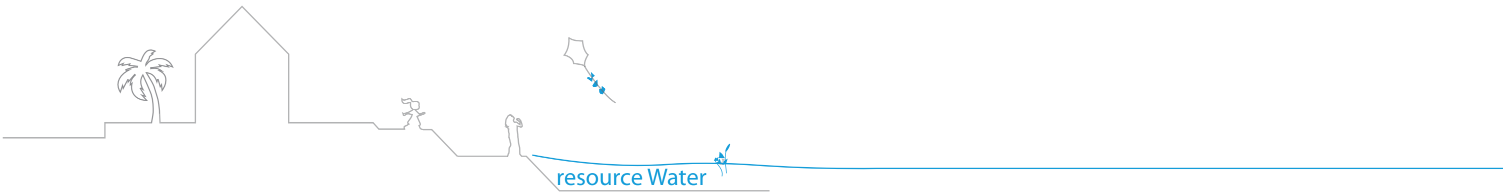
resource Water

reSOURCE Water

...closing the cycles

by

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When I started my position as an architect and urban planner at the Technical University of Darmstadt in 2012, I had the chance to work in the interdisciplinary project ‚Semizentral‘, which deals with the water supply of Asian cities. At this point, I was not aware of the far-reaching consequences this project would have for my personal development. For me this project meant the first professional contact with water in a technical context and this experience shapes and fascinates me in all its facets until today.

The interdisciplinary cooperation within the framework of this project with the Institute of Wastewater Technology (IWAR) of the TU Darmstadt, external companies, research institutions and engineers of different disciplines and cultures, has contributed significantly to the idea of ‚reSOURCE Water‘ and the thesis defence of this dissertation in December 2017 undoubtedly represents an important climax of the last years, but even more a great starting point for my future research in the context of Water Sensitive Urban Design.

With my two supervisors Prof. Dr. Annette Rudolph-Cleff and Prof. Dr. Martin Wagner I got the perfect framework to work out and discuss the ideas at the interface between architecture, engineering, hydrology and landscape design. Through their great support I had access to a scholarship ‚Clean Water China and South East Asia‘ financed by the ‚German Academic Exchange Service‘ (DAAD) which regularly brought me into contact with other non-European universities and gave me the opportunity to present my work and ideas regularly to a broad, interdisciplinary audience.

I would like to mention that the intensive technical support of the Department of Wastewater Technology of the Institute IWAR, especially by Prof. Dr. Martin Wagner, my second Supervisor, were the most important reasons to give me confidence and motivation to work constantly on this interdisciplinary topic - especially at those points were I felt lost inbetween engineering knowledge at the edge of membrane technologies, aeration and water treatment. Furthermore, long discussions with my former colleagues Dr. Susanne Bieker and Dr. Johanna Tolksdorf have accompanied the development of the idea in the beginning and their engineering perspective has sometimes slowed me down, but also motivated me much more often. I would also like to say thank you to my colleague Lucia Wright for long and important discussions at the beginning of this research and motivational-inspiring at the end.

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Thank you!

Simon

I hereby affirm that I have completed this dissertation without the help of third parties only with the stated sources and tools. All passages and /or informations from sources are marked as such. This work has not yet been submitted in the same or similar form to any local authority.

Darmstadt, 05. 12. 2017

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Abstract

Many Cities in South East Asia are struggling to manage their water demand by today, and many more will do so in future.
In addition to the intensification of the hydrological cycle, which is to be expected as a result of climate change, the mismanagement of the existing centralized infrastructure can also be seen as one reason, especially in the context of the Asian Megacities. Water shortages, dry riverbeds as well as heavy rainfall events during the monsoon season will lead to an increase pressure to the local water infrastructure, which affects water supply, reclamation of used waters, as well as storm water evacuation and flood protection issues.
This doctorate follows the idea of Water Sensitive Urban Design, by designing a *Water Resource Management System*, which recycles any available drop of water, on a localized scale, by creating a highly livable environment within an urban context. The interaction between Water reclamation technologies and nature based solutions, in the Context of Ecosystem services, are in the focus of this research, which aims to design a medium dense *zero Water City* in the urban context in Ha Noi, Vietnam.

Zusammenfassung

Viele Städte in Südostasien kämpfen bereits heutzutage darum, ihren Wasserbedarf zu decken und es wird erwartet, dass die Zahl in Zukunft weiter steigt.
Neben der durch den Klimawandel zu erwartenden Intensivierung des natürlichen Wasserkreislaufs, kann auch Missmanagement der bestehenden zentralen Infrastruktur als ein Grund gesehen werden, insbesondere im Kontext der asiatischen Megacities, die einen unendlichen Durst nach Ressourcen haben, der durch die konventionelle zentrale Infrastruktur nicht gedeckt werden kann.
Wasserknappheit, trockene Flussbetten sowie heftige Regenfälle während der Monsunzeit werden zu einem erhöhten Druck auf die lokale Wasserinfrastruktur führen, der sich auf die Wasserversorgung, die Rückgewinnung von benutztem Wasser, sowie auf die Regenwasserableitung und den Hochwasserschutz auswirkt.
Diese Doktorarbeit folgt der Idee des Water Sensitive Urban Design, indem sie ein Water Resource Management System entwirft, das alle verfügbaren Wasserströme auf einer lokalen Ebene recycelt und gleichzeitig eine lebenswerte Umgebung in einem städtischen Kontext kreiert. Die Wechselwirkung zwischen Wasseraufbereitungsverfahren und naturbasierten Lösungen im Kontext von Ökosystemdienstleistungen stehen im Mittelpunkt dieser Forschungsarbeit, deren Ergebnis ein Entwurf für eine zero Water city im urbanen Kontext von Ha Noi (Vietnam), ist.

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All figures, illustrations and pictures within this doctorate are, created or taken by the author, unless not stated otherwise

1.1. Content and relevance

In today's cities water appears as drinking water, used water, rainwater and runoff, as well as natural and artificial water bodies. These different water qualities play a key role in the urban metabolism and the management of the associated water streams especially depends on networked infrastructure which is mostly constructed underneath the streets to renders them invisible for the public.
The concept of networked infrastructure can be described as an out of sight out mind strategy (Hoyer 2011; Wong 2006), which significantly contributes to the public perception of our water bodies. It consists of several kilometres of pipes and sewers, which convey tap-, storm- and wastewater from one place to another, usually from and to the peri-urban areas, where the treatment facilities are normally located.

The need for water infrastructure evolved around 1800 and was mostly constructed after the industrialization, as an engineered answer to the poor hygienic situation in the cities, especially in dense urban areas. A harmful consequence was the outbreak of diseases like cholera and typhus fever (Gleick 2003; Domenech 2011), which were directly related to the contamination of the freshwater sources with human and animal faeces, due to a lack of a proper management in terms of the disposal of used waters and water supply.
Heavy rain events, which resulted in flooding, due to sealed surfaces, which preventing the occurring Stormwater Runoff to infiltrate into the ground, facilitated the outbreaks further.

In order to improve this situation, engineers started to collect domestically used waters and conveyed it out of sight, therefore out of mind. Through large scale pipes and sewers used water is carried to the city outskirts and got discharged to the rivers. At a later stage, treatment facilities were added to these centralized structures to reduce the impacts on the environment due to high organic and nutrient loads which were spilled to the nature. Following the idea of centralized infrastructure, water treatment facilities were also constructed outside the city at the same time. Those pump water to a distribution grid in order to serve the urban areas with piped 'Tapwater' all the time (see Dingle 2008; Domenech 2011).

Beside the used water, it was also necessary to handle Stormwater, which occured during heavy rain events on the urban surfaces. Therefore, the sewers were either designed to convey additional Stormwater, or a separated Stormwater sewer system was installed to provide flood protection

It can be seen as the beginning of large scale water infrastructure, that helped to improve the situation within the urban areas and in fact becomes the todays standard in most areas of the world.

The possibility to transport water to the city and to discharge the used and Stormwater beyond it made the urban areas more and more independent from the locally existing water sources. Ultimately cities were enabled to grow and develop. Today most of the urban areas in cities all over the world are equipped with such networked infrastructures. The technical layer of water infrastructure allows the use of water at any time and any place. The area above it is characterized by highly sealed surfaces, which are constructed to convey the Runoff as quick as possible to the sewer system, where it is transported out of the city.
The consequent movement of water and the concentrated discharge of used and Stormwater leads to an eutrophication of lakes and rivers, falling groundwater tables underneath the urban areas, loss of habitat, absorption of toxins by humans and a risk to the public health, disappearance of vegetation and wetlands and other change to the hydrological system (Nelson 2012).

The situation is challenging, particularly in the context of climate change. The capacity of the networked infrastructure to convey either additional to the domestic flows, or separated Stormwater is designed to fulfil its purposes for maximum amounts based on statistical studies of the past: 'designed storms' with a calculated probability and designed intensity. If the real Intensity of a rainfall event exceeds the designed one, the infrastructure fails, resulting in malfunction of the urban drainage, sewer overflows, water pollution and localised flooding (Winker et al. 2017, in press). In recent years, climate change and the expected intensification of the hydrological cycle mean an increase of heavy rain events consequently an increase of urban Runoff, which results to additional pressure to the urban infrastructure.

Sealed surfaces can even be as high as 90% in dense urban areas. (Schueler, 2000) Furthermore, they influence the natural cycle of precipitation, infiltration and evaporation, which leads to heat island effects by suppressing adiabatic cooling processes and absorbing the sunlight. This result in temperature differences up to 10 Centigrade (Kennedy et al. 2007), what significantly influence the urban climate. The surface temperature can differ up to 20 Centigrade between vegetated zones and sealed areas (WSBE2017:1352).

By evacuating the Runoff within urban areas, rain water cannot refill local aquifers, hence dropping groundwater tables can be observed underneath the cities and can let the cities ‘driing out’. This has a major influence on the water supply and the vegetation within the cities.

Conventional systems, also called ‘grey infrastructure’, remain inflexible as they cannot adapt to changing conditions. This is particular of interest in the context of climate change. It might even lead to an unmanageable Stormwater Runoff on sealed surfaces induced by heavy rain falls, which are supposed to happen more often and more intense.

It seems that the engineered driven construction of ‘grey infrastructure’ doesn’t treat water as a useful resource, which can bring benefits to the urban areas.

Today many cities are struggling to manage their water effectively and many more will fight in future due to increasing pressure of the climate change, population growth, energy shortages and fluctuating economic conditions (Howe 2012: 98).

The failing centralized infrastructure of cities along the East Asian coastline from Vietnam to China reached a dimension, where the influences on the environment are already visible: land subsidence, dry riverbeds, earthquakes, and highly polluted water bodies, as a consequence from the concentrated discharge of the used water flows, can be observed.

The construction of more ‘grey infrastructure’ automatically leads to more water use, and until today most of the flood protection for newly build urban areas relies on it (Nelson 2012). To meet the cities water demand, new water sources must be developed, which is expensive and energy intense due to more extensive treatment or pumping per delivered liter (Kenway & Lant 2012). For Australia, energy needed for it‘s centralized water grids is expected to double compared to 2006 in the next years (ibid).

As long as the water streams, particularly used- and Stormwater, are flushed away from the cities, the cities lose a valuable good. Without a major shift from the conventional approaches towards a more sustainable approach, the situation will get worse. The bigger the grey infrastructure is, the more vulnerable it becomes to external shocks and equipment failure (Nelson 2012). Beside the rainwater, which was an important source for water supply before the cities were equipped with infrastructure, the domestic used water must be seen as a valuable stream.
Shrinking the water cycles and the reuse of the domestic water flows can significantly reduce the external water demand (Shannon 2010; Nelson 2012), which conversely will reduce the pressure of the cities on the environment.

1.2. State of the art

Although the negative impacts to the environment were known from the beginning, infrastructure was constructed throughout most of the cities in the world. An awareness for 'sustainable' water infrastructure is already described for movements in Australia, which can be dated back to the 1960's (Roy et al. 2008). This understanding raised during the 1990's, due to political support for holistic sustainable approaches and a big Australian drought in the beginning of the 21st century, lead to public discussion about the role of Stormwater. In fact, these circumstances can be seen as a turning point, where the perception of Stormwater as a nuisance completely changed into a valuable good, resulting in major changes in the Stormwater management of Australia (ibid).
It can be seen as the starting point of Water Sensitive Urban Design (WSUD), which was first released by the local Australian Governments between 1994 and 1999. Later on, during the drought, the local guidelines were replaced by the National Water Initiative (NWI) in 2004, which was launched by the federal government in order to increase the efficiency. The NWI includes WSUD (Australian Gov. Guidelines).
WSUD considers any water stream within a city as an important resource with diverse impacts on the biodiversity, water, land, and the community. It takes further recreational and aesthetic issues into account.
It is designed to reduce Stormwater Runoff by infiltration or collection by closing the loop and bringing the water back to a nature oriented water cycle. Decentralized

systems are widely used to describe WSUD approaches. Although WSUD is common all over the world, several other terms are used to describe sustainable Stormwater management: Low Impact Development (LID), Sustainable Urban Drainage System (SUDS), Best Management Practices (BMP), Decentralised Rainwater Management (DRWM).

The influence of sustainable Stormwater Management can be found broadly, since nature oriented water cycles came into the focus of planning and design disciplines. Moreover, engineers are more and more oriented towards nature in order to learn how to reengineer products and processes (Shannon 2008) and to optimize treatment technologies on a decentralized level. The combination with nature based solutions lead to further synergies of design, economics and abundance of positive effects on the society (Nelson 2012).

Although WSUD considers all parts of the urban water cycle, Stormwater remains one of the most important issues (Melbourne Water 2005). When it comes to projects which were developed under these guidelines, domestic flows are often not considered (Barton and Argue 2007). However, the respect of all water flows can bring a lot of benefits to the urban residents, which is integrated part of this research.

Comparable to the described situation above, water scarcity and the sustainable management of Stormwater influence several research approaches all over the world. The Baltimore Charter for Sustainable Water Systems sets guidelines for a sustainable water management, which can be seen as a nature based approach and works with the nature and mimics their processes (Nelson et al. 2007). This approach uses ecosystem services to hybridize infrastructure in order to provide potable water and to prevent pollution before its discharge to the water bodies. The reduction of transportation energy for water and used water, as well as the recycling instead of discharge, nutrient recovery and the improvement of the natural environment are described within these guidelines (Nelson 2012; Nelson 2007).

All these approaches must be handled in an interdisciplinary context, where different disciplines are working together right from the beginning. The development of holistic projects includes not only water, it also affects other urban infrastructures, such as transportation, energy, the building itself and other urban environment (Nelson 2012).

Several projects can be found in the literature, for instance “eco – block” (Frank and Wurster 2008), which includes wind and wall cooling and community gardens. Also, “Ecohydrology”, that can be seen as an interdisciplinary approach to tackle hydrological and biological processes for a functioning ecosystem in order to enhance resiliency against human impacts and to strengthen the ecosystem services (Wagner et al. 2009; Wagner & Zalewski 2011). This approach is mainly researched for semi-natural large scale systems with the goal to improve the absorption capacity for anthropogenic influences and to increase the resiliency. Recently it was assumed, that this concept can be translated in it’s main parts to urban areas (Zalewski & Wagner 2005; Wagner & Zalewski 2009; Wagner et al. 2008) with the overall goal to reduce costs for infrastructure while enhancing the natural efficiency.

Furthermore, It should be noted that today it is possible to produce absolute nutrient free and clear water by using Nanofiltration and/or reverse osmosis. Engineered solutions can purify the water, probably even better than the nature itself (Simpson 2012). However, the public perception of those recycling systems is difficult, which might be a consequence of negative images and a lack of knowledge about water treatment systems. This lack of knowledge influences the perception and acceptance of those systems, since the reuse of water can easily evoke negative images (MacPherson 2012). Considering that the river Thames is receiving the effluent of 360 conventional treatment plants and serves 7 million people daily, or that each drop of water gets used 7 times by humans before it actual receives the water grid of London, it becomes clear that water reuse is a question of scale. The river Rhine serves 20 million people although it was one of the most polluted water bodies of Europe in the 1980’s. Those examples can be found everywhere in the world and render water reuse probably to „the best kept secret of engineers“ (MacPherson 2012; Simpson 2012).

Singapore´s “Newater” is a good example for water reuse in combination with a large scale of educational programme. By using Microfiltration, followed by reverse osmosis and UV Disinfection, Singapore is producing ‘Newater’ out of used water, which is collected with big sewers constructed underneath the whole country of Singapore. The

quality of 'Newater' consistently exceeds the requirements stipulated in the USEPA and WHO guidelines (for reference visit: pub.gov.sg)
Newater is safe to drink and due to its pure quality ready for industrial use, where it is distributed by a separated water grid. Additional Newater is pumped to the local water reservoirs, mixed with the reservoir water and finally becomes the basis for the Singaporean water supply. By 2010 Newater, which is produced in five water reclamation plants, contributed up to 30% to the countries water demand (Cain 2011) . Along with the development of Newater, Singapore launched a marketing and educational programme to inform every citizen about water treatment technologies and water issues on the one hand, and to introduce words like "Water Reclamation Plant" instead of 'Wastewater Treatment Plant' on the other hand.

A research conducted in Australia showed that the number of people accepting a direct potable reuse could be raised from 39% to 56% by sharing information about treatment technologies (Simpson 2012). Furthermore, A survey done by (Lohmann & Miliken, 1985)stated that the effects of a tour through a reclamation plant can significantly increase acceptance of water re-use projects.
Although Newater is indeed treated out of domestically used water it is widely accepted throughout the local citizens and shows the importance to actively involve all stakeholders (Studie KPMG).

This doctorate follows the idea of Singapore and goes one step further by avoiding the use of words which are directly related to the negative images of the watercycle. Used Water is considered more as a resource, which should be recalimed and is described as a natural element, that can support water supply, food security and biodiversity within the global water cycle than wastewater, which needs a proper treatment in a wastewatertreatment plant, where sludge is removed as an fertilizer or soil conditioner for agriculture. Although the sentences have the exact same meaning, the message is different: One story is about nature, the other one about technology. Although nature is the basis for any life and therefore for any technologic inventions, the technological approach is much more present.

1.3. The goal of this research

Many Countries in South East Asia are characterized by a lack of proper infrastructure and a poor Tapwater quality. Despite this Asian Megacities found along the coastline from China to Vietnam, rapidly develop and attract millions of people daily, who move from the countryside to the urban areas. This development can be seen everywhere in Asia, including Myanmar, Thailand, Vietnam and China. This doctorate analyses available water flows and sets them in relation to the water needs of residential communities, constructed in those countries. It considers domestically used water flows as well as natural flows. In contrast to the engineered driven approaches, where used water is cleaned through modern technologies and mostly used as service water for toilet flushing, this doctorate sets the focus on urban interactions between high tech solutions, nature, architecture and urban development.

The focus is a hybrid Water Resource Management System (WRMS), which is part of the urban design of a small to medium scale neighborhood, by closing the gap between inhabitants and technological solutions. This WRMS is in its perception comparable to an artificial storage lake, which should bring people closer to the water. Also, it is based on the assumption that people, who can touch, smell and see the 'reclaimed' water within a functioning biodiverse environment more easily accept the reuse of water.

The WRMS collects any available water drops from natural streams, such as rainwater, domestic streams, black – and greywater and provides service- and/or Tapwater for the residents throughout the year. The concept includes the collection of Stormwater during the monsoon season, which is stored in its structure to ensure water provision during the dry season. The inflows as well as the intake of Tapwater define the water volume of the storage lake throughout the year.

The holistic approach, which goes some steps further than 'WSUD' could be describes as 'Water Based Urban Design'. Water should not only become a valuable good, it should furthermore become part of the urban development.

This WRMS combines hydrological aspects of flood protection, biological aspects of the ecological system of water bodies and technological aspects of water reclamation with architectural and urban planning aspects, by using available synergies of these disciplines to design a zero Water City. A zero Water City is characterized by a high recycling rate and thus independent from the external water supply and discharge network.

Therefore, the idea of a Water Resource Management System (later in this doctorate WRMS) goes far beyond water recycling, when it is location specific applied to an urban community.
In general, it can be said that location specific concepts like this WRMS, can influence the urban development not only on a water level. Beside the significant reduction of the external water supply the urban community will need less energy to pump the water streams due to the smaller water cycles. The production of biogas and fertilizer or soil conditioner from the treatment processes allows the production of energy, which is nearly sufficient enough to reach autarky. The combination of eco-system services with ‚bio manipulation' technologies, like fish stockings or plant harvesting, provides options for aqua cultural purposes. Also, dried sludge from the reclamation technologies can be used as fertilizer for agricultural activities in the surroundings. It might become of further interest to recycle nutrients locally out of the streams. Especially Phosphorous which is expected to become more expensive in the future can create a feasible Economy (Mitchell et al. 2011) and ultimately can support this concept on a financial perspective. The developed Water Resource Management System requires professional and local labour which furthermore produces jobs within the urban context. The overall design can improve the air quality, support biodiversity, livelihood, recreation, architecture, landscape design, beauty and aesthetics, and increase property values (Nelson 2012) as well as influence the local climate by adiabatic cooling processes.

1.4. Research objectives

The WRMS aims to collect and store water within a local community in (sub-)tropical Asia. After the water is stored in a volume flexible reservoir, it is used as ‚potable water' for the residents.

The key of this interdisciplinary approach is to develop an integrated methodology, which in its core bases on a combination of modern water reclamation processes with eco-system services. The nature based solution within this WRMS is in its structure comparable to a natural lakesystem, that handles Stormwater Runoff, as well as the effluent of the water reclamation by using its ecosystem services.
The system has losses from natural processes, like evapotranspiration or infiltration and the efficiency of the technologies due to harvesting and maintaining activities.

The system combines water reclamation, flood protection and lake management into a holistic design. The goal is to reduce external water supply as high as possible which can reach up to 100%, if Tapwater use is intended.

It can be seen as a Design tool for Urban Development in (sub-)tropical Asia, which is written for planners. Its aim is to translate technical installation, processes and structures into architecture, to provide a guidebook for the development of those projects. It bases on the strategy of Water Sensitive Urban Design, but goes one step further, as water is not only considered as a valuable good, but as basic element in urban planning.

1.5. Research hypothesis

The combination of high tech solutions for water reclamation with a nature-based solution allows the development of a holistic concept for medium dense local community (plot ratio: 0.3 / Floorspace ratio 1.8) within an urban or peri-urban area, which is characterized by a highly liveable environment, while providing a resource-sufficient water supply.

1.6. Research questions

Therefore the following research questions are adressed within this research project:

How can design influence the lakes ecosystem?
How can the interfaces between Reclamation Technology and Nature-based solution be designed?
How can the combination of different domestic and natural water streams within a urban area be designed? How big is the influence of an artificial retention lake?
How can architectural design improve the natural Ecosystem in this context?
How can design support the development of such Communities?
How does technology and nature based solutions influence the design?

1.7. Methodology

The work is based on a comprehensive literature research and, due to the interdisciplinary nature of the subject, uses different literature resources and sources for the scientific-theoretical part. The initial hypotheses and research questions are mathematically balanced in an explorative application case and examined in a conceptual design.

The conceptual development of this system bases on three important steps:

1. Analyzing the processes which happens inside a natural or technical water body.
2. Identification of necessary active/passive treatment steps for the input to the lakes water and the anthropogenic pressure on the water system.
3. Analyzing the processes which are important in lake restauration and management strategies.

For the case of application, an urban area in northern Vietnam (Ha Noi) was selected, since the challenges arising from the climate zone and urbanisation are transferable to many locations in Southeast Asia, as well as a personal connection and local knowledge about the City.

This Dissertation contains eight Chapters, which can be organized into three parts, whereas each part can be seen separately from each other.

The first part gives an overview about the context (*Chapter 1 - 4)* and analyses the available natural and domestic water flows within a community, while evaluating appropriate reclamation technologies for domestic flows, especially in the context of the performance and their use in combination with ecosystem services. This includes the needed space, resiliency, and other influences to the inhabitants. Passive measures, which bases on the guidelines of Water Sensitive Urban Design, are set into the context of the natural flows induced by rainfall. By using Ecosystem services, flood protection is of further importance, to avoid damages to the system. The influences of heavy rainfall events were estimated by weather data and simplified models, like the SCS method. They were discussed with experts (*Chapter 5*).

After the basic overview and the available water streams were introduced, this doctorate describes a lake ecosystem in the (sub-)tropical zones of Asia and analyses anthropogenic influence on the one hand, while analysing the impacts of the seasonal weather changes in (*Chapter 6*) on the other hand. After the basic limnology is described, the Chapter ends with a description of technical measures to improve the ecological system of a tropical lake.

Chapter 7 can be seen as the second part of this doctorate, where urban and architectural translation of the physical, biological and chemical measures take place in the context of a subtropical lake with the goal to enhance their resiliency against the anthropogenic pressure. It bases on Literature reviews, Interviews and informative discussions about the design ideas. Most of the technical measures base on lake restauration strategies, which are applied to tropical lakes in order to protect their ecosystem or improve an already degraded system. Some measures are also applied in water treatment or polishing ponds. The conclusion of this Chapter is a catalogue of *Implications* and *Design Solutions*. While the implications can be seen as the structure of the WRMS, which have a strong influence on the design, the *Design Solutions* can be seen as a toolbox to improve the systems resiliency. They are adjustable and flexible.

Chapter 8 contains the conceptual design of a WRMS within an urban context. The results of the previous parts are set into the context of real weather data, water use, and architectural amenities. The package bases on calculations, balance sheets and statistical data, which is implemented and integrated into an adaptive Excel Calculation. The results of this conceptual approach and the *Design Solutions* are furthermore transferable in different urban, peri-urban and rural areas all over the world.

1.8. Scope and limitations

This research contains the conceptional idea of combining urban architecture and water. Although various projects are available, that have some similarities, they mostly focus on the sustainable use of Stormwater and flood protection or the reuse of domestic water flows for service water purposes. This, however, is mostly limited to toilet flushing or garden irrigation due to local regulations, which make it difficult to use recycled water within a community, as the local authorities follow inflexible law regulations.
This situation results in obstacles for real estate developers to create sustainable projects with a concern for urban infrastructure, as they either don't want to take any risk, or they are not allowed to do so. If the government would become part of these pilot projects, it probably would be easier to achieve.

This doctorate bases on the deep research of limnological restoration strategies, which are translated into architectural context to become part of the WRMS. Tropical lake limnology is limited in contrast to the limnology of the temperate climate zones: authors state that the processes which happen inside these systems are often rarely understood and described by the literature more as an art than a science (Padisak 2004; Sas 1989; Istvanovics & Herodek 1994; Padisak & Reynolds 1998).

Furthermore, It must be noted that projects which include the nature have to be developed in the regional context. This affects the weather, the temperature, the interactions with vegetation, nature and other complexities and requires a deep observation and analysis of the local environment, which cannot be answered within this doctorate.
On the other hand, ecosystem services are much more flexible than 'grey infrastructure' which allows designers and managers to adjust and optimize the system in case of malfunction. It is very likely, that the in *Chapter 7* described *Implications* in combination with *Design Solutions* can fullfill the idea of this doctorate in a realized project, even when the first attempts fail.

This doctorate contains engineered technologies for water reclamation, which are described in *Chapter 6* and used within the conceptual design of *Chapter 8*. As the technical available und theoretical usable water flows are in the context of the research project, the reclamation technologies focus on the treatment performance and the effectiveness, which is affected by occurring side products, such as sludges and process waters. A treatment or disposal of these products is not considered within this project, since this only has a minor influence on the overall design and several ways are available to manage these streams. The focus is set on the effluent quality and quantity. Anaerobic sludge digestion can be sued to produce biogas, or the dried sludge can be used as fertilizer or soil conditioner for agricultural activities.

1.9. Further outline

Chapter 2

A general overview about the water issues in South East Asia and China is given in the next Chapter to frame the topic into a larger scale. It is discussed if large scale infrastructure can be a sustainable solution. Examples from China are given, as this country answers to tackle their water issues with the construction of the biggest water diversion network in history. The Chapter ends with an introduction about mismanagement of existing water sources, which can lead to water scarcity areas, although the areas aren't characterized with real physical water stress. The idea of decentralised small scale solutions are set in contrast to the megastructures, which are described in the first section. The last paragraphs introduce potentials of combining architecture and water.

Chapter 3

Chapter 3 introduces basic limnology processes and gives the foundation for previously described Water Resource Management System. It introduces the role of aquatic plants and describes the interactions between Macrophytes, algae's, the internal and external nutrient loads, sedimentation processes and the biological growth, as well as the climatic conditions which have to be considered.

Chapter 4

This Chapter discusses the role of natural flows in the context of the development of a WRMS. Water Qualities, Quantities, Flood protection issues and Water Sensitive Urban Design are introduced, as well as passive treatment technologies, which can be applied to the natural flows.

Chapter 5

Chapter 5 discusses the domestic flows like black and greywater in terms of quantities and qualitites in the context of modern reclamation technologies: Rotating Biological Contactors (RBC) as a low-tech solution and Sequencing Batch Reactors (SBR) beside advanced Membrane Biological Reactors (MBR) as modern solutions.

Chapter 6

This Chapter sets the previously described lake limnology into a (sub-)tropical context, and introduce several lake restoration strategies which have been successfully applied in this climate zones, while considering the specific characteristics of the in *Chapter 4* and 5 described water flows.

Chapter 7

This Chapter analyses the natural environment of a subtropical lake and translates it to a Design. It furthermore analyses the structure of subtropical lakes, in the context of the occurring processes which improve or decrease the stability of their ecosystem. The empirical findings are translated into *Implications*, which can be seen as the basis for the WRMS. The Chapter ends with *Design Solutions*, an additional toolbox to improve the lake resiliency. This Design Solution are developed in the context of architectural amenities, while providing benefits for the ecosystem.

Chapter 8

The final Chapter uses the *Implications* of *Chapter 7* to develop a conceptual structure for the WRMS, in the context of real weather data of Hanoi. Additional to the Implication a WRMS is equipped with *Design Solutions* and calculated in the context of its resiliency and water supply for a medium dense urban area in Ha Noi.

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2.1. Water issues in South East Asia and China

In the last 50 year the world population has increased 2.5 times to 7 billion. At the same time, the worlds water demand increased 4 times. The United Nations Environment Programme Report of 2003 predicted that at this rate up to 7 billion people in sixty countries may possibly face water scarcity by the year 2050 (Richardson 2013). While 20% (ca. 1 billion) of the worlds population is living in China, only 7% of the worlds water sources can be found there.

