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River Design and Restoration in an Urban Environment

Exploitation of the Potential in Victoria (Seychelles)

Master's Thesis
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"Space is our friend in stream restoration […] but it's at a premium in urban areas"
(Landers, 2010, p. 68).

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Executive Summary

Rivers fulfill many ecological, economic and social functions that benefit humans. They range from habitat provision for aquatic life and flood protection to local recreational areas and touristic use. Over the years, many rivers have been subject to major changes as a result of human influence. As a consequence, they show major deficits, especially in urban areas. Upgrading measures are aimed to reduce these deficits to better fulfill the original tasks. This was also recognized in the Seychelles, for which reason the project "Opening up the waterways" has been included in the planning guideline Victoria Masterplan. This master's thesis is a continuation of the project. The thesis aims to identify the deficits of the current state of the rivers in Central Victoria and to derive possible ideas for improvement measures to reduce these deficits. A study area analysis of Victoria was carried out and the rivers were assessed with a river assessment tailored to Victoria. Using expert interviews and a survey, the ecological and recreational requirements for the rivers were determined. Possible improvement measures were discussed with local decision makers in a workshop.

Six rivers flow through Central Victoria: English River, Rivière Moussa, Rivière Maintry, Rivière St. Louis, La Poudrière River and Rivière Trois Frères. The land reclamations carried out in Victoria in recent years led to the artificial extension of natural rivers in the shape of straightened channels to prevent flood risk. The detailed river assessment has shown that particularly in the area of reclaimed land, the rivers are far from their natural state. In their present state, they are more similar to sewers than to natural rivers. Especially a large amount of waste and pollution in the rivers pose an existing problem. Furthermore, a considerable number of river bed and bank base constructions, the channeled form without water level width variability, the absence of a riparian area and the large number of pipes in the river bed are deficits. The lack of shade is not only an unwanted condition for pedestrians, but also undesirable from an ecological point of view. From a sociocultural point of view, rivers exhibit many of the well-known deficits of urban rivers such as lack of accessibility and approachability, little nature experience, little recovery value and poor identification with the river. Further aggravating conditions are caused by sea-level rise and population growth. The latter exacerbates the already existing availability of space. However, the rivers in Victoria lie in strategically favorable locations for improvement measures and these are conceivable even in the face of the prevailing shortage of space.

The ideas for improvement measures consist of general and specific suggestions. The general suggestions should be considered as a prerequisite for specific suggestions. General suggestions include, for instance, law enforcement, detailed and proactive planning, a greater exchange between the institutions involved, water quality improvement and relocation of utility pipes. The concrete suggestions were classified into seven categories: Education, nature experience, sports activities, cafés and restaurants, relax, socialize and walking promenade. The bordering of a greenfield along the river as well as a café and restaurant promenade are regarded as very popular conditions for the future. Large-scale improvement measures are possible in today's undeveloped areas, such as green spaces or areas, which are about to be rebuilt.

Especially the area along Freedom Square, Peace Park and Paradise Des Enfants has great potential. The river with the probably most potential for upgrading is the Rivière St. Louis. From an ecological point of view, its length is particularly important as a connection between land and water. Its location next to an existing green space on a long stretch is also suitable for upgrading measures from a social point of view. Ultimately, these proposals serve the Seychelles Planning Authority as a basis for developing and implementing specific measures.

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I would like to thank all the people and institutions who supported me during the last 6 months. It would not have been possible to write this master's thesis without them.

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Acronyms

CAMS	Climate Adaption and Management Section
GIS	Geographic Information System
GOS	Government of Seychelles
LWMA	Landscape and Waste Management Agency
MEEC	Ministry of Environment, Energy and Climate Change
MHILT	Ministry of Habitat, Infrastructure and Land Transport
NBS	National Bureau of Statistics
PPID	Project Planning and Implementation Department
PUC	Public Utilities Corporation
SD	Standard Deviation
SPA	Seychelles Planning Authority
SSLUDP	Seychelles Strategic Land Use and Development Plan
TdLab	Transdisciplinarity Lab

Table of contents

List of figures

List of tables

1 Introduction

1.1 Background and initial situation

The master's thesis originated within the framework of the Transdisciplinarity Lab (TdLab), which began working with Seychelles in 2015. It is located at the Department of Environmental Systems Science at ETH Zürich and has expanded its cooperation with various stakeholders in Seychelles in recent years (Krütli et al., 2018). The development of this master's thesis represents the first cooperation with the Seychelles Planning Authority (SPA).

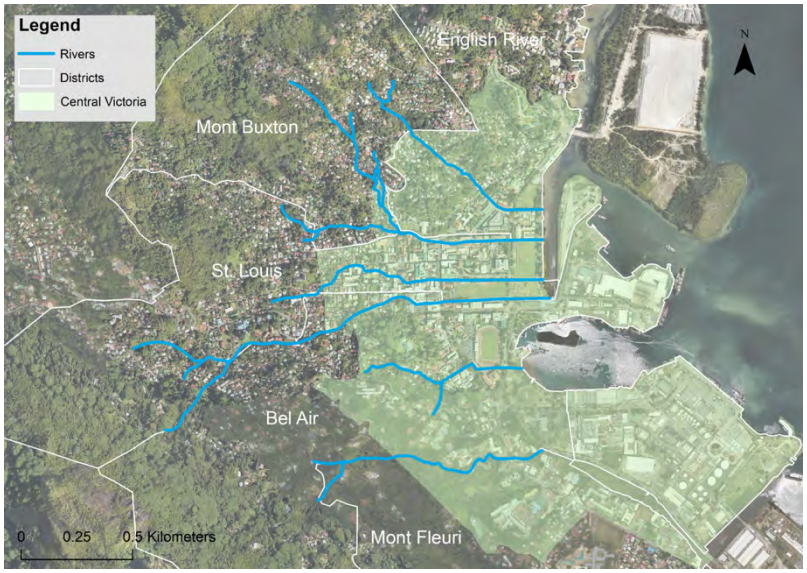


Figure 1: Study area overview (data provided by Seychelles Planning Authority, 2019[1]).

The master's thesis covers the topic of improving the rivers of Central Victoria. This is a sub-topic of the long-term guiding documents of SPA until 2040, consisting of the Seychelles Strategic Land Use and Development Plan (SSLUDP), the Framework plan for Mahé and the Victoria Masterplan. The main aim of the Victoria Masterplan is to exploit the maximum potential of Victoria's assets of the waterfront, port, natural environment or the culture towards an attractive and vibrant Creole town where people can visit, socialize, work, live and invest. More specifically, the topic is based on project 12 "Opening up the waterways" which is one of the 15 future key projects of the Victoria Masterplan. The area of Central Victoria ranges from Ile du Port in the north to the Commercial Port in the south, including the Botanical Gardens and the city center in the west. The districts included are English River, Bel Air, St. Louis, Mont Buxton and Mont Fleuri (see Figure 1) (Arup, 2014, 2015a).

The history of Victoria is strongly based on the relationship between the historic center of Victoria with the sea and the establishment of the central market at the waterfront. Due to extensive land reclamation in the past (see chapter 2.1.3), a disconnection between the historic city center of Victoria and the coast emerged resulting in a loss of Victoria's traditional character.

[1] Data collected from Belle, B. and Low, J. in March 2019, further explanation Appendix A

Outside of business hours, Central Victoria is unattractive due to the lack of residential areas, hotels and limited leisure, beverage and food offer. The aim is to reconnect the sea again with the historic part of the city by increasing the attractiveness of the waterfront and enhancing existing linkages. The location and connecting function of the rivers in town are suitable possibilities to improve these linkages across the city. Regrettably, many river sections are enclosed, canalized or culverted, access for people is deficient, water quality is poor and utility pipes are visible, which is why the appreciation of the rivers in town is low. It is regarded as an opportunity to open up the rivers in Victoria, changing them into green ribbons while incorporating and enhancing existing open spaces. By combining these potentials and including a walking-friendly network, an integrated multi-functional network of green and blue infrastructure arises. This leads to high quality public open spaces which are popular and frequently used by locals and visitors. The possibility to provide spaces for outdoor or recreational activities, events, pleasure and biodiversity increase leads to a vibrant destination which improves the public realm and offers micro-climate benefits. Further, the aim of greening the rivers can contribute to reduced flood risk (SPA, 2015b).

1.2 Objective of the thesis

The master's thesis aims to further elaborate and specify the general and broad proposals of project 12 of the Victoria Masterplan. Without giving a reason or a process, the proposed bank improvements on both sides of the rivers have been divided into a hard edge, formal soft edge, informal soft edge and residential edge (see Figure 2). Formal soft edge means to rehabilitate riverbanks with soft engineering measures to allow public access/interaction with rivers, while informal soft edge means the rehabilitation of riverbanks back to the natural state, as explained by the SPA[2]. This master's thesis sheds light on the existing deficits of the rivers in Victoria, gives a more substantiated basis than in project 12 of the Victoria Masterplan and provides ideas of improvement measures. It also suggests suitable places in town for the implementation of these improvement measures. The target is to show possibilities to transform the unattractive, monotonous rivers landscape into a valued and livable place for recreational activities by incorporating environmental aspects.

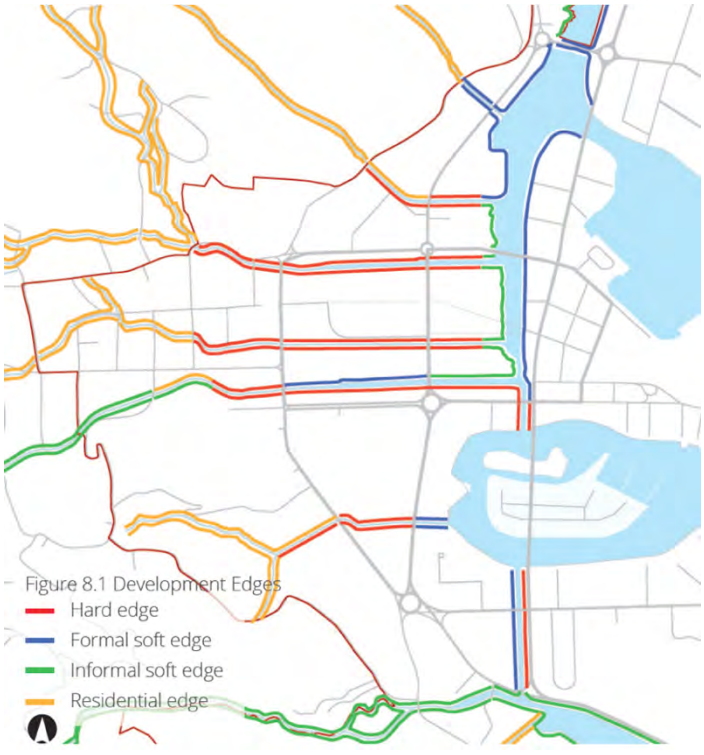


Figure 2: Overview of project 12 of Victoria Masterplan (Arup, 2015f, p. 184).

[2] Conversation with Low, J. on 15/03/2019

1.3 Seychelles

The Seychelles consist of 115 islands comprising of 41 granitic and 74 coralline islands in the western Indian Ocean (Hasan, 2008). They have a total area of 1.4 million km^2, where only 452km^2 is land area. The islands are separated into the Inner and Outer islands group. Mahé, Praslin and La Digue are the main islands belonging to the Inner island group. The largest island is Mahé (4 degrees south latitude and 55 degrees east longitude) with a length of 27km and a width of 11km. The total area is 148km^2 (JICA and MEE, 2013; Seetaram and Joubert, 2018). Mahé consist of a coastal zone which is about 1km wide and around 2-3m above mean sea level with a steep rise towards the interior with a maximum peak of 905m (Morne Seychellois) (Arup, 2014; Payet, 2016). The majority of the population and economic activities are situated on the coastal flatlands (JICA and MEE, 2013), where tourism and fishing are the two largest economic sectors (Seetaram and Joubert, 2018). Victoria is the place with the highest amount of economic, public, administrative and commercial activities (Drainage task force committee, 2005) including the international port (Nolting and Taylor, 2009). Approximately 90% of the around 97'000 Seychelles citizens live in Mahé and about one third in Victoria, the capital of Seychelles on the east coast of Mahé. More than half of Mahé is either protected area or forest and the share of residential area is about 30%, but increases (JICA and MEE, 2013; Arup, 2014; NBS, 2019). The vegetation is largely rain forest (Payet, 2016). The cultural mix is a strong element of Seychellois identity, which is reflected in everyday life such as local art, cuisine and architecture. Among all the African Countries, Seychelles have the highest Human Development Index (Arup, 2014) and belongs to the high-income countries, although the inequality is large (Central Intelligence Agency, 2019)

The Seychelles was first settled by the French in 1756 (Nolting and Taylor, 2009) and Victoria was founded in 1778, whereby the city developed from the then existing "Establissement du Roi" (Arup, 2015f). In 1794, the Seychelles were taken over by the English and in 1903 became a British Crown Colony. In 1976, Seychelles gained its independence. The Seychelles have been politically stable for over 40 years and have a democracy (Nolting and Taylor, 2009). The organization of the government consists of the President (Mr. Danny Faure) and Vice President (Mr. Vincent Meriton), eleven Ministries and Constitutional Bodies. The Ministries are Ministry for Local Government; Education and Human Resource Development; Health and Social Affairs; Home Affairs; Tourism, Civil Aviation, Ports and Marine; Youth, Sports and Culture; Habitat, Infrastructure and Land Transport; Environment, Energy and Climate Change; Employment, Entrepreneurship Development and Business Innovation; Fisheries and Agriculture; Finance, Trade and Economic Planning. Seychelles Planning Authority belongs to the Ministry of Habitat, Infrastructure and Land Transport (JICA and MEE, 2013; Government of Seychelles, 2015).

1.4 Urban river systems

This chapter gives an overview of the importance of urban waters from the past to the present. It also discusses the main characteristics of urban waters and what services they offer.

1.4.1 Definition and history

"Urban watercourses are the stream and the river in the city, which are subject to the special influencing factors of this highly remote natural space" (Schuhmacher and Thiesmeier, 1991, p. 17).

Many cities were built along a river (Cengiz, 2013), whereby people have used the riparian area as habitats and taking advantage of the provided watercourse functions. The most important functions in earlier times were water supply, sewage disposal and waste removal, opportunities for defense, bridge toll, industrial and commercial production, energy supply, transport route or irrigation (König, 2011; Way, 2018). At the beginning of the 19th century, many stretches of rivers within cities were still undeveloped (König, 2011). Due to increased danger of droughts, floods or diseases, to establish efficient transport routes and the availability of improved technical possibilities, the water bodies were enlarged, constrained, culverted, re-routed, fortified and high banks were created to make them hydraulically smoother (Booth and Bledsoe, 2009; König, 2011; Komínková, 2012; Simsek, 2012; Åberga and Tapsell, 2013; Cengiz, 2013). The result was straightened concrete channels without a riparian area, environmental functions or ecological habitats (Maddock, 1999; Simsek, 2012). Increasing population growth and urbanization has risen the need for maximum space usage, putting further pressure on water bodies in urban areas (Baker, 2009; Perini and Sabbion, 2017).

While the chapter so far generally applied to urban river systems, the following sections largely refer to European countries. The focus on reduction of wastewater pollution has risen between the 1950s and 1970s. In the last 40 years, increased prosperity and environmental awareness have led to a shift not only considering economic and production aspects but also ecological and aesthetical components in dealing with urban rivers. It was realized to remedied structural deficits of water bodies, with the focus more on rural areas.

Figure 3: State of the Cheonggyecheon river before (left) and after (right) the restoration project (Woo, 2010).

The focus on urban waters only came to the foreground a few years ago to design and characterize the cityscape by incorporating water bodies. An attempt is made to create an interdisciplinary view between river, nature, community and human aspects (König, 2011; Simsek, 2012). Urban river restoration projects nowadays contain city planning, river engineering, recreational aspects and nature conservation (Binder, 2008). Best practice examples worldwide show that a combination of these factors can be easily reconciled. Probably the most prominent example is the Cheonggyecheon river in Korea (see Figure 3).

1.4.2 Characteristics and services

Rivers have a high social, cultural, environmental and economic value and provide a variety of ecosystem services (Lifang et al., 2008; Cengiz, 2013). These are services which are provided by nature and can be used by humans. These are water supply, food products, drainage, flood protection, water purification, regulation of the water balance and local climate, provision of habitats, biodiversity, maintenance of food networks, spread of organisms, transport of substances, leisure, health, recreation, tourism, aesthetics, illustrative examples for environmental education and training and identity building (König, 2011). These services vary both temporally and spatially depending on river size, climate and geological setting and landscape location (Yeakley et al., 2016). In the past, human influence has directly and indirectly changed chemical, physical, biological and social characteristics of urban rivers in a wide-ranged and multi-faceted pattern as shown in chapter 1.4.1(Maddock, 1999; Booth and Bledsoe, 2009; Everard and Moggridge, 2011). Basically, urban rivers in their present state differ from natural rivers in three points: geomorphic simplification, ecological simplification and social value degradation (Bernhardt and Palmer, 2007), with the most important points explained below.

The consequences of embedded canals include altered runoff and flow behavior, a reduction in sediment and depth variability, standardization of flow conditions, a reduced habitat supply for aquatic organisms, a greatly reduced exchange between the river and the riparian area and groundwater. In addition, the water profile for connection to sewer pipes is often lowered, resulting in steep banks. As a consequence of these factors, biodiversity in aquatic habitats is reduced and migration corridors in longitudinal and lateral directions are prevented (Bernhardt and Palmer, 2007; König, 2011; Verdonschot et al., 2015). In addition, canals embedded in concrete simply transfer the water and, although they can prevent flooding locally, they cannot minimize the risk of flooding downstream (Booth and Bledsoe, 2009). Another threat to urban ecosystems, especially biodiversity, poses invasive species (ECRR, 2014).

In urban areas, a large number of impervious surfaces and the increasing drainage density of storm sewers lead to a spread of runoff. The water is no longer infiltrated and retained naturally into the soil and is transported away quickly (Bernhardt and Palmer, 2007; König, 2011). This increases respectively decreases the volume and velocity of the flood runoff respectively the low water runoff (see Figure 4).

The consequences are increased hydraulic loads on the water bed and bank, altered sediment transport, reduced groundwater recharge, reduced resilience to droughts, an increased risk of flooding and a restriction of the continuity of aquatic organisms (Schanze and Olfert, 2004; Booth and Bledsoe, 2009; König, 2011; Hohensinner et al., 2018). The effects will be intensified by more extreme heavy rainfall events and longer droughts due to global climate change. Particularly, the continuity is essential on islands, as the organisms must be able to link freshwater and saltwater for their life cycle (March et al., 2003). Flow regulation and changes are also altered by water withdrawals or dams (Maddock, 1999). Access to freshwater is especially limited on islands. Since groundwater resources are often insufficient to meet human needs, the rivers or other surface waters are used as a water supply (March et al., 2003). Large water withdrawals can lead to river dehydration and should be considered. In addition, impervious surfaces transport surface oils, heavy metals, pesticides, urban and industrial waste, fertilizer and other contaminants directly into the river (Schanze and Olfert, 2004; Cengiz, 2013; RESTORE, 2013).

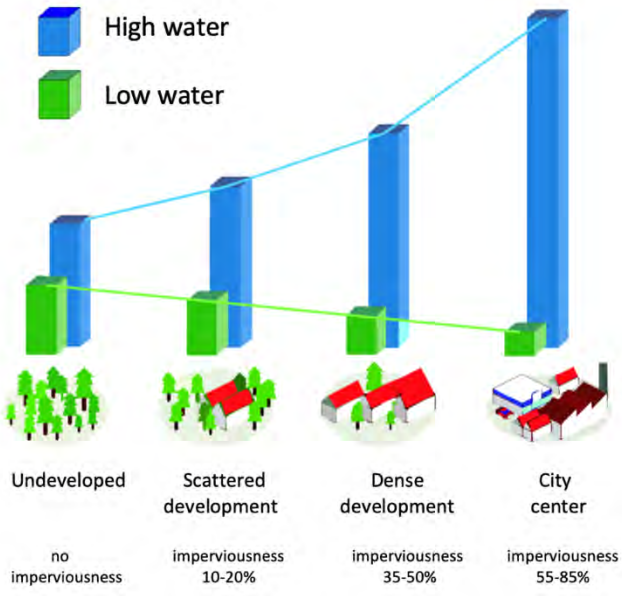


Figure 4: Illustration of the discharge spread (König, 2011, p. 18).

Water temperature in urban areas may be higher due to the return of heated cooling water from energy and industrial use. Moreover, direct heat sources such as traffic, proximity to highly heat-absorbing or radiation-reflecting buildings, or lack of shade due to the absence of vegetation may also have a direct impact on the high water temperature (König, 2011; Landscape Interface Studio, 2014; Verdonschot et al., 2015). This has an impact on aquatic organisms and oxygen levels, which in turn affects the rate of degradation of substances contained in the water (König, 2011). Known as the Urban Heat Island effect, urban areas have generally higher temperatures than the surrounding countryside. However, green spaces or rivers can make a positive contribution to the Urban Heat Island effect (Landscape Interface Studio, 2014). The local climate is influenced by urban waters in a balancing way, with the surrounding environment having a significant influence. Planting the riparian area promotes this effect. In the vicinity of open waters, the evaporation of water creates a cooling effect and increases humidity. In addition, the surface of a water body heats up less strongly than concrete or asphalt. Rivers can thus mitigate the effects of climate change which are particularly noticeable in cities (König, 2011; Landscape Interface Studio, 2014). This contributes to a more climate-resilient city (Herman et al., 2018).

Although highly developed sewerage and wastewater treatment methods are used in some parts of the world, urban waters are exposed to higher point or diffuse loads of pollutants than land (König, 2011). Water quality has deteriorated in many places due to eutrophication or organic pollution from agriculture or urbanization (Maddock, 1999; Verdonschot et al., 2015). This can even lead to a situation where bacteria and viruses restrict recreational use. As a consequence, the resistance and resilience of the river ecosystem is reduced (König, 2011).

Many cities have recognized the need for action and the value of a healthy, natural and functioning river system and are planning and taking measures to rehabilitate them (Maddock, 1999; Cengiz, 2013). The upgrading of the green infrastructure (open spaces such as parks, avenues, forest areas, etc.) in combination with the blue infrastructure (surface waters such as streams, rivers, canals, ponds, etc.) is a useful and necessary measure (Classen and Kistemann, 2017). Rivers and their surroundings are often the only way to reconnect nature with the city and its people (Åberga and Tapsell, 2013; Herman et al., 2018). Four different river upgrading measures can be distinguished (Schanze and Olfert, 2004; Wagner et al., 2008):

- **Restoration**: Bringing the degraded river back to its completely natural state
- **Renaturalisation**: The conservation of biodiversity and aquatic habitat states, bringing the river back to a natural state without completely restoring its pre-disturbance state
- **Rehabilitation**: The re-establishment of lost or diminished biotic and ecological functions of ecosystems; partial functional and/or structural return to a good working order
- **Enhancement**: Improvement of ecological conditions where environmental changes are irreversible regarding the river's natural state; considering social, aesthetic and economic features

Since it is often no longer possible to return to the natural state in urban areas due to the high population density and the lack of space, only the latter two forms of upgrading can be considered. In addition to the ecological demands on the river, there are also sociocultural and economic requirements that need to be taken into account in the context of urban river improvement. In the context of urban improvement, greater attention should especially be given on the sociocultural functions offered by urban waters. Sociocultural requirements include for instance recreation, aesthetic and amenity aspects, access to water, relaxation, leisure or experiencing nature activities (Schuhmacher and Thiesmeier, 1991; Schanze and Olfert, 2004; Lifang et al., 2008; König, 2011). Nevertheless, even today, many sections still show sociocultural deficits (see Table 1) which reduces the recreational quality and awareness of rivers. (König, 2011).

Table 1: Typical sociocultural characteristics of urban river nowadays (König, 2011, p. 22).

Primary deficits	Secondary deficits
• Blocked access to waterways for reasons of liability and traffic safety obligation • Technical, monotonous installation • Overbuilt, piped, low-lying • Numerous sources of disturbance (garbage, stench, noise etc.) • The historical orientation of the city towards the water has disappeared • No designated recreational areas and usable areas • Poor infrastructure along the watercourse • Poor condition of cultural-historical buildings • Missing utilization concepts	• Poor accessibility • Low attractiveness and residence quality • Little nature experience • Lower recovery value • Little perceptibility • Limited visibility • Poor integration into the cityscape • Poor identification with the water body • Economic losses (no use in tourism, low land and real estate prices along the watercourse) • Low acceptance of measures etc. • Usage conflicts • Lack of awareness of environmental concerns on watercourses or lack of environmental education

Enhanced urban rivers and their surroundings offer public open space and cost-effective flood control. Also, they are the starting point for urban quality of life, represent an attractive space for social activities, play an important role in creating identity in the design of the cityscape, offering a range of tourist attractions and can increase the surrounding property values. The well-being and health of the residents and visitors are influenced in a positive way (König, 2011; Åberga and Tapsell, 2013; Cengiz, 2013; Classen and Kistemann, 2017; Perini and Sabbion, 2017; Blau et al., 2018). In particular, the upgrading of the riparian area is of crucial importance in the implementation of measures due to the human-nature interaction (Grêt-Regamey et al., 2016). Well planned urban river enhancements have the potential to restore many of the lost ecosystem services to a certain degree (Cengiz, 2013; Perini and Sabbion, 2017). The focus of upgrading measures can have different focal points (RESTORE, 2013), but should always be considered integrally due to the multifunctional characteristic of rivers (Cengiz, 2013; Perini and Sabbion, 2017). Different focal points are access and recreation (areas for walkers, families etc.), green space (attractive, accessible environments), biodiversity, heritage and cultural environment, education (signs, student projects), natural flood risk management or maintenance cost (drainage improvement) (RESTORE, 2013). The most important benefits of urban river upgrading are summarized below (RESTORE, 2013, p. 13):

- Improved quality of housing, landscape and biodiversity
- Improved sustainable transport - footpaths and cycleways, jogging
- Opportunities for education and informal learning about the environment
- Having a positive impact on people's health and well-being
- Climate change adaptation and reduction in flood risk
- Improving the river corridor and green space networks
- Increasing access to nature and recreation
- Addressing water quality and land drainage

1.5 Structure of the thesis

The main part of the master's thesis is divided into three sections: (I) Study area analysis, (II) requirements for the future river system in Victoria and (III) potential improvement measures and implementation. The amount of practical work is large, as there is very scarce information about the rivers in Victoria and a basis has first to be created. The study area analysis consists of two sections. It gives an overview of the main features of the city and considers certain developments, both relevant to river improvement measures. This is based on a literature review supplemented with gained local expert knowledge when information was not available in the literature. The third section, the chapter "Detailed assessment of rivers in Victoria", is the core of the study area analysis. The assessment system has been specially tailored for Central Victoria and examines in detail the current state of the rivers. In total, Part I serves as a collection of a complete analysis to implement further measures on a well-established basis. Part II addresses the ecological, recreational and decision-maker requirements for rivers in the city. The analysis of the ecological requirements is based on expert interviews and the one of recreational requirements on a survey conducted with residents and employees. Based on initial findings of the work already carried out, rough ideas were developed and discussed in a workshop with relevant decision-makers. The conduction of the workshop gave a further perspective on the issue from other stakeholders and their interests. The participants commented on what needs to be considered when proposing improvements. The total insights gained will be combined in Part III, taking into account reference examples. The aim is to identify possible improvement measures on a general and river-specific level. The left figure illustrates the structure of the master's thesis.

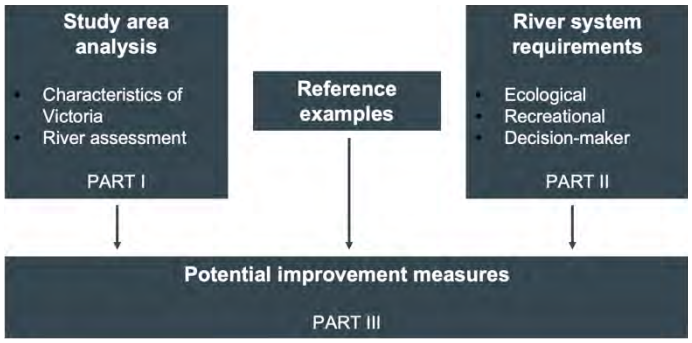


Figure 5: Structure of the master's thesis.

1.6 General limitations

Data availability, data transparency and data quality are not comparable to those in Switzerland. Information and data are often available, but mostly not written down and usually very decentralized. The data are often outdated and only partially available in digital form. In addition, data collection is time consuming. It is challenging to get data because people are very busy and sometimes restrained when it comes to sharing data. A personal pick-up or the collection of the data itself is often the only solution. The points mentioned refer specifically to the data on rivers and their relationships in the city. The work has also been written in English, which represents a language barrier because is not the native language.

2 Part I - Study area analysis

2.1 Characteristics of Victoria

2.1.1 Overview

Victoria is generally flat, located at the foot of the mountains Trois Frères, St. Louis and Signal Hill (Drainage task force committee, 2005). This chapter gives a brief overview of the city structure. The most important places are mentioned by name, whereas the work refers to these places again in subsequent chapters. Victoria consists mainly of commercial units, retail, community facilities and restaurants. The Sir Selwyn Selwyn-Clarke market is the most popular retail facility in town offering spices, fresh vegetables, fish and souvenirs. The Peace Park opened a few years ago and is an attractive place with public art, seating possibilities and a fountain (see Figure 6). The Freedom Square is on the opposite side of the 5th June Avenue and is used for celebrations, different kind of sports activities or political gatherings. Unfortunately, Jardin Des Enfants is an unused and dilapidated green spot nowadays. Another green patch is the Paradise Des Enfants, which stretches along the lagoon from the Rivière St. Louis up to the English River. All of them are in relatively close distance but not interconnected und generally underutilized, which has therefore a great opportunity for the future (Arup, 2015f, 2015a). The old esplanade along Francis Rachel Street represents the earlier character of Victoria's waterfront and is therefore protected (Arup, 2015f). The map also shows the national monuments, the bus station, the police station, religious infrastructure and schools.

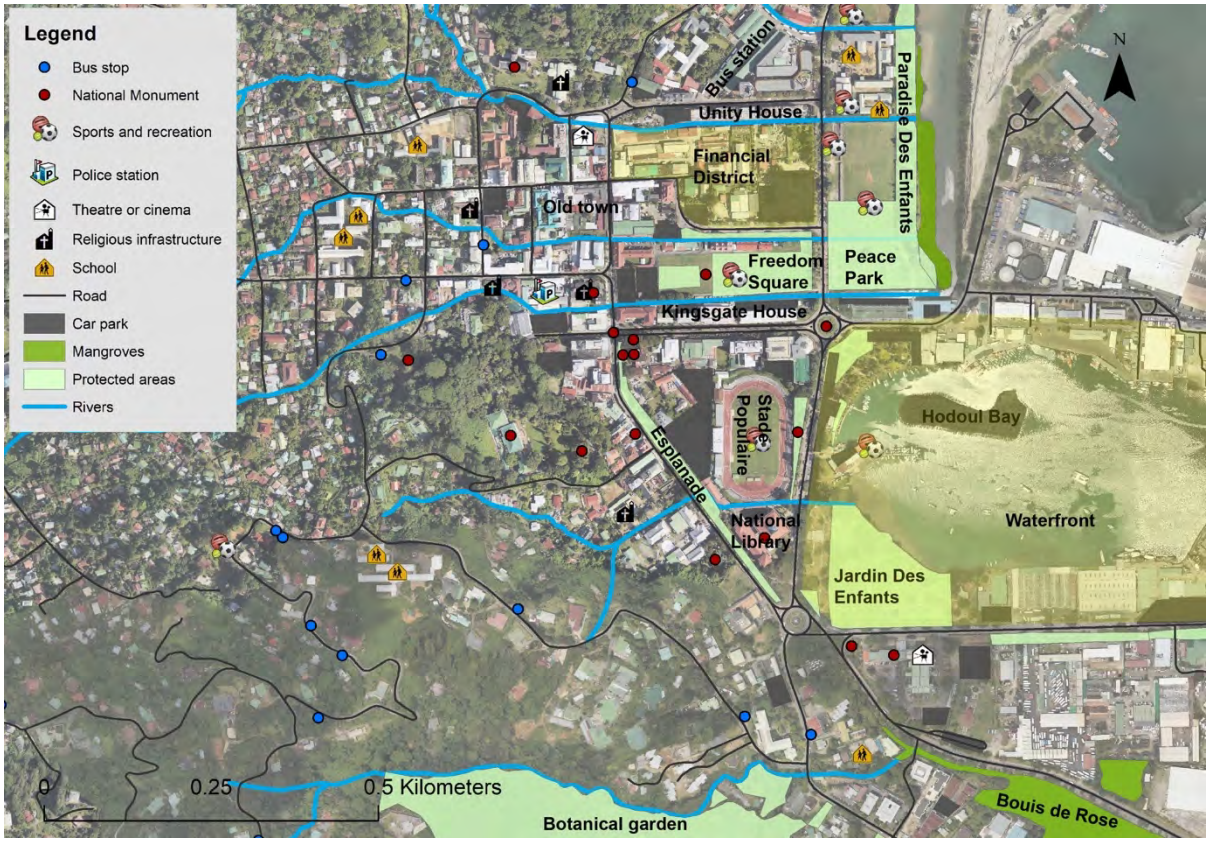
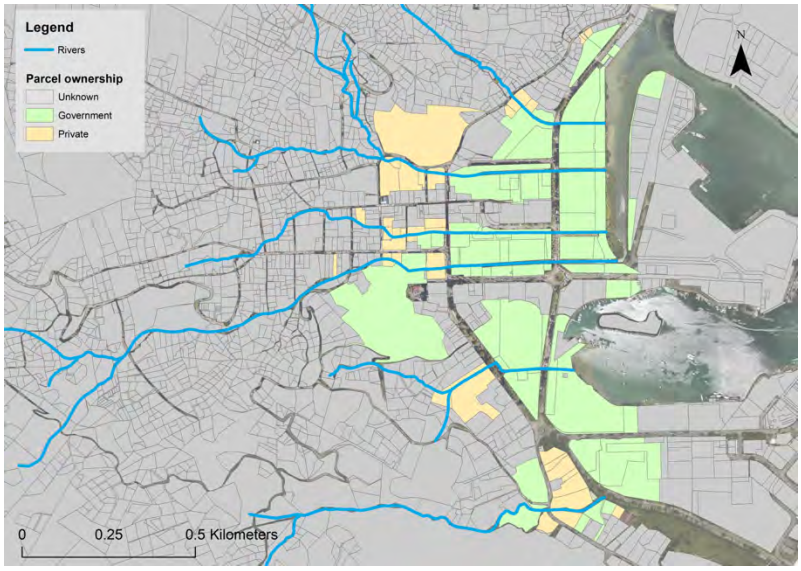


Figure 6: Functional overview of Victoria (date provided by Seychelles Planning Authority, 2019[3]).

[3] Data collected from Belle, B. and Low, J. in March 2019, further explanation see Appendix A



The ownership of a plot is of crucial importance for river upgrades when it comes to the land adjacent to the river. The land ownership of parcels adjacent to the river is shown in the figure on the left side. A detailed overview of the land use adjacent to the river is given in Appendix B and Appendix C.

Figure 7: Land ownership of parcels adjacent to rivers (data collected from Land Registration Office[4] and provided by Seychelles Planning Authority[5]).

2.1.2 Regulatory frameworks

There are several laws and regulations affecting rivers or their surroundings in town. The policy considered as the most important about all is the *State Land and River Reserve Act (1903)*. 146 rivers are listed under Schedule A of the *State Land and River Reserve Act* and are designated as River Reserves (Arup, 2015b). No development or cutting off trees are allowed within a distance of 10m on each side of the river (Government of Seychelles, 2017b). This distance of 10m was chosen with regards to the river's importance to socioeconomic development and human populations (Government of Seychelles, 2011), to protect the river from pollution (Government of Seychelles, 2010) and to safe the vegetation and the natural flow of the river (statement of SPA[6]). Further planning requirements are a minimum setback of 15m from a soakaway to a river (Government of Seychelles, 2010). The minimum distance of 10m, however, is little enforced in several places (Government of Seychelles, 2011, 2017a). This is the case particularly in Victoria due to the limitation of space (statement of the SPA[7]). Some of the buildings are even built directly on the river's edge or across. The issue in Victoria is known and it is already becoming the norm. The act is considered as out of date. A review is needed because the river provides a physical realm around the built-up area. The aim should go towards the already contained section in the *State Land and River Reserve Act* to cover about 3-3.5m with brushwood or trees (Government of Seychelles, 2017b; Low et al., No date-b) or the existing *Urban Design Guidelines* for Central Victoria (Arup, 2015f). The Guideline for Revolution Avenue, Quincy Street and Independence Avenue dedicates a relatively long chapter to landscaping. In very high-density areas (reclaimed land), 20% of the area has to be landscaped which is 40% in high-density areas. Roof scaping is also included in this percentage.

[4] Personal transcription of the parcel owners at the land registration office in March 2019

[5] Data collected from Belle, B. and Low, J. in March 2019, further explanation see Appendix A

[6] Conversation with Low, J. on 15/03/2019

[7] Conversation with Belle, B. on 19/04/2019

The landscaped area should contribute to an increase of water infiltration to the ground and the reduction of the heat island effect. A minimum setback of 2.5 - 3m from the river has to be maintained (Low et al., No date-c).

Public Utilities Corporation Act (1985) contains controlling measures about irrigation and potable water usage. Water is considered as a public domain in Seychelles. The Rivers Committee is authorized by this act to manage all the water abstract applications and control of the pollution of freshwater resources from various governmental views (PUC, 2011) then the Rivers Committee is made up of various organizations (Ministry of Health, Public Utilities Corporation, Ministry of Agriculture, Ministry of Environment and Natural Resources, Ministry of Land Use and Habitat and the Ministry of Industry and International Business) (FAO, 2005). Public Utilities Corporation (PUC) has the responsibility to collect, store and distribute water in Seychelles (Martin, 2010).

The *Town and Country Planning Act (1972)* provides the legal basis for assigning or rejecting building permits (JICA and MEE, 2013) and for land use respectively development planning (Arup, 2014, 2015e). The establishment of the Seychelles Planning Authority is based on this act to oversee the contained requirements. The act also controls environmental regulations for rainwater management, landscaping, sewage, etc. (JICA and MEE, 2013). However, it is regarded as out of date and currently under revision while it should further include the involvement of stakeholders and biodiversity conservation (Ministry of Environment and Energy, 2013; Arup, 2015b). Most probably it will include the 25m setback from the high tide watermark in future, which has been proposed by the Ministry for Environment (Government of Seychelles, 2018). SPA is working on *Land Use Plans (LUP)* for all the districts of Mahé which identify the current land use and at some places even the proposed land use, including zones of no-development and avoiding adjacent incompatible uses. A standardized classification is used to assign each parcel (Arup, 2014). They are updated every five years and reviewed every ten years (Arup, 2015e).

The *Removal of Sand and Gravel Act (1991)* regulates sand and gravel removal from surface waters such as rivers, streams and coastal areas. The *Environmental Protection Act (1995)* covers waste management and water pollution (effluent standards) and contains information to the environmental impact assessment process (Government of Seychelles, 2012; JICA and MEE, 2013). The *National Monuments Act (1980)* protects the cultural heritage of Seychelles. Further related policies are the *Land Reclamations Act (1961), Storm water Drainage Design Guidelines for Seychelles (1999)* (Arup, 2014) *and the Public Health Act (1960)* and *Disaster and Risk Management Act (2004)* (Government of Seychelles, 2017b).

Original coast line

Pre-1970

1970s

1980s

1990s

Figure 8: Time series of land reclamation (data based on Lablache, 2019[8] and (Drainage task force committee, 2005).

2.1.3 Land reclamation

Victoria is mostly situated on reclaimed land. This is the result of a natural landslide in 1862 and man-made expansions towards the ocean between the 1960s to the present day (see Figure 8). Land reclamation was needed due to increasing commercial, construction and recreational activities and the lack of suitable land for development since Mahé have steep land conditions (Drainage task force committee, 2005; JICA and MEE, 2013). Development in the early 1960s was mostly around the Central Victoria area and the old port "Long Pier" was the only access point to the world outside (see Appendix D). In the 1980s, the first commercial port was built (Drainage task force committee, 2005). Most of the oldest monuments, main landmarks and Creole buildings are found in the capital Victoria (Arup, 2014).

2.1.4 Climate

The climate of the Seychelles is tropical, warm and humid all year round. The average daily temperature is approximately 29°C (Drainage task force committee, 2005) with small variations between 24°C and 32°C around the year (Payet, 2016). The climate is influenced by two main seasons: From May to October the Southeast Tradewinds are relatively dry, cool and windy, while from November to April the Northwest Tradewinds are rainy, warm and with a generally calm sea (Drainage task force committee, 2005; Hasan, 2008). Large variability of spatial and temporal rainfall pattern is present on Mahé and is linked to global circulation, such as the El Niño-Southern Oscillation (Arup, 2014) on a two to four-year cycle (Arup, 2015b). The rainfall pattern over Seychelles can be classified into three groups while Mahé belongs to the wettest group. Mahé's spatial rainfall pattern can be classified into the North (includes Victoria), Central and South Area where the North Area is the wettest and the South Area the driest. The average rainfall is relatively high but unevenly distributed throughout the year (Hasan, 2008; Arup, 2014). The annual rainfall on the coast is about 1'500mm and 3'500mm in the mountainous area, while January is the wettest and July the driest month of the year.

[8] Personal meeting with Lablache, P. on 24/04/2019

Typical climate conditions are summarized in Appendix E. Although the total annual rainfall will increase in future, the pattern is changing towards a drier dry season and a wetter rainy season (Drainage task force committee, 2005; Arup, 2014, 2015b; Payet, 2016).

2.1.5 Natural hazards and climate change

Susceptibility to landslide is considered very low for the Central Victoria area (Arup, 2014). Due to the geographical position and geology, the Seychelles are located outside the cyclone belt and severe thunderstorms or storm surges occur rarely compared to neighboring countries (Drainage task force committee, 2005; JICA and MEE, 2013; Arup, 2014). Nevertheless, the far-reaching effects of tropical storms in other areas of the Indian Ocean can be observed resulting in gale-force winds, thunderstorms or flash floods (Arup, 2014). Although disasters are rare in Seychelles, past events with severe damages were the "El Niño" rainfall (August, 1997), the tropical depression "01S" (September, 2002), the tsunami (December 26th, 2004) and the torrential rainfall (December 28th – 30th, 2004). Further, but events with less impact, were another tsunami (27th August, 1883) and the tropical depression "Ikonjo" (18th May, 1990) and "Bondo" (20th December, 2006). Unfortunately, no detailed information about the frequency, duration and depth of past flooding damage records are available (Hasan, 2008; JICA and MEE, 2013). Occasionally, Victoria experiences flash floods after short-term rainfalls within a few hours. The greatest risk of flooding occurs during heavy rainfall coincide with high tide. Most of the flooding events are caused by increased runoff associated with newly developed areas over the years (even in the upstream catchment area) resulting in a reduced retention capacity and increasing soil erosion. Additionally, another cause is the insufficiently planned, designed and maintained drainage system, which no longer meets the requirements. The current drainage system in Victoria was mainly designed by local experience and engineering judgment in the colonial era without specific guidelines for drainage systems, which only exists since 1999. The natural land drainage is provided by the six main rivers, whereby cross and roadside drains serve as storm water runoff and discharge into the natural drains. In some places, pipes and concrete structures reduce discharge capacity (Drainage task force committee, 2005; JICA and MEE, 2013; Arup, 2014). Drainage task force committee (2005) found that the runoff capacity, regardless of tidal movement, is insufficient for bridges or culverts at the Rivière Moussa, Rivière Maintry, Rivière St. Louis and La Poudrière River near Albert Street and Francis Rachel Street (see Appendix F). English river has sufficient runoff capacity and no data is available for Rivière Trois Frères (Drainage task force committee, 2005). Although the removal of these bottlenecks has been considered as a high priority, there is no precise plan and it is not clear what has already been implemented since 2005. Nevertheless, de-silting processes have been undertaken since 2010, which served to prevent flooding in Victoria. The process consists of the de-silting of the six main rivers crossing Victoria (see Appendix G). The amount of silt removal is fluctuating due to different factors such as human activities or climate conditions (see Appendix H) (Labrosse, 2019). However, most of the flooding issues in town is not caused by insufficient river capacity but by insufficient capacity of the cross and roadside drains (see Appendix I) (JICA and MEE, 2013). This drainage network has been abused for utility pipes and poor maintenance in the past led to waste accumulation or silting up the drainage network.

Some areas of Victoria are even lower than the coastline, which challenges the drainage system. It is visible that the flooded areas are along the insufficient cross and roadside drainage system (Drainage task force committee, 2005). This implements to improve the cross and roadside drainage system in the short-term while river improvements need to be done in the medium-long term (JICA and MEE, 2013).

To sum up, the likelihood of flash floods occurrence is possible but the severity of consequences is regarded as insignificant and the overall level of risk as low. Most of the flooding area is less than 30cm and only over a short period of time (JICA and MEE, 2013). The narrow coastline with its concentration of economic activities makes Seychelles particularly vulnerable to climate change (The Seychelles National Climate Change Committee, 2009) why the before mentioned likelihoods for the future will increase to likely, moderate and moderate due to sea level rise and further development (JICA and MEE, 2013). Nonetheless, the general impact on Mahé will only be low to moderate. The local sea-level rise is comparable with the global mean and assumed to be 1.8mm/year and assumed to be the major impact of future natural hazards (JICA and MEE, 2013; Arup, 2015b). At present, it is not possible to evaluate how tropical cyclone/depression intensity or storm tracks will change (JICA and MEE, 2013).

2.1.6 Water supply, wastewater, water abstraction and water quality

Seychelles treated water consumption is around 14 million m^3/year and is expected to increase by 8-10% annually where domestic and tourist use are by far the highest. Surface water is the most commonly used source while the two raw water dams at Rochon and La Gogue serve the denser populated areas around Victoria. The other areas are supplied by direct abstraction from rivers, making them dependent on their water level (Arup, 2014). 95% of the buildings are connected to the water supply network (see Appendix J) whereby the rest is using rain or river water (Martin, 2010). In total, 38 treatment plants exist. During the drier months of June, July and August, the water supply is insufficient from natural sources and leads to water shortage. This is going to be reinforced by future climate change. Four desalination plants were installed and used during that period nowadays (Arup, 2014). Water shortage is not caused by too little rainfall but due to underdeveloped storage capacity and high water losses of sometimes up to 50% on Mahé (ECODYS Nederland BV, 2007). Possibilities for improvements are rainwater harvesting, reduction of water loss through leakage by replacing the generally old pipes and the efficiency increase of water usage and distribution (Arup, 2014).

