buildings
- Analysing the demand for compost in the city
- Finding vegetable seller groups to create partnership

Financing

- Looking for a seed fund from NGO, municipality and other donor organisations
- Taking loan for business from already existing women's saving group

Summery of second phase: SWOT analysis of the site

Strength

The site is already proposed as a public function (children's playground), so there will be no negotiation needed for the surrounding communities to keep this land free of construction.

The site has roads on all four sides, which makes it accessible from the whole neighbourhood.

The way the neighbouring community uses a part of the site is very efficient and something to learn from for any planner/designer. Multiple use of the same space in different times of the day collectively fulfils the needs that are lacking in individual households

Weakness

- Lack of spatial identity
- Lack of aesthetic diversity
- Ecosystem is fragmented and neglected
- Contamination of soil and water

Opportunities

- Preserving ecosystem
- Sharing space
- Economic development
- Networking opportunities.
- Partnership opportunities

Threat

- Conflict within the community
- Limited financial resource within the community
- Limited financial support from the municipality

Phase three: Possible design solutions and feedback

Images from workshop with children

Workshop with children

Since the site was proposed as a neighbourhood playground for children according to the masterplan, it was important to involve children in designing the park. The workshop took place for several days in the afternoon, when the children of neighbouring communities come back from school. Not only the children of the community, but also children from other communities who were passing by, contributed their idea of a playground by building a model. The children had their own saving group, inspired from the adult saving group. With the money they aim to arrange picnic, or buy storybooks.

Requirements by the children

A- Source of light
B- Animal
C- Water plant with flower
D- Plants with fruit
E- Boat
F- Place to store their books, to sit and paint or rest or to arrange a picnic
G- Replicating '*Smriti Shoudho*' (National Monument), to create a sense of pride in the playground.
H-Boundary, for sense of security
I- Rides

Work presented in the community

At the end of the field research, an idea was presented of how to manage the household wastewater and storm water close to the community that would not need extensive construction work and cost. This idea involved connecting the ponds in the site and treating the water through plants and landscape elements.

Scale: 1:1700

Sediment pond:

Wastewater is first collected in this pond, where primary sedimentation will take place. This pond will house water hyacinth to start with the water treatment process. Fish cultivation will be introduce in the pond (and continue to all the ponds) in order to control algae bloom and mosquito larvae control. Water will then flow through the shallow infiltration-treatment pond.

Shallow infiltration-treatment pond:

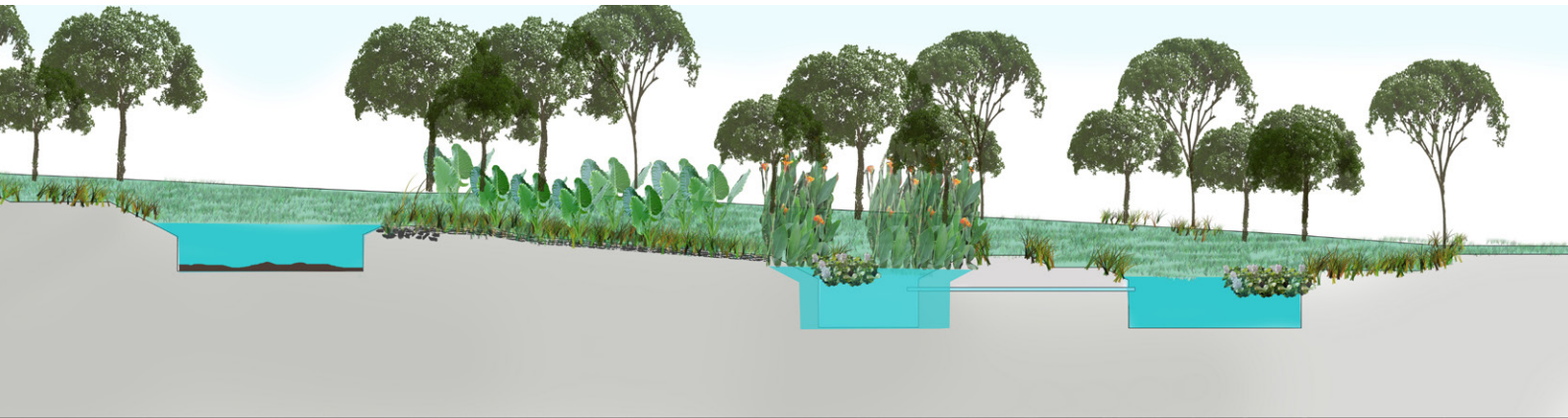
This channel will have a bed consisting of gravel and coarse sand. The surface is elongated to slowdown the flow of the water. Through the gravel bed, water is filtered to wetland. The plant introduced here is "taro" (Colocasia esculenta), which is edible and a popular vegetable in Bangladesh. This channel will also grow marshland grass, which is also food for the livestock.

Wetland treatment pond

Wetland treat pond can include both floating wetland plants and plants on the sides. Canna indica or Colocasia esculenta are two suggested wetland plants for tropical wetlands.

Slow retention pond

The final destination for water is slow retention pond. Here, the water is safe for the communal use of taking baths.



Summery of third phase: Feedback from probable user

Threat:

- The informal characteristic of the empty plot might get lost in the process. In that case the community will have no space for gathering, group meeting etc.
- The non biodegradable waste might end up in the water treatment system.
- Fish farmers practice monoculture production of Silver-carp, which is an introduced and invasive species for the context. They might not agree to make any changes in the farming.
- Internal conflict of community might surface often.

Opportunity

- Solution from the water clogging problem
- Solution for waste management, if maintained properly
- Successful implementation would make the community an example for others.
- Other activities (such as community gardening) will make the space vibrant, thus inspire the community to maintain the water treatment system.

Decisions by the community:

- Community can already start building the drain that will connect the households to the water treatment system.
- Community can negotiate to lease the land for community based urban farming and the ponds for community based fish farming

Conclusion of the field research: Project positioning

What	Why
Water treatment: Household wastewater treatment Storm-water Management	Wastewater management is the concern of highest priority for the community.
Communal space: Space for communal activity (shared space) Bathing space near the pond Economic development through Urban agriculture	Since the individual houses are built on very small pieces of land, the community depends on the nearby road and the presently empty site for a majority of their daily activities. Water ponds are also the biggest source for many daily activities, such as bathing and washing cloths.
Neighbourhood playground: Playground for children of different age groups Water pavilion for children	Originally the site is designated to develop a neighbourhood playground. This thesis would like to take the opportunity to exercise merging water management to the function of a playground.

Whom	How
For whole neighbourhood	• Using the already exiting water ponds. • Introducing range of plants in constructed wetland in and around the ponds.
Mostly for women	• Dividing the site into community space, neighbourhood play ground buffer zones between different functions and access from the main road. • By enhancing women's saving group.
Children	• Designing the playground keeping the findings from children workshop in mind • Creating awareness about water using the water pavilion.

Chapter five:
Technical tools and application in design

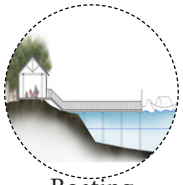
Technical tools from WSUD and DEWATS

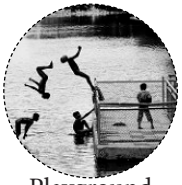
There are few approaches, known by different initials in different countries that manage urban water system differently than conventional piped water management system. The core principle of these approaches is to manage urban water cycle similar to the way nature manages its water cycle. Water Sensitive Urban Design (WSUD), also known as Low Impact Development (LID) and Decentralised Water Treatment System (DEWATS) are two such approaches. Both approaches were developed by international networks of organisations and experts which are ongoing researches till date.

A list of technical tools are discussed briefly in the next section, though it is not limited to this list. Often, these tools contributes to more than one type of performance. Below is the list of tools, indicating what can they perform with the coloured dots.

Performance	Tools
Transportation	Evapotranspiration Bioswale Bioretention Opendrain
Reuse	Rainwater collection(from roof) Rainwater collection (from surface)
Storage	Detention pond Geocelluler system
Infiltration	Infiltration zone Permeable pavement
Managing micro-climate	Rain garden Roof garden
Conserving biodiversity	Biotope Wetland plants
Treatment	Constructed wetland

Possible application in design


Boating

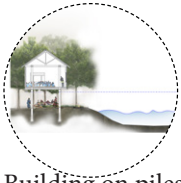

Playground


Park


Sports ground

Recreational facility (Urban scale)

High water period can introduce additional urban recreational activities, such as park, boating, Sports ground or playground. Boating facility can run all year around, if the water body is not completely dry. Sports facility and playground can accommodate range of fields with gallery for visitors. By being at a waterside, it can enhance the water experience both for facility users and visitors. The images- top-right and bottom left: Dhanmondi lake, Dhaka, bottom right: Cox's bazar, Chittagong.


Building on piles


Floating building


Flood tolerant building

Building scale

The height of the piles can be determined so that the usable space is never flooded. Any public functions, specially the ones need to be always safe(emergency shelter, schools, etc.) can adapt building on piles as design strategy. This way the built structure does not the interrupt water way and the space under the floor can be used for temporary functions in the dry season, for example, seasonal market.

An appropriately adapted building can be subjected to flooding without sustaining significant damage. For example, having floors and walls protected from water. The image belongs to fish auction market in Hamburg that is adapted in this way.

The floating or amphibious buildings have become very diverse in recent years supporting the discussion of 'how to build in the era of climate change. The image belongs to informal settlement in Cambodia.

Economic activity


Food growing


Fish farming


Animal grazing


Poultry raising

The water bodies can provide a lot of economic benefits to the cities habitant, of course if that response to their interest. Both food growing and fish farming can take place in any scale, from the river bank to the house roof. The reclaimed water and nutrient can be used for food growing and fish farming.

Animal and poultry raising need more space than food and fish farming, so might not be possible in building scale. These are very common practices though, in the low income communities of medium and smaller cities in South Asia.

Occasional activity


Event ground


Weekend market

The bank of water bodies, as extensive open area, can provide sites for open air cultural and religious festivals such as *mela* (fair) during Bengali new year, *Eid* or *Puja*. Such big festivals might be difficult to house in any other open spaces. Other than the festival time, the space can be used as weekend markets during dry season. This kind of function only need few installations that can be dismantled.

Daily activity


Washing


Bathing

Everyday activity, such as washing and bathing, takes place in communal water sources in many parts of South Asia. This is culturally not only excepted, but also celebrated. A lot of religious rituals also begin with taking a bath in the common water source. While designing flood plain or water bodies, designers can be uplift this cultural activities to the next level.

Accessibility

Path

Ramp/slope

Overhang/balcony

'Ghat' or steps to water

Setting up a pathway involves differentiating between inaccessible, occasionally used and frequently use area of flood plain. The pathways are design to reach water and thus become an important element for designers to connect urban design to water. The pathways can be of different varieties, narrow or broad, playing with the slope or to stop on a balcony during the walk. 'Ghat' is a concept with cultural and religious significant in South Asian region. The images- top-left: Dhanmondi park, Dhaka, top-right: Observation Spot Located under the water level in Austria, bottom-left: Platform of hope, Karail, Dhaka, bottom-right: Ghat at Varanasi, India

As landscape elements

Submersible furnitures

Art installation

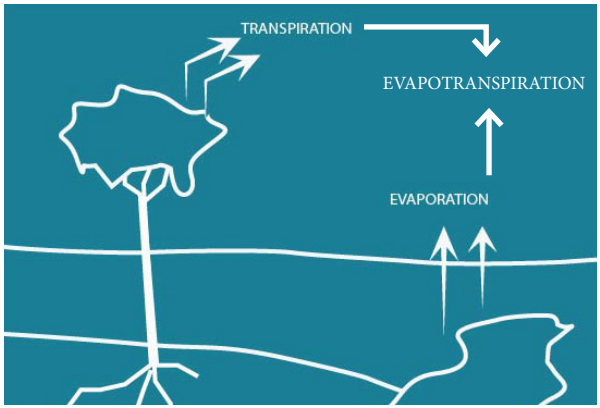
Submersible furniture or art installation that address the element of water and its processes enhance the value of the watercourses. They can make draw attention to the dramatic fluctuation in water level. The image of submersible furniture is from Bloom 2011 – water in the show gardens and art installation is from Winter Gardens in Sheffield, South Yorkshire, UK.

Visual barrier

Physical barrier

Division of functions in public space do not necessarily need complete isolation from one another, but some degree of control to increase/ decrease others interest by making it partially invisible. To limit the visual connection of two different functions in public space, the height of the wetland plants can be used. The width and depth of water management units, such as bioswales or rain gardens can also create physical barrier between functions.

Evapotranspiration



Evapotranspiration is the sum of evaporation and transpiration of plants. Water from ground and different water sources that are exposed to sun evaporate and plant consume water and transpire. Evapotranspiration can be two types, active and passive. (Hoyer, et al., 2011)

Advantage

- This is nature's way to manage water cycle.
- This process has influence on temperature, humidity and precipitation.

Evapotranspiration can be incorporated in both indoor and outdoor to manage temperature and humidity. The physical expression to accommodate this system can be creative installation, fountain, pond, etc. Controlling air temperature like this also saves energy of 'air-conditioning'.

Application in urban design/architecture

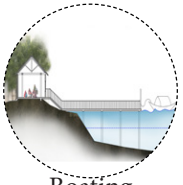

Floating building


Flood tolerant building


Building on piles

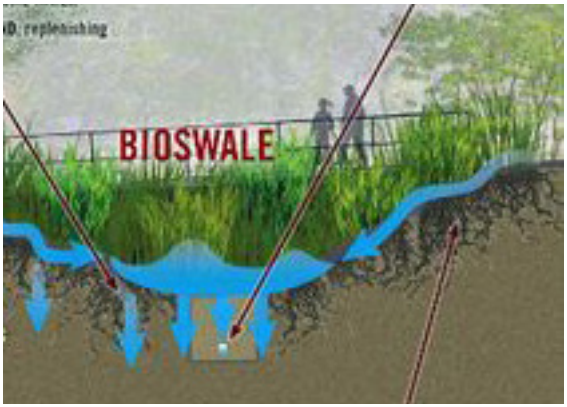

Park


Art installation


Boating

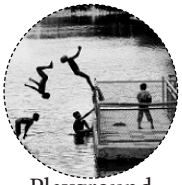
Bioswales

Bioswale, USA (Martin, 2008)



Application in urban design/architecture

Visual barrier



Playground

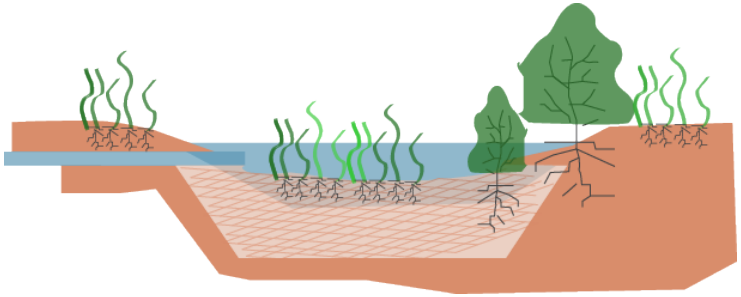
Physical barrier

Bioswales are linear space either to store or transport stormwater through vegetation planted. These can have both permeable or impermeable soil structure and piping system, which is used respectively to infiltrate and to drain water faster to other system (such as downstream). (Hoyer, et al., 2011)

Advantage

- Infiltrates and recharges aquifer.
- Accommodates large amount of stormwater.

Bioswales have very delicate slope, which can be excellent to design the landscape for 'stepping into the water' or 'playing with water' for children.



Bioretention


(The 21st Street project, California, n.d.)

Bioretention is a system where the runoff is drained from a shallow depression in the landscape, typically into the perforated drain below. Through the engineered soil and vegetation, the runoff gets infiltrated and treated before it joins the stormwater management system. (Hoyer, et al., 2011)

Advantage

- Infiltrates and recharges aquifer.
- Remove pollutants before releasing the water to aquifer or stormwater system.
- Reduces stress on stormwater management by slowing down the water flow.