Most of the freshwater sources in China and its southern neighbours depend on river basins which comes from the Himalayan Region (Lee 2013). The "roof-of-the world", the Tibetan plateau, plays the most important role in the water supply of this region. Its headwaters feed most of the great rivers of Asia: Yangze and Yellow river for China; The Mekong for Southeast Asia; The Irrawaddy and Salween for Myanmar; and Ganges, Indus, Brahmaputra for India and Pakistan.

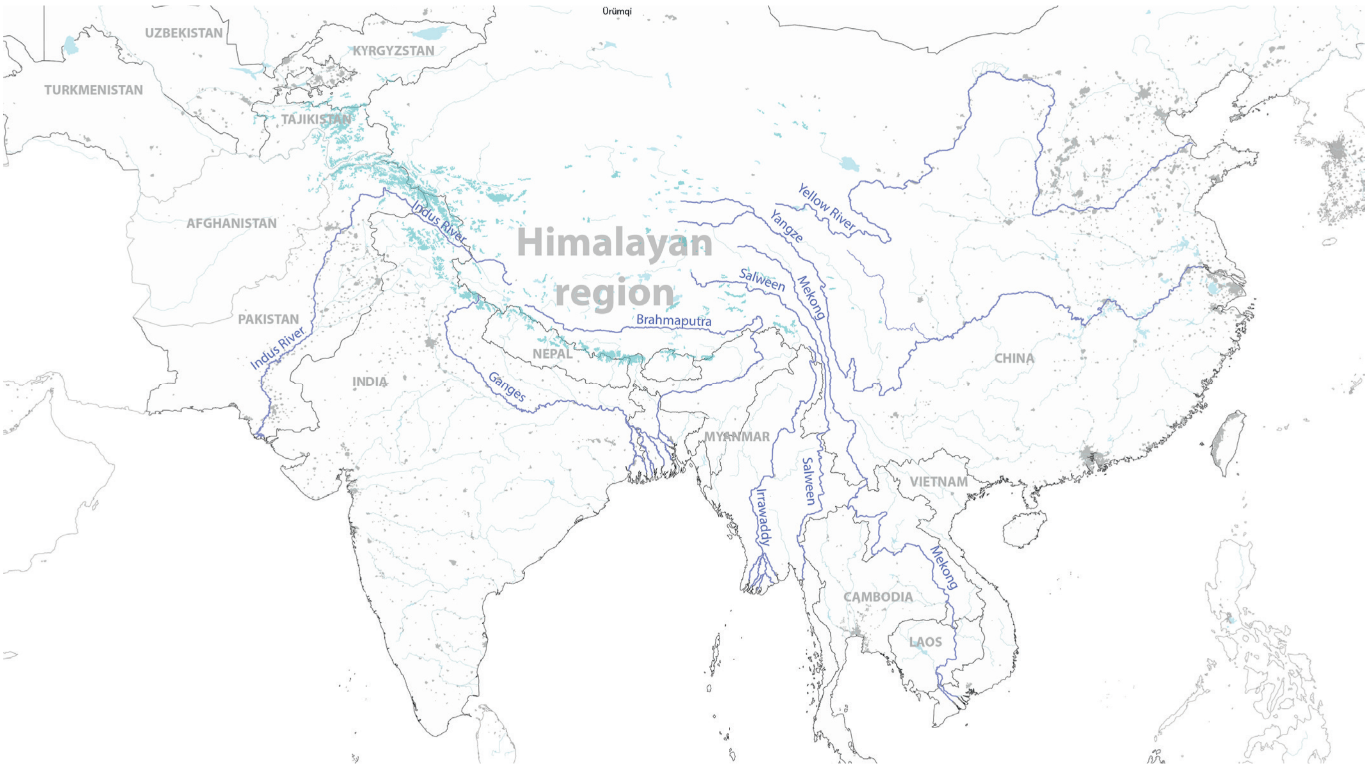

fig. 1:
About half the humanity receive their water from the himalayan region.

Chinas is highly depending on the river basin for its water supply. In 2005 the overall water withdrawal of China relied on surface water with 79,3 %. Groundwater 18,3%, seawater desalination 0.002%, and the direct use of treated wastewater 2.4%.

About 90% of the water withdrawals bases on surface water, i.e. the rivers. In the southern parts of China, up to 90% of its water withdrawals are coming from surface water, whereas in the northern provinces of China, the main source is groundwater.
The intense use of groundwater in North China, has caused a lowering of the water tables: for example the sustainable annual withdrawal amount of groundwater in the area of the Hai river basin is estimated as 17.3 km^3. The infact withdrawal is 26.1 km^3. which means an over extraction of 8.8 km^3 (Xie 2009). As a result the deep groundwater tables have dropped up to 90 m, the shallow ones, up to 50 m . In the last decades, the groundwater tables in Beijing have dropped 100-300 m (ibid). This means, that the use of groundwater in the arid northern areas, is getting more and more difficult. The average annual renewable water resources per capita is 2.079 m^3/a, which renders this country regarding to the worlds average of an annual 6.225 m^3/capita water scarce (AQUASTAT 2011: 4) - but it should be noticed, that wide variations could be found over the absolute waters in the country: 500 m^3/a, in the north – 2500 km^3/a in the southwest. (ibid). That means in the context of the urban dense, up to annually 25.000 m^3/capita in the southwest.

Even more than China, the southern neighbour Vietnam got more than 98% of its water withdrawal from surface water, which mainly depends on the Mekong river basin, and the Red River basin. Almost 60% of this countries water resources are generated outside this country, in the upstream neighbours of e.g. the Mekong, which makes this country susceptible for the water management of its neighbours. As the whole Country of Vietnam faces the tropical, or subtropical climate conditions, it is affected by the monsoon: 70-75% of the surface Runoff is generated within three or four months. Although Vietnam has an estimated annual renewable freshwater source of 10.174 m^3/capita (Frenkel 2013), it faces water shortages during the dry seasons. In the urban areas of VN, like Hanoi or Ho-Chi Minh City the groundwater is mainly used for the water supply. But this is technically complicated, as it is natural polluted with nitrogen and heavy metals, which are poison (Berg et al. 2001).

fig. 2:
60% of Vietnams Tapwater relies on rivers, which origin in foreign countries.

Most of the rivers in South East Asia, starting their journey to the sea in the Himalayan region. Therefore this region is responsible for the water supply of half of the humanity (Lee 2013). Besides being the primary source of water, the rivers are the basis for agricultural field irrigation, fishery and, especially in the last decades, also contribute to the energy production due to hydropower. After analyzing the data of more than 600 Chinese weather stations, it was found that the Tibetan glaciers, which are at the end responsible for the rivers shrinking 7% each year (Reuters 2006). The melting glaciers will affect the whole area. It is estimated that, regarding the increasing population of China, the Chinese internal freshwater resources per person amounted to just 1890 cubic meters per year by 2033 (Frenkel 2013), about one third of the world average and less than half the East Asia and Pacific average.

As in Vietnam, water scarcity affects Asian countries, especially during the dry seasons. The local farmers have adapted agricultural cultivation techniques for the dry and rainy seasons. However, although water scarcity is not a problem of the modern times, it increased in the last decades dramatically. The water surplus area of the Himalayan region has become a key role in Asia in the last decades and in regard to water sources. To ensure the water supply for the future and to reduce the impact of the global warming several projects in different scales can be found.

A couple of big scale projects tries to conquer the nature, with technically engineered solutions. Hydrologists and engineers are thinking about shifting, rebuilding or canalizing whole rivers to redirect their waters from the water surplus regions to the scarce dry areas, or to dam the rivers and store the water in large reservoirs. As most of the rivers of the Himalayan region have transboundary basins, it is clear that those projects, when planned on a national level, could cause a lot of stress between the affected countries. A look in the past, to the Altai mountain region, with special attention to the Irtysh River, already illustrated since the 1980's the impacts of national projects on transboundary river basins. Although this river is not directly feed from the Himalayan region, it is a good example to describe the situation:

In 1987 China started to intake water from Irtysh river – *the 5th big river in the world (total length 4.410 km), which starts in the Altai mountain and runs through China for 525 km until it reaches the border of Kazakhstan* – to support the refill of the Lake Ulungur, as its level had fallen dramatically due to the use of its main effluent for agricultural irrigation (Petr 1999). Later, the water scarce western regions of China were planned for development in the frame of the 10th Chinese five-year plan (2001-2005).

Therefore, the Chinese government started in 1998 to build a 22 meter-wide, and 300 kilometer-long canal, which is connected to the Irtysh River, called the Irtysh Karamai-Urumqi Canal. Since this year, at least 15% of the river´s freshwater is used for the irrigation of the depopulated areas in Western China. The estimated annual intake ranges from 10% of the rivers water, to 50% annually (Sieverts 2001).

As the Irtysh River provides drinking water for the capital of Kazakhstan, Astana, as well as three other Kazakh cities (Lee 2013) this project affects several million people, which relies on this water source. However, the diversion of the Irtysh is not a Chinese issue, as Kazakhstan has its own Canal, which got built by the Soviet Union from 1962 to 1974, and in fact 13 years earlier than the Chinese started their intake. The Kazakhstan Irtysh-Karaganda Canal takes water from the river to bring it to an industrial area in the arid north and to support on its 451 kilometer-long way a couple of water reservoirs. The canal also supports the water supply for Astana since 2013. This canal was built during the Soviet regime so the affection to other countries was limited, or politically accepted. Today the river crosses the border to Russia.

Officially in 2001. the Chinese government launched another, much bigger water diversion project: „South-to-North Water Diversion Project“ (SNWDP) (Wirsing et al. 2013). The Chinese north has only 14 percent of available freshwater sources, but its south has 86% (Shalizi 2006) The Chinese engineers want to pump 44.8 million cubic meters of freshwater annually from the south to the dry northern parts of China by 2050. This project would become, if completed like planned, probably the biggest infrastructure project of the world: a mix of dams, reservoirs, pipelines, aqueducts, tunnels and canals. The base of this project consists of three routes: the eastern route (Yangshou to Tianjin), the central route (Nanying to Beijing), and a western route, which should bring water from the Himalaya to the northern parts, by using mainly the yellow river. The construction of the western route did not start yet, because this route is the most complicated topographically (Wirsing et al. 2013). The construction of the two others are either partly finished or still under construction, as they started in 2003. Since 2014 Beijing receives water from the central route (Guardian 2014)

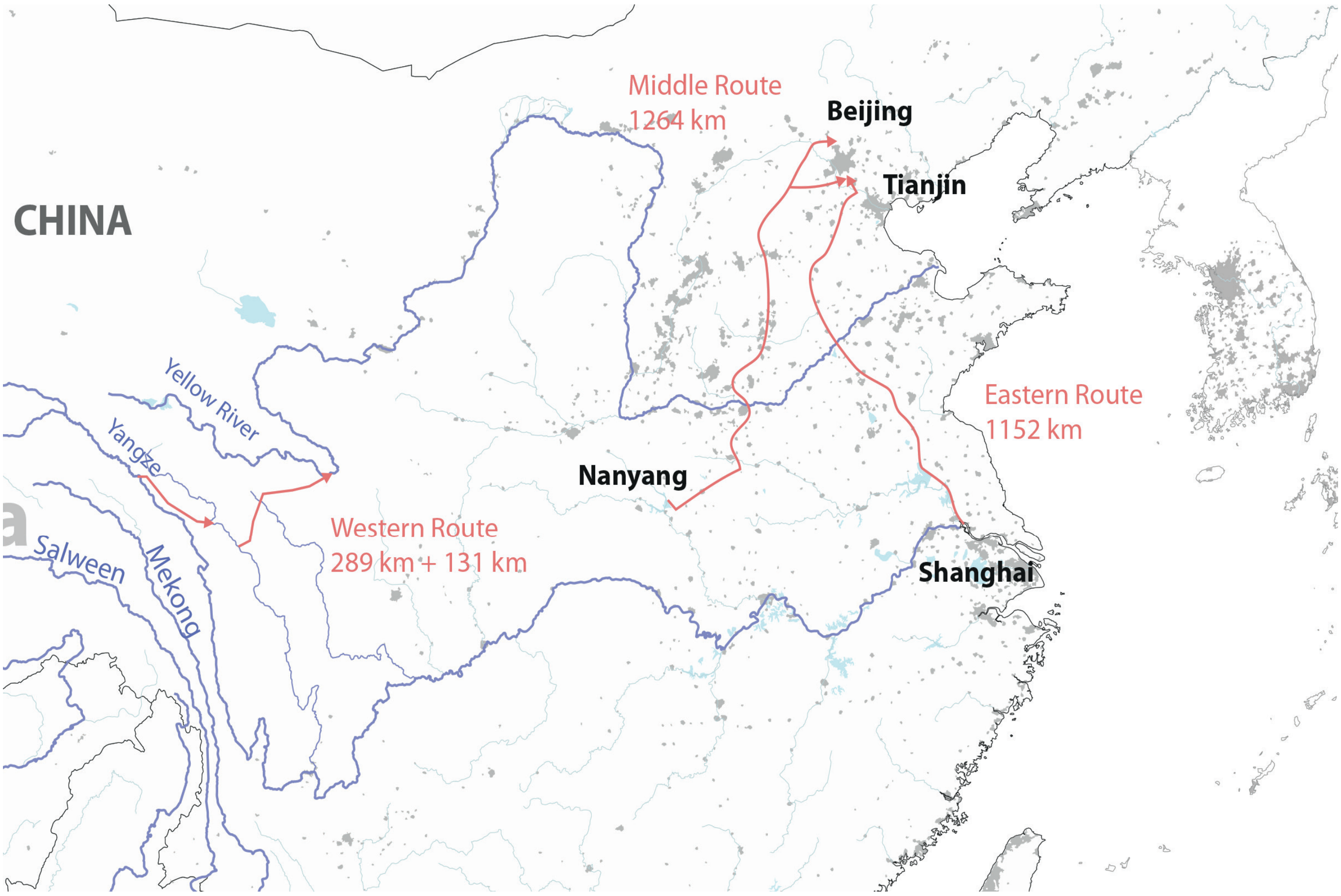

fig. 3:
The chinese water diversion project.

A comparable situation could be found in India, where the north and northeast areas have water surplus, due to the big rivers, which were responsibly for 61% of the countries freshwater, while large areas in the south and west, are scarce of water (Wirsing et al. 2013). Like the SNWDP, India launched its own river linking program: The „Indian Rivers Inter-link“. This project is split into three main parts: the Himalayan component, with 14 river links, the peninsula component with 16 links, and the interstate project with includes 36 river links. The objectives of this project are, beside the water transportation, an improved flood-control, water storage, agricultural irrigation and the production of hydroelectricity (Mirza 2008). On October 2015 the first Link got completed, 33 years after this project was launched. If this project got ever finished in the planned version is not clear. (Wirsing et al. 2013).

Scientists, government authorities and international diplomats claim that the risk of wars fought over water is increasing (Lee 2013). Reasons for this could be illustrated through cases like the Bramhaputra basin in the border region between China and India. However, a research conducted by the Oregon State University showed, on the other hand, that water is more important than war, as the rate of cooperation overwhelmed the conflicts (vgl. Wolf 1998). The Mekong Committee, established by Cambodia, Laos, Thailand and Vietnam in 1957, to manage information exchange and the cooperation between the affected countries survived the Vietnam War, although Thailand was a US-ally against communist regimes in Indochina. The Mekong Committee was forerunner of the today's Mekong River Commission, yet China was never, and is still not a member of this commission (Lee 2013), although dialogues between the countries have commenced.

Although these cases, show that water issues should be considered at a transnational level, architects, urban planners and engineers can do a lot to optimize the infrastructure on a national level, as well as in small- or medium-sized projects.

Not every country, which faces waterscarce, has the opportunity to link or rebuild rivers. Hong Kong and Singapore, had those problems since long ago.
Beginning in the 1950 Hong Kong started to use seawater for toilet flushing, to save freshwater, which more or less was restricted. In the 1960 during the drought seasons, which were forced by the political situation, Hong Kong introduced the water restriction policy. Due to that policy water was sometimes only available on 4 hours a day. To lower the dependence of its water supply to China, the first official buildings used seawater for toilet flushing. Today a big seawater grid can be found inside the streets of Hong Kong, which serves nearly 90% of all households in Hong Kong. With this project, Hong Kong can save 20% of it's freshwater. Today Hong Kong is since 1998 a Special Administrative Region (SAR) of the People's Republic of China (PRC), therefore the political frame, regarding its water supply changed.

As Hong Kong's water supply was fully addicted to China, the water supply of Singapore was fully dependant on Malaysia. To lower the dependence to this relationship, Singapore started in 1974 to recycle used water. As this procedure, which bases on adavanced membrane technologies, and reverse osmosis, was too expensive, the pilot plant was closed in 1975. In 1998 the Public Uitlity Board of Singapore (PUB) and the Ministry of the Environment and Water Ressources (MEWR) started the Singapore Water Reclamation Study. In this frame it was determinded if either seawater desalination, or water recycling could be a viable source to reduce the water import from Malaysia, which was a source of friction between both countries. The first Newater plant started its operation in 2002. Today Singapore uses four Newater plants, to produce clear water for mostly industrial processes. Newater can be also pumped in the water reservoirs during the dry seasons to support the Singapore water supply. It meets up to 40% of the national water needs. Regarding to PUB, Singapore plans to increase this number to 55% by 2060. The quality exceeds the requirements set by USEPA and WHO and is cleaner than the other sources. (PUB 2018)

2.2. Mismanagement of the watersources

As seen in the previous parts, the Asian water situation is complex and could become more complex in the frame of the climate change and the continuously increasing world's population. Rockström (2003) identifies four main reasons for the pressure on the worlds water issues: At first the anthropogenic pressure on the finite freshwater sources increases arithmetically as a result of the basic human water requirements; second the direct water withdrawal increases exponentially with the development of urban and indutrial zones. The withdrawal had increased six times, while the world's population only tripled (industrial production increased 12 times); third the humans destroy their water sources. Freshwater sources in the developed countries are polluted by industrial waste, which is particular the case in South East Asia. The groundwater in industrialized countries is not potable, due to nitrogen leaching from over intensive agriculture; fourth human kind is affecting the source of water, the intricate weather system governing the hydrological cycle of the earth, due to climate change or land degradation

According to Rockström (2003) several water assessment and research projects, which mainly focused on the availability of freshwater (country, regional or global level), estimates that 30 percent of the worlds population will be directly affected by water scarcity in the next generation.

Regarding to those studies, an estimated amount of freshwater of 12.500 km^3 could be globally withdrawn each year out of an available average of 38.000 km^3 (Postel et. al 1996), which corresponds to 11% of the annually precipitation over land surfaces. In this context, an annual actual estimated freshwater withdrawal of 3970 km^3 (Shiklomanov 2000), appears to be less compared to the total possible amount. These 3790 km^3 are used to cover water needs in industry (23%), household and municipal use (8%), and the agricultural use (69%). Additionally a great amount of this withdrawn water, is getting back to the hydrological network, if the urban drainage works effectively (Shiklomanov 2000).
The global per capita average to cover this needs would be about 190 m^3 per year (Rockström 2003). This means, regarding to a population of 7 billion people, that the humankind would need 1330 km^3 each year, or only 9,4% of the globally renewable available freshwater.

These numbers show clearly, that water scarcity is on a global scale far away from real, physical water stress. The assumption that the main problem of those countries is often mismanagement of the water bodies is likely. A special case in Asia, is the presence of dense urban space, which leads often in the frame of the growing population, and the growing economy, to Megacities along the east coastline in China. Megacities have a high demand on infrastructure, to serve its needs. In the case of water supply they affects the whole area in their surrounding. The idea that mismanagement of the available water sources is most responsible for the water stress especially in those areas, instead of real, physical water stress has been recognized (e.g. Tortajada 2008). Chinas Capital Beijing for example, had severe three water shortages since 1960. Since that year the groundwater of Beijing was overextracted up to 6 billion m^3. which causes land subsidence and degradation of water quality. Today most rivers in the vicinity of Beijing are dry for a large part of the year and Beijing major river, Yongding, even for decades. Regarding the water diversion project, Beijing might be a good case, for a city which is hardly dependant on big scale water shifting and therefore tries to conquer the nature through engineered technology (Li et al. 2015).

Mismanagement includes often political, financial or cultural issues, on a local, regional or national level. In Manila on the Philippine Islands, as an example for South East Asia, it may not be realistic to introduce a regional trunk water supply system, like in other Megacities. The reasons could be described due to a lack of financial resources, but mostly because of the local market and institutions. Pumping the available groundwater or managing the water supply from a private market is cheaper than piped water (li et al. 2015), and therefore the most common way.

A Mismanagement also includes the pollution of rivers and lakes, due to discharge of industrial, non-treated used water and waste, which happened and still happens for example in Vietnam, and lead to environmental impacts. The poisonous blue-green algae outbreak in the Tai Lake and Yangtze River in the area of Shanghai (Engel et Al 2011), are caused by too much nutrients in the water, which mainly came from industrial discharges, although the availability of freshwater is abundant in that area (Li et al. 2010)

It also includes overextraction of groundwater, which can cause rapidly fallen groundwater levels, like it happens in Beijing or Ha Noi. Those negative impacts on the groundwater can furthermore cause a couple of impacts on the environment. Beside land subsidence, dry rivers, or saltwater intrusion near the coastal areas, it can lead to an ecological collapse like the case of Aral lake, in Kazakhstan which dried out by 2014 in consequence of the massive mismanagement of its inflows.

Water stress can also come from illegal connections, or broken pipes, which causes water losses. In some areas the water losses are up to 40% (Tortajada 2009), which makes the reliable operation of the water supply impossible.

Mismanagement is often one of the main reasons of water scarcity. Most areas could have enough water, when the accessible sources would be protected and used in a sustainable way. However, the natural distribution of the freshwater sources on the planet varies widely. A couple of areas can be found, especially in Asia, Middle East and Africa, which are facing real, physical water stress. Regarding to (Shiklomanov 2000) the African Continent has an overall freshwater amount of 5720 m^3 per capita per year, which is basically enough for the inhabitants, and more than the average Asian capita per year with 3920 m^3. However, this water can be mainly found in central and southern areas of Africa, while the northern parts only provide 0.71 m^3 per capita per year and 95% of this water are already withdrawn (ibid). Like the riverlinking projects of China and India, a comparable project can be found in Africa, as Lybia tries to reduce the water scarce in its arid south.

Wether or not mismanagement of the earth's urban water source is the biggest problem, a sustainable ecologic urban planning is the basis of our future cities. Li (2015) claims that water is a contextual problem, 'that has to be managed in its geographical setting'.

2.3. The role of centralized systems

Before engineers started to develop concepts for shifting water hundreds of kilometres through whole countries, they thought about how to do this within the cities boundaries, as the natural local ressources where sufficient to support the city.
Most of the water supply systems which can be found in the urban areas are central conceptions, which bases on the physical separation of freshwater supply and wastewater treatment, as well as the separation of the place where the wastewater occurs, and the place where it got treated. (Bieker 2009).
Those concepts were implemented in the European cities by the 19th century, to improve to sanitation and health situation in the cities, which were characterized by poor hygienic environments, which leads to the outbreak of diseases as cholera and typhus fever (Gleick 2003; Domenech 2011) . One of the biggest concerns was the contamination of the freshwater supply, which mostly based on local water including, surface, ground and Tapwater (Geels 2005), with human and animal faeces.

To improve this situation it was necessary to implement a piped water supply, as well as a sewer network, to evacuate the contaminated faeces from the city (Dingle 2008; Domenech 2011; vgl. Bieker 2009). In Consequence the cities were equipped with big sewer networks, and water pipes, to bring the different waters from one point to

another, usually to the peri-urban areas, where the infrastructure treatment facilities are located.
The Distribution and Transport of the water are the most expensive part. Beside the energy, which is necessary to move and transport the wastewater through the sewers, a big amount of freshwater is needed for the continuous flow. The bigger and older the sewer network is, the bigger is the maintenance effort, resp. the cost.

The advantages for a central Wastewater treatment system, beside the separation, are the reduced possible impacts on the environment/neighbourhood, like noise and odour. The land costs, are normally cheaper in the peri-urban area, than inside the city and this will lead to cheaper operational costs (Bieker 2009). Centralized systems are furthermore mostly operated by governmental institutions, which guarantees a professional operation, which regarding to safety, malfunction or disastroeus events could be an advantage. In the last years, however, water systems has increasingly privatized , implying therefore changes of the water flow or the control over it (Gandy 2004).

2.3.1 The centralized approch in the context of Megacities

In a lot of Countries in the world we are facing, especially in recent times, an interesting urban situation: the existence and development of Megacities, especially along the eastern coastline of China.
Megacities have an extremely high demand on centralized infrastructure, to serve its needs and an extreme thurst on ressources, which affects the whole area around the City. The centralized infrastructure on the one hand need to exploit and supply enough water for the City and discharge the used one on the other. This creates an enormous pressure to the environment, as the population and industry dense in the surrounding areas of megacities can't be fed sustainable, as the urban density is too high.
The water supply often relies on groundwater which is stored in the aquifer. As long as the water extraction rate matches the recharge rate of the aquifer, we can consider this as sustainable. Megacities need more water, than the natural system can provide. To support the Cities economy and secure the water supply, the aquifers often got overextracted without any concerns for the environment.
Chinas Capital Beijing for example, had severe three water shortages since 1960. Since this time, the local water supply Companies, started to pump the groundwater in

unsustainable amounts. The groundwater of Beijing was overextracted up to 6 billion m^3. which causes land subsidence and degradation of water quality. Today most rivers in the vicinity of Beijing are dry for a large part of the year and Beijing major river, Yongding, even for decades. Regarding the above introduced chinese water diversion project, Beijing is be a good case, for a city which is hardly dependant on big scale water shifting and therefore tries to conquer the nature through engineered technology (Li et al. 2015).

China in general is highly dependant on big, large scale, centralized infrastructure, to meet its demands in water and energy. It also shows, a strong the correlation between urban development and bigger, large scale infrastructure, which leads to an unmanageable situation in the terms of sustainable resource management: The City needs energy and water to grow, and puts more and more pressure to the surroundings to get it – despite the consequences.
Those fast growing urban areas, does affect every kind of infrastructure: Water, Energy and Wastewater.
A simplified illustration of the altering processes is given in with the follwing illustrations:

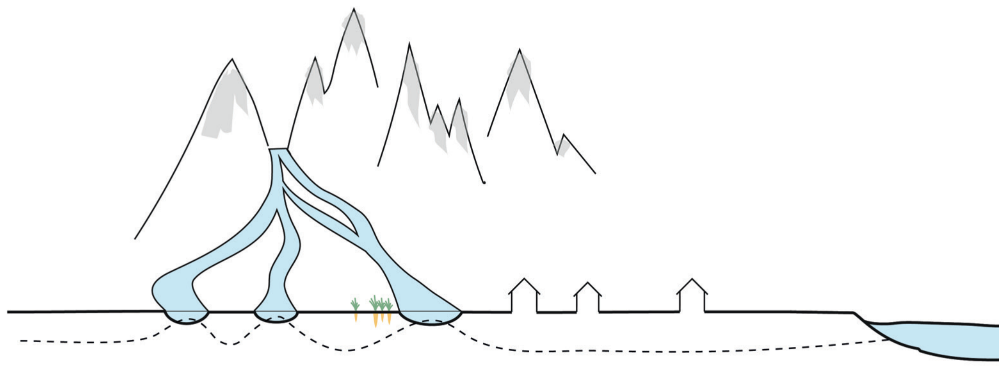

fig. 4:
First villages without infrastructure. Natural water bodies were important for the development of the village.

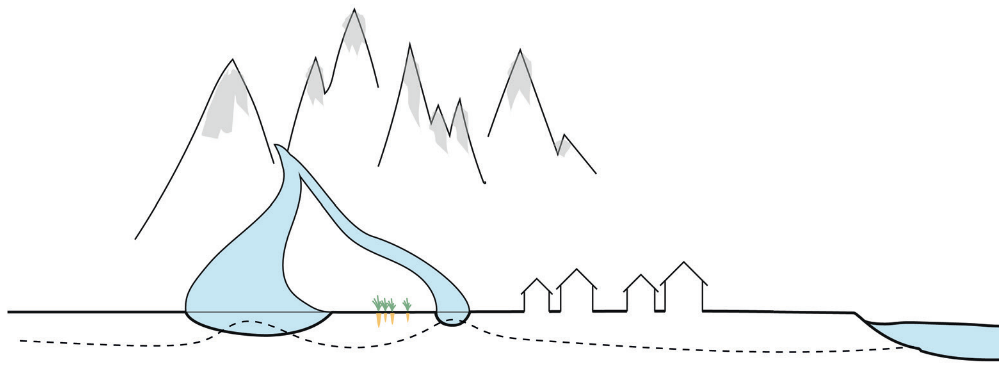

fig. 5:
With the growing village, the waterbodies were straightened.

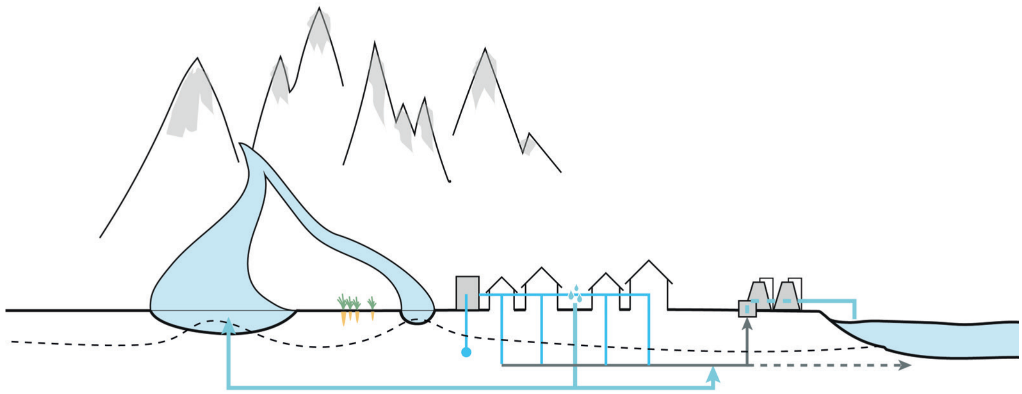

fig. 6:
First infrastructure
was installed.