The densely populated areas around Victoria are a rare place on Seychelles where a sewage system exists (Arup, 2014). About 15%-25% of the population is connected to a sewage treatment system, whereby this percentage is close to 100% in the area around Victoria, as communicated verbally by PUC[9]. The remainder of the population uses septic tanks or on-site disposal systems, which causes pollution of groundwater, surface water and the sea (Arup, 2014, 2015c).

[9] Conversation with Cesar, K. on 16/05/2019

This development is not sustainable for the future and will be intensified when the population continues to rise (Arup, 2015c; Government of Seychelles, 2017b). Further, PUC suffers from a lack of financial resources due to low water supply and sewage tariffs which makes it difficult to maintain or even increase the network (ECODYS Nederland BV, 2007). Since no standard for utility corridors exists, utility pipes are installed in the easiest location using gravity, sometimes even in or along river sections (see Figure 9). This affects the channel capacity and leads to pollution if pipes are leaking (Arup, 2014, 2015c). Although it has been said by PUC[10] that currently no danger from sewage pipes in close distance to rivers exists, any possible occurring damage such as natural hazards can cause damage with serious consequences to the environment (Arup, 2015c). Extreme flood events can cause the sewage system to overflow (Arup, 2014).

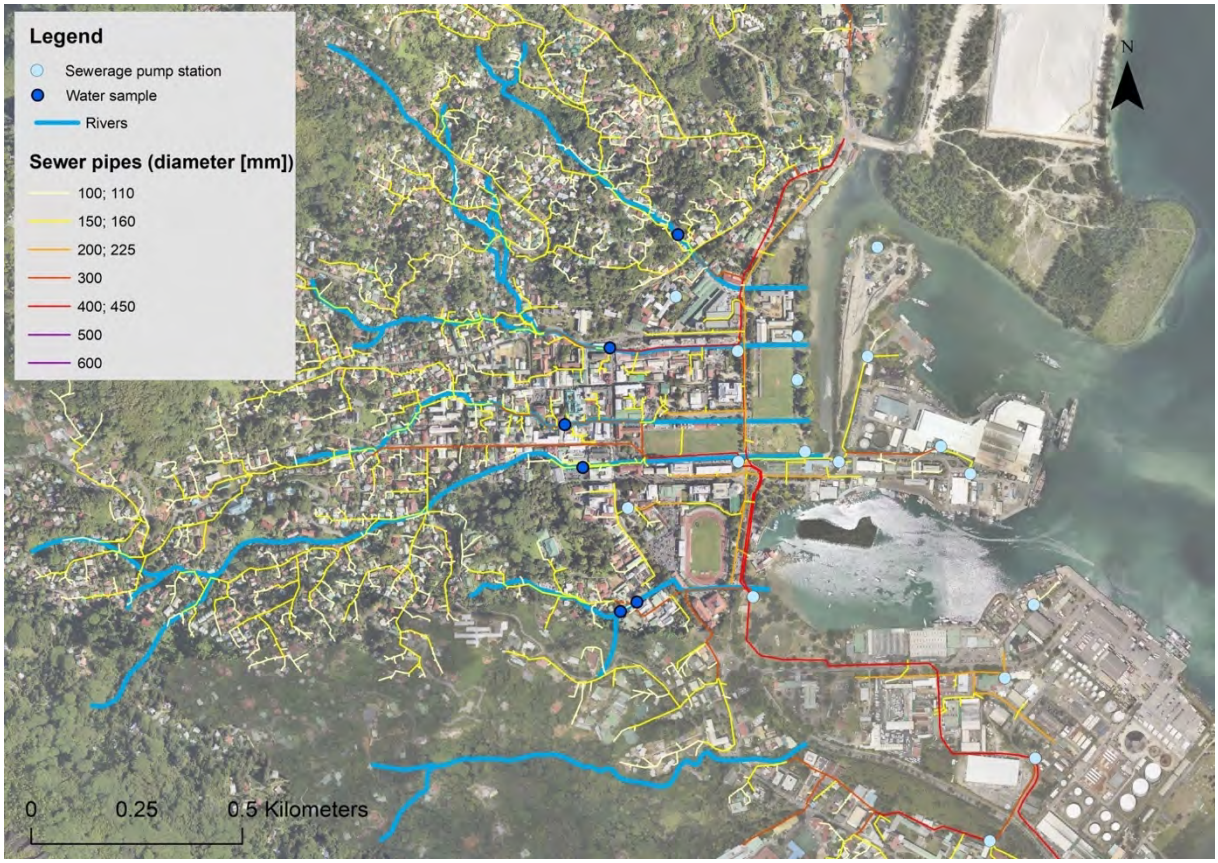


Figure 9: Sewerage network around Victoria (data provided by PUC, 2019[11]).

No water is abstracted in the area of Victoria (Arup, 2015d), which has been confirmed by PUC[12] since it is not economically feasible and the water is already polluted. As told by PUC[13] verbally, the only allowed water abstraction is done by a car wash company, estimated to be about 100m³/day at a place along Rivière St. Louis. From the author's observation, it was recognized that the water is not only taken from the river, but the wastewater is led back into the river, which in turn has a negative influence on the water quality.

[10] Conversation with Cesar, K. on 26/04/2019

[11] Data collected from Agricole, I. on 09/04/2019; further information see Appendix A

[12] Personal meeting with Alexis, G. and Henriette, A. on 21/03/2019

[13] Personal meeting with Alexis, G. and Henriette, A. on 21/03/2019

Although an application fee for any water abstraction would be required (PUC, 2011), some illegal abstraction is done for household purposes which is assumed to be about 5% of the total flow, as told verbally by the SPA[14]. This abstraction is putting additional pressure on the water supply that would be required elsewhere (PUC, 2011). Agriculture is not practiced within the catchments of the rivers considered, which does not further affect water quality (Arup, 2014). No current measurements for water quality exist on Mahé for the area around Victoria. However, the water quality is assumed to be very poor because of littering and sewage of anthropogenic sources. Previous research has even shown microorganisms coliform concentrations to be present in some rivers which can cause serious illnesses (Arup, 2015b). The results of the self-conducted sample carried out with the help of Vel T.[15] are shown in the following table (further data see Appendix K). The locations of the water samples are shown in Figure 9. These values revealed that some of them are even higher than the allowed limits of effluent water standards (pH = 5.5-8.5, phosphate = 5mg/l and nitrate = 15mg/l) (Government of Seychelles, 2012).

Table 2: Water quality of the rivers in Victoria (own source).

River	Phosphate [mg/l]	Nitrate [mg/l]	pH-value
English River	9.19	4.9	6.8
Rivière Moussa	8.23	10.5	6.8
Rivière Maintry	7.79	8.1	6.8
Rivière St. Louis	7.19	7.7	6.7
La Poudrière River	16.38	4.9	6.6
Rivière Trois Frères	-	-	6.9

2.1.7 Natural aspects

As a result of their long time in isolation from the outside world since 65 million years, the biodiversity of the Seychelles is very high, especially the level of endemic species (Arup, 2015b). This is particularly the case on the main island Mahé, as the mountain area offers a large variety of habitats. The Morne Seychellois National Park consists of a large area located in the north-west of the island. Further protected areas are distributed over the island including public parks (Freedom Square, Peace Park, Jardin Des Enfants and the Botanical Gardens) and green spaces. An important habitat are the wetlands, including areas of mangroves. These areas have been strongly reduced in recent years to about 10% of natural occurring lowland wetlands, especially on the east coast, due to development and needed wood products (Government of Seychelles, 2011; Arup, 2014; Government of Seychelles, 2014b; Arup, 2015b; Government of Seychelles, 2017b).

[14] Conversation with Belle, B. on 16/05/2019

[15] Water sample collection for water quality testing on 13/04/2019 and 14/04/2019 (help of two further students).

However, the inshore lagoons created by land reclamation serve as traps for sediment transported by rivers before entering the sea[16], and have led to the formation of secondary mangrove areas (Government of Seychelles, 2011). These secondary areas of mangroves can also be found in Victoria (see Figure 6). Key mangrove sites still exist in Police Bay in the south and Anse Intendance, Grand Anse and Port Launey in the west. Mangroves provide natural mitigation against wave action, storm surge and flooding events, prevent erosion, filtrate river water, traps sediments before flowing into the sea and serve as an important nursery ground for bird and marine species (Arup, 2014, 2015b; Government of Seychelles, 2017b).

While rivers were used for laundry and bathing in former times, they serve today mainly as a source for drinking water and as a habitat for many aquatic species such as fish, plants and invertebrates. Especially rivers and streams show a high level of endemic species (Government of Seychelles, 2011, 2014a). Rivers are an important corridor between the ocean and freshwater habitats in the mountainous interior (Arup, 2015a). No river flowing through Central Victoria touches protected or key biodiversity areas in the upper reach but are in close distance to some (Arup, 2015b). A major threat to biodiversity lies in the fact that many rivers use hard engineering approaches (canalization) to control areas affected by flooding (Government of Seychelles, 2018). Other main threats for aquatic biodiversity on Mahé are increased water abstraction, pollution from litter and sewage and invasive species. Invasive species mainly originate from aquarium trade, when pet owners abandon their animals (Government of Seychelles, 2014b). While the condition of rivers in the lower reaches has deteriorated due to development, progress has been made in the mid to upper reaches over the last 50 years. This is mostly due to the maintenance of catchment areas and riverbank habitats and recovery of forest cover. However, the rising demand for water results in withdrawals in the upper reaches of rivers which have a further inevitable impact on habitats and the ecosystem in the lower reaches (Government of Seychelles, 2011).

2.1.8 Traffic

Today's transport system in Victoria is often overloaded, especially in the morning and evening hours, due to the volume of traffic and the lack of alternatives. Although public transport suffers the same problem, the usage is at a very high level whereby all bus routes coincide in Victoria. For slow traffic activities, some formalized footways or segregated footpaths exist within the city (see Figure 10). Although some of them are well-used routes, most of them have no shadow which reduces their attractiveness and crossing facilities are often at undesirable places (Arup, 2014). The surface materials and levels of the walking network are inconsistent (Arup, 2015f). The SSLUDP aims to improve and promote a high-quality walking and cycling network contributing to a healthier and more active lifestyle. Associated infrastructure such as seating possibilities needs to be considered (Arup, 2015a).

[16] Personal meeting with Lablache, P. on 24/04/2019

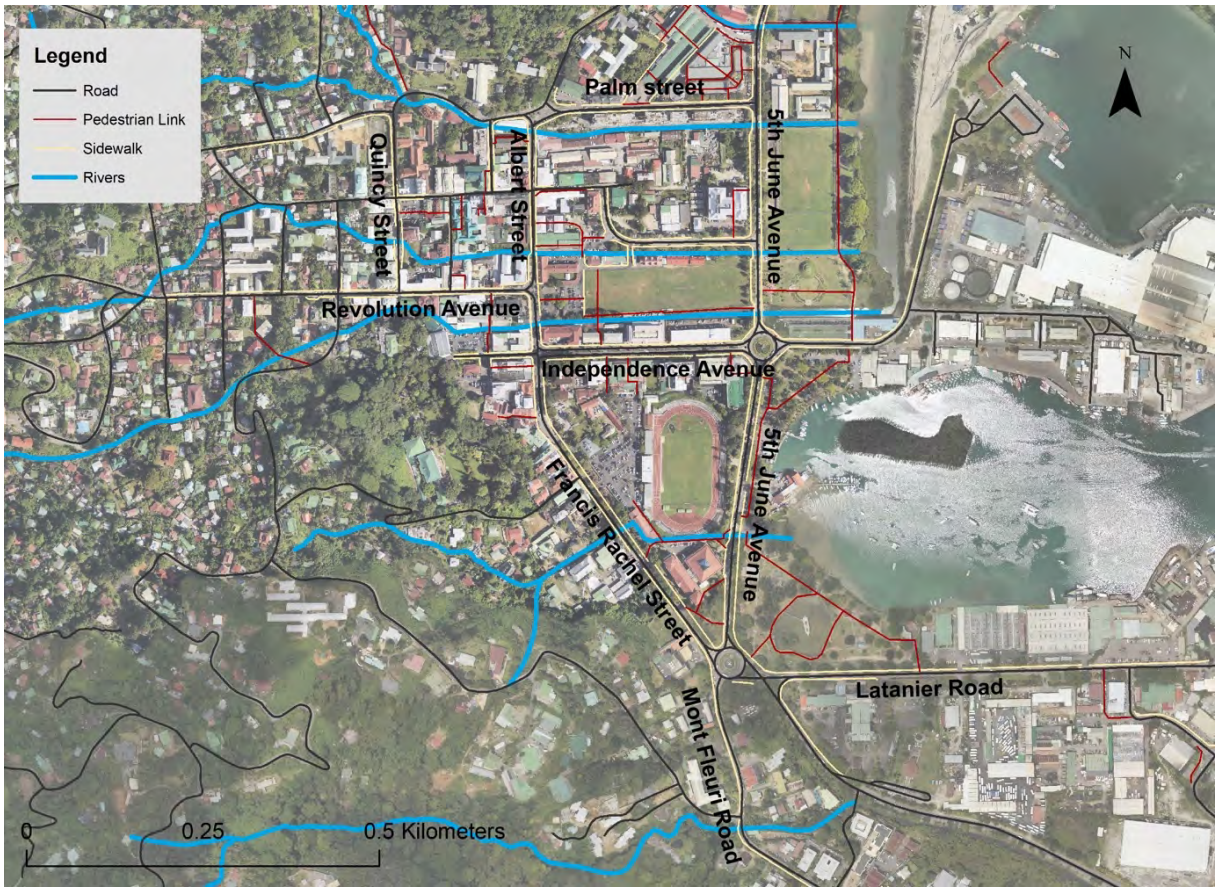


Figure 10: Existing pedestrian network and roads in Victoria (data provided by Seychelles Planning Authority, 2019[17]).

2.1.9 Rivers in Victoria

Mahé is a granitic island covered with a clay-like, red, iron-rich overlying soil stratum. This build-up causes the poor absorbent qualities resulting in a relatively large storm water runoff volume and the presence of a large number of small streams with erratic flow. On the whole island of Mahé, there are 25 main rivers and around 70 – 100 small ephemeral streams (Arup, 2014). The rivers originate in the mountainous region and discharge into the Indian ocean. While lower areas consist of flood plains, wetlands and minor river deltas the steep-sided valleys act as natural water catchments (Drainage task force committee, 2005; The Seychelles National Climate Change Committee, 2009; Arup, 2014; Payet, 2016). The river basin of Mahé is divided by a northwest-southwest mountain range at the center into an east and west part. Most of the catchments are smaller than 1.0 km² (JICA and MEE, 2013). A catchment is the area drained by a river or body of water (Ministry of Environment and Energy, 2013). The majority of the rivers are in a natural state apart from the river mouth and the ones flowing through Central Victoria. The surrounding of the rivers in Victoria is very urbanized (JICA and MEE, 2013). Central Victoria area is drained by the six perennial rivers English River, Rivière Moussa, Rivière Maintry, Rivière St. Louis, La Poudrière River and Rivière Trois Frères (see Figure 11) and several small streams.

[17] Data collected from Belle, B. and Low, J. in March 2019, further explanation see Appendix A

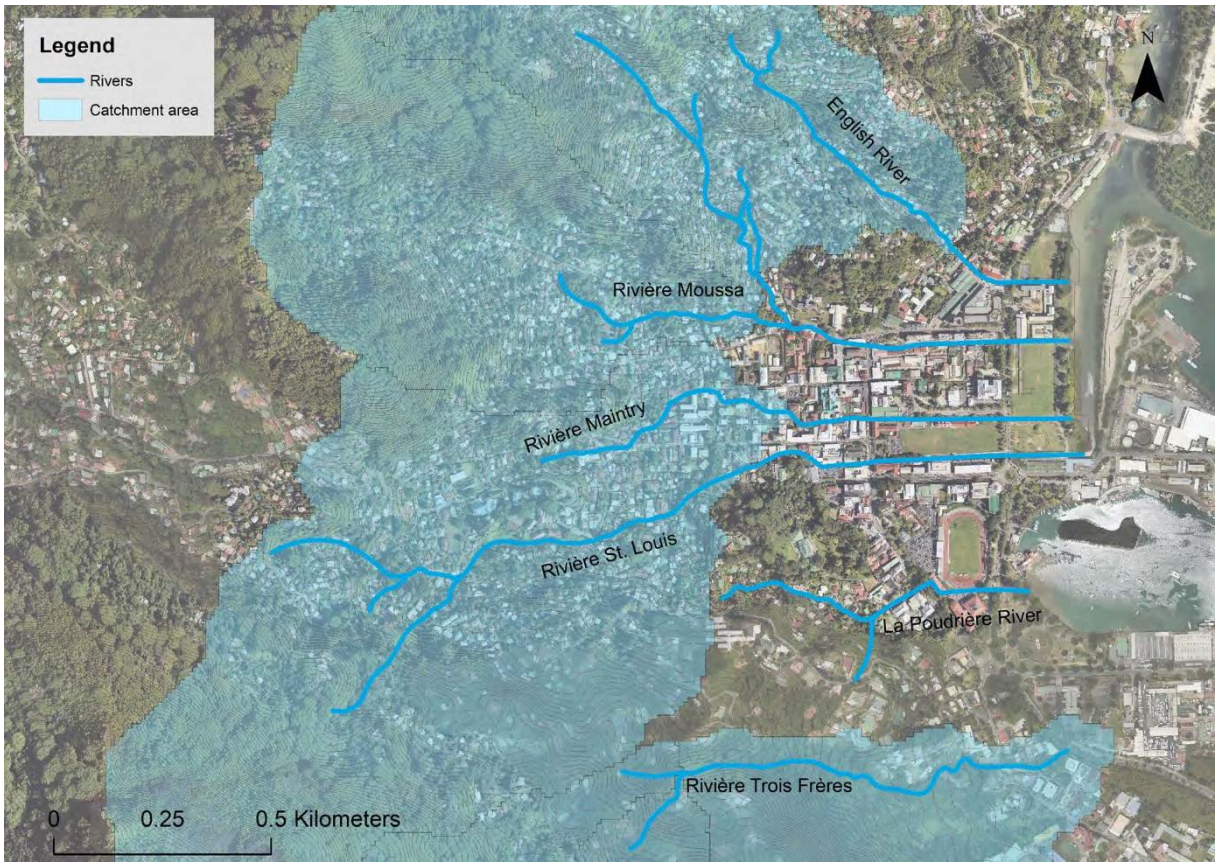


Figure 11: Overview of the rivers flowing through Central Victoria (data provided by Seychelles Planning Authority, 2019[18] and Center for GIS, 2019[19]).

The following table shows some characteristic sections of the rivers in Central Victoria. More detailed information is available in Appendix L.

Table 3: Pictures of the six natural rivers flowing through Victoria.

No	Name	Picture 1	Picture 2
1	English River		
		Representative images of English River between 5th June Avenue and the lagoon (left, 18/04/2019) and next to the bus station (right, 10/03/2019) (own source).	

[18] Data collected from Belle, B. and Low, J. in March 2019, further explanation see Appendix A

[19] Data collected from Coeur de Lion, F. on 18/03/2019, further explanation see Appendix A

No	Name	Picture 1	Picture 2
2	Rivière Moussa		
		Representative images of Rivière Moussa between 5th June Avenue and the lagoon (left) and along Unity House (right) (own source, 10/03/2019).	
3	Rivière Maintry		
		Representative images of Rivière Maintry next to Freedom square (left, 10/03/2019) and between Benezet and Albert street (right, 27/03/2019) (own source).	
4	Rivière St. Louis		
		Representative images of Rivière St. Louis next to Freedom square (left) and the car park attached to State House Avenue (right) (own source, 10/03/2019).	

No	Name	Picture 1	Picture 2
5	La Poudrière River		
		Representative images of La Poudrière River next to Seychelles National Library (left, 10/03/2019) and along Francis Rachel Street (right, 20/04/2019) (own source).	
6	Rivière Trois Frères		
		Representative images of Rivière Trois Frères between Mont Fleuri Road and Bois de Rose Avenue (own source, 10/03/2019).	

Due to land reclamation in Victoria, the natural courses have been artificially lengthened in masonry-lined shaped channels. Consequently, their channel profiles are relatively flat which reduce the flow rate. Further, they are influenced by the tidal movement which again influences their hydraulic behavior (Drainage task force committee, 2005). Typical tidal movements are shown in Table 4.

Table 4: Typical tidal movements on Mahé (JICA and MEE, 2013, p. 32).

• Highest astronomical tide: 2.10m • Mean high water spring: 1.63m • Mean high water: 1.45m • Mean high water neap: 1.27m	Mean Level: 1.10m	• Mean low water neap: 0.81m • Mean los water: 0.63m • Mean low water spring: 0.45m • Lowest astronomical tide: 0.20m

2.1.10 Future developments of Victoria

Figure 12: Proposed development of Victoria (Arup, 2015f, p. 41).

It is assumed that the large economic and population growth of recent years will continue (see Appendix M) (Arup, 2014). The concentration of growth will be focused on the Greater Victoria and Anse Royale area. The number of people living in the Central Region of Greater Victoria is assumed to increase from about 30'000 to 45'000 in 2040 resulting in about 6'300 additional homes through intensification of the existing residential areas. Consequently, this is putting further pressure on the rivers and their surroundings why foresighted planning is to be pursued (Arup, 2015a, 2015b, 2015f). The followed projects are considered as short to medium-term projects mainly affecting the rivers in town and are therefore shortly explained. Figure 12 shows the general overview.

Waterfront

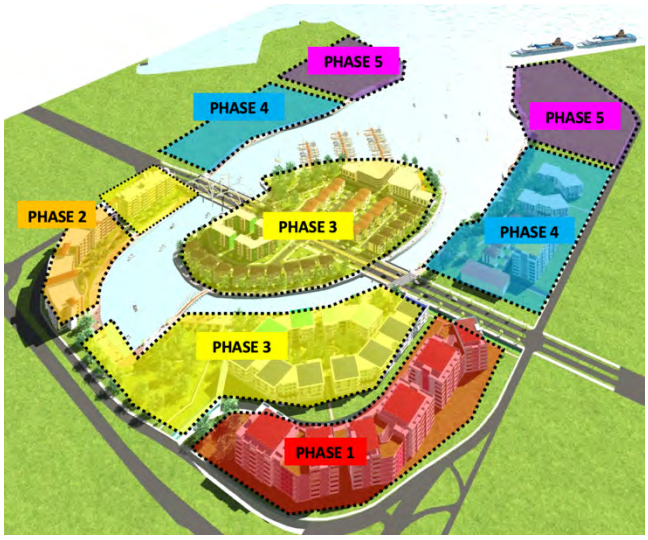


Figure 13: Proposed waterfront project (Low and Felix, 2019, p. 25).

The waterfront of Victoria is planned to be upgraded by creating an area of mixed-use spaces with retail, commercial, office and residential uses incorporating a suitable walking network. The proposed intra-island connector road has the aim to relocate the main traffic axis to improve the quality of the waterfront and allow to connect the historical central part with the waterfront (Arup, 2015f). The area spans over 23 hectares and is planned in five phases, including further land reclamation (see figure on the left).

The project wants to increase the water circulation of existing lagoons and the water in the Hodoul Bay by connecting them with two canals (Arup, 2014; Low and Felix, 2019). As communicated verbally by the SPA[20], planning phase one is already well progressed and the social and environmental impact assessment is awaited.

Financial district

Figure 14: Concept plan of the financial district (Low et al., No date-a, p. 19).

In the financial district, mixed uses with attractive office spaces, as well as residential areas and cafés should be created (Arup, 2015f). The focus lies in a pedestrian-friendly area with Creole architecture and open space. Sidewalks with trees and public seating are proposed on both sides of the river (Low et al., No date-a). The masterplan and concept plan have already been approved (see Figure 14). However, it has been criticized that a proper connection towards the market is missing and the reconfiguration of plots should be taken into consideration to get more open space (Arup, 2015e).

Old town

The aim is to provide high-quality streets and public spaces by incorporating cultural and heritage assets of Victoria. Some suggestions include to change the existing car park next to Freedom Square into a public space and the Freedom Square itself into a world-class park. Additional improving of beverage and food, entertainment and cultural offers will lead to a vibrant capital (Arup, 2015f).

Transport network

An improved slow-traffic network (cycling and walking) is the target. The proposed relocation of the bus station to a northern and southern station, while the previous one is being abolished, is already out of date. Discussions at the SPA[21] have shown that a reduction, but not a complete closure of the existing bus station is desired (Arup, 2015f).

[20] Conversation with Low, J. on 21/05/2019

[21] Conversation with Low, J. on 21/05/2019

2.2 Detailed assessment of rivers in Victoria

In this chapter, the state of the rivers is examined in detail using morphological, planning and sociocultural criteria. For this purpose, an evaluation system tailored to Victoria was designed.

2.2.1 Aim of the method

Rivers in urban areas have great potential to take on ecological, social and water management tasks, which must first be identified and used (Renner et al., 2017). The aim of the method is an orienting assessment of the naturalness and recreational value of current running rivers and their surroundings in Victoria. The focus is on the clear and comprehensible recording of the water status and its deficits. The consideration of adjacent land use provides the basis for further spatial planning activities and improvement measures. Sociocultural characteristics cover especially the features, which are important for recreation and clearly demonstrate their deficits. As an objective and systematic evaluation of the present situation, together they form the basis for decision-making processes, to define development areas and goals and to plan suitable measures.

2.2.2 Description of the method and procedure

Urban rivers are exposed to some threats and conflicts of interest as shown in chapter 1.4.2. Precise knowledge of the condition of water bodies is needed to ensure comprehensive protection (Göggel and Wagner, 2006). An appropriate assessment system is essential for the identification of river deficits, the assessment of development potential, the targeted and successful planning and monitoring of river development projects. With the success monitoring, even small improvements and upgrades show that, even under high anthropogenic pressure of use in urban areas, the river segments can fulfill ecological and sociocultural tasks (Göggel and Wagner, 2006; König, 2011).

An assessment system assesses the structural status of water bodies and evaluates the deviation from the natural status of a river on a predefined parameter system. Based on the evaluation, measures can be derived to get improved river conditions (LANUV, 2018). To get an appropriate assessment of the physical condition of the rivers in Victoria, a consultation of different methods has been made. The physical habitat is a useful element for the assessment of the river as it represents the link between the physical environment and its inhabitants (Maddock, 1999). The creation of a suitable rating system is largely based on the three existing systems: Swiss methods of "Ecomorphology[22] level F (regional)" (Hütte and Niederhauser, 1998) and "Ecomorphology level S (system scale)" (Göggel and Wagner, 2006) as well as the German method "Anleitung für die Strukturkartierung Kleiner urbane Fliessgewässer" (Renner et al., 2017).
Since the Swiss assessment methods are successfully applied methods and easy to use, they have been chosen for this master's thesis.

[22] Ecomorphology means the totality of structural conditions in and around water bodies. More precisely, the structure of the channel, river bed and riparian area as well as the networking of watercourses (Göggel and Wagner, 2006)

They evaluate physical river characteristics of small and medium-sized rivers in flat areas using short segments for the evaluation (Hütte and Niederhauser, 1998; Göggel and Wagner, 2006). The German assessment concentrates on urban rivers and their sociocultural aspects, which is a rarity among river evaluation methods. This is the reason why it is taken as further basis for the assessment.

The procedure of the assessment is shown in Figure 15 and is explained in more detail below. It should be noted that the whole chapter is a complete analysis of the current river state and no further comments are made. The evaluation criteria have been derived from the methods mentioned above and are listed on a standardised data form (see Appendix N and Appendix O). A selection of representative characteristics and conditions within and in the immediate vicinity of the rivers has been taken. Some parameters of the three methods needed an adaption to local conditions and were changed accordingly. A few necessary features of other evaluation systems were included for the assessment. Certain characteristics are listed on the data form but were not further consulted in the standardized evaluation process (marked grey in Appendix N and Appendix O). Nevertheless, they contain useful information and can be included in the evaluation in a descriptive way. These evaluation criteria can be classified into morphological, sociocultural and planning aspects, as well as building constructions and falls. More detailed information can be found in chapter 2.2.4. Once the data have been collected, the information is further processed for the analysis.

The result of the method is a clear presentation of the current physical condition of the six rivers in Victoria with regard to social, cultural and ecological assessment points. The consideration of the rivers is limited to areas, where action is needed. The endpoint of the data collection for the assessment was dependent on the multiple factors accessibility, usefulness, condition and characteristics of the rivers. In most cases, the rivers in these regions become narrower, the gradient increases, the adjacent land becomes private, the alignment changes and structural measures on the bank decrease. These were clear separation characteristics. For example, once the river became inaccessible and private land was adjacent, no further investigation was carried out, as it does not contribute to the basic objective of the work. The analysis of the river is determined in all conscience on the basis of the accessibility, respectively approachability and visual approach to conduct the analysis.

The analysis is divided into the parts: Closeness of nature, deficit analysis and sociocultural analysis. In short, the closeness to nature assessment is based on the method "Ecomorphology level F", while the deficit analysis is based on the method "Ecomorphology level S". The deficit analysis is further divided into the analysis of the structure, the aquatic environment and the longitudinal cross-linking. The sociocultural analysis is based on a part of the German method.

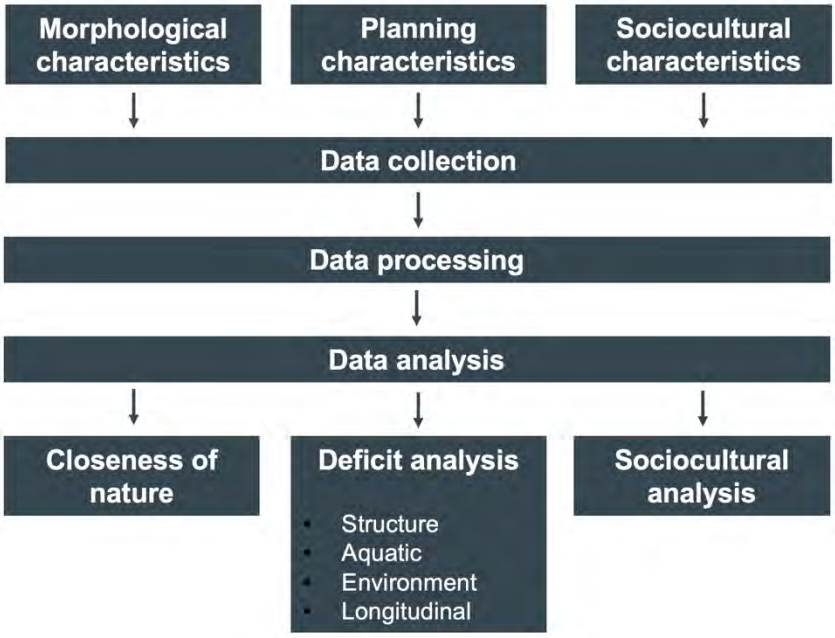


Figure 15: Procedure of the river assessment.

2.2.3 Implementation of the method

Using prepared data forms (see Appendix N - Appendix P), the relevant characteristics have been recorded and documented during several on-site inspections. Before the actual mapping, a test mapping was carried out to check the raw version of the data form and make any necessary changes. A 1:5'000 scale map was taken for the on-site inspection for orientation and recording of important features. In addition, a GPS was used to store the coordinates of the river sections, building structures, falls and water samplings. The data was transferred afterwards to ArcMap from Esri's ArcGIS. Some coordinates had to be entered manually because either the accessibility to the place was not given or the GPS showed an error message.

The assessment of the river sections is upstream, starting at the lagoon. It was carried out during low tide in order to better identify all the relevant river structures. The water body is divided into several segments depending on the characteristics, whereby these characteristics stay the same within a segment. "Left" and "Right" is always considered in flow direction (Hütte and Niederhauser, 1998). Width and length measurements were carried out with a laser measuring device.

It was challenging to find a suitable reference condition for the evaluation, as most of the flat part of Victoria is reclaimed land and thus the course and characteristics of the rivers are often manmade. A natural river section would occur after the abandonment of existing uses and the removal of all structures (LANUV, 2018). This condition is not to be fully achieved, but it gives an indication in which direction the development should go (Göggel and Wagner, 2006).

For the reference state, a natural stretch of water with a small to very small gradient was taken near the sea. A suitable place was found in Port Glaud/Grand Anse on the western part of Mahé. Two different, naturally occurring rivers states can be taken as a reference. In the area of influence of seawater, the reference condition is considered as the one showed in Figure 16, in the area in which only freshwater occurs, the reference condition was determined as the one illustrated in Figure 17.

Figure 16: Natural flowing waterway in the influence area of salt water (Grand Anse, own source, 14/04/2019).

Figure 17: Natural flowing river in only freshwater environment (Port Glaud, own source, 14/04/2019).

2.2.4 Evaluation criteria

The evaluation criteria consist of features that support the aim of this thesis and can be collected with the available equipment to assess the rivers. For a classification of the river section, metadata has been collected (see both following chapters). Morphological, planning and sociocultural characteristics are mentioned in the subsequent chapters. The rivers in the urban area flow to a large extent on reclaimed land and lie right around sea level. This results in the influence of the tides, which must be taken into account accordingly for some characteristic expressions.

2.2.4.1 General information

General information is specified in the header of the data sheet. The river name, the person carrying out the river assessment and the date of the survey are recorded. This must be entered since only in this way a unique assignment of the data form to the valuation of the respective river segment can be made (Renner et al., 2017).

2.2.4.2 Segment information

A segment is considered as a river section in which the characteristics remain the same. A new segment begins when at least one characteristic strongly changes its expression. Each segment is given a name and a number. The start and end of each segment are recorded using GPS coordinates. The name of the segments is composed of the letter S followed by either the first or the first two letters of the river's name. The effective length of a segment was determined in ArcMap. The minimum length of one segment is 20m. The exception is the crossing of larger roads (5th June Avenue, Albert Street and Quincy Street), where the delimiter is set at 15m. The distance of 15m is taken to cover only main roads and not smaller roads. Another reason is that some features change markedly from one side of the street to the other, whereby the street acts as a separator. A culverted river section of less than 20m is considered as a passage and is listed on the table of building structures.

2.2.4.3 Morphology characteristics

Bed width

The bed width is the average width of the river bed within a section and thus serves as a rough indication of the river size and its space requirements. The bed width corresponds to the distance between the left and the right riverbank base. It is usually rearranged during flooding in a natural river and thus free from higher land plants (see Appendix Q). The water level width and the bed width need not necessarily be the same. An average value of the bed width must be estimated if it varies (Hütte and Niederhauser, 1998). If possible, the laser measuring device was used to measure the distance. The distance measurement function in GIS is used to check the data of the laser measuring device and to measure the distance at points where the laser could not be used. The width is specified with a value rounded to 50cm.

Alignment

The characteristic alignment describes the curvature of the river. This has been analysed according to the two options stretched or curved (see Table 5), whereby the curved water course represents the reference state. Stretched watercourses have a changed bedload balance, stronger depth and bank erosion and in many cases it is no longer possible for them to restore these natural structures (LANUV, 2018). This criterion is an additional characteristic, which has been collected but not directly included in the standardized evaluation. It is already indirectly included in the water level width variability.

Table 5: Condition characteristics of the river course (LUNG M-V, 2014).

Feature	Description
	Stretched: The river course in the segment is straight and channel-like.
	Curved: The river course in the segment is a slight regular or irregular lateral oscillation of a slightly to moderately curved baseline.

Culvertisation

Figure 18: An example of a culverted river segment (La Poudrière River, own source, 10/03/2019).

Culvertisation means the complete coverage of a river segment. As explained in chapter 2.2.4.2, the river segment needs to be 20m at least (large roads are an exception). If they are shorter, they are listed in the table of building structures (see chapter 2.2.4.6). No further characteristics are collected for a culverted segment. A culverted river section is depicted on the left.

Profile shape

The cross-sectional profile of the water body is recorded on the basis of three categories: natural, trapezoidal and box-shaped (see Table 6). This is an additional characteristic that has been collected but not directly included in the standardized evaluation. Indirectly, it is already included in the water level width variability.

Table 6: Categories of profile shape (LUNG M-V, 2014).

Profile shape type	Description	Sample image
Natural	The river bed basically corresponds to the natural state of the river and is not influenced by hydraulic engineering or water maintenance work.	 Source: Own source (English River, 14/03/2019).

Profile shape type	Description	Sample image
Trapezoidal	The river bed is equipped with an artificial, trapezoidal cross section, usually made out of stone or concrete.	 Source: Own source (Rivière Maintry, 10/03/2019).
Box-shaped	The river bed is equipped with an artificial, rectangular cross section, usually made out of stone or concrete.	 Source: Own source (Rivière Maintry, 15/04/2019).

Water level width variability

This characteristic represents the change of the water level width within a segment. The water level is the flooded area of the river at medium water level. The structural diversity of the bed and the water-land interconnection can be indicated by the water level width variability, whereby a large width variability is usually associated with a good water-land interconnection, a large depth variability, a large flow diversity and a large bed particle size distribution, resulting in a high number of species (Hütte and Niederhauser, 1998). The situation at low tide was considered in order to assess the variability in water level width and can be divided into the three categories shown in Table 7 or Appendix R.

Table 7: Categories of water level width variability (Hütte and Niederhauser, 1998).

Water level width variability	Description	Sample image
None	Parallel running shorelines with very little to no water level width variability.	 Source: Own source (La Poudrière River, 10/03/2019).
Limited	Strong straightening of the shoreline with rare changes of water level width, small bulges without great effect on the flow pattern.	 Source: Own source (Rivière St. Louis, 17/03/2019).
Pronounced	Major water level width variability with varying flow pattern.	 Source: Own source (Rivière Trois Frères, 14/04/2019).

River bed construction

This feature evaluates the extent of the artificial construction of the bed in order to stabilize it. Large-scale river bed structures are serious interventions in the ecological functioning of a water body. The structure gets lost, the bedload is no longer rearranged and exchange of river water with groundwater is no longer guaranteed. The extent of construction is estimated according to the percentage of the obstructed area and divided into six categories (see Table 8) (Hütte and Niederhauser, 1998). Since the effective subsoil is often covered by sand or other material, it is difficult to estimate the extent of the construction. Two categories of river bed construction are shown in the figures below.

Table 8: Categories of construction of bed (Hütte and Niederhauser, 1998).

Construction of bed	Specification
None	Bed is free from every construction
<10%	Punctual constructions
10 to 30%	Moderate constructions
30 to 60%	Large construction
>60%	Dominant constructions
100%	Complete constructions

Left
Figure 19: Example of large construction of bed with impermeable material (Rivière Moussa, own source, 14/04/2019).

Right
Figure 20: Transition between complete bed construction and a natural river bed in the Rivière Moussa, also applicable to English River, Rivière Maintry and St. Louis (Rivière Moussa, adjacent to the lagoon, own source, 20/04/2019).

Material of river bed construction

The knowledge about the type of material of river bed construction serves for the assessment of ecological effects, water maintenance activities or for renaturation projects. For this assessment, the categories none (no constructions, see the lowest picture in Table 7), impermeable (mostly concrete, see Figure 19) and loose pipes (large visible sewage pipes, see Figure 25) was used (Hütte and Niederhauser, 1998).

Bed substrate variability

The expression of this criterion contributes greatly to the natural structural diversity within the water body. Diverse habitats arise when these characteristics exhibit a large degree of variability. Especially a heterogeneous substrate is of great importance for many aquatic organisms. The presence of rapids and scours ("pools") can be used as assessment criteria (Göggel and Wagner, 2006). However, for the assessment a distinction must be made between the two states of pure fresh water and the sphere of influence of salt water. Considering the reference state, this characteristic is very pronounced in the pure fresh water area (see Figure 17) but classified as low in the shallow saltwater area (see Figure 16). The characteristic is classified either as limited or pronounced. In the limited state, the substrate diversity is uniform and has only minor local differences. In the pronounced state, the substrates change strongly and show clear local changes.

Flow variability

Like the characteristic mentioned above, flow variability also contributes to the structural diversity of habitats (Göggel and Wagner, 2006). Very shallow stretches of water without large inclination, such as those present in the saltwater sphere of influence, exhibit a low flow variability by nature. However, in the pure freshwater influence area the flow variability is considered as very high. The characteristic is divided into either low, moderate or high (see following figures). Low considers the state of a uniform water surface without large differences. In the moderate state, the water surface changes the flow velocity, but the current diversity is mostly low. In the high flow variability state, the change of the water surface and the current diversity is large (LANUV, 2018).

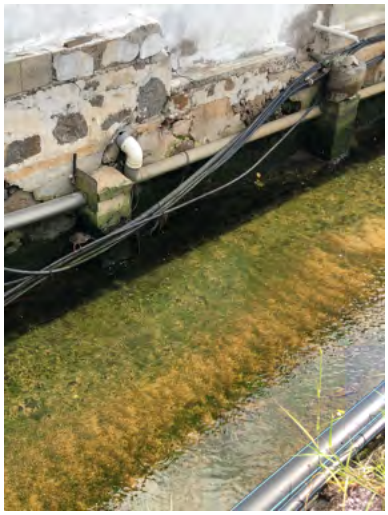


Figure 21: Low flow variability (Rivière Maintry, own source, 10/03/2019).

Figure 22: Moderate flow variability (Rivière St. Louis, own source, 17/03/2019)

Figure 23: High flow variability (Rivière St. Louis, own source, 10/03/2019).

Bank base construction, material and condition

This criterion evaluates the extent of the artificial construction of the bank base in order to stabilize it. The transition between the bed and the bank in a natural river system is understood as the bank base. The construction of the bank base serves as a prevention of lateral erosion and to fix the watercourse (Hütte and Niederhauser, 1998). Particularly in urban areas, the bank base is of central importance, as it can be rich in structure, even if space is very limited. If possible, such transition zones should be flat and unobstructed. A narrow, flat bank base with a life structure or even rockfill can fulfill important functions in the transition zone of terrestrial and aquatic environments (Renner et al., 2017). From an ecological point of view, impermeable and even structures are disadvantageous as they impair the exchange between the river and groundwater. In order to assess the degree of construction, the percentage share of the built-up area is estimated for both the left and right bank sides (see Table 9). The material of the bank base is divided into the two categories impermeable and permeable. The current condition of the bank bed is divided into the categories poor, medium and good on the basis of a visual assessment (see Figure 24 - Figure 26) (Hütte and Niederhauser, 1998). In the case of shoreline structures in poor condition, the first priority should be to ensure that the riparian area is sufficiently wide rather than to replace it immediately (Göggel and Wagner, 2006).

Table 9: Categories for construction of bank base (Hütte and Niederhauser, 1998).

Construction of bank base	Specification
None	Bank is free from every construction
<10%	Punctual constructions
10 to 30%	Moderate constructions
30 to 60%	Large constructions
>60%	Dominant constructions
100%	Complete constructions

Figure 24: A permeable bank bed in a poor condition (Rivière Maintry, own source, 14/04/2019).

Figure 25: A bank bed in medium condition (English River, own source, 13/04/2019).

Figure 26: An impermeable bank bed in a good condition (English River, own source, 18/04/2019).

Bank height

The bank height is another feature, which is not directly included in the standardized evaluation. In order to avoid the influence of the tides, the height was estimated from the river bottom directly adjacent to the wall. A wall is the most common form of bank design in town. If an additional wall borders directly on the riverbank, it is added to the bank height. The determination of this characteristic serves to estimate future planning possibilities and provides an additional point of reference for the evaluation of sociocultural characteristics. The height is specified with a value rounded to 50cm.

Riparian width and area character

The riparian width is understood as the mean width of the riparian area within a section. The riparian area is regarded as the area above the bank base until the border of intensive land uses such as paths or roads, buildings, intensive agriculture, etc. (see Appendix S). This is the area available to the water body in independence to its ecological quality. Land areas directly adjacent to the water are of particular importance for water ecology, which are flooded in the event of high water and can, therefore, be subject to intensive water-land exchange (Hütte and Niederhauser, 1998). Rivers naturally do not have rigid bank lines. The lateral range of motion must be large enough for natural running and profile development. If these areas are not sufficiently available, ecologically intact rivers can no longer be created (LANUV, 2018). The riparian area can only fulfill its natural function if it is free of any use, sufficiently wide and with typical local vegetation (König, 2011). It can function as a separate habitat from a width of 15m and upwards. The area is further important for the scenery, as a buffer zone between terrestrial and aquatic habitats, for water body structure, dynamics and biology and for the recreational value of a river (Renner et al., 2017). Since these factors are difficult to find in urban areas, a desirable condition has already been achieved with a narrow bank area (König, 2011). For this reason, the width of the bank up to 5m is assessed, which corresponds to the minimum bank width to ensure minimum ecological functions and flood protection (Göggel and Wagner, 2006).

An average riparian area width is estimated when the riparian area varies. If a (vertical) wall is adjacent to the river, the riparian area width is considered as 0m and therefore no riparian area exists. The left and right side of the river is always considered separately. The evaluation of the riparian area is based on its area size, which is rounded to an exact 50cm value. This is divided into the categories sufficient, insufficient and no riparian area (Hütte and Niederhauser, 1998). Sufficient is the width of 5m and a width between 1-4m is regarded as insufficient.

The vegetation on the banks provides information on the pressure of use and the development of the water body (LANUV, 2018). The subdivision of the riparian area character is made into three vegetation categories: None, artificial and natural (see Figure 27 and Figure 28) (Hütte and Niederhauser, 1998).

Left

Figure 27: Natural flowing river through private property with artificial riparian area (Rivière Maintry, own source, 18/04/2019).

Right

Figure 28: Riparian area with natural and abundant vegetation (Rivière Trois Frères, own source, 14/04/2019).

Further channel structures

Figure 29: Further channel structure (gravel accumulation) in Rivière Moussa (own source, 27/03/2019).

Other structures, such as gravel accumulations in the middle of the body of water or at the edge, further contribute to the diversity and structures of habitats. The classification in the assessment system was made on the basis of missing or available. In the reference state, these structures are present. An example is shown on the left.

2.2.4.4 Planning and additional characteristics

Pipes

Most of the rivers of Victoria are equipped with many utility lines, mainly for sewage and water supply. The pipes in the river are not only unaesthetic, they affect the flow dynamics of the river as well and can also be a major source of pollution. Sewer pipes, in particular, can leak and pollute the water.