Since the system varies in shapes and accommodates different kind of vegetation, this can be used a landscaped part in urban area. While dry, the space can be used for recreational purpose. Even after rainfall, the water can be enjoyed by people if it is kept in mind while designing.

Application in urban design/architecture


Animal grazing


Submersible furnitures

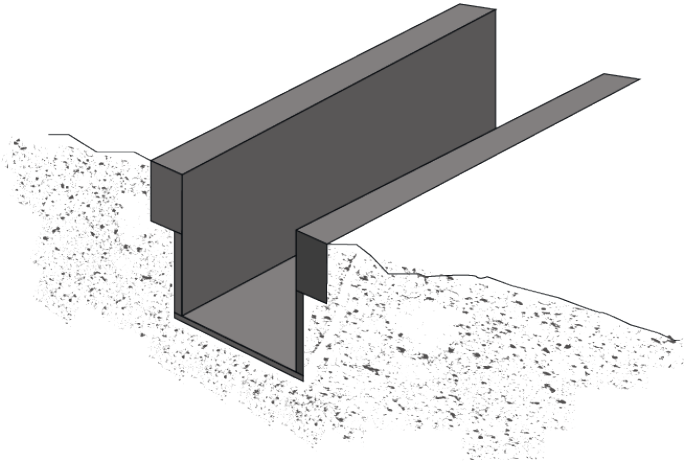

Art installation


Visual barrier


Physical barrier

Open drain

Augustenborg, Mälmo, (Mälmo stad, 2011)



Application in urban design/architecture

Open drain can be considered as an alternative to underground drainage that transports water from impervious surface, such as road or roof top to the main stormwater management system.

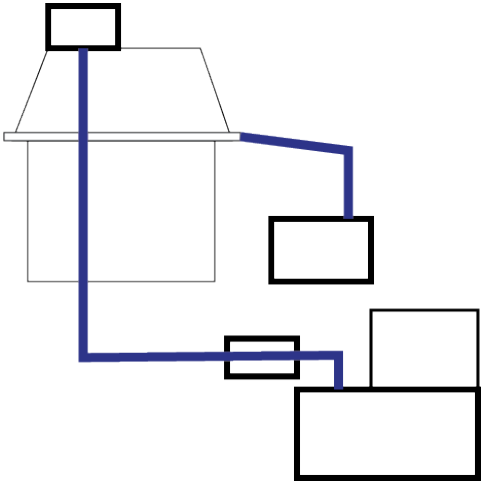
Advantage

Contributes to evaporation.

Disadvantage

Does not contribute to aquifer recharge.

Open drain can be designed as an exciting feature in urban landscape as it contain water flow. It can be incorporated with fountain, pool or rainwater harvesting system.
Because of its visual feature, this can be used as an interaction medium of water cycle for adults and children.



Roof collection

(Rainwater harvesting, n.d.)

Harvesting rainwater from the roof of a built structure is a widely excepted system, mostly in the rural areas of South Asian countries. The rain water is collected from roof in an above or underground cistern through a filtering system to discard unwanted objects from the water and used later.

Advantage

Even without any treatment, the water is safe to use for irrigation, in toilet or in fire sprinklers.
The water can be stored for potable use as well, after running it through filtering system.

Rainwater harvesting from roof of a building or complex can be an integral part of the architectural design from the conception.
If rainwater is stored in aboveground facility, it can be designed as an interactive art, architectural or landscaped feature for public, as fountain, pond etc.

Application in urban design/architecture

Washing

Bathing

Food growing

Art installation

Surface collection

Bishan park, Singapore (Atelier Dreiseitl, n.d.)

Food growing

Art installation

Fish farming

Poultry raising

While collecting from roof can be an individual building operation, the rainwater can also be collected from other surfaces, like pathway, road etc. The purpose would be to keep the water rather on-site.

Advantage

- Increases reuse of water without spending much energy.
- The water can be used for irrigation, flushing toilet.
- Collection tank can be placed underground, if needed.
- The water storage can be of any size, from small water body or tank to big pond. The design will then depend on that. If designed as a pond, it can accommodate all the other features (aquatic plant or habitat).
- Also, it can be designed as fragmented water planters, beside side walk.

Application in urban design/architecture


Food growing


Fish farming


Animal grazing


Poultry raising

Detention pond


(Tanner springs park, Oregon, USA n.d.)

Detention pond is surface water storage system. It can be both dry or wet. The dry detention pond, as the name suggests, dries out after the rainy reason. The wet detention ponds are designed to hold the water. After treatment processes through wetlands, the water is used for irrigation. (Hoyer, et al., 2011)

Advantage

- Infiltrates and recharges aquifer.
- Remove and treat pollutants through wetland before releasing the water to a different system.
- Stored water can be used for fish farming, irrigation, community swimming pond, etc.

When dry, it can used for recreational purpose, for walking or children's' playing. The wet ponds can be aesthetically enhanced urban amenities that help to reduce temperature in hot summer days.

Geocellular system

(Gelsen kitchen, Germany, n.d.)

Application in urban design/architecture

Food growing

Geocellular system is consisted of underground structure that stores stormwater and slowly infiltrates the water. The structure can be of various sizes. (Hoyer, et al., 2011)

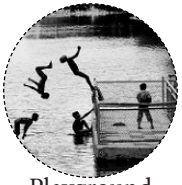
Advantage

- Infiltrates and recharges aquifer.
- Accommodates large amount of stormwater.
- Suitable for highly dense urban areas as the structure can be located under any other structure or road surface.

As a structure, geocellular system is invisible in urban setting since it is hidden under the ground. The top of the structure can be almost anything, from highly busy, functional space, road or recreational space.

Application in urban design/architecture


Overhang/balcony


Playground


Park


Sports ground

Infiltration zone


(Rain Garden, Police department, City of Brisbane, California, USA, n.d.)

Infiltration zone is engineered soil for infiltration. Designing the gravel, sand, minerals and other substructure can be highly technical, depending on the rate of infiltration needed and on intensity of rainfall. Design criteria is highly related to the local soil characteristics and available space. (Hoyer, et al., 2011)

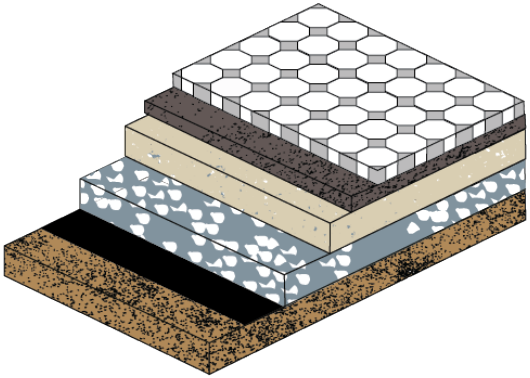
Advantage

- Engineered soil removes the pollutant from the water.
- Can be incorporated in the pocket spaces of urban settings.

Infiltration zones can be incorporated into multiple urban facilities with the probation of having garden, courtyard, planter, park, etc. whether private or public. When integrated in busy urban area, it can become the breathing space for that area. An infiltration zone can be an urban design element for controlling traffic flow.

Permeable pavement

Permeable driveway, New York City, USA (Kidwell-Ross, 2016)



Permeable pavement is designed within paving, asphalt or concrete, etc., for the water to penetrate through the hard urban surface. Usually under the paving material there would sub-grade gravel layer to ensure the infiltration into the ground or evaporate.

Application in urban design/architecture

Event ground

Weekend market

Advantage

- Hard surface for faster movement and soft surface for water to penetrate can co-exist in the same place. Apart from pathways, it can also be used in driveways or open parking areas.

Permeable surface can be designed for both vehicular and pedestrian traffic in an urban setting. The semi soft surface would add a different dimension in the conventional urban scenario.
Design patterns and specifications can used to differentiate the types of traffic, for example, between slow and fast traffic or among car, bicycle and pedestrian lane.

Chapter six:
Design sketches

Strategies for sustainable water management for Jhenaidah

A set of strategies has been derived to answer the thesis question (How to manage household grey water and surface water resources sustainably for present and future generations through urban design and planning in Jhenaidah, Bangladesh), which is listed below:

1. Maximising the use of existing water bodies, (Ditches, ponds and low lying areas) for water treatment:

2. Using decentralised methods to keep the water closer to the generating source:

List of criteria that can influence the prioritisation of selecting water treatment development area:

- Present density
- Projected future density and growth
- Elevation of land
- Available public building/space
- Available land
- Available community group

3. Reducing peak flows and runoff from the urban environment by providing for infiltration and groundwater recharge:
Change in building regulation: Floor area ratio for residential building and for public building.

4. Integrating stormwater treatment into the performance based landscape so that it offers multiple beneficial uses(social, visual, cultural and ecological values) such as water quality treatment, wildlife habitat etc:
Implementing law for soil treatment and landscape for the public buildings

5. Protecting and enhancing creeks, rivers, ponds and wetlands within urban environments:
Bangladesh is blessed with large rivers flowing within. Moreover, there are several other naturally and man-made large scale water bodies create the landscape of Bangladesh. However, this water is contaminated with agricultural, industrial and urban pollution . The country depends on groundwater for drinking water. Bringing back the quality of water in to a state, which will be viable for further treatment to obtain drinking water can a long term goal through this process.

6. Scope of expansion of water bodies in urban area for high water season:

7. Restoring the urban water balance by maximising the reuse of stormwater, recycled water and greywater:

8. Incorporating user and service providers participation in design, in order to work with the conceptions.

9. Easy and cost effective implementation and maintenance to allow widespread application.

An design example: Mohishakundu shordarpara neighbourhood playground

The site that was suggested by the field research contributors for this thesis is proposed as neighbourhood playground at Mohishakundu according to the municipality's masterplan. I had chosen this site to showcase some design exercises about decentralised water management and how it can be merged with in public space. Functions that were generated from the field research (page 79-80) will be elaborated in this chapter under following titles:

Site development,
Masterplan,
Function plan,
Wastewater treatment:

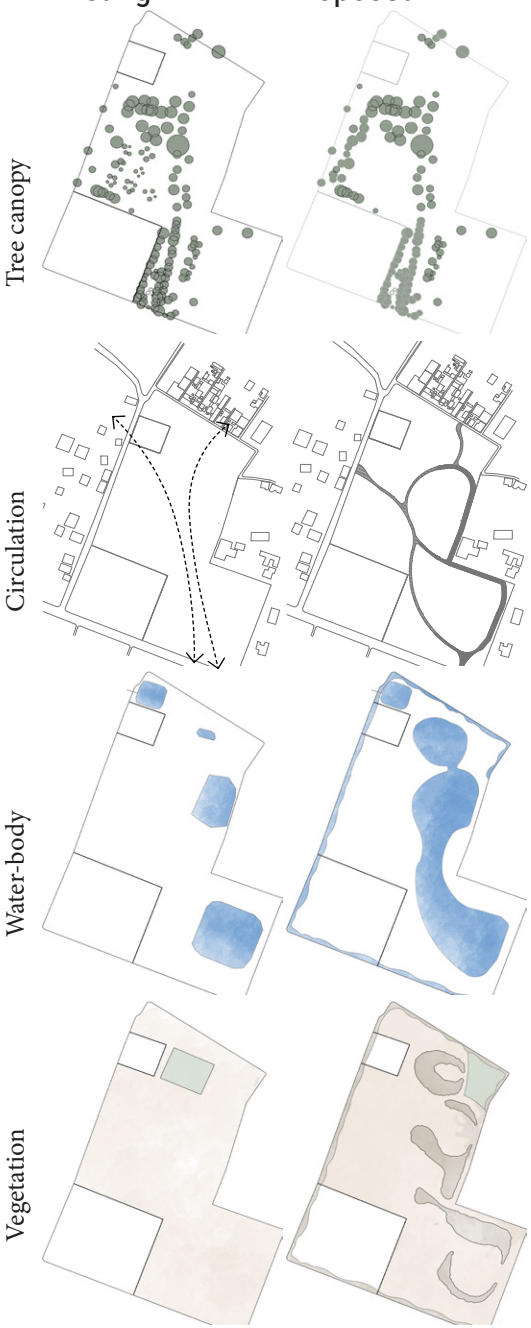
- Discussion and drawing about how constructed wetland treats household greywater and runoff.
- Bioswale and how the households will be connected to it.

Water pavilion for children:

- The stage
- The pavilion

Communal space:
The pathway
'Ghat' or steps to the pond
Community garden
Community space

Site development



Removal of eucalyptus tree which is harmful for the context.
Using the freed space as play area for ball sports.
Compensating with more trees on the west side creating a physical border for the site.

Defined pathway with varied unfolding view that leads different user group to enter the park from different points. For example the local community will enter from the north, while visitors from other part of the city will enter from south.

According to the proposal, existing waterbodies on the site would be connected and the intervention in the landform would allow the ponds to expand during the heavy rainy season.

Introducing wetland plants around ponds that treats wastewater.

Vegetable garden
Wetland

Scale: 1: 700

Figure: The master plan of the site

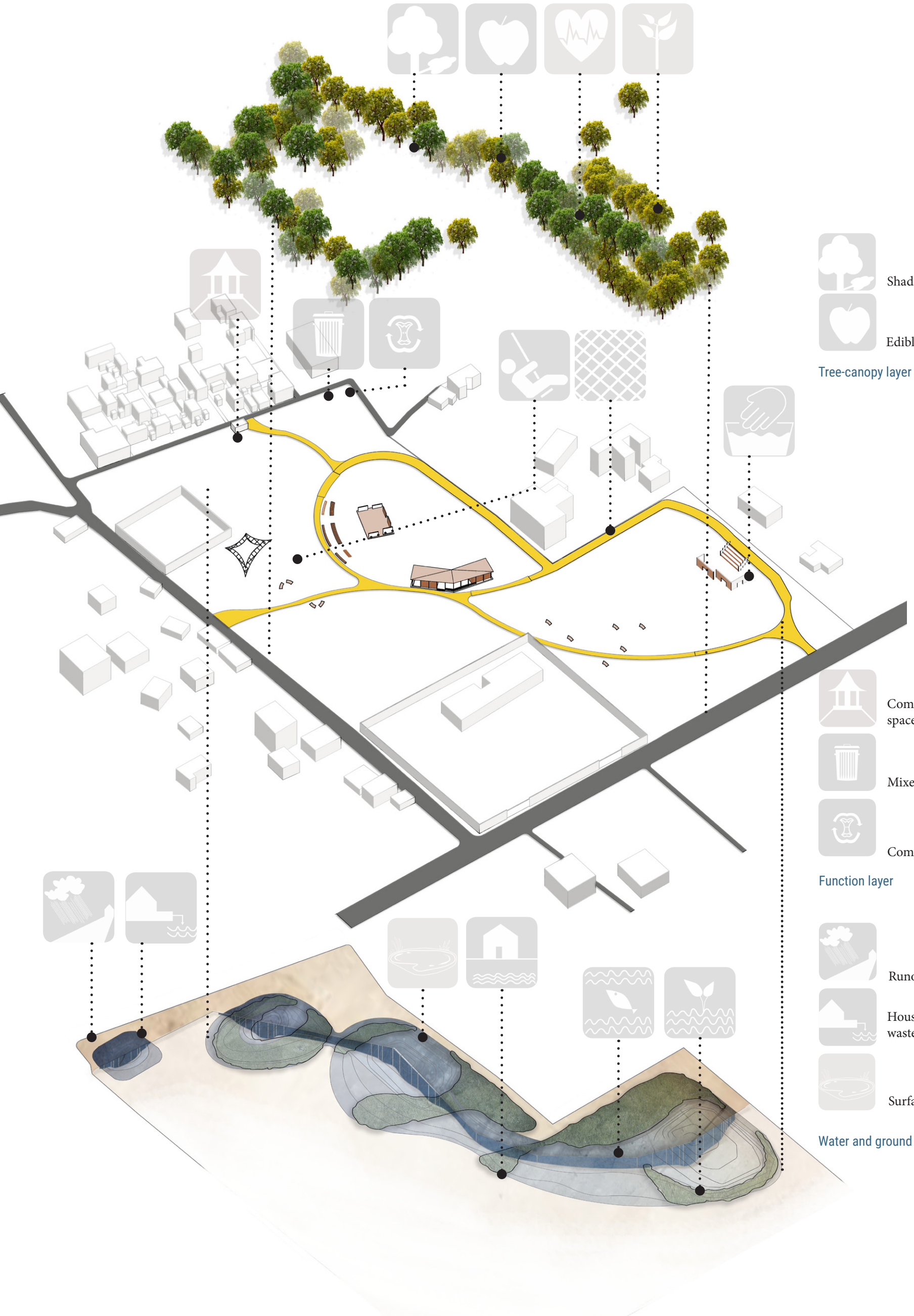
Figure: Schematic plan of the site

Functional plan

The site will be divided in to communal space and public space (playground) through pathway and wetland plants. Closest to where the community live, is the community space and community garden. Then the inlet pond and its plant create some privacy and opens up to children play ground and water pavilion. From the roadside, again the outlet pond and its plants create a buffer zone to enter in to the play area. The bioswale around the site discourages to access from everywhere and pathway gives the access from certain points. Thus, the need of boundary wall is eliminated.