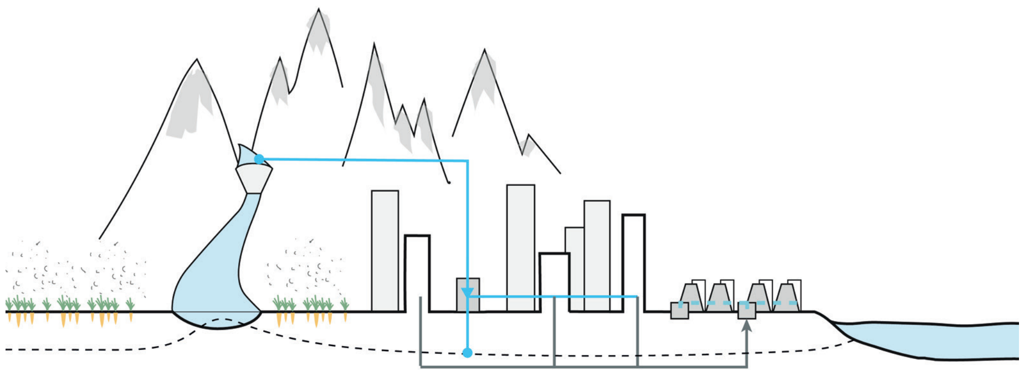

fig. 7:
The City became independet
from local water sources.

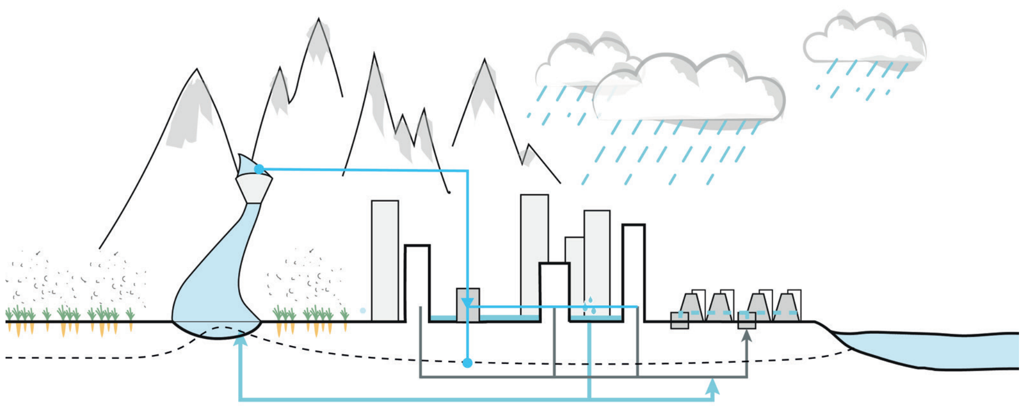

fig. 8:
bigger Cities, need more
infra- structure, more
water and more food.

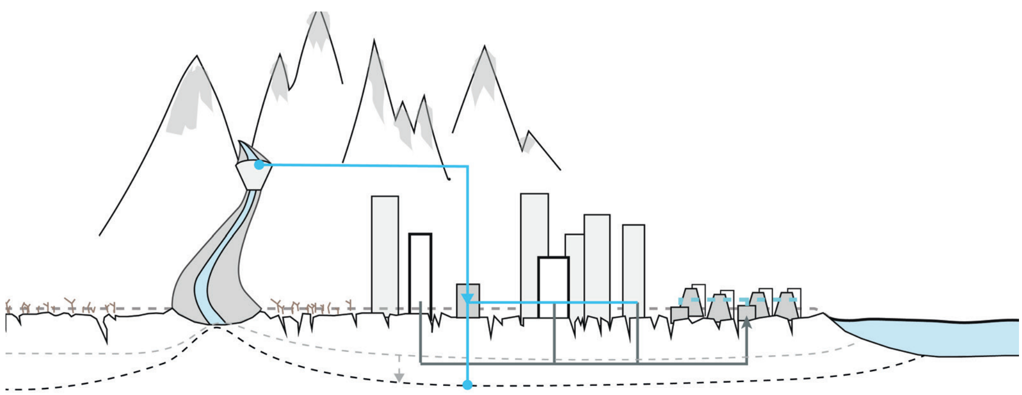

fig. 9:
The infrastructure can't
handle the city, as the thirst
to water is too high. the
additional con sequent eva-
cuation of Stormwater leads
to dropping groundwater
tables and land subsidences.

2.3.2 Still the right answer?

According to Bellefontaine (1999) the highest cost in Western centralized wastewater systems could be identified in the sewer network, for the capital investment (38%) and operational costs (16%). The situation in the water supply is similar. According to Trifunovic (2006) the total costs of the Netherlands water supply system, were assessed in 1988 to a total value of 5.000.000.000 USD. 63% of this costs are responsible for the water transport, distribution, including service connections; only 32% for treatment and extraction. Furthermore from the annual estimated ongoing investments of the Netherlands, which are estimated to 500.000.000. 48% are dedicated to Distribution.

Today, centralized projects are characterized by distribution losses, which can either occur due to broken or old pipes of the sewer, or broken pipes and illegal connections for the water supply. Especially the water losses in the water supply (Non-revenue water), could influence the investment plans, as they are in some areas up to 60%.

Regarding the wastewater treatment, the dilution of the wastewater, which mainly occurs due to rainwater in mixed sewers, as well as the use of drinking water for toilet flushing, could lead to a less effective treatment, due to an artificial raise of the treated water amount. Furthermore the physical separation of doemtic grey- and blackwater streams, which is not common in centralized projects, could influence the treatment effectiveness as well (Bieker 2009; Otterpohl 2001; Wilderer 2007; Cornel et al. 2004).

2.4. Breaking the cycles, working with the nature

Several authors aknowledge the advantages for centralized projects, regarding e.g. a reliable water supply, flood control, food production and hydroenergy use (vgl. Gleick 2003; Gleick et al. 2013). In industrial countries, the centralized sytems might work well, as all the water sources has been developed, and the treatment works effective. However, within the last years, especially in the frame of the climate change and the water crisis, increasing concerns about the environmental impacts and social costs of large-scale centralized projects are brought into the debate on water policy (McCully 2001; Sauri and del Moral 2001). Instead of large-scale infrastructure, which serves several billion people, the introduction of small-scale infrastructure as well the shrinking and fragmention of the distribution cycles is increasingly recognized as an alternative to the centralized end-of-pipe approaches (Domenech, 2011), which doesn't allow the physical sustainable closure of the watercycle (vgl. Bieker 2009) and therefore the reuse of nutrients, which occur in the wastewater.

A more localized water management, could work better with its local context, and prevent mismanagement, while decreasing the vulnerability in case of desasters. The Resiliency of large scale, centralized structures especially in the context of water supply as critical infrastructure is more and more discussed (Rudolph-Cleff 2015) and localised smaller water cycles could lead to more flexibility (Bieker 2009).

In the last years water managers and planners are changing their perspective, as they try to understand how to best meet the human water needs. The unquestioned construction of centralized waterinfrastructure, is not longer in the focus of planning processes. Instead, the understanding of the true economic, social and environmental costs of that infrastructure" (Gleick 2003a) are getting more and more attention. This change also means that local sources like rain- or Stormwater, aswell as already used water with its different black or greywater characteristics (Semizentral) are considered as usable watersources, especially in nowadays, where the overall sustainability of cities becomes more important. In the frame of the Agenda 21, at least 45 spanish cities by 2011 approved regulations for the local use of those waters, including the reuse of swimming-pool water Domenech (2011). As this dissertation tries to figure out the possibilities and potentials which can be found in closing the water cycles, rainwater, greywater and blackwater are in the focus of localized water sources, including the possibilities the store it from the monsoon season, to the dry season.

2.5. Conclusion: Working with the nature - living with the water

Since the beginning of the earth, billion years ago, water is the basis for any life on earth it appears e.g. as rivers, lakes, streams, creeks, and together with the ocean it forms the most important part of the hydrological cycle and the world's environment. Water usually flows as river from the mountain areas to the ocean, where it evaporates by the sun, condensate as clouds and come back to the mountain areas as rain. Part of this rainwater receives the rivers directly via Runoff, other parts infiltrate to the ground, which contributes the groundwater discharge, and therefore the spring of a river. The natural water bodies, in partulcar lakes, are an important part of the biological setting of the earth. They are habitat for birds, fishes and other species, which uses the lake for grazing or breeding. The Lakes native residents helps to bring the Lake ecological system into a balance with its environment. Furthermore it is recognized that all life on earth started at or near the lakes (Marthur & da Cunha 2014).

Management of the earth's water source is mostly an engineered driven discipline, following the western idea of centralized networks, although it affects everybody in any place in any environment and in any culture. The above described parts, explains the situation from a technical perspective and how these approaches lead to a wide range of negative impacts to the environment. The basis for this research is the addition of an architectural, and natural layer to this technical perspective, which contributes to the holistic perception.

Living with the water was often the basis for the ancient cultures. It can be found everywhere, regardless if we are looking at the Roman Empire, or the settler in the subsaharian continent, or even today in the Asians Megacities. The shore between sea and sand is the area were many settelements have their beginning despite the fluctuating waters (Leatherbarrow 2014). However, the presence of these water bodies is essential for the people. In fact, water was part of the urban settlement, visible for everyone, and important source for agricultural activities, fish production, and water supply, until it was hidden by engineers and infrastructure.

Growing Cities attracted more people and needed more land, which was captured by the urban settlements Land Use changes happened and the cities were often characterized by marshes and wetlands, which attracted mosquitos, and faced more and more hygienic aspects, Lakes and rivers were polluted and the seasonal floodings causes damages to the cities, and created unpleasable hygienic situations. The construction of infrastructure was meant to collect the polluted Runoff from the City and conveye it to the rivers. Lakes and rivers became in the further Development more and more polluted as they became part of the infrastructure, which was constructed to remove the Cities garbage und used waters. Step by step this development was extended with a piped water supply.

The sewers and watergrids allowed the City to develop completely independently from the available waterbodies, which had a high impact on the land use and to the hydrological system. With the growing Population and the rapidly growing urbanization, especially in the recent decades, the water bodies were more important than ever, to support the urban development. Engineers constructed dams along rivers, which created artificial lakes, for flood protection reasons and water supply, without concerns for the environment.

Later they tend to divide rivers, to serve artificially build canals, for irrigation purposes in arid zones, to increase the food production in areas, where water is not available naturally. In recent years, hydropower and flood protection issues became the driving force for engineers, to reshape the water bodies in their size, their form to serve the human needs all over the world. With a lot of steel and concrete, to conquer the nature as an important part of modern Society, with less or no regards for its natural environmemt. Today many Cities struggle with their waters and the consequences are visible as degradation in the ecological system, which are not directly. When Chinas Capital Beijing sinks 30 m due to groundwater over extraction, which is induced to protect the economical Development of the area, it is not really visible for the individual resident, but affects the whole area.

It might be in our Genes, that we are attracted by or to water, despite the danger who comes with it, in any scale of civilization. In africa, it could be noted that water is an important product for clay production, but heavy rain destroys Clay-buildings. On the Phillipines, where people don’t use clay buildings, heavy rain events causes a lot of human lifes, due to a lack of infrastructure and protection facilities and in the western world, heavy rain events which can not be handled by the infrastructure causes damage mostly to the Cities (Mathur & da Cunha 2014).

Grey infrastructure became in recent decades an important element of our daily life, and without it, the daily life of our cities would be much more diverse. The development of grey infrastructure protects our Cities from flashfloods, and allowed especially in the recent decade, several landuse changes, which were mostly driven by economic parameters. Today the scale of infrastructure often reaches dimensions which are too big, to be considered as sustainable and with a look at the chinese water divertion project, they raise the questions if they are ever manageable. The pressure they are putting on the natural system, causes the destruction of it, with harmful consequenceses for the nature, and later for the cities. The answer of engineers is mostly to construct bigger infrastructure, which aims to manage larger areas, to solve the bigger problems. This approach, of the bigger the problem, the bigger the solution, will produce gigantic problems, which require gigantic solutions for the next generations, as long as the grey infrastructure doesn't value the nature. According to Gleick (2003) the twentieth century approach of creating infrastructure is a hard path that adresse water issue sonly in terms of their quantity, to solve water shortages by exploiting new sources, rather than manage the available sources sustainable. Water is judged by its history, and not by its quality (Nelson 2012).

Leon Battista Alberti (1988) whose work "art of building architecture in ten books" is considered as one of the first theoretical printed books about architecture, describes water as 'the most fundamental and at the same time most destructive of the world's basic elements'. The perception of people who grow up in an urban environmentt, might differ from this perspective.

Kongja Yu (2011), a famous chinese landscape designer, describes that the perception of water of our modern society starts in the primary school, where he learned that water is more a "tasteless, colorless and odourless" fluid, in contrast to his childhood memories, were he played with a sometimes greenish, blueish UV breaking stream, observed frogs, and constructed dams.

The approach of this research tends to bring back the water to the people and to the cities, by designig it as integrated part of them. We have a big knowledge about water treatment and a deep understanding of the chemical processes. Despite the fact, that it is possible to produce absolute clear water, which is ready to drink, people have problems to accept it, as long it is not sold in plastic bottles, marked as "sparkling", "fresh" or "from the mountains".

The Combination of modern water treatment facilities, with the origin appearance of water in the nature, can be used to create Cities where water is a Design Element, which supports the perception as a valuable good, instead of something which must be managed by large scale infrastructure. From an engineering perspective, technological measures can mimic the nature, or can do their job even better (Nelson 2012). From a holistic, architecturally driven approach, it seems more pleasurable, to use this technologies, to enhance living with the water, like it was planned by the nature. This research assumes, that children who can play with frogs, inhabitants who can see the greenish, blueish shiver on the surface, smell, touch and feel the water in their environment, will lose their skeptics about water recycling and that in consequence the user acceptance increases. The overall goal is to give the conceptual basis for n urban context, which is independent from external water supply and furthermore protects the nature by providing a highly livable Environment.

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For an engineer a lake is an infrastructure element, which can be used for water supply or the release of treated or untreated domestic flows. For a Biologist, a lake can be described as the habitat for fishes, birds, and other species, which fed on plants or the lakes environment. An architect might see a lake as the perfect place to create a building, for housing developers a lake is the promise to sell high value livelihoods. According to urban planners the lake might be important to influence the local climate and building breathable cities by using adiabatic cooling effects.

When architects, urban planners, biologists and environmental engineers try to overlap their view on "lakes" it can create an interesting matrix,including water storage and water production, recreational space, animal-, fish- and bird habitat and also contribute to the local climate and a sustainable urban development by providing high quality livelihood to its citizens. This means that a lake can be even more than a lake, once all involved professionals from different disciplines shift their perception towards an integrated approach. This is exactly what water bodies are considered to do by nature: serve the needs of their environment in a local sustainable scale. What would happen if all the energy of those planners focus on the potential interactions between human settlements and water bodies? Especially once considering that every lives have started with the freshwater lakes and it is still depending on it?

One of the main aspects of this research is to reconsider the conventional approach of managing water streams in an residential area. This means that every drop of used water, as well as rainwater should get collected, treated, stored and finally recycled.
Beside a technical solution, the focus here is on the potential influences to and by the architecture. A water storage facility can easily be installed in or under the house but it can also be designed as a visible open space, an open 'lake' within a residential area. Lakes and water bodies always face social, cultural and recreational issues and a lot of the world's Lakes can be used for swimming, give children playgrounds, where they can experience water, flora and fauna, or even educate people in terms of water by experiencing it together with flora and fauna.

3.1. The ecosystem of a natural lake

The ecosystem of lakes is very complex and not understood in every detail. The basics are described in the following paragraphs, as the processes, which happens are one important part of this research. Temperate lakes, of the European and American regions are discovered relatively good, in comparison to tropical lakes, which are less researched. Although there is a lack of knowledge for tropical lakes, lakes ecosystem are in their basic structures comparable (see *Chapter 6*).

Modern, conventional water reclamation have their roots in the ecosystem of lakes and rivers, as these technologies base on the abundance of bacteria's and microorganism, which usually live in natural water bodies. In the treatment facilities, those bacteria's live in a technical controlled steady-state environment, which enhances their power and therefore their effectiveness.

The fact, that it is possible to enhance the purifying power of water bodies, is not only the basis for water reclamation, but also comes into the mind, when engineers and/or 'lake managers' try to improve water bodies, which faces pressure from pollution, degradation and nutrient input.

It is the basis for the development of the Water Resource Management system in the context of this research. The overall goal is to improve the processes of natural systems with technical installations and translate it into architecture and landscape design, to develop a highly resilient ecosystem.

A natural lake ecosystem is in a steady exchange with its environment. Apart from the exchange with groundwater streams, the water is exposed to UV radiation, and receives oxygen through air as well as mechanical input through wind induced turbulences. These processes build up the basis for a balanced system, which provides habitat for fishes, birds, and other animals, phytoplankton, zooplankton, microorganisms and other aquatic plants. This complex ecological system needs nutrients, in particular nitrogen and phosphorous to maintain its growth, together with the of use of sunlight and oxygen. The main nutrients, phosphorous and nitrogen can arrive in the lakes water in different chemical conditions. The ecosystem of the lake can transform them to make them available for plant uptake. Nitrogen can get absorbed by plants on different chemical structures, for example the poisonous form of nitrate (NO_3^-) or ammonium (NH_4^+). The available structure of nitrogen depends on several factors, among the most important are pH and the Oxygen saturation of the water. Phosphorus is often bound to particles or stored in dead biomass. Before plants can use it, it has to get subverted by bacteria's. These processes depend on the oxygen saturation and the pH as well. The ecosystem of a lake can also provide an environment, which bounds the phosphorous to the sediment, and thus isolating it from the water.

The growth within the ecosystem is stimulated as long as these elements, "nutrients" are available. The Redfield (1934) balance describes the Composition of Phytoplankton with 106C to 16N to 1P for Carbon, Nitrate and Phosphorous. The balance of these three elements can be seen as an indicator for the ecological structure of the lakes ecosystem.

According to Winter (2004:101) 1 mg phosphorous, which enters the lake, can lead to the synthesis of 100 mg algae mass within an aquatic ecosystem. However, out from this 1 mg Phosphorous, the part of it, which is bounded to organic substances settles to the ground immediately and enters the sediments where it can be degradated, stored, accumulated and released. These parts can count up to 60 to 70% of the avauilable P. Another part is directly available for plant uptake, as it floats 'free' in the water column, while the rest might get adsorbed to iron oxide, which is naturally available in water and inactivates the Phosphorous (see *Chapter 6*). Under the availability of Phosphorous, the ecosystem will produce biomass as long as nitrogen or light does not become a limiting factor (Padisak 2004). The inactivation by iron has a major influence on the availability and takes place as long as the lakes water is saturated with Oxygen (Phillips 2004).

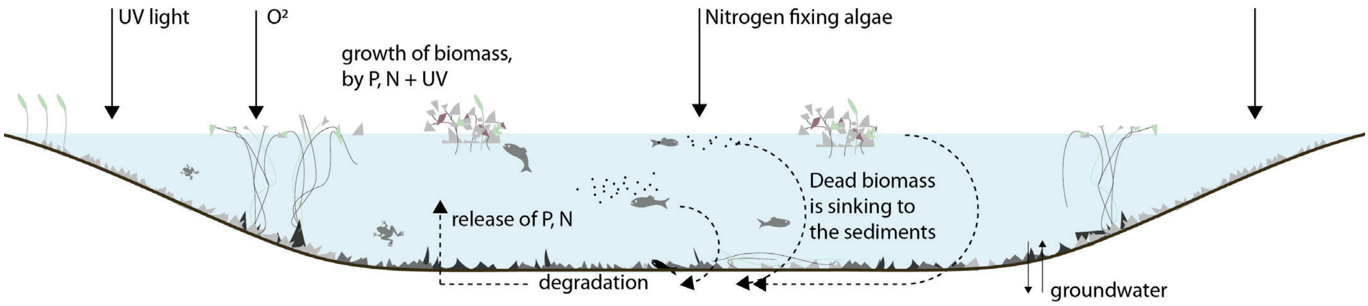

fig. 10:
Simplified illustration of a lakes ecological system

Iron bound Phosphorous will stay as inorganic particles in the lakes 'seston' or sediments (Padisak 2004) together with dead biomass of aquatic plants and/or phytoplankton, or get re-suspended to the water column by biological activities, which can then lead to oxygen depletion and anoxic or anaerobic conditions. Oxygen depletion stimulates the release further as the iron will lose its chemical affinition to P under anoxic conditions. particles will release the previously bounded Phosphorous to the water column, which further stimulates the growth of biomass in the upper layer. It is a 'vicious cycle', that is one of the key steps in eutrophication processes. In the context of the prospected income flows of the WRMS, including the domestic used waters, it is very likely that this will put a strong pressure to the ecosystem. Therefore, controlling the nutrient cycle is from major importance.

Phosphorous is considered as most important and as soon it is depleted in this system, the growth of the biomass will stop (Padiask 2004). The lake is considered as 'P-limited'. Some lakes, where P is abundant tend to deplete Nitrogen first, which let them become Nitrogen limited. The Redfield Relation of N:P 16:1 is often used as an indicator for the lakes structure and can be seen as a basis for the development of aquatic plants. More phosphorous in relation to nitrates (<16:1) ultimately means that the lake is nitrogen limited, while a relation of >16:1 can be an indicator for P-limitation.

A simplified illustration of the Phosphorous cycle, as well as the nitrogen cycle is given below:

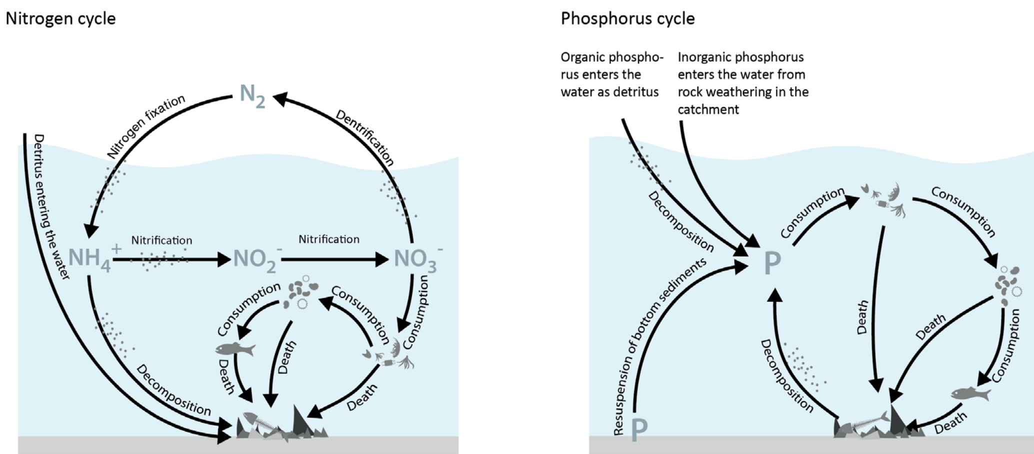

fig. 11:
Phosphorous and Nitrogen Cycle of a Lakes ecosytem

Source: own illustration, (adapted from https://wetland-info.ehp.qld.gov.au/wetlands/ecology/aquatic-ecosystems-natural/Lacustrine/non-flood-plain-soil-lake/nutrients.html)

Some species of plants have the ability to fix nitrogen from the air while floating on the water surface. In combination with the P from the lakes water column, they can grow – and these species are the only one which can grow under these conditions. Due to their ‘blue’ and ‘green’ appearance on the water surface, they are called blue-green algae. Most of these algal contain cyanobacteria’s, which can be toxic to the lake ecosystem. Those effects have been studied since 1878 (Francis 1878). Although they don’t have toxic effects to humans (Padisak 2004), the water is not usable anymore without high-tech treatment. Therefore, the right balance of Carbon, nutrients, sunlight and Oxygen is a major issue for a healthy ecosystem to prevent blue-green cyanobacterias.

Trophic Classification	Ultra-Oligotropic	Oligotrophic	Mesotrophic	Eutrophic	Hypertrophic
Tot. Phosphor. [mg/m³]	<4	<10	10 - 35	35 - 100	>100
Chlorophyll [mg/m³]	<1	<2.5	2.5 - 8,0	8,0 - 25	>25
Transparency [m]	>12	>6	6-3	3 - 1.5	<1.5

tab. 1:
Classification of the Water quality in natural waters, according to OECD (1982)

The general enrichment of natural ecosystems with nutrients is called 'eutrophication' and leads to an enhanced plant growth, which produces visible algal mats, benthic algae and stimulates different kind of Macrophytes. The subversion of this organic material causes depletion of oxygen leading to an array of further problems, such as fish kills, liberation of gases and other undesired toxic materials (Padisak 2004:264) as well as the release of Phosphorous from the sediments. The major source for eutrophication, which in fact can be seen as an increased nutrient supply is from anthropogenic sources. The nutrient load of a system can be described by the widely used system of the 'trophic state' which was developed by the OECD (Vollenweider 1982).

A healthy ecosystem where the nutrients, oxygen and UV saturation are balanced can be considered as mesotrophic. This means that the biological productivity is limited by phosphorous or nitrogen and that a harmful Oxygen depletion will not occur in a large scale

3.1.1 The lakes stratification

Due to UV radiation and the access of the UV light, to the water column as well as climatic influences, the lakes water near the surface has usually a different temperature from the deeper parts, which leads to a thermal stratification of the lakes water, due to differences in the waters density. This phenoma is called Lakes stratification and can be described for most lakes in the world. It divides the lake into an Epilimnion and Hypolimnion, whereas the thermocline acting as a barrier between these two layers by preventing the exchange of gases, nutrients and other relevant things.

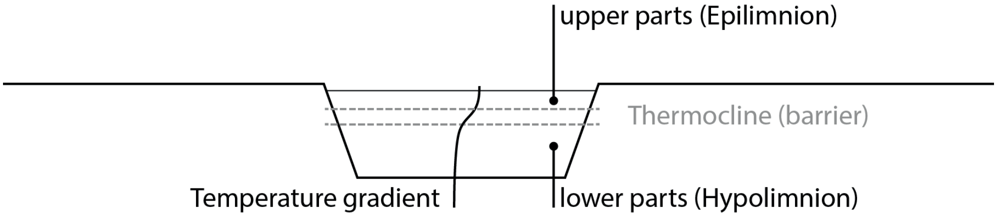

fig. 12:
Lakes stratification due to density differences throughout the water column

For instance, deep lakes in temperate climate zones stratify themselves during summer, once the surface of the lake is exposed to strong UV-light. During autumn, when UV light is less intense, the temperature gradient of the lake is reduced and the stratification gets interrupted until the surface water is colder during winter and the stratification occurs again. Lakes which stratify themselves two times a year, are called dimyktic, lakes which stratify themselves more than two times, are polymictic. During the periodical destratification a complete mixing of the water column happens, which is for further interest for the nutrient cycle of the lake.

3.1.2 The role of the sediments

The sediments of a lake which accumulate on the bottom, are one of the most important parts of the ecosystem. They consist of particles, rotten plant material, dead biomass algae and everything which enters the lake. Therefore, the sediments are rich of phosphorous and nitrogen and can be described as the 'internal nutrient loads', which can supply the lakes ecosystem for years, although the external supply is stopped or reduced. As soon as bacterias deplete the dissolved oxygen by subverting the lakes biomass, the environment becomes oxygen free,called 'Anoxia'. An anoxic environment has the capability to change $NO_3^- \rightarrow NO_2^- \rightarrow NO + N_2O \rightarrow N_2$. This reaction belongs to the basics of wastewater treatment and is called denitrification, which is further described in *Chapter 6* in the context of water reclamation. Although this reaction is from major importance in the treatment of used waters, anoxic conditions have some side effects as the iron particles on the sediments re-suspend bounded phosphorous, which might be released to the water column to enhance productivity.

A lakes stratification can form a barrier between the deep areas of the lake near the sediments where UV light is abandoned and the lakes surfaces, which are usually oxygen rich and exposed to UV light. As soon as dead biomasses settle to the sediments by gravity, they are blocked from the upper parts. As the stratification prevent that oxygen rich water enters the bottom of the lake, it is likely that anoxic will occur, when the settling biomass exceeds the lakes capacity of subversion. Beside the release of phosphorous, those anoxic conditions near the lake bottom can become toxic for its ecosystem with harmful effects to fishes, which like to live near the lakes bottom. As soon as a destratification occurs due to temperature changes or mixing, the toxic environment mixes with the water column, which results in further productivity and might lead the fast development of blue-green cyanobacteria's.

3.1.3 Clear water macrophytes vs. turbid water algae

The answer of a lakes ecosystem to nutrient enhancement are aquatic plants or algae. Most lakes are either dominated by the abundance of Macrophytes or algal, independently from the climatic situation. Algal are small free floating plants throughout the water column, which increases the water turbidity, when they are the dominant species. In contrast to that, a Clearwater state without algae is characterized by the abundance of Macrophytes, which are rooted, or free floating. Macrophytes have the ability to protect this Clearwater state, as they are dependent on the availability of light within the water column (Phillips 2004 Jeppesen et al. 1990; Moss 1990; Blindlow et al. 1993).

In reality it is often a mixture of both, whereas one species is dominating the system. Lakes can also develop areas of turbid waters, which coexist to Clearwater zones.

Both kind of vegetation compete for nutrients, oxygen and UV light. While Macrophytes might suppress algal growth by releasing special substances, dense algal mats can shade the submerged parts of Macrophytes from the sunlight, which might force them to die. On the other hand, floating Macrophytes can shade the water column, which suppress the development of algae by light limitation. It can be seen as a continuous fight between both species. A shift from a Macrophyte community to algae dominated structure is more likely than shifting the system back, since algae are more flexible regarding their living conditions and need by far less carbon dioxide for their reproduction.