Pipelines can block wood and other objects (e.g. waste), especially during high water, which can lead to flooding. In addition, the presence of pipes, especially those inside the water, poses major problems during maintenance work such as de-silting processes (statement of CAMS[23]). The data form distinguishes between longitudinal and transverse pipes. A further distinction is made between no pipes, inside the water and outside the water. Longitudinal pipes are further divided into left, right and central. For transversal pipes, the first number gives the position (inside or outside the water) and the number in brackets the number of pipes. If they are bundled, they are recorded as one pipe but listed on the form for building structures where the size is mentioned. If longitudinal pipes are embedded in concrete on the ground, it was added to the criterion of construction of river bed and was not rated as a pipe again. Transversal pipes from a diameter of approximately 30cm were listed again in the building structures as they are larger point structures. Pipelines below a bridge or a culvertisation were not considered, as they are often difficult to recognize. Pipes are only taken up from a diameter of approximate 5-10cm. For smaller pipes, it is assumed that they can be transferred easily and the influence on the river is comparatively small. Different arrangements of pipes are demonstrated in the pictures below.

Left
Figure 30: One central laying clear visible loose sewage pipe (English River, own source 13/04/2019).

Right
Figure 31: Unused pipes on a scaffold along the right side of the Rivière Moussa (own source, 10/03/2019).

Left
Figure 32: Large accumulation of pipes with concrete structures on the left side of the Rivière Moussa (own source, 10/03/2019).

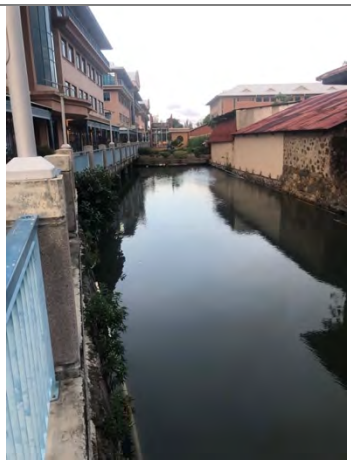
Right
Figure 33: Many possible characteristics of pipes united at one point (Rivière Maintry, own source, 14/04/2019).

[23] Personal meeting with Pillay, S. on 15/03/2019

Tidal influence

As already mentioned, the rivers are influenced by saltwater intrusion in the area of land reclamation. This characteristic is used to assess whether the water is in the tidal range or not. On the one hand, this is important for the water level in the water body and thus for other planning aspects, but on the other hand, other characteristics depend on the condition of this feature. For example, the variability of the flow in the area without influence is very large, while in the influence area it can be classified as rather low. The difference from the maximum water level (flood) varies over the day by only a few 10cm (Seychelles Meteorological Authority, 2019). In addition, the water level or the area of influence can be read off well at the riparian area or the wall. Therefore, a section can be clearly categorized into either in the influence of tidal range or not (see table below).

Table 10: Examples of low and high tide.

Name	Low Tide	High Tide
La Poudrière River		
	Difference between low (left, 17/03/2019) and high tide (right, 18/04/2019) (La Poudrière River, own source).	
Rivière Moussa		
	Difference between low (left, 18/04/2019) and high tide (right, 21/04/2019) (Rivière Moussa, own source).	

Name	Low Tide	High Tide
Rivière St. Louis		
	Difference between low (left, 20/04/2019) and high tide (right, 22/03/2019) (Rivière St. Louis, own source).	

Predominant surrounding land use

As already mentioned, an exchange between waters and adjacent land is important. Unfortunately, this exchange is no longer present in urban areas because the environment has lost its naturalness (Renner et al., 2017). This criterion records the use of the land adjacent to the water body. A distance of 5m is considered on both sides of the river. The recording of this characteristic serves primarily to record the current state of the surrounding area in order to estimate the further procedure or potential of future uses. These were divided into nine categories (street, parking area, building with or without open space, pedestrian walkway, green space, brownfield, natural vegetation and others) and are listed in the following table. The category "building with open space" was assigned if the building has a minimum distance of 5m to the water. If this distance is less, it was judged to be building without open space.

Table 11: Type of surrounding land use.

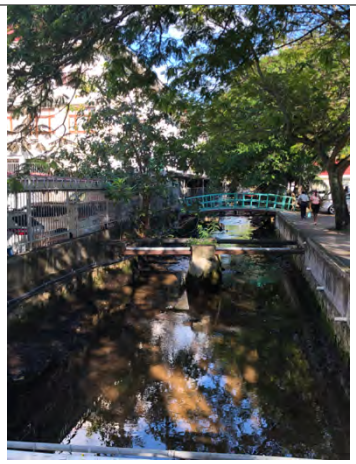
Type of surrounding	Picture	Type of surrounding	Picture
Parking area and buildings without open space next to the river		Brownfield	
	(Rivière Maintry, own source, 10/03/2019).		(Rivière Trois Frères, own source 14/04/2019).

Type of surrounding	Picture	Type of surrounding	Picture
Example of regular planted trees with a pedestrian path along the river on the left side	 (Rivière St. Louis, own source, 10/03/2019).	Green space (park) on the right side of the Rivière Maintry	 (Rivière Maintry, own source, 10/03/2019).
Adjacent street on the left side of the Rivière Maintry	 (Rivière Maintry, own source, 24/05/2019).	Buildings with and without open space	 (Rivière Moussa, own source, 10/03/2019).
Natural vegetation on both sides of the river	 (La Poudrière River, own source, 18/04/2019).		

Shading of channel

The balance between shade and sun also has an influence on habitat quality. Depending on the degree of shading, solar radiation is influenced, which in turn has an effect on water temperature and plant growth (Renner et al., 2017). For the assessment of this criteria, three categories are given: shady, semi-shady and sunny (see Table 12). A semi-shaded area is one where only one side of the shore is shaded or where a rapid change between sunny and shady areas occurs. For the assessment, the dominant state is recorded in each case. The reference state can generally be assumed to be shady. In shallow areas, where salt water has an influence, semi-shady areas are also present. No natural condition shows extensive sunny sections.

Table 12: Type of shading of channel.

Type of shading	Picture	Type of shading	Picture
Shady channel	 (Rivière St. Louis, own source, 24/05/2019).	Shady channel	 (Rivière St. Louis, own source, 15/04/2019).
Semi-shady channel	 (La Poudrière River, own source, 10/04/2019).	Sunny channel	 (English River, own source, 18/04/2019).

Trees

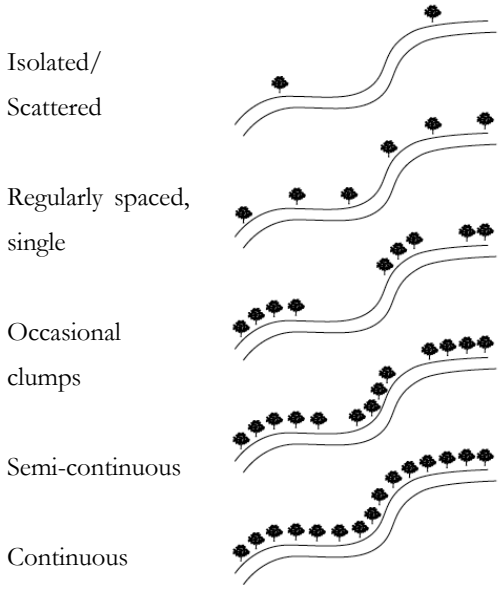


Figure 34: Categories for tree arrangement (SEPA et al., 2003).

Trees along a river increases the attractiveness of the place. The evaluation of this criterion is based on the different tree arrangement categories showed on the left. This characteristic has no direct influence on the standardized evaluation system, as it already indirectly influences the degree of shading. Nevertheless, knowledge of the current situation may be relevant, for example for planning measures.

Aquatic vegetation (Algae and aquatic plants)

The natural state of rivers is generally free of any vegetation, except in mangroves, which grow on the edge of the river course or even in it. The vegetation assessed under this criterion does not refer to higher aquatic plants (e.g. mangroves). Different factors can influence the presence of aquatic vegetation, such as solar radiation or water quality (LANUV, 2018). The presence of aquatic plants, in turn, can alter the structure and flow within a water body and could be a disruptive factor in water maintenance work. On some parts of the river, algae can be found, sometimes even in lush vegetation. This criterion is divided into none, present and abundant aquatic vegetation (see following figures).

Left
Figure 35: Rivière Maintry with present vegetation and a bird chasing fish (own source, 18/04/2019).

Right
Figure 36: Rivière Maintry with abundant vegetation between and adjacent to buildings without open space (own source, 18/04/2019).

Surrounding vegetation

Figure 37: Rivière Maintry with abundant vegetation on the left side and present vegetation on the right side (own source, 10/03/2019).

Naturally, bank areas have a lot of vegetation consisting of forb, shrubs or copses, which not only stabilizes the banks but also shades the water or offers a habitat for various creatures (Renner et al., 2017). The natural vegetation is no longer present in many places in urban areas. Although this characteristic is not directly included in the standardized evaluation, as it already indirectly influences the degree of shading, it is collected for additional information. For assessment purposes, the criterion was subdivided into three forms: None, present or abundant (see Figure 37).

Solid waste

Looking at the rivers in Victoria, it is noticeable that most sections of the rivers show waste. The type of waste ranges from PET bottles, take-away boxes and aluminium cans to umbrellas and even car batteries. Such items have no place in a river. Certain things, such as car batteries, can be a serious danger to river creatures. The classification of waste is divided into three parts: none, present and abundant as shown in the following pictures.

Left

Figure 38: La Poudrière River showing the categorization present with a car battery as an example (own source, 13/04/2019).

Right

Figure 39: English River showing the categorization abundant amount of solid waste (own source, 13/04/2019).

2.2.4.5 Sociocultural characteristics

The integration of rivers into the urban space can be done by using sociocultural characteristics. They also serve to assess the possibilities of using and perceiving water bodies for recreational and leisure purposes. The below explained sociocultural characteristics are based on the three parameters accessibility, approachability and quality of stay (König, 2011; Renner et al., 2017).

Accessibility

Good accessibility of a river is the basic prerequisite for its use and stay. This depends on the one hand on the accessibility by car or public transport and on the other hand on the availability of a path network for pedestrians or cyclists in the immediate vicinity of the river. Whereas the highest possible density is desirable for the path network, this is not necessarily the case for car parks and public transport stops, as this reduces the aesthetics of the river and/or increases noise pollution. The reference condition is a very easily accessible water body which has a path network, is close to car parks or a public transport service is very easily accessible (König, 2011; Renner et al., 2017). Each bank side was rated separately. The categorization of accessibility can be found in the following table.

Table 13: Categorization of accessibility (based on König, 2011; Renner et al., 2017).

Feature	Description	Index
Excellent	Both a continuous public path network and a good connection to the public transport and/or car is given	1
Good	At least partly a public path network exists and a public transport stop or a parking lot is nearby	2
Restricted	The network of paths only leads to the water at certain points OR a continuous public path network exists but no public transport connection and/or car park nearby	3
Bad	Pedestrians and cyclists can only reach the river via unsuitable areas	4
None	No access to the water	5

Approachability

Figure 40: An example of an excellent accessible but not approachable river segment (Rivière St. Louis, own source, 10/03/2019).

This parameter measures the possibility of a direct physical contact with the water and should not be confused with the parameter accessibility, which characterizes the access to the river. Approachability is a prerequisite for water activities such as swimming or kayaking and essentially depends on the bank design regarding slope angle, shoring or artificial access. The reference condition is a possible direct contact with the river without significant obstacle. Stairs or shallow banks providing access to the river (König, 2011; Renner et al., 2017). Each bank side was rated separately. An example of a not approachable river segments is illustrated on the left. The categorization of approachability can be found in the following table.

Table 14: Categorization of approachability (based on König, 2011; Renner et al., 2017).

Feature	Description	Index
Direct	Direct contact with the water without any obstacles is possible and can be facilitated by stairs or flat banks	1
Restricted	Approach is possible at a reasonable cost and without significant obstacles OR throughout approach is not possible but is guaranteed by several accesses	2
Difficult	Approach is possible in principle, but only at a more difficult cost; the water body is inaccessible in principle and access possibilities are only provided in a few places; fences, low walls, bushes or steep banks make approachability difficult	3
Unapproachable	No approachability or the effort and/or the risk of accident is too high; e.g. wall with a fence, high wall, house directly next to the waterfront	4
None	The river flows underground or below buildings	5

Quality of stay

How often and for how long people like spending their leisure time near the water is judged by the quality of their stay. The reference condition is a location with a high quality of stay, whereby the disturbance factors are clearly lower compared to the elements promoting the stay. The quality of stay is assessed by factors of urban integration as well as the characteristics of the river's amenities (see Appendix T). Positive factors that increase the quality of your stay include e.g. peace and quiet, sanitary facilities, natural diversity and a beautiful view of the water. Negative factors are e.g. noise, smell, mosquitoes or poor water quality (König, 2011; Renner et al., 2017). The categorization of quality of stay can be found in the following table.

Table 15: Categorization of quality of stay (based on König, 2011; Renner et al., 2017).

Feature	Description	Index
Very high	Many positive factors are present, some few negative factors may be present	1
High	Positive factors outweigh the negative ones	2
Medium	There are about as many positive as negative factors	3
Low	Negative factors outweigh the positive ones	4
None	A stay at the water is not possible, e.g. because of directly adjacent houses or private properties	5

2.2.4.6 Continuity barriers

Longitudinal cross-linking is particularly important for aquatic organisms and can be interrupted by continuity problems such as vertical falls or other building structures. The aim is to provide longitudinal connectivity from the mouth of the river to the first natural expansion barrier (Hütte and Niederhauser, 1998).

Building structures

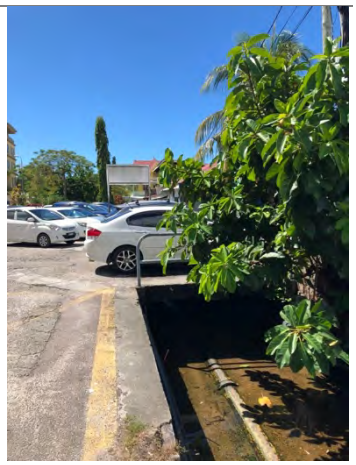
Figure 41: Small picnic area above the river illustrating the clear height, width and length of an object (Rivière Moussa, own source, 10/03/2019).

Passages change the light and flow conditions in the river, while the river bed is usually obstructed without any natural substrate. The barrier effect is essentially dependent on the design of the passages. The structures are passable without restriction if all organisms can cross the obstacle without problems, which depends on the water depth, flow velocity and the continuity of the river bed. The water depth and flow velocity were not recorded as these were not classified as restrictions in the area of Victoria (König, 2011). As building structures, all punctual structures that cross the water bodies or otherwise influence them are recorded. This includes, for example, pedestrian bridges, large crossing lines or parking areas (see Table 16 and Appendix P). Even if certain objects do not represent barriers to propagation, they are recorded in order to store the information and to consult it for further measures, e.g. as development restrictions in the case of planning interventions. The recording of building structures (name) is composed of the letter B followed by either the first or the first two letters of the river's name. The building structures are registered as points and are recorded by GPS and subsequently displayed on a map. The type of building structure was divided into six different classes and included in the data form accordingly. Other characteristics recorded for each object were the clear height (Ch), the length (L), the width (W), the continuity of the substrate and if the object is overflowable (see Figure 41, Figure 42 and Appendix P).

Figure 42: Example of a non-continuous bed substrate beneath a road (Rivière Moussa, own source, 14/03/2019).

The clear height is considered as the distance from the ground to the lower edge of the construction (Göggel and Wagner, 2006). However, the water level in the tidal range has a simplified assumption of approximately 1m distributed over the day (JICA and MEE, 2013; Seychelles Meteorological Authority, 2019). This means that in order to evaluate the criterion of continuity disturbance, one meter must be subtracted from the height of fall collected in order to obtain a correct result. If the object lies in the water, this is marked with the clear height 0m. The height and length are estimated exactly to 50cm. The width is only specified if the object influences the cross section respectively the flow regime of the river, e.g. has a pillar or narrows the course of the river from the side (lateral constriction) (see Table 17). The form of expression "in water" refers to the pillar and "side" to the lateral constriction, whereby both specifications are given in brackets. Many pillars have a pedestal on the ground. This value was recorded for the width measurement. A value of 0m indicates that the object does not influence the width of the river. The substrate does not have to be continuous in all diffusers. Some passages also have concrete as a bed covering (see Figure 42) (Göggel and Wagner, 2006).

Table 16: Type of building structures.

Type of building structures	**Picture**	**Type of building structures**	**Picture**
Road	 (Rivière Maintry, own source, 24/05/2019).	Car parking	 (Rivière Maintry, own source, 24/05/2019).
Pedestrian bridge, pipes in concrete and massive sewage pipe (from back to front) which crosses the Rivière Moussa	 (Rivière Moussa, own source, 10/03/2019).	Bundle of transversal pipes	 (La Poudrière River, own source, 18/04/2019).

Type of building structures	Picture	Type of building structures	Picture
Building, Butcher's Grill, which has been built over the Rivière Moussa	 (Rivière Moussa, own source, 10/03/2019).	Large crossing pipe in concrete at the bottom	 (Rivière St. Louis, own source, 13/04/2019).

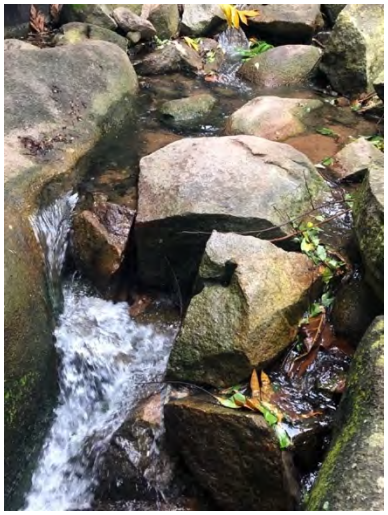
Table 17: Objects influencing the cross-section of a river.

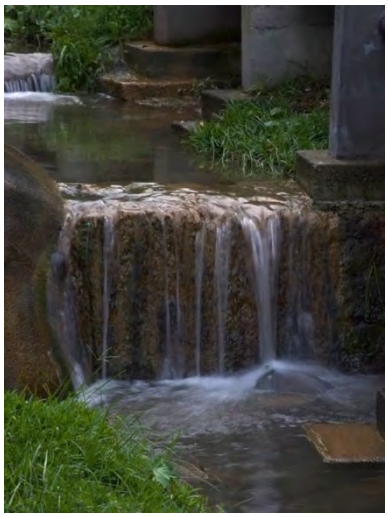
Object	Picture	Object	Picture
Side narrowing of the river due to a crossing street	 (English River, own source, 13/04/2019).	Pedestal with a smaller pillar on it	 (Rivière Moussa, own source, 14/04/2019).

Falls

The name of the falls on the data form is composed of the letter F followed by either the first or the first two letters of the river's name. The falls are also registered as points and are recorded by GPS and subsequently displayed on a map. The fall height is the distance between the two water levels (see Appendix U). A fall was recorded if it has a fall height of at least 20cm. Lower falls are not considered. However, it should still be attempted to remove these within the framework of water maintenance, so that the river is continuous for all organisms (Göggel and Wagner, 2006). Falls, where the tides have an influence, were only recorded if an offset exists during high tide. The accuracy of fall heights below one meter is 10cm, above one metre is 50cm. The falls were divided into three categories: Natural, artificial and unknown, whereby the type of material was divided into rock/stone and concrete (see Figure 43 and Figure 44).

In the hillier area, some natural falls occur in short succession. This circumstance is taken into account in a further "natural falls" category and assessed separately for each segment. In each case, the largest existing fall is recorded (Hütte and Niederhauser, 1998).





Left
Figure 43: Natural fall of about 30cm in height (English River, own source, 13/04/2019).

Right
Figure 44: Artificial fall of about 1m height (Rivière Maintry, own source, 19/05/2019).

2.2.5 Analysis

The analysis is divided into three parts: Closeness of nature analysis, deficit analysis and sociocultural analysis. The closeness of nature analyses is based on the morphological evaluation criteria explained first. The deficit analysis consists of a mixture of evaluation criteria and planning criteria, while the sociocultural analysis is based on the collection of the sociocultural characteristics.

2.2.5.1 Closeness to nature of the rivers

The aim is to obtain an easily understandable overview of the ecological status of a river segment, which can be clearly listed and evaluated on a map. Systematic and recurring data collection over a longer time series can show the development and change of the conditions of the river over time (Hütte and Niederhauser, 1998). The main features water level width variability, river bed construction, bank bed construction and riparian area are assessed on the basis of a point system. For the evaluation in the respective sections, each characteristic receives a score for closeness to nature, whereby the characteristic itself and its expression are weighted by the size of the score. For example, the degree of the river bed is considered to be more negative than the bank bed construction. The following table gives an overview of the point system (Hütte and Niederhauser, 1998).

Table 18: River feature classification and point system (based on Hütte and Niederhauser, 1998, p. 33).

Feature	Description		Points
Water level width variability	**Expression**		
	Pronounced		0.0
	Limited		2.0
	None		3.0
River bed construction	**Construction level**		
	None		0.0
	< 10%		1.0
	10 - 30%		2.0
	> 30%		3.0
Bank base construction	**Construction level**	**Permeability**	
	< 10%	Permeable	0.0
		Impermeable	0.0
	10 – 30%	Permeable	0.5
		Impermeable	1.0
	30 – 60%	Permeable	1.5
		Impermeable	2.0
	> 60 %	Permeable	2.5
		Impermeable	3.0
Riparian area	**Width**	**Quality**	
	Sufficient	Natural	0.0
		Artificial	1.5
	Insufficient	Natural	2.0
		Artificial	2.5
	No riparian area	-	3.0

Characteristics, which were assessed separately on both sides of the river, are evaluated individually, then the average was taken and rounded up to a whole number. The value of the sum of the points determines the category of the river segment. These are shown in Table 19 and range from natural to non-natural/artificial. Two further categorizations, culverted and not mapped river segments, are also listed. The individual river segments are then graphically displayed on a map in GIS. The scale is chosen in such a way that both the individual segments and other structural features can be distinguished and clearly displayed (Hütte and Niederhauser, 1998).

Table 19: Overview table for the classification of the river segments and the corresponding graphical representation (based on Hütte and Niederhauser, 1998, p. 34).

Total score	Category	Description	Graphical representation
0 to 1	I	Natural	Blue line
2 to 5	II	Little impaired	Green line
6 to 9	III	Strongly impaired	Yellow line
10 to 12	IV	Non-natural / artificial	Red line
-	V	Culverted	Dashed Red line
-	VI	Not mapped	Purple line

2.2.5.2 Deficit analysis

The deficit analysis can be divided into the categories structure, aquatic environment and longitudinal crosslinking. To assess the deficits, a reference condition is used that would occur on the island of Mahé without major human influence. Vel T.[24] mentioned two different states which can occur (see Figure 16 and Figure 17). These reference states serve to guide the development goals regarding ecological improvements. Classification I (no deficit) considers the reference state, whereby the water body is more and more affected by humans towards class V (very large deficit) (see Table 20).

Table 20: Classification of deficits (based on Göggel and Wagner, 2006, p. 21).

Deficit	Natural water properties and functions	Structure (river bed, bank base, channel)	Aquatic environment	Longitudinal crosslinking
I **No deficit**	Fully guaranteed (= reference state)	Natural characteristic and dynamic	Unused, natural morphohydraulics possible	Unimpaired
II **Small deficit**	Substantially guaranteed	Essentially natural characteristic and dynamic	Un- or extensively used, some morphodynamic processes possible	Slightly impaired
III **Moderate deficit**	Restricted	Partly natural characteristic	Insufficiently available, partly alien to the water	Moderate impaired
IV **Large deficit**	Severely restricted	Rudimentarily natural characteristic	Hardly available, alien to water	Severely impaired
V **Very large deficit**	No longer guaranteed	No natural characteristic, artificial	Non-existent or artificial	Very severely impaired
C **Culverted**	Culverted, completely covered segments			
Not mapped				

[24] Personal meeting with Vel, T. on 13/04/2019

Structure

River bed

In order to assess the deficits of the river bed structure, the degree of river bed construction and the material is used. The following table shows the related deficit class.

Table 21: Deficit river bed structure (based on Hütte and Niederhauser, 1998, p. 23).

I - II No – small deficit	III Moderate deficit	IV Large deficit	V Very large deficit
No construction of river bed	Construction of river bed <10%	Construction of river bed 10-30% or permeable construction of bed >30%	Impermeable construction of bed >30% and pipes as construction of bed >30%

For the evaluation, an undeveloped base is assumed as a reference, which is permeable and has a natural particle size distribution.

Bank base

In order to assess the deficits of the bank base, the degree of bank base construction and the permeability is considered (see table below).

Table 22: Deficit bank base structure (based on Hütte and Niederhauser, 1998, p. 24).

I - II No – Small deficit	III Moderate deficit	IV Large deficit	V Very large deficit
Construction of bank base <10%	Construction of river bed 10-30%	Construction of bank base 30-100% (permeable) or construction of bank base 30-60% (impermeable)	Construction of bank base >60% (impermeable)

Channel

A channel is understood to be the river bed, including the water body, through which water flows at an average water level. It is very important for habitat quality and habitat structures (Göggel and Wagner, 2006). The evaluation system was adapted to the circumstances and conditions on site. In total, six parameters are evaluated to assess the channel condition.

Firstly, the water level width variability should be in a pronounced condition as this would be the natural state of the river. Secondly, the characteristics flow and substrate variability also have an influence on the structural diversity of water bodies (Göggel and Wagner, 2006).

As already mentioned in the feature description, it is important to distinguish between the two states with (considered as brackish water) and without saltwater influence. The third criterion is further channel structures. The presence of aquatic vegetation is considered as the fourth criterion. A further criterion are the pipes which have various negative effects on the river system and which are distinguished into longitudinal and transversal pipes (see Table 23). For the evaluation, the worse value of the longitudinal and transversal pipes is taken in each case.

Table 23: Deficit of the channel structure (based on Göggel and Wagner, 2006, p. 27).

	I **No deficit** **(6)**	**II** **Small deficit** **(7-8)**	**III** **Moderate deficit** **(9-12)**	**IV** **Large deficit** **(13-15)**	**V** **Very large deficit** **(16-17)**
Water level width variability	Pronounced (1)	Pronounced (1)	Limited (2)	Limited (2)	None (3)
Flow variability	High for freshwater (1) AND Low or moderate for brackish water (1)	High for freshwater (1) AND Low or moderate for brackish water (1)	Moderate for freshwater (2) AND High for brackish water (2)	Moderate for freshwater (2) AND High for brackish water (2)	Low for freshwater (3) AND High for brackish water (2)
Substrate variability	Pronounced for freshwater (1) AND Limited for brackish water (1)	Pronounced for freshwater (1) AND Limited for brackish water (1)	Limited for freshwater (2) AND Pronounced for brackish water (2)	Limited for freshwater (2) AND Pronounced for brackish water (2)	Limited for freshwater (2) AND Pronounced for brackish water (2)
Further channel structures	Available (1)	Available (1)	Missing (2)	Missing (2)	Missing (2)
Aquatic vegetation	None (1)	Present (2)	Present (2)	Abundant (3)	Abundant (3)
Pipes	None (1)	Edge, outside water (2) OR Transversal, outside (2) OR Central, outside (2)	Edge, inside water (3)	Central, inside water (4) OR Transversal, inside (4)	Central, inside water (4) OR Transversal, inside (4)

The evaluation is carried out in five classes using Table 23. The value of the respective criterion is estimated in the field, whereby a specific numerical value is assigned to each field. The sum of these numerical values results in an overall value from which the overall structure of the water body is derived.

Aquatic Environment

The aquatic environment encompasses the channel, bank base and the riparian area (see Table 24). To assess the aquatic environment, the width and condition of the riparian area as well as the degree of shade are recorded. A fundamental prerequisite for the natural morphology of a water body is a sufficiently large riparian area. The reference condition is assumed to be a width so that the bank vegetation and the channel can form close to nature (Hütte and Niederhauser, 1998). As explained above, the reference state of a river is shady or even semi-shady for the brackish water area.

Since the area is reclaimed land in an urban environment with high pressure of use and the course of the rivers are artificial, the required width was modified and simplified as described in the method "Ecomorphology level S" (Hütte and Niederhauser, 1998). As a minimum width, a natural riparian area of 5m is considered (see description of the feature riparian area). The evaluation is carried out in the same style as the one above for the channel. The field values were awarded in such a way that the bank width has the greatest influence and the shading of the channel only has a secondary influence. An artificial bank area results in the deteriorating of one class. Meaning, if there is a moderate deficit due to the consideration of the degree of shading and the riparian area width, the river would show a large deficit if the bank is artificially designed.

Table 24: Deficit aquatic environment (based on Göggel and Wagner, 2006, p. 30).

	I **No deficit** **(1.5)**	**II** **Small deficit** **(1.75-2.75)**	**III** **Moderate deficit** **(3-4)**	**IV** **Large deficit** **(4.5-5)**	**V** **Very large deficit** **(5.5-6)**
Riparian area width	5m (1)	3.0 - 4.5m (2)	1.5 - 2.5m (3)	0.5m - 1m (4)	0m (5)
Riparian area character	Natural	Artificial	Artificial	None	None
Shade of river channel	Shady (0.5) OR Semi-shady (brackish water) (0.5)	Semi-shady (freshwater) (0.75)	Sunny (1)	Sunny (1)	Sunny (1)

Longitudinal networking

Longitudinal cross-linking refers to the up- and downward cross-linking for the spread of aquatic organisms. Both anthropogenic and natural continuity problems are recorded. A distinction is made between the categories of falls and building structures (e.g. pipes, passages, bridges, etc.). There are no other forms of continuity problems in the area of Victoria. Building structures are only considered to be restrictions if they have lateral edgings, large river bed shoring or pillars (see Table 17). The classification criteria can be found in Table 25.

Table 25: Deficit longitudinal networking (based on Göggel and Wagner, 2006, p. 33).

	I - II **No – small deficit**	**III – IV** **Moderate – large deficit**	**V** **Very large deficit**
Falls	-	Fall height 20cm – 70cm	Fall height >70cm
Building structures	Ch ≥ 1.0m of L > 3m or Ch ≥ 0.5m of L < 3m AND Bed substrate continuity present OR Width <20% of river bed (not overflowable) OR If Ch = 0, width <50% of river bed (overflowable)	Ch ≥ 0.5m of L > 3m or Ch ≥ 0.0m of L < 3m AND Bed substrate continuity absent OR Width <50% of river bed (not overflowable) OR If Ch = 0, width >50% of river bed (overflowable)	All other cases

The reference condition is assumed to be a condition without anthropogenic continuity barriers.

Data aggregation

The sub-ratings mentioned in the previous sections are summarised, leaving three totals. For the structure and aquatic environment, the deficits per segment are aggregated, while for the continuity deficits the value is taken directly (see Table 26). For the sections structure and aquatic environment, the worst partial value determines the total value of the ecomorphological river quality, since the individual factors cannot be compensated by another. These totals show the most important deficits as well as important approaches for improvement measures. A further aggregation is omitted because too much information would be lost.

This classification of deficit classes is supplemented by a verbal assessment. The condition of the riverbank and, in particular, the muzzle area is mentioned. The muzzle area is extremely important for the networking of habitats but is not formally evaluated specifically. However, their deficits are taken into account in the assessment of continuity disturbances, water body structure or aquatic environment. The focus should be on continuity disturbances as well as the construction of the river bed and the bank base. The reference state represents a structurally diverse and morphodynamically active state of rivers (e.g. no anthropogenic passage disturbance, unobstructed river bed and bank base) (Göggel and Wagner, 2006).

Table 26: Summary deficit analysis (based on Göggel and Wagner, 2006, p. 39).

Categories					
Structure					
River bed	I-II		III	IV	V
Bank base right	I-II		III	IV	V
Bank base left	I-II		III	IV	V
Channel	I	II	III	IV	V
Total Value Structure	I-II		III	IV	V
Aquatic environment					
Riparian area right	I	II	III	IV	V
Riparian area left	I	II	III	IV	V
Total Value Aquatic Environment	I	II	III	IV	V
Continuity					
Continuity problems	I-II		III-IV		V

2.2.5.3 Sociocultural analysis

The three parameters of the sociocultural analysis result in a separate assessment because these criteria are very different from other assessment methods (Renner et al., 2017). The evaluation is based on Renner et al. (2017), which in turn is derived and adapted in a simplified form according to König (2011). The sociocultural characteristics are evaluated by averaging the respective index value of the three characteristics and are applied to one side of the water. The categories are listed in the table below.

Table 27: Summary sociocultural analysis (based on Renner et al., 2017).

Category	Description	Index range
I	Highly suitable for staying	1.0 – 2.0
II	Limited suitable for staying	2.1 – 3.9
III	Not suitable for staying	4.0 – 5.0

2.2.6 Results

This section contains the results of the entire assessment. The closeness to nature analysis, deficit analysis (subdivided into structure, aquatic environment and continuity) and sociocultural analysis are included. A visual representation of these analyses is provided on the succeeding maps. The rivers show large deficits in the flat area but become more natural towards the mountainous regions. The same applies to the deficit analysis, which reveals very large deficits in the low-lying region. The continuity is given for most rivers and obstacles occur only rarely. Especially the presence of pipes on some sections and solid waste on almost all sections were notable. The sociocultural analysis provided a different picture for each river. Apart from one exception, however, no segment can be considered as highly suitable for staying. The results of the individual rivers are explained in detail in the following.

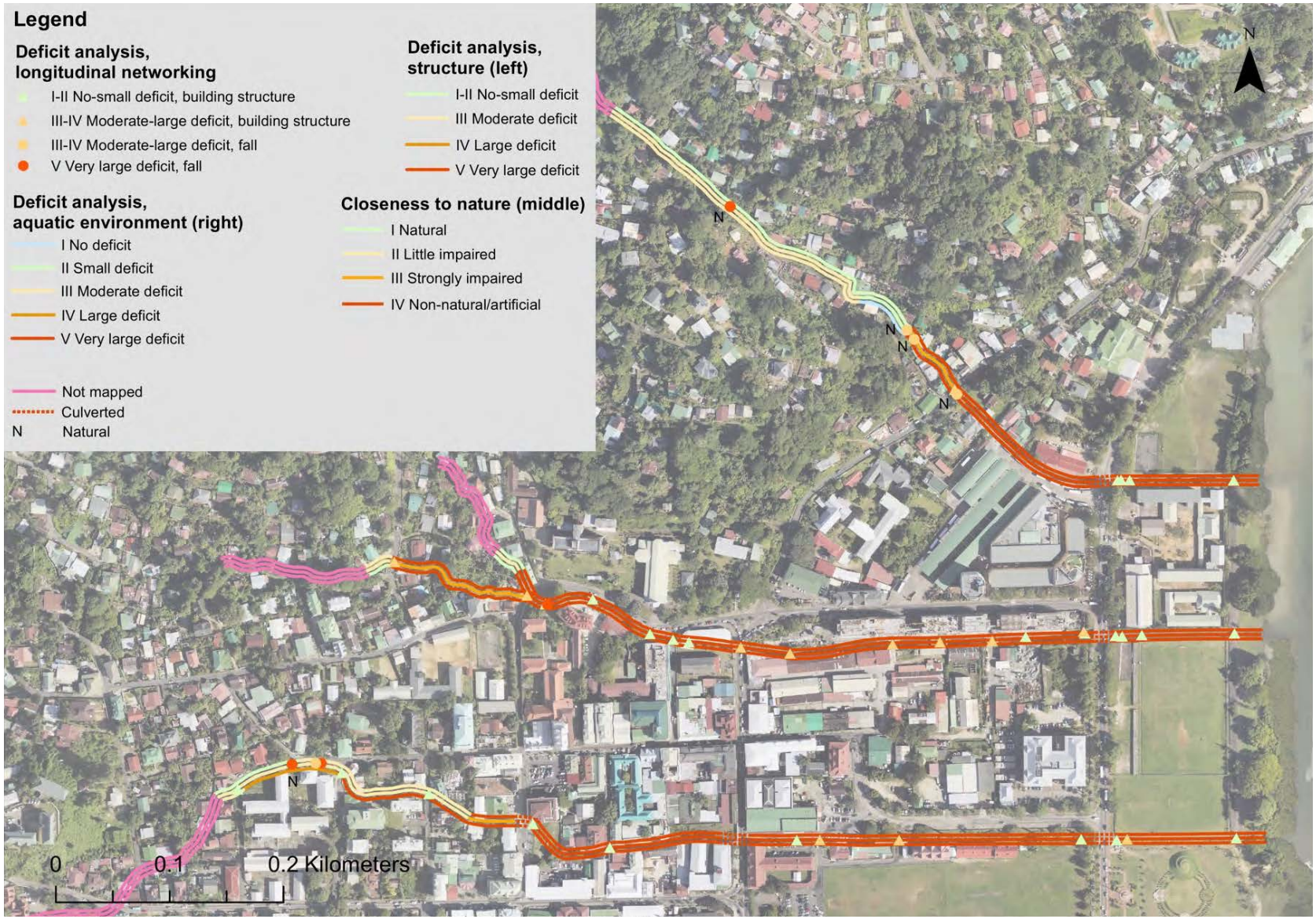


Figure 45: Closeness to nature and deficit analysis of English River, Rivière Moussa and Rivière Maintry.

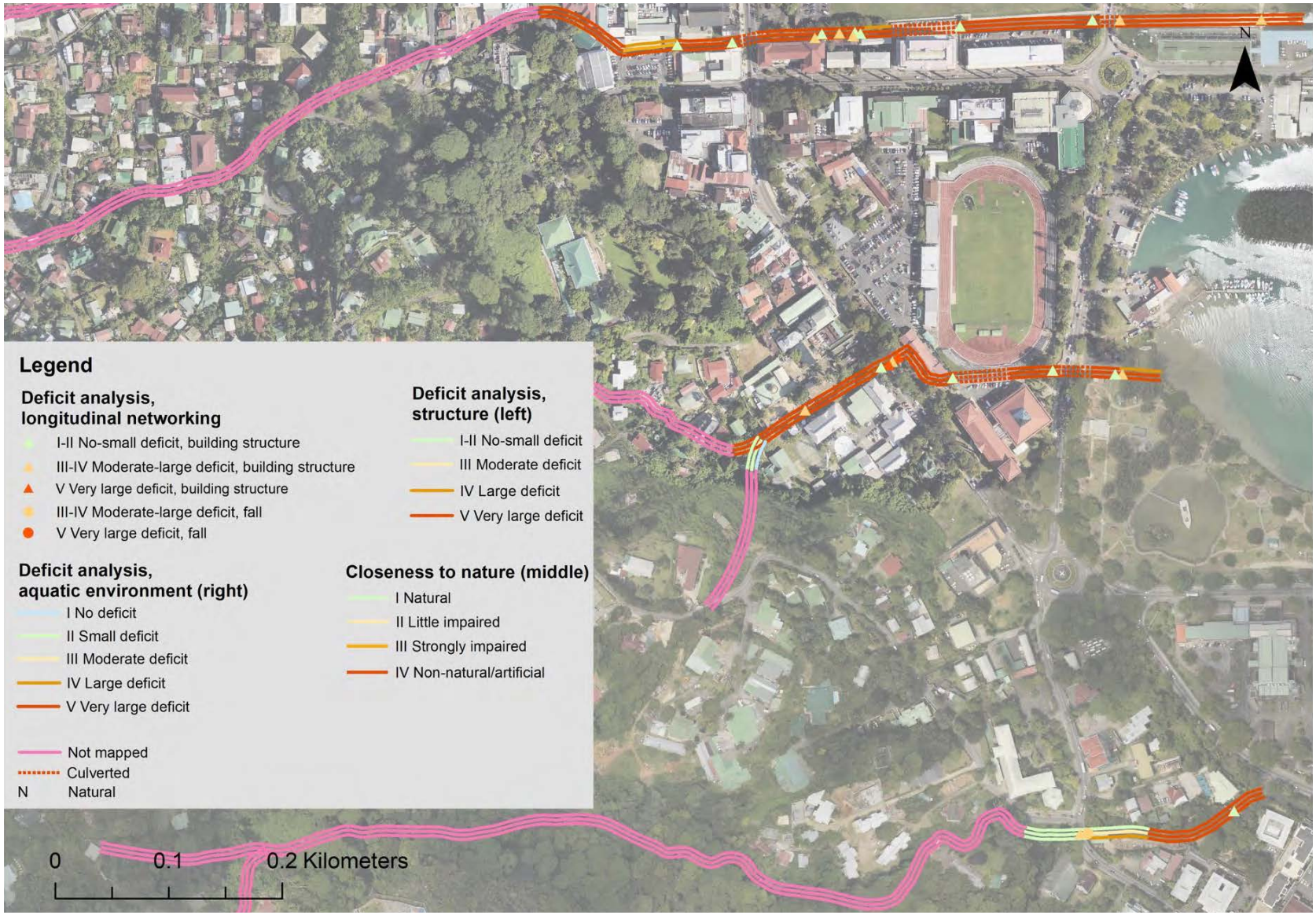


Figure 46: Closeness to nature and deficit analysis of Rivière St. Louis, La Poudrière River and Rivière Trois Frères.

Figure 47: Sociocultural analysis of the English River, Rivière Moussa and Rivière Maintry.

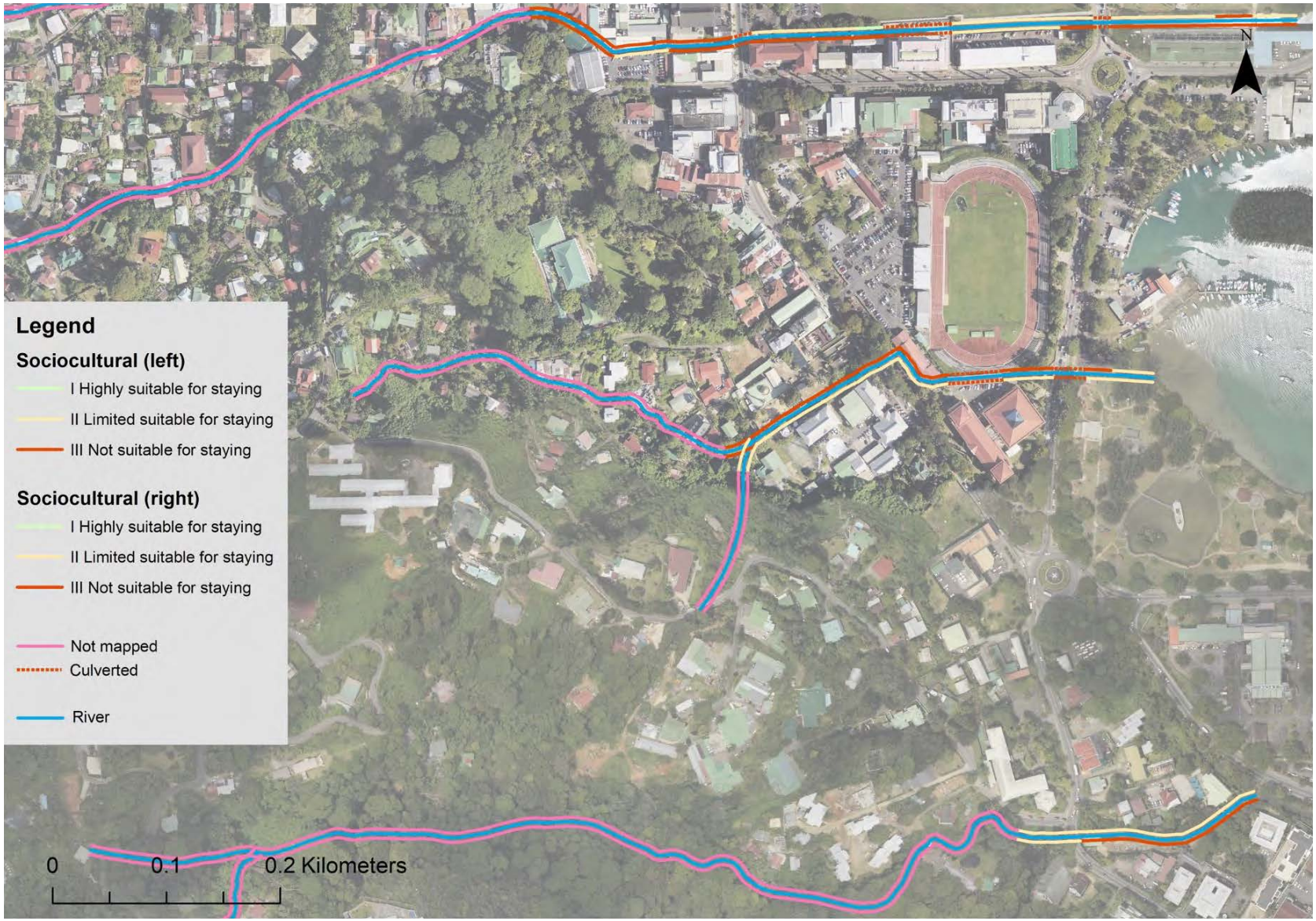


Figure 48: Sociocultural analysis of the Rivière St. Louis, La Poudrière River and Rivière Trois Frères.

English River

The English River, in general, is very unnatural in the flat area and becomes more and more natural towards the hilly landscape. 50% of the assessed river section can be classified as a large to very large deficit in terms of closeness to nature. Especially in the lower part the river is very obstructed and has a trapezoidal shape in a good condition. 8% of the river can be classified as natural and 40% as little impaired. Only very short sections (2%) are culverted (see Appendix V).

The result of the deficit analysis (structure) is divided into two parts. Almost 50% of the assessed river is classified as no-small deficit, while the remaining part is non-natural/artificial. Particularly the river bed, bank base construction and the lack of the water level width variability influence it negatively. In one segment, next to the bus station, a large sewage pipe is clearly visible.

The aquatic environment shows no deficit at all on 8% of the assessed distance. 40% of the stretch has a moderate deficit, while the remaining 50% has a very large deficit, which is mainly because of the absence of a riparian area in the lower river section. Trees are not present on many sections. Animals such as birds or a ray could be observed during evaluation.

While in the lower section of the river building structures show small deficits, in the upper section it is mostly natural falls with moderate to very large deficits regarding longitudinal networking (see Figure 45). No river sections are highly suitable for staying. Instead, 83% on the left side and 54% on the right side are not suitable for staying (see Figure 49). Since mostly no path is leading to the water and often high walls border the river, this results in a poor rating for accessibility, approachability and quality of stay. One segment even showed an abundant amount of solid waste.

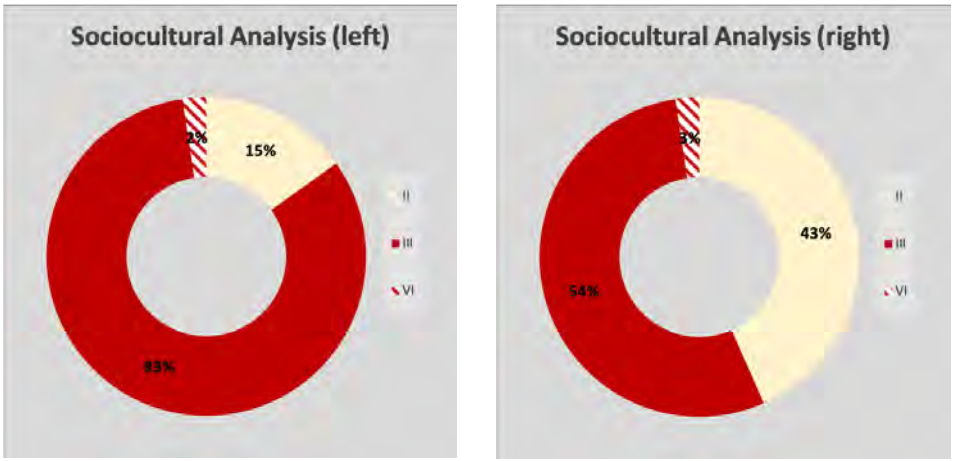


Figure 49: Sociocultural analysis English River (own source).