Legend of schematic plan

- Ponds at normal water level
- Wetland
- Community garden
- Communal space
- Children's play area
- Children's play area (divided for age group)
- Children's water pavilion
- Communal bathing space
- Buffer from main street



Shade

Habitat

Edible

Plants

Tree-canopy layer

Community space

Bathing

Mixed waste

Children's park

Compost

Permeable surface

Function layer

Runoff

Aquatic Habitants

Household wastewater

Aquatic plants

Surface water

Subsurface water

Water and ground layer

Wastewater treatment

The treatment of household greywater and stormwater will be done in a series of four ponds. Two ponds and two ditches are currently available in the site. This thesis proposes to convert the ditches into ponds of required size. Also the two existing ponds have to be dig to create slope so that the ponds can expand during high water season. These ponds will then be connected to each other with underground line or gravity slope on surface. The proposed system will serve 66 families around the site.

Bioswale(S)

Bioswale collects the runoff and the wastewater from household around the neighbourhood. Runoff will be directed into bioretention swales direct surface runoff. The bioswale will be covered with grass to prevent odour and unpleasant view of wastewater. This grass can be regularly harvested by the community as the food for their domestic animals (Cows and goats). In this way, the maintenance cost of the bioswale will not only be less, but also be taken care of. Introducing fishes (Guppy and Whitespot) in bioswale will help to prevent mosquito larvae development. The soil treatment of the bioswale will also allow the water to infiltrate underground. The slope of the system should stay between 1%-4%.

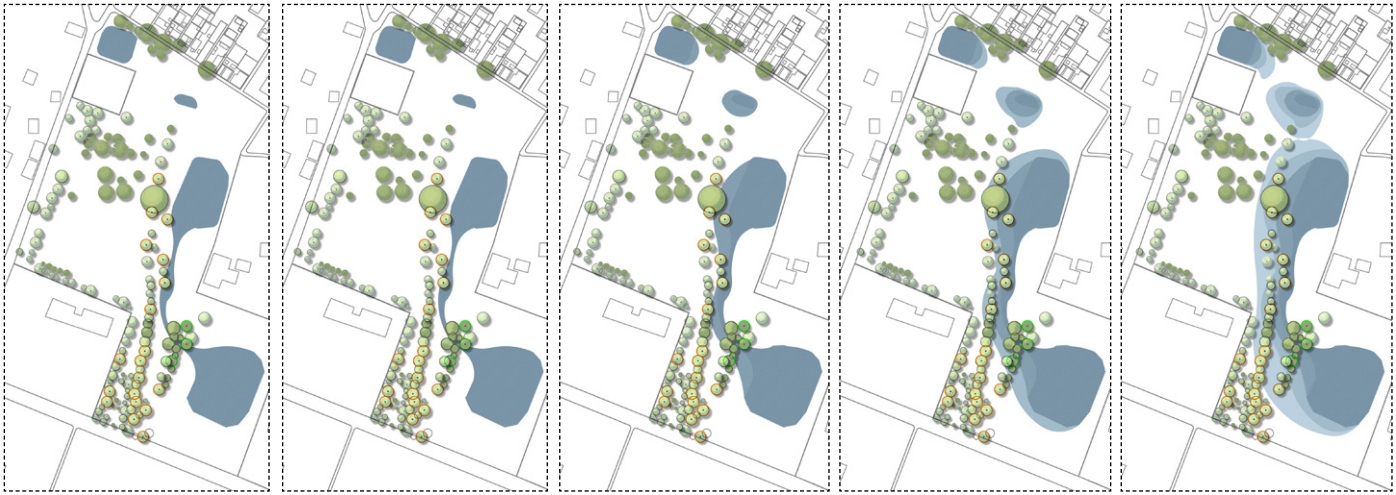


Figure: The expansion of the pond during high water season, if needed

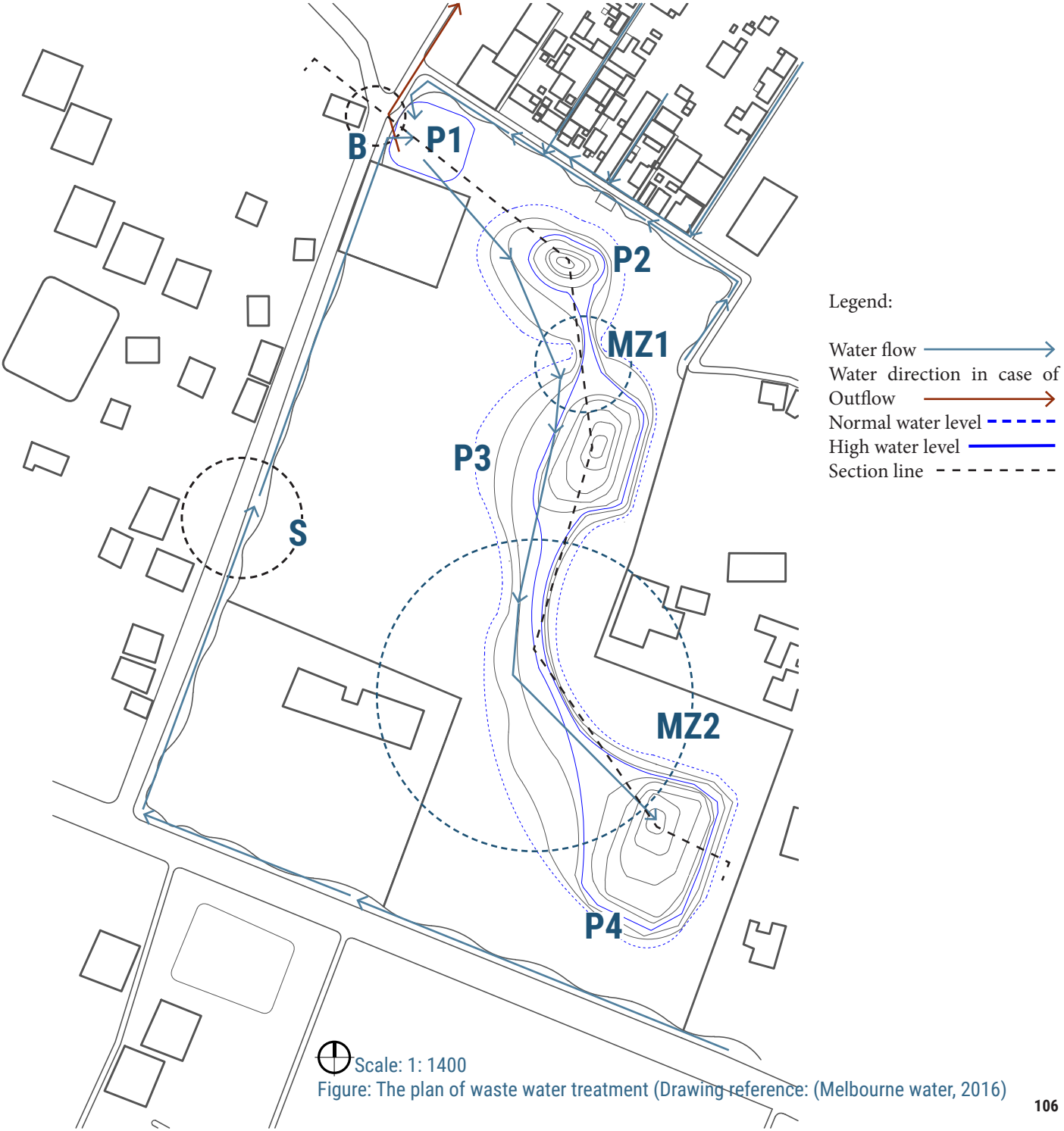


Figure: The plan of waste water treatment (Drawing reference: (Melbourne water, 2016)

Sediment Pond (P1)

The sediment pond is the first pond which will collect the water from bioswale. As the name suggests, this pond is employed to remove (by settling) coarse to medium-sized suspended solids through processes of temporary detention and reduction of flow velocities. The larger particles has low levels of contamination and is unlikely to require special handling and disposal. The water will be then transferred to the inlet pond through a underground channel.

Overflow bypass (B)

Overflow bypass is connection from sediment pond to existing drain. In case of heavy rainfall, the overflow pass will divert the excess of water to the river Noboganga. Only in that case, water is being released to the river without any treatment.

Inlet pond (P2)

The inlet pool is introduced to receive the water and slowing transfer the water to intermediate pool (over 3 days) through a Macrophyte Zone (MZ1)

Intermediate pond (P3)

After the discharge of water from the inlet zone into the macrophyte zone for removal of fine particulates and dissolved contaminants through the processes of filtration and adhesion, water enters to intermediate pond. From intermediate pond, water enters the next microphyte zone where it gets treated through the process of biological uptake.

Outlet pond (P4)

Outlet pond will be free from finer pollutants and safe to use for all the external use for the community (bathing, playing etc.)

Macrophyte zone (MZ1 & MZ2)

A comprehensive wetland planting program has to be taken and maintained. The plants selected for wetland must be of local indigenous stock. A list of suitable plants for area has been added at the end as appendices. This wetland is essential for the different stages of treatment processes to perform. It will also contribute to the structural integrity of the asset by protecting batters and beds from erosion. It will provide high aesthetic and habitat values. Success selection of types of plant to be together reduces weed development and thus reduces maintenance cost.

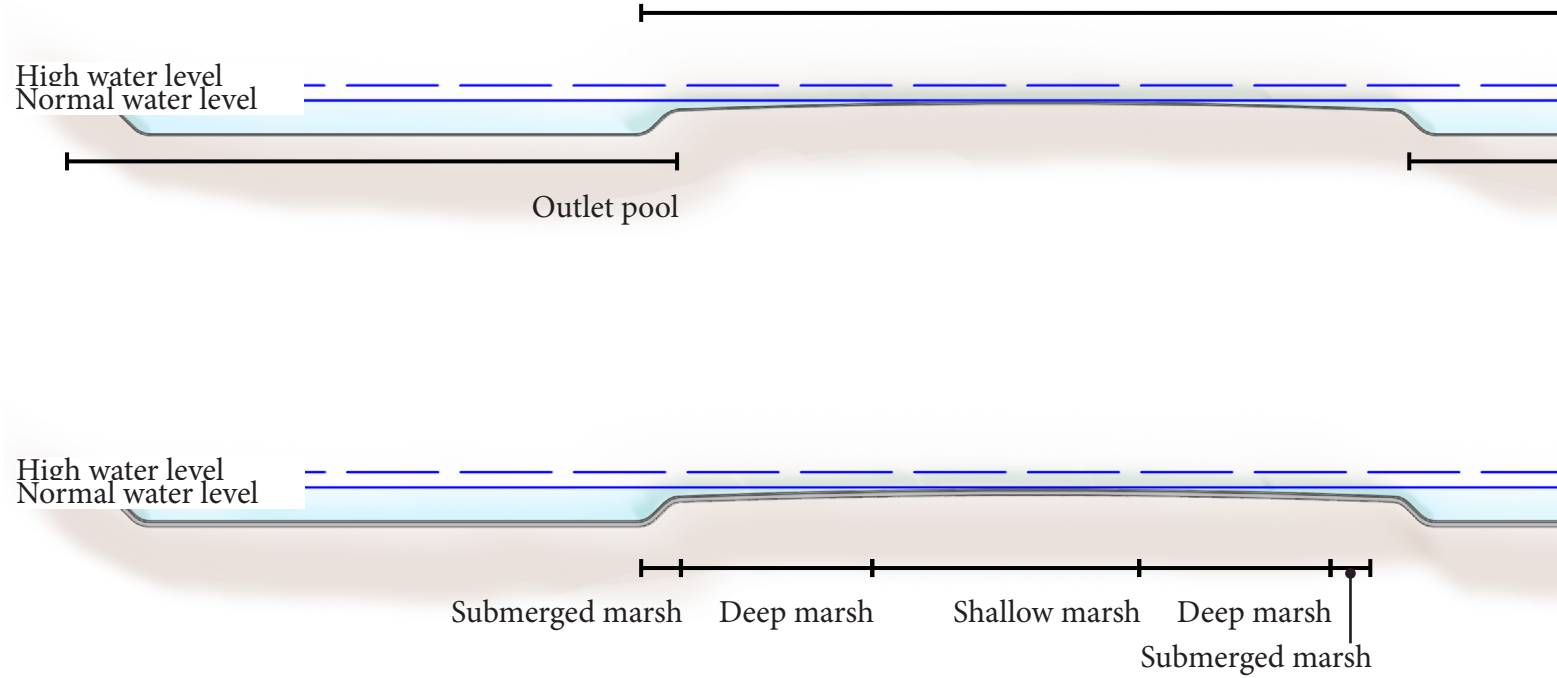
A General percentage of how to distribute the Plants in different sections of Macrophyte zone is given below-

OpenWater	10%
Submerged Marsh	10%
Deep Marsh	25%

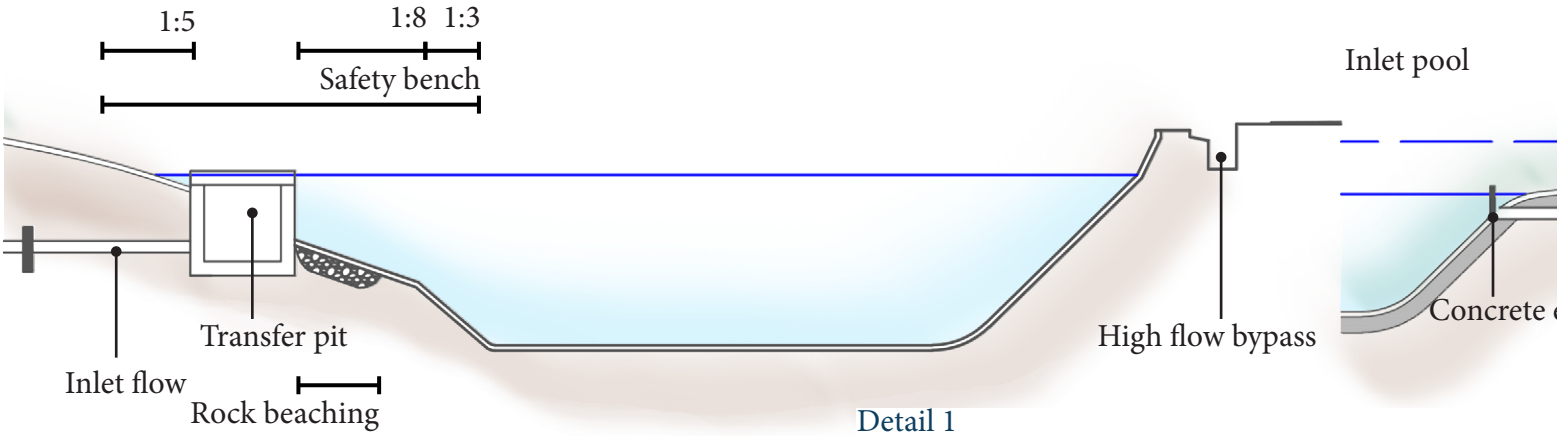
Marsh	25%
Shallow Marsh	25%
Littoral (edges)	5%

(Melbourne water, 2016)

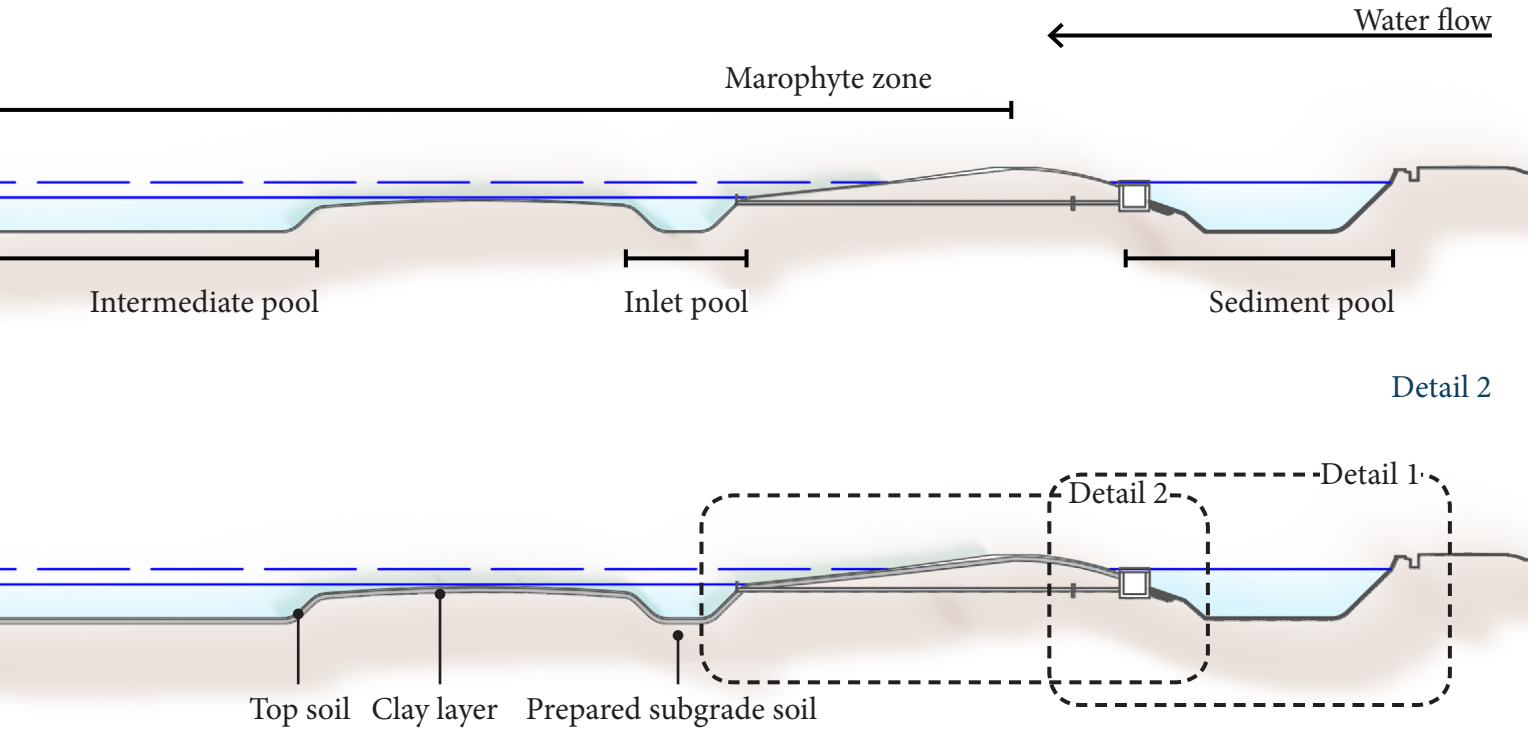
Introducing a proper selection of fishes in all parts will be beneficiary for the health of the whole constructed wetland to control the algae bloom and mosquito larvae. 'Proper' selection means selecting a range of fishes that balances the ecosystem of the water-bodies, in contrary to present practice of cultivating of foreign, invasive fish that destroys the whole ecosystem. The community can be beneficiary economically as well, by consuming and creating community based social enterprise for fish supply. A list of indigenous fishes for pond ecosystem has been added as appendices.

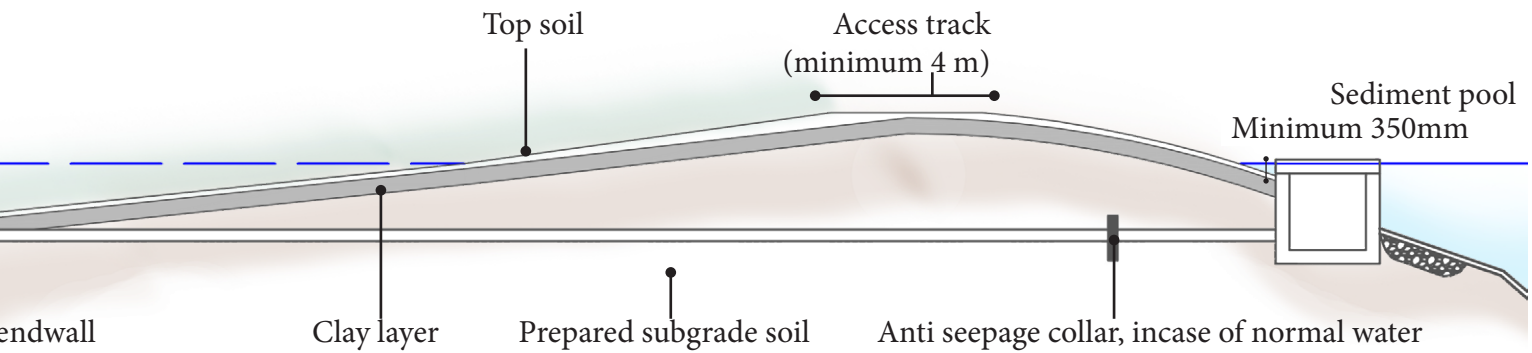


Section
Scale: 1: 700



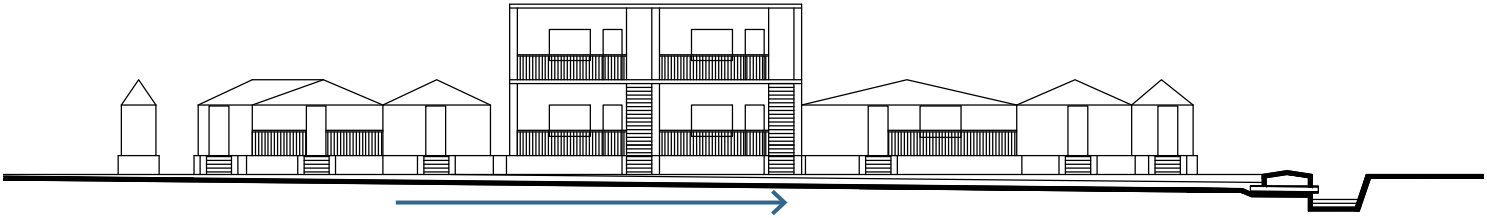
Detail 1
Scale: 1:200
(Melbourne water, 2016)



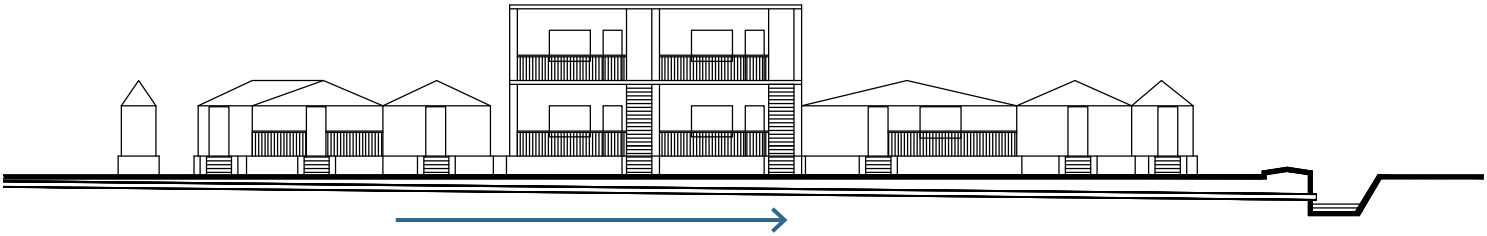


Detail 2
Scale: 1: 200
(Melbourne water, 2016)

Bioswale



Water flow from the surface (Slope 1:100)



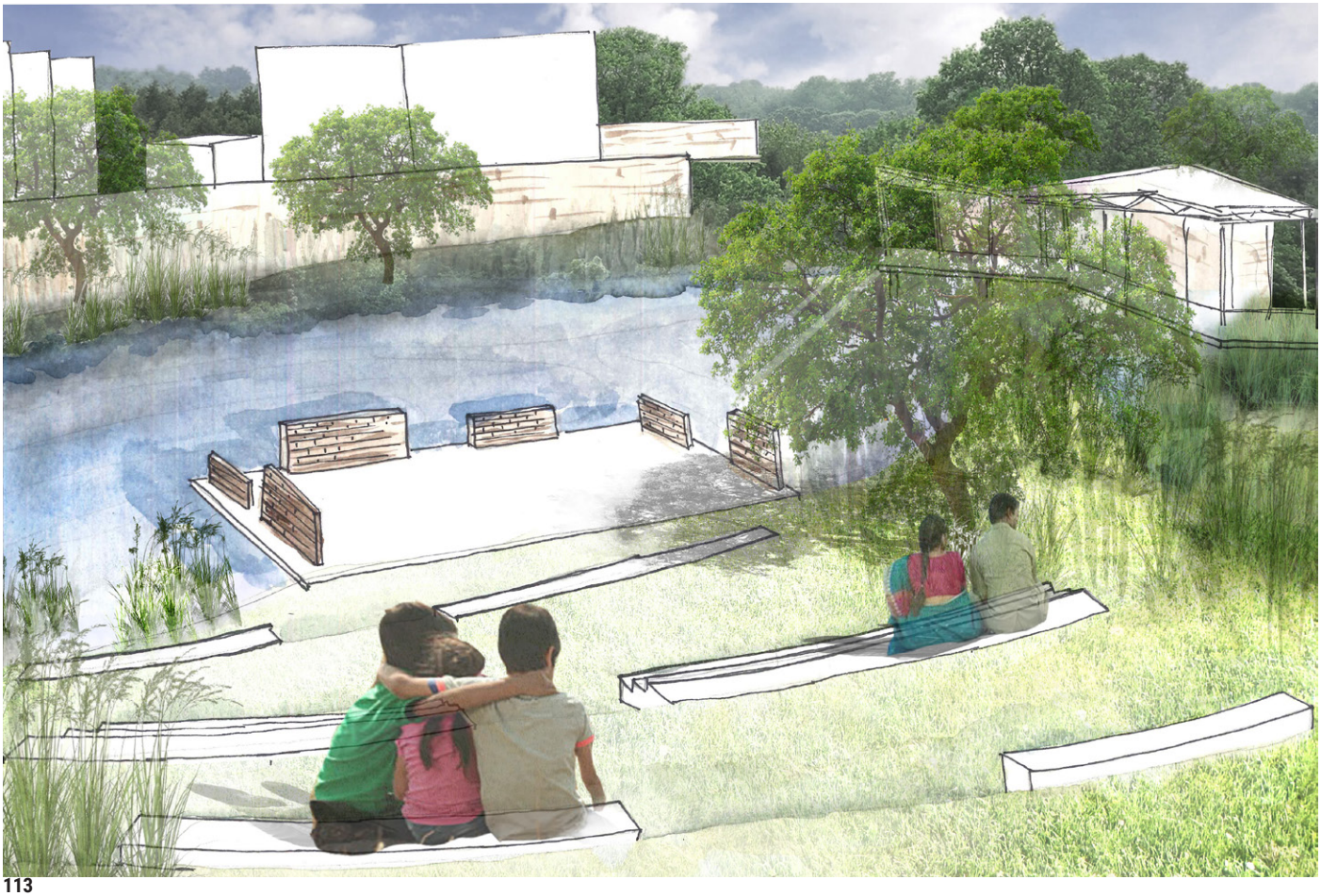
Water flow through underground pipe (Slope 1:100)

Figure: How water from the household will be collected to the bioswale


Gravel, or similar coarse material
Coarse sand
Fine sand
Subsoil

Water pavilion for children: The stage

The water pavilion for children consists of two part, the outdoor stage+sitting arrangement for cultural permanences arranged by/for local children, and a indoor space for various activities.



Scale: 1:400

Figure: The plan of water pavilion and outside stage

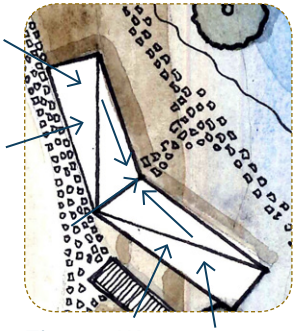
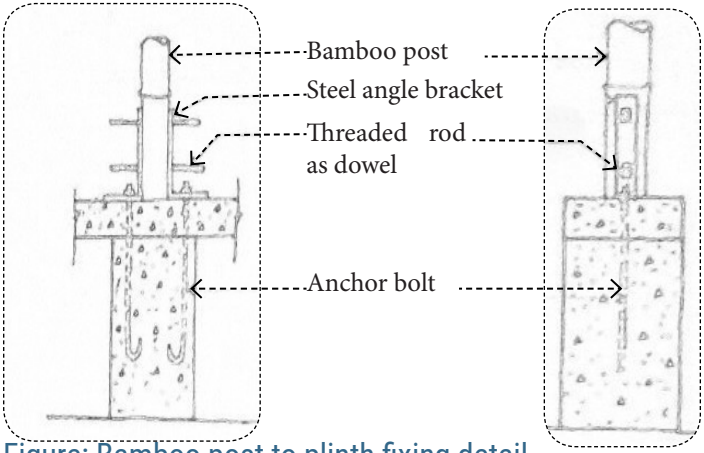


Figure: Water accumulation on the roof

The pavilion

The water pavilion consists of two enclosed spaces for book library and tool library and semi open sitting space for children that can accommodate any kind of workshop they want. The roof of the pavilion will be of CI sheet that will collect the rain water in one point and release it to the wetland. This would create a view from inside and also a shallow marsh to interact with water on the outside.



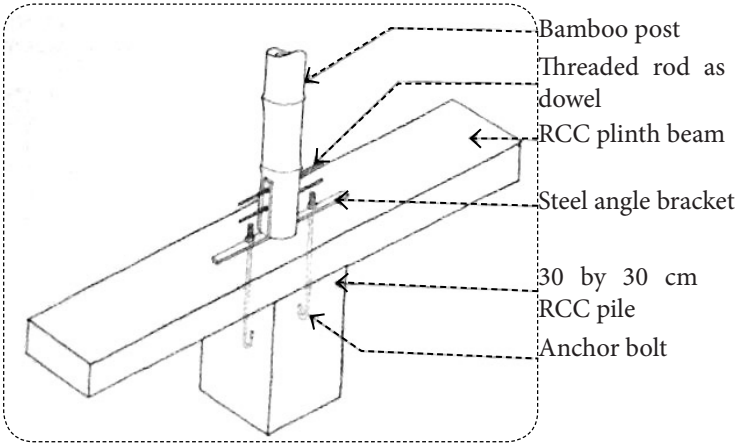


Figure: Bamboo post to plinth fixing detail

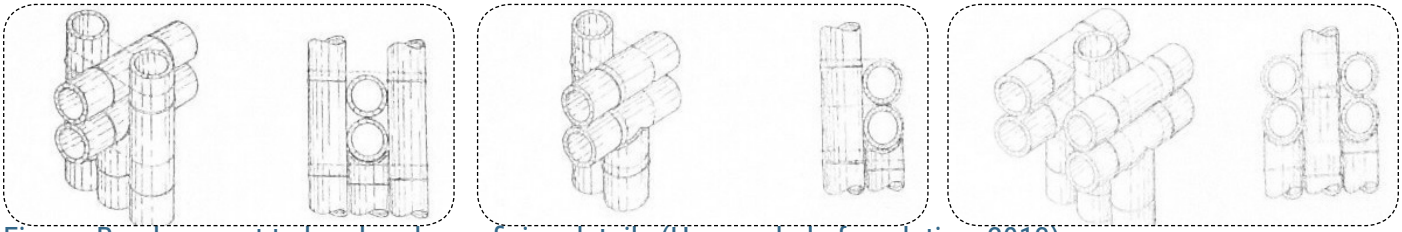


Figure: Bamboo post to bamboo beam fixing details (Hunnarshala foundation, 2013)

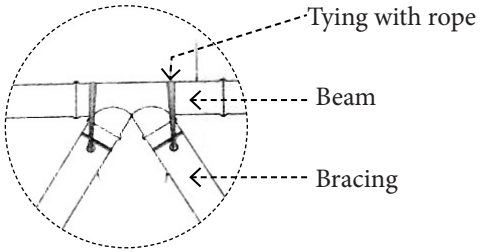
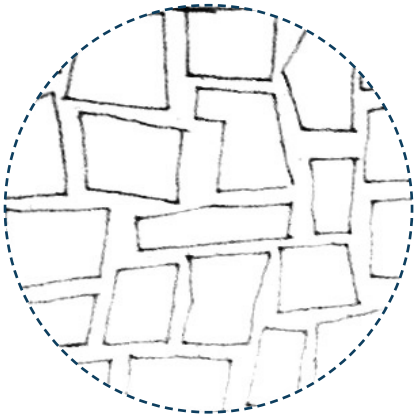
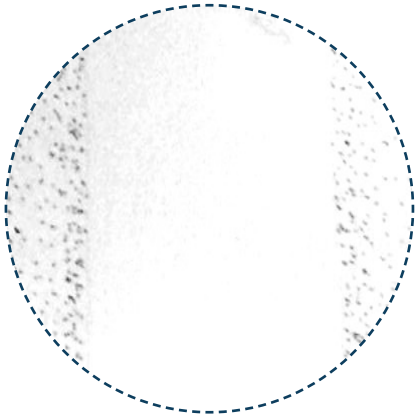


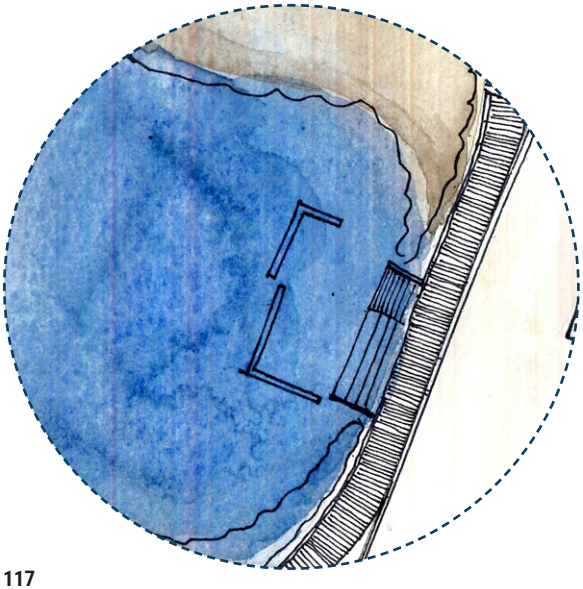
Figure: Detail on the roof





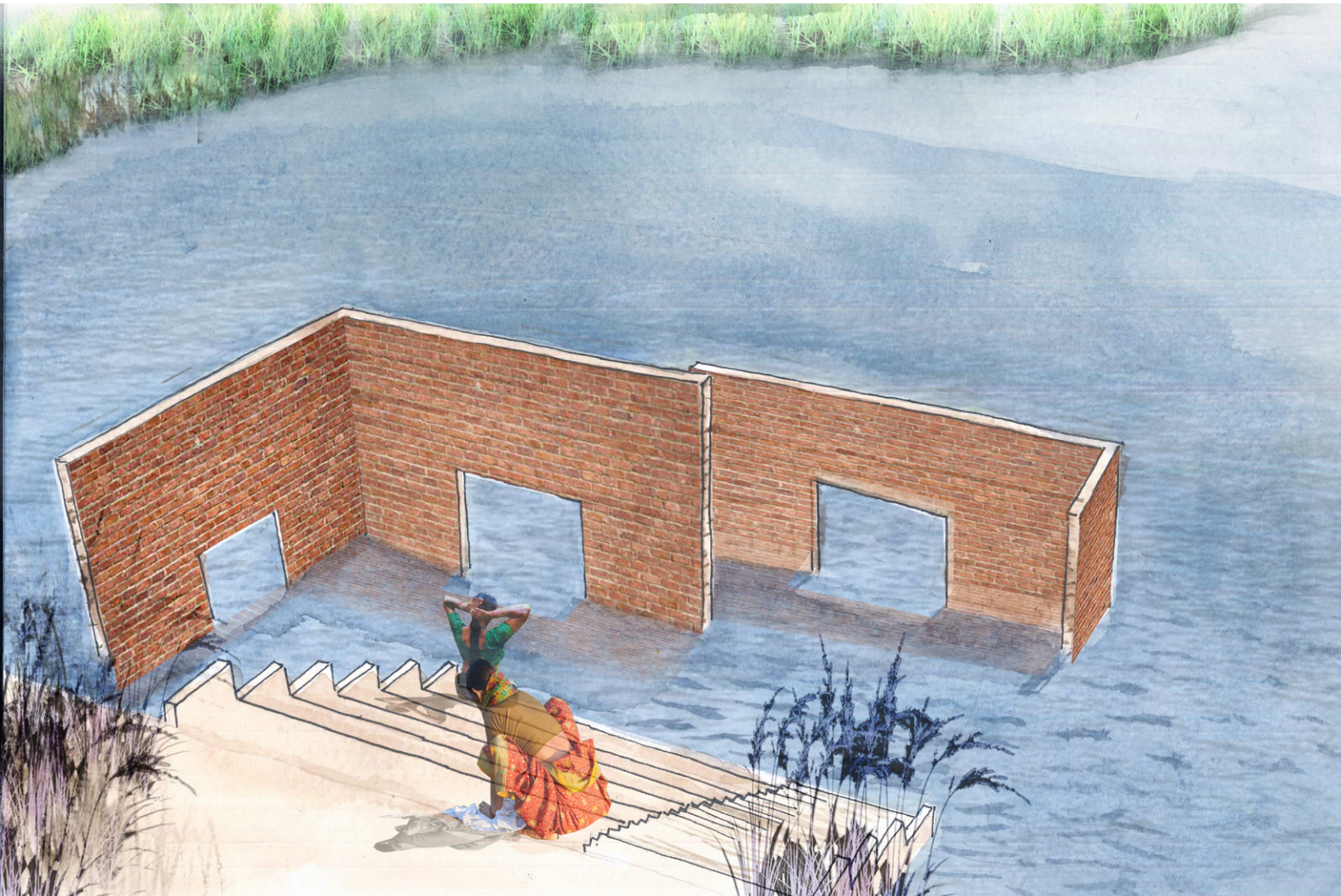
Pathway

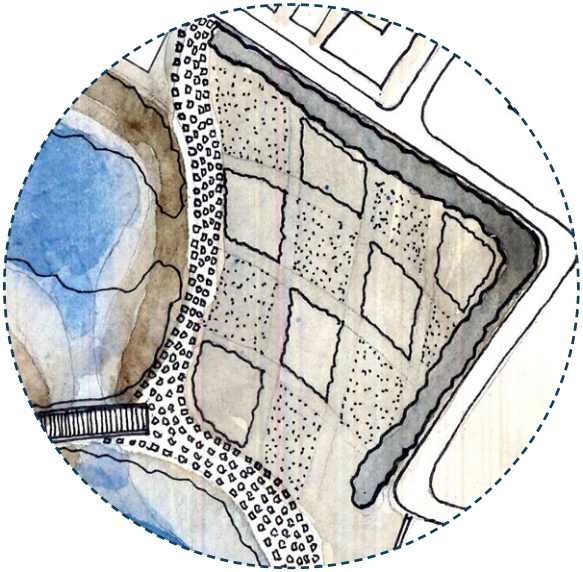
The pathway will be covered with hard surface as minimum as it needs so that the infiltration is maximised everywhere in the site. The material proposed for the pathway is reclaimed/reused concrete or brick from demolition work.



Ghat: Steps to the outlet pond

The ghat provides with larger steps in order to wash cloths. Since privacy was an issue for women, specially the young one, and will continue to be one if the playground is open for public. Fragmented brick wall has been proposed through the next sketch.





Community garden

The idea is to manage the community garden as a group (not individual families). This way the group can manage buying seeds, plants by taking loan from their own savings and operate as community base enterprise. The area also includes two separate bins for waste, one for organic waste and another for others. The compost can later be sold outside if it is run successfully. Collecting waste in one place is crucial for the water treatment system to perform. Otherwise, the waste might end up in the ponds or wetlands and thus compromise the efficiency of the system.

Figure above: The empty site at the present; below: Possible outcome from community gardening

Communal space

Organising the wastewater streams from the communal taps and households to bioswale and then to the ponds will provide the community with uninterrupted space for their daily activity. In the proposed sketch, a piece of ground has been provided for the community, where they can gather, perform the household chores (preparing for cooking, drying cloths or just hanging out) as before.

Advantage and risk of the proposal

Advantage

This proposal allows the city to act as a sponge to absorb the water as much as possible in its aquifer, before it can run to the downstream (river). Also, this system ensures the quality of the water that will run to downstream. Since the water is kept in the ponds for long time, it also provides for micro-climate through evaporation.

The primary advantage of the wastewater treatment is- it is based on available local resources and it is very flexible to accommodate heavy rainfall. During the rainy season some of the park space will turn into extension of the ponds and during dry season the ponds will leave more space to the park.

Apart from fulfilling basic requirement of draining out household greywater and runoff, this system also provides the sensitive layer of appropriate natural space for different species within a urban area. The interaction between different habitats and children would nurture the children to have more sensitive and aware mindset.

In this proposal, the wastewater treatment is merged in public space (playground). Since land availability is a huge issue in Bangladesh, multiple use of land is very crucial. Decentralised wastewater treatment can be merged with almost all kind of public spaces that has been proposed by the masterplan of Jhenaidah (page 39) .

Risk

Constructed wetland can turned into an unbalanced system if it is not understood and taken care properly. The municipality has no waste management system at this moment. This leads the residents not developing/practicing any particular habit towards waste management. If the household waste end up in the wetland ponds, the balance of ecosystem in the pond will be hampered and thus the wetland will not be able to clean water as it supposed to do. An unbalanced water treatment system might house life threatening diseases, such as dengue or cholera. So the components of water treatment and waste management has to go hand in hand, together with proper maintenance and awareness.

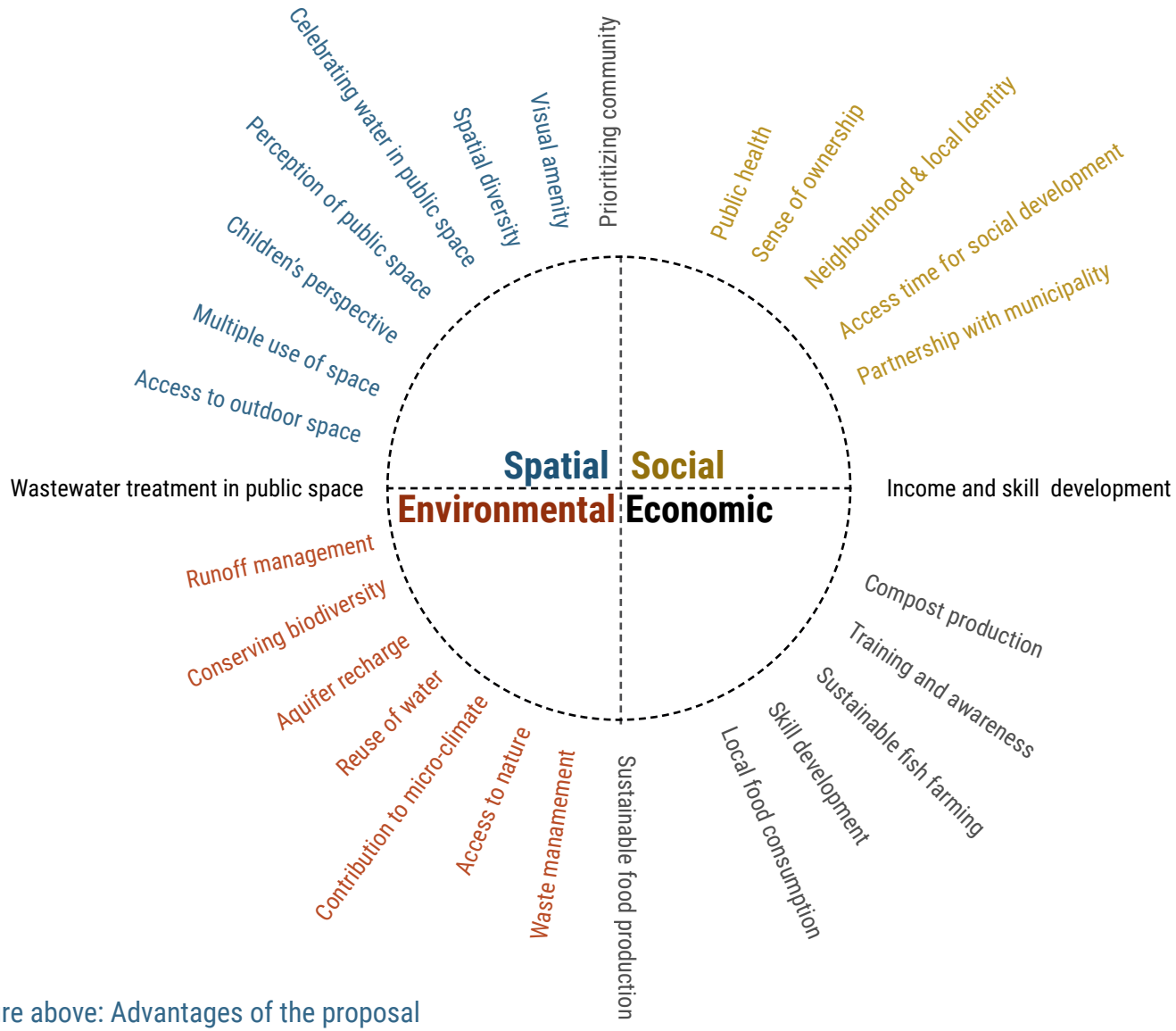


Figure above: Advantages of the proposal

Chapter Seven:
Final Discussion

Critical requisites for implementation

The first message the result of thesis wants to convey is, setting a goal future does not really contradict the aim to solve present problems. We do not need to or better to say should not wait for 'solving our basic problems' and then 'improve' it to be sustainable. There will be no time to improve, there will always be shortage of safe water if we do not keep it safe today.

Demonstration project:

Treating water through landscape is a proved method, however, will it work in this specific context? This can only be answered after a demonstration project. Though this system is flexible, therefore, can be altered according the context's requirement, there are many things that can disrupt the system's performance. Waste management is one of those issues. If waste is not handled properly, the whole water treatment system can collapse. This is the reason, why blackwater has not been included in the proposal. Blackwater, as well can be treated within the site, with few more steps. After monitoring the demonstration project, blackwater treat can be included for next site or community.

Acknowledging the communities as main resource:

The community based organisations possess most potential as workforce, as they are the driver to change. By enabling these communities, municipality can delegate some work and go for partnership with community based organisations. As the first diagram shows on the next page, in the beginning the external support groups (architects, engineers, researchers) will play (in fact, it has started already) a major role, not only with their specific skills and professions, but also as community mobilisers. NGO-s can help to design the necessary trainings and replicate similar process in other communities. Later, when few communities have grown in terms of their savings and experience, these front runner communities can take the role of community mobilisers and trainers. Architects or other professional can step back and continue supporting the communities with their professional skill. **The most important role for an architect would be to transfer skill to the community network, rather than designing detail for them.**

Involvement of community during design and construction process:

Active participation of community members in the design and construction process of water treatment would benefit to build consciousness about environment. Acknowledging the importance of healthy environment for human, ecosystem and biodiversity will come from the involvement of residents of the area.

Figure : The role of support group is important in the beginning, while city-wide network and municipality will build their capacity

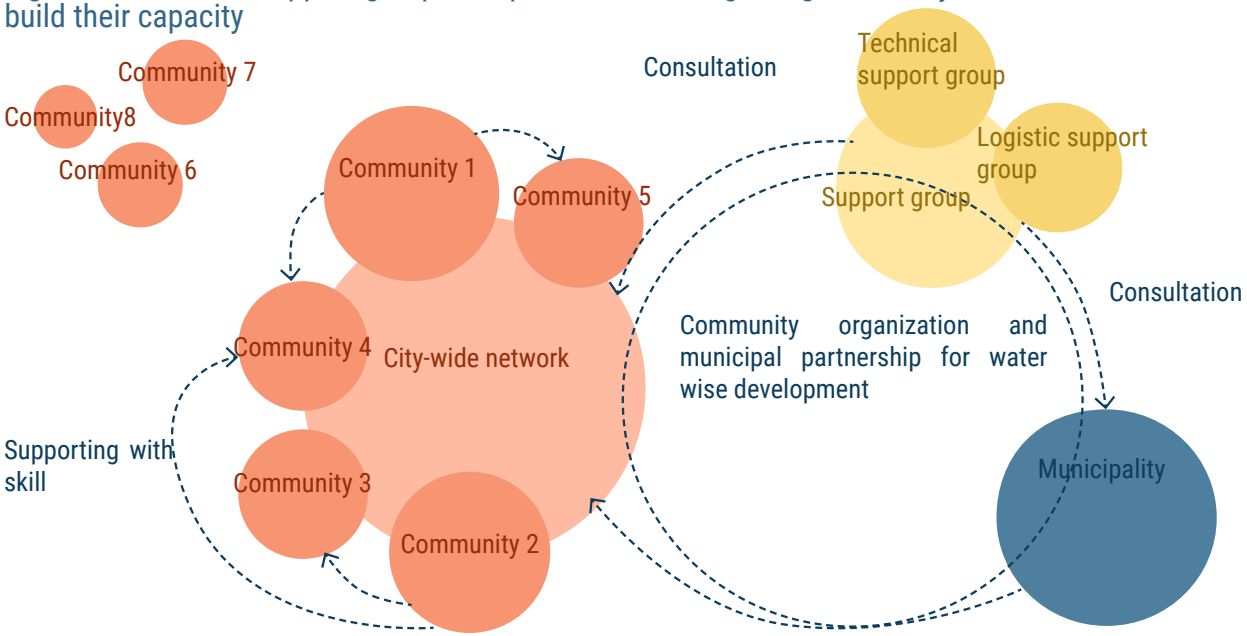


Figure : The role of support group should be limited to technical support in the later phase, bringing city-wide network in the lead.

Further research:

The proposed treatment system and spaces designs are more suggestive that definitive. This thesis has done research on existing projects other countries than Bangladesh. More accurate knowledge has to be generated regarding the local climate, vegetation and aqua habitat by experimental research. Then it has be tested to determined the efficiency. With the increased efficiency the system can also treat the black water of the neighbourhood, which is not suggested in the proposal right now.

Multidisciplinary team of experts

The solution needs input from multiple disciplines, architecture, landscape architecture, urban planning and designing, civil engineering, biotech engineering.

Creating transferable/communicable database

To make it scalable, it is important to take the concept from theory to data that can communicate with other professionals that designers.

Setting guideline and standard

Guideline and standard has to be derived according to local requirement and capacity.

Personal reflection:

The thesis began a personal quest to find out what architecture/urban planning contribute to sustainable water management system. From the many literatures that I studied, I understood that architecture/urban planning and water management are still two very different sectors and hardly collaborate with each other. Therefore, I see this thesis as, probably not an accomplished final product, but a starting for dialogue process between these two sectors, especially for the professionals of developing countries of South Asia.

Participatory work in design profession varies a lot from global north to south that I had read before, and now I have experienced by my own through the thesis work. Throughout the time, I had struggled to find a balance for the thesis between 'a student project that will be present in Swedish context' and 'a new discussion for the design professional and local government in Bangladeshi context'.

Throughout my stay within the community, I observed a lot more that I could have found out through any kind of formal research method of survey or interview etc.

I had an opportunity to discuss the result of the thesis with the mayor of Jhenaidah city, who was very enthusiastic and aware about the cause. A demonstration project to create this constructed wetland system to treat water is a matter of time now. My plan is to present the full result of the thesis to the contributors (the students, the communities and the municipal authority) when I go back to Bangladesh and invite them to create collaboration during the demonstration project.

The thesis can still be benefited from further research as I have discussed in previous section. As an architect, the next thing I would like to map or measure is, how this design concept actually changes human behaviour.

Appendices and references

Appendix A: Water dictionary

Aquaculture --farming of plants and animals that live in water, such as fish, shellfish, and algae.

Aquifer--a geological formation or structure that stores and/or transmits water, such as to wells and springs. Use of the term is usually restricted to those water-bearing formations capable of yielding water in sufficient quantity to constitute a usable supply for people's uses.

Aquifer (confined)--soil or rock below the land surface that is saturated with water. There are layers of impermeable material both above and below it and it is under pressure so that when the aquifer is penetrated by a well, the water will rise above the top of the aquifer.

Aquifer (unconfined)--an aquifer whose upper water surface (water table) is at atmospheric pressure, and thus is able to rise and fall

Artificial recharge--an process where water is put back into groundwater storage from surface-water supplies such as irrigation, or induced infiltration from streams or wells.

Base flow--sustained flow of a stream in the absence of direct runoff. It includes natural and human-induced stream flows. Natural base flow is sustained largely by groundwater discharges.

Blackwater -- waste water and sewage from toilets.

Condensation--the process of water vapour in the air turning into liquid water. Water drops on the outside of a cold glass of water are condensed water. Condensation is the opposite process of evaporation.

Domestic water use--water used for household purposes, such as drinking, food preparation, bathing, washing clothes, dishes, and dogs, flushing toilets, and watering lawns and gardens.

Effluent--water that flows from a sewage treatment plant after it has been treated.

Evaporation--the process of liquid water becoming water vapour, including vaporization from water surfaces, land surfaces, and snow fields, but not from leaf surfaces. See transpiration

Evapotranspiration--the sum of evaporation and transpiration.

Flood--An overflow of water onto lands that are used or usable by man and not normally covered by water. Floods have two essential characteristics: The inundation of land is temporary; and the land is adjacent to and inundated by overflow from a river, stream, lake, or ocean.

Flood plain--a strip of relatively flat and normally dry land alongside a stream, river, or lake that is covered by water during a flood.

Freshwater--water that contains less than 1,000

milligrams per litre (mg/L) of dissolved solids; generally, more than 500 mg/L of dissolved solids is undesirable for drinking and many industrial uses.

Greywater--wastewater from clothes washing machines, showers, bathtubs, hand washing, and sinks.

Groundwater--(1) water that flows or seeps downward and saturates soil or rock, supplying springs and wells. The upper surface of the saturate zone is called the water table. (2) Water stored underground in rock crevices and in the pores of geologic materials that make up the Earth's crust.

Groundwater, confined--groundwater under pressure significantly greater than atmospheric, with its upper limit the bottom of a bed with hydraulic conductivity distinctly lower than that of the material in which the confined water occurs.

Groundwater recharge--inflow of water to a groundwater reservoir from the surface. Infiltration of precipitation and its movement to the water table is one form of natural recharge. Also, the volume of water added by this process.

Groundwater, unconfined--water in an aquifer that has a water table that is exposed to the atmosphere.

Hydrological cycle--the cyclic transfer of water vapour from the Earth's surface via evapotranspiration into the atmosphere, from the atmosphere via precipitation back to earth, and through runoff into streams, rivers, and lakes, and ultimately into the oceans.

Layer--a layer of solid material, such as rock or clay, which does not allow water to pass through.

Infiltration--flow of water from the land surface into the subsurface.

Livestock water use--water used for livestock watering, feed lots, dairy operations, fish farming, and other on-farm needs.

Organic matter--plant and animal residues, or substances made by living organisms. All are based upon carbon compounds.

Pathogen--a disease-producing agent; usually applied to a living organism. Generally, any viruses, bacteria, or fungi that cause disease.

Permeability--the ability of a material to allow the passage of a liquid, such as water through rocks. Permeable materials, such as gravel and sand, allow water to move quickly through them, whereas impermeable material, such as clay, don't allow water to flow freely.

Potable water-water of a quality suitable for drinking.

Precipitation--rain, snow, hail, sleet, dew, and frost.

Public supply--water withdrawn by public governments and agencies, such as a county water department, and by private companies that is then delivered to users. Public suppliers provide water for domestic, commercial, thermoelectric power, industrial, and public water users.

Recharge--Water added to an aquifer. For instance, rainfall that seeps into the ground.

Reclaimed wastewater--wastewater-treatment plant effluent that has been diverted for beneficial uses such as irrigation, industry, or thermoelectric cooling instead of being released to a natural waterway or aquifer.

Recycled water--water that is used more than one time before it passes back into the natural hydrological system.

Reservoir--a pond, lake, or basin, either natural or artificial, for the storage, regulation, and control of water.

River--A natural stream of water of considerable volume, larger than a brook or creek.

Runoff--(1) That part of the precipitation, snow melt, or irrigation water that appears in uncontrolled surface streams, rivers, drains or sewers. Runoff may be classified according to speed of appearance after rainfall or melting snow as direct runoff or base runoff, and according to source as surface runoff, storm inter flow, or groundwater runoff. (2) The total discharge described in (1), above, during a specified period of time. (3) Also defined as the depth to which a drainage area would be covered if all of the runoff for a given period of time were uniformly distributed over it.

Self-supplied water--water withdrawn from a surface- or groundwater source by a user rather than being obtained from a public supply.

Septic tank--a tank used to detain domestic wastes to allow the settling of solids prior to distribution to a leach field for soil absorption. Septic tanks are used when a sewer line is not available to carry them to a treatment plant. A settling tank in which settled sludge is in immediate contact with sewage flowing through the tank, and wherein solids are decomposed by anaerobic bacterial action.

Settling pond (water quality)--an open lagoon into which wastewater contaminated with solid pollutants is placed and allowed to stand. The solid pollutants suspended in the water sink to the bottom of the lagoon and the liquid is allowed to overflow out of the enclosure

Sewer--a system of underground pipes that collect and deliver wastewater

to treatment facilities or streams

Storm sewer--a sewer that carries only surface runoff, street wash, and snow melt from the land. In a separate sewer system, storm sewers are completely separate from those that carry domestic and commercial wastewater (sanitary sewers)

Surface water--water that is on the Earth's surface, such as in a stream, river, lake, or reservoir.

Suspended solids--solids that are not in true solution and that can be removed by filtration. Such suspended solids usually contribute directly to turbidity. Defined in waste management, these are small particles of solid pollutants that resist separation by conventional methods.

Transpiration--process by which water that is absorbed by plants, usually through the roots, is evaporated into the atmosphere from the plant surface, such as leaf pores. See evapotranspiration.

Wastewater--water that has been used in homes, industries, and businesses that is not for reuse unless it is treated.
Water cycle--the circuit of water movement from the oceans to the atmosphere and to the Earth and return to the atmosphere through various stages or processes such as precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transportation

Water quality--a term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.

Water table--the top of the water surface in the saturated part of an aquifer.

(adapted from The USGS water science school, u.d.)

Appendix B: Research diary

Interview with POCAA

At the very beginning of the thesis work, an interview was conducted to understand the ground rationale of the municipality, with one of the architect, Suhailey Farzana, who is responsible for POCAA's Jhenaidah project. The interview lasted for an hour.

Question: Would you please tell me about the running project in Jhenaidah by POCAA?
Suhailey: We have been to 4/5 communities for the ACCA project and found one of the communities more organised than the others and decided to start working there immediately. By organised, we mean the community was more cohesive and they had some sort of savings group that works as a welfare fund for the community. Anyone could borrow loan from the fund if it is needed in case of emergency. The community members belong to Hindu low caste group. They own their lands (individually), though each of the plots is very small. The plot size, owned by a family, ranges from around .5 shotok to 5 shotok (20 sqm. to 200 sqm). This plot is again about to be divided among the heirs of the family. Most of the houses in the community are temporary earthen structures. The community resides by a road and it is called Mohishakundu shordarpara.

Question: Does the community locate alongside the river?
Suhailey: No, it is very close to the river though. We have selected other communities for ACCA's small project intervention, which are even closer to the river. For establishing a citywide network of such communities, we are trying to start organising the communities one by one , a different process from our previous experience. In our previous project (in Comilla City), we have worked with communities which were more organised as they had their savings groups and they also organised funding by themselves. Hence we could start talking about city wide networking with them. However, since UNDP's UPPR project is not active yet in this city , these communities are not organised enough. Therefore, we have started by organising one community in the beginning and the next communities are in the pipeline for the fund. The first community we are working with right now also belongs to an indigenous group, and they already receive a government fund for indigenous people. As a result, they have some sort of experience in handling fund, although in not so much of an effective manner. Besides, they already have an organisational structure within the community. So, when we went there we could just ask the existing body if they wanted to save up for housing development and they agreed to do so. After a few meetings, they had decided to save 50 taka per week. POCAA had an opportunity to exchange experience in Srilanka with the Women's Bank and two of the community members from this community accompanied us. After coming back from there, the community got more

motivated to run the saving project full-fledged. Apart from this community planned for a big project, there are four other communities that we think could start working on their savings for development. They are the selected communities for small interventions now and in the pipeline for revolving fund, after the first community start to pay back their loan. One of these next communities live on a private plot and rent it from the owner. This community has around 20/25 families. The condition of toilet, sewerage was disorganised and bad in this community. This community is also saving money, mainly to buy their own land. Till now, this community has been able to save some money and managed to improve a bit of their toilet condition. Another community at Vennatola has been saving money for some time and recently they are giving loan from their savings to their community members for house repairing purpose, which will also be revolving. Shoshanpara, another community has started saving but has not done or planned anything to do with the savings yet. At the first phase of the big project, twenty houses are being built and it is almost completed up to the first phase. Each of these families got Bdt. 1, 00,000 tk. After this, we are going to work with the small projects. The funding for small projects are already partially handed over to the communities.

Question: Have the beneficiaries from the big project started to pay back the loan?

Suhailey: There was a contract agreed and signed between this community, its individual member and citywide community network. The contract said the beneficiary will start giving back the loan once their houses are complete. We have mostly finished the structures of the houses, we still have work left to do, for example, putting doors and windows.

Question: How will the project go to the next phase or the next group of people?

Suhailey: Mohishakundu shordar bari community had 52 families, who were interested in the project. After the first 20 households, the fund will go the next 20 households of this community. And then it will go to the next community from the city network. All the communities for big and small projects build the city network.

Question: Let's focus on the water situation in the city. What can you tell me about water issues from your experience? How is it with the natural disasters like flood?

Suhailey: Jhenaidah is almost free from flood or any other natural disaster. This is the reason why you wouldn't see someone from Jhenaidah migrated to Dhaka for jobs, which is very common for other areas in Bangladesh, effected by natural disaster. About other water issues, we have talked to the community close to the river, we asked them if the water level rises a lot. The community informed that the water level never rose enough that it would enter in the houses. In that sense, Jhenaidah is better than many

other cities. There are both possibilities and issues regarding water in the city. We have talked to people, who see business opportunities in the river, but can't go forward because of capital/investment. Though there is no boat in the river anymore, we have travel once by a boat we managed and we have seen the common issue that you will see anywhere in Bangladesh or may be even all through the world, which is land grabbing. Everyone is grabbing land from the river, no matter rich or poor. In Most of the cases, you can't really approach to the river, because someone has a house there. Almost all the houses have their latrine on the riverside, directly discharging the waste into the river. Even an NGO, which is working for the betterment of the city has their outlet to the river. Along with these, the municipality has installed a huge pipe that is discharging the wastewater into the river. The market places dispose their waste in the river, slaughter houses dispose their waste in the river. All the toilets, built by the municipality, is on the riverside, doing the same, throwing waste into the river. There is actually no good example in the city for looking up to.

Question: How is the toilet condition in the community POCAA has worked with? Since UPPRP is not active in Jhenaidah, is there any other organisation/NGO who works with similar projects? (Providing shared toilet or tube well)

Suhailey: The NGOs in Jhenaidah only works with micro finance, not with providing toilet and tube well or as such. The municipality itself has built quite a few toilets for people, which looks like a proper toilet, spacious, clean, tiled floor. However, these toilets are not in use. There is always a toilet in poor condition, covered with temporary material (jute sacks) .We have asked why they don't use the municipal toilet. In Many cases they denied the fact that they are not using the better toilet, though it is kind of obvious. One of the reasons stated was the material. The old people are scared of going to a toilet that has shiny, slippery floor material. Another reason was possible dispute. Since the toilet was given, the community is unsure who will be responsible to empty the ring of the toilet once it gets full. Also, they themselves are not ready to take the responsibility. So they think it is better not to use the toilet at all, otherwise there will be problems with smell when the pit is full and no one is emptying it.

Workshop with Student of architecture, Brac University

Workshop: The session started with a presentation about the thesis topic 'Water-wise city: exploring possibilities for urban water efficiency through participatory design' to introduce myself to the group of students. The presentation discussed about water related issues in urban area globally as well as in local cities, problem generated from

conventional 'piped' water infrastructure and the scope of work within the thesis.

The workshop was divided into two parts. The first was 'role playing'. The students played roles of city mayor, city engineer, architect, urban planner, community leader, young person as old as 17, woman with 2 children and other citizens. Through role playing, first they discussed about 'water related problems in their allocated site' (Shatbaria), second, 'how to solve these problems' and finally 'how each individual role can contribute to the problem solving'. This part of the workshop discussed about immediate problems and solutions to those. The second part of the workshop focused on future. Through 'brain writing' activity, students wrote about their aspirations about Jhenaidah municipality's future in 25 years. They discussed about 'Where do you see Jhenaidah in 2040?'. They also discussed about their concerns, where the municipality might get stuck and not achieve much by those years.

Finding from the first part of the workshop

Problems:

- Health problem: Water borne (cholera) and water related (dengue) diseases, especially to children.

- Inadequate drainage system: Informal growth of the city makes it difficult to continue the conventional drainage everywhere.

- Inadequate waste management: Both the municipality and the inhabitants dump waste (solid waste, wastewater) into the river.

- Water quality: Presence of mineral (iron) beyond acceptable level. Also, not good for fish farming.

- Conflict: Relationship among community members are not always strong; there are complaints about killing each others' fish by poisoning.

- Lack of public space: There is not enough space children to play. The existing spaces are often clogged with water.

- Limitations of municipality: Lacks human resource to reach everyone in the city with water and drainage services. Lack of anticipation from root level

Solutions:

- Infrastructure : Planning for proper road network, drainage system, tube-well for potable water, waste management system.

- Water-system efficiency: Capturing rain water. Water run-off to river safely. Only treated

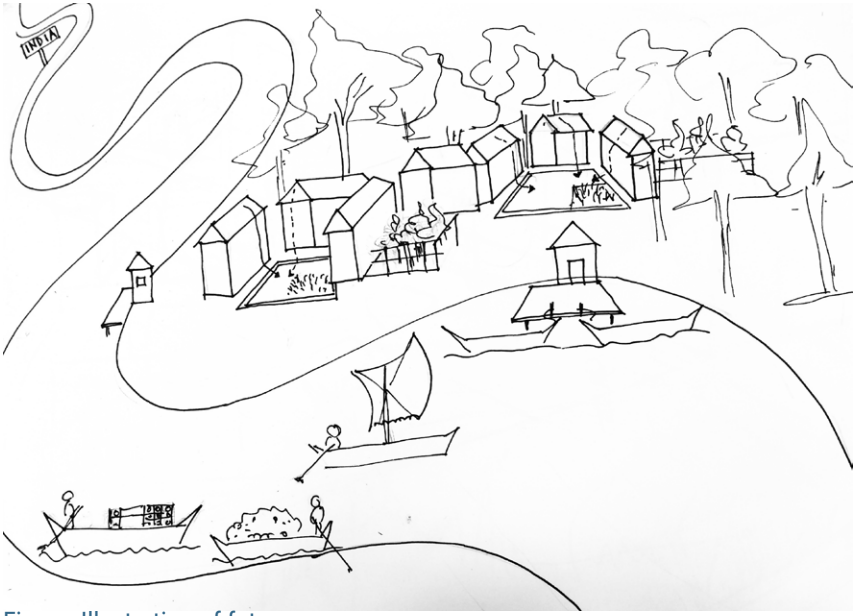


Figure: Illustration of future Jhenaidah, aspiration received from the workshop

run-off should go to the river.

- Strengthening community: Developing the skill of the community people so that they have skill to solve their own issue. The city needs to create liveable atmosphere with a relationship with river.

- Community-led maintenance : Cleaning the water edge collectively and making it accessible for public activities, for example, bathing or fish farming. Water should be treated to improve waterfront activities. This might help to influence attitude towards waste and water resource.

- Public space: Providing open/public space, space for children that can also work for water permeability

- Design with people: Design process has to include direct dialogue of community and service providing professional (politicians, engineers, architects, etc.).

Finding from the second part of the workshop: A future picture of Jhenaidah city in 2040

- A lively river with more water flow (Let us negotiate with the neighbouring country, India as the river is a trans-boundary water body), more water activities, waterway transportation, marketplaces in and around the river. The city will be connected through the river.
- Inhabitants will be 100% educated. Health awareness will increase.
- There will not only be 'courtyard', there will also be 'court-water'.
- Example for other cities about how city's internal communities can create self-sufficiency.
- A blue and green economy.
- "I would like to see Jhenaidah as the secondary city as it is right now, not a mega-city like Dhaka."
- Technologically advanced.
- Proper road network.
- Floating architecture and water ways for commuting as water-level is rising all over the world.
- Stronger and durable building structure with Eco and climate friendly material.

Figure: Municipal drain (nearest to Mohishakundu shordarpara

- Self-sustainable city, where people learn to use their own resources and develop their skill
- A city with all necessary facilities so that the dependency on capital city (Dhaka) reduces.
- A clean and green city, where people are aware of their own action.
- A city where the air is clean to breathe, water is safe and pure with green all around. A place that promises good health mentally and physically.
- A modern and sustainable city that respects environment and nature
- People will live 'with' the river. Communities will be self-dependent and they will solve their problems, there will be no complaints
- It will be 'houses within forest' rather than 'trees with in cities'.
- There is a danger of Jhenaidah becoming another Dhaka, with completely dried up river, may be technologically improved, but health and environmentally degraded.

Walking in the city

'Walking in the city' member from Mohishakundu shordarpara: About ten women from Mohishakundu accompanied us to visit three other communities in Mohishakundu, Shoshanpara, Vennatola and the river side. Since these women have actively participated in improved housing project and savings group with their own community, they can take lead to show other communities how to work together as a community for development. Our visits included experience sharing sessions with other communities, where they shared their activities, challenges and experiences. From my own experience and from the interview with POCAA's architect, it appeared clear to me that women in these communities stand far behind than their male counterparts. With a male presence, the women groups are quiet and shy. But when they discuss with women from different communities, they share their problems and challenges more openly. This exchange was significant for the reason of gender equality.

Focused group discussion at Arappur daspara:

The savings group at Arappur daspara seems to perform better than all other communities. The savings is distributed through small loans for business as most of the community members generate their income through business. A discussion was held about how women of the community can also contribute in family

Figure: New, but unused toilet at Mohishakundu

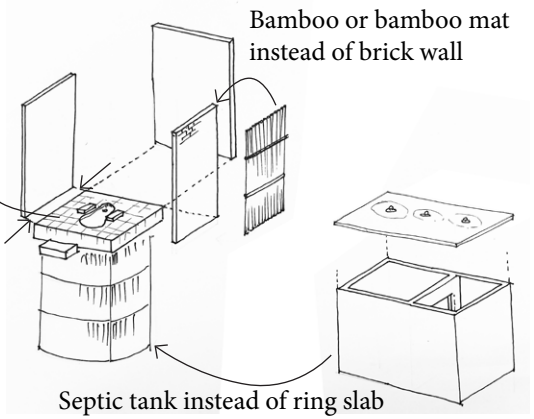


Figure: Illustration of community aspiration of toilet from the workshop

income by producing hand crafted products. There are some skills already mastered within the community.

Workshop findings at Mohishakundu Shordarpara:

Municipal toilet

Cost: The cost (Bdt 80,000, while the community is building improved houses with Bdt 1, 00,000) of the toilet can be reduced, by reducing size. Reducing cost can increase the number of toilets with the same budget.

Location: The toilets' location has to be on more strategic points. Not consulting the household owners collectively results in positioning the toilets on inaccessible or disputed piece of land. More appropriate land could have been found for sharing toilet by multiple families if the decision were made after consulting the beneficiaries as a community rather than as individuals.

Size: The size of the toilets are bigger than minimum standard, which is many cases unnecessary for the users. The size of the toilet is too big for some families to place it on the land they own.

Material: Use of material sees some criticises as well. Tile is an unknown material for the economic status of the community and it provides sense of shiny and slippery floor to the elderly people.

So, they do not feel safe about going to the toilet. Chosen materials are also expensive, these can be replaced with cost-effective material. The saved money can rather be used for septic tank, instead of ring slab.

Sharing about knowledge exchange visit to SAFE (Simple Action for Environment), Dinajpur

A group of people from Mohishakundu shordarpara had visited an NGO, SAFE , who works with improved housing in a cost effective manner. SAFE is running their activity in a village in the north-western part of Bangladesh. There, they learned about making cement-stabilised block, urine as fertiliser and construction with treated bamboo. To the question, if those learning could be effective for the Jhenaidah city, specifically to this community, the community members' reaction was mixed. To their opinion, since the economy varies between a city and a village, making cement stabilised block in an urban context will not be economical. Treating the urine seems a better idea for the community, though the community agrees that they do not have such agricultural land as the village they visited does. Constructing houses with Bamboo which seemed quite nice in a rural context does not give the sense of security in an urban context because of higher crime rate in city. However, the community agreed that making toilets with bamboo will be safer and less expensive.

Figure: Household tube well and wastewater management

Drain

The houses are not connected to city's drainage system, so each household manage their wastewater in their own way. Almost all the households have ditches near the tube well for the wastewater. If the family is small and water use is not much, the water gets penetrated into the ground. However, for the larger family, managing the waste water is a misery, since they have to empty the ditch in every two /three days, manually, with a bucket. (After the workshop when I visited each ditch for a closer look, I discovered that the ditches are perfect for producing mosquitoes. The penetration of polluted water could cause contamination in the tube well water, because of their proximity.) Some household cannot use their tube wells at all, even if they have one, as there is no way for the water to be drained out. So, they use common tape provided by municipality on the opposite side of the road. The waste water from these common tapes go to two bigger ditches nearby.

Figure: Map for drainage, developed with Mohishakundu

Since the community is residing on a lower land than the surrounding, draining off the runoff is also a problem. The back of the community was empty until few years back, which helped them to drain off the runoff to that land. But with new house being developed on that empty land, the community is facing water congestion in their households for last few years.

Mapping exercise for drainage

With the community a map for drainage has been developed. Since the community owns a small piece of land with any proper access road, it was difficult to identify how each households can be connected to the drain. Two separate lines has been drawn, which could connect most of the houses to the proposed drain, still they will not serve all the houses. The community aspires to have drain, running underground, that will later be connected to one of the municipal sewerage line.

Workshop 3 at Vennatola

Vennatola saving group was consisted of only male members of the community. Because of POCAA's influence, the community has made their female counterpart as members replacing the males before. During the meeting at Vennatola, 10 women from Mohishakundu shordarpara had joined us. These women shared their experience with saving group and house construction activity of their community. A map of Vennatola community had been produced later. This map shows who lives beside whom to visualise the relationships in the community. Here, women from Mohishakundu shordarpara took lead to explain what can a map do and how to make a map.

Appendix C: Water Sensitive Urban Design (WSUD)

Water-sensitive urban design (WSUD) is a land planning principle, which combines bio-engineering design approaches. It integrates the urban water cycle, including stormwater, groundwater and wastewater management and water supply, into urban design to minimise environmental degradation and improve aesthetic and recreational appeal. The term WSUD is mostly used in Australia and middle East. Almost similar approach is called Low Impact Development in United states and sustainable urban drainage systems (SUDS) in the United Kingdom

A lot of research and work has been done in Australia in this field. Since the late 1990s there has been an increasing number of initiatives to manage the urban water cycle in a more sustainable way. These initiatives are underpinned by key sustainability principles of water consumption, water recycling, waste minimisation and environmental protection. The integration of management of the urban water cycle with urban planning and design is known as Water Sensitive Urban Design (WSUD). WSUD has multiple environmental benefits including improving urban landscape, reducing pollutant export, retarding storm flows and reducing irrigation requirements. Urban stormwater managed both as a resource and for the protection of receiving water ecosystems is a key element of WSUD.

Objectives

- Reducing potable water demand through demand and supply side water management; Incorporating the use of water efficient appliances and fittings;
- Adopting a fit-for-purpose approach to the use of potential alternative sources of water such as rainwater;
- Minimising wastewater generation and treatment of wastewater to a standard suitable for effluent reuse and/or release to receiving waters;
- Treating stormwater to meet water quality objectives for reuse and/or discharge by capturing sediments, pollution and nutrients through the retention and slow release of stormwater; Improving waterway health through restoring or preserving the natural hydrological regime of catchments through treatment and reuse technologies;
- Improving aesthetics and the connection with water for the urban dwellers;
- Promoting a significant degree of water-related self-sufficiency within urban settings by optimising the use of water sources to minimise potable storm and waste water inflows and outflows through the incorporation into urban design of localised water storage;
- Counteracting the 'urban heat island effect' through the use of water and vegetation assisting in replenishing groundwater.

Principles

Water sensitivity: • To bring urban water management closer to natural water cycle;
Functionality: • To adapt the local basic conditions and intended use. • To be considered possibilities for adaptation to uncertain and changing basic conditions • To create places that are usable for recreation and/nature conservation purposes.
Physical Integration • To adapt the design of the surrounding area.
Interdisciplinary solution • To plan in interdisciplinary co-operation of urban planning and design, landscape architecture, ecological engineering and water engineering.
Aesthetics • To combine aesthetic (where it is possible) with function and use.
Maintenance • Needs to be considered the maintenance requirement. (Hoyer, et al., 2011)

Examples: Bishan park, Singapore

Designed by: Studio Dreiseitl

Background

Bishan Park is one of Singapore's most popular parks in the heartlands of Singapore. As part of a much-needed park upgrade and plans to improve the capacity of the Kallang channel along the edge of the park, works were carried out simultaneously to transform the utilitarian concrete channel into a naturalised river, creating new spaces for the community to enjoy. At Bishan Park, a 2.7 km long straight concrete drainage channel has been restored into a sinuous, natural river 3.2 km long. Sixty-two hectares of park space has been redesigned to accommodate the dynamic process of a river system which includes fluctuating water levels, while providing maximum benefit for park users.

Community Space

This project is part of a long-term initiative to transform the country's water bodies beyond their functions of drainage, into vibrant, new spaces for community bonding and recreation.

Three playgrounds, restaurants, a new look out point constructed using the recycled walls of the old concrete channel, and plenty of open green spaces complement the natural wonder of an ecologically restored river in the heartlands of the city. (Ramboll studio dreiseitl, u.d.)

Augustenborg, Sweden

Background

Ekostaden Augustenborg is the collective name for a program to make Augustenborg into a more socially, economically and environmentally sustainable neighbourhood. This was supported by the government´s Local Investment Programme and also financed by key local partners within Malmö City and the MKB housing company.

Designing with people

One of the key aims of the project is to enable residents to take a leading role in the ideas, design and implementation of the project. Residents, pupils and people working in the area have been involved in the design of the outdoor environment to create new habitat whilst increasing amenity.

Stormwater and green roofs

The stormwater system has gone through a major change. Green roofs and open stormwater channels leading into ponds have stopped the flooding in the area and have created a beautiful environment with richer biodiversity. There are a total of 6 km canals and water channels in Augustenborg. 90% of the stormwater from roofs and hard surfaces is led into the open storm-water system in the housing area. The aim the project was that 70% of all stormwater should be taken care of for the whole of Augustenborg. (Mälmo

stad, u.d.)

Appendix D: Decentralized Water treatment System (DEWATS)

"Decentralised Wastewater Treatment Systems" (DEWATS) incorporate lessons learned from the limitations of conventional wastewater-treatment systems, thereby assisting to meet the rapidly growing demand for on-site-wastewater solutions. DEWATS are characterised by the following features:

- DEWATS encompass an approach, not just a technical hardware package, i.e. besides technical and engineering aspects, the specific local economic and social situation is taken into consideration

- Provide reliable and efficient treatment of domestic and process wastewater

- Require only short planning and implementation phases

- Moderate investment costs

- Limited requirements for operation and maintenance

- DEWATS can treat wastewater from domestic or industrial sources. They can provide primary, secondary and tertiary treatment for wastewater from sanitation facilities, housing colonies, public entities like hospitals, or from businesses, especially those involved in food production and processing.

- DEWATS can be an integral part of comprehensive wastewater strategies. The systems should be perceived as being complementary to other centralised and decentralised wastewater-treatment options

- DEWATS can provide treatment for wastewater flows with close COD/BOD ratios from 1m3 to 1000m3 per day and unit

- DEWATS can provide a renewable energy source. Depending on the technical layout, biogas supplies energy for cooking, lighting or power generation

(Gutterer, et al., 2009)

Recycling Sewerage, Bhuj, India

Designed by: Hunnarshala Foundation and the municipality of Bhuj.

Background:

The rivulet in Bhuj was facing many problems that the cities in India are facing, losing the streams and water bodies to waste fill and pollution. In many cases, it results into flooding in monsoon. Filled with solid waste, sewage etc. , the rivulet's bank of Bhuj municipality was once the back of the city and place for open defecation. In Bhuj, the collaboration has installed three DEWATS units that includes a unit to recycle 15,000 litres of wastewater and 1 km of transformation in the landscape of city's rivulet's bank.

Retrieving the city's rivulet:

In DEWATS treatment plant, the municipal sewage is fed to the microorganism. Treated water is discharged in to the rivulet to bring its life back, to make it as lungs of the city. The treatment is based on the gravity flow and needs no technical maintenance.

Creating public space:

Date tree has been planted to transform the rivulet's bank into a green belt. The only maintenance the whole treatment plant needs is looking after the trees. The green space is designed so that it can be used for morning or evening walking, yoga, children's playing, etc.

Social and behavioural changes:

In the beginning, Hunnarshala and the collaborating organisations took initiation on their own to start cleaning the garbage to inspire the citizen not to dump waste in the rivulet. Now, with the changed scenario of the rivulet, the city is gradually turning towards the rivulet as opposed to before.

Hunnarshala and the municipality of Bhuj is now planning to develop an urban watershed project to ensure effective use, re-use and recycle of water in city life. They are aiming for 60% of sewage water recycling and thus reducing the water demand of Bhuj city by 30%. (Hunnarshala foundation, u.d.)

Appendix E: List of indigenous wetland plants

Name	Scientific name	Family	Availability	Size	Use
Harkuch Kanta	*Acanthus ilicifolius Linnaeus*		Occasional	Prickly shrub, up to 1.5 m high, in clumps. Leaves 15 cm long	Medicinal use, Apiculture
Sanche/Chhanchi/ Haicha, Sachishak	*Alternanthera Sessilis (L.) R. Brown ex A.P. De Condolle*	Amaranthaceae	Common		Fodder (including fish feed), Medicinal use, Edible
Thankuni/ Thulkuri/ Takamanik/ Brahmmakuti/ Ada gunguni	*CENTELLA ASIATICA (L.) Urban*	Apiaceae	Common	A slender creeping herb. Leaves with long petiole, 1-3 from each node of the stems, lamina 1.3-6.3 cm diam., orbicular-reniform, rather broader than long, shallowly crenate	Fodder (including fish feed), Medicinal use
Kachu/ Mukhikachu/ Bahumukhi/ Mokaddam kachu	*COLOCASIA ESCULENTA (L.) Schott.*	Araceae	Common	Tall herb with underground tuberous stem. Petiole erect, up to 1.2 m. long	Very common in local cuisine
Topapana/ Tokapana/ Phena	*PISTIA STRATIOTES L.*	Araceae	Common	A floating, stemless, stoloniferous herb; roots of tufted simple, white fibres. Leaves 3.2-10 cm long	Fodder (including fish feed), Water purification, Manure
Kesuti/ Kesraj/ Kalokeshi/ Bhimraj	*ECLIPTA ALBA (L.) Hassk.*	Asteraceae	Common	A slender, diffuse or suberect herb; stem and branches strigose with appressed white hairs	Medicinal use
Helencha/ Hinchashak/ Harhach	*ENHYDRA FLUCTUANS Lour.*	Asteracea	Occasional	A trailing marsh herb, also floating on water; stem 30-60 cm long, rooting at the nodes.	Fodder (including fish feed), Medicinal use
Kanchira/ Dholpata/ Jatakanchira	*COMMELINA BENGHALENSIS L.*	Commelinaceae	Common	A slender dichotomously branched creeping herb, 60-90 cm long.	Fodder (including fish feed)
Kalmi/ Kalmi Shak	*POMOEA AQUATICA Forsk.*	Convolvulaceae	Common	A glabrous trailer on ground or floating on water, stem hollow, rooting at the nodes.	Very common in local cuisine

Name	Scientific name	Family	Availability	Size	Use
Burachucha	*CYPERUS IRIA L.*	Cyperaceae	Occasional	A glabrous, annual sedge; root fibrous. Stem tufted, 35-50 cm long, triquetrous.	Thatching, Fuel
Mutha, Nagarmutha, Bhadailla	*CYPERUS ROTUNDUS L.*	Cyperaceae	Occasional	A slender, glabrous sedge; stolons slender, 10-20 cm long	Fuel, Soil binder
Dadmari, Jangli Mendi, Ban Marach.	*AMMANNIA BACCIFERA L.*	Lythraceae	Occasional	An erect or suberect herb, 15-20 cm high, sometimes more.	
Chandmala, Chandmona, Panchulli	*NYMPHOIDES HYDROPHYLLA (Lour.) O. Kuntze.*	Menyanthaceae	Common	An aquatic herb with floating leaves and long stem bearing tuft of roots at the nodes.	Water purification, Medicinal use
Sapla, Sada Sapla, Shaluk	*NYMPHAEA NOUCHALI Burm. f.*	Nymphaeaceae	Common	A large aquatic herb; leaves 15- 30 cm broad, sagittate to cordate, sharply sinuate-toothed, floating, petiode very long. Flowers 5-15 cm across; petals linear or ovate-oblong, white, rose or red.	Edible, Medicinal use, Listed for religious use, beautification of lakes and reservoirs, National flower of Bangladesh
Kesardam, Mulcha, Mulsi; Molchi	*LUDWIGIA ADSCENDENS (L.) Hara.*	Onagraceae	Common	A floating herb, rooting at the nodes, and cluster of conspicuous white, spindle-shaped, pneumatophores at the nodes.	Fodder (including fish feed), Listed for religious use, Medicinal use
Tasbi, Gurgur, Kalo Kunch, Kawoakathi	*COIX LACHRYMA - JOBI L.*	Poaceae	Common	A stout, perennial grass, 0.9-1.5 m high	Fodder (including fish feed), Listed for religious use, Medicinal use
Dhan	*ORYZA SATIVA L.*	Poaceae	Common	An annual crop, 60 cm to 120 cm tall.	Staple food in local cuisine, Fodder (including fish feed), Fuel, Medicinal use

Name	Scientific name	Family	Availability	Size	Use
Kachuripana/ Jarmuni	*EICHHORNIA CRASSIPES (Mart.) Solms.*	Pontederiaceae	Common	Aquatic, free floating herb, sending down a large bunch of long fibrous roots from a very short, leafy, main stem	Fodder (including fish feed), Water purification, Manure
Brahmishak/ Adhabirani/ Dhupkamini	*BACOPA MONNIERA (L.) Pennel.*	Scrophulariaceae	Common	A small, much branched, creeping herb, rooting at the nodes; branches 10-25 cm long	Fodder (including fish feed), Medicinal use
Karpur/ Ambuja	*LIMNOPHILA INDICA (L.) Druce.*	Scrophulariaceae	Occasional	A small aromatic herb, 7.5-20 cm high, smelling strongly of turpentine; stems subquadrangular, rooting at the lower nodes	Medicinal use, Aquarium plant
Bhui Okar/ Karghas/ Bakkan	*PHYLA NODIFLORA (L.)*	Verbenaceae	Occasional	A prostrate, much branched annual herb, often rooting at the nodes, up to 75 cm long	Medicinal use

(Adapted from the book Ecology and traditional wetland practice: Lessons from wastewater utilisation in the East Calcutta Wetlands (Ghosh, 2005))

Appendix F: List of indigenous fishes suitable for pond

About 12 different species of fish can be raised which occupy different ecological niches of the pond ecosystem, including major indian carps – catla(surface), ruhi(column) and mrigal(bottom) mourala, and the freshwater giant prawn. These 12 species are-

- Knifefishes
- Snakeheads
- Needlefishes
- Minnows, Rasboras, and bards
- Loaches
- Anchovies and sardines
- Spiny eels
- Climbing perch
- Gobies
- Mud Perches
- Glassfishes
- Fresh water prawns

Name	Scientific name	Family	Size	Habitat	Diet
Catla	*Catla catla*	Cyprinidae		Surface	Predominantly zooplankton feeder, occasionally decaying macrovegetation, phytoplankton and smaller molluscs
Ruhi	*Labeo rohita*	Cyprinidae	2 m	Column	Vegetable matter including higher plants, detritus
Mrigal carp	*Cirrhinus cirrhosus*	Carp	1 m	Bottom. Inhabits fast flowing streams and rivers, but can tolerate high levels of salinity	Filamentous green algae, diatoms, pieces of higher plants, decayed vegetable, mud and detritus
Long-whiskered catfish	*Sperata aor*	Bagrid catfish	180 cm		
Bengal danio	*Devario devario*	Minnow	10 cm		Annelid worms, small crustacean,s and insects
Bata	*Labeo bata*		25–35 cm	Surface	Crustaceans and an insect larva in early stages; protozoa, algae, and tiny fishes
Whitespot	*Aplocheilus panchax*		9 cm		Mosquito larvae
Scribbled goby	*Awaous grammepomus*	Goby	15 cm		

Name	Scientific name	Family	Size	Habitat	Diet
Dusky goby	*Eleotris fusca*	Goby	26 cm		
Target fish	*Terapon jarbua*		36 cm	Surface and middle rivers and lakes	Insects, plant matter, small fish, fish scales and crustaceans
Queen loach	*Botia dario*		154 cm		Sinking pellets as well as algae wafers
	Gagata gagata	Sisorid catfish	30.5 cm		
Indian river shad	*Gudusia chapra*	Clupeidae			
Giant danio	*Devario aequipinnatus*		10 cm		Exogenous insects, but is also supplemented by worms and crustaceans.
Squarehead Catfish	*Chaca chaca*	Angler catfish	20 cm		
Indian featherback	*Chitala chitala*	Knifefish	75 cm		
Honey gourami	*Trichogaster chuna* *Gobiopterus chuno*		7 cm		
Glass goby	*Esomus danricus*	Goby			
Indian Flying Barb	*Schistura scaturigina*		15 cm		
	Notopterus notopterus	Ray-finned fish			
Bronze featherback	*Rasbora daniconius*		60 cm		
Slender rasbora	*Rasbora rasbora*	Cyprinidae	15 cm		
Gangetic scissortail rasbora	*Glyptothorax botius*	Rasbora			
		Catfish			

Name	Scientific name	Family	Size	Habitat	Diet
Ceylon snakehead	*Channa orientalis*	Snakehead	10cm		Predatory fish that feed on plankton, insects, and sometimes small amphibians
Dwarf snakehead	*Channa gachua*	Snakehead	20 cm	Canal, river , lake	Insects and small fish
Grey eel catfish	*Plotosus canius*	Eeltail catfishes			
	Gagata cenia	Sisorid catfish	15 cm		
	Gogangra viridescens	Sisorid catfish	8.5 cm		
Gangetic mystus	*Mystus cavasius*	Catfish	40 cm		
Freshwater hatchetfish				Surface	
Freshwater garfish	*Xenentodon cancila*	Needlefish	40 cm		Predator that eats animals such as week-old labyrinth fish and frogs
Rice-paddy eel	*Pisodonophis boro*	Worm/snake eel	70-100 cm	Freshwater, often in rice paddies during the rainy season. Usually, in lagoons, estuaries and coastal rivers	Bony fish and crabs such as Uca annulipes
Climbing gourami	*Anabantidae*			Surface	
Walking catfish	*Clarias batrachus*	Catfish	.5 m	Bottom, with occasional trips to the surface to gulp air. Usually found in stagnant, frequently hypoxic waters and are often found in muddy ponds, ditches and similar.	Omnivorous; it feeds on smaller fish, molluscs, and other invertebrates, as well as detritus and aquatic weeds
Snakehead murrel	*Channa striata*	Snakehead	1m	Freshwater plains, where it migrates from rivers and lakes into flooded fields, returning to the permanent water bodies in the dry season, where it survives by burrowing in the mud.	Frogs, water bugs, and smaller fish, and it will attack anything moving when breeding

Name	Scientific name	Family	Size	Habitat	Diet
Ocellated pufferfish	*Leidon cutcutia*	Pufferfish	15 cm	Fresh and brackish waters	
Tor mahseer	*Tor tor*	Cyprinidae	36 cm	Fast-flowing rivers and streams with rocky bottoms	

(Froese, 2016))

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