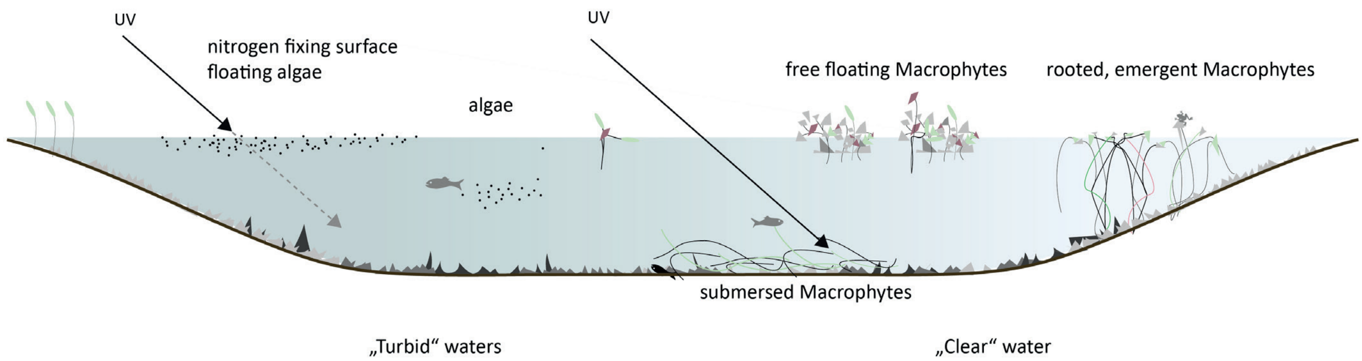

fig. 13:
Different plant species in the lakes ecological system

According to several researchers it is not completely clear why and how lakes switch from one stable state to another, or develop a turbid part next to a clear water part. However, when the lakes water changes from clear to turbid, the algae's and phytoplankton prevent the sunlight to enter the water column, which decreases the Macrophyte photosynthesis. Although Macrophyte crops are somehow resilient to those influences, it might happen that they decrease due to less UV Exposure and thus less photosynthetic activity.

Less photosynthetic activity means further less Oxygen in the water, which can lead to the nitrogen-fixing cyanobacteria's, which are responsible for the poisonous algae blooms, as described above.

Once the Macrophyte Crops disappeared form a lake they usually won't come back without intervention or bio manipulation. Furthermore, a switch from the turbid water state to the clear water state is not completely discovered and relatively rare.

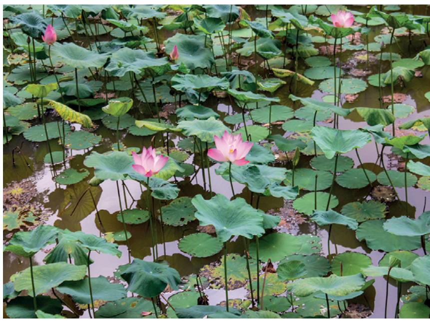

fig. 14:
Floating (top) and submersed (bottom) Macrophytes

Experiments with Macrophytes dominated communities showed that the shift to algae communities mostly happens when the plants are physically removed (Balls et al. 1989; Irvine et al. 1989). Phillips (2004) furthermore states that it is easier to prevent a Macrophyte dominated lake from shifting into the algal state than returning to it.
Several authors describe successful regrowth of Macrophytes as a consequence of bio manipulation (Phillips 2004; Lauridson et al. 1994) but for several lakes they subsequently declined, which might be related to the failure of the development of a stable fish/zooplankton community within this ecosystem. The interaction between Macrophytes and the ecosystem are not understood very well, which needs further research.

When the Water areas of the WRMS should address social, cultural and recreational Opportunities, the clear water state is desirable, as the turbid water state can develop a lot of negative impacts on the lakes water.

Therefore, it might be necessary to avoid the change to the turbid state, which means the lake could have the possibility to get supported by technical installation facilities, which strengthen the ecosystem.

The Macrophytes in the clearwater state consists of different species. Once the water is clear enough UV radiation can reach the lakes bottom to support photosynthesis, which enable Macrophytes to produce Oxygen at daytime, that they release to the Sediments in order to prevent the development of anoxic conditions. The same plants use this oxygen at night and respire it as the counterpart to photosynthesis. In a clear and stable Macrophyte dominated lake this system is balanced. The Plants can produce more oxygen than they use at night, what means that the lake waters oxygen saturation is good all the time and doesn't face anaerobic conditions. Once the water starts to get turbid certain chain reactions are caused: the plants can't do the photosynthesis what might lead to a decrease in the oxygen saturation and ultimately cause the Macrophyte to disappear. The lake is turned into the turbid state with nitrogen fixing cyanobacteria's as a consequence of the released nutrients from the sediments.

3.2. Anthropogenic influences

54% of the lakes in Asia pacific are eutrophicated (Chrous and Bartram 1999)
The major source for phosphate, nitrates and other pollutants which accumulates in the water bodies is the human water use. According to the Eutrophication tables by the OECD, a healthy 'mesotrophic' system contains 0.01 - 0.035 mg phosphate (and 1 mg nitrate) per liter, which is very low. It is very likely, that any system, which has more available nutrients, faces eutrophication processes asdescribed above which lead to marshing over decades due to the slow accumulation of biomasses and sediments.
Water bodies, such as lakes or rivers receive nutrients from wastewater treatment and agricultural fertilizers due to storm water Runoff. Those nutrients are available to the ecosystem and increase the biological production rapidly and unnaturally. The oxygen demand in the ecosystem increases due to biological subversion and as soon as the oxygen saturation is less than 1mg/L the nutrients get released from the sediments (Parma 1980), which increases the biomass production in the ecosystem in order to close the vicious cycle.

To control the nutrient inflow to the water bodies modern wastewater treatment facilities are equipped with high-tech solutions, which are able to reduce the phosphorous significantly by using chemical precipitation. Those technologies usually use highly reactive iron or aluminum ions to bind the phosphorous in the treatment facilities. The result is a sludge, which can be collected easily. Although all technologies can effectively reduce the phosphorous concentration in the effluent to less than 1 mg/L, it is still too high to be considered as natural, meaning that it still has fertilizing effects to the environment.
In order to avoid harm to the ecosystem rivers or lakes, where the concentrations got further subverted, water streams must be diluted. It should be noted that these techniques were mostly researched and discovered in the recent decades and the effluent concentration of conventional treatment facilities, whichb are equipped with

modern technolgies, can be more than 1 mg/L, which is still 500 times higher than its occurrence in natural, mesotrophic waters.
Furthermore, especially in Vietnam, reclamation facilities are in general rare and used water is often spilled to the water bodies without treatment, which stimulate immensely eutrophication. This, in consequence, can lead to a whole series of biological changes within an ecosystem and ranges from practical problems, like the use as water source to toxic algae blooms and reduced values for recreation and fishery (Beklioglu et al. 2014).

3.3. The WRMS as an adaption of a natural lake

The WRMS is a conceptual storage structure aiming to collect the available domestic flows (black- and greywater), as well as the natural flows (Stormwater) in the monsoon season to provide it during the dry season as Tapwater.
To ensure a sufficient water quality for its use as Tapwater, the ecosystem within this structure is from major importance. Strong eutrophication processes can lead to the poisonous blue-green algae production, which would render the intended use impossibly . Furthermore, anaerobic gas production, odors, filamentous algae or invasive Macrophyte weeds, which easily become a nuisance, are examples for unwanted side effects of eutrophication affecting inhabitants and the livability of the whole environment.

The lakes ecosystem depends on the available nutrients in the water column, which are the main driver for eutrophication. Other important factors are the transparency of the water, that allows light to enter the water column. As the lake mainly receives its waters from anthropogenic sources, the nutrient cycle inside the lake is from major importance.

The system must:

- collect water and store it, over several months
- handle different water levels
- develop an ecosystem which can handle hypertrophic conditions
- improve the water quality further as polishing pond
- stay mostly in the Macrophyte dominated „clear water“ state
- easy to influence or manipulate in case of failure

The idea of the WRMS includes the development of a technical controlled environment, which prevents eutrophication processes by stabilizing the Lakes Ecosystem. The natural and domestic inflows to the WRMS, as well as the outflows are described in the next Chapter.

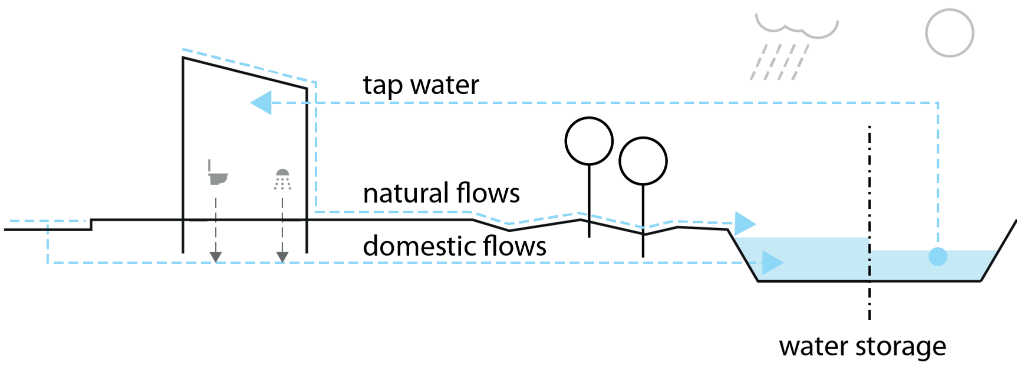

fig. 15:
The conceptual structure of the WRMS

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4.1. Rainwater as water source

Pandey et al. (2003) gives a quick overview about rainwater harvesting in the ancient times: Besides rivers, rainwater also was an important source for their water in some cultures before the system was reengineered. Also, today most of the infrastructures relies on ground- and surfacewater.

Nowadays a lot of projects could be found all over the world where rainwater harvesting is in the focus of research. As this Dissertation especially focuses on the Asian region, rainwater is an issue, which more or less affects everybody on a daily or at least periodically base. The climate in the subtropical or tropical Asia is characterized by different monsoon seasons which leads to heavy rainfall in areas like Hong Kong, Hanoi or Singapore. A closer look to the weather data of these cities shows that Hanoi receives 1676 l/m^2 annually showing a clear peak of 318 l/m^2 in August during the local monsoon (may - september). The minimum rainfall can be found in January during the dry season with only 18l/m^2. The situation in Hong Kong is similar as it receives 2398 l/m^2 annually with its maximum in june: 456,1 l/m^2 and respective to Hanoi 24.7l/m^2 in january. Singapore is affected by the northeast-monsoon (November - march), as well as the southwest monsoon (june - september), as it is near the equator. Therefore, it rains nearly every day with an annual rainfall of 2150 l/m^2. A look on the weather data shows that the time between the monsoons receives less rain but still 140 l/m^2. which is compared to the maximum of 304 l/m^2 still a lot.

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tab. 3:
Rainfall data of Hanoi, Hong Kong and Singapur.

Sources:

[1]: World Weather Information Service 2016 (WWIS); http://worldweather.wmo.int/en/pilot.html

[2]: https://www.klimatabelle.info/asien/singapur

Area		Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Ha Noi	Rainfall [l/m^2]	18,6	26,2	43.8	90.1	188,5	239,9	288,2	318,0	265,4	130.7	43.4	23.4	1676,0
	Rainy days	8,4	11.3	15	13.3	14,2	14,7	15,7	16,7	13.7	9	6,5	6	144,5
Hong Kong	Rainfall [l/m^2]	24,7	54,4	82.2	174,7	304,7	456,1	376,5	432.2	327,6	100.9	37,6	26,8	2398,0
	Rainy days	5,4	9,1	10.9	12.0	14,7	19,1	17,6	16,9	14,7	7,4	5,5	4,5	137,8
Singapore	Rainfall [l/m^2]	198	154	171	141	158	140	145	143	177	167	252	304	2150
	Rainy days	19	12	17	19	18	18	18	17	18	19	23	22	220

The big potential which can be seen in rainwater becomes clear when the annual rainfall is calculated in the context of the population density of Hanoi which is over the urban area around 2300 inhabitants/km^2 (Vietnam 2014). An annual rainfall of 1676 l/m^2 means that for each inhabitant of Hanoi the country receives an annual average of 200 l/daily. If it is possible to collect a significant amount of rainfall, it can become an important part in the water supply. Furthermore, if water is infiltrated to the hydrological cycle after its usage, it would also support the local environment.

4.2. When Rainwater becomes Stormwater and Runoff

Stormwater is the Runoff from urban surfaces during rain events. In urban areas this Runoff could be collected from different type of surfaces, e.g. rooftops, streets, greenspaces, pathways, building facades etc. In rural areas , the hydrological cycle consists of different simplified stages, which are in a balance between rain-, surface- and groundwater. After rain reaches the earth it gets either partly infiltrated to the soil (i.e. groundwater) or flows as Runoff to the water bodies (i.e. surface water). Depending on the local environment the Runoff will partly join the hydrological cycle directly through evaporation or transpiration.

In urban areas (i.e. in the cities) the hydrological cycle is disturbed and out of balance. Due to sealed surfaces in the city the Runoff cannot infiltrate in the soil. If this Runoff is not managed properly, meaning the draining and evacuation of the Runoff is not as quickly as possible, the runoff leads to floodings of the city., (Domenech 2010: 297). In most cases the urban areas are either connected to a sewer system, which transport the Runoff mixed with the wastewater to a treatment plant (mixed sewer), or connected to a Stormwater conveyance system, which directly moves the Runoff to a receiving water body (separated sewer) (vgl. Hvitved-Jacobsen, 2010; Ferguson 1998).

Rainwater before it touches the urban surfaces is characterized by very high quality (quality of what? amout?), which is ready to use for nearly every purpose (Domenech 2010). However, urban areas are characterized by a wide range of human-made pollutants. Those pollutants can either be air-borne, like substances from industry or traffic, or they can be found directly on the surface like petrol, oil, carwashing detergents, illegal spills or leaks from factories (vgl. Hvitved-Jacobsen), which directly affects the Runoff quality. These circumstances influence a possible immediate Stormwater use. Although the pollution might be lower in stormwater compared to wastewater, stormwater pollution is still not as low as sanitary engineers believed 30 to 40 years ago. Detention ponds or other facilities are therefore necessary in a separate sewer system to treat the urban Runoff before it should be discharged to the water bodies (ibid).

In case of a mixed sewer system the Runoff got treated together with the used water in the reclamation plant. As rainwater is characterized by a relative low content of biodegradable organic matter, it therefore affects the biological treatment of conventional wastewater treatment plants by dilution of the wastewater. Since the capacity of a mixed sewer system is limited it cannot handle excess Runoff, which might occur due to heavy rain events. In this case, that could happen 2 to 20 times a year (ibid), the sewer system is equipped with overflow structures which discharge the diluted wastewater to the water bodies. The overflow of the sewer causes a direct contamination of the water bodies with diluted wastewater, which nevertheless has different nutrients and could cause impacts like eutrophication.

The above examples clearly show that storm water, which is separated from its natural balanced cycle, leads to bigger infrastructure andinfluences the urban space as well as the connected treatment facilities and the local hydrological cycle. Architects, Engineers and urban planners are responsible for the protection of the urban areas in the frame of heavy rain events, which can cause floodings. Therefore, in many cases it makes sense to implement localized infrastructure to evacuate the rain e.g. from streets and sealed surfaces.

Jackson et al. (2001:1) claims that the climate change will intensify the earth's water cycle leading to more rainfall, more evaporation and more storms. This however, might be too much for the nowadays centralized infrastructure as there are already areas where the above explained overflow situation occurs several times a year.

4.3. Stormwater as a natural stream

Water is in a constant interchange with the environment. This includes processes like evaporation to the air, transpiration by plants or infiltration to the soil. By designing a Community which intends to recycle every single drop of water a hydrological understanding of the different stages of rainwater respectively the Runoff is important to estimate the potential of its usage. Its water management has to be a design criteria to ensure that as much water as possible can be collected. Depending on the location where the rain is hitting the earth's surface to become Runoff, transpiration, evaporation or infiltration occurs with different characters. While the Runoff on impervious surfaces is mostly reduced by evaporation, it can be said that on sandy soils the losses through infiltration dominate. An important value to estimate the 'usable' parts, which means in the authors understanding those parts of the Runoff that can get captured, is the Runoff Coefficient RC. It is an indicator expressing the percentage of stormwater, which becomes Runoff and survives the travel over the watershed. The Runoff Coefficient can be as low as 0.1 for sandy soils without gradient and as high or even higher as 0.95 for sloped roofs with metal pavement (refer to table 3). The theoretical usable amount of stormwater within a catchment area can be described as the product of the local precipitation (P), the size of the catchment (A) and the Runoff Coefficient:

$$\text{Runoff} = P * A * RC$$

This can lead to the theoretical situation that light rain might not produce any Runoff, if the infiltration capacity of the soil is higher than the amount of rain.

4.4. Where Stormwater becomes Runoff

Within reSOURCE Water Community the rainwater can either fall on a roof of a building or on its façade, as well as streets and pathways, green spaces or other sealed and unsealed surfaces, which also might include designated service areas, like garbage collection or parking spaces. As soon as the rainwater touches any surface, it is considered as stormwater and the movement of this stormwater to the sewers is considered as Runoff.

4.4.1 Runoff from the roofs

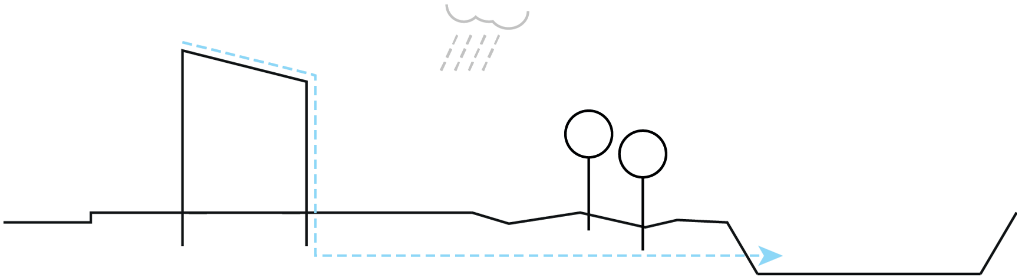

fig. 16:
The Runoff from the roofs, is characteriozed by a high quality. A divertion of the ‚First Flush' can improve the quality further

A nearly perfect situation in terms of rainwater harvesting can be found on the roof. Roofs are constructed to protect the houses from rain, meaning the material usually doesn't allow any infiltration. Therefore, most parts of the rainwater will become Runoff, which quickly find its way to the sewers and thus reduces the evaporation due to UV Exposure. In dense urban areas roofs can represent up to 50% of the sealed surfaces (Farreny et al. 2005), which makes them an important source for harvesting storm water. Without infiltration processes and a negligible evaporation the theoretical available amount of usable storm water can be as high as 95%, which corresponds to a Runoff Coefficient of 0.95.

Architects cannot influence the annual rainfall but they can influence on the one hand the size of the roof and on the other hand the used materials and the structure. The texture of the used materials might cause some retention and influence the behavior of the roof under different weather conditions (Goebel 2007; Farreny et al. 2011). Furthermore, the Runoff Coefficient might include losses due to leakage, spillage, catchment wetting and evaporation (Singh 1992).

The table below shows typical Runoff coefficients of different roof types based on a literature review done by Farreny et al. (2011).

·	Material	RC	Reference
Roofs (in general)		0.7 - 0.9	*Pacey and Cullis (1989)*
		0.75 - 0.95	*ASCE (1969), McCuen (2004), Singh (1992),TxDOT (2009), Viessman and Lewis (2003)*
		0.85	*McCuen (2004), Rahman et al. (2010)*
		0.8 - 0.9	*Fewkes (2000)*
		0.8 - 0.9	*Ghisi et al. (2009)*
		0.8 - 0.95	*Lancaster (2006)*
Sloping roof	Concrete/ asphalt	0.9	*Lancaster (2006)*
	Metal	0.95	*Lancaster (2006)*
		0.81 - 0.84	*Liaw and Tsai (2004)*
	Aluminium	0.7	*Ward et al. (2010)*
Flat roof	Bituminous	0.7	*Ward et al. (2010)*
	Gravel	0.8 - 0.85	*Lancaster (2006)*
	Level cement	0.81	*Liaw and Tsai (2004)*

tab. 2:
Runoff coefficients for different roof types.

The highest Runoff Coefficients can be found in sloped roofs with metal pavements, which can be as high as 0.95. While a typical flat roof ranges between 0.7 for bituminous pavement to 0.8 for gravel or level constructed cement.

A sloped roof with a high gradient will support the fast movement of the Runoff to the gutters or pipes and prevents the Runoff from Evaporation. A flat roof in contrast carries the water slowly to the gutter or pipes and will support the evaporation, which significantly reduces the Runoff Coefficient (RC). The surface temperature of the roof also influences the evaporation potential, especially during light rain events.

The quality of the Runoff can be seen as acceptable for non-potable uses as they might carry some pollutants, far less than other sources of Runoff though. Since rainwater is by nature clear and in theory ready to use for any purpose (Domenech 2011) it might get polluted by airborne pollutants, which get captured during the falling phase. Furthermore, dry precipitation, especially due to industrial activities in the close surrounding, might be a problem. Natural sources, like animal faeces as well as plant material, might be available on the roof, as well as chemical substances, i.e. heavy metals from the used construction materials, which can leach into the Runoff (e.g. Lye 2009). A study done by Li et al. (2014) showed significant differences between the roof Runoff of Beijing, Nanjing and Shenyang (see table XX). While COD, TN, TP might be influenced by the direct surroundings (e.g. rotted leafs, animal faeces, dust and dirt), heavy metals which are also present in the Runoff are most likely dependent on the used construction materials, that can be prevented by a proper selection. The same study found out that more than 90 percent of Cd and Pb got washed away with the first flush at least for tiled and concrete roof types. The influence of the first flush on COD, Cu and Zn were estimated to 85 %, and the probabilities for TN and TP at least 40% (Li et al. 2014a). This shows that a diversion of the First Flush might be a proper solution to enhance the quality of the Runoff in areas where this is necessary, although it might influence the Runoff Coefficient. In that case, it might be feasible to treat the first flush together with the black water stream.

Roof	PH	COD	TSS	TN [mg/L]	TP [mg/L]	Cd [µg/L]	Pb [µg/L]	Cu [µg/L]	Zn [µg/L]	Reference:
normal roof	7,2	na	5,8	0.6	0.06	-				Van Seters et al. (2009)
	na	0.41 - 22.31	18,55 - 70.34	0.36 - 2.50	0.01-0.25	0.02 - 0.7	0 - 22.9	1.3 - 25,4	2.1 - 109,1	Li et al. (2014)
	na	0.2 - 23.56	6,99 - 94,29	0.6 - 9,85	0.06 - 0.13	0.02 - 0.7	0 - 22.9	1.3 - 25,4	2.1 - 109,1	Li et al. (2014)
						0.05 - 1.2	2.0 - 61.3	7,7 - 36,9	32 - 468	Zhang et al. (2011)
	na	0.4 - 650.3	0.6 - 187,0	0.1 - 24	0.0002 - 2.4					Ren et al. (2013)
	na	16,5- 108,5	6,1 - 116,0	1.5 - 8,2	0.02 - 0.3	0.6 - 0.7	2.6 - 6,0	2.9 - 11.6	13.8 - 47,2	Zhang et al. (2012a,b)
green roof	8,1	na	na	1.1	0.3					Van Seters et al. (2009)
		100.4+/- 24,8	13.3 +/-6,5	3.58 +/- 0.7	0.1 +/-0.02					Wang et al. (2015)

tab. 4:
Runoff Quality for normal roofs, and green roofs

The above table shows, that greening of the roofs can significantly reduce the amount of suspended solids and other pollutants within the Runoff, but increase TN due to the absence of vegetation and reduces significantly the RC, as evaporation and transpiration happens, as well as wetting of the soil. As TN is beside TP one of the critical elements, regarding the eutrophication of water bodies, a green roof is not considered as an option within the Scenario Development of *Chapter 8*..
As the pollution of the roof Runoff, is usually sufficient for for the use as non-potable water, this Dissertation bases on the assumption that the roof Runoff, is from high quality, and the roofs within 'resource' are constructed with a RC of 0.95.

However, in case that the roof Runoff is heavily polluted due to the absence of industrial pollution, the roof can get constructed with a First Flush Diverter or the Runoff might receive a proper treatment before its use.

4.4.2 Runoff from the green areas

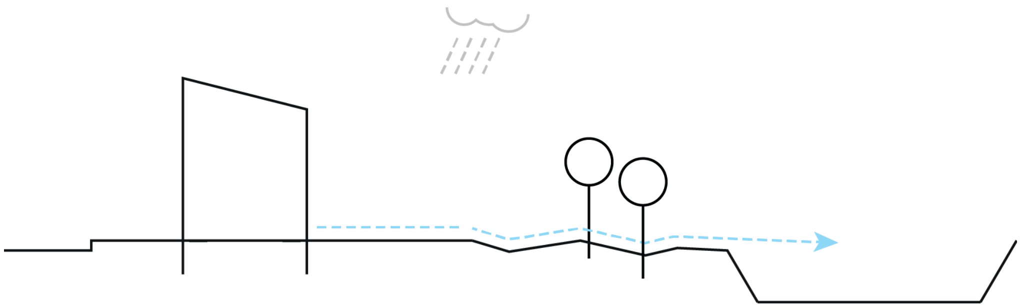

fig. 17:
The Runoff from Green spaces might contains particulate matter, and nutrients, which are mostly washed out from the soil.

When the rainwater touches a green space it becomes far more complex than in the previous described context of the roof. The first thing which happens is highly dependent on the soil and the vegetation. Depending on the climate, the UV Exposure, air humidity, and the vapour saturation pressure and the timespan to the earlier storm (to name a few) the soil is either saturated with water, over-saturated with water, or dry, or something in-between. If the soil is dry a significant amount of the rainfall is directly infiltrated to it until it reaches its saturation.
After the soil is saturated the storm water will stay on the surface by building water layer up to 1 to 3 mm. This might lead to the situation that at least light rain events may happen without a usable Runoff. When this 'layer' of storm water reaches a specified volume it starts to flow and the water masses become Runoff, which tend to flow 'downwards'. This specified volume is dependent on the kind of vegetation and soil, its roughness and on the slope gradient. The 'first flush' earlier described for the roofs happens, too.

Calculation of the usable water masses from green open spaces is as challenging as complex. As described above, a significant amount of the storm water is infiltrated to the ground until the ground reaches its saturation, which depends on the character of soil and vegetation. The Runoff is exposed to UV Radiation and complex interactions with the nature, which includes the recirculation to the atmosphere by evaporation and transpiration. Evaporation is the process where water is converted to water vapor and removed from soils and wet vegetation, pavement or water bodies due to sunlight. Beside this direct processes, transpiration consists of the indirect vaporization of water within plants and the subsequent loss of water as vapor through the leaf stomata (vgl. Zotarelli 2013). These processes can be simplified described as "Evapotranspiration". Besides infiltration they are an important point in calculating the usable amount of stormwater. To estimate the amount of Runoff, e.g. for the design of sewers or flood protection installations, engineers use empirical data of rainfall patterns and equation like the rational formula to estimate the Runoff and the peak flows. The Runoff Coefficient for urban areas highly depends on the infiltration rate, the gradient of the slope, and the vegetation. To simplify the estimation several methods are available. In the following sections, the 'rational method', as well as Kennessy method, (Farina 1990) are described, which allow a first quantification of the expected Runoff. Both methods are using different values and coefficients. Based on the rational method, which was first discovered, the U.S. Soil conservation services has classified 4 groups of soils, depending on the measured, minimal infiltration rates.

Group A (0.3 in/hr) : Deep sand; deep loess, aggregated soils
Group B (0.15 – 0.3 in/hr): Shallow loess, sandy loam
Group C (0.05 – 0.15 in/hr) : Clay loams, shallow sandy loam, soils low in organic content; soils high in Clay
Group D (0 – 0.05 in/hr): Soils that swell significantly when wet; heavy plastic clays, certain saline soils.

Table 5 shows the estimated Runoff coefficients of different soil-groups (i.e. infiltration rates). By choosing a developed land, and a slope gradient, the estimated Runoff Coefficient can be simply identified.

According to the rational method, the Runoff Coefficient of a green area (Meadow), with a slope of more than 6% and a mostly clayed soil, can be estimated to 0.5.

Soil Type	A			B			C			D		
Slope	<2%	2 - 6 %	> 6%	<2%	2 - 6 %	> 6%	<2%	2 - 6 %	> 6%	<2%	2 - 6 %	> 6%
Forest	0.08	0.11	0.14	0.1	0.14	0.18	0.12	0.16	0.2	0.15	0.2	0.25
Meadow	0.14	0.22	0.3	0.2	0.28	0.37	0.26	0.35	0.44	0.3	0.4	0.5
Pasture	0.15	0.25	0.37	0.23	0.34	0.45	0.3	0.42	0.52	0.37	0.5	0.62
Farmland	0.14	0.18	0.22	0.26	0.21	0.28	0.2	0.25	0.34	0.24	0.29	0.41
Res. area 1 acre	0.22	0.26	0.29	0.24	0.28	0.34	0.28	0.32	0.4	0.31	0.35	0.46
Res. area 1/2 acre	0.25	0.29	0.32	0.28	0.32	0.36	0.31	0.35	0.2	0.34	0.38	0.46
Res. area 1/3 acre	0.28	0.32	0.35	0.3	0.35	0.39	0.33	0.38	0.45	0.36	0.4	0.5
Res. area 1/4 acre	0.3	0.34	0.37	0.33	0.37	0.42	0.36	0.4	0.47	0.38	0.42	0.52
Res. area 1/8 acre	0.33	0.37	0.4	0.35	0.39	0.44	0.38	0.42	0.49	0.41	0.45	0.54
Industrial	0.85	0.85	0.86	0.85	0.86	0.86	0.86	0.86	0.87	0.86	0.86	0.88
Commercial	0.88	0.88	0.89	0.89	0.89	0.89	0.89	0.89	0.9	0.89	0.89	0.9
Streets	0.76	0.77	0.79	0.8	0.82	0.84	0.84	0.85	0.89	0.89	0.91	0.95
Parking	0.95	0.96	0.97	0.95	0.96	0.97	0.95	0.96	0.97	0.95	0.96	0.97
Disturbed Area	0.65	0.67	0.69	0.66	0.68	0.7	0.68	0.7	0.72	0.69	0.72	0.75

tab. 5:
Runoff Coefficients, depending on the soil structure.

Like the rational method, the Kennessey method bases on different Coefficients for the slope(Ca), the vegetational cover(Cv) and the permeability of the soil (Cp). Each of these attributes has different characteristics, which has to be set in function to the Index of Aridity (Ia). Ia thereby is a local factor, which takes the aridity of a specific location into account.

tab. 6:
Runoff Coefficients, according to the Kennessy method.

Similar to the rational method, also the Kennessey method bases on different Coefficients for the slope(Ca), the vegetational cover(Cv) and the permeability of the soil (Cp). Each of these attributes has different characteristics, which has to be set in function to the Index of Aridity (Ia). Ia thereby is a local factor, which takes the aridity of a specific location into account.