Rivière Moussa

The Rivière Moussa can be classified as negative from an ecological point of view. Almost all of the river sections assessed have major deficits. Only 16% of the criterion closeness to nature is assessed as little impaired. The rest is strongly impaired and a very large part even non-natural/artificial. The reason for this lies in the fact that almost all the factors evaluated for this are very deficient along the entire length of the river. The profile shape in the lower part is mainly trapezoidal and in the upper part mostly box-shaped. The condition of these structures is moderate to good. Likewise, only 2% of the assessed river sections are culverted (see Appendix W). One large restaurant with a length of 16m is built over the river and between 5th June Avenue and Albert Street the river is half covered by a road. In the flatter area, the river shows around the same amount of no-small and moderate-large deficit building structures which influences the longitudinal networking. However, there is only one large, but artificial, fall in the upper area (see Figure 45). The upper segments are also obstructed with large pipes on the left riverside. Especially in the lower part of the river, there are no trees. The resulting problem is the lack of shade.

The deficit analysis, both from a structural and an aquatic environmental point of view, is desolate. In each category, 92% of the assessed river sections show large deficits. This is because there is the deficient water level width variability, high river bed and bank base construction and no riparian area. However, a ray could be observed during evaluation.

The sociocultural analysis shows that a bit more than half of the places of the river are not suitable for staying (left, 59% and right, 56%) (see Figure 50). Especially the approachability is considered as very negative.

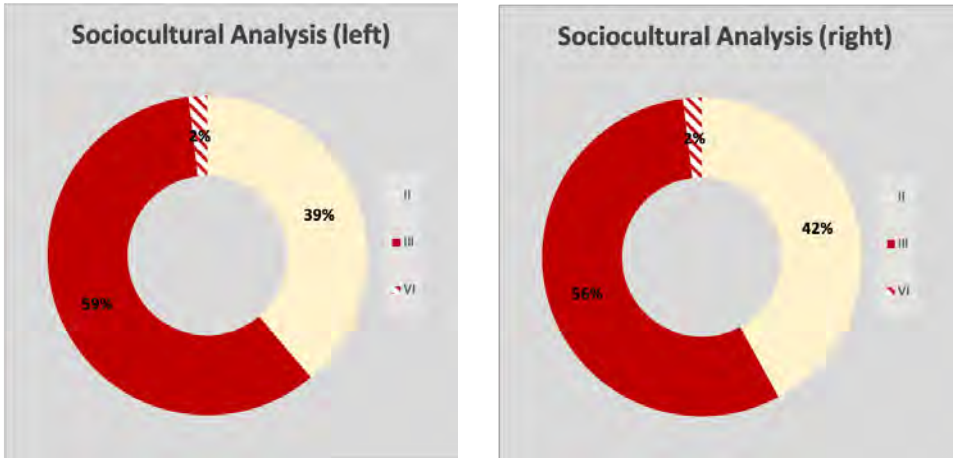


Figure 50: Sociocultural analysis Rivière Moussa (own source).

Rivière Maintry

With regard to closeness to nature assessment, about a quarter is assessed as little impaired. A short section is strongly impaired and 63% are non-natural/artificial. Between Quincy street and the lagoon, all of the influencing factors are considered as poor and the shape is either box-shaped or trapezoidal. At one point, the riverbank is in a very bad condition. There are several building structures with no-small deficits and a few with moderate-large deficit. The falls, a total of three, concentrate on a short stretch with only one being natural (Figure 45). 7% of the river sections are culverted.

The structural deficits can be classified as less negative than the aquatic environment deficit. From a structural point of view, 8% of the river shows a no-small deficit, 18% a moderate deficit and 67% a very large deficit. In the aquatic environment, it is only 2% moderate deficit, 10% large deficit and even 81% very large deficit (see Appendix X). The bank base and the water level width variability were considered as very bad almost along the whole assessment length. The river bed construction is very poor between 5th June Avenue and the lagoon. In the middle part, the river has many pipes and one pipe is even leaking which leads to colored water and relatively strong algae growth in this area. In the upper area there is an area with a relatively large population of tilapia (fish). In contrast to other rivers, this river has many trees in the lower part.

From a sociocultural point of view, there are big differences from the left to the right riverside. While on the left side 52% are judged as limited suitable for staying and 41% as not suitable for staying, on the right side only 25% are judged as limited suitable for staying and 68% as not suitable for staying (see Figure 51). The accessibility is mostly not the problem, but the approachability and quality of stay is considered as negative.

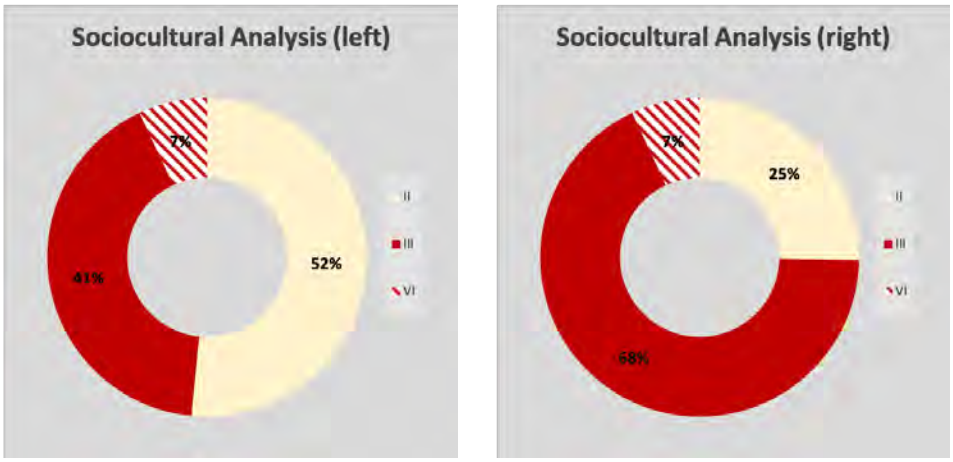


Figure 51: Sociocultural analysis Rivière Maintry (own source).

Rivière St. Louis

This river is similarly negative to Rivière Moussa. It is not convincing when it comes to closeness to nature and deficit analysis. 79% of closeness to nature is assessed as non-natural/artificial. 7% are strongly impaired, which is at the same time the maximum of this evaluation. Apart from the river bed construction all relevant evaluation points are assessed with the minimum. With 14% also quite a lot is culverted (see Appendix Y). The reason for this is a relatively large car park with a length of about 60m which was built over the river. In the rated river sections, there are about the same number of building structures with no-small deficit and moderate-large deficit. There are no falls (see Figure 46).

10% of the river has a large structural deficit and 76% a very large deficit. This circumstance is even more pronounced in the aquatic environment assessment, whereby with the exception of the culverted segments, everything is assessed with a very large deficit. The lack of river bed width variability and the riparian area as well as the high bank base construction is the reason for this. In one segment, the bank is in a very bad condition. In the upper part, one river segment contains a very large population of tilapia.

Here, too, there are major differences in the sociocultural analysis between the left and right riverside, with the left bank being of much higher quality than the right. 4% are even judged as highly suitable for staying. Exactly half of them is judged as limited suitable for staying and only 32% as not suitable for staying. On the right, the latter is 65% and the limited suitable for staying segments have a share of 21% (see Figure 52). The approachability is in general very bad. Whereas the accessibility on the right is very difficult in the lower part, it is very difficult or even non-present on the left side in the upper part.

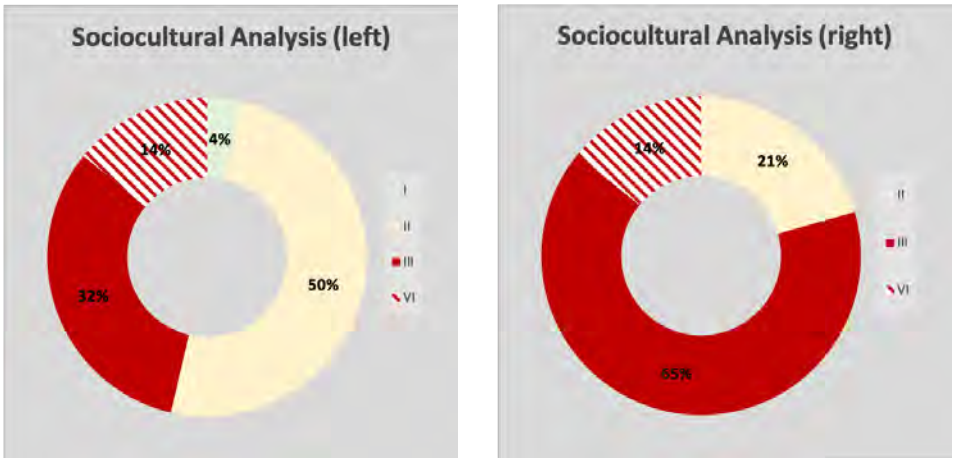


Figure 52: Sociocultural analysis Rivière St. Louis (own source).

La Poudrière River

The closeness to nature and deficit analysis is assessed as extremely negative. The worst category takes a high value in all three assessments. Thus, 75% are non-natural/artificial, 67% have a very large deficit in terms of structural assessment and 75% in terms of the aquatic environment (see Appendix Z). The no-small deficit sections are very small with 7%. The river is mostly in a box-shaped profile and in some places in a bad condition. Apart from the absence of any river bed construction on mostly all the segments, the other evaluation criteria are assessed very badly. This stream also has dominant pipelines along the river. A ray could also be observed in this river. In the upper part a pipe is also leaking, which leads to a discoloration of the water and a strong aquatic vegetation growth. There are almost no trees along the river. With 18% the river is culverted over very long distances (see Figure 53).

On a relatively long section, selling stands were built over the river. This river has in the assessed parts no falls, but some moderate-large and very large building structures (see Figure 46). The sociocultural assessment here is also very different from one side of the river to the other. While 67% on the left side is assessed as not suitable for staying, 76% on the right side is assessed as limited suitable for staying. No section is judged as highly suitable for staying (see Figure 53). The accessibility on the left riverside and the approachability in general is very difficult.

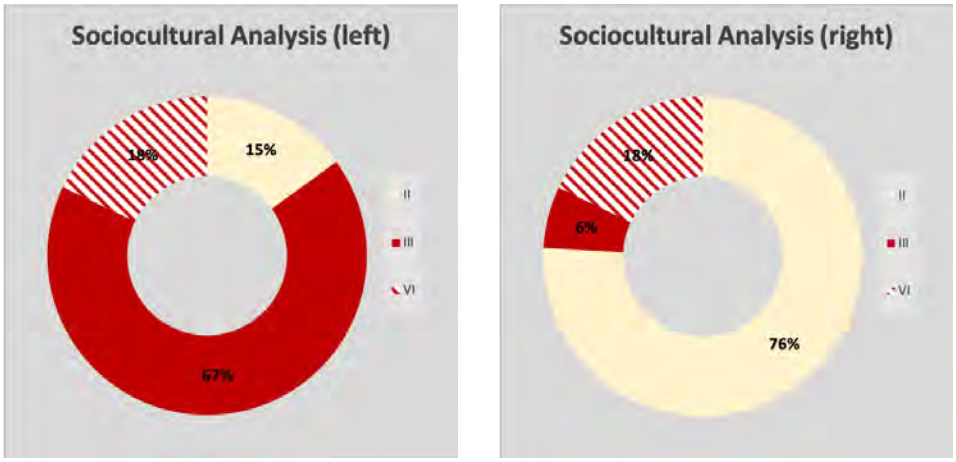


Figure 53: Sociocultural analysis La Poudrière River (own source).

Rivière Trois Frères

This is the only one of the six evaluated rivers which is not culverted. However, it should be noted that only 17% of the total river was rated and the division into only four segments is very small (see Appendix AA). On the evaluated segments there is one building structure with no-small deficit and one with moderate-large deficit and one fall with moderate-large deficit (see Figure 46). The profile is in a moderate to good condition and also in this case the water level width variability, bank base construction and riparian area are assessed badly. The evaluated part consists of about one quarter each of the categories natural and little impaired and about half non-natural/artificial. This division is also found in the deficit analysis of the aquatic environment but in the categories small deficit and large deficit and also half of very large deficit.

The structural assessment is 49% no-small deficit and 51% very large deficit. The left side is completely assessed as limited suitable for staying, while the right side was assessed as 25% limited suitable for staying and 75% not suitable for staying (see Figure 54). The approachability is very bad and especially on the right side the accessibility as well.

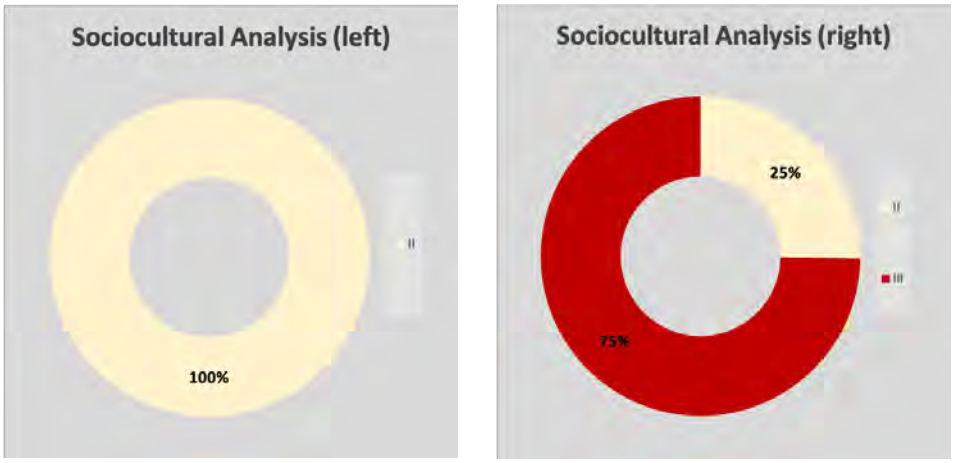


Figure 54: Sociocultural analysis Rivière Trois Frères (own source).

2.2.7 Limitations

The valuation method could have been compiled from a variety of different valuation methods and valuation criteria. The author has limited himself to three well-founded methods, which are often used in practice. Approachability to the rivers was a major problem for the river assessment, as some house fronts border on the banks of the river. The tools available to carry out the assessment were limited and some electronic tools had technical problems which needed to be solved. The subjective survey bears the risk of a bias. However, this can be put into perspective since it was always the same person who carried out the assessment. The weighting of the evaluation criteria was evaluated on the basis of the consulted methods, but could have been different, which in turn could have led to major changes in the evaluations.

3 Part II – Requirements for a future river system in Victoria

This section is based on the three parts ecological requirements, recreational requirements and decision-maker requirements. These three sub-chapters take different perspectives into account and provide information on the future requirements for rivers in the city. At the beginning of each chapter, background information is presented and the used methodology is explained. The other part shows the obtained findings.

3.1 Ecological requirements

The general basis of information about the rivers of Victoria is rare. This is especially true for the ecological status and the desired future changes. Therefore, an expert interview was carried out to provide this knowledge gap.

3.1.1 Background

An expert interview is applied on a particular topic where data, as in the prevailing situation for ecological requirements of urban rivers in the Victoria area, is not available. An expert interview is a form of qualitative data collection, whereby the evaluation is based on identifying the most important statements and finding similarities (Mieg and Näf, 2006). When creating the interview guide as well as conducting the interview, the work of Mieg and Näf (2006) was used as a guideline.

In this case, the expert interview was used to include and highlight the perspective of nature and ecology for future upgrading measures. Five ecologists, who are familiar with the topic of rivers and in the best case in the urban area, were interviewed. These were Katy Beaver (environmental educator for all education levels), Jude Bijoux (expert in marine conservation, fisheries and climate change), Lindsay Chong-Seng (botanist), Gilberte Gendron (marine biologist working at Seychelles National Park Authority) and Terence Vel (environmentalist and scientist at University of Seychelles and member of Wildlife Clubs of Seychelles). The expert interview should cover different topics. As a basis, the expert interview should provide an idea of what a natural state that is not in urban space looks like, to see how much it differs from the current state. It should also show which species are already present in the system and which are desirable in the future. Positive aspects and challenges of the ecological state are to be pointed out, with which the present condition of the rivers has to struggle and how this can be improved. The question whether a combination with recreational usage is possible is also addressed. Finally, the question of which rivers should be treated as a priority was considered. The topics mentioned were carried out using a semi-structured interview. The used interview guide can be found in Appendix BB. The interview guide was sent to the experts before the actual interview. In one case, no personal interview could take place, which is why the answers were given in a written form. During the interviews, the statements were written down and recorded with an audio recorder for backup. The evaluation took place in the form of a summary of the statements made by the experts.

The structure of the following chapters follows the logic that the main statements are mentioned at the beginning. Interesting further statements have been added to the respective main statements. As not every statement could be reconfirmed by the experts for reasons of time, the individual names are not given.

3.1.2 Findings

3.1.2.1 Natural state of a river

This point addresses how respondents describe a natural state of a river on Mahé. For this purpose, a comparable condition to Victoria was asked, like an area on which the river flows with a shallow gradient for a long distance. The natural state was described similarly by all. There was agreement that the base substrate is sand, mud and gravel with a few large granite boulders. They are important because they offer hiding places and extend the habitat range for species. A good natural example comparable to town is Port Launay, in the area where the river borders the mangroves. One expert even mentioned the presence of mangroves in the city area in earlier times. Another expert said that the natural river state gets rockier in the direction of the mountain area, where no brackish water is present anymore.

Especially the river mouth is an important habitat as a nursery ground for marine species and needs to be well opened to guarantee a good connection, whereby the migration path, in general, should be guaranteed. A very important feature, mentioned by three people, is the presence of a riverbank structure. A gradual slope with low brush canopy and higher canopy with large trees. Straight impermeable walls are to be avoided. No riverbank is available in Victoria at the moment. Variable riverbank structures with small pockets would be important as habitats for species.

All respondents shared the opinion that the river should be shady and trees should be present next to the river or along the river. Ideally, they can be connected to the river. This would also be stated in the *State Land and River Reserve Act*, which was mentioned by three people. Trees along the river serve to protect the river in order to reduce water evaporation so that the rivers do not dry up. This environment is an important place to infiltrate the water into the ground, as one person said. Aquatic vegetation is normally not present in the river, which was mentioned by two people.

According to the interviewed people, a natural river condition is in general free of concrete and pipes, not canalized, no waste, no pesticides or herbicides, no detergents are present, has no invasive species and has clear and clean water, which was mentioned by several people.

3.1.2.2 Animals and plants

This section explains what kind of animals and plants should occur in Victoria in the future and what is necessary. There is a consensus among all respondents that endemic species need to be promoted, both in animals and plants.

All people mentioned fish (e.g. endemic Gourzon, eel, snakehead), birds (grey and green heron, cattle egret), crustacean (crayfish, crabs, shrimps, prawns) and caecilians. The latter are legless amphibians which lives along the river and looks similar to a big earthworm. Especially the currently very rare eel was mentioned by all respondents, as the river sections in town are an important habitat or connection path for the eel. The eel, once fully grown, lives in freshwater and spawns in saltwater. The connection between the mountain area and the sea must consequently exist. Other important animal species which were only mentioned by two or three people are arthropods, insects (dragonfly, spiders, water strider), lizards, snakes, frogs, snails and turtles (e.g. Pelusios).

Among the plants, the respondents usually divided the plants adjacent to the water into two classes: Large trees (Indian almond, Takamaka tree, Ficus, Barringtonia, Badamier, Kascuarina, native palms, Bois de Rose and Bois de Natte) and smaller plants (ferns, sedges and different species of grass). Especially the Takamaka tree and the Ficus, as well as the ferns and grasses, were mentioned by several people. In the water itself, there are normally no plants. In the flat area plants in slow flowing shallows are to be preferred (e.g. species from mangrove or freshwater marsh). The advantage of large plants is that they provide both, a good habitat for animals and shade. One expert even mentioned bamboos, although introduced, because it can filter and clean the water especially in the upper area (freshwater).

The three most important factors to ensure the survival of the animals and plants, which was mentioned by all respondents, are (I) good water quality, (II) suitable habitat and the (III) absence of invasive species. Especially the aquarium trade has an important function, which can spread plants as well as animals if the owner exposes them. Examples are the guppies, red-eared slider (freshwater turtle) or waterweed, which spread extremely strongly. However, some respondents do not regard the guppies as a big problem because they are more resilient, survive better in difficult areas and reproduce faster for better control of mosquitos. Although Tilapia is not a native fish either, it is seen as part of today's river system and is seen by many as an attraction.

All experts agreed regarding the point of the reintroduction of the animals. The animals will return to the river when the condition becomes more natural and the plants are introduced, assuming that the animals are not completely extinct. The amount of concrete, walls and pipes must consequently be reduced and at best removed. The water quality needs to become better with less pollution and litter, more shady areas and the absence of invasive species is very important. Nevertheless, reintroduction would increase the spread of the species.

3.1.2.3 Positive aspects related to the ecological river state

Only very few points could be made to presently prevailing positive conditions. The most frequently mentioned point is the presence of life, although the current condition with the existence of concrete and pipes is desolate. One expert took the opinion that tourists are curious to observe this wildlife.

3.1.2.4 Challenges related to the ecological river state

This section highlights the difficulties and challenges rivers in Victoria are facing from an ecological point of view and why the condition looks the way it is. Some experts have even indicated how this is related to river upgrading measures. Law enforcement is a huge challenge mentioned by most experts. An example is the ban on clearcutting within 10m on each side of the river.

The will and knowledge about the function and importance of a river within the town area as well as in the whole ecosystem is mostly missing, why the current state is unattractive and nothing is going to be implemented. Further, the raising of financial resources is a problem that has been mentioned by all interviewed people. Priorities have to be set and rivers have unfortunately not been the top priority until now. One expert believes that the financial business district planning can be used to ensure that each adjacent owner puts a certain amount of money into a fund which is used for river maintenance and management activities.

Another big problem mentioned by everyone is the lack of space within the city due to the existence of infrastructure. Many stretches of water have adjacent buildings, walls or sewer pipes, which makes it difficult to implement relatively simple improvements. The great development in recent years, also within the catchment area of the rivers, has resulted in a large amount of impervious floor area and consequently in more runoff. This increases the erosion force and water availability becomes lower in the dry months as water is no longer stored in the soil, as one expert said. Developments in recent years, including the catchment area, have additionally led to a major source of pollution (see Figure 55). Solid waste, detergents, bad sewage treatment and many further factors have led to poor water quality, which was highlighted by all respondents.

Figure 55: Dirty surface of Rivière St. Louis (own source, 13/04/2019).

Four people underlined the importance of a well implemented coordination, planning and management, but which is often not available. This is usually caused by poor communication between different ministries and stakeholders. Three people believed that this is especially missing in the area of maintenance. One person highlighted the delay and long duration of the processes as another general problem toward endemic species. All people consider the presence of invasive species to be a major problem. One expert added the consideration, assessment and estimation of other factors such as sea-level rise, coastal protection and engineering opportunities.

3.1.2.5 Improvement measures directly on the river

In this chapter, proposed improvement measures directly on the river are explained. In order to not include already mentioned activities (improved water quality, reduction of invasive species, etc.) only new and sometimes innovative proposals are described. An important point mentioned by three people is the installation of signs. Two believe that littering could be reduced with the use of suitable signs. One person thinks that the signs should contain further information about the river (conservation, history, names, ecological importance, etc.). The river should generally be given a higher value, used as a place to walk, cycle or sit, which is supported by all respondents. Less water abstraction was also mentioned by three people, especially in the higher part of the catchment area. The abstracted or used water limits the amount of clean water that flows into the sea. The usage of an abstraction fee could help.

Two people stated the danger of leaking sewage pipes, which should thus be removed. If the risk of leakage does not exist, they should at least be hidden. Maintenance, especially de-silting, was mentioned by four people. One expert explained in detail how it came to this issue: In the past, many people used to take silt or gravel out of the river to build. With the introduction of the *Removal of Sand and Gravel Act* this was prevented, which leads to silt and gravel accumulating especially in the flat reclaimed area. To avoid flooding and a too shallow river bed, the river must be desilted from time to time. Besides, deeper places can be created as a habitat for different kind of species. One expert sees the point of widening the river but that leads to more siltation. In the flat town area, a channel which increases the flow speed and therefore reduces silt accumulation is also suitable. But he suggests the concept of key biodiversity areas. Improvement measures cannot be implemented everywhere, which is why they should be done in selective, well-suited locations, so-called key biodiversity areas. Key biodiversity areas can be identified by carrying out an assessment. A suitable place is, for example, along the Rivière St. Louis behind the police station where many Tilapias already exist. The concept is supported by another expert who believes that a combination of factors should be made. It is better to restore one river as much as possible rather than implement one measure on all rivers. Green walls and benches, possibly wooden decking, a few stones and possible bank rehabilitation measures would be improvements that could be successful and well implemented interventions, which is confirmed by all respondents. However, it should always be ensured that the overall discharge capacity is maintained or even increased.

3.1.2.6 General improvement measures

In addition to the improvement measures directly on the river described above, general suggestions for improvement are listed in this chapter. The involvement of all stakeholders, overall coordination and view as well as overarching policy was mentioned by four respondents. Today, each stakeholder pursues his interest and everything is scattered. The existing River Committee was mentioned by three people and explained in detail by one person: The River Committee is now to be changed more formally. It had not worked so far, is too little active and almost unknown. Nowadays, it deals only with the issue of water abstraction in connection with PUC.

It should oversee all rivers on the island (any activity, legislation, projects, providing information, etc.). Many more decision-makers should be represented in the committee, such as the planning office, environmental wetland unit or climate change to discuss overall issues affecting the rivers.

Three people mentioned the importance of a proper planning and management plan defining what and how something needs to be done, the resources (rivers) and their demands and the expected outputs. One person believes that in a first step a precise river inventory has to be carried out (rivers and their surroundings), in a second step the evaluation of people's opinions and ideas and in a third step the analysis of a whole concept and the approval to be obtained and implemented. Another one also mentioned forest guards or river inspectors who will go along the river and serve as an early warning system (e.g. invasive species).

Another point mentioned by four experts is the education and awareness of the public and children about the importance of the river, using various media and examples from abroad. Three people think that the civil population should be involved. Because the more people you involve, the more you get them on board. The enforcement of the law is important and was mentioned by all respondents. One person took even the opinion that improvement can only be achieved through the introduction of fines.

3.1.2.7 Combining natural and recreational requirements

All respondents thought that the ecological and recreational needs of the rivers can be combined, although the available space in town is limited. A seating area inviting people to linger must be available to observe the river or simply to relax. The attractiveness of the place would be increased by the addition of a nice walking trail along the river. Walls must be removed or other possibilities to observe the river (e.g. platform) have to be provided. If possible, environmentally friendly materials such as wood should be used instead of concrete. Trees should be present to provide shade and use the coolness of the river, which also benefits the ecology. Good water quality without bad smell and the absence of waste, which is e.g. possible by providing enough waste bins, has an advantage for both the ecological and recreational aspect. Nobody wants to be next to a polluted river. One expert believes that people will like to stay along attractive rivers and then realize what a river has to offer. Another expert said that curious tourists and school classes visiting Victoria are already very interested in the rivers, which could be further increased by improvement measures.

3.1.2.8 Priorization of river segments

This chapter is intended to show at which specific locations in Victoria ecological improvement measures would be useful. There were two trends in the prioritization of river improvement measures. The rivers that flow past green areas, which is mainly near the lagoon, near the Peace Park, Freedom Square and Paradise Des Enfants, can be improved. The situation looks worse in the central area of the city, where many infrastructures and buildings exist. For this reason, the Rivière St. Louis has been classified by all as the most important one. Other proposals were very different.

Reasons why the Rivière St. Louis is so popular are the absence of an adjacent road, a green area nearby and no infrastructure on one side, which allows relatively simple improvement measures. The widening of the river in this area, as well as the transformation of walls into a nice riverbank, would be an important measure from an ecological point of view but also concerning flooding. Furthermore, it is already severely affected by the car wash above and the large car park that was built over the river and thus represents a compensatory measure. Access by foot and seating should be available to increase the value of the river. Someone said it is one of the main rivers that many people see and can be shown that clean and healthy rivers are possible to exist in town. The last point also applies to the rivers Maintry, Moussa and Trois Frères.

Rivière Moussa offers different areas for improvement. Two people said there is a small green spot near the cinema and a little one below for upgrading. Further down it is strongly developed and unfortunately cannot be upgraded. Negative aspects include the large amount of litter and infrastructure around the river. English river has less priority because it is heavily polluted, a sewage pipe lies in the middle of the stream and the surrounding is heavily obstructed further down. La Poudrière River was named by two people. It has high priority, as a value should be given to the river segments near the tourist kiosk. The problem is that it is heavily polluted and the smell is problematic. One expert thinks that all rivers are important because they end up in the lagoon and are therefore responsible for the water quality there.

3.1.3 Limitations

The experts have given some interesting statements and hints to the questions. However, there are few people in the Seychelles who are well versed in the specific area. Although attempts were made to cover the spectrum of experts as much as possible, some questions could not be answered. Even in the case of supposed experts, the knowledge about the ecological state or its desired development in urban space is not available, since it is not their field of study, no recent studies have been made and the knowledge about urban systems is small. In many cases, they reported on natural systems and their earlier experiences before Victoria was as developed as it is today.

3.2 Recreational requirements

No information is available on the importance, perception or attitude of the people about the present and future desired state regarding recreational aspects of the river system in Victoria. A survey conducted with residents and employees should close this gap.

3.2.1 Study design

A survey is an important and popular form of socioeconomic data collection (Kelley et al., 2003; United Nations, 2005). The data was gathered in the form of a questionnaire using a face-to-face survey.

3.2.1.1 Aim of the method

Long-term solutions can only be found if the needs of the various stakeholders are addressed, especially the community (Grêt-Regamey et al., 2016). This is covered by the survey. The first part of the questionnaire intends to assess people's level of knowledge about the importance, value and function of a river. The second part of the questionnaire aims to find out what the current state of knowledge and personal opinions of Victoria's residents and employees are. The third part of the questionnaire shows future development possibilities or potentials of the rivers in the city regarding recreational aspects. The aim is to derive tendencies of which type of river and what kind of adjacent use of the local people are desired in order to include it in future development planning.

3.2.1.2 Implementation of the survey

The sample size depends on the target of the master's thesis, the resources available and the statistical quality needed for the survey (Kelley et al., 2003). For the purpose of this thesis the target number of completed questionnaires was 120 to serve as a sufficiently large basis for an appropriate evaluation. Since the response rate is expected to be 60-70% (statement of NBS[25] and Krütli, P.[26]) the aim was to distribute the questionnaire to around 200 people. A pre-test was conducted with some people in the planning authority to see if the questionnaire was understandable, how long they need to fill out the questionnaire, if sufficient response options were available or if there were any ambiguities (Kumar, 2006). A few small adjustments had to be made, such as the hint that there is a second page of the survey.

In most cases, the only possible method of collecting information is to conduct a personal survey (Kumar, 2006), which was also applied here. The advantage of the personal survey is that the interviewer can talk to people and learn additional interesting aspects as well as local knowledge that is not explicitly asked in the questionnaire (BMU, 2009). Therefore, the questionnaire was printed out and given the paper to the participants, as paper-to-pencil questionnaires. The respondents were given a brief introduction about the master's thesis and then the questionnaire was handed out. If there were any questions, the interviewer was available to answer them. In principle, the questionnaire was completed by the participants themselves. In a few exceptional cases, the interviewer had to fill in the questionnaire himself by talking to the participants in person. Participation in the survey was completely anonymous for the respondents. People aged 15 and over were included in the survey as this is the minimum age of employment (MEIC, 2019). The maximum age for interviewees was set at 63, as this corresponds to the retirement age (Ernesta, 2017).

The questionnaire should be distributed to about half people living in Victoria and half people working in Victoria, as both stakeholder groups are affected. The survey conducted by these two groups differed. The survey with residents is based on a randomized sample which was prepared with the help of the NBS.

[25] Personal meeting with Payet, M. on 22/03/2019

[26] Personal meeting with Pius, K. on 20/03/2019

The sample design is a stratified four-stage sampling. The choice of households was based on randomized selection. A total of 100 households were selected (Maria Payet, 13/05/2019). The places surveyed are shown in Figure 56. The survey was conducted at the weekend or during the week after 4pm, as people were most likely to be at home during these time periods. Pillay G., an employee of the Planning Authority, helped to carry out the survey. It was a great advantage, as the language barrier and any cultural obstacles could be overcome. The questionnaire was distributed in the Creole version as it was assumed that English might not be sufficient to fill in the questionnaire independently and the native language is easier to understand. The questionnaire was translated by the NBS. The reason NBS was taken is because the questionnaire has already been discussed with them and they are familiar with the subject, they are fluent in English and Creole and they have a background in survey research. These are the requirements that are needed to avoid mistakes in the translation of the questions, which later results in errors in the data gathered (Kumar, 2006). For the analysis, the open questions were translated back into English by Pillay G.

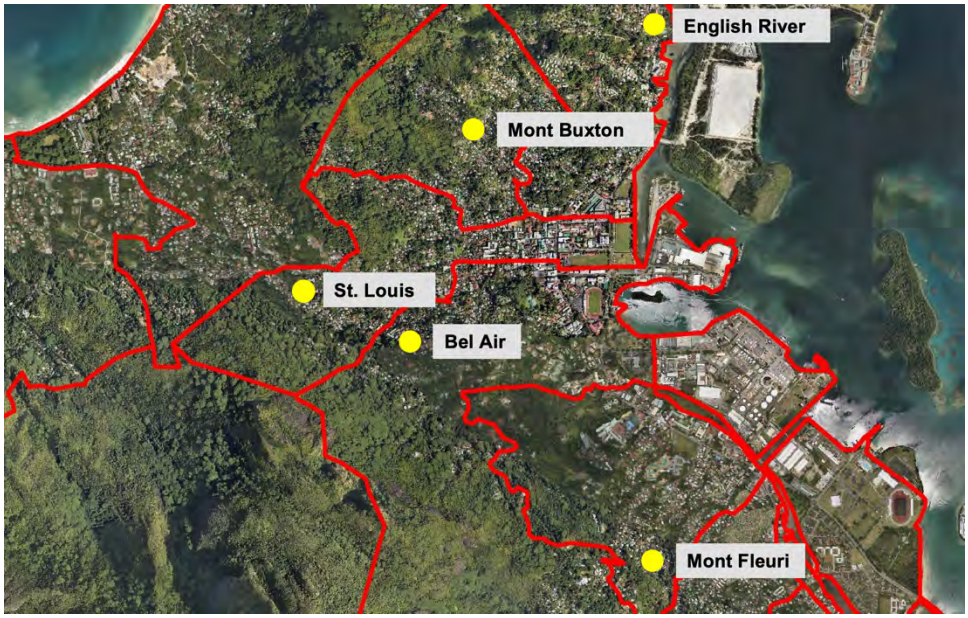


Figure 56: Map of the five districts with their names and their questionnaire sites (yellow dot).

A complete, accurate and up-to-date list of companies in town to survey employees is unfortunately not available. A randomized selection could therefore not be made, why a suitable alternative had to be found. The survey with employees is based on a sample along streets and rivers in town. The employee survey was designed to cover different areas of the town and different business sectors. The survey perimeter covers the area shown in Figure 57. This extends roughly from Orion Mall in the north to the Seychelles National Library in the south and from Quincy Road in the west to 5th June Avenue in the east. The main focus was on the areas close to the river, as people do not travel long distances on foot. Based on the business sectors made by SeyBusiness (Multimedia Operating, 2019), an overview of different company groups was derived and used for the survey. These company groups were visited personally and the questionnaires were distributed to them.

Since this is not a randomized survey, the risk of biased selection must always be taken into account. Therefore, an attempt should be made to make the sample as representative as possible (Kumar, 2006). When conducting the survey, care was given to guarantee that the sample was balanced in terms of age and gender and to ensure that no expats who would leave Seychelles in a few years were surveyed, but rather employees who work there for a longer period of time. The employee survey was conducted during office hours on working days. Employees are assumed to speak English well enough to understand and complete the survey in the English version.

Figure 57: Survey perimeter of the questioned employees.

3.2.2 Questionnaire

The recommendations and hints regarding questionnaire design of Kelley et al. (2003) and Kumar (2006) were applied for the preparation of the questionnaire used in this thesis. The survey has been designed in a short and compact way in order to increase people's willingness to participate. The questionnaire starts with personal data, continues with the current situation and opinions of the people about the rivers specifically in Victoria and ends with the desired future situation for Victoria's rivers (see Appendix CC).

The questionnaire consists of eight questions, of which four are open (respondents compose the reply) and the others are closed (pre-coded response options available to be chosen by respondents). Closed questions are used for topics, where the possible response is known, are quickly to answer, easier to analyze and the answers are comparable (Kumar, 2006). Open questions are asked when either the answers can be very variable or an answer is not known, giving an interesting and rich insight of the field (Kelley et al., 2003). In addition, they are more prone to errors, since the evaluator has to interpret the open answers and categorize them accordingly (Kumar, 2006).

The questionnaire begins with a short introductory section and can then be divided into five parts. The first part, the one in the box, asks about the respondents' demographics. The other four parts are a mixture of open and closed questions.

After the demographic information the survey continues with a basic question to gather an idea of people's knowledge. The question is about the general functions a water body can fulfill. These functions are subdivided into five groups, whereby each of these are supplemented in brackets with corresponding examples (see Appendix DD - Appendix GG). Although criticism is often voiced when the answer option is designed for five, where a "comfortable middle" is available, this was used in the survey. Another reason, as various conversations with local experts before the setup of the questionnaire revealed, the level of knowledge of people about the rivers in Victoria is assumed to be low and therefore no statement can probably be made. In addition, there should be an intermediate answer option, if no evaluation tendency can be identified, even after thorough consideration (BMU, 2009).

The next question about the number of rivers in the city aims to obtain a rough overview of whether people are even aware that natural rivers flow through the city. Again, conversations in advance have shown that some of them probably think that it is a part of the canal system that is influenced by the tides rather than a naturally flowing river coming down from the mountains.

Questions 3, 4 and 5 ask for people's personal opinions on the current state of the rivers in town and want to find out what they like and dislike about the present situation. Question number 6 deals with future development possibilities and ideas of the river system in Victoria, whereas questions number 7 and 8 are based on this. The question was made with six different pictures to give an illustrative idea. The different situations shown in the pictures should reflect the appearance of the river as well as its adjacent use. In order to avoid ambiguities as far as possible, each illustration is supplemented with a short text description above the picture. From the six different development possibilities, people were advised to judge each picture individually on a scale from 1 "not wanted" to 5 "very much wanted", whether they like it or not. Question 7 respectively 8 asks for the favorite respectively least favorite future state and the reason for it.

3.2.2.1 Sample description

As mentioned above, the questionnaire was distributed in five different districts. A total of 72 questionnaires were returned, with a response rate of 69.9% within the expected range (see Appendix HH). The response rate among workers was significantly higher at 82.3%, with a total of 94 questionnaires completed (see Appendix II). This results in a total of 166 completed questionnaires.

A little more than half of the respondents are residents and therefore live within the five districts close to town. 72% of the respondents belong to the employees' group. Taken together, it is more than 100%, as some people are both employees and residents. Among those surveyed, the proportion of women is slightly higher (see Table 28). It is noticeable that many people are traveling by car or public bus. Only a quarter of respondents travel on foot and even less by motorbike. Again, the sum is not 100%, as one person may have ticked several transport options. The majority of respondents completed post-secondary school as the highest level of education.

Table 28: Indication of the absolute and relative frequency of the demographic data of the people surveyed (own source).

	Absolute frequency	**Relative frequency**
Employees	119	72%
Residents	90	54%
Gender		
Female	96	58%
Male	70	42%
Transport mode		
Public (Bus)	78	47%
Car	88	53%
Scooter/Motorbike	3	2%
Walking	42	25%
Level of education		
Secondary school	28	17%
Post-secondary school	98	59%
University	40	24%

The age distribution is given in Figure 58. Especially the proportion of 20-30-year-olds is relatively high. The age range is from 15 to 70 years. This distribution tends to be somewhat younger than the effective age distribution in the population. Nevertheless, the average age of 36 years and the median age of 33 years are very close to the effective median age of 34.4 years (Lexas, 2019). The actual gender distribution of the Seychelles population is almost balanced, with a slightly higher proportion of men (NBS, 2019). In order to recognize the variability of a characteristic, the standard deviation is calculated. The calculated standard deviation for the age is 12.9.

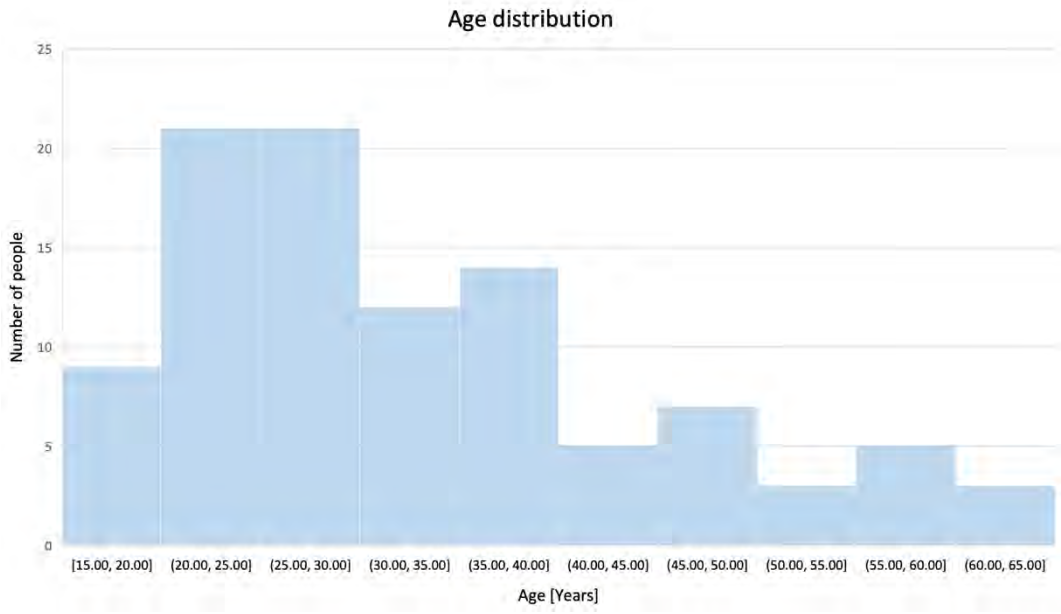


Figure 58: Age distribution of the respondents (own source).

3.2.3 Data analysis

As the questionnaires were filled in on paper, they had to be digitized first for data analysis. The questionnaires' content (raw data) was manually entered into Excel in tabular form. Further data preparation was also carried out in Excel. Closed questions such as those for ticking or the ones asked for an exact number were analysed statistically. For the analysis of the open answer questions 4, 5, 7 and 8 appropriate categories were created on the basis of the answers (see Figure 61 and Figure 62).

The aim of the evaluation is to summarize the collected information to make it easy to understand. This will be divided into two sections descriptive evaluation (percentage and absolute frequencies, mean and median values and standard deviation) and correlations (BMU, 2009). An interesting comparison with respect to the goal of the work is considered as the one between the study group (residents, employees or both) and the future desired state of the river. To compare mean values between the residents and employees' group, the t-test was used. This is a frequently used test in statistics, which checks whether the mean values of two independent samples differ significantly. The Bravais-Pearson method was applied for the correlation, which investigates the linear relationship between two variables (Universität Zürich, 2018). The software used for this is Microsoft Excel and SPSS, a widely distributed statistics program.

3.2.4 Results

3.2.4.1 Descriptive results

Importance of the river functions

This criterion was the initial question and aims at revealing how much the population knows about the functions of a river and for what it can be used for. Although a river can fulfill much more than the functions which are summarized in the five categories, the survey was limited to these five categories, as they were considered to be the most relevant for the questionnaire. The five categories are utilities (e.g. wastewater discharge, room for pipelines, washing), natural hazards (e.g. flood protection), leisure (e.g. relaxing, eating, etc.), water provision (e.g. drinking and process water, groundwater enrichment) and nature (e.g. biodiversity). The results are shown in Figure 59. It is noticeable that the categories nature and water provision are particularly important (median = 5). With an average of 4.7 respectively 4.5 and a standard deviation (SD) of 0.9 each, this value is quite stable and shows a low spread. The same can be said for the category of natural hazards (median = 5). Slightly more than half of the respondents find it very important. The average value of 4.1 is also quite high (SD = 1.2). The two functions leisure and utilities are considered as less important compared to the others (average value 3.6 and 3.1). Nevertheless, people think that Leisure tends to be more important than unimportant (median = 4). The dispersion is relatively large in both categories (leisure, SD = 1.4; utilities, SD = 1.5). The proportion of people who rated the Utilities category as very important and not at all important is about a quarter each. It is noticeable that almost half of the respondents consider the function of the category Utilities to be important (median = 3).

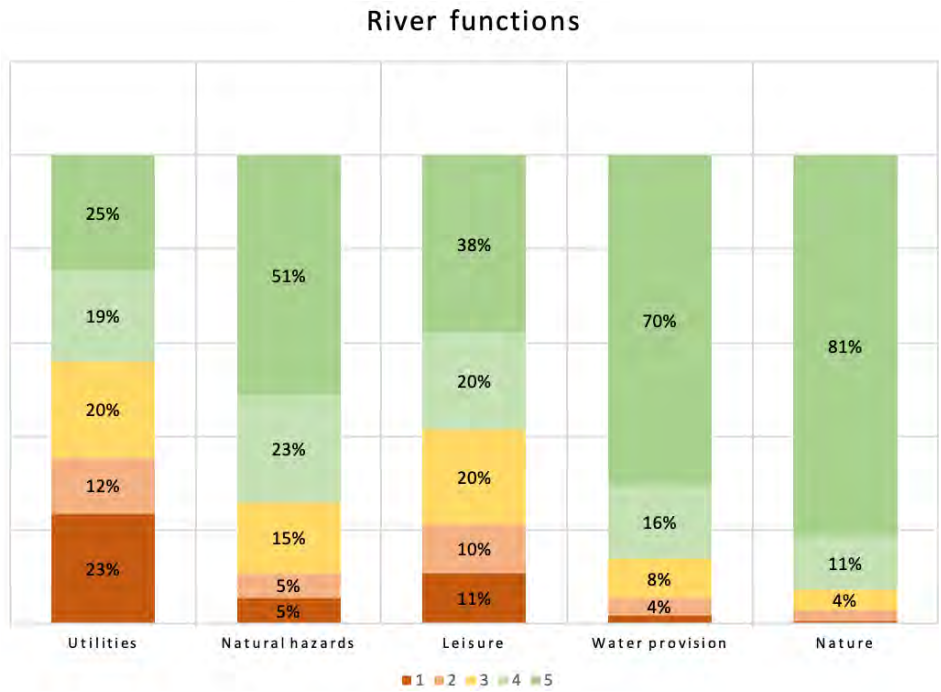


Figure 59: Graphical evaluation of the question about the importance of the functions of a river with 1 = «not at all important» and 5 = «very important» (own source).

Number of rivers flowing through Victoria

This question investigates the people's knowledge regarding the river situation in Victoria. Strictly speaking, there would be eight rivers flowing through the Central Victoria area. But if only the city center is considered, there are five to six. The distribution shows that the number of rivers in the city is clearly underestimated. The average is 4.1 and the median is 4.0. The standard deviation is relatively large (SD = 3.1). The majority of people say that there are two to five rivers in the city.

Characterization of the current state

The characteristics and evaluation of the current state in relation to appearance is an essential point and was asked in the questionnaire. The possible answer selections consist of five states from very unattractive to very attractive. About half of the respondents rated the current state of the rivers as unattractive or very unattractive. Approximately one third thinks that the appearance of the river is indifferent and almost 20% find the current condition attractive or very attractive (see Figure 60)

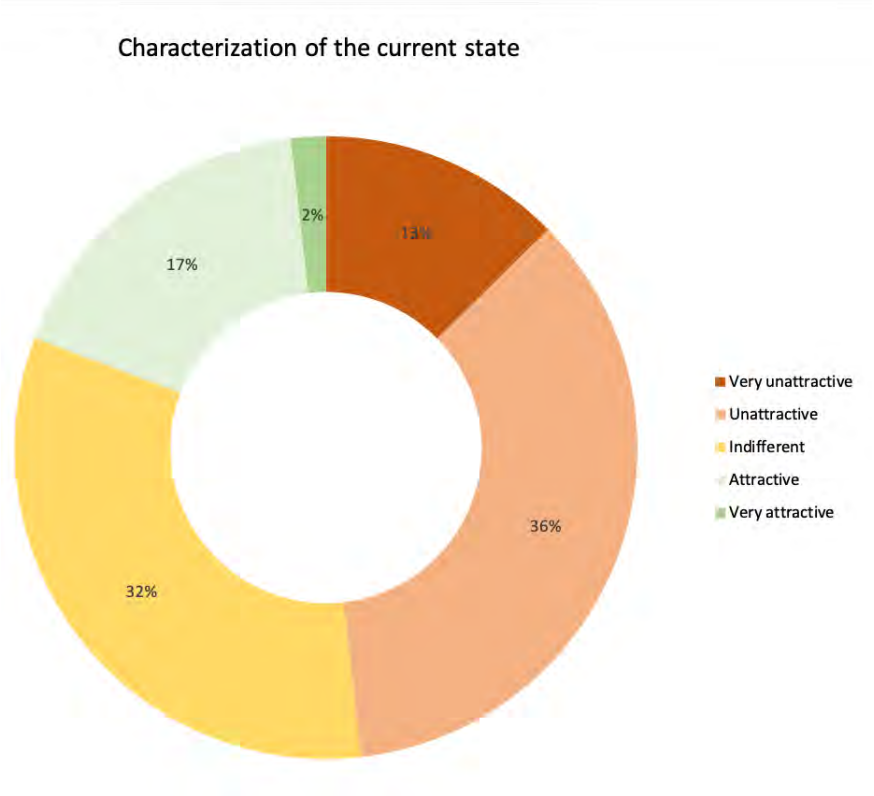


Figure 60: Characterization of the current state of the rives in Victoria (own source).

Positive characteristics of rivers in their present state

The question about the characteristics of what is appreciated about the current state of the river and what is not satisfying were open questions. The answers were therefore summarized into appropriate groups. 12 groups were built for the characteristics people like (see Figure 61). The most frequently mentioned point was Biodiversity with 24%, whereby the presence of fish was usually the main reason. During conversations with respondents, it was also told that in the 90s there were still shrimps and a lot of fish in the rivers.

The categories cleanliness (e.g. clear water, good care) and others (e.g. secure, potential for rehabilitation, historic, washing) each achieved 9% of the answers. Many categories reach a share of three to four percent. These are cools the environment, nice and peaceful (e.g. calm, relaxing), location (e.g. well visible, present), current state (e.g. stable structure, size), recreation, naturalness (e.g. gives character to town, combines nature and town, brings nature closer to community), water provision (e.g. drinking water, irrigation) and water discharge (e.g. flood control, rainwater discharge). The no answer category also received a very large share. Some of them, in total nine people, even said that nothing is positive about the rivers in Victoria which is part of the category others. Many people simply did not think of anything they appreciated about the current situation. This was also frequently mentioned during the conversations with the respondents.

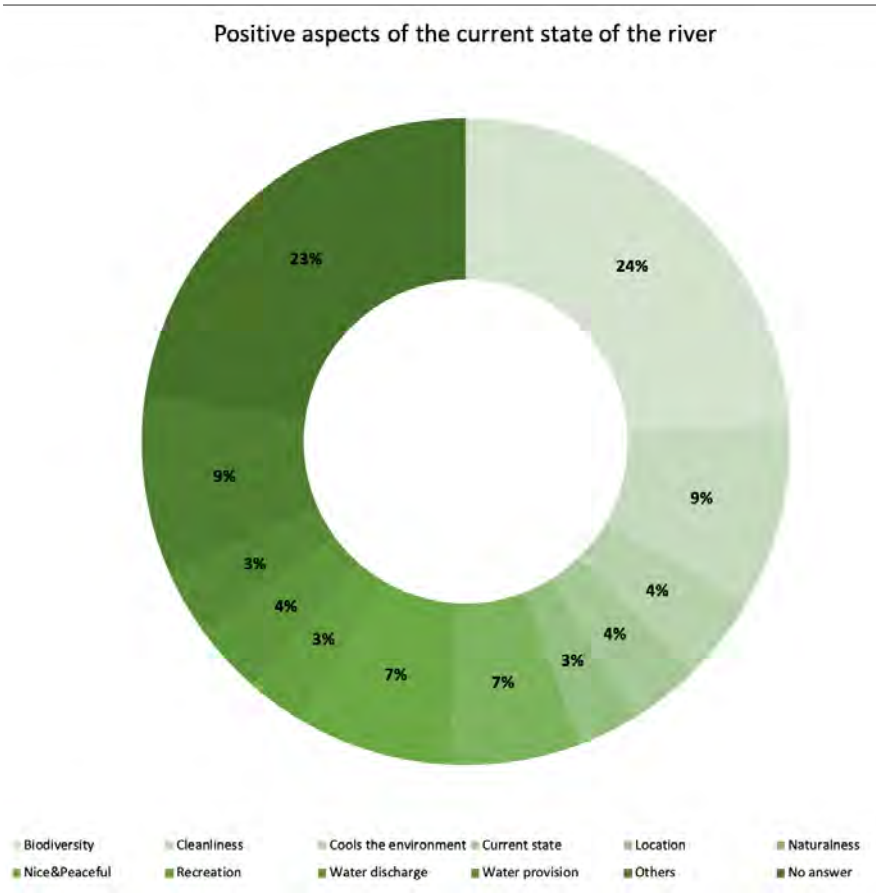


Figure 61: Positive reasons of the state of the river in the city (own source).

Negative characteristics of rivers in their present state

The characteristics, what is not liked about the current state of the rivers, are divided into 14 categories (see Figure 62). As in the above analysis, there were some categories of characteristics which were mentioned in 2-4% of the cases. These include artificial (e.g. canalized, line-shaped), diseases and pests (e.g. rats, mosquitos), drought, flooding, lack of space (e.g. nearby development, not enough space for development, narrow), unattractive (e.g. not nice for tourists, at hidden places, lack of seating areas/relaxing zone, no interaction with public), unclear water (e.g. muddy, murky, brownish-colored water) and utilities (e.g. household purposes, pipes, washing especially of cars and clothes, wastewater).

Bad smell and others (e.g. no signs, not environmentally friendly, lack of fish, illegal activities, no respect and lack of importance, unused potential) each achieved a 7% share. Especially the low appreciation of rivers was mentioned and discussed with some people during the survey. While the river was used for various purposes in the past (e.g. drinking, washing, swimming), it had to be protected, cared for and respected by people and was accordingly valuable. Today it is no longer given much attention as the water comes directly from the tap and the connection to the natural water source has been broken. Also mentioned during the survey and contained in the category others is the fact that the water flows unhindered into the sea and is gone. Instead, it would be necessary to store the water to use it further for other purposes. The share of the category pollution (e.g. contamination, bad water quality) and poor maintenance (e.g. too little gravel removement, not properly managed to maximize its purpose, not well taken care of) is slightly higher. By far the largest share has the category waste (e.g. dirty, take-away boxes, bottles). Particularly the takeaway boxes have been mentioned several times. Especially with the last three mentioned categories, it is extremely difficult to make a clear separation. However, if the categories are added together, they have a share of 53%. At 11%, the share of no answer is much lower than for the question of what is liked about the current state of the river. This was also noticed during the survey that it is easier for people to tell negative points than positive points about the current condition of the rivers in town.

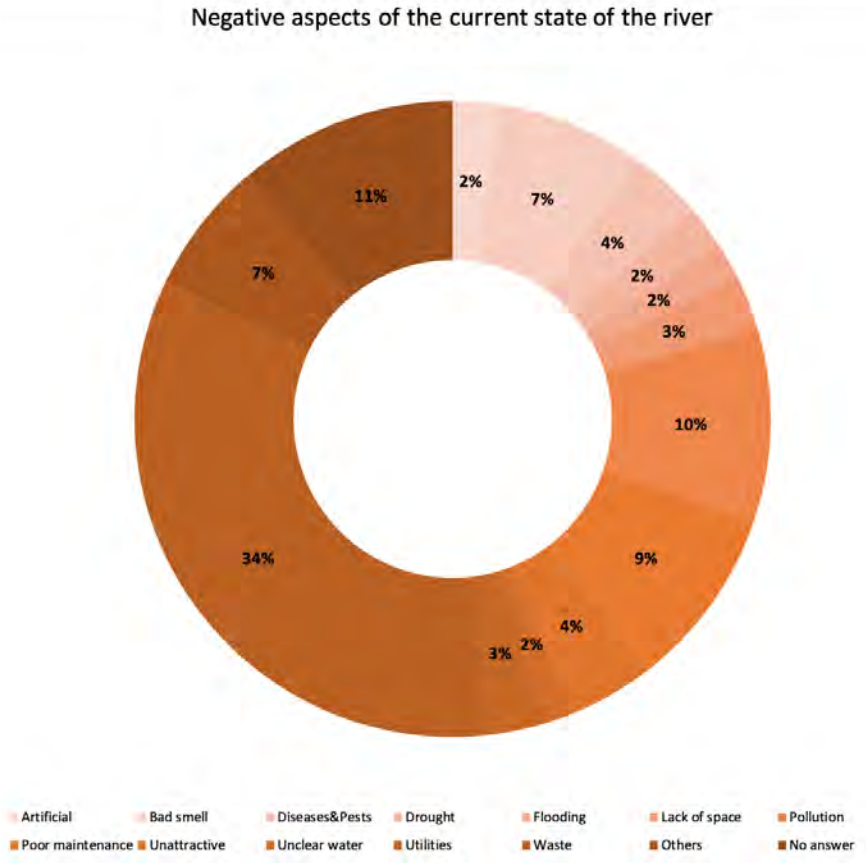


Figure 62: Negative reasons of the state of the river in the city (own source).

Potential development

The images in the questionnaire showed ideas of a state of possible future development of rivers in Victoria. The pictures could be evaluated according to the degree to which this state is desired. It is noticeable that the current condition, a canalized river with a hard bank and pipes is not desired (see Figure 63). The average value as well as the median are at 2.0 and thus very low (SD = 1.2).

The other conditions are generally highly accepted (see Figure 63). Especially a possible park area or a greenfield, which can be combined with swimming, as well as cafés and restaurants directly next to the river are popular (mean value = 4.4, median = 5, SD = 0.9; mean value = 4.3, median = 5, SD = 1.1). The natural state with the presence of mangroves as well as the picture with seating along the river in combination with a river pathway each achieves a mean value of 4.0 (median = 4.0, SD = 1.1). The barbecue area is a popular destination, but the fear of rubbish occurrence is assumed to be high which most probably will end up in the river, which is why it is rated more negative than the other images (mean value = 3.7, median = 4, SD = 1.3). This was told by several people during the survey and can be viewed in the evaluation below.

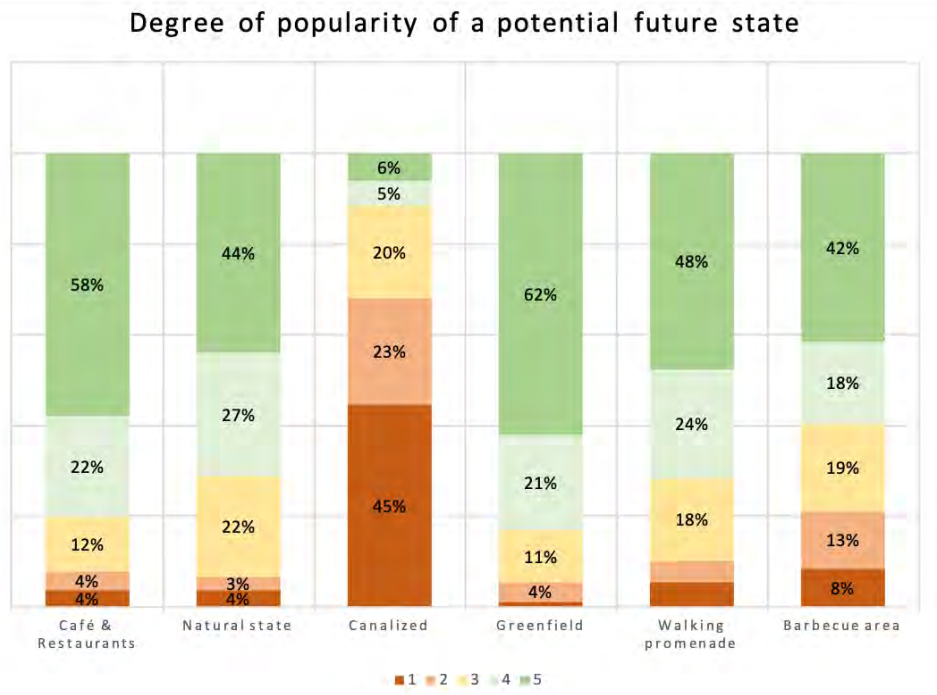


Figure 63: Popularity of the different sceneries about future condition, distribution with 1 = "not wanted" and 5 = "very much wanted" (own source).

Naturally, the above findings can also be applied to the most desired or least desired state. The results of the most desired state are shown in Figure 64. The most desired or least desires states are quite complementary to each other. This means if one condition is desired by many people, it is not desired by many people and vice versa. Only in the condition of the barbecue area, this is more balanced. The explanation is given below.

As a consequence of what was shown above, the park or greenfield is the most desired condition. The state is judged as particularly attractive, natural, good to relax and socialize, peaceful and enjoyable. It is good for children to play, environmentally friendly and cools the environment. Certain people, according to what they have communicated orally, have even noticed that such a state in the city can represent a nice alternative to the beach. The state of café & restaurants follows after that. What people generally like about this condition is that it is attractive, clean, relaxing and suitable to socialize with family and friends. Other points are that cafés or restaurants next to the river are nice places for business meetings or tourists. What is not appreciated, however, is that the condition is still artificial and waste can be thrown into the river with this kind of usage. The natural state with mangroves, the walking promenade and the barbecue area are approximately equally popular. In the natural state people especially appreciate the fact that both the environment and the people benefit from it as well as that the place is peaceful and calm. Some people have also mentioned a suitable habitat for fish, the possibility of exercising leisure activities and the presence of shade. What is appreciated about the walking promenade state is that it is attractive and clean, relaxing and good to socialize, the urban environment and nature is united and interacts with the surrounding area. People also like the fact that they can walk along the river and it has seating possibilities. The only negative point mentioned was that the space needed for this development is probably not available in the city. Although the barbecue area is regarded as very attractive and suitable to relax and socialize next to the river, it is assessed as negative because there is a great fear that a lot of waste will end up in the river with this type of use and that sufficient waste bins would be needed. Some people think that the city is the wrong place for a barbecue area. Many people do the barbecue at home or at the beach.

The current condition clearly drops off. As the only positive point, it was mentioned that space is needed for the pipes and this is a suitable place. On the other hand, there are a lot of negative feedbacks. For example, the danger of leaking pipes and pollution or blockage related to flooding during heavy rain. Further listed as criticizing points are the bad smell, the channelled structure, the presence of waste and that it is dirty, the wrong place for pipes as well as unhygienic and danger for diseases. Also, nearby development and the presence of a road right next to the river as well as no interaction with the surrounding was rated negatively. Some respondents have said verbally that there has been much development in recent years, but rivers have not been taken into account and thus constricted. The most often mentioned negative point is that the river in this state is unattractive.

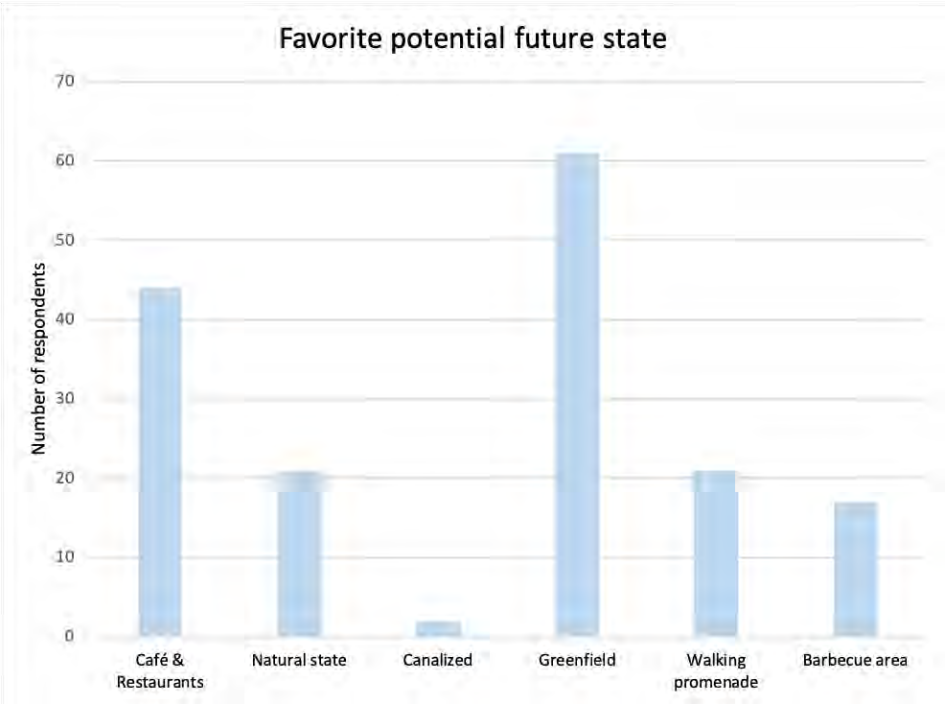


Figure 64: Overview about the favorite potential future state (own source).

Comparison between residents and employees

Table 29 shows some small differences in the mean values between the groups. More detailed information is contained in Appendix JJ. Especially the employees, but also people who work and live in Victoria, appreciate cafés and restaurants along the river more than people living in Victoria. The natural state is generally very popular but is least liked by employees. Today's condition, with lots of pipes and concrete in and around the river, is the least popular condition. The employees are the group who like it the least and the people who work and live in the city the most. The greenfield is the most popular state of all and similarly distributed across all three groups. The average values of the walking promenade vary around 4.0, with people who live and work in Victoria liking the state the most and the one only working in town the least. The barbecue area is moderately popular, with the working people liking it more than the other groups.

However, the t-test is used to determine whether these differences are statistically significant (see Appendix KK - Appendix MM). In the present cases, a significant difference could only be found in two of them. This is the case with the two future states natural state and canalized and in both instances between the employees' group and the people who work and live in Victoria at the same time. The employees' group appreciate the natural state less than the people who both live and work in the city ($p = .038$). Applied to the canalized state, this also means that the employees like this state less than the people who live and work in Victoria ($p = .023$).

Table 29: The mean value and the standard deviation of the criterion potential future state of the river of the respective study groups (own source).

Future state	Group	Mean value	SD
Café and Restaurants	Residents	4,11	1,202
	Employees	4,37	,921
	Both	4,26	1,136
Natural state	Residents	4,13	1,096
	Employees	3,87	1,050
	Both	4,28	,984
Canalized	Residents	2,09	1,299
	Employees	1,84	1,033
	Both	2,37	1,273
Greenfield	Residents	4,43	,972
	Employees	4,37	,964
	Both	4,37	,846
Walking promenade	Residents	4,06	1,187
	Employees	3,97	1,143
	Both	4,12	1,179
Barbecue area	Residents	3,57	1,193
	Employees	3,89	1,312
	Both	3,56	1,532

3.2.4.2 Correlations

Following the descriptive analysis, the data are examined for correlations. The correlation analysis was carried out with all available data. There is talk of a bivariate relationship since two variables are always compared with each other. A distinction is made between positive or like-minded correlation and negative or opposite correlation. Unfortunately, only very few interesting correlations could be found. Effect strengths also indicate how important the event is. A distinction is made between weak (r = .10), medium (r = .30) and strong (r = .50) (Universität Zürich, 2018).

The significant correlations are marked in blue color in Appendix NN. Those in dark blue indicate those that were considered interesting with regard to the goal of the master's thesis. Especially the variable age shows two interesting correlations. There is a positive correlation between age and walking (r = .218, p = .005, N = 166) and between age and the desired future state of cafés and restaurants (r = -.181, p = .020, N = 166). This means that the older the people are, the more likely they are to walk and the less they like cafés and restaurants next to the river. However, the correlation has a weak to medium effect.

It is also noticeable that the variable walking correlates significantly with the possibly naturally prevailing condition in the future (r = .250, p = .001, N = 166). This means the more people walk, the more they like the natural state of the rivers. The correlation is almost moderate. Another interesting correlation is between the evaluation of the utilities function and the future desired state concerning canalization (r = .222, p = .004, N = 166). The correlation is weak to medium. The more people consider the function of the river as utilities corridor as important, the more they like the canalized state. The correlation is weak to medium.

3.2.5 Limitations

The proportion of women in the survey was significantly higher than that of men. This was especially noticeable among the residents. Men have very often passed the questionnaire to women when they were at home. Another reason is that men often came home late after work and were therefore not present when the survey was carried out. A different time could have been chosen for the conduction of the survey, but it was difficult to implement this due to the need of a local supporter. It was recognized that the people were much more open when they were approached in Creole. The large proportion of young people can be explained by the fact that the proportion of employees was higher and many of them were of low age. It happened several times that in a shop the older person passed the questionnaire to the younger person to fill out.

3.3 Decision-maker requirements

This chapter describes the workshop that was held. It served to discuss the already made ideas with an audience, which has a large influence on the actual implementation of revaluation measures.

3.3.1 Aim of the workshop

The workshop aimed to discuss important issues concerning the further development of rivers within Victoria with relevant decision-makers. Various people from different institutions or ministries were invited (see Appendix OO). Representatives from PUC, SPA, Landscape and Waste Management Agency (LWMA), Project Planning and Implementation Department (PPID) and Climate Adaption and Management Section (CAMS) attended the workshop.

The workshop focused on the discussion and possible improvement measures of four different case studies, which were based on the then-existing evaluation regarding site analysis, river assessment and survey. The case studies should reflect various development possibilities and contain provocative proposals. Participants should consider their background to provide an interdisciplinary perspective on future developments. During a discussion round, other relevant aspects regarding rivers in Victoria were debated.

3.3.2 Workshop procedure

The workshop can be divided into three parts (see Appendix PP). After the introduction, a short (I) presentation about the master's thesis was made so that all participants of the workshop are on the same level of knowledge. The followed (II) discussion covered five different topics, with the participants arguing from the perspective of their institution. These topics included positive and negative aspects of the rivers, their future functions, what else needs to be considered and which rivers should be prioritised concerning revaluation measures. After a break, the core element of the workshop followed. The *4 Corners* method was used to conduct the workshop part with the (III) case studies (Humber College, 2019). This method is well suited to analyse, assess and discuss new ideas, concepts or case studies or even to propose solutions. Another advantage of the method is that the participants have to move actively. The case studies are placed individually at four different locations in the room. The members were divided into four different groups of two people each. Care was taken to ensure that they were well mixed. Unfortunately, some deviations had to be made because the two CAMS participants had to leave the workshop early and could not complete the evaluation of the case studies. Each group had received a pencil, whereby the colors differed between the groups. This made it clear at the end which points came from which group. Each group was assigned to a case study at the beginning and wrote down their ideas for 7-8 minutes (see Figure 66). Arguments for the categories opportunities, challenges and other ideas (e.g. improvements) had to be listed and should be evaluated from the perspective of the participants' institution. After the time ran out, the location was changed and the same procedure repeated at the next case study. This was done a total of four times until each group was at their originally assigned case study (see Figure 65). Each group then presented the case study in which they had started. They explained their arguments and made comments on what they thought about the points of the other groups (Humber College, 2019). This resulted in a short discussion.

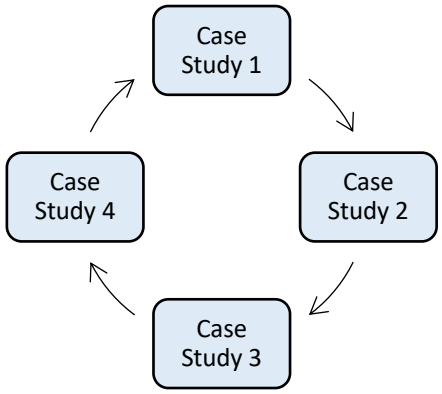


Figure 65: Illustration of the 4 Corners method (own source).

Figure 66: Case study discussion during the workshop (own source, 21/05/2019).

3.3.3 Results

The evaluation of the workshop is based on qualitative analysis. The discussion session and case studies are evaluated in the following.

3.3.3.1 Discussion session

The answer to the five debated topics of positive and negative aspects of the rivers, their future functions, what else needs to be considered and which rivers have priority concerning revaluation measures are explained in the following. According, to the majority of the participants, the rivers serve primarily as outlets of water that accumulates in the mountain area and the town. They are an extension of the natural rivers in the shape of channels that were established during land reclamation. The rivers, therefore, contribute to avoid flooding in town. Also, the water can be used in the dry season to irrigate the plants in the city as the LMWA mentioned during the discussion. For this purpose, up to 15'000 liters of water are taken daily from the Rivière St. Louis.

In contrast to the positive aspects, some negative aspects mentioned were the rivers being ugly, obstructed, many encroachments and that littering is a problem. Especially the topic littering was discussed. This is not necessarily only a problem within the city, but also already upstream in the catchment. The waste does not always get directly into the river but also indirectly.

The waste is put on the riverbank or in the front garden and in case of wind or rain it is fed into the river and ends up in the river. Furthermore, over the years, the waste accumulates on the riverbank, mixes and compacts with other material, which leads to a narrowing of the river cross-section and poses a big problem, as one participant mentioned. It also limits the speed of flow, which can be problematic. Not only solid waste is a problem, but also chemicals. For example, if maintenance work is done at home, the cans and brush are still washed with running river water because it is easier than in other places. As a consequence, this has a major ecological impact. A negative point, especially in town, is the maximization of property of the landowners thus build as close to the river as possible. A big discussion topic was the presence of utility pipes inside the river bed. On the one side, PUC argues that gravity sewage pipes run at the lowest point of ground with natural gradients and that this is the only available site. On the other side, the counter-arguments from other institutions were that it looks unattractive, risk of leaking exists, it can lead to blockages and that this carries the risk of flooding. Another extensively discussed aspect is the problem of carrying out maintenance work in de-silting processes. The presence of pipes makes this activity extremely difficult and leads to massively higher costs. The problem of blockage mainly affects crossing pipes. Unfortunately, a common solution could not be found within the discussion but it was possible to agree on a potential redesign of the pipes' layout. In particular, the crossing pipes are necessary at certain points but should cross the flow at the highest possible level. The flooding events in 2004 have led the Seychelles Planning Authority to be very restrictive and objecting about any proposal near rivers. They have become more conscious about keeping the rivers open, also concerning maintenance work.

In the future, rivers should no longer be polluted. It would be nice if something could be done for biodiversity. The planning office looks at the rivers from two different perspectives. On the one hand, they are aware that it is a simple solution for the PUC to run the pipes in the river and thus maintain the whole network. On the other hand, due to their location, rivers are very well suited for the establishment of a people network movement through Victoria. In large cities, paths along the river can be used for walking or jogging. They offer high value of visual aspects in town, a place where you can rest and relax over lunch, as long as there are seating possibilities like benches or steps. People try to walk in the shade, which could be provided well with trees along the rivers. However, they should be safe in the way that no one can fall dangerously into the river.

The question arose whether the discharge capacity was ever designed for the catchment and still meets today's requirements to avoid flooding. It had been calculated for a particular runoff, but this had happened long ago during land reclamation when not quite as much was developed as it is today, one person explained. The consensus was that it needs to get recalculated accordingly. The lack of space within the city was also addressed during the discussion. Buffer zones along the rivers need to be created to guarantee access to the water. The rivers should be seen as a nice feature and their value should be raised. The river should be considered in future developments as a nice feature and it should be tried to combine everything.

It was also mentioned that in the context of the development of the Victoria Masterplan in 2015, the idea arose to widen and deepen river sections to use them as transport routes or ferry services. An example would be the supply to the fish market, which could be used by fishermen and reduce the traffic combustion in the morning.

It was pointed out that one or two rivers should be properly upgraded instead of several a bit, choosing the most appropriate one. Rivière St. Louis was mentioned as a very suitable river. A footpath already exists, although not as a recreational area, but due to the green area adjacent there is potential for improvement. Rivière Moussa was also seen as a potential, especially in the context of the Financial District development plan. However, this will be more on a commercial basis where a public square with a walkway should be available. Further, the La Poudrière River was also seen as a river with potential for upgrading.

3.3.3.2 Case studies

As mentioned before, the case studies are four different places where suggestions for improvement have been made by the author. The workshop participants evaluated the case studies in groups of two and briefly discussed them in a group discussion. Each case study is explained briefly at the beginning including an illustration. In the second part the discussed points of the participants during the workshop are explained.

English River

This case study is an improvement measure next to the bus terminal. A large concrete staircase instead of the currently existing high concrete wall is proposed to ensure access to the water and is considered as a suitable waiting area for people who use the bus (see figures below). To achieve this, a reduction in the size of the bus terminal is probably necessary. However, this is envisaged in future developments.

Figure 67: Case study 1 – English River, current state (own source, 24/05/2019).

Figure 68: Case study 1 - English River, future approach.

The available space is seen as a great difficulty, which makes communication with the landowners along the area necessary. It is also a challenge to convince the authorities to downscale the bus station. The size of the river is considered too narrow compared to others and it is currently surrounded by relatively high walls on both sides, which results in high costs for improvement measures.

The possibility of increasing the discharge capacity in the event of an improvement measure is seen as an opportunity. The site would also be a suitable place for waiting commuters. Instead of the concrete wall, a see-through fence was proposed to ensure at least visibility of the river. Instead of fixed staircases, green areas with trees, grasses, etc. were suggested. A direct link to Castor Road as a shortcut would be an additional opportunity for improvement that could be considered. It would be an attractive and fast link used by people living in English River. The completed poster of the workshop with the points challenges, opportunities and other ideas are included in Appendix QQ.

Rivière Moussa

The section of the Financial Business District development along Rivière Moussa is regarded as a possible site for river upgrading measures (see Figure 69). A staircase is proposed on the left side, but not as massive as the one at English river. On the right side, an area with cafés and restaurants along the river is proposed in the upper part. The lower area should be suitable for a shaded path with benches (see Figure 70).

Figure 69: Case study 2 – Rivière Moussa, current state (own source, 24/05/2019).

Figure 70: Case study 2 – Rivière Moussa, future approach.

Figure 71: Rat walking on pipes (Rivière Maintry, own source, 14/05/2019).

A major problem mentioned was the predominance of buildings and infrastructure on both sides. The walls on the left are retaining walls, which already leads to major limitations in terms of improvement measures. Pillars, which are placed in the middle of the river, additionally obstruct the outflow of the river. Another problem is the predominant littering, especially takeaway boxes and plastic. People, unfortunately, have the habit of leaving their waste lying around or even throwing it directly into the river. Further, many pests like rats are present (see left figure).

However, this place would be a good short cut, especially to get from the city center (Market street) to the bus station, the two busiest places in town. Except along busy roads, there is no way to cover this distance, as one person highlighted. Another opportunity is the availability of more seating possibilities which would lead to the river being a more relaxed place than it is today. Further, water features like fountains or lights could be included. The whole area could be used as a tourist attraction, which could even be complemented with small boats for recreation, as the bridges are too low for effective commercial boat transport on the water. An idea would be the so-called Pirogue boat, a traditional fishing boat, one participant said. A small painted wooden boat, which is moved with a long wooden stick (e.g. bamboo). For this, a wide and deep enough river is needed. The completed poster of the workshop with the points challenges, opportunities and other ideas are included in (Appendix RR).

Rivière Maintry and St. Louis

A particularly large project was deliberately proposed here. Around half of the Freedom Square and the entire Peace Park are to be redesigned. These two areas are the only larger green areas in the vicinity of the city center that borders a river and are therefore predestined for upgrading (see Figure 72 - Figure 75). The two rivers are to be united in the middle of Freedom Square. On the right side, a natural river area with mangroves is proposed, while on the left side a greenfield site along the river is planned (see Figure 76). The left side is similar to the already existing area, only with the difference that the approachability to the water is given and can be used as a recreational area.

Figure 72: Case study 3 – Rivière Maintry (Freedom Square), current state (own source, 10/03/2019).

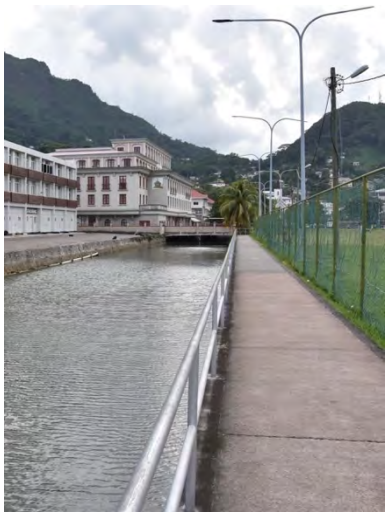


Figure 73: Case study 3 – Rivière St. Louis (Freedom Square), current state (own source, 10/03/2019).

Figure 74: Case study 3 – Rivière Maintry (Peace Park), current state (own source, 24/05/2019).

Figure 75: Case study 3 – Rivière St. Louis (Peace Park), current state (own source, 24/05/2019).

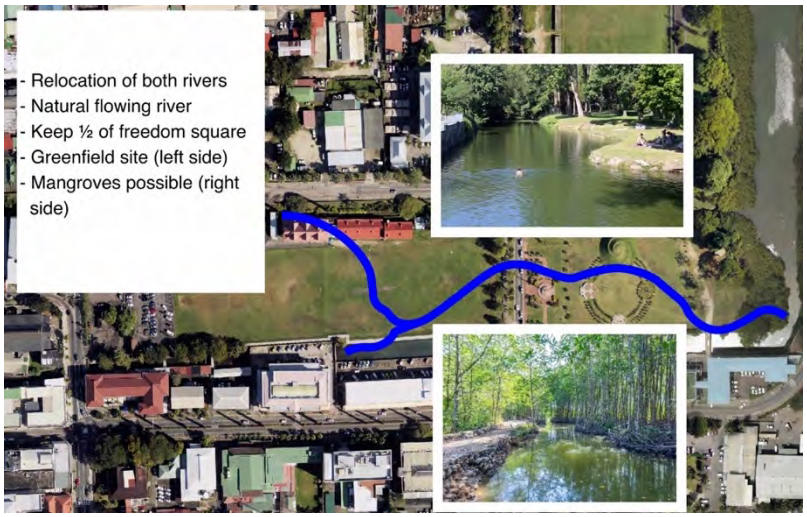


Figure 76: Case study 3 – Rivière Maintry and Rivière St. Louis (Freedom Square), future approach.

The excavation of the new river path is seen as a challenge, while the two channels at the edge of the two green areas will be removed. The size of the project is also criticized, as the Freedom Square is already reaching its capacity limits in terms of the number of people on certain activities and the Peace Park is already a local recreation area. At this size, the project leads to high costs which would be massively increased by the necessary underpass at 5th June Avenue. In addition, it is feared that the river will take its natural path if this form of upgrading is made. In the discussion that followed, it was mentioned that the risk of flooding exists as the discharge capacity could not be sufficient due to the merging of the two rivers. Another problem is to convince property owners that upgrading the river is an enrichment and upgrading of the land so that the project can be implemented.

The relocation of the rivers would be a nice upgrade for the Peace Park, although it has only existed in this form for 12 years. A redesign by incorporating the river adds freshness, can be complemented with additional plants, is a pleasant feature, relaxing and also results in an ecological upgrading. Especially the location of the river path was discussed. It was agreed that the rivers would only be united after the crossing of 5th June Avenue and that the location along Freedom Square would be preserved. But the section should be completed with more trees and maybe the area behind the post office can be taken into account for the upgrading (e.g. sitting area). Ona participant was of the opinion that it makes no sense financially to change the river path on this short stretch at Peace Park in such a way. The location of the rivers should be maintained, but approachability to the river can certainly be improved. Some people replied that it would be worthwhile to relocate the rivers. Instead of just making a promenade or a sitting area, the river can also be transformed into a so-called water park. Whether there is a large pond in the middle after the rivers merge with a large outlet towards the lagoon, whether they are brought together and meandering into the lagoon or meandering individually, remains to be decided. The completed poster of the workshop with the points challenges, opportunities and other ideas are included in Appendix SS.

La Poudrière River

The last case study is the one at La Poudrière River along the esplanade and tourist kiosks (see Figure 77). Relatively similar upgrading measures are proposed on both sides of the river. The building of the National Arts Council could be extended and thus contains not only one but two floors, whereby a reduction of the floor plan results. On both sides, a footpath with small steps and greenings in between is proposed (see Figure 78).

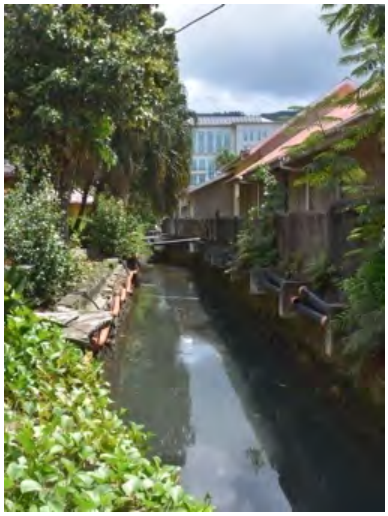


Figure 77: Case study 4 – La Poudrière River, current state (own source, 24/05/2019).

Figure 78: Case study 4 – La Poudrière River, future approach.

A major challenge is the lack of space and the presence of pipes. The relocation of buildings and other structures (e.g. sewage pipes) is also considered as a challenge, which is made more difficult by discussions with involved landowners. The adjacent busy road and the highly frequented footpath along the river are regarded as difficulties, especially during the work on the upgrading measures.

However, it was seen as an opportunity to improve the flow and reduce pollution after the upgrading activities. One participant also noted that there are already many crabs along the river. An attractive alternative could also be found for the utility corridor. Aesthetic value can be improved. Two examples were given which have even a secondary function. On the one hand, the wrapping of wooden cases which can be used for planting (e.g. grasses) or, on the other hand, wooden floating decks which hide the pipes and have the function as a seating possibility. Furthermore, the tourist kiosks have the possibility to expand their business and offer food, juices, entertainment, etc. Another enhancement is the re-orientation of the kiosk or its fronts used on both sides so that the footpath can be made closer to the river section. The building built over the river next to the Seychelles National Library can only be relocated if an alternative is made available to the business owners. Maybe they will move to the area of the new land reclamation behind the music school next to English river. On a width of about 5m land reclamation will be done there. But the authorities must first be convinced what the viability of the project is in order to see the positive aspects of it. In addition, one person mentioned that the enhancement of the aesthetic value in contrast to the recreational value should be in the foreground since this is rather understood by the people in Seychelles. In the first step, it should be said that it does not look nice and in the second step, the reference to the recreational value can be made. The selling point is important, which is given by using the term of aesthetic upgrading. In short: The aesthetic pulls along the recreational aspect. The completed poster of the workshop with the points challenges, opportunities and other ideas are included in Appendix TT.

Further points raised during discussion

During the discussion following the respective case studies, some interesting points were mentioned which are briefly mentioned here. One person would like the river edges to be redesigned generally. The runoff should always be guaranteed. By means of a trapezoidal profile or even better the usage of stairs, which also guarantee access to the water, the discharge capacity can be enormously increased during a flood event. This is because as the water level rises, more volume is available, and the discharge capacity increases enormously. Staircases, therefore, have two functions: They serve both as flooding prevention and support access to the river. Another point was the maintenance of Rivière Trois Frères in its natural state, as in contrast to those rivers in central Victoria, it still corresponds more or less to its natural state and discharges into a natural habitat, the Bois de Rose mangroves. The proposed channel to Hodoul Bay was also briefly mentioned. In particular, the roads (e.g. highway) and the buildings were regarded as severe restrictions. However, it would be a clear improvement measure for the circulation of water, also in view of its former condition. It was also mentioned that the environmental or ecological aspect could not be considered enough in the workshop, which can be explained by the cancellation of the participation of the Department of the Environment.

4 Part III – Potential improvement measures

This chapter describes potential river improvement measures and can be seen as the discussion chapter. All previous information flows together in this section. The chapter is divided into general and river specific improvement measures.

4.1 General improvement measures

The general improvement measures start with basic points that need to be considered when implementing river improvement measures and become more and more specific. The individual points cannot always be assigned to clear topics, which is why there may be some overlaps.

Stakeholder involvement

The lack of communication between the various parties involved in a project is a major problem (Arup, 2014) and has been identified personally by the author on site. Various stakeholders and experts should be engaged in the process and forms the basis of long-term and sustainable improvement measures, even though sometimes a compromise solution has to be found. Relevant stakeholders include engineers, economists, policymakers and ministries, planners, environmentalists, local community and NGO's, to name just a few (Komínková, 2012; Cengiz, 2013; Arup, 2015a). River improvement measures should benefit all to gain acceptance and support. This applies in particular to the local community, which will make use of the river in the end (Åberga and Tapsell, 2013; RESTORE, 2013; Grêt-Regamey et al., 2016). As the survey shows, around half of the respondents found the river unattractive or very unattractive. By far the most popular point in the present state is the presence of species still in existence, despite the poor framework conditions. This should be taken into account when implementing the ideas. Especially the popular rated conditions of a greenfield that reaches directly to the water or cafés and restaurants at the river should be considered in future improvement measures. Nevertheless, clear leadership is important. Since the impression was that rarely someone takes responsibility, this should be taken over by the government. The government has a great role to play in setting a good example and initiating a project (Simsek, 2012).

Detailed and proactive planning

Detailed and long-term planning is of great importance for the implementation of measures. According to the expert interview conducted, this is currently not the case for the rivers in Victoria. Detailed planning can be achieved in the form of a river management plan that regulates responsibilities (Cengiz, 2013). A clear goal, the consideration of several options, the comparison of the current and future situation as well as the early involvement of relevant stakeholders and experts including their expectations and the clarification of funding helps and is necessary to implement the plan (RESTORE, 2013).

In the implementation of river improvement measures, planning authority, in this case, the Seychelles planning authority, has a major responsibility. As they are the ones who want to implement the improvement measures, they have to think ahead and involve all the relevant stakeholders.

Integral approach

As experienced during the research for the underlying thesis, many issues are already addressed, but need to be properly implemented with an integral approach. River upgrades should not only focus on a specific subject area. The river improvement projects should cover as many different areas as possible and preferably combine them in one project. In terms of urban river improvement measures this involves use of open space, ecology and flood protection. Keywords are more space for people, more space for plants and animals and more space for the water (Prominski et al., 2012; Cengiz, 2013; Perini and Sabbion, 2017). This is particularly important as the Seychelles grow and urbanization will increase, putting further pressure on rivers. Tidal influences and future climate changes such as sea-level rise or changes in precipitation patterns must be taken into account as well when implementing the measures.

Even small measures such as changing the riverbank can have major impacts. For example, changing the riverbank towards a slope instead of the hard vertical obstruction and the reduction of impervious areas have not only a recreational or environmental value but can also help to minimize flood risk due to the multi-functionality of the river (RESTORE, 2013). The reduction of impervious area is an approach to tackle the cause, not the symptoms, which is beneficial (Landers, 2010). Furthermore, the reduction of impervious areas reduces the entry of hazardous substances into the aquatic environment as shown in chapter 1.4.2 and can decrease water shortage due to increased water infiltration. Possible measures to reduce impervious areas include greening the roofs, permeable paving or promoting the mentioned green-blue infrastructure (Arup, 2015f; Blau et al., 2018). Another example, especially suited to Victoria, is the removal of pipes inside the river. This not only enhances the aesthetic value but also increases the discharge capacity and thus reduces the risk of flooding, simplifies the de-silting process and lowers the risk of the pipes polluting the water in case of leakage.

Furthermore, in the best case, the extent of improvement measures should look beyond local measures and include the whole catchment, as interventions above can have an impact on the areas below and vice versa (Cengiz, 2013). Pollution in the upper part of the river, for example, has a consequence for lower sections, while a connection barrier in the lower part affects the upper part.

For recreational values, a wide range of possibilities should be available, be it nature observation, walking, sitting by the river, etc. (Cengiz, 2013). A visual change in the river can lead to a change in people's attitudes towards the river and a more sustainable and careful way of interacting (Åberga and Tapsell, 2013).

Figure 79: River Mardan in Calne after river improvement (Bainbridge, 2009).

The river improvement example of river Mardan in Calne (UK) is a successful measure in the urban area and has a comparable river size to the ones in Victoria (see Figure 79). The straightened section of the river has been upgraded with stones, gravel and plants and has been made more natural, which both provides access for the population and reduces the risk of flooding (RESTORE, 2013).

Establishment of a comprehensive overview

The lack of a comprehensive overview was criticized during the expert interviews. In Seychelles, there is no institution or department as well as no national law or policy that takes full care of the river system (PUC, 2011; Government of Seychelles, 2017b). The coordination between the bodies that protect the rivers, regulate development in the catchment or along the rivers, conduct de-silting processes and use the rivers for water supply is missing (Vel, 2014). Responsibility and tasks are spread across various parties, which is why the use of water is not sustainable and must be radically changed. The current River committee meets only rarely and deals only with water abstraction at rivers. Creation of an institution with a comprehensive overview or a transformation of the existing River Committee towards this state should be a targeted option which was also addressed during the expert interviews. The proposal of an Integrated River Basin Management which includes integral coordination, acting at a strategic level (e.g. setting policies) and implement actions has been mentioned by PUC (2011) (see Figure 80).

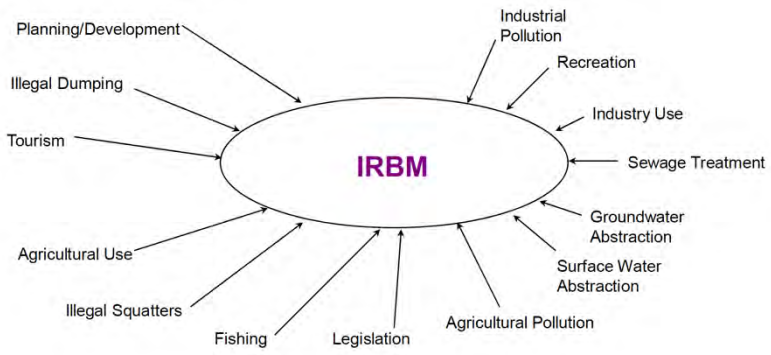


Figure 80: Integrated River Basin Management (PUC, 2011, p. 101).

Education

General education should be promoted. This was a topic in the survey, the expert interviews and the workshop. It can be seen that the importance of the river as a leisure opportunity was considered comparatively low in the survey. This can be interpreted as a lack of awareness among the population that the river can be used as such. The beach is much more popular in Seychelles and the most frequented local recreation spot where many activities take place, according to the survey. Especially as Victoria has no beach and no other local recreation areas available apart from a few underused green areas, rivers offer a possible alternative. This should be promoted to the general population. Both in the expert interview and in the workshop, the topic of education was mentioned mainly concerning the waste problem.

Especially the presence of take-away boxes was mentioned in the survey several times. Perhaps the fact that rivers do not look like rivers, but rather like a drainage system, is responsible for the fact that no attention is paid to the river and, for example, waste is simply put into the river, as mentioned by PUC[27]. The survey has shown that people are aware of the importance of the river for nature. Education should serve to make people aware of river functions, to take care of them and what the personal benefit can be. If this succeeds, it is assumed, the attitude towards the river will change and people will begin to recognize and respect it as part of the whole ecosystem (Kondolf and Pinto, 2017). A suitable method is to put signs near the river to draw attention to these facts, which was mentioned both in the workshop and in the expert interviews. A location has to be determined for Victoria whereby highly frequented pedestrian routes are suitable. This was also a project of the Wildlife Club of Seychelles a few years ago. Signs were specially designed for Victoria, containing historical information, images and advice on river protection. Further, the project pursued various campaigns to draw attention to the threat and the conservation of the rivers and to push the topic especially in school lessons (Wildlife Clubs of Seychelles, 2012; Vel, 2014). However, it is not clear which activities were implemented. Especially for teachings of ecological aspects in schools, the rivers are very educational. For example, a so-called outdoor classroom could be created in places where the river has been upgraded and there is a school nearby. The project would serve at the same time as education as well as for monitoring the development of the condition (Wild et al., 2009). There is a similar example at the Independence School north of Victoria, in which mangroves are promoted in the form of a school project (International Union for Conservation of Nature, 2018).

Law enforcement

Law enforcement is generally a problem in Seychelles as revealed during the expert interview and by Vel (2014), PUC (2011) and ECODYS Nederland BV (2007). In the future, clear and strict guidelines will be needed, which will firstly have to be applied and secondly applied equally to everyone. People still pollute the rivers and build structures next to the rivers without permissions, although respective policies and laws would be in place (Vel, 2014). Here, the SPA takes an important function and responsibility, because it is the SPA that permits the construction of a building or other kind of development (Arup, 2014). Vandalism on PUC infrastructure is another problem which occurs and has a major impact on rivers, particularly if they are in close distance to them (Vel, 2014). Illegal water abstraction and the increase of water consumption must be taken into account. This will lead to further difficulties in the event of future climate change with water shortage during the dry period. It would also be necessary to consider whether a minimum flow rate should be guaranteed, or else the improvement measures would not make sense (Schanze and Olfert, 2004).

[27] Personal meeting with Alexis, G. and Henriette, A. on 21/03/2019

Buffer zone creation

It is generally important that sufficient space (buffer zone) is available for improvement measures, which was also mentioned in the workshop. This is often a major problem in urban areas. On many sections of the rivers in Victoria, building fronts reach close to the river. Nevertheless, forward-looking planning and the introduction or implementation of policies should attempt to preserve this space and not obstruct it further. Nowadays undeveloped spaces should be protected and existing buildings that do not have a buffer zone should be relocated or the minimum distance should be implemented when a new building is constructed. This is particularly suitable for Seychelles as the *Land Use Plans* are in progress and such a buffer zone can be integrated there. The width is of secondary importance. It is important to have at least a buffer zone on each side of the river. The wider the better, but even a small buffer strip helps to take measures to upgrade the buffer (Bernhardt and Palmer, 2007). The basic elements of the *State Land and River Reserve Act* or the *Urban Design Guidelines* with a minimum development distance of 10m or 3m would exist. A width of 5m for the design would be particularly suitable, as this corresponds to the minimum width of a well-functioning riparian area (see chapter 2.2.4.3). A buffer zone helps to be flexible in the future and to be used for the respective need. It can not only be used for recreational aspects but also to stabilize the riverbank, as the provision of shadow, improvement of habitat connection, for visual attractiveness, as flood control or also for climate change and its consequences (Cengiz, 2013; JICA and MEE, 2013).

Mobilizing resources

One of the biggest problems facing the implementation of the improvement measures is the lack of financial resources (Findlay and Taylor, 2006; RESTORE, 2013). This was also mentioned during the expert interviews. The amount of space available in the densely built-up city (buildings, infrastructure, etc.) and the fragmentation of the land into individual plots is a further problem. However, in urban areas, it is an advantage that most of the land is owned by the state or other public institutions. This is beneficial in land negotiations for improvement measures. As shown in Figure 7, this also applies to Victoria (Schuhmacher and Thiesmeier, 1991; Bernhardt and Palmer, 2007). Due to the lack of space, in-channel improvements are often the most frequently applied improvement measure. In-channel improvements are measures that enhance the flow with simple, efficient, quickly implementable and cost-effective methods and do not require much additional space. Examples are the removal of the river bed and bank fixation, re-profiling, adding of structures such as groynes, addition or removal of sediment or the formation of shallows near the bank. In the case of Seychelles, big granitic boulders in the river bed to serve as shelter from the current and small amphibian zones would be possible solutions. The primary aim is not to achieve a high ecological quality, but to improve the current situation (Prominski et al., 2012). Stepping stone biotopes should be created which enable the migration of organisms. The typical characteristics of the river should always be taken into account and local building materials (plants, wood, stones) should be used. In-channel improvement measures primarily have an ecological benefit but also enhance the appearance of the river and make them more attractive to look at (FIBER and SFV, 2014; Verdonschot et al., 2015). These measures are also well applicable in Victoria, as infrastructure and buildings reach up to or into the river.

An additional problem is often the missing know-how to implement the measure. This also applies to the situation in Seychelles, where one person is responsible for a lot of things and at the same time few people know a specific subject. All those are reasons why the improvements are made in places where they appear feasible and not in those places where they would be more relevant and more effective (Schuhmacher and Thiesmeier, 1991; Bernhardt and Palmer, 2007). This should be taken into account in the case of river improvement measures in Victoria.

Other approaches than concrete channels for flood protection

The current channelized conditions of the rivers in Victoria are used to protect against flood risk, as mentioned during the workshop. Although storm water management is very important, traditional hard construction measures are not sustainable and by far not the only methods to minimize the flood risk at river sections, apart from a few exceptions. They have ecological and recreational deficits and cannot reduce the flood risk for areas below. Rather, other approaches such as soft-engineering approaches, reducing the impervious areas in catchment, improving the river at suitable places, upgrading the riverbank by changing the profile and reduce the rate of construction should be considered as possible solutions (Cengiz, 2013; RESTORE, 2013; Grêt-Regamey et al., 2016; Perini and Sabbion, 2017). Previous rough calculations have already shown that the problem of flood risk lies in the drainage system and not in the capacity of the rivers. For this reason, measures along or within the river are also possible. Nevertheless, to understand the problem of flood risk in detail and use it for further planning decisions, the missing knowledge should be created first. Discharge calculations consist only of rough calculations and there is no gauging station that provides more detailed information (Arup, 2014). This has been shown in the literature and mentioned in the workshop as well.

Water quality improvement and waste reduction

As mentioned in the survey, the expert interview, the workshop and in the literature review, the water quality is assumed to be very bad and pollution is regarded as a threat to rivers. Improvements can be achieved, for example, by improving wastewater treatment, enlarging the sewage network, reducing the numbers of septic tanks, better rainwater management, educating people, law enforcement and introduction of water standards that comply with international law, reducing leaking of pipes, reducing the impervious area or with water purifying plants (Bernhardt and Palmer, 2007; Arup, 2015b; Blau et al., 2018). Since a large amount of waste does not come from the city center itself but is washed down from the upper catchment area as mentioned during the workshop, the introduction of a so-called trash trap (see Appendix UU) should be considered. In this case, the responsibility of maintenance task, flood risk and the continuity for species would have to be considered in the sense of an integral approach. Local waste reduction could be achieved with the provision of waste bins, as explained in the expert interview. An improvement in water quality does not only have an impact on ecological aspects but also on health and recreational aspects (Kondolf and Pinto, 2017; Blau et al., 2018). As pointed out in the survey, a stay near the river is not desirable if it smells badly.

Riverbank improvement

Many of the rivers in Victoria consist of a concrete canal with a vertical wall and do not allow for any interaction between the bank and river. This disruption of vertical networking should be reduced by improvement measures (Kondolf and Pinto, 2017). The improvement of the riparian area is important for various reasons (RESTORE, 2013). Soft or permeable engineering approaches can perform functions equivalent to hard structures while simultaneously offering some advantages. They dissipate flow energy during flooding events, improve water quality, reduce water temperature by providing shade, allow space for flood attenuation, provide habitat diversity for aquatic life, provide aesthetical value, etc. Further, leaf litter and woody debris goes into the river and becomes an important part of the food chain. Planting can involve grasses, ferns, bushes, trees, etc., but attention should be given to endemic species, as the expert interviews showed (Schanze and Olfert, 2004; Cengiz, 2013). Especially the provision of shade is important, as temperatures up to almost 32°C were measured in the rivers (see Appendix K). While riverbank improvements are short-term measures, the implementation of buffer zones, for example, is a long-term measure. A combination of the two has proven successful in the past and should be pursued (Komínková, 2012).

Further relevant factors

In principle, the first step for river improvement measures should be daylighting. This means the water body must be revealed so that a river improvement measure can be started at all (Schanze and Olfert, 2004; Wild et al., 2009).

From the population's point of view, it is important that the rivers are easily accessible and equipped with seating to ensure interaction with the river, provide space to sit and relax and increase attractiveness (see chapter 1.4.2). These two factors are not present in Victoria. As can be seen from chapter 2.2.5.3, most river sections are difficult to access and approachability is a challenge. There is no suitable seating available anywhere along the river. Often there are a lot of sections in the sun (see Appendix VV and Appendix WW), which makes a stay at the water not very pleasant. An avenue of trees that provides shade does not only offer an improvement for the people, but also has a positive effect on the microclimate and the species living in the river. Obstacles such as unused pipes or concrete elements which are no longer needed or can simply be removed, should be taken away. This increases both the drainage capacity and the aesthetic value. It is recommended to include this in future regulations.

From an ecological point of view, it should also be noted that the control of invasive species is particularly important (Schanze and Olfert, 2004), another issue mentioned in the expert interview. Although no river in the upper catchment area is connected to the key biodiversity areas, continuity should be ensured. The continuity is especially important for the eel, as mentioned in the expert interview. Continuity is mainly restricted by culverted sections, unnatural morphology and transverse structures. The latter is by far the smallest problem in the investigated area. The removal or bypassing of these barriers is to be targeted for migration (Schanze and Olfert, 2004; Wild et al., 2009).

Even if hard structures, as mentioned earlier, are not to be preferred from an ecological point of view, staircases offer a pleasant place for people to stay and at the same time serve to reduce the local flood risk. These measures are also valuable in the city and should be used at appropriate locations. Another point that was mentioned during the workshop is the importance of how to promote the project. In Seychelles, the focus should be on aesthetics. The main focus of improvement measures related to recreational aspects should be on reclaimed land, as this area disconnects the waterfront from the old town. Furthermore, it is the only place which has free areas at the moment and is not as densely built-up as the city center. Besides, the plots belong almost exclusively to the government, which is a huge benefit for improvement measures. To emphasize the importance of this measure, the removal of visible pipes is mentioned again. This has not only an aesthetical view but also reduces flood risk, simplifies de-silting process and reduce the risk of pollution.

4.2 Specific improvement measures

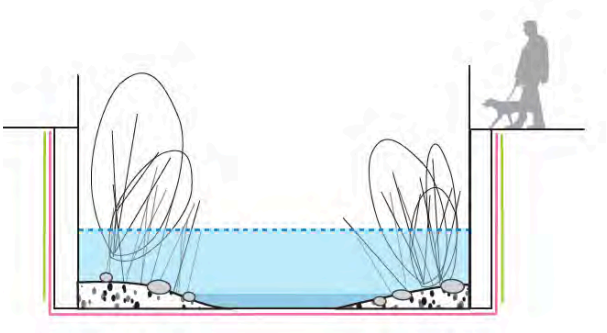


Figure 81: River bed improvement measures without additional space requirements (Prominski et al., 2012, p. 236).

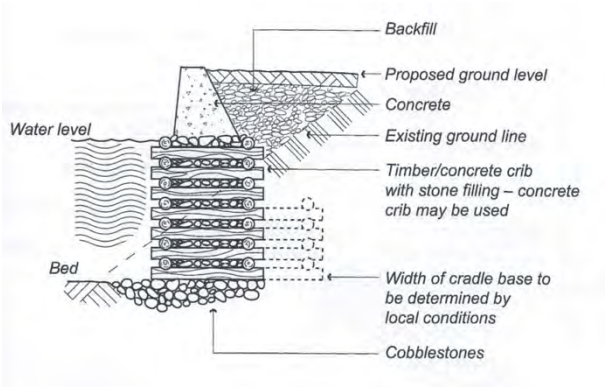
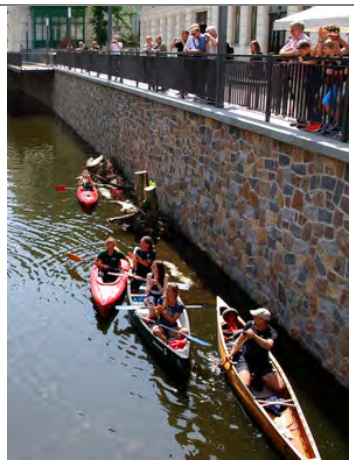


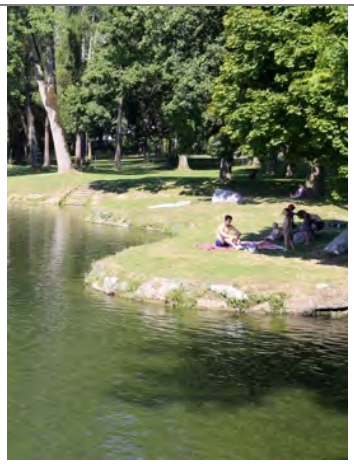
Figure 82: River improvement measures without additional space requirements using a permeable wall (Littlewood, 2001, p. 125).

River-specific suggestions at certain locations give ideas on where and what can be implemented in Victoria. The description begins at the most northern river and continues south, always starting from the lagoon or the sea going upstream. The improvement measures can only be considered in the area covered by the river assessment. Moreover, the area further up quickly gets fragmented in small und private parcels and is no longer accessible to the public. Requirements mentioned in the previous chapter must always be taken into account. All rivers in the assessed area suffer from channelization. In general, for all river sections, the possibility of in-channel improvement measures should be checked at places where the building fronts or other infrastructure facilities reach up to the rivers. Illustrations of those measures are shown in the figures on the left. As mentioned before, improvements can have different focuses. The following map gives an overview of ideas to be implemented in the city. This is based on seven categories (see Table 30). They should be considered as ideas and are also subject to change. Further information is given in the river descriptions below.

Figure 83: Mapping of possible improvement measures.

Table 30: Description of improvement measures.

Symbols	Pictures	Description
Education	 Source: International Union for Conservation of Nature (2018)	Rivers used as an outdoor school room for educational purposes
Nature experience	 Source: Own source, 28/04/2019	Trail or viewing platform to experience the nature and wildlife as a recreation site
Sports activities	 Source: Stadt Leipzig (2019)	Use river for leisure and sports activities with kayaking or traditional Pirogue to float on the water

Symbols	Pictures	Description
Cafés and restaurants 	 Source: Prominski et al. (2012)	Creation of an area along or on the river with cafés and restaurants
Relax 	 Source: Bloder (2019)	Nice seating area or greenfield adjacent to the water to relax and enjoy the river
Socialize 	 Source: Dreysse (2019)	Seating possibilities along the river to spend time with family and friends

Symbols	Pictures	Description
Walking promenade 	 Source: Walkinghighlands (2018)	Attractive path design along the river with approach points at some places

4.2.1 English River

The English River is located in the northern area of Central Victoria and runs past the bus station. The river is not quite as wide as other rivers in the city but goes quite far up towards the interior of the island. The ecological condition of the river is assessed as positive until a relatively long way towards the flat area. Artificial waste or building structures are not included in the overall assessment area. For these reasons, it is particularly suitable for ecological upgrading. The school located between 5th June Avenue and the lagoon could be included in the upgrading by creating an outdoor classroom. The already existing path connection on the overlying side of the school should be used to include the green space at Paradise Des Enfants as a whole up to the Rivière St. Louis (for a more detailed description see below). The existing interruption at the Paradise of the Enfant should be removed.

Although there is a high wall at the bus station and a large sewage pipe in the middle of the river bed, accessibility to the river should be included in any future reduction of the bus station. For example, staircases with green patches in between offer the opportunity to turn the current condition into a nice waiting area.

4.2.2 Rivière Moussa

The Rivière Moussa is the longest river in Central Victoria and passes Unity House. Especially in the lower part, the river is nowhere accessible, although on the right side an open area extends directly up to the river. This area should be networked from the English River to Rivière St. Louis. This is not the case today. Apart of the Paradise Des Enfants all other green spaces along the lagoon are separated from each other. There are fences or there is no crossing over the rivers. The concept of the green-blue infrastructure can be applied well in this area. The size of the Paradise Des Enfants can be reduced and the free space can be used for other purposes. The green area along the Rivière Moussa is particularly suitable for future upgrading with a riparian area, a staircase or a greenfield reaching to the water.

The latter was very popular in the survey as it was considered to be attractive, natural, enjoyable, relaxing and peaceful. The Rivière Moussa would be a good starting point for nature observations due to its width and the direct border to the mangroves. A platform or a pathway could lead over the water and is possibly to be continued up to the Rivière St. Louis. At the same time, it would also be suitable for jogging or walking. Furthermore, the adjacent lagoon is suitable for sports activities such as kayaking or a tourist attraction with the Pirogue (see Appendix XX) because of the low flow rate. The latter, a traditional small fishing boat from Seychelles with a wooden stick for movement would be an attractive leisure attraction within the city. Similar to what is known in England as "punting". Provided that the bridge is passable, it would be possible to move from the mangroves far into the city, if there is no low tide.

Figure 84: Present condition of Rivière Moussa with view on the financial district (own source, 24/05/2019).

Upstream of this green space, the large planning area of the Financial district with the planned pedestrian-friendly area can be regarded as a potential. The river is to be included in the concept. The quality of mix-used places will be improved by visual and physical interaction with the river (Cengiz, 2013). The inclusion of the river should show people that the river can be used as an attractive place in the city. As foreseen in the concept plan, the existing front of buildings directly reaching the river (see Figure 84) should be relocated in the future. For example, a café or restaurant promenade would be suitable here. This can be supplemented with a floating raft (see Figure 85). The survey has shown that this is a popular river condition. The place is relaxing, attractive and suitably to socialize. Especially younger and working people seem to like this place.

In the upper area, the artificial falls, which show a big deficit, should be removed or a bypass should be offered for species migration. The possibility of removing and relocating the pipes above the cinema should be considered.

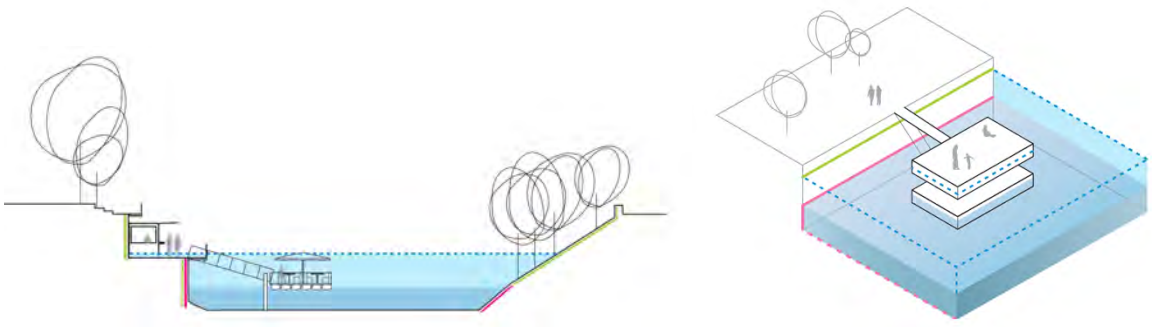


Figure 85: Sketches of a raft that moves with the water level (Prominski et al., 2012, pp. 64,156).

4.2.3 Rivière Maintry

The Rivière Maintry is one of the city's narrowest rivers and flows right through the city center past the Sir Selwyn Selwyn-Clarke Market along Freedom Square and Peace Park. Especially due to its location, it has great potential. The City Center can be directly connected to the lagoon along this river. In particular, the accessibility and sociocultural value is already relatively good and should be used as a starting point for upgrading measures, as a wall still separates the river from the surrounding land. Upgrading measures at the Peace Park are described in the following chapter. The wall at Freedom Square is in poor condition while water approachability can be directly improved during restoration. Between Albert Street and 5th June Avenue, on the left side, there is already a relatively wide, beautifully designed green belt with tropical plants. Here, too, a wall interrupts the access to the river and the footpath is not integrated into this green belt. Both points should be combined in upgrading measures, as this is easy to achieve. This green strip is terminated by a car park upstream. This parcel, which is directly adjacent to Albert Street, has a large vacant building (see Figure 86). Therefore, a redesign and the continuation of the green space are imaginable. For example, the street adjacent to the river could be moved to the other side of the existing building. However, this area has a lot of pipes, which makes upgrading a more difficult task. Upstream a continuation is currently impossible, as both left- and right-sided building fronts border directly to the river. In-channel measures are conceivable. In the further future, it may be conceivable to create a connection to the city center if, for example, the introduction and consequent realization of a buffer zone would be implemented. However, this will be very difficult to achieve as many plots are privately owned and the area is heavily built. In the upper area, the same is proposed as for Rivière Moussa. The fall with a large deficit should be removed and the possibility of relocation of the pipes investigated.

Figure 86: View on the current state of the possible continuation of the green space existing downstream adjacent to the river (own source, 24/05/2019).

4.2.4 Rivière St. Louis

This is the widest river in the city and reaches far up into the mountainous region. It flows behind the Police station passing Freedom Square until it reaches Peace Park. The green area on the left side of the river leads far into the city center. At Peace Park, it borders on a narrow strip of existing mangroves and a pedestrian walkway exists along Freedom Square. Similar to the Rivière Maintry, this river is excellently suited to connect the waterfront with the city. It is especially important for the connection between the waterfront project and the old town, which is especially attractive for tourists (see next chapter). Although the Peace Park has only been upgraded a few years ago, it has shortcomings in terms of river approachability. A high wall separates the river from the Peace Park (see Figure 87). Due to its central location in the "Green L" (Freedom Square, Peace Park up to the English River), the Peace Park has a lot of potential. These green spaces should be maintained and can be linked together with regard to the concept of green-blue infrastructure by eliminating all interruptions between the green spaces and promoting access to the water.

Figure 88 shows a possible form of upgrading the Peace Park with a focus on approachability to the water. Due to its width, it is conceivable to promote the mangroves a little further towards the city. As with the Rivière Moussa, an alternative would be direct access in the form of a greenfield, a nice riparian area or a staircase as seating possibilities. Whether the Rivière Mainty merges with the Rivière St. Louis in the Peace Park and, for example, a large pond is created, or whether the two rivers will continue to be managed separately and their riparian areas will be upgraded, must be decided. Sports activities or nature experiences described at the Rivière Moussa are also applicable here.

Figure 87: Today's state of the Peace Park along the Rivière St. Louis (own source, 24/05/2019.

Figure 88: Possible improvement measures at Peace park along the Rivière St. Louis (own source).

The planned channel into the Hodoul Bay is to be welcomed in principle, but should not be designed like the existing rivers in a concrete way. The connection should be better integrated into the environment through an integral approach. The connection of the water bodies is to be welcomed, which comes closer to the original state of a connected water zone. The circulation of water is improved and networking between the water bodies is restored.

Only a few people are using the today's existing unattractive pedestrian connection without shade along the Freedom Square (see Figure 89). This could be improved by using trees or palms that provide shadow and make it more appealing and attractive. The shore area can also be improved and if possible equipped with wooden decking and seating possibilities (see Figure 90). Further options for the design are given in Figure **91**. A lowering of the path would have to be considered to facilitate access to the water body and at the same time increase the cross-sectional area, which improves the discharge capacity. The culverted section, about 60m long, should be removed in the medium to long term. All land in this area belongs to the government, which facilitates its implementation. In the direction of the car park, the wall is already in poor condition, thus river upgrading can be carried out in the event of construction measures being taken anyway.

Figure 89: Today existing pedestrian connection along Freedom Square (own source, 24/05/2019).

Figure 90: Future opportunities for improvement along the Freedom Square (own source).

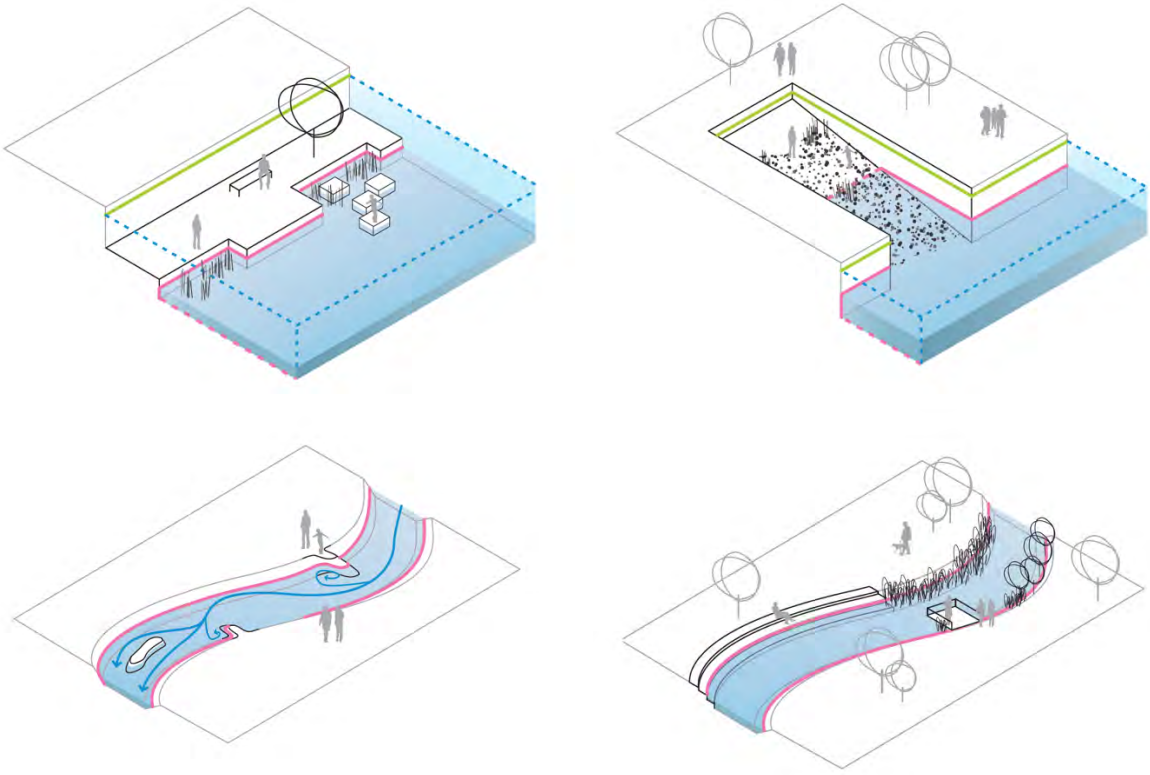


Figure 91: Possible design of the riverbank along a river (Prominski et al., 2012, pp. 54,60,112,123).

A lot of life exists next to the police station, which was also rated as positive in the survey. Creating a narrow riparian area and providing seating facilities to observe the fish can improve this space. A sign with information about the river would also be suitable here, as a highly frequented pedestrian walkway passes by. The ecological potential of the river is generally high, as it is very long and therefore plays an important role as a connection between the mountains and the sea. It has no falls and borders directly on mangroves at the bottom. Especially the needs of the eel should be considered, as the expert interview revealed. The car wash above should be relocated so that it does not continue to pollute the river.

4.2.5 La Poudrière River

This river is short and narrow and is influenced by the tides over a long distance. The river is only accessible on the right side. It leads along the esplanade past the Seychelles National Library to the Jarin Des Enfants. Depending on the development of the Jardin Des Enfants, the emphasis of the improvement may have a different focus. In any case, it should be sustainably integrated into the waterfront project, as the existing area is protected. Measures in the categories socialize and walking pathway would be suitable. However, the current waterfront plan does not follow this. The development is very dense and high with little space for landscaping. There is potential for improvement both in the design of the pedestrian network and in the integration of the river. Based on the documents provided, it can be seen that no attention is paid to the traditional architectural style and existing buildings. Since tourism is an important economic sector and the project is located near the port where the cruise ships moor, the project is of great importance. It is the first impression tourists get of Seychelles.

Upstream from the Jardin Des Enfants the river is culverted on a 50m long stretch. This should be removed in the medium term to create a continuous connection. The one-sided orientation of the tourist kiosk, facing away from the river, should be improved (see Figure 92). An orientation facing the river would be suggested and has great potential, as this creates a separation from the busy Francis Rachel Street. This can be done, for example, with seating in the form of stairs or natural stones, whereby green sections in between increase the attractiveness (see Figure 93). This was also a popular state in the survey. The protected esplanade is thus upgraded and a direct slow traffic connection between the Jardin Des Enfants and far into the city center is conceivable. This connection would be particularly interesting for tourists and can be seen as an attractive gateway to the city.

Figure 92: Current state of the river section along the tourist kiosks (own source, 24/05/2019).

Figure 93: Possible improvement measures along the tourist kiosks (own source).

4.2.6 Rivière Trois Frères

This river is located in the south of Central Victoria and flows through the Botanical Garden. Compared to the other rivers, this river is already in a good ecological condition. Only shortly before entering the Bois de Rose mangroves it is channelized. This section has to be ecologically upgraded as it is an important link between the mangroves and the natural state in the upper part. The school next door offers to use this area for educational purposes. In the Bois de Rose Mangrove a circular path through the mangroves, a mangrove walkway, would be imaginable. This allows the nature experience in the middle of the city. With its proximity to the city center and the arrival of the cruise ships, it may be a popular future sight and recreational area in Victoria. Mangroves were also a popular condition in the survey as they provide a particularly peaceful and calm state. On the brownfield on the right side, a visitor center could be built which serves as a starting point. However, this area is partly private land, which can make land negotiations more difficult.

The connection to Hodoul Bay would be beneficial due to the reasons mentioned above. However, the proposed route is not the optimal one. The wetland or the river should rather be led along the road on a narrow broad towards the city. If these ideas can be implemented, a connection to water would be possible in the Jardin Des Enfants close to the roundabout. Compared to the other proposal, this route would be simpler and cheaper to implement since less infrastructure needs to be crossed.

5 Conclusion

The rivers in Victoria have major ecological and sociocultural deficits and are rather unattractive in their appearance. Hard concrete structures, littering and pollution, large sewage pipes within the river bed and lacking approachability characterize the condition many rivers are in. This master's thesis aims to show the deficits and develop suitable ideas for improving the rivers' conditions in Victoria. The findings have shown that the rivers in the city possess great potential for improvement and play an important role within Victoria. Before considering specific improvement measures, it is important to create the necessary framework conditions. These include particularly detailed and proactive planning, law enforcement, space availability, improvement of water quality, education, relocation of utility pipes, stronger involvement and exchange between all involved actors. In a second step, specific improvement measures such as the upgrading of the riparian area, improved accessibility and approachability and nature and recreational experience need to be considered. First and foremost, simply implementable measures are to be applied. This is particularly the case for already existing green spaces or on large-scale planned area developments. With regards to Victoria, these would be the existing green belts at the Rivière St. Louis and Rivière Maintry or the large-scale planned developments along the Rivière Moussa or La Poudrière River. Such upgrades should be used to exploit the potential of rivers and to show the population that the rivers have much more to offer than their current state. Popular improvements such as the presence of a greenfield adjacent to the river or a café and restaurant promenade should be targeted. It is crucial to think long-term, as the lack of space in the urban area is an aggravating element in improvement measures and space is becoming an increasingly scarce resource as population growth increases. For instance, the introduction of a buffer zone provides the basis for having sufficient space reserves for upgrading measures in the long term. In summary, the suggested measures are as follows:

1. Create preconditions
2. Apply simply implementable improvement measures
3. Long-term thinking

The prioritization of improvement measures is challenging. Depending on the focus, various river sections should be allocated a higher priority. The Rivière St. Louis should have a high priority when considering the ecological and sociocultural potential at the same time. From an ecological point of view, the length of the river is beneficial because it is of great importance as a migration corridor for species from the mountain region to the sea. At the same time, it does not have any falls that might affect it. From a sociocultural point of view, it is important because it is a broad river that is present in the public mindset and flows through the middle of the city. Also, a footpath already exists on the left side and a long wide green corridor bordering the river reaches far into the city center.

The work has identified a wide range of ideas for improvement measures and thus created the basis for further developing them. The potential of the rivers in the city has to be recognized and suitable ideas have to be further developed. Using detailed and proactive planning, the proposed measures have to be defined in depth, suitable locations have to be specified, incorporated into future projects and finally implemented.

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7 Declaration of originality

ETH

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Eigenständigkeitserklärung

Die unterzeichnete Eigenständigkeitserklärung ist Bestandteil jeder während des Studiums verfassten Semester-, Bachelor- und Master-Arbeit oder anderen Abschlussarbeit (auch der jeweils elektronischen Version).

Die Dozentinnen und Dozenten können auch für andere bei ihnen verfasste schriftliche Arbeiten eine Eigenständigkeitserklärung verlangen.

Ich bestätige, die vorliegende Arbeit selbständig und in eigenen Worten verfasst zu haben. Davon ausgenommen sind sprachliche und inhaltliche Korrekturvorschläge durch die Betreuer und Betreuerinnen der Arbeit.

Titel der Arbeit (in Druckschrift):

River Design and Restoration in an Urban Environment - Exploitation of the Potential in Victoria (Seychelles)

Verfasst von (in Druckschrift):
Bei Gruppenarbeiten sind die Namen aller Verfasserinnen und Verfasser erforderlich.

Name(n):	**Vorname(n):**
Meister	Nicolas

Ich bestätige mit meiner Unterschrift:
- Ich habe keine im Merkblatt „Zitier-Knigge" beschriebene Form des Plagiats begangen.
- Ich habe alle Methoden, Daten und Arbeitsabläufe wahrheitsgetreu dokumentiert.
- Ich habe keine Daten manipuliert.
- Ich habe alle Personen erwähnt, welche die Arbeit wesentlich unterstützt haben.

Ich nehme zur Kenntnis, dass die Arbeit mit elektronischen Hilfsmitteln auf Plagiate überprüft werden kann.

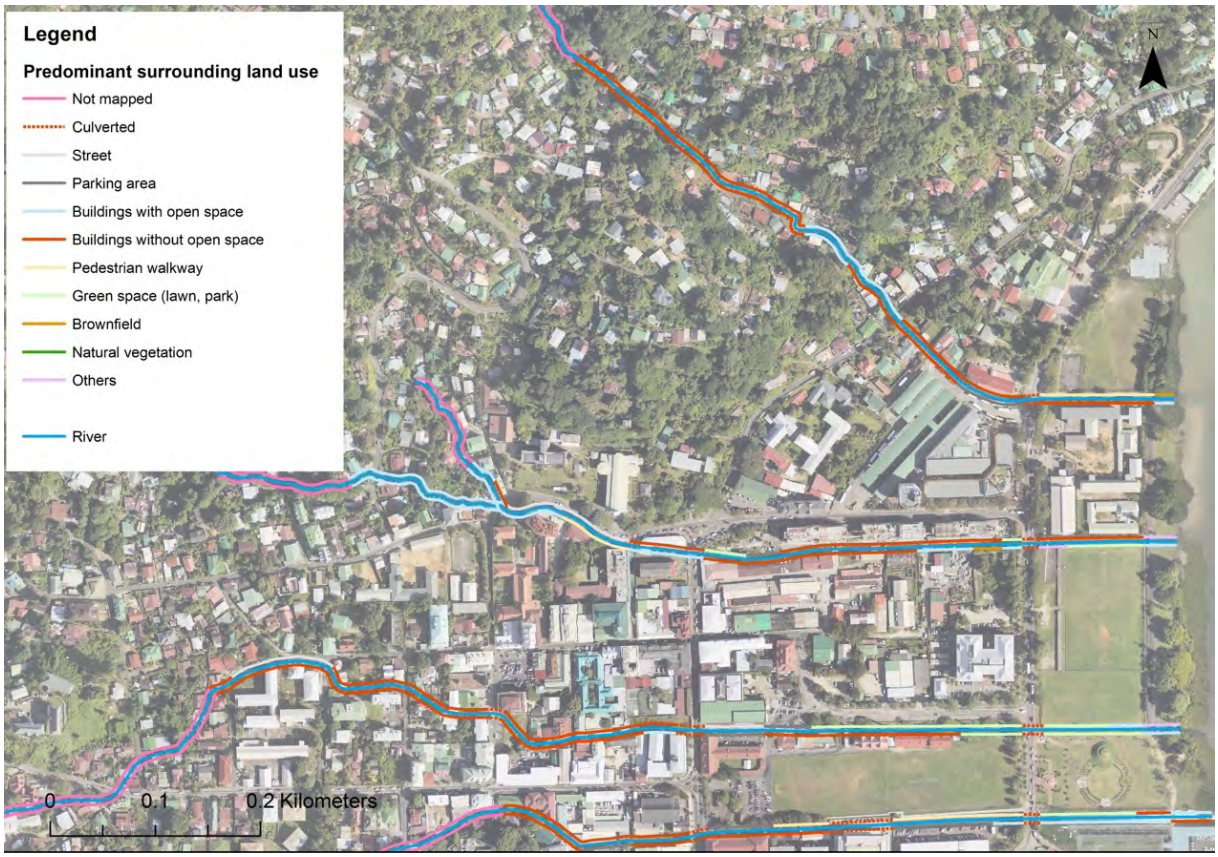
Ort, Datum	**Unterschrift(en)**
Feusisberg, 12.08.2019	N. Meister

Bei Gruppenarbeiten sind die Namen aller Verfasserinnen und Verfasser erforderlich. Durch die Unterschriften bürgen sie gemeinsam für den gesamten Inhalt dieser schriftlichen Arbeit.

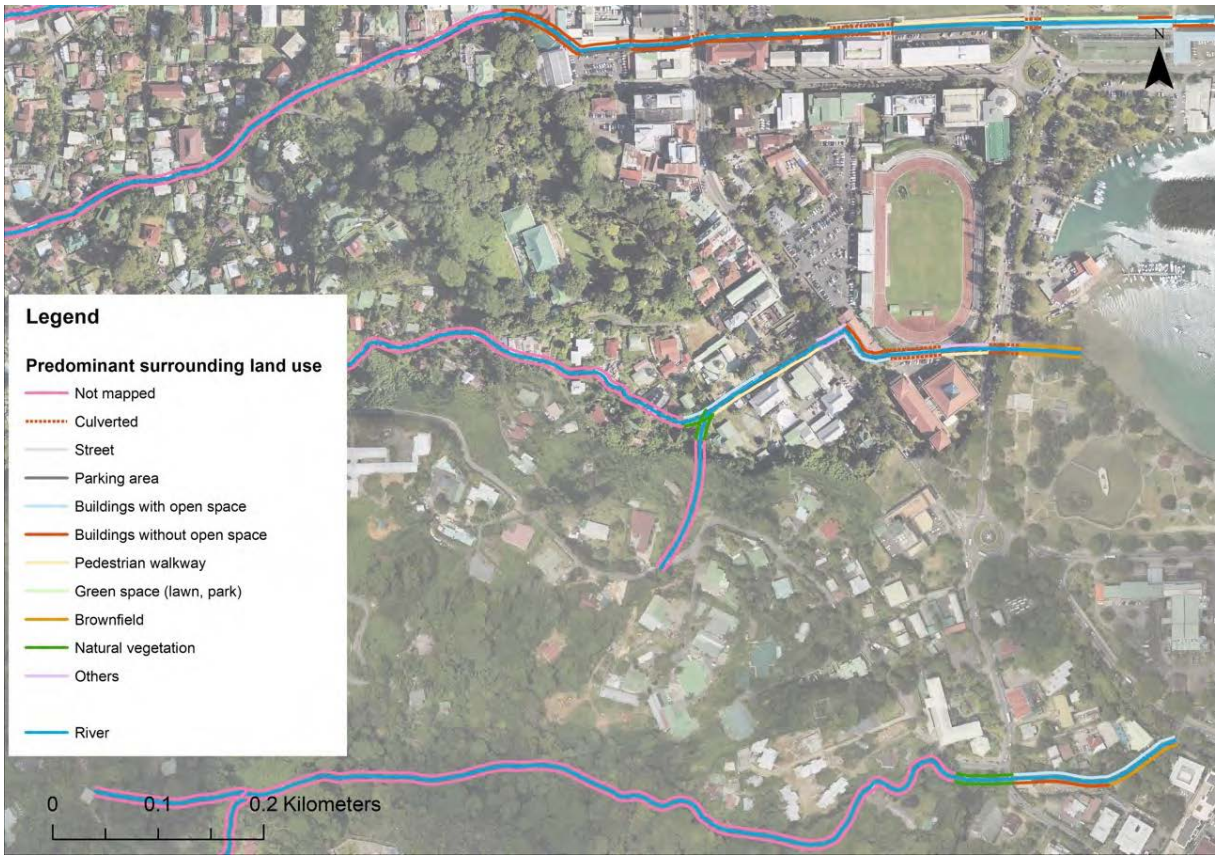
8 Appendix

The conditions on site during the field phase are not comparable to scientific standards, which is why some difficulties have arisen in the transparent and comprehensible handling of sources. The author has always acted to the best of his knowledge and conscience and always in the sense of scientific honesty. However, even local experts did not know the actual origin of individual data sets or statements.

Appendix A: Personal remark of the author.



Appendix B: Adjacent land use of English River, Rivière Moussa, Rivière Maintry and Rivière St. Louis (own source).

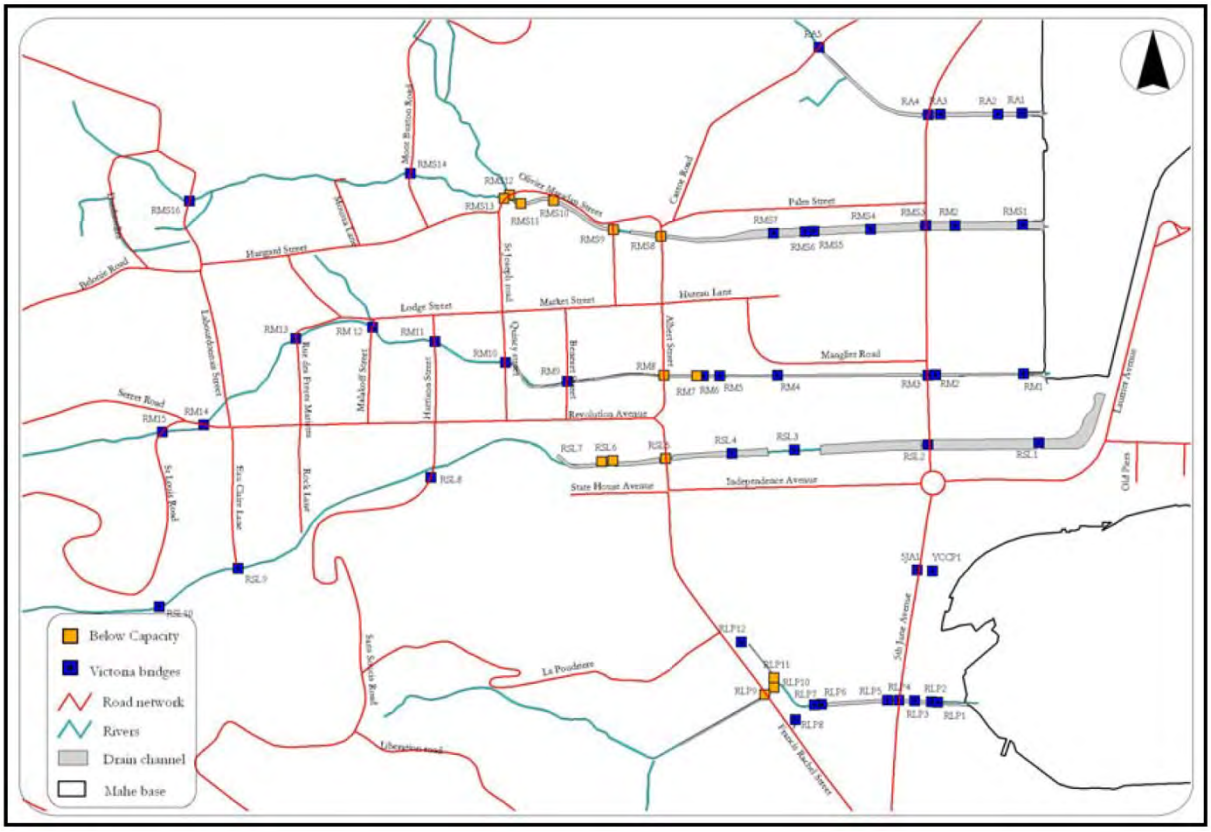


Appendix C: Adjacent land use of Rivière St. Louis, La Poudrière River and Rivière Trois Frères (own source).

Appendix D: Victoria in the year 1960 (Drainage task force committee, 2005, p. 4).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rain fall (mm)	402.6	283.2	194.9	186.7	151.6	105.1	76.6	119.3	154.0	189.7	206.3	302.8
Temperature (°C)	26.9	27.4	27.8	28.1	27.8	26.7	26.0	26.0	26.5	26.9	26.9	26.9
Humidity (%)	82	80	80	80	79	79	80	80	79	79	80	82
Wind Direction	NW	NW	NW	SW-NW	SE	SE	SE	SE	SE	SE	SW-NW	NW
Wind Speed (knots)	6.3	6.3	5.2	4.9	7.8	10.4	11.4	12.1	11.3	7.9	5.4	5.4

Appendix E: Seychelles typical annual climate conditions (average from 1972 – 2010) (JICA and MEE, 2013, p. 19).

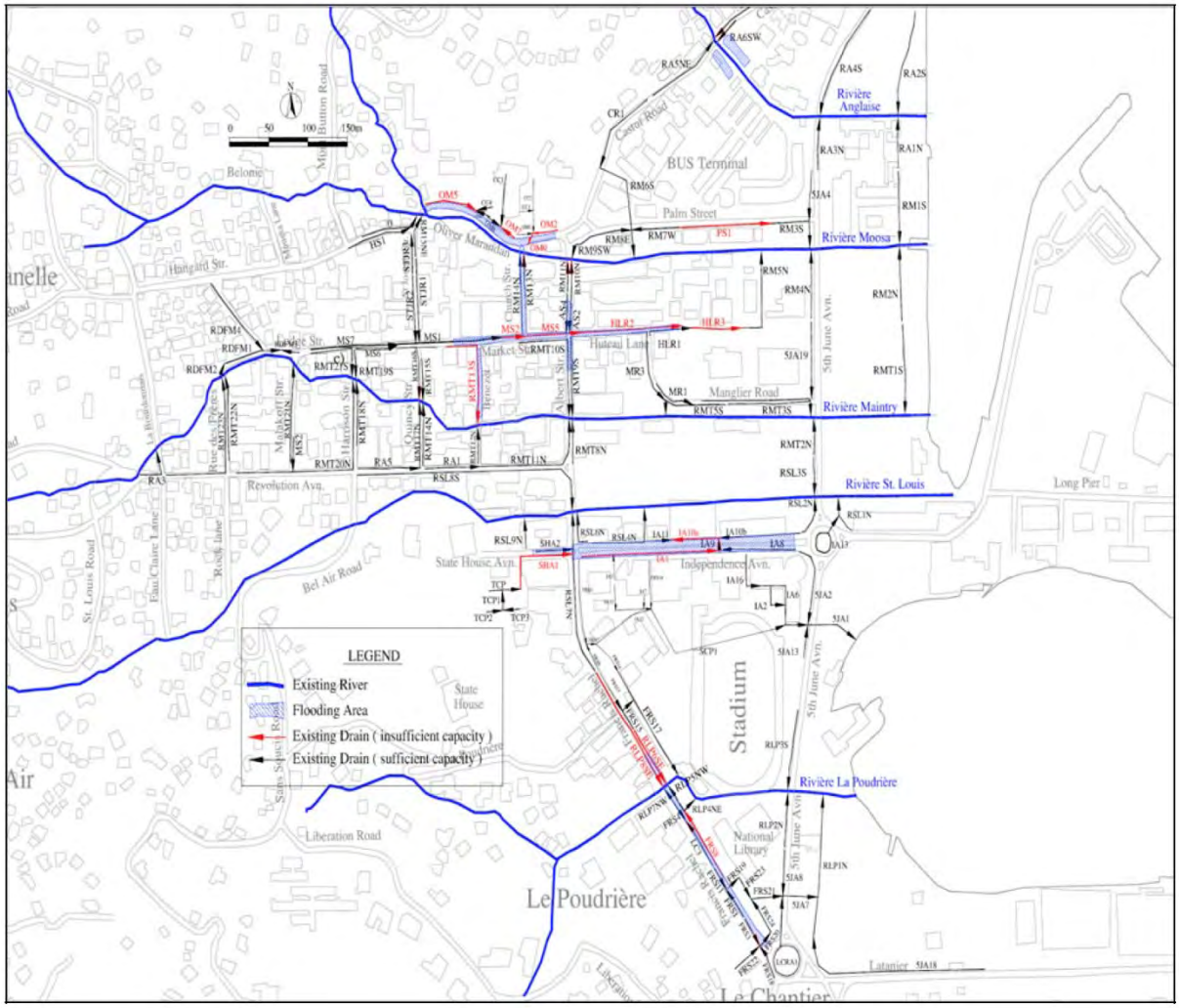


Appendix F: Capacity review of bridges and culverts in Central Victoria (Drainage task force committee, 2005, p. 14).

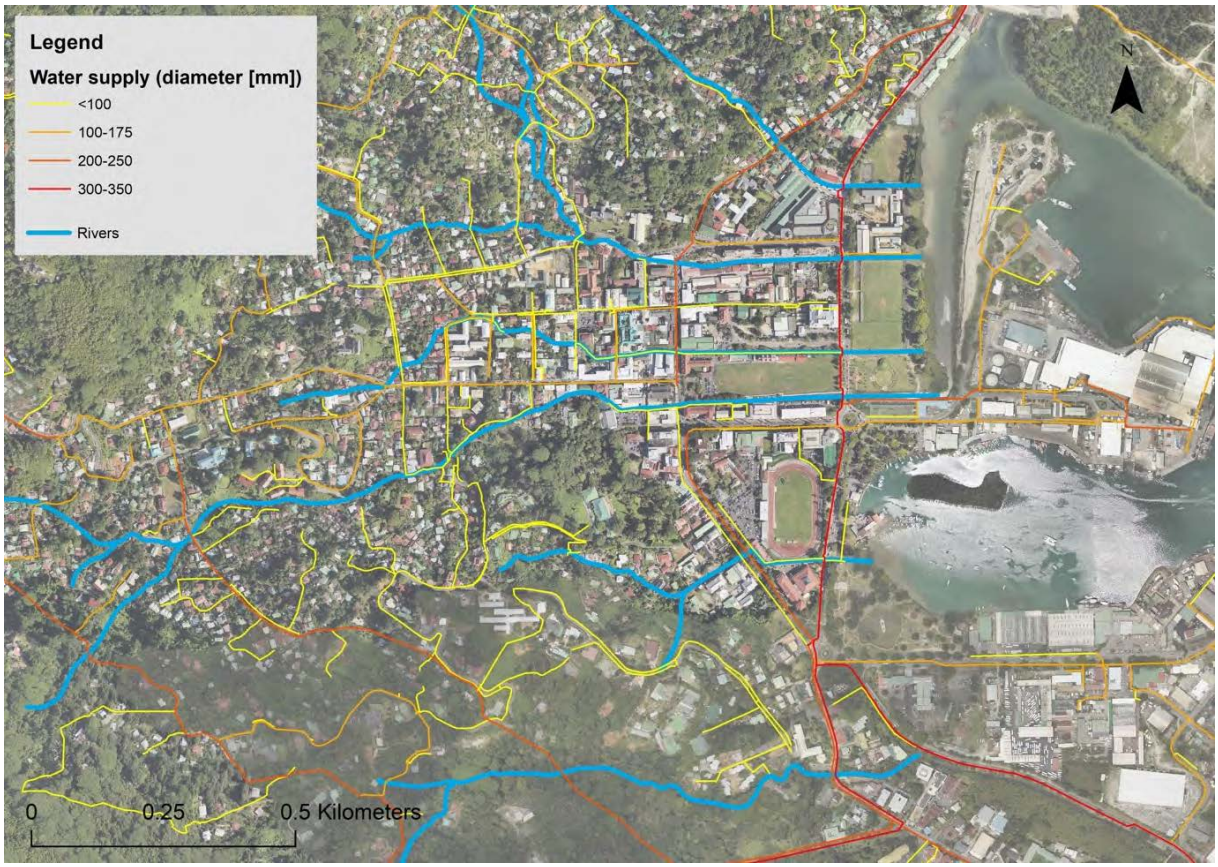
Appendix G: Pictures before and after silt-removal at English River (Payet, 2016).

	2011	2013	2018
Rivers	Amount of silt collected on site (tons)	Amount of silt collected on site (tons)	Amount of silt collected on site (tons)
English River	585	0	300
Rivière Moussa	1227.8	390	498
Rivière Maintry	302.3	219	102
Rivière St. Louis	2077.5	236.9	840
La Poudrière River	270	162	372
Rivière Trois Frères	2192	0	2584

Appendix H: Information on the amount of silt removal of the years 2011, 2013 and 2018 (Payet, 2016).



Appendix I: Result of hydraulic analysis of Victoria Town (JICA and MEE, 2013, p. 165)



Appendix J: Water supply network of Victoria (data provided by PUC, 2019[28])

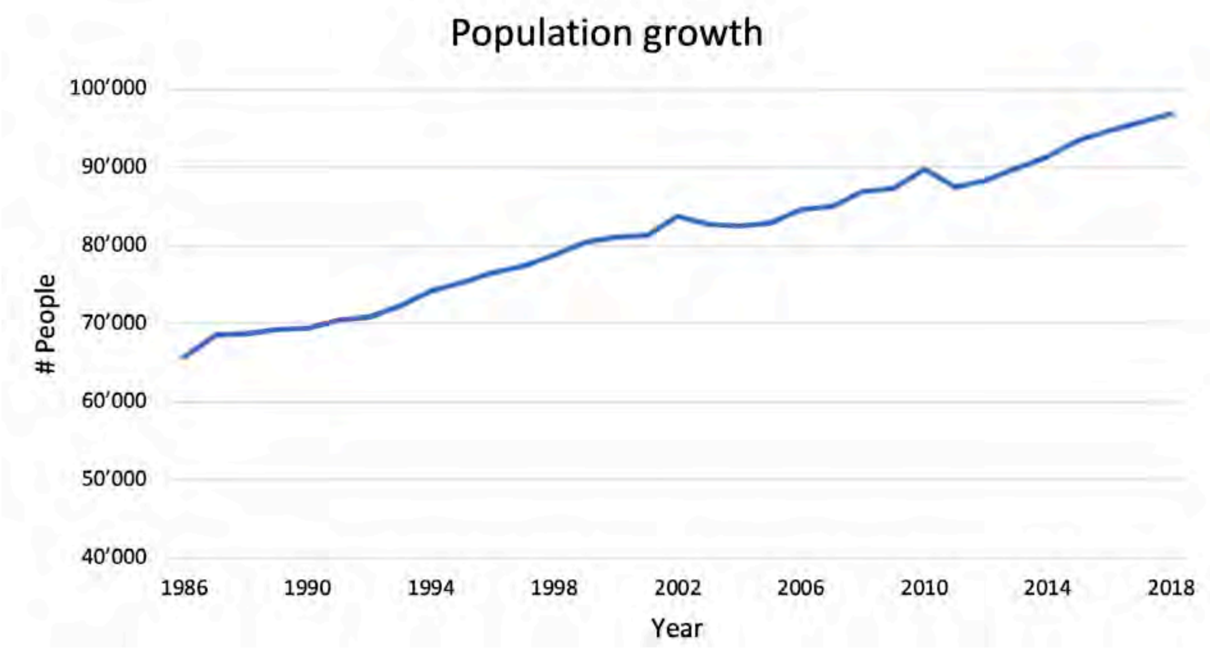
[28] Data collected from Agricole, I. on 09/04/2019; further information see Appendix A

River	Number of analysis	Date	Time	Temperature [°C]	Salinity [%]	pH-Value	Dissolved Oxygen [mg/l]	Electrical conductivity [µS/m]	TDS
English River	WQE1	13.04.19	09:18	31.21	30.9	6.83	25.3	43	30.96
English River	WQE2	13.04.19	09:41	31.27	27	6.89	39	46	27.17
English River	WQE3	13.04.19	09:50	29.5	10.23	6.73	32.3	19	11.6
English River	WQE4	13.04.19	10:02	29.05	10.54	6.75	30.5	19.74	11.82
English River	WQE5	13.04.19	10:27	28.55	0.22	6.79	31.5	48	0.265
Rivière Moussa	WQMo1	13.04.19	10:48	31.8	25.9	6.69	25.9	46533	26.7
Rivière Moussa	WQMo2	13.04.19	10:54	31.05	19.7	6.8	25.4	37431	21.8
Rivière Moussa	WQMo3	13.04.19	11:00	31.68	24.05	6.82	25.5	42934	24.67
Rivière Moussa	WQMo4	13.04.19	11:04	30.4	13.33	6.79	25.8	23381	13.9
Rivière Moussa	WQMo5	13.04.19	11:10	31.4	2.45	6.86	25.2	6961	3.605
Rivière Moussa	WQMo6	13.04.19	11:14	30	0.17	6.87	26.9	393	0.233
Rivière Moussa	WQMo7	13.04.19	11:26	29	0.11	6.74	25.6	265	0.159
Rivière Maintry	WQMa1	13.04.19	11:36	29.06	0.16	6.68	29.1	376	0.226
Rivière Maintry	WQMa2	13.04.19	11:46	29.68	0.18	6.76	29.5	412	0.246
Rivière Maintry	WQMa 3	13.04.19	11:54	29.8	0.31	6.76	28.9	700	0.417
Rivière Maintry	WQMa 4	13.04.19	11:59	30.4	0.69	6.76	25.2	501	0.89
Rivière Maintry	WQMa 5	13.04.19	12:03	31.6	1.56	6.91	26.9	3381	1.953
Rivière Maintry	WQMa 6	13.04.19	12:07	31.15	10.68	6.7	26	22197	12.79
Rivière Maintry	WQMa 7	13.04.19	12:12	31.6	27.54	6.7	28	48722	28.11
Rivière St. Louis	WQS1	13.04.19	12:25	30.62	19.6	6.71	22.1	33425	19.64
Rivière St. Louis	WQS2	13.04.19	12:31	30.9	13.62	6.69	20.9	25548	14.86
Rivière St. Louis	WQS3	13.04.19	12:35	30.98	13.39	6.67	19.6	25495	14.77
Rivière St. Louis	WQS4	13.04.19	12:41	28.66	0.24	6.81	21.2	476	0.295
Rivière St. Louis	WQS5	13.04.19	12:47	28.68	0.11	6.73	19.8	255	0.154
Rivière St. Louis	WQS6	13.04.19	12:52	28.2	0.1	6.64	19.4	215	0.132
La Poudrière River	WQP1	13.04.19	13:09	29.04	0.4	6.73	29.1	546	0.33
La Poudrière River	WQP2	13.04.19	13:14	32.5	9.67	6.98	19	19055	10.83
La Poudrière River	WQP3	13.04.19	13:22	30.87	6.92	6.66	20.1	13684	7.983
La Poudrière River	WQP4	13.04.19	13:26	30.33	8.9	6.66	19.9	14457	8.836
La Poudrière River	WQP5	13.04.19	13:33	30.55	8.25	6.17	19.6	16459	9.533
Rivière Trois Frères	WQT1	14.04.19	10:23	28.6	2.99	6.79	7.5	6060	30.609
Rivière Trois Frères	WQT2	14.04.19	10:30	29.2	6.5	6.7	7.9	12805	7.674
Rivière Trois Frères	WQT3	14.04.19	10:42	28.85	7.15	7.2	7.9	14050	9.633
Rivière Trois Frères	WQT4	14.04.19	10:45	26.46	0.04	6.88	8.5	83	8.053

Appendix K: Water quality values of several parameters tested (own source).

No	Name	Location	Total length [m]	Assessed length [m]
1	English River	Northern part of the city, crosses Paradise Des Enfant, next to the main bus station in Victoria	1'167	702
2	Rivière Moussa	Central part of the city, crosses Paradise Des Enfant, along Unity House, next to Deepam Cinema and Immaculate Conception Cathedral	2'704	868
3	Rivière Maintry	Central part of the city, crosses Paradise Des Enfant, along Freedom Square, close to Sir Selwyn Selwyn-Clarke Market	1'309	960
4	Rivière St. Louis	Central part of the city, crosses Paradise Des Enfant, along Freedom Square, close to the Victoria Clocktower, next to Central Police station	2'588	686
5	La Poudrière River	Central to southern part of the city, at the border of Jardin Des Enfants, between the Seychelles National Library and athletic stadium, along the company building Cable&Wireless	935	443
6	Rivière Trois Frères	Southern part of the city, adjacent to the botanical garden, entering the Bois de Rose Lagoon	1'326	222

Appendix L: Detailed information of the six natural rivers through Victoria.



Appendix M: Population growth over the last 30 years (NBS, 2019).

Evaluation Sheet Stream Physical Analysis Seychelles (Victoria)

Stream name		Essayer		Date	

Segment information			Morphology characteristics																						
				1 = stretched 2 = curved	0 = no 1 = yes	1 = natural 2 = trapezoidal 3 = box-shaped	0 = no 1 = yes	0 = none 1 = limited 2 = pronounced	0 = none 1 = punctual (<10%) 2 = moderate (10-30%) 3 = large (30-60%) 4 = dominant (>60%) 5 = complete	0 = none 1 = impermeable 2 = loose pipe	1 = limited 2 = pronounced	1 = low 2 = moderate 3 = high	0 = none 1 = punctual (<10%) 2 = moderate (10-30%) 3 = large (30-60%) 4 = dominant (>60%) 5 = complete		1 = impermeable 2 = permeable		1 = poor 2 = medium 3 = well						0 = none 1 = artificial 2 = natural		1 = missing 2 = available
Segment number	Segment start (S)	Segment finish	Average bed width [m]	Alignment	Culverted	Profile shape	Many natural falls	Water level width variability	Construction of bed	Material construction of bed	Bed substrate variability	Flow variability	Construction of bank base		Material of bank base		Condition of bank base (visual)		Bank height [m]		Riparian width [m]		Riparian area character		Further channel structures (e.g. bars)
													left	right	left	right	left	right	left	right	left	right	left	right	

Appendix N: Part A of the evaluation data sheet: general information, segment information and morphology characteristics.

	Additional characteristics														Sociocultural characteristics					Comments
	0 = none 1 = inside water 2 = outside water			0 = none 1 = inside water 2 = outside water	0 = no 1 = yes	1 = Street 2 = Parking area 3 = Buildings with open space 4 = Buildings without open space 5 = Pedestrian walkway 6 = Green space (lawn, park) 7 = Brownfield 8 = Natural vegetation 9 = Others		1 = shady 2 = semi-shaded 3 = sunny	0 = none 1 = isolated / scattered 2 = single / regularly spaces 3 = occasional clumps 4 = semi-continuous 5 = continuous		0 = none 1 = present 2 = abundant	0 = none 1 = present 2 = abundant		0 = none 1 = present 2 = abundant	1 = excellent 2 = good 3 = restricted 4 = bad 5 = none		1 = direct 2 = restricted 3 = difficult 4 = unapproachable 5 = none		1 = very high 2 = high 3 = medium 4 = low 5 = none	
Segment number	Longitudinal pipes			Transversal pipes	Tidal influence	Predominant surrounding land use		Shading of channel	Trees		Aquatic vegetation	Surrounding vegetation		Solid Waste	Accessibility		Approachability		Quality of stay	
	left	right	cent.			left	right		left	right		left	right		left	right	left	right		

Appendix O: Part B of the evaluation data sheet: additional characteristics, sociocultural characteristics and comments.

Building Structure (B)

Stream name		Essayer		Date	

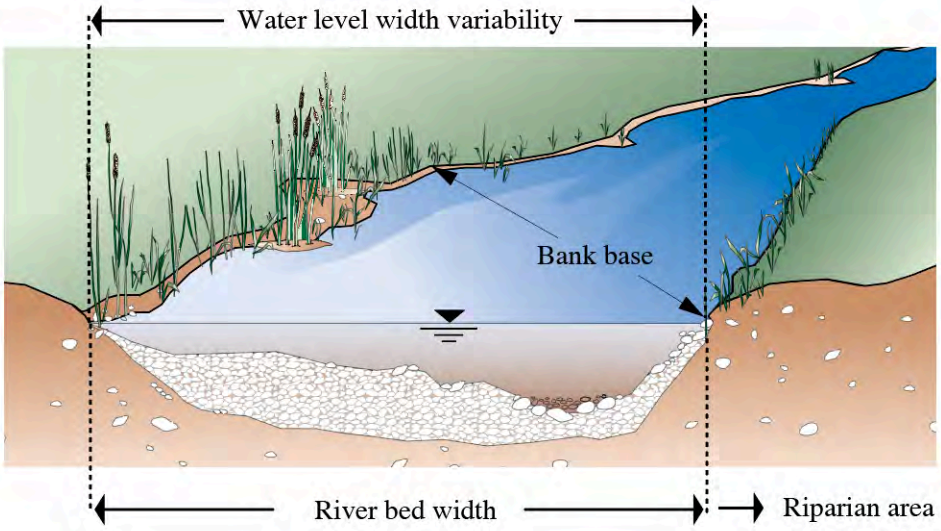
Building number	Segment-Building construction number (Format 0-00 e.g. 4-11)	Location	Type of building construction (1 = unknown / others; 2 = bed ramp; 3 = passage; 4 = pedestrian bridge; 5 = road; 6 = big pipe (longitudinal); 7 = big pipe (transversal))	Clear height [cm]	Length [m]	Bed substrate continuity (0 = no; 1 = yes)	Overflowable (0 = no; 1 = yes)

Falls (F)

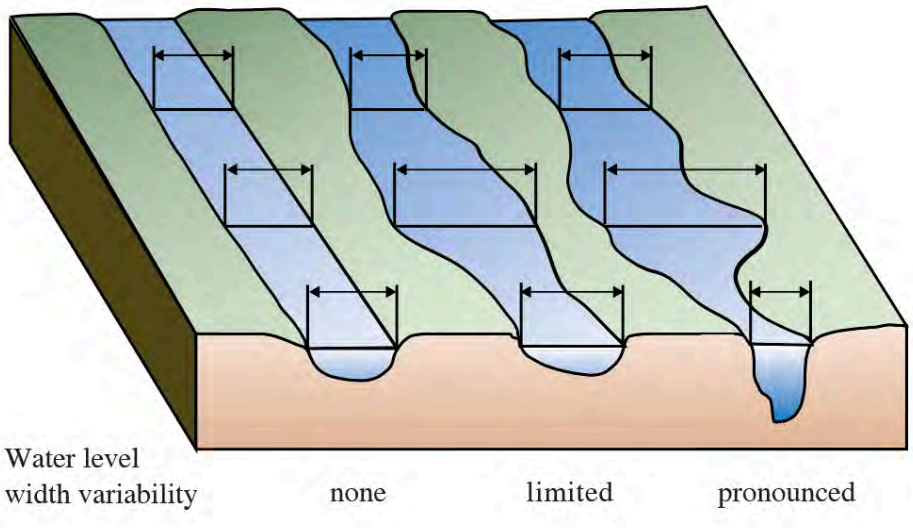
Stream name		Essayer		Date	

Fall number	Segment-Fall number (Format 0-00 e.g. 4-11)	Location	Type of fall (1 = unknown; 2 = natural; 3 = artificial)	Material of fall (1 = natural / none; 2 = wood; 3 = rock / stone; 4 = concrete; 5 = others / unknown)	Fall height [cm]

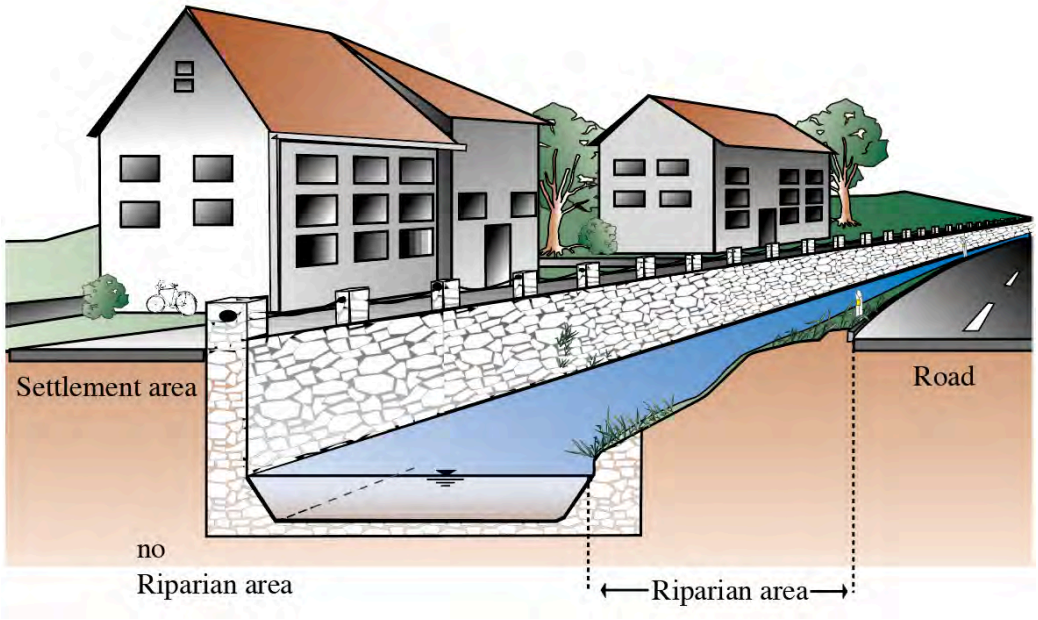
Appendix P: Part C of the evaluation data sheet: building structures and falls.



Appendix Q: Characteristics from ecomorphology level F (Hütte and Niederhauser, 1998, p. 8).



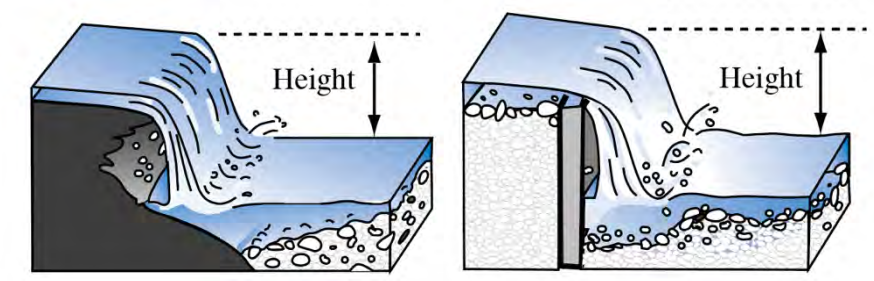
Appendix R: Characteristic dimensions of the water level width variability (Hütte and Niederhauser, 1998, p. 8).



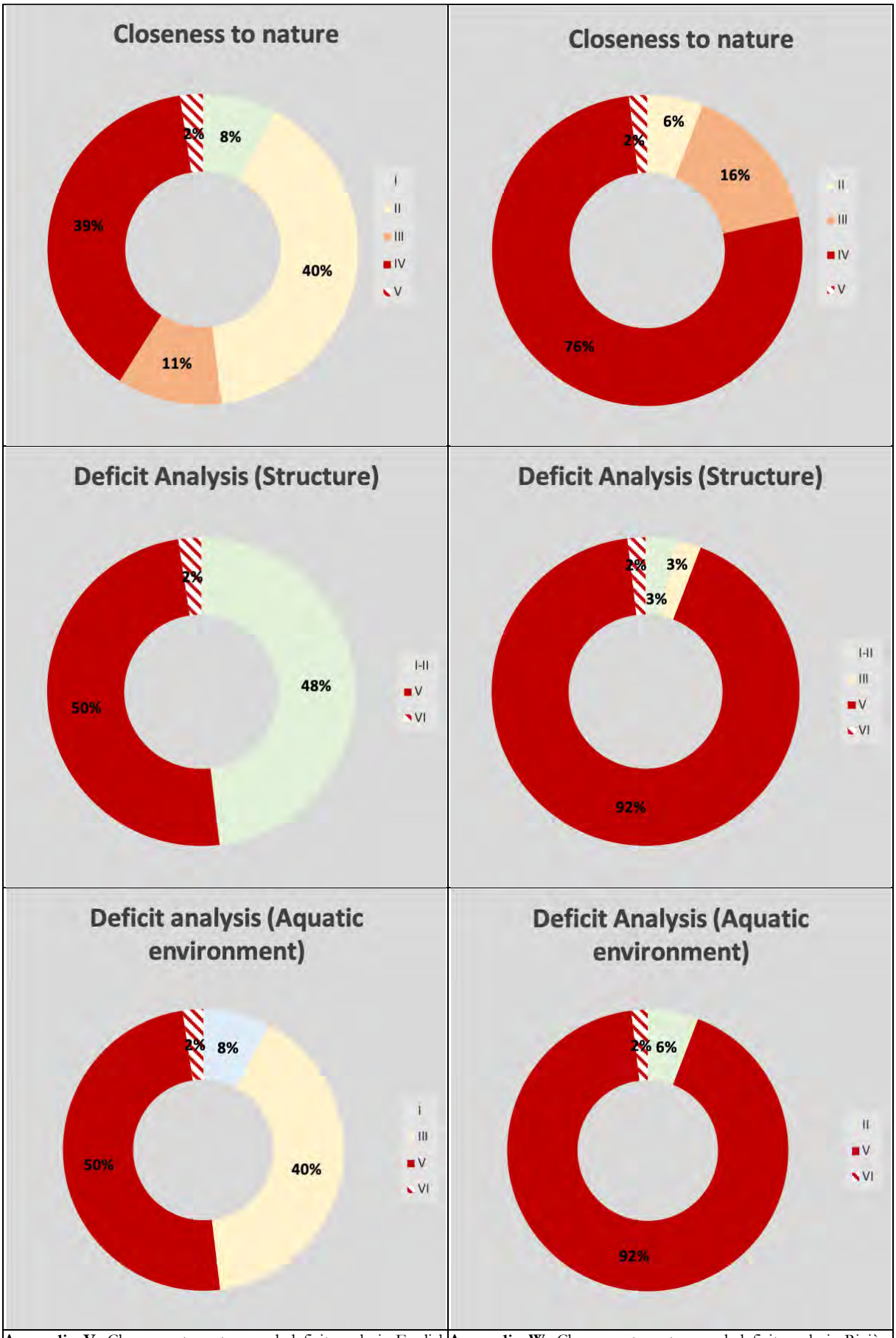
Appendix S: Information on the width of the riparian area (Hütte and Niederhauser, 1998, p. 18).

Positive factors	Negative factors
• Peace and seclusion • Natural diversity • View of the watercourse is possible • Attractive banks with scenic effect • Seating facilities, e.g. cafés and benches on the water's edge • Historical elements belonging to the water body, e.g. mills, bridges, weirs, etc. • Works of art that are thematically or spatially related to the body of water • Nature trails or information boards related to water • Calm shallow water areas, suitable for splashing and playing • Bathing sites with a water depth of >1m and water quality suitable for bathing use • Playing and lying areas (do not have to be officially designated as such) • Barbecue sites (only officially designated, no wild fireplaces) • Regularly emptied garbage cans • Sanitation facilities • Sports facilities, such as volleyball courts and table tennis tables • Boat rentals	• Noise (e.g. road traffic) • Smell (emissions from sewage treatment plants, industry, road) • Visual impairments and visual field disturbances due to main roads, unattractive buildings, etc. • Mosquitoes, vermin • Animal excrement • Garbage and rubbish on the bank or in the water • Overgrown vegetation • Poor water quality

Appendix T: Evaluation criteria quality of stay (Renner et al., 2017, p. 37).

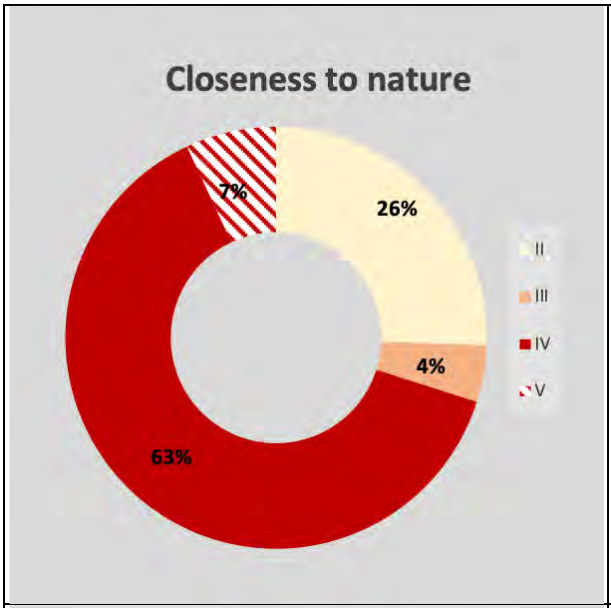


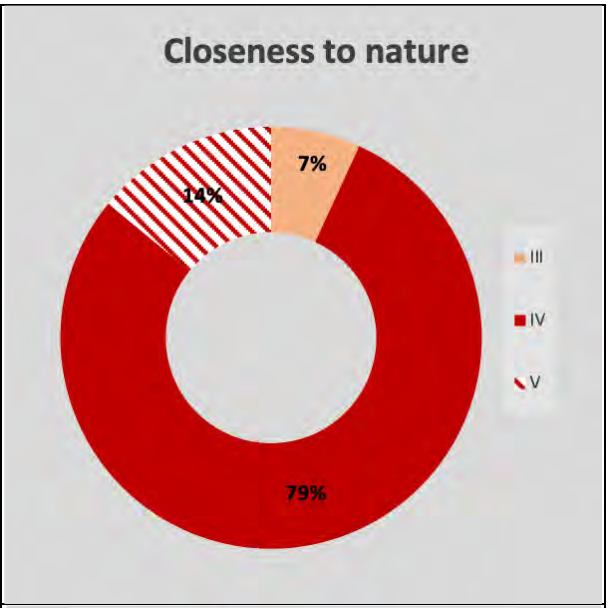
Appendix U: Schematic representation of a natural (left) and an artificial (right) fall (Hütte and Niederhauser, 1998, p. 25).

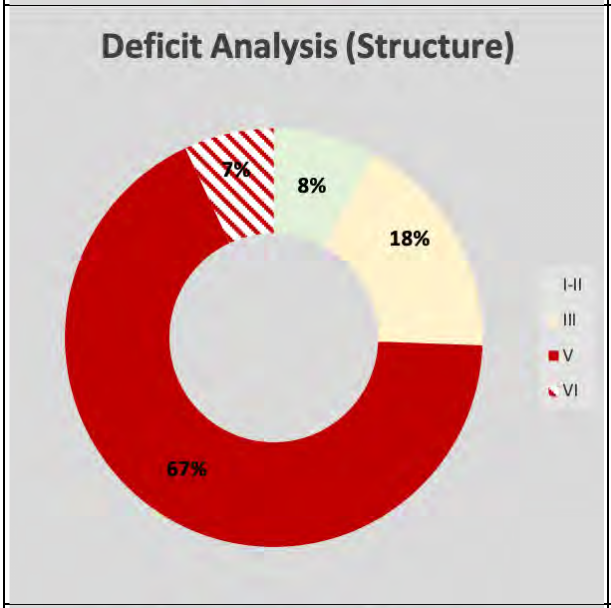


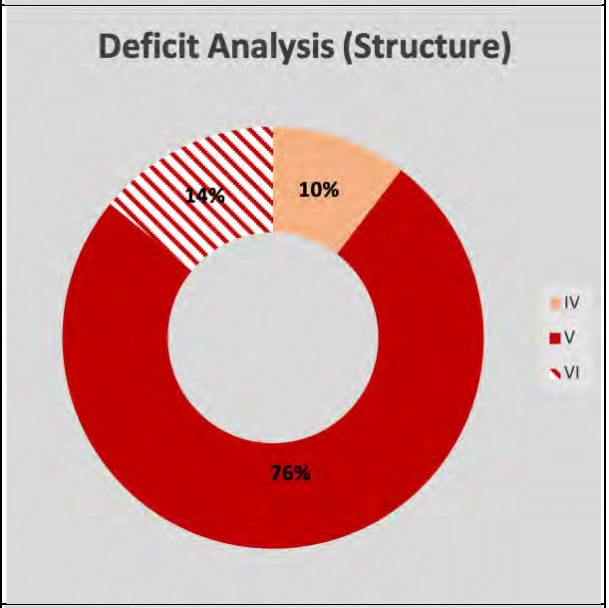
Appendix V: Closeness to nature and deficit analysis English River (own source).

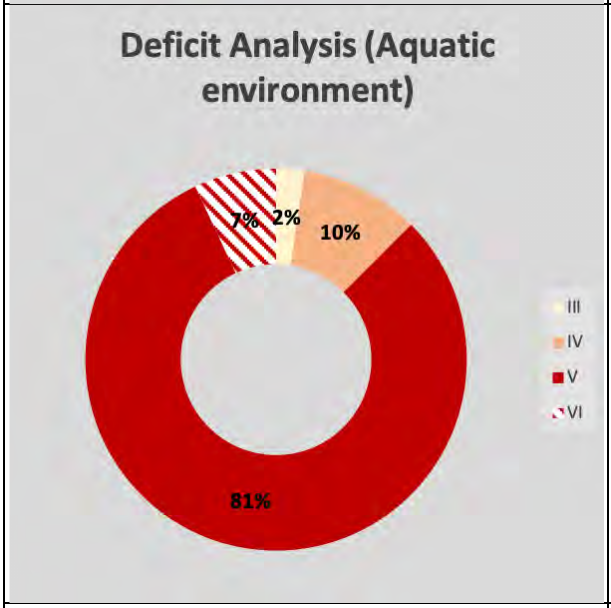
Appendix W: Closeness to nature and deficit analysis Rivière Moussa (own source).

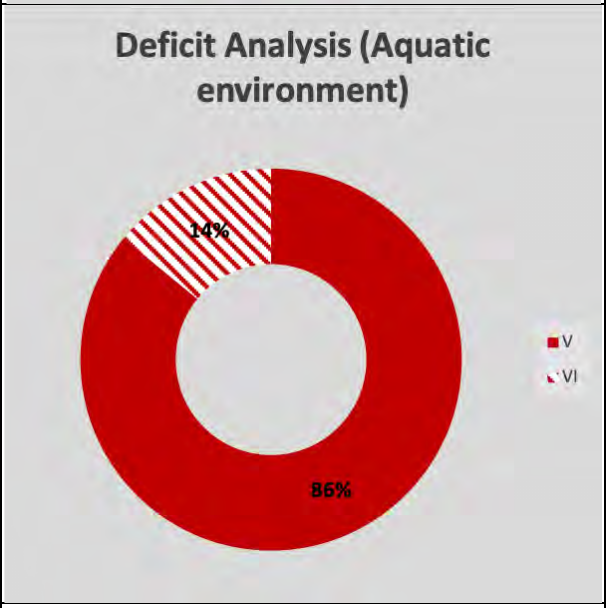






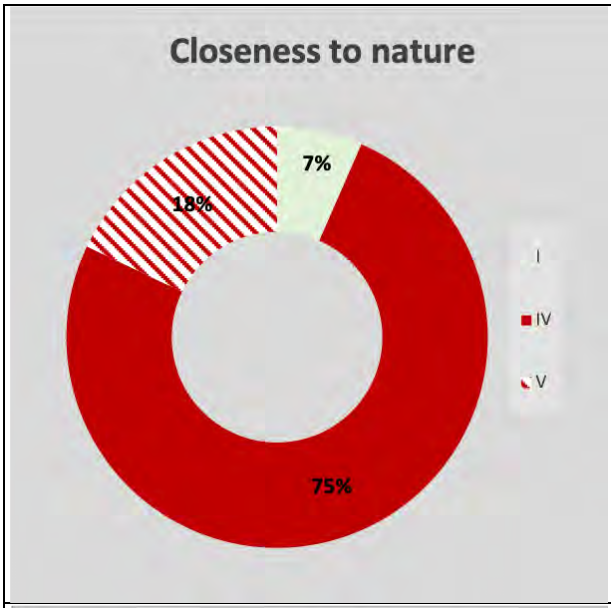


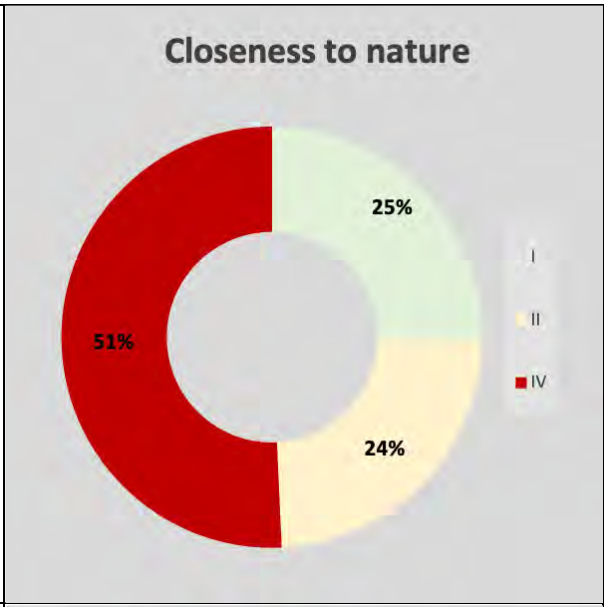


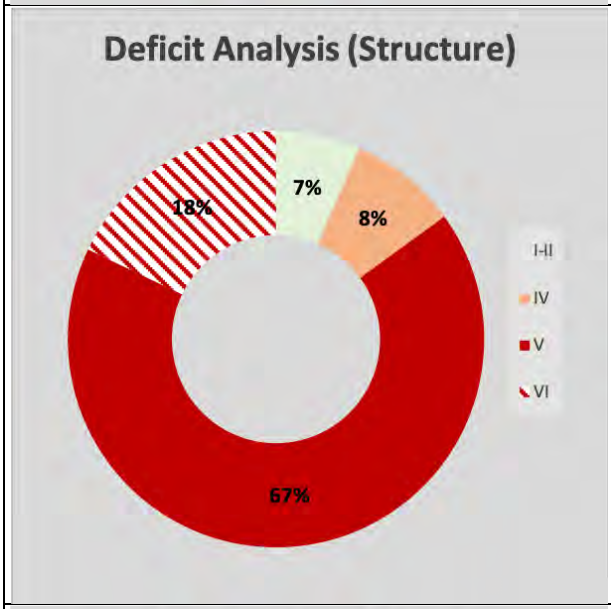


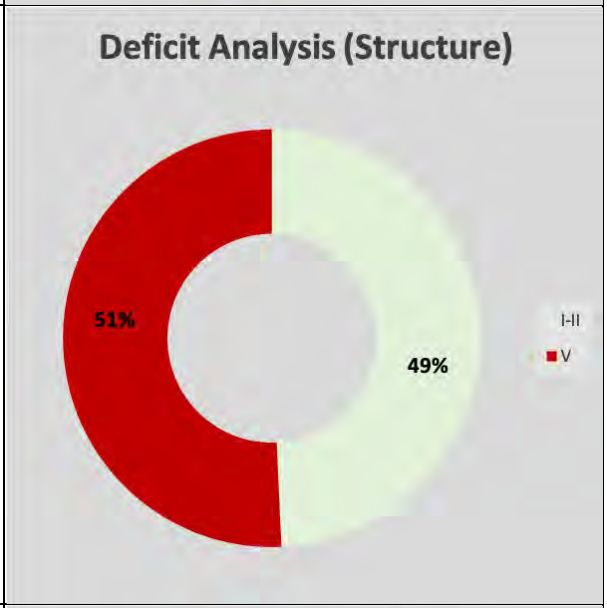
Appendix X: Closeness to nature and deficit analysis Rivière Maintry (own source).

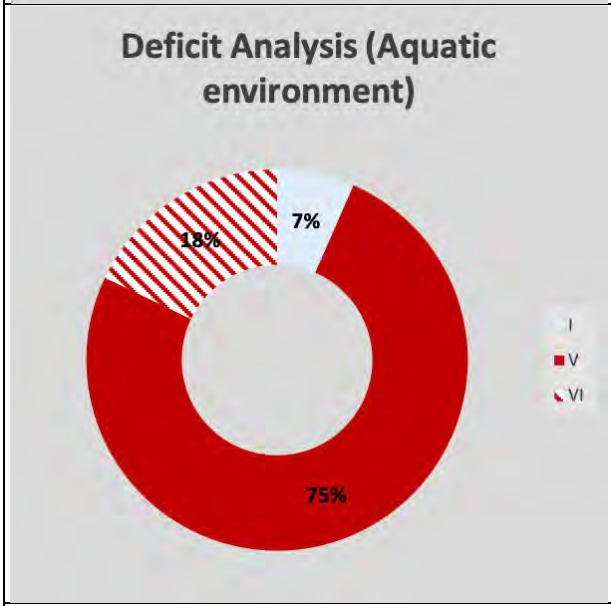
Appendix Y: Closeness to nature and deficit analysis Rivière St. Louis (own source).

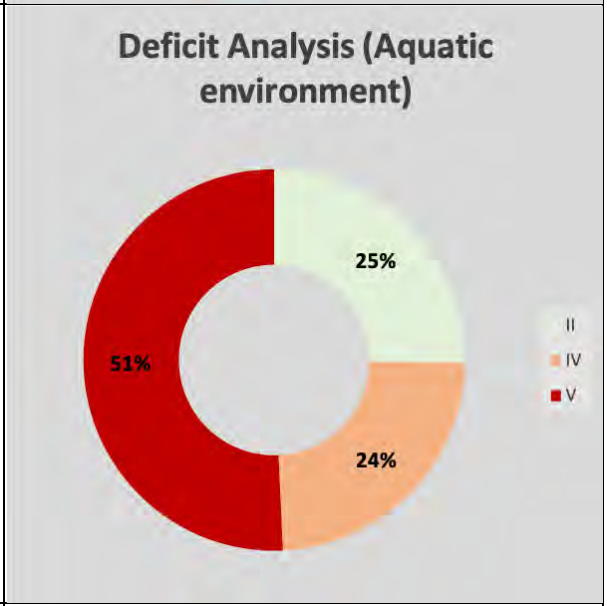












Appendix Z: Closeness to nature and deficit analysis La Poudrière River (own source).

Appendix AA: Closeness to nature and deficit analysis Rivière Trois Frères (own source).

Expert Interviews Ecologists – Ecological needs evaluation (Interview guide)

1. What is your area of expertise?
2. The current state of the rivers in Victoria is mainly manmade and canalized due to land reclamation. What kind of characteristics, you think, a natural river in Mahé in a flat area should have regarding ecological aspects?
3. Do you already see some positive points/developments of the river's condition in Victoria from an ecological point of view?
4. What kind of animals and/or plants should be present within or along the rivers in Victoria? Why?
5. Are these animals and/or plants likely to settle themselves (again) or do they need to be reintroduced in an active way? Why?
6. What other aspects have to be taken into account in order to facilitate a natural state of the rivers in a successful way? Why?
7. What should be the first respective most important measure to change the conditions of the rivers into the direction of a more natural state? How difficult is it to implement? Why?
8. According to your opinion, what do you see as the biggest challenges to implement these measures?
9. Do you consider instream renaturation as an appropriate solution? Why?
10. Which of the rivers in Victoria are essential to be improved in the near future and which have less priority? Why?
11. Do you regard a combination of the ecological and recreational needs of the rivers in Victoria as a possible option? How would you do it?

Appendix BB: Expert interview questions (own source).

Victoria residents	Victoria employee	District of residence	Gender	Age	Public (Bus)	Car	Scooter/Motorbike	Walking	Level of eduction	Question 1A	Question 1B	Question 1C	Question 1D	Question 1E	Question 2	Question 3	Question 4A	Question 4B	Question 5A	Question 5B	Question 6A	Question 6B	Question 6C	Question 6D	Question 6E	Question 6F	Question 7	Question 7 reason	Question 8	Question 8 reason

Appendix CC: Questionnaire structure.

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Survey Lo Aktivite Rekreasyonal Pou Bann Larivyer Dan Victoria

Mon apel Nicolas Meister. Mon pe fer sa sondaz pour mon Master Thesis, an kolaborasyon avek Seychelles Planning Authority e Swiss Federal Institute of Technology, Zurich. Topik sa sondaz i 'Larivyer dan Victoria'. Lobzektif sa sondaz se dekouver lopinyon e konesans piblik lo bann larivyer ki pas atraver Victoria. Lenformasyon ki ou pour donnen pour ed mwan atenn sa lobzektif. Eski ou dakor pour partisip dan sa sondaz? Sa sondaz pou pran zis 5 a 10 minit ou letan. Larepons ki ou donnen i konfidansyel.

☐ Rezidan Victoria ☐ Travay Victoria (Reste e travay Victoria)

Distrikt: _____

Gender: ☐ Male ☐ Femal

Laz: _____

Fason deplase: ☐ Bis piblik ☐ Loto/lezot transpor ☐ Scooter/Moter ☐ Marse

Pli o nivo ledikasyon:

☐ Primer ☐ Segonder ☐ Post-segonder ☐ Liniversite

1. Ki fonksyon en larivyer i sipoze deservir? Anba i annan en lalis bann keksoz ki posibleman enportan. **Grad sa bann larepons avek en tik** dapre lenportans ki ou asosye avek en larivyer.

	Pa tro importan 1	2	3	4	Tre importan 5
Son litilite (Par egzanp, anmas desarz, donn landrwa pour tiyo pase, pour lav lenz ouswa lezot keksoz)	☐	☐	☐	☐	☐
Proteksyon kont dezas natirel	☐	☐	☐	☐	☐
Lwazir (par egzanp pour detann, anmize, asize, manze, zwe, lape)	☐	☐	☐	☐	☐
Pour donn delo (par ezanp delo pour bwar, delo pour servi, delo pour plante)	☐	☐	☐	☐	☐
Pour lanatir (par egzanp biodiversite, labita pour bann zannimo/plant).	☐	☐	☐	☐	☐

2. Konbyen pti larivyer i pas atravey Victoria?

_____

3. Ki manyer ou pour karakteriz leta bann larivyer dan Victoria (Konsider zot laparans):

☐ Vreman pa atiran ☐ Pa atiran ☐ Napa lide ☐ Atiran ☐ Vreman Atiran

4. Nonm 2 karakteristik ki ou **kontan** avek sa bann larivyer ki egziste an se moman dan Victoria.

a) _____

b) _____

5. Nonm 2 karakteristik ki ou **pa kontan** avek sa bann larivyer ki egziste an se moman dan Victoria.

a) _____

b) _____

Page 1 ➤

Appendix DD: Creole version of the survey, page 1.

6. Sa bann zimaz swivan i montre lafason ki bann larivyer Victoria i kapab ete dan le fitir. Sa bann lekritir par lao zimaz i dekrir sa zimaz. Note ki sa bann portre i zis en ilistrasyon me non pa pe montre ki manyer Victoria i ete an se moman. Silvouple **grad sa bann portre dan sa bann bwat par anba**.

a) En lapromenad obor larivyer, ki annan café e restoran

Vreman pa anvi 1 2 3 4 5 Vreman anvi

b) En pti semen marse (pathway) obor en pti larivyer (e.g. Mangroves)

Vreman pa anvi 1 2 3 4 5 Vreman anvi

c) En larivyer kin ganny fer ekspreseman pour pasaz tiyo, ansanm ek en pti semen obor

Vreman pa anvi 1 2 3 4 5 Vreman anvi

d) Pe detann e anmize lo zerb obor delo

Vreman pa anvi 1 2 3 4 5 Vreman anvi

e) En lapromenad ansanm ek peron pour assize, obor en pti larivyer natirel

Vreman pa anvi 1 2 3 4 5 Vreman anvi

f) Landrwa pour fer barbeque obor larivyer

Vreman pa anvi 1 2 3 4 5 Vreman anvi

7. Lekel zimaz ki ou pli kontan/apresye/favorize parmi sa 6 zimaz (swazir enn zimaz)? Ekrir let alfabet ki al ek sa zimaz ki oun swazir . **Eksplike akoz ou prefer sa zimaz**.

8. Lekel zimaz ki ou pli **pa kontan/apresye** parmi sa 6 zimaz (swazir enn zimaz)? Ekrir let alfabet ki al ek sa zimaz ki oun swazir. **Eksplike akoz ou pa apresye sa zimaz**.

Page 2

Appendix EE: Creole version of the survey, page 2.

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Survey on Recreational Meaning of Rivers in Victoria

I am Nicolas Meister from Switzerland. This survey is embedded into my Master Thesis in collaboration with the Seychelles Planning Authority and the Swiss Federal Institute of Technology Zurich about the rivers in Victoria. The aim of the survey is to find out more about people's thoughts and the public awareness of the streams in Victoria. Your information contributes to this aim and is therefore very useful. Would you be willing to answer the questions? It will only take about 5-10 minutes. Your answers are entirely anonymous.

☐ Victoria Residents ☐ Victoria Employee (both options are possible)

District of residence: _____

Gender: ☐ Male ☐ Female

Age: _____

Usual transport mode: ☐ Public (Bus) ☐ Car ☐ Scooter/Motorbike ☐ Walking

Highest level of education:

☐ Primary school ☐ Secondary school ☐ Post-secondary school ☐ University

1. What do you consider as the main functions a river has to achieve? Please **rate the importance of the functions with a tick** in the boxes provided. There is no right or wrong answer.

	Not at all important 1	2	3	4	Very important 5
Utilities (e.g. waste water discharge, room for pipelines, washing)	☐	☐	☐	☐	☐
Natural hazards (e.g. flood control and protection)	☐	☐	☐	☐	☐
Leisure (e.g. relaxing, enjoying, sitting, eating, playing, fishing)	☐	☐	☐	☐	☐
Water provision (e.g. drinking and process water, groundwater enrichment)	☐	☐	☐	☐	☐
Nature (e.g. biodiversity, habitat for species, microclimate regulation)	☐	☐	☐	☐	☐

2. What do you think: How many rivers flow through the Inner Victoria area?

   _____

3. How would you characterize the current state of the rivers in Victoria in terms of appearance?

   ☐ Very unsightly ☐ Unsightly ☐ Indifferent ☐ Attractive ☐ Very attractive

4. Please mention two characteristics you **like** about the rivers in Victoria in their existing shapes:

   a) _____

   b) _____

5. Please mention two characteristics you **dislike** about the rivers in Victoria in their existing shapes:

   a) _____

   b) _____

Page 1 ➤

Appendix FF: English version of the survey, page 1.

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Survey on Recreational Meaning of Rivers in Victoria

I am Nicolas Meister from Switzerland. This survey is embedded into my Master Thesis in collaboration with the Seychelles Planning Authority and the Swiss Federal Institute of Technology Zurich about the rivers in Victoria. The aim of the survey is to find out more about people's thoughts and the public awareness of the streams in Victoria. Your information contributes to this aim and is therefore very useful. Would you be willing to answer the questions? It will only take about 5-10 minutes. Your answers are entirely anonymous.

☐ Victoria Residents ☐ Victoria Employee (both options are possible)

District of residence: _____

Gender: ☐ Male ☐ Female

Age: _____

Usual transport mode: ☐ Public (Bus) ☐ Car ☐ Scooter/Motorbike ☐ Walking

Highest level of education:

☐ Primary school ☐ Secondary school ☐ Post-secondary school ☐ University

1. What do you consider as the main functions a river has to achieve? Please **rate the importance of the functions with a tick** in the boxes provided. There is no right or wrong answer.

	Not at all important 1	2	3	4	Very important 5
Utilities (e.g. waste water discharge, room for pipelines, washing)	☐	☐	☐	☐	☐
Natural hazards (e.g. flood control and protection)	☐	☐	☐	☐	☐
Leisure (e.g. relaxing, enjoying, sitting, eating, playing, fishing)	☐	☐	☐	☐	☐
Water provision (e.g. drinking and process water, groundwater enrichment)	☐	☐	☐	☐	☐
Nature (e.g. biodiversity, habitat for species, microclimate regulation)	☐	☐	☐	☐	☐

2. What do you think: How many rivers flow through the Inner Victoria area?

   _____

3. How would you characterize the current state of the rivers in Victoria in terms of appearance?

   ☐ Very unsightly ☐ Unsightly ☐ Indifferent ☐ Attractive ☐ Very attractive

4. Please mention two characteristics you **like** about the rivers in Victoria in their existing shapes:

   a) _____

   b) _____

5. Please mention two characteristics you **dislike** about the rivers in Victoria in their existing shapes:

   a) _____

   b) _____

Page 1 ➤

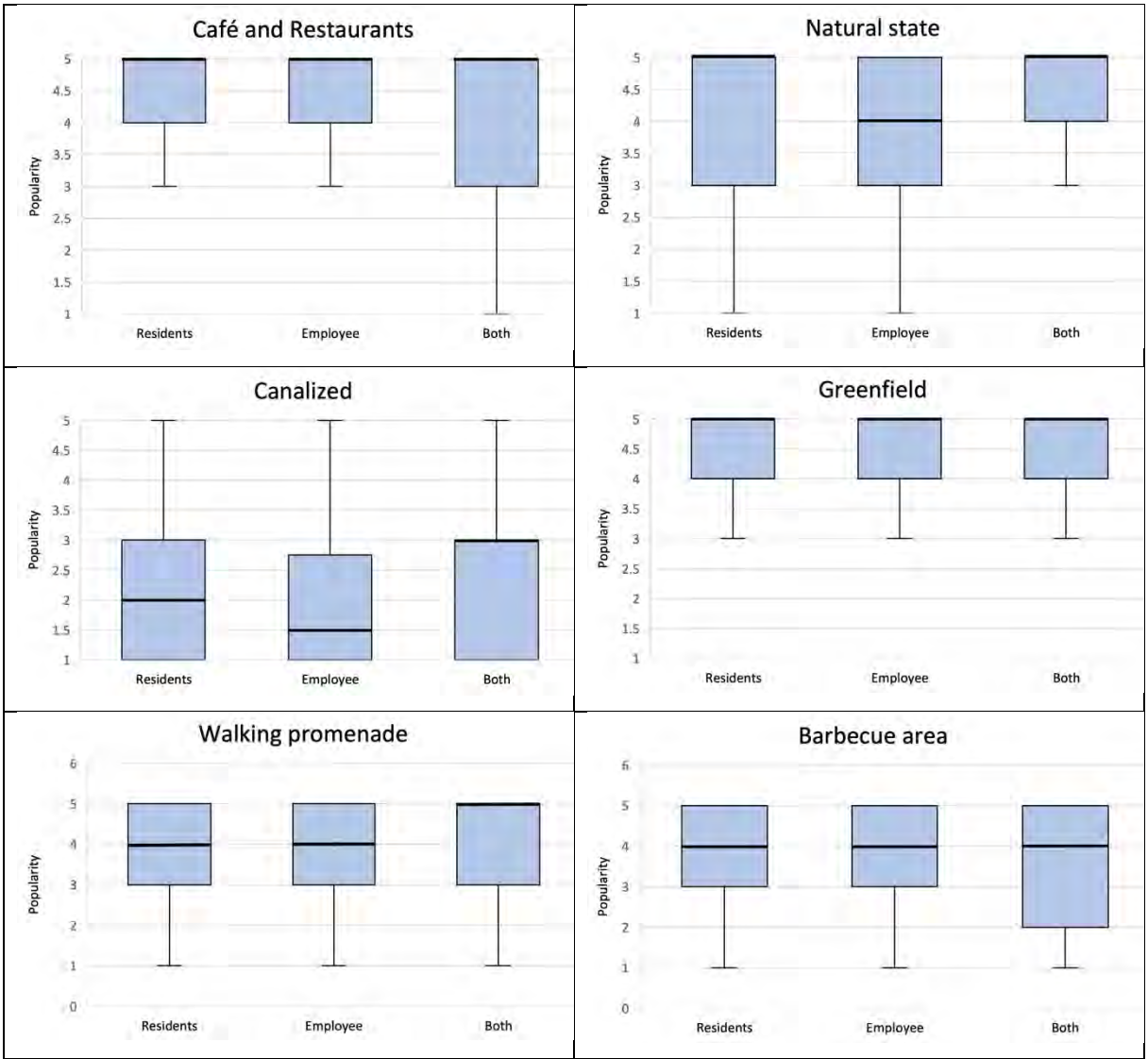
Appendix GG: English version of the survey, page 2.

	Available	Rejected	Not at home
Bel Air	14	2	4
Mont Buxton	16	3	3
St. Louis	17	4	2
Mont Fleuri	10	2	5
English River	15	4	2
Sum	72	15	16

Appendix HH: Overview about the number of questionnaires for residents.

	Available	Rejected
Restaurant and café	7	-
Travel and Transportation	9	-
Financial businesses	19	1
Electronic businesses	8	3
Kiosk & Souvenir stores	6	6
Fashion and Accessoires	6	2
Administrations	20	4
Museum and Art Gallery	8	1
Others	11	2
Sum	94	19

Appendix II: Overview about the number of questionnaires for employees.



Appendix JJ: Boxplot about potential future states of the rivers divided into the three groups residents, employees and both (own source).

t-Test (Residents/Employees)

		Levene-Test der Varianzgleic		T-Test für die Mittelwertgleichheit						
		F	Signifikanz	T	df	Sig. (2-seitig)	Mittlere Differenz	Standardfehler	95% Konfidenzintervall der Differenz	
									Untere	Obere
Question6A	Varianzen sind gleich	1,966	,163	-1,362	121	,176	-,262	,192	-,643	,119
	Varianzen sind nicht gleich			-1,280	79,102	,204	-,262	,205	-,670	,145
Question6B	Varianzen sind gleich	,262	,610	1,309	121	,193	,259	,198	-,133	,651
	Varianzen sind nicht gleich			1,295	94,401	,198	,259	,200	-,138	,657
Question6C	Varianzen sind gleich	1,098	,297	1,147	121	,254	,243	,212	-,176	,662
	Varianzen sind nicht gleich			1,087	81,394	,280	,243	,224	-,202	,688
Question6D	Varianzen sind gleich	,048	,827	,318	121	,751	,057	,179	-,298	,412
	Varianzen sind nicht gleich			,318	96,943	,751	,057	,180	-,300	,414
Question6E	Varianzen sind gleich	,008	,929	,419	121	,676	,090	,215	-,336	,516
	Varianzen sind nicht gleich			,415	94,757	,679	,090	,217	-,341	,521
Question6F	Varianzen sind gleich	,264	,608	-1,361	121	,176	-,320	,235	-,786	,146
	Varianzen sind nicht gleich			-1,392	104,646	,167	-,320	,230	-,777	,136

Appendix KK: Result of the t-Test between residents and employees concerning potential future states of the rivers (own source).

t-Test (Residents/Both)

		Levene-Test der Varianzgleic		T-Test für die Mittelwertgleichheit						
		F	Signifikanz	T	df	Sig. (2-seitig)	Mittlere Differenz	Standardfehler	95% Konfidenzintervall der Differenz	
									Untere	Obere
Question6A	Varianzen sind gleich	,022	,883	-,605	88	,547	-,149	,247	-,640	,342
	Varianzen sind nicht gleich			-,606	87,903	,546	-,149	,246	-,639	,340
Question6B	Varianzen sind gleich	,477	,492	-,687	88	,494	-,151	,220	-,589	,286
	Varianzen sind nicht gleich			-,691	87,972	,492	-,151	,219	-,587	,284
Question6C	Varianzen sind gleich	,693	,407	-1,057	88	,293	-,287	,272	-,827	,253
	Varianzen sind nicht gleich			-1,058	87,578	,293	-,287	,271	-,826	,252
Question6D	Varianzen sind gleich	,064	,801	,277	88	,782	,053	,193	-,330	,437
	Varianzen sind nicht gleich			,279	87,787	,781	,053	,192	-,328	,434
Question6E	Varianzen sind gleich	,037	,848	-,210	88	,834	-,052	,250	-,549	,444
	Varianzen sind nicht gleich			-,210	87,390	,834	-,052	,250	-,549	,444
Question6F	Varianzen sind gleich	5,329	,023	,057	88	,955	,016	,288	-,556	,589
	Varianzen sind nicht gleich			,056	79,257	,955	,016	,291	-,564	,596

Appendix LL: Result of the t-Test between residents and both concerning potential future states of the rivers (own source).

t-Test (Employees/Both)

		Levene-Test der Varianzgleic		T-Test für die Mittelwertgleichheit						
		F	Signifikanz	T	df	Sig. (2-seitig)	Mittlere Differenz	Standardfehler	95% Konfidenzintervall der Differenz	
									Untere	Obere
Question6A	Varianzen sind gleich	2,961	,088	,588	117	,558	,113	,192	-,267	,492
	Varianzen sind nicht gleich			,555	73,404	,581	,113	,203	-,292	,517
Question6B	Varianzen sind gleich	,052	,821	-2,096	117	,038	-,411	,196	-,799	-,023
	Varianzen sind nicht gleich			-2,134	92,146	,035	-,411	,192	-,793	-,029
Question6C	Varianzen sind gleich	5,458	,021	-2,468	117	,015	-,530	,215	-,955	-,105
	Varianzen sind nicht gleich			-2,330	73,452	,023	-,530	,227	-,983	-,077
Question6D	Varianzen sind gleich	,275	,601	-,021	117	,983	-,004	,176	-,353	,345
	Varianzen sind nicht gleich			-,022	97,056	,983	-,004	,170	-,341	,334
Question6E	Varianzen sind gleich	,097	,757	-,646	117	,519	-,143	,221	-,579	,294
	Varianzen sind nicht gleich			-,641	85,037	,523	-,143	,223	-,585	,300
Question6F	Varianzen sind gleich	3,364	,069	1,264	117	,209	,337	,266	-,191	,864
	Varianzen sind nicht gleich			1,211	76,698	,230	,337	,278	-,217	,890

Appendix MM: Result of the t-Test between employees and both concerning potential future states of the rivers (own source).

		Victoriaresidents	Victoriaemployee	Both	Group	Age	PublicBus	Car	ScooterMotorbike	Walking	Levelofeduction	Question1A	Question1B	Question1C	Question1D	Question1E	Question2	Qestion3	Question6A	Question6B	Question6C	Question6D	Question6E	Question6F	Question7	Question8
Victoriaresidents	Korrelation nach Pearson	1	-,578**	,543**	-,030	,188*	-,031	-,138	-,057	,312**	-,143	,075	-,032	-,062	,086	,230**	-,031	,010	-,090	,157*	,160*	,017	,050	-,122	-,038	,112
	Signifikanz (2-seitig)		,000	,000	,700	,015	,690	,075	,467	,000	,067	,334	,678	,424	,272	,003	,699	,901	,251	,043	,040	,829	,525	,117	,624	,154
	N	166	166	166	166	166	166	166	166	166	166	166	166	166	166	166	158	166	166	166	166	166	166	166	166	165
Victoriaemployee	Korrelation nach Pearson	-,578**	1	,372**	,833**	-,218**	-,078	,051	-,015	-,126	,092	-,049	,060	-,066	-,098	-,129	,050	-,009	,094	-,047	-,020	-,027	-,015	,067	,100	-,040
	Signifikanz (2-seitig)	,000		,000	,000	,005	,317	,511	,847	,105	,236	,531	,441	,398	,208	,098	,531	,904	,228	,544	,803	,729	,847	,392	,200	,607
	N	166	166	166	166	166	166	166	166	166	166	166	166	166	166	166	158	166	166	166	166	166	166	166	166	165
Both	Korrelation nach Pearson	,543**	,372**	1	,823**	-,010	-,116	-,105	-,080	,225**	-,067	,035	,025	-,139	-,004	,129	,017	,001	-,005	,130	,161*	-,009	,041	-,070	,059	,085
	Signifikanz (2-seitig)	,000	,000		,000	,897	,137	,180	,304	,004	,390	,650	,750	,074	,963	,098	,829	,986	,947	,096	,038	,913	,600	,370	,449	,275
	N	166	166	166	166	166	166	166	166	166	166	166	166	166	166	166	158	166	166	166	166	166	166	166	166	165
Group	Korrelation nach Pearson	-,030	,833**	,823**	1	-,139	-,117	-,031	-,057	,057	,017	-,009	,052	-,123	-,062	-,002	,041	-,005	,055	,048	,084	-,022	,015	-,001	,096	,026
	Signifikanz (2-seitig)	,700	,000	,000		,073	,134	,693	,466	,468	,832	,910	,508	,114	,425	,979	,608	,949	,485	,537	,281	,782	,846	,992	,217	,736
	N	166	166	166	166	166	166	166	166	166	166	166	166	166	166	166	158	166	166	166	166	166	166	166	166	165
Age	Korrelation nach Pearson	,188*	-,218**	-,010	-,139	1	-,129	,023	-,017	,318**	-,196*	-,022	-,001	,000	,148	,171*	,110	,054	-,181*	,068	-,026	-,005	-,130	-,101	-,081	,050
	Signifikanz (2-seitig)	,015	,005	,897	,073		,098	,772	,826	,005	,012	,781	,986	,996	,057	,027	,168	,493	,020	,385	,744	,950	,094	,197	,299	,526
	N	166	166	166	166	166	166	166	166	166	166	166	166	166	166	166	158	166	166	166	166	166	166	166	166	165
PublicBus	Korrelation nach Pearson	-,031	-,078	-,116	-,117	-,129	1	-,516**	,053	-,020	-,145	,028	-,083	,122	,045	-,135	-,098	,099	,038	-,066	-,059	-,040	,075	,091	,091	-,117
	Signifikanz (2-seitig)	,690	,317	,137	,134	,098		,000	,494	,794	,062	,719	,286	,117	,562	,083	,221	,204	,628	,398	,453	,610	,337	,244	,244	,134
	N	166	166	166	166	166	166	166	166	166	166	166	166	166	166	166	158	166	166	166	166	166	166	166	166	165
Car	Korrelation nach Pearson	-,138	,051	-,105	-,031	,023	-,516**	1	,037	,313**	,107	-,004	-,041	-,024	,098	,203**	,073	-,186*	-,026	,020	-,023	-,012	-,033	-,010	,022	,054
	Signifikanz (2-seitig)	,075	,511	,180	,693	,772	,000		,635	,000	,170	,960	,601	,757	,207	,009	,359	,017	,735	,796	,771	,878	,671	,901	,776	,490
	N	166	166	166	166	166	166	166	166	166	166	166	166	166	166	166	158	166	166	166	166	166	166	166	166	165
ScooterMotorbike	Korrelation nach Pearson	-,057	-,015	-,080	-,057	-,017	,053	,037	1	,025	,056	-,069	-,011	,036	,074	-,071	-,006	,055	-,205**	,080	-,082	-,105	-,043	-,005	-,075	,080
	Signifikanz (2-seitig)	,467	,847	,304	,466	,826	,494	,635		,749	,476	,375	,893	,650	,341	,366	,941	,479	,008	,307	,295	,178	,579	,948	,339	,309
	N	166	166	166	166	166	166	166	166	166	166	166	166	166	166	166	158	166	166	166	166	166	166	166	166	165
Walking	Korrelation nach Pearson	,312**	-,126	,225**	,057	,348**	-,020	-,313**	,025	1	-,088	-,028	,026	,020	-,011	,027	,017	,024	-,106	-,250**	,117	-,077	-,090	-,022	-,011	,070
	Signifikanz (2-seitig)	,000	,105	,004	,468	,005	,794	,000	,749		,260	,718	,738	,801	,886	,729	,829	,757	,173	,001	,135	,321	,248	,780	,886	,369
	N	166	166	166	166	166	166	166	166	166	166	166	166	166	166	166	158	166	166	166	166	166	166	166	166	165
Levelofeduction	Korrelation nach Pearson	-,143	,092	-,067	,017	-,196*	-,145	,107	,056	-,088	1	-,064	-,066	-,131	-,020	,034	-,097	-,041	,115	-,077	,003	,096	-,028	,045	,026	-,090
	Signifikanz (2-seitig)	,067	,236	,390	,832	,012	,062	,170	,476	,260		,410	,400	,093	,800	,666	,223	,599	,141	,322	,966	,221	,719	,563	,736	,250
	N	166	166	166	166	166	166	166	166	166	166	166	166	166	166	166	158	166	166	166	166	166	166	166	166	165
Question1A	Korrelation nach Pearson	,075	-,049	,035	-,009	-,022	,028	-,004	-,069	-,028	-,064	1	,088	,165*	,149	,004	,058	,208**	,049	-,026	,622**	-,057	,050	,152	-,043	-,094
	Signifikanz (2-seitig)	,334	,531	,650	,910	,781	,719	,960	,375	,718	,410		,257	,033	,055	,958	,468	,007	,534	,740	,004	,465	,520	,050	,579	,229
	N	166	166	166	166	166	166	166	166	166	166	166	166	166	166	166	158	166	166	166	166	166	166	166	166	165
Question1B	Korrelation nach Pearson	-,032	,060	,025	,052	-,001	-,083	-,041	-,011	,026	-,066	,088	1	,233**	,110	,133	-,008	-,106	,064	,208**	,119	,151	,118	,144	,009	,025
	Signifikanz (2-seitig)	,678	,441	,750	,508	,986	,286	,601	,893	,738	,400	,257		,002	,160	,087	,917	,173	,416	,007	,127	,052	,129	,065	,910	,746
	N	166	166	166	166	166	166	166	166	166	166	166	166	166	166	166	158	166	166	166	166	166	166	166	166	165
Question1C	Korrelation nach Pearson	-,062	-,066	-,139	-,123	,000	,122	-,024	,036	,020	-,131	,165*	,233**	1	,078	,035	,137	,171*	,132	,063	,044	,094	,212**	,080	,016	,020
	Signifikanz (2-seitig)	,424	,398	,074	,114	,996	,117	,757	,650	,801	,093	,033	,002		,320	,657	,085	,028	,089	,423	,571	,227	,006	,303	,842	,794
	N	166	166	166	166	166	166	166	166	166	166	166	166	166	166	166	158	166	166	166	166	166	166	166	166	165
Question1D	Korrelation nach Pearson	,086	-,098	-,004	-,062	,148	,045	,098	,074	-,011	-,020	,149	,110	,078	1	,395**	,010	-,090	-,158*	,199*	,033	,178*	,062	,133	,125	,046
	Signifikanz (2-seitig)	,272	,208	,963	,425	,057	,562	,207	,341	,886	,800	,055	,160	,320		,000	,905	,251	,041	,010	,670	,022	,425	,089	,107	,561
	N	166	166	166	166	166	166	166	166	166	166	166	166	166	166	166	158	166	166	166	166	166	166	166	166	165
Question1E	Korrelation nach Pearson	,230**	-,129	,129	-,002	,171*	-,135	,203**	-,071	,027	,034	,004	,133	,035	,395**	1	,038	-,151	-,056	,236**	,038	,335**	,261**	,095	,130	,093
	Signifikanz (2-seitig)	,003	,098	,098	,979	,027	,083	,009	,366	,729	,666	,958	,087	,657	,000		,638	,052	,475	,002	,626	,000	,001	,222	,095	,236
	N	166	166	166	166	166	166	166	166	166	166	166	166	166	166	166	158	166	166	166	166	166	166	166	166	165
Question2	Korrelation nach Pearson	-,031	,050	,017	,041	,110	-,098	,073	-,006	,017	-,097	,058	-,008	,137	,010	,038	1	,209**	,081	-,004	,034	,053	,040	-,025	,075	-,057
	Signifikanz (2-seitig)	,699	,531	,829	,608	,168	,221	,359	,941	,829	,223	,468	,917	,085	,905	,638		,008	,311	,962	,671	,512	,618	,758	,348	,480
	N	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	157
Qestion3	Korrelation nach Pearson	,010	-,009	,001	-,005	,054	,099	-,186*	,055	,024	-,041	,208**	-,106	,171*	-,090	-,151	,209**	1	,044	-,075	,110	-,103	-,014	,080	,010	-,184*
	Signifikanz (2-seitig)	,901	,904	,986	,949	,493	,204	,017	,479	,757	,599	,007	,173	,028	,251	,052	,008		,576	,335	,157	,185	,858	,306	,893	,018
	N	166	166	166	166	166	166	166	166	166	166	166	166	166	166	166	158	166	166	166	166	166	166	166	166	165
Question6A	Korrelation nach Pearson	-,090	,094	-,005	,055	,181*	,038	-,026	-,205**	-,106	,115	,049	,064	,132	-,158*	-,056	,081	,044	1	-,076	-,039	,257**	,450**	,291**	-,096	-,149
	Signifikanz (2-seitig)	,251	,228	,947	,485	,020	,628	,735	,008	,173	,141	,534	,416	,089	,041	,475	,311	,576		,328	,619	,001	,000	,000	,216	,057
	N	166	166	166	166	166	166	166	166	166	166	166	166	166	166	166	158	166	166	166	166	166	166	166	166	165
Question6B	Korrelation nach Pearson	,157*	-,047	,130	,048	,068	-,066	,020	,080	,250**	-,077	-,026	,208**	,063	,199*	,236**	-,004	-,075	-,076	1	,109	,252**	,088	-,033	-,027	,257**
	Signifikanz (2-seitig)	,043	,544	,096	,537	,385	,398	,796	,307	,001	,322	,740	,007	,423	,010	,002	,962	,335	,328		,161	,001	,261	,672	,726	,001
	N	166	166	166	166	166	166	166	166	166	166	166	166	166	166	166	158	166	166	166	166	166	166	166	166	165
Question6C	Korrelation nach Pearson	,160*	-,020	,161*	,084	-,026	-,059	-,023	-,082	,117	,003	,622**	,119	,044	,033	,038	,034	,110	-,039	,109	1	-,093	,038	,073	,032	-,071
	Signifikanz (2-seitig)	,040	,803	,038	,281	,744	,453	,771	,295	,135	,966	,004	,127	,571	,670	,626	,671	,157	,619	,161		,232	,624	,350	,680	,368
	N	166	166	166	166	166	166	166	166	166	166	166	166	166	166	166	158	166	166	166	166	166	166	166	166	165
Question6D	Korrelation nach Pearson	,017	-,027	-,009	-,022	-,005	-,040	-,012	-,105	-,077	,096	-,057	,151	,094	,178*	,335**	,053	-,103	,257**	,252**	-,093	1	,441**	,160*	,014	,020
	Signifikanz (2-seitig)	,829	,729	,913	,782	,950	,610	,878	,178	,321	,221	,465	,052	,227	,022	,000	,512	,185	,001	,001	,232		,000	,039	,859	,801
	N	166	166	166	166	166	166	166	166	166	166	166	166	166	166	166	158	166	166	166	166	166	166	166	166	165
Question6E	Korrelation nach Pearson	,050	-,015	,041	,015	-,130	,075	-,033	-,043	-,090	-,028	,050	,118	,212**	,062	,261**	,040	-,014	,450**	,088	,038	,441**	1	,357**	,078	-,050
	Signifikanz (2-seitig)	,525	,847	,600	,846	,094	,337	,671	,579	,248	,719	,520	,129	,006	,425	,001	,618	,858	,000	,261	,624	,000		,000	,321	,527
	N	166	166	166	166	166	166	166	166	166	166	166	166	166	166	166	158	166	166	166	166	166	166	166	166	165
Question6F	Korrelation nach Pearson	-,122	,067	-,070	-,001	-,101	,091	-,010	-,005	-,022	,045	,152	,144	,080	,133	,095	-,025	,080	,291**	-,033	,073	,160*	,357**	1	,216**	,400**
	Signifikanz (2-seitig)	,117	,392	,370	,992	,197	,244	,901	,948	,780	,563	,050	,065	,303	,089	,222	,758	,306	,000	,672	,350	,039	,000		,005	,000
	N	166	166	166	166	166	166	166	166	166	166	166	166	166	166	166	158	166	166	166	166	166	166	166	166	165
Question7	Korrelation nach Pearson	-,038	,100	,059	,096	-,081	,091	,022	-,075	-,011	,026	-,043	,009	,016	,125	,130	,075	,010	-,096	-,027	,032	,014	,078	,216**	1	-,143
	Signifikanz (2-seitig)	,624	,200	,449	,217	,299	,244	,776	,339	,886	,736	,579	,910	,842	,107	,095	,348	,893	,216	,726	,680	,859	,321	,005		,067
	N	166	166	166	166	166	166	166	166	166	166	166	166	166	166	166	158	166	166	166	166	166	166	166	166	165
Question8	Korrelation nach Pearson	,112	-,040	,085	,026	,050	-,117	,054	,080	,070	-,090	-,094	,025	-,020	,046	,093	-,057	-,184*	-,149	,257**	-,071	,020	-,050	-,400**	-,143	1
	Signifikanz (2-seitig)	,154	,607	,275	,736	,526	,134	,490	,309	,369	,250	,229	,746	,794	,561	,236	,480	,018	,057	,001	,368	,801	,527	,000	,067	
	N	165	165	165	165	165	165	165	165	165	165	165	165	165	165	165	157	165	165	165	165	165	165	165	165	165

** Die Korrelation ist auf dem Niveau von 0,01 (2-seitig) signifikant.
* Die Korrelation ist auf dem Niveau von 0,05 (2-seitig) signifikant.

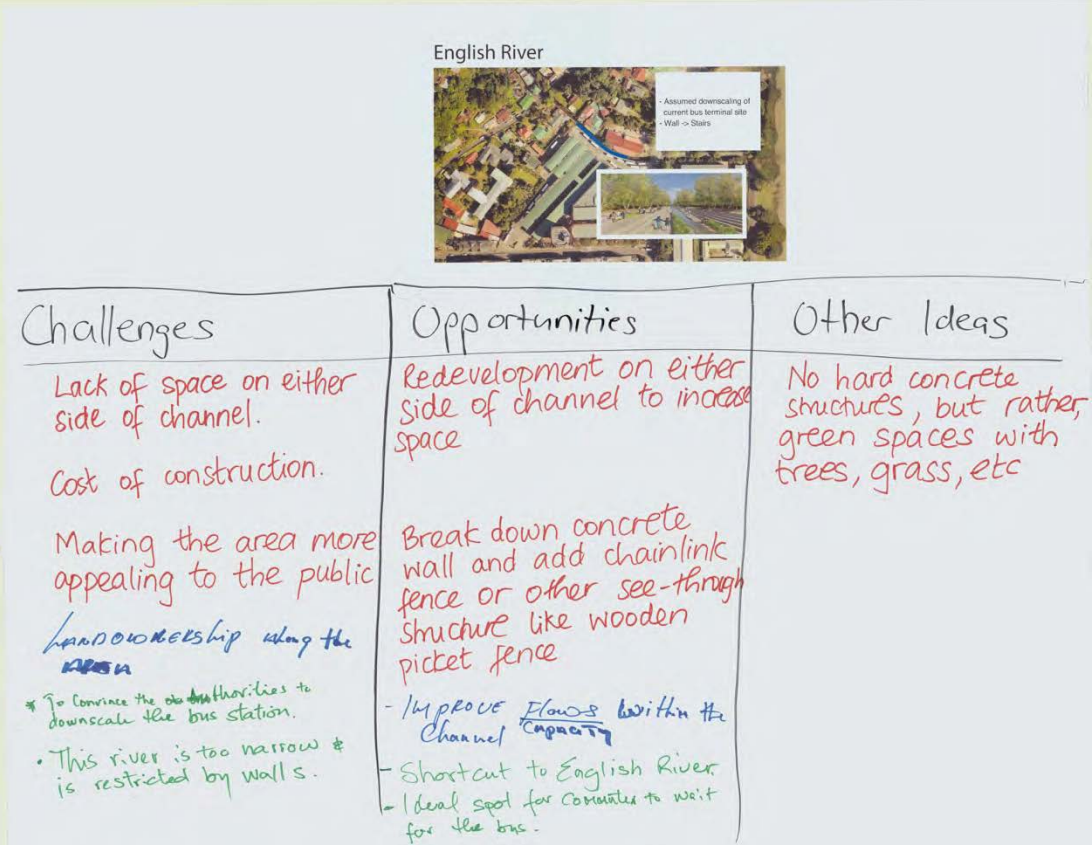
Appendix NN: Correlation analysis of the questions contained in the questionnaire (own source).

Name	Institution	E-Mail	Group
Ginnie Alexis	PUC	glaurencine@puc.sc	red
Franky Dupres	PUC	fdupes@puc.sc	-
Bernard Belle	SPA (MHILT)	bbelle@mluh.gov.sc	red
Sharia Likonda	LWMA	sharia.likonda@gov.sc	black
Steffi Morel	LWMA	steffi.morel@gov.sc	green
Gerry Joseph	LWMA	gerry.joseph@gov.sc	black
Michel Laporte	PPID (MHILT)	mlaporte@mluh.gov.sc	green
Yves Choppy	PS PPID (MHILT)	ychoppy@mluh.gov.sc	-
Selvan Pillay	CAMS (Climate Change)	s.pillay@gov.sc	blue
Jean-Claude Labrosse	CAMS (Climate Change)	j.labrosse@env.gov.sc	Blue
Rejected requests from Tourism Department, Environment Departments, Seychelles Land Transport Authority and the Mayor of Victoria			

Appendix OO: Workshop participants.

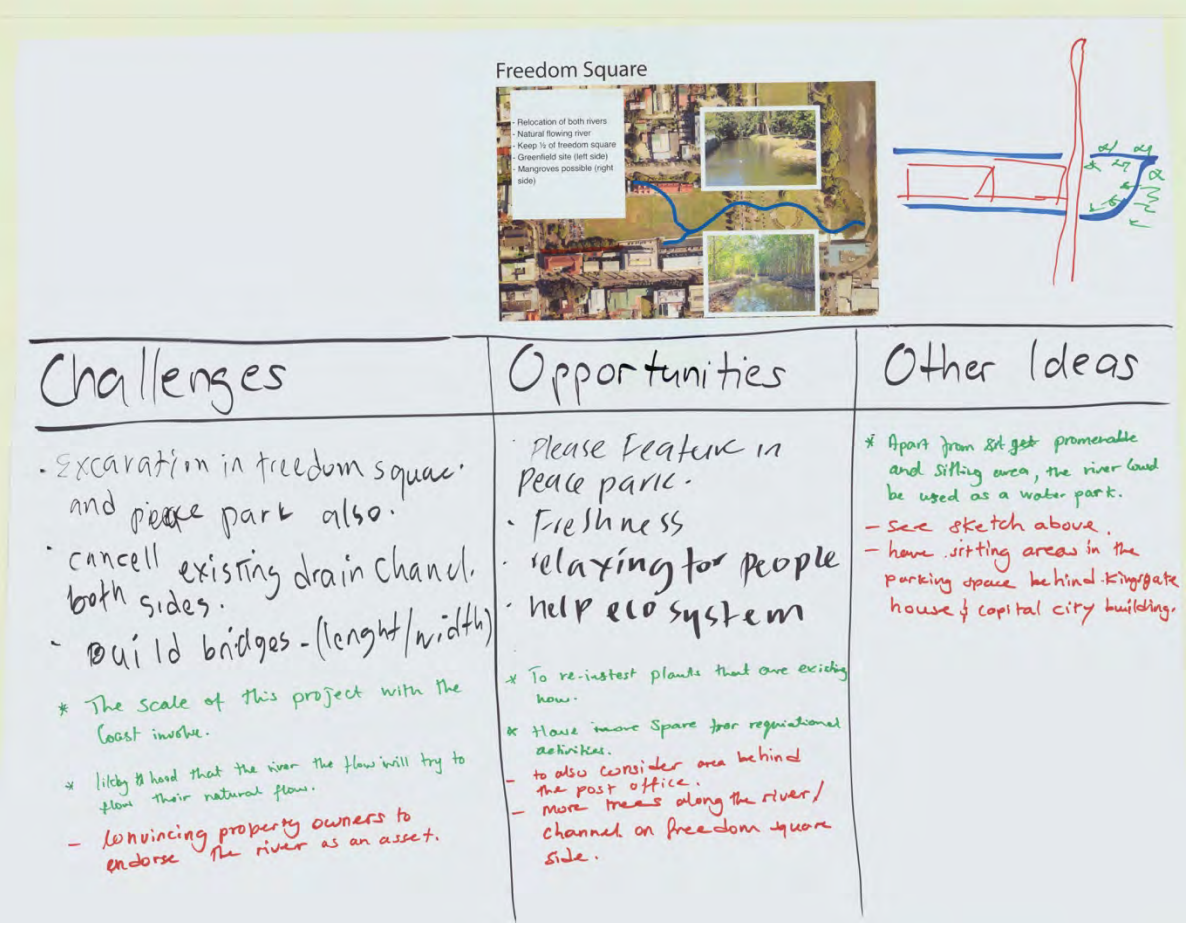
09.30am – 09.35am	Welcoming
09.35am – 09.45am	Introduction
09.45am – 10.00am	Presentation Master's Thesis
10.00am – 10.30am	Discussion
10.30am – 10.40am	Break
10.40am – 11.10am	Case Study Assessment
11.10am – 11.30am	Case Study Presentation and Discussion
11.30am – 11.45am	Summary and Feedback

Appendix PP: Timetable workshop.

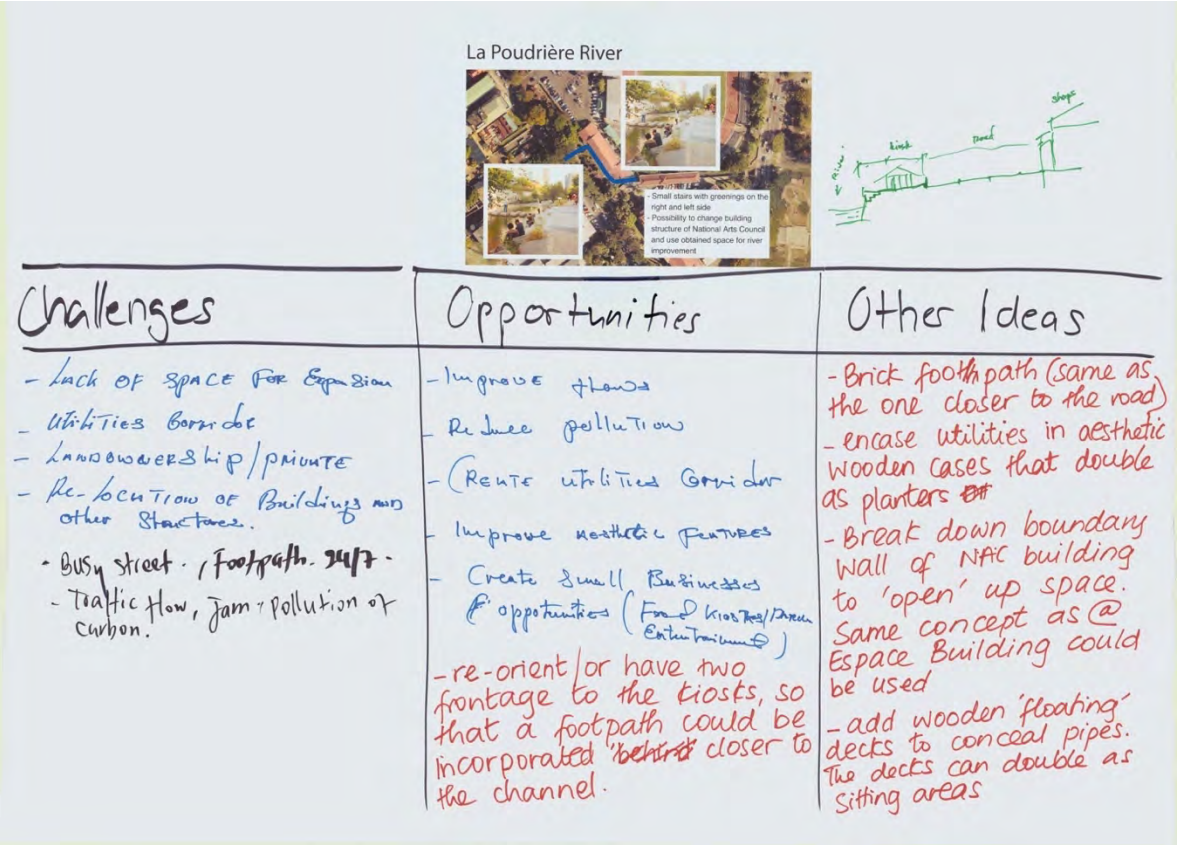


Appendix QQ: Poster case study 1 - English River.

Appendix RR: Poster case study 2 – Rivière Moussa.



Appendix SS: Poster case study 3 – Rivière Maintry and Rivière St. Louis (Freedom Square).



Appendix TT: Poster case study 4 – La Poudrière River.

Appendix UU: Example of a trash trap (Storm water systems, 2019).

Appendix VV: Degree of shade of English River, Rivière Moussa, Rivière Maintry and Rivière St. Louis (own source).

Appendix WW: Degree of shade of the Rivière St. Louis, La Poudrière River and Rivière Trois Frères (own source).

Appendix XX: Photo of a "Pirogue", a traditional fishing boat of the Seychelles (own source, 25/05/2019).