LOTUS AND THE MACHINE

Architecture for the symbiosis of cities and urban hydrology

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Many thanks to all the architects, planners, engineers and ecologists who provided wisdom and guidance for the development of this interdisciplinary design.

Abstract

Despite the abundance of fresh water produced in the mountains surrounding Cape Town, a range of factors contribute towards the imminent water crisis felt locally and internationally. While governing bodies have management strategies and infrastructural upgrades planned, these interventions address issues of water quantity only. Steadily declining water quality is an equally important issue which will continue to impact on available fresh water quantities if action is not taken.

The threats on water availability in cities stem from growing urbanization itself. The question this dissertation poses is how architecture can encourage a symbiotic relationship between built and natural environments, with special regard for urban water systems. The answer is found in the balance of quantity management, quality improvement and long-term protection of water - a symbiosis between city and urban hydrology.

This dissertation documents the research and design of a speculative architectural proposition to embody such a symbiosis. It is hypothesized that the design must address quantity and quality issues simultaneously by coupling infrastructure with community facilities. This will ensure immediate remediation of a water system and encourage a long-lasting protection of water quality through passive education and public conscientizing.

The research identifies the Lotus River, located near the Philippi Horticultural Area in Cape Town, as an appropriate representative of the urban hydrological cycle in Cape Town. Through an understanding of the major pollutants in the river and a study of current technology, an industrial process which recycles pollution into fertilizer is proposed as the major programme of the project. This programme is overlaid with an agricultural training center and public amenities which encourage and incentivise environmental awareness among the community.

The architectural theories of *symbiosis* and the *social condenser* are proposed as precedent for the way in which architecture has, through the creation of *transitional spaces*, attempted to usher society into a new way of living. This project explores the creation of a transitional space between building and nature to encourage a symbiotic relationship between urbanity and water, where the Lotus meets the Machine.

Keywords

Urban hydrology | river remediation | social condenser | symbiosis | Lotus River

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Glossary of terms

Lotus River: The river system includes the Great and Little Lotus river. For the purpose of this document the term will refer to only the Great Lotus River.

Hydrology: The scientific study of water systems on earth. Note, hydrogeology is the study of ground water systems.

CFAU: Cape Flats Aquifer Unit. One of the most extensive ground water bodies in South Africa that is located beneath the Cape Flats in a layer of shallow sandy soil.

Vlei: The Afrikaans word of Middle Dutch origin for wetland, marsh or shallow pond.

PHA: Philippi Horticultural Area. An important urban agricultural area in Cape Town. The land is constantly being threatened by development and the need for space for housing, although the City of Cape Town has identified an urban edge around the land to protect it from any official building.

Eutrophication: The build up of unwanted nutrients in water systems which makes the water uninhabitable for many animals.

Catchment: An area of land which collectively drains rainwater to an identifiable point of study.

Struvite: Magnesium ammonium phosphate - A phosphate fertilizer which can be manufactured from waste water with high nitrogen and phosphorous concentrations. If used correctly struvite is considered more environmentally stale than other chemical fertilizers, due to slow nutrient release and high efficiency. (Rahman et al., 2014)

1 Introduction

We find ourselves in an age of exponential development. As our numbers grow and we place more pressure on the natural systems which sustain us, we are forced to evolve, adapt and design our way out of difficult situations. As Kisho Kurokawa (1994) has theorised, we have moved beyond the *age of machine* into the *age of life*, and it is our responsibility to design and live according to the new paradigm.

The imminent *water crisis* is an environmental stress which is threatening cities around the world. Locally, despite the abundance of fresh water provided by the mountains surrounding Cape Town, increasing urbanization and the pressures of climate change are affecting the ability to hydrate the city. While reports are available on the predictions of water supply for the future, an alarmingly small portion of the public are aware of this problem, and as we will discover, the problem is compounded by the unaware behaviour of many communities.

This paper begins with the discussion of the current climate trends and pressures on urban fresh water supplies. Attention is paid to the governmental plans for supply increase and demand reduction, and a critique of the underutilization of the Cape Flats Aquifer Unit is posed.

With reference to Kisho Kurokawa's theory of *symbiosis,* and the soviet Constructivists' theory of the *social condenser*, a hypothesis is proposed regarding the creation of *intermediate spaces* which encourage the cross programming of paradigms for the ushering of society into a time of change.

Rivers are proposed as sites for social condensers, and the case of the Lotus River is explored in depth as specific pollutants are mapped, modes of contamination are discovered and interaction with the greater hydrological cycle is understood.

A site is selected along the river based on its locality to major pollutants and a poor community in need of amenity. Of note is the site's proximity to the Philippi Horticultural Area, a major source of pollution to the aquifer and river.

The programme development follows the process of polluted water through the building as it is cleaned. A recycling depot for litter collection is followed by an industrial chemical removal plant which recycles valuable compounds polluting the river. These fertilizers can then be sold back to the agricultural sector, which, coupled with an education center, encourages a long-term improvement and protection of urban water systems. Intertwined with this is the public pedestrian network of recreational spaces, aquatic and terrestrial, which follow existing pedestrian routes across the site.

The desired effect is to transform the river into something of value to the industrial, agricultural and residential communities which overlap on the site. Exposing the public to the process of river remediation, and offering them the benefits of an improved environment would promote a type of passive education, resulting in both immediate remediation of the polluted water and a sustained protection of it.

The overall proposal attempts to create an intermediate space of industry and community, an overlap in building and landscape, and a symbiosis of cities and urban hydrology.

2 Water Pressure : Framing the Water Crisis

> *The water cycle is one of the most critical processes to supporting life on this planet, and fresh waters are central to all aspects of our lives. Historically, urbanisation has led to the loss and degradation of wetlands, rivers and groundwater resources through pollution, resource depletion and construction within natural flood plains.* (Woods-Ballard et al., 2007)

With increasing urbanization comes increasing stress placed on natural systems. The hydrological cycle is one on which people and nature rely heavily, especially in semi-arid climates such as that of the Western Cape. Unfortunately our relationship with the hydrological cycle does not reflect our dependence upon it, and an alarming portion of the public seem to be unaware of the imminent *water crisis* expected to hit vulnerable areas of South Africa.

The basic premise of this water crisis is that, despite the abundance of fresh water provided by the mountains surrounding Cape Town, climate change, population increase, pollution and mismanagement are threatening the ability to hydrate the city of the future.

Climate Change

Climate change is defined as the “upward trend of annual means over time“ with regards to weather indicators (Kabat et al., 2012). The graphs on the following pages show the trends for Cape Town in a selection of major climatic variables with a clear gradual increase. Designing for these changing climatic conditions has been a topic of governmental consideration, and it has been identified by professionals as an important topic for the city to plan for. (Kabat et al., 2012).

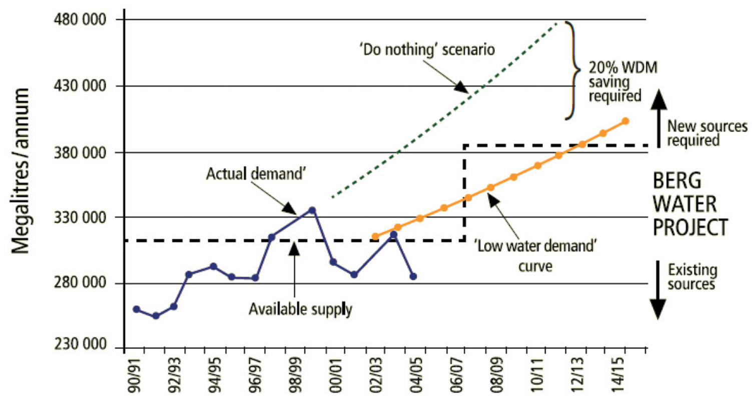
Semi-arid cities such as Cape Town are reported to be at highest risk of the impact of climate change on water systems. The city is expected to experience drastically

reduced rainfall and higher temperatures. These conditions lead to increased evaporation of terrestrial water bodies and result in less water availability in many of the city’s drinking water reservoirs. In addition, the conditions are favourable for algal blooms which further threaten potable water supplies. (Kabat et al., 2012).

It is predicted that one of the largest impacts of climate change will be the effects on rivers. In a semi-arid climate like the Western Cape which experiences less than 500mm of rainfall per year, a 10 percent reduction in rainfall will lead to a 50 percent reduction in river run-off due to such a high rate of evaporation (Kabat et al., 2012). This has the potential to drastically effect the city’s ability to store water in open-air reservoirs. Which, as we will see, is the City of Cape Town’s primary focus area for meeting water demand of the future. Reduction in river flow also means that pollutant concentrations will be higher, reducing the tolerance of aquatic plants and animals which are already under threat of reduced water availability.

The graph below depicts historical and extrapolated water demand figures overlaid on the available supply. Notice that the major increase of supply is due to the Berg Water Project - a terrestrial water supply which, according to the calculations at the time, would still not be enough to meet the demand by 2013 (Mukheibir et al., 2006).

Figure 1: Water supply and demand in Cape Town 1990- 2015



(Mukheibir et al., 2006)

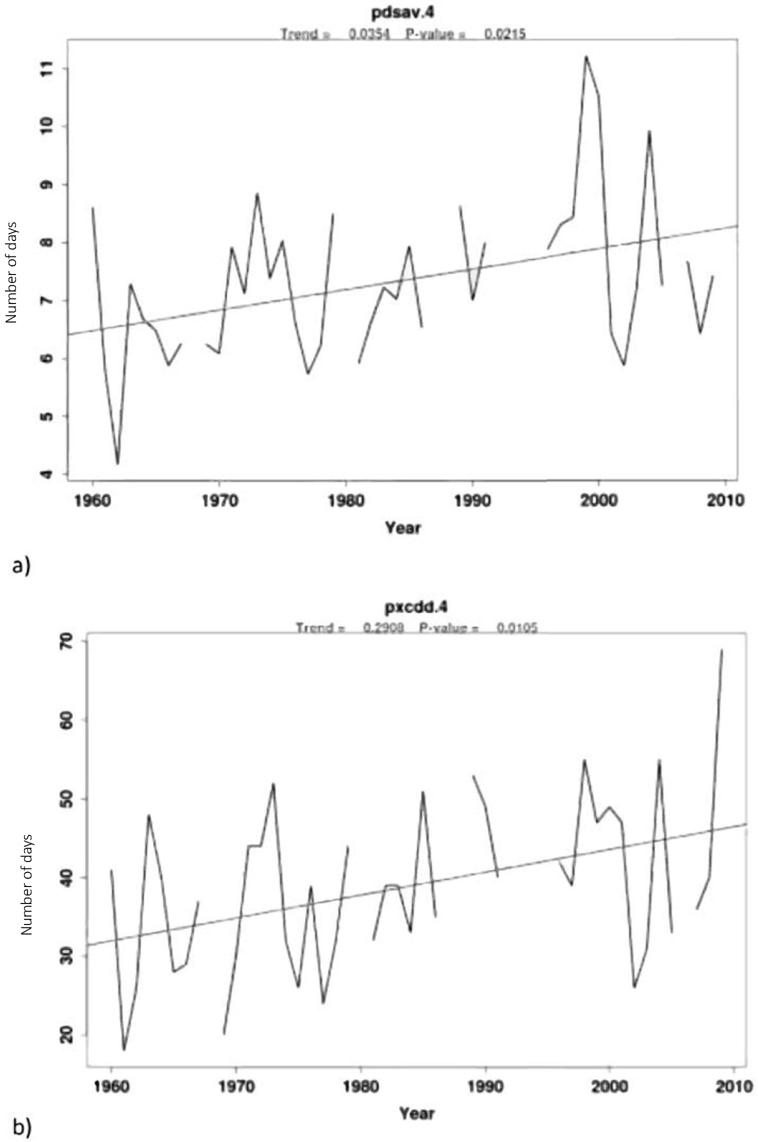


Figure 2: Climate trend graphs : dry spells

Trends in annual average (a) dry spell length, (b) maximum number of consecutive dry days (Tdross et al., 2012)

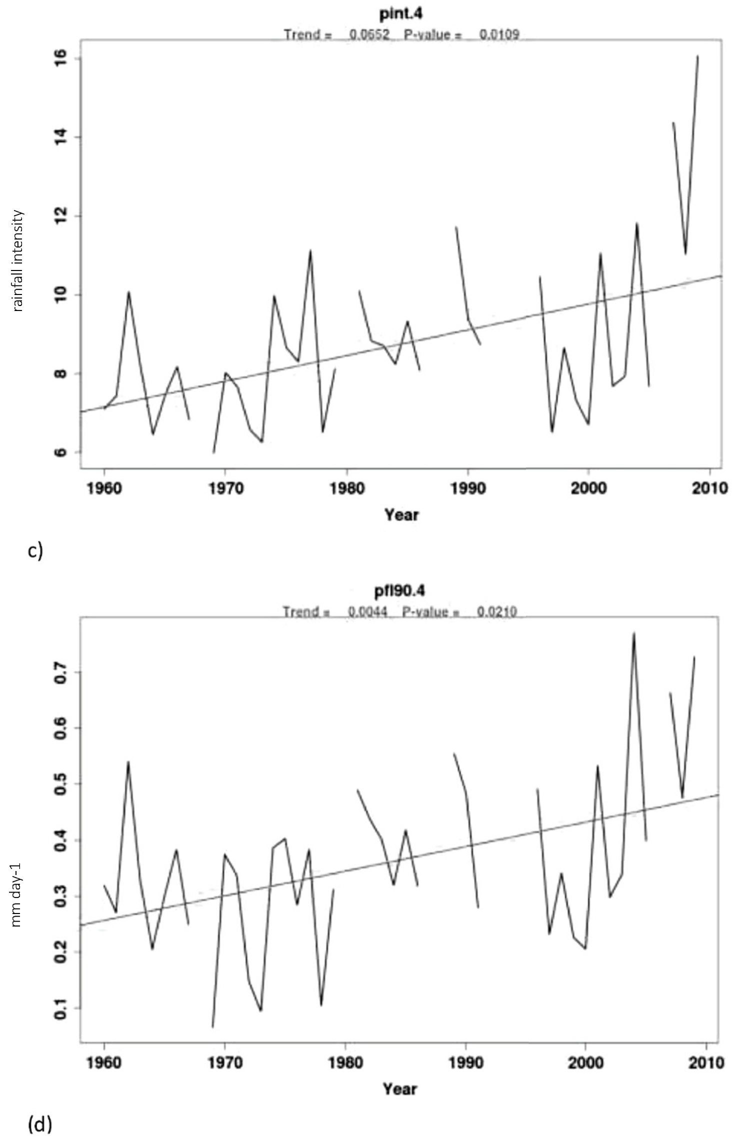


Figure 3: Climate trend graphs : rainfall intensity

Trends in annual average (c) rainfall intensity, (d) frequency of rainfall events exceeding the long term 90th percentile daily rainfall event, showing increasing occurrences of erratic weather. (Tadross et al., 2012)

Population Increase

To exacerbate these climatic induced pressures, the population of the City of Cape Town is predicted to increase at a yearly rate of 3.5% (Tadross and Johnston, 2012), placing even greater strain on already dated infrastructure, increasing the density of low and medium income areas and increasing the demand for water.

Kabat et. al (2012) state that since the early 1970's water consumption in the greater Cape Town municipal area has increased by 300% due to immigration - reiterating the importance of preparation for higher demand despite the drastic reduction in availability.

Pollution

As a result of population growth and informal settlement growth urban waterways which should contain relatively clean storm water now begin to function as open sewers in places where proper sanitary infrastructure is not provided (Grobicki, 2001). Water borne diseases are transported downstream to recreational spaces such as dams and seas, and expose other vulnerable informal communities to dangerous bacteria.

Additionally, urbanization results in increased impervious surfaces, preventing rain water from infiltrating into the ground (Shaver et al., 2007). The runoff of these surfaces is often contaminated with oils, heavy metals and litter which negatively impact on river ecologies downstream. Litter can block drains resulting in overflows and floods in time of heavy rain, and can cause harm to animals found along the riverine habitat.

Uninformed agricultural operations such as those found on the Cape Flats at the Philippi Horticultural Area (PHA) contribute largely to water system pollution by over-fertilizing crops with inorganic chemical fertilizers (Grobicki, 2001). Chemicals that are not taken up by crops enter into the ground water and eventually drain into rivers, wetlands and the ocean, resulting in further chemical build-up.

The chemical build-up occurring in natural systems leads to severely degraded ecologies. This is especially devastating in the Western Cape where endemic biomes are threatened to extinction. The sheer amounts of pollutants lead to the death of aquatic fauna and flora which normally have the ability to clean the water of smaller amounts of pollutants.

Mismanagement

The mismanagement of water resources by the local government is a considerable factor affecting the availability of drinking water for the city. In Cape Town it is reported that 23% of municipal water is lost due to infrastructural problems, and that by 2022 the Western Cape water supply will be in deficit (Mukheibir, 2008; Pithey, 2007).

3 Devising a Solution

We have reached a point in global climatic conditions where we can no longer prevent changes from happening - the only way forward is to *adapt*. According to the City of Cape Town's (CoCT) official climate change adaptation plan, "adaptation is an adjustment in bio-physical, social and/or economic systems in response to an actual or expected climatic impact and its effect" (Mukheibir and Ziervogel, 2006). In response, the CoCT has identified two types of adaptation into which their plans fall:
demand reduction and supply increase.

Demand Reduction

The Municipal Development Adaptation Plan of 2006 (Mukheibir and Ziervogel) identifies the "minimization of demand increase" as the first response. This demand reduction can originate from a government level such as the implementation of water tariffs and incentives, leak and pressure management, and city-scale black-water recycling from sewage treatment facilities (a surprisingly viable option - as we will discover later, human waste contains valuable compounds which can be recycled. The treated water is then suitable for irrigation of parks and fields).

Another important part of the government framework for demand reduction is the initiation of awareness campaigns. Household consumption accounts for the largest portion of municipal water demand, and with effective education and the installation of water-wise fittings consumption could be greatly improved.

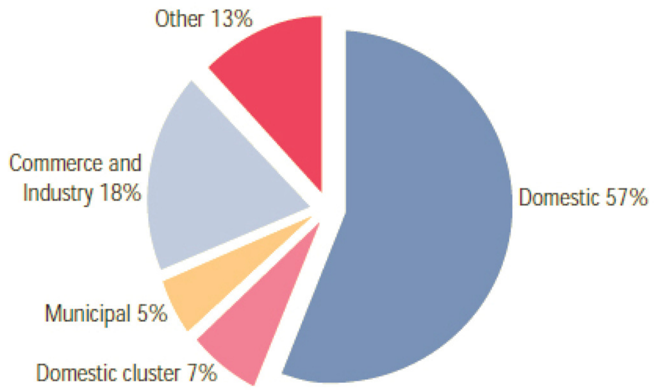


Figure 4: Municipal water consumers in Cape Town (Mukheibir et al., 2006)

Supply Increase

The Municipal Development Adaptation Plan of 2006 (Mukheibir and Ziervogel) acknowledges that reduction of demand is not sufficient to meet future demand. The Supply Initiative of the Adaption Plan proposes the following large scale infrastructural changes in order to meet future demand:

- Use of the Table Mountain Group aquifer: a considerable amounts of research is still required on sustainability and environmental impact
- Development of two retention schemes on the Berg River
- Diversion of the Lourens and Eerste River schemes
- Modification of catchment vegetation: the removal of invasive species with high water uptake
- Domestic seawater usage (for swimming pools and sewage)
- Desalination
- Use of the Cape Flats Aquifer Unit

Given the threat of increased evaporation of terrestrial water bodies that is associated with the rising temperatures of climate change, aquifer utilization appeals as an intriguing opportunity for water supply increase.

Cape Flats Aquifer Unit

The Cape Flats Aquifer Unit (CFAU) is reported to be one of the most extensive bodies of ground water in South Africa (Maclear, 1995). According to Maclear (1995) the shallow water table sits at an average of 3.75m below surface level making it easily accessible. The water is classified as fresh with a low salinity level and flows in a layer of course grained sand which is ideal for utilization; however, it remains relatively untapped with only a few small scale agricultural consumers in the Philippi area.

The aquifer is suspected to be polluted beyond acceptable drinking standards, although registered boreholes do supply agricultural land in the Philippi Horticultural Area (PHA) with ground water irrigation.

The pollutants present in the aquifer water are a result of poor farming practices. The use of inorganic fertilizers, leeching of untreated manure and sewage sludge are among the sources of many of the heavy metals, ammonia and phosphates contaminating the water. (Meerkotter, 2012, Bertram, 1989).

The issue is compounded by pollutants that enter the system via the unlined section of the Lotus River which runs through the Philippi Horticultural Area. In addition to depositing pollutants into the aquifer, the river picks up seepage from the aquifer due to the low lying water table in the area. Meaning the river pollutes the aquifer, and vice versa.

In summary, the aquifer, river and horticultural area are closely related parts of the greater hydrological and nutrient cycle. The aquifer has potential as a water source for the future of Cape Town, if it can be protected from pollutants entering it from the Lotus River and Philippi Horticultural Area.

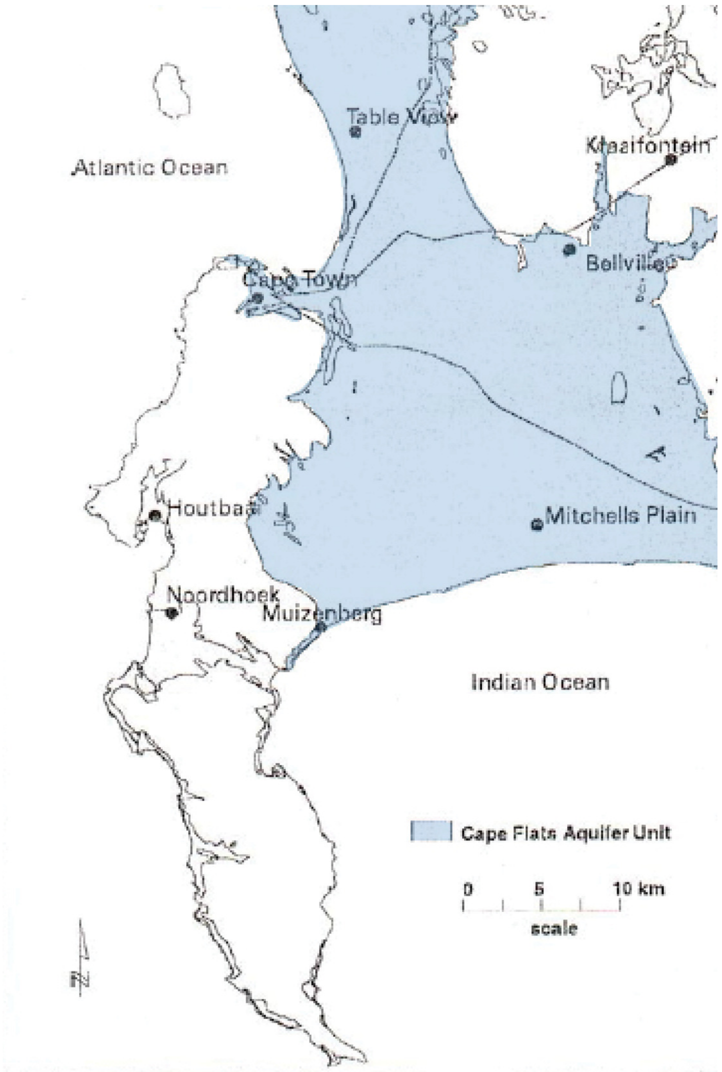


Figure 5: Map of the Cape Flats Aquifer Unit (Maclear, 1995)

4 Design proposition

The condition of the Lotus River and CFAU are just two example of the interaction between built and natural environment, and they tell a story of obvious and hidden disregard, as well as the lack of foresight for the future.

There is a need for cities to begin transitioning into a harmonious relationship with natural systems, before it is too late for their citizens to survive. Some examples of this transition are already visible, such as the growing popularity of Sustainable Urban Drainage Systems, legislation on the planting of green roofs in France (The Guardian, 2015), and wildlife crossings in Canada (images on the following page).

The question this dissertation poses is how architecture can encourage a symbiotic relationship between the built and natural environments, with special regard for urban water systems.

The age of life

Kisho Kurokawa's book "The Philosophy of Symbiosis"(1994) discusses his predictions for the transition from the twentieth century "age of machine" into the twenty first century "age of life". It is important to note that he does not suggest a radical shift, but encourages a subtle merging of paradigms to enable the transition.

This theory came as a response to the industrialised, consumer-driven dominance of Americanized world views, but encourages a movement towards the symbiosis of humankind and nature, of intellect and emotion, of art and science, of public and private, of work and play, and of industry and society - basically a symbiosis of the duality western thinking is based on - and often the cause of many environmental issues.

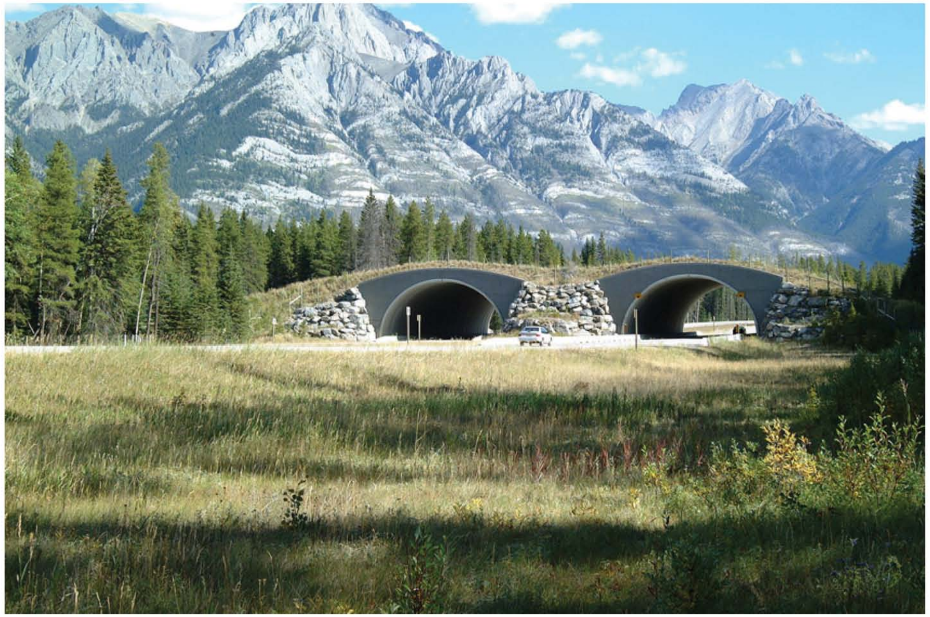


Figure 6 (top) : Symbiosis in architecture: Animal crossings in Canada allow the effects of highways on the migration of animals to be reduced. (Hagood, 2015)

Figure 7 (bottom) : Symbiosis in architecture: SuDs at Potsdamer Platz, Berlin. Water from impermeable surfaces run into ponds for infiltration into the ground and cleaning of pollutants by planting. (Lee, 1998)

Figure 8 : Symbiosis in architecture: Kuala Lumpur International Airport by Kisho Kurokawa.

Palm and rubber trees cultivated around the airport block noise from therun way and encourage the regeneration of Malaysian tropical rain forest, reflecting the theory of symbiosis in architecture (Kurokawa et al., 1999). Sacred space of forest overlaps with sacred space of machine in this image, where tree-like columns support the roof. (image: Nazrey, 2003)

In Kurokawa's theory, opposing elements are granted "sacred space": dedicated zones where that particular element's identity is maintained. The elements meet in what Kurokawa describes as "intermediate spaces": zones where the elements must abide by common rules and understandings, and neither are given preference. It is the "presence of the intermediate spaces which make possible a vibrant symbiosis that incorporates opposition" (Kurokawa, 1994). These spaces feature interpenetration of internal and external spaces, indistinct boundaries and tolerance between the two.

Kurokawa's theory provides design guidance for the creation of space for the transition of one paradigm into another, and encourages a celebration of both rather than a drastic shift. This is relevant in current time where decades of environmental summits cannot get governments to commit to environmental legislation. Perhaps the paradigm shift can begin on the scale of individual farmers and home owners, especially in the case of a local river and aquifer.

The social condenser

The concept of the social condenser originated in soviet Constructivism in the 1920s. According to the architectural historian Catherine Cooke it developed as a response to the existing structure of cities which inhibited social reform during the revolution. The concept is based on the premise that spatial planning and architecture can influence social behaviour. (Cooke, 1983)

The theory is best known in Moisei Ginzburg and Ignaty Milinis' Narkomfin Communal House, 1928. Ginzburg, heading up the OSA (Organization of Contemporary Architecture), aimed at creating an entirely new way of daily life based on socialist ideals. For this reason the building features a range of apartment types, from bourgeois units to communist units - which varied in the provision of private or shared facilities such as kitchens or lounges (Rendell, 2012). The idea was to ease people from one living pattern to the other through direct contact with different groups of people: a passive shift encouraged by space sharing.

Cooke (1983) curtly describes this process in the following way:

> *Low voltage activity and a weak consciousness would be focused through the circuits of the social condenser into a high-voltage catalyst of change, in the habits and attitudes of the mass population.*

This overlapping of contrasting social groups in the social condenser is further described by Jane Rendell (2012) as "transitional space": the space for experience that lingers between two conditions. This would be a zone of sharing, passive learning and exposure to other ways of thought - an "intermediate" space for transformation.

Hypothesis

It is the hypothesis of this dissertation that, through the creation of an intermediate and transitional space between built environment and natural environment, public awareness of environmental issues can be encouraged, and a shift into a symbiosis between city and nature can begin.

Kurokawa argues that "if the architecture of the machine age expresses function, the architecture of the age of life expresses meaning" (Kurokawa, 1994). With these theories in mind and the intention to help transition our society into the "age of life", the creation of a transitional space between building and nature could express the very meaning of symbiosis.

5 Urban Mapping - The Case of the Lotus River

Rivers as Social Condensers

It was identified earlier that the Lotus River is a significant part of the hydrological cycle for its unique relationship with the Cape Flats Aquifer Unit. Rivers also poses a special condition as a point where urban and natural environments meet, and so have the potential to behave as social condensers or intermediate space between these two worlds.

In addition to this, the indiscriminate meandering of a river through areas of different social groups make them appropriate places for broad-spectrum environmental education.

The Lotus

> *The Lotus River catchment makes and excellent case study of a highly impacted urban system, demonstrating the whole spectrum of land uses, socio-economic variations and housing types found in South African cities.* (Grobicki, 2001)

The Lotus River network (comprising of the Great and the Little Lotus) represents the height of human intervention in the urban hydrology. These rivers are almost completely artificial, built by the city as infrastructure where seasonal wetlands once lay. The Lotus (from now on referring to the Great Lotus River only) suffers extremely poor water and habitat quality due to 95% canalization. According to the River Health Indices on which the quality of rivers are assessed (as shown in the adjacent images), the Lotus River scores the lowest possible scores for habitat integrity, riparian vegetation, fish index, water quality and invertebrate habitat (South African Scoring System) (CSIR River Health Programme, 2005).

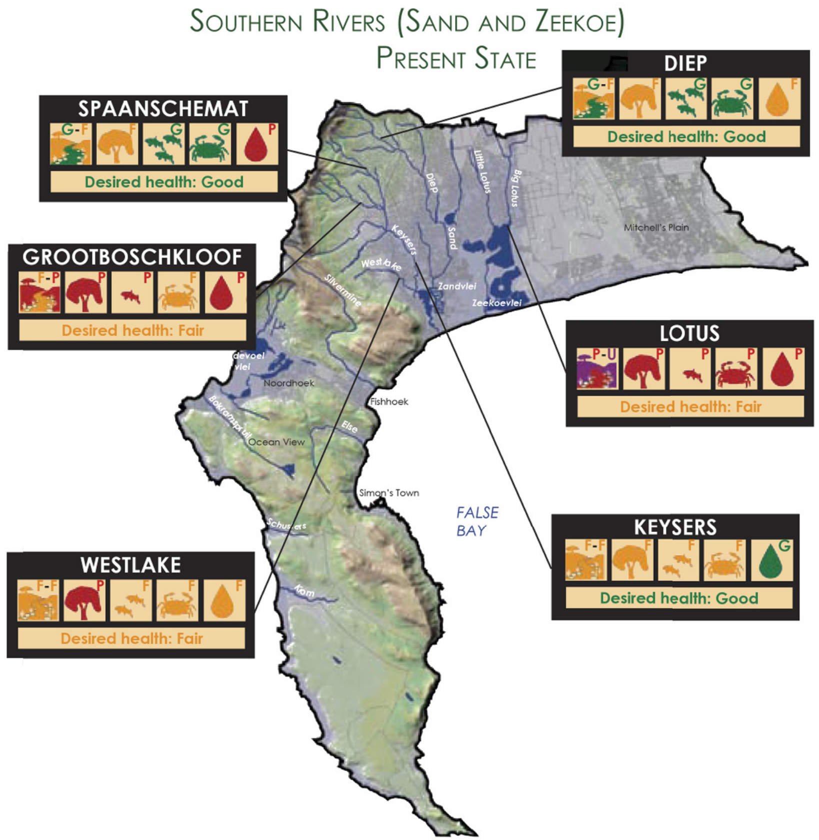
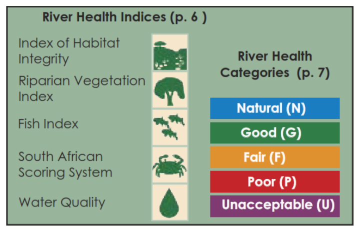


Figure 9: State of the Southern Rivers map (above) showing the state of the Southern Rivers of Cape Town on the River Health Index scale. The Lotus River achieves a score of "poor" and "unacceptable" for all indices, with a desired future state of "fair". (CSIR River Health Programme,



Category and score description for the River Health Index. (CSIR River Health Programme, 2005) At the time of publishing the report, the "unacceptable" category was newly created, reflecting the unprecedented degradation of rivers in Cape Town.

The Lotus River originates in Borchard's Quarry in the Cape Town International Airport industria. It runs through a mixture of land uses, including formal and informal residential, light industry and agricultural land, as shown in figure 12 on page 32. All of these land-uses contribute towards the increasing pollution in the Lotus River in different ways, as discussed in the next section.

The river runs south and flows into the Zeekoevlei, an important recreational and ecological wetland. The False Bay Nature Reserve surrounding the Zeekoevlei is identified on a list of international ecologically significant wetlands by Ramsar, an intergovernmental wetland conservation treaty. According to Ramsar (2014) the area includes the critically endangered Cape Flats Sand Fynbos and Cape Flats Dune Strandveld biomes, and is home to species of vegetation that are listed as extinct in the wild.

Figure 10: Location of the Lotus River

(Image adapted from Google Earth, 2013)

The Zeekoevlei water flow is controlled by a weir which is regularly opened to allow for build up of pollution to exit the recreational area. This results in contamination of the False Bay marine environment and pollution of the beaches.

It is for these reasons that the health of the Lotus River has been the topic of in-depth study and scrutiny in the past. However, despite the studies, few actions have been implemented in order to preserve these natural resources.

The table below shows the quantities of pollutants measured in the Lotus River for the period from 1981-1997. It is reasonable to assume that these figures have probably increased in the last 9 years. In many cases these pollutants can be broken down by biological remediation, but it was suggested by professionals that the pollution levels observed in the Lotus River are too great for natural, passive methods of remediation such as this.

Parameter	DWAF TWQR (mg/*l*)	Great Lotus (5th Ave) (mg/*l*)
Ammonia	≤ 0.007	Min = 0.0039 95 percentile = 0.0112 Mean = 0.77 Max = 5.42
Total Nitrogen (Inorganic)	< 0.5 (oligotrophic) 0.5 – 2.5 (mesotrophic) 2.5 – 10 (eutrophic) > 10 (hypertrophic)	Min = 1.25 95 percentile = 1.346 Mean = 6.49 Max = 21.7
Total Phosphorus (Inorganic)	< 0.005 (oligotrophic) 0.005 – 0.025 (mesotrophic) 0.025 – 0.25 (eutrophic) > 0.25 (hypertrophic)	Min = 0.14 95 percentile = 0.2114 Mean = 0.703 Max = 2.31
Total Suspended Solids	< 100	Min = 1 95 percentile = 0.0112 Mean = 32 Max = 400

Figure 11: Table of the pollutant levels of the Lotus River (Grobicki, 2001)

Major pollutants of the Lotus River tabulated against the Department of Water Affairs' water quality guidelines, showing 95% of ammonia levels to be up to 1.6 times the acceptable level, and 95% of phosphorous levels to be within the eutrophic (high amount of nutrients) category. In general, all pollutants measured have maximum levels which far exceed the allowable amount. (Grobicki, 2001)

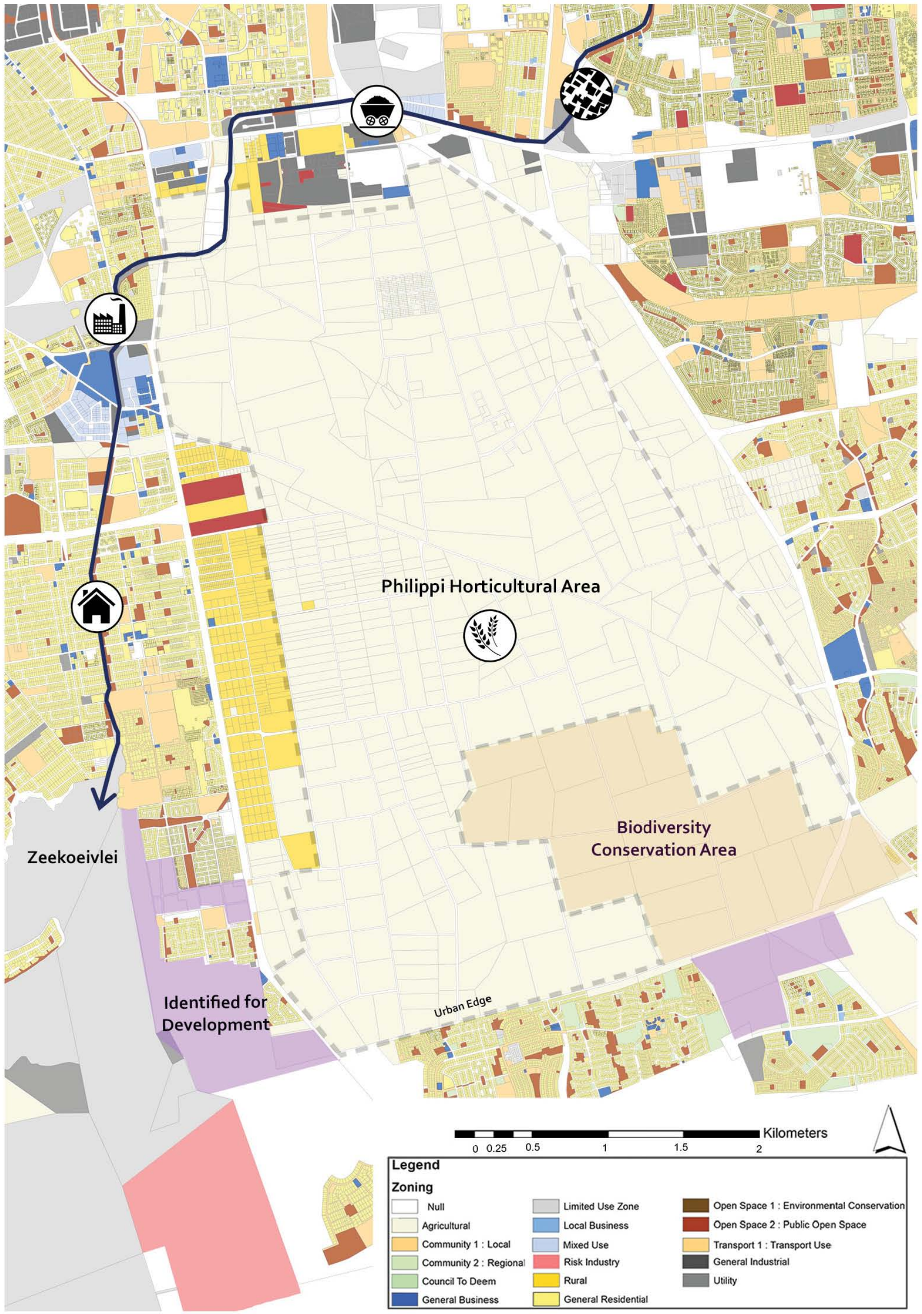


Figure 12: Mixed mapping 1: Lotus River and PHA

The map shows the zoning and land-use surrounding the Lotus River. A prominent element in the image is the urban edge of the Philippi Horticultural Area, indicating where agricultural land is protected from creeping urban growth. (GIS Maps, 2015)

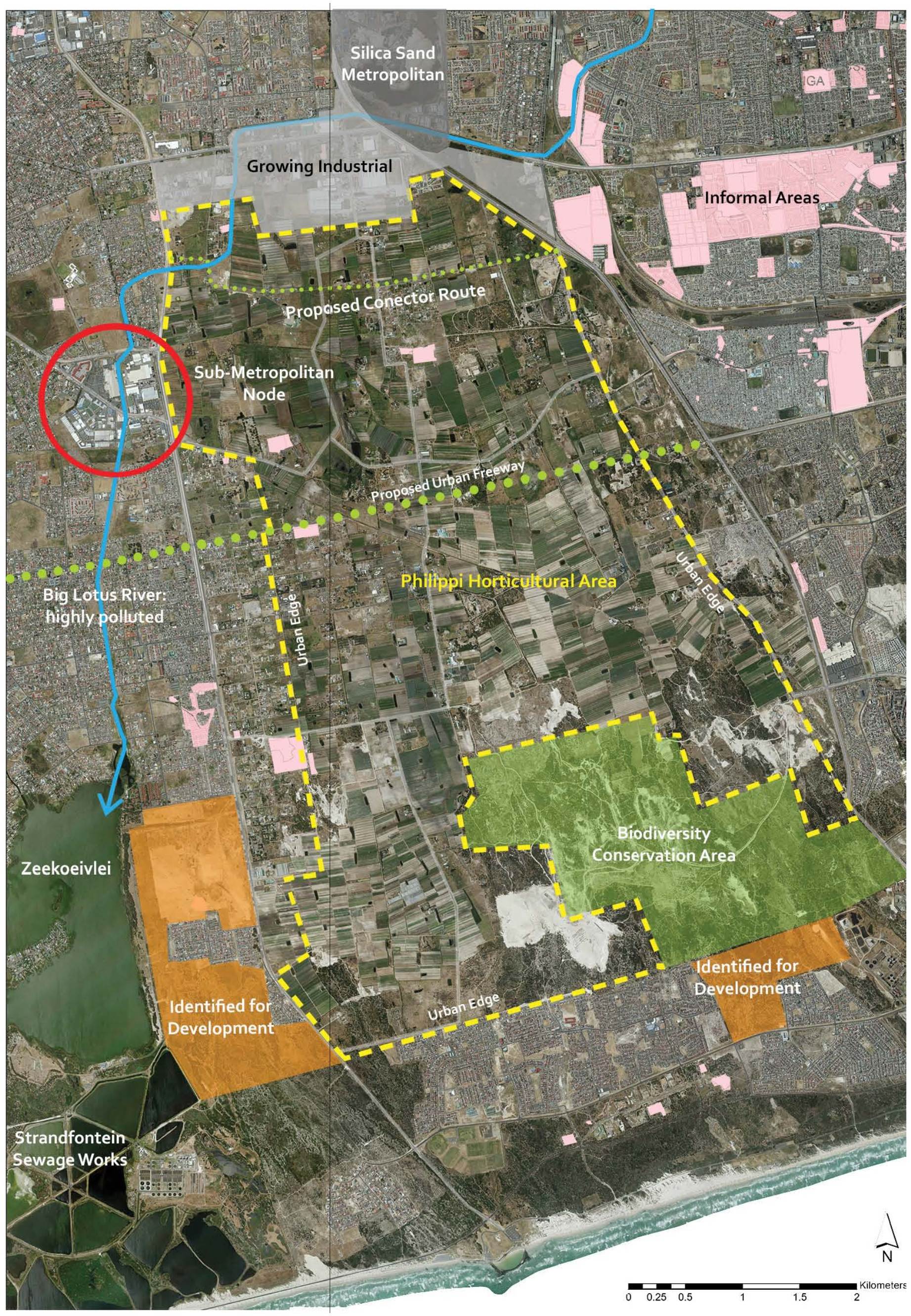


Figure 13: Mixed mapping 2: Lotus River and PHA.

Aerial imagery of the Lotus River and PHA highlighting zones which threaten and are threatened by the state of the river. The PHA sits between growing industrial area and protected natural habitats. The red circle indicates a CoCT defined "sub metropolitan node" and proposed roads are indicated with dotted lines. (GIS Maps, 2015)

Environment and ecology

Phosphorous

Phosphorous occurs naturally in animals and plants in the form of phosphates, which plays an important role in energy transfer and DNA. Natural process can normally break down tolerable levels of phosphorous, however human behaviour has radically imbalanced the phosphate cycle through the use of phosphate-rich manures, fertilizers and detergents.

In its most dangerous form, white phosphorous - which is a product of many industries, exposure to humans is fatal and causes skin burns, damage to the liver, heart and kidneys. White phosphorous is converted into less harmful particles in air, but in water decomposition is slower and phosphorous typically accumulates in the bodies of aquatic organisms or becomes sedimented in soils.

In the case of phosphate fertilizers, soil can normally break down phosphorous in several days but the large amounts associated with chemical fertilizers and mismanaged practices mean excess phosphates are not taken up and seep into ground water systems.

The build up of this excess phosphorous in water encourages the growth of phosphate-dependent organisms such as algae and duckweed. These organisms consume large amounts of oxygen and cloud the water, preventing sunlight from entering and making the water uninhabitable for many other organisms. This process is known as eutrophication. (Lenntech, 2015)

Nitrogen and ammonium compounds

Nitrogen is the common element in various ammonium compounds which are used for chemical processes of all kinds. For example ammonia gas (NH_3) is used for cleaning and bleaching. Ammonium sulphate $(NH_4)_2SO_4$) is a salt fertilizer, ammonium chloride (NH_4Cl) is used in medicine, metalwork and also fertilizers.

Nitrogen is an important part of natural energy cycles and provides plants and animals with valuable resources, however nitrogen compounds are not usually present in water systems as they are “locked away” in organisms.

When industrial ammonia comes into contact with water it is converted into a toxic ionized state. High levels of the ammonium ion severely affect the growth and development of fish, plants and invertebrates found in river systems. Exposure to high levels can also be fatal to humans. (Water Research Watershed Center, 2014)

Sources of ammonia and nitrogen in urban water systems are primarily due to the over-use and mismanagement of fertilizers which seep into ground water systems before draining into canals. In the case of the Lotus River the high levels of ammonia are also indicative of the faecal contamination as a result of upstream informal settlements. (Grobicki, 2001)

Mapping the Pollution

A thorough study of the Lotus River was conducted by the Water Research Commission in order to identify the sources of major pollutants. The following mappings graphically summarize the findings of the study, located in the government publication “Integrated catchment management in an urban context - The great and little Lotus Rivers, Cape Town” by Abbott Grobicki.

The study looked at water samples taken at significant points along the Lotus River, such as tributary inflows and suspected diffuse sources. A description of each sub-catchment and land-use is included in the following study. All data and information was gathered from the Grobicki report, unless state otherwise.

1. Airport Industria

The sub-catchment of 1610.2ha features mostly hard open surfaces such as parking lots, runways and industrial space. The lack of vegetative land results in heavy surface runoff into the river which pollutes the water with litter and oils found on roads.

Notably, 17 % of total nitrogen content of the river appears to originate from this sub-catchment, while phosphorous contribution is negligible.

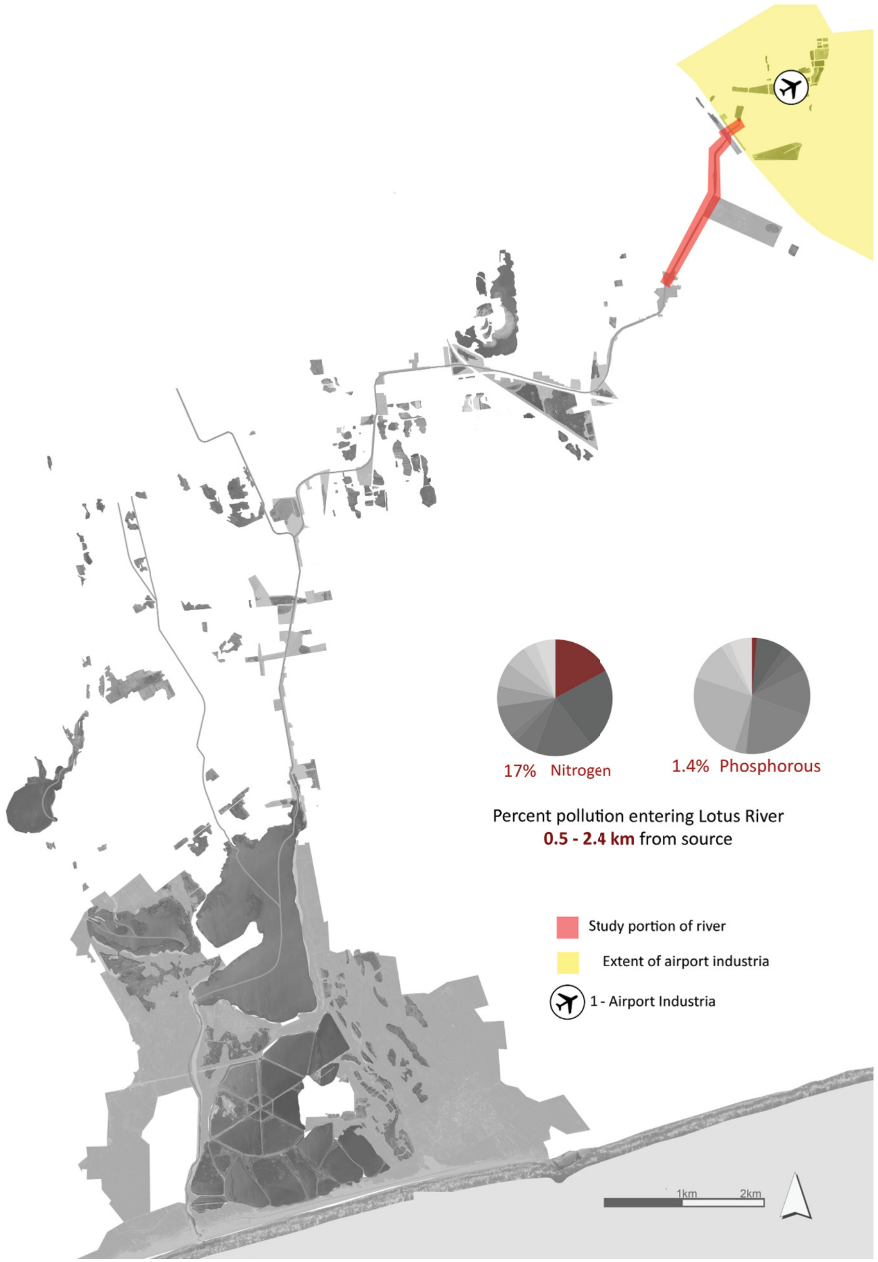


Figure 14 (right): Pollution mapping: Airport Industria (adapted from GIS Maps, 2015)

2. Nyanga and Gugulethu

Comprising of 5 sub-catchments with a total area of 559 ha, the area is characterized by a combination of formal and informal dwellings. According to the 2011 census, 31.7% and 47.8% of the population of Nyanga and Gugulethu, respectively, reside in informal dwellings. 19.2% and 37.4%, respectively, make use of toilets that are not linked to the municipal sewage system .

A major source of water pollution is thus the use of the Lotus River canal for waste and sewage removal. For this reason a large amount of total nitrogen, 22.5%, in the Lotus River originates from these sub-catchments.

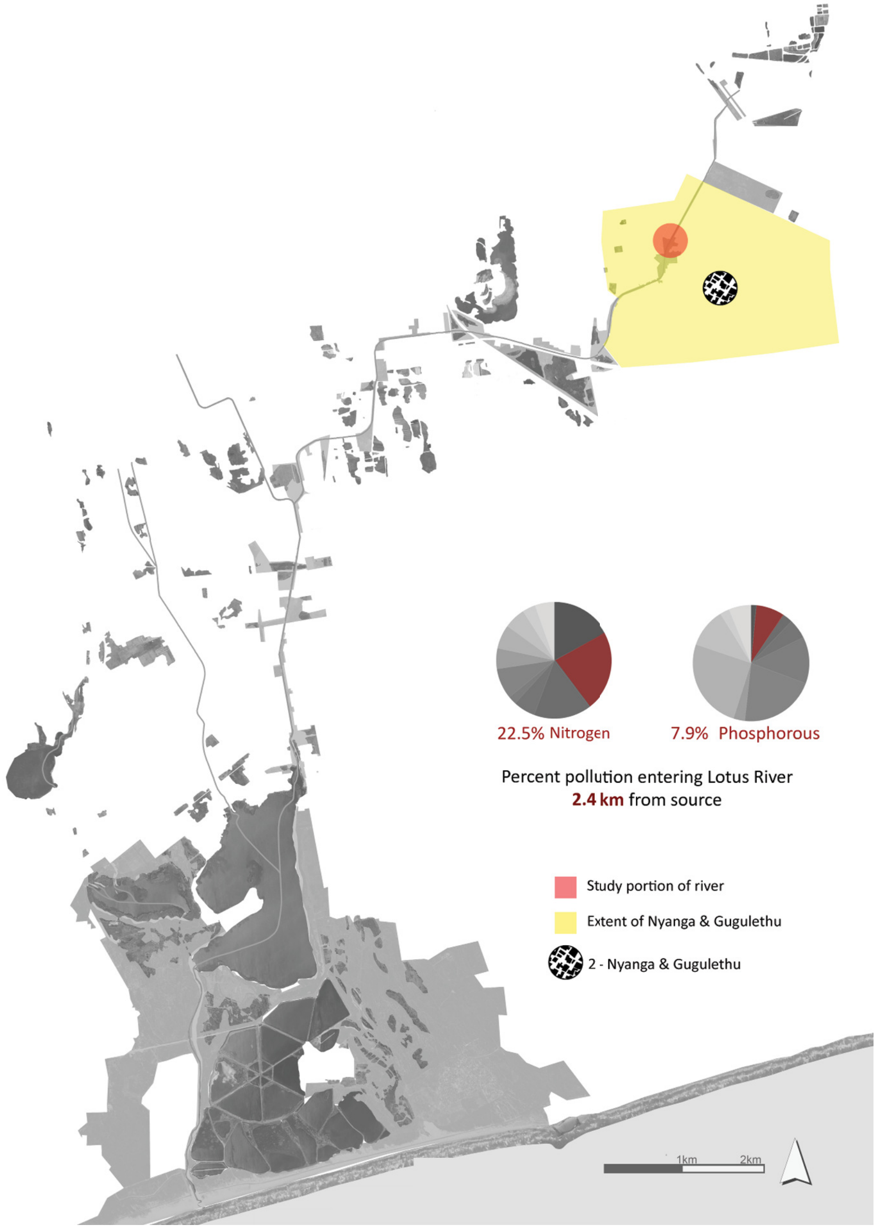


Figure 15 (right): Pollution mapping: Nyanga and Gugulethu (adapted from GIS Maps, 2015)

3. DHS Silica Sands (Pty) Ltd and Philippi East, Philippi West and Crossroads

The sub-catchment features one of Cape Town's major open cast mining operations for high quality glass silica sand. While the operations EIA reports that the impact of mining on ground water is minimal, it is suspected that secondary pollutants could easily occur from mismanagement and human error. Similar pollutants to those originating from roads , here associated with heavy mining machinery would have the opportunity to enter the hydrological cycle through the unlined surface of the mining operation.

The tributary draining the industrial area also drains the residential areas of Philippi East, Philippe West and Crossroads. Growth of informal settlement within these areas means similar pollutant loading to those found in Gugulethu and Nyanga.

Notably, 16% of nitrogen in the Lotus River originates from this sub-catchment. Phosphorous loading is negligible.

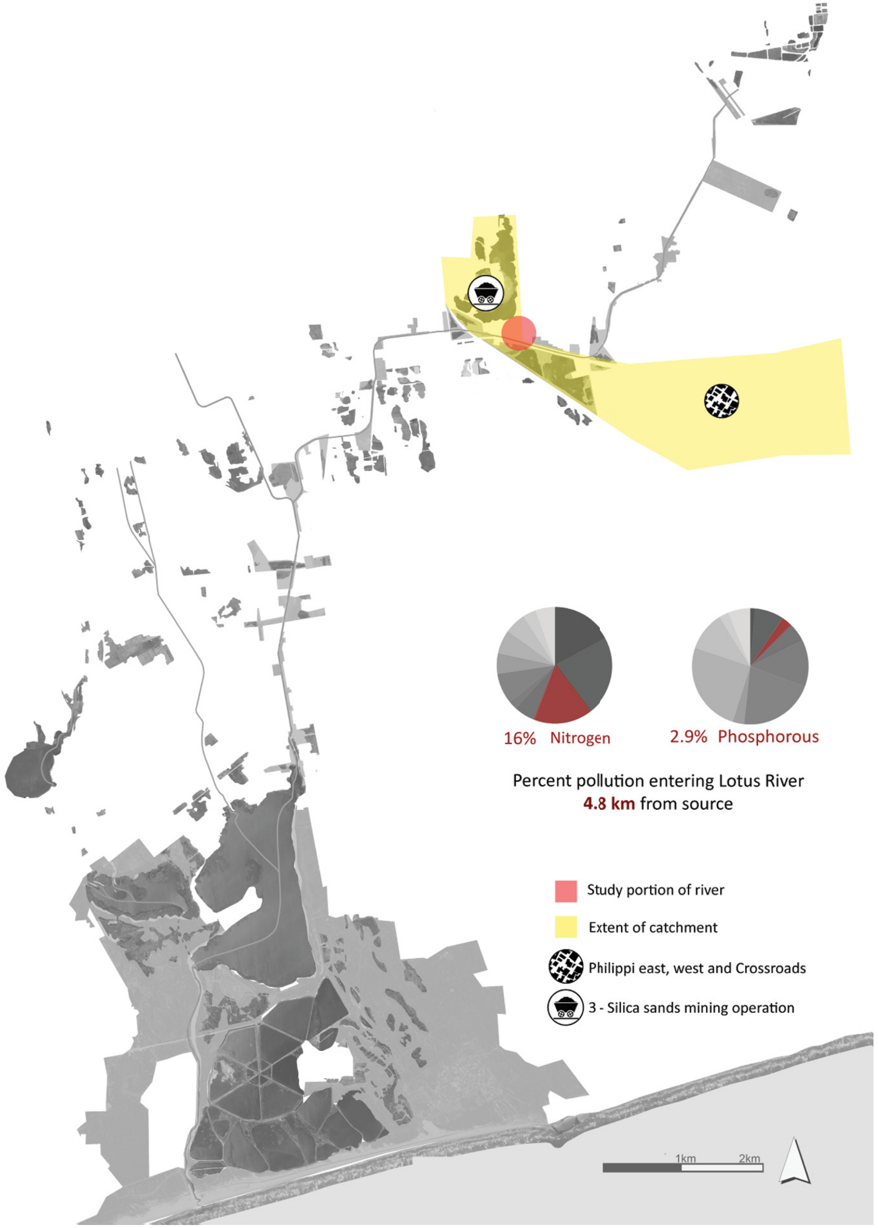


Figure 16 (right): Pollution mapping: DHS Silica Sands (Pty) Ltd and Philippi East, Philippi West and Crossroads (adapted from GIS Maps, 2015)

4. Philippi Horticultural Area (PHA)

The area comprises of 12 sub-catchments with a total area of 2279 ha draining into the Lotus River. The area is characterised predominantly by agricultural land, cultivated and unused. The perimeter of the PHA is under pressure of growing informal settlements which have the same polluting effects as discussed above for Nyanga and Gugulethu.

Studies have shown the PHA to be the single greatest contributor to pollutant loading in the Lotus River. This is due to environmentally inappropriate and outdated farming techniques such as over-use of inorganic fertilizers, over irrigation and leeching from farm animal manure. Nutrients from all of the above soak into the ground water and are transmitted into the Lotus River via the unlined sections of the canal which run through the north east section of the PHA.

This catchment contributes 17.4% of total nitrogen present in the river, and a massive 58.3% of phosphorous.

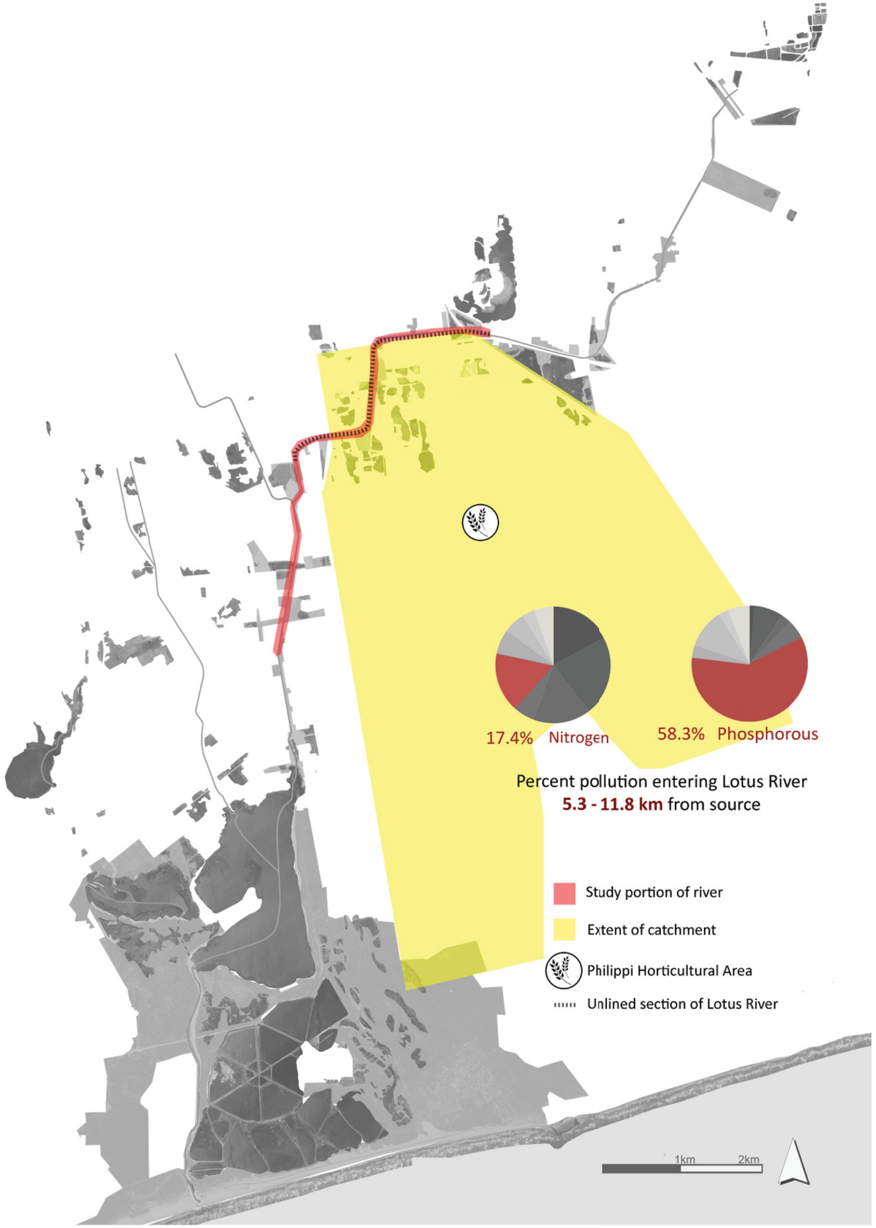


Figure 17 (right): Pollution mapping: Philippi Horticultural Area (adapted from GIS Maps, 2015)

5. Ottery Light Industria

This area is characterised by dense industrial and commercial buildings which feature hard surfaces, parking lots and factory roofs. Very little vegetative land is located here and water runoff is either transported to storm water detention ponds or the Lotus River. Litter and oils from roads and paved surfaces gather and enter the water system in this manner.

A mixed range of industries are represented including ammonia refrigerator and freezer services, chemical cleaning manufacturers (also using ammonia), aluminium extrusion and printers. Chemicals used in these processes are found in abundance in the Lotus River canal. Although evidence of this area being a contributor to pollution was not found due to restricted access of the factories, it is suspected that some factories do not adhere strictly to chemical disposal protocol, resulting in spillages and leaks being washed into the storm water system and entering the river network.

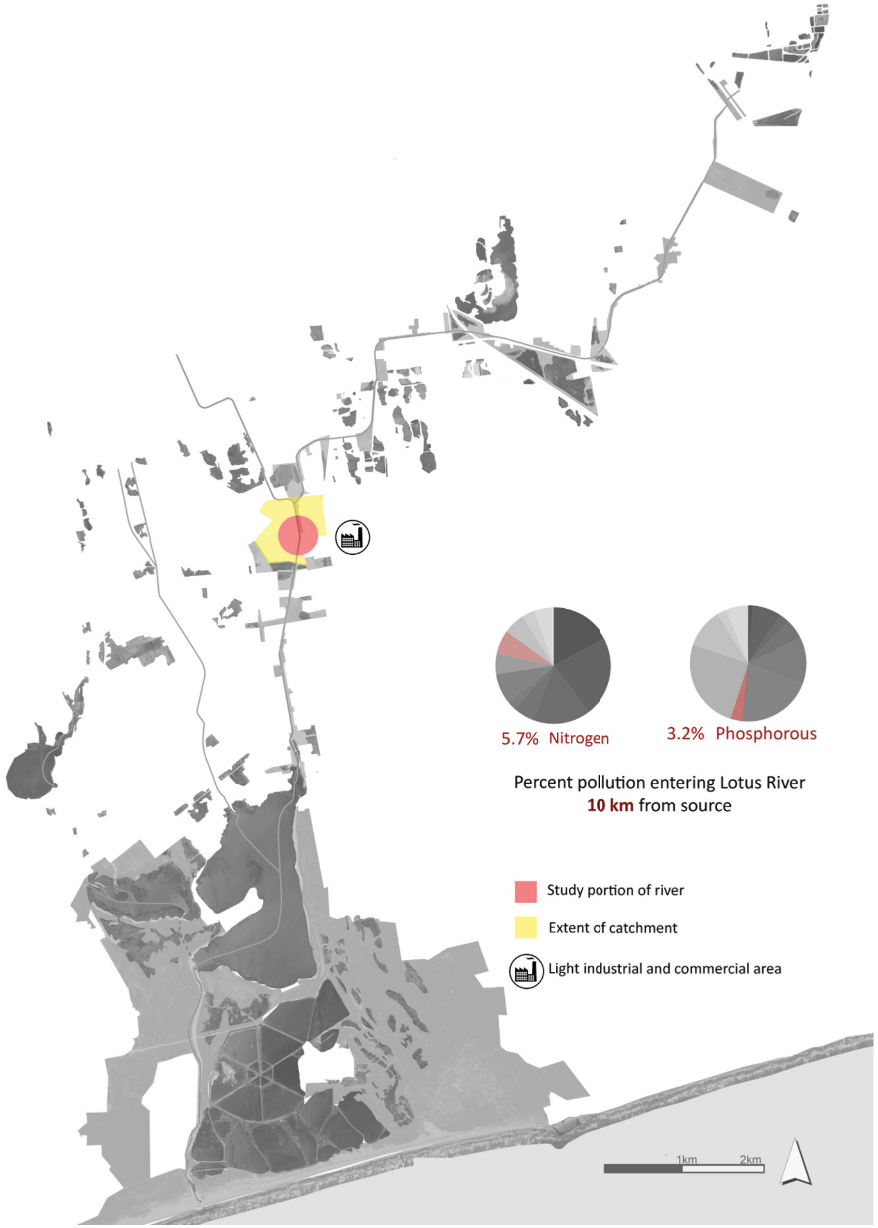


Figure 18 (right): Pollution mapping: Ottery light industria (adapted from GIS Maps, 2015)

6. Lotus River Residential

This area is characterised by formal residential units, including social housing type blocks of apartments. Back yard shacks are apparent from aerial imagery. From observation it is apparent that the area is highly polluted with litter and illegally dumped building rubble. Many disused vegetative areas are located along the river.

The are contributes very little in terms of nitrogen and phosphorous pollution, but litter appears to be a considerable problem.

South of this area the canal breaks open into naturalized river which connects directly to the Zeekooivlei.

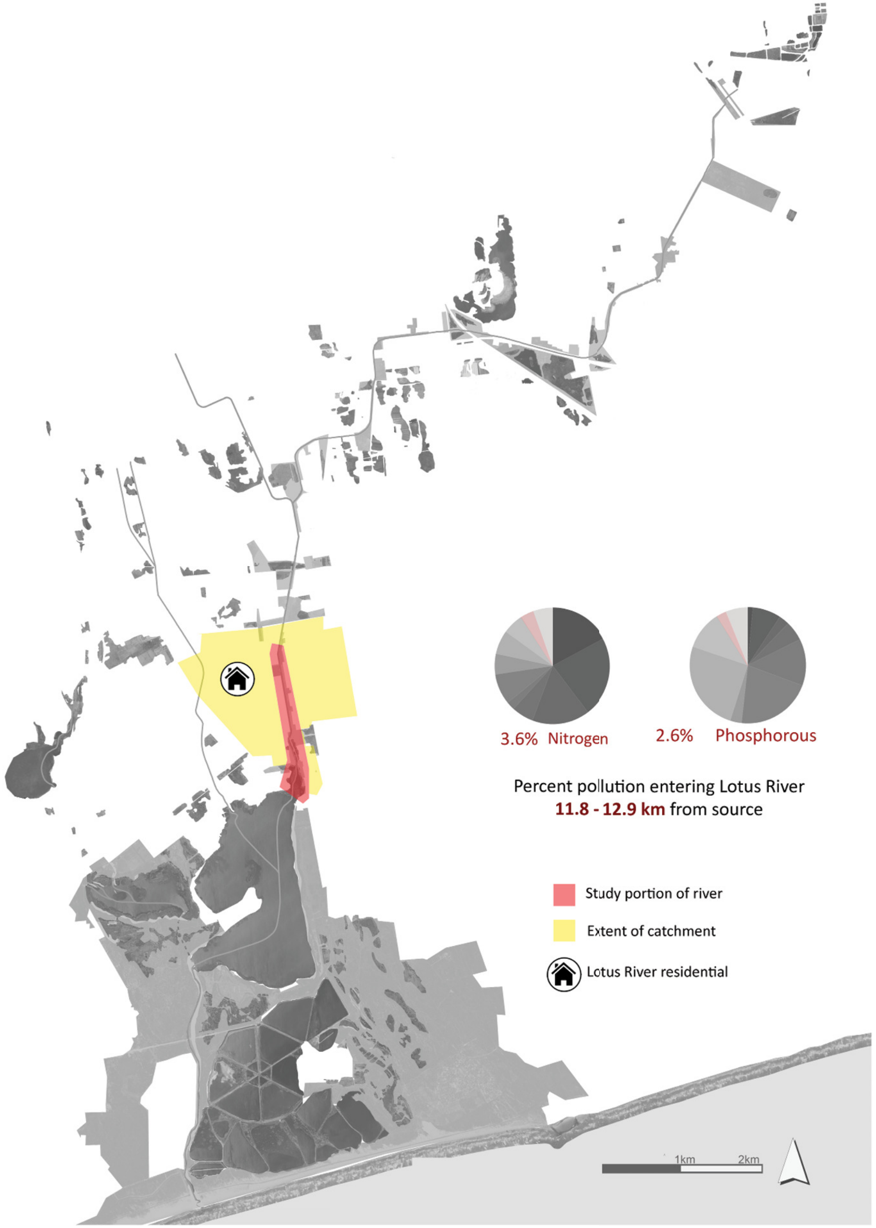
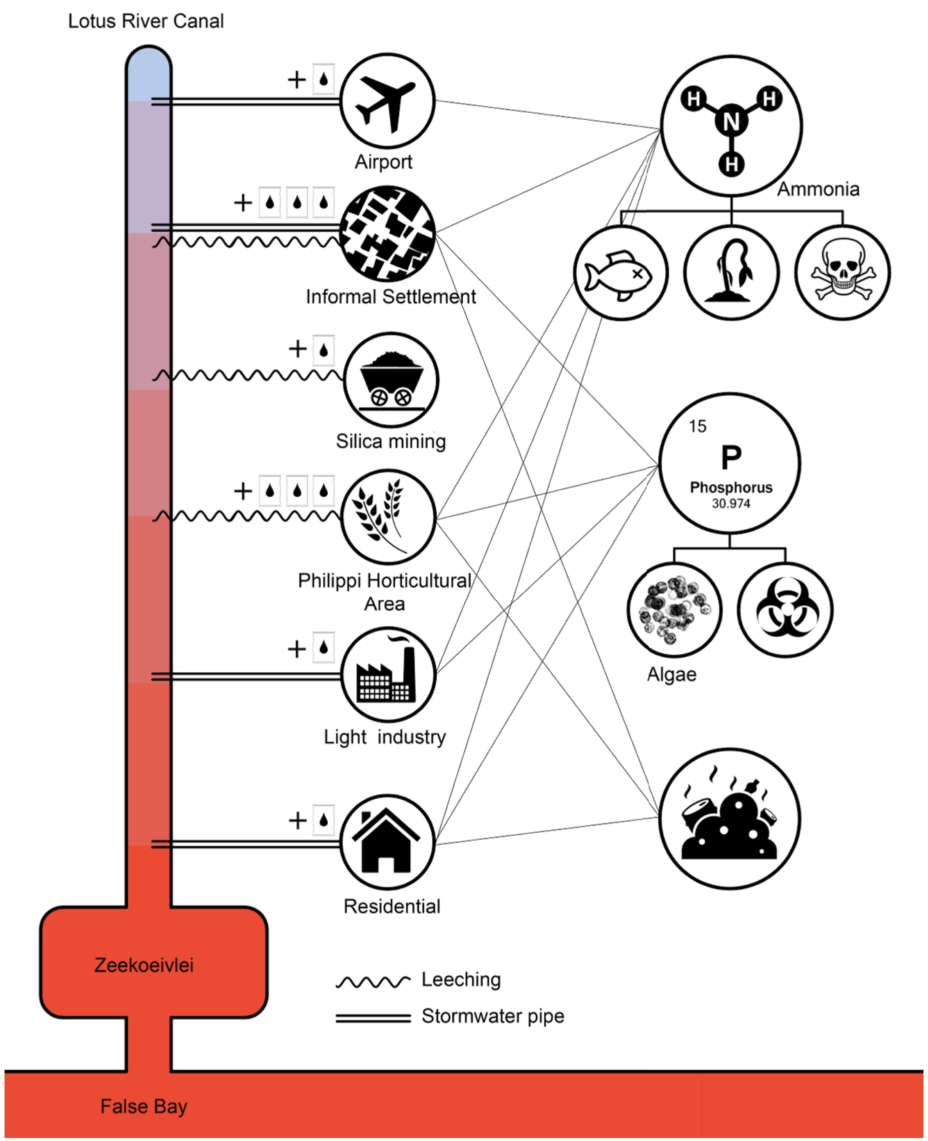


Figure 19 (right): Pollution mapping: Lotus River residential (adapted from GIS Maps, 2015)

The infographic below summarises the sources, pollution types and modes of infiltration into the lotus river, as well as the effects of each pollutant on plants and animals.

Figure 20: Infographic 1: Lotus River pollution cause and effect



Proposed Solutions

Due to the variety of sources of pollution along the Lotus River, the full remediation of the river would require a complex treatment train of varying process, tailored to specific sources. Consultation with ecologists and engineers helped with the identification of site-specific interventions for each of the catchments identified in the above mapping. These are summarized on the next page.

General improvement could be achieved through broad spectrum catchment management. The Water Research Commission study of the Lotus River catchment area(Grobicki, 2001) makes the following suggestions for this kind of intervention:

- Energy must be put into increasing public, corporate and government awareness of the importance of catchment management. This would provide management committees with greater control of the quality and quantity of water runoff and/or infiltration.
- More focus must be given to "quality of life" factors such as the provision of recreation facilities and biodiversity conservation initiatives. This both improves water infiltration and runoff and reconnects communities with natural environments.
- Integrated water service institutions must become linked with land-care, demand reduction and water reuse as part of a greater government management best practice scheme.

In summary, the report makes the statement:

> *The most important recognition in catchment management, especially in the urban context, is that social and institutional process should take precedence over purely technical decisions. This has been shown over and over again in successful catchment management projects worldwide*. (Grobicki, 2001)

Site-specific remediation interventions

1. Airport Industria

Filtration mechanism at storm-water tributaries. Litter and grease traps, followed by reed beds for nitrogen fixation.

2. Informal settlements

Cut off drains divert tributaries to sewage pipes before water flows into canals. Litter traps in canal.

3. Silica Sands Mining

Continuous environmental management and government tracking on mining site. Cut off sewer drains on tributaries upstream of outlet into Lotus River.

4. Philippi Horticultural Area

Convert unlined drainage channels into reed beds for nitrogen fixation. Farmer education and provision of alternative non-ammonia/phosphate based fertilizers.

5. Ottery light industria

Chemical removal through industrial treatment process.

Passive education and awareness campaigns.

6. Lotus River residential area

Constructed wetland recreational space, reed beds for litter control and nitrogen fixation. Education and awareness campaigns. Habitat rejuvenation.

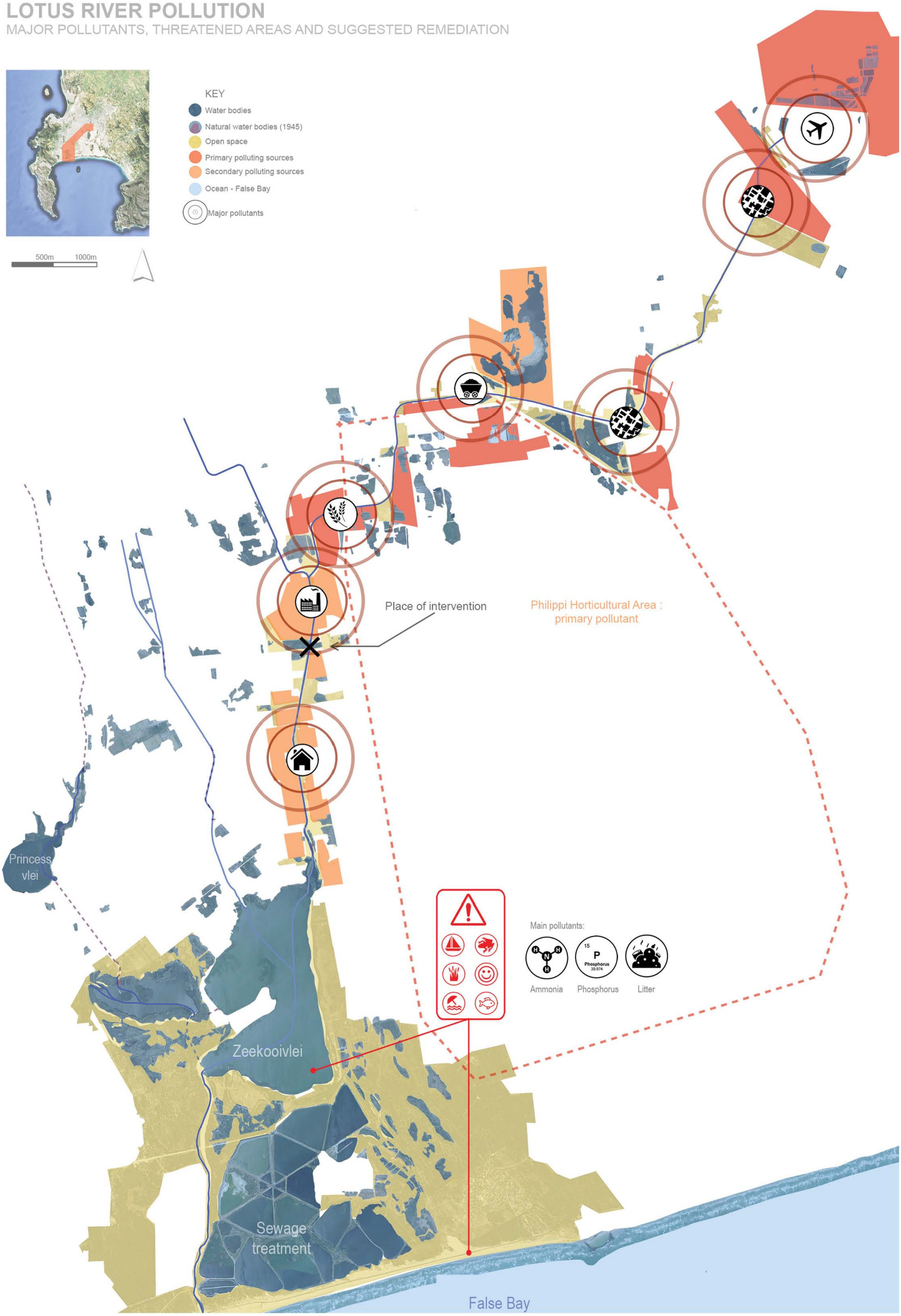
The map on the following page summarises the findings of the mapping exercises. Information contained in the map includes:

- Location of primary and secondary pollutants - shaded up to 2km of the river
- Open space available for intervention
- Open waters in the Lotus River Network
- Threatened regions and activities
- The urban edge of the Philippi Horticultural Area
- The location of the project

Figure 21 (following pages): Mixed mapping 3: Lotus River pollution (adapted from GIS Maps, 2015)

LOTUS RIVER POLLUTION

MAJOR POLLUTANTS, THREATENED AREAS AND SUGGESTED REMEDIATION



6 Site

Based on the findings of the pollution mapping, an appropriate site was chosen for the project with the following logic (diagrams not to scale):

The site is downstream of primary pollution sources to clean the maximum amount of pollution before the water enters the Zeekooivlei.

The site is upstream of the residential area to provide clean water and safe recreational space for the local community which is in need of recreational facilities.

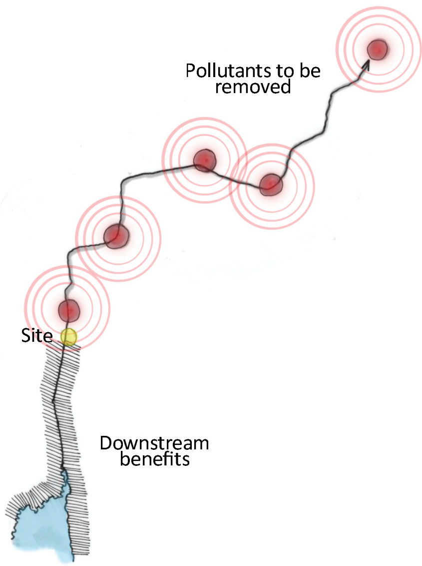


Figure 22: Site location and pollution

The site is located within a metropolitan node which is identified for development by the CoCT.

The site is located on a significant buffer zone between residential, industrial and agricultural areas - all of which are major sources of pollution in the river. A facility built here will engage different groups of people and industries, resulting in a broader target audience and field of effect.

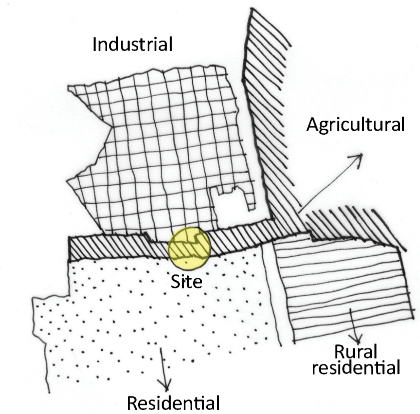


Figure 23: Site location and land use

The site is easily located along a major road which connect all land-uses.

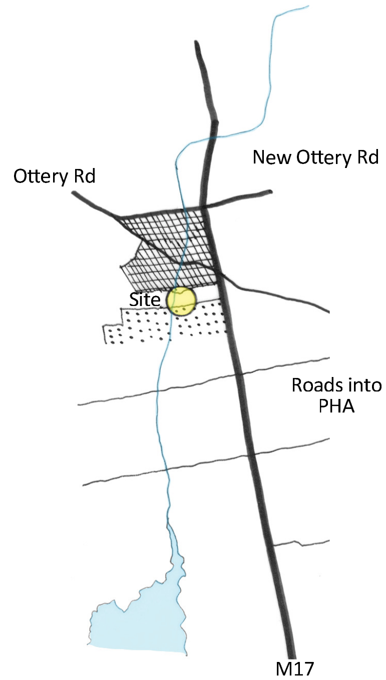


Figure 24: Site location and road access

The site is located on a conspicuous tract of land connecting the Lotus River with the Philippi Horticultural Area, making the function of integration and education more possible.

The site is located on a storm-water retention pond, an important part of the hydrological cycle. The site therefore has a natural tendency to fill seasonally with water and can support indigenous riverine vegetation and animals without much artificial intervention.

The site is large enough for industrial scale buildings and has space for future growth if necessary.

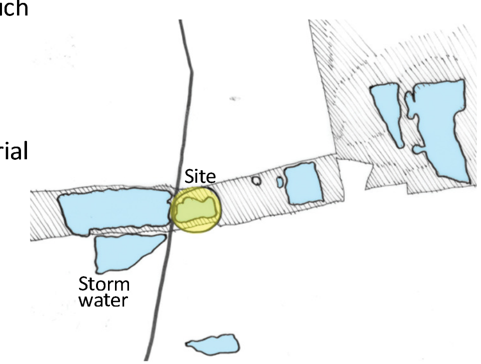


Figure 25: Site location and water bodies

Figure 26 (top) : Site photograph showing pedestrian route along the river- looking south west

Figure 27 (bottom): Site photograph showing storm water pipe entering the Lotus river from Ottery light industria - looking west.

Figure 28 (top): Site photograph showing litter, rubble and farming activities on the site.

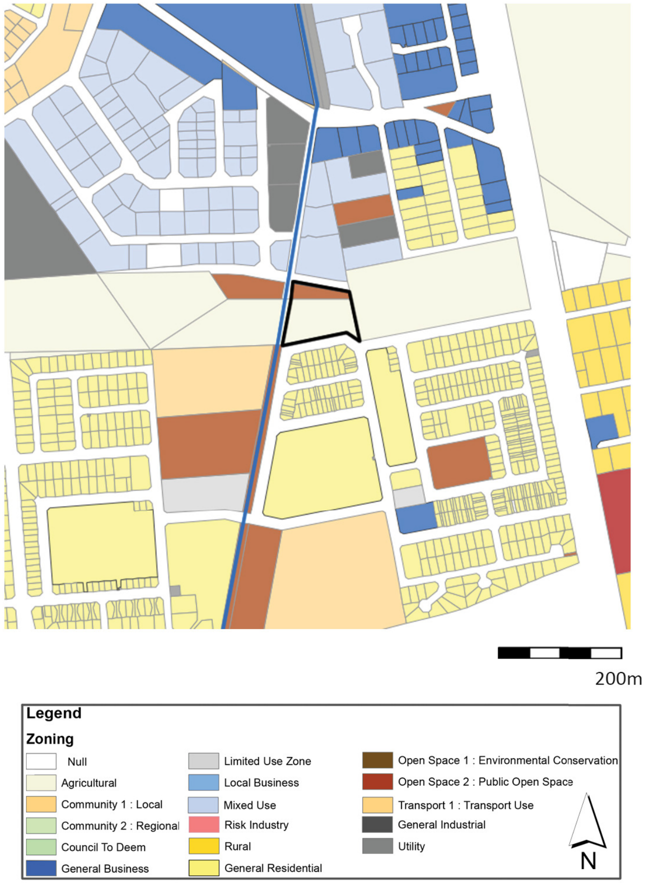
Figure 29 (bottom): Site photograph showing miscellaneous rubbish blocking the canal.

Site analysis

Zoning

The site, indicated by the black line, is bounded by the river, to the west, and straddles two erfs which are zoned for agriculture and public open space.

Figure 30: Site zoning (GIS Maps, 2015)



Pedestrian routes

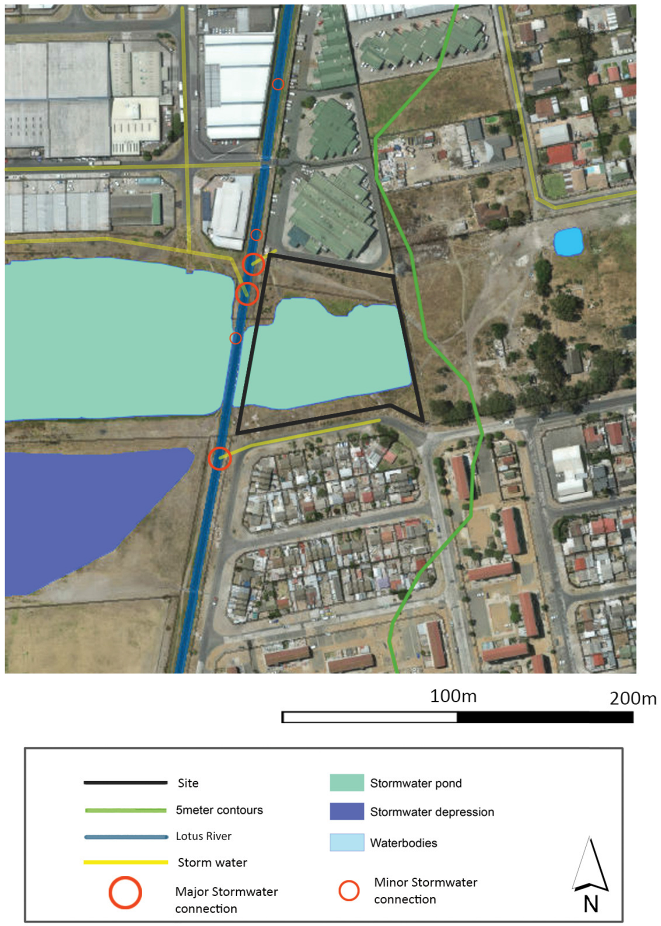
Many pedestrian routes cut through the site and surrounding open land. Pedestrians use a popular route along the river heading north to the Ottery shopping center. The open space along the routes are considered highly dangerous by residents.

Figure 31 (left): Pedestrian routes on site (GIS Maps, 2015)
Figure 32 (right): Connection to Ottery shopping district (GIS Maps, 2015)

Water

The site is located on a storm-water pond system where major local inlets join the river. Slow moving sludge is visible entering the river from storm-water pipes. Litter blocks the river and pipes during dry periods.

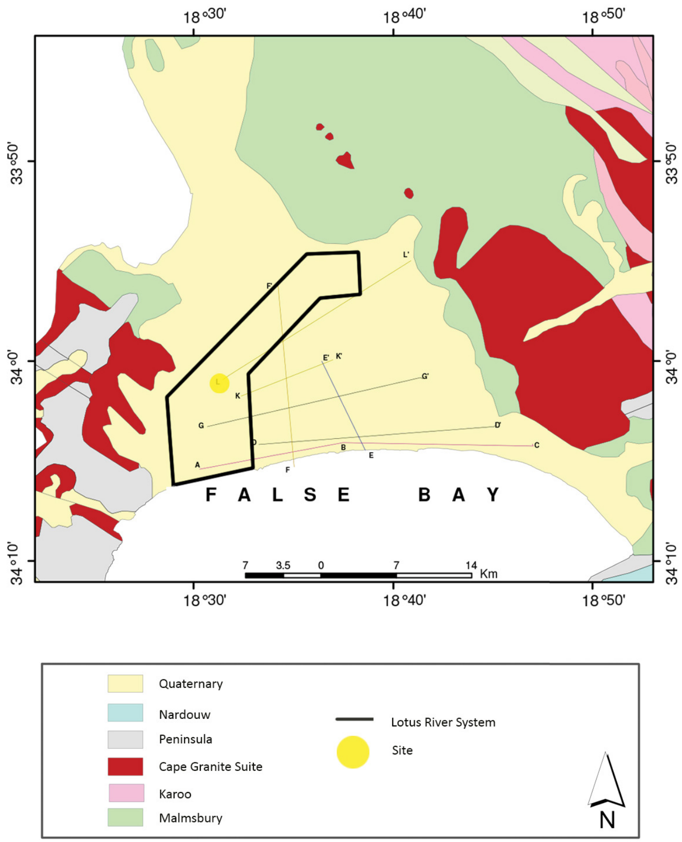
Figure 33: Site water distribution (GIS Maps, 2015)



Geology

The site geology comprises of 10-20m of sandy soil with peat intrusions, on Malmsbury shale. The sections on the following page indicate the geology of the river (red) and the site (yellow). It is estimated that the groundwater table sits between 1 and 3m below ground level and that deeper waters become more brackish - meaning that the best quality ground water is very easily accessible and also at risk of pollution. (Blake, 2014)

Figure 34: Geology of the Cape Flats (adapted from Adelana et al., 2010)



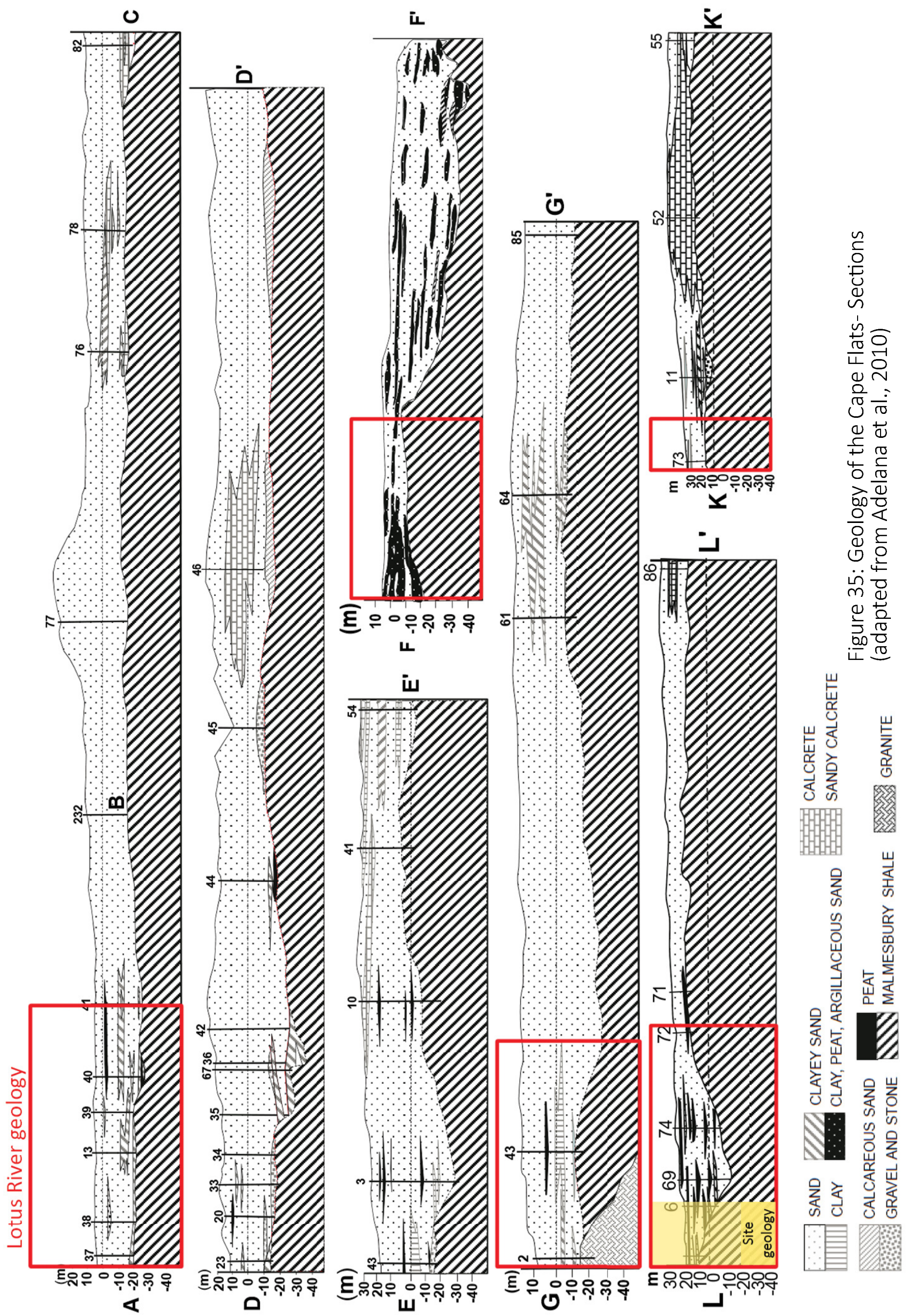


Figure 35: Geology of the Cape Flats- Sections (adapted from Adelana et al., 2010)

Local community

Socially, this low income area is characterized by violence, drug abuse and gangsterism which is the top community concern according to a needs analysis of the Lotus River and Grassy Park area (The Unit for Religion and Development Research, 2005). Among the top ten community concerns, cleaning of the area ranked second, with provision for community facilities and playgrounds ranking 6th and 7th respectively.

In low income areas such as Lotus River, the provision of beautiful spaces and recreational facilities is severely lacking. It is arguable that the provision of such spaces could provide an alternative activity to youths who become involved in drugs and gangsterism due to boredom. On one site visit, young people were seen taking drugs in the bushes on the site. It can be strongly argued that the use of this space for something productive and inspiring could have a positive impact on this kind of activity.

7 Programme

The concept of the *social condenser* was described by Rem Koolhaas (2004) as the,

> *...programmatic layering upon vacant terrain to encourage dynamic coexistence of activities and to generate, through their interference, unprecedented events.*

This programmatic layering is the essence of the *transitional* or *intermediate* space discussed by the Constructivists and symbiosis theory, and the discovery of these programmes became an important part of the design development.

The project ultimately aims to create the intermediate space between building and nature to encourage the symbiosis of the two - the symbiosis of the *Lotus and the Machine.*

In a nutshell, the programme of *the Lotus* is that of landscape, community and passive education; the programme of *the machine* is an industrial processing facility which recycles the main pollutants in the water into fertilizer. The result is the immediate and long-term remediation of the river, to provide sustainably for future needs, as represented below. The infographic on the next page summarizes the action of the building and surrounding landscaping on the water quality of the Lotus River.

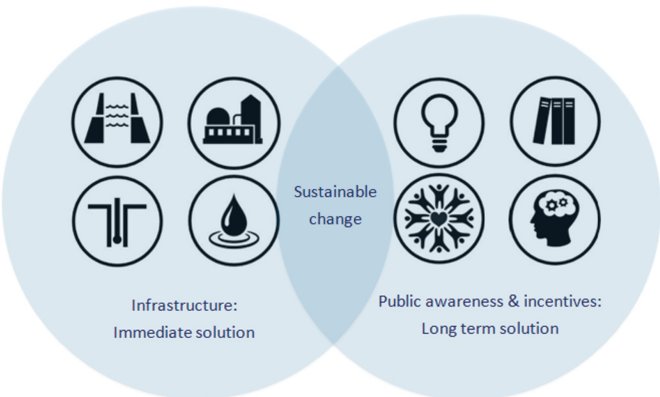
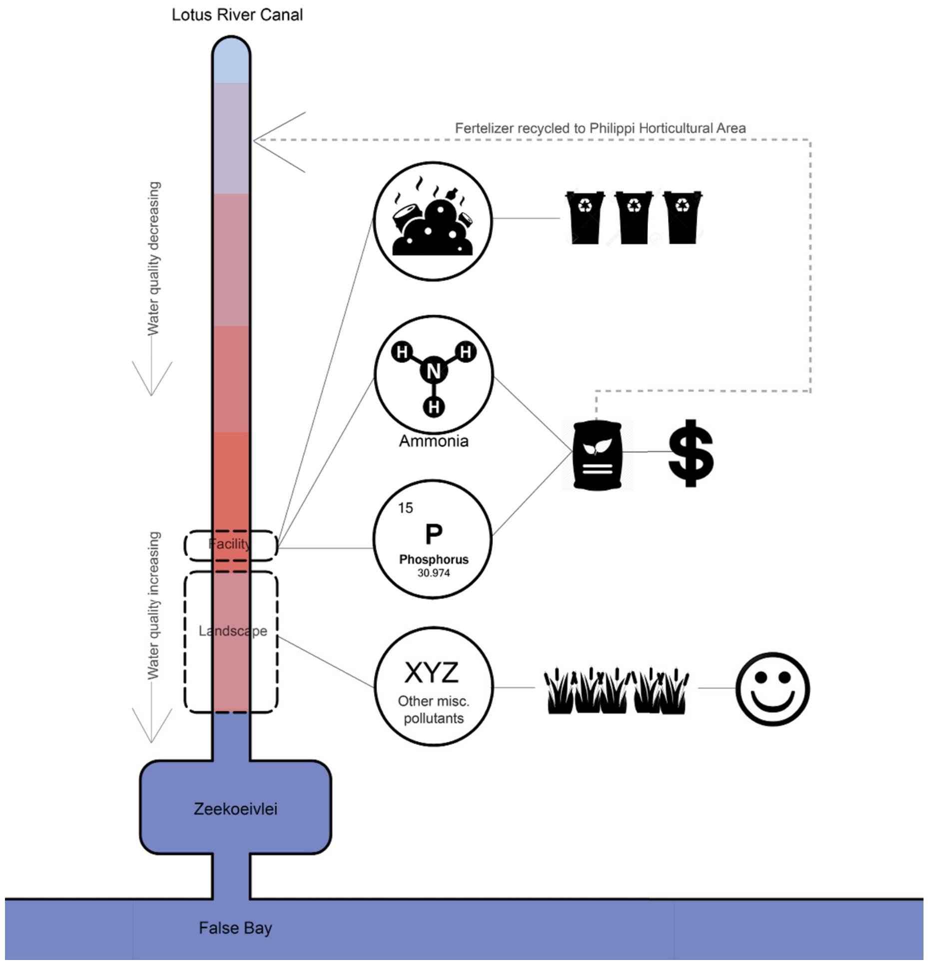


Figure 36 (left): Visualization of immediate and long term impact of a combination of infrastructure and community facilities on the Lotus River.

Figure 37 (below): Infographic 2: Remediation function of the facility.
The build-up of pollutants seen in Infographic 1 on page 48 are reduced at the facility by the pollutant recovery process. Litter is collected and recycled by the recycling depot. Ammonia and phosphorous are recycled into fertilizer which can be sold back to the farming community. Other trace pollutants are synthesized naturally by the planting of the naturalized river system downstream of the facility.



The Machine - Industrial programme

Investigation of recyclability of major pollutants and consultation with a chemical engineer revealed a process which recycles both ammonia and phosphorous. This process is currently being implemented on waste streams locally and internationally. The process manufacturers a fertilizer known as *struvite*, a crystalline, slow-release fertilizer which minimises chemical runoff, making it less environmentally detrimental than other chemical fertilizers (Ostara, 2015).

Struvite Manufacturing Process

Struvite, or magnesium ammonium phosphate hexahydrate ($MgNHPO_4 6H2O$), is an agricultural fertilizer which is delivered in the form of dried pellets. The conversion of ammonia and phosphorous into struvite is a simple chemical reaction that can be done on any scale, dependent on the flow rate of the source to be processed.

Various technologies and systems exist for the crystallisation or precipitation of struvite pellets. In a study of the available options, Ostara Pearl technology was identified as the most appropriate for the South African waste water recovery context (Sikosana, 2015). The company specialises in the provision of fully functional systems, literally plugged into a waste water stream. The schematics on the following page show an overview of the functioning of the system.

The Ostara Pearl process produces a product called Crystal Green, a trademarked fertilizer pellet of particularly high quality. The company advertises that the product is the most environmentally sustainable fertilizer available, stating that the slow release action minimizes nutrient runoff and non-point source pollution (Ostara Nutrient Recovery Technologies, 2015).

Assumptions and Limitations

It is important to note that while this technology is used for waste water streams this typically refers to waste water from a point source, such as municipal sewage works or industrial processes. No examples of this kind of nutrient recovery from contaminated river water were found.

In addition, this project assumes that other pollutants present in trace amounts do not affect the struvite manufacturing process.

The calculations for equipment sizing are based on data gathered between 1980-1997 for the Lotus river (Grobicki, 2004). It is assumed that pollutant levels have only increased since then, and calculations based on the old data provides conservative figures for amount of product manufactured and amount of revenue gathered.

Figure 38 (left) and figure 39 (right): Micro scale and industrial scale reactors for the precipitation reaction of struvite.

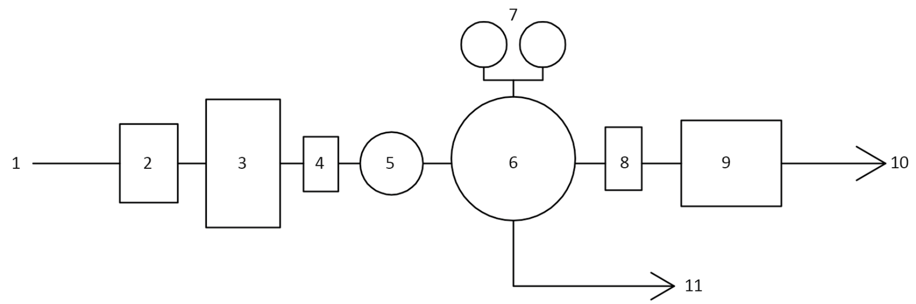
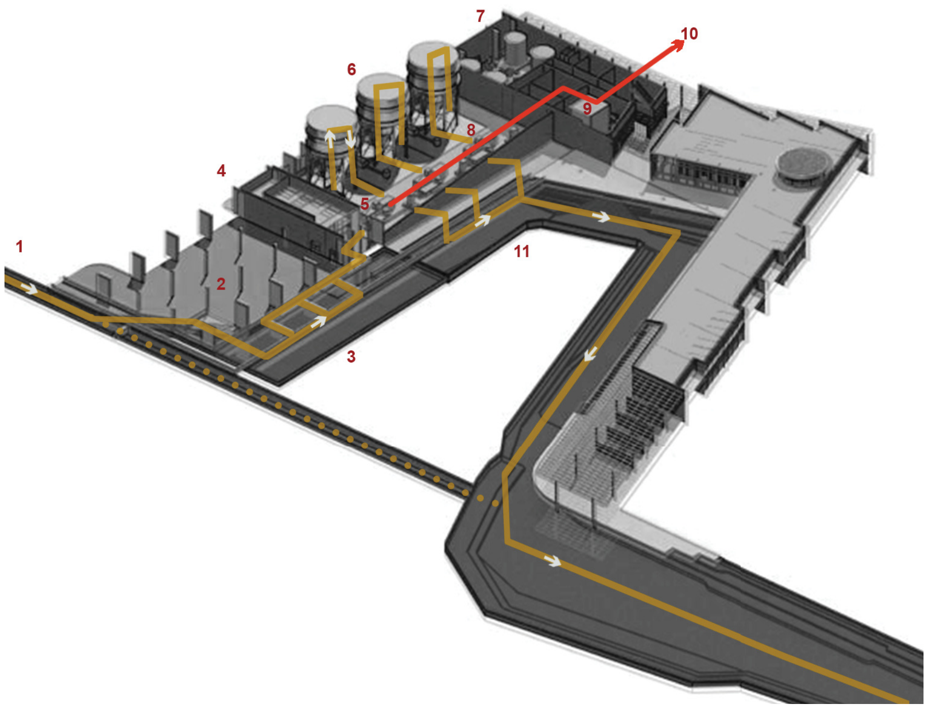


Figure 40 (above) and 41 (below): Schematic of the struvite process (above) and integrated in the building, with three reactors, driers and buffer tanks (below).

1. Dirty water in
2. Solid waste removal- recycling depot
3. Aeration pond- raises the PH for preparation of chemical process
4. Filtration and pump station
5. Buffer tank for pressure control
6. Stirred tank reactor- main chamber of the reaction
7. Reagents (MgCl and NaOH) added to the reactor
8. "Sludge" passes through a drier to be made into pellets of fertilizer
9. Bagging mechanism packages pellets for sale
10. Fertilizer sold
11. Clean water exits reactor



In a study conducted for a waste stream producing 200ML/day (100 times the amount calculated for in this project) it was determined that the revenue gained from struvite fertilizer sales could only recover 1-3% of the plant cost in 20 years (Sikosana, 2015). It is therefore not yet economically viable in South Africa.

However, part of the Ostara business model is to purchase sludge from local waste water treatment facilities for conversion into fertilizer. Augmentation of the pollution processed with that from facilities around Cape Town could increase the viability of the programme and remains to be investigated further.

System Design

Consultation with specialists (Malissa Sikosana - Chemical Engineer) allowed sizing of equipment to be done according to the flow of the river and pollution quantities. Data and calculations can be found in Appendix A.

Calculations were based on the total annual runoff volume, amounting to 55ML/day. This proved to be unfeasible due to the large reactor size required and the site restrictions. Calculations were extrapolated down using the average flow rate for the summer (low flow) months of the year. As the river is fully swollen in winter, the concentration of pollutant is expected to be lower, for this reason it is logical to propose that the facility would only be operational for the months of September to April where the maximum flow rate is 2.16Ml/day. Data used can be found in Appendix B.

Space requirements

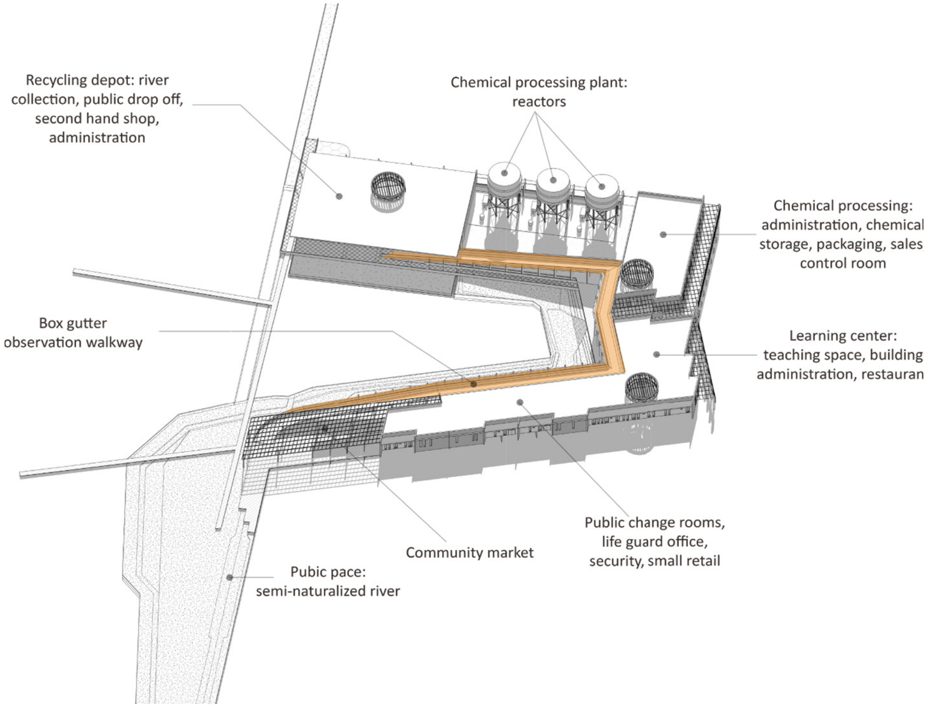
On consultation with Ostara manufacturing the number of reactors, driers and bagging systems was determined. The plan of a typical Ostara plant was acquired, upon which space requirements for the design were calculated (Plan attached in Appendix B). Advice was provided regarding the ancillary space requirements, product storage space and drying/packaging equipment. As the operation is fully automated, few personnel are required to operate the plant and service spaces only include office space and toilet facilities for 2 people.

Public Interface

The end of the manufacturing process includes a sales point for the product, where bulk purchase can be made by local farmers. Access for delivery vehicles is provided and service spaces such as offices and storerooms are included. More importantly, however, is the indirect contact people can have with the chemical remediation process, provided by walking routes, views and an elevated viewing platform, all of which integrate the industrial and public realms.

The viewing platform takes the form of a pedestrianised box gutter which wraps around the internal space of the building, linking the different parts of the building together. This gutter collects rain water which is dramatically deposited into the swimming ponds at strategic positions,but also functions as part of the pedestrian route around the site.

Figure 42: Identification of main parts of the building, with dramatic box gutter highlighted.



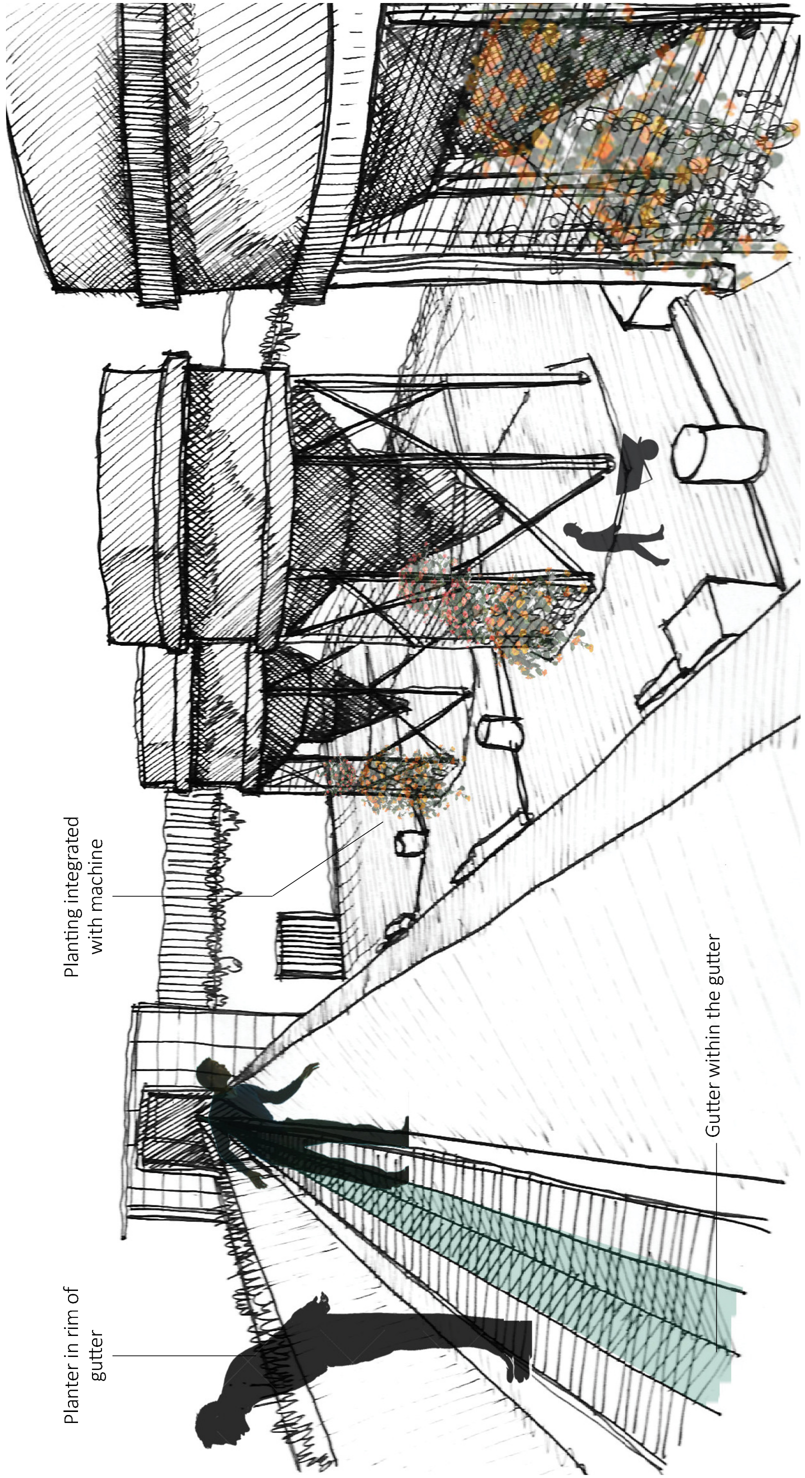


Figure 43: View from the box gutter into the reactor space

Recycling depot

The river, as it enters the site, is diverted through a recycling depot where solid waste can be removed from the water, sorted and transported to larger facilities for processing. Limited recycling facilities are located in the surrounding neighborhoods and the area is highly contaminated with litter and rubble. A buy-back programme could be implemented to encourage the community collection of recycling. This also supports the major premise of this dissertation, that community involvement and awareness is an important factor in environmental remediation.

Aeration pond

Fountain displays function to aerate the stagnant river water before entering the processing plant. This increases the PH of the water which enables better removal of pollutants, but also provides a visual attraction to this part of the site.

The Lotus - Social programme

It is argued here that environmental awareness is an important factor in environmental remediation. This is especially so in an agricultural area where farmers' actions are the cause of much of the pollution present in the local water system. This dissertation suggests that by confronting a community with the process of river remediation, and showing them the benefits of keeping it clean the public can be passively educated, conscientised and incentivised for sustainable improvement of water quality. To supplement the passive exposure to the industrial process, the project incorporates an education wing including a lecture theater and two multi-purpose spaces.

These spaces would be used by the chemical plant for education on the correct use of the fertilizer, for broad spectrum agricultural and environmental training, and for training of new technicians - a type of qualification which is severely lacking in South Africa, according to Sikosana.

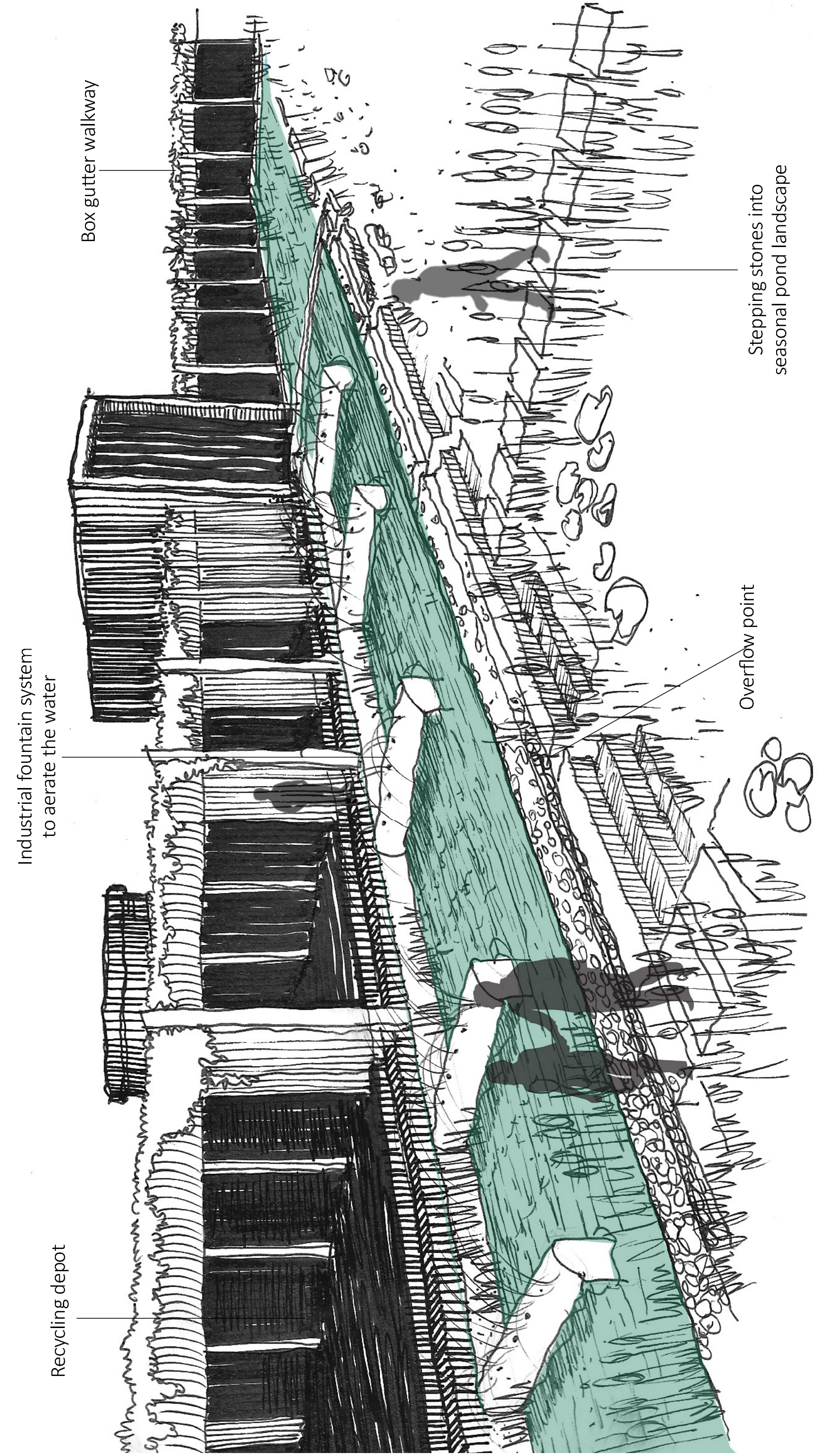


Figure 44: View of the aeration pond

These spaces would also be available to visiting groups of scholars, researchers or to the community in general. The lecture theater is designed to accommodate 100 people, while the two sub-divisible spaces can seat 50 each.

Supportive spaces

A restaurant and commercial spaces activate the residential edge of the facility, encouraging people to spend more time at the water edge and providing a level of passive surveillance over the pedestrian network and swimming pond. Tenants might include a grocer stocking fresh produce from the surrounding area, security office or life guard office. Simple market stalls are also included to provide spaces for local farmers to sell their produce.

Fresh water swimming pond

Clean water from the processing plant is pumped into an artificial pond area featuring plants which aid in the remediation process. Banks and floor of certain parts of the pond are lined to ensure water remains in the pond all year round. In times of heavy flow the pond overflows into the river and storm-water detention area.

Pedestrian network

This set of pathways follows the desire lines existing on the site, and offers a secure pathway between the residential and commercial districts along the existing canal. Walkways also offer a tour of the water remediation facility, and stepping stones encourage interaction with the water and wetlands. This network will connect to surrounding areas and continue up and down the river to create a continuous pedestrian network. The route is dotted with security booths, light masts and information boards.

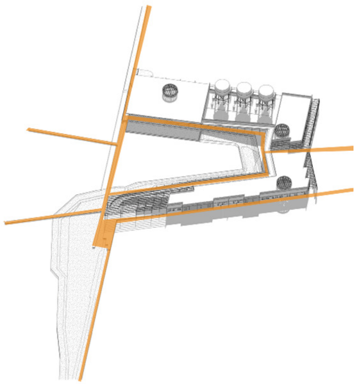


Figure 45: Pedestrian network highlighted

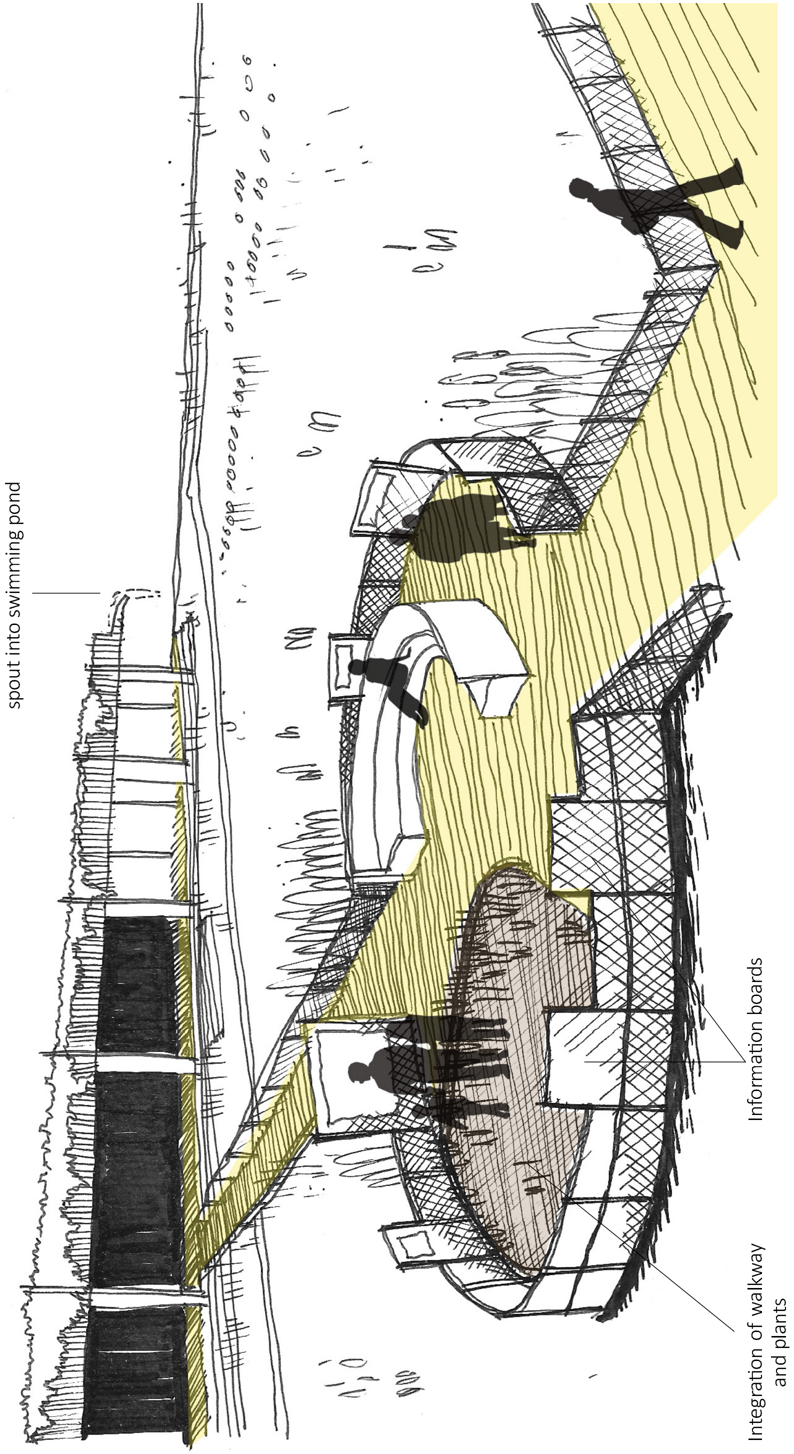


Figure 46: View of pedestrian route and learning reactors

Information boards and learning spaces

In line with the passive teaching function of the project, information about the chemical plant and natural system are provided at critical parts along the pedestrian network. Meeting points along the pedestrian network allow for tour groups to gather, observe and learn.

Bulrush piers and animal watching

The pedestrian network extends out into the surrounding landscape and stormwater depression on the other side of the canal. Here bulrushes and other aquatic grasses grow naturally and assist in nitrogen and phosphorous decomposition. These piers offer the community access to learning spaces all year round, especially when the ponds are wet. Constructed habitats for birds, fish, frogs, invertebrates like crabs, and mammals such as the water mongoose can be observed from a distance

SuDS park land

Some of the principals of Sustainable Urban Drainage Systems include allowing flood water space to rise, and reducing urban runoff into rivers through the construction of swales and detention ponds. These spaces, while wet in the winter months, would provide recreational park land during summer.

Overview

The overall effect of this integration of programmes is to encourage a blending of landscape and building. In all spaces, water, planting, public and process spaces overlap to encourage new interactions between the community and nature.

Precedent

Projects used as precedent for the desired look and feel show strong integration with nature and water, a focus on landscape design and/or the monumentality of powerful spaces, designed to inspire and impress.

.

Figure 47:
Landschaftpark - Peter Latz, Germany.
An industrial process which has been adapted into a landscaped park The contrast between industrial equipment and nature represents the spirit of Lotus and the Machine. (image: Germany Travel, 2015)

Figure 48:
Vihan Sabaha-
Le Corbusier,
Chandigarh India.
The box gutter and reflection pool make indirect connections with nature.
(image:Travel Blog, 2014)

Figure 49:
Brion Cemetery-
Carlo Scarpa,
Treviso, Italy.
The appearance of being taken over by nature is designed.
(image:Travel Blog, 2014)

8 Facility of the future

A project with such hope for a cleaner, greener future creates an existential problem for itself: what will this facility become when it succeeds? When the water is clean and the farmers are educated and there are no more pollutants to recycle?

As was mentioned before, chemical plants of this kind sometimes supplement their pollutant recovery by purchasing sewage from government waste water treatment plant (WWTP). This could prove to be a viable option, as the closest WWTP is just 10km away, at the Cape Flats WWTP in Pelican Park.

Alternatively, the facility could serve as a municipal pump station for ground water, given the likeliness of terrestrial water source depletion with the increased temperatures of climate change.

9 Design Development

The development of the design is documented in the following pages in a collection of snapshots at significant moments in the process.

The most significant moment was the sizing of industrial equipment, which lead to the realization that the project would be much bigger than expected. This resulted in the transformation of what was initially intended to be a small scale and subtle intervention, into the industrial machine it is now.

This drove the core concept of the project: *Lotus and the Machine* - the contrast between industry and nature which is celebrated in the creation of this transition space between the two.

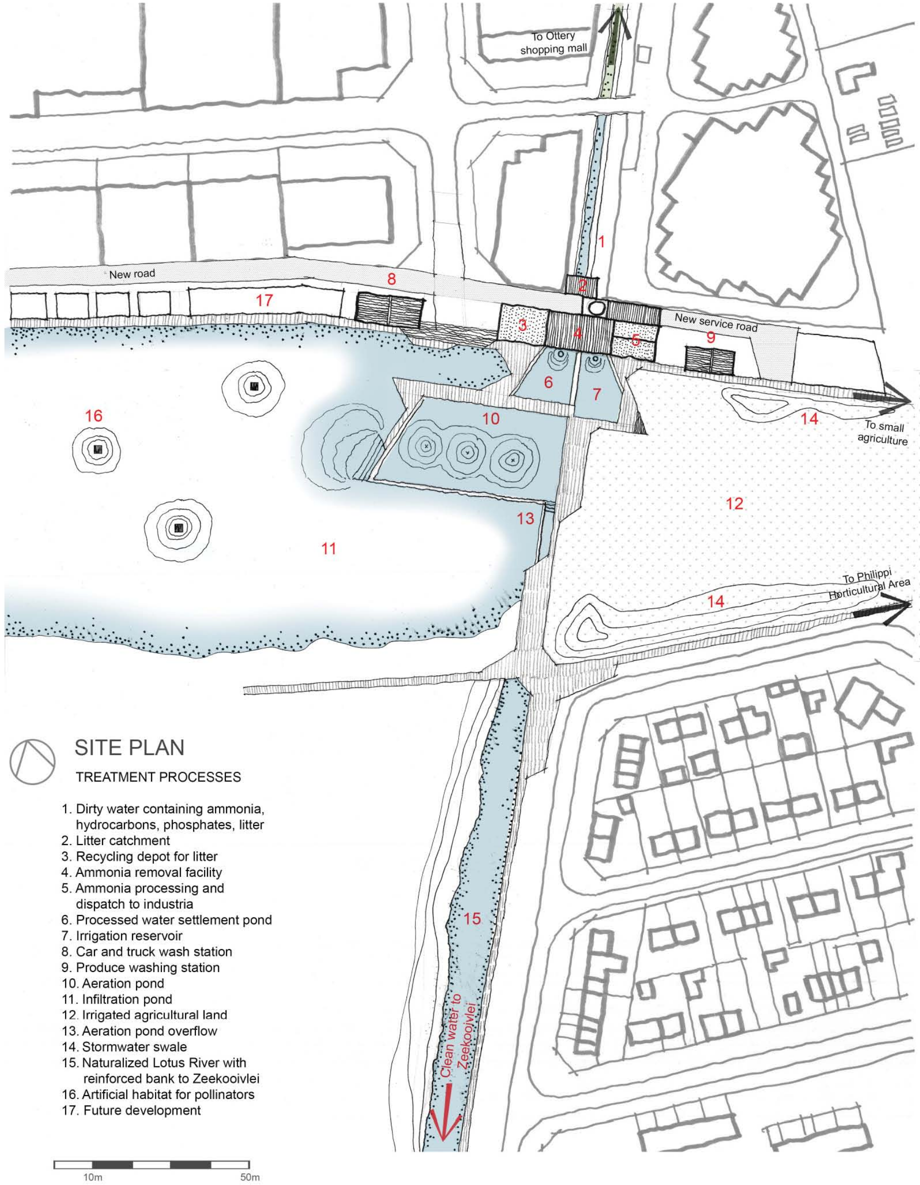


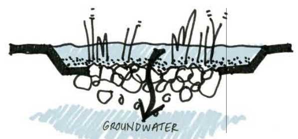
Figure 50: Sketch proposal- May 2015- Site Plan
Focus was given to the site planning and subdivision of water process. Little was known about the industrial process at this point, and the project was imagined to be small in scale.

8 and 9

8 and 9: Produce, car and industrial equipment cleaning. Structures that recycle water used for cleaning can store and filter soapy water before pumping it back into the cycle. Rain water can easily be added to the system.

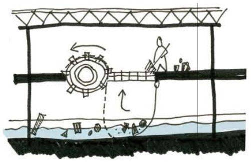
10

10. Aeration pond: disturbing the surface and sucking up water from the bottom allows carbon dioxide to escape and oxygen to enter the water - allowing plants and animals to grow and encouraging healthy bacteria.



11

11. Specially engineered pond floors allow water to gradually seep into the ground water system, while being filtered naturally by plants and rocks.



2

2. Litter removal becomes a spectacle on the main walkway to draw attention to the process of cleaning and including the public in the responsibility of keeping their area clean.

A

B

A Feature walls can filter water using simple sand and charcoal filter processes to perform a physical act of cleaning and passively educate the public.

B Stairwells and fire escapes can double as artificial urban habitats for important pollinators.

Figure 51: Sketch proposal- May 2015
Moments of interaction between nature and community were imagined.

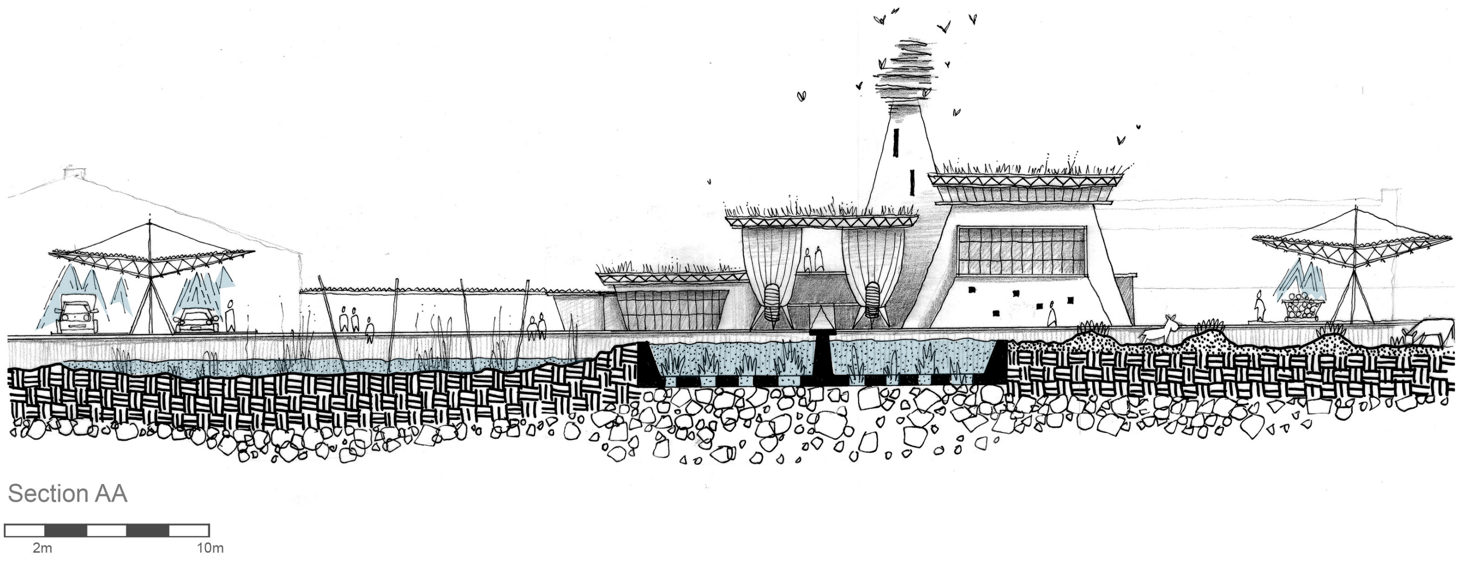


Figure 52: Sketch proposal- May 2015

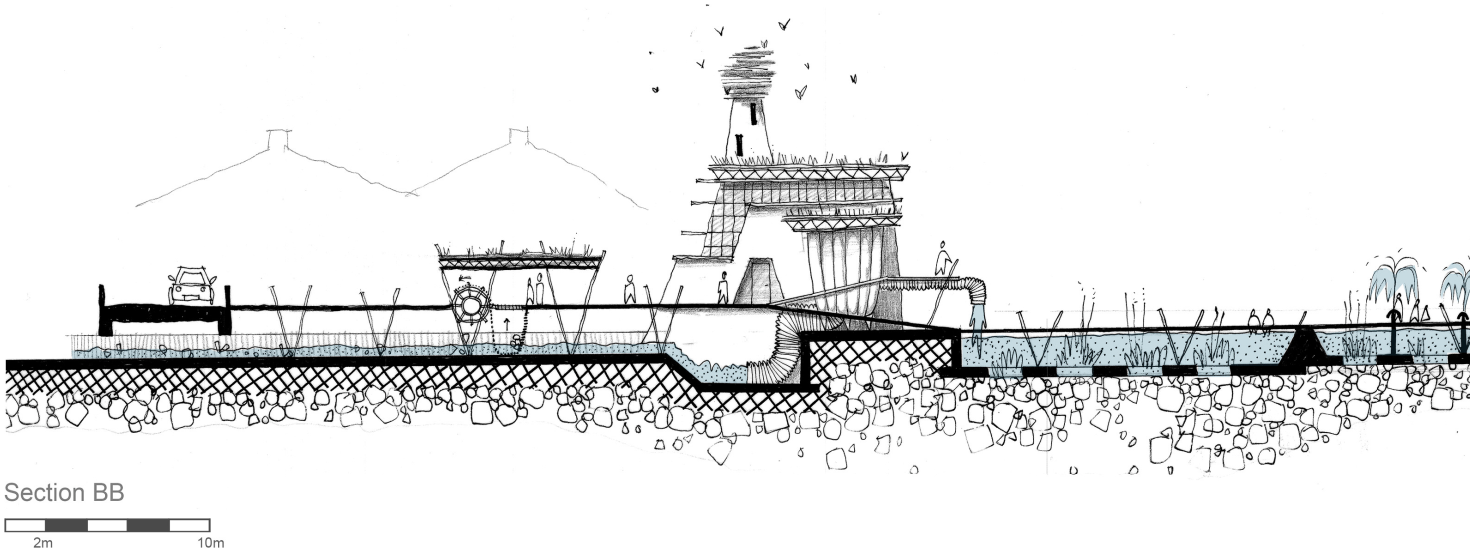
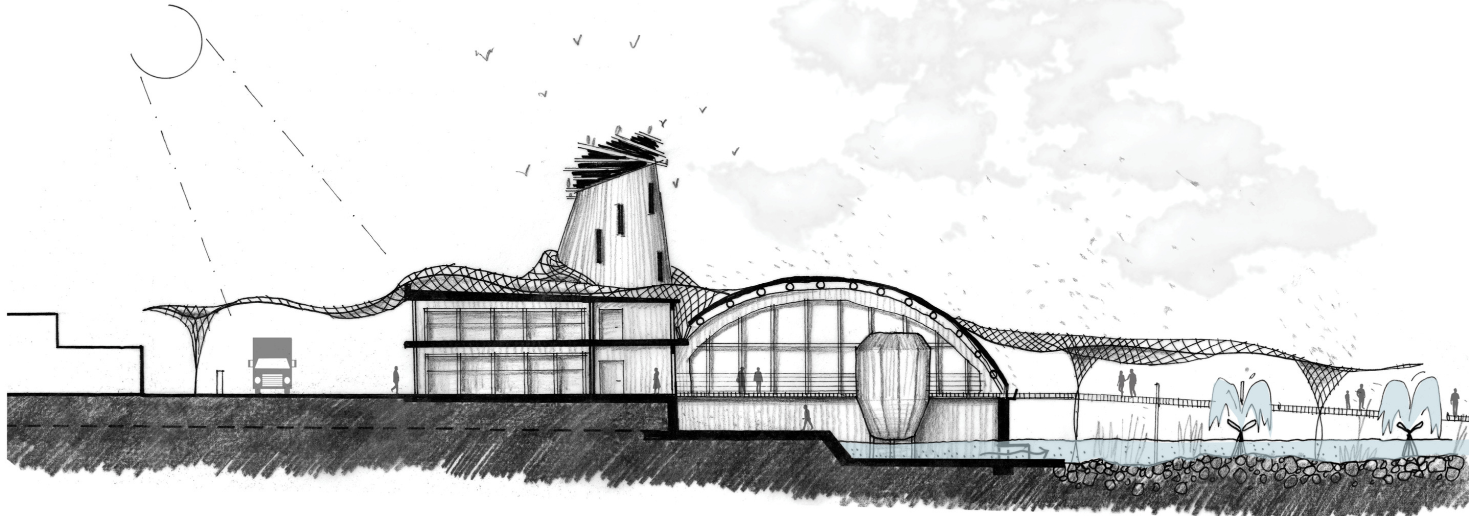


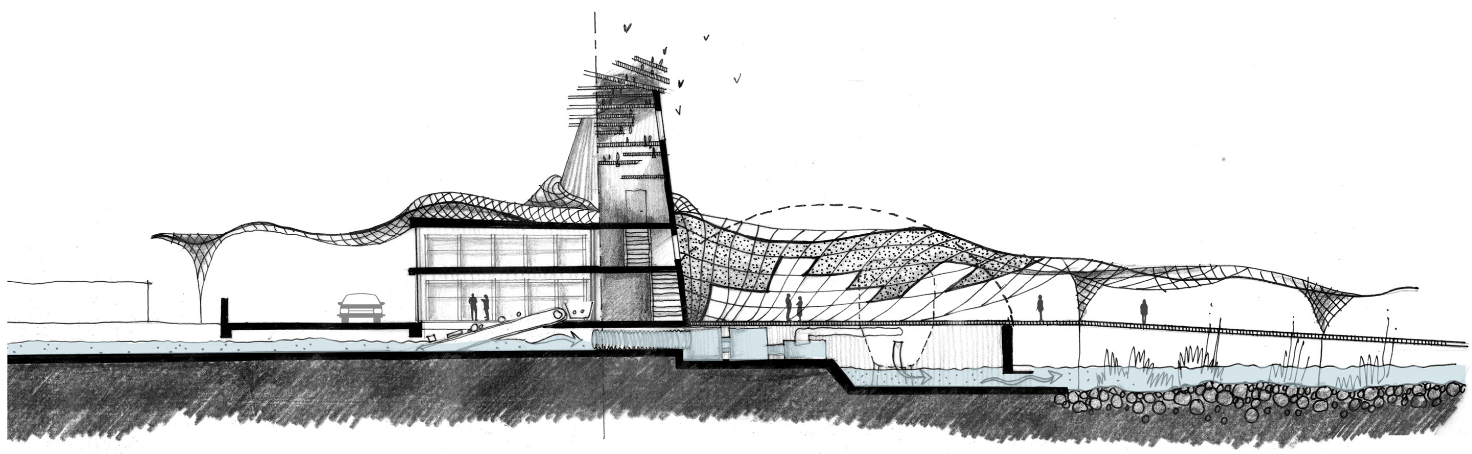
Figure 53: Sketch proposal- May 2015



Section AA

2m 10m

Figure 54: Sketch design 2- June 2015- Sections
The concept of a *fluid language* to connect different elements of the project together developed into an organic roof for rain water collection



Section BB

2m 10m

Figure 55: Sketch design 2- June 2015- Sections

Figure 56: Sketch design 2- June 2015

Conceptual model showing different building components (red) connected by a fluid roof (wire) overlaid on a rectilinear public network (timber).

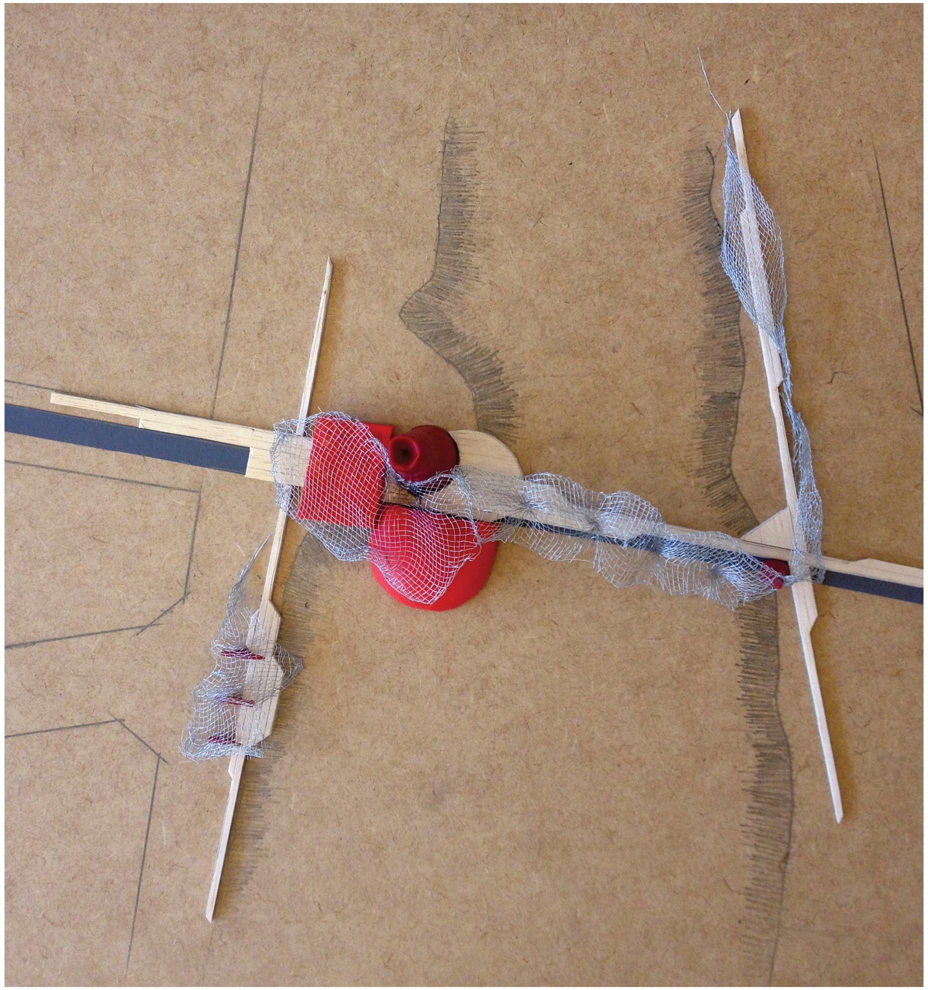


Figure 57: Sketch design 2 - June 2015

Conceptual model highlighting rain catching roof structure.

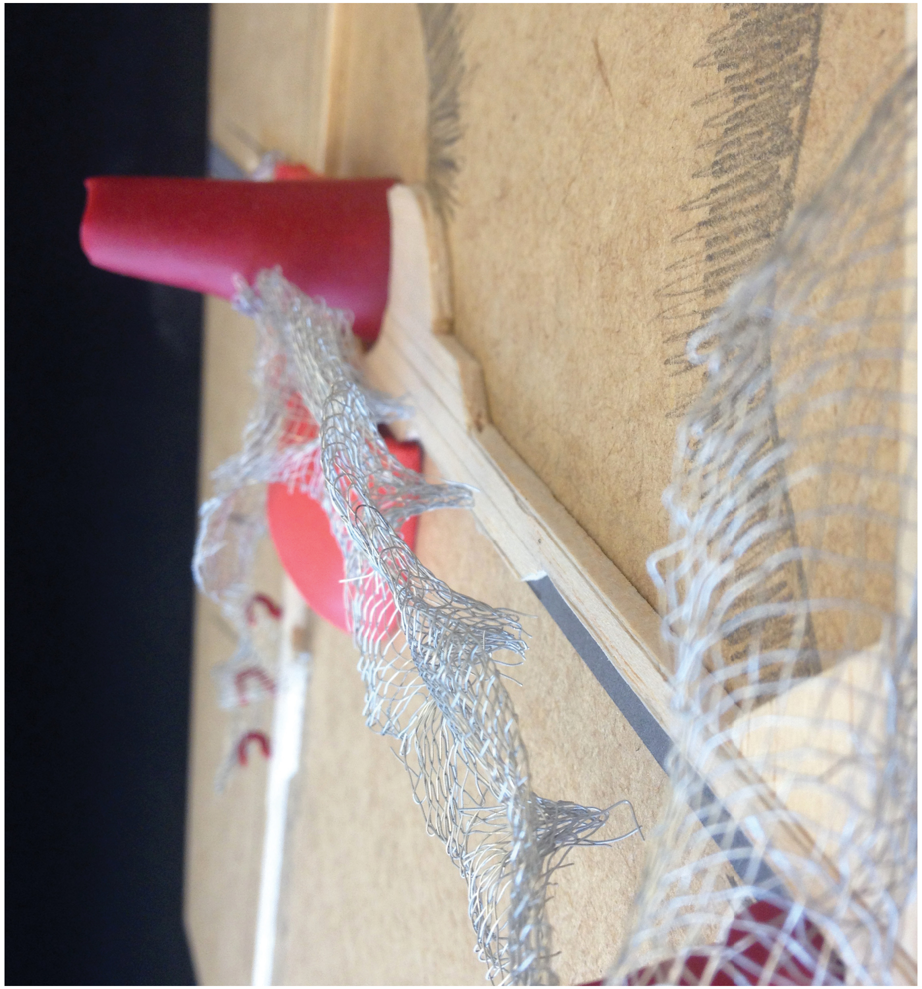


Figure 58: Urban scheme development- August 2015

The central facility acts as a gate to the waterscape and public network connecting the surrounding areas.

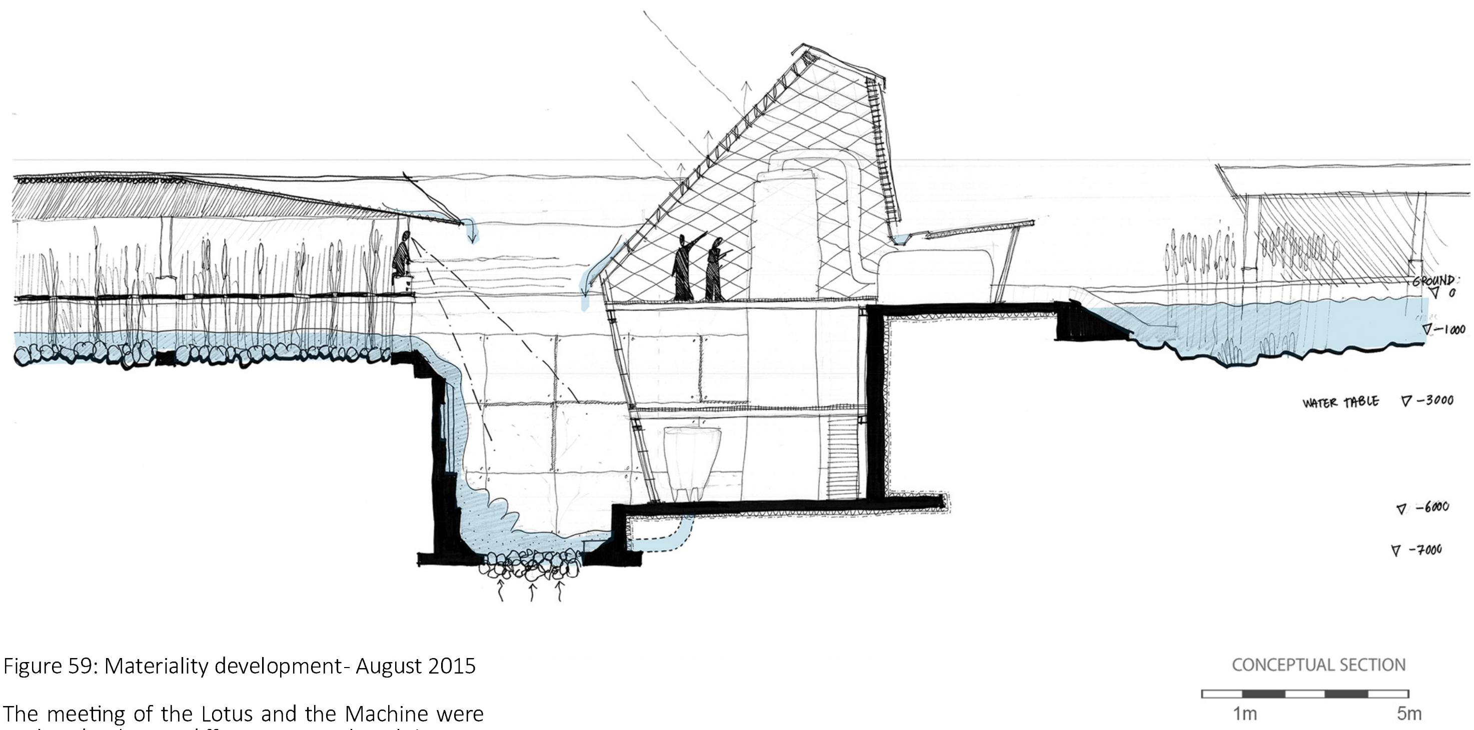
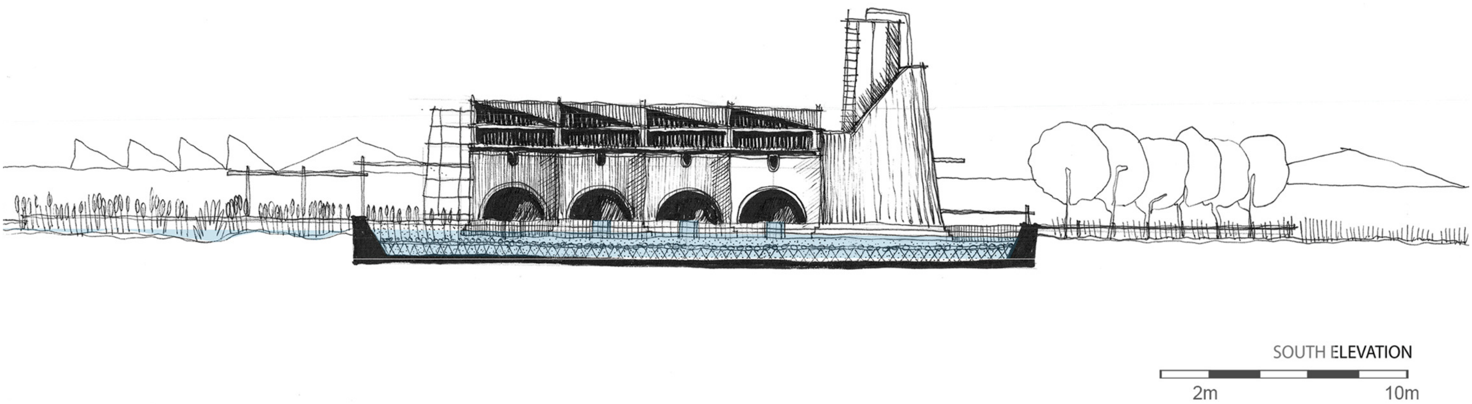


Figure 59: Materiality development- August 2015

The meeting of the Lotus and the Machine were explored as having different material qualities. The idea of digging into the site was developed.



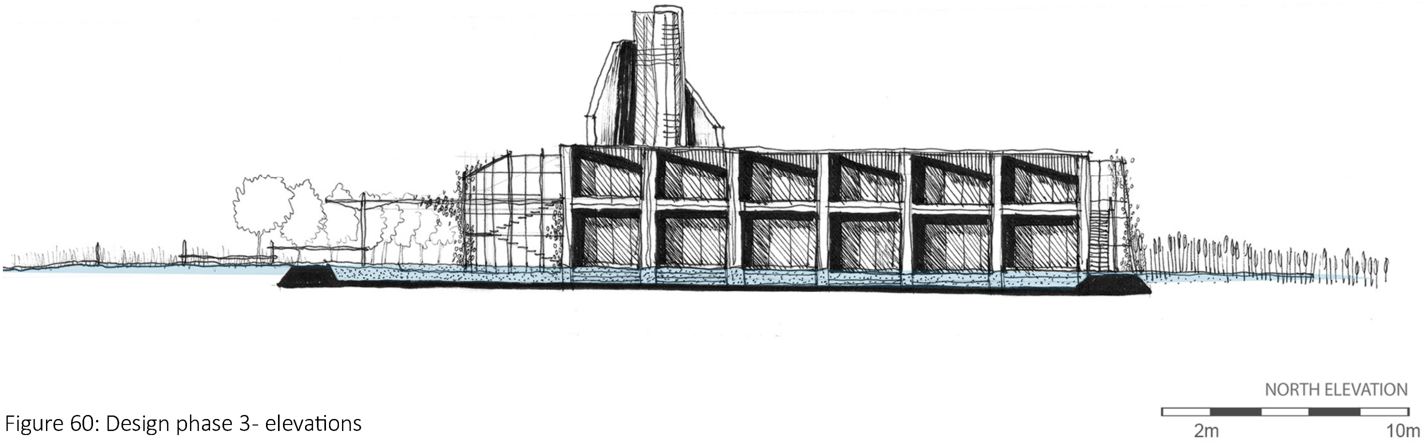


Figure 60: Design phase 3- elevations

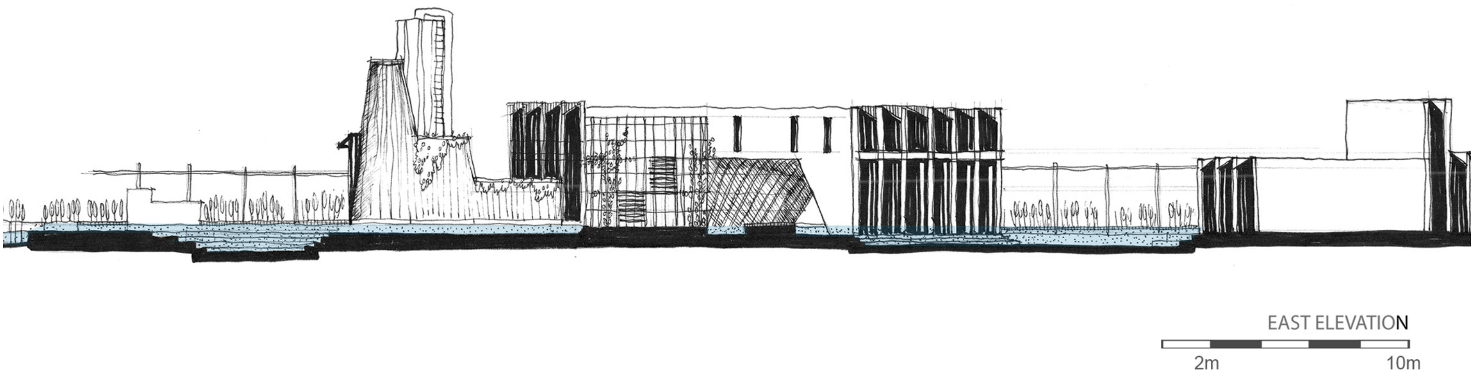
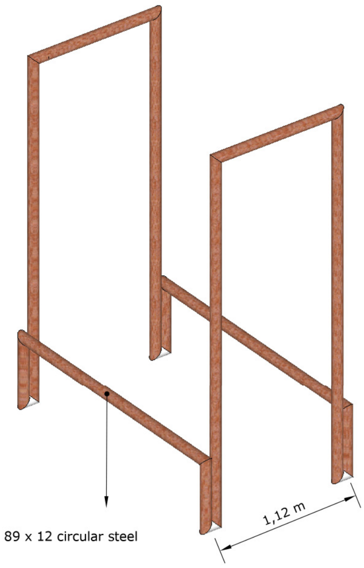
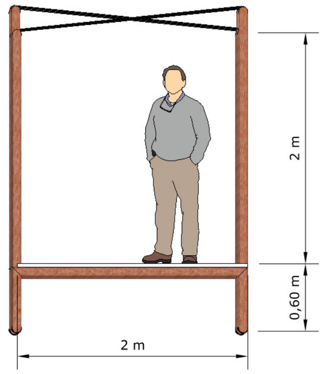


Figure 61: Design phase 3 - August 2015

A deeper understanding of the industrial process allowed for integration of building and infrastructure. Exploration of repetitive forms and their reflection in water.





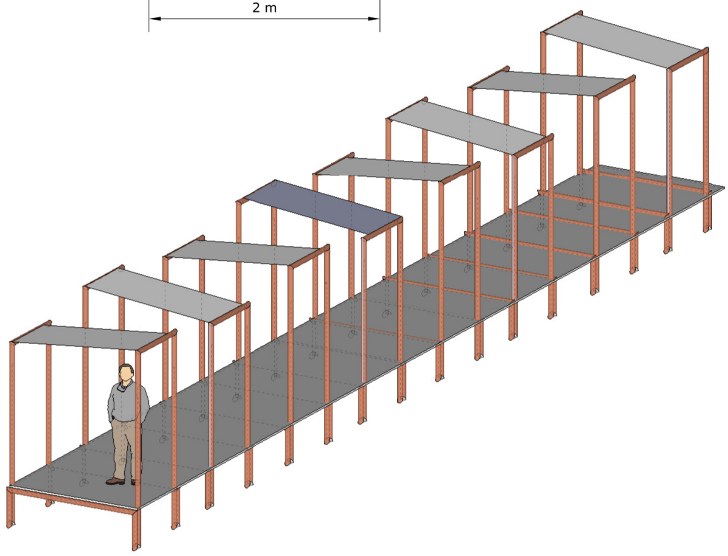
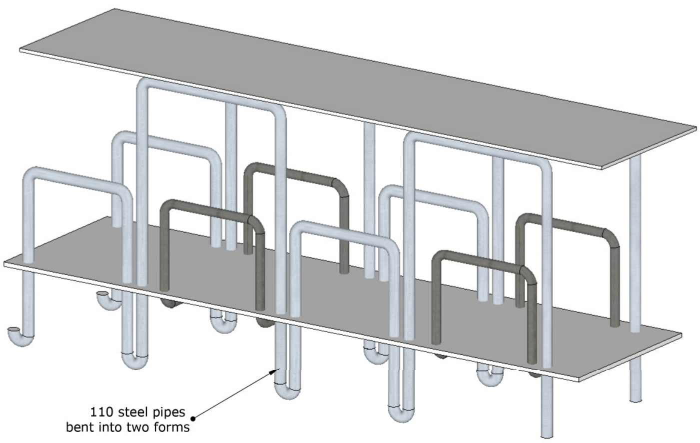
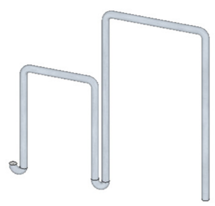


Figure 62: Detail exploration

Integration of industry and public - pipes become part of the infrastructure for the public network





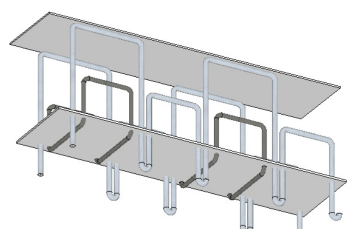


Figure 63: Detail exploration

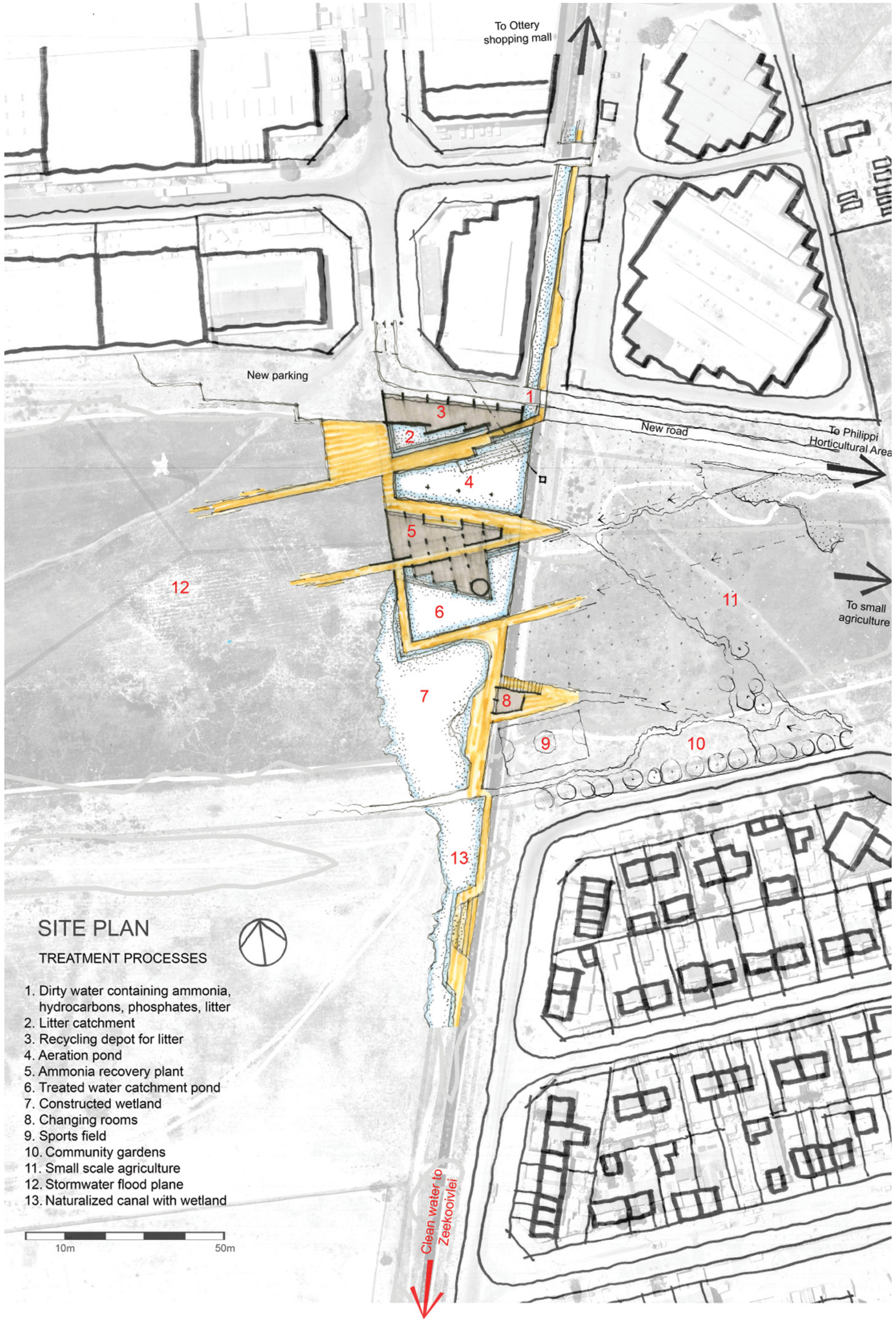


Figure 64: Design phase 3 - August 2015- Site Plan

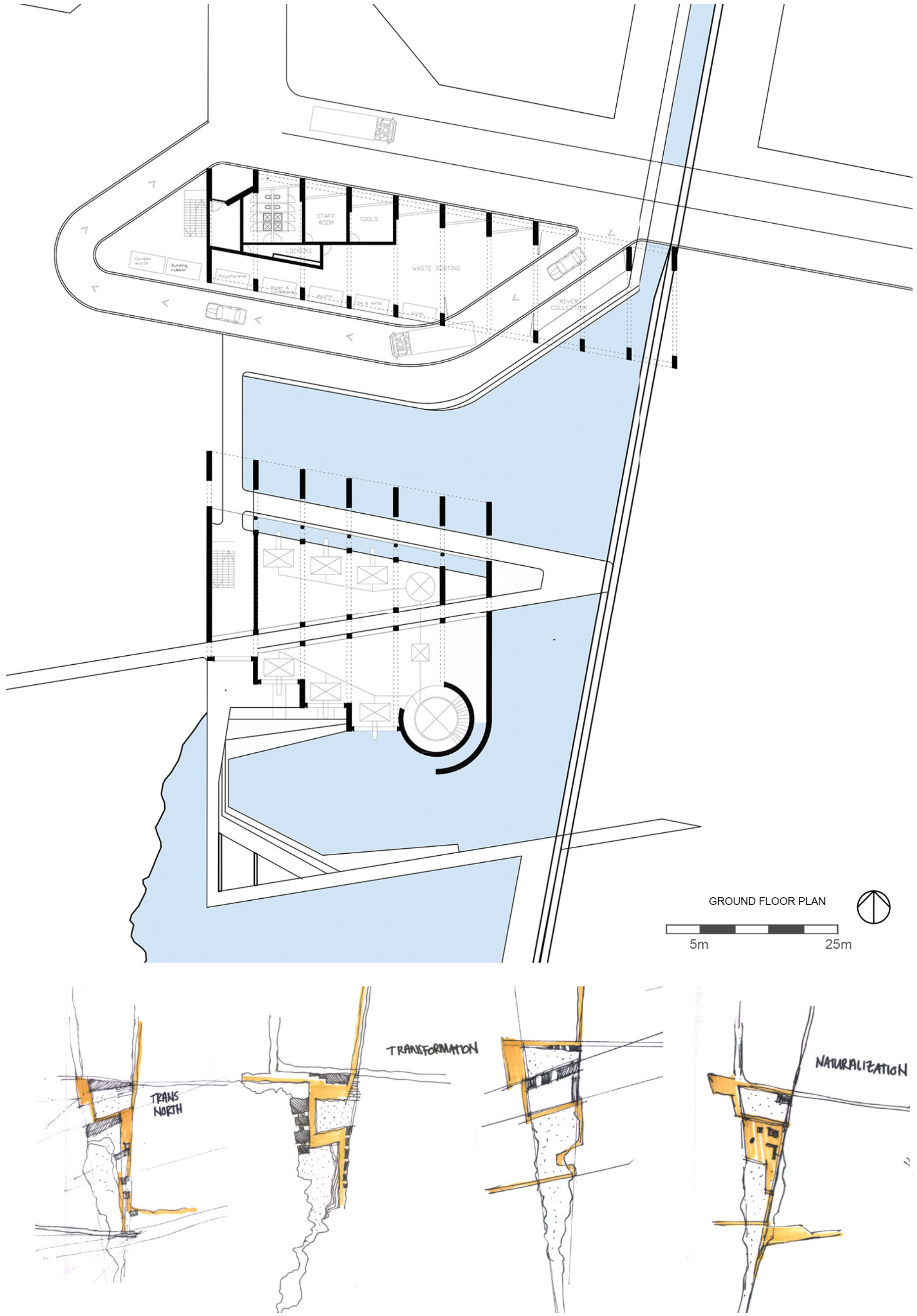


Figure 65: Design phase 3 - August 2015- plan development
Exploration of separation of building elements

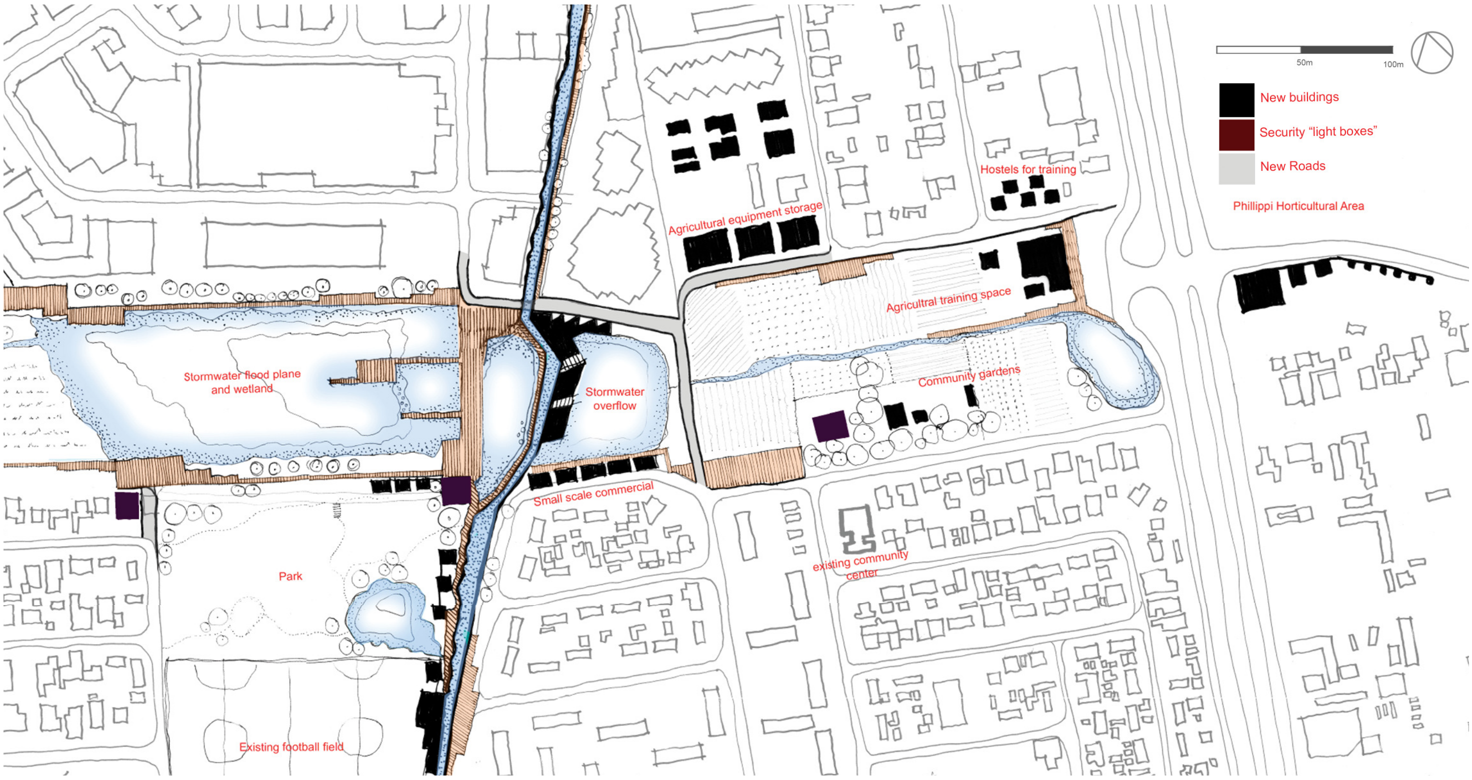


Figure 66: Urban scheme development - August 2015
Repositioning the building on site to allow for natural habitat to continue up the river. Conceptualization of future development of surrounding areas with an agricultural school and more public facilities to activate the public network around the site.

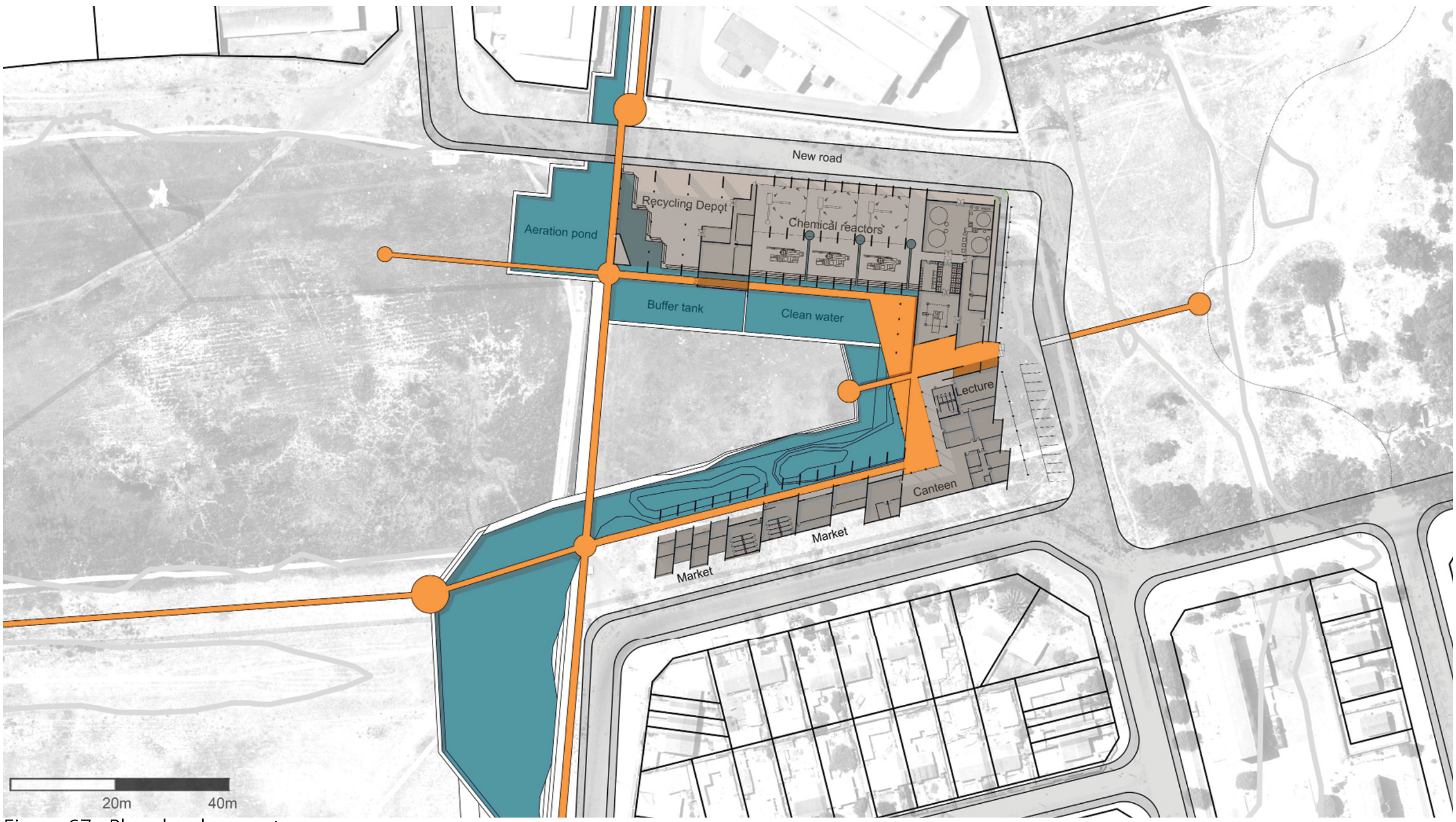


Figure 67: Plan development
Specialist sizing of chemical process equipment resulted in the massive growth of the project. The site plan was adjusted to create a "meander" of the diverted river. Development of the concept of the "learning reactor" (orange round spaces on public network).

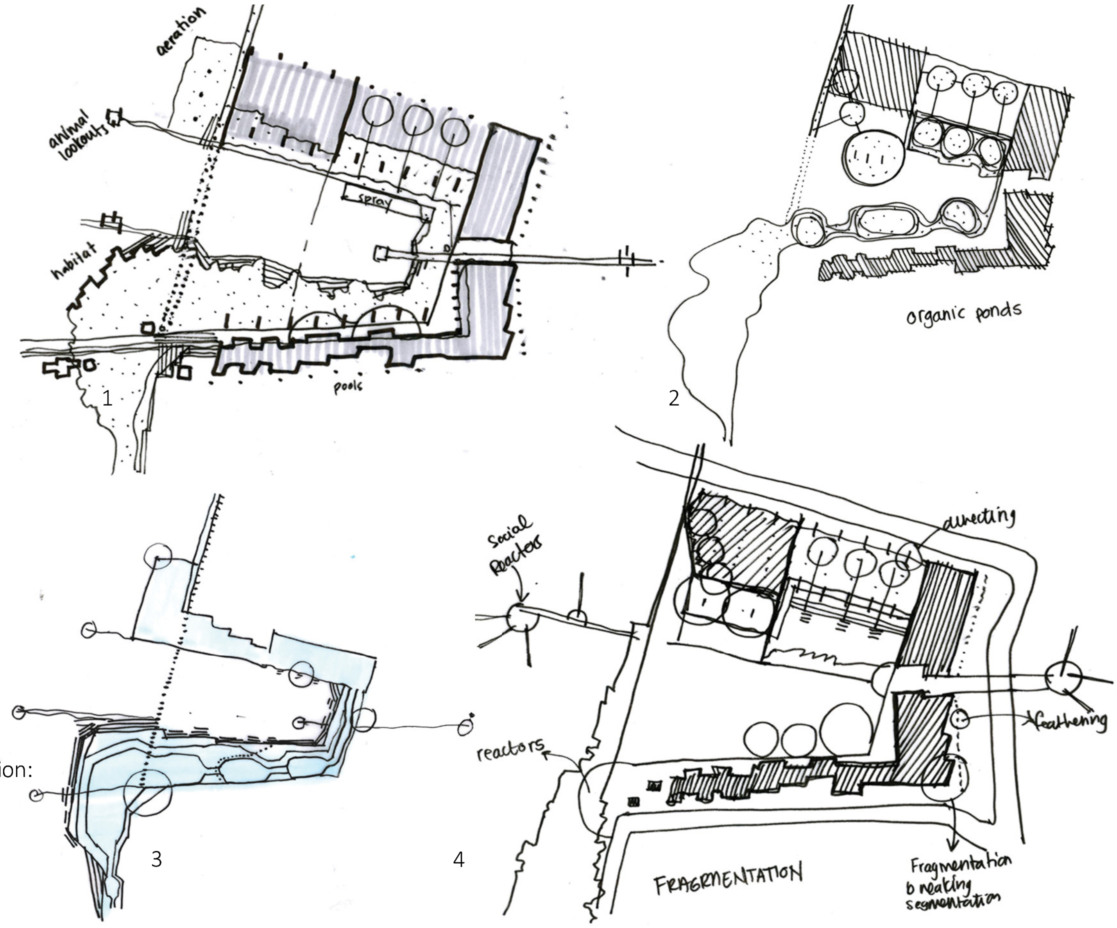
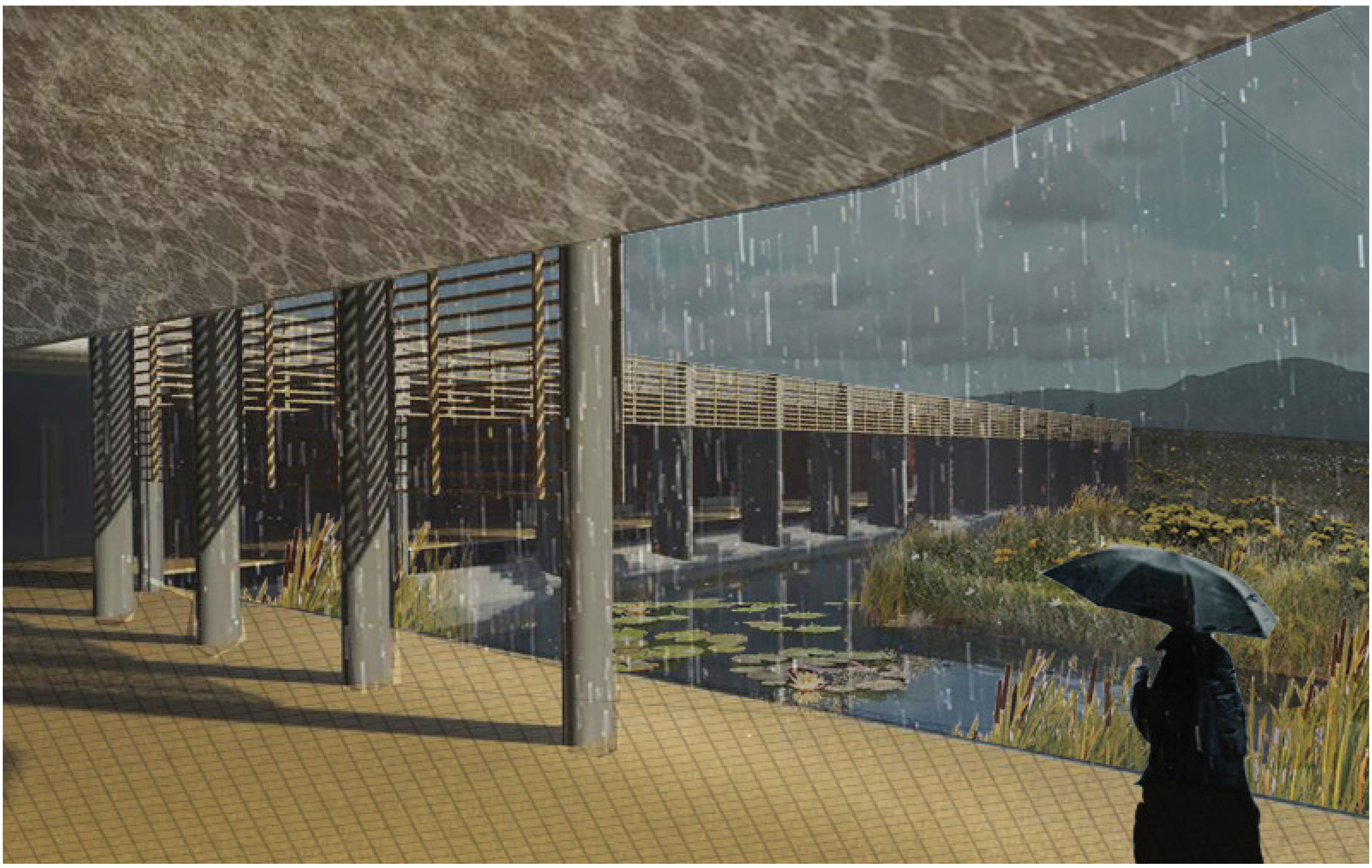


Figure 68: Landscape design exploration:
1. Breakdown of canal
2. Organic shaped ponds
3. Hybrid ponds
4. Fragmentation of ponds

Figure 69 (below): Site in the rain



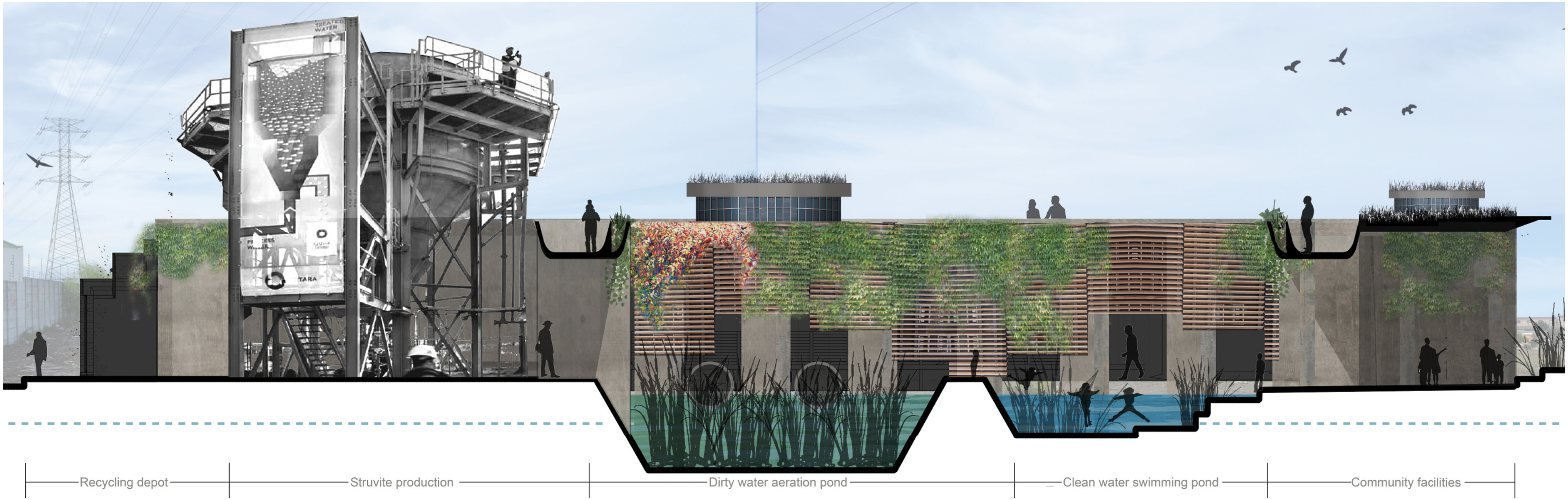


Figure 70: Diagrammatic section through the Lotus and the Machine

10 Conclusion

Using the Lotus River and its connected hydrology network as a case study, this project has revealed the impact that urbanity has on the water systems that cities are dependent on. Given the current trends in climate change and other pressures on water systems, the sustainability of urban water supply is an important topic to address.

Through an in-depth study of pollution sources and a review of available solutions, a proposal was developed for the immediate improvement of the system in a way that not only removes pollutants but recycles them into a product of change - a fertilizer which can act as a catalyst of agricultural education and awareness towards our individual impact on water systems.

The importance of community involvement and public awareness in the healing of natural systems has been emphasized throughout this dissertation, and the coupling of environmental infrastructure with community facilities aids in the passive conscientizing of the public and the long term protection of natural resources.

Kurokawa's theory of *symbiosis* and the Constructivists' concept of the *social condenser* has shown that architecture has through the creation of transitional spaces, in many different times and places, attempted to usher society into a new way of living so as to better the world we live in. This project has explored the creation of this kind of space, where nature and urbanity operate harmoniously and encourage a symbiotic relationship between building and landscape, industry and community, and the Lotus and the Machine.

Bibliography

BERTRAM, W. E. 1989. Geohidrologiese opname in die Philippi-landbougebied, Kaapse Vlakte. Technical report no. GH 3595. Cape Town: Geohydrology Directorate, DWAF.

BLAKE, D. 2014. Hydrogeological Specialist Study. Umvoto.

CITY OF CAPE TOWN CENCUS 2013. City of Cape Town 2011 Cencus Suburb Nyanga. Cape Town.

CSIR RIVER HEALTH PROGRAMME 2005. State of the Rivers Report: Greater Cape Town's Rivers 2005.

GERMANY TRAVEL. 2015. Parc paysager Duisburg-Nord [Online]. Available: http://www.germany.travel/fr/villes-et-culture/chateaux-parcs-et-jardins/mondes-thematiques/galerie-parc-paysager-duisburg-nord.html [Accessed 2015/10/18.

GIS MAPS 2015. Greater Philippi Horticultural Area. In: PLESSIS, C. D. (ed.). Cape Town: Esri ArcMap 10.2.1.3497.

GOOGLE EARTH 2013. Greater Cape Town. 34'03'15.01"S ; 18'49'02.98" E.

GROBICKI, A. 2001. Integrated catchment management in an urban context: the Great and Little Lotus Rivers, Cape Town, Water Research Commission.

HAGOOD, S. 2015. Whats been done about roadkill [Online]. United States: Humane Society. Available: http://arc-solutions.org/new-solutions/ [Accessed 2015/10/17.

J LEE. 1998. Potsdamer Plaza Berlin [Online]. Available: http://www.dreiseitl.com/index.php?id=82&lang=en 2015/10/17].

JOSLIN, A. 1972. Brion-Vega Cemetery [Online]. MIT Libraries,. Available: http://dome.mit.edu/bitstream/handle/1721.3/68174/131313_sv.jpg?sequence=2 2015/10/18].

KABAT, P., LUDWIG, F., VAN DER VALK, M. & VAN SCHAIK, H. 2012. Climate change adaptation in the water sector, Routledge.

KOOLHAAS, R. 2004. Content, Taschen New York.

KUROKAWA, K. 1994. The philosophy of symbiosis, London, Ernst & Shon.

KUROKAWA, K., SHARP, D., SLESSOR, C. & ŌHASHI, T. 1999. Kisho Kurokawa: Kuala Lumpur International Airport, Edition Axel Menges.

LEATHERBARROW, D. 2014. Horizon of all Horizons. In: MATHUR, A. & DA CUNHA, D. (eds.) Design in the terrain of water. Pennsylvania: Applied Research + Design Publishing.

LENNTECH. 2015. Chemical properties of phosphorus - Health effects of phosphorus - Environmental effects of phosphorus [Online]. Rotterdam. Available: http://www.lenntech.com/periodic/elements/p.htm [Accessed 2015/09/04 2015].

MACLEAR, L. G. A. 1995. Cape Town Needs Groundwater - A note on the potential of the Cape Flats aquifer unit to supply groundwater for domestic use in Cape Town metropolitan area. Cape Town: Geohydrology Directorate, Department of Water Affairs and Forestry.

MEERKOTTER, M. 2012. Sources of heavy metals in vegetables in Cape Town, and possible methods of rehabilitation. PhD, University of the Western Cape.

MUKHEIBIR, P. 2008. Water resources management strategies for adaptation to climate-induced impacts in South Africa. Water Resources Management, 22, 1259-1276.

MUKHEIBIR, P. & ZIERVOGEL, G. 2006. Framework for Adaptation to Climate Change in the City of Cape Town. Cape Town: University of Cape Town.

NAZREY. 2003. Kuala Lumpur International Airport [Online]. Available: http://www.skyscrapercity.com/showthread.php?t=331041&page=68 [Accessed 2015/10/17.

OSTARA NUTRIENT RECOVERY TECHNOLOGIES 2015. Pearl 10000 Nutrient Recovery Process. Vancouver.

PITHEY, S. 2007. Water and Sanitation in the City of Cape Town–Integrated Analysis Baseline Report. Report compiled for the UN DP. Stellenbosch: Sustainability Institute.

RAHMAN, M. M., SALLEH, M. A. M., RASHID, U., AHSAN, A., HOSSAIN, M. M. & RA, C. S. 2014. Production of slow release crystal fertilizer from wastewaters through

struvite crystallization–A review. Arabian Journal of Chemistry, 7, 139-155.
ROADS AND STORMWATER DEPARTMENT 2009. Floodplain and River Corridor Management Policy. Cape Town: City of Cape Town.
SAITO, Y., TOYODA, H. & FURUYA, N. 1997. Carlo Scarpa, Toto Shuppan.
SHAVER, E., HORNER, R., SKUPIEN, J., MAY, C. & RIDLEY, G. 2007. Fundamentals of Urban Runoof Management: Technical and Institutional Issues. 2 ed. Madison.
SIKOSANA, M. 2015. A technological, economic and social exploration of phosphate recovery from centralised sewage treatment in a transitioning economy context. M.Eng, University of Cape Town.
TADROSS, M. & JOHNSTON, P. 2012. Sub-Saharn African Cities: A five-Ciy Network to Pioneer Climate Adaptation through Participatory Research & Local Action. Cape Town: ICLEI.
THE GUARDIAN. 2015. France decrees new rooftops must be covered in plants or solar panels [Online]. Available: http://www.theguardian.com/world/2015/mar/20/france-decrees-new-rooftops-must-be-covered-in-plants-or-solar-panels [Accessed 2015/10/17.
THE RAMSAR CONVENTION SECRETARIAT. 2014. Ramsar Sites Information Services [Online]. Switzerland. [Accessed 01/09/2015 2015].
THE UNIT FOR RELIGION AND DEVELOPMENT RESEARCH 2005. Grassy Park Lotus River Transformation Research Project. University of Stellenbosch Transformation Africa.
TRAVEL BLOG. 2014. Corbusiers Chndigarh [Online]. Available: https://www.travelblog.org/Asia/India/Punjab/Chandigarh/blog-124819.html.
WATER RESEARCH WATERSHED CENTER. 2014. Ammonia in groundwater, runoff and streams [Online]. Available: http://www.water-research.net/index.php/ammonia-in-groundwater-runoff-and-streams [Accessed 2015/10/13.
WHO 1996. Ammonia in Drinking Water - Background document for development of WHO Guidelines for Drinking water Quality. 2 ed. Geneva: World Health Organization.
WOODS-BALLARD, B., KELLAGHER, R., MARTIN, P., JEFFERIES, C., BRAY, R. & SHAFFER, P. 2007. The SUDS manual, Ciria London.

Appendix A - Transmutation exercises

The period leading up to the beginning of the project involved a series of creative exercises involving the continuous transmutation of an artifact in order to stimulate personal conceptual interests. The pages included here emphasize the inspiration I draw from the natural world.

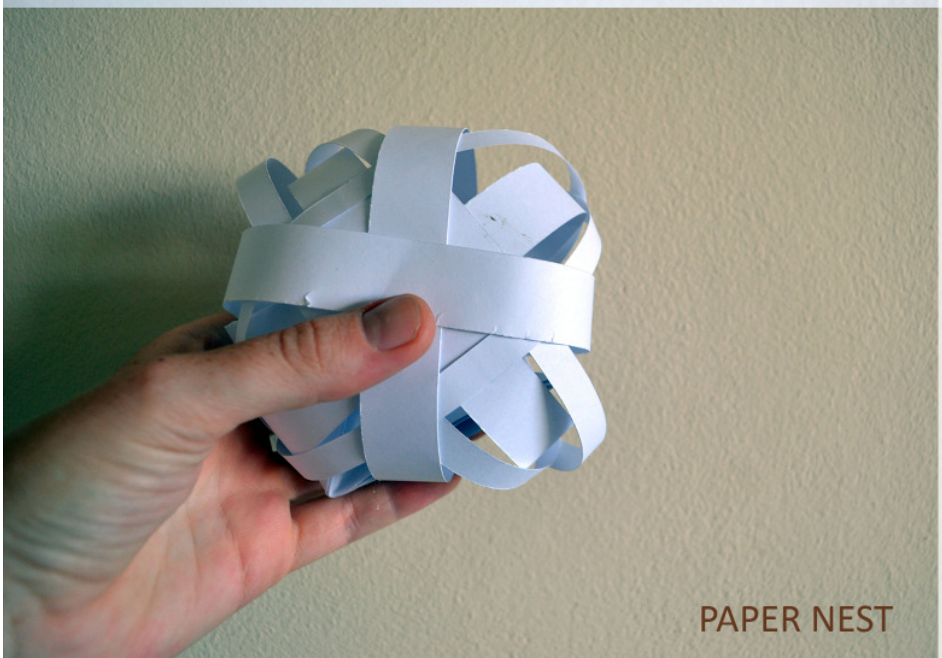
IDEA INTO ARTEFACT

HUMAN BEHAVIOUR is influenced by a combination of *internal factors* (personality, origin, background, physical wellbeing) and *external environment* (the world we interact with and react to). By shaping the outer environments architects have the ability to control the behaviour of the user.

(Foucault; Markus; Hillier & Hanson)

EUCALYPTUS POD

The **eucalyptus pod** bounces as a result of the supple leaves, and changes direction as a result of the inner pebble. The leaves are foreign to our country, but have become a naturalised part of our environment that is carried around with us.



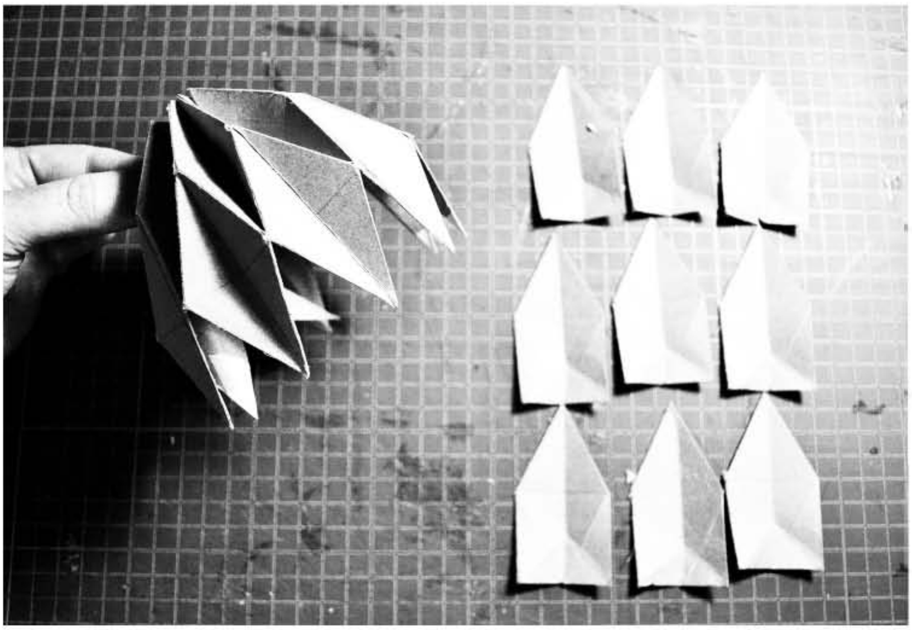
PAPER NEST

The **paper nest** is fragile because of its material, and can be broken apart by the hard inner stones.

ORIGAMI POD

The **origami pod** is strong due to the process of construction. Its' folds are both the strength of the material and the weakest point.

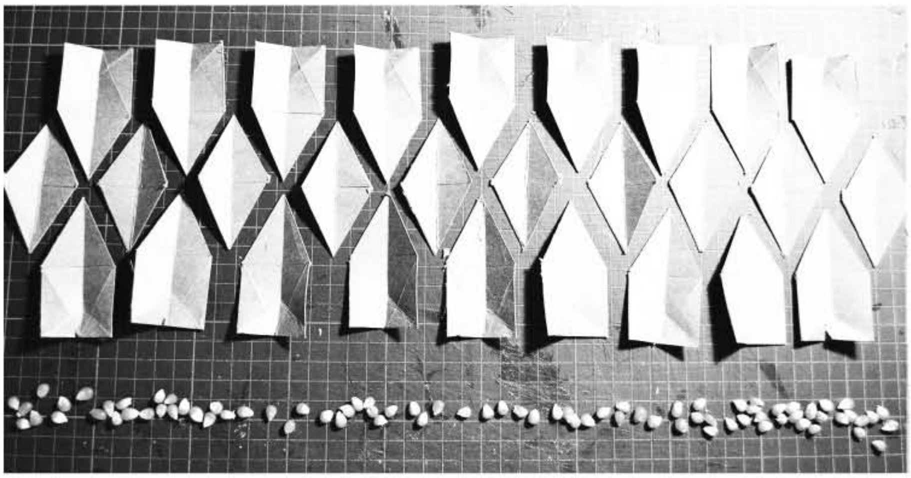
Keywords: Behaviour | internal | external | foreign | material



TRANSMUTATION 1

Theme: Nature and Science

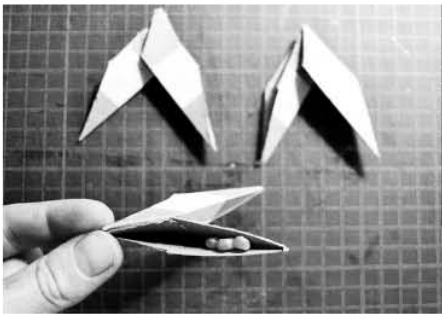
Task: "Find a logic and process to disassemble your artefact and then work through another system or process to re-assemble it. (Roni Horn's red pigment and varnish assemblies, and Gerhard Marx's map fragments)."

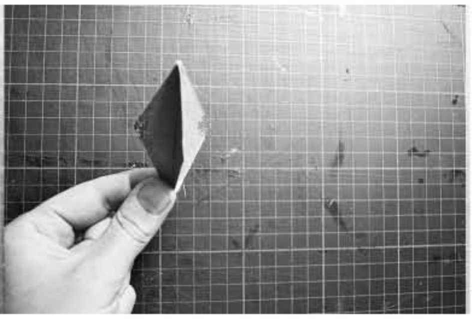


ORIGAMI POD

Nature disassembles via decomposition – a reduction in mass from the most outer fragile points first.

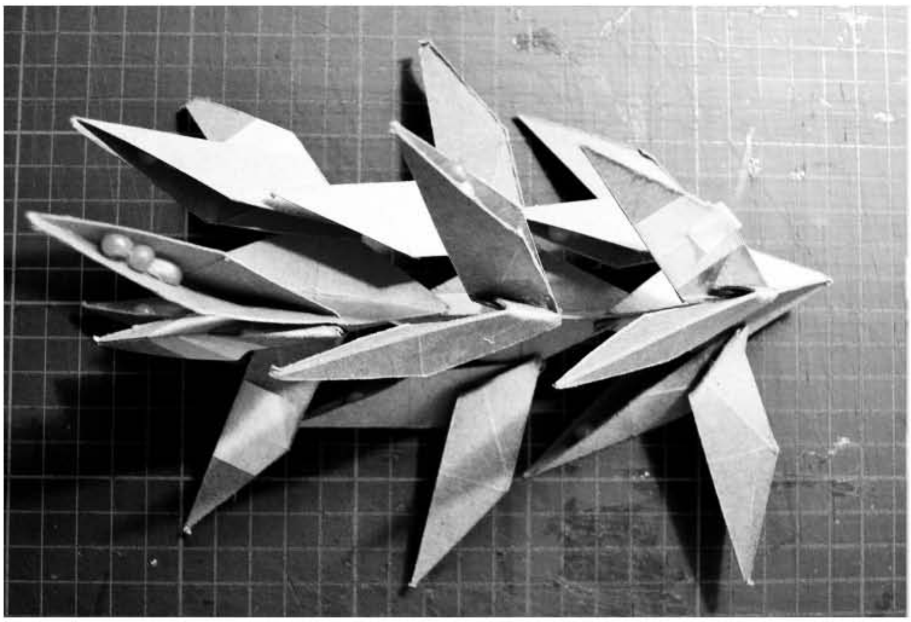
The pod is sliced open along the weakest points (the folds) and broken down into the basic building blocks of the original geometry.





Nature builds from elements, to molecules to compounds to material.

The broken pod elements are combined to make compounds which are in turn combined to make a larger structure : a methodical and repetitive process.



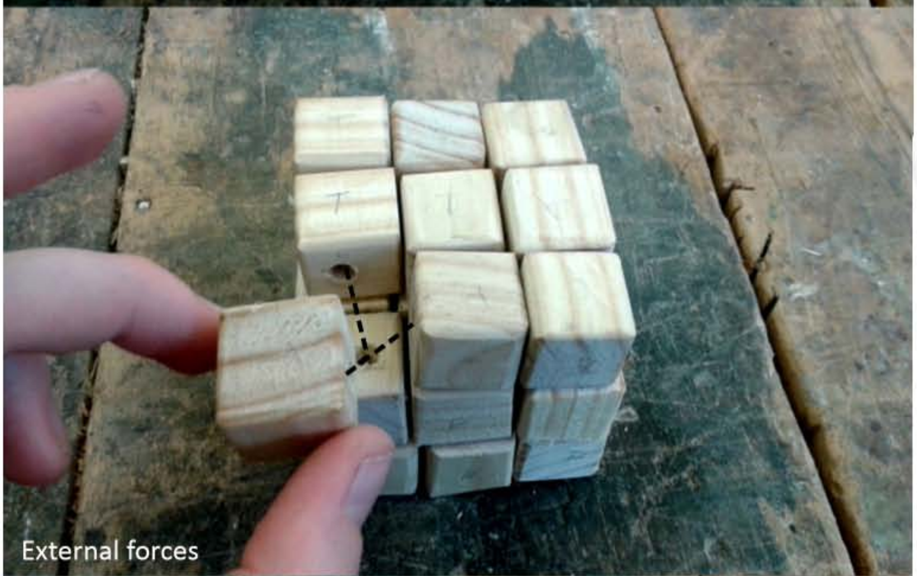
Conclusion: While the DNA remains the same, the new forces on the object change its form and behaviour.

The sum of the parts is not equal to the whole ; configuration is key to character.

Keywords: Process | DNA | Growth | Form | Change

Ground state

External forces



External forces

Internal forces return block to ground state

TRANSMUTATION 2

Theme: Geography

Task: "Locate and record your artefact in relation to the four elemental conditions: earth, air, fire, water."

WATER:

The only elemental condition whose structure, form and behaviour can shift drastically while the **fundamental elements remain unchanged** - such was the behaviour of the pods in transmutation 1.

Water changes state as a result of external environmental forces and conditions; under normal conditions it always **tends back to its ground state**: liquid water.

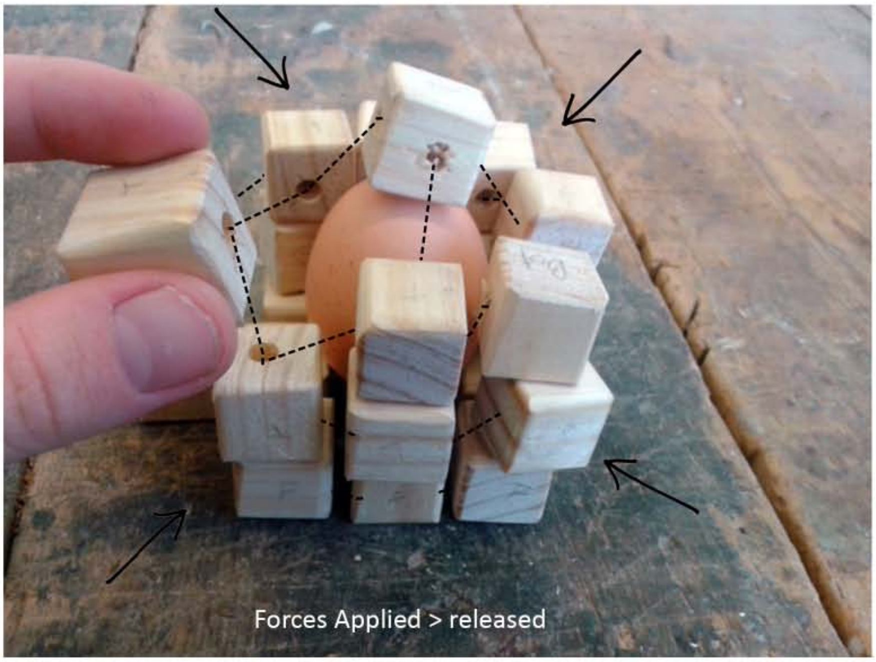
The cube is held in its ground state by interrnal elastic forces. When external forces are applied, the cube can shift to accommodate the change. Once the forces are released it tends back to its original shape.

DYNAMIC INTEGRITY:

As buildings face increasing threat of changing environmental forces, is it time to build with a dynamic integrity: one that can adapt rapidly to catastrophe and return to the human comfort zone when threats are reduced?

Keywords:

elements | ground state
internal | external | forces
dynamic | integrity



Forces Applied > released

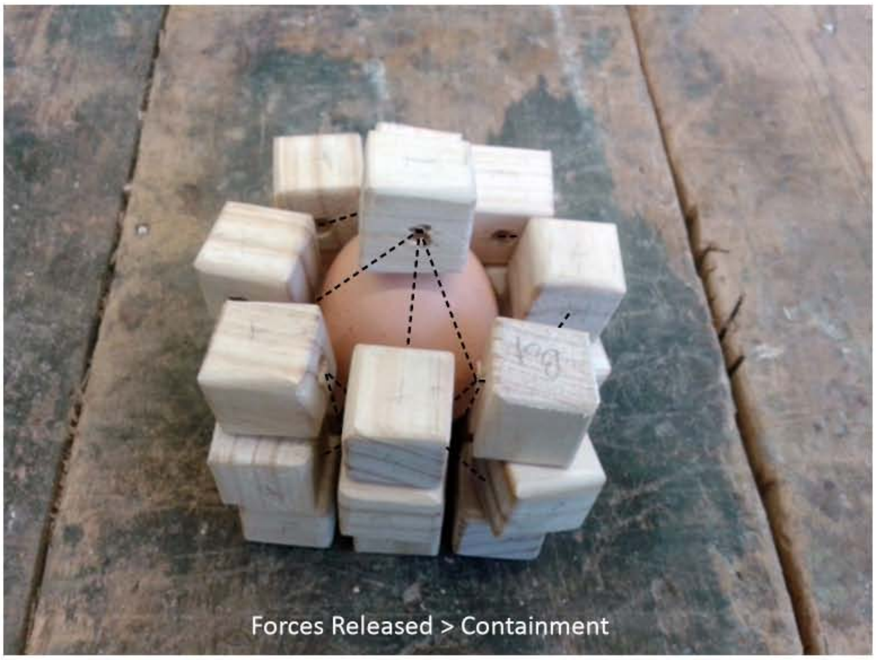
TRANSMUTATION 3

Theme: Art and Literature

Task: “Articulate the notions of release and containment as found in your artefact.”

Conventionally, the notion of containment is associated with applied force, and release associated with the opposite.

In the artefacts ground state or lowest energy level, it takes on a contained shape. If the artefact is put under external force to “open” it and something is inserted into it, when the forces are removed the internal forces relax and hold the object in place.



Forces Released > Containment

Conventionally:
reduce the force > object is released

Artefact:
reduce force > object is contained

INVERSION OF THE NORM:

In a world of changing forces, architecture needs to be robust but yielding, have flexible and dynamic integrity and allow for change that will not leave permanent damage.

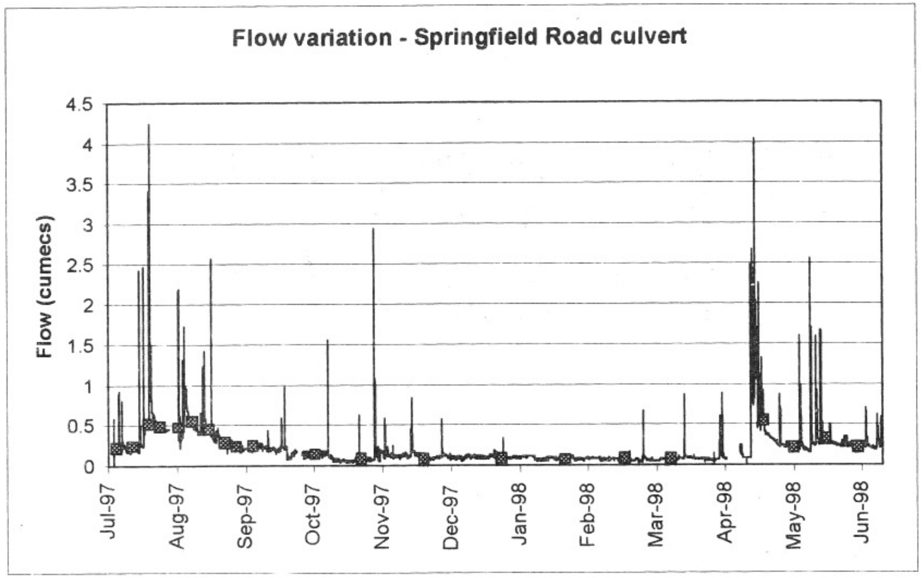
Keywords:

Inversion | dynamic

Appendix B - Calculations and data

Calculations on the feasibility of the struvite manufacturing process were conducted by Malissa Sikosana, a chemical engineer specializing in this process. Included in this appendix are her findings, the data used for the calculations and extracts from the data sheets of the technology incorporated into the design.

Data from the following graph was used for the calculations of the reactor sizing which was implemented in the project. As mentioned in the “assumptions and limitations” section, the process is assumed to be feasible only for the dry months from September to April when pollutant concentrations are high.



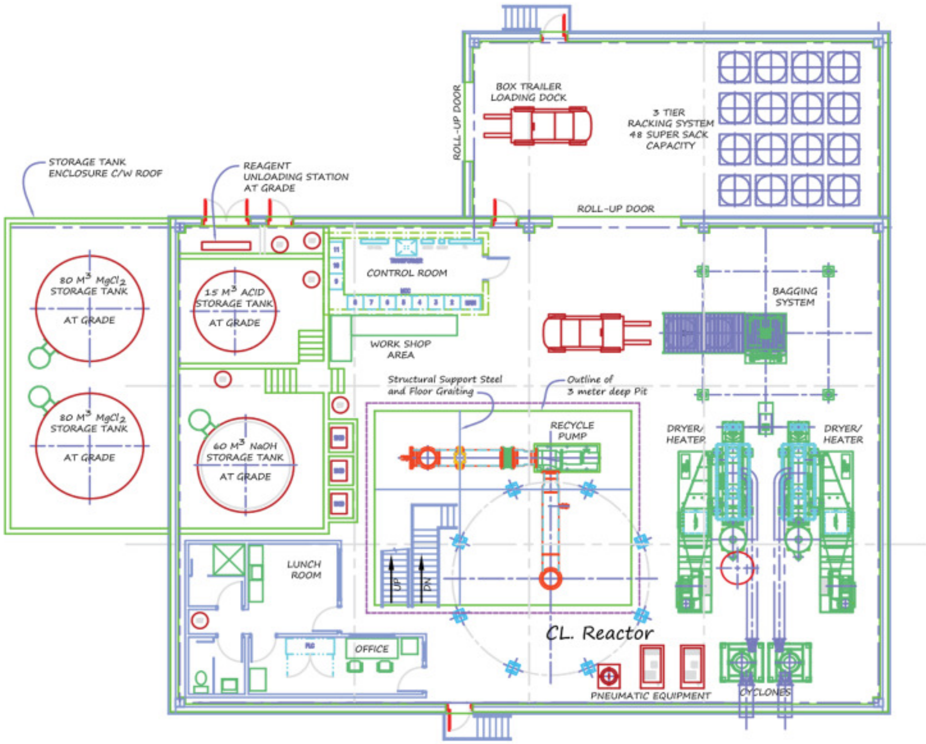
Summary of the results for the struvite manufacturing calculations

LOTUS RIVER STRUVITE MANUFACTURING

River data		
Phosphorus Concentration (max)	2,3 mg/L	Grobicki et al. 2001
River Flow Rate	55 ML/day	Grobicki et al. 2001
Struvite produced		
Product	288 kg/day	Sikosana, 2015
Conversion	90%	
Mass flowrate dry struvite	288,9 kg/day	
Moisture content wet	1,5 wt%	
Wet struvite	722,25 kg/day	
Other input required		
Magnesium Oxide	70 kg/day	
Total energy used	21 kW	
	912 kWh	
Reactor Sizing		
Reactor volume required	2400 m3	
Pearl 2000 volume/reactor	73 m3	
No Pearl 2000 Reactors required	33	
Pearl 10000 volume/reactor	365 m3	
No. Pearl 10 000 Reactors requirec	7	
Revenue		
Struvite produced kg/day	288,901	
Struvite produced kg/year	105448,961	
Potential revenue	R 39 016,11	

Extracts from the Ostara Pearl 10000 Reactor data sheets

Below is the floor plan of a typical Ostara struvite plant, as provided by the company. This was used as the basis for spatial and access requirements of the plant. Note that the project incorporates 3 reactors and 3 driers, which according tot he supplier, are the only pieces of equipment which need duplicating for large volumes to be processed.



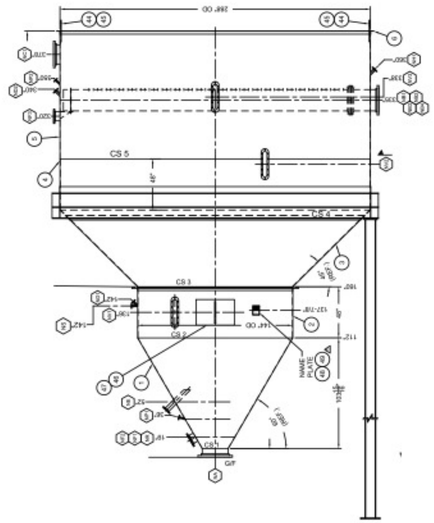
Plant requirements for a single reactor operation

Pearl 10000 Technical Data

Nominal Capacity	
Phosphorus Recovery	1,260 kg PO_4-P per day
Ammonia Recovery	570 kg NH_3-N per day
Fertilizer Production	10,000 kg per day

Dimensions	
Installed Height	15 m
Diameter	7.3 m

Weights	
Empty	21 tonnes
Operating	365 tonnes



Pearl System Footprint

# Reactors	Building Area
1 Pearl 10000	~ 500 m²
2 Pearl 10000	~ 750 m²
3 Pearl 10000	~ 1,000 m²
4 Pearl 10000	~ 1,200 m²

EBE Faculty: Assessment of Ethics in Research Projects

Any person planning to undertake research in the Faculty of Engineering and the Built Environment at the University of Cape Town is required to complete this form before collecting or analysing data. When completed it should be submitted to the supervisor (where applicable) and from there to the Head of Department. If any of the questions below have been answered YES, and the applicant is NOT a fourth year student, the Head should forward this form for approval by the Faculty EIR committee: submit to Ms Zakiya Chikte (**Zakiya.chikte@uct.ac.za**); New EBE Building, Ph 021 650 5739). Students must include a copy of the completed form with the dissertation/thesis when it is submitted for examination.

Name of Principal Researcher/Student: Claire du Plessis **Department:** EBE

If a Student: **Degree:** M(Arch)Prof **Supervisor: Kevin Fellingham**

If a Research Contract indicate source of funding/sponsorship:
n/a

Research Project Title:
Hydreveal: Architecture for the social and physical remediation of urban waterways

Overview of ethics issues in your research project:

Question 1: Is there a possibility that your research could cause harm to a third party (i.e. a person not involved in your project)?	YES	NO X
Question 2: Is your research making use of human subjects as sources of data? If your answer is YES, please complete Addendum 2.	YES	NO X
Question 3: Does your research involve the participation of or provision of services to communities? If your answer is YES, please complete Addendum 3.	YES	NO X
Question 4: If your research is sponsored, is there any potential for conflicts of interest? If your answer is YES, please complete Addendum 4.	YES	NO N/A

If you have answered YES to any of the above questions, please append a copy of your research proposal, as well as any interview schedules or questionnaires (Addendum 1) and please complete further addenda as appropriate.

I hereby undertake to carry out my research in such a way that

- there is no apparent legal objection to the nature or the method of research; and
- the research will not compromise staff or students or the other responsibilities of the University;
- the stated objective will be achieved, and the findings will have a high degree of validity;
- limitations and alternative interpretations will be considered;
- the findings could be subject to peer review and publicly available; and
- I will comply with the conventions of copyright and avoid any practice that would constitute plagiarism.

Signed by:

	Full name and signature	Date
Principal Researcher/Student: Claire du Plessis	[signature]	26/08/2015

This application is approved by:

Supervisor (if applicable): Kevin Fellingham	[signature]	26/08/2015
HOD (or delegated nominee): Final authority for all assessments with NO to all questions and for all undergraduate research.	[signature]	15/9/15
Chair : Faculty EIR Committee For applicants other than undergraduate students who have answered YES to any of the above questions.		

Approved

ADDENDUM 1:
Please append a copy of the research proposal here, as well as any interview schedules or questionnaires:

ADDENDUM 2: To be completed if you answered YES to Question 2:

It is assumed that you have read the UCT Code for Research involving Human Subjects (available at http://web.uct.ac.za/depts/educate/download/uctcodeforresearchinvolvinghumansubjects.pdf) in order to be able to answer the questions in this addendum.

NA

2.1 Does the research discriminate against participation by individuals, or differentiate between participants, on the grounds of gender, race or ethnic group, age range, religion, income, handicap, illness or any similar classification?	YES	NO
2.2 Does the research require the participation of socially or physically vulnerable people (children, aged, disabled, etc) or legally restricted groups?	YES	NO
2.3 Will you not be able to secure the informed consent of all participants in the research? (In the case of children, will you not be able to obtain the consent of their guardians or parents?)	YES	NO
2.4 Will any confidential data be collected or will identifiable records of individuals be kept?	YES	NO
2.5 In reporting on this research is there any possibility that you will not be able to keep the identities of the individuals involved anonymous?	YES	NO
2.6 Are there any foreseeable risks of physical, psychological or social harm to participants that might occur in the course of the research?	YES	NO
2.7 Does the research include making payments or giving gifts to any participants?	YES	NO

If you have answered YES to any of these questions, please describe how you plan to address these issues (append to form):

ADDENDUM 3: To be completed if you answered YES to Question 3:

NA

3.1 Is the community expected to make decisions for, during or based on the research?	YES	NO
3.2 At the end of the research will any economic or social process be terminated or left unsupported, or equipment or facilities used in the research be recovered from the participants or community?	YES	NO
3.3 Will any service be provided at a level below the generally accepted standards?	YES	NO

If you have answered YES to any of these questions, please describe how you plan to address these issues (append to form)

ADDENDUM 4: To be completed if you answered YES to Question 4 NA

4.1 Is there any existing or potential conflict of interest between a research sponsor, academic supervisor, other researchers or participants?	YES	NO
4.2 Will information that reveals the identity of participants be supplied to a research sponsor, other than with the permission of the individuals?	YES	NO
4.3 Does the proposed research potentially conflict with the research of any other individual or group within the University?	YES	NO

If you have answered YES to any of these questions, please describe how you plan to address these issues(append to form)