		Aridity Index		
		I(a) <25	25<I(a)<40	I(a)>40
Slope Component C(a)	>35%	0.22	0.26	0.3
	10 - 35 %	0.12	0.16	0.2
	3.5 - 10%	0.01	0.03	0.05
	<3.5%	0	0.01	0.03
Permeability Component C(p)	Very Poor	0.21	0.26	0.3
	Poor	0.17	0.21	0.25
	Moderate	0.12	0.16	0.2
	Good	0.06	0.08	0.1
	Very Good	0.03	0.04	0.05
Vegetation Component C(v)	Bare rock	0.26	0.28	0.3
	Grass land	0.17	0.21	0.25
	Farm land	0.07	0.11	0.15
	Forest land	0.03	0.04	0.05

Rc = Ca + Cv + Cp

Rc = 0.05 + 0.25 + 0.25 = 0.55

4.4.3 Nutrient export of green spaces

The Runoff from green spaces contains more nutrients than the Runoff from roof areas. Especially fertilized lawns from residential areas can contain high amounts of Phosphorous and Nitrogen, as the fertilizer is easily washed out during rain events and finally released to the water flow. Furthermore, the Runoff induced by heavy rain events can include particles which are bounded in biomass from the lawns vegetation, particles of the soil, sand and other substances, such as animal faeces or even smaller animals, like mice.

Empirical data from unfertilized lawns are rarely available, especially from subtropical climate zones. Some data from the south parts of the United States measured mean values for TP/TN of 0.43 m /0.42 mg/L for medium and high Density Residential areas in Florida with a watershed size of 3.6 to 50 ha, which includes roads, green spaces and other residential structures (Yang and Toor 2017). Other studies indicate that the Runoff from gardens, grassed areas and cultivated lands contains 0.09 mg/L P (Gobel et al. 2007). A study conducted by Wherley et al. (2014) showed that the TP Export of unfertilized turfgrass lawns was 1.05 mg/L and 1.34 mg/L during August and September, which fits to reference values of 0.5 mg/L TP to 5.5 mg/L TP of the introduced reference projects. Fuchs et al. (2010) claims that the dissolved fractions TN and TP of the Runoff from natural grassland and open zones can be estimated to 0.0. which in turn indicates that the available nutrients of the Runoff are mainly bounded to particles, which underlines the need for a proper retention.
The size of watershed area and therefore the pathlength and contact time of the Runoff with the lawn or grassland are from further importance. A long contact time will result in a bigger load of the stream as more particles can get washed out. A reduction of the contact time and shrinking of the watershed where the Runoff is captured decentralized and conveyed within small drainage structures, like tubes and pipes, can decrease the available dissolved particles.

Newly constructed lawns can export a lot of sediments, soil particles and sands, which include nutrients. This is from further importance for the first years of operation. The first flush after a period of dry weather can have significant amounts of particles and suspended solids, which must be filtered.

Therefore, This research project is based on the assumption that the Runoff from green spaces contains 0.2 mg/L TP and less than 1 mg/L Nitrogen after passing a proper retention. This is particular of interest as the natural flows will dilute the domestic flows during the monsoon season.

fig. 18:
A canal in Singapore, which carries pollutants, washed out from a nearby lawn, during a rain event

4.4.4 Runoff from streets, parking places and walkways

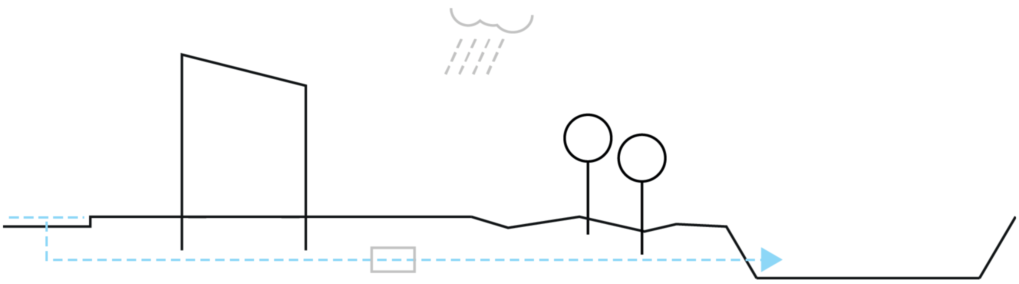

fig. 19:
The Runoff from streets is highly polluted

Streets and walkways differ from green as they usually consist of sealed surfaces instead of a vegetated soil. These sealed surfaces prevent infiltration and by choosing the right material, streets and walkways which have a Runoff Coefficient of 0.8 can be easily achieved, according to the in the previous parts described methods.
However, It must be considered that at least for streets, which allow traffic by cars and motorbikes, the Runoff might be heavily polluted by rubber particles, oil, petrol, or invasive elements, from outside regions. Therefore, a technical treatment for this Runoff (e.g. together with blackwater) must be considered necessarily.

Another critical area within residential areas are the places where the garbage is stored, managed, divided and collected by the collection service. This area, resp. this areas Runoff need special attendance if they are not fully integrated into the building

fig. 20:
Urban Runoff is discharged to a small Stream in Singapore.

Beside the nutrients urban Runoff might have significant amounts of particulates and other suspended solids, which get washed out from lawns, walkways and other urban surfaces, like earth, stones, garbage, grasses etc. Although these pollutants don't have a direct influence on the ecosystem, they have an indirect effect, as they might increase the turbidity of the water at least until those pollutants are settled down. This turbidity can shade the water and thus affect the UV availability for aquatic plants, which might be dangerous for them (for instance, see *Chapter 6*).
These pollutants are harmful for the ecosystem and before this water is used within a WRMS, it must be ensured that they are removed to protect the ecosystem. Furthermore, the velocity of the water stream can have significant power when stormwater enters the lake, which has further negative impacts to the Ecosystem, like the physical resuspension of Sediments.
The Runoff stream therefore has to be evacuated from the direct inflow to the water system. Appropriate Treatment includes the removal of nutrients and particulates, as well a controlled inlet structures. Reducing the kinetic energy of the waterstream is absolutely necessary.

4.5. Process engineering

Managing the Runoff and closing the water cycles might require some treatment steps before the water is ready for reuse, especially when it contains particulate matter, nutrients and other dissolved substances which got washed into the Runoff from green spaces and walkways. Several passive treatment opportunities, like wetlands, bioretention areas, re/detention ponds, bioswales are available which can reduce the loads of the Runoff significantly. For areas which are fertilized or highly polluted, like streets a technical treatment might be the better option, which can get realized by combing its treatment together with the domestic streams (see *Chapter* 5.2.).

There are many different technologies available to fulfill treatment requirements for sustainable Stormwater management and its reuse. These measures were developed in a specific context in a specific climate on a unique site with different disadvantages and advantages. An Appropriate selection is necessary for the success of the project but the 'right answer' does not exist (Hoyer et al. 2011). In fact, the ideal solution is often several methods appropriately linked (Woods-Ballard 2007, Hoyer et al. 2011).

Some of these Measures are described in the next parts of this Chapter with focus on treatment and conveyance, especially for the Runoff of green spaces. A good overview is given by Hoyer et al. (2011), which is the basis for the following descriptions:

4.5.1 Biotopes

A Biotope in context of Water Sensitive Urban Design (WSUD) is an area with several plants and animals, which should improve ecological stability. The processes within a biotope contain natural oxygenation of water, typically by wetland growth. The whole system of resource Water can be described as a biotope.

4.5.2 Bioretention and raingardens

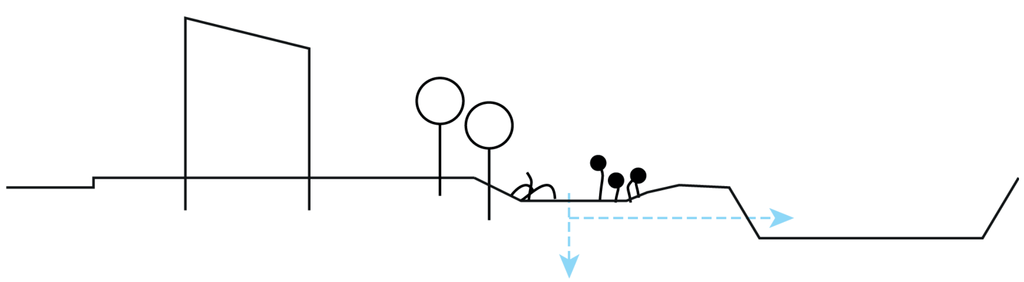

fig. 21:
Retention areas can be used to retain the Stormwater, and reduce its pressure, before it is released to the WRMS.

Bioretention Zones can be described as a shallow, vegetated depression, which relies on engineered soils. They are designed to treat the Runoff from rain events to reduce its particulate matter while filtering the nutrients and other organics due to its dense vegetation before the water got infiltrated and/or collected through an engineered soil. Bioretention Zones can be designed as recreational zones and/or playground for children during dry season and if designed properly visitors can enjoy the retained water as a water surface during its retention time after heavy rainfall events. (Hoyer et al. 2011)

4.5.3 Gravel or sand filters

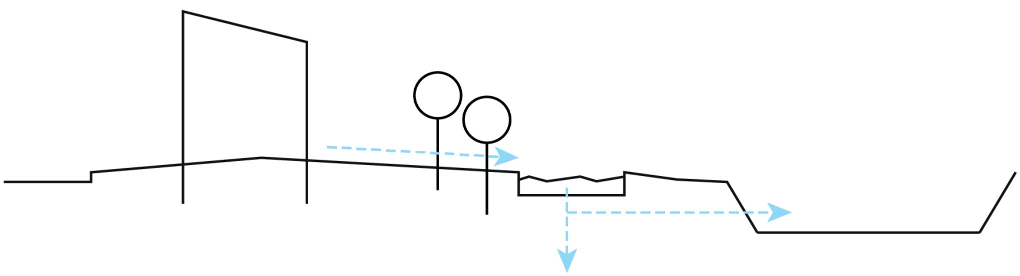

fig. 22:
Gravel or sand filters can be used to filter particles, before the water is released to a transpoprtation system.

Stormwater Runoff can be filtered with gravel or sand. Gravel and sand filters are usually part of an underground conveyance network and are not designed to remove small particulates and sediments. Therefore a grass channel or filter strip should be used to prevent clogging and failure.

4.5.4 Permeable paving

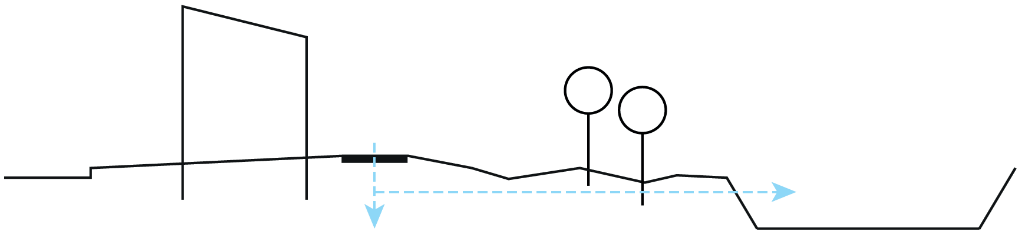

fig. 23:
Permeable pavings allow the infiltration of Stormwater through the walkways or streets

Permeable paving’s are materials for streets and walkways, which allow the Runoff to infiltrate through it. Underneath the pavement gravel beds, or specifically deisgned structures can either infiltrate the water to the ground, or drain it out of the system, for further use. It is particular of interest for the walkways within resource water, as they allow both uses: hard surface and infiltration.

4.5.5 Bioswales

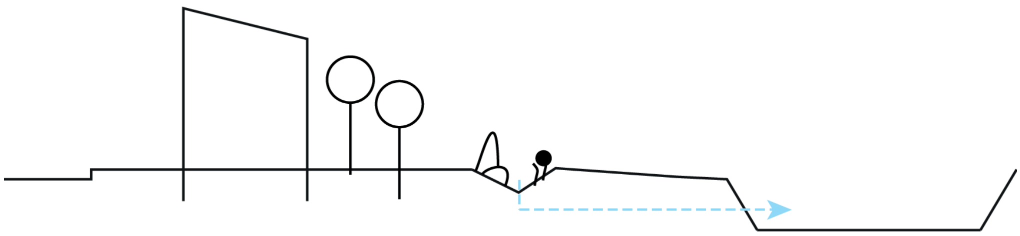

fig. 24:
Bioswales might be designed with terrestrial plants, and equipped with stones or other elements,

Bioswales are linear vegetated drainage structures that convey Stormwater. They can either have an impermeable base when they are designed for transportation and downstream management, or permeable to allow infiltration during the transport. Swales can be planted with filtering plants, which slows the waters and promotes the settlement of particulates significantly. They cannot treat the Runoff to meet water quality objectives but they can provide an effective pre-treatment in combination with

fig. 25:
Bioswale in the Ang Mo
Kio parc in Singapore

bioretention. Swales can be integrated into public spaces and if designed properly, they can attract children to play during the dry season and can be used for recreational purposes. The slope can get designed as a place to sit and bridigng the slope can create interesting features which further attract children.

4.5.6 Dry detention ponds

A detention pond is a surface storage basin that collect and hold Stormwater Runoff. During these process particulates can settle to the ground while the water is slowly infiltrated to and additional conveyance system or released to surface waters. Those ponds are usually dry until periods of heavy rain. They can be equipped with low lying drainage structures underneath a bioengineered layer of gravel or sand to filter the particulate matter before the water is released. The use of a small parapet, which is designed for a fixed storm event can furthermore remove the surplus waters by an open channel, in case that this event is exceeded..
Those structures can remove up to 90% of the particulate matter, which significantly improves the water clarity and prevents the nutrients, which are bound to particulates from entering the further system.

Wet Detention ponds, geocellular systems, which store the water underground as well as systems which are designed to evaporate the water locally or infiltrate it to the ground are not considered within this research, as it would reduce the available water amount. However, in a local concept can be additional features in the case that enough water is available or as an emergency installation for flood protection.

Green roofs are also not considered in this dissertation, as they will reduce the Runoff up to 50%. However, they can provide benefits in energetic perspective, as they can have major influence on the cooling demand. Furthermore, in cases where the roof Runoff is highly characterized by organics from dry precipitation or trees etc, they can help to improve the quality.

4.6. Flood protection

Rainwater can be destructive. As soon as the rainwater touches the ground it is considered as Runoff, which moves to land depressions, rivers, or the sewer system. The volume of this moving masses can be huge, which requires a proper management and conveyance system to avoid any damages.

150 mm rainfall can be very easy to handle, if the timespan is half a month and this expresses roughly the 'normal' situation during the monsoon season in the south east Asian climate zones. But the same amount can also come to earth within a couple of hours during a typhoon event and can cause major damages on buildings, streets, vegetation, and particular in the rural areas to human life, as this water might wash everything away.

fig. 26:
protected Inlet Structure in Singapore

Management of these water volumes means the safe conveyance of Stormwater, from the place where it occurs to its destination, which is usually the hydrological cycle or in case of this research the WRMS. Especially the tropical regions of Asia receive huge amounts of rainfall annually, which can be described as heavy rain events, with a lot of rainfall during a relatively short time period.

Urban areas are usually supported by 'grey infrastructure', which is installed under the streets and pathways. The size of these elements are based on statistical calculations from the weather data and economic assumptions. Depending on the local context it is usually designed to handle a 'statistically' designed storm, which is supposed to occur to a fixed frequency. This whole process is invisible for the public and can be described as an 'out of sight of mind' strategy. This reduces the Runoff Coefficient in relation to the visible parts of the urban space significantly.

By designing an area which is supposed to collect as much Runoff as possible flood protection is a major concern and a high Runoff Coefficient is desirable. This approach differs from the conventional approach, as this volumes must be treated and conveyed within the urban context by ensuring flood protection on the same time.

A storm event can be described with 4 attributes: Volume, Intensity, Duration and Frequency.

The Volume describes the amount of water. Its dimension is normally mm. The absolute volume of rainwater (e.g. 10 mm) can be easily calculated by multiplying this value (e.g. 1 m^2) with the affected area:
10 mm * 1 m^2 = 10 mm/m^2
As 1 mm/m^2 corresponds to 1 l/m^2. The absolute volume of rainfall is 10 liter

The Intensity describes the velocity of the rain at which rate the rainfall falls from the sky. For example, when the volume of 10 mm rainfall, occurs in 1 hour: 10 l/h
Basing on the rainfall intensity the flow rate can be calculated:10 l/h * m^2
The flowrate is one important value for the dimension of Stormwater facilities.

The Duration describes the timespan of a specified storm event.
The Frequency describes 'the storm return period' of a specified storm event, regarding its volume and duration. In statistical analysis it means the exceedance probability, that the event will be exceeded in a specified time period, which is almost one year. T=1/p. In case of a 2% probability of a specified storm, we could expect it every 50 years: T=1/0.02=50.

To design infrastructure which is supposed to fulfill flood protection issues those values are important to calculate the occurring Runoff (Stahre und Urbonas 1990). In contrast to grey infrastructuree, which is placed underneath the city, green Infrastructure can include: swales, channels, gutter, raingardens.
Rainflow intensities, volumes and durations are necessary to calculate the occurring Runoff.

The usual situation in Asia, at least during the monsoon season, can be described as fast rainfall with 'fat' drops over a relative short duration. As climate Change means an intensification of the hydrological cycle, where precipitation forms the most important part, it is considered that rain events will become more frequent and strong in future.

Another value, the ‘time of concentration T’, which describes the response time of a watershed to transform rainfall to Runoff, can become important, especially in large watershed areas. This value is based on the design of the surface, its vegetation and slope, as well as infiltration capacity. Hydrologists can use the volume, the intensity and the response time to calculate the peak discharge of a watershed, which happens after the surface is saturated and the masses starts to flow. It can be described as a ‘wave’ which starts to move. This ‘peak Discharge’ has the highest potential for destruction, as the Runoff after the peak can be seen as a direct translation to the rainfall, which is usually lower in its volume. Therefore, a proper Calculation and management of these water streams must be the basis for designing flood protection

4.6.1 Designed Storm

The most important tools for engineers, to calculate the peak flows of rain events are the Intensity - Duration Charts (IDF). Records of rainfall data of the last decades are being analysed, compiled and transformed to estimate the occurrence probability of similar volume, intensity and duration of rainfall events (Stahre & Urbonas 1990). Engineers can use this empirical data to calculate the expected intensity for a given rain event, with a selected occurrence probability.

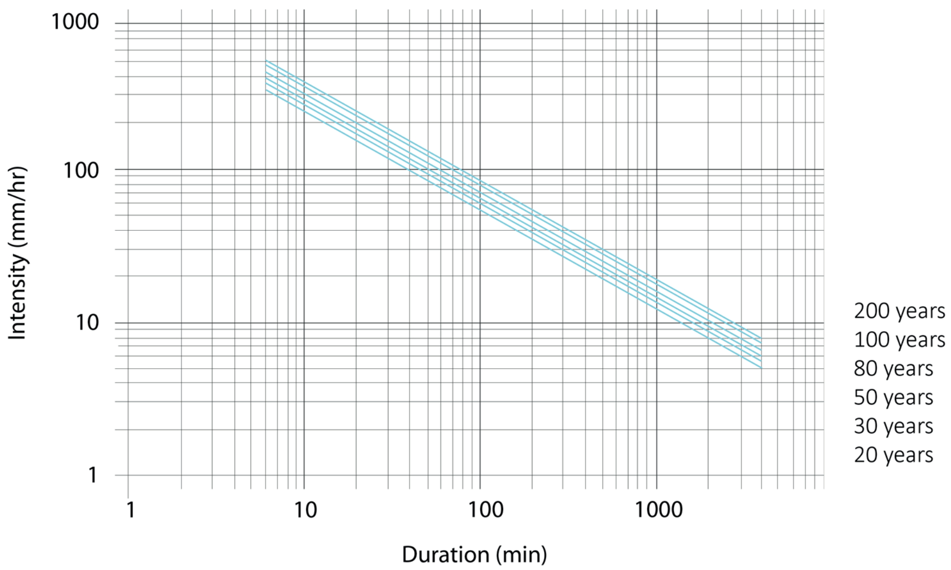

fig. 27:
IDF Chart for Ha Noi.
Source: Trevor and Tabios (2008)

By analyzing the graphs above, it becomes clear that in Ha Noi the occurance probability of a 2 hrs rain event, which brings 30 mm of rain, is 20 years. For instance, the probability for the same designed storm in Shanghai is 25 years.

By combining this with the existing watershed, which means structure of the soil, its vegetation and its slope, it is possible to calculate the Runoff and discharge rates, which are the basis for the flood protection and the basis for the dimension of the green infrastructure.

Several methods are available to calculate the Runoff volumes. Among the most applied one is the SCS methods. An example Calculation for the Runoff volumes, including retention times for a 5 years storm event, a 20 years storm as well as a 50 years storm event is given in *Chapter 8*, with details in the Appendix.

By designing the watersheds retention areas for the occurring Runoff volumes, it must be considered that the space inbetween buildings is limited. Therefore, the areas can be designed for a twenty years event and be equipped with overflow structures in case of its exceedence. Those overflow structures can be designed for a 100 years rainevent and convey the Runoff to special retention zones, which can handle more volume, in case of a 100 years strom.

4.7. Conclusion natural flows

The Runoff from roofs, and green spaces is characterized by a relative high quality and low nutrient concentrations. Both streams can be considered within this research project. The Runoff from streets and parking lots, as well as other places like the garbage storage zones might contain chemical elements and more pollutants, which are hard to filter and is thus not considered.

The described Chapter above, underlines the need of carefully selected roof materials, which are characterized by a low roughness to ensure in combination with a sloped roof a high Runoff Coefficient. A Runoff Coefficient from 0.95 or higher is therefore easy to achieve for roof Runoff. Sloped roofs can be seen everywhere in Asia, there-

fore the influences on the architecture are less, or zero, as this typology already exists. The use of the right material must ensure that heavy metals, or other particles which are related to the construction don't leach into the Runoff.
For the green spaces a Runoff Coefficient of 0.5 seems realistically and easily achievable. The RC is a theoretical value, which bases on the empirical evaluation of different rainwater patterns, soil structures, vegetation covers and slope gradients. However, it must be noted that this theoretical value is highly dependent on the local context and therefore might differ to both sides, although it is likely that it varies from 0.6 to 0.8. Examples from Watershed managers can be found in the literature, where it was expected that a Runoff won't occur due to infiltration capacity and vegetation structure on the ground but significant amounts of Runoff were observed. Furthermore, the Runoff Coefficient increases during the monsoon season, as the soil is saturated and the rain events often occur.

In the humid tropic areas, it is common to calculate water retention or storage ponds by considering a Runoff Coefficient of 0.5 (Silveira et al. 2001). This gives further evidence that an assumption of RC 0.5 is sufficient for further research in this Dissertation.

Furthermore, the Runoff Coefficient can be significantly improved by using biotechnical engineering, like textiles or drainages.

For the concept development of resource Water it is assumed that Runoff from green spaces can be calculated with an RC 0.5 and Runoff from the roofs with RC 0.95.

Calculating infrastructure for Flood protection is a highly complex task. On the one hand it is necessary to increase the Runoff, while on the other hand flood protection is a major issue.
Taking into account that an urban structure, e.g. a lawn, is designed with a slope of 6% produces a high volume of Runoff, it can also be used to improve flood protection by the controlled conveyance of the stromwater to the lowest point and therefore protects the elevated areas from floodings. The combination of flood protection and Runoff collection, as well as retention treatment is from further importance for this research project.

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5.1. Household water use or the ‚domestic flows'

Domestic flows contain any water which is used within a household or community. This includes water which is used for food preparation or other purposes in the kitchen, as well as shower water, water from any hand basin, laundry machine and the toilet flushing.

In case of toilet flushing the used water is considered as blackwater, as this contains human faeces and coliform bacterias. The other sources can be described as greywater, while there a differences in the characteristics of the water. Water, which is collected from the kitchen and the dish washer is characterized by relatively high level of nutrients, oil, fats, and bacterias, while the water from the shower or hand washbasins is usually less polluted. The greywater from laundry services highly depends on the used detergents, which might contain significant amounts of Phosphorous. Furthermore, local behavior can influence the water quality.

These domestic water flows have different characteristics in comparison to the above described natural flows and are much higher polluted though. They are constantly available and have no significant changes in their volume, which renders them to a relatively easy controllable flow as long as they are not mixed with urban Runoff, which dilutes it in the case of rain events.

The average supply rate for Tapwater in Vietnam can be estimated to an average of 80 – 90 liters per Capita per day, whereas a peak of 130 liters per day can be identified in large cities (ADB 2010), and is therefore comparable to german value of 111 liters per capita per day (DWA 277).

Due to a lack of data, the poor quality of the water grid and differences in households being only connected to the municipal water supply, while others are using additional private wells, it is difficult to estimate the exact values of grey and blackwater. Also, the individual behavior of the families complicates the assumptions even further.

In context of the resource Water families live rather in multi story buildings, than in single households. This leads to the assumption that the water use is comparable to the german distribution pattern, while taking into account that more water is used for personal hygiene due to the tropical climate.

Use:	Germany	Vietnam (estimated by the author)
Toilet:	33	33
Hygiene:	44	63
Laundry:	15	15
Cleaning/Gardening:	7	7
Cooking drinking:	5	5
Kitchen/dishwasher:	7	7
Total:	111	130

Recycling of these waterflows and the energetic use of the side products of the treatment processes, like sludge, as well as the recovering of nutrients like Phosphorous, are in the focus of several research projects all over the world (e.g. Semizentral / CuveWaters, both funded by the BMBF, Germany).

Modern technologies like reverse osmosis allow the recycling of nearly any water despite the high energy demand, which is necessary for the treatment process and the necessary post-treatment of the effluent, as the water is pure H_2O. In addition to these technical issues recycled domestic waters also have to face a lot of obstacles regarding their acceptance in the public. The processes that are happening are usually in a controlled technical environment and completely evacuated from the public. The recycled water is mainly used as toilet flushing water.

In recent years, especially in Germany, the reuse of greywater was more focused on as several household tried to run their laundry with recycled greywater from the bathroom. However, this is not allowed by law, since the Trinkwasserverordung (2001) regulates domestic water use in Germany and requires the highest qualities for the following purposes:

personal hygiene and bodycare (article 3. a), the cleaning of stuff which comes in contact with foods (article 3. b) and the cleaning of stuff, which is in a permanent contact with the human body (article 3. c).

The third paragraph was in focus of the discussion whether it should be applied to laundry or not.
Although the local authorities usually don't allow any other use for the laundry except of Tapwater, several judges in Germany stated that the strict use of Tapwater for laundry should be reconsidered. According to them the use of water which doesn't fulfill the requirements, e.g. rainwater, should be allowed (BVerwG 2020.2011.BayVGH 2009, VW Würzburg 2008, VG Arnsberg 2005). These decisions, underline that a change in the perception is already happening in Europe and that people start to rethink conventional Water use. In 2016 the DWA goes one step further and explicitly allows the use of greywater for laundry machines after mechanical, biological treatment and disinfection (DWA M277 2016:18).

This development, and the changes in german laws, that are usually relatively inflexible, can be described as a small shift in the perception for water reuse.

Closing the water cycles and the reuse of the domestic streams is therefore an important point to save water and improve the situation, especially for areas which can be seen as water scarce.
One of the main ideas for this doctorate is the assumption that people who are able to see, smell and touch reused water in a natural environment will probably reduce their obstacles and use the water for domestic purposes.
From an architectural perspective the development of water technologies happens extremely intransparent and thus still contributes to the public perception of the reuse of water being a very dirty source, that should take place out of sight, out of mind.

If the Expectations of the UN (2014) would become true and in 2050 66% of the global population would live in cities, we have to develop new solutions. The classical approaches of the centralized infrastructure cannot be feasible anymore: Treatment facilities have to become part of the urban areas. Therefore, treatment technologies, which require less space by delivering good results are introduced in the next Chapter in the context of the domestic water flows.

5.2. Greywater

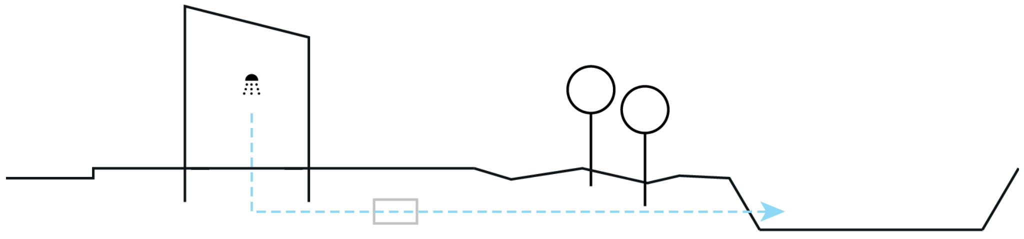

fig. 28:
Domestic Flow: Greywater is mostly collected from shower and personal hygiene.

Greywater can be divided into light polluted and heavily polluted. The shower and wash basins water, which is mostly used for personal hygiene purposes, is characterized by low nutrients, low bacteria's and low contamination, and thus requiere a comparable low treatment level to be ready for its reuse. In europe, these waters are regulated by the "bathing water guidelines", as well as the EU-Guideline 2006/7/EG and since 2017 DWA M277, which give the opportunity to recycle greywater within an urban context. For South East Asia, China and Vietnam, comparable guidelines are available.

Light polluted Greywater:	Hygiene:	63 L/C * d
	Total:	63 L/C * d

5.2.1 Characteristics

Country	COD	SS	NH4N [mg/L]	N [mg/L]	P [mg/L]	E. coli	Source
Germany	150 - 400	35 - 70	4 - 16		-		fbr H201
UK	367 - 587	58 - 153		6,6 - 10.4	0.2 - 0.8	2*10^3	Laine (2001)
UK	96,3	36,8		4,6	<4	3.9*10^5	Birks et al. (2006)
DK	142 - 600		5,2		0.6	1.4*10^5	Eriksson (2007)

tab. 7:
Greywater characteristics. light polluted

Greywater which is collected from the kitchen and the laundry machine, requires a higher treatment for its reuse as this flow contains more bacterias and pollution. The potential of its reuse becomes clear, when taking into account, that the dishwasher, the kitchen and the laundry contributes up to 40% of the daily greywater flow (DWA M277). Therefore its recycling can be considered as an important water source. Although the highly polluted greywater has different characteristics, it is considered within this doctorate.

Highly polluted Greywater:	Laundry:	15
	Kichen/dishwater:	7
	Cooking:	4
	Cleaning:	3
	Total:	29 L/C * d

Country	COD	SS	NH4N [mg/L]	N [mg/L]	P [mg/L]	E. coli	Source
China	250 - 1111	36 - 1475	0.3 - 7,4	5,2 - 34	0.7 - 2.7		Chen (2006)
Israel	702 - 984	85 -285	0.1 - 0.5	25 - 45	17 - 27	9*10^4 - 10^8	Gross (2006)
Germany	235,0			4,3	0.4		Hegemann (2001)
Germany	258 - 584			8 - 17	3 - 8		IWA
Nether-lands	600.0			13.0	7,0	1.2*10^5	Knerr (2008)
Vietnam	208,0	63.0		24,3	4,9	4,7*10^3	Paris (2010)
Malaysia	212.0	76,0	12.6	37,0	2.4		Morel and Diener (2006)
Nepal	411.0	98,0	18,0		3.0		

tab. 8: Greywater characteristics, including laundry

The difference to the Greywater which only contains shower and wash basin, is the higher nutrient load. While the light polluted Greywater contains phosphorous which is usually less than 1 mg/L, it can be far higher when the laundry is included.

The decision for the right treatment is based on several factors: Beside the needed water quality, the required space (which includes construction & maintaining space), the vulnerability and reliability must be taken into account. Furthermore, by designing those treatment facilities for a community, emmissions, like noise, odour, garbage disposal and influences due to maintaining and/or breakdowns must be considered.

As Greywater is in comparison to blackwater relatively light polluted, conventional technologies can be considered, as they achieve good results. The basics of water reclamation, as well as technologies, which fulfill the requirements, are described further in the *Chapter* 5.3.

5.3. Blackwater

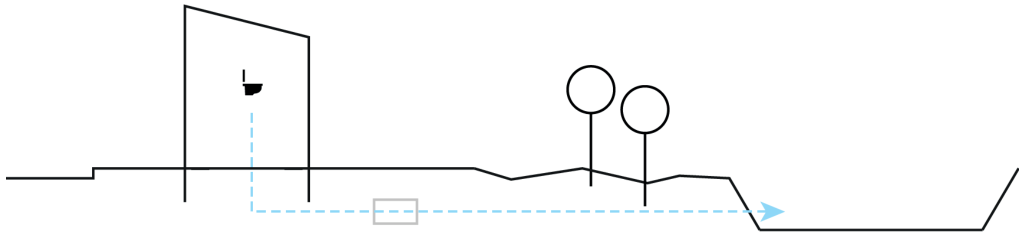

fig. 29:
Domestic Flow: Blackater is used for toiletflushing

Blackwater are these parts of the domestic flows, which are in contact with human faeces, therefore water which is used for toilet flushing. It therefore contains high organic loads, high nutrients, and coliform bacteria's, which are a threat to human health. Blackwater needs intensive treatments, which has to ensure an appropriate effluent quality.

Within resource Water blackwater is considered to be a Water source, that can be used but without a priority. Modern treatment facilities are able to achieve effluent results, which correspond to those of greywater treatment and research sometimes indicates, that a diversion of greywater and blackwater is not necessary the best option (Tolksdorf 2018).

As blackwater recycling is by far a more intense obstacle than, greywater recycling it is considered as optional in reSOURCE Water.

Blackwater:	toilet flushing:	33	L/C*d
	Total:	33	L/C * d

Different options are available for the treatment of blackwater streams, which are characterized by several benefits and obstacles.

As the idea of this doctorate intends to close the water cycles in a relatively small scale, safety issues are from major concern. the Advanced Membrane Biological Reactor ('MBR') is the only technology, that produces a bacteria and pathogen free effluent. this technology is further discussed for the blackwater stream, which follows the conceptual design of the project "Semizentral - Ressourceneffiziente und flexible Ver- und Entsorgungsinfrastruktursysteme für schnellwachsende Städte der Zukunft" (#02WC-L1266A) where the 'MBR' was discovered as the most feasible technique. More informations are avalaible under: http://www.semizentral.de.

5.4. Basics of water reclamation

5.4.1 Biological degradation

Biological transformations of dometic wastewater constituents and pollutants require the activity of microbial communities (IWA,2001:1). These activities, the different stages and the different processes are complex natural processes, which are not subject of this dissertation. Nevertheless, it is important to understand the main aspects as well as the basic knowledge of the activated sludge technologies as a biological process. The Activated Sludge Technology is amongst the most important technologies in current municipal wastewater treatment processes. Resch and Schatz (2011) describe it as an artificial imitation of natural processes, which happens for example during the self-cleaning of natural rivers. The natural cleaning power of surface water is based on different bacterias and microorganisms which can be found in the water and in the soil. Therefore, a wide range of complex chemical and biological reactions occur under different conditions: aerated, anoxic or unaerated (ibid:61). After a while the different microorganisms found a healthy river environment undermine most of the biological constituents of the pollution and the river recovers its ecological balance.

By simplifying these processes the same results may be achieved inside a bioreactor in a controlled steady-state environment, which is the basis for wastewater treatment. This artificial reactor is more powerful and requires less space due to the control of the concentration of microorganisms and bacterias, as well as the nutrients and the dissolved and solved oxygen, which are required for them to live and grow (IWA, 2001). This artificial environment is called 'activated sludge technologie' and was first discovered by Ardern and Lockett (1914). The raw-water which was filled into the 'reactor', meets in different controlled phases, different stages of aerobic, anoxic and/ or anaerobic conditions, which creates an environment where microorganism and bacterias can grow and degradate the biomasses in their natural components. Due to this technical control the bioreactor is much more effective than a river under natural conditions, although these processes might further contribute to the water quality in the retention lake of reSOURCE Water.

As shown in Fig. 28 the basic system of the activated sludge technologie consists of three main components:

The aerated tank (biological reactor) (1), the settlement/clarifier (2) and the recycled sludge transportation system (3).

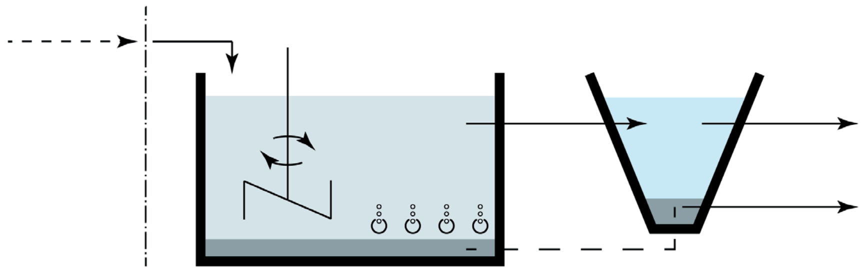

fig. 30:
Conceptaul illustration of the typical treatment steps for domestically used water.

After pre-treatment, which mostly consists of sieve or screen and a grid chamber, a sake and an optional sedimentation tank, the raw-water influent will flow into the aeration tank, which is in fact the starting point of the 'active-sludge treatment'. This first tank is artificial aerated and /or equipped with a mixer. The aeration of the raw-water increases the amont of microorganisms and bacteria's, since oxygen is important for the growth of the microbes (aerobic). The mixed, aerated water then flows into the clarifier. As the clarifier is not aerated the sludge will separate from the water and settle on the ground (anaerobic/anoxic). The bacterias which are already grown inside the settled sludge can now maximize their community by using the nutrients of their environment as their food source (anerobic/anoxic). This so called 'activated sludge', which is characterized by huge masses of different bacteria's and microorganisms, is pumped back into the aerated tank. The growth rate of the microorganisms are recycled and pumped back increases again as soon as the recycled stream meets the influent (IWA,2001:1), and thus 'new' nutrients. Due to this effect, the amount and efficiency of the microorganisms and bacterias, which degradate the biological constituents (i.e. the carbon compounds) increases appropriate in each cycle until the system reaches a biological balance of bacteria's, microorganisms and carbon compounds/nutrients.

Beside the reduction of the carbon compounds, which is measured as BOD/COD and the biological degradation of Ammonium (NH_4), the main goal of the municipal water reclamation is the elimination of the nutrients, like phosphor. As the Phosphor concentration is higher in greywater, than in the first section described Stormwater Runoff, it's removal is particular of interest, before the water got discharged to the lake.

A detailed look of the environment and the different kind of bacteria's, which are necessary for the cleaning power of biological reactors, was done by Henrik Petersen (1999:45). He characterized the following types:

Autotrophic bacterias:
During the aerated phase, the autothropic bacterias are able to oxidize ammonium NH_4 to nitrate (NO3), which is important for the heterotrophic bacterias during the anaerated phase (Resch and Schatz, 2001:61).

$$NH_4 + 2\ O_2 \text{ -> } NO_3 + 2H^+ + H_2O + \text{Energy}$$

This process is called Nitrification. And is particular important for the Water Resource Management System, which is further described in *Chapter 6*

Heterotrophic bacterias:
During the aerated phase, the heterotrophic bacterias use oxygen for the subversion of carbon compounds. This leads logically to a decreased level of carbon compounds in the water, which is measured as COD and BOD, and which can be seen as the most important target of water reclamation. Beside that aerated degradation of carbon compounds, the heterothrophic microorganisms can change their metabolism to a nitrogen based one, during the anaerated phases, leading to a decreased level of nitrogen (Resch and Schatz, 2001:S.61).:

$$NO_3 + 1/2\ H_2O \text{ -> } ½\ N_2 + 5/2O + OH^-$$

This process is called Denitrification. And is particularly important for the Development of the WRMS.

5.4.2 Phosphate removal

The Poly-P bacterias belong the the heterotrophic group and are able to bound phosphate with their molecules under an aerobic environment. They can be extracted from the water after a couple of biological reactions in an anaerobic environment. According to Resch and Schatz (2010) usually 20 - 40% percent of phosphate can be removed during the biological treatment.

This amount could increase through a modification or combination of the different stages or by adding metal salts to the SBR to force a chemical reaction to Phospormetal compounds, which can then be easily removed with the sludge. This reaction occurs in natural waters, as metalsalts, such as alum or iron are natural compounds of the soil (refer *Chapter 6*). In cases where the concentration is high enough this reaction can significantly contribute to the Phosphor Inactivation of rivers and/or lakes.

$$[PO_4]3- + FeCl_3 \text{->} FePO_4 + 3Cl-$$

5.5. The decision for the right reclamation technology

Several water reclamation technologies have several impacts to the design of facilities and to the environment, if they are designed within an urban context. The following parts introduce three Technologies, which can be considered applicable within dense urban structures since they require less space than conventional treatment facilities while reducing the negative impacts on their environment. Two of them are extended developments which are based in their core of the activated sludge processes, while the third one is based on the biological purification.

5.5.1 The Sequenced Batch Reactor (SBR)

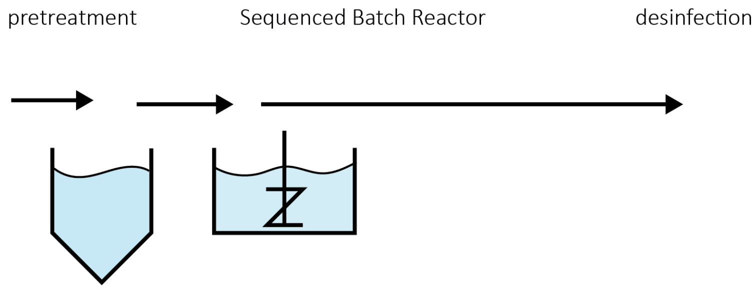

fig. 31: Conceptual Illustration of an SBR

The SBR (Sequencing Batch Reactor) is one of the modern systems which uses the activated sludge technology to improve the used water quality. Instead of different continuous-flow tanks, including a sludge recycling as shown in the previous Chapter the SBR uses only one tank. Inside this tank everything occurs sequentially. That means that the different steps of the cleaning process are characterized by a chronological order, without changing the tank. The influent of the raw-water is normally the first step, and happens intermittently, and so does the effluent, as the last step. In between those phases are different steps which can provide aerated, unaerated or anoxic conditions, and which exact duration and combination depending on the expected cleaning results.

Referring to IWA (2001:3) a typical process cycle could be described as follow:

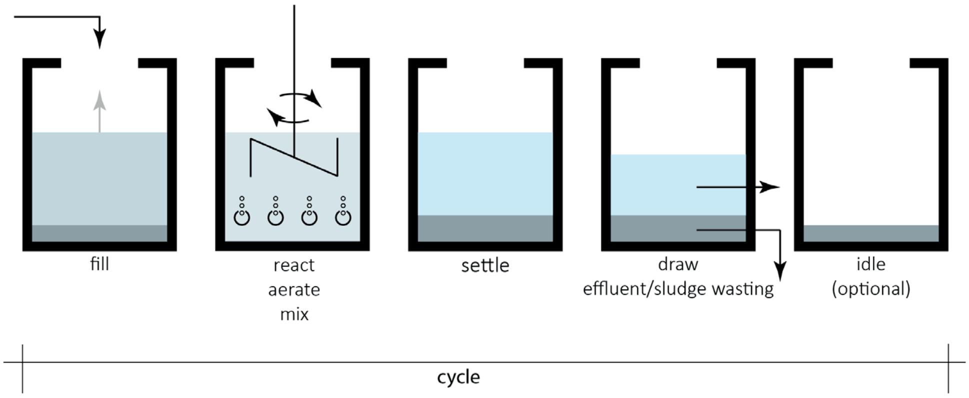

fig. 32:
Different phases of
an SBR process

During the filling phase the raw water will flow into the tank. Afterwards, the treatment continues with the reactive phase, where the water is normally mixed or aerated. Finally, the microorganisms start to subvert the carbon compounds. In the third phase the biomass/sludge can settle on the bottom and the treated water can be withdrawn. The sludge remains in the tank and is mixed with the influent of the new raw water. After a possible idle phase, which may not be necessary, a equalization or holding tank or some other method is available to collect the water before it flows to the reactor. The surplus sludge which accumulates after a while can be wasted at any time, depending on the system. Aerobic, anoxic and anaerobic reaction occur constantly, and help to grow the microorganism which improves the used water.

Many of the SBR concepts use a pre storage tank to balance different concentrations of the wastewater, as well as the occurring amount, which is very variable due to a day-cycle. People shower in the mornings or evenings, which causes some peak flows. In contrast to the nighttime when everybody sleeps the occurring water is very low. With this kind of installation the biological processes can be decoupled from the influent fluctuations (Schreff, 2004), which is also interesting for safety and maintenance reasons. Within the last years the prestorage tank was also in the focus of researches to increase the efficiency of the SBR's

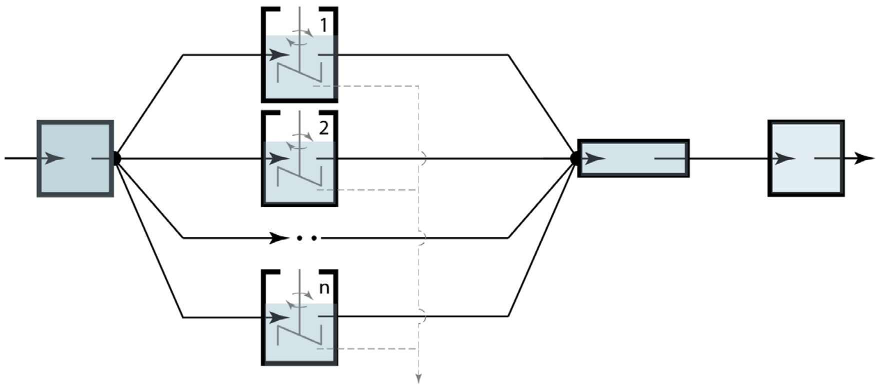

fig. 33:
Design Scheme of a typical SBR.
(adapted from IWA 2001)

After the optional prestorage tank an SBR system is composed usually of different reactors, which can be run either parallel or alternating. Due to high differences in the inflow amount of water, it is often part of the concept, that not all the SBR Reactors are running all the time. Depending on the hydraulic load, some reactors could be shut down, or just run in a supporting way during the peak hours (Schreff, 2004).

The SBR has proven to be an alternative to continuous-flow systems in carbon and nutrient removal (Artan et al. 2001). It was originally designed as a low-tech solution to reduce the carbon compounds, as well as phosphorus (Scheumann, 2010). Due to a couple of modifications the SBR has also achieved good results regarding nitrification and denitrification (Kargi and Uygur 2003; Ketchum 1997). The easy flexibility concerning adjusting, modifying or combining different phases, as well as the one tank concept is one of the main differences to the common active sludge treatment.

In the year 2000 more than 1300 SBR plants could be found in America, to treat up to 40.000 m^3/day. Most of them were integrated in the municipal wastewater treatment with a capacity up to 4.000 m^3/day. (IWA, 2001)

The SBR Technology can be used for Grey and Blackwater. Typical performance values are listed below:

SBR Greywater:

COD [mg/L]	BOD [mg/L]	TS [mg/L]	TN [mg/L]	NH4N [mg/L]	TP [mg/L]		
12	7	23		6,2	8,7	Source:	Lamine et al. 2014
82+/- 47			31+/-20	0.35 +/- 0.2	4,4 +/-2	Source:	Hernadez et al. 2010
13.2	2.7		3.2	<0.5	0.4	Source:	Regelsberger et al. 2009

tab. 9:
Greywater perfomance of SBR

SBR Blackwater:

COD [mg/L]	BOD [mg/L]	TS [mg/L]	TN [mg/L]	NH4N [mg/L]	TP [mg/L]	Source
24,4	6,2		5,8	0.9	1	Rotaria
69	12	10	9	-	1	Biogest international
60	10	10	10	-	1	Biogest international
50	5	10	10	-	2	Biogest international

tab. 10:
Blackwater perfor-
mance of SBR

5.5.2 Rotating Biological Contactor (RBC)

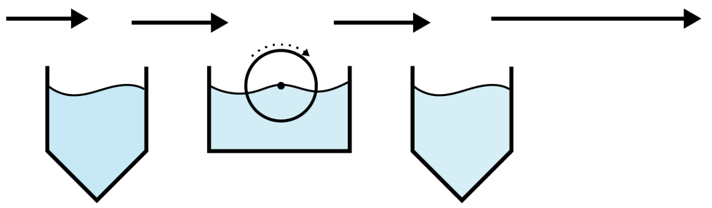

fig. 34:
Conceptual Design of a Rotating Bioloigcal Contactor

Another technology is the rotating biological contactor ('RBC'), which can be seen as a low tech solution. After a primary treatment, including a screening and settling chamber, the raw water is pumped in the RBC reactor. The RBC reactor contains rotating disks (2 – 4 m in diameter), which are mounted on a rotating shaft in a distance of 6 to 8 cm. The shaft is installed closely over the water surface which means that 40% of the disc surface are submersed.

The surface of the discs is equipped with a material which supports biological growth on it. During the rotation of the disk, 95% of the disc surface and the bacterias are intermittent exposed to air and water, which corresponds to the classical aeration. bacterias which grow on the surface are hence able to subvert to biodegradable ingredients of the raw water during their submersed stage. After their submersed stage, they are exposed to air again, ultimately Oxygen Depletion won't occur.

Furthermore, the biological layer on the disks is characterized by anaerobic zones underneath the aerobic zones, which can support nitrification processes. By using a RBC different modules and stages can be installed, depending on the intended performance for the effluent quality and the quality of the rawwater. Usually several stages are applied in a row while in the first stages, the carbon degradation takes place and the later stages are characterized by nitrification processes. The effluent is withdrawn through a sedimentation basin, which clarifies the water from solids and oxidized materials.

Benefits of the RBC are that this system requieres relatively low space and that the use is easy and de facto free of maintenance. A good feasibility can be described for dimension around 5000 L greywater per day, which corresponds to 500 inhabitants. The size for such a system can be estimated to 20 m^2.

Without further treatment the effluent characteristics are only suitable for toilet flushing, according to the german DWA. The further use of the effluent, for instance for laundry purposes, requires at least disinfection and or further polishing activities, depending on the effluent quality.

The energy demand of an RBC can be estimated to 0.04 to 0.1 kWh/m^3, which is very low compared to other technogogies.

The typical effluent characteristic of a RBC used in a greywater conception is listed below:

COD [mg/L]	BOD [mg/L]	TS [mg/L]	TN [mg/L]	NH4N [mg/L]	TP [mg/L]	Source:
	5 +/-0.5	2 +/- 0.2	0.3 +/- 0.03			Abdel-Kader 2013
7,6	3.8	1.7	0.2		0.5	Baban et al. 2015
6,6	5,6	3	0.9		1.1	Baban et al. 2015

tab. 11:
Greywater effluent quality of the RBC

The application within a WRMS in the context of this doctorate can be discussed for greywater, which is lightly polluted.

5.5.3 Advanced Membrane Biological Reactor (MBR)

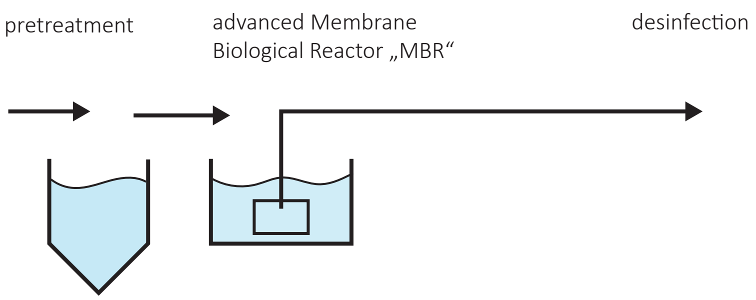

fig. 35:
Conceptual Design of an MBR. An additional clarifier is not neccessary.

Advanced membrane technologies can be described as the combination of biological wastewater treatment and an additional filter process, which replaces the settling tank in the post treatment. While first membranes were tested already in the 1960's the technology was expensive and the economic value of a clear effluent was lower, compared to today. Furthermore, the technology was relatively vulnerable as the membranes had to deal with fouling issues, which happened during the process.

In recent years a lot of research about this technology made it more feasible and resilient. One of the most important changes, in contrast to the first membranes, was that the membrane module was placed and submerged within the biological treatment tank, which requires less space and merges two treatment steps together. Aeration of the membranes module further reduces the fouling issues and the membrane surface is used more effectively. Aeration of the modules is one of the most important factors in the modern MBR technologies, regarding to the process performance, which further improves the effluent quality. The lower operational costs, in contrast to the first generations of MBR's´, lead to an incrase in the installed MBR's since the 90s. New research, especially regarding the oxygen demand and the solid Retention times within the reactor, further improved the quality, which helped the MBR to become a feasible alternative for municipal water reclamation.

The technical evolution showed that almost perfect results for any kind of water flows can be feasible.

After the used rawwater is treated in the biological tank, where microorganisms subvert the organic compounds and bound the nutrients, which settle to the sludge, the water got withdrawn through the membrane module. The quality of this withdrawn water depends on the used membrane module, which works as a filter for solids and other ingredients, based on the meshsize of the membrane (0.2 – 0.04 Micrometer)

Membrane modules are available in different mesh sizes:

- Microfiltration
- Ultrafiltration
- Nanofiltration
- Reverse Osmosis

Microfiltration thereby starts with a mesh size of > 50 nm , which filters solids, turbidities and bacterias. A pressure of 0.5 – 5 bar is necessary for the procedure (Zularisam et al 2010).
The effluent is not free of pathogens, but is ready to use for toilet flushing within private properties (DWA M277).

Ultrafiltration goes one step further and filtrates the water through a mesh size of 10 nm. This leads to an additional filtration of macromolecules, viruses and colloids, which in fact produces water that fulfills the characteristics to “Trinkwasser”. Its usage as ‚Servicewater‘ is therefore allowed in private properties and public spaces.
The pressure which is needed can be estimated to 0.5 to 5 bar (Zularisam et al 2010).

Nanofiltration uses a mesh size of less then 2 nm. Beside the above described filtration capacities of the mico and ultrafiltration, nanofiltration can filter divalent ions and nearly all organic substances. This system requires a constant pressure of 1 to 15 bar (ibid). The effluent is partially demineralized, which requires further treatment steps for its use as drinkable water, like enrichment with salts.

Reverse Osmosis, only allows solved molekules to enter the membrane since the last filter technology uses mesh sizes smaller than 0.001 µm. The pressure must be higher than the osmosis pressure, which can reach up to 50-80 bar (ibid). The effluent of the RO Membranes is completely demineralized and is equivalent to distilled water, which requires further treatment before its use as drinkable water. Reverse Osmosis is often used in desalination plants, where seawater is turned into drinkable water. Singapore's NEWater bases on Reverse Osmosis, as an additional treatment process after a classical Microfiltration (MF).

The MBR performance decreases with the filtration time, as bacterias soluble and particulate materials deposit in the membrane or get stucked during the filtration process. These challenges have been under investigation since the first reactor and remains the challenging issues for the further MBR development.
Preventing the fouling processes, which ensures the MBR performance might contain complexes backwashing operations, as well as the use of chemicals on a daily, weekly or annually cycle. Those processes require professional staff, which renders the MBR as a High-Tech solution, in contrast to the above described SBR or RBC.

The advanced Membrane technologies can be applied for Blackwater and Greywater.

Typical Blackwater MBR Effluent:

COD [mg/L]	BOD [mg/L]	TS [mg/L]	TN [mg/L]	NH4N [mg/L]	TP [mg/L]	Source:
15-20	3	2	5 - 150		0.2 -5	Veoliawatertechnologies.com
13 +/- 3.3	8 +/- 4	2 +/- 1.19	19 +/- 4,73			Atasoy et al. 2007
23 -24				0.15	0.32	Krebber 2013

tab. 12:
Blackwater effluent quality of an MBR.

Typical Greywater MBR Effluent:

COD [mg/L]	BOD [mg/L]	TS [mg/L]	TN [mg/L]	NH4N [mg/L]	TP [mg/L]	Source:
13 +/- 3.3	<5	2 +/- 0.4	0.55 +/-0.2			Atasoy et al. 2007
164 +/-59	20.8 +/-5,8		0.2 +/-0.2 (NH4N)			Lamine et al. 2012
29	6		22		3	Santasmasas 2013
65		<1	11.5		0.18	Bani-Melhem & Smith 2012
24		<1	10		3.5	Lesjean & Gnirrs 2006

tab. 13:
Greywater effluent quality of an MBR.

5.6. Tapwater

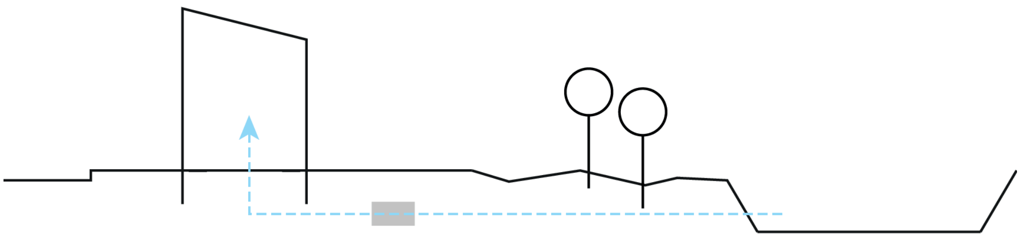

fig. 36:
The Water, stored in the WRMS should be used as ‚Tapwater', or ‚Servicewater'.

An Ultrafiltration (UF) or Nanofiltration (NF) membrane can be used for the production of Tapwater. Whereas an UF treatment with additional disinfection usually reaches the quality standards to fulfill the german 'Tapwater guidelines'.

5.7. Disinfection

Every water flow which is considered to be reused must receive a disinfection after the treatment to ensure safe water in case of contact with humans. This might include a casual contact by splashing water but this also has to include somebody who enters the waters by accident, for instance a playing children. To ensure that the water is not dangerous, a closer look to the European "Badewasserrichtlinie" might be interesting, where regulations for waters are given, which are used for recreation and swimming in inland waters and seawater. For inland water including lakes and rivers the concentration of escheria coli must not exceed 900 cfu/100ml and the intestinale Enterokokken 330/100ml.

Not only the effluent of treatment facilities has to fit into the range, it must be further ensured that pathogen bacterias entering the lake system cannot build a community, which would stimulate their growth.

Several disinfection opportunities are available for modern water treatment, which have their own benefits and disadvantages and must be evaluated in the context of resource Water. A good overview is given by Popp (2001):

5.7.1 Membrane systems

Membrane technologies are able to remove bacterias and viruses by filtering, which in fact produces a pathogen free effluent, even at the lowest meshsize (MF). Under certain circumstances related to fouling, damages in the membrane, or the backwashing procedure, some pathogens can develop communities at the Clearwaterside of the module, which can than flux into the effluent. If a pathogen free effluent is required the membrane must be backwashed and cleaned with the help of sterilising chemicals.

5.7.2 Thermal processes

Thermal processes are the best and safest way to kill all pathogens.
It is used by hospitals and by medical doctors to sterilise and hygenate infectious products, like blood. However, this treatment requires high temperatures (124 Centigrade) over longer periods (20 min), which cannot be generated in a sustainable way. Therefore, these technology is not valuable for the use in domestic water reclamation.

5.7.3 UV technology

The Exposure of pathogens will lead to the destruction of their DNA.
The performance of a disinfection systems which uses UV light depends directly on the ability to enter the whole water. Solids or some turbidities in the water, which can be found in the effluent of SBR or RBC systems, can influence the efficiency. However, in combination with MBR, where the effluent is free of solids und turbidities, nearly 100 % of the pathogens can be killed. The energy demand which is necessary for UV Disinfection can be estimated between 0.04 and 0.1 kwh/m^3.

Furthermore, Studies done by the University of Applied Sciences, Aschaffenburg showed that Water Disinfection by UV-LED Light can further reduce the already low energy demand in future without a reduction of the efficiency.

UV Exposure does not have any side effects. Since UV is also not a dangerous process it is furthermore not necessary to consider security issues or protection zones in buildings, as it is the case with chlorine or ozone.

5.7.4 Ozone O3

Ozone is a very effective way to kill pathogens in waters. It is commonly used in swimming pools and sometimes for the disinfection of Tapwater. Ozone O3 is very instable while it is necessary to produce it artificially onsite by combing dry air and oxygen.
It is highly toxic which requires extensive security measures and the technical removal of residual ozone, which might be available in the water can require further technical steps, such as an additional UV Camber.

From an environmental perspective it can be seen critically as there is a probability of the development of free radicals.

5.7.5 Chlorine disinfection

Chlorine Disinfection is available as a proper and reliable treatment for more than 100 years. The Most common one is the disinfection by using Chlorine gas Cl_2. sodium hypochlorite NaClO, or Chlorine dioxide (ClO_2). It can be applied to biological wastewater, since the pathogens will die after the contact with chlorine. The use of chlorine for disinfection purposes can create organochlorin compounds, which cannot get subverted: Chlorphenol and other haloformes. If chlorine disinfection is used before the effluent is discharged into a river, it is absolutely necessary to dechlorinate the water, as it might affect the ecosystem of the water: concentrations higher than 0.3 mg/L are hazardous for the waters ecosystem and above 0.05 mg/L hazardous for fish communities.

As Chlorine is highly explosive it needs, like ozone, extensive security measures at least at those places where the chlorine is stored.
Many countries in the world are using chlorine as a standard procedure for Tapwater disinfection, so do China and Vietnam. Beside cheap operational costs, other benefits

are that chlorine can successfully supress any regrowth in the whole water distribution grid as long as it is available.

In Germany, the use of chlorine is strictly regulated, which allows its use only in case of an emergency.

If the water should be reused within a closed system, like resource Water, the use of chlorine should be avoided.
If the water reuse concept integrates the use as Tapwater, chlorine can be added as an additional safety barrier. As soon as chlorine is added to water streams it suppresses any biological growth. If chlorine is available in the domestic water streams it is likely that it will further reduce its concentration, due to chemical processes. Although it is likely that the chlorine concentration is very low when those flows reach the reclamation facility it must be ensured that the chlorine is completely removed after the treatment.
An accident that spills chlorine to the WRMS can be fatal and kills any biological communities including fishes, plants and algaes.

5.8. Conclusion domestic flows

Modern technologies can be used to achieve very high water qualities, like the Advanced Membrane Reactor (MBR), where the water has to pass a tight mesh, which prevents viruses and bacterias to pass through. These technologies require professional staff and maintenance, which is not available everywhere in South East Asia. Once Tapwater use is intended within a WRMS the use of this technology is required and also followed by an additional disinfection. However, low tech solutions can be applied in areas which are not easy to reach or in projects, where the intended design goal is the reuse as ‚servicewater'.

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Developing a conceptual design which recycles every drop of water within a closed system can be challenging. The effluents from an advanced Membrane Reactor (MBR) after chemical precipitation (as explained previously in *Chapter 5*), still contain around 0.4 mg of phosphates and 10 mg of nitrates per litre. The runoff from green spaces (see *Chapter 4*) contains 0.2 mg of phosphate and 3 mg of nitrates, which are washed out during events of heavy rain which despite being low in concentration are still important. Thus, the importance of correctly managing these streams becomes clear, especially under the circumstances where the concentration of phosphate and nitrates does not exceed 0.01 – 0.035 mg TP/L and 1mg N/L for a mesotrophic water body.

Additionally, the challenges of WRMS are due to the fact that this system is not natural— it is artificial. The dilution capacity of a closed system is limited in contrast to rivers and lakes under natural conditions, due to the restrictive water exchange. The challenge hence, is to develop or design a structure which can handle the anthropogenic nutrient concentration, while providing a healthy ecosystem which can be beneficial for the residents technically, culturally and recreationally. Therefore, this Chapter aims at describing the microbiology, the interactions between the plants and water and, to formulate a foundation for the design solutions and implications being researched in this study.

6.1. The Water Resource Management System

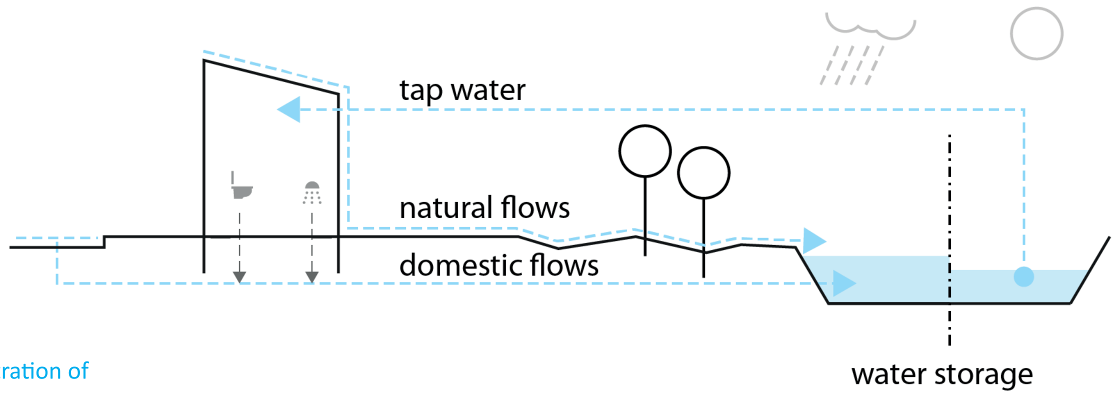


fig. 37:
Conceptual Illustration of the WRMS

The idea of this research is based on the assumption that a WRMS can collect and store as much water as possible, to provide water supply during the dry season. Such a lake system has to face several challenges, with regards to its volume namely:

1. Changing water levels on a seasonal scale, induced by seasonal climate condi tions
2. Changing water levels on a daily base, induced by events of heavy rain
3. Changing water level by evaporation, induced by UV exposure of the water surface
4. Water losses through infiltration to the ground

All of these factors have a huge influence on the structure of a WRMS system. Whether it consists of one or several reservoirs, the system must not only be flexible in its volume but also answer architectural, biological and technical requirements. The next section, thus looks at the resiliency of reservoirs.

6.1.1 The Resiliency

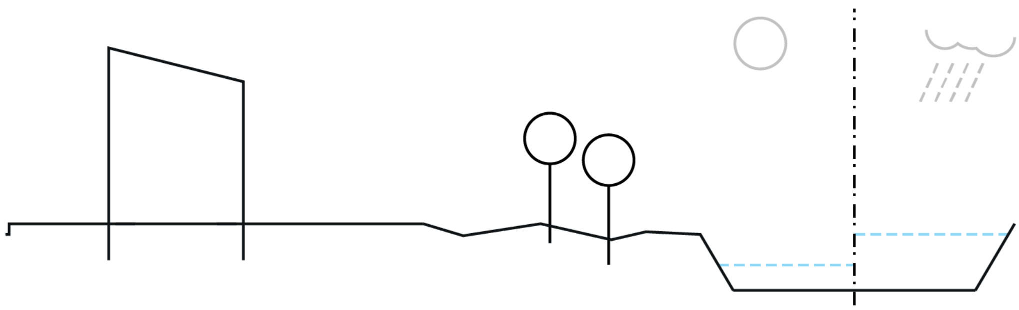
The reservoir system faces varied challenges but one of the biggest is to develop a resilient system, with clear water Macrophytes, which can handle high level nutrients and the effects of eutrophication. A new reservoir doesn't possess a stable ecosystem, which makes it resilient. In addition, the inflow waters are the dominant nutrient source besides soil release, due to the non-existence of the structure which protects the sediments. As a new reservoir doesn't possess any biomass, it is highly vulnerable to algae blooms and cyanobacteria (Jiang et al. 2004:326).

Furthermore, a reservoir which has already developed an ecosystem consisting of—zooplankton communities, fish, aquatic plants and sediment—can be seen as being more resilient. The constituent elements further help in suppressing algae outbreaks. Moreover, research with constructed wetlands showed, that high initial biomass of the aquatic plants reduced light and nutrient availability for algal, which prevented their overgrowth even at high nutrient concentrations (Babourina and Rengel 2014).

Another challenge is the aftermath of heavy rains which leads to —rapid changes in the water level, influences the pH value, washes nutrients, and suspends solids and other particles in the reservoir causing turbidity (Jiang et al. 2014; Ansari 2014). In addition, a hydro-mechanic action can occur due to waves which occur in the inlet structures. This action can directly re-suspend nutrients and algal cells which are bound to the sediments, thus stimulating algae blooms (Xing and Hu 2006; Ansari 2014). The next section now moves its focus towards differing levels of water based on seasons.

6.1.2 Changing water levels on a seasonal scale

fig. 38:
The system is characterized by different water levels.



The different water streams which enter a lake are determined by the time of the year (described in *Chapter 4*). While the daily input in the dry season may be much lower when compared to the monsoon season, the lake has to provide an appropriate storage capacity to function as a recreational area during both seasons. Hence, the WRMS is designed as a storage basin, which must capture storm water during the monsoons to replenish the lower input during the dry season.

While designing such a system, the structure of the shore is considered to be of importance. As the lake's bed is fixed, additional storage capacity must be provided through an extension of the lakes surface. This can happen through namely the construction of more than one lake, an increase in the lake's water level (i.e. depth) or through a mixture of both. Additionally, while a surface extension requires availability of space horizontally, the improvement of the lake depth demands more space vertically. The improvement of the lake's depth therefore, might need infrastructure to protect the existing steep slopes and ensure the constructed deep hole, which can get filled or emptied up to certain level. This in turn adheres to how big scale water reservoirs are designed. Moreover, if the lake shores are accessible, the lake might produce a steep slope or a cliff in the dry season when the water level is low. Within the neighbouring urban space, this can pose a serious risk and isn't a viable option and the technically constructed water reservoir must be protected from being entered, which however is beyond the scope of this study.

An increased lake surface on the other hand face might also present some conflicts with regards to the intended land use and density. Conflicts can arise due technical, architectural or financial obstacles present in the local context, which can lead to space restrictions for the lake. In addition, the design of these "extended areas" must also be considered very carefully as it could potentially attract mosquitos and enhance evaporation. Furthermore, during the dry phase, these areas can get dirty and swampy by sediments which settle down. Lastly, in the case of grasslands or other vegetation getting flooded, the ecological system of the lake might also be posed with the danger of complete oxygen depletion due to subverting and/or decomposing processes.

Therefore, both examples highlight a detailed interaction of the lake system with its surrounding. While both approaches might work from a technical or a nature-based perspective, they should be combined to provide safety, optimized land use and sufficient storage capacity.

6.1.3 Changing water levels on a daily base due to heavy rain

In addition to the seasonal changes in the water volume, the lake also has to handle large input streams due to heavy rain. With regards to natural flow as previously explained in *Chapter 4* (and in the succeeding *Chapter 8*), a 50 years rain event can produce precipitation of 90 mm/hr, which combined with a 350 m^2 large watershed will lead to a runoff from 0,0147 m^3/s that gets carried to the lake from green spaces. This runoff can then lead to an increase in the water level of a 300 m^2 lake surface by 15 cm within an hour. The water streams which enter the lake during rain or afterwards can be very powerful, especially if they occur during a short period. They can damage the structure and lead to the sediments being physical penetrated, leading to re-suspension of bound particles like P, N, K and algal cells. Furthermore, the rapid increase of 15 cm means that the shore structure of the lake has to adapt quickly to the modified environment. This can therefore, possibly influence the use of vegetation and the structure of the lake.

6.1.4 Changing water level through evaporation

Another challenge faced by the system is direct evaporation of the water surface to the atmosphere, making it also a major reason for water losses within the system. As long as the relative air humidity is less than 100%, water tends to evaporate due to UV exposure. Nonetheless, several methods are available to calculate this evaporation. One of the most important and accurate way is the Penman Equation, which was developed by Howard Penman in 1948 (Penman 1948). This model is based on empirical studies and uses the local daily mean air temperature, the wind speed, the air pressure and solar radiation, to calculate reliable values for the water loss. The Penman formula expresses the expected Evaporation in mm/m^2. [1]

$$E_{\text{mass}} = \frac{mR_n + \rho_a c_p (\delta e) g_a}{\lambda_v (m + \gamma)}$$

where:

E = Evaporation [mm/m^2]

m = Slope of the saturation vapor pressure curve (Pa K−1)

Rn = Net irradiance (W m−2)

ρa = density of air (kg m−3)

cp = heat capacity of air (J kg−1 K−1)

ga = momentum surface aerodynamic conductance (m s−1)

δe = vapor pressure deficit (Pa)

λv = latent heat of vaporization (J kg−1)

γ = psychrometric constant (Pa K−1)

1 Details for the Calculation are given in Appendix 9.1.

By using the local climate data of Hanoi, 5 mm/day, which corresponds to 150 mm/ month are lost from each square meter of open water surfaces. By using the local data of Shanghai, the results are 4 mm/day, and 140 mm/month.
150mm/m^2 is equivalent to 150 liter, for each square meter lake surface. This makes clear, that evaporation is a big factor while designing resource water. Deeper lakes, with smaller surfaces, evaporate less water, than shallower, with lategr surface areas. Details in the context of Evaporation are provided in *Chapter 8*, as well as in the Appendix.

Deeper lakes, with smaller surfaces, evaporate less water, than shallow lakes with larger surface areas. By using the local climate data of Hanoi which is 5 mm/day, calculations conclude that 150 mm/month is lost from each square meter of open water surfaces. Additionally, the local data of Shanghai highlights a loss of 140 mm/month, based on a 4 mm/day loss. Conversions show that 150 mm/m^2 is equivalent to 150 liters, for each square meter of lake surface. This helps determine that evaporation is a big factor to be considered while designing resource water. [1]

6.1.5 Water infiltration in the ground

The next factor that influences the lake system is its interaction with the surrounding ground. A natural lake is always in a steady exchange with the aquifers or underground rivers, which not only bring water to the lake but withdraw it. This is part of the ecological system of lakes and reservoirs. The characteristics of these exchanges depend on the attributes of the soil, the depth of the aquifers, the vegetation in and around the lake, as well as the organisms (e.g. fish) who live in the lake. A mostly clay soil structure can decrease or prevent these water exchanges however; a sandy soil supports it.

In addition, a water exchange with groundwater can also be viewed as another input stream for a water reservoir in the context of Water Resource Management System, if the environment allows it. An iron-rich soil, which is often found in Vietnam; especially in the northern parts along the Red River, can also support the lake’s ecosystem

1 Details in the context of Evaporation are provided in Chapter 8, as well as in the Appendix.

by binding phosphorous and therefore, controlling the biological activities. However, arsenic based soil, which can be likely found in Hanoi, can poison the whole lake water, making it difficult for further use. An active exchange between the reservoir and the surroundings can further improve the water quality by removing nutrients and bringing oxygen rich freshwater. Conversely, it can also degrade it by bringing nutrient rich water into the system, which might contain other detrimental substances. Therefore, the exchange in a reservoir can benefit a water reservoir or can potentially cause harm. It is highly dependent on the local context, thus assumptions made without having an exact site are not reliable.

6.2. A subtropical reservoir/lake as a reference for the WRMS

This section aims at providing a broad understanding of the basic processes which can be used to describe the activities that occur in tropical lakes, for urban planners and architects. However, it is not aimed as a biological analysis. While the ecological system of a lake has been discussed earlier (see *Chapter 4*), the following sections refer to the specific characteristics relevant for subtropical lakes to describe the most important differences.

The WRMS, which can be seen as an artificial storage lake possesses some similarities with (tropical) water reservoirs. The changing water levels due to storm water collection correspond with reservoirs which can be found within floodplains in the tropical areas, which may also exhibit higher levels of water during the monsoon season and lower levels in the dry season. Some areas of the littoral zones of both systems are exposed to water or UV exposure during a seasonal change. Additionally, most research on lakes and ecological systems can be found in the temperate regions of the world and focus mainly on deep lakes. Osborne (2004) and Beklioglu et al. (2010) describe the knowledge about tropical limnology as being quite limited. Although scientific research was conducted in the 1980s on tropical lakes (Osborne 2004, Beadle 1981, Payne 1986, Lowe-McConnell 1987), it focused mostly on deep lakes of volcanic or tectonic origin, ignoring small lakes (Crisman & Streever 1996; Beklioglu et al. 2010)

Moreover, Osborne (2004) has described tropical lakes as being characterized by warm water throughout the year, high rate of biomass production, intense solar radiation on cloudless days, high rates of nutrient assimilation, cycling and decomposition. Although previous research has been focused on temperate lakes, several authors (Phillips 2004; Thienemann 1918; Pearsall 1921) state that the basic structure of temperate lakes are comparable with (sub-)tropical lakes. One of the main differences however, is that chemical processes increase in warm water lakes and occur faster (Bloesch 2004; von Sperling 2005). In addition, sub-tropical and tropical lakes are characterized by a different fish community, which are small omnivorous fish which eat zooplanktons, thereby reducing the predatory pressure on algal and potentially stimulating their growth (Beklioglu 2010. Meerhoff et al. 2006; Jeppessen et al. 2005).

6.3. Shallow lakes

It is very likely that any constructed water reservoir within an urban settlement has a depth of less than 3 m due to construction, safety, or land use reasons. According to several authors, a lake is scientifically considered as shallow when allows wind fetch but the mixing prevents stratification. In fact, this can be applied to any lake which has a depth of less than 3 m, as wind induced mixing, and turbulences can reach to the ground beyond that depth (Talling 1992; Dumont 1992). The relationship of the water column to the lake bottom, (i.e. the sediment) is much higher compared to deep lakes, which expand the role of sediments and phosphorous accumulation dramatically (Padisak 2004). This relationship further plays an important role by enhancing decomposition and nutrient regeneration. However, anoxic conditions near the sediments might rarely occur, as oxygen rich water from the surface is constantly conveyed to the ground, due to the mixing due to wind fetch (Osborne 2004).

Furthermore, the littoral zone of natural tropical shallow lakes is usually characterized by wetlands and/or expansive vegetation, which can be identified as a driver for productivity in such ecosystems (Osborne 2004; Wetzel 1999). Inflowing waters can be effectively filtered by the surrounding wetlands, which can be used as a trap for endemic materials. Wetlands which are constructed in the bay areas of a shallow lake, might have a major influence on the nutrient availability for cyanobacteria (Silva 2005).

6.3.1 Enhanced internal nutrient cycling

Apart from external nutrient input by water streams in tropical shallow lakes, phosphorous (which is bound into the sediments) is one of the most important source of nutrients within the lake's ecosystem as shallow lakes possess a higher water surface-volume ratio than deep lakes. It is described that in tropical areas due to a higher energy input, internal loads from sediments are relatively more important than external inputs. This is due to faster accumulation and re-suspension processes in tropical shallow lakes, when compared to temperate lakes (Beklioglu et al. 2007; Meerhoff and Jeppessen 2009).

The nutrient supplies form these internal loads and can be several potencies higher than the external loads. Therefore, lakes in tropical areas can take decades until their ecological production declines, once the external sources are under control (Jeppessen et al. 2005; Sas 1989; Scheffer et al. 1993). In such ecosystems when discussing water management options, the influence and control of the sedimentation-resuspension cycle then becomes a major challenge. The physical removal of the sediments or a chemical treatment are then employed as options to disturb this cycle, to prevent or reduce the impacts of eutrophication processes.

6.3.2 The role of Macrophytes

In tropical lakes, the role of Macrophytes and their influence on the ecological system is more complex compared to temperate lakes. Due to the warm climate and higher UV radiation combined with the increased nutrient cycling, it is possible for all life forms of aquatic plants to co-exist. However, while in temperate lakes; the introduction of Macrophytes can be seen as a key factor in lake management, conversely, they can easily become a nuisance in the tropical lakes (Jeppessen et al. 2005).

Typically, shallow clear water lakes are dominated by Macrophytes and recent studies have demonstrated the role of Macrophytes, within the ecosystem of shallow lakes and the proportion of the lake basin they occupy (Phillips 2004; Carpenter & Lodge 1986; Hootsman & Vermaat 1991). They show strong positive effects on—the water clarity as they provide a habitat for zooplanktons which feeds on algal (Timms & Moss, 1984; Lauridsen et al. 1996; Burks et al. 2002), their roots stabilize the sediments and thereby prevent disturbances (Vermaat et al. 1990; Phillips 2004; Blindlow et al.

1993). A stable Macrophyte crop can develop resiliency against fluctuations in nutrient concentrations and changing pH and oxygen saturation, because they can influence their environment through biological processes. Macrophytes take up nutrients through their leafs and roots. Additionally, rooted Macrophytes do not compete with non-rooted ones since they receive their nutrients directly from the sediments, making them extremely resilient to changes in the water column. Research also indicates that that Macrophytes can produce allelopathic substances which can suppress algal growth (Phillips 2004, Gopal & Goel 1993; Wium-Anderrssen 1987; Hilt & Gross 2008). Macrophytes further, provide a habitat and food for fish, concentrate nutrients in their biomass, and produce oxygen, which in turn supports the lake ecosystem. They also provide a surface for bacterial growth, which conduct the same tasks. Macrophytes can oxygenate the sediments and the water (FAO).

Moreover, the abundance of Macrophytes depends upon multiple factors namely—wind/waves, fish, sediment composition, grazing by waterfall and invertebrates (Phillips 2004; Weinser et al. 1997; Barko & Smart 1986; Sondergaard et al. 1996; Jacobsen & Sand-Jensen 1992; Van Dok & Otte 1996). However, the availability of light amongst all the others is the key factor (Spence 1982). Studies indicate that clear water allows good penetration of sunlight for the underwater parts of Macrophytes, which further stimulates their photosynthesis and reproduction and leads to positive effects on the ecosystem. In addition, due to high UV radiation in the tropical areas. Macrophytes can grow yearlong (Beklioglu et al. 2010) making the process more complex than in temperate lakes. Macrophytes can also develop high photosynthesis rates which oxygenates the water and converts ammonia to nitrate (Denitrification) and can also oxygenate the sediments (FAO). Furthermore, Macrophytes produce oxygen at daytime and respire it at night. Different species of Macrophytes can be characterized by a different relation between respiration and production, which can lead to oxygen saturation, or deficit in the water. Respiration/Photosynthesis rates ranges from 6% to 50% (Pokorny and Kvet 2004; Salvucci & Bowes 1982;) and dense crops of Macrophytes can have large daily amplitudes in the oxygen concentration (Pokorny and Kvet 2004).

The system of respiration and oxygenation must be balanced in theory but the roots can release oxygen for the sediments (Phillips 2004; Wium Andersen & Andersen

1972; Carpenter et al. 1983). This helps in preventing a large scale development of anoxia and re-suspension of phosphorous to the water.

The decomposition of Macrophytes in warm eutrophic water bodies may occur faster than under temperate conditions. Some detritus which contains dead biomasses from Macrophytes might accumulate near the sediments, where oxygen is also required for its decomposition. This may lead to the scenario where oxygen depletion occurs, thereby producing phosphorous, which in turn could enhance the lake's productivity (Pokorny and Kvet 2004). Conversely, it can lead to an uncontrolled growth of the Macrophytes causing them to be a nuisance. This is particularly important in the case of tropical lakes as the natural growing cycle is not interrupted by winter. Examples for this also can be seen widely within rural areas in Indonesia or Vietnam, as a direct consequence of hypertrophic conditions, further stimulated by the discharge of untreated sewage to water bodies. Lastly, these ultra-dense Macrophytes crops are also often dominated by one species (e.g. Salvina Molesta, eichhornia Crassipes), which can create a shade on the whole water surface and may produce completely deoxygenated conditions underneath. After the collapse of the Macrophyte communities, the lake will switch to an algal state.

These processes are described in the literature as an uncontrolled eutrophication processes of Macrophyte dominated water. With the ongoing eutrophication process, the water body can either develop a highly biodiverse crop of different Macrophytes or dense algal matts. In the case of Macrophytes, it is described that only a couple of highly adaptive species survive, which leads to mono-cultural crops before the whole system collapses. Various authors describe this as a third stable system apart from clear water and turbid water, dominated by free floating plants occurring in the tropical areas (Beklioglu et al. 2010; Scheffer et al. 2003). However, it is assumed that the effects of floating Macrophytes are weaker than those of submerged ones and a large floating cover can seriously disturb biodiversity due to oxygen depletion underneath it.

Due to less oxygen in the water, denitrification is thought to reduce phytoplankton, by reducing the N-availability. It is known to increase with increased water temperature (Goltermann 2000. Pinay et al. 2007). Therefore, it has often been described, that warm lakes tend to be more N-limited (Lewis 1996, Drowning et al. 1990), which stimulates the growth of nitrogen fixing blue-green algae. However, according to Beklioglu et al. (2010), the extensive growth of submersed Macrophytes does not lead to lower inorganic N-concentrations in subtropical lakes, which requires further research. To prevent Macrophytes from becoming a nuisance, the management of harvesting is necessary. The manual removal of Macrophytes requires viable accessibility (Wege, Anfahrt und Abfahrt) and storage space for the removed material. Another option could be stocking vegetarian fish, who feed on Macrophytes to control their growth. Several examples can be found in the literature, where fish stocking is a successful bio manipulation technique for Macrophytes (Hosper et al. 2005).

Although a full understanding is unavailable at present of this concept, nonetheless, an increase in the chlorophyll concentration in the water column could also act as an indicator for an upcoming shift to the algal state. An enhanced phytoplankton growth results in light limitation and subsequent loss of plants (Beklioglu et al. 2010).

Moreover, Macrophytes can be seen as an indicator for a healthy environment and although they can maintain a clear water state by suppressing algae growth, they are dependent on clear water for photosynthesis. Therefore, any external influence, which might influence the suspended solids and particles might be seen as a critical 'forward switch', which stimulates algal growth. The conditions for a healthy clear water state of artificial water bodies have not yet been discovered though. It is likely that it could be due to limiting phosphorous below 0.025 TP, which in turn has been observed to limit the phytoplankton growth in the water. Rooted, submerged Macrophytes can also dominate the water by getting their nutrients from the sediments (Beklioglu et al. 2010). According to Kosten et. al (2009), a study of 782 lakes showed that Macrophytes tend to disappear with an increasing nutrient level, leading to the ecosystem to switch to a turbid algal state. The decline of Macrophytes was observed to be the largest between concentrations of 0.05 0.2 mg/L TP. Furthermore, Beklioglu et al. (2010) describes that lakes and ponds which are situated in the tropical areas are much more sensitive to water temperature changes, water level changes and nutrient loadings than their temperate counterparts. Thus, a stable ecosystem dominated by Macrophytes is the preferred situation for a lake system in the context of resource water.

6.4. Algae

Algae can be viewed as a competitor against Macrophytes for nutrients as they are more flexible and can grow faster, which can overwhelm the Macrophytes. Additionally, the is a higher risk of filamentous algae developing in warmer climates. Their dense 'mats' can cover the water surface if their growth is not suppressed. However, as soon as the water column stops receiving sunlight, the pH levels are bound to increase and along with depleted carbon dioxide can pose a serious threat to all other aquatic species (Pokorny and Kvet 2004). Within tropical areas, low levels of carbon dioxide, in combination with rapid nutrient cycling in shallow water also promotes the growth of toxic nitrogen-fixing cyanobacteria. Furthermore, according to Reynolds (1992) shallow lakes are less likely to experience light limitations than deep lakes, which render phosphate and/or nitrogen as critical for shallow lakes. As soon as the lake is limited by nitrogen, the risk of blue-green algal developing becomes high.

6.5. Concluding Remarks

Independent from the existing construct of lakes systems (one big lake or several small lakes), resource water has to deal with issues of—surfaces; which are constantly under water, shallow shore areas; which have to face different water levels, and areas; which can be periodically flooded—to enhance the storage capacity of the lake. It must be noted that lakes rather behave individually (Padisak 2004; Sas 1989; Sommer et al. 1993; Istvanovics & Herodek 1994;Padisak & Reynolds 1998), which can lead to the assumption that lake management is often more an art, than only science. Therefore, flexibility of the system gains prominence within this study and a look towards how engineers can manipulate the system in case of its failure, then designing a technical controlled lake, becomes more important.

6.6. Technical measures to improve the ecosystem of a (sub-)tropical lake

Subtropical lakes are characterized by a high rate of nutrient cycling, leading to an increased biomass production than seen in temperate lakes. This effect is observed to be even more increased within shallow lakes.
Although the lake structure can have a significant influence on the overall system, it has to face a high nutrient pressure from anthropogenic streams, which when compared to a natural system, can be extremely high. There are several measures available

to improve the lake's ecosystem. These technologies are namely physical, biological or chemical and they can be used to improve the self-purifying capabilities of the lake or improve the ecosystem directly.

Most of these measures tend to manipulate the internal nutrient cycling process, through its removal, subversion, or depletion. Other measures include using chemicals to suppress the biomass growth. The following paragraphs therefore, introduce some measures which have been successfully tested for restoration of shallow lakes in different climate zones. In addition, they also provide an overview on the basic processes where some are facing Macrophyte control and others, algal control. A detailed description of these measure can also be found in Restoration and Management of lakes and reservoirs (Cooke et al. 2005) and The Lakes Handbook Vol. 2 (O'Sullivan and Reynolds 2005).

6.6.1 Sediment removal (Algae / Macrophytes)

The internal nutrient loads from the sediment can be considered to be a major source for biomass production, especially in shallow lakes which aren't able to stratify themselves. The nutrients are available all over the year, due to suspension and resuspension processes. Sediment removal (or Dredging) is therefore, considered as a very effective measure to remove nutrients out of the system. In natural lakes, dredging can become complicated due to the use of heavy equipment. The dredged material consists of 90% water and only 10% of solids, also taking into account the drying and deposition times (Cooke et al. 2005). However, dredging can improve the lake's water quality by—removing decomposed materials and nutrients, deepening the lake and reducing Macrophytes in order to avoid them becoming a nuisance. Several examples can be found where dredging has been a part of a successful restoration strategy, although it is usually expensive. Additionally, dredging can also be combined with water level draw down, in order to simplify the access to the lake's sediments. Dredging can re-suspend sediments and lead to highly turbid water, whilst during the dredging operation. Nonetheless, there are several dredging techniques that are available namely from cutter heads with a hydraulic pipeline to dustpan technologies.

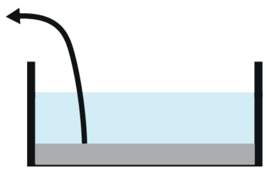


fig. 39:
The removal of the sediments is a powerful measure to manipulate the ecosystem.

However, the manual control of the sediments can be an important measure to control the internal loads. Removal of sediments can be seen as a removal of nutrients.

The influence of the bottom structure has been discussed previously, hence any depressions on the bottom can lead to accumulation of sediments due to wave activities. The removal of these sediments then, can be seen as an effective measure to control the sedimentation within the water net. Thus, the fixed dredging infrastructure installed within the lakes depression zones can easily remove them when designed properly. Wave action can then distribute new sediments immediately to the 'cleaned ones' which leads to a permanent, qualitative control of the lake's internal loads. It must however be considered, that young sediments are usually flocculent and consist of 90% water, which can complicate the treatment. The use of filter chambers in this case, can help divert the sediments from the water and recirculate the water back to the lake system. These sediments can then be further used as fertilizer or for the biogas production. That however strongly depends on the ecosystem, e.g. fish stockings, phosphate and nitrate concentrations, within the sediments.

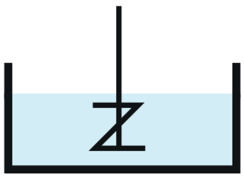


fig. 40:
Mixing of the lake breaks the thermal stratification.

6.6.2 Artificial mixing and aeration

Another option for shallow lakes is artificial mixing and aeration, which constantly produces mixed water by breaking the thermal stratification.

6.6.3 Hypolimnic withdrawal (Algae)

Hypolimnic withdrawal discharges the bottom water of a lake system, which is usually rich in nutrients and low in its oxygen saturation. This method is very effective for lakes which stratify themselves and is less effective for shallow lake without stratification. It is unlikely that a water resource management system will develop stratification as the reservoir is generally to small and too shallow during the dry season. However, it can be used during the monsoon season to remove surplus water from the system by the use of an Olseski tube as an additional feature, which reduces the retention time in the system and removes oxygen-less water, in case oxygen depletion occurs near the sediments.

fig. 41:
Removing the deeper waters, can prevent oxygen depletion..

6.6.4 Aeration (Algae and Macrophytes)

Aeration is one of the most powerful processes to enhance the purifying capabilities of a water system and can be applied to any lake which faces eutrophication. It is furthermore, the most important measure in the treatment of domestic water streams all over the world. As shallow lakes are considered to be mixed throughout the whole water column, the distribution of oxygen can be considered to be relatively balanced in theory. However, it can differ from the surface areas to the bottom; due to waves, algal distribution and photosynthetic activities of Macrophytes, who produce oxygen at daytime and respire it at night.

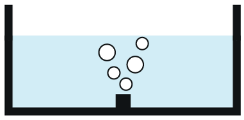


fig. 42:
Aeration of the water, improves the Oxygen saturation, which increases the purifying capabilities by aerobic bacterias.

Additionally, during the night-time, dense crops of Macrophytes, can lead to oxygen depletion near the lake's bottom, which in return releases nutrients from the sediment. The depletion of oxygen is further stimulated by the biological subversion of biomass near or within the sediments. As soon as oxygen depletion occurs, the sediments release nutrients, which stimulates existing biological growth. However, as a consequence the development of algal biomass can shade the water surface, produces anoxic conditions, and might lead to cyanobacteria, which release toxic substances into the water leading to the lake shifting to a potentially turbid state, after Macrophytes hhave disappeared step by step.

Furthermore, artificial aeration is an effective measure to prevent oxygen depletion and can strengthen the ecosystem. It can suppress nutrient release due to anoxic conditions and reduce harmful $NH4^{+}$. By suppressing anoxic conditions, the chemical reaction between phosphorous within the water column and iron ions gets promoted, making phosphorous unavailable for the lake's ecosystem. This iron ions can also either be natural or added artificially (for more details see: 6.6.5 P Inactivation).

Several other methods are also available based on the lake structure, its depth and the trophic state. They can be implemented by mechanical agitation, injection of pure oxygen or injection of air. However, shallow lakes may not be able to dissolve the injected oxygen or air completely, as even the smallest bubbles need several meters of water column to get completely dissolved. Therefore, aeration in this specified context is usually visible and can be combined with other technologies.

6.6.5 P inactivation (Algae)

Phosphorous inactivation is a chemical treatment were iron, calcium or alum are added to the lake. It is a common treatment to control the lake's internal loads, which are mainly responsible for algae blooms (Cooke et al. 2005; Cullen and Forsberg, 1988; Sas et al. 1989; Welch and Cooke 1995). By adding them to the water column of a lake, a chemical reaction occurs immediately leading to flocculation with the available phosphorus. This settles to the ground where it forms a protective layer over the already existing sediments and suppresses the release of nutrients from the area underneath it. Thus, available phosphorous is reduced, the internal cycling is broken and the water transparency increases dramatically and rapidly. In addition, the use of Alum continues the chemical reaction and binds and retains P even after the floc's settled to the sediment, in contrast to iron. Alum is further stable under anoxic conditions, while iron leads to the release of P under Anoxic conditions. Alum specifically is amongst the most effective ways to mark P as a limiting factor and in controlling the growth of biomasses. It can also successfully suppress algae blooms which rely on freely available P. It has been used for more than 200 years and is probably the most commonly used drinking water treatment as well (Cooke et al. 2005).

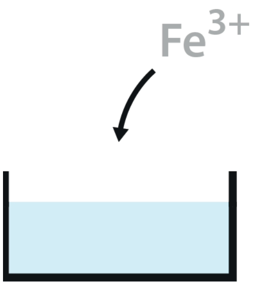


fig. 43:
Alum or Iron Application will immediately bound the Phosphorous.

It does present some risks however as, although aluminium is widely available in the nature, the reactions are not completely understood (Cooke et al. 2005; Dentel and Gossett 1988). Alum, which is hydrated potassium aluminium sulphate and mostly used by lake managers, becomes toxic in concentration from 0.1 to 0.2 Al/L at pH 4.5 to 5.5 (Cooke et al. 2005; Baker, 1982; Havens, 1993), which can further lead to high photosynthesis/respiration activities that can influence the ph. Therefore, controlling the pH also becomes important.

The chemistry of iron and calcium is better understood than Aluminium and they can be used with less concern regarding the pH (Cooke et al. 2005; Stumm and Lee, 1960; Stumm and Morgan 1970), although they are both less effective than aluminium and iron is sensitive to anoxic Conditions. Therefore, the use of iron must ensure that oxygen saturation near the bottom should not drop below 1mg/L, as the bound P can get released in to the water (Cooket et al. 2005). Authors Carlton and Wetzel (1988) describe lakes where this process happens rapidly on a daily base. Therefore, iron has been observed to work best in combination with aeration, and during photosynthetically high ph.

Additionally, the effects on Macrophytes of these processes are minor as they are less dependent on the high nutrient levels in the water column and rooted Macrophytes often get their nutrients from the sediments (Barko et al. 1986). Although P inactivation is mostly applied in stratified lakes, it has also shown positive results in shallow unstratified lakes all over the world, swimming pools and small ponds. Furthermore, there are several ways to apply Alum or iron in the water. They can be applied directly to the water column, placed in bags or injected to the inflows. Earlier studies highlighted that bags which were placed under the floating structures were sufficient enough to suppress algae blooms for 12 months in New South Wales (May and Baker 1978), at a dose of 100g Alum/m^3. Alum Treatment can therefore, be seen as an ultimate measure, to improve the water quality directly, in case of unwanted algal growth.

Although Alum application can be seen as an 'ultimate' measure to improve the water quality, it is advised to be varied out in combination with automatic dredging structures. This is important as it controls the sediments which contain the Alum salts and includes the continuous withdrawal of the sediments or at least the possibility to do so, if necessary.

6.6.6 Water level drawdown (Algae and Macrophytes)

Water level draw down is mostly applied for the removal of sediments and manual control of Macrophytes (Cooke et al. 2005). The water level of a lake (mostly manmade, as they have effluents) is drawn down in order to get access to the shore and bottom of the lake. It can also be used to concentrate the biomasses, in combination with fish stockings to improve the efficiency. The effects of this process on the ecosystem however, have not yet been fully explored. It can also lead to big changes within the ecological system, especially in the occurrence of different plant species with some new species experiencing an increase, some decrease and some may remain unaffected (Cooke et al. 2005). All these effects must be taken into account, especially that the plant species in a WRMS might change from season to season, depending on the system's reaction to the seasonal drawdown.

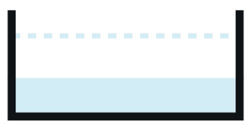


fig. 44:
Water level drawdown is an effective measure to concentrate the biomass, for further manipulation.

The removal of accessible, dried sediments during the drawdown state is considered as a proper measure to cut the cycle and to remove nutrients from the system. This has been applied in many projects with success. However, the effects of 're-flooding' are found to be 'uncommon and conflicting' (Cooke et al. 2005: 330). Previous research indicates that refilling of a lake might cause a switch to a turbid state (Cooke et al. 2005; Hulsey, 1958; Beard, 1973) due to the direct P-release of the dried sediments, which do not get removed during the drawdown. It is also assumed that dried sediments have significant lower affinity to P than wet ones (Cooke et al. 2005, Balwin 1996). Therefore, it must be guaranteed, that areas which go through this flooding cycles are free of sediments before they get flooded, in order to prevent the resuspension of P which is bound to the dried sediments and/or surfaces. This process highlights the massive influence on the design of adaptive zones.

6.6.7 Surface shading (Algae and Macrophytes)

Surface shading can be described as a reduction of the light availability for the water column, which inhibits the growth of algal and Macrophytes. As UV exposure is the basis for biological activities, a reduction of it inhibits growth within the system. However, engineered surface shading can be applied with artificial sheets or floating plastic balls in order to protect water reservoirs, exemplified in the USA. However, these measures have a huge impact on the aesthetical quality of lakes and their value as recreational spots. Therefore, engineered shading activities are not being considered within this research.

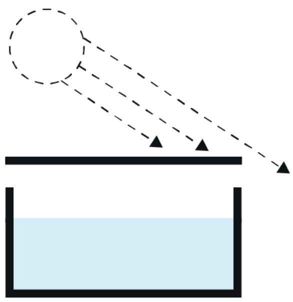


fig. 45:
shading of thew water suppresse any bioloigcla growth. The system becomes light limited.

Beside engineered solutions, trees which are planted by the lakes shore can shade the water column near the riparian zones, which reduces the Macrophytes in those areas and can prevent them from becoming a nuisance. Other shading structures like floating wetlands can also shade the water while improving the water quality underneath its structure by biological activities. These structures can be designed to be accessible for public use. The planted vegetation is easy to maintain and can be harvested directly from the floating deck, without needing big equipment or entering the water. The roots of the plants can be a habitat for mineralization of the bacteria, which play a significant role in water purification (Peimen 2005). Several experiments have shown

that floating wetlands have significant effects on the water quality, including removal of heavy metal like copper, zinc and Mangnesium (Cooke et al. 2005).
The interaction of the floating structure with the lake surface in the context of a WRMS is particularly important as the lake can expand its surface in the monsoon season and reduce it in the dry season. In relation to the surface area, the same floating structure can shade a bigger surface in the dry season and a lower one in the monsoon season. This effect can then be used to reduce the light availability significantly during the dry season in order to inhibit the biological activity and protect the ecosystem. Hence, floating structures can play a major role in protecting reservoirs with changing water levels from eutrophication.

6.6.8 Chemical control (Macrophytes and Algae)

Another effective way to control the ecosystem is through chemical controls of aquatic production. It contains the use of chlorine, herbicides and other toxic substances which have inhibitory effects on the ecosystem and suppress any growth successfully. Nonetheless, the use of chemicals should always be carefully considered due to health, safety and environmental issues. But since they are considered cheap and effective, this consideration isn't always taken (Cooke et al. 2005). To exemplify, an overuse of sodium arsenate happened in the 1970's when 789 kg were added to 167 lakes. (Lueschow, 1972). The environmental impacts of the treatment were not monitored and turned large parts of the sediments into hazardous waste, which also made any further treatment extremely complicated (Cooke et al. 2005; Dunst, 1982). Thus, when chemicals are used properly, they can be seen as a powerful tool (Cooke et al. 2005), but as the case mentioned above shows, they can influence their public perception and acceptance. Based on this, although chemical treatment can be a tool for lake management, after careful consideration given to appropriate consequences, they are not viewed as option for a WRMS.

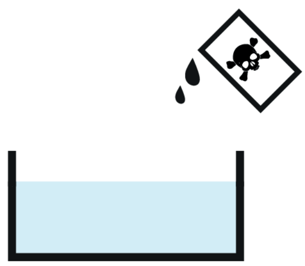


fig. 46:
The application of chemicals, should be avoided in the terms of an WRMS. However, it can be very effective, when applied properly.

6.6.9 Biomanipulation with plants: supporting Macrophyte Communities (Algae control)

Supporting Macrophyte communities can be described as the protection, re-cultivation or restoration of a controlled growth of Macrophyte. It can happen at the bottom of a lake, at its surface or the shore. Several research projects have been based on the hypothesis that the (re)introduction of carefully selected Macrophytes can show significant success in results.

Macrophytes have shown a significant influence on the ecosystem, by shading the water, suppressing algal growth, provided a habitat for young fish and zooplanktons, as well as influenced the oxygen saturation in the sediments and the water column. Several approaches can be found, where Macrophytes have been reintroduced to the water systems from where they have disappeared. Macrophytes are known to have a strong power to spread their roots and increase their biomass, which makes them become a nuisance, as long as the environment is suitable for Macrophytes. A suitable environment for Macrophytes is characterized by shallow, clear, non-toxic water, with low fish predation on their biomass. Furthermore, a stable water level, the abundancy of residual plants and a moderate to low organic matter content with moderate to high sediments, can be seen as factors that promote a 'natural' Macrophyte habitat . As long as these attributes are available, Macrophytes tend to invade the waters without further manipulation. Turbid waters, fluctuating water levels, the abundancy of toxic or non-desirable plants as well as a low density of sediments, combined with high organic matter are negative factors which lead to the inhibition of a Macrophyte community (ibid).

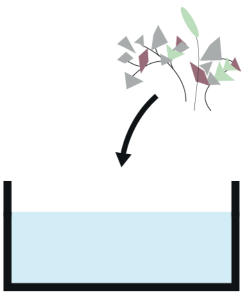


fig. 47:
The ‚protected' introduction of Macrophytes can improve the systems resiliency, to suppress algal growth.

Approaches to support Macrophyte communities, by supporting plants that are trying to resist the negative influences of the environment, are namely—using physical measures like the construction of enclosures, stabilizing the water levels, protection of shorelines or manual removing of non-desired plants. The overall goal is to create a supportive environment, which allows Macrophytes to grow, by manual reduction of negative factors.

The construction of enclosures in lakes in order to give Macrophytes a predator free habitat, is a powerful tool to separate vegetarian fish from them (see: Beklioglu et al. 2010; Lauridsen et al. 2003). The 'protected' growth of the plants can then quickly improve the water's transparency (Peimin 2005) and therefore its quality. This method has been observed to be promising for small lakes.

The manual use of floating plants (e.g. Eihhornia Crassipes, Water Hyacinth, Hydrocharis dubia, Alernanthera philoxeroides) which are often found on water, can also be viewed as a short-term measure. This is because they can compete with algae for nutrients and might be able to suppress their growth when they are introduced to the water surface (Peimen 2005). Beside the direct uptake of nutrients out of the water column, the free-floating roots can further provide a habitat for bacteria which subvert organic materials. Thus, floating plants can easily become a nuisance and a harvesting plan becomes absolutely necessary.

Another approach is the manipulation of the shorelines. Although it is expensive, labour-intensive and has a high probability of failure, it can still be controlled (Cooke et al. 2005). It is similar to a protection zone (described in the previous Chapters), which is a typical characteristic of tropical lakes and reservoirs. The plants can be planted at the riparian zone and fulfil different attributes, like fish habitat, nutrient reduction, or aesthetic attributes (ibid). Rooted emergent or floating leaf plants can play a major role in these areas as they can be tolerant to changing water levels and turbidity,

For all the approaches described, more research needs to conducted to survey the native species within the local context. In case of this research, it can also be more useful to use species which are locally available. Local species have the most successful chances to survive while invading plants, can easily become a nuisance, requiring a lot of management to control it.

6.6.10 Biomanipulation with plants: Controlled nutrient removal

In the last 40 years, the controlled growth of plants like Duckweed was researched for their wastewater purification capabilities. Duckweed can also be used for livestock and poultry, as well as an energy source (Landesman et al. 2010). Like water hyacinth, duckweed tends to become a nuisance, which covers the whole area very quickly, as they can double their biomass within two days or even less (Culley et al. 1981). They can also lead to the complete depletion of the available oxygen, which stimulates denitrification on the one hand, but suppresses every other species on the other (Landesman et al. 2010; Pokorny and Rejmankova 1983; Leng et al. 2004). They have been studied and utilized in the treatment of domestic used water for more than 20 years

(Landesman et al. 2010; Oron et al. 1988). Lastly, they can also be part of a wetland or used in a polishing pond, where the treated effluent is improved (Landesman et al. 2010; Alaerst et al. 1996).

fig. 48:
The controlled growth of ‚Duckweed' in a conventional reclamation plant in northern Vietnam

Harvesting these kinds of plants can effectively remove the nutrients from water and it can be used at the same time to produce energy, or biofuel (Landesman et al. 2010). Duckweed systems can remove 50 – 60% of nitrogen and phosphorous from domestic wastewater, or even 73 – 97% of TKN and 63 – 99% of P, in duckweed covered domestic wastewater (Körner and Vermaat 1998). The removal of COD, BOD5, NH3-, TN and TSS can reach up to 84, 88,68,58 and 87% respectively under optimum conditions (Landesman 2010; Krishna and Polprasert 2008). In addition, due to its surface cover, duckweed further reduces water loss through direct evaporation from the water surface, almost by 20%, which is considered quite significant (Landesman et al. 2010).

However, these planted areas need proper and continuous management, where they can be manipulated very easily and effectively. Therefore, this kind of 'Macrophyte Treatment' is applied best in areas which are separated, to ensure sufficient accessibility. Due to the complete depletion of oxygen in these ponds, it becomes necessary to aerate the water before its further use. Due to their green colour and structure, duckweed or water hyacinth also have the potential to be used as a design element. However, NH3 must be avoided as this can be harmful for duckweed. A very effective way of controlling ht eoccurance of NH3 is the manipulation of the pH. (Korner et al. 2001).

fig. 49:
Floating Macrophytes in Manila, which shades the water completely.

Comparable results can be achieved with the controlled growth of other Macrophytes, like Eichhornia Crassippes, along with the controlled growth of algae. Most aquatic plants can take up NH3 and NH4 but prefer one of them. This varies from species to species (Crawford and Glass 1998) and can be determined by temperature, time, season and pH values (Babourina and Rengel 2010). There can also be differences in the leaves and stems, as well as underwater and floating parts. The right choice of plants can therefore, be adjusted to the water quality. The next section focuses on bio-manipulation with fish.

6.6.11 Biomanipulation with fish (Macrophytes / Algae)

Ecosystem management of tropical lakes might include specific fish stockings, which are an essential element within the food-web. Several research projects have been conducted in tropical climates, where 'fish stocking' was used as an important measure to reduce eutrophication processes. The character of the fish community and different species can have a major influence on the ecosystem.

fig. 50:
Floating Macrophytes in Manila, which shades the water completely.

Firstly, 'Omnivores fish' eat everything. Their daily diet includes algae, zooplanktons and parts of Macrophytes, which might be a threat for them as long as they are not protected (see previous Chapters). The grazing pressure on Macrophytes can lead to a turbid state, which is dominated by algae as they grow faster and are more flexible. The removal of omnivorous fish especially in the tropical areas is important, when fish bio manipulation is considered as an option (Jeppessen et al. 2005).

Secondly, 'Benthivores fish' get their diet from the sediments by stirring them up. This re-suspends the sediments to the water column, which has a major impact on the availability of the nutrients for the ecosystem.

Thirdly, 'Planktivores fish' eat zooplanktons and phytoplankton. A reduction of phytoplankton can have a significant influence on the availability of algae and therefore prevent them from blooming. However, feeding on zooplankton means an increase of phytoplankton as a direct consequence of the lower grazing pressure. The use of Planktivorous fish can thus be an option, to reduce phytoplankton and algae, when dense Macrophyte Crops can be a daytime refuge for the zooplankton (Timms & Moss, 1984).

Thirdly, Herbivores' fish eat mainly Macrophytes. They can be used to control Macrophyte growth, in case of a nuisance.

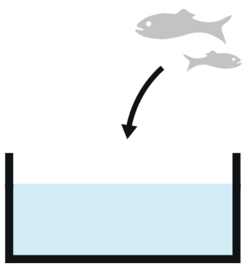


fig. 51:
The introduction of fish stockings, is the classical Approach of Biomanipulation.

Lastly, 'Piscivores fish' are predators. The can get used to controlling other fish communities. However, research indicates, that the use of piscivores alone has shown the lowest success rate in most projects when other species are not removed (Drenner & Harmbright, 1999).

Hence, the manipulation in a tropical ecosystem is complex and only a few studies are done for the effects of bio manipulation. According to earlier research (Jeppessen et al. 2005), most projects focus on the control of cyanobacterial blooms in eutrophic tropical waters via enhanced grazing by omnivorous fish species, like silver carp (Reddy 2005; Arcifa et al. 1986; Northcote et al. 1990; Saha & Jana 1998). The results can be considered successful, although more research is needed and the information is too limited.

Generally, the potential of using fish to convert parts of the lakes nutrients to 'fish biomass' deserves attention. Experiments in eutrophic, tropical lakes with omnivorous silver carps have shown that stockings of 400g/m^3 and 800 g/m^3 (Juveniles/Adults) can successfully suppress algae blooms by intense filter activities of silver carp, while supporting the lakes ecosystem without supplementary feeding (Jeppessen et al. 2005). A survival of 90% showed, that silver carp can adjust itself to the tropic eutrophic conditions (Reddy 2005; Starling et al. 1990).

Species, which feed on Macrophytes like grass carp, can further be used to control the plants growths and to prevent them from becoming a nuisance. Experiments with dense stockings of grass carps showed, that these species are able to kill all Macrophytes in relatively short time, which might result to a turbid state. Lesser stockings resulted in the successful control of the Macrophytes (reduction of 50%) and a significant reduction of filamentous algae (60%) (Jeppessen et al. 2005). Similar results were observed in the hypertrophic Dinachi Lake, were stockings of silver carp and bighead carp, successfully suppressed algae blooms (Peimin 2005; Xie, P. and Liu, J. 2001 / Reddy).

Another typical approach for bio-manipulation with fish is the stocking of the ecosystem with Piscivore fish, which feed on the planktivorous organisms. This reduces the pressure on zooplanktons, which in return enhance the grazing pressure on phytoplankton and algae by zooplankton (Beklioglu 2014; Timms and Moss 1984). Bio-manipulations with fish stockings can thus, be a powerful measure for controlling algae and Macrophytes. Special attention should be given to control the fish community and the interactions between Macrophytes. The use of extensive fish stockings might be an effective way of suppressing algae blooms in a tropical ecosystem, but it must be compatible with other aspects of a WRMS, like the use of tap water or service water.

Extensive fish stocking can further lead to highly toxic sediments, which produce odour and therefore influence the whole neighbourhood, similar to aquacultures with the subtropical areas.

6.7. References

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A Water Resource Management System (WRMS), which is not connected to an external water system, like a river or a natural lake, will face a lot of pressure on its ecological state, especially when the main inflows are storm- and reclaimed water, as the natural dilution Capacities are zero, at least limited. To prevent this ecosystem from developing unwanted conditions, the system, which includes the open water surfaces, the riparian zones, the lakes bottom and the inner structure can be engineered to support and enhance the lakes ecological system.

The overall goal of this research project is the development of guidelines, which can be used to design zero Water Cities, which are based on a WRMS, which collects, stabilizes, treats and store every drop of water within an urban context. The previous Chapters introduced hydrological, biological, chemical and engineered knowledge which is the basis for the Design.

The following paragraphs, translates the knowledge of hydrology, biology and engineering step by step into *Implications* and *Design Solutions*, to combine technology, with nature and architecture. The approach differs from engineered driven projects, as the focus is shifted to natural Ecosystem services, which are rather supplied by technologies, instead of being the focus. Biodiversity and the contact to the nature are the visible and experiential interface between the engineered solutions and the urban context, which can be seen as the starting point for this project.
Inhabitants or visitors as well as the urban public should get brought as close to the water as possible, where the perception of nature is rather a source of water, than just an environmental barrier within a technical water cycle. This holistic approach includes the release of the technically cleaned streams into the Water Resource Managemet System, where they got mixed and/or diluted with the natural streams. This conceptual management of the waterflows differs from the engineering perspective, which states that separated streams should stay separated. The Expression 'Naturizing' the flows may be used to describe this project, in the same way than 'infrastructurizing' can get used to describe conventional approaches, where infrastructure is in the focus. The first thought of people should be connected to nature, instead of technical diffusion of water molecules, through semipermeable membranes.

7.1. The choose of the right reclamation technolgoy.

Chapter 5 described the basics of water reclamation and introduced three possible treatment systems. Whereas the SBR and MBR are based on the activated sludge process, the RBC bases on the degradation by bacterias, which are placed at the rotating discs.
All of these technologies can be used within an urban context, as they require less space, compared to other technologies. All of the introduced technologies gives the possibility to get adjusted to changing conditions. While the MBR produces absolute clean waters for black and greywater flows, the Water Quality of the SBR can fulfill the 'Badewasserrichtlinie' after additional disinfection, while the RBC can reach the 'Badewasserqualität' after additional disinfection when it is applied for greywater only.
The MBR need a proper maintenance and well educated staff, which run this facility professional, while the SBR is less complex, but requires some adjustments and cleaning procedures, and the RBC, as a low tech solution, runs de facto without any maintenance.

The designed project is placed in the urban context of Ha Noi in northern Vietnam and includes the use of both domestic streams, to realize a zero Water City, where the recycled water is used as Tapwater for any purpose. Therefore the conceptual design uses the MBR technology for both streams. While an additional Nanofiltration with chlorine disinfection can be applied for the Tapwater intake. This requires the possibility of reacting fast to shocks, stresses or malfunction and the availability and involvement of professional companies, who are involved in that project.

In areas which are more rural and not easy to access, the MBR might not be the best solution as professional staff, which might include spare parts and or chemicals, might have difficulties to reach the site in case for manintainace purposes or in emergencies. Those projects can be designed with an SBR who is in its core technology more resilient to shocks and stresses than the MBR. Very rural areas, in the mountainous regions of asia, or without a transportation infrastructure can furthermore use RBC technology in a greywater only concept, with additional disinfection. The use of the stored water should therefore be limited to the use as service water, which might include laundry. Although the Quality can be very high, and in theory ready to reuse as

Tapwater, The reaction time for maintenance, shock and stresses might be to long to ensure a proper operation phase.

7.2. General structure

After the decision for an appropriate reclamation technology, the design of a Resource Water Management System, can be done. In General, this design consists of two stages. The first stage can be described as *Implications* for the basic structure. It consists on hydrological calculations, the needed storage area, affects vulnerability questions and can be seen as the fundament to manage the water flows. The *Implications* for the structure are thereby translated from engineering projects, water reclamation facilities, polishing lakes, natural streams and includes aspects from the basic limnology. It is translated into 10 *Implications*, which must be considered into the overall design, as soon as a new development projects evolve, as it has fundamental influenced on the needed space and the land use. The interactions with the environment must be considered and evaluated at that time.

The Second part consist of *Design Solutions*, which can be applied to the basic structure to strengthen the ecosystem and control the water quality, flows and provide on the same time a highly livable environment. The basics for this translation comes mainly from biological activities within reclamation facilities, ecological systems, the influences of anthropogenic pressure to lakes ecosystem, as well as restoration strategies, which are applied to improve already degradated lakes.

Both Stages are developed within a strong architectural context, where the interaction between people and water is one of the driving forces. The following paragraphs are the basic knowledge for the subsequent research and development of a sample project in *Chapter 8*, where a lake system is conceptually sized and designed for a project in the climate of northern Vietnam, near Ha Noi.

The interaction with the riparian zone and the environment
Several authors acknowledge the importance of the riparian zone of a lake for its ecosystem. It is often characterized by a wide range of different plants, which includes

submerged, emergent, semi-terrestrial and terrestrial structures, high species diversity, very high biomass and productivity, high retention of materials and periods of significant export of dissolved and particulate organic material that subsidize aquatic food web. Sometimes these zones are part of a wetland or act as wetland with major influence on the lakes ecosystem and its nutrients supply. Its removal allows the uncontrolled flow of Runoff to the system, and can lead to turbidity and nutrient release from suspended sediments (Beklioglu 2010; Barko and James 1998).
This natural protection zone has a significant influence on the removal of nitrates and the improvement of the water quality. Schueler (1992) describes pond / wetland systems as one of the most effective systems. In his work, he determines that 45% of such a system should be designed as a lake “deep pool”, and 55% as marsh zones. 25% of these marshes are flooded on a daily basis, and 30% only occasional during storms. These underlines that natural (sub-)tropical lakes often consist of shallow bays, which are characterized by wetland plants.

This zone can be seen as the natural protection zone for a lake. A transformation of these structures into a controlled environment is therfore the first step to design a Waterresource Management System.

7.3. Implications for the basic structure

7.3.1 Designing a protection zone (IM1)

The Stormwater Runoff streams in the WRMS can be seen as the major input to the lakes ecosystem.
To avoid uncontrolled eutrophication, those inflows must be managed, as it is done by the wetlands and marshes which emerge at the riparian zones in natural systems. By designing an artificial lake system, it is therefore necessary to design an artificial protection zone, which prevents the uncontrolled inflow to the lake, as the Runoff from shoreline lawns and lawns which are connected to the lake, can be considered as the major nutrient sources (Cooke et al. 2005; Shuman 2001; King et al. 2001).

This zone, must fulfill the following tasks, in analogy to a natural lake system:

1. filtering of suspended solids
2. filtering of organic bound nutrients
3. Protecting the riparian areas from destruction, which is induced by the veloci ty of the Runoff.
4. Protecting the riparian areas from influences due to changing water levels.

As described in *Chapter 5* most of the natural water streams can get collected on site in small retention areas or raingardens and conveyed by underground pipes to the lake system, where it is released to the water. Interconnected, large retention areas, which are designed for a 100 years storm, fulfill flood protection issues. Those areas are designed to collect the storm water which is not collected in the raingardens, and their overflows in case of a strong wind. To avoid the use of drainages and sewers, they can get designed as open spaces. To save infrastructure for transportation, it makes sense to concentrate those retention structures near the lake, which is the final destination for the natural streams. At the same time, these areas are designed to remove and filter most of the particulate matter of the Runoff to prevent turbid waters. These settlement processes usually take from several hours up to a couple of days, according the sedimentation velocity which mainly depends on the particulates and the water temperature.

The overall goal must be to design a landscape which can handle the Runoff of a 100 years storm by preventing an uncontrolled entering of the Runoff to the system.

1. Translation of the natural buffer zone into a constructed barrier.

A protection zone, which secures the lake system from the surroundings, is therefore absolutely necessary in any project and any context. There are several options to design a physical barrier: depressions, walls, drainage structure, gutters, swales…the list is endless and subject to landscape designers. Those elements can be integrated and “architecturally hidden” into walkways, swales, parks, bridges and playgrounds to render them ‘invisible’.

This Design Implication must ensