Exploring Architectural Knowledge in Water Sensitive Design

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Abstract

Across the academic sphere, much research has been conducted into the development of water-sensitive elements to address issues around urban water management. However, these elements are commonly investigated in isolation, with little consideration for initiatives from other disciplines that may support their success. This research aims to demonstrate the value that an architect may bring in incorporating ideas drawn from various disciplines to create a water-sensitive design solution with multiple ecosystem benefits, taking into account the human experience of space and place-making. In doing so, the design demonstrates that a water-sensitive building is aesthetically pleasing, viable and achievable. The feasibility of water-sensitive designs has been noted as a focus area by the South African Water Research Commission; one which is particularly pertinent in our present water-scarce environment in South Africa.

This applied study is based on a previous Master of Architecture (Professional) dissertation building design, which is used as the unit of analysis. The building focuses on restoring the quality of water in the Liesbeek River in Cape Town using passive filtration methods. The objective of this study is to gain new insights into the design process and planning of water-sensitive architectural buildings, which assists in understanding when collaborating across disciplines. The research is guided by Deep Ecology, phenomenology and Ecological Urbanism. Research by Design is used as the method of the study, in which different design iterations based on the raw data of the original building are investigated and analysed, as well as evaluated by specialists from various disciplines in order to create a best-fit design solution.

The revised building takes into account the practical, site-specific and architectural qualities of a water-sensitive design to create a people-centred building that incorporates ecological and engineering demands in greater detail. Key outcomes of the study include a typical design process for a WSAD and architectural guidelines for water-sensitive buildings, grounded in the diverse values of water and its relationship to people and nature. The dissertation aims to contribute to the academic discourse around water-sensitive design. Further, the guidelines developed may be used to inform the design of conventional buildings.

Keywords

Deep Ecology, Ecological Urbanism, Phenomenology, Research by Design, Water Sensitive Architectural Design.

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Glossary

Cross-disciplinary: A term used in this study broadly defined as a project contributed to by specialists from different disciplines.

CoCT: City of Cape Town

CTSDF: Cape Town Spatial Development Framework

D1: The unit of analysis in this study.

D2: The revised building, based on the design of the unit of analysis.

D3: The revised building, based on specialist's comments and evaluation.

D4: The final product of the RBD process.

Effects analysis: This compares the design as it is (ie D1) to what it could be (ie the final design iteration), according to criteria outlined by De Jong and van der Voordt (2002).

FISRWG: The Federal Interagency Stream Restoration Working Group

GBCSA: Green Building Council South Africa

Gestalt principles: Gestalt is a phenomenon wherein a concept is comprised of multiple individual parts, but simultaneously has meaning as a whole and therefore can be perceived in different ways (Naess, 1989).

Informant: A design informant is an aspect of design, or a guideline, derived from the theory discussed in the literature reviewed in this study.

Inter-subjective: Can be understood by those in different disciplines.

Instrumental value: Value in terms of means.

Intrinsic value: Value in itself.

HCI: Human-Computer Interaction

ME: Millennium Ecosystem Assessment

MOSS: Metropolitan Open Space System

Participant: A person invited to participate in the study. In this study, participants were drawn from the different disciplines that influenced the design of D1.

Procedural knowledge: Practical or skills-based knowledge.

Propositional knowledge: Can be explained through language and is taken as true belief, associated with explicit knowledge (Niedderer, 2007).

RBD: Research by Design

Research method: The manner by which to study the process of inquiry (Groat and Wang, 2002).

Research strategy: The structure of the study and over-arching research plan (Groat and Wang, 2002).

Research tactics: The specific techniques that are made use of in order to conduct the study (Groat and Wang, 2002).

SUDS: Sustainable Urban Drainage Systems

Tacit knowledge: Not easily defined, associated with experiential knowledge (Niedderer, 2007).

TRUP: Two Rivers Urban Park

USGS: United States Geological Survey

UN: United Nations

UNEP: United Nations Environment Programme

US EPA United States Environmental Protection Agency

UWM: Urban Water Management

Value: The worth and usefulness of an object or being.

WRC: Water Research Commission

WSAD: Water Sensitive Architectural Design

WSD: Water Sensitive Design

WSC: Water Sensitive Cities

WSUD: Water Sensitive Urban Design

Chapter 1| An Introduction

Context

Water is a fundamentally important resource and forms an essential component of all life. Globally, of the 2.5% of freshwater available, 68.7% is glaciers, 30.1% is groundwater and 1.2% is surface water. (USGS, 2016). Surface water comprises lakes, rivers, ice and swamps. Potable water, or water that is clean enough for human consumption, is predominantly obtained from rivers and groundwater sources. Globally however, water is under stress. Mis-allocation of water, loss through leakage, pollution and an ever-increasing demand all contribute to a shortage of water (Srinivasan et al, 2012:1; UN, 2015a:2). The scarcity of water is further compounded by a growing population, natural population increases resulting from rural to urban migration, and higher standards of living (UN, 2015a:4). Globally, the urbanised population is expected to increase from 54% in 2014, to 66% by 2050, which will increase the demand on resources (UN, 2015b:xxi). Additionally, climate change amplifies water problems. Changes in rainfall patterns negatively affect freshwater supplies, while extreme weather conditions contribute to large-scale floods and droughts (UN, 2015a:4).

Rivers, as one source of potable water, face multiple pressures. Alien vegetation on river banks increases water extraction, as these plants require more water than indigenous species. Industrial effluent adds excess nutrients to the water, causing the growth of unwanted flora. Canalisation prevents the absorption of excess water by the surrounding earth during rainy months when stormwater levels increase, contributing to flooding. Impervious surfaces contribute to large-scale surface run-off. Rivers tend to be polluted at the lower reaches, and sediment deposits create problems at river mouths (Brown et al, 2009; CoCT, 2002 and CoCT, 2005).

The United Nations has classified South Africa as a water-stressed country (UN, 2015a:12). It is predicted that this situation is likely to worsen by 2050, at which stage South Africa is expected to be facing severe water stress, having over-exploited its sources of water (UN, 2012:125). South Africa's erratic rainfall patterns are already an issue, with the result of a history of country-wide water restrictions (Hedden & Cilliers, 2014:7). Simultaneously, the country experiences large-scale shortages of electricity. Water and electricity are interconnected, as both require the other for generation and distribution. In South Africa, this presents a problem as electricity generation plays a large role in the consumption of water, where the parastatal Eskom uses 1.35l of water to generate 1kW of electricity (GBCSA, 2013b:5).

Cape Town, as one of the main cities of South Africa, faces extreme water challenges and is currently experiencing its third drought since 2001 due to below average annual rainfall (Baigrie, 2017; De Lille, 2017; and Winter, 2017). The CoCT (2012:22) has predicted that climate change will alter the city's normal climate patterns: Cape Town is to experience an increase in summer rains followed by long periods of drought, with an overall reduction in the amount of rainfall. Its proximity to the sea means that as sea water levels rise due to melting polar ice caps, portions of the city will be under threat of flooding. This is a substantial deviation from normal climatic patterns, as the city typically experiences a moderate Mediterranean climate with winter rainfalls.

The bulk of the City's potable water is drawn from surrounding dams (Winter, 2017:1). As of April 2017, it is calculated that the usable water in total dams are at 17.3% (De Klerk, 2017 and Gosling, 2017). These water challenges are compounded by urban drainage management issues, including leaking municipal water supply systems (Baigrie, 2017). An ever-increasing population places further pressures on the limited water supply available. The population in Cape Town is set to increase from 3.7 million in 2010 to almost 5 million by 2030, which is in part due to high levels of rural to urban migration (CoCT, 2012:18 and Geyer et al, 2011:41). Cumulatively, these pressures will have a substantial effect upon water resources.

Having contextualised water issues globally, within South Africa and in Cape Town; it becomes evident that sustainable solutions for environmental problems such as these are required. These solutions may be implemented at a variety of scales for success. However, rigorous research is required in order to address such problems. Academic research into these issues therefore becomes invaluable, as it allows for the generation and testing of new ideas and concepts which could then be implemented in reality.

In the engineering disciplines, much effort has been made into the development of physical water-sensitive infrastructural elements in urban environments (See Abbot, 2013; Armitage et al, 2014; Brisbane City Council, 2010; GBCSA, 2013; Luthi, 2011; Public Utilities Board, 2009; Sisolak and Spataro, 2011; Wong, 2006). Although not exhaustive, this list includes detailed research into the surface treatments of permeable paving, swales, biofiltration cells, attenuation ponds, sedimentation and detention ponds. Other initiatives include rain-water harvesting, underground storage tanks and green roofs. These are supported by investigations at the theoretical level in disciplines within humanities, architecture, economics and planning; in which proposals ranging from water-wise education to urban planning framework policies are presented (UWM, 2016). After the author's initial informal discussions with consultants across the engineering, environmental science, ecology and architecture fields, it became apparent that each research initiative tends to be investigated in isolation, without much consideration for initiatives from other fields that may support its success.

To truly create effective areas of water management, a cross-disciplinary approach is proposed as a possible solution, supported by Wong et al, 2011:1. In this research, the term *cross-disciplinary* and its derivatives are used. These terms are elaborated upon later in this chapter. Mostafavi (2010:29) discusses the need for interaction between disciplines, which allows knowledge and research from various fields to come together. Both the established ways of thinking and the capacity to respond to ecological issues are limited when considering a single discipline. Although it can be argued that divisions are important in developing discipline-specific knowledge, Mostafavi (2010:29) suggests that the cross-disciplinary approach is more suitable in addressing current ecological issues at multiple scales, as it provides a larger pool of knowledge and experience to draw from. A cross-disciplinary approach could therefore assist in creating synergistic solutions to problems surrounding water management and use.

The architect is ideally situated in this context, as by its very nature, architecture draws upon knowledge rooted in many different disciplines (Frederick, 2007:20).

According to Groat and Wang (2002:xii), *"the most innovative research in architecture is interdisciplinary, requiring atypical or unexpected combinations of methods".* As architects draw from different academic disciplines to create designs, architectural research therefore draws upon the multiple strategies and tactics present in other disciplines in order to achieve its aims. It is therefore only through an understanding of the attributes from other disciplines that meaningful architecture can be created; one which takes into account all the different forces that act upon a building.

Groat and Wang (2002:xii) identify seven different strategies for architectural research. Of these seven, one is most relevant to this study: simulation and modelling research allows for the assessment of variables in a controlled simulated physical reality (Klassen, 2002). In this study, the qualitative approach Research by Design (RBD) is used. RBD in this study deals with modelling to explore a chosen reality (Klassen, 2002). Although the particular method of RBD is not identified by Groat and Wang in their list of architectural research strategies, RBD was chosen as it is an experimental approach specific to the design field. Additionally, RBD would yield the process and results sought after by the kind of study presented here.

Scope of the Study

Water Sensitive Urban Design (WSUD) offers an opportunity to address the issues of urban drainage, climate adaptation, reducing flood risk, managing water scarcity and improving water quality in urban areas (Fletcher et al, 2014: 528). WSUD achieves this through integrated urban water management, in which multiple physical water-related passive technologies may be integrated into larger urban water management networks dealing with water supply, sanitation and drainage (Wong, 2006). WSUD has been well researched and documented both in the academic and practical spheres (CoCT, 2011; Lüthi 2011; Mitchell, 2006; Sisolak and Spataro, 2011 and Wong, 2013). In South Africa, the term Water Sensitive Design (WSD) has been adopted from the principles of WSUD by the South African Water Research Commission (WRC) to allow for the inclusion of peri-urban and rural areas (WRC, 2017).

In order to be effective, it is proposed that a WSD would need to have interventions at multiple levels of overlapping scales. Traditional models of water management in urban areas are segregated, and these must be viewed in a cyclic framework in order to gain maximum benefits and ecosystems services. WSUD deals with the principles for urban water management using passive technologies (Wong, 2006:214). These are highly dependent on urban planning and design at the specific scale of the urban arena. Bacchin et al (2013:1) argues for a multi-scalar approach, which takes into account landscape, stormwater drainage, structural composition and configuration, urban morphology and aspects of ecosystem services. The design is considered robust when the different aspects of a multi-scalar approach can be tested at a variety of scales. Every aspect of urban water systems must be considered in order to qualify as a robust design, from the microscopic facilitation of the transfer of nutrients in a water solution, to the macro-scaled revitalisation of whole ecosystems. Robustness and scale are discussed further in Chapter 3.

The scales of intervention identified by Bacchin et al (2013:2) are described as follows: the macro, which deals with the urban catchment area at the city or regional scale; the meso, which is comprised of green ecological corridors that connect core areas; and the micro, which deals with the neighbourhood and facilitates design at the urban scale. It is at this scale that WSD retrofitting can be considered and the suitability of each site can be evaluated. This includes the *"protection of existing green areas, wetlands and open water spaces, the design of new landscape elements, and the restoration and maintenance of landscape connectivity at different scales"* (Bacchin et al, 2013:3). Although this particular study does not deal with the retrofitting of a WSD, the principles are useful in identifying some design characteristics of a successful WSD. To these scales, this study introduces the microscopic scale – the scale at which micro-organisms and nutrients are considered.

This study focuses on the architectural aspects of WSD. Water Sensitive Architectural Design (WSAD) is introduced as a noun to describe sustainable architectural design at the scale of the building that is informed by water-related initiatives drawn from different disciplines. This dissertation builds upon the author's Master of Architecture building design, which is used as the unit of analysis and is referred to as D1. D1 included proposals at the three scales of urban, neighbourhood and site. Multi-scale design is important, as environmental systems are not defined by man-made notions of boundaries or suburbs. Rather, environmental networks stretch across cities, range in scale and have overlapping and porous boundaries.

Cape Town is world-renowned for its natural beauty. Table Mountain dominates the landscape, and the city is bordered by both the Atlantic and Indian oceans. Rivers, once a source of potable water, have increasing levels of pollution along their length, thus impacting on the surrounding areas (CoCT, 2005:30). The river systems across the greater Cape Town are broken up, shown in Figure 1: The southern rivers flow through the Cape Flats region and include the Bokramspruit, Krom and Silvermine Rivers. The eastern rivers are situated in and around the Stellenbosch region, and include the Jonkershoek and Eerste rivers. The northern rivers are located around Atlantis, and include the Buffels and Sout rivers (CoCT, 2005:20). The Central River System is unique in that it connects different socio-economic zones across the city. One of these is the Salt River System, which originates as the Liesbeek River at the foothills of Table Mountain and joins with the Black River in the Cape Flats area to exit into the sea as the Salt River. The focus area of this study is along the banks of the Old Liesbeek River within the Salt River catchment area, shown in Figure 1.

At the macro-scale, D1's urban plan was informed by the 2012 Cape Town Spatial Development Framework (CTSDF) in order to situate the site of intervention within the greater river catchment area. This 20-year structuring framework for the city focuses on a variety of different sectors, including the economy, urban growth, social development, biodiversity and transport networks in order to guide spatial development in the city from 2012 to 2032 (CoCT, 2012:2). D1 specifically focused on the CTSDF's aims of dealing with natural assets and the environment. Five major structuring elements are identified as the aims within this sector of the framework. These five structuring elements are: interconnected networks of water bodies, high value agricultural and biodiversity areas, coastal areas and scenic landscapes (CoCT, 2012:30). These green-blue networks across the city are shaded grey in Figure 1.

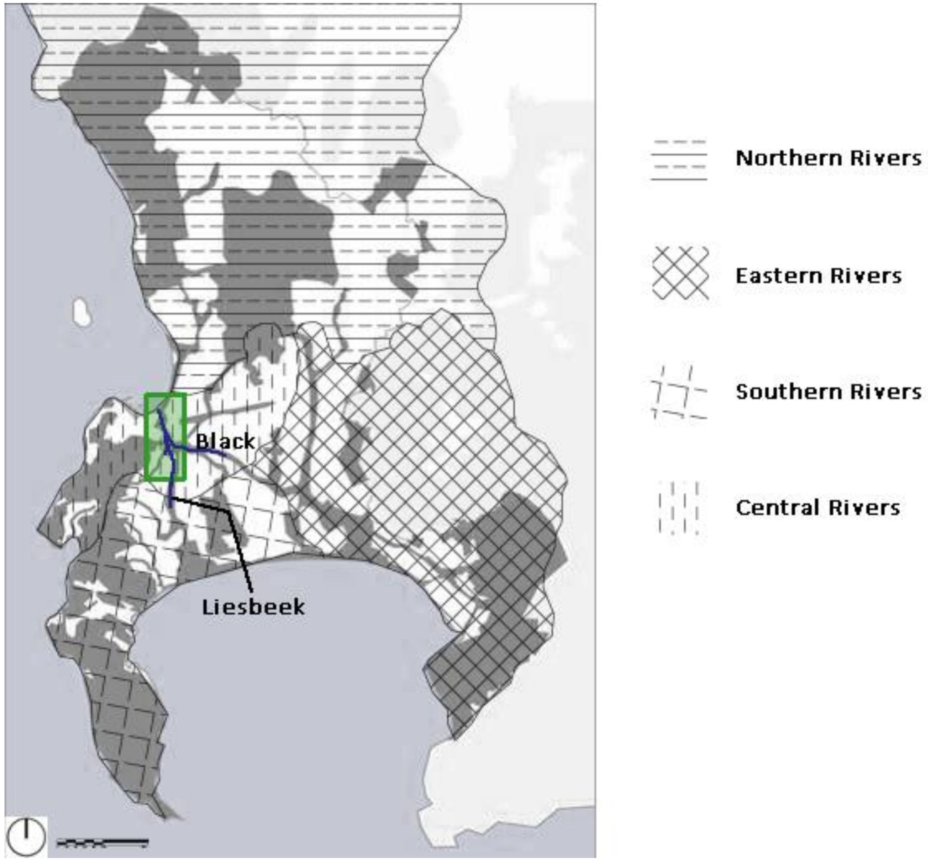


Figure 1: The greater Cape Town Region. River catchment areas are hatched and natural assets are shaded. The study area is highlighted (Author, 2016. Adapted from CoCT, 2005:8; CoCT, 2012:29).

The CTSDF speaks of destination spaces in the natural environment, which could become focal points for public recreation (CoCT, 2012:30). The macro-proposal for the design situated D1 as part of a CTSDF scenic landscape, thereby creating opportunities to add to the recreational and environmental value of the region. Creating identity is important, while still conserving and supporting biodiversity on site.

At the meso-scale, the building was located at the confluence of the Old Liesbeek and Black Rivers, which forms part of the larger Metropolitan Open Space System (MOSS) framework. This framework aims to facilitate conservation and recreation by linking green open spaces across the city (CoCT, 2012:102). This is in line with the policies of the CTSDF, which recognises that MOSS is essential for the protection of biodiversity in the city. Although the CTSDF deals with biodiversity at the macro-scale, MOSS aims for a continuous and extended open space system, and to manage the interface between the natural and built environments (CoCT, 2012:102). In following the goals of MOSS, the City aims to improve the Salt River System by rehabilitating wetlands and riparian vegetation for flood control, improving water quality, de-canalising rivers and dealing with industrial effluent (CoCT, 2012:97).

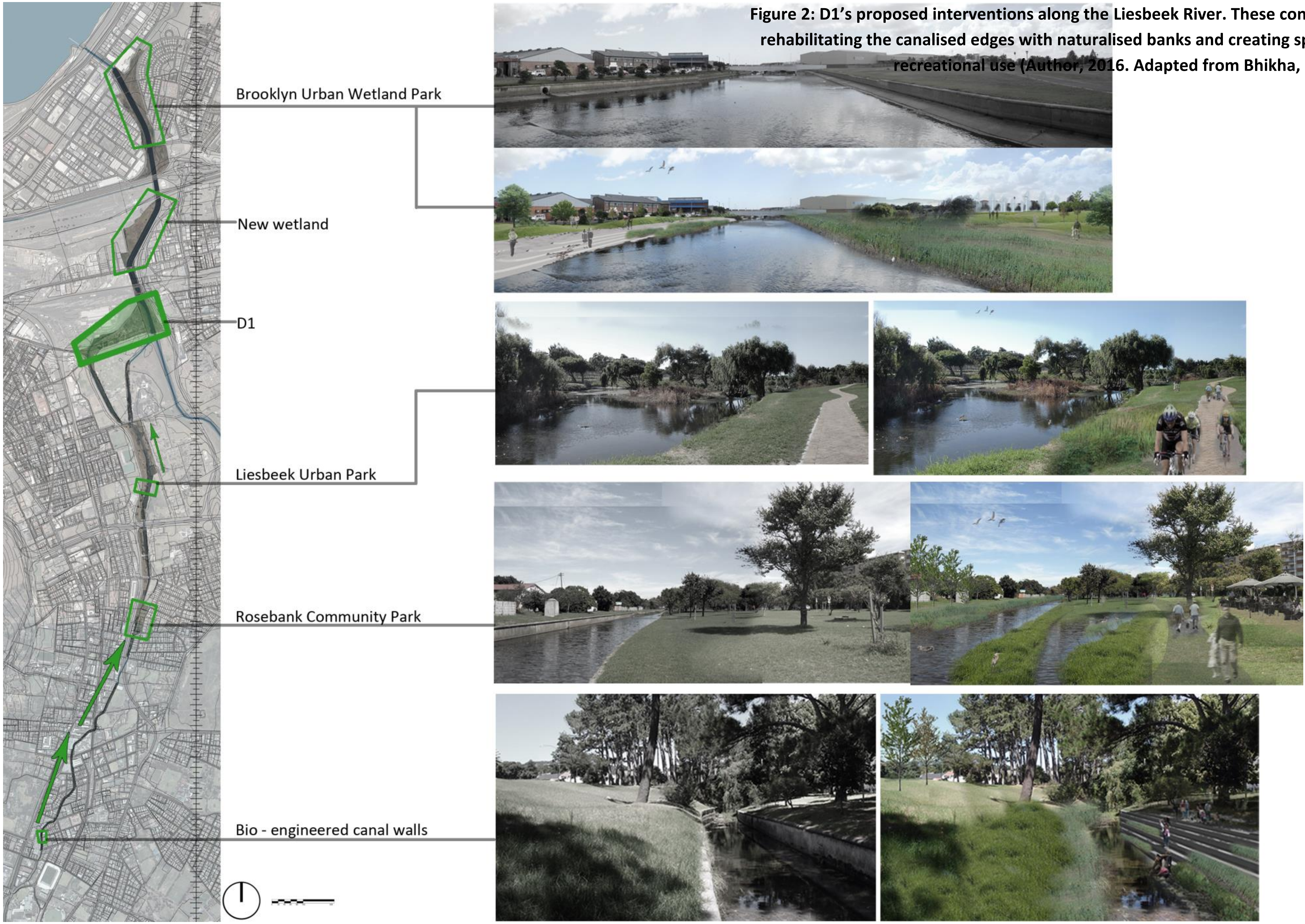


Figure 2: D1's proposed interventions along the Liesbeek River. These consisted of rehabilitating the canalised edges with naturalised banks and creating spaces for recreational use (Author, 2016. Adapted from Bhikha, 2013:35)

The Liesbeek River is included in the MOSS framework across the city. At this scale, D1's urban catchment proposal comprised of a network of interventions along the Liesbeek River. These focal points, shown in Figure 2, included wetland parks in which canals are removed to allow wetland vegetation to be reinstated, thereby restoring wetland processes at key areas along the Liesbeek River. Through rehabilitating river edges in D1's proposal, absorption and retention of water was facilitated, thereby assisting in addressing issues around flooding and stormwater control (Bhikha, 2013:48).

Within this larger MOSS framework, D1 was located in the Two Rivers Urban Park (TRUP) region, shown in Figure 3. The TRUP area contains important institutions, including heritage buildings, and "*sensitive ecological systems and habitats*" (CoCT, 2002:1). The zone is ear-marked for environmentally-responsible development due to its location as a culturally, historically and environmentally important precinct along the greater Salt River system (CoCT, 2002:1). It is one of the few places in the city where the natural endangered riparian and wetland vegetation has been retained, which assists with flood control in rainy months through the retention of excess water (CoCT, 2002:27). D1 was located at the North end of the TRUP zone, shown in the green zone in Figure 3. D1 proposed to add to the natural and cultural value within this region through site rehabilitation and creating public recreational facilities on site.

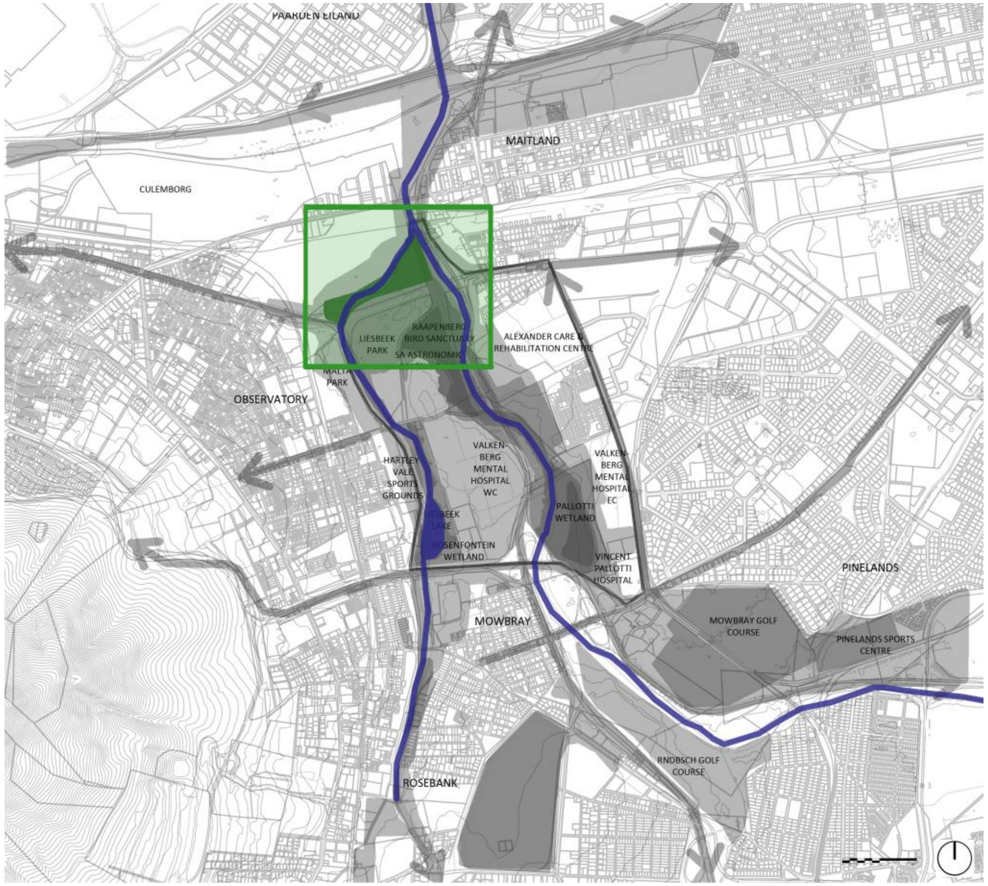


Figure 3: The TRUP is outlined. Green corridors are shaded grey. Major traffic routes are indicated with grey arrows. The site of the building is highlighted in green. (Author, 2016. Adapted from Bhikha, 2013:18)

Unit of Analysis

This study predominantly focuses on the micro-scaled proposal for D1 as the unit of analysis. At this scale, D1 became an opportunity for the testing of WSD initiatives in an indoor-outdoor laboratory testing facility on the site chosen. The D1 building was located at the confluence of the Old Liesbeek and Black Rivers, in an area called the Raapenberg dump site, 6.4km away from the Central Business District of Cape Town. The site is so named as it served as an area for the dumping of removed non-toxic rubble and earth during the construction of the neighbouring Black River Parkway (Bhikha, 2013:9). The Raapenberg dump site is situated at the North West of the River Club golf estate. It is flanked by the Black River Parkway and Business Park on its East and the Transnet Railway Workshops on the West side. The site is currently unused and is an empty tract of land. Small mounds of earth and building material are collected on the site, while plants and shrubs grow in areas where there is no immediate visible evidence of building rubble. Visitors to the site experience constant mild breezes. Table Mountain dominates the landscape, as seen in Figure 4. There is a steep drop from the site down to the river due to the mechanical river-widening done annually to cope with seasonal flooding.

Figure 4: The site of intervention, with a mound of earth in the foreground. Note the view of Table Mountain and the dominance of the earth and sky (Bhikha, 2013).

This site was chosen as it provided an ideal opportunity for site repair, as it has not been previously developed but contains a unique mix of construction rubble and earth situated in a natural wetland area. Additionally, this undeveloped wetland area required minor interventions in order to increase its value as a successful natural, ecological and recreational landscape. However, these unique aspects of the site made it a challenging environment in which to design, thereby adding richness to the context of the proposed building.

Together with the macro- and meso-scaled proposals, D1 aimed to test the passive cleansing of the Liesbeek River as it traversed from its origin to its confluence with the Black River (Bhikha, 2013:34). This occurred across the different scales ranging from the macro to micro, explained in Figure 6. By rehabilitating river edges at the macro- to micro-scales, riparian and wetland vegetation provided a buffer for flood events by absorbing and retaining excess water for later release. Natural riparian conditions attracted fauna and flora to the area, thereby restoring natural systems along the river. The river edges became aesthetically pleasing natural environments and provided green relief for people in the surrounding suburbs.

Functionally, D1 included passive outdoor water filtration systems, support facilities and public amenities; all situated within a greater wetland recreational park. The passive water filtration systems are comprised of a sedimentation pond, which filters out solid contaminates from the river water on site. This is combined with bio-filtration cells, inspired by constructed wetland systems, which purified river water through flora, sands and rocks for various uses on site. This indoor-outdoor testing facility was supported by a water-focused laboratory, a restaurant, a public swimming pool and an open area for outdoor food markets. The wetland park allowed visitors to meander around the site and engage with the natural conditions of a riparian landscape by providing areas for picnics, outdoor games, pathways for running and cycling and bird hides for bird-watching. Chapter 4 goes into greater detail around the design considerations and product of D1.

D1 aimed to make the building and site one and the same, with the intervention serving as the physical manifestation of the process of water filtration. This was achieved by investigating the various ideas around passive water filtration that are rooted in other disciplines, as shown in Figure 5. The design process drew upon ideas from the mechanics of wetland rehabilitation, rooted in civil engineering; water filtration methods rooted in chemical engineering; spatial planning and development frameworks rooted in urban planning; water education initiatives and guidelines rooted in education; and the fauna and flora native to rivers in Cape Town, rooted in ecology (Bhikha, 2013:32). The intention was not for the author to become an expert within these different fields, but rather to draw ideas from the various processes in order to inform the building from a functional perspective.

The disciplines covered in Figure 5 are not exhaustive, and other disciplines may have been selected to inform the design of D1. However, this study will focus on these six disciplines identified in the design process of D1 in order to focus the scope of this study. Key aspects from each discipline are identified in Figure 5, along with lines which link similar themed aspects across the different disciplines. Landscape architectural theories, including those by Corner, Descombes, Girot, Leatherbarrow, Manfredi, Reed, Wall and Weiss were drawn upon in the design and planning of D1. These theories were discussed in the dissertation text accompanying the original Masters design project submission. As landscape architecture heavily informed the design of D1, it was elected that this aspect of the design will not be covered in this dissertation in order to intersect ideas around scope.

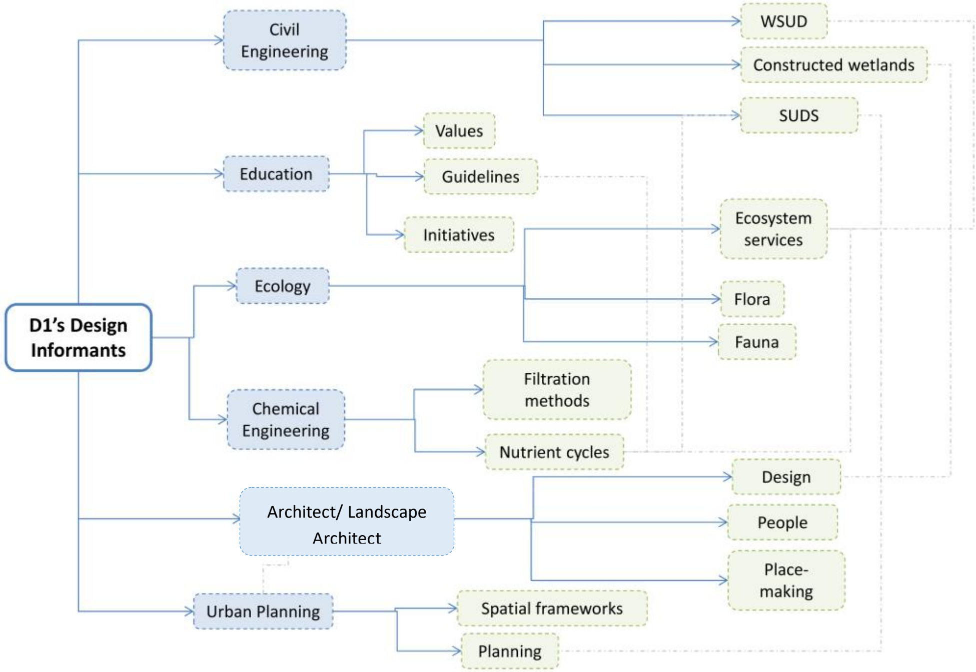


Figure 5: This diagram shows the design informants for D1, which were drawn from different academic disciplines. Note the links and interdependencies of the different themes across the disciplines, shown with grey dotted lines. The sub-headings in green show the key focus areas drawn upon for the design of D1 from each respective discipline. (Author, 2016).

Figure 6: Locating the project within multi-scalar contexts. Clockwise, from top left: greater Cape Town, showing the catchment areas with natural assets shaded. CTSDF across the city, with existing natural assets shaded. The Liesbeek River in the TRUP, demarcated by the thick black line. The site locality plan, showing the laboratory in the wetland recreational park. The building plan, showing the indoor-outdoor water laboratory (Author, 2016. Adapted from Bhikha, 2013).

Research Problem

Examples of integrated WSD technologies used in existing buildings can be found both internationally and South Africa, although the initiatives tend to focus on specific scopes and scales. The Sidwell Friends School Middle School in Washington DC uses constructed wetlands to filter sewerage water for reuse (Sidwell Friends Schoool, 2017). Hotel Verde in Cape Town uses integrated grey water recycling systems and harvests rainwater for cleaning, irrigation and car-washing (Abdinor, 2013). In Cape Town, the different aspects of WSD are explored through research by the cross-disciplinary UWM research unit at the University of Cape Town, supported by the WRC's WSD Lighthouse Initiative (WRC, 2017). To the authors' knowledge, however, there have been few research attempts in the local body of research within the architecture and urban design fields that consider the integration of WSD initiatives drawn from different disciplines at the scale and to the depth covered in this study. This study therefore attempts to contribute architectural insights to the greater discourse around WSD.

Given this context, the Water Research Commission (WRC) of South Africa is encouraging researchers to move beyond the focus on methodologies to that of supporting implementation (Schreiner 2011:1). This study is undertaken as part of the UCT Urban Water Management research group, funded by the WRC. The research forms part of a feasibility study which aims to evaluate WSD principles in strengthening planning for Water Sensitive Cities. Further, it aims to analyse and test both the concept and value of WSD architecture within a particular ecological context in Cape Town, in this case dealing with the natural wetland environment around the Liesbeek River (UWM, 2016:7). The users and visitors to the building are also considered and designed for.

The research objectives that guide this study on considering the feasibility of a WSD from the architectural standpoint are as follows:

- What lessons are yielded when an architect engages in the process of water-sensitive design for a building?
- In such a process, what are the major design leverage points?
- How can these major design leverage points inform water-sensitive design for future buildings?

The research intends to be explicit and inter-subjective. Inter-subjectivity is important in this study, as the researcher must aim to produce knowledge that can be used and understood by those in other disciplines. This is challenging when discussing questions that are not quantifiable. This challenge is addressed by using the qualitative method of study, RBD, which is discussed further in Chapter 3. The research outcomes aim to contribute to architectural knowledge around WSD.

Limitations of Study

This study aims for inter-subjectivity in order to make the findings accessible to actors from other disciplines. Bias towards architectural thinking is inevitable, as the author has an architectural background. A number of terms have been further clarified in text so as to define the parameters of the study and limit the outcomes. This is important when considering jargon that is particular to one discipline, i.e. architecture. Concepts and ideas familiar to architects may be commonly understood within the field, but may seem foreign to those from other disciplines. Concurrently, architects may not be familiar with the terms used in this study, and these explanations will aid in understanding the concepts discussed.

In this study, the term *cross-disciplinary* and its derivatives are used. Cross-disciplinarity is defined as people across disciplines working together. Although this is a simple definition of the term, it is deemed sufficient in order for any reader to understand this study. This study explores issues around cross-disciplinarity, but caution is exercised when discussing this aspect. Multiple terms, distinctions and hybrids thereof exist between the terms cross-disciplinary, trans-disciplinary, multi-disciplinary and inter-disciplinary (Van den Besselaar and Heimericks, 2001:1). Stock and Burton (2011) define these terms as follows: Multi-disciplinary refers to a study in which different consultants share knowledge and offer their opinions, but this is not an iterative process and is therefore the least integrated option. Inter-disciplinary research requires consultants to mutually agree on the problem, method and processes used in the study in order to jointly generate new knowledge that spans across discipline boundaries. The trans-disciplinary approach is a holistic one, in which specialists and non-specialist participants aim to transcend discipline-specific knowledge in order to solve a problem by means of generating new disciplines and theories. Stock and Burton (2011:1) note that cross-disciplinary is a general term used to denote research in which different disciplines are integrated, which they call 'integrated research'. Although this study is multi-disciplinary in the strictest sense, the term *cross-disciplinary* is used to encompass multi-trans-inter-disciplinary research. A limitation of this study is therefore that as a single study, the author consults with specialists from other disciplines, but does not work directly with other specialists in a collaborative manner. An aim of this study is to demonstrate that the cross-disciplinary approach is a more successful and inclusive option than trying to solve urban water issues from any single discipline, and therefore this general term is used to denote all types of integrated research. Specialists in different disciplines are consulted throughout the study and the results of these discussions are included within the text. The author proposes that the architect's strength within the cross-disciplinary workspace is in synthesising ideas, and does not seek to position the architect as a specialist in any other discipline (Frederick, 2007:21). Further, although this study positions cross-disciplinarity as an opportunity to integrate ideas from different disciplines, the final design outcome of this project is not a true reflection of the trans-inter-disciplinary approach, as defined by Stock and Burton (2011). Rather, specialists' input are synthesised and considered, but the project is not initiated and followed through by a team of consultants. The multi-trans-inter-disciplinary approach could be explored further in future studies.

The study is limited in scope, as it deals only with one theoretical proposal of a water-sensitive building design. Thus outcomes are based only on this proposal. Different outcomes may have been realised if the study had focused on a different or multiple buildings. This study does not aim to prescribe the definitive answer to questions around the design of water-sensitive buildings. Rather, it aims to add insights to the discussion around the topic. D1 specifically did not deal with the major socio- economic issues that arise in Cape Town in order to focus the study on the ecological issues surrounding rivers. In future research, consideration of the socio-economic realms of a WSAD will contribute an aspect missing in this dissertation. Although a variety of qualitative and mixed methods could be used to conduct the study, RBD has been chosen due to its qualitative and experimental nature. This is discussed further in Chapter 3. Different outcomes may result when using a different research strategy, which could be explored in future studies within architecture and WSD.

Structure of Dissertation

This dissertation is guided by the research objectives, presented as a series of linked chapters, shown in Figure 7. The architectural process itself is rarely linear, but the research is presented as such to clarify argumentation and enhance intersubjective communication.

The research project is introduced in this chapter, Chapter 1. The contextualisation of water issues globally and locally locates the reader in the study. The unit of analysis, D1, is introduced through the different scales of the macro, meso and micro. This leads to the explanation of the research problem, as well as the limitations of the study. The structure of the dissertation is briefly explained, before the chapter is concluded.

Chapter 2 begins with a discussion of the theoretical framework. This framework covers Deep Ecology, and one of the supporting concepts of the research strategy, phenomenology. Both are contextualised through integrated literature reviews. A brief explanation of the sustainability movement is given to situate Deep Ecology, which focuses on the human link with nature and on the collective self. Deep Ecology is closely linked to phenomenology, which deals with space and place-making.

Chapter 3 explores the conceptual framework in two parts. Part 1 introduces Ecological Urbanism. Located within the Ecological Urbanism umbrella are the various WSD initiatives, which place WSAD within the research field. Ecological Urbanism considers all scales, from the macro to the micro. The microscopic scale is added to this group in this study, all considered from the architectural viewpoint. The second part of Chapter 3 contextualises RBD as the method chosen for this study. To define this process, the strategies and tactics for conducting the study are discussed, supported by the relevant literature.

Chapter 4 focuses on the WSD proposal at the Liesbeek River, used to show how different WSD elements are integrated through design at the architectural scale. The study begins with a description of the graphic and text-based components of D1. Theories that influenced the design are briefly discussed in order to gain further understanding. The second part of Chapter 4 deals with the analysis of the raw data. These raw data comprise of sketches, models, text and drawings. The analysis is done by evaluating, learning from and iteratively testing scenarios for a WSD building. The results of this process, D2 and D3, are evaluated based on values generated by the theoretical framework in this study, as well as testing the design with different user groups and experts.

The best fit solution, D4, is then interrogated and analysed to gain insights into the process of designing a WSAD in Chapter 5. The outcomes of this process reveal general principles for WSD's that may be considered when designing similar buildings. Chapter 6 concludes the project with a discussion of the results, as well as providing a summary of the study.

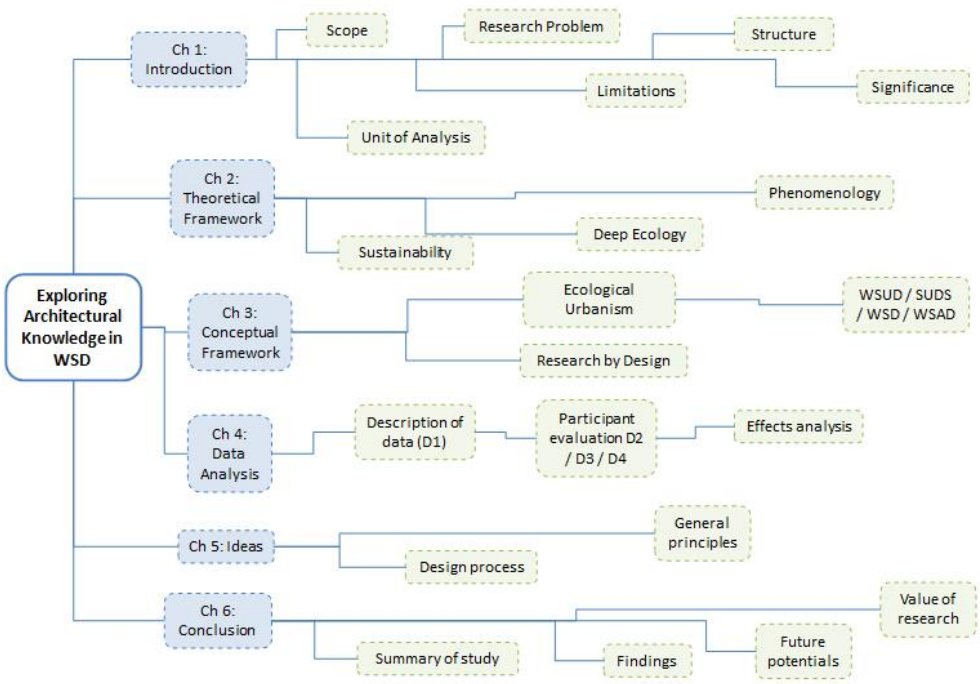


Figure 7: A summary of the structure of this dissertation. This diagram shows the main themes of each chapter (Author, 2016).

Significance of Study

This research is significant in that it aims to address a knowledge gap in the South African research sphere around the links between architectural design and sustainable urban water cycle management as an integrated system. To the author's knowledge, this is one of the few studies to focus on WSAD in the global academic sphere. The notion of feasibility is explored in a WSD as the combination of practical, functional, aesthetic and ecological values. The value added in creating a WSD is not only quantifiable in monetary terms, but in the numerous values that man derives from water and in the intrinsic value of water for nature. A WSD therefore becomes an entity which people can understand and relate to.

The results of this study may be useful to specialists who engage with topics linked to WSD planning, such as urban and city planners, architects, environmentally-aware developers and engineers. Further, the results of the study, which considers an 'ideal' building example modelled in 3D in context, allows for the testing of all WSD principles explored, informed by the literature reviewed. In doing so, successful principles that may be transferred to more conventional buildings may be revealed.

Outside of the built environment industry, the study may be useful to ecologists, environmental specialists, activists, policy makers and building users. In the academic field, the results aim to add to and build upon the existing knowledge around the relationships between people, water and the built environment.

Conclusion

This chapter introduces the study to be conducted. The water crisis globally, in South Africa and in Cape Town is contextualised, thus identifying the need for solutions to water-related issues. WSD is positioned as a possible solution to such water-related problems in the urban context. Much research has been conducted into water-sensitive initiatives across academic disciplines, but these initiatives are often not integrated further. The architect is ideally positioned in this context, as architects draw from other academic areas to create successful design solutions. Water Sensitive Architectural Design (WSAD) is proposed, in which WSD is addressed through architectural principles and design. The unit of analysis, D1, is introduced across the macro-, meso- and micro-scales. D1 focused on testing passive filtration technologies on water drawn from the Liesbeek River. In doing so, the viability of integrating water initiatives from different disciplines at multiple scales was explored.

The objective of this study is to gain new insights into the design process and planning for WSDs. This assists in understanding approaches when working in a cross-disciplinary manner. The research problem is discussed and key objectives of the study are identified, which deal with the feasibility of a WSAD. This research forms part of an ongoing WRC feasibility study that explores the potential of using WSD principles at the theoretical level to support planning for Water Sensitive Cities of the future. The limitations of the study are then identified, including the various hybrids of the term ‘cross-disciplinary’, the scope of the study proposed and the study method used. The structure of the dissertation is explained, before the chapter concludes with an acknowledgement of the significance of the study.

The next chapter, Chapter 2, introduces the theoretical framework used in this study. The chapter will delve into the sustainability movement, Deep Ecology and phenomenology, which guide the study going forward.

Chapter 2| Theoretical Framework

Introduction

The theoretical framework serves as an introduction to the main theoretical underpinnings of the project. It allows for the contextualisation of the research study, and also focuses on the themes reviewed and evaluated, guided by the various literature (Ngulube and Mathipa, 2015:14).

In this chapter, an overview of the sustainable design movement is given as a prelude to the theoretical framework. Situated within this movement is Deep Ecology, which moves away from an anthropocentric model towards an understanding that nature is intrinsically linked to humanity. Deep Ecology arises from a phenomenological standpoint. Various aspects of phenomenology are explored, including the nature of space, place and identity, and the link between people and environment. Linked to phenomenology are the different ideas relating to the 'boundary' as an element with multiple meanings. D1 conceptualises the river as both a boundary and as a zone in which multiple phenomena are present. The boundary, which marks the transition between different spaces, is discussed in the section on phenomenology. Salient points from Deep Ecology and phenomenology are then identified in the text as key informants for multi-scalar water-sensitive architectural design. The chapter concludes with a summary of the themes covered as part of the theoretical framework.

Sustainable Architectural Design

Sustainability as widely understood today began in the 1960s with the realisation that resources are finite and that the environment needed to be protected from the prevailing destructive processes of production and consumption. Instrumental to this realisation was Carson's book *Silent Spring* (1962), which raised awareness around the often negative impact of people and their lifestyles on the environment, thereby limiting growth of society (Krebs et al, 1999:611). The Brundtland Report (1987) continued the discussion around sustainability by identifying the need to conserve and protect the environment to ensure that future generations have access to the finite natural resources available to aid in economic growth and development as a society (UN, 2015a:vii).

Sustainable architectural design must be prefaced by a discussion dealing with sustainable development, which is a contentious issue amongst the academic community due to the ambiguity in the interpretation of its definition (Guy & Farmer, 2001; Pieterse, 2010; Sanya, 2007). In simplest terms, sustainable development can be defined "*quantitatively and qualitatively in relationship to man whereby development should provide for his needs today while taking into account the needs of future generations*" (Sanya, 2007:4). It must be noted, however, that this is an anthropocentric construct. Sustainable development focuses on conserving non-renewable resources for future generations, while still facilitating development at present. This links to architecture and urban planning, in which buildings play a large part in the consumption of resources through building materials, water and electricity. To illustrate this, the construction and maintenance of buildings globally consumes 40% of energy, 25% of global water available and generates a third of all carbon emissions (GBCSA, 2013a:3, UNEP, 2017). The GBCSA suggests that buildings can save 25-50% energy when designed according to green principles compared to a building designed according to the South African National Standards specifications (GBCSA, 2017).

Mostafavi (2010:17) suggests that three narratives may be used as evidence to address the fundamental questions of sustainability in architecture, which is being accepted as a mainstream design practice. The first narrative shows us that there is an urgent need to design efficient and alternate ways of using energy resources. The second narrative demonstrates that guidelines are required to evaluate the impact a building has on a city, as well as on the rights we as individuals have on a share of a city's resources. The final narrative shows that a collaborative and productive ground for communication may be created when we connect with nature (Mostafavi, 2010:18). These narratives frame the design informants used within this study, as they situate the need for an architecture that is conscious about the environment. Further, this framing situates the need for a WSD: the scarcity of water means that existing resources need to be used efficiently, while alternate sources of water must be investigated. To this, ideas around the well-being of society and the benefits of healthy ecosystems to both the environment and the community can be added. Guidelines could assist in the design and planning of water-sensitive cities and buildings in order to mitigate the negative effects of urbanisation on water courses. Finally, a cross-disciplinary approach is suggested in this study as a means to approach urban water management.

Sustainability in architecture introduces ideas relating to the relationships between people, nature and the built environment. This relationship is a key theme explored within this study. Guy & Farmer (2001:557) are critical of the sustainable architectural movement. "*Following the collapse of public and professional faith in modernism and a long period of uncertainty, drift and discord…the idea of 'sustainability' appears to have given architecture a new mission and identity*." They challenge architects to look beyond the label of a 'sustainable' design and to introduce critical doubt (Guy & Farmer, 2001:557). Architects are requested to look towards buildings that are site-specific and that respond to local environmental challenges. Young architects now form a part of the 'post-sustainability' generation. JDS Architects (2010:122) identify the challenge for this generation as a shift in mind-set from 'sustainable' to 'able. They encourage "*precise, beautiful and systematic instigations for change*" (JDS Architects, 2010:122). Placed in this context, a WSD provides an opportunity to create attractive architectures for the revitalisation of the links between people and nature with definite design goals, which aim to facilitate a change in the approach to urban water management. By thus connecting people and nature, a WSD may be a versatile means to meet the aims of Deep Ecology.

Deep Ecology

One of the most radical and progressive concepts to come about during the first thrust of the sustainability movement is that Deep Ecology by Arne Naess (Kwinters, 2010:104). This environmental philosophy, discussed at length by

Naess (1989), recognises that nature must be valued independently of man's desires or needs. Naess's ideas on Deep Ecology arose from the writings of two philosophers, Bateson and Gauttari. Bateson argues that "*the unit of survival is organism plus the environment*" (Mostafavi, 2010:22). Guattari articulates this notion further through the introduction of the '3 Ecologies'. This concept focuses holistically on the relationships between the environment, social relations and human subjectivity. Guattari elaborates on Bateson's notion of the role that humanity plays in addressing ecological issues through practice and lifestyle, as well as the relationship between group action and the individual responsibility. People are encouraged to engage with the environment in a manner different to that of existing practices so that current ecological problems become opportunities to explore and express a new way of living (Mostafavi, 2010:26). Guattari challenges humanity to engage at a deeper level within their daily lives and take responsibility for their actions. In doing so, people realise the negative impacts their everyday actions have on the natural environment. People therefore become aware of the effects of a consumerist culture on the environment, which results in the removal of non-renewable resources from nature. Thus, a new way of living within the natural environment is defined (Mostafavi, 2010:26). When considering Guattari's approach, design should not only acknowledge the environment, but should use the limitations on resources as an opportunity for innovation.

Naess draws on Guattari's theories in the influential text *Ecology, Community & Lifestyle (*1989*).* The idea of a Deep Ecology is proposed, in which humans are inseparable from nature. People must begin to develop an intuition around the value of nature, which resounds with their individual experiences and attitudes. At its root, Deep Ecology works against the anti-ecological socio-political landscape by employing the two ecological principles of unity and diversity (Naess, 1989:4). This entails an agreement (and thus unity) on issues relating to nature by a group of people who have diverse views and approaches. Deep Ecology is an eco-centric movement that reacts to present unsustainable environmental practices and a lack of policies governing population increases. Our current unsustainable practices are supported by limited ecological knowledge and a lack of specific scientific answers. For example, climate change is a well-known issue, but the exact date at which various catastrophic phenomena will occur is unknown. This leads many to dismiss the ecological crisis, despite it being an important one. Naess (1989:26) suggests that we use this crisis as an opportunity for "*progress, efficiency and rational action".* A similar motivation for a paradigm shift is used by the Ecological Urbanists, explored in in greater detail in Chapter 3. The result of this shift is "*new social forms for co-existence together with a high level of culturally integrated technologies, economic progress… and a less restricted experience of life."* (Naess, 1989:26)

A Deep Ecology is one which looks at the very root of ecological issues. Naess differentiates between a 'shallow' and 'deep' approach: A shallow ecology is anthropocentric, in which people are at the centre of all ecosystems. Thus the conservation of resources and the environment serves only to ensure that people are able to survive across generations. The Brundtland sustainable development model, discussed at the beginning of this chapter, takes the shallow approach to sustainability, wherein the futures of the next generations are secured. A Deep Ecology views people as fundamentally part of nature, each other, other species and our environment. Nature has intrinsic value in itself, and every plant, animal and natural cycle is interconnected with its own intrinsic value, which is separate from man's need to survive.

Ecological problems cannot be solved only through the use of technology. Rather, Naess (1989:97) introduces the idea of soft technologies, which take into account the natural cycles that occur in our environment. Every item is reused and returned to the earth for the next generation. Naess (1989:5) encourages his readers to find their own reasoning process in which the objective is to realise that it is imperative that change occurs in the relationship between man and nature. He uses gestalt principles to show that concepts are nested and viewed through a field of related concepts. A gestalt is a phenomenon wherein a concept is comprised of multiple individual parts, but simultaneously has meaning as a whole and therefore can be perceived in different ways. Singular concepts have an organic identification in themselves, but also form part of a larger network of connecting concepts. This larger network is able to move as a singular entity, which also has its own identity. Thus gestalt thinking does not deal with the concepts of 'either/or', but rather 'both/and' across scales from the micro to the macro and beyond. An example of this idea is found in the term 'milieu'. This is the environment that surrounds us – not just the physical, but all the gestalts in the environment that we identify with. Thus milieu is the plants, earth, insects and animals that make up a forest, as well as the forest itself. A gestalt switch occurs when formerly hidden aspects surface, creating another way of understanding an issue (Naess, 1989:7). In the example of a forest, a gestalt switch may occur when one realises that not only are the organisms in a forest connected, but that these organisms are connected to a greater green network that links multiple natural environments across a landscape. Removing any organism from the forest will affect all forests linked in the natural environment, thus disturbing the fragile ecosystem balance. A person's awareness of being becomes richer when one expands this realisation, as natural landscapes are directly linked with every individual's health and well-being.

Naess proposes that there must be a deeper engagement with a variety of gestalts and the self-realisation that humanity is intrinsically connected to nature. This derivation allows us to locate the gestalt whole clearer. The idea of a greater Self becomes apparent, one in which all organisms, including people, are fundamentally linked with nature. No one organism is considered to be more valuable than another. When people understand that they are part of the greater Self, the realisation that in continuing with current practices of production and consumption, we are hurting the environment and by extension, ourselves, becomes apparent (Naess, 1989:26). This relationship between man and nature is reiterated by the Ecological Urbanists, who explore the value of nature in urban environments. This is discussed in greater depth in Chapter 3.

Despite the criticisms for its idealistic aims, Deep Ecology is recognised as a seminal precursor to other ecological philosophies (Keller, 2008:210). The Deep Ecology philosophy goes beyond the purely anthropogenic perspective, in that it calls for fundamental shifts in the ways in which we live. As we become more in-tune with our greater Selves, we understand that our environment is a fundamental extension of ourselves. The movement calls for people to recognise the intrinsic value of nature through this connection to the environment, and therefore our connection with the greater lifeworld. This concept, that of the intrinsic links between man and nature, is selected as informant 1 in this study.

When considering this idea in the context of architecture, phenomenology could provide an opportunity to enrich the relationship between man and nature through the expressive qualities of architecture.

Phenomenology

Deep Ecology forms part of the philosophical underpinnings of architectural phenomenology, as it is based on the connections between humanity and the way in which the world is experienced. Naess states that *"A joyful experiencing of nature is partially dependent upon a conscious or unconscious development of a sensitivity for qualities*" (Naess, 1979:51). The idea of a 'sensitivity of qualities' may be linked to themes from phenomenology. Phenomenology is defined as "*a return to things*" in the everyday lifeworld (Norberg-Shultz, 1979:129). These 'things', or phenomena, refer to the different elements that comprise a place. The elements may be divided into tangible phenomena, which have shape, texture, colour and substance; and intangible phenomena, which consist of feelings and experiences (Norberg-Shultz, 1979:6). Tangible phenomena may be experienced by the five senses of smell, sight, touch, sound and taste. A place therefore gathers the environment, comprised of different phenomena. Naess (1989: 51) alludes to a similar concept in nature, which contains primary, secondary and tertiary qualities. These qualities include the psychical, sensations and feelings, and perceptually complex elements (such as an open or closed landscape) that make up nature. Thus a place is a total and qualitative phenomenon, which cannot be reduced to its components of tangible or intangible phenomena without losing its concrete nature (Norberg-Shultz, 1976:414).

The structure of a place is defined by space and character (Norberg-Shultz, 1976:415). The structure of a place is not a fixed entity, but may be interpreted in different ways by receiving different phenomena. A space is defined by the organisation of the phenomena that make up a place, i.e. the tangible and intangible phenomena. Gestalts of phenomena determine the essence of a place through its character, or the atmosphere. This essence or spirit of a place is known as the *genius loci* (Norberg-Shultz, 1976:418). Genius loci *"describes places that are deeply memorable for their architectural and experiential qualities"* (Frederick, 2007:9). The genius loci originates from the organisation and articulation of places of spaces and character. Architecturally, space may be articulated through extension, enclosure, centre and rhythm (Norberg-Shultz, 1976:420). Extension refers to the extensions of the building into the environment. Enclosure is defined by the boundary, which will be unpacked in depth shortly. Centre refers to creating a focal gathering point architecturally, while rhythm refers to using architectural elements such as a column to create patterns within a space. Character may be articulated through form and material (Norberg-Shultz, 1976:414). Form refers to the shape of the building. Material refers to the tectonic elements of texture and detail-making used to explain the building.

Situated in this context is man's need to dwell. Through dwelling, man is exposed to the environmental character of a place. Simultaneously, dwelling implies an identification with the environment, in common with Deep Ecology. Through identification, man experiences his environment as meaningful (Norberg-Shultz, 1979:21). When the genius loci is concretised, or made visible, man is able to 'dwell poetically' in a place and not feel lost. A dwelling is therefore a space in which the lived experience occurs. The genius loci may be concretised using certain architectural elements summarised in Figure 8, which will be identified and discussed in the next few paragraphs. Architecturally, dwelling may be facilitated through orientation and identification. Identification allows man to gain an existential foothold through the process of dwelling by forming a bond with the environment (Norberg-Shultz, 1979:19). Orientation comprises of node, path and district (Norberg-Shultz, 1976:416). Paths in and through buildings connect different spaces. Districts are created by gathering different phenomena within a place. Nodes are similar to centres, and are created as focal points within places and buildings.

Through the process of settling in a place, man is able to find his own identity. Gathering, symbolism and visualisation are key aspects of settling, which links to dwelling in a space (Norberg-Shultz, 1979:170). The phenomena comprising a place may be organised to achieve gathering. According to Norberg-Shultz (1979:51), man tends to build what he sees in nature in order to concretise the genius loci of a place by tuning into site factors as a departure point for design. The intention is to make structures in nature more precise through visualising the understanding of the environment across scales. This is aided by a process of symbolism, where man represents his understanding of nature through construction (Norberg-Shultz, 1976:416). Architecture is therefore a way to make human existence meaningful by concretising the genius loci. The building thus becomes an opportunity for the various properties of a place to be gathered close to man, from the smallest detail to the larger built whole. Groat and Wang (2002:x) explain this notion as follows: *"Successful built environments are successful not just because of their physical attributes, but also because of many human considerations. These include subjective preferences, memory, physical comfort…a sense of one's social roles…By understanding human relationships with built forms at these levels, we enhance our ability to create meaningful architecture".*

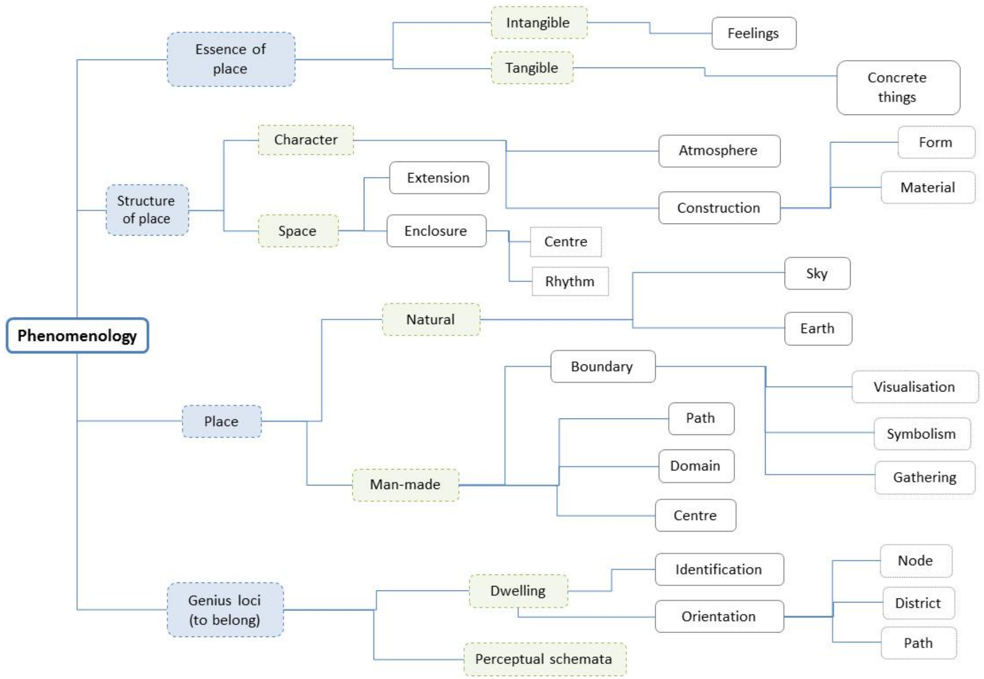


Figure 8: Summarising phenomenological principles drawn from Norberg-Schultz (1979). The main themes of phenomenology are shown in blue and are comprised of sub-elements that may be linked together (Author, 2016).

Norberg-Shultz further defines place as either natural or man-made. In a manner similar to Naess, Norberg-Shultz (1979:23) explains nature as being comprised of multiple, inter-linked phenomena. Natural places are made distinct by the characteristics and relationships between sky and earth, of which either may dominate (Norberg-Shultz, 1979:24). An understanding of this environment implies both an understanding of the concrete representation of mythologies, as well as an acknowledgment of the linked gestalts of nature. The basic elements of the landscape are formed by the relationships between vegetation, water, surface and topography (Norberg-Shultz, 1979:26). These act at variety of scales, from the micro-scaled grain of sand to the macro-scaled mountain. The sky is an important boundary, as it denotes the extent of a space. The genius loci of a natural place is defined by this relationship between earth and sky. In a natural place such as a desert, the sky dominates, while the rising and setting of the sun creates a temporal rhythm. Water sustains life for plants and animals in this landscape, linking to the greater desert ecosystem. Norberg-Shultz (1976:417) suggests that designers should differentiate, make visible and concretise the physical character and essence of a place. Place is therefore defined in reference to the earth and sky. Architecturally, this is articulated through the basic components of a building, in which the roof or ceiling becomes the sky, the walls become the horizon, and the floor becomes the earth.

By contrast, in a man-made place, man's ability to dwell poetically is more complex. The structure, spatial properties and character of such a place is defined by boundaries, which allow for openness and enclosure. (Norberg-Shultz, 1979:59). The boundary itself becomes the transitional zone, which can take the form of the walls, floor, and roof of a building. Openings define the transition between inside and outside space, as well as make light tangible. Norberg-Schultz (1979:59) explains boundary as a space-defining element. The openings in a boundary denote its enclosing properties, and give dis/continuous rhythm and direction. The boundary can either be seen as a limiting element, or as a permeable and changing zone. This can be most accurately demonstrated when viewing an electronic map on a computer. Initially, a river is shown as a single line, drawn over the landscape by the planner. As one zooms closer, it quickly becomes apparent that the element is more than just a line. The river is informed by speed, texture, shape and form, and is influenced over time by cultural, historical and urban development. The landscape dips where the rivers rests, a sinuous element which ebbs and flows according to seasonal changes.

The idea that a boundary is a single line becomes void – it is in fact a transitional zone made up of multiple layers of phenomena across all scales, augmented by past, present and future conditions. Mostafavi (2010:30) supports this notion in Ecological Urbanism, where the blurring of boundaries allows for a greater connection between different areas at the macro- to micro-scales. Heidegger (1971:154) notes that the boundary is "*not that at which something stops, but...that from which something begins its presencing*". The boundary is therefore understood as an ever-shifting element which tends towards another state. This zone allows for change over time and reveals more than what is superficially visible upon first glance. The boundary becomes a nebulous entity in which the tangible and intangible meet to define identity in ourselves and our natural environment.

Although the ideas discussed here may initially appear abstract to the reader, it is evident in Norberg-Schultz's text that man-made and natural places are the references across multiple scales in the making of architecture, explained in a language understood by architects. By explaining built form as an extension of nature into the man-made realm at every scale, the natural environment is acknowledged as an integral part of humanity. Temporal considerations highlight nature in every context, and locate us within the greater lifeworld. Naess (1989) reiterates this: It is only through finding our identity that we are able to connect with each other, other species and the natural environment. In using the five senses to make people more aware of nature at its multiple scales, we can heighten awareness of the greater Self. As our self unfolds to become our Selves, we become connected to the surrounding phenomena and form part of the ecosphere. When this is forgotten, man becomes alienated and there is disruption in the environment (Norberg-Shultz, 1976:425). Thus phenomenology can be linked back to the current state of ecological crisis.

We can draw directly from the natural properties of the sun, wind and views to create architecture that allows the natural environment into our lives. This enables a deeper appreciation of nature, which in turn allows for greater engagement with our current ecological issues. This concept, namely that of using phenomenological principles in order to create opportunities for enhancing the relationship between man and nature through the expressive elements of architecture, is selected as informant 2 in this study. By using the expressive elements of architecture, opportunities are created to use the five senses to heighten the awareness of the greater Self at multiple scales.

Concluding Remarks

In this chapter, the theoretical framework is explored. The chapter began by contextualising the sustainability movement. This is used to demonstrate the need for sustainable architecture, as it deals with ideas relating to man, nature and the environment. The relationship between these three entities is a key theme used throughout this study. Thereafter, Deep Ecology is introduced. Deep Ecology, as a worldview, deals with the links between humans and their environment. It acknowledges the intrinsic value of nature, and situates man as part of the greater Self gestalts that encompasses all natural and living things.

In order to provide opportunities to enhance the relationship between man and nature, phenomenology is introduced, which discusses the expressive elements of architecture. Phenomenology situates the human experience of place. Both the tangible and intangible phenomena between and within nature and buildings contribute to the genius loci of the site. This creates a greater connection between man and nature, thereby allowing for the acknowledgement of the intrinsic value of all entities.

By combining Deep Ecology and phenomenology, the human experience of nature can be heightened in a particular space, thereby extending our inherent Self to include an appreciation for the natural environment. Space- and place-making adds value to the human experience, as we are able to resonate with our environment. This gives value to nature, and therefore to the feasibility of a WSD intervention. The links between man, nature and object becomes apparent. Thus, at the junction between these phenomena, a WSD would be ideally located.

Two key informants are derived from the theory presented: The intrinsic links between man and nature is selected as informant 1 in this study, as derived from Deep Ecology. Using phenomenological principles in order to create opportunities for enhancing the relationship between man and nature through the expressive elements of architecture, is selected as informant 2 in this study. Informant 1 and 2 are developed upon in the next chapters, and both form an idea thread which runs throughout the study.

The next chapter is made up of two parts. Ecological Urbanism examines ecologically-sensitive design and may be applied across the macro-, meso- and micro- scales. Within the Ecological Urbanism umbrella, various WSD initiatives are introduced and unpacked. The role of the architect within WSD is discussed, leading to the generation of values which are derived from the theory presented thus far. These values are used to derive design informants, which then guide the research part of this study. Once this conceptual landscape is introduced, the research strategy of Research by Design is discussed. This assists in contextualising the study to be conducted in uncovering the value of architectural knowledge in a WSD.

Chapter 3| Conceptual Framework

Introduction

The conceptual framework discusses the relationship between the concepts explained in the theoretical framework and the study that will be conducted. It also introduces the research method for the study (Ngulube and Mathipa, 2015:50).

This chapter begins with unpacking ideas around Ecological Urbanism. Ecological Urbanism acknowledges and attempts to deal with ecological issues using design across the macro-, meso- and micro-scales. Further, it explores ideas around ecology, man and ecosystem services. The value of water within ecosystems is discussed, before the various WSD initiatives are located within the Ecological Urbanism umbrella. These initiatives include Water Sensitive Urban Design (WSUD), Sustainable Urban Drainage Systems (SuDS) and Water Sensitive Architectural Design (WSAD). Ecological Urbanism and WSD are premised as a paradigm shift, as both concepts call for new ways of thinking about ecological issues. The role of an architect within WSD is discussed, leading to the identification of a set of values derived from the theory presented thus far. Design informants that may be applied across scales are then derived from this set of values.

Having unpacked the theoretical and conceptual frameworks used to set up this research, RBD is introduced as the method used for conducting the study. The process of inquiry is explained, including the strategy approaches, limitations and means of overcoming these. Actors and projects that have been involved in this research movement are identified in order to contextualise the research method. The conceptual framework concludes with a summary of the themes discussed in this chapter. The design informants from the theoretical and conceptual frameworks are then used to guide the study in Chapter 4 and 5.

Ecological Urbanism

Located at the macro, or urban scale, the Ecological Urbanism design movement is an eco-centric, cyclical model concerned with flows in landscapes. In the introduction to the collection of essays that comprise "Ecological Urbanism", Mostafavi (2010:13) reveals the rationale behind the movement: "*Because the challenges of rapid urbanisation and limited global resources have become much more pressing, there is a need to find alternative design approaches that will consider the large scale. The urban is used as the focus, as it is comprised of complex relationships in the political, social, economic and cultural realms. In order to address both present and future conditions, a complex range of perspectives and responses will be required by designers*".

Ecological Urbanism is presented as a framework that addresses the conflicting ideas of urbanism and ecology. The words 'ecological' and 'urbanism' can be unpacked further to assist in understanding the concept: 'Ecological' is defined in relation to nature and is an eco-centric construct. The ecological component of this study engages with water, which leads to WSD, including WSUDs, SuDS and WSAD. 'Urbanism' deals with cities and buildings, and is therefore defined in relation to people. The components of this include urban planning and design, as well as architecture. There are multiple elements of Ecological Urbanism. These include plants, water, nature, animals, earth, geographical formations, as well as people, cities, buildings, electricity and gathering spaces, to name a few. Each of these aspects is linked and functions together as gestalt systems. When viewing Ecological Urbanism from the anthropocentric standpoint, the goods and services from nature that man can benefit from can be identified. These ecosystem services and benefits are discussed later within this chapter.

In Ecological Urbanism, problems are viewed as opportunities for new design approaches to be defined, similar to that of Deep Ecology. The movement aims to make use of "*old and new methods, tools and techniques in a cross-disciplinary and collaborative approach toward an urbanism viewed through the lens of ecology*" (Mostafavi, 2010:26). It is characterised by diversity, multiplicity, plurality and complexity (Lister, 2010:536). Ecological Urbanism can therefore be defined as the study of interactions and relationships between entities, built form and nature in places where there is a community of people inhabiting a region. When these ideas are viewed through the lens of Deep Ecology, the quality of our lives can be directly linked to the quality of our environment and our connection with nature (Foreman, 2010 and Reed, 2010).

Belanger (2010:347) identifies the need for using and integrating infrastructure as landscape. This is particularly important in any WSUDs intervention in order to connect man-made structures with natural systems. This landscape, containing essential resources, ecosystem services and processes, supports urbanity. Foreman (2010:317) suggests that natural landscapes in urban areas can be improved through planning and design. This notion recognises the dynamic nature of relationships in ecological systems, in which materials move and are exchanged between gestalts. Such a system is successful in that it harnesses an ecosystem's ability to adapt to fluctuating environmental conditions. Felson and Pollock (2010:356) suggest that innovation is required when forming design approaches that deal with ecological issues in order to maintain the fragile relationships between humanity and nature. In a gestalt manner, the city is a living entity with multiple services and relationships between and within entities.

Mori (2010:572) advises that architects must acknowledge the ecological impact their designs have on the environment, especially due to the high resource consumption levels attributed to buildings. A generic solution for an ecologically-suitable building cannot be given (Mori, 2010:577). Instead, a flexible and dynamic site-specific strategy must be developed for vibrancy. "*For buildings to become agents of change, they have to engage the user with their whole physicality. They have to demonstrate a respectful relationship to the natural environment and a certain economy in their use of resources, but at the same time they have to celebrate the joy of being*" (Saurbach, 2010:583). Thus meaningful architecture can only be realised when the site is taken into account, thereby embracing the genius loci of a place.

The Ecological Urbanism movement draws from both Deep Ecology and Phenomenology. Place-making and human identification with the natural environment forms the basis of the movement. Simultaneously, design is highly influenced by present ecological issues and responds with innovative new ideas to enable man to dwell poetically in the environment. For Kwinters (2010:103), "*We especially must not make the mistake of believing that one can detach the human* *and natural from aesthetic and still maintain that we have met the challenge of ecological thinking and ecological praxis*". Naess (1989:55) echoes this idea: man is both part of *and* within nature, which allows him to acknowledge his environment. This environment is more than just the physical or constructed one, but also reflects the memory and values of a place. Importantly, the experience of the place brings it 'place-ness' (Moore, 2010:470).

An ecological aspect of Ecological Urbanism, water, has already been identified as the focus of this project. The problems relating to water management have been contextualised in Chapter 1. However the importance of water has not yet been discussed. All living things depend on water for survival, from microorganisms to greater ecosystems. Equally important for all living things is water for drinking. In a river system, water is both the habitat and a source of life for the organisms in the ecosystem, as seen in Figure 9. Nitrogen and phosphorus are introduced into river waters upstream from sources such as leaf litter, decomposed organisms and wastewater (FISRWG, 2001: 2-36). Microbes feed on fine organic and inorganic matter in the water. By-products created by microbes and riparian plants are fed on by invertebrate micro-organisms. The different invertebrate micro-organisms species may be grouped as shredders, grazers, collectors and predators. These invertebrate species are fed on by fish, which are at the top of the food chain in river systems (FISRWG, 2001: 1-5).

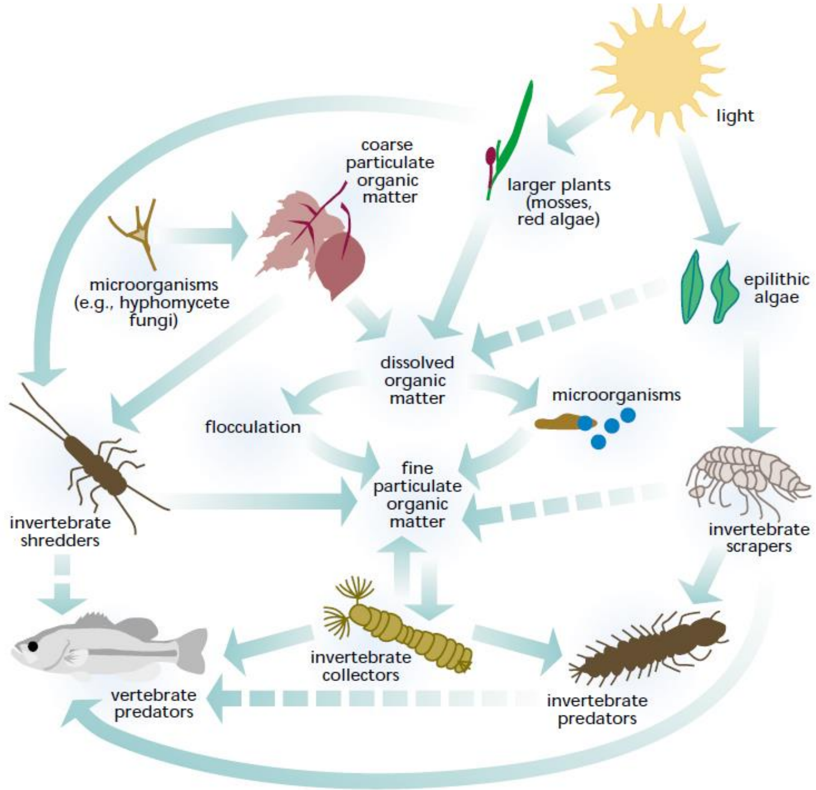


Figure 9: A typical food chain in a river. Organic matter is processed by micro-organisms. By-products produced by these microorganisms feed larger shredder, grazers, collectors and predator invertebrate species. These species are fed on by fish at the top of the food chain (FISRWG, 2001: 2-64r).

However, water in itself is not an isolated element. It forms an essential part of nature, people and plant life. Water therefore rejuvenates ecosystems and must be examined in conjunction with nature, people and the built environment. Thus Ecological Urbanism is valuable in this conceptual framework as it values both humans and nature (and by extension, water). When viewed through the lens of

Ecological Urbanism, water must be fully integrated in urban environments for optimal benefits to man and natural systems. Buildings designed to accommodate for ecosystems and nature could therefore derive the greatest benefit to man. This leads to the WSD approach, which considers buildings, nature and water holistically.

Water Sensitive Design

Globally, buildings consume 40% end-use electricity, 12% freshwater and are responsible for 40% of waste generated (GBCSA, 2013a:3). A building that is designed to accommodate for the natural environment and minimise resource usage therefore becomes a major opportunity to address climate change, resource scarcity and gaseous, liquid and solid waste.

In this study, WSD is defined as building design or planning that is sensitive and considerate to water. Located within WSD are the range of initiatives around water and space planning. These initiatives include Water Sensitive Urban Design (WSUD) and Sustainable Urban Drainage Systems (SuDS). Sisolak and Spataro (2011) and Luthi (2011), identify the key elements of the approach to a successful WSD as efficiency, diversity of water sources, SUDS, alternative sanitation systems, fitness for scale and purpose, and water and nutrient recycling. When applying these WSD principles, the built environment can heighten the properties of recreational value, human well-being, aesthetics and the general ability to dwell with comfort in space. As discussed in Chapter 1, the WRC is investigating the possibility of using WSD principles to strengthen planning for Water Sensitive Cities (WSC). This WRC study looks at the kinds of design that would be appropriate at the urban scale, as well as the interventions that may positively impact on the quality and quantity of adjacent water sources (Carden, 2016:8). As part of this, the WRC has identified key elements of WSD in the urban realm, as shown in Figure 10. Of importance in this study are the aspects seen on the design and planning side of the diagram. These four aspects, that of celebrating local character and community, improving liveability, optimising cost-benefits and providing resilience are discussed in greater detail later in this chapter. First, WSUD as the umbrella concept is elaborated upon.

WSUD is an Australian initiative, which views cities as water supply catchment areas. WSUD aims to "*integrate water cycle management with the built environment through planning and urban design*" (CIRIA, 2013:6). The initiative addresses the impacts of urbanisation on water bodies, thus benefitting both the environment and humanity (Wong, 2013:3). The guidelines react to the various negative effects of urbanisation on water, including the loss of biodiversity and ecosystem functions, issues around flooding in urban areas, deteriorating water quality and diminished groundwater recharging (CoCT, 2011:1).

WSUD assists in the management of water in urban environments. Non-potable water (water that is not safe for human consumption) may be sourced from stormwater and rainwater collected from rooftops (Sisolack and Spataro, 2011:32). This water may be filtered and treated according to its end-use. Non-potable water as a term also refers to water sourced from indoor uses that is not safe for human consumption. This spans the range from grey water, which includes water from sinks, showers or washing machines contaminated with soaps and detergents; and black water, which includes water from kitchens and toilets contaminated with greases, oils, fats and faecal matter (Sisolack and Spataro, 2011:32). Any kind of non-potable water may be treated for potable use in a process involving filtration, bio-filtration and chemical treatments (Sisolack and Spataro, 2011:32).

There are different aspects of WSUD. These include Sustainable Urban Drainage Systems (SuDS) which deals with stormwater management, groundwater management, water supply options including making use of alternative sources of water to reduce the consumption of potable water, and reducing the generation of wastewater and sanitation water (Wong, 2006:2, Armitage et al, 2014:x). Wong (2006:1) notes that the focus of WSUDs has shifted from one primarily concerned with stormwater management to a more holistic framework for sustainable urban water management and WSC's. WSUD signifies a paradigm shift from a linear and techno-centric water management model, to one that involves a circular metabolism and is ecocentric. (Brown et al, 2008:2). This same paradigm shift can be explained when contextualising Deep Ecology, which requires a modification of our norms and values. Naess (1989:97) introduces soft technologies, which take into account the naturally-occurring cycles in our environment. In a similar way, WSUD moves towards a cyclical and environment-focused way of planning urban areas, moving away from the wasteful effects of a linear, technologically-focused design.

SuDS, as an element of WSUD, was used as one of the primary informants for the spatial and system design of D1. SuDS mimics natural drainage systems through a variety of technologies in order to restore natural flow systems in the urban environment (CoCT, 2011:2). In doing so, SuDS aims for the management of the quality and quantity of stormwater run-off, as well as enhancing the biodiversity and amenity of urban drainage systems (Armitage et al, 2013:iii).

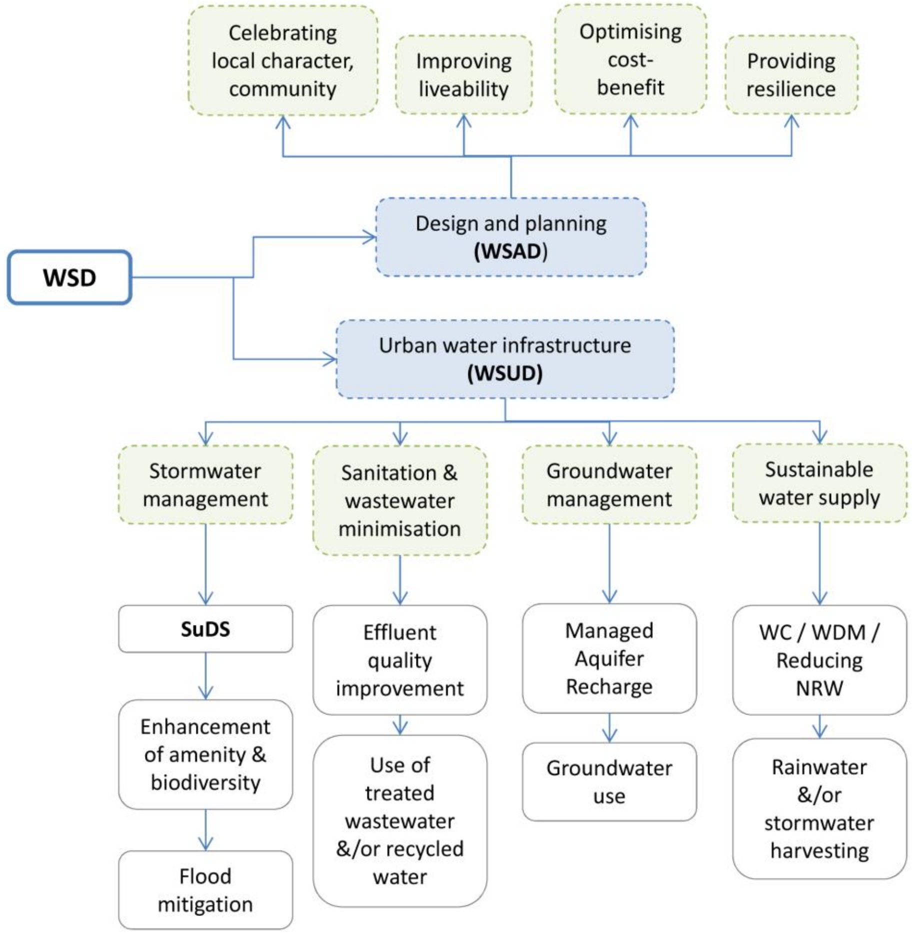


Figure 10: Key elements of WSD in the urban realm, focusing on WSUD and WSAD. In this study, the ideas within design and planning are most relevant (Author, 2016. Adapted from Carden, 2016).

The negative impacts of stormwater on the environment may be addressed by focusing on these four values in SuDS. In this scope, the quality of water refers to increasing the overall water quality of water run-off using passive technologies. Stormwater quality management focuses on sedimentation, filtration, biofiltration, adsorption, biodegradation, volatilisation, precipitation, plant-uptake, nitrification and photosynthesis (Grant, 2011:4). The quantity of water refers to managing the flow and volume of the water run-off in the chosen area by reducing it using passive technologies. This includes investigating rainwater harvesting as an alternative water source, and the infiltration, detention, conveyance, long-term and extended storage of water.

Amenity is focused on people. It refers to health and safety, recreation, aesthetics, environmental risk management and assessment, education and awareness through the use of SuDS principles (Armitage et al, 2013:4). Biodiversity refers to increasing and maintaining the biodiversity in the chosen area through the introduction of passive technologies which provide habitats for the settlement of diverse fauna and flora. This includes the protection, maintenance and monitoring of the chosen area (Armitage et al, 2013:4).

Different SuDS controls are used in order to mitigate the detrimental effects of stormwater mismanagement on receiving water bodies. Non-structural measures include planning and developmental controls which reduce pollution and the volume of stormwater to be dealt with. Structural controls are engineered elements which are designed to improve the quality of water. These include filter strips, swales, infiltration, green roofs and permeable paving among others (Grant, 2011:19). The different SUDS elements may be linked sequentially to form a treatment train, which was done in D1 (Armitage et al, 2013:4). This treatment train is fully integrated into the landscape at different scales, and forms levels of water filters. The cumulative effect of these filters is an improvement on the four values of water quality, water quantity, amenity and biodiversity (Armitage et al, 2013:4). The selection of the elements is dependent on the site, and act at a range of scales. Vegetation and soils used for these controls must be carefully selected in order to maximise filtration capacity (CoCT, 2011:4). Armitage (2013:6) suggests that a SUDS treatment train may provide several ecosystem services.

Ecosystem services, a term mentioned earlier in this chapter, are *"the benefits people obtain from ecosystems… The human species, while buffered against environmental changes by culture and technology, is fundamentally dependent on the flow of ecosystem services"* (ME, 2005:V). Through the use of SUDS, the following ecosystem services may be supported: regulated climate and water supply, water and air purification, erosion and sediment control, waste treatment, habitat functions, mitigation of hazards, and human-related benefits (Armitage, 2013:6). ME (2005:V) differentiates between four types of ecosystem services which are represented graphically in Figure 11. Provisioning services include food, water, energy, raw materials, bio-chemicals and genetic resources. Regulating services regulate water, climate and disease. Cultural services include those of aesthetic, educational, spiritual and recreational benefit. Supporting services deal with soil formation, photosynthesis and nutrient cycling (Sanya, 2016:3 and ME, 2015:V). Ecosystem services are an essential part of life for people, who depend upon the goods and services derived from natural systems in order to survive. These services are important informants for a water-sensitive proposal that considers the scales of the macro, meso and micro.

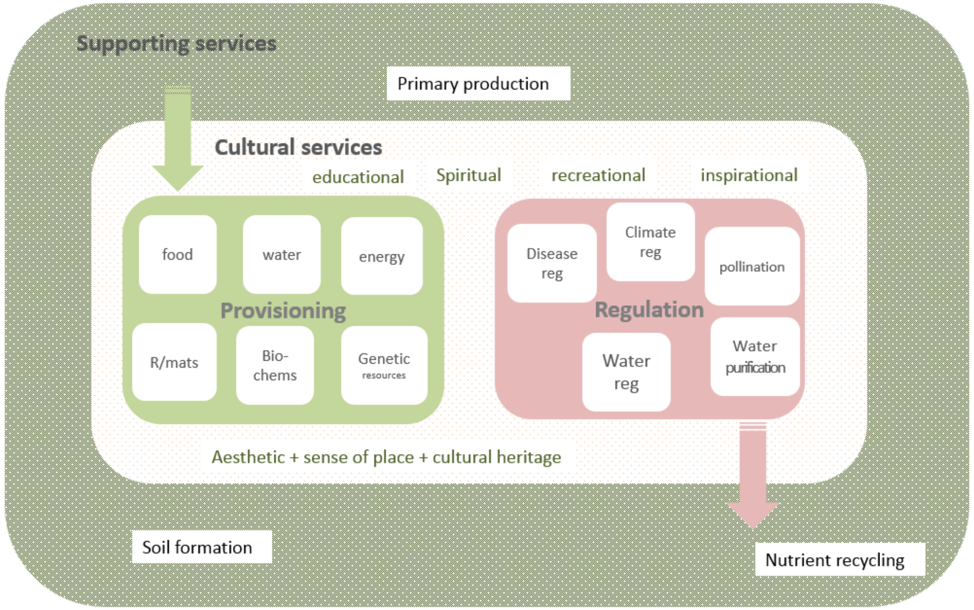


Figure 11: The four types of ecosystem services are interlinked, as shown in this diagram. Ecosystem services are used to generate design imperatives in this study (Sanya, 2014:3).

A successful WSC is one where water is carefully considered at all scales throughout the city and where water-sensitive initiatives are fully integrated throughout the design. WSUD is the process that is used to create WSC (CIRIA, 2013:6). Brown et al (2008:2) argue for a paradigm shift when looking at WSC through the transitions framework. The transitions framework deals with the times in history when changes have occurred around urban water management due to social and institutional factors. Each transition in history is marked by its own complexities and challenges. A WSC is characterised by three key aspects which are integrated into the urban fabric: First, different centralised and decentralised infrastructures facilitate access to a variety of different water sources. Second, ecosystem services for natural and man-made environments are provided. Finally, sustainability is driven by socio-politics. As a result of the transitions framework, communities experience an ecologically-sustainable lifestyle which acknowledges the symbiotic relationship between natural and man-made environments (Wong, 2009).

Complexities around WSUD appear to be at the level of implementation. In Australia, Murphy et al (2009) note the issues that arise when trying to implement WSUD. These include the hydro-geological setting, the perception that WSUD costs more than conventional systems to maintain, a lack of knowledge and a lack of integration across disciplines. However, when successfully implemented, water in urban areas becomes a space for recreation, provides passive cooling and is a source of quality water (Wong, 2009). While WSUD can be said to be idealistic, it is a bold attempt at addressing key issues around water management in urban environments.

A WSD offers multiple benefits to the built environment, people and nature when considering the benefits derived from its components of WSUD, WSAD and SuDS. The water quality of stormwater run-off can be increased, while stormwater run-off volume and flow could be decreased in urban areas. An improved water quality reduces the possibility for the growth of disease-causing pathogens. An improved water quality also introduces a higher quality of water into the adjacent environment, while the decrease in run-off flow prevents the degradation of the environment through erosion. Making use of alternative water sources such as rainwater harvesting decreases the amount of stormwater run-off, as well as reduces the demand on potable water. Recycling wastewater reduces wastage of useable water, decreases potable water demand and ensures water usage for sanitation is minimised. Groundwater is replenished through groundwater recharge from WSUD approaches. Flood attenuation is enabled as soils are able to retain excess water.

Water treatments, both naturally occurring and man-made, have three key stages. This includes sedimentation, wherein solid particles are settled out of water; the breakdown of organic matter by anaerobic or aerobic bacteria; and the removal of nutrients (Pescod, 1992; US EPA, 1988:4; Sisolack and Spataro, 2011:79). Pollutants of water at the micro-scale include nitrates, phosphates and pathogenic micro-organisms. Dissolved salts, fats and oils, heavy metals and non-dissolvable organic compounds also pollute water (Sanya, 2016). These elements are usually filtered out in the biological filtration phase of wastewater treatments. Biochemical Oxygen Demand (BoD) measures the amount of oxygen required to break down nutrients in water by microorganisms. A high BoD and eutrophication are the results of incomplete treatment of water, resulting in a decreased water quality, as well as insufficient oxygen available in the water for fauna and flora (Penn et al, 1997:278). Unlike conventional centralised treatment systems, bio-filtration purifies water through the natural means of settling, anaerobic processes and the removal of excess nutrients by plant and animal species. These may be considered at the subterranean, aquatic, terrestrial and atmospheric levels, as shown in Figure 12 (FISRWG, 2001). At the subterranean level, water and air are filtered through permeable soils, allowing heavy particles to settle out. Bacteria then break down nutrients in the water in anaerobic and aerobic processes (US EPA, 1988:2). Bacteria, animals, insects, plants and microorganisms form a food chain that depends on water ingress through soil.

In the aquatic environment, animals, plants, fish, amphibians, microorganisms benefit from a healthy and clean habitat (FISRWG, 2001:2-64r). Organic matter is broken down by bacteria, which are then fed on by shredder, collector, scraper and predator invertebrate microorganisms. These are preyed upon by fish and other amphibians. Bacteria growing on plant roots suspended in water break down excess nutrients (US EPA, 1988:2). Water is shaded by overhanging plants, preventing the growth of algae and reducing the leaching of gasses by winds. Water flow and pollution is minimised, thus creating a healthy ecosystem.

At the terrestrial level, trees, animals, plants, insects, microorganisms benefit from habitat creation and access to clean water and air. Purification of water through sedimentation and biofiltration ensures the removal of excess nutrients and pathogens (FISRWG, 2001). As a result of the bio-filtration process, birds, airborne insects, microorganisms have access to clean and healthy food and water. Benefits to people, fauna and flora occur at multiple scales when using the WSD approach. A WSD allows for the creation of plant and animal habitats which are aesthetically pleasing and provide ecosystem benefits.

Wong (2013:13) suggests that a WSD is able to make visible the relationships between water and landscape by creating a network of blue and green passages. This creates multiple spaces which celebrate nature and situate humanity within this.

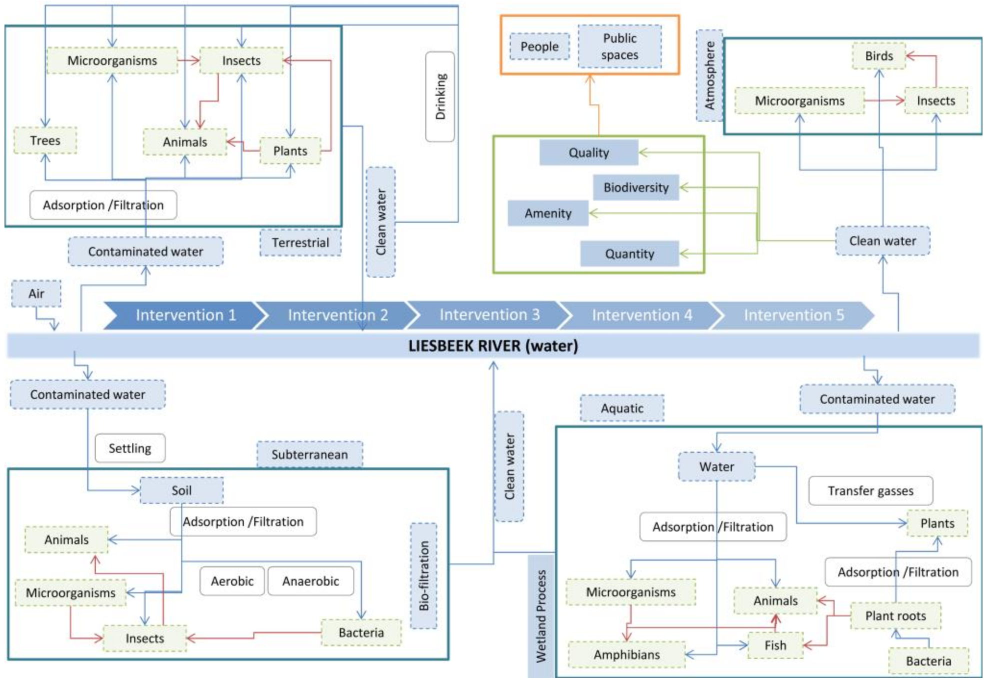


Figure 12: Ecosystem benefits when using WSD. The diagram indicates a cyclical flow between water, fauna and flora in this riparian ecosystem (Author, 2016, using information from US EPA, 1988;2).

All blue-green areas must be connected across the city in order to survive and thrive. By implementing WSD in different areas over time, ecosystems are rejuvenated first locally and then across the entire blue-green network. This enables cross-pollination, movement of fauna and flora across the land, and an increase in the overall quality of water and ecosystems across the city. A healthy ecosystem provides recreational and aesthetic benefits to man, as well as educating people on the importance of the links between clean water and the environment. Soil formation and nutrient cycling can be supported in such an ecosystem. Agriculture becomes a sustainable and low-impact option for using land and water to provide food for people and animals. Flora, including trees, shrubs and bushes, small plants and seedlings, weedy flora and microflora have healthy habitats in which to thrive (FISRWG, 2001). This draws fauna, including large animals, small animals, birds, insects and microorganisms. The benefits of the WSD approach are thus experienced across scales. In the SUDS guidelines for South Africa, Armitage (2013:7) recognises that the architect (and landscape architect) brings value in conceptualising infrastructure and aesthetics within the WSD realm. This shows an important link between WSUD and the use of WDS principles at the architectural level. The architect is therefore ideally placed to create sustainable urban spaces that are informed by WSD.

Deriving Design Imperatives

In this study, Water Sensitive Architectural Design (WSAD) is introduced as a new neologism to refer to sustainable architectural design relating to water management at the scale of the building. To the author's knowledge, there has been little engagement with the links between water and design at the architectural scale in the South African context. Thus, WSAD as a concept has not been discussed in current literature. This research is perhaps the first to offer a WASD framework based on analyses as described in text. A WSAD falls under WSD, and makes use of principles drawn from the different water-related initiatives proposed by other disciplines to address questions relating to water and ecology at the scale of the building. This study focuses on the creation of a successful WSAD. Having explored the pertinent themes around Ecological Urbanism, a few questions arise which relate to the objectives of this study:

- How could one derive value from the two concepts of 'ecological' and 'urbanism', taking into account the theoretical framework presented?
- How could these values be useful in this study?

These questions are linked to the objectives of the study, which deal with identifying the major design leverage points of a WSD and how these points may inform water-sensitive design for future buildings. The values identified from Ecological Urbanism could be used to derive the specific design leverage points and moves an architect could make in a WSAD at the micro-scale of the building, which will impact upon the macro- and meso-scales that contextualise the building. The design moves made can therefore be directly linked to the theoretical and conceptual frameworks presented here. From Carden (2016), four key aspects relating to the design and planning for a WSUD are identified: celebrating local character and community, improving liveability, optimising cost-benefits and providing resilience. These aspects could be integrated into a WSAD. The success of a WSAD that makes use of such design moves to fully integrate water into the proposal would need to be evaluated. The evaluation aims may be arranged into two groups: first, how well the design has met the research objectives. This is defined by means of values derived from the conceptual and theoretical frameworks. Second, how well the design has aligned to the research method criteria. This is defined by the pre- effects analysis criteria as set out by De Jong and van der Voordt (2002) for RBD, which is identified here but discussed in greater detail later in this chapter.

Two design informants guiding this study have already been identified in Chapter 2: These are the intrinsic links between man and nature; and using phenomenological principles to create opportunities for enhancing the relationship between man and nature through the expressive elements of architecture. Building upon this, the values derived from Ecological Urbanism can be understood as follows: the ecological objective of a WSAD is to facilitate conservation, enhancement and creation for the ecosystem's health, diversity and resilience. The design imperatives or moves to achieve this ecological objective across scales must therefore be uncovered. These design imperatives may be derived from the ecosystem services, which are divided into expressive and functional values, demonstrated graphically in Figure 13. In this study, expressive values are derived from cultural ecosystem services and focus on the human experience. These values dealing with aesthetics, sense of place, spiritual value, cultural landscapes and educational value may be addressed by phenomenological principles. Functional values are derived from the regulatory, provisioning and supporting ecosystem services. These values deal with the functioning of a system and are addressed using the different WSD initiatives discussed under Ecological Urbanism. Important to note is the distinction between instrumental and intrinsic value. Intrinsic value deals with value in itself, while instrumental value refers to value in terms of means. Ecosystem services relate mainly to instrumental value, because value is given through the services provided. By using these values, how well the design has met the research objectives may be evaluated.

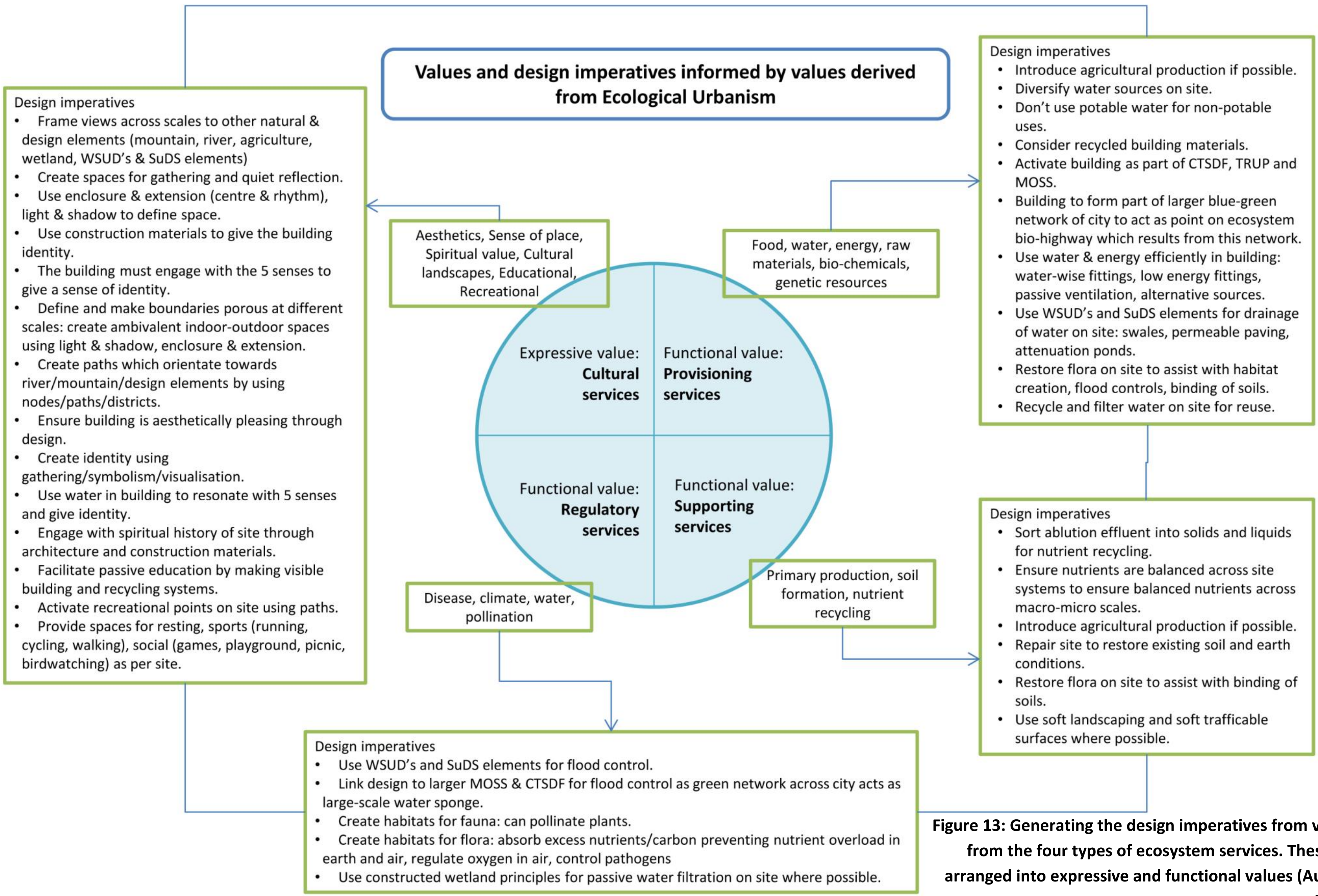


Figure 13: Generating the design imperatives from values from the four types of ecosystem services. These are arranged into expressive and functional values (Author, 2016).

The second evaluation deals with how well the design has met the research method criteria. This relates to the pre-analysis criteria for RBD as the research method used in this study and will be discussed in depth shortly. As the prelude to this discussion, the following pre-analysis criteria are identified by De Jong and van der Voordt. (2002):

- Explicitness & Expressiveness: This criterion deals with the legibility of a plan. From the plan, one should quickly be able to understand the concept of the design, as well as understand the arrangement of spaces.
- Comparability: Plans must be of equal scale and legend.
- Documentation & recoverability: The documentation of the design process must be conducted in such a manner that recoverability is easily achievable.
- Context & perspective: The political, cultural, technical, economic and ecological aspects of the building must be established.

Further to these criteria, the design should be 'robust'. A robust design is one that is successfully able to accommodate programmes across scales (De Jong, 2002:174, Bacchin, 2013:1). Further explanation is given for each pre-analysis criterion in Chapter 5, where the final design iteration is evaluated.

Research Method

A *research method* is defined as the manner by which to study the process of inquiry (Groat and Wang, 2002:10). This is the action plan for the process of beginning at a research question and progressing to deriving knowledge from the research study. In architecture, knowledge of a vast array of phenomena is required, which results in a number of items that need to be identified when looking at a research method (Frederick, 2007:20). In this study, a qualitative framework is used, which deals with non-numerical evidence and allows for the understanding of a process (Flick, 2007b:3). A qualitative approach tends to be holistic and divergent, which is what this study aims for (Groat and Wang, 2002:178). Attributes include an open-ended approach to both the theoretical concepts used and the design of the research itself; analysis through text; the researcher as the primary device of measurement and a subjective approach to writing style. Groat and Wang (2002:176) note a few characteristics of a qualitative strategy in architecture, highlighted below:

- The natural settings of the building are emphasised. The context and setting of the building are a key part of the architecture, as the building is not studied in isolation. This links to the integration of the building across scales when considering the ecosystem services and benefits generated from a WSAD.
- Interpretation and meaning is focused upon. The value of the architect in the interaction with the subject studied is acknowledged. The role of

interpretation and creation are important aspects in the findings of the study.

The *strategy* is defined as the structure of the study and over-arching research plan (Groat and Wang, 2002:10). In this study, the method is based on RBD, supported by phenomenology and Ecological Urbanism. RBD deals with research and new knowledge generated through the process of design. Design itself is a reflective process, in which the architect poses a question and generates various complex solutions. Each solution is tested based on an evaluation of programme, context and knowledge (Hauberg, 2011:50).

The *tactics* used are defined as the specific techniques that are made use of in order to conduct the study (Groat and Wang, 2002:10). A literature review is used to understand the current theoretical and conceptual landscape surrounding water-sensitive design. This has been done in Chapters 2 and 3. Through the course of this research, the aim is to connect the topic of inquiry to existing knowledge. Literature reviews are beneficial as large amounts of information can be synthesized in order to gain an understanding of the current philosophical landscape. The main tactic for the analysis of D1 is a process by which data from D1 is collected, displayed and interpreted. Subsequent design iterations are subjected to a series of participant analyses in order to find the best-fit solution. Conclusions are drawn from these data through pattern identification, explanatory concepts and evaluative interpretations. The researcher must seek to be reflexive and critically asses the data as well as take into account personal bias (Flick, 2007a:101). This tactic is discussed later in this chapter. For now, the focus returns to RBD.

Research by Design

In 1993, Freyling introduced points of distinction and interaction between research and design (Godin & Zahedi, 2014:1). Findeli then refined Freyling's ideas as three forms of design research: Research *for* design looks at guiding and developing design practise, in which designers and their practices become the object of study. Research *into* design, which documents phenomena, materials and the histories of design, occurs mainly at university level. Research *through*, or *by* design, is embedded within the design process (Godin & Zahedi, 2014:2). RBD is specific to architecture, while research through design covers all the other disciplines. Godin & Zahedi (2014:1) state that RBD *"takes advantage of the unique insights gained through design practice in order to better understand complex and future-orientated issues in the design fields."* Multiple methods exist for doing this kind of study. Research through design was first used in the Human-Computer Interaction (HCI) field, before spreading into the design fields (Zimmerman et al, 2007:494). The HCI literature on research through design can be arranged into five aspects, described below:

- The ontological deals with the reality that can be proved through research through design. This includes analysis, or what it is; projection, or what it could be; and synthesis, or what it should be.

- The epistemological deals with what can be learnt. Importantly, research through design cannot be validated by the standard method of replication, as every designer will approach a problem differently.

Instead, validity is obtained through recoverability (Godin & Zahedi, 2014:7).

Recoverability is a key aspect of this research method. It deals with documenting the design process in order for another person to perform the same moves to arrive at the same design. By doing so, the design and rationale is fully considered. Credibility of the process is achieved as the design becomes replicable when following the same 'formula' to arrive at the design end-product.

- The expected contributions deal with the knowledge that is expected to be gained. Design becomes *"a reflective practice where designers reflect back on the actions taken in order to improve design methodology"* (Godin & Zahedi, 2014:8). This is separated into reflection in-action, which is during the design process; or reflection on-action, which is after the design process.

- The most important aspect is the documentation of the process so that anyone might recover the design process.

- Finally, Godin and Zahedi (2014:10) identify a limit to research through design. Knowledge associated with practice, called tacit, personal or experiential knowledge is difficult to define using language. This is because it is embedded within the design process and artefacts. This issue will be discussed in greater depth shortly.

These five aspects of research through design are carried through to RBD, which is a relatively new research method within the architectural realm. RBD is essentially a process in which the researcher generalises and rationalises by extracting rules from an object or drawing about the process of design. Hauberg (2011:52) calls this process nomothetic research. In 2012, The European Association of Architects defined RBD as *"any kind of inquiry in which the architectural design process forms the pathway through which new insights, knowledge, practices or products come into being."* (Verbeke, 2012:11). In the book *Ways to Study and Research,* De Jong and Van Der Voordt (2002) compiled a collection of essays which discuss the different ways to use RBD in the academic architectural context. The authors identify the process as generating new design variations using design itself as the process for the study. This generates new concepts and an understanding of the implications of design decisions.

There are various methods for researching by design. In architecture, RBD is an interactive, open-ended iterative approach, wherein the researcher is a key part of the outcome of the design. The researcher enters into the study without preconceptions. By doing so, the researcher allows the resulting concepts to emerge and surface from the data collected. New knowledge is generated through the design process, which generates critical inquiry through design (Hendrickx, 2008a:269). This research is done by continuously proposing and projecting solutions, evaluating, adapting problems and repeating the process. Data collection and analysis must take place on an iterative level in order for knowledge and ideas to emerge. Thus, process work is used as evidence for the best-fit solutions (Groat and Wang, 2002:179). In this way, the research method and the design process follow the same structure, where ideas are distilled and reworked into new questions.

Canons

Globally, there are various conferences that deal with different aspects of RBD. PhD by Design, the Research through Design Conference and the Design Research Society are active in the dissemination of practice-based design research. These consist of workshop sessions covering making and outputs, supported by questions posed by delegates. The Research Training Seminars, held by the Delft University of Technology, are the most relevant within the architectural sphere. Literature from this series of workshops is collected as published volumes, known as the *Reflections+* series. The contributors explain RBD as an experimental approach to develop alternate strategies for knowledge in architecture and design. In doing so, knowledge is generated when the outcomes derived transcend from only applying to one design to something that may be considered at the more general level.

Reflections+3 focused on the foundational elements of RBD: Reflection is the continuous process that generates new questions and ideas, in which the design is documented in order to understand the process and product (Janssens et al, 2006). This allows for communication and criticism. Reflection ends when something is considered 'good enough'. This phrase refers to satisfying the design brief, as well as the subjective notion the designer has when they consider the design to have met all the design criteria set out by the brief. Knowledge is produced through reflection at all stages of the design/analysis process. This design/analysis process is documented, communicated and reflected upon. Finally, writing becomes the tool through which to research (Janssens et al, 2006). The successive Research Training Seminars have built upon these foundational aspects.

As an example, Hendrickx (2008a:273) examines interactive architectural design through the use of a 3D gaming program. Buildings are constructed in a virtual landscape in a first-person shooter game, which actively allows players to use and explore space. Hendrickx (2008a:273) carried out a series of experiments within this virtual landscape. Figure 14 refers to an exercise in designing a family house. The children in this family were able to give feedback on their rooms through exploring the house using the 3D software. Hendrickx's findings suggest that 3D gaming software can allow for the communication of the expressive aspects of architecture that may not be able to be shown using other media.

Figure 14: Designing a house using virtual reality (Hendrickx,2008a:273).

Issues and Solutions

In general, there are two distinct research focus areas in research as a whole: Science-based research has a formal methodology for generating new knowledge:

a question is posed, a test is executed and is either proved correct or not, which results in a discussion. Science-based research focuses on providing explanations using linear methods and the exact, which can be proven and tested (Hauberg, 2011:47). Humanities-based knowledge is concerned with theories. The research can be considered subjective, as it involves a discussion and argument in order to prove or disprove a theory (Hauberg, 2011:47). Architectural knowledge straddles both these realms (Hauberg, 2011:47). Research is generated from design involving drawings and models. This raw data embodies both ideas as well as documents a process of testing solutions. A design sketch therefore is the architect's attempt at rationalising solutions to a problem through testing and selecting in an iterative manner.

The Royal Institute of British Architects (RIBA) elaborates on this by presenting three arguments (Till, 2005). The first argument given is that architecture is wildly different from any other discipline and therefore cannot be subjected to the same norms. The second argument is that in order to establish credibility, architecture must be subservient to the authority of other disciplines. The method to be followed therefore must be from another discipline. Architectural research is thus confined in this manner. The final argument given is that there is little acknowledgment between research in practice and the academic world. To solve this, RIBA suggests that the products and performance of architecture must be informed by the knowledge produced during the design process, which thus entails RBD.

Niedderer (2007) explores this problem further, with reference to the meaning and relevance of design-based research. The author identifies different types of knowledge: Propositional knowledge is easily explained through language, and describes knowledge that can be taken as true belief. This is associated with explicit knowledge, which is knowledge that is easily articulated. Procedural knowledge is practical or skills-based, while experiential knowledge is gained through experiences. Procedural and experiential knowledge are linked to tacit knowledge, which is not as easily defined as explicit knowledge (Niedderer, 2007:7). However, all these forms of knowledge are linked and overlap. Niedderer (2007:11) notes that the problem with non-propositional knowledge (and therefore design-based knowledge) is that it does not conform to the conventions of establishing knowledge in the linear sense. In principle, tacit knowledge can be included in an academic study as rigorous research, as non-propositional knowledge contains propositional content which can be made explicit through analysis and evaluation post-design. Further, Niedderer (2007:11) finds two issues with design-based research. The first is that methodologies are undefined, which results in a loose use of design in theoretical studies. This causes limitations in the recognition of the validity of arguments. To overcome this, it is suggested that tacit knowledge be correctly framed within the research, and that the intrinsic value of this knowledge be acknowledged. The second issue deals with the way in which tacit knowledge is communicated. Niedderer suggests this might be made more explicit through research into methodology.

In this study, tacit knowledge includes that which is generated by analytical sketches. The value of this knowledge is important in the RBD process. An effort is made to make this research as explicit as possible, using descriptive and interpretative analyses to explain the design process. The actual process of RBD depends heavily upon the project being evaluated and the outcomes sought.

Multiple solutions exist that may satisfy the requirements of the brief for the chosen building. It must be iterated that the design solution presented in this study may not be what other designers would consider the best-fit solution. Architecture is a subjective field, and therefore what is considered 'good enough' for one designer may not be true for another designer. The point of research done using RBD is to open up possibilities instead of proposing an actual solution (Shaeverbeke, 2009:149). When considering this idea, RBD is selected as the ideal method for this kind of study. The objective of this study is not to create an ideal version of a WSAD. Rather, the objective is to create a building which displays all the design imperatives discussed in the theoretical and conceptual frameworks thus far.

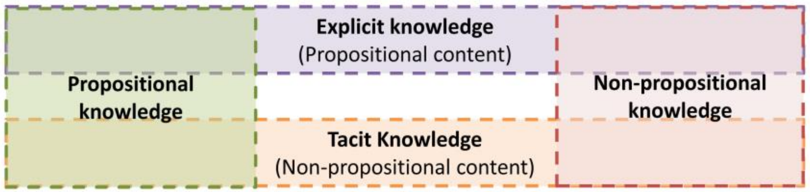


Figure 15: Locating types of knowledge (Author, 2016; adapted from Niedderer, 2007:7).

RBD in this Study

In this study, the process for using RBD is as follows: The raw data from D1 are collected and described. This raw data consists of process work, renders, drawings, models and a text summarising the design process and product. The data is analysed using explanatory interpretations and analytical sketches against the design imperatives generated from the theoretical and conceptual frameworks presented. Further, the author identifies strengths and weaknesses of the design with regards to the functional and expressive aspects of the building. Effectively, the designer reflects on the design by continuing to design (Jakimovicz et al, 2010:45).

Various specialists were consulted during this iterative analysis stage. The focus of the interviews with these specialists was to ask questions about the building, with the aim of optimising the building's design. The topics of discussion referred to the optimisation of the architectural design to create a successful and practical WSAD. The interview stage of the research study involved an analysis of the design by the participants, and a subsequent development of the design in reaction to the comments and resultant thoughts that arose from the exercise. The interviews were limited by time and the availability of the specialists, as well as the personal bias of the interviewee. A conscious effort was made to ensure that the interview information was used without bias.

The study as presented thus far is shown diagrammatically in Figure 16. Importantly, it must be mentioned that a range of possible best-fit design solutions exist. It is through testing alternatives that the most suitable design is uncovered. The study concludes with an effects analysis of the final design iteration presented. This compares the design as it is (ie D1) to what it could be (ie the final design iteration). This method was chosen as it reveals multiple aspects of the design. Through this process, it is hoped that new knowledge relating to WSAD may be generated by generalising and rationalising rules about the process of design.

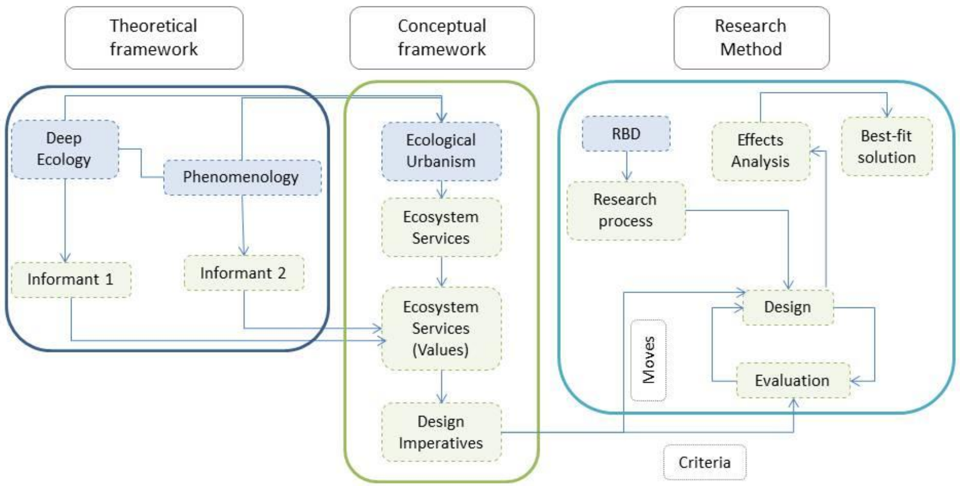


Figure 16: The links between the conceptual framework, theoretical framework and the research method used in this study (Author, 2016).

Concluding Remarks

This chapter documents the conceptual framework developed for this study. The conceptual framework delves further into the relationship between man, nature and the environment, which is a key theme used throughout this study. The conceptual framework began by exploring Ecological Urbanism, which is shown to have links to Deep Ecology and Phenomenology. Ecological Urbanism is a macro-scale movement that deals with the flows and relationships between nature and the built environment in the urban landscape. The term 'Ecological Urbanism' is unpacked in order to derive meaning around nature and man. The multiple natural and man-made aspects of Ecological Urbanism function together in gestalt systems. Pertinent points from the literature reviewed are discussed. These include the integration of urban infrastructure with the natural landscape, that architects must develop site-specific solutions which consider the ecological impact the building has on the environment, and that man is a part of nature, which thus references Deep Ecology.

Water, as an aspect of Ecological Urbanism, is then explored in terms of its value. This leads to the WSD approach to design and planning, which considers water at every stage of the design. WSD comprises a variety of initiatives, one of which is WSUD. WSUD deals with integrated urban water management through the use of passive technologies. Within this WSUD umbrella is SuDS, which deals specifically with stormwater management in the urban environment. SuDS aims to improve the amenity, biodiversity, water quality and quantity values associated with water. As part of this, ecosystem services are explored. Ecosystem services are all the goods and services generated by nature which man benefits from, and are essential for man's survival. The transitions framework is then introduced, which considers the WSC that benefits from a WSD approach. The benefits of WSD to people and nature are then explored from the micro- to macro-scale in order to demonstrate the value of a WSD approach.

WSAD is then introduced. WSAD refers to architectural design which has water at its core. After exploring key themes within Deep Ecology, phenomenology and Ecological Urbanism, the question of how value can be derived from these concepts is raised. Two evaluation criteria are identified: first, how well the design has met the research objectives. This is defined by values derived from ecosystem services which inform a set of design imperatives. These design imperatives are used to guide the study going forward. Second, how well the design has met the research method criteria. This is defined by the pre- effects analysis criteria for RBD.

Having understood Ecological Urbanism, the focus moves to RBD as the method chosen for conducting this study. As a relatively new method within the architectural sphere, RBD is unpacked to understand its history and general themes. Previous research in this field is explored, and the issues and solutions presented by the pertinent literature reviewed are noted. The method for using RBD in this study is then explained.

The next chapter deals with the study to be conducted. D1 is unpacked through documentation of the raw data. This consists of models, drawings and text of the process and product work. The second part of the chapter deals with the analysis of D1 using RDB, informed by the theoretical and conceptual frameworks.

Chapter 4| Data and Analysis

Chapter 4 is divided into two parts. First, the raw data from D1 is described. This raw data consists of images, drawings, mappings, models and renders of the design process and final product. To give context to D1, the conceptual underpinnings used to inform the design are explained. This includes an exploration of the historical, architectural, natural and cultural boundaries of the site. WSUD, SuDS and constructed wetlands were major informants of D1's design, and were investigated through a technical exploration. The design process and the final building are then presented. Each stage of this process is presented roughly in chronological order, so as to display the design process. However, it must be noted that the design process is rarely linear.

The second part of Chapter 4 deals with the RBD process used in this study for uncovering knowledge around WSAD using D1 as the unit of analysis. This analysis process is conducted using sketches that consider the building at the macro-, meso- and micro-scales. All sketches done during this process are compiled in the appendix. The most important sketches are selected for discussion in-text. In this RBD process, D1 is analysed to pin-point the strengths, weaknesses and opportunities of the design. These aspects are informed by the design imperatives, as well as themes from the theoretical and conceptual frameworks. An evaluation informed by the author's opinion based on experience, knowledge in the field and spatial perceptions is then performed.

To aid in understanding, key diagrams are used throughout this chapter in order to quickly and succinctly describe the design moves discussed. As this research is qualitative, the author plays a major role in the direction of the research. The author's options are revealed throughout this chapter. These opinions are informed by gut feelings, experience and factual research done into WSD initiatives. It must be noted that architecture, like all design fields, is highly subjective. Rationales for the design moves are explained as far as possible in order for the reader to understand the train of thought. However, it is not expected that the reader agree with all or any of the thoughts presented. Rather, the objective of this chapter is to demonstrate the process that lead to the design decisions made.

The outcomes of the analysis of D1 are used to inform a new design, coded as D2. D2 is evaluated by various specialists according to the design imperatives, which become the criteria for evaluation of a WSAD. These specialists were chosen from the variety of fields from which knowledge was drawn to inform D1. In the spirit of RBD, further design iterations are required to begin uncovering patterns for knowledge-building. D3 was the result of this participant analysis. D3 was subjected to a series of discussions with an architect, environmental/ecological specialist and a water engineer. These specialists were chosen due to their links with ecology, water, people and space-planning. D4 was then developed as the best-fit WSAD solution. This design takes into account all comments from participants, the discussions with the three specialists, as well as the reflection on the design by the author. In the final stage of the analysis, D4 was subjected to an effects analysis as outlined by De Jong and van der Voordt (2002).

The results and insights gained during this RBD process are then explored in the next chapter, Chapter 5. It is hoped that through the RBD process, new insights may be gained into both the design process and the possible outcomes for the creation of a successful WSAD.

D1-Conceptual Underpinnings

D1 was initiated by an interest in the Liesbeek River. The river links different socio-economic areas across Cape Town, and is one of the least polluted in the city (CoCT, 2002:27). At the macro-scale, the river was investigated using Heidegger's definition of a boundary, which facilitates transition and change in the boundary zone. The exploration of the different boundaries of the Liesbeek was a task in understanding the river and its constituents, as well as a search for a suitable site for the building. These manifested as the historical, architectural, cultural and natural boundaries of the river. Although other aspects of the river could have been focused on, the choice was made to focus on boundaries that dealt more with possible design informants and nature. A conscious choice was made at the project's inception not to focus upon the socio-political context of the site, as it was felt that this would draw focus away from issues relating to water management. Themes such as the socio-political context of the site may be explored further in other research projects focusing on WSD.

To initiate the study of D1, the river was investigated from the historical and architectural standpoint. These boundaries tracked development along the Liesbeek River. Pre-colonisation, indigenous people allocated special sacred places along the river for celebrations and gathering. The Dutch settlers arrived in the 1400's and set up farm lands along the banks of the river (Bhikha, 2013:12). Subsequent development included the establishment of a railway line and suburbs along the river banks, a legacy left by the farmlands. This development has shaped urban planning along the river, as seen in Figure 17. Canalisation has had the biggest impact on the landscape, both visually and environmentally. Aside from the canals, the architectural and cultural legacy left by the historical boundary includes mills, bridges and a brewery. The natural boundary explored the CTSDF, TRUP and MOSS initiatives across the macro-and meso-scales. These frameworks are discussed in Chapter 1 and used to locate D1 across the different scales.

Figure 17: Development along the Liesbeek River from 1660 to 2009. (Bhikha, 2013:13)

The exploration of these different boundaries resulted in the selection of the Raapenberg dump site as the site of intervention. This site was selected due to its lack of prior programme, unique location and wetland edge conditions. The site became an ideal location for site repair. Alexander (1977: 509) suggests that the worst part of a site should be selected in order for site repair to take place. In this study, it was proposed that the existing building rubble be removed and the natural systems on site be restored. By creating multiple interventions along the river, including the proposal for D1, the greater blue-green network as part of the CTSDF would be restored.

The technical exploration dealt with the different processes involved when designing for water as the focal point (Bhikha, 2013:22). WSUD, SuDS, constructed wetland systems and wetland rehabilitation were investigated at this stage. Principles from these initiatives were extracted and used to inform D1. These systems all fall under WSD, discussed in Chapter 3.

Finally, the investigation was supported by an interest in machines – not as those conventionally understood as an object, but rather as a process in which multiple elements are linked to form a system. The idea generated was that of a soft machine, which draws water from the Liesbeek River and filters it through the constructed wetlands of the building (Bhikha, 2013:28). This idea was expanded upon to form a productive landscape, in which the filtered river water is used for small-scale wetland and agricultural production, supported by a laboratory facility. The wetland plants cultivated on-site are used for river rehabilitation, while agriculture is identified as a means to restore value to the site and retain historical links to the river (Bhikha, 2013:25). To this end, the second part of technical exploration discussed different types of hydroponic systems. Human interaction with this large-scale living machine was added as another layer. The aim was to create a scenic destination space as part of the CTSDF where the public can better understand the value of the Liesbeek River and wetland rehabilitation.

Having understood the conceptual underpinnings of D1, a few significant design informants can be extracted from the explorations done. These design informants may be used when considering WSAD and are added to the list generated in Chapter 3.

- The different boundaries of the site must be explored. This includes the historical, cultural, architectural and natural boundaries. This assists in understanding the local context of the site, as well as the role of the site across the different scales.

- Site repair minimises the impact the building has on the site, by identifying the worst part of the site and using the building for rehabilitation (Alexander, 1977: 509).

- Ideas behind the soft machine, which considers systems in which multiple elements are linked across site, must be reflected. When the idea of the soft machine is viewed through the lens of Ecological Urbanism, ‘ecological infrastructure’ results. This is supported by Belanger (2010:347), who notes the need for integrating infrastructure as landscape. This ecological infrastructure could contain multiple interlinked elements across the site, forming complex systems which revolve around ecological considerations.

Returning to the description of D1, the conceptual underpinnings explored formed the basis for the design and approaches taken. This leads to an explanation of the process and product work.

D1-Process Work

The process work consists of images, drawings, models, explorations and text that came about during the design process of D1. The macro- and meso-scaled urban proposals have already been discussed in Chapter 1 in order to locate the study. These are briefly summarised as follows: the CTSDF deals with a spatial and urban planning proposal for the city. The proposal considers the economy, urban growth, social development, biodiversity and transport networks (CoCT, 2012:2). D1 focused on the CTSDF aims around natural assets and the environment. The CTSDF develops ideas relating to scenic landscapes, which promote recreational and environmental value (CoCT, 2012:30). D1 aimed to be part of such an intervention in the greater CTSDF.

The meso-scaled urban proposal addressed the interlinked frameworks of MOSS and TRUP. MOSS links green spaces in the city in order to facilitate conservation and recreation (CoCT, 2012:102). This includes the blue-green network of the Salt River system across the city, of which the Liesbeek River is a component. The CTSDF acknowledges MOSS as a key framework for biodiversity conservation in the city. D1 proposed a series of interventions along the Liesbeek River that considered both water and the ecological aspects of the different sites. Over time and along with subsequent layered interventions, the entire blue-green network along the Liesbeek River would be rejuvenated. This would ensure an increase in water quality, a decrease in the negative effects of stormwater, an increase in localised urban water management and an increase in biodiversity. The TRUP is located within MOSS and focuses on the zone around the confluence of the Liesbeek and Black Rivers. The TRUP has a rich historical and cultural legacy (CoCT, 2002:1). Natural riparian vegetation has been retained in this zone (CoCT, 2002:27). By implementing D1's meso-proposal, natural and cultural value was added to the TRUP. These unique characteristics provided the ideal background for a WSD to be located.

The micro-scale proposal consisted of the site and building works of D1. The conceptual underpinnings of the project were used to guide the design process and inform the design moves. It must be noted that the process work shown here is not intersubjective. Non-architects may find the plans and diagrams difficult to read. However, this project was for a Master of Architecture degree. The work therefore had to speak to an architectural audience, as well as show a refinement of architectural skill and knowledge. Explanations are given for this process work to assist in understanding.

The design process for D1 began with a site mapping to understand the site as it currently is. The site mapping, shown in Figure 18, locates the different trees and shrubs on site. It also shows existing paths, views and berms. This assisted in understanding the site conditions and the profile of the land. After reflection on the different site conditions, the Figure 18 mapping was used to create thumbnail sketches shown in Figure 20. These sketches identified characteristics of the site and were used to generate site cues for the form and placement of the building.

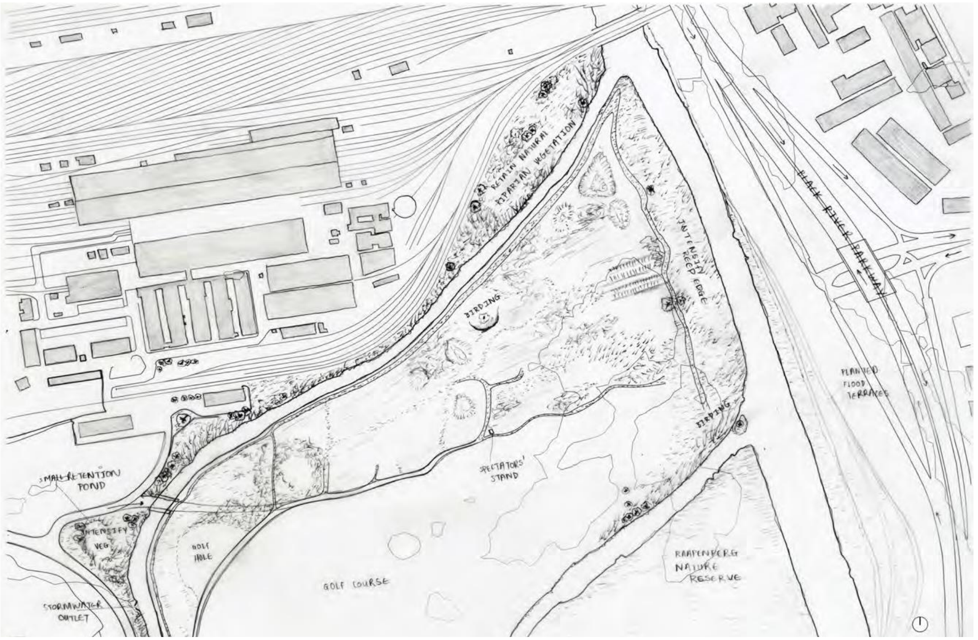


Figure 18: Existing conditions on site. Shrubs, paths and land textures are mapped in this diagram (Bhikha, 2013:37).

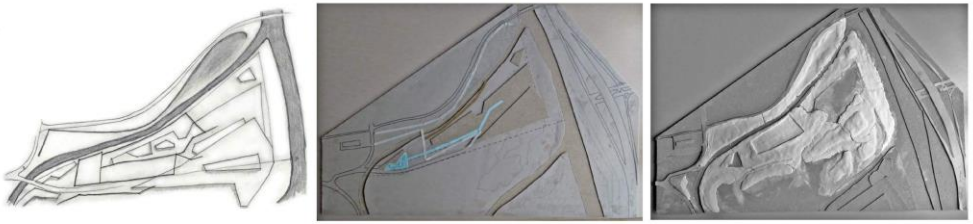


Figure 19: Massing the building. From left: abstracting the contours and profile of the site, modelling the abstracted site with movement routes, modelling to shape the site (Bhikha, 2013).

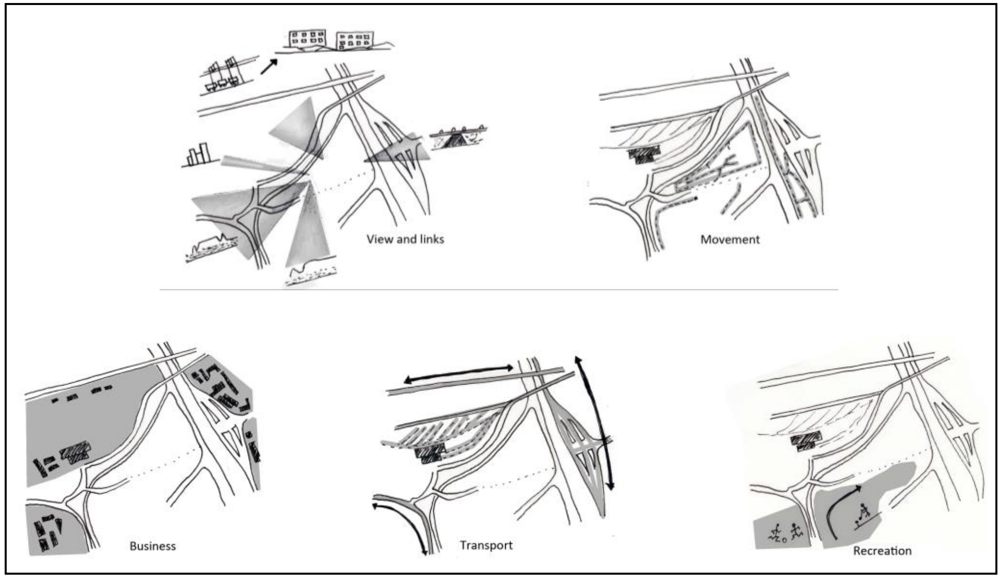


Figure 20: Thumbnail sketches to distil ideas from the site mapping, shown in Figure 18. Clockwise from left: Views and links, existing movement routes on site, existing recreation facilities and opportunities around the site, existing transport networks including road and rail, existing places of business (Bhikha, 2013:36).

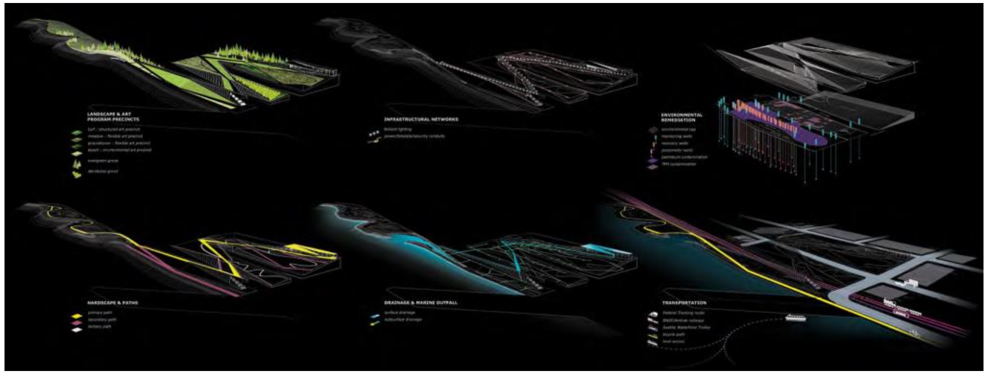


Figure 21: Layering programme and systems on the site in the Seattle Olympic Sculpture Park. Clockwise from left: landscaping, electricity and lighting, environmental remediation, transport, water, movement routes (Manfredi et al, 2008).

This lead to the sketch design phase, which was concerned with the massing of the building and shaping the site. The massing of a building refers to the larger shapes and principles used to guide the form of the building. This massing process is shown in Figure 19. First the site was abstracted and then movement routes were overlaid. Based on these explorations, the site was shaped using clay to cut into and build upon the earth.

The first iteration of the sketch design considered building processes across site. This ecological infrastructure was inspired by Weiss/Manfredi's Olympic Sculpture Park in Seattle, shown in Figure 21, which considers the different programmes and systems used on site. These systems inform the shaping of the site. Weiss and Manfredi design landscaping, electricity and lighting, environmental remediation, transport, water and movement routes as overlapping and linked systems. In order to achieve a similar system, D1 was layered with these different systems. The first iterations of D1 explored the movement of water across the site at a functional level and grappled with geometries. Figure 22 shows the first iteration, which considered water flowing across the site through different WSUD and constructed wetland processes. This process was explored in section in Figure 23, which shows the building, site works and river in context. Issues that arose related to scale, movement routes and access.

The second iteration of the design developed the ecological infrastructure of the site. Ideas from the programme were integrated in the design, with a focus on understanding the functioning of the wetland cells within the cultural and ecological boundaries of the site. This layering of systems and programme is shown in Figure 24. The diagram explores movement of water on site, landscaping which links to shaping the site by cutting into and building onto the earth, and finally the proposed movement routes.

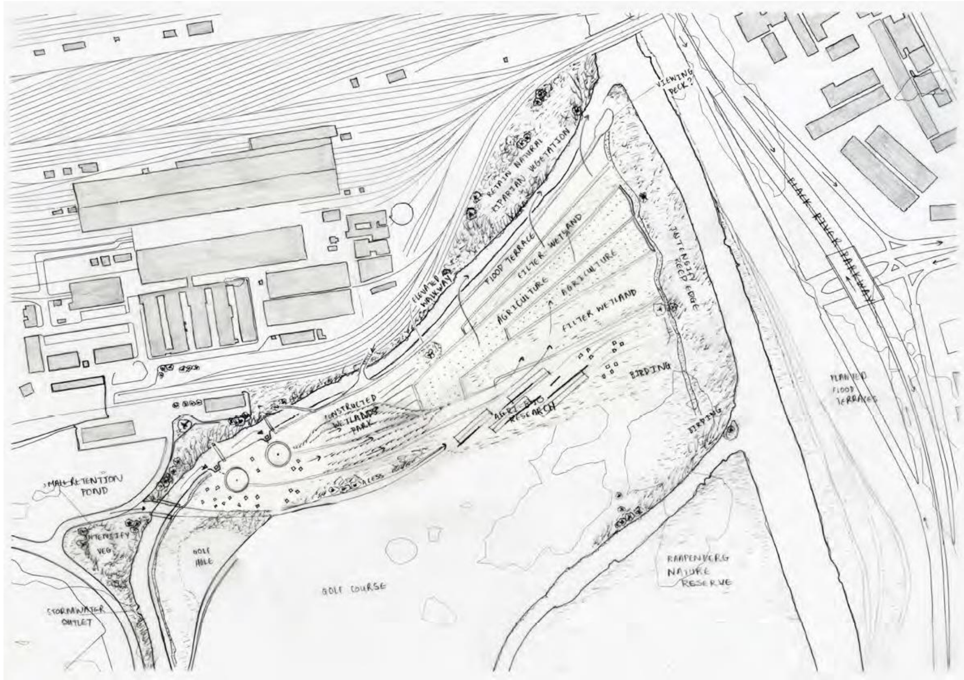


Figure 22: The first iteration of the design. Ecological infrastructure, particularly water and the filtration process from the left to right of the site is explored in this design (Bhikha, 2013:41).

Figure 23: Exploring the section by shaping the site and experimenting with levels. The section shows that a multi-level intervention would not fit into the flat surrounding landscape (Bhikha, 2013:45)

Figure 24: Layering programme on site, referencing Weiss/Manfredi's Olympic Park schematic shown in Figure 21. Left: water systems and movement across the site. This includes water filtered in the wetland cells and in the naturally occurring wetland on site. Centre: landscaping, including shaping the site. Right: movement routes for people on site (Bhikha, 2013:43).

The design development phase built upon these ideas by focusing on the public aspects of the building and the interaction with its surroundings. Particularly challenging once the land was sculpted was the design of the individual buildings. The programme for D1 was generated from the conceptual underpinnings (Bhikha, 2013:31): Water drawn from the Liesbeek River was filtered through treatment cells for use. Hydroponic growing beds were used to cultivate endangered wetland plants and agricultural crops. Next, an on-site laboratory facilitated water-related research along the Liesbeek River for researchers and students. Finally, public interaction with the building was facilitated though a café, change rooms, a public pool, promenade and a wetland recreational park. These elements are shown in Figure 25, which reveals a geometric massing. The building design converged ideas generated from the historical, cultural, architectural and natural boundaries on site with WSD and hydroponics. The site was linked to a proposed wetland park on the Transnet side of the river in order to facilitate engagement with the river.

Figure 25: A geometric massing is revealed during the design development stage (Bhikha, 2013).

D1-Final Work

The final design proposal consisted of a full set of working drawings, renderings, a spatial model and text summarising the project. The text, which is referred to throughout this study, documented the design process of the building. The complete set of drawings is shown in Appendix B, but smaller images are shown in text for quick reference. Figure 26 explains the macro-scaled approach in order to situate D1. In this image, a phased approach allowed for different sections of the Liesbeek River to be rejuvenated through various interventions. These interventions, which act at a local scale, include restoring canals to their natural state, rehabilitating naturally occurring wetland and riparian vegetation, creating public recreational parks along the river, educating people through programmes and stricter legislations relating to water pollution and stormwater.

Figure 27 shows the site plan, which takes into account the built form, the wetland park across the river on the Transnet side and the meandering walkways through the wetland edges of the site. A zoomed-in version of the built form is shown in Figure 28, in which the wetland cells, buildings and the Transnet wetland park are shown. As the journey through D1 is important, Figure 29 assists in understanding the different spaces of the design in section. Light and shadow are highlighted, as well as the different levels of the augmented site. Figure 30 demonstrates the flow of water within the built form. Water from the river was filtered through a series of constructed wetland cells, taken through agricultural hydroponic cells, into a public pool and then back into the river. A model was built in order to demonstrate D1 in 3D. This model, shown in Figure 31, showed the relationship between the river and the proposed built form.

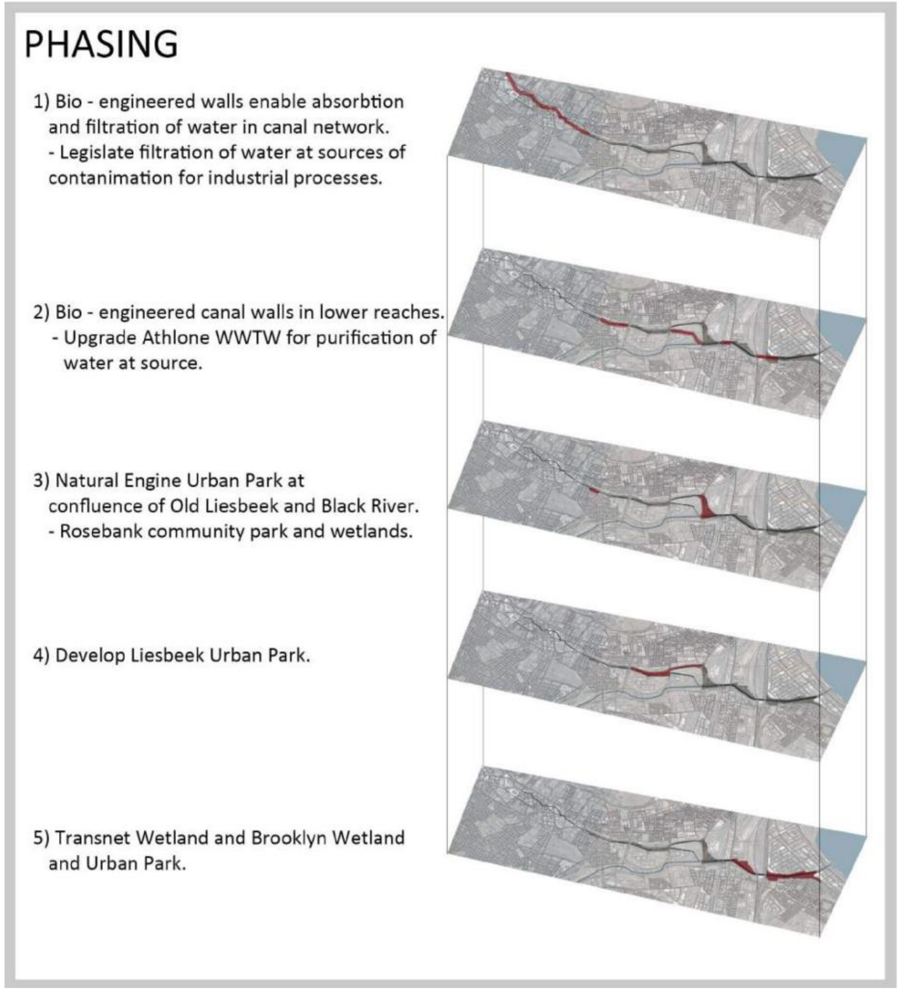


Figure 26: Explaining phasing at the macro-scale. Different interventions are proposed along the river over time in order to rejuvenate the greater green-blue network (Bhikha, 2013).

The shaping of the site is more obvious when shown in 3D, as the viewer is able to see where the site has been excavated or built up. Two perspectives are shown in Figure 32 in order to provide a visual of the proposed design.

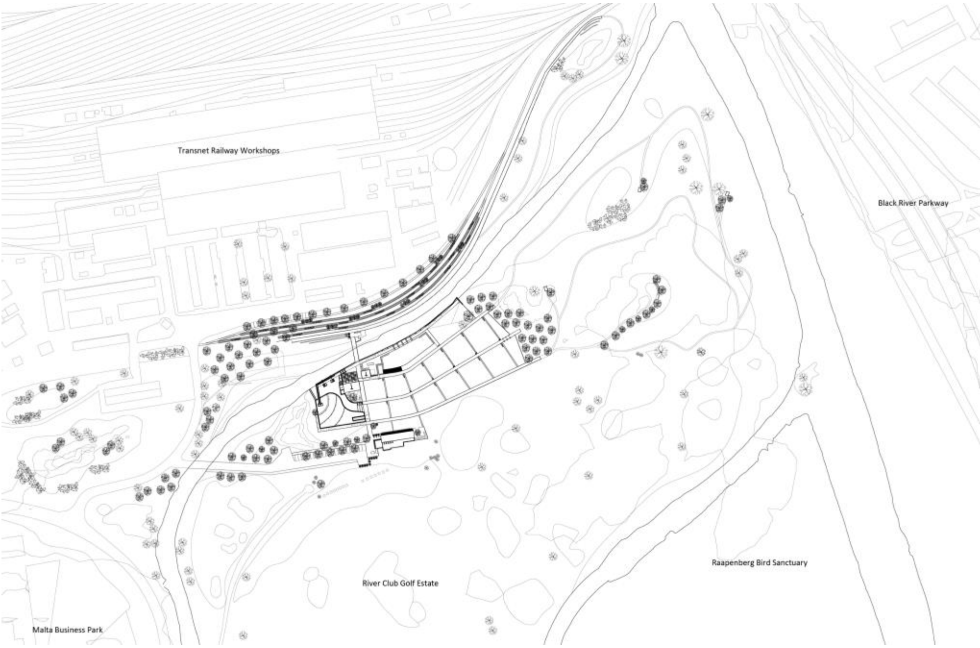
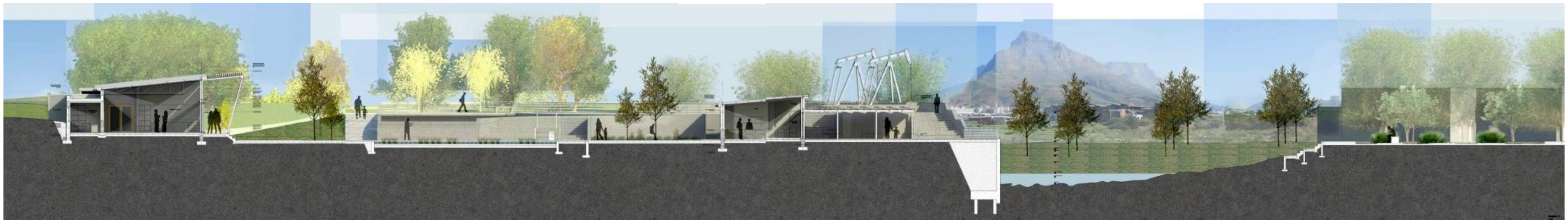


Figure 27: The site plan shows the overall plan for D1 at the micro-scale. This includes the building itself, the adjacent wetland park and the meandering paths through the rest of the site. These paths are important in facilitating recreational activities such as running, cycling and bird-watching (Bhikha, 2013).

Figure 28: The zoomed-in plan at the micro-scale focuses on the built intervention. This includes the buildings on site, the filtration and agricultural production cells, the public pool, pathways and the adjacent wetland park (Bhikha, 2013).

Figure 29: D1's section is explored in order to highlight level changes. The different spaces are defined in section, which is animated through the use of light and shadow (Bhikha, 2013).



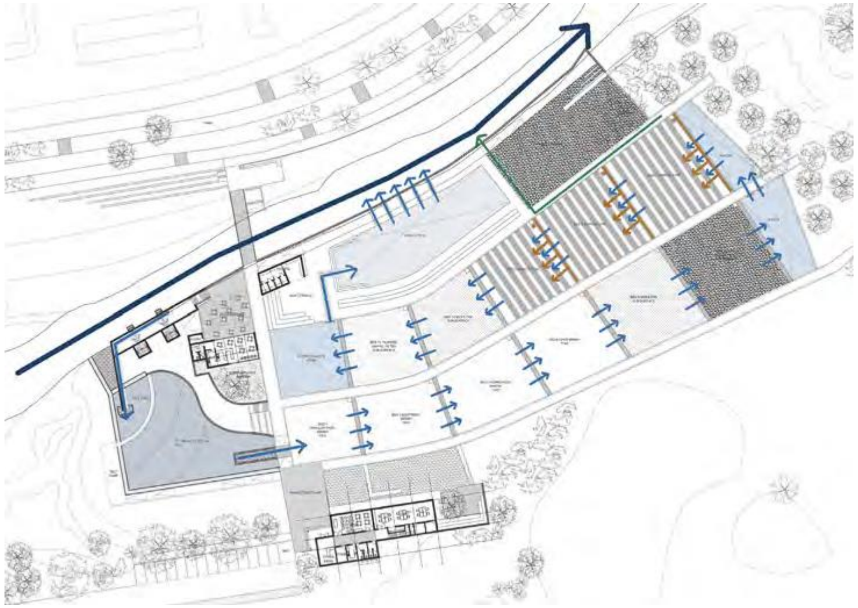


Figure 30: Diagram showing the movement rotes of water across the site. This movement route is one of the main drivers for the design, including the sizing and arrangement of the wetland cells (Bhikha, 2013).

Figure 31: A 3 dimensional model assists in understanding the different spaces created in D1 (Bhikha, 2013).

Figure 32: The 3D renders show a vision of the animated site. The top image shows the walled edge of the site, along with the connection across to the adjacent wetland park. The bottom image shows the different wetland cells, with a view towards Table Mountain in the background. This image contextualises the site in the macro-scale environment (Bhikha, 2013).

Analysis of D1

The preceding section of Chapter 4 described the process that lead to the design product of D1. The focus of the study now shifts to the analysis of D1 using RBD. According to Hulsbergen and Van Der Schaaf (2002:161), the analysis may consist of iterations of the design in which scenarios are tested, using the existing building as a base. Importantly, only three or four scenarios must be tested in order to avoid the assessment covering too much material (Hulsbergen and Van Der Schaaf, 2002:161). As there are multiple ways in which to research by design, this study evolved organically within the framework for RBD presented in Chapter 3. Three design iterations were proposed after the analysis of D1. These different designs were informed by the author's opinions, participant analyses and specialists' comments. The different iterations were evaluated using the design imperatives generated from the theoretical and conceptual frameworks. These design imperatives were added to by those mentioned in the first part of this chapter. The completed list of design imperatives is shown in Figure 39.

The evaluation of D1 aimed to identify opportunities for improving and optimising the design in order to generate ideas around WSAD. As part of the analysis of the expressive values of D1, thumbnail sketches evaluated the building at the micro-scale according to architectural characteristics, shown in Figure 33 and Figure 34. These terms describe different common architectural characteristics of any building design. It is noted that this phase of the evaluation is not intersubjective as non-architects may find these diagrams and architectural characteristics difficult to understand. Explanations of the characteristics are therefore given to assist with this. The diagrams were based on the plans, sections and elevations of the project, which were described and shown at the beginning of this chapter. The structure of D1 showed that the building was defined by its forms. Façades of the different buildings opened up towards the river. The plan to section relationship compares similarities in profile between the plan and the section. D1 showed similar form-making in both drawings, although the forms in plan were larger than in section. This is a consequence of an early decision to have low buildings on site. Low buildings do not dominate the flat site, thus allowing the natural environment to take precedence. The small rectangular components of D1 were symmetrical, but the larger site form was organic.

The additive to subtractive relationship shows how the whole form is added to or subtracted from in order to form the smaller components of the design. In D1, smaller forms were cut out of the larger one, with the central path and main building added to this form. The circulation-to-use relationship shows the link between the different programmes on site and how movement occurs between these. In D1, circulation defined the design as it was used as the primary design cue. The buildings and pool on site balanced each other, but there is little balance elsewhere in the design. The repetition-to-the-unique relationship describes the links between repeating elements of the design. In D1, this was evident in the repeating form of the cells. The geometry of the design describes the how the building can be arranged within geometric forms. As D1 was not symmetrical, few parts of the building were geometrical aside from the rectangular components. The hierarchy of the design describes which components of the design form take precedence over others. This is useful in focusing the design forms. In D1, the buildings sat low in the landscape. In plan and section the site works took precedence over the buildings.

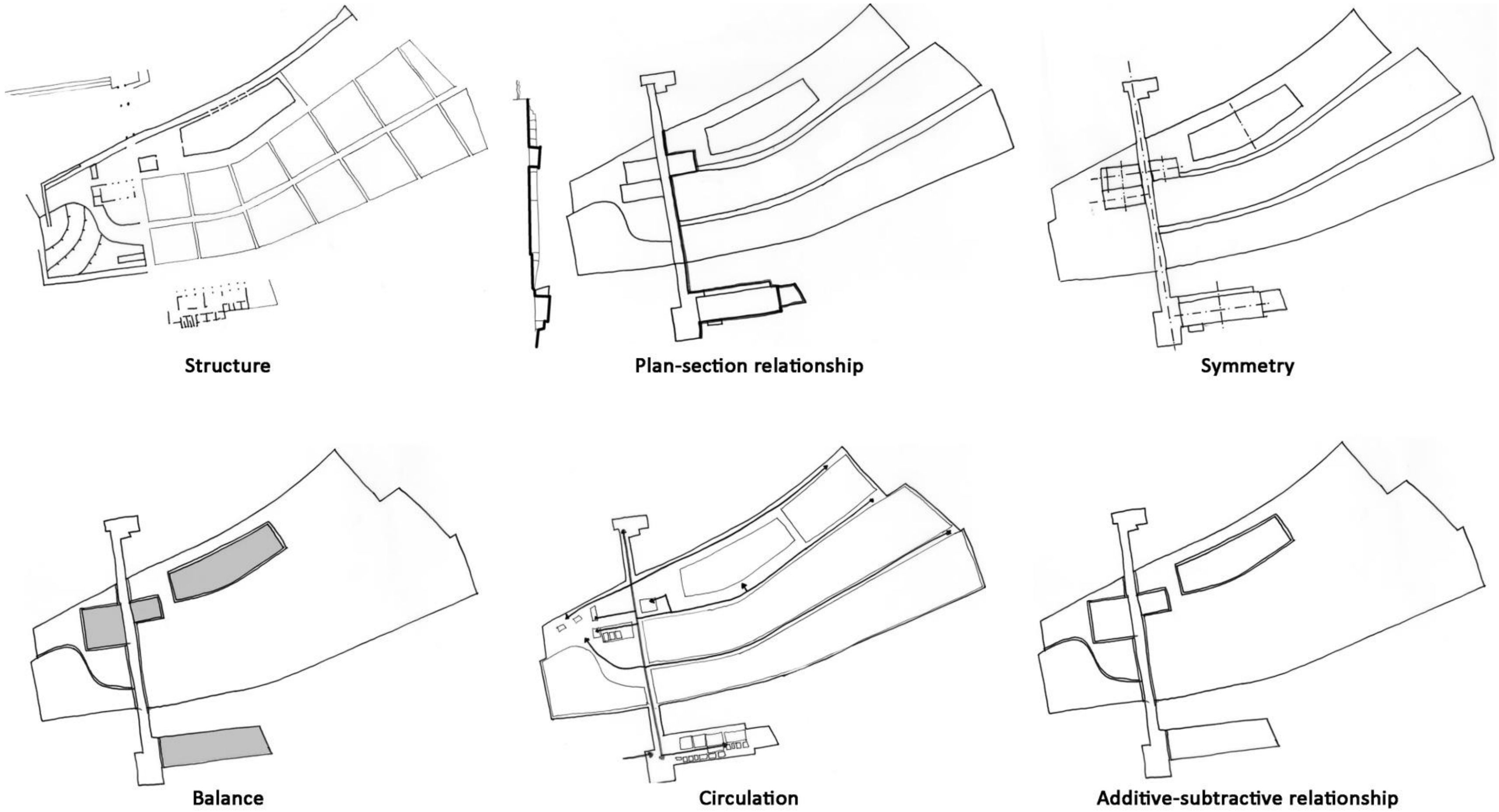


Figure 33: Analysing D1 according to architectural characteristics. Clockwise from left, Structure, plan-to-section relationship, symmetry, additive-to-subtractive relationship, circulation and balance (Author, 2016).

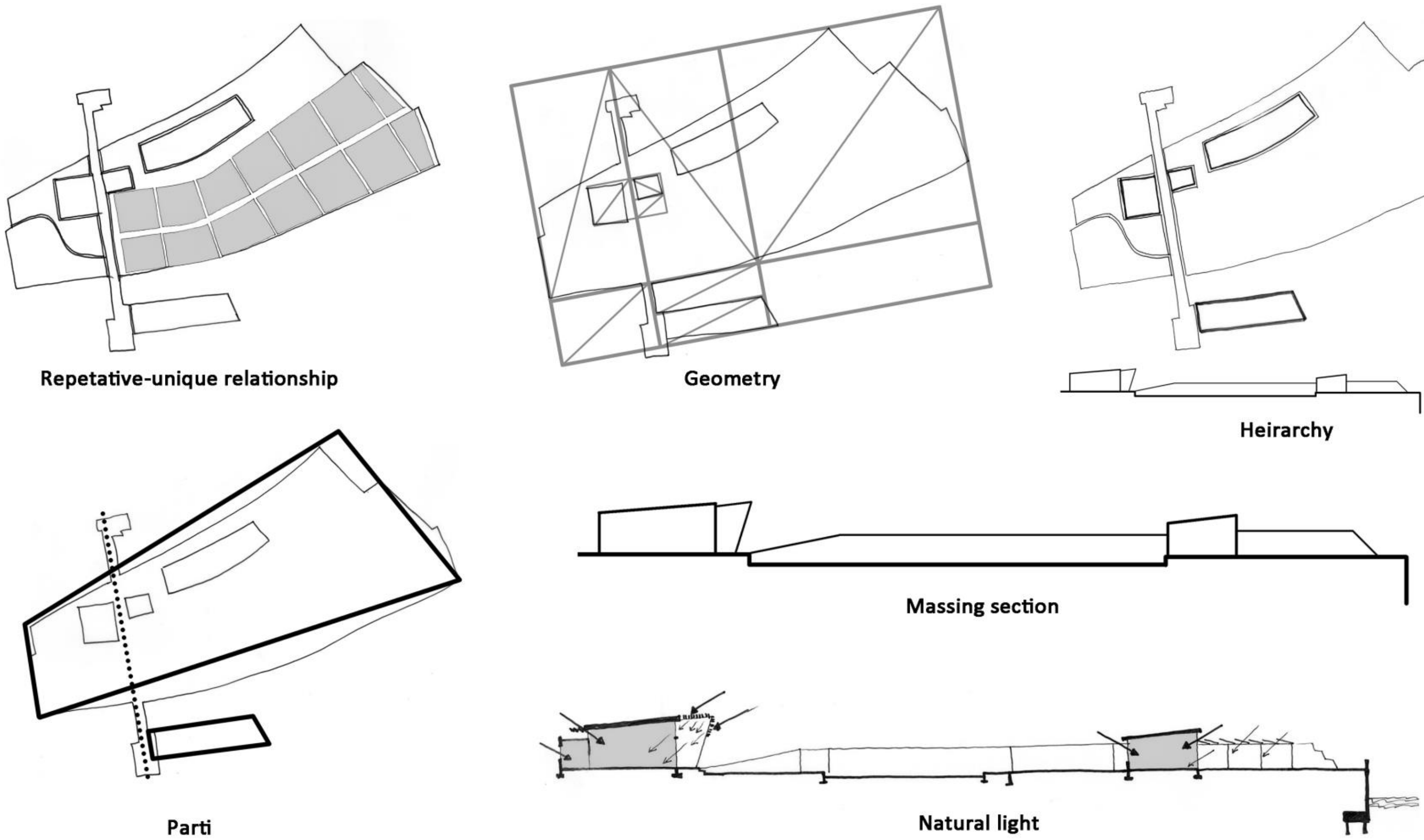


Figure 34: Analysing D1 according to architectural characteristics. Clockwise from left, the repetitive-to-unique relationship, geometry, hierarchy, massing in section, natural light and parti (Author, 2016).

The massing section is used to show the dominance of the overall forms on the landscape. In D1, the building forms were sloped to open up towards the river edge and formed bookends to the flat landscaping of the production cells. Natural light was allowed into the buildings, but was screened in order to protect from the harsh Northern light. The parti of a building refers to the concept of the design (Frederick, 2007:15). The parti of D1 showed two angular forms connected by a single line.

The next phase of the subjective analysis of D1 dealt with the potential opportunities of the design. The opportunities for improvement were informed by the author's opinion and explained in text as far as possible to facilitate inter-subjectivity. The rationale for the subjective and opinion-based evaluation of D1 was that the author could self-evaluate and criticise the design. By doing so, key ideas would emerge around the opportunities for the design that may have been missed previously.

The subjective analysis was explored through sketches, arranged chronologically in Appendix C. It is noted that the sketches shown do not record the complete interrogation process that occurred. Constant reflection and evaluation occurs during a sketch, which also occurs over a certain timeframe. Interrupting the flow of thought as the sketch is being made in order to take descriptive notes on the process may have negative consequences on the thoughts still to be formed. Instead, the author has elected to show the completed sketches. These sketches are all shown at full scale in the appendix, wherein the text is more legible. In the appendix, each sketch is explained in detail in order to aid in inter-subjectivity.

Figure 35 shows the opportunities analysis done at the macro-scale, specifically considering how D1 fits into and supports the greater MOSS framework. MOSS, as explained in Chapter 1, deals with the green-blue network across the city. D1 proposed several interventions which consider WSD along the river. In this analysis, further opportunities exist to expand upon these individual interventions. Multiple, layered and phased interventions have a greater impact across the river, thereby increasing water quality, decreasing stormwater quantity, and increasing biodiversity and amenity along the Liesbeek River. The whole river could be rejuvenated using such an approach. This results in an increased ability to manage floods, heavy rains and stormwater across the MOSS system. In creating a park-like intervention, D1 becomes a natural scenic destination space as per the CTSDF aims for natural assets. This adds value to the cultural, social and ecological aspects of the site, thereby benefitting the TRUP.

In Figure 36, the micro-scaled elements of D1 are isolated and scrutinised. The impacts of these elements are considered at the meso- and macro-scales. This diagram identifies D1's strength in retaining and rehabilitating the natural wetland of the site, which connects the meso-scaled proposal to the greater green-blue network of MOSS shown in Figure 35. The edge conditions of the building need to be softened and made more natural in order to form a part of the green-blue network. A natural river edge adds further ecological value to the TRUP zone, where natural riparian conditions are retained. Questions around the building's geometry are raised, as the present forms may be too rigid and geometric. This is explored in later design iterations. The scale of the different design components needs to be revisited. Finally, the ecological infrastructure and the integration of the buildings on site are identified as areas for further consideration.

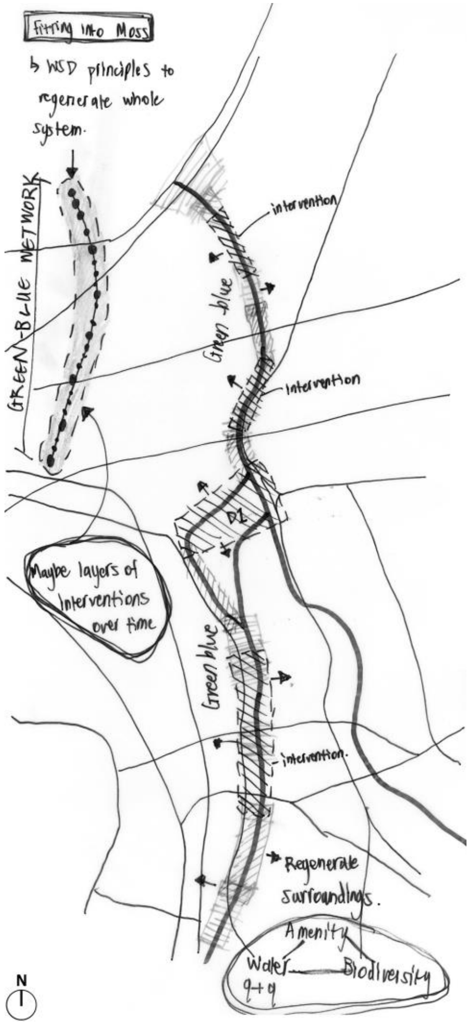


Figure 35: A sketch analysis uncovering opportunities for D1 at the macro scale. In this diagram, the way in which D1 fits into the MOSS framework is considered. The black hatching indicates the proposed interventions along the river. In this sketch, these individual interventions are developed upon. Multiple, layered, phased interventions across the river over time will result in the rejuvenation of the river through the use of WSD principles. The aims of MOSS, that of connecting the blue-green networks across the city, could be met by instituting such a layered intervention. In this way, the quality of water will be improved, the quantity of stormwater is decreased and the amenity and biodiversity values of the river and surrounding land is increased (Author, 2016).

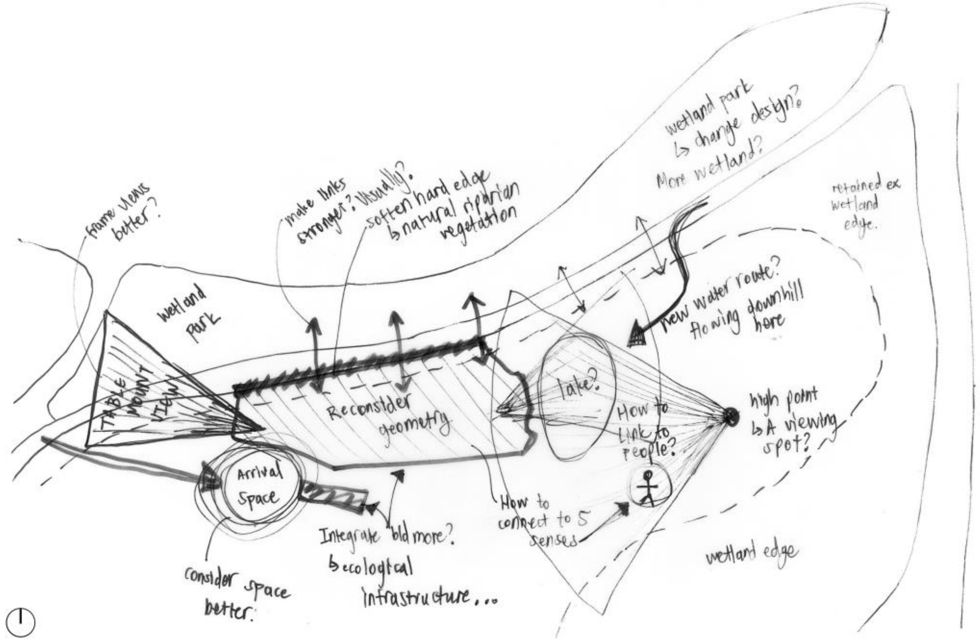


Figure 36: An opportunities analysis of D1. This diagram reflects concerns around views, the building form, site cues and the role of the building in the greater D1 proposal (Author, 2016).

The final analysis of D1 evaluated D1 against the design imperatives generated in this study. Comments were given for each criterion and considered the macro-, meso-, and micro-scales. Figure 37 was used as a quick reference image for this evaluation process. The outcomes of this analysis, shown in Figure 39, revealed that D1 met some of the design imperatives generated in this study. The subjective analysis aimed to improve the design of the next design iteration before external participants were involved in the study. This allowed for more critical and useful feedback from the study participants.

Figure 37: The same perspective of each iteration is created as a quick reference for the reader. The image contextualises the design in the macro- and meso-scale using an aerial view with Table Mountain in the background. Note the bio-filtration ponds facing the Liesbeek River (Author, 2016).

The findings of this analysis were that views within the building needed to frame the ecological infrastructure and Table Mountain in order to link the macro-scale proposal to the building when viewed from indoors. Further opportunities were available to enhance identity through construction material use, enhance the use of the five senses when visiting the building and to create ambivalent boundaries. Water integration in the building was limited in that water and filtration systems were not visible around the site. D1 formed a hard, impervious edge from which the river was observed, but not engaged with. This was in contradiction with the research presented for WSD, where water edges accommodate for seasonal change. A flow diagram for the D1's processes showed that the systems used on site focus on water, as shown in Figure 38. As WSAD considers ecological systems and people in addition to water, these aspects need to be integrated into future design iterations.

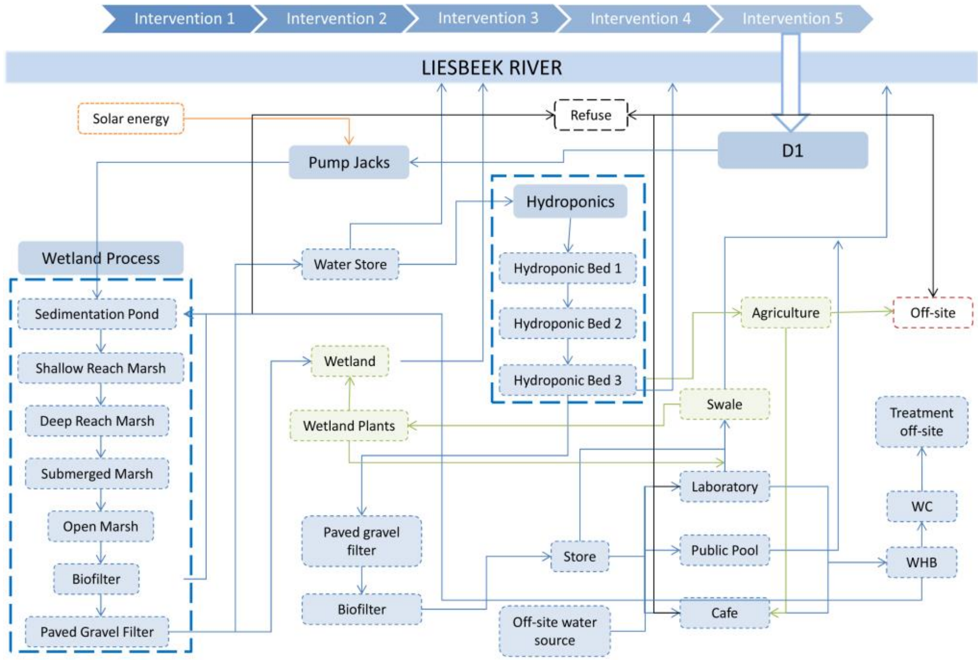


Figure 38: Flow diagram for the design proposal for D1. In this diagram, the flow of water, plants, energy and refuse is shown (Author, 2016).

D1 Evaluation - Author

Criteria for evaluation: Light grey- did not achieve Medium grey- achieved Dark grey- Excelled

Design imperative	Evaluation comments	Evaluation
Cultural services: Aesthetics, sense of place, spiritual value, cultural landscapes, educational, spiritual, recreational		
Ensure building is aesthetically pleasing through design.	Attractive building, although more programme could be accommodated.	
Consider architectural elements of point, line, plane, form, massing, hierarchy, ordering systems, geometry, rhythm, thresholds, and ergonomics.	Form, massing and thresholds need to be improved.	
Frame views across scales to other natural & design elements.	Views from building to mountain not framed.	
Engage with spiritual history of site through architecture and construction materials.	This aspect was not focused upon in this design.	
Create identity using gathering/symbolism/visualisation.	Design creates gathering spaces for the confluence of movement route. Symbolism and visualisation of natural environment is minimal through tectonics. Constructed wetland cells do mimic natural processes.	
Make building comfortable for people.	Greater emphasis on light and connection in buildings required. Buildings do take into account scale and spatial use by people.	
The building and the water in it must engage with the 5 senses to give a sense of identity.	Design does not engage fully with touch, sound, smell or taste senses.	
Create paths which orientate towards river/mountain/design elements by using nodes/paths/districts.	Achieved.	
Use enclosure & extension (centre & rhythm), light & shadow to define space.	Building could make better use of these principles.	
Use construction materials, detailing and making to give the building identity.	Building could make better use of these principles. Building does make use of recycled materials.	
Define and make boundaries porous at different scales: create ambivalent indoor-outdoor spaces using light & shadow, enclosure & extension.	Not achieved. Hard river edge designed which does not allow for transfer of elements across boundary. Spaces are not ambiguous.	
Activate building as part of CTSDF, TRUP and MOSS.	Achieved, although more explanation required across scales.	
Create spaces for gathering and quiet reflection.	Achieved.	
Provide spaces for resting, sports, and social.	Achieved. More programme could activate the site better by drawing the public.	
Link recreational focus areas on site using paths.	Achieved.	
Make visible building and recycling systems.	Not fully achieved. Indoor systems not visible.	

Comments: Greater emphasis required on people in landscape and buildings. More connections required between scientific processes on site and the public for educational purposes.

Design imperative	Evaluation comments	Evaluation
Regulatory services: Disease, climate, water, water, pollination		
Create habitats for flora.	Achieved.	
Aerate water through vertical movement.	Achieved, but more emphasis need to be placed on this.	
Use constructed wetland principles for passive water filtration on site.	Achieved.	
Use WSUD's and SuDS elements for localised flood control.	Achieved.	
Link design to larger MOSS & CTSDF for flood control	Achieved.	
Create habitats for fauna: can pollinate plants.	Achieved.	

Comments: Minimised vertical movement of water a design choice.

Design imperative	Evaluation comments	Evaluation
Supporting services: Primary production, soil formation, nutrient recycling		
Introduce agricultural production.	Achieved.	
Restore flora on site to assist with binding of soils.	Achieved.	
Repair site to restore existing soil and earth conditions.	Achieved.	
Use soft landscaping and outdoor trafficable surfaces	Achieved.	
Sort ablution effluent into solids and liquids for nutrient recycling.	Self-composting toilets used, which do not sort ablution effluent into solids and liquids but does create compost for use.	
Ensure nutrients are balanced across site systems.	Achieved, although care needs to be taken to ensure all nutrients are not removed from system as over-provision of wetland cells in design.	

Comments: Wetland cell sizes could be reduced for a more efficient system.

Design imperative	Evaluation comments	Evaluation

Provisioning services: Food, water, energy, raw materials, bio-chemicals, genetic resources		
Introduce agricultural production if possible.	Achieved.	
Diversify water sources on site.	Rainwater needs to be used.	
Don't use potable water for non-potable uses.	Achieved.	
Building to form part of larger blue-green network of city.	Achieved.	
Use WSUD's and SuDS elements for drainage of water on site.	Achieved.	
Recycle and filter water on site for reuse.	Achieved.	
Strategy required for alternative sanitation systems.	Achieved.	
Consider recycled building materials.	Achieved.	
Use water & energy efficiently in building: water-wise fittings, low energy fittings, passive ventilation, and alternative sources.	Achieved, although this can be explored further.	
Restore flora on site to assist with habitat creation, flood controls, binding of soils.	Achieved.	

Comments:

Design imperative	**Evaluation comments**	**Evaluation**
Design values (from D1)		
Understand and incorporate the local context of the site by exploring the boundaries of historical, cultural, architectural, natural…	Achieved, although this can be explored further. Historical aspects of site not focused on in this design.	
Facilitate site repair.	Achieved.	
Consider ecological infrastructure: integrating infrastructure as landscape, link multiple elements and systems across the site.	Achieved, although this can be explored further.	

Comments:

Figure 39: (And previous page) D1 is evaluated against the design imperatives list. This evaluation considers the design across scales (Author, 2016).

From this analysis process, a few thoughts were put forward in order to guide the next design iteration, coded as D2. These thoughts were formed in response to the reflection and knowledge-building that occurred during the analysis of D1 as a result of RBD. The thought stream is documented in Appendix, C but is summarised here:

- Water in D1 flowed against the slope of the land by building up the site. Water in a WSAD should move in the direction of gravity in order to reduce manipulation of the land when not required.
- D1 had a hard, impervious boundary against the river. A more natural river edge should be created in line with WSD principles covered in Chapter 3. This permeable edge can adapt to changing water levels over time, as well as restore natural wetland processes along the site edge. This allows for the rehabilitation of the river edge, with subsequent benefits of water quality, quantity, amenity and biodiversity as per the SuDS model.
- A greater emphasis must be placed upon revealing and enhancing the journey of water across the site so that it is accessible to the public. At the meta-level, questions that arose from D1 included ascertaining the value of water as a whole and the value of water as a connector of communities. D1 did not put enough emphasis on the journey of water or ecosystems in the landscape.
- Ramirez (2015:137) suggests that architecture is not meaningful until humans interact with it, which results in an architectural performance. It

is only through this performance that architecture is able to make an impact in and around its surroundings. A greater emphasis must be placed on facilitating opportunities for people to connect and engage with water and nature in the design. This can be assisted by the phenomenologically-inspired aspects listed in the design imperatives for expressive values. This is in line with the design informants from Chapter 2, which deal with the intrinsic links between man and nature and using phenomenological principles in order to create opportunities for enhancing the relationship between man and nature through the expressive elements of architecture.

The final thoughts from the analysis processes raise questions relating to the value of an architect in a WSD. What does an architect add to a WSD? How does the architect engage in the WSD? What are the links between WSD and architecture? These questions were developed from discussions with specialists during the study. The architect can be said to add value through their skills. This is because an architect is able to draw inspiration from different disciplines to create design solutions, coordinate ideas between actors from different disciplines, and interrogate, evaluate and synthesize design ideas through the process of design (Frederick, 2007:21). This idea is developed further in Chapter 5.

These thoughts, as well as the design imperatives generated, provided guidelines for the next iteration of the design, D2. It was decided that the macro- and meso-scaled proposals for D1 sufficiently dealt with water and were retained for future design iterations. A change made to the macro-proposal was to layer multiple overlapping interventions over time. This created a network of interventions along the river which aid in rejuvenation, as shown in Figure 35. Links with these scales and the design iteration investigated will be discussed in text. This was done to retain perspective across scales.

D2-Process and Product

In the RBD manner, D2 design was informed by the thoughts derived from the analysis and reflection of D1. Further, it was guided by the design imperatives discussed previously. The design process for D2 began with an identification of the programme for the site. A broader and more considered programme was selected in order to better facilitate the implementation of WSD principles discussed in Chapter 3. The programme included an attenuation pond, bio-filtration cells, stormwater management strategies, agricultural growing beds and a wetland plant nursery. These WSD elements were chosen from WSUD and SuDS in order to manage issues relating to water quality, quantity, amenity and biodiversity. Supporting programmes included a research office and laboratories, a conference centre, a restaurant and a public space for festivals or markets. These programmes were chosen to facilitate more opportunities for public engagement on the site compared to that in D1. In this study, WSAD is proposed to have three key focus areas: that of the relationships between people, nature and architecture. As it was felt that public engagement was not sufficiently provided for in D1, D2 considered these elements from the start of the design process, as shown in Appendix D.

The design process began with the building concept, shown in Figure 40. The design started with the localised context: the river, Table Mountain and Black River formed key points both visually and topographically for the site. Phenomenological principles guided that paths and connections are important, as well as creating identity. Using these principles, a primary line was created parallel to the river connecting the two geographical points to visually and architecturally link the building form to the points. A centre was then drawn, which became the point of gathering for all paths and the centre for the massing. A centred rectangle was drawn as the mass of the building, which was bisected across the primary line. This mass represented a central gathering space connecting to the river. At either end of the rectangles along the primary line two circular bookends were created. These represented the organically-shaped water bodies. An 'x' located on the central rectangle linked the built mass to the river. These became pathways or visual links across the river. Finally, arrows indicated a relationship between the built mass and the river edges, which needed to be porous and ambiguous as per the design imperatives. The building therefore opened up to the river. The design imperatives drawn from the expressive values were used as the primary drivers for this process. These values deal with the sense of place, spiritual value and cultural landscapes. This was done in order to connect the building spatially to its environment and create a sense of place by using the rivers and mountain as points of interest in the landscape.

The subsequent explorations developed on this concept diagram. At this stage, scale is irrelevant as concept is the more important aspect of the design. The next step dealt with programme and site elements. First, the natural elements were investigated in Figure 41. The existing birding areas and wetland zones were retained. Links across the river were important in order to experience the site as a whole. The entire site was comprised of different boundaries: the river, the edges, the built form itself and the components of the building. Flows across the site were explored, based on the movement patterns identified in D1. The nature of *boundary* was then explored. The flow of water on site was flipped and river edges were restored to reclaim the natural river edge.

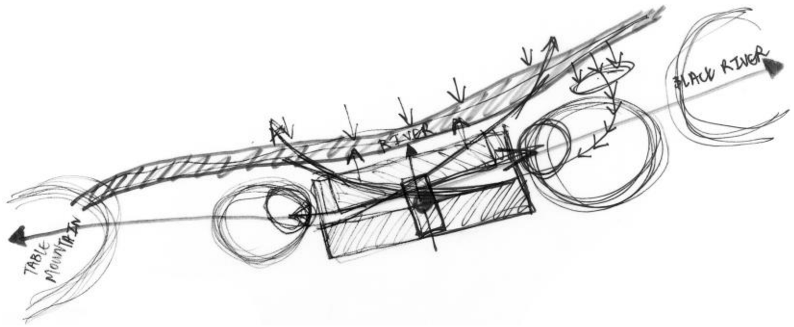


Figure 40: Understanding D2's concept. The description for the process of this diagram is given in text below. The massing exercise is informed by phenomenologically-derived design imperatives, which deal with expressive values (Author, 2016).

Next, programme was investigated. Zones for programme were roughly placed on site, as shown in Figure 42. The buildings on site were placed on the South end of the concept diagram, forming a built up area on the axis of the forecourt. This was done for ease of access and views across from the higher point of the site towards the river. The production cells became the mass rectangle located closest to the river. This was done in order to navigate the transition from the river, to the wetland nursery, to the man-made production cells, and finally to the buildings themselves. In this way, the boundary of the river opened up to include the D1 building. Links across the river became bridges to an adjacent wetland park. Water bodies as part of the filtration system formed the bookends of the concept diagram. Finally, recreational paths linked focus areas across site, including a pavilion at the highest point of the land. In refining the design for D2, a campus of water- and ecologically-related components that facilitates human interaction was uncovered.

The final planning diagram, shown in Figure 43, was concerned with the articulation of boundaries and the placement of the building components. The diagram is simplified as far as possible to aid in understanding. An emphasis was placed on the ecological aspects of the site: organic forms created habitats for fauna and flora to thrive and the wetland nursery draws insects to the area. Phenomenological aspects discussed in Chapter 3 were used to define the design: gathering courtyards became centres with a hierarchy of pathways giving direction linking the different elements on site. Views framed within buildings aimed to display the dominance of the sky and earth in the project, particularly towards Table Mountain and views over the different wetland and water processes. Importantly, the new design took into account the effects of the building on the natural water cycle on site through the use of green roofs, water recycling and collection, swales and a wetland nursery. The plant incubation facility would provide plants for the rejuvenation of the localised context, as well as the greater green-blue network along the Liesbeek River. This is in line with the design imperatives for this study.

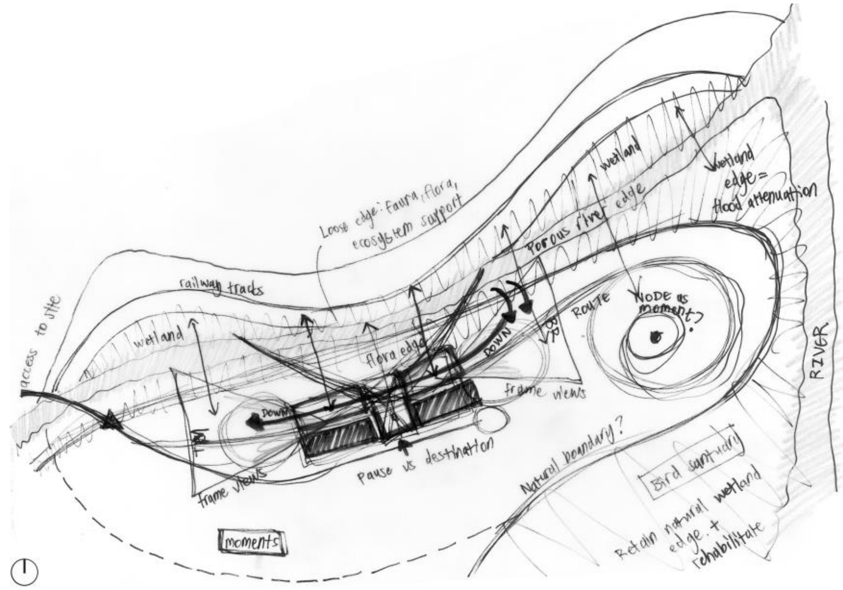


Figure 41: Exploring the natural boundary (Author, 2016).

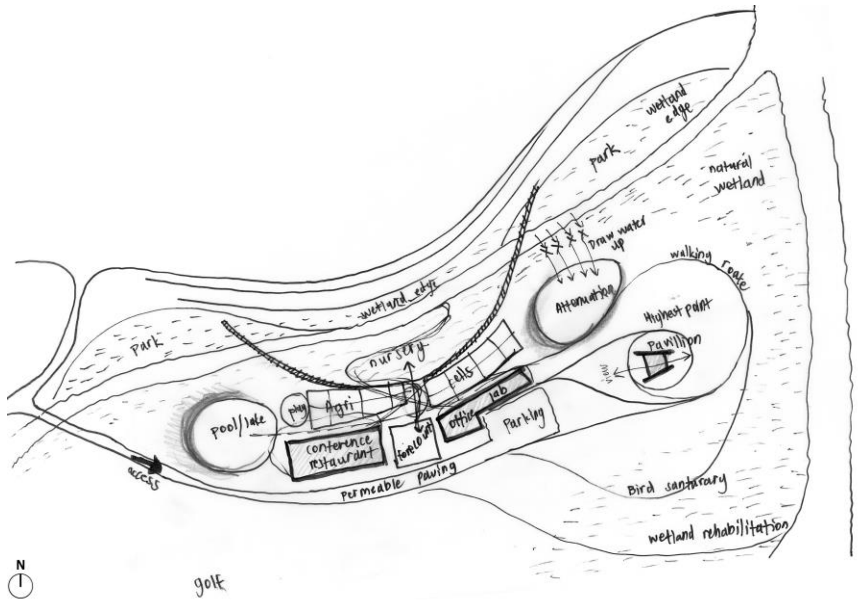


Figure 42: Roughly placing programme on site (Author, 2016).

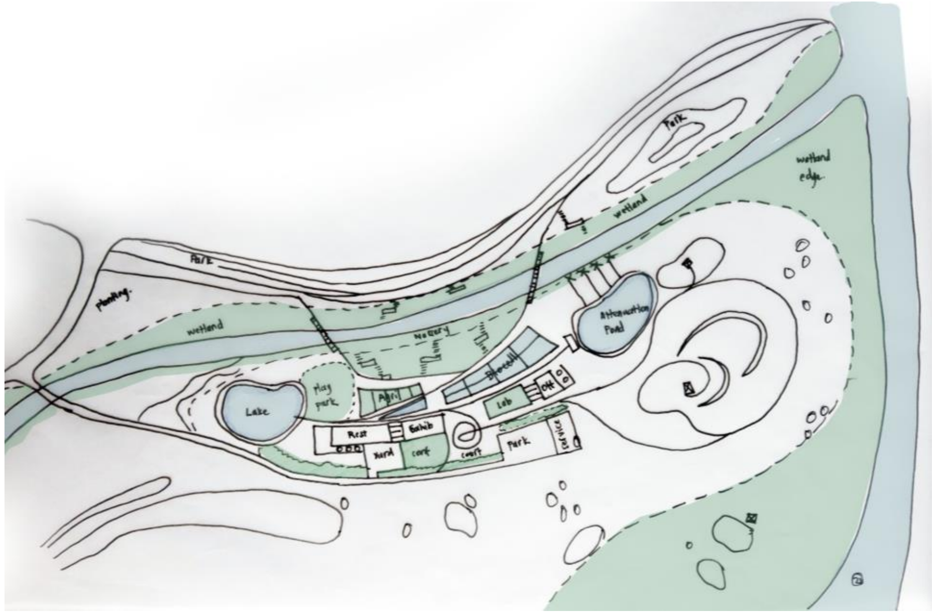


Figure 43: The final planning diagram (Author, 2016).

The design was then modelled in 3D in order to understand spatial dimensions in a more tactile manner, as seen in Figure 44. In the 3D environment, the different components of the building were resolved by means of testing scenarios through quick side sketches and then modelling the result. This allowed for real-time feedback from a person's perspective of the building. Particularly important was the development of the boundary in the design. Thresholds to buildings were staggered through the use of pergolas, creating indoor-outdoor spaces. A semi-covered office courtyard provided a space for resting and working outdoors, thereby enhancing the connection to the landscape. Large glazed walls minimised boundaries between the indoor and outdoor environments. The natural line of the river spilt into the wetland and nursery areas, which in turn linked with the different man-made, natural and water components of the site. When looking at the building at the meso-scale, the site became part of the greater blue-green network of the city and the building became part of the river environment itself. Once outside, the pathways direct the visitor towards the Black River or Table Mountain, creating an identity for the building and situating the visitor and daily user in the greater city context.

Figure 44: D2 (Author, 2016).

The visitor's journey through the building aimed to tell the story of water: the site is accessed via a bridge over the Old Liesbeek River off the main road, which leads to a parking area. From here, visitors move past swales and heavy sloped greened roofs to a public forecourt. This forecourt opens up to a view across wetland cells, urban agriculture and down to the river itself, with the adjacent wetland park. From the central forecourt, the visitor is able to follow the journey of water across the site. A walk to the pavilion located at the apex of the land opens up to multiple soft landscaped paths. These paths lead to bird hides and areas for viewing the natural and rehabilitated wetland edge. The paths facilitate walking, running and cycling across the site. Returning to the pavilion, the landscape is dominated by Table Mountain towards the South West. The entire site is visible from this vantage point, which allows for an understanding of the embedded process of water filtration.

Water is drawn up onto the site by means of wind pumps as a soft energy source. After discussions with a water engineer, this is a viable energy source as there are constant winds in this area of Cape Town. Thereafter, solids are settled out of the water in the attenuation pond. This pond also serves as a habitat for plants, insects and small animals such as birds and reptiles. Water is then funnelled into a holding cell, before being filtered in bio-filtration cells. These cells contain different soils, rocks and plants which filter out solids and small organisms from the river water. This water is clean enough for general use, but is not potable. The water is funnelled into a small trough which spans the built form. This trough is derived from the primary movement line across the site and is trafficable due to overlaid stepping stones. Water from this trough is either directed to a gathering pool, or stays in the primary axis. The primary axis passes a play park before terminating at a small recreational lake. This lake provides a habitat to fauna and flora. It also serves as a gathering and pause space for people to relax around. The gathering pool feeds a variety of different activities. Water from the gathering pool is used to irrigate an urban agriculture cell using sub-surface water feeds in order to maximise water use. The produce from this cell is consumed on site or is sold at weekly markets on site. Water may also filter down to a wetland nursery located at the river's edge. This provides plants used for rehabilitation of the rest of the river.

Overlooking the production cells are the buildings themselves, which form the South conceptual rectangle. This rectangle is broken up into different built forms: a restaurant and a conference and exhibition centre is located to the West of the forecourt. The research facility, comprising laboratories and a research office, is located to the East of the forecourt. Finally, water drawn from the gathering pool is treated in filtration tanks indoors for potable use.

D2-Evaluation

D2 was then evaluated by a panel of specialists. This panel consisted of an architect, water engineer, chemical engineer, lawyer, non-specialist users of the building representing the public layman and an ecologist (See Appendix F). Although the design was incomplete at this stage, the evaluation was done in order to understand which aspects of the design were unsuccessful and could be improved upon. This fits in with the RBD method, as emphasis is not placed on the outcome but rather on learning through the process of design.

During initial informal discussions with the panel of experts from the different disciplines consulted during the pre-evaluation stage of D1, the author attempted to explain the gestaltic manner in which architects work. This included the natural, iterative and instinctive way in which the architect designs in order to respond to site cues, the research done and the precedent consulted through sketches, discussion, model-making and designing in 3D. These ideas were initially included in the evaluation sheets, with statements evaluating the identity of a place and the feeling of being inside a space. However, the architectural gestaltic design process and ideas were not understood by the panel. After discussions with these experts, it was proposed that ideas conventionally understood by architects should be limited in the evaluation of the study, with the author remaining the architectural expert. As a result, the evaluation criteria were reformulated throughout the study in order to be universally understood. The study continued on the basis that the author would take into consideration the evaluations based on the seemingly 'non-gestalt', but explore them in a gestaltic approach. This was particularly important in light of the aims of the study, which is to allow the study to be easily understood by actors from different academic backgrounds.

Participants were shown a series of images that created a journey through the landscape, as seen in Appendix E, and were then asked to rate the design according to different criteria. These criteria are derived from the design imperatives, but arranged differently in order target the response sought. The different criteria were further explained on the evaluation sheet in order to assist the participants in the kind of way they should be evaluating the design. Verbal clarification was given where required. The scale used to evaluate the criteria was white-did not achieve, grey- achieved, black-excelled.

The main comments from the evaluation included the view that there was insufficient detail from the images to make an evaluation regarding indoor filtration processes, energy initiatives, identity and location. The mountain was not shown in these images as the design was still a work in progress, but this meant the participants were unable to locate themselves within the building. Identity as a concept was flagged by all non-architect participants for further explanation during the evaluation process. As a result, the images had to be explained verbally and therefore cannot be considered inter-subjective. This participant evaluation assisted in identifying both presentation and design weaknesses.

At this stage an architect was consulted for design input, using the same images shown to the participants. Comments arising from discussions around the architecture included the view that energy and water efficiency needed to be considered holistically, that water processes needed to be more visible on site, that ecological systems must be emphasised and that the visitor's experience must be fully considered. The outcomes of this discussion revealed that there needed to be greater ambiguity between the edge conditions of the buildings. This ambiguity could be underpinned by the ecological aspects of the design imperatives. Ambiguity may be achieved through the use of solid-void, light-shadow and inside-outside elements in order to enhance the porosity of boundaries of the walls, roof and floor planes.

To end off the evaluation stage of D2, the flow of water across the site was created and is shown diagrammatically in Figure 45. This diagram revealed that there are further opportunities for the integration of ecological systems and people within the site processes. This confirms the outcome from the discussion with the architect, where emphasis needed to be placed on the expressive values of the design.

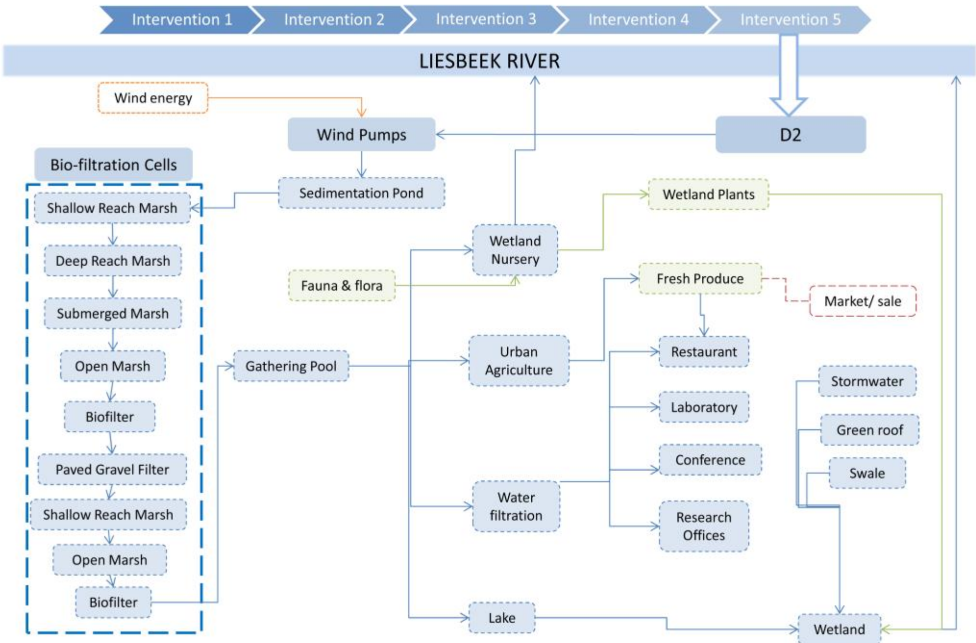


Figure 45: Flow of elements in D2. This diagram considers the flow of energy, water, plants and services in D2's design (Author, 2016).

D3-Process and Product

D3 was developed in order to address the issues upon reflection of the evaluation for D2. This is an important step in the RBD process, as reflection uncovers new ideas around the design. Issues raised by participants are noted as new design considerations. To begin the process for the design of D3, D2 was reflected upon in a sketch. This sketch, shown in Figure 46 and Appendix G, revealed that views connecting the building to the local context needed to be reconsidered as they did not frame the built and natural site-defining elements sufficiently. Ambiguity was required to create indoor/outdoor spaces with blurred boundaries. This may be achieved using light and shadow to define spaces.

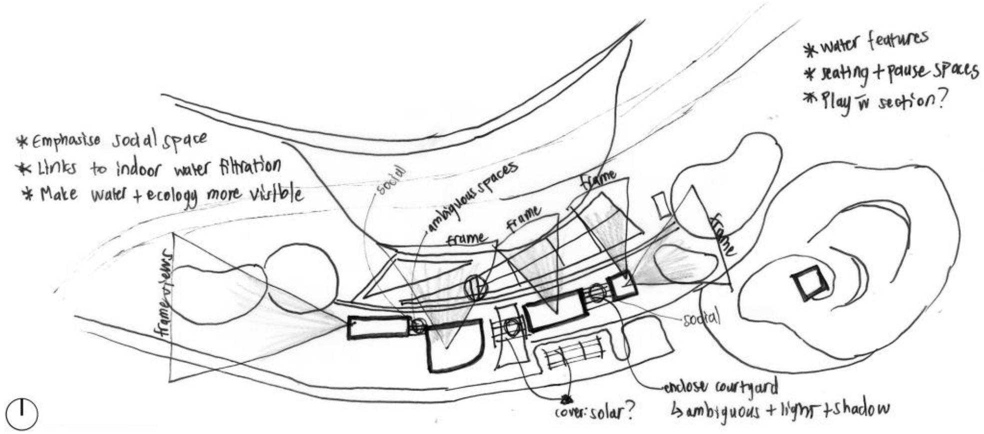


Figure 46: A reflection on D2's design based on comments from the participant evaluation (Author, 2016).

D2's evaluation revealed that water and energy processes need to be considered more holistically. These aspects may be embedded in the ecological infrastructure of the site. When reflecting upon water, the different filtration processes on site needed to be more visible. This facilitates passive education relating to water management and use. This passive approach would allow people to understand the value of water in their journey across the site. In order to do so, interaction with water must be facilitated through the five senses. Indoor filtration tanks could be made a feature and put on display, thereby engaging with sight. Water drinking fountains were placed across the site, thus engaging with the sense of taste. Water features such as fountains or waterfalls made the journey of water across the site more tactile. Water features are added across the site to serve as focus elements in gathering spaces. The sounds from moving water in these water features became a characteristic of the site, engaging with the sense of sound, smell, touch and taste. A subjective decision was made not to use large fountains or vertical water features in the design.

As energy is not a focus of the design, passive energy initiatives were not fully considered in D2. However, greater emphasis needed to be placed upon energy efficiency in the design. Solar energy was introduced as an alternative energy source. Solar panels were installed on the flat roofs, as well as made to form shading for cars in the parking areas. Passive ventilation and passive lighting were added. The heavy green roofed buildings contributed to thermal mass. The fully glazed Northern façade was shaded with pergolas containing solar panels. Energy-efficient lighting, light zoning and energy-sub metering was introduced as energy-saving strategies for the design.

Figure 47: D3 (Author, 2016).

The visitor's experience must be fully considered. Gathering spaces needed to be more defined and made into places. This was achieved by looking towards the phenomenological principles of gathering, symbolism, node and centre. Levels inside the building were manipulated, although it was decided in D1 that a double- story building would not be suitable in this landscape. As a result, the research offices were dropped into the earth with an adjoining isolated research garden. The building was given a mezzanine level, which is accessible off the outdoor meeting courtyard. The research office was chosen as the building with the manipulated levels as it was located at the highest point on site. Thus only heavy floods events are likely to cause damage to the building. These changes were implemented and modelled in 3D, as shown in Figure 47. Rendered images were generated from this model for use in the evaluation stage for D3, as seen in Appendix H.

D3-Evaluation

D3 took into account participants' comments from D2's evaluation, as well as the thoughts generated from the evaluation process. As a result, a subjective analysis was conducted for the completed D3 design, as shown in Figure 48. This was done in order to ensure all thoughts derived from the RBD process thus far were reflected upon and implemented. As per D1, the analysis was done using the design imperatives, with comments explaining the evaluation done. Comments were given for each criterion and considered the macro-, meso-, and micro-scales. Additionally, the comments aimed to cover points raised through the evaluation of D2. The objective of this analysis was to be as critical as possible, as well as consider the architectural design. The outcomes of the subjective analysis revealed that a level of architectural refinement was required. This also referred to the graphics of the design presented. Ambiguity of boundaries needed to be explored further. Soft outdoor landscaping had hard edges, building edges were heavy and rhythm in the design must be considered.

Various aspects were identified for discussion with a specialist: that of nutrient cycles created within the production cells and how to deal with ablution and kitchen water waste. Nutrient cycles are important for plants and soils. Plants need a range of nutrients to grow. Water entering the river system is rich in both wanted and unwanted nutrients and pathogen brought in from the Liesbeek River. These enter the water across the macro-scale water system. Although not an exhaustive list, the nutrients are a result of pollution, plant and animal matter, detergents and contaminants from roads collected in stormwater. Nutrients and pathogens are filtered out of water by plants and soils.

In D3's water system there may be an over- or under-provision of nutrients due to the filtration and production systems chosen. An alternative for self-composting toilets must be investigated as the level of maintenance required for such a system is high. The toilets must be cleaned, visitors need to be educated on their use, odours need to be managed and a system would need to be put into place for removal of waste. However, this is still a valid and sustainable system for dealing with waste. Further, greater emphasis was required on ecological systems for benefit to the city at the macro-scale. Figure 49 demonstrates a more complex system of flows than in D2. Water systems dominate the diagram, but an emphasis on the relationship between fauna, flora, people and water is missing.

After this reflection on the evaluation, a water engineering specialist and an ecologist/environmental specialist were consulted. This was done to discuss D3 with regards to the different design informants, evaluating the success of the design from these different viewpoints. The evaluation sheet used was the same one used for the participant study in D2's analysis. These evaluations may be found in Appendix I. Various points of concern were noted form the discussion and evaluation of the design. Recycled materials needed to be emphasised in the design. Recycled materials reduces demand on virgin building materials and adds vibrancy to the design. From an environmental perspective, these materials must be sourced close to the site. This notion is supported by the Green Building Council in their guidelines for a sustainable building (GBCSA, 2014).

D3 Evaluation - Author

Criteria for evaluation: Light grey- did not achieve Medium grey- achieved Dark grey- Excelled

Design imperative	Evaluation comments	Evaluation
Cultural services: Aesthetics, sense of place, spiritual value, cultural landscapes, educational, spiritual, recreational		
Ensure building is aesthetically pleasing through design.	Achieved. Detail refinement required: roof edges heavy, pergola components bulky. Hard edges of pathways don't show soft landscaping correctly. Softer, ambivalent edges.	
Consider architectural elements of point, line, plane, form, massing, hierarchy, ordering systems, geometry, rhythm, thresholds, and ergonomics.	Achieved.	
Frame views across scales to other natural & design elements.	Achieved, but needs refinement.	
Engage with spiritual history of site through architecture and construction materials.	This aspect was not focused upon in this design.	
Create identity using gathering/symbolism/visualisation.	Gathering spaces more defined. More emphasis on ecological systems? Site context missing.	
Make building comfortable for people.	Achieved. Resting and recreation facilitated.	
The building and the water in it must engage with the 5 senses to give a sense of identity.	Achieved, needs refinement.	
Create paths which orientate towards river/mountain/design elements by using nodes/paths/districts.	Achieved.	
Use enclosure & extension (centre & rhythm), light & shadow to define space.	Consider rhythm in tectonics.	
Use construction materials, detailing and making to give the building identity.	Building could make better use of these principles. Building makes use of recycled materials – needs to be shown.	
Define and make boundaries porous at different scales: create ambivalent indoor-outdoor spaces using light & shadow, enclosure & extension.	Partially achieved. Indoor/outdoor courtyard/meeting spaces created. Buildings and production cells still defined.	
Activate building as part of CTSDF, TRUP and MOSS.	Achieved. Plant incubator for MOSS and therefore benefits CTSDF. Value added increases natural & cultural value of TRUP.	
Create spaces for gathering and quiet reflection.	Achieved.	
Provide spaces for resting, sports, and social.	Achieved.	
Link recreational focus areas on site using paths.	Achieved.	
Make visible building and recycling systems.	Partially achieved. Ablution systems not visible.	

Comments: Ecological layer missing in site processes. Building more people-orientated & accessible than in D1.

Design imperative	Evaluation comments	Evaluation
Regulatory services: Disease, climate, water, water, pollination		
Create habitats for flora.	Achieved.	
Aerate water through vertical movement.	Achieved with small vertical movement. Subjective design not to use large fountains or waterfalls.	
Use constructed wetland principles for passive water filtration on site.	Achieved.	
Use WSUD's and SuDS elements for localised flood control.	Achieved.	
Link design to larger MOSS & CTSDF for flood control	Achieved.	
Create habitats for fauna: can pollinate plants.	Achieved.	

Comments: Minimised vertical movement of water a design choice.

Design imperative	Evaluation comments	Evaluation
Supporting services: Primary production, soil formation, nutrient recycling		
Introduce agricultural production.	Achieved.	
Restore flora on site to assist with binding of soils.	Achieved.	
Repair site to restore existing soil and earth conditions.	Achieved.	
Use soft landscaping and outdoor trafficable surfaces	Achieved.	
Sort ablution effluent into solids and liquids for nutrient recycling.	Self-composting toilets used. Needs to be discussed with specialist.	
Ensure nutrients are balanced across site systems.	Partially achieved. Needs to be discussed with specialist.	

Comments: Nutrients in system to be discussed with specialist.

Design imperative	Evaluation comments	Evaluation
Provisioning services: Food, water, energy, raw materials, bio-chemicals, genetic resources		

Introduce agricultural production if possible.	Achieved.	
Diversify water sources on site.	Achieved. Rainwater collected for irrigation & filtration for potable water.	
Don't use potable water for non-potable uses.	Achieved.	
Building to form part of larger blue-green network of city.	Achieved.	
Use WSUD's and SuDS elements for drainage of water on site.	Achieved.	
Recycle and filter water on site for reuse.	Achieved.	
Strategy required for alternative sanitation systems.	Achieved.	
Consider recycled building materials.	Achieved.	
Use water & energy efficiently in building: water-wise fittings, low energy fittings, passive ventilation, and alternative sources.	Achieved. Solar energy added.	
Restore flora on site to assist with habitat creation, flood controls, binding of soils.	Achieved.	

Comments: Indoor water systems more visible?

Design imperative	**Evaluation comments**	**Evaluation**
Design values (from D1)		
Understand and incorporate the local context of the site by exploring the boundaries of historical, cultural, architectural, natural…	Partially achieved, but must be shown in design. Historical aspects of site not focused on in this design.	
Facilitate site repair.	Achieved.	
Consider ecological infrastructure: integrating infrastructure as landscape, link multiple elements and systems across the site.	Partially achieved. More emphasis on ecological aspects.	

Comments: Greater emphasis on ecology and people required.

Figure 48: (And previous page) Subjective analysis of D3 (Author, 2016).

A discussion around nutrient cycles and ablution waste was initiated after both issues were highlighted in the subjective analysis. Nutrient overload is possible in the system when considering urban agriculture, even though agriculture is a low impact and efficient use of water and soil resources from the environmental perspective. However, this issue can be solved using nutrient monitoring within the agricultural cell. From the engineering perspective, the most efficient nutrient balance would be one driven by phosphorus. Should nutrients necessary for agricultural production be drawn out of the water by the time it enters the agricultural cell, compost would replenish these in the system. Although the water system shown in Figure 49 is not a completely closed system, in closed-loop systems salt balances also become an area of concern. This can be solved by monitoring the system and adding the necessary nutrients when required.

The next discussion revolved around black water on site, and how this should be dealt with. In D3, black water is sourced from the kitchen and ablutions. A methane digester was proposed to deal with fats produced in kitchen. Care must be taken with disposal of black water into the system, but this is easily achieved by educating staff. Water from the laboratory is not heavily contaminated, as it contains plant matter and nutrients. This water can be added to the methane digester. Ablution water can be separated into solids and liquids. The liquid component is used for composting, while solid matter can be introduced to the methane digester. The methane gas produced can then be used in the kitchen for cooking.

The effects of climate on water is another point of concern in the design. As temperatures increase, oxygen in the water decreases. To keep water oxygenated, vertical flow of water is important for aeration. As a result, fountains and waterfalls are required in the design. Water is also subject to evaporation under hot and windy conditions. This is amplified by the temperature of the water in the system on hot days, when gas solubility is high. In D3, most areas which contain water are planted. This offers shading and protection from the elements. Water used for irrigating the agriculture cell travels through a sub-surface system. The larger pools of water, such as the lake, are exposed in areas. Planting around these areas provides some protection, but evaporation will occur in the system and is considered as part of the water cycle.

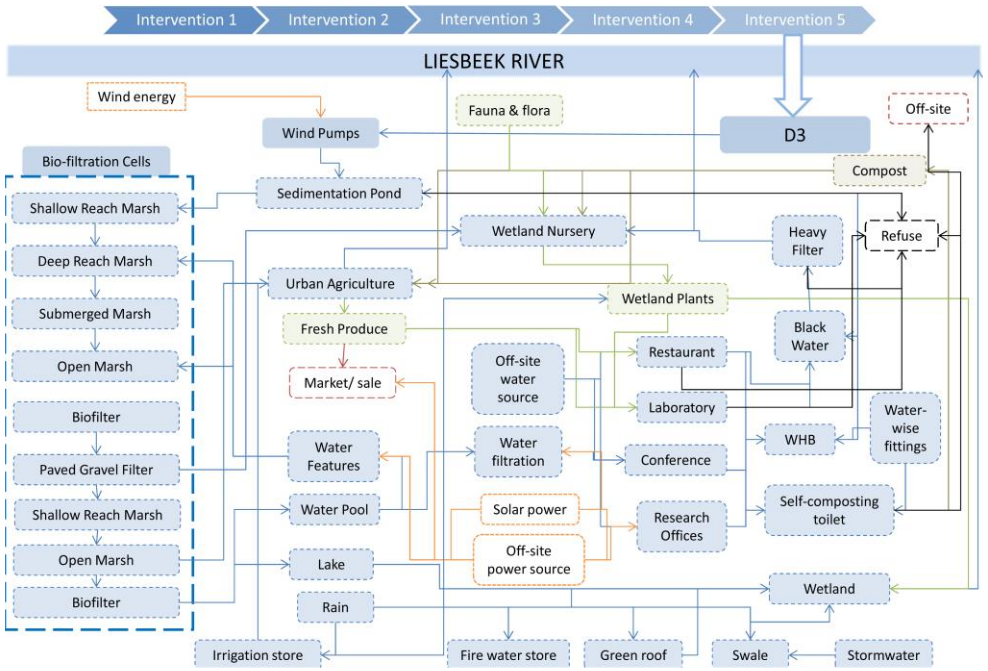


Figure 49: The flow of elements in D3. In this diagram, the flow of energy, water, services, plants and refuse is shown (Author, 2016).

Although the socio-economic context is avoided in this study as explained in Chapter 1, both specialists discussed the benefits D3 could have at the macro- and meso-scales. There are direct economic benefits through the prevention of the degradation of water system, which is the aim of this design. This includes the monetary value associated with flood and urban water management. Through the different interventions along the river, the overall aesthetics of the natural environment is increased. Public recreation along the river is facilitated, which gives value for the public. Returning to the micro-scale, D3 offers an opportunity for job creation and awareness around water. Both aspects uplift communities through knowledge-building and economic value. The evaluation and discussions for D3 were used to inform the final design iteration, D4.

D4- Process and Product

As a result of the discussion and evaluation process in D3, D4 was created as the best-fit solution that considers all aspects of the research, as well as the reflections done on the evaluations of D2 and D3. The results of the process and design thus far were discussed with an architect to gain another architectural perspective on the design. The design imperatives speak of rhythm, which is not considered fully in D3. As a result, the structural system of D3 was rationalised on a five meter grid across the buildings. The areas of the different spaces within the buildings were adjusted to fit into this grid. The original concept, as shown in Figure 40, was reflected upon with reference to the product of D3. In D3, the building massing was broken up programmatically with different roof types, although still symmetrical around the centre axis. In order to return to this concept, a new roofscape is proposed. This green roof covered the building mass on either side of the central forecourt in order to create a more cohesive and simplified form, as shown in Figure 50. Green roofs were used in D2 and D3 in order to minimise the impact of the building on the land by 'replacing' the land built on at a higher level. This assists in habitat creation for flora and fauna. In expanding this roof, more green roofscape is created. The roof form was based on a repeating parabola and echoes waves and the movement of water. Voids are cut where required to let light and ventilation into the building below. The pergola on the north façade was retained in order to provide shading to this elevation.

After reflection on the comments in D3's evaluation and in discussion with the architectural consultant, edges were softened and timber construction members were made lighter. Small waterfalls and fountains were introduced across the site system for aeration of water, dealing with concerns relating to the deoxygenation of water in the system. Ground-level solar-powered lights were introduced along walkways to animate spaces at dusk and dawn. Recycled timber and stone was used throughout the design. Views were better framed within the different spaces. Ambiguity between inside and outside spaces was achieved through the use of large glazed facades, which slide open. Covered courtyards below the green roofscapes created indoor/outdoor meeting spaces and provided spaces for educational discussion or recreation. Methane digesters and rainwater tanks were made more visible, although the ablution systems were kept concealed due to their back-of-house location. These methane digesters and rainwater tanks were clad with information posters which explain the processes being used on site to deal with rainwater, grey water and black water.

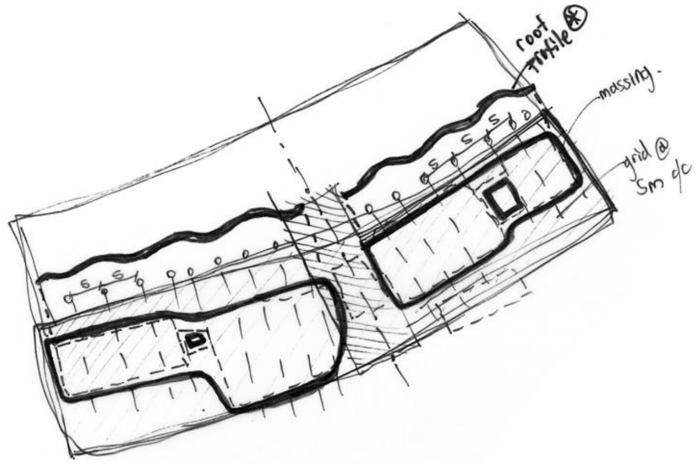


Figure 50: D4 roof design investigation (Author, 2016).

In reviewing the design imperatives, drainage considerations were touched upon. Drainage has not yet been discussed in the text, but has informed the different design iterations. Permeable paving at the South end of the site drained into an adjacent swale, taking water down to the river. Grey water within the building was recycled and filtered for further use. Black water was processed in methane digesters. Rainwater was allowed to infiltrate the production system or be absorbed by the earth. Rainwater on roofscapes was absorbed by the green roof layer, before filtering into rainwater tanks. This water was then used for irrigation. These different design considerations informed the modelling of D4 in

3D. The renders created were then manipulated to show the local context in order to locate the site in its meso- and macro-contexts, as seen in Figure 51 and Appendix J.

Figure 51: D4, the best-fit design solution (Author, 2016).

D4-Evaluation

D4 was created as the best-fit design solution and constitutes the culmination of the RBD process. This is in line with the RBD suggestion made by Hulsbergen and Van Der Schaaf (2002:161), who suggest that only three or four iterations must be created. This allows for patterns and similarities to be uncovered, but also restricts the study extents. D4 was first discussed in terms of the system flows on site and is then subjected to a RBD evaluation called an effects analysis.

The D4 flow diagram reveals integrated systems dealing with ecological considerations, people and water across scales. It was noted in D3's evaluation that a greater emphasis needed to be placed on ecological systems and the relationships between nature and people in the ecological infrastructure of the site. In D4, an ecological system was considered independently, and then woven into the existing flows of D3. This consideration had impacts across scales. In Figure 52, the impacts of the different interventions across the MOSS system, focusing on the Liesbeek River, are shown. Through D4, different sections of the river are rehabilitated, enhancing both water and the environment in this area. A by-product of this is an increase in public interest in this area.

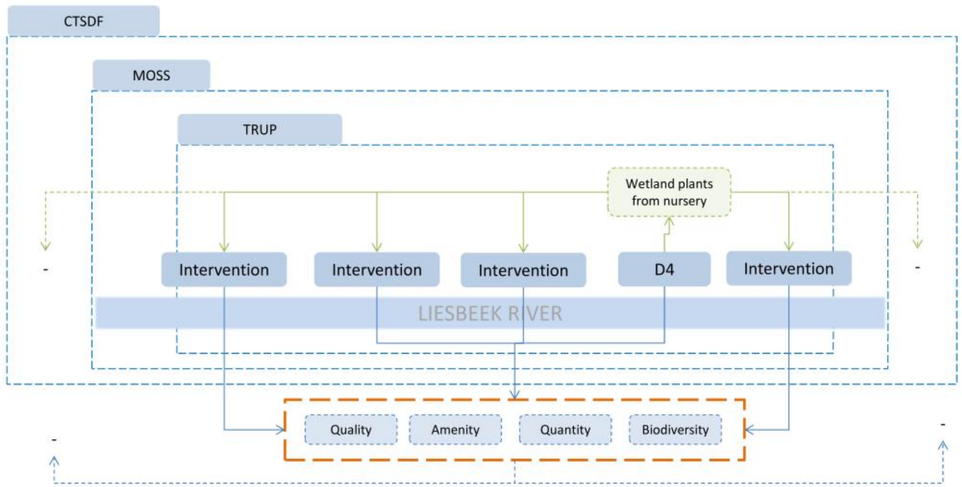


Figure 52: D4 flow diagram at the macro-scale (Author, 2016).

Figure 53 shows D4's flows at the macro-scale. This diagram explains the interconnections and woven systems of water and the environment, as well as the benefits to man in such an intervention. The more complex system demonstrates the possible systems that could be present in a WSAD.

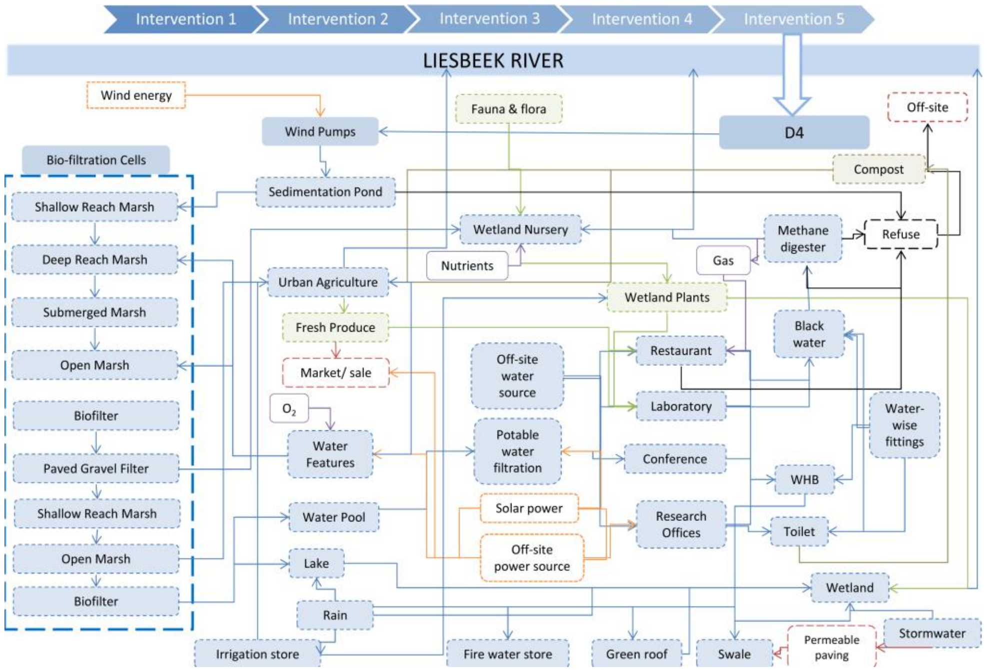


Figure 53: D4 flow diagram at the micro-scale (Author, 2016).

D4 is then analysed using the same architectural characteristics D1 was subjected to, as shown in Figure 54 and Figure 55. The architectural characteristics analysis revealed that the design of D4 is based upon symmetry. The structure for the buildings was based on a five meter grid and spaces are arranged around these. Natural light filtered through on the north and south façades. Light and shadow were used to define indoor/outdoor ambivalent spaces. The massing section shows that the buildings were constructed at the highest points of the site, while the site works form part of the gradient leading down to the river.

The plan-to-section relationship showed a similar principle, although only single-story buildings are created. As mentioned previously, it was felt that any larger sized building would be overly dominant in the flat landscape of the Raapenberg site. D4 was balanced around its axis, with the built form forming an approximate mirror of the bio-filtration cells along this line. Circulation within the building was predominantly linear, in keeping with the primary movement line which defines the axis parallel to the river leading towards Table Mountain. The additive to subtractive relationship was also defined according to the movement routes on site. The building's repetition-to-unique relationship shows the patterning caused by the filtration cells. Geometry, hierarchy and parti were all defined by the masses in the concept diagram of Figure 40, and were guided by rectangles intercepted by pathways.

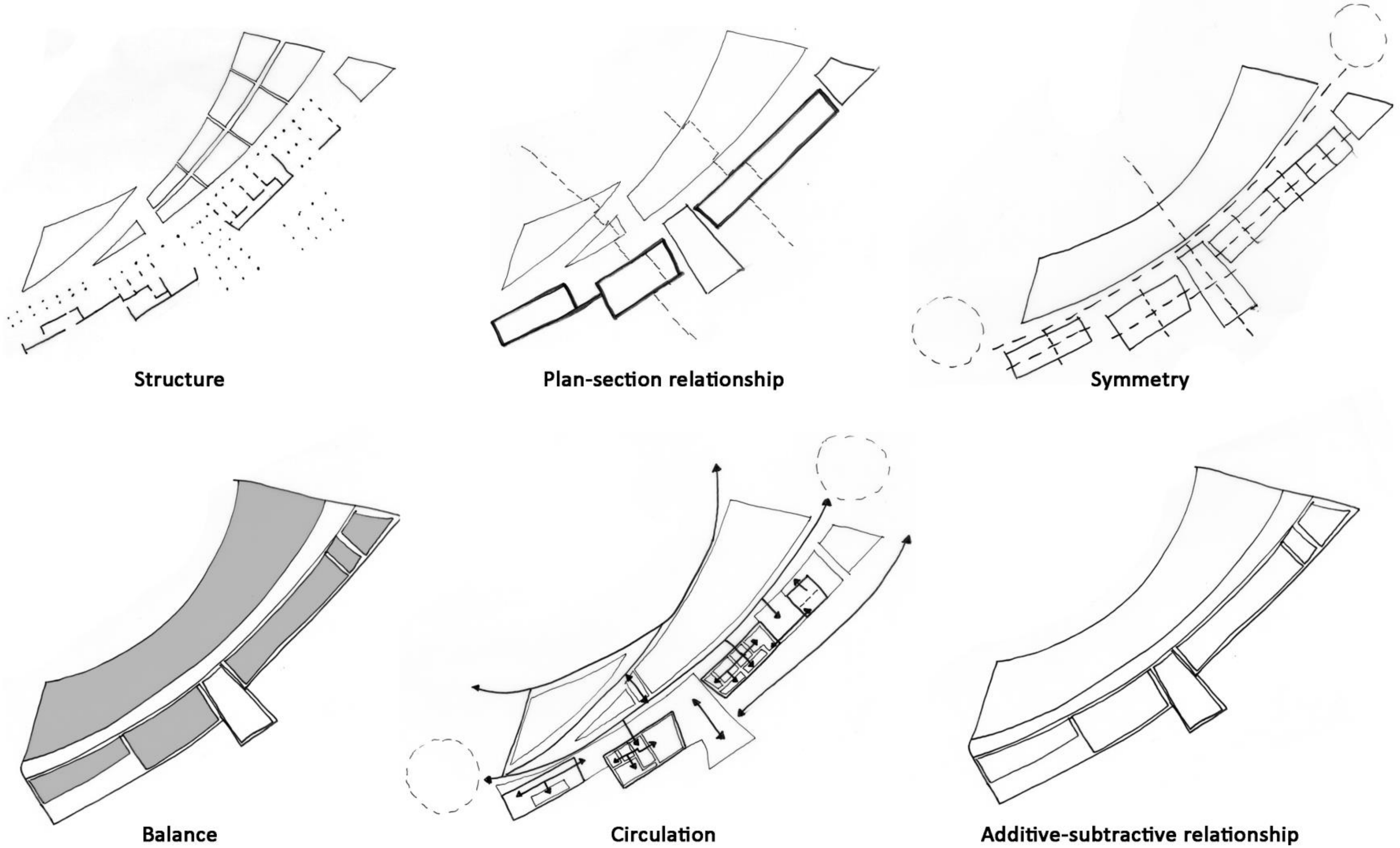


Figure 54: Analysing D4 according to architectural characteristics. Clockwise from left, Structure, plan to section relationship, symmetry, additive to subtractive relationship, circulation and balance (Author, 2016).

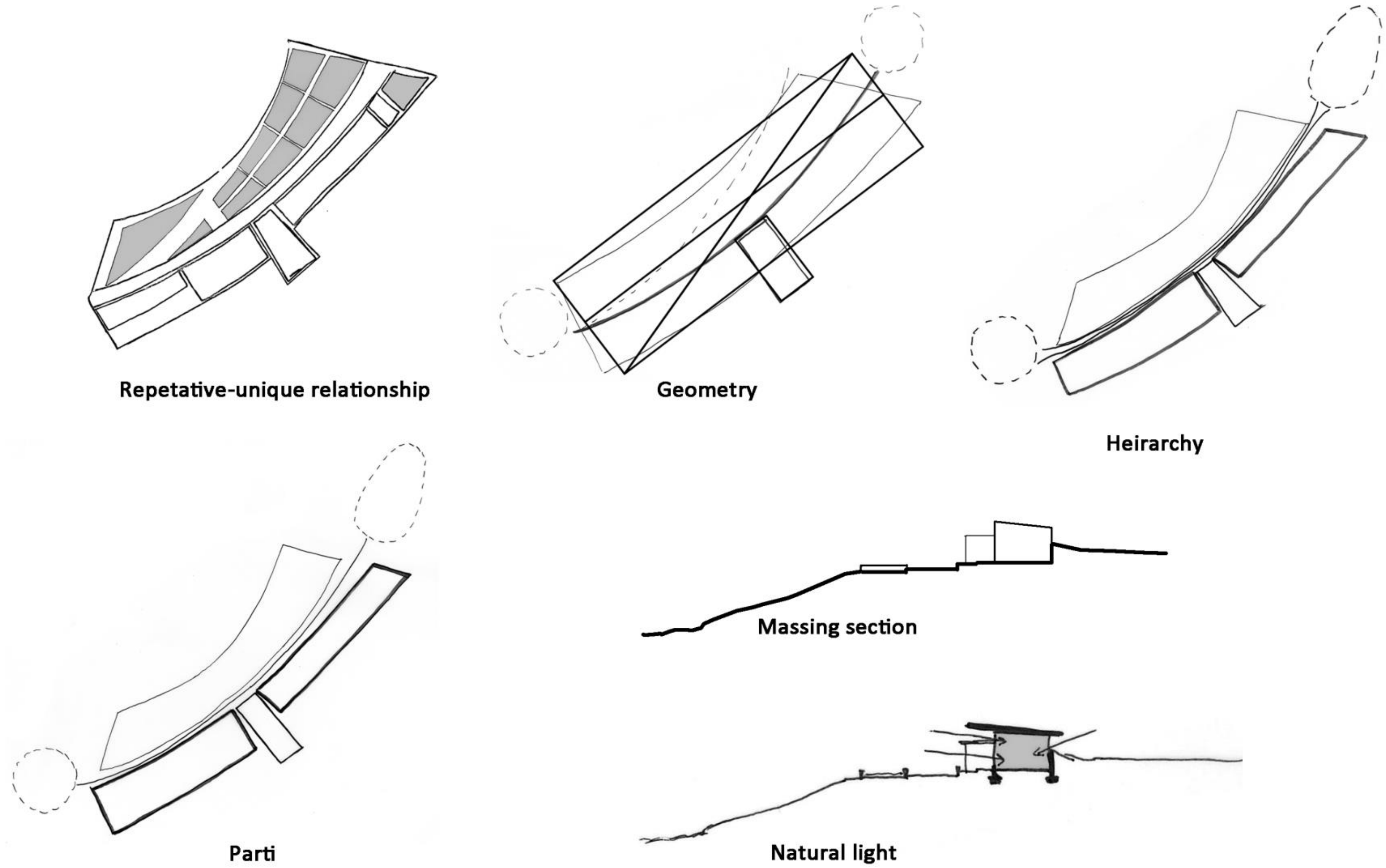


Figure 55: Figure 56: Analysing D4 according to architectural characteristics. Clockwise from left, the repetitive to unique relationship, geometry, hierarchy, parti, massing in section and natural light (Author, 2016).

Having understood the different elements that comprised D4, the evaluation turns to the effects analysis. An effects analysis is a RBD tactic used to compare different iterations of a building. In this project, an effects analysis reveals the development of D4 by comparing D4 to D1. In *Ways to Study and Research* De Jong (2002:173) identifies the criteria that must be met prior to an effects analysis. These criteria are briefly mentioned in Chapter 3, which discuss the evaluation objectives and process for RBD. Each criterion is explained, before D4 is compared to D1.

1) Explicitness & expressiveness: This criterion deals with how easy the plans are to read, and how rich and revealing they are about the design. D4 was not presented to the same level of depth that D1 was required to do, as this study has different aims to that of the previous one. The explanations given and sketch diagrams shown allow the programme and processes used in both designs to be shown. This level of detail is sufficient in this study, as the focus is not solely on the design itself, but rather on the ideas informing the design.

2) Comparability: The plans must be of an equal scale and legend in order to be compared. Both buildings' macro-, meso- and micro-scale sketch proposals were designed using the same scale and a similar style of drawing. It must be noted that the design process was accelerated in D4. This was a result of time availability, experience and end objectives. As the author has more experience as an architect than during the design of D1, concepts and links are made at a faster pace.

3) Documentation and retrievability: This criterion deals with how the design process is documented. In this study, the design process for D1, D2, D3 and D4 has been explained in detail. The reflection processes for D1, D2 and D3 are summarised in the appendix. The reflection process involved drawing through thinking, and thinking about the design being made. The thought stream therefore is a part of the RBD process in uncovering ideas relating to a WSAD. As discussed in Chapter 3, a problem of design-based research is in the reliability of the results. By documenting the design process, the study gains credibility in that the design moves are accessible and the process is thus retrievable.

4) Supposed context and perspective: This criterion deals with the different political, cultural, technical, economic and ecological/ environmental aspects of the building. The strategies for dealing with these criteria were established during the process of D1 and were taken as the same during the scenario-testing process. D4 attempted to spatialize the ecological and water systems on site with the assistance of different participants, including a water engineer, architect and ecologist. Additionally, D4 aimed to create opportunities in which the relationship between man and nature may be enhanced through the expressive aspects of architecture. Thus, greater emphasis is put on the design imperatives drawn from the cultural values of ecosystem services, as discussed in Chapter 3. Economically, the project adds value through selling produce at markets, but also in the value of river rehabilitation and the positive effects this has on the environment and community.

D4 adds value to the cultural landscape of the city, as it becomes a place for meeting others and interacting with the environment through various site activities. The building has avoided dealing with the greater socio-political challenges affecting the city, including a lack of housing and poverty. It was felt in D1 that these issues would detract from the focus on natural systems in the design. D4 adds value to the technical landscape by combining different WSD initiatives, as discussed in Chapter 3, to form a WSAD. Through flood attenuation and decreasing erosion, the building decreases soil build-up at the river mouth and the need for artificial widening of the river to deal with flooding. Spatially, the building attempts to embody the different aspects of phenomenology by using expressive values. These values deal with framing views, creating centres, highlighting directional paths and giving identity.

D4 has multiple ecosystem services and benefits across the macro-, meso- and micro-scales. These include the benefits of erosion and sediment control, waste treatment, wetland rehabilitation, water treatment, habitat creation for fauna and flora and mitigation of hazards such as pathogens in urban water systems. Human-related benefits include that of recreational value, understanding the values of water through education, the productive use of water for agriculture, potable water supplementation and agricultural crops.

5) Intended and unintended effects: De Jong (2002:173) suggests that the design must be evaluated against the original design criteria. D1 and D4 are different studies and therefore have different aims. However, a similarity between both studies is a concern for water and wetland rehabilitation through WSD means. Three design imperatives were drawn from D1 during the description of the raw data at the beginning of this chapter. These imperatives were added to the list defined in Chapter 3 and used alternatively as guidelines or evaluation criteria for the successive design iterations. Thus D4 is an extension of the design discussed in D1.

The intended effects of this RBD process include a change in design from D1 to D4, greater socio-economic benefits in D4, a greater emphasis placed on the role of people and ecology in the design and a building that embodies the design imperatives uncovered. Vitruvius's architectural principles of firmness, commodity and delight are taken into consideration: the building must be able to stand robustly while remaining in a good condition; it must be suitable for the purpose it has been designed for and must be aesthetically pleasing (Macdonald, 2007:xi). Both D1 and D4 adhere to these guidelines. After discussions with the consultants, an unintended effect is that the design could be adapted to draw water from the Black River into site systems in a future phase, assuming the Black River is rehabilitated.

6) The effects analysis

The aim of the effects analysis is to identify the similarities and differences between the plans and compare the effects. To do so, the differences between plans are identified and described. A difference is selected as the subject, and the positive or negative effects of the suffering objects are determined. The effects are then listed and a conclusion is drawn (De Jong, 2002:174). In the participant analyses, the participants used criteria that were developed from ideas drawn from the conceptual and theoretical frameworks instead of those drawn directly from the design imperatives themselves. It was hoped that by doing so, the evaluation process would initiate discussions around the different criteria, thereby highlighting issues in that specific design iteration. A new set of criteria developed directly from the design imperatives was used for both the subjective analyses for D1 and D3, as well as the effects analysis. This effects analysis is shown in Figure 57.

As value is a focus in this study, an additional values analysis is conducted, based on Ramirez (2015:138). Although this kind of analysis is not generally used in RBD, it became apparent that such an analysis was required. This is because D4 is considered at multiple scales and levels simultaneously, and cannot be explained fully using only one type of analysis. The functional value assesses the usefulness of an object, in this case D4 (Ramirez, 2015:137). The building successfully meets its aims as a place in which river rehabilitation can occur through the use of passive filtration on-site. By exposing the public to water in its different forms throughout the site, opportunities for the interaction with water and the acknowledgment of the value of nature is facilitated. Ecologically, the building restores natural riparian systems and provides habitat for fauna and flora. The various publicly-accessible programs on site add to its usefulness within the community.

Economic or exchange value evaluates the trade worth of a building (Ramirez, 2015:138). This relates to the feasibility of the design from a financial perspective, as well as the value of non- monetary exchanges. This project has not dealt with the direct monetary value of the building, but there is possibility for further research in this area. The monetary benefits of rejuvenating the Liesbeek River across MOSS could be investigated further. This aspect is discussed in Chapter 6.

In terms of exchange value, education through interaction with nature on site sensitises people to the value of water, which can be transferred back to their communities. Volunteer participation in the cultivation of crops and wetland plants transfers essential skills to the community. Agricultural produce grown on site is used in the restaurant and also sold for profit on community market days, further exposing people both directly and indirectly to the value of water. Although the socio-political and economic aspect has been avoided in this study, an effect of this intervention is job creation. Employees are to be sought from neighbouring suburbs, which include both affluent and poorer communities. By working in this environment, people return to their communities with both knowledge and spending power. Through supporting small local businesses, these employees uplift communities.

The symbolic value assesses the attachment and self- awareness of people to the building (Ramirez, 2015:138). In making the building an experiential journey through the wetland park, people gain self- awareness as well as contextualise their Selves within the greater landscape. Through recreational activities and interaction with the campus, people understand the value of nature and their role in its conservation, which strengthens their attachment to the site due to its character and identity. This links to the Deep Ecology and the design informants identified in Chapter 2; and therefore achieves the aim of enhancing human interaction with nature.

Design imperative	D4 evaluation comments	D1 evaluation comments
Cultural services: Aesthetics, sense of place, spiritual value, cultural landscapes, educational, spiritual, recreational		
Ensure building is aesthetically pleasing through design.	Achieved. Detail refinement achieved: softer edges, lighter architectural elements, new roof design to accommodate massing and 'replace' land lost by building. At the meso-scale, the building blends into the landscape.	Attractive building, although more programme could be accommodated.
Consider architectural elements of point, line, plane, form, massing, hierarchy, ordering systems, geometry, rhythm, thresholds, and ergonomics.	Achieved.	Form, massing and thresholds need to be improved.
Frame views across scales to other natural & design elements.	Achieved.	Views from building to mountain not framed.
Engage with spiritual history of site through architecture and construction materials.	This aspect was not focused upon in this design.	This aspect was not focused upon in this design.
Create identity using gathering/symbolism/visualisation.	Architectural routes are gathered at nodes. Water and nature is on display throughout the building. Site processes symbolised and echo natural processes.	Design creates gathering spaces for the confluence of movement route. Symbolism and visualisation of natural environment is minimal through tectonics. Constructed wetland cells do mimic natural processes.
Make building comfortable for people.	Achieved. Recreation, education, production facilitated.	Greater emphasis on light and connection in buildings required. Buildings do take into account scale and spatial use by people.
The building and the water in it must engage with the 5 senses to give a sense of identity.	Achieved.	Design does not engage fully with touch, sound, smell or taste senses.
Create paths which orientate towards river/mountain/design elements by using nodes/paths/districts.	Achieved.	Achieved.
Use enclosure & extension (centre & rhythm), light & shadow to define space.	Rhythm introduced through grid and roof pattern. Light & shadow used for screening.	Building could make better use of these principles.
Use construction materials, detailing and making to give the building identity.	Recycled materials used.	Building could make better use of these principles. Building does make use of recycled materials.
Define and make boundaries porous at different scales: create ambivalent indoor-outdoor spaces using light & shadow, enclosure & extension.	Indoor/outdoor courtyard/meeting spaces created. Buildings and production cells defined but edges softened.	Not achieved. Hard river edge designed which does not allow for transfer of elements across boundary. Spaces are not ambiguous.
Activate building as part of CTSDF, TRUP and MOSS.	Achieved. Plant incubator for MOSS and therefore benefits CTSDF. Value added increases natural & cultural value of TRUP.	Achieved, although more explanation required across scales.
Create spaces for gathering and quiet reflection.	Achieved.	Achieved.
Provide spaces for resting, sports, and social.	Achieved.	Achieved. More programme could activate the site better by drawing the public.
Link recreational focus areas on site using paths.	Achieved.	Achieved.
Make visible building and recycling systems.	Partially achieved. Ablution systems not visible.	Not fully achieved. Indoor systems not visible.

Design imperative	D4 evaluation comments	D1 evaluation comments
Regulatory services: Disease, climate, water, water, pollination		
Create habitats for flora.	Achieved.	Achieved.
Aerate water through vertical movement.	Achieved with waterfalls and fountains throughout.	Achieved, but more emphasis need to be placed on this.
Use constructed wetland principles for passive water filtration on site.	Achieved.	Achieved.
Use WSUD's and SuDS elements for localised flood control.	Achieved.	Achieved.
Link design to larger MOSS & CTSDF for flood control	Achieved.	Achieved.
Create habitats for fauna: can pollinate plants.	Achieved.	Achieved.

Design imperative	D4 evaluation comments	D1 evaluation comments
Supporting services: Primary production, soil formation, nutrient recycling		
Introduce agricultural production.	Achieved.	Achieved.
Restore flora on site to assist with binding of soils.	Achieved.	Achieved.
Repair site to restore existing soil and earth conditions.	Achieved.	Achieved.
Use soft landscaping and outdoor trafficable surfaces	Achieved.	Achieved.
Sort ablution effluent into solids and	Achieved. Separation for methane	Self-composting toilets used, which do not sort ablution

liquids for nutrient recycling.	digester and nutrient cycling.	effluent into solids and liquids but does create compost for use.
Ensure nutrients are balanced across site systems.	Achieved. Nutrient monitoring.	Achieved, although care needs to be taken to ensure all nutrients are not removed from system as over-provision of wetland cells in design.

Design imperative	**D4 evaluation comments**	**D1 evaluation comments**
Provisioning services: Food, water, energy, raw materials, bio-chemicals, genetic resources		
Introduce agricultural production if possible.	Achieved.	Achieved.
Diversify water sources on site.	Achieved. Rainwater collection.	Rainwater needs to be used.
Don't use potable water for non-potable uses.	Achieved.	Achieved.
Building to form part of larger blue-green network of city.	Achieved.	Achieved.
Use WSUD's and SuDS elements for drainage of water on site.	Achieved.	Achieved.
Recycle and filter water for reuse.	Achieved.	Achieved.
Strategy required for alternative sanitation systems.	Achieved.	Achieved.
Consider recycled building materials.	Achieved.	Achieved.
Use water & energy efficiently in building: water-wise fittings, low energy fittings, passive ventilation, and alternative sources.	Achieved. Solar energy added.	Achieved, although this can be explored further.
Restore flora on site to assist with habitat creation, flood controls, binding of soils.	Achieved.	Achieved.

Design imperative	**D4 evaluation comments**	**D1 evaluation comments**
Design values (from D1)		
Understand and incorporate the local context of the site by exploring the boundaries	Local context understood and referenced where possible.	Achieved, although this can be explored further. Historical aspects of site not focused on.
Facilitate site repair.	Achieved.	Achieved.
Consider ecological infrastructure: integrating infrastructure as landscape, link multiple elements and systems.	Achieved.	Achieved, although this can be explored further.

Figure 57: (Left and previous page). The effects analysis for D4 (Author, 2016).

The sign value deals with how people identify with the environment at a scale larger than the building itself (Ramirez, 2015:139). The D4 macro-scale proposal put forward a larger network of river rehabilitation interventions along the TRUP framework, which are all dominated by Table Mountain in the background. In using the mountain as an anchor in the landscape, people are able to understand that the water on site is only a portion of the greater green-blue network across the city. Thus people are able to identify with the larger water issues experienced within the city.

Concluding Remarks

Chapter 4 was divided into two parts: The first part deals with describing the process and product of D1. The second part of the chapter deals with the analysis of D1, informed by the design imperatives generated from values derived in Chapter 3.

In part 1, D1 is introduced through the conceptual underpinnings of the design. These underpinnings guided the design and gave context to the design decisions made. First, the different boundaries of the site are explored. These include the historical, architectural, natural and cultural boundaries of the site. The technical exploration delved into WSD elements discussed in Chapter 3, including WSUD, SuDS and constructed wetlands. Agriculture, an activity closely linked to water, is explored through hydroponic systems as an alternate production method. The idea of a soft machine is then introduced, which deals with integrating infrastructure in the landscape and embedding multiple linked systems within this. Key ideas are drawn from the underpinnings and are used to create design imperatives, which are added to those listed in Chapter 3. These include the exploration of the boundary of a site, site repair, and ecological infrastructure, which is morphed from the soft machine.

The D1 process is then described across scales using images to support the text. This raw data includes sketches, models, drawings and diagrams which communicate the different design decisions discussed. The final product draws from the different ideas from the conceptual underpinnings to propose a design that filters river water for a variety of different uses.

The second part of this chapter covers the analysis of D1 using RBD. D1 is analysed subjectively using the design imperatives developed in Chapter 3. Key architectural concepts are shown using thumbnail sketches, which serves to identify elements of the design. A reflection on this process generates thoughts which serve as the basis for the design of D2. D2 is subjected to analyses by participants against the design imperatives. A reflection on the comments made results in the design of D3. After a subjective analysis, D3 is discussed with a water engineer and an environmental specialist to gain in-depth insights into the processes embodied. The knowledge drawn from the previous iterations along with the participant evaluations is used to create D4, which serves as the best-fit design solution. D4 is then subjected to an effects and values analysis in order to support validity of the evaluation done using the design imperatives.

In the next chapter, the different outcomes of the RBD process presented are discussed. The best-fit solution, D4, is unpacked in depth. Patterns and similarities uncovered through the RBD process of iteration-evaluation-reflection result in two learning outcomes. This includes the design process of a WSAD, as well as potential guidelines for such an initiative as part of WSD.

Chapter 5| Results and Insights

In this chapter, the results of the RBD process are discussed thematically. First, D4 as the final design is explored. D4 is based on the design and RBD learning outcomes of D1, D2 and D3. It is further informed by the design imperatives generated in Chapters 2, 3 and 4. Together, these concepts call for a more eco-centric and water-sensitive building.

Having reviewed D4, the focus shifts to the RBD outcomes of the study. In following the RBD process, similarities and patterns are identified between the different design iterations. These are arranged into two groups: the design process for a WSAD and design guidelines for potential WSADs. During the design process for a WSAD, emphasis is placed upon water and people as the main design informants. Further, the design imperatives uncovered in this study are arranged to reveal general principles that may be taken into account when designing a WSAD. Although this list of design imperatives is not exhaustive, it is a start in creating guidelines for the design of a successful WSAD. These principles may contribute towards the planning and development of a WSC, as per the WRC objectives of the feasibility study discussed in Chapter 1. The chapter concludes with a brief summary of the material covered. This leads to the conclusion of the research study in Chapter 6.

Reflections on D4: The Best-fit Design Solution

The D4 design iteration is the result of the RBD process followed in this study. The building is proposed as the best-fit design solution for a WSAD when considering the process and informants of this study. In designing D4, the learning outcomes of D1, D2 and D3 are considered. These learning outcomes are explained through the process sections for each of the different iterations in Chapter 4. The RBD process for each proposal followed a pattern of process-iteration-evaluation-reflection. By following this, constant feedback about design decisions made is received through the process of sketching and reflection. D4 was therefore informed by the process, product, evaluations and outcomes of the different iterations. The design process was guided by the design imperatives uncovered in Chapters 2, 3 and 4. Finally, feedback received from various specialists around the optimisation of the design was taken into account.

The effects analysis, shown in Figure 57, reveals that D4 meets most of the design imperatives set out in this study. Each imperative is discussed with reference to the process and product of D4. This is done to assist in understanding the study conducted, as well as to make the results more accessible to the reader. First, the expressive values of the design imperatives are discussed. The expressive values informed by guidelines from phenomenology results in the creation of paths, nodes and focus points in the building. Aesthetically, D4 blends into the landscape at the meso-scale, thereby becoming part of the greater blue-green network of MOSS. In doing so, the river boundary becomes a transitional zone that accommodates for the rehabilitation of natural and water systems. Recreational activities are facilitated, while movement is directed towards Table Mountain and the Black River. This grounds the site in the local context. Views from within the building frame outdoor elements where possible. Although the spiritual history of the site is not fully engaged with, it may be considered in future studies. Identity is created through symbolising the natural processes of water filtration, as well as making water and natural processes visible on the site. Further, the five senses are engaged: water reflections, the sound of animals and insects moving about, the taste of freshly filtered water, the smells of the natural environment and the touch of a cooling spray of water from a fountain all contribute to the feeling of identity a visitor might get when visiting this intervention. However, the actual experience of the building is subjective and is informed by the individual's background. It is hoped that these tactile characteristics sensitise people to the intrinsic and instrumental values of water and ecosystems.

Rhythm is introduced into the design through the use of a structural grid and the undulations of the green roof above. Recycled construction materials minimise the impact of demand on virgin raw materials. At the macro-scale, the boundary formed by the river becomes a connector across the city, both visually and through its characteristic as a bio-highway. Through multi-scalar design, D4 becomes part of a series of destination points along the Liesbeek River in which boundaries shift according to environmental changes. D4 therefore adds value to the MOSS and TRUP frameworks by increasing biodiversity and water quality along the Liesbeek River. This supports and enhances existing ecosystems by aiding in the passage of fauna and flora along the river. At the micro-scale, the different boundaries become transitional zones: windows frame the transition between inside and outside; and also connect the landscape with the individual buildings. Boundaries in the building are visually softened with planting and the use of light building elements where possible.

The functional values are in most part addressed using WSUD's, SuDS and other WSD initiatives. First, the regulatory ecosystem services are addressed. Habitats are created for fauna and flora through rehabilitating the river edge across scales. The wetland nursery draws fauna and flora to the area. The naturalised river edges at the meso-scale allow for flood attenuation and remove water-borne pathogens across the larger MOSS framework. Constructed wetland principles are used for the bio-filtration of river water for further use. Water on site is aerated through waterfalls and fountains to counteract the negative effects of warmer temperature on water bodies.

A key focus of the supporting ecosystem services was that of enabling nutrient cycling. This was achieved after discussions with a water engineer. Monitoring ensures a balanced nutrient cycle. Ablution and kitchen water waste are dealt with using methane digesters, which provide gas for cooking. Soft outdoor landscaping surfaces and permeable paving allows water to be absorbed by the earth, facilitating soil production. Soil binding is facilitated over time through the establishment of plants on site. Site repair is enabled as the site is rehabilitated from the dump site it once was. Finally, agricultural production ensures a localised source of food.

Under provisioning ecosystem services, water sources are diversified by using rainwater, stormwater and water sourced off-site to supplement water drawn from the Liesbeek River. Each aspect of water was carefully considered in the design, including storm, rain, waste, potable and river water. Water is treated differently according to its use and is displayed at almost every stage of the building in its different forms. Drainage on site is facilitated through SuDS initiatives. Finally, low-energy initiatives reduce the building's demand for energy. Solar glazing, solar panels and windmills provide an alternative source of energy.

On reflection, the different design imperatives are addressed across the scales of macro, meso and micro. According to Bacchin et al (2013:1), this quality allows D4 to be considered as a robust design, as it is able to be tested across scales. As design is a subjective field, there may be opportunities for the further development of the water and ecological aspects of the design. However, the design is considered sufficient for the demonstration of the WSAD aspects for this study.

Complex interlinked ecological and water systems are designed for as part of the ecological infrastructure of D4. The design becomes a catalyst for the return to nature by enhancing, protecting and creating aspects of water and ecological systems on site. First, water is focused on. Water bodies on site become spaces of gathering and play. The bio-filtration cells allow for the understanding of on-site water filtration processes, as the outcome is visibly cleaner water compared to that of the river. The value of water as a life-giving source is fully demonstrated through urban agriculture and the wetland nursery. Rainwater tanks store rainwater for irrigation and supplement potable water on site. Water filtration processes are displayed within the buildings. Simple grey water systems show water recycled for use in ablutions and for irrigation. Black water is treated on site in order to make compost and methane gas. Water from the kitchens and labs are filtered in complex grey water treatment systems for reuse.

Turning to the ecological benefits of D4, flood attenuation is increased along the river's edge and the erosion of the river banks is decreased due to river restoration. Through restoring the natural riparian edge, indigenous fauna and flora are attracted to the site. Plants used in the design are mostly indigenous. These plants are able to survive in the particular climate and micro-climate along the river. Xeriscaping, which makes use of plants that consume little to no additional water, may also be used within certain areas on site. Cultivation of crops is a productive and sustainable use of river water, thus providing both agricultural crops and wetland plants for river restoration elsewhere. Agriculture is also a low-impact activity on the land, adds diversity, brings value to the building and provides a means of education for visitors. The wetland park at the Transnet site retains the existing train tracks, but restores the natural river bank though planting. This park serves as a quiet space for visitors and workers to rest. Where possible, care is taken to mitigate the effects of the building on the landscape by providing green roofs; swales to offset non-porous paved areas (which are kept at a minimum); and using soft landscaping for paths wherever possible. This increases water absorption by the earth, causing minimum disruption to natural wetland processes.

From the reflection on D4, as well as discussions with consultants in the creation of this final iteration, two observations emerge: although visitors to the site may be unaware of the means used to emphasise cultural ecosystem services; an architect may make use of both space planning skills and an understanding of everyday experiences to emphasise cultural ecosystem services, which add value and identity to the site. If successful, the architect is able to provide opportunities to heighten the experience of place for visitors.

Second, the idea of a cross-disciplinary approach must be explored. After discussion with consultants and a review of the analyses, it becomes evident that a successful WSAD is one where each initiative drawn from the different disciplines is maximised without negative effects on any other in order to optimise the building and systems within it. This notion is added to the list of design imperatives for a successful WSAD.

General Principles for a WSAD

The design imperatives developed in this study are used to guide and evaluate the different design iterations resulting from the RBD process. These imperatives are developed throughout the study to address the theoretical and conceptual frameworks used. The frameworks have a common focus on the relationships between man, nature and water, which constitute key themes in this study. From the theoretical framework, two design informants are uncovered: The intrinsic links between man and nature and using phenomenological principles to create opportunities for enhancing the relationship between man and nature through the expressive elements of architecture. These informants are used to guide the conceptual framework, which discusses ecosystem services. Design imperatives are developed to respond to the four different ecosystem values of cultural, supporting, regulating and provisioning services. The analysis of D1 reveals further design imperatives. This includes ideas relating to site repair, ecological infrastructure and the boundary. The reflection on the D4 product in this chapter adds a final design imperative, referring to drawing from different elements in a cross-disciplinary manner. Together, these different design imperatives are used to form a basis for general principles for the design of a WSAD, as shown in Figure 58.

Three observations are made when reflecting upon these design guidelines: in a WSAD, water defines and gives identity to a place. The most important factors of a WSAD are therefore the relationship between people, water and natural systems. Second, the landscape, community and character of the place should be enhanced through the design (CIRIA, 2013, Carden, 2016). Ecological and water cycles in nature must be used as a guideline for systems on site. These interventions in the natural realm of the site add value and character to the building. Finally, in order to build successful WSC's, the public must be educated on the value of water and ecosystems. Thus community involvement becomes important. This starts at the level of the building as a WSAD. Through the acknowledgement of the intrinsic value of nature after visiting such a WSD building, people are able to share knowledge in their communities in order to create a more water-aware public.

Design Process

In reflecting upon the analysis process that was undertaken to achieve the design of D4, the RBD process of process-iteration-evaluation-reflection becomes evident. This process is followed for each iteration developed.

General design principles for a Water Sensitive Architectural Design

Expressive value: ***Cultural services***

- *Aesthetics, sense of place, spiritual value, cultural landscapes, educational, spiritual, recreational*

Design imperatives

- Ensure building is aesthetically pleasing through design.
- Consider architectural elements of point, line, plane, form, massing, hierarchy, ordering systems, geometry, rhythm, thresholds, ergonomics (Norberg-Shultz,).
- Frame views across scales to other natural & design elements (Norberg-Schultz, 1979)
    - Nearby elements
    - Landscapes
- Engage with spiritual history of site (Adapted from Norberg-Schultz, 1976)
    - Architecture
    - Construction materials.
- Create identity using gathering/symbolism/visualisati (Norberg-Schultz, 1979)
- Create paths which orientate towards river/mountain/design elements by using nodes/paths/districts (Norberg-Schultz, 1979).
- Make building comfortable for people.
    - Consider ergonomics
    - Places for resting
- Use enclosure & extension (centre & rhythm), light & shadow to define space (Norberg-Schultz, 1979).
- Use construction materials, detailing and making to give the building identity (Norberg-Schultz, 1979).
- The building and the water in it must engage with the 5 senses to give a sense of identity.
- Define and make boundaries porous at different scales (Heidigger, 19871; Norberg-Schultz, 1979)
    - Create ambivalent indoor-outdoor spaces using light & shadow, enclosure & extension
- Activate building as part of macro- and meso-scaled frameworks
    - CTSDF, TRUP and MOSS.
- Create spaces for gathering and quiet reflection.
- Provide spaces for resting, sports , social
- Link recreational focus areas on site using paths.
- Make visible building and recycling systems.

Functional value: ***Regulatory services***

- *Disease, climate, water, water, pollination*

Design imperatives

- Create habitats for flora (FISRWG, 2001):
    - Absorb excess nutrients & carbon preventing nutrient overload in water (Luthi, 2011)
    - Regulate oxygen in water (Penn et al, 2009).
    - Control pathogens.
- Aerate water through vertical movement (FISRWG, 2001).
- Use constructed wetland principles for passive water filtration on site (Wong, 2006 and Armitage et al, 2013)
- Use WSUD's and SuDS elements for flood control (Sisolak & Spataro, 2011 and Fletcher et al, 2014).
- Link design to larger MOSS & CTSDF for flood control
- Create habitats for fauna (FISRWG, 2001)

Functional value: ***Supporting services***

- *Primary production, soil formation, nutrient recycling*

Design imperatives

- Introduce agricultural production if possible
- Restore indigenous flora on site to assist with binding of soils (USEPA, 1988)
- Repair site to restore existing soil and earth conditions (Alexander, 1977)
- Use soft landscaping and outdoor trafficable surfaces
- Sort ablution effluent into solids and liquids for nutrient recycling (Pescod, 1992)
- Ensure nutrients are balanced across site systems (FISRWG, 2001).

Design values *(from D4 reflection)*

- Each initiative drawn from the different disciplines must be maximised without negative effects on any other initiatives in order to optimise the building and systems within it.

Functional value: ***Provisioning services***

- *Food, water, energy, raw materials, bio-chemicals, genetic resources*

Design imperatives

- Introduce agricultural production if possible.
- Diversify water sources on site (Sisolak & Spataro, 2011).
    - Rainwater harvesting
    - Greywater filtration
    - Stormwater filtration
- Don't use potable water for non-potable uses (Sanya, 2016).
- Building to form part of larger blue-green network of city (Wong, 2006).
- Use WSUD's and SuDS elements for drainage of water on site: swales, permeable paving, attenuation ponds (Armitage et al, 2013).
- Recycle and filter water on site for reuse (Wong, 2006).
- Strategy required for alternative sanitation systems (Wong, 2006).
- Consider recycled building materials.
- Use water & energy efficiently in building(GBCSA, 2017)
    - Water-wise fittings
    - Low energy fittings
    - Passive ventilation
    - Alternative sources.
- Restore flora on site (Brown et al, 2009)
    - Habitat creation
    - Flood controls
    - Binding of soils.

Design values *(from D1 conceptual underpinnings)*

- Understand and incorporate the local context of the site by exploring the boundaries of historical, cultural, architectural, natural…
- Facilitate site repair (Alexander, 1977).
- Consider ecological infrastructure: integrate infrastructure as landscape, link multiple elements and systems across the site (Belanger, 2010).

Figure 58: General principles for a WSAD, derived from this study (Author, 2016).

However, an understanding of the complete WSAD process has positive effects: non-architects are able to understand the process followed by architects, which may be beneficial in the cross-disciplinary workspace. Non-architects and architects could therefore agree on the design process to follow and have a better idea of how to work together. Further, outlining the process could assist other architects aiming to achieve successful WSADs. As a result, the design process used from D1 to D4 is discussed.

It must be noted that designers do not follow the same process. However, generalisations can be made about their diverse processes. First, (or at any stage of the initial design process) the topic and context are identified. D1 began with an interest in water and filtration methods. Concerns around water are recognised as the focal issue. Source material relating to the conceptual underpinnings of the project may then be gathered, along with precedent studies. In the case of D1, this entailed gaining an understanding of the different aspects of the Liesbeek River, as well as the processes and methods of water filtration. In D4, this consisted of a discussion around the principles of Deep Ecology, Phenomenology and Ecological Urbanism. These concepts aid in the understanding of a WSAD as they relate to the relationships between man, water and nature, as well as adding value by strengthening the design underpinnings. In D1, site selection is made through various site analyses. The site's conditions are mapped and understood in order to provide cues for the placement of the components of the design. These tasks can happens at any stage during the initial design phase, and often occurs simultaneously.

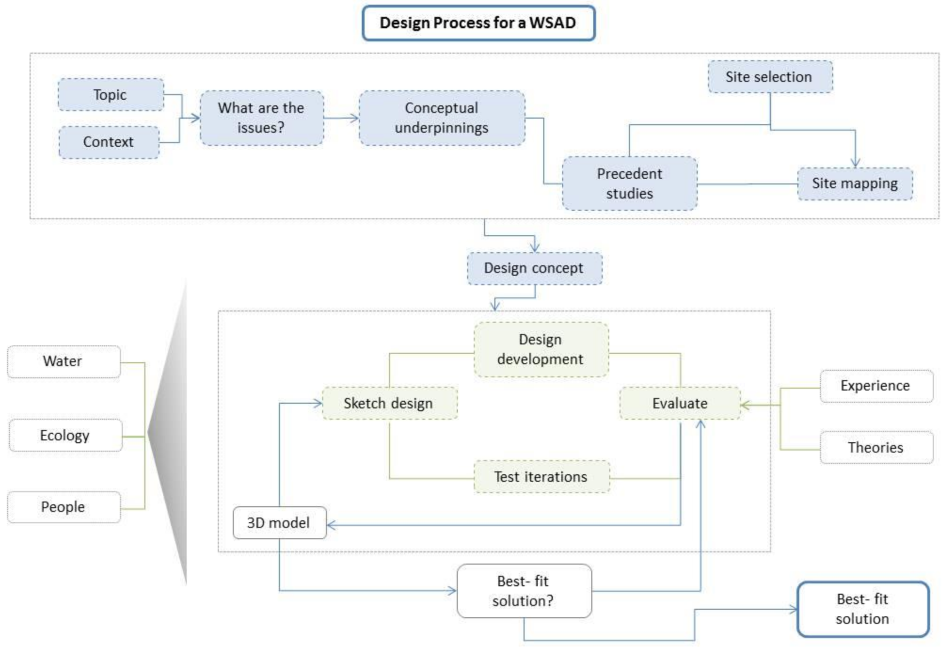


Figure 59: The design process, derived from the RBD process as followed in this study (Author, 2016).

The design itself begins with a concept. In D1, the concept was that of forms expanding out into the landscape. Once the concept is decided upon, various iterations of the design are tested in plan, section, elevation and 3D. This is illustrated in part by the RBD procedure described in this study. Each iteration is evaluated based on a variety of themes: intangible themes include the designer's intuition and feelings on spatial flows. Fact- based themes revolve around the research done, the conceptual underpinnings of the project and the feasibility of the design. Further, the relationship between man, water and ecosystems must be considered at every step of the design.

The design is then developed upon using 3D models in conjunction with sketches, which allow for an understanding of the spatial dynamics of the building. This process is not linear as the designer may circle back to earlier iterations at any time. The design is considered complete when it is fully functional, meets all the design objectives and is subjectively considered to be the best-fit solution. This process is shown diagrammatically in Figure 59.

Concluding Remarks

In this chapter, the outcomes of the RBD process discussed in Chapter 4 are explored. First, the different aspects of D4 are discussed. In reflecting on the design iterations and evaluations of D1, D2, D3 and D4, patterns and similarities across the different proposals are uncovered. This results in the addition of a final design imperative that deals with the optimisation of design elements in a cross-disciplinary manner.

The RBD process reveals similarities in the approach to a WSAD. An outline for a WSAD process is discussed. This is useful in assisting both architects and non-architects to understand the non-linear design process used. Further, the process reveals how different WSD initiatives may be combined. It is hoped that this understanding may assist architects and non-architects to work together in a more considerate manner when working across disciplines.

Finally, the learning outcomes from this study results in guidelines that may be used for future WSADs. These guidelines are informed by the theoretical and conceptual frameworks, D1's conceptual underpinnings, the learning outcomes from the RBD process and D4. The guidelines will need to be adapted to the context, site and design objectives of other potential WSADs.

The next chapter concludes this research study. The different chapters are summarised in order to give the reader an overview of the material covered. Finally the outcomes of the study are reflected upon.

Chapter 6| Summary and Conclusion

In this final chapter, the study is reflected upon. First, the study is summarised in order to give an overview of the material covered, including a reflection on the various ideas discussed. The design process followed in this study is put forward as a typical design process that may be followed when creating a WSAD. The design imperatives derived from Chapters 2, 3 and 4 are suggested as basic guidelines for a WSAD, which may be transferred to conventional buildings. These guidelines are also proposed as an addition to current knowledge around WSD in academia. Finally, the future potentials for the research are evaluated. The study concludes with a discussion of the value of the research presented in the greater academic community.

Summary of the Study

The research study was introduced in Chapter 1. The contextualisation of water issues globally, within South Africa and in Cape Town is given to locate the reader. Water-related initiatives are researched within different disciplines, but often do not take into account initiatives from other disciplines to create successful solutions to water-related problems. The architect, as an agent who is required to draw from other disciplines in creating design solutions, is ideally placed in the context of creating WSD's. This research forms part of an on-going feasibility study by the WRC that evaluates the potential of using WSD principles to strengthen planning for WSCs of the future.

The unit of analysis, D1, is a previously-designed building located on the banks of the Old Liesbeek River. This building, which included proposals at the macro-, meso- and micro-scales, used design elements drawn from a variety of disciplines. The resulting design is an aesthetically-pleasing, functional and feasible building with multiple ecosystem services and benefits. The value that an architect may bring in linking different design elements can be unpacked through studying a building such as this one as an integrated entity.

Chapter 2 introduces the theoretical framework of Deep Ecology and phenomenology. Deep Ecology is concerned with the links between man and nature. Through the acknowledgment of the intrinsic value of nature, man understands that he is part of the greater natural world and is more aware of the negative effects that affect this realm. Deep Ecology arises from a phenomenological standpoint. Phenomenology deals with the nature of place - its defining elements, its character and its spirit. This is supported by the boundary zone, which is both a tectonic and expressive element of architecture.

Chapter 3 explores the conceptual framework in two parts. Ecological Urbanism is a macro-scale movement that attempts to resolve issues in the natural world in urban contexts. Located within Ecological Urbanism is WSD, which is explained along with other water-sensitive urban initiatives. Design imperatives are drawn from the different ecosystem services discussed within Ecological Urbanism. The research method chosen for this study, RBD, is then introduced. RBD deals with uncovering the process of design through testing scenarios. The strategies and tactics for conducting the study are discussed, supported by the relevant literature.

In Chapter 4, D1 is introduced through a description of the raw data, consisting of sketches, models and drawings. A process and product analysis was then conducted, using the raw data of D1 in order to create and test new scenarios for an optimised design, D2. D2 was subjected to a participant analysis in order to understand and learn from the unsuccessful design aspects of D2 and D3. The different iterations were evaluated on criteria based on the design imperatives generated in Chapters 2 and 3. Although the design evaluation template developed was seemingly simplistic, a discussion with the panel of experts revealed that the author, as the architectural expert, would employ the gestaltic methods usually used by architects in practice. The final design, D4, was informed by the learning outcomes from the participant analysis, as well as the conceptual underpinnings of this study. D4 was then analysed using an effects and value analysis.

Insights

In Chapter 5, the different aspects of D4 are discussed, which answer the research objectives discussed in Chapter 1: *What lessons are yielded when an architect engages in the process of water-sensitive design for a building?* The results of the RBD process revealed similarities and patterns between the different design iterations presented. The lessons yielded when an architect engages in the process of water-sensitive design for a building are arranged into two groups: ideas relating to the design process for a WSAD and general principles relating to WSADs that can be considered when designing similar buildings.

In such a process, what are the major design leverage points? The design guidelines become the major leverage points in the process of an architect engaging with WSD at the scale of a building. Imperatives drawn from the functional values are covered in part by the WSD initiatives of WSUDs, SuDS and WSD. These design guidelines aim to create attractive architectures for the revitalisation of the links between people and nature by defining design goals as mentioned in Chapter 2, thereby facilitating a change in the approach to urban water management, informed by landscape architectural theories that defined the design of D1. In doing so, WSD is offered as a versatile means to meet the aims of Deep Ecology.

How can these major design leverage points inform water-sensitive design for future buildings? Linking these functional values to the expressive values guided by phenomenological principles offers opportunities for a different approach to solving problems relating to water use and management. Thus, these major design leverage points may be used to inform future WSAD's, which will assist in designing a WSC. Further, testing these principles in an 'prototype' building modelled in 3D in context allowed for the identification of successful principles that may be transferred to more conventional buildings. Although the guidelines presented are not prescriptive, other designers and planners may select one or more guidelines and integrate them in their own, possibly more conventional, designs. As an example, the guidelines developed in this study were given to practising architects who are collegues of the author for an informal evaluation. The feedback from this discussion was that the ideas generated would be easily applicable in current projects.

The design process for a WSAD is then outlined. Design development is a cyclical process, in which ideas are sketched, tested and evaluated in a gestaltic manner. This process may take place a number of times before the design is considered the best-fit solution. Crucially, a WSAD process should be guided by water, ecology and people at every stage. An understanding of the architectural design process may assist practitioners from other disciplines to understand the manner in which architects design. This helps with coordination when considering a WSD.

The value of an architect in making WSAD a feasible option is revealed in their ability to draw inspiration from different disciplines to create a successful design solution. Architects are able to coordinate ideas between actors in a cross-disciplinary team, as well as spatialize themes in an attractive and workable manner. The architect's ability to synthesise and make visible design elements is a strong skill in bringing different disciplines together (Frederick, 2007:21). As the design process includes constant reflection and evaluation, architects are constantly able to sense-check design objectives for a WSAD in a gestaltic manner. D4 becomes an example of the way in which disparate WSD elements can be brought together to create a functional and integrated entity that is both a feasible and an attractive space to be in.

Potentials for and Value of Research

There are many opportunities for future research based on the study presented. The list of ideas discussed here is not exhaustive, but aims to present a few possible perspectives.

First, the economic benefits of a WSAD could be investigated, as these are avoided in this study as discussed in Chapters 1 and 5. The feasibility of the building in terms of its economic value could be examined. This includes considering the impacts of a WSAD across scales. The monetary value of a revitalised river system could be investigated, along with its consequences of an increased water quality, decreased stormwater quantity, increased biodiversity and increased amenity value. At the meso-scale, the impacts of such an intervention on the surrounding communities could be investigated. This entails considering job creation, educational value and community upliftment. At the micro-scale, the building itself could be quantified. This would entail unpacking the materials used in the building, quantifying them and costing each to see if the project would make a monetary profit or loss. This evaluation would have to take into account both the physical value, as well as the monetary value of the ecosystem benefits and risks associated with the WSD.

The socio-political impacts of a WSAD such as D4 could be investigated further. Again, this aspect was avoided in this study in order to focus on the natural assets as seen in the CTSDF. This includes the non-quantifiable benefits of a WSAD in a community: the effects of passive education, community upliftment and general awareness around water. Further, the impacts of a WSAD on a community with regards to the design informants could be of interest. These informants deal with the intrinsic links between man and nature and using phenomenological principles to create opportunities for enhancing the relationship between man and nature through the expressive elements of architecture.

The general principles of a WSAD could be developed and tested further. The list presented here is not exhaustive and further development of each aspect could be used to create standards to be considered for a WSAD at all scales. These could also be integrated into design and building standards. This study deals with only one theoretical proposal of a WSAD. Alternative outcomes may result when considering different and multiple designs and these could develop upon the general principles for a WSAD. Additionally, the experimental nature of RBD adds complexities to the outcomes. Alternate methods used in future research could yield different results. The trans-inter-disciplinary approach could be explored in future studies, which would also yield different results.

The study deals with an aspect not yet engaged with in the present landscape of research around WSD: linking sustainable urban water management with urban and building-scaled design concepts. This research is valuable in that it explores the design aspects of a WSAD in the specific catchment area of the Liesbeek River, as part of the WRC K5/2412 project. Ideas relating to the process of designing a WSAD and general principles for the design of a successful WSAD are considered. Although some of the ideas referring to the WSAD guidelines presented are discussed in literature around WSD (See Abbot, 2013; Armitage et al, 2014; Brisbane City Council, 2010; GBCSA, 2013; Luthi, 2011; Public Utilities Board, 2009; Sisolak and Spataro, 2011; Wong, 2006) the integration of the expressive architectural elements with these ideas at the scale of the building offers new opportunities for WSC's. The knowledge contributed by architecture to the WSD realm becomes evident, as architecture allows for the successful and attractive spatialisation of WSD initiatives from other disciplines.

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Appendix A- Theoretical and Conceptual Framework

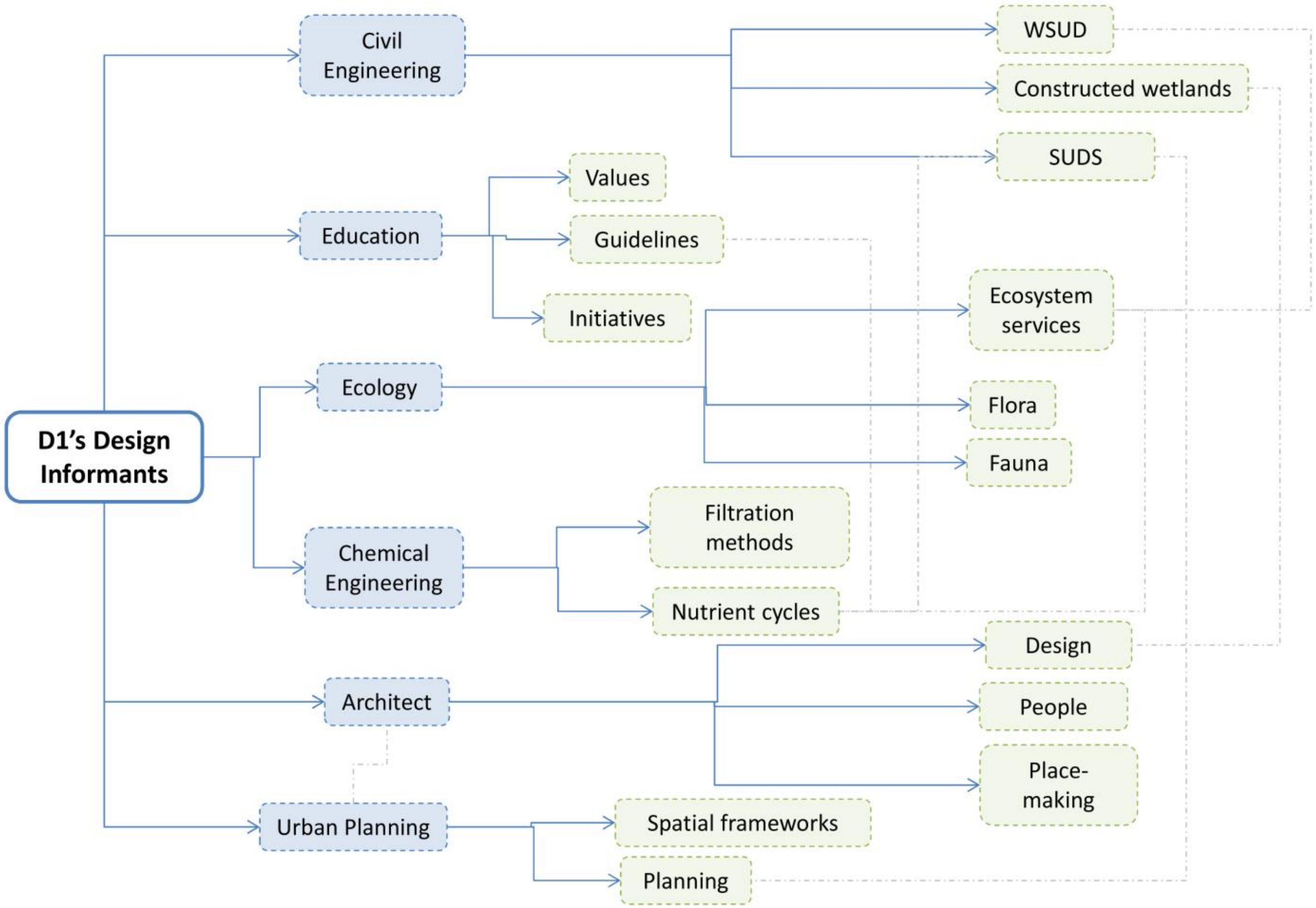


Figure 60: This diagram shows the design informants for D1, which were drawn from different academic disciplines. Note the links and interdependencies of the different themes across the disciplines, shown with grey dotted lines. The sub-headings in green show the key focus areas drawn upon for the design of D1 from each respective discipline. (Author, 2016).

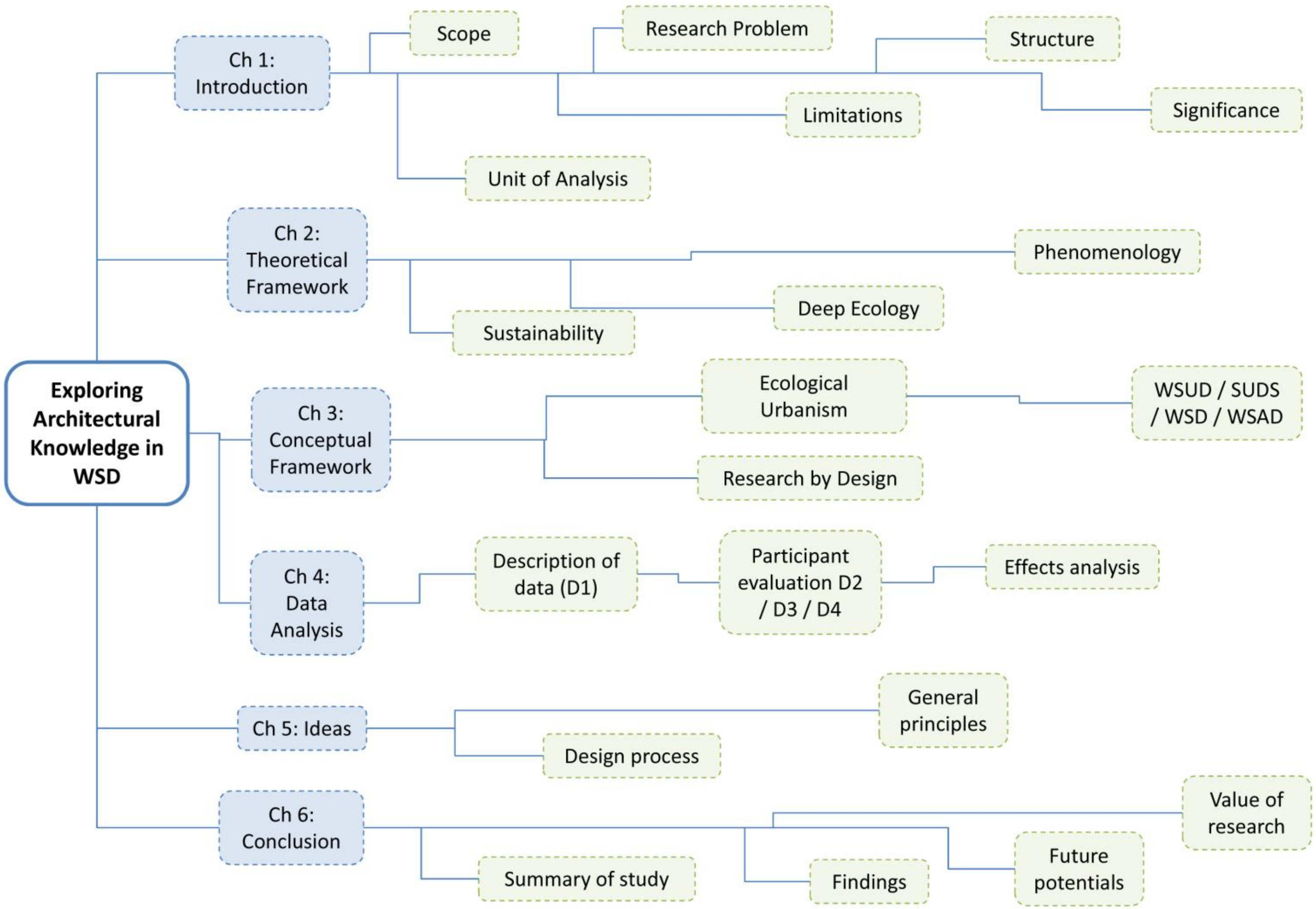


Figure 61: A summary of the structure of this dissertation. This diagram shows the main themes covered in each chapter (Author, 2016).

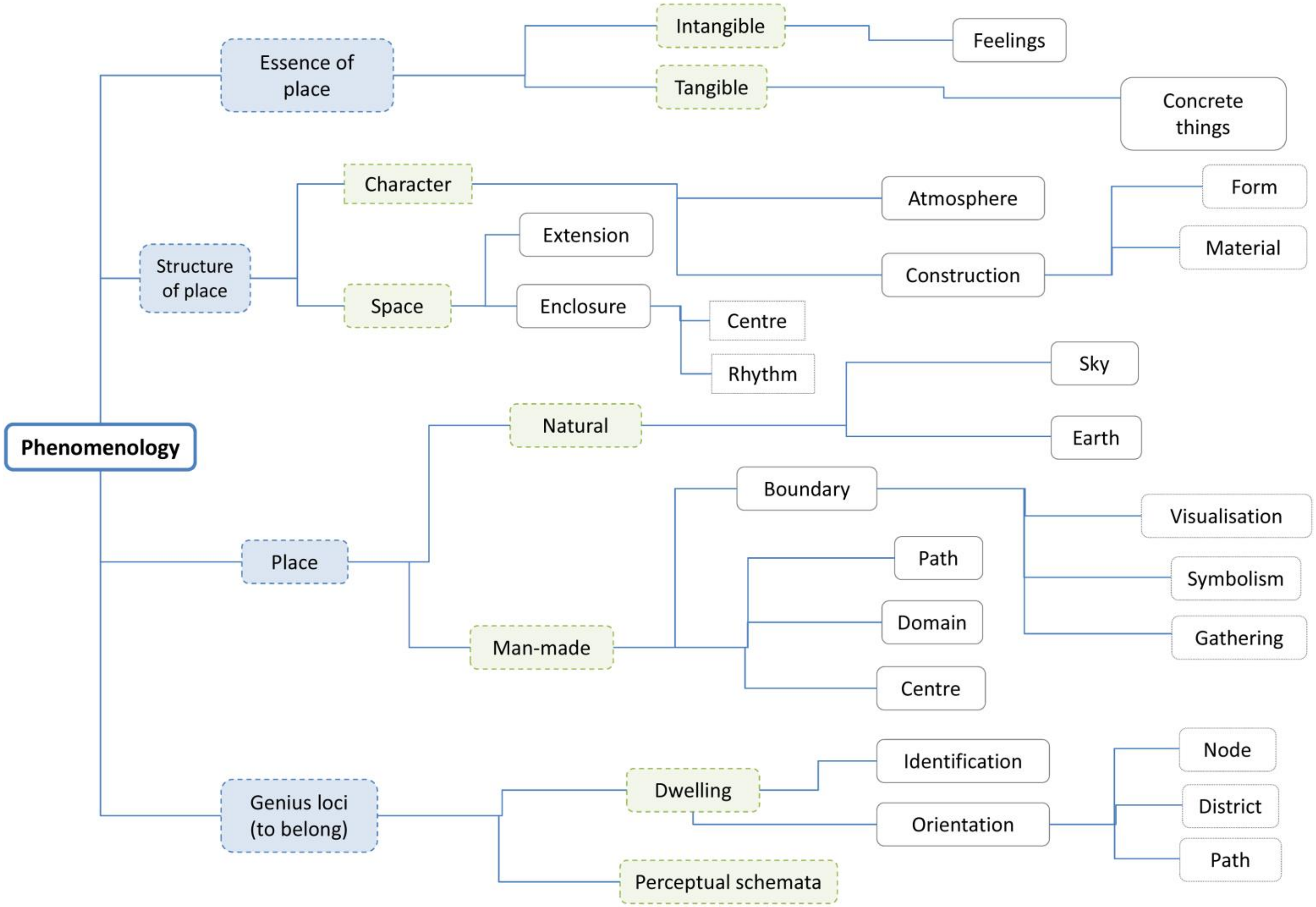


Figure 62: Summarising phenomenological principles drawn from Norberg-Schultz (1979). The main themes of phenomenology are shown in blue and are comprised of sub-elements that may be linked together (Author, 2016).

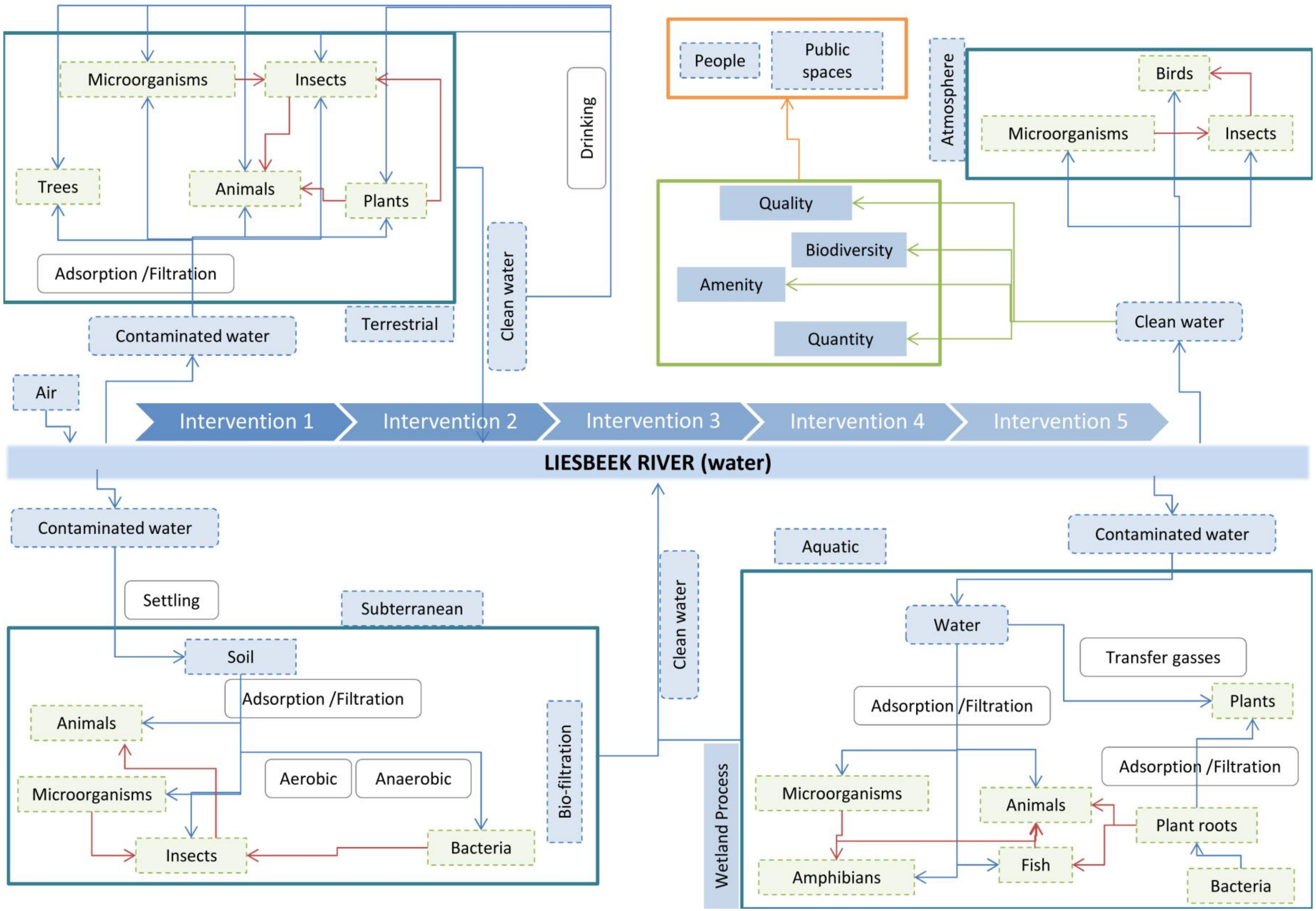


Figure 63: The cyclical flow of water, fauna and flora in a riparian ecosystem, shown at the subterranean, aquatic, terrestrial and atmospheric levels. Blue arrows indicate the flow of water, while the red arrows indicate food chains within each level (Author, 2016).

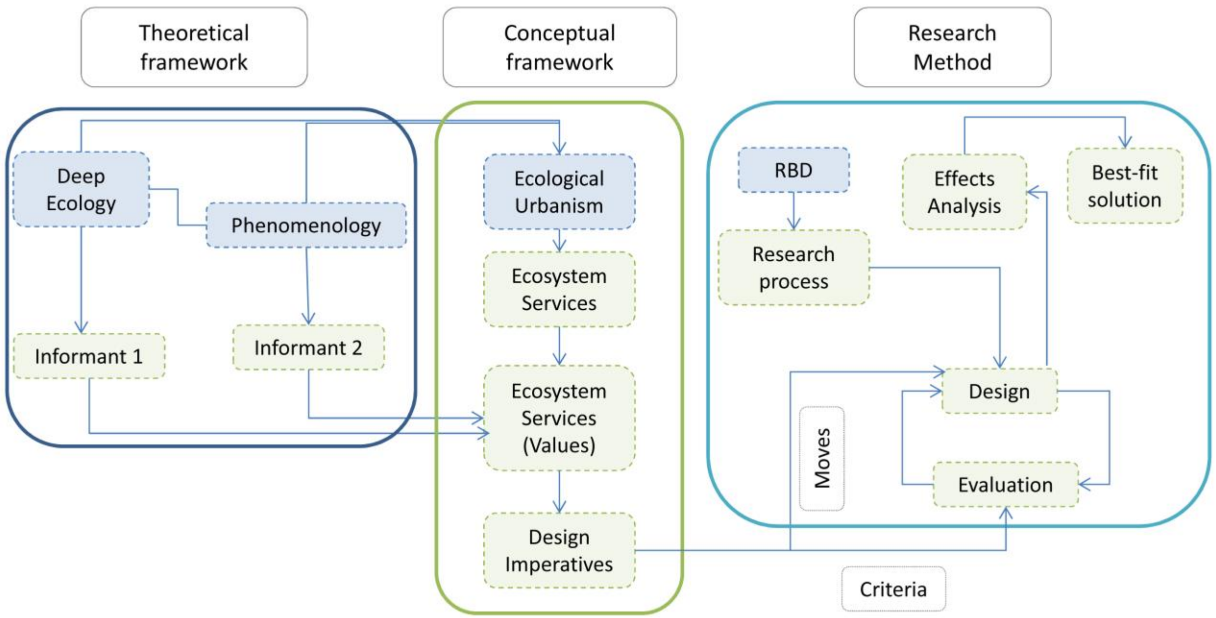


Figure 64: The links between the conceptual framework, theoretical framework and the research method used in this study (Author, 2016).

Appendix B- D1 Raw Data (all from Bhikha, 2013)

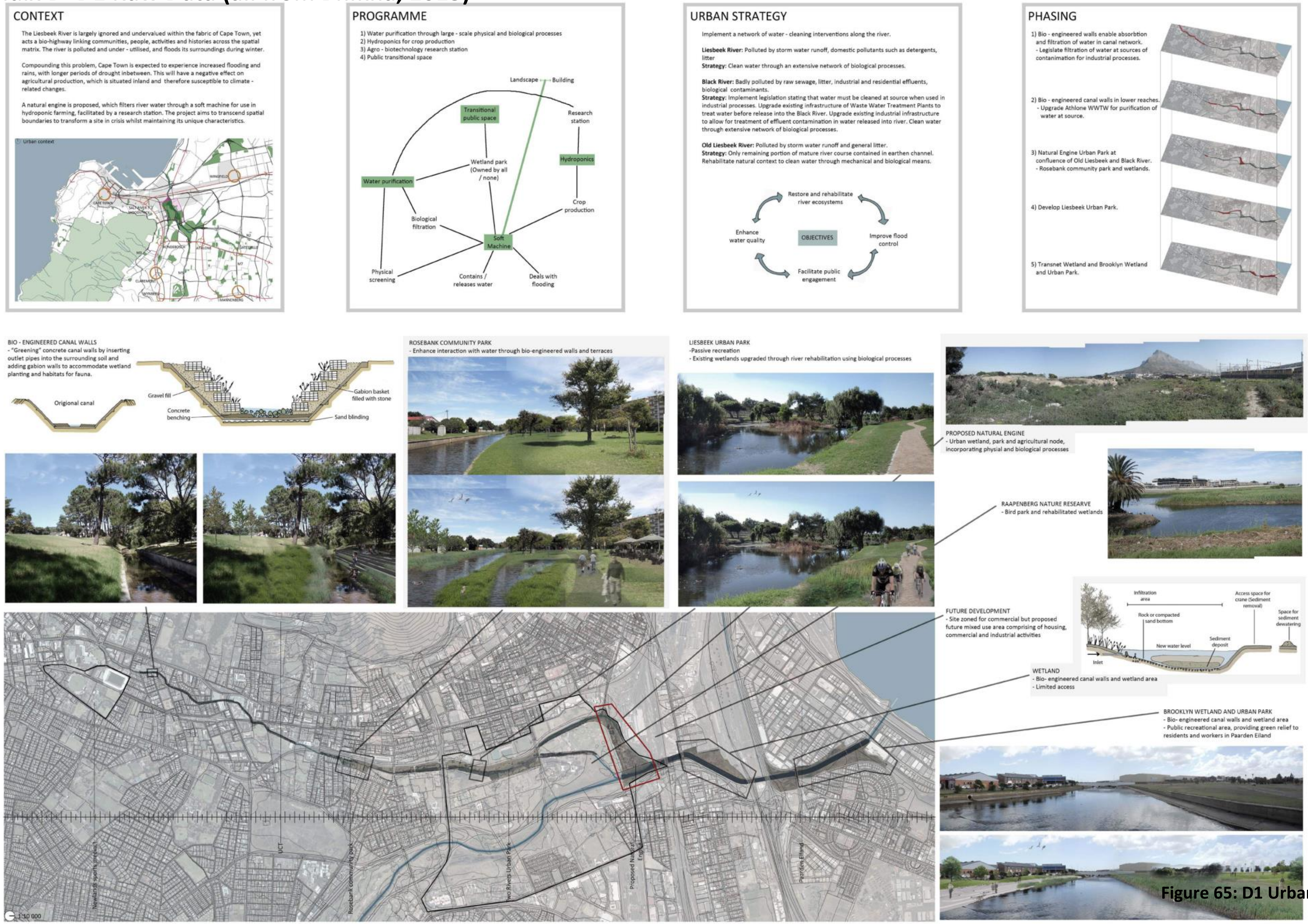
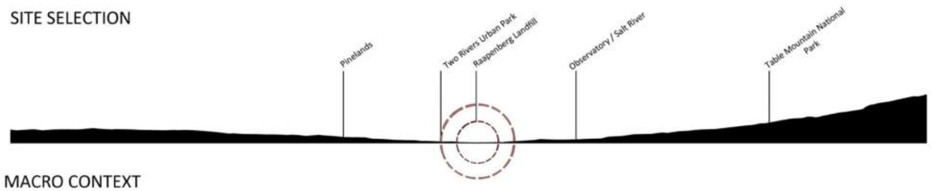


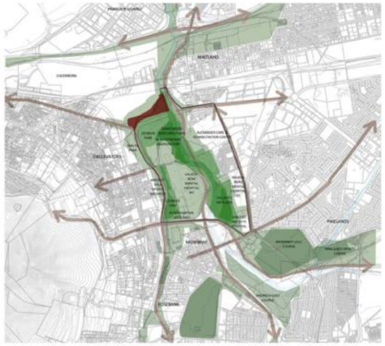
Figure 65: D1 Urban concept

SITE SELECTION



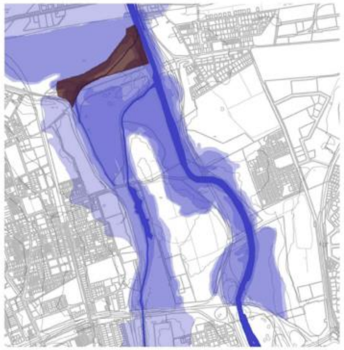
MACRO CONTEXT

The Raapenberg Landfill is located at the confluence of the Black and Old Liesbeek Rivers, and is part of the greater Two Rivers Urban Park focus area.



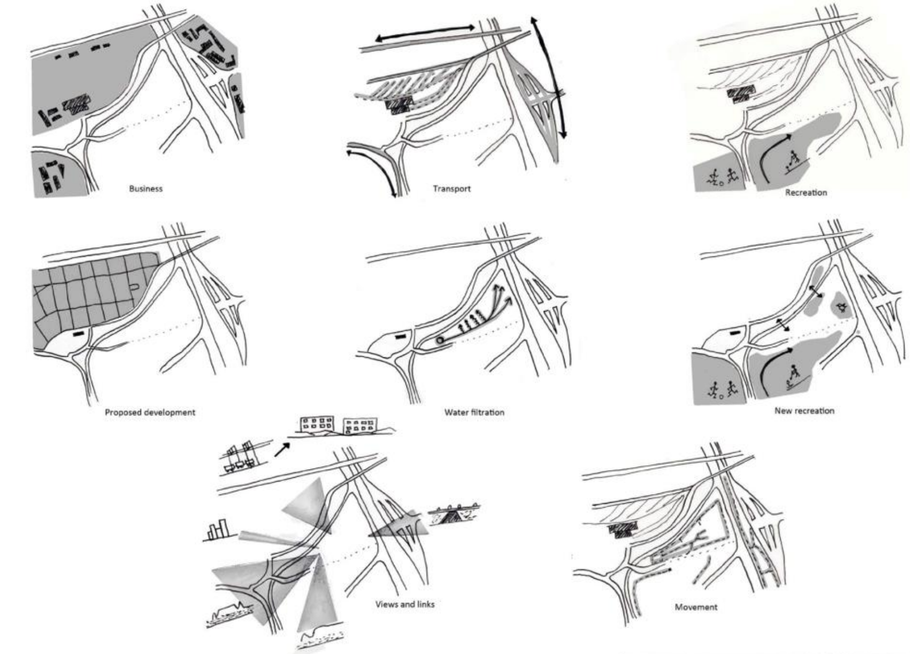
The site forms part of the Metropolitan Open Space System (MOSS), in which the CoCT has allocated a network of open spaces across the city for green relief within the dense urban fabric. Areas of special conservational interest are highlighted in the diagram.

The TRUP forms part of the Central City Regeneration Programme, and is earmarked for development as part of a mixed-use high-density, sustainable, low-car, NMT and public transport - orientated neighbourhood.

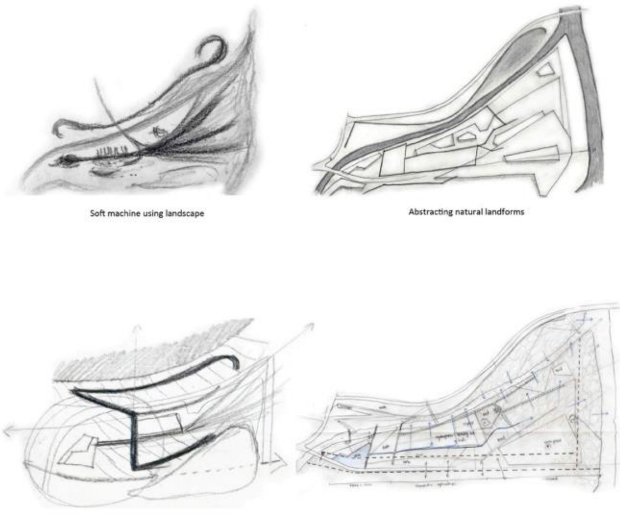


Most of the TRUP is within the floodplain. The River Club experiences seasonal flooding, inhibiting access to and from the Observatory. The Old Liesbeek and Black Rivers are being widened in an effort to mitigate the effects of heavy winter rains in the area.

PATTERNS OF USE



SHAPING THE SITE



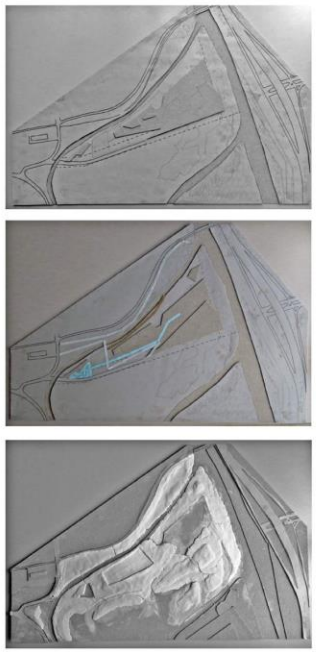


Figure 66: D1 urban planning and concepts

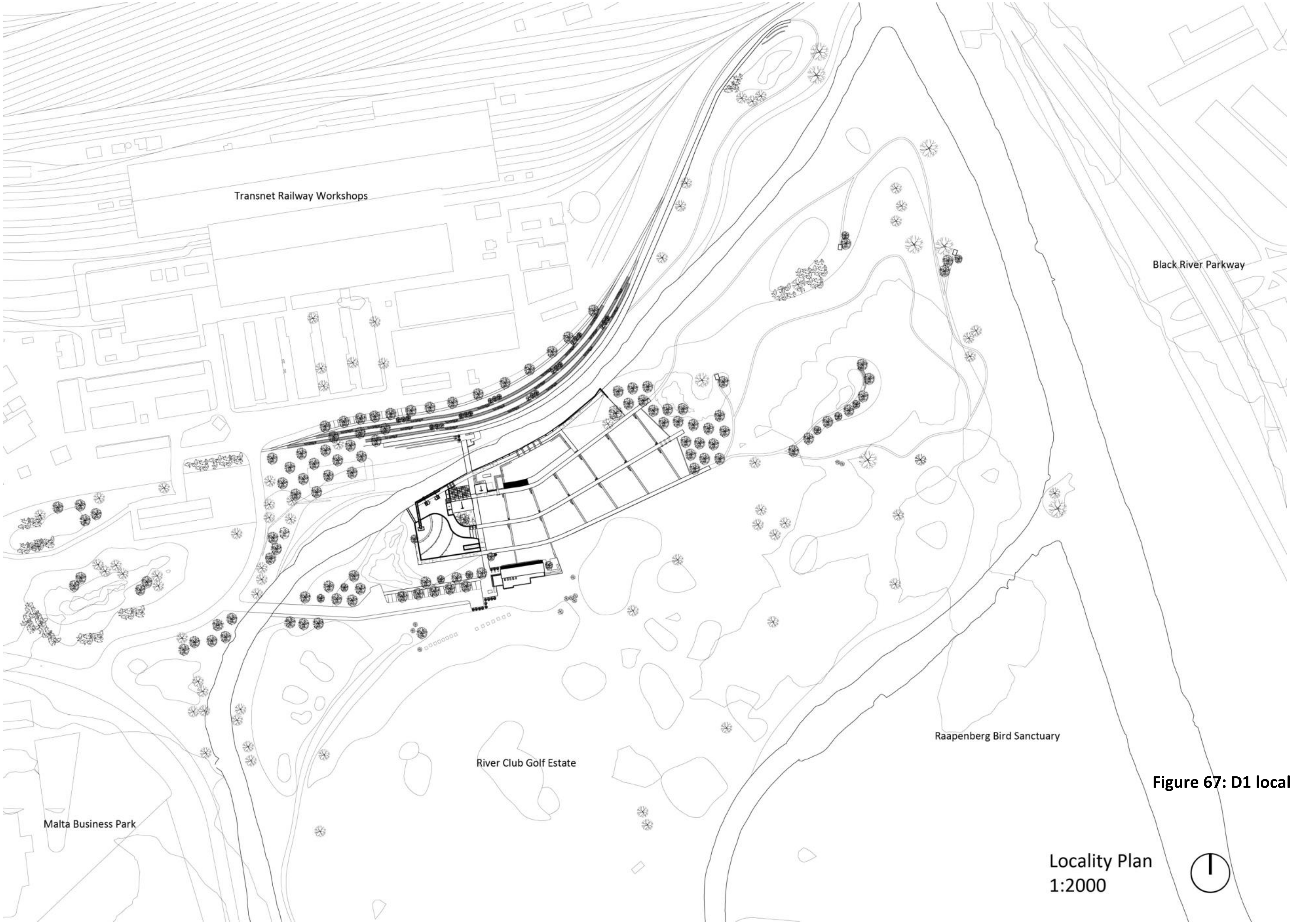


Figure 67: D1 locality plan

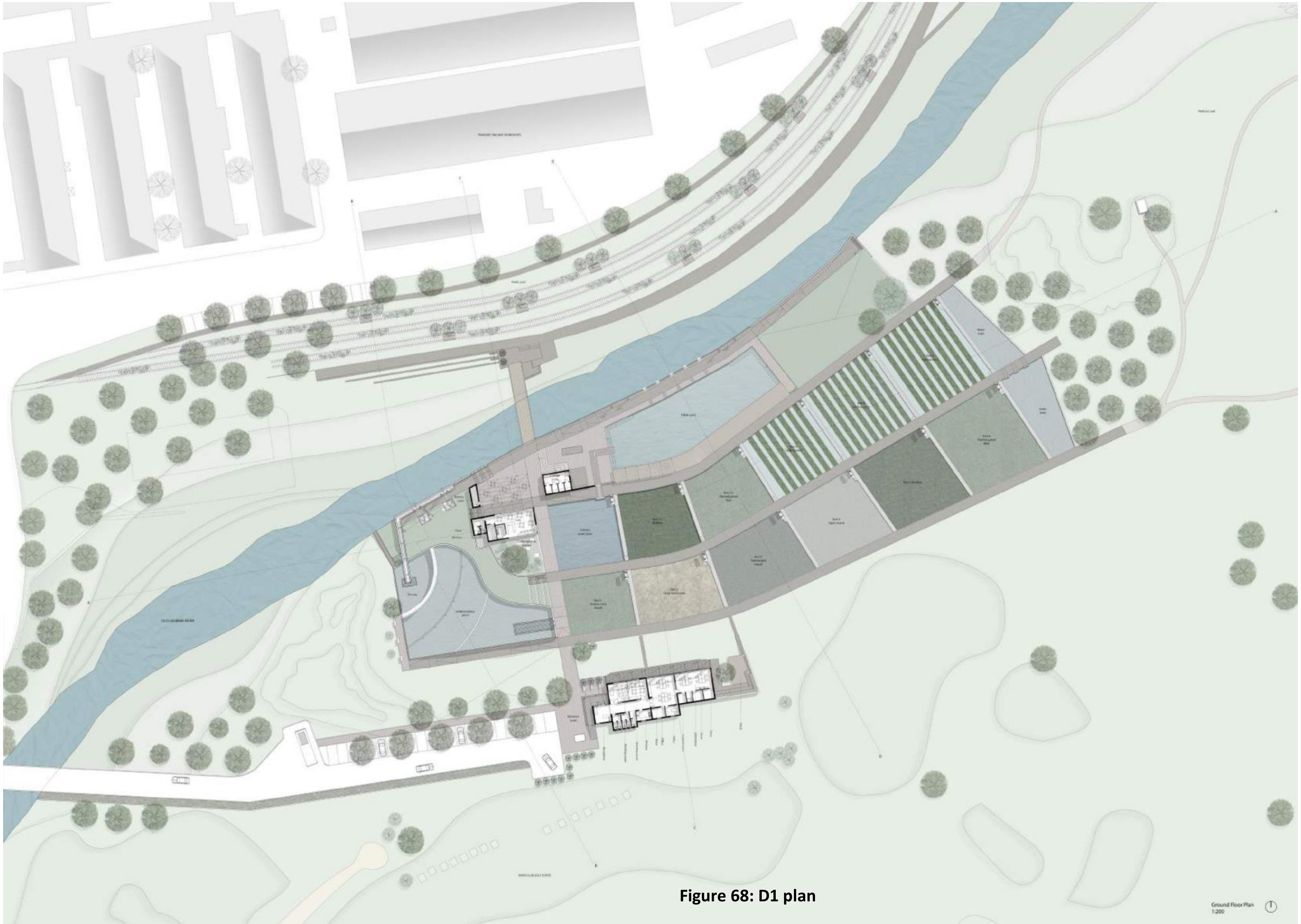


Figure 68: D1 plan

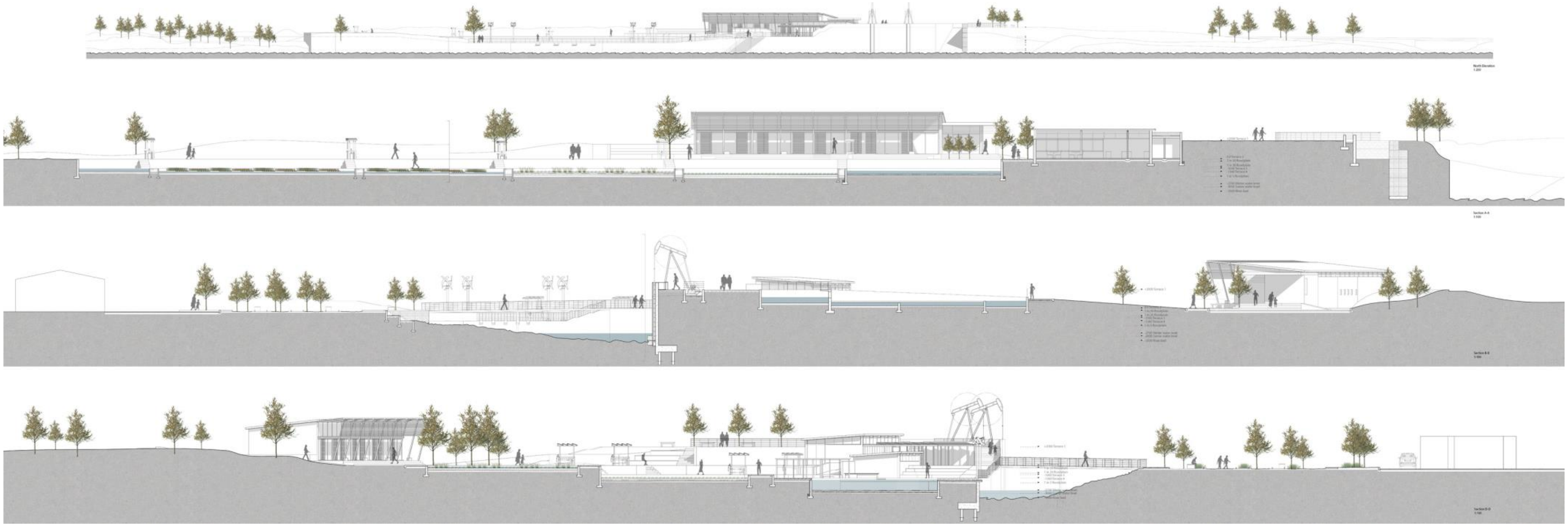


Figure 69: D1 Sections through site

Figure 70: D1 Section through river

Figure 71: D1 perspectives.

Top: View across river. Bottom: View across bio-filtration cells

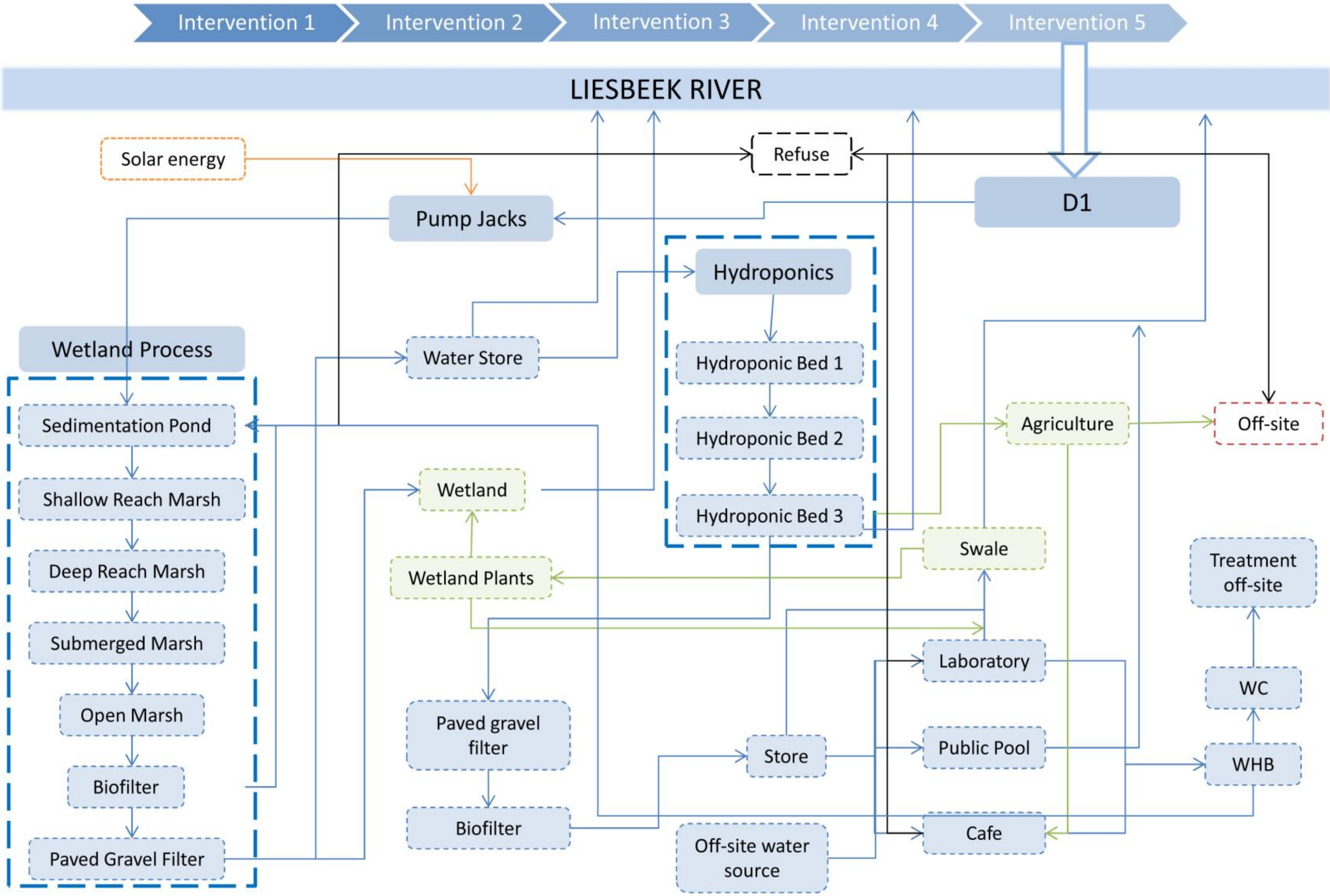


Figure 72: Flow diagram for the design proposal for D1. In this diagram, the flow of water, plants, energy and refuse is shown (Author, 2016).

Appendix C- D1 Sketch Analysis (all Author, 2016)

The following sketches record the author's reflection and thoughts on the design of D1. The sketches aim to analyse and evaluate the strengths, weaknesses and opportunities of D1. The analysis process allowed the author to uncover different aspects of the design, thereby understanding the design decisions made. Each of the following sketches is layered with different ideas, recorded with accompanying notes. The sketches were completed over a period of 10 to 30 minutes and may have been added to at a later stage as new ideas were processed by the author. The sketches are arranged roughly in chronological order in this appendix so as to take the reader through the author's journey of understanding the design. A short explanation of each sketch is given to provide context. The lessons learnt from each sketch is summarised below the explanation in the exact manner in which it was recorded during the reflection on the sketches. This allows the reader to understand the thought process followed during each analysis.

The comparability criteria suggested by De Jong and van der Voordt (2002) as part of the pre-analysis criteria for RBD states that the plans of the buildings that are to be compared must be of equal scale and legend. The following sketches are not drawn to scale, but are all of equal scale and therefore comparable. This is important to note as the aim of the sketch analysis is to understand the design decisions made. As mentioned in text, D1's macro- and meso-scaled proposals are retained through the RBD process as the design successfully deals with water and ecosystems at these scales. The micro-scale proposal was therefore focused upon in the analysis.

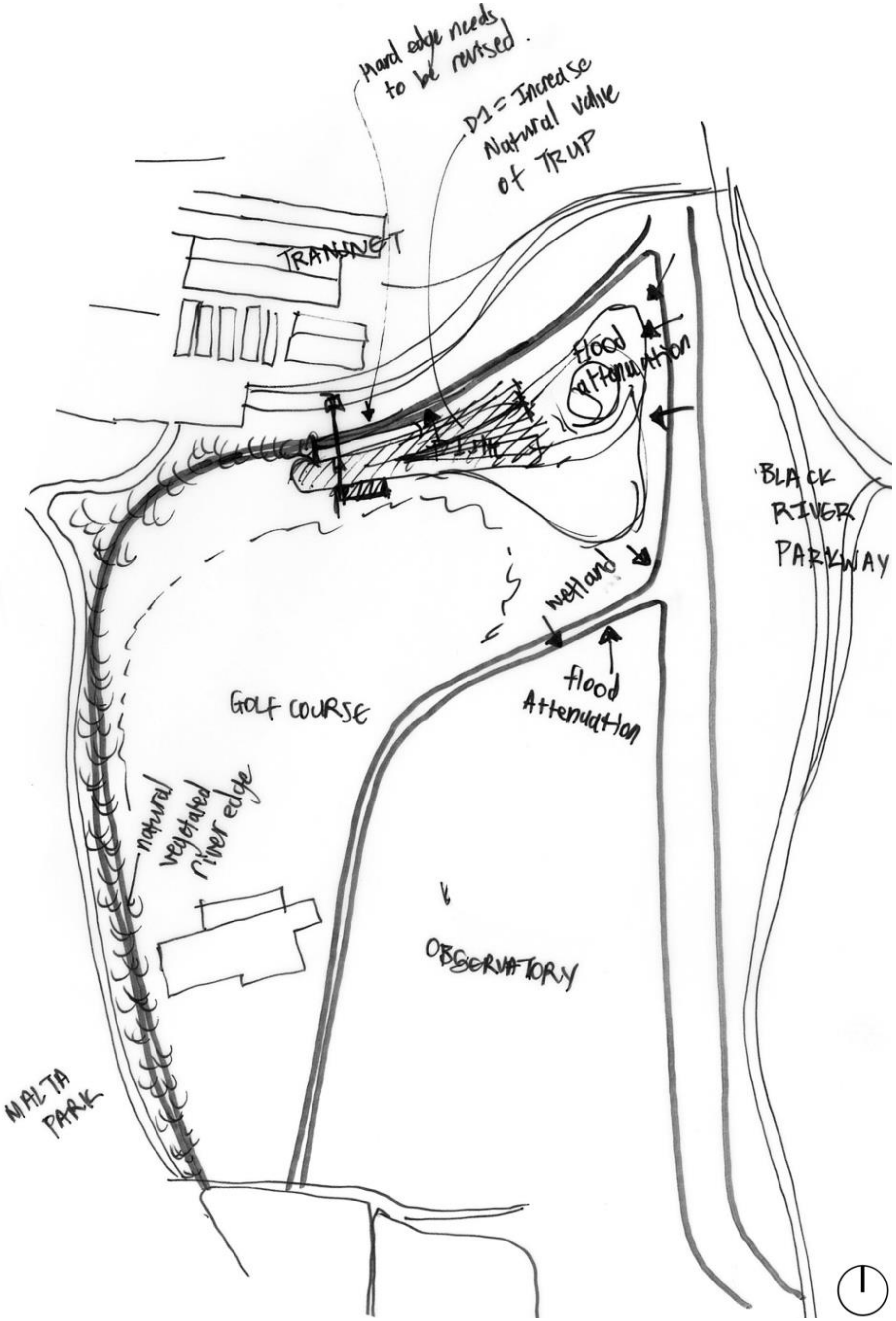
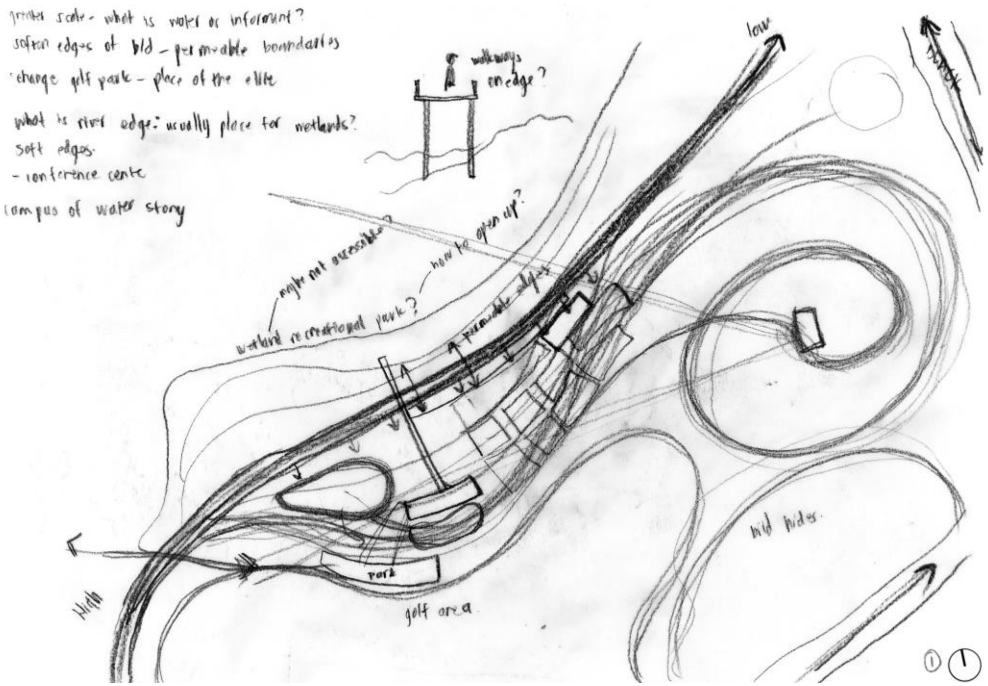


Figure 73: (Right) This sketch shows a portion of the TRUP, focusing on the area around D1. D1 aimed to increase the natural value of the TRUP by restoring riparian vegetarian and thereby benefiting naturally- occurring ecosystems in the area. The sketch locates the surrounding landmarks in the area, including the South African Observatory premises; the River Club Golf Course, Black River Parkway, Malta Business Park and the Transnet site. The Old Liesbeek and newer Liesbeek Rivers join with the Black River to form the Salt River at the top of the sketch.

Sketch thoughts:

- **Edge conditions of the site?**
- **What are the impacts the site has on the greater region? – TRUP and MOSS…**
- **Consider links between site and TRUP and MOSS!**
- **Naturalise Old Liesbeek River edge: becomes part of a bio-highway for plants and animals along river.**
- **The design fits into existing green-blue corridors. Emphasise this in future iterations?**
- **Wetland edges: allows for water attenuation during large rainfall events.**



Sketch thoughts:

- **Greater scale- what is water as the informant?**
- **What is a river edge? Is it usually a wetland?**
- **Soften hard edge of building – permeable boundaries as per Heidegger. The whole building is built of layers of boundaries? What is the river edge naturally, and how can we get back to this edge? Open up edges…accessible edges but still able to accommodate for change. Nursery…allows for flood attenuation and prevents erosion on site…indigenous plants.**
- **Show story of water: runs from highest to lowest points naturally! D1 is counter-intuitive in that earth is manipulated in order for the water flow to work…maybe flip entire design? This way, water is drawn to highest part of site and flows to lowest. Will probably still manipulate the land to an extent in order to form berms and valleys, but must go with the natural fall of the site.**

Figure 74: This sketch was the first drawn to explore D1 at the micro scale. Flows on site exaggerated in the design are noted. The success of the design of the adjacent wetland recreation park is questioned. It was noted that a campus to show the story of water should be created. The edge conditions of the site are questioned. A hard edge along the river was created in D1, whereas the research conducted called for a permeable boundary. The edges of the site and building should therefore be naturalised in order to create a visually softer boundary. This new naturalised boundary may be linked to the macro- and meso-scaled proposals, thereby contributing to the natural value of the area by reinstating riparian vegetation and providing an opportunity for ecosystems to flourish.

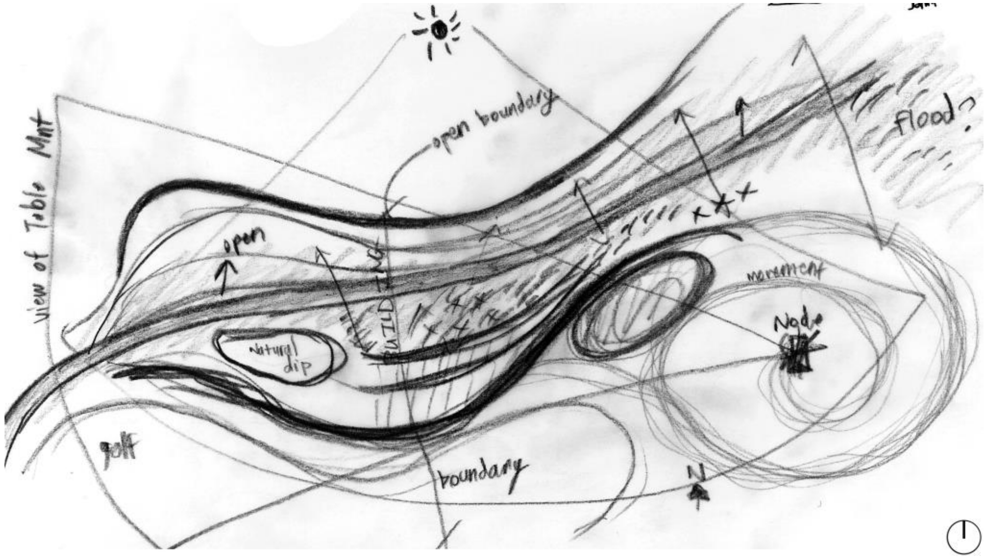


Figure 75: In this sketch, the site is abstracted in order to understand the essence of the landscape. The river is a dominant element in the landscape. Existing movement routes on site could form the basis for design changes. The land on either side of the river is considered and should be thought of as one landscape in further design iterations.

Sketch thoughts:

- **Water has multiple values…links to WSD. How to show value?...explore each and integrate fully into design. Enhance D1 in D2's design.**

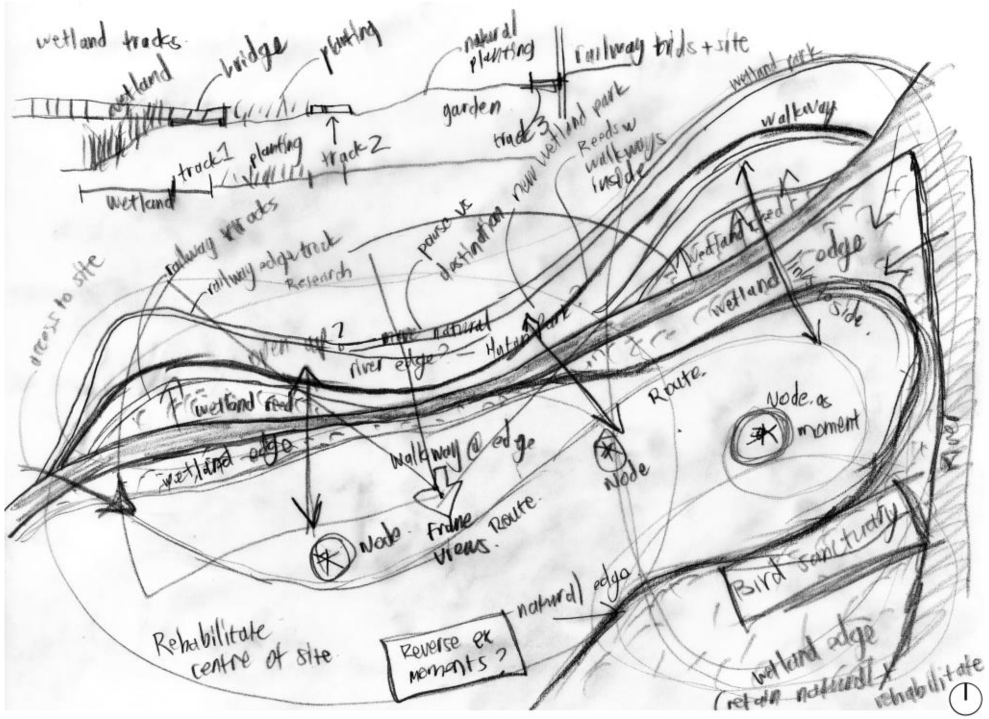


Figure 76: Exploring the natural boundary. In this sketch, the links across the river to the adjacent wetland recreation area was explored. Sight lines, views and areas of interest are noted. Site repair was noted as a focus for the design through rehabilitating the natural wetland and riparian edges. Design elements such as pause spaces versus destination spaces are considered according to the desired functions. These spaces need to be integrated with the natural ecosystems on site. A rough section in the top left corner shows how the wetland park could work, integrating the existing railway tracks with natural vegetation to become a space for recreation and reflection.

Sketch thoughts:

- **How to spatialize ecological systems on site? How do we return to nature and improve our relationship with water/ site/ nature?**

- **Walking in the wetland-how to make this a tactile experience? Elevated timber walkways?**

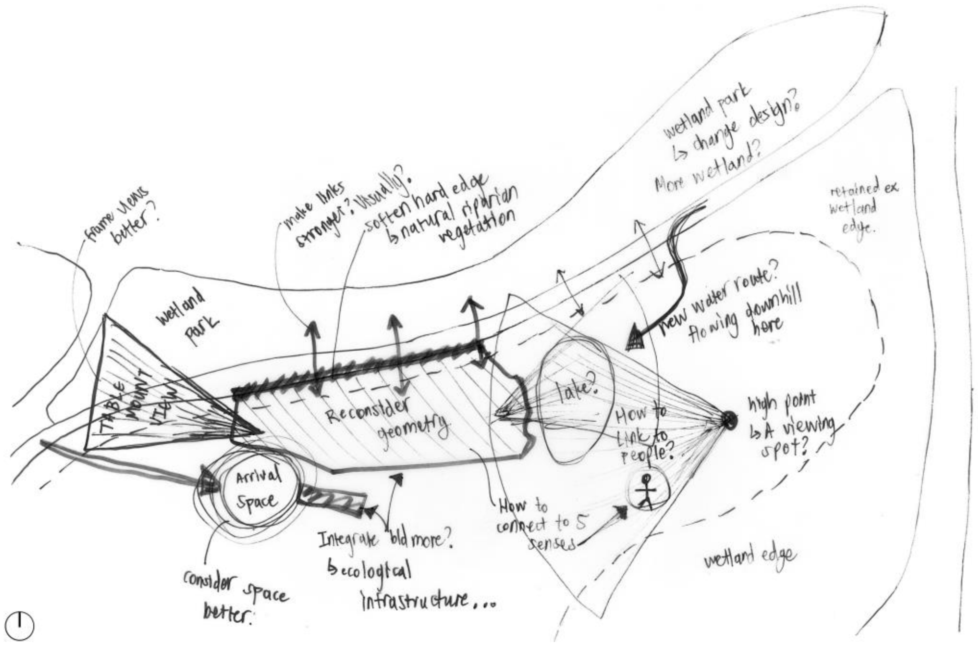


Figure 77: This sketch considers the building as it was. It became apparent that the flow of water in D1 goes against the natural flow of land. A new water route across the site should be considered. Views from different parts of the site are noted, and may be used to inform the design. The original geometry of D1 could be reconsidered to take into account the existing land form. The hard boundaries of D1 need to be naturalised in order to create habitats for fauna and flora along the site.

Sketch thoughts:

- **Forms too geometric and clean- nature is curvy and messy. Get back to natural forms in order to enhance ecology on site. Note: create little habitats for fauna and flora to thrive. How to do this? Need shelter and food…must use indigenous species that are well adapted to the climate and conditions on site. River restoration = more fauna and flora in area.**

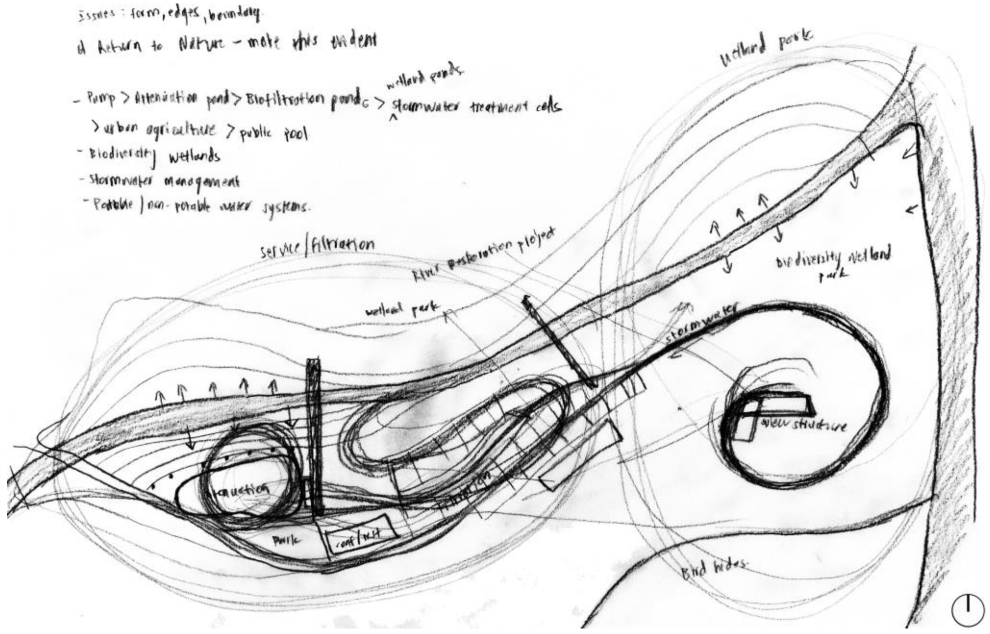


Figure 78: The form of the building is explored in this sketch. Movement routes are used to inform the placement of the different building elements. The flow of these different building elements within a WSAD building is considered to optimise systems on site.

Sketch thoughts:

- **Not enough emphasis on people, ecology in design- change the way the site is viewed: changing scales through the design process is important. How to make this a good design? How to make it a good place to dwell? Must be comfortable in environment.**

- **How to make more public? – Start with water and people as informants of design! Look at the different water, natural and ecological systems on site at the different scales- how to integrate these into site properly and responsibly?**

- **Look at all aspects of water on site: ground, rain, storm, river, potable, non-potable effluent – how to deal with each efficiently? How to really show the flows of water across site; make people aware of its journey…make water and processes relating to it visible – which is the objective of creating knowledge**

and awareness around water as a resource. How to integrate sanitation/indoor filtration systems to show people…put on exhibition, make transparent so people can see inner workings of the different systems?

Sketch Thoughts: Scenario objectives for D2

Lessons learnt from the analysis of D1 generated thoughts and ideas around the direction of the development of the design into the next iteration, D2. These lessons are recorded exactly as noted during the reflection of the sketches shown in Appendix B.

Links to the urban scale

- How does it connect to the urban proposal…how to rehabilitate the whole river, increase water quality and create a more water sensitive urban environment? Perhaps the site is focus area of intense rehabilitation and together with the macro plan; the river is rehabilitated by restoring natural river banks and reinstating wetland plants from a riparian and wetland plant nursery on site.

Water and ecosystems

- Water as driver for design: draw up onto site, rehabilitate, test and release.
- Try to restore the natural water cycle on the site…Ecological Urbanism and WSUD. Every design move must aim to do this.
- Layering systems and services: attenuation pond> bio-filtration ponds> stormwater treatment> research offices> research laboratories> biodiversity pond for recreation> urban agriculture> conference centre and offices> restaurant> wind pumps> solar energy> potable water on site and how to deal with this> grey water> black water> parking> wetland recreational park and route through to bird hides> pause areas> picnic spots> wetland plant cultivation> movement routes on site.
- Water: need strategies for storm, grey, black, potable, river, rain…

People and architecture

- Create a focus area of river rehabilitation. How do people engage with this? Make people aware of the value of water…feedback to communities, to own homes and environment.
- Activities: market days> festivals> conferencing> urban agriculture> outdoor sculpture park.
- A focus on a single workable building that combines aspects of the precedent, conceptual underpinnings and D1 as a best-fit design.
- Look at value in the design: relationships between man and nature, power, nature, economic, social, political and cultural.
- Wetland recreational park? Growing plants for rehabilitation on river. Shangai Huton Park: bridges across river and planting. Volunteer cultivation sessions from community? Connect to site across the river.

Appendix D- D2 Process

The following sketches record the author's design process for D2, taking into account the thoughts described in Appendix A and B. This proposal considers D1's macro-proposal very briefly, refining ideas from the original design for future iterations. The process predominantly focuses on the design of the micro-scaled proposal. Several sketches are developed, which deal with space planning, the human experience, defining positive and negative space, natural systems including ecosystem services, water function on site and view framing, among other themes. The design process resulted in a colour diagram showing the different spaces created, which was used to create a 3D digital model to test the ideas produced.

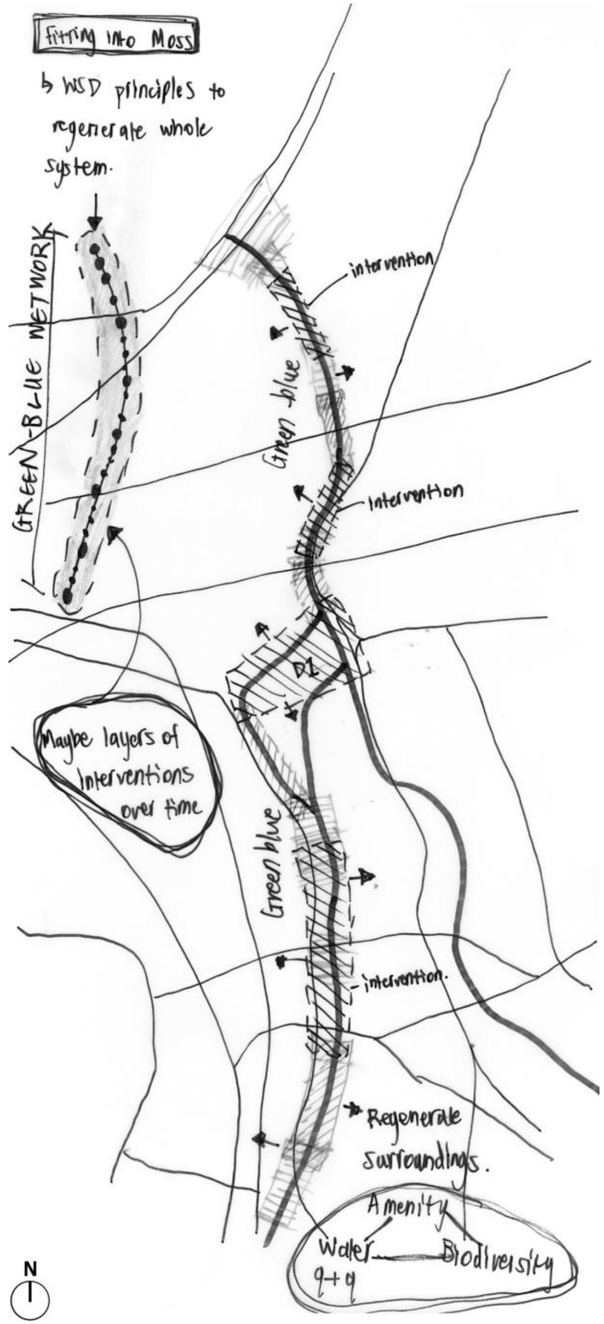


Figure 79: Fitting a new design proposal into MOSS and the CTSDF. In this diagram, the opportunities for regenerating the river system at the macro- and meso-scales using WSD are explored. Multiple layers of interventions are proposed, building upon D1's urban proposal. These interventions are phased: in the first phase, primary focus areas that will have the greatest impact upon the community and the environment are developed. The next phase considers secondary focus areas and makes used of WSUD principles for river restoration. The final phase develops the areas between the primary and secondary focus areas to regenerate the river surroundings and add value to the greater green-blue network. These layered and overlapping interventions across the course of the river make use of WSD principles to regenerate the entire river system. This results in a positive effect on the amenity, water quality, water quantity and biodiversity values across the Liesbeek River.

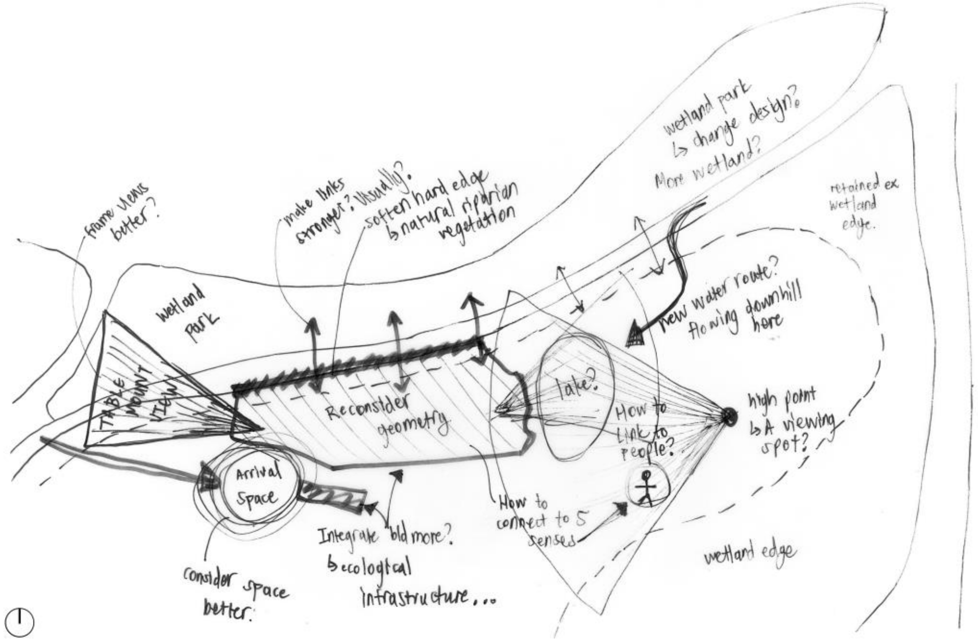


Figure 80: This diagram analyses the opportunities for D2's design based on the sketch thoughts developed in Appendix A and B. Views, spatial arrangements and the building's geometry need to be reconsidered. The flow of water on site should be fully integrated into the new design. Understanding the visitor's experience to the site is an important design informant.

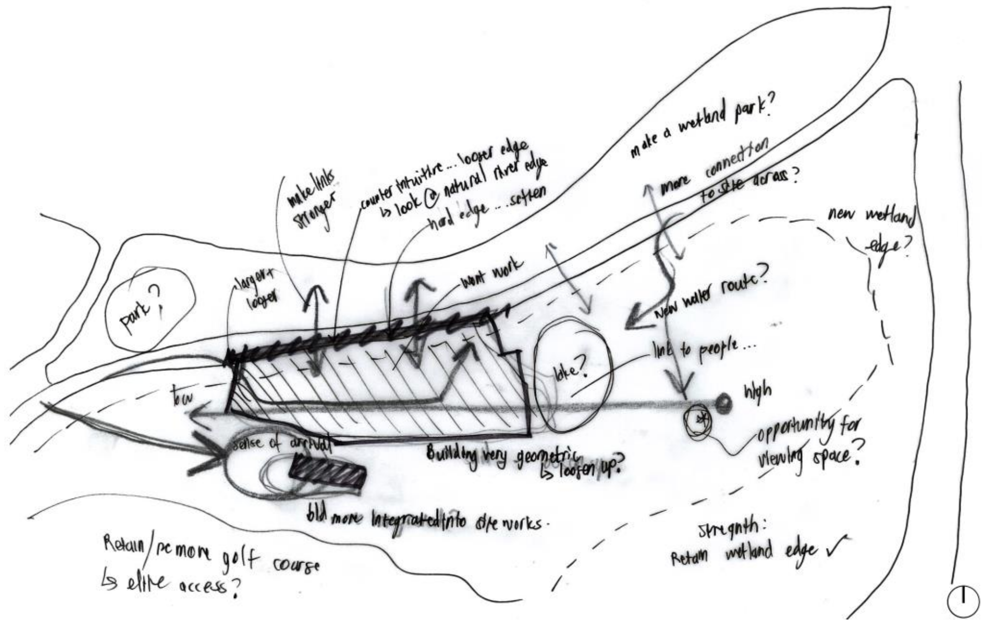


Figure 81: This diagram analyses the strengths of D1's design based on the sketch thoughts developed in Appendix A and B. Wetland edges are to be retained and developed further to provide habitats for fauna and flora on the site. A more permeable river edge should be created.

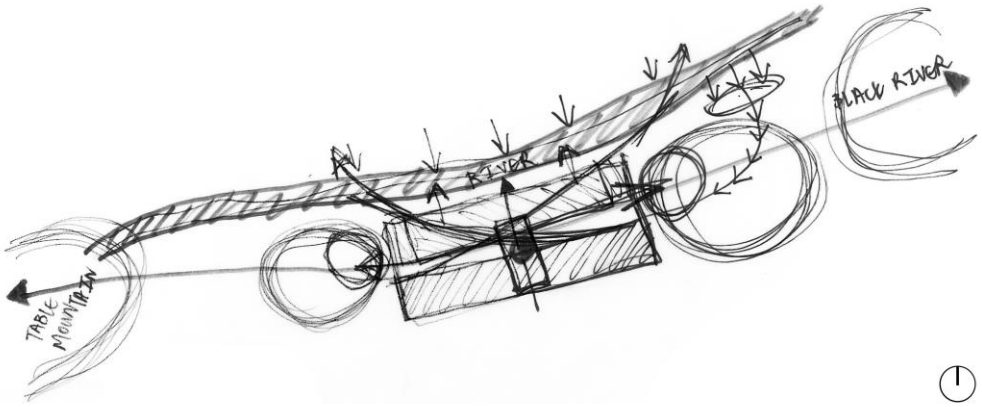


Figure 82: Concept diagram for D2. The massing exercise is informed by phenomenologically-derived design imperatives, which deal with the expressive ecosystem values discussed in Chapter 3. A central rectangle is broken up by a major axis parallel to the river line. This axis is anchored by the view of Table Mountain and the Black River. Flow lines across the river bisect the rectangular forms, creating a central node. This central node forms a community gathering space, demarcated by a smaller rectangle. The mass is bookended by two circles, indicating natural spaces.

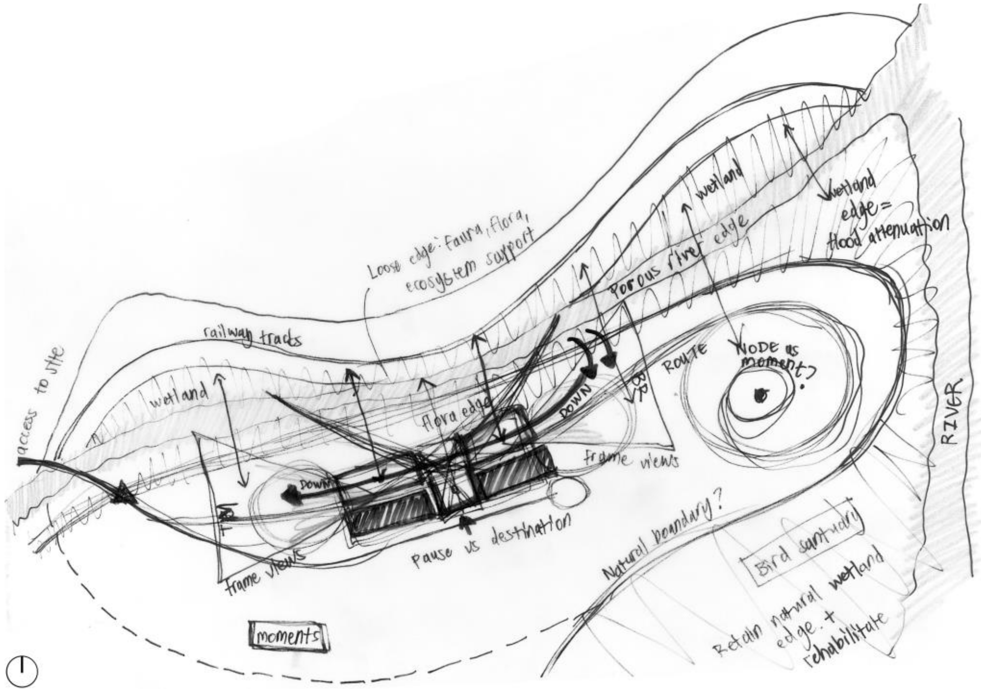


Figure 83: Exploring the natural boundary. In this sketch, the concept diagram for D2 is placed upon site in order to explore the effects a new design will have on site. The wetland zone evolves from D1's design to become a part of the site's edges, making it a more permeable and soft edge as per the principles discussed in phenomenology. D2's concept is clarified and the building mass becomes apparent as four rectangles framing a central gathering space.

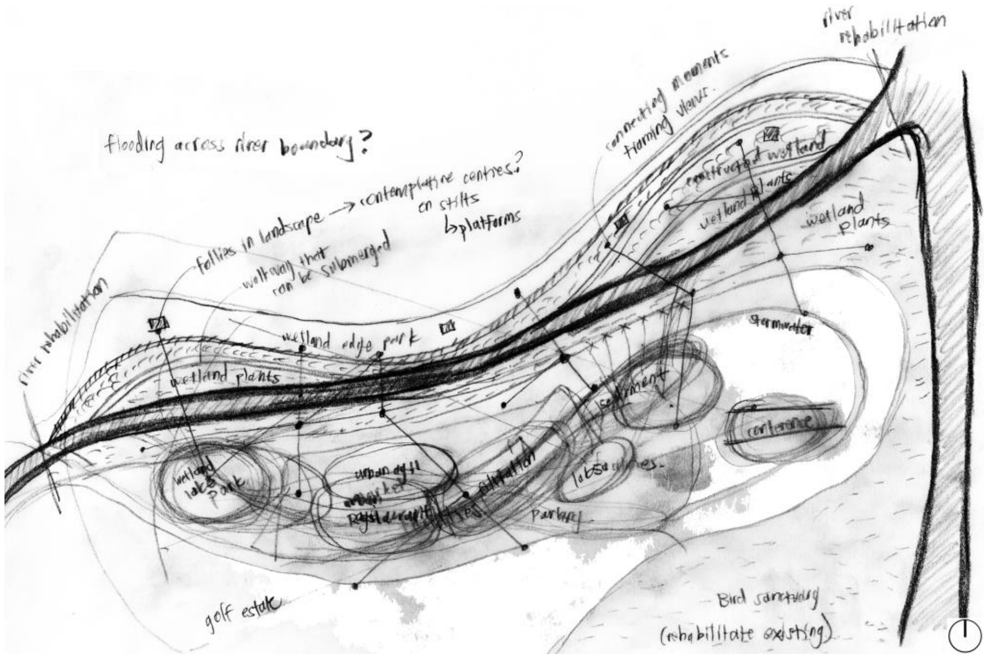


Figure 84: Roughly placing programme on site. Zones for different programmes are arranged on site, based on function. Water flow drives the placement of water filtration processes and elements. Adaptive edges for flood control are noted.

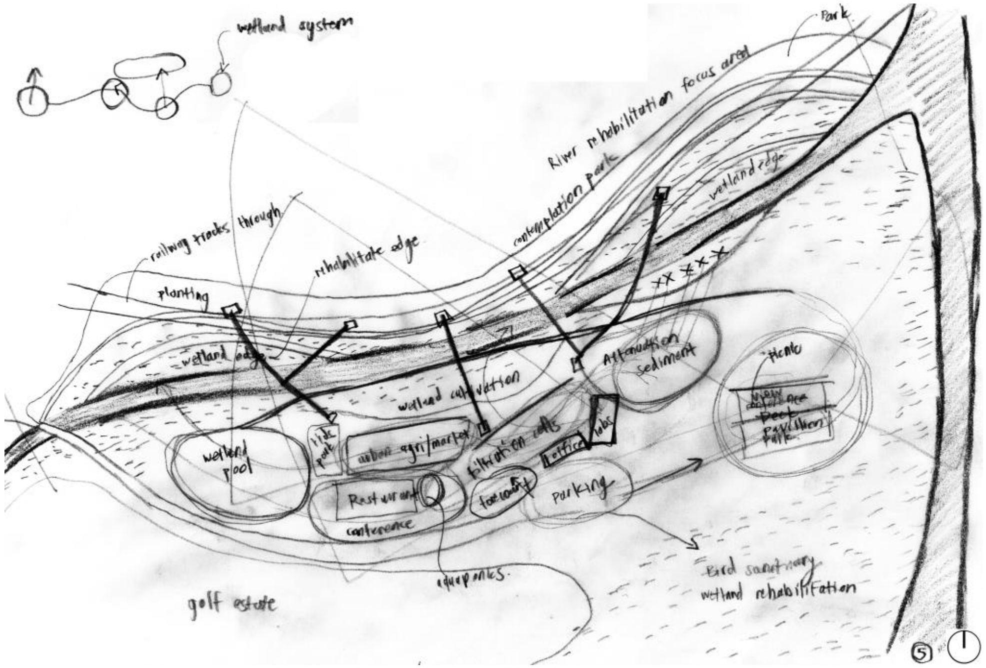


Figure 85: Roughly placing programme on site. Links across the site are emphasised. Programme placement is clarified.

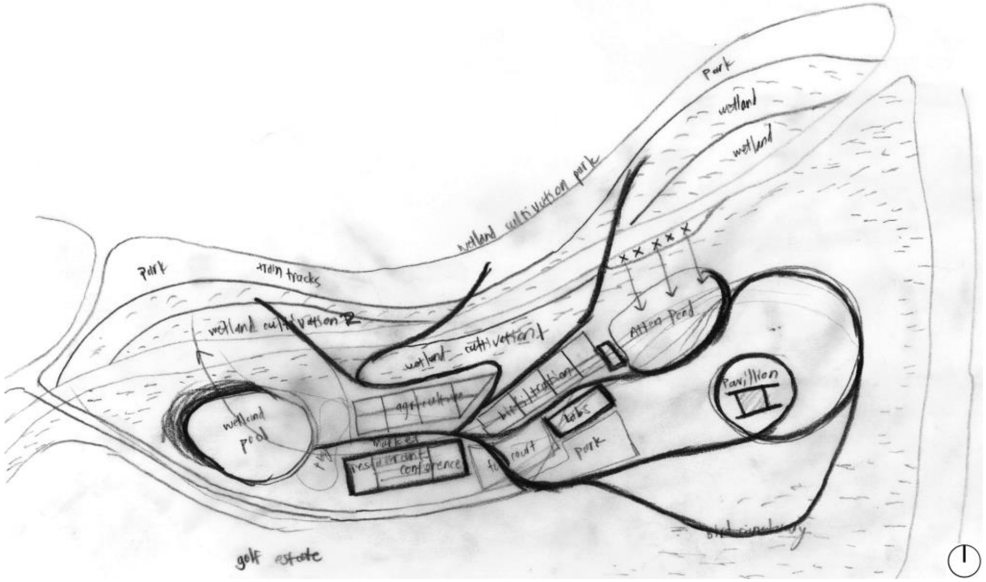


Figure 86: Exploring movement routes around the placement of programme. The existing bird sanctuary on the wetland edge is noted as a possible destination area along the meandering routes across the site.

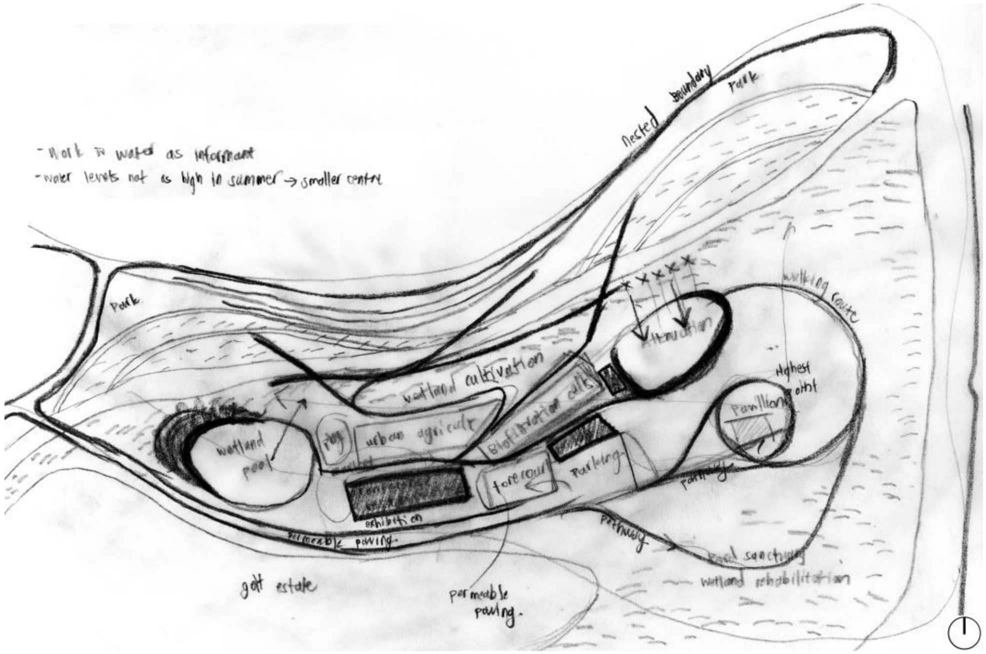


Figure 87: Ideas on programme and movement routes are clarified. It is noted that water must be the ultimate design informant. Flood control at the adaptive edges of the site means that the building itself must be a smaller element of the overall design. The building should be located at a higher point of the site to accommodate for seasonal flooding.

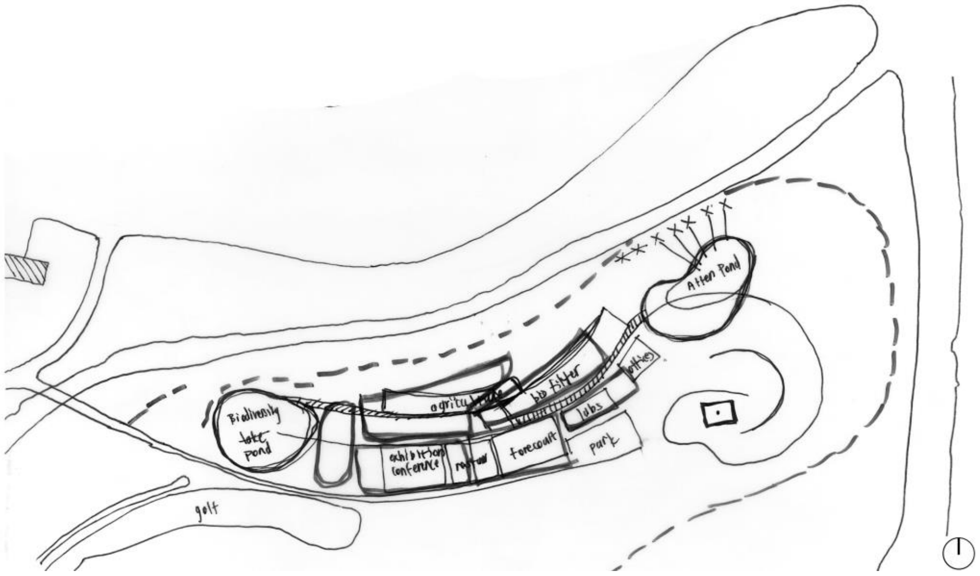


Figure 88: Programme arrangement is clarified. The forms and exact positioning of the building is experimented with.

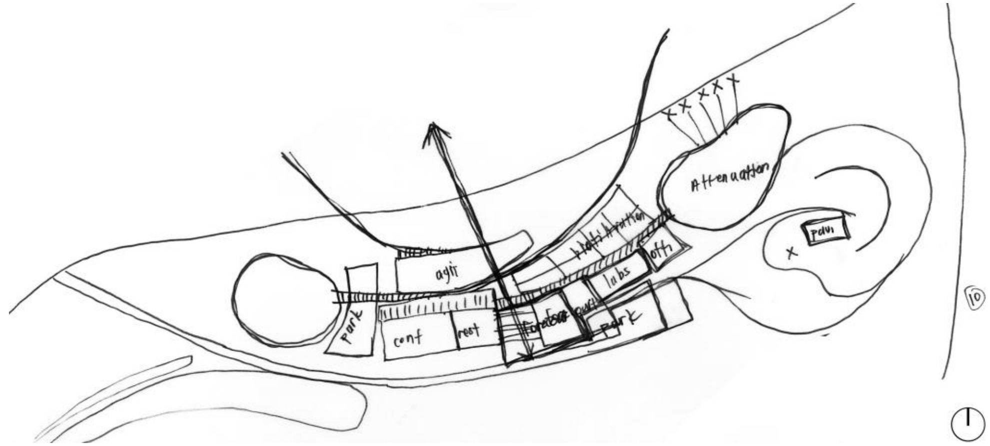
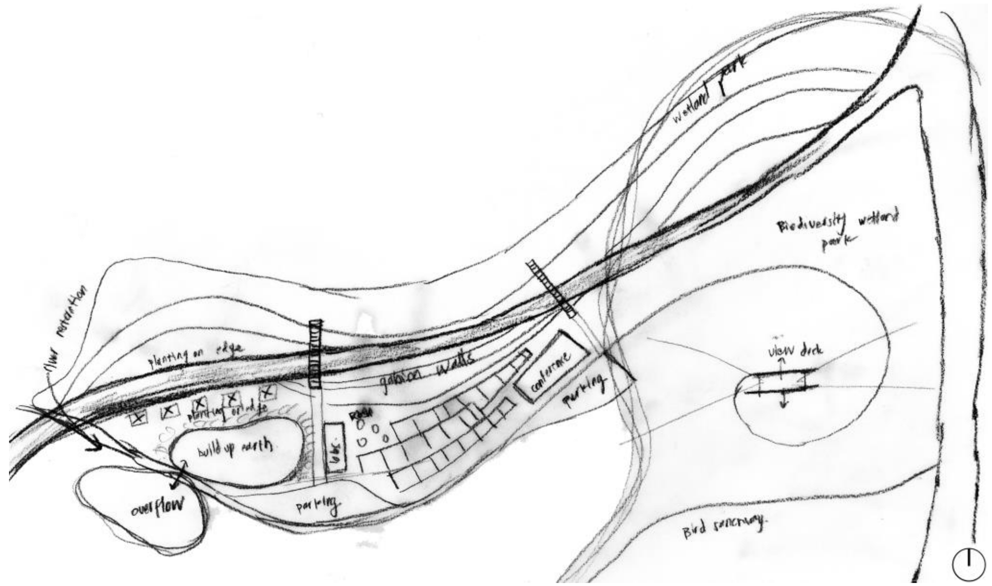


Figure 90: This sketch clarifies the movement routes across the site. The building massing begins to take shape.

Figure 89: (Right) This sketch shows a deviation from the concept. A different placement of programme is explored. This idea was discarded as the design elements are too isolated on site and the parti is not cohesive.



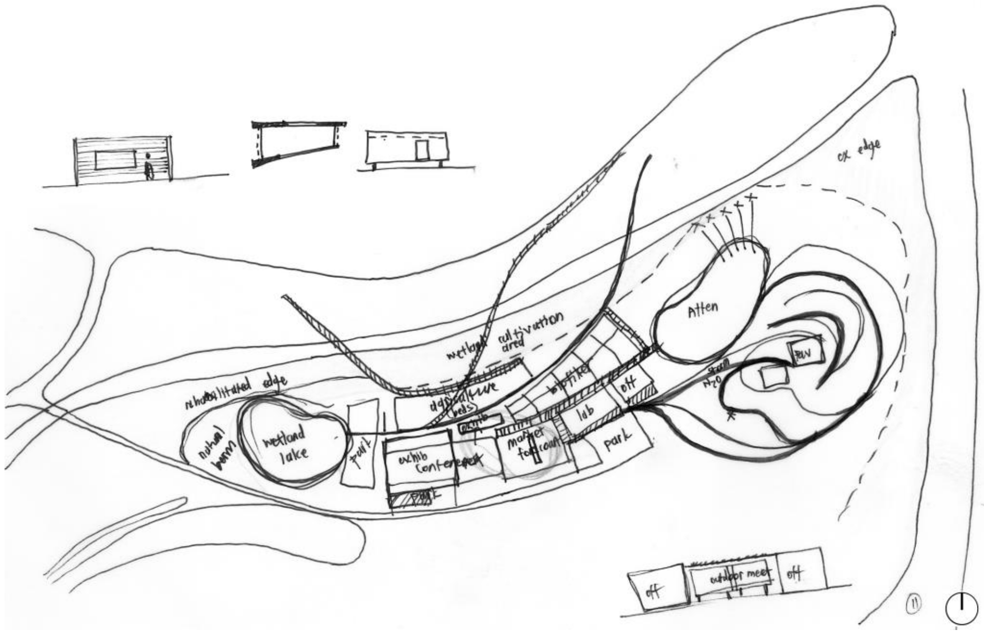


Figure 91: Returning to the design concept for D2, this sketch shows the design ideas developing in plan and section. Thoughts on the kind of spaces created and the visitor's experience within each space are considered, with reference to phenomenology.

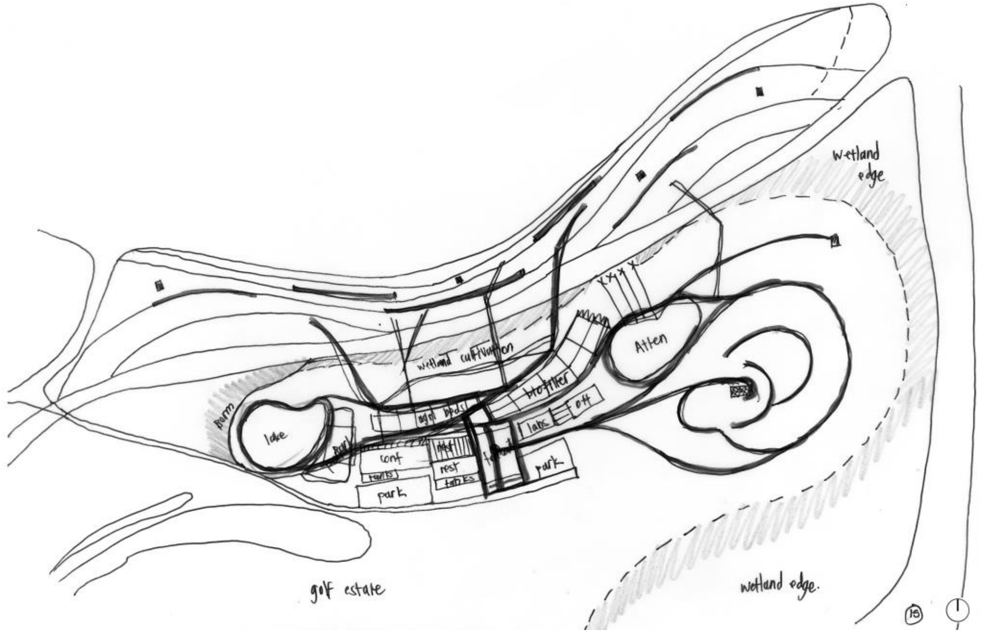


Figure 92: Movement routes on site are refined. The sketch shows an attempt to reconnect design ideas around programme with the concept diagram.

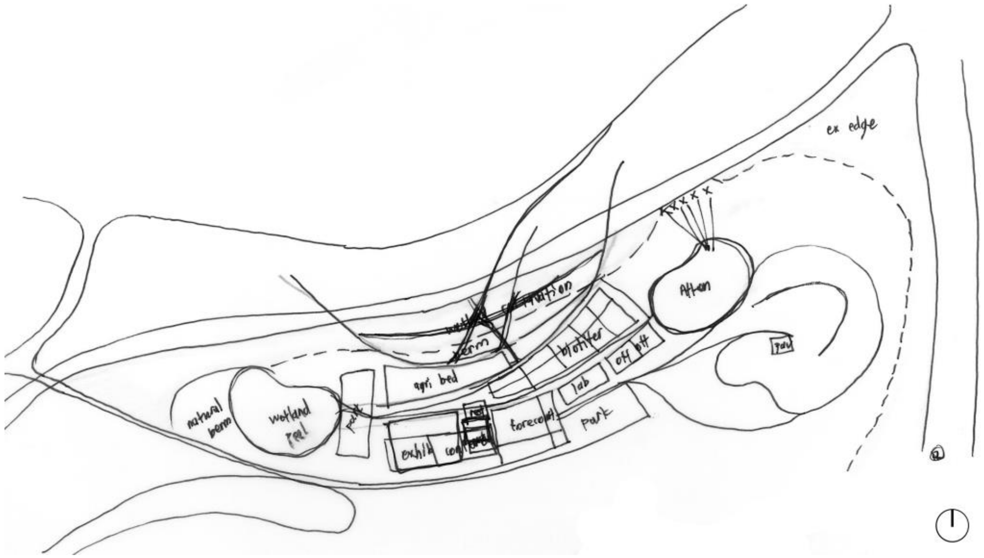


Figure 93: The design is simplified to its base elements in order to identify problem areas. Movement routes are still focused upon, as is the placement of different programmes.

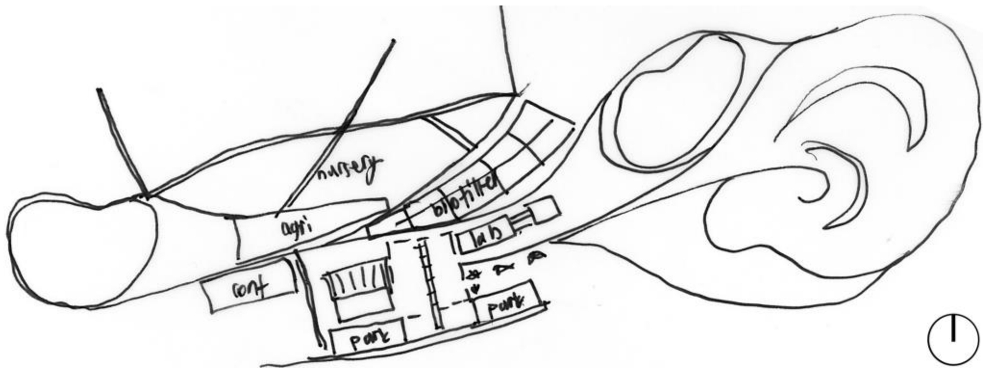


Figure 94: A quick sketch exploring the geometries of the different spaces.

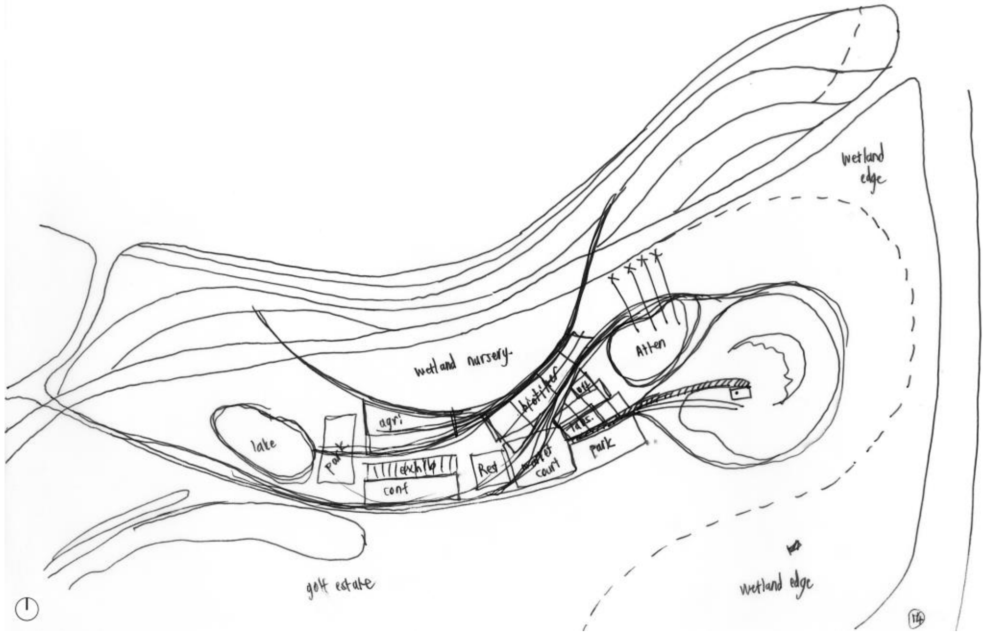


Figure 95: This sketch explores movement routes. The visitor's experience is considered, and the pathways created aim to frame views, become destination spaces or become routes for activity.

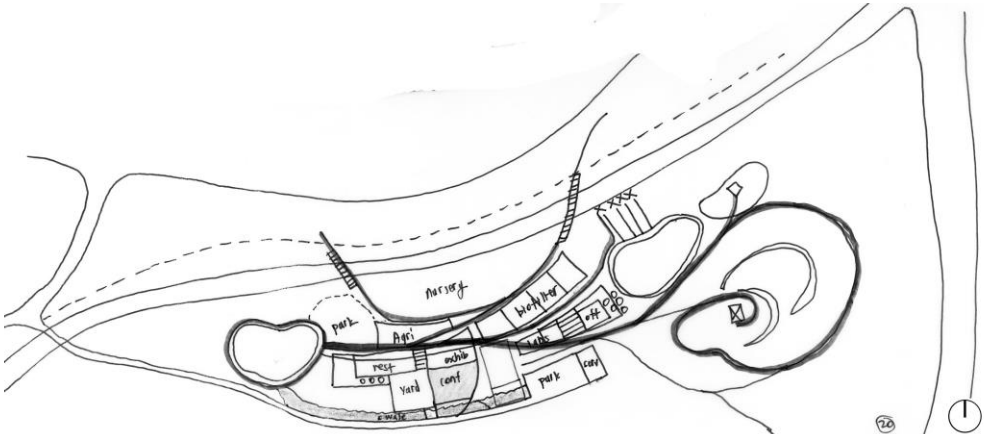


Figure 96: This sketch revisits the main movement axis from the concept diagram. Placement of certain programmes and their geometries are explored.

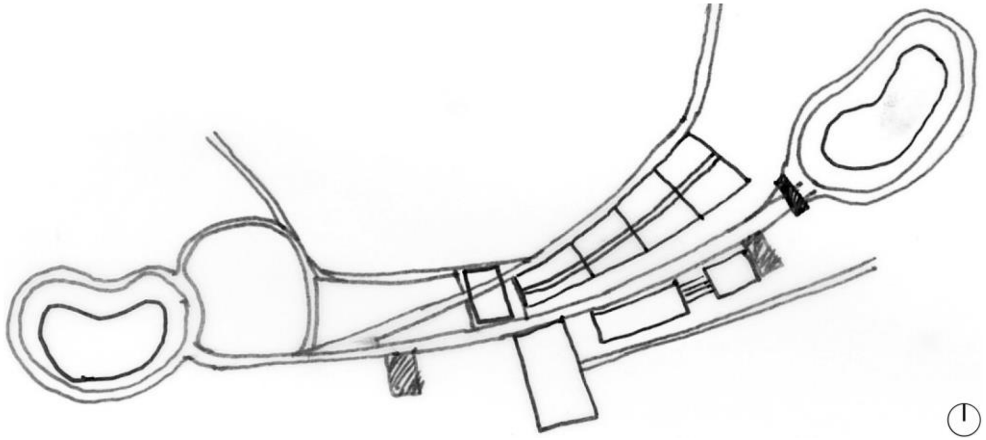


Figure 97: A quick sketch to understand the massing of geometries.

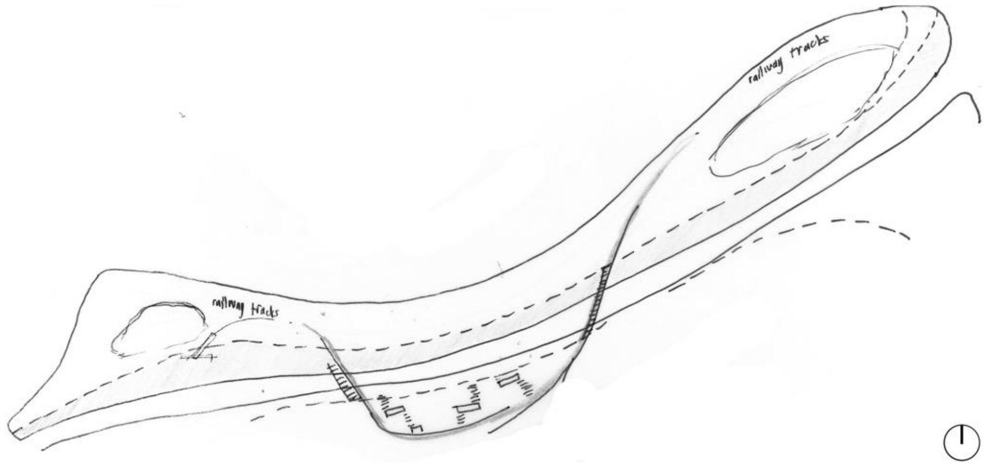


Figure 98: A quick sketch to explore the placement of the landings and stairs in the wetland nursery.

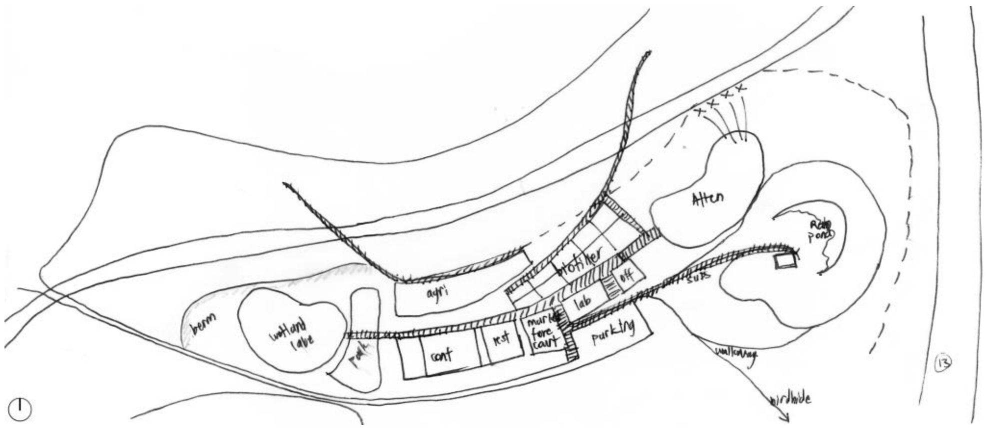


Figure 99: Finalising the placement of programme.

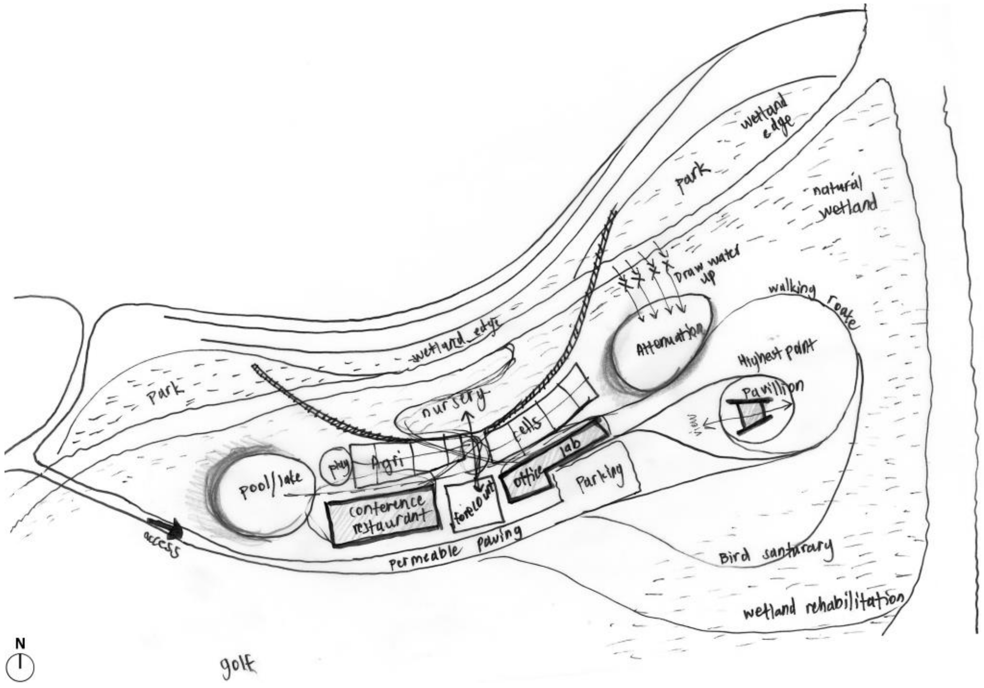


Figure 100: The sketch design is refined. Massing and movement routes are explored, along with the flow of water through the different filtration processes on site.

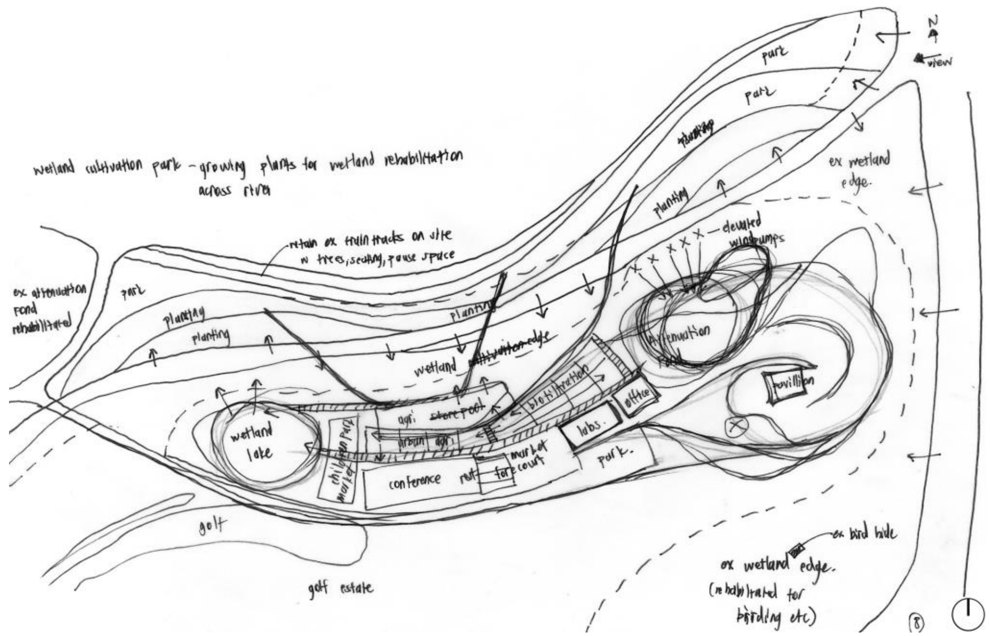


Figure 101: Refining the design. This sketch explores movement routes as well as the experience of the different spaces created. The wetland edge is focused upon. The riparian plant nursery will provide plants for the meso-scaled river restoration.

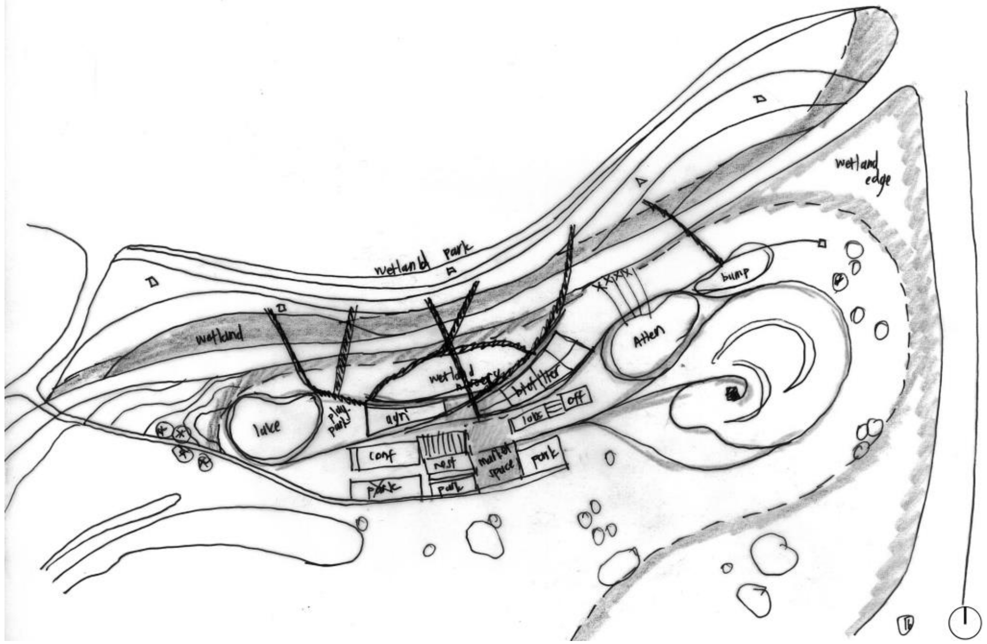


Figure 102: This sketch explores the river edge conditions and the links across the site. The form of the building is clearly linked to the building concept.

Figure 103: Refining movement routes and experiences through the building.

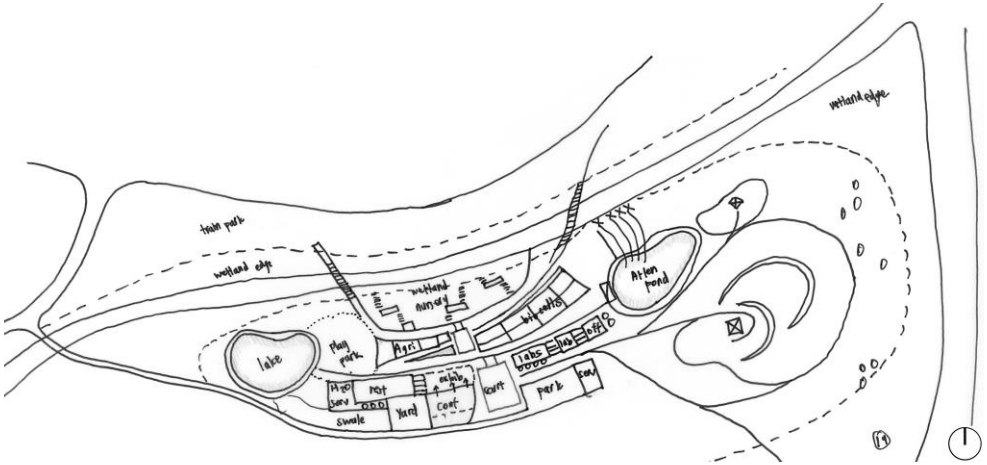


Figure 104: Clarifying the design.

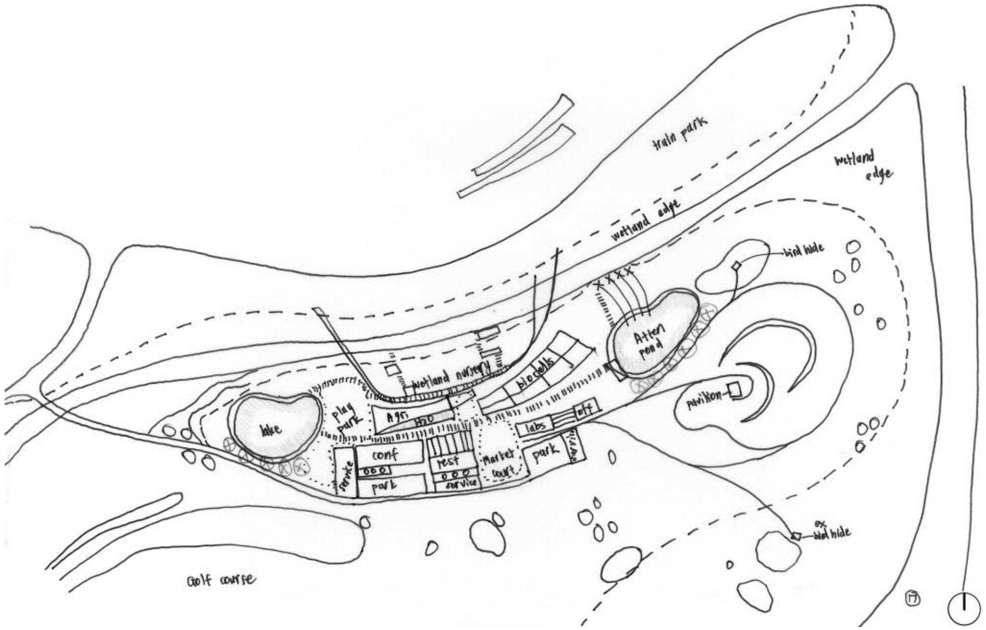


Figure 105: Exploring tectonics, with soft edges demarcated with dashed lines.

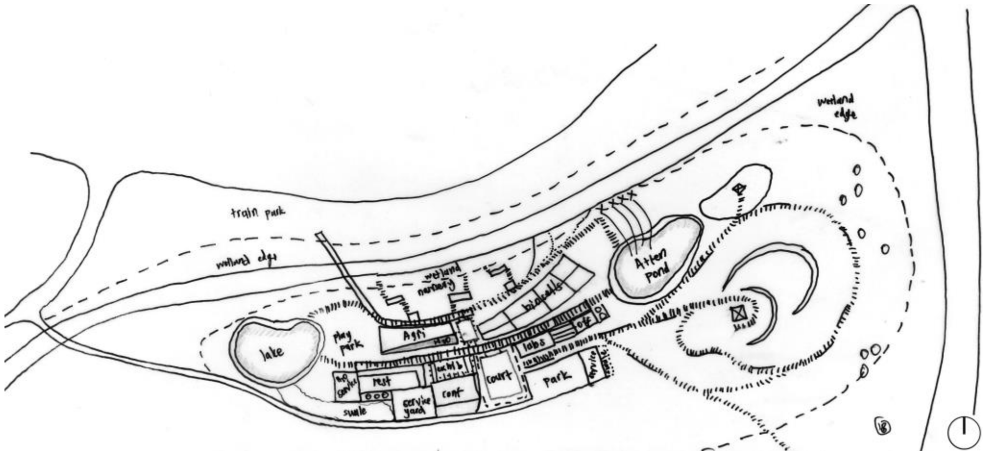


Figure 106: Refining the design's movement routes and defining spaces.

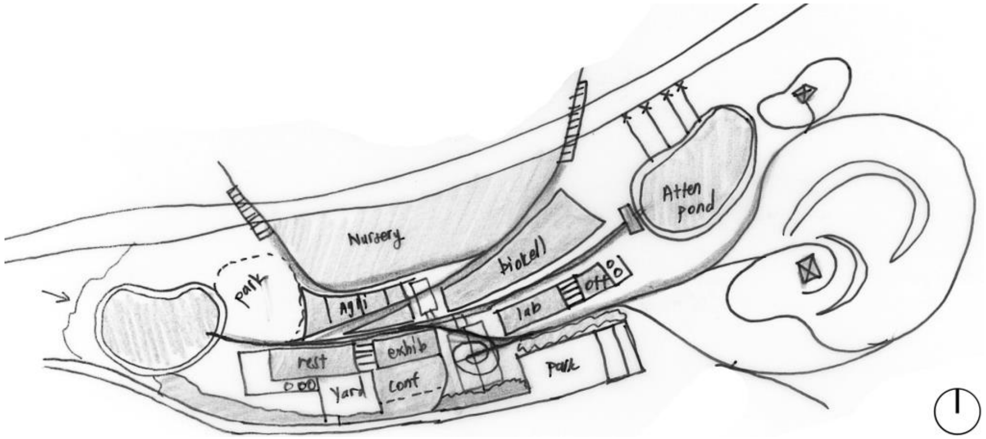


Figure 107: A quick sketch to finalise programme, movement routes and negative space.

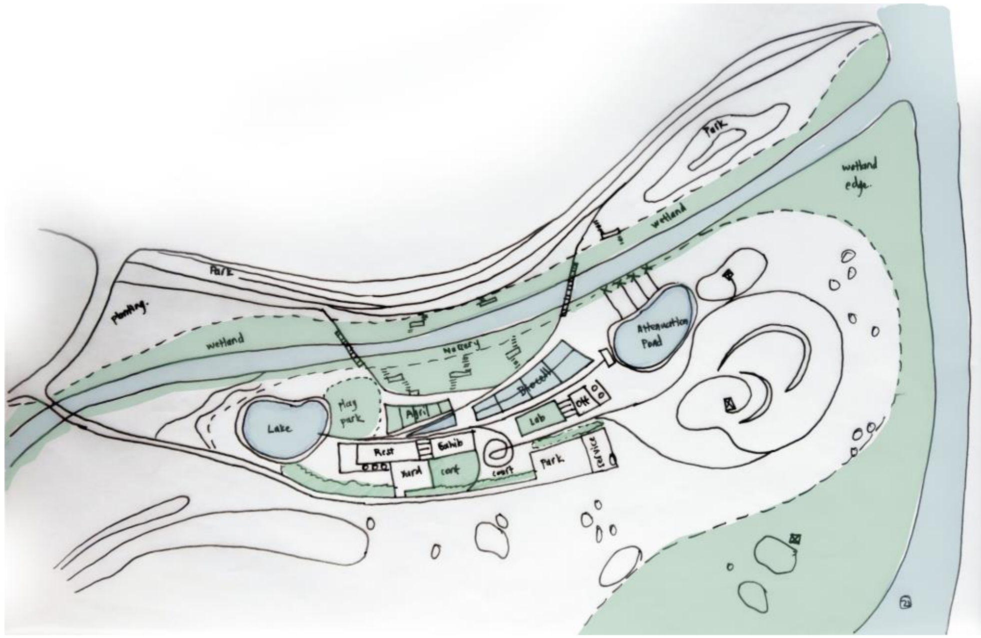


Figure 108: The final planning diagram. This diagram was used as a basis for the 3D digital model of D2.

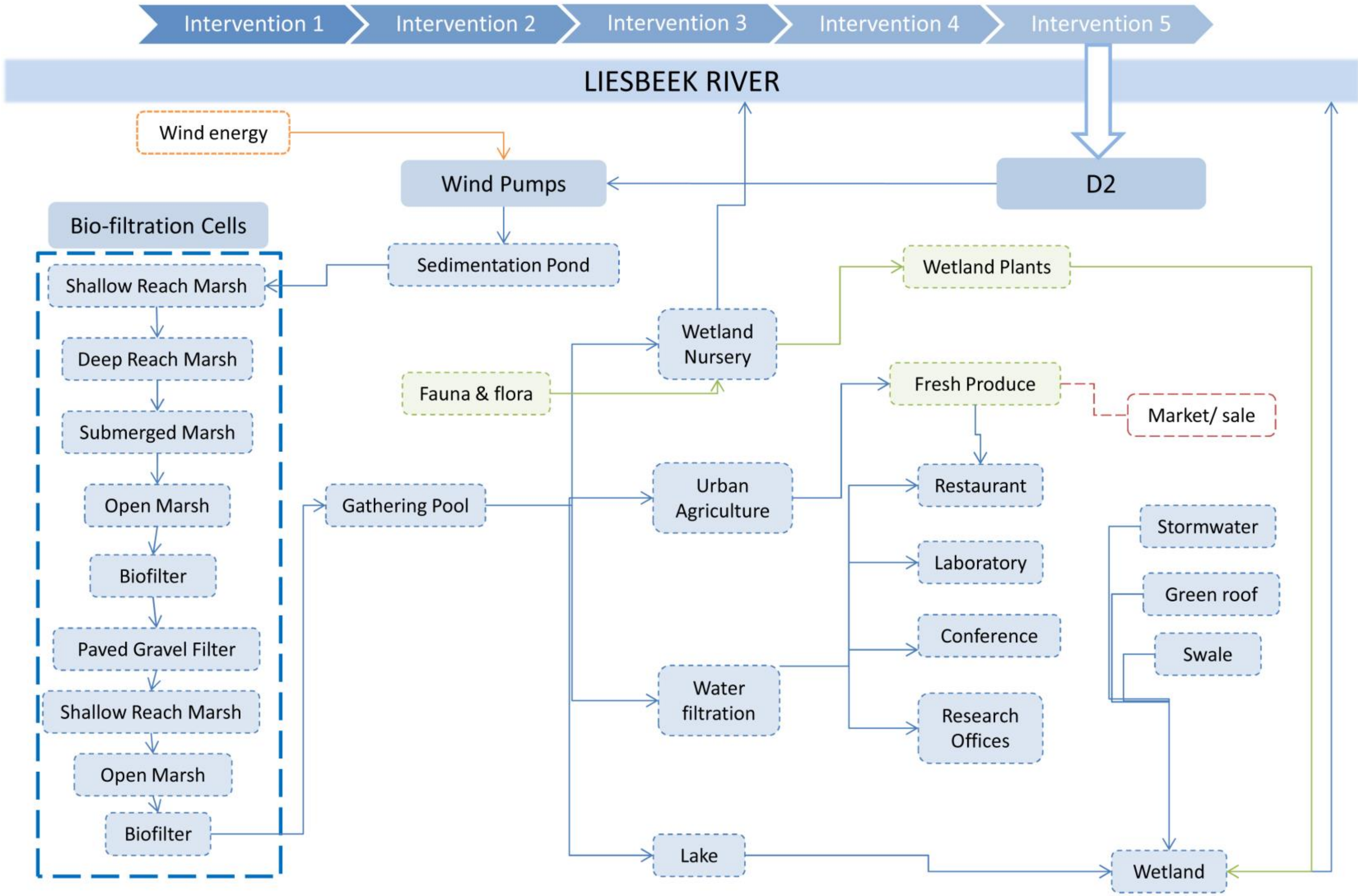
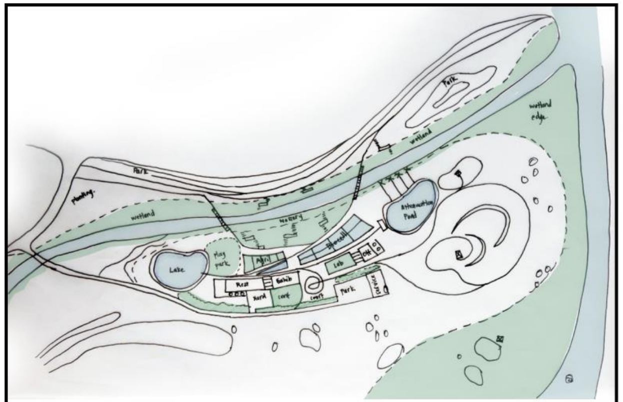


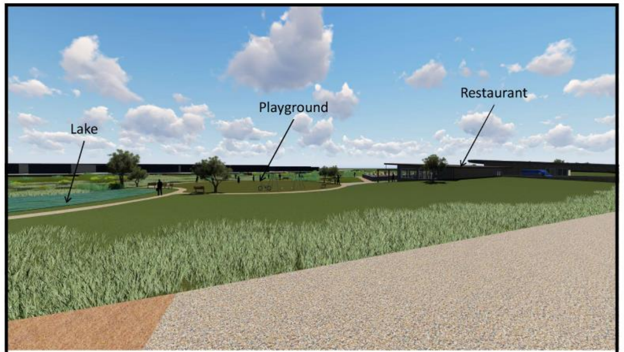
Figure 109: Flow of elements in D2. This diagram considers the flow of energy, water, plants and services in D2's design (Author, 2016).

Appendix E- D2 Product

The following images show a visitor's journey through D2. These images were shown to each participant for the evaluation of the design. Participants were able to ask questions about different aspects of the design. The images shown here were not digitally manipulated due to time constraints and so the complete context is not shown.



Sketch plan of site

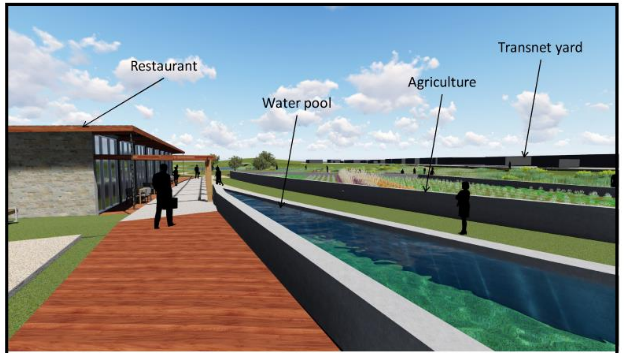


Approach towards building off Liesbeek Parkway.

Entrance to campus. Note water tanks for storing water at different stages of filtration, and swale for treatment of stormwater from non-porous paved areas.

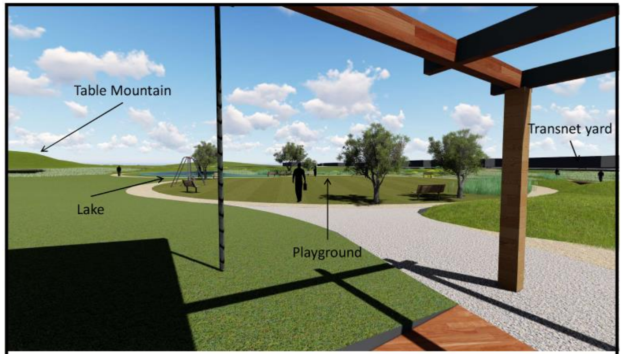
Entrance plaza

Walkway looking towards Table Mountain

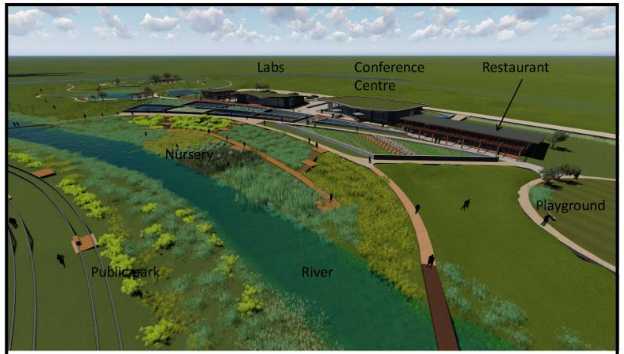


Walkway looking towards Table Mountain, with restaurant on left.

Walkway looking towards Table Mountain, with agriculture on right.

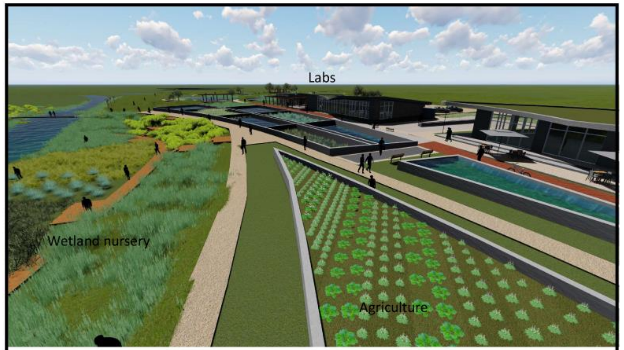


Walkway looking towards Table Mountain, with playground and lake in front.

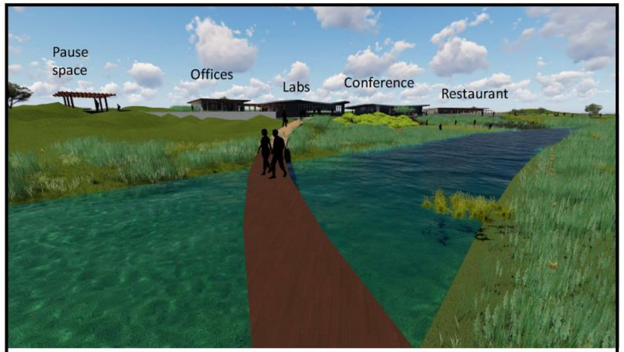


Overview of site, looking towards Black River Parkway.

View from public park across Liesbeek River to buildings.



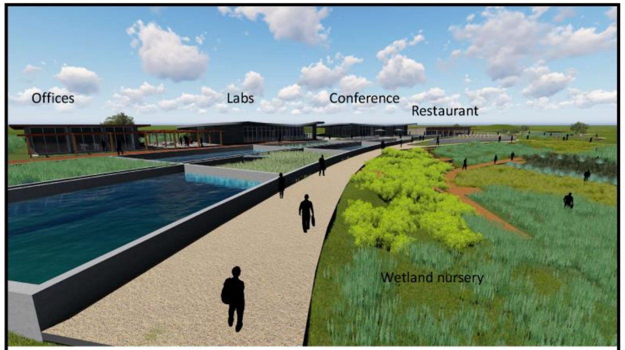
View of agriculture cell. Note wetland nursery on left.



View from public park across bridge, looking towards Table Mountain.

View from pavilion on top of hill on site towards Table Mountain.

View of attenuation pond on left and filtration cell on right.

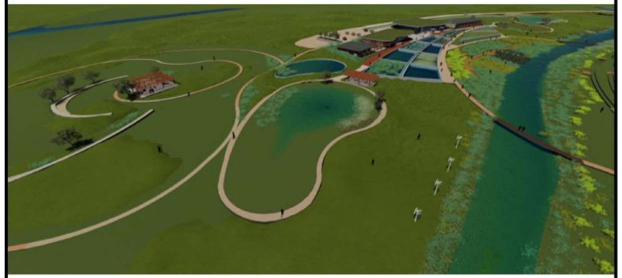


View towards Table Mountain. Note bio-filtration cells on left, wetland nursery on right.

View towards Table Mountain. Note bio-filtration cells on left, wetland nursery on right.

Courtyard between labs and offices. Water is filtered in the labs for consumption on site, and is also tested for research purposes.

View from inside the office towards bio-filtration cells and plaza.



View overlooking site. Note park on left and building infrastructure on right.

View overlooking site towards Table Mountain.

View overlooking site. Buildings on left and wetland nursery on right.

Appendix F- D2 Participant Evaluations

University of Cape Town

Information Sheet & Notice of Consent

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Criteria for Evaluation

Light grey- Did not achieve   Medium grey- Achieved   Dark grey- Excelled

Evaluation of Design

Part 1: Issues relating to water on site

Attribute Evaluated	*Explanation of attribute*	*Evaluation*
Urban water management	Are systems for dealing with water in its various forms considered in the design?	
Recreational value	Is the building a good or bad place to relax in?	
Human well-being & comfort	Is the design comfortable for people?	
Aesthetics	Is the building attractive? Would it be considered a nice space to be in?	
Natural cycles	Have these been considered in the design?	
Quality	Has the quality of water been considered in the design?	
Diversity	Is there diversity in the use and types of water used on site?	
Amenity	Is the water used productively?	
Energy & water savings	Have these been considered in the design?	
Water management in the building	Have these been considered in the design?	
Water & nutrient recycling	Have these been considered in the design?	
Fit for purpose & scale	Does the building fit its context?	

Notes:

- Water use productively: The use of the water is not fully visible e.g. is grey water used for flushing toilets? Is there water collection on the roof?
- Energy and water saving: Water saving is immediately apparent, but energy saving is not. For example, are there solar panels on the roof?

Part 2: Issues relating to design & systems

Attribute Evaluated	*Explanation of attribute*	*Evaluation*
Design	Could this be considered a successful example of a building that is sensitive to water?	
Does the building respond to the local environment?		
Is the building site specific?		
Is the infrastructure integrated into the landscape?		
Ideas drawn from multiple disciplines	Are the various initiatives around water from different academic fields considered?	
Systems	Are ecological, man-made and natural systems visible?	
Links between entities on site	Are the different ecological, man-made and natural systems considered on site?	
Ecological impact of building on site	Is accommodation made for the impacts the design may have on the natural/ecological systems on the site?	

Notes:

Part 3: Issues relating to expressive values

Attribute Evaluated	*Explanation of attribute*	*Evaluation*
Ecological values	Are there multiple ecosystem benefits to both man and nature in the design?	
Does the building recognise the intrinsic value of nature?		
Identity	Is an identity revealed through the design?	
Make visible the essence of the landscape		
Are phenomena on site linked?		
Space	Is this a good space to be in? Does it feel comfortable?	
Are the spatial properties of extension, enclosure, direction & rhythm considered?		
Is the character of the site revealed?		

Boundary	Are there multiple boundaries on site? Are there layered and porous?	
Are boundaries in the project defined? Do they have the properties of path, domain and centre?		
Dwelling	Would the building be comfortable to inhabit? Is this a nice space to be in?	
Does the building give identity?		
Is the space conducive to gathering and meeting other people?		
Can you orientate yourself in the landscape using the building?		

Notes:

- The exact identity of the building is not immediately apparent. Maybe an explanation of the character that is sought to be achieved will help to answer whether or not it has been achieved.

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Criteria for Evaluation

Light grey- Did not achieve Medium grey- Achieved Dark grey- Excelled

Evaluation of Design

Part 1: Issues relating to water on site

Attribute Evaluated	*Explanation of attribute*	*Evaluation*
Urban water management	Are systems for dealing with water in its various forms considered in the design?	
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Energy & water savings	Have these been considered in the design?	
Water management in the building	Have these been considered in the design?	
Water & nutrient recycling	Have these been considered in the design?	
Fit for purpose & scale	Does the building fit its context?	

Notes:

Part 2: Issues relating to design & systems

Attribute Evaluated	*Explanation of attribute*	*Evaluation*
Design	Could this be considered a successful example of a building that is sensitive to water?	
Does the building respond to the local environment?		
Is the building site specific?		
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Ideas drawn from multiple disciplines	Are the various initiatives around water from different academic fields considered?	
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Ecological impact of building on site	Is accommodation made for the impacts the design may have on the natural/ecological systems on the site?	

Notes:

Part 3: Issues relating to expressive values

Attribute Evaluated	*Explanation of attribute*	*Evaluation*
Ecological values	Are there multiple ecosystem benefits to both man and nature in the design?	
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Are boundaries in the project defined? Do they have the properties of path, domain and centre?		
Dwelling	Would the building be comfortable to inhabit? Is this a nice space to be in?	
Does the building give identity?		
Is the space conducive to gathering and meeting other people?		
Can you orientate yourself in the landscape using the building?		

Notes:

University of Cape Town

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Criteria for Evaluation

Light grey- Did not achieve   Medium grey- Achieved   Dark grey- Excelled

Evaluation of Design

Part 1: Issues relating to water on site

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Urban water management	Are systems for dealing with water in its various forms considered in the design?	
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Energy & water savings	Have these been considered in the design?	
Water management in the building	Have these been considered in the design?	
Water & nutrient recycling	Have these been considered in the design?	
Fit for purpose & scale	Does the building fit its context?	

Notes: Not possible to assess the design of the building due to insufficient design information (no layout or internal views.)

Part 2: Issues relating to design & systems

Attribute Evaluated	*Explanation of attribute*	*Evaluation*
Design	Could this be considered a successful example of a building that is sensitive to water?	
Does the building respond to the local environment?		
Is the building site specific?		
Is the infrastructure integrated into the landscape?		
Ideas drawn from multiple disciplines	Are the various initiatives around water from different academic fields considered?	
Systems	Are ecological, man-made and natural systems visible?	
Links between entities on site	Are the different ecological, man-made and natural systems considered on site?	
Ecological impact of building on site	Is accommodation made for the impacts the design may have on the natural/ecological systems on the site?	

Notes: Mountain?

Part 3: Issues relating to expressive values

Attribute Evaluated	*Explanation of attribute*	*Evaluation*
Ecological values	Are there multiple ecosystem benefits to both man and nature in the design?	
Does the building recognise the intrinsic value of nature?		
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Boundary	Are there multiple boundaries on site? Are there layered and porous?	
Are boundaries in the project defined? Do they have the properties of path, domain and centre?		
Dwelling	Would the building be comfortable to inhabit? Is this a nice space to be in?	
Does the building give identity?		
Is the space conducive to gathering and meeting other people?		
Can you orientate yourself in the landscape using the building?		

Notes: The building could not be assessed due to insufficient design information.

University of Cape Town

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Criteria for Evaluation

Light grey- Did not achieve   Medium grey- Achieved   Dark grey- Excelled

Evaluation of Design

Part 1: Issues relating to water on site

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Diversity	Is there diversity in the use and types of water used on site?	
Amenity	Is the water used productively?	
Energy & water savings	Have these been considered in the design?	
Water management in the building	Have these been considered in the design?	
Water & nutrient recycling	Have these been considered in the design?	
Fit for purpose & scale	Does the building fit its context?	

Notes: Building needs to be put into context. More explanation required for water on site.

Part 2: Issues relating to design & systems

Attribute Evaluated	*Explanation of attribute*	*Evaluation*
Design	Could this be considered a successful example of a building that is sensitive to water?	
Does the building respond to the local environment?		
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Notes: Maybe more explanation required – everything looks thought out but not enough info to judge on.

Part 3: Issues relating to expressive values

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Are boundaries in the project defined? Do they have the properties of path, domain and centre?		
Dwelling	Would the building be comfortable to inhabit? Is this a nice space to be in?	
Does the building give identity?		
Is the space conducive to gathering and meeting other people?		
Can you orientate yourself in the landscape using the building?		

Notes: Put in context for orientation.

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Water management in the building	Have these been considered in the design?	
Water & nutrient recycling	Have these been considered in the design?	
Fit for purpose & scale	Does the building fit its context?	

Notes: Put in context- where is the mountain? Show more of the water systems- look like they are hidden in the building.

Part 2: Issues relating to design & systems

Attribute Evaluated	*Explanation of attribute*	*Evaluation*
Design	Could this be considered a successful example of a building that is sensitive to water?	
Does the building respond to the local environment?		
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Ideas drawn from multiple disciplines	Are the various initiatives around water from different academic fields considered?	
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Notes:

Part 3: Issues relating to expressive values

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Are boundaries in the project defined? Do they have the properties of path, domain and centre?		
Dwelling	Would the building be comfortable to inhabit? Is this a nice space to be in?	
Does the building give identity?		
Is the space conducive to gathering and meeting other people?		
Can you orientate yourself in the landscape using the building?		

Notes:

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Criteria for Evaluation

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Water management in the building	Have these been considered in the design?	
Water & nutrient recycling	Have these been considered in the design?	
Fit for purpose & scale	Does the building fit its context?	

Notes:

- Show how water is used productively

- Enhance ecological systems on site- show birds etc. Show how the site was meant to be used with markets and people properly.

Part 2: Issues relating to design & systems

Attribute Evaluated	*Explanation of attribute*	*Evaluation*
Design	Could this be considered a successful example of a building that is sensitive to water?	
Does the building respond to the local environment?		
Is the building site specific?		
Is the infrastructure integrated into the landscape?		
Ideas drawn from multiple disciplines	Are the various initiatives around water from different academic fields considered?	
Systems	Are ecological, man-made and natural systems visible?	
Links between entities on site	Are the different ecological, man-made and natural systems considered on site?	
Ecological impact of building on site	Is accommodation made for the impacts the design may have on the natural/ecological systems on the site?	

Notes: Show systems inside the buildings. How does sanitation work?

Part 3: Issues relating to expressive values

Attribute Evaluated	*Explanation of attribute*	*Evaluation*
Ecological values	Are there multiple ecosystem benefits to both man and nature in the design?	
Does the building recognise the intrinsic value of nature?		
Identity	Is an identity revealed through the design?	
Make visible the essence of the landscape		
Are phenomena on site linked?		
Space	Is this a good space to be in? Does it feel comfortable?	
Are the spatial properties of extension, enclosure, direction & rhythm considered?		
Is the character of the site revealed?		
Boundary	Are there multiple boundaries on site? Are there layered and porous?	
Are boundaries in the project defined? Do they have the properties of path, domain and centre?		
Dwelling	Would the building be comfortable to inhabit? Is this a nice space to be in?	
Does the building give identity?		
Is the space conducive to gathering and meeting other people?		
Can you orientate yourself in the landscape using the building?		

Notes:

- Show landscape properly.

Appendix G- D3 Process

D3's process work predominantly occurred through testing ideas in the 3D model in order to visualise the implication of each design move. The quick sketches below explore specific aspects of the design, which were then tested and modelled in 3D.

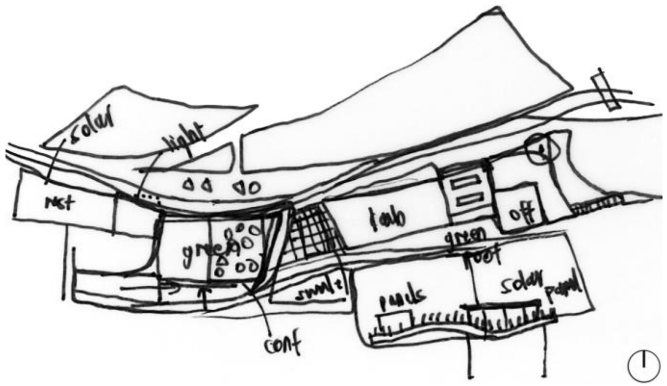


Figure 110: Rough sketch exploring placement of programme. Movement is focused upon in this sketch and is used to define different spaces.

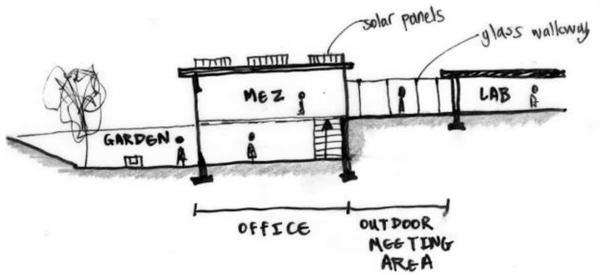


Figure 111: A quick sketch to understand the implications of a sunken garden adjacent to the laboratory office. A glass walkway and semi-covered courtyard is introduced to create ambivalent indoor-outdoor spaces.

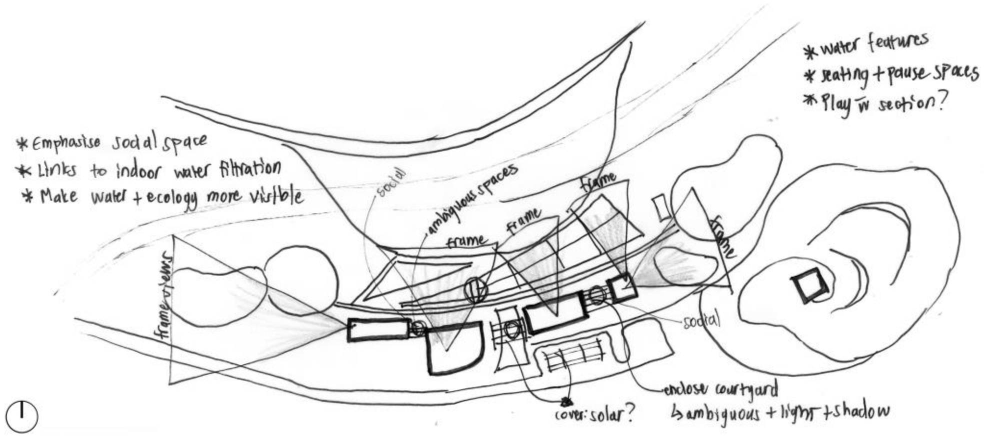


Figure 112: Rough sketch reconnecting the design to the concept diagram. Water features, seating spaces and social areas need to be emphasised. Links to indoor water filtration processes are required. Water and ecosystems must be made more visible in the design.

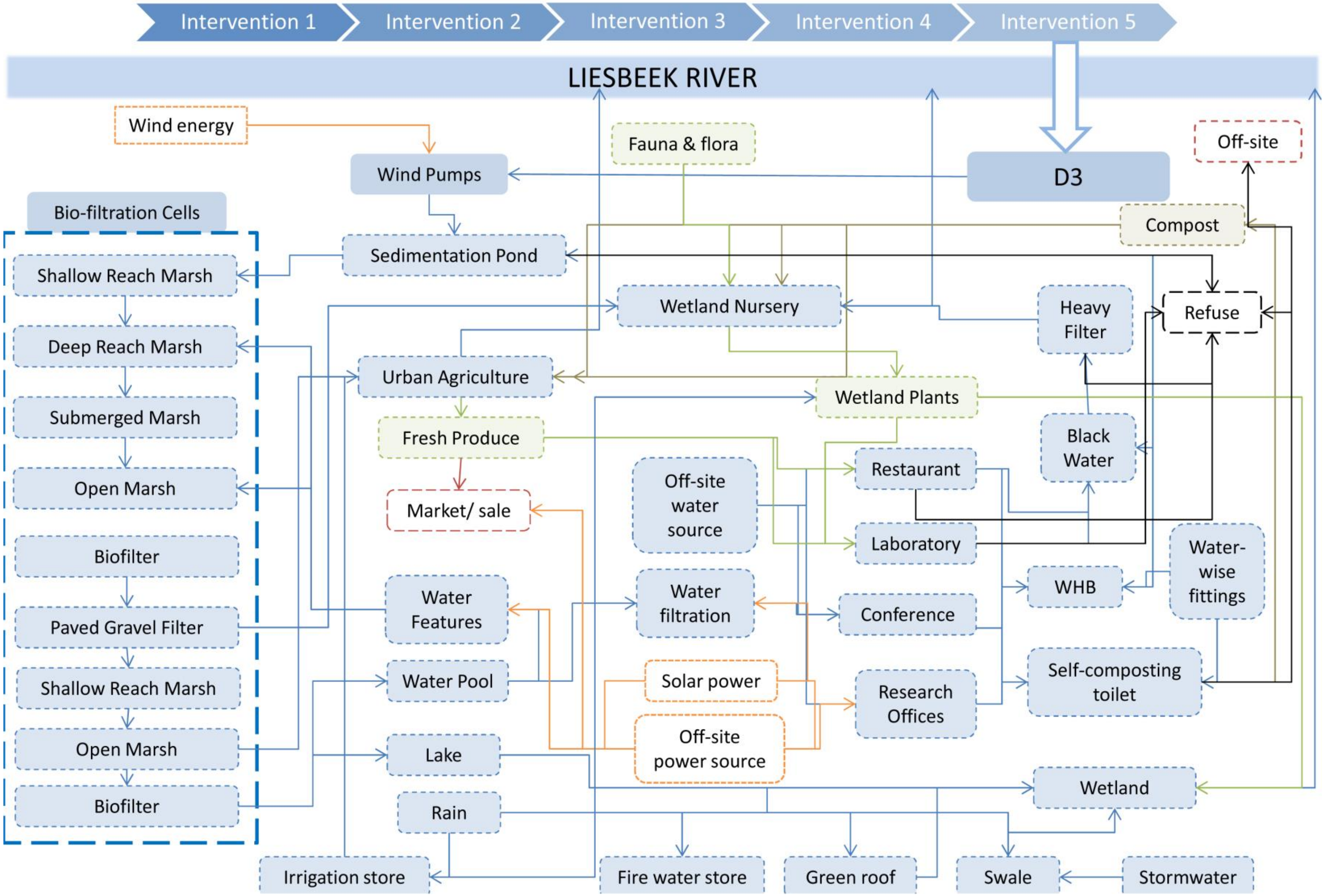


Figure 113: The flow of elements in D3. In this diagram, the flow of energy, water, services, plants and refuse is shown (Author, 2016).

Appendix H- D3 Product

Design ideas drawn from the participant evaluation of D2, as well as the author's reflection upon the design produced resulted in a new iteration, D3.

In this iteration, a greater emphasis is given to integrating water elements in the architecture. Place-making becomes a focus point in an effort to create indoor-outdoor places of gathering. The images below form a journey through the site of intervention, and were shown to specialist to evaluate the success of D3.

Entrance to campus. Note swale for treatment of stormwater from non-porous paved areas. The heavy built form channels visitors into plaza.

Entrance plaza with view towards parking area, covered by solar panel pergola.

View of plaza. Note rainwater tanks and water features. Plaza can be used for markets and outdoor community events.

View from plaza to laboratory building. Note the framed filtration tanks and water fountain.

View from plaza towards conference centre.

View of conference centre on left and filtration cells on right.

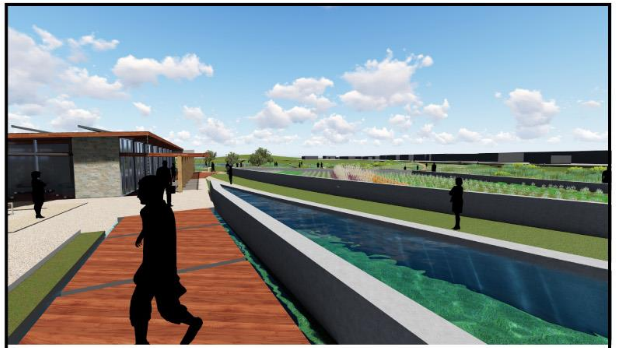
Inside of conference centre. Note views across filtration cells.

View of conference centre on left, courtyard and restaurant on right.

Courtyard with water feature to create indoor-outdoor ambivalent spaces.

Courtyard on left, restaurant on right.

View towards restaurant and Table Mountain.



View towards restaurant and Table Mountain, with filtration and agriculture cells.

View out towards courtyard from restaurant lounge.

View of outdoor seating of restaurant, looking towards Table Mountain. Note solar panel pergola.

Framing views towards playground and Table Mountain at the restaurant.

Interior of restaurant.

Interior of restaurant. Note framed view of Table Mountain.

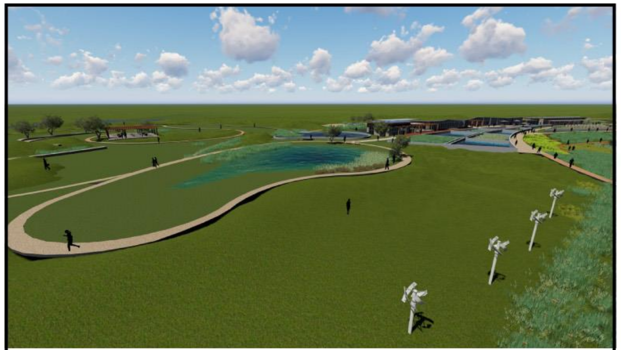
View of buildings and agriculture cell, with restaurant on right.

Overview of campus with wetland nursery in centre.

View of buildings from across the river.

Platforms and walkways in wetland nursery, with buildings in background.

View towards filtration cells, with agricultural cell in foreground.

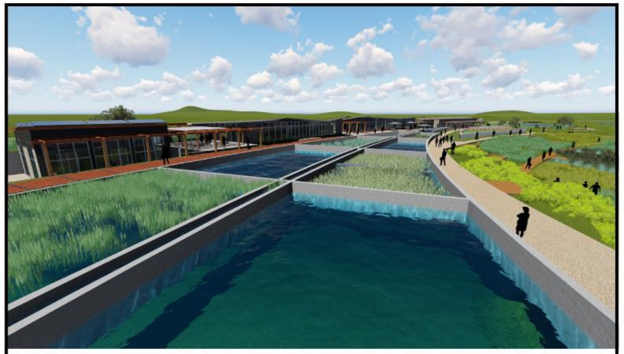


View over sedimentation pond, with windmills in foreground.

Views from pavilion.

View towards sedimentation pond and recreational park.

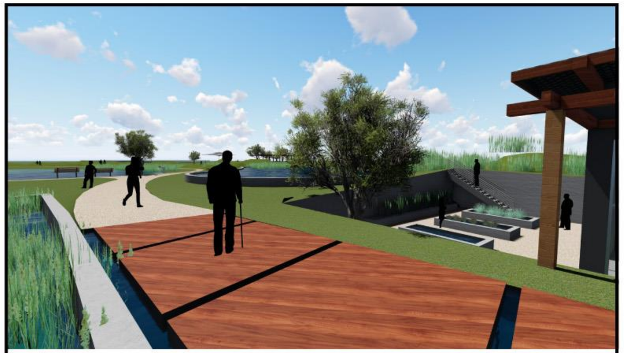
View over filtration cells towards buildings.



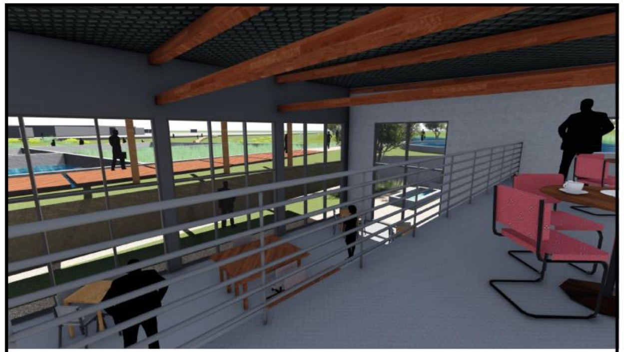
View over filtration cells.

View over filtration cells and wetland nursery towards Table Mountain.

View of laboratory offices.



View of sunken garden adjacent to laboratory offices.



Interior of laboratory offices, with views out towards filtration cells.

View from glazed walkway through courtyard, with laboratory office on right. Note indoor-outdoor ambivalent spaces.

Laboratory courtyard, which may be used for outdoor meetings or resting.

View of glazed walkway linking laboratory offices on either side of courtyard.

Interior of laboratory office adjacent to courtyard.

Interior of laboratory with views over filtration cells.

Appendix I- D3 Author's Analysis

D3 Evaluation - Author

Criteria for evaluation: Light grey- did not achieve Medium grey- achieved Dark grey- Excelled

Design imperative	Evaluation comments	Evaluation
Cultural services: Aesthetics, sense of place, spiritual value, cultural landscapes, educational, spiritual, recreational		
Ensure building is aesthetically pleasing through design.	Achieved. Detail refinement required: roof edges heavy, pergola components bulky. Hard edges of pathways don't show soft landscaping correctly. Softer, ambivalent edges.	
Consider architectural elements of point, line, plane, form, massing, hierarchy, ordering systems, geometry, rhythm, thresholds, and ergonomics.	Achieved.	
Frame views across scales to other natural & design elements.	Achieved, but needs refinement.	
Engage with spiritual history of site through architecture and construction materials.	This aspect was not focused upon in this design.	
Create identity using gathering/symbolism/visualisation.	Gathering spaces more defined. More emphasis on ecological systems? Site context missing.	
Make building comfortable for people.	Achieved. Resting and recreation facilitated.	
The building and the water in it must engage with the 5 senses to give a sense of identity.	Achieved, needs refinement.	
Create paths which orientate towards river/mountain/design elements by using nodes/paths/districts.	Achieved.	
Use enclosure & extension (centre & rhythm), light & shadow to define space.	Consider rhythm in tectonics.	
Use construction materials, detailing and making to give the building identity.	Building could make better use of these principles. Building makes use of recycled materials – needs to be shown.	
Define and make boundaries porous at different scales: create ambivalent indoor-outdoor spaces using light & shadow, enclosure & extension.	Partially achieved. Indoor/outdoor courtyard/meeting spaces created. Buildings and production cells still defined.	
Activate building as part of CTSDF, TRUP and MOSS.	Achieved. Plant incubator for MOSS and therefore benefits CTSDF. Value added increases natural & cultural value of TRUP.	
Create spaces for gathering and quiet reflection.	Achieved.	
Provide spaces for resting, sports, and social.	Achieved.	
Link recreational focus areas on site using paths.	Achieved.	
Make visible building and recycling systems.	Partially achieved. Ablution systems not visible.	

Comments: Ecological layer missing in site processes. Building more people-orientated & accessible than in D1.

Design imperative	Evaluation comments	Evaluation
Regulatory services: Disease, climate, water, water, pollination		
Create habitats for flora.	Achieved.	
Aerate water through vertical movement.	Achieved with small vertical movement. Subjective design not to use large fountains or waterfalls.	
Use constructed wetland principles for passive water filtration on site.	Achieved.	
Use WSUD's and SuDS elements for localised flood control.	Achieved.	
Link design to larger MOSS & CTSDF for flood control	Achieved.	
Create habitats for fauna: can pollinate plants.	Achieved.	

Comments: Minimised vertical movement of water a design choice.

Design imperative	Evaluation comments	Evaluation
Supporting services: Primary production, soil formation, nutrient recycling		
Introduce agricultural production.	Achieved.	
Restore flora on site to assist with binding of soils.	Achieved.	
Repair site to restore existing soil and earth conditions.	Achieved.	
Use soft landscaping and outdoor trafficable surfaces	Achieved.	
Sort ablution effluent into solids and liquids for nutrient recycling.	Self-composting toilets used. Needs to be discussed with specialist.	
Ensure nutrients are balanced across site systems.	Partially achieved. Needs to be discussed with specialist.	

Comments: Nutrients in system to be discussed with specialist.

Design imperative	Evaluation comments	Evaluation
Provisioning services: Food, water, energy, raw materials, bio-chemicals, genetic resources		

Introduce agricultural production if possible.	Achieved.	
Diversify water sources on site.	Achieved. Rainwater collected for irrigation & filtration for potable water.	
Don't use potable water for non-potable uses.	Achieved.	
Building to form part of larger blue-green network of city.	Achieved.	
Use WSUD's and SuDS elements for drainage of water on site.	Achieved.	
Recycle and filter water on site for reuse.	Achieved.	
Strategy required for alternative sanitation systems.	Achieved.	
Consider recycled building materials.	Achieved.	
Use water & energy efficiently in building: water-wise fittings, low energy fittings, passive ventilation, and alternative sources.	Achieved. Solar energy added.	
Restore flora on site to assist with habitat creation, flood controls, binding of soils.	Achieved.	

Comments: Indoor water systems more visible?

Design imperative	**Evaluation comments**	**Evaluation**
Design values (from D1)		
Understand and incorporate the local context of the site by exploring the boundaries of historical, cultural, architectural, natural…	Partially achieved, but must be shown in design. Historical aspects of site not focused on in this design.	
Facilitate site repair.	Achieved.	
Consider ecological infrastructure: integrating infrastructure as landscape, link multiple elements and systems across the site.	Partially achieved. More emphasis on ecological aspects.	

Comments: Greater emphasis on ecology and people required.

Participant Evaluation: Environmental Perspective

Evaluation of Design

Part 1: Issues relating to water on site

Attribute Evaluated	*Explanation of attribute*	*Evaluation level assigned*
Urban water management	Are systems for dealing with water in its various forms considered in the design?	2
Recreational value	Is the building a good or bad place to relax in?	2
Human well-being & comfort	Is the design comfortable for people?	2
Aesthetics	Is the building attractive? Would it be considered a nice space to be in?	2
Natural cycles	Have these been considered in the design?	2
Quality	Has the quality of water been considered in the design?	2
Diversity	Is there diversity in the use and types of water used on site?	2
Amenity	Is the water used productively?	2
Energy & water savings	Have these been considered in the design?	2
Water management in the building	Have these been considered in the design?	2
Water & nutrient recycling	Have these been considered in the design?	2 / 1 nutrient
Fit for purpose & scale	Does the building fits its context?	2

Notes:

Nutrient recycling
Building is unobtrusive in environment and therefore acceptable to community

Part 2: Issues relating to design & systems

Attribute Evaluated	*Explanation of attribute*	*Evaluation level assigned*
Design	Could this be considered a successful example of a building that is sensitive to water?	2
Does the building respond to the local environment?		2
Is the building site specific?		2
Is the infrastructure integrated into the landscape?		2
Ideas drawn from multiple disciplines	Are the various initiatives around water from different academic fields considered?	2
Systems	Are ecological, man-made and natural systems visible?	2
Links between entities on site	Are the different ecological, man-made and natural systems considered on site?	2
Ecological impact of building on site	Is accommodation made for the impacts the design may have on the natural/ecological systems on the site?	2

In this evaluation, the participant rated the design with 0-did not achieve, 1-achieved and 2- excelled.

Notes:

Part 3: Issues relating to Phenomenology & Deep Ecology

Attribute Evaluated	*Explanation of attribute*	*Evaluation level assigned*
Ecological values	Are there multiple ecosystem benefits to both man and nature in the design?	2
Does the building recognise the intrinsic value of nature?		2
Identity	Is an identity revealed through the design?	2
Make visible the essence of the landscape		2
Are phenomena on site linked?		2
Space	Is this a good space to be in? Does it feel comfortable?	2
Are the spatial properties of extension, enclosure, direction & rhythm considered?		2
Is the character of the site revealed?		2
Boundary	Are there multiple boundaries on site? Are there layered and porous?	2
Are boundaries in the project defined? Do they have the properties of path, domain and centre?		2
Dwelling	Would the building be comfortable to inhabit? Is this a nice space to be in?	2
Does the building give identity?		2
Is the space conducive to gathering and meeting other people?		2
Can you orientate yourself in the landscape using the building?		2

Notes:

Participant Evaluation: Water Engineering Perspective

Evaluation of Design

Part 1: Issues relating to water on site

Attribute Evaluated	*Explanation of attribute*	*Evaluation level assigned*
Urban water management	Are systems for dealing with water in its various forms considered in the design?	1
Recreational value	Is the building a good or bad place to relax in?	2
Human well-being & comfort	Is the design comfortable for people?	
Aesthetics	Is the building attractive? Would it be considered a nice space to be in?	2
Natural cycles	Have these been considered in the design?	1
Quality	Has the quality of water been considered in the design?	1
Diversity	Is there diversity in the use and types of water used on site?	1
Amenity	Is the water used productively?	1
Energy & water savings	Have these been considered in the design?	1
Water management in the building	Have these been considered in the design?	1
Water & nutrient recycling	Have these been considered in the design?	1
Fit for purpose & scale	Does the building fit its context?	2

Notes:

Part 2: Issues relating to design & systems

Attribute Evaluated	*Explanation of attribute*	*Evaluation level assigned*
Design	Could this be considered a successful example of a building that is sensitive to water?	2
Does the building respond to the local environment?		1
Is the building site specific?		1
Is the infrastructure integrated into the landscape?		1
Ideas drawn from multiple disciplines	Are the various initiatives around water from different academic fields considered?	2
Systems	Are ecological, man-made and natural systems visible?	2
Links between entities on site	Are the different ecological, man-made and natural systems considered on site?	2
Ecological impact of building on site	Is accommodation made for the impacts the design may have on the natural/ecological systems on the site?	1

In this evaluation, the participant rated the design with 0-did not achieve, 1-achieved and 2- excelled.

Notes:

Part 3: Issues relating to Phenomenology & Deep Ecology

Attribute Evaluated	*Explanation of attribute*	*Evaluation level assigned*
Ecological values	Are there multiple ecosystem benefits to both man and nature in the design?	1
Does the building recognise the intrinsic value of nature?		1
Identity	Is an identity revealed through the design?	2
Make visible the essence of the landscape		2
Are phenomena on site linked?		1
Space	Is this a good space to be in? Does it feel comfortable?	2
Are the spatial properties of extension, enclosure, direction & rhythm considered?		1
Is the character of the site revealed?		1
Boundary	Are there multiple boundaries on site? Are there layered and porous?	2
Are boundaries in the project defined? Do they have the properties of path, domain and centre?		2
Dwelling	Would the building be comfortable to inhabit? Is this a nice space to be in?	1
Does the building give identity?		2
Is the space conducive to gathering and meeting other people?		2
Can you orientate yourself in the landscape using the building?		1

Notes:

- Vertical elements missing

Appendix J- D4 Product

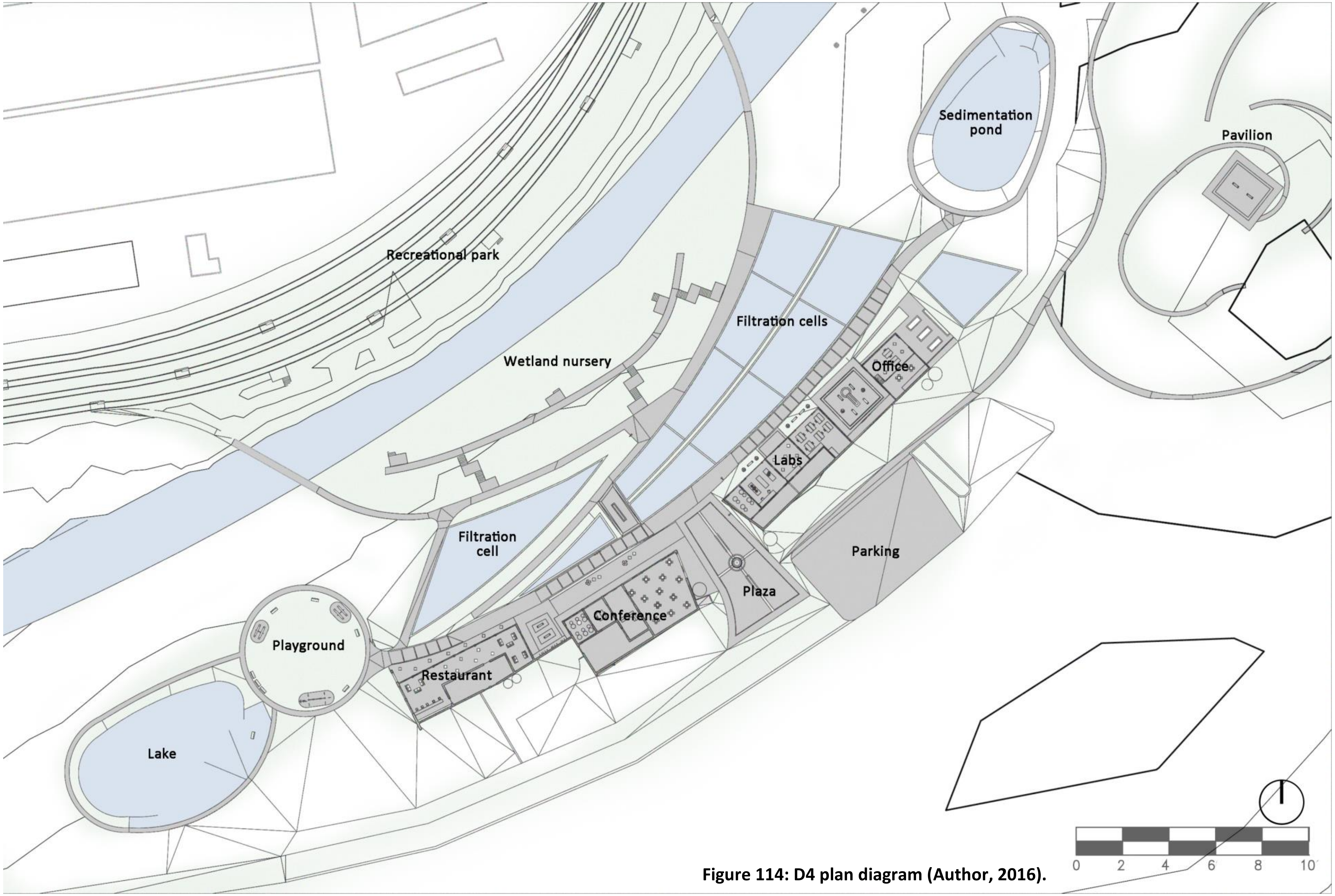


Figure 114: D4 plan diagram (Author, 2016).

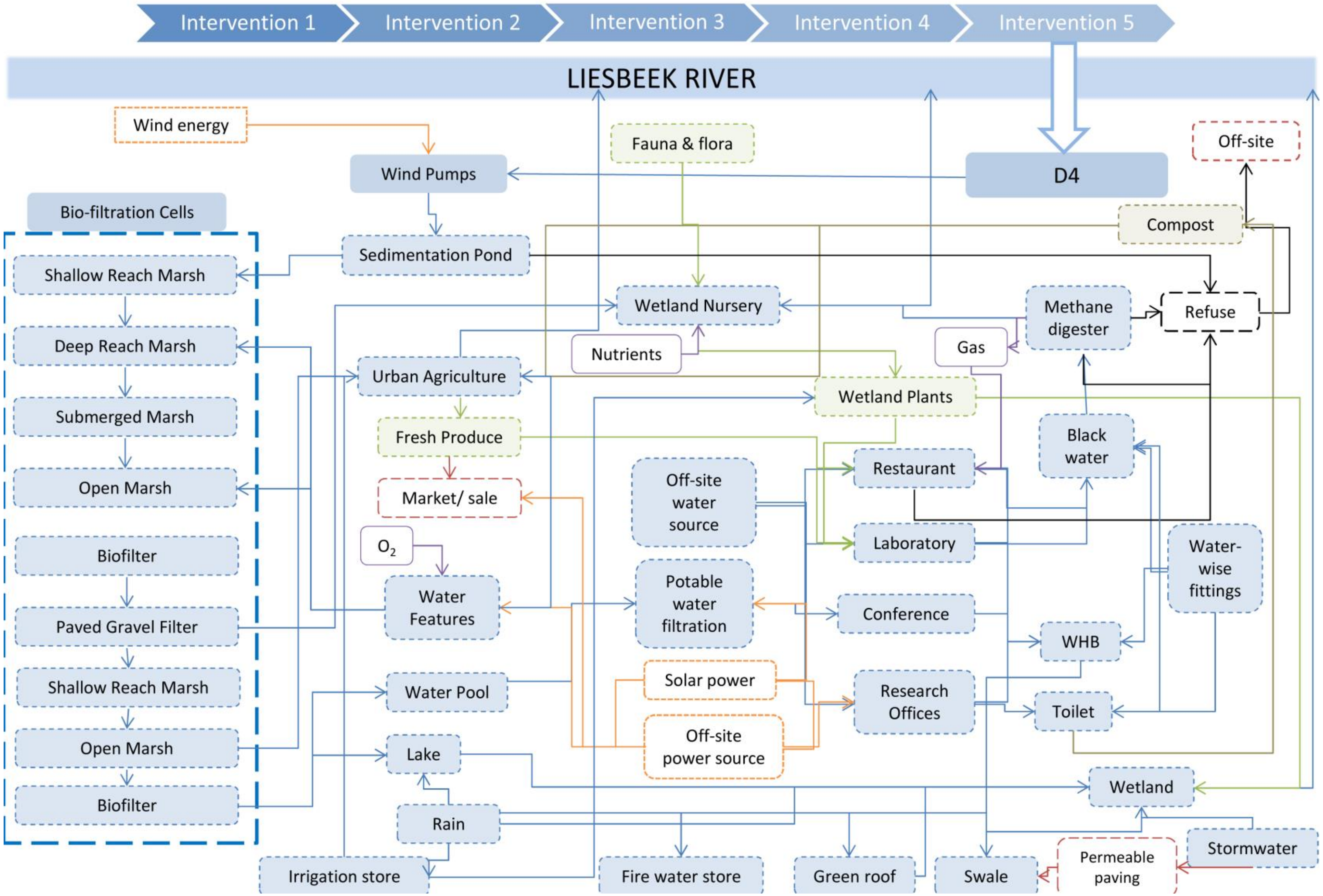


Figure 115: The flow of elements in D4 at the micro-scale. The energy, water, gas, services, plants and refuse flows are shown (Author, 2016).

D4 developed from the various participant analyses, design ideas and the author's reflection on the design of D3. In this design, views are framed and negative spaces are defined using movement routes. A system of columns is introduced to create rhythm in the architecture, as per the phenomenological principles.

The edges of architectural elements are softened visually using vegetation and materials. A greater emphasis is placed upon the integration of water across the design. As before, these images show a visitor's journey through the site of intervention and were used to evaluate the success of D4.

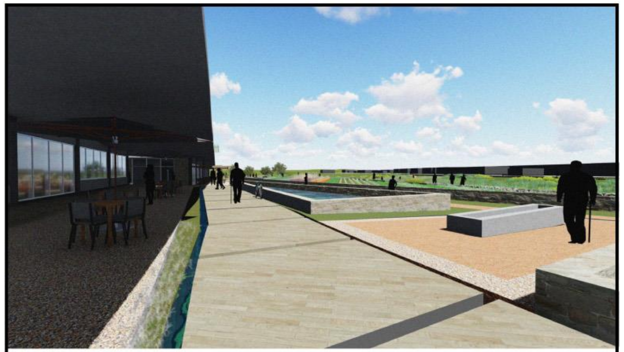
Entrance to campus. Note swale for treatment of stormwater from non-porous paved areas. The heavy built form channels visitors into plaza.

Entrance plaza with view towards parking area, covered by solar panel pergola.

View of plaza. Note rainwater tanks and water features. Plaza can be used for markets and outdoor community events.

View from plaza to laboratory building. Note the framed filtration tanks and water fountain.

View from plaza towards conference centre.



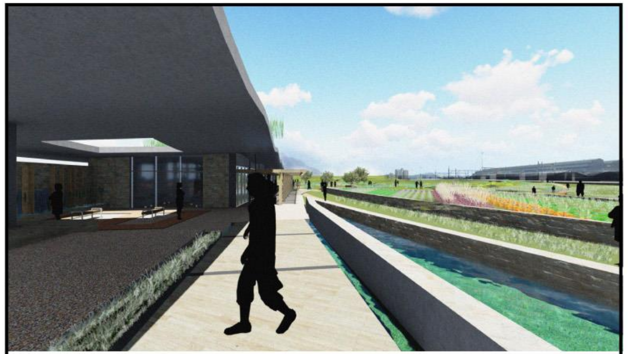
View of conference centre on left and filtration cells on right.

Inside of conference centre. Note views across filtration cells.

View of conference centre on left, courtyard and restaurant on right.

View towards restaurant from courtyard.

View towards restaurant.



View towards restaurant and Table Mountain, with filtration and agriculture cells.

View out towards courtyard from restaurant lounge.

View of outdoor seating of restaurant, looking towards Table Mountain. Note solar panel pergola.

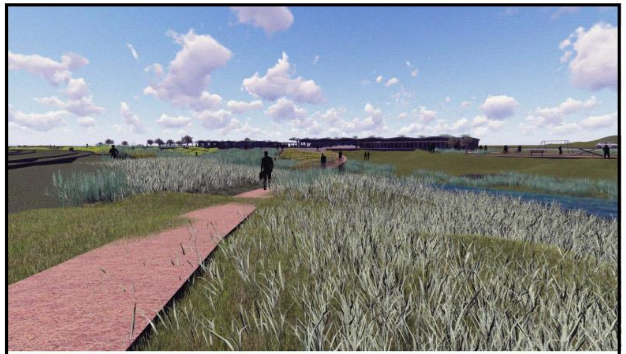
Framing views towards playground and Table Mountain at the restaurant.

Interior of restaurant.

Interior of restaurant. Note framed view of Table Mountain.

View of buildings and agriculture cell, with restaurant on right.

Overview of campus with wetland nursery in centre.



View of buildings from across the river.

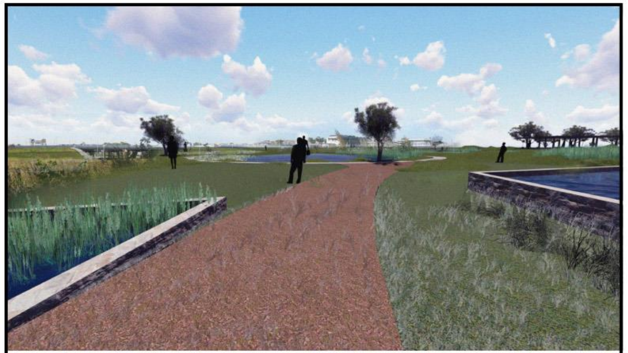
View of buildings towards Table Mountain from bridge.

Platforms and walkways in wetland nursery, with buildings in background.

View towards filtration cells, with agricultural cell in foreground.

View over sedimentation pond, with windmills in foreground.

Views from pavilion with creepers on pergola.



View towards sedimentation pond and recreational park.

View over filtration cells towards buildings.

View over filtration cells.

View of laboratory offices.

View of sunken garden adjacent to laboratory offices.

Interior of laboratory offices, with views out towards filtration cells.
Note layering of thresholds.

View from glazed walkway through courtyard, with laboratory office on right. Note indoor-outdoor ambivalent spaces.

Laboratory courtyard, which may be used for outdoor meetings or resting.

View of glazed walkway linking laboratory offices on either side of courtyard.

Interior of laboratory office adjacent to courtyard.

Interior of laboratory workroom with views over filtration cells.

Interior of laboratory with views over filtration cells. Note framed view of filtration tanks.

Appendix K- D4 Effects Analysis

Design imperative	D4 evaluation comments	D1 evaluation comments
Cultural services: Aesthetics, sense of place, spiritual value, cultural landscapes, educational, spiritual, recreational		
Ensure building is aesthetically pleasing through design.	Achieved. Detail refinement achieved: softer edges, lighter architectural elements, new roof design to accommodate massing and 'replace' land lost by building. At the meso-scale, the building blends into the landscape.	Attractive building, although more programme could be accommodated.
Consider architectural elements of point, line, plane, form, massing, hierarchy, ordering systems, geometry, rhythm, thresholds, and ergonomics.	Achieved.	Form, massing and thresholds need to be improved.
Frame views across scales to other natural & design elements.	Achieved.	Views from building to mountain not framed.
Engage with spiritual history of site through architecture and construction materials.	This aspect was not focused upon in this design.	This aspect was not focused upon in this design.
Create identity using gathering/symbolism/visualisation.	Architectural routes are gathered at nodes. Water and nature is on display throughout the building. Site processes symbolised and echo natural processes.	Design creates gathering spaces for the confluence of movement route. Symbolism and visualisation of natural environment is minimal through tectonics. Constructed wetland cells do mimic natural processes.
Make building comfortable for people.	Achieved. Recreation, education, production facilitated.	Greater emphasis on light and connection in buildings required. Buildings do take into account scale and spatial use by people.
The building and the water in it must engage with the 5 senses to give a sense of identity.	Achieved.	Design does not engage fully with touch, sound, smell or taste senses.
Create paths which orientate towards river/mountain/design elements by using nodes/paths/districts.	Achieved.	Achieved.
Use enclosure & extension (centre & rhythm), light & shadow to define space.	Rhythm introduced through grid and roof pattern. Light & shadow used for screening.	Building could make better use of these principles.
Use construction materials, detailing and making to give the building identity.	Recycled materials used.	Building could make better use of these principles. Building does make use of recycled materials.
Define and make boundaries porous at different scales: create ambivalent indoor-outdoor spaces using light & shadow, enclosure & extension.	Indoor/outdoor courtyard/meeting spaces created. Buildings and production cells defined but edges softened.	Not achieved. Hard river edge designed which does not allow for transfer of elements across boundary. Spaces are not ambiguous.
Activate building as part of CTSDF, TRUP and MOSS.	Achieved. Plant incubator for MOSS and therefore benefits CTSDF. Value added increases natural & cultural value of TRUP.	Achieved, although more explanation required across scales.
Create spaces for gathering and quiet reflection.	Achieved.	Achieved.
Provide spaces for resting, sports, and social.	Achieved.	Achieved. More programme could activate the site better by drawing the public.
Link recreational focus areas on site using paths.	Achieved.	Achieved.
Make visible building and recycling systems.	Partially achieved. Ablution systems not visible.	Not fully achieved. Indoor systems not visible.

Design imperative	D4 evaluation comments	D1 evaluation comments
Regulatory services: Disease, climate, water, water, pollination		
Create habitats for flora.	Achieved.	Achieved.
Aerate water through vertical movement.	Achieved with waterfalls and fountains throughout.	Achieved, but more emphasis need to be placed on this.
Use constructed wetland principles for passive water filtration on site.	Achieved.	Achieved.
Use WSUD's and SuDS elements for localised flood control.	Achieved.	Achieved.
Link design to larger MOSS & CTSDF for flood control	Achieved.	Achieved.
Create habitats for fauna: can pollinate plants.	Achieved.	Achieved.

Design imperative	D4 evaluation comments	D1 evaluation comments
Supporting services: Primary production, soil formation, nutrient recycling		
Introduce agricultural production.	Achieved.	Achieved.
Restore flora on site to assist with binding of soils.	Achieved.	Achieved.
Repair site to restore existing soil and earth conditions.	Achieved.	Achieved.
Use soft landscaping and outdoor trafficable surfaces	Achieved.	Achieved.
Sort ablution effluent into solids and	Achieved. Separation for methane	Self-composting toilets used, which do not sort ablution

liquids for nutrient recycling.	digester and nutrient cycling.	effluent into solids and liquids but does create compost for use.
Ensure nutrients are balanced across site systems.	Achieved. Nutrient monitoring.	Achieved, although care needs to be taken to ensure all nutrients are not removed from system as over-provision of wetland cells in design.

Design imperative	**D4 evaluation comments**	**D1 evaluation comments**
Provisioning services: Food, water, energy, raw materials, bio-chemicals, genetic resources		
Introduce agricultural production if possible.	Achieved.	Achieved.
Diversify water sources on site.	Achieved. Rainwater collection.	Rainwater needs to be used.
Don't use potable water for non-potable uses.	Achieved.	Achieved.
Building to form part of larger blue-green network of city.	Achieved.	Achieved.
Use WSUD's and SuDS elements for drainage of water on site.	Achieved.	Achieved.
Recycle and filter water for reuse.	Achieved.	Achieved.
Strategy required for alternative sanitation systems.	Achieved.	Achieved.
Consider recycled building materials.	Achieved.	Achieved.
Use water & energy efficiently in building: water-wise fittings, low energy fittings, passive ventilation, and alternative sources.	Achieved. Solar energy added.	Achieved, although this can be explored further.
Restore flora on site to assist with habitat creation, flood controls, binding of soils.	Achieved.	Achieved.

Design imperative	**D4 evaluation comments**	**D1 evaluation comments**
Design values (from D1)		
Understand and incorporate the local context of the site by exploring the boundaries	Local context understood and referenced where possible.	Achieved, although this can be explored further. Historical aspects of site not focused on.
Facilitate site repair.	Achieved.	Achieved.
Consider ecological infrastructure: integrating infrastructure as landscape, link multiple elements and systems.	Achieved.	Achieved, although this can be explored further.

Appendix L – The Design Process

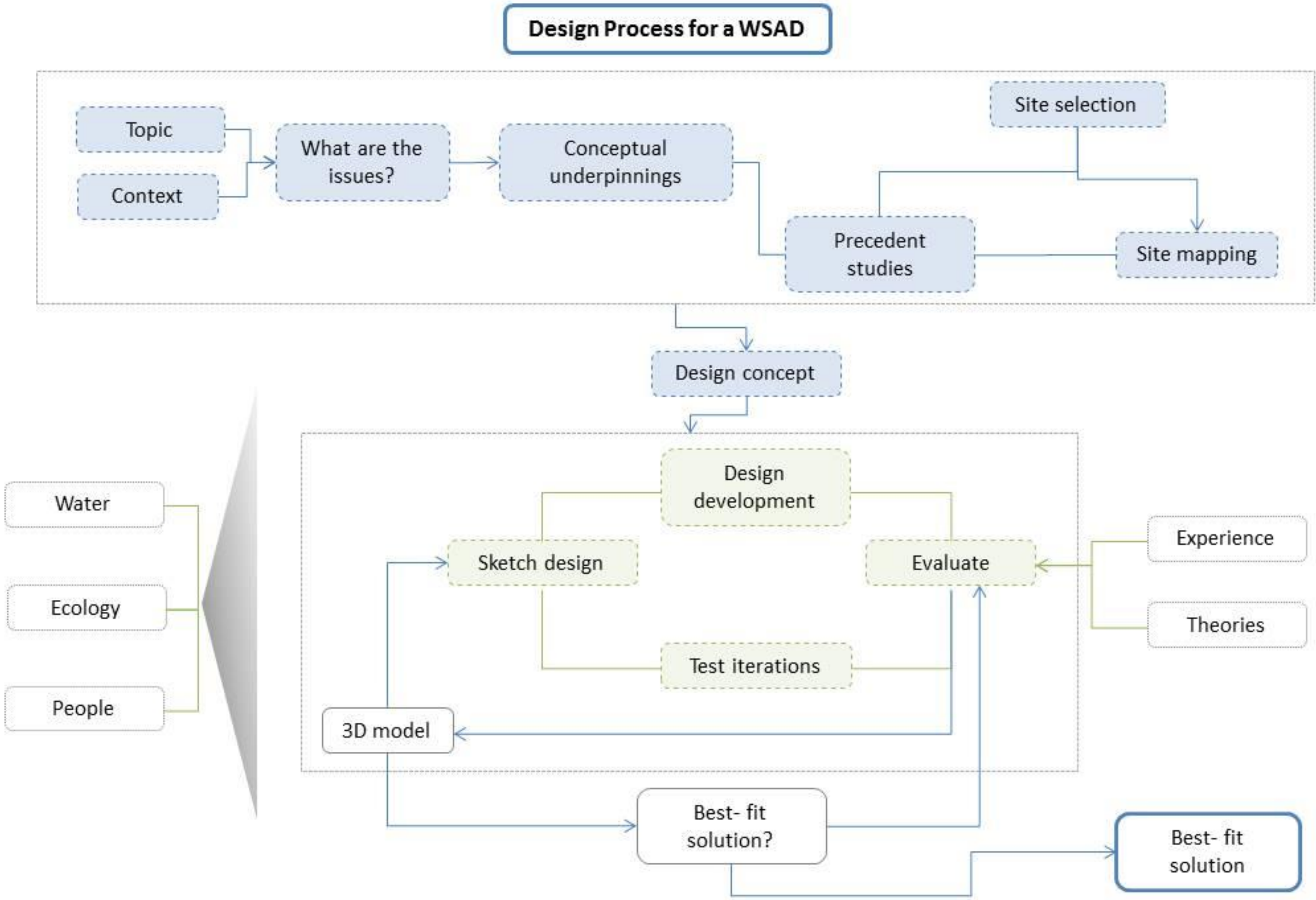


Figure 116: The design process, derived from the RBD process as followed in this study (Author, 2016).

Appendix M – Ethics

Application for Approval of Ethics in Research (EiR) Projects
Faculty of Engineering and the Built Environment, University of Cape Town

APPLICATION FORM

Please Note:
Any person planning to undertake research in the Faculty of Engineering and the Built Environment (EBE) at the University of Cape Town is required to complete this form **before** collecting or analysing data.The objective of submitting this application *prior* to embarking on research is to ensure that the highest ethical standards in research, conducted under the auspices of the EBE Faculty, are met. Please ensure that you have read, and understood the **EBE Ethics in Research Handbook** (available from the UCT EBE, Research Ethics website) prior to completing this application form: http://www.ebe.uct.ac.za/usr/ebe/research/ethics.pdf

APPLICANT'S DETAILS		
Name of principal researcher, student or external applicant		Preetya Bhikha
Department		Architecture, Planning & Geomatics
Preferred email address of applicant:		preetya.bhikha@gmail.com
If a Student	Your Degree: e.g., MSc, PhD, etc.,	Master of Philosophy
	Name of Supervisor (if supervised):	Dr Tom Sanya
If this is a research contract, indicate the source of funding/sponsorship		None
Project Title		Exploring Architectural Knowledge in Water Sensitive Design

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	Signature	Date
Principal Researcher/ Student/External applicant	Preetya Bhikha	Signed	2016-06-08

APPLICATION APPROVED BY	Full name	Signature	Date
Supervisor (where applicable)	Dr Tom Sanya	Signed	Signed
HOD (or delegated nominee) Final authority for all applicants who have answered NO to all questions in Section1; and for all Undergraduate research (Including Honours).			
Chair : Faculty EIR Committee For applicants other than undergraduate students who have answered YES to any of the above questions.	G. Sithole	Signed	17/06/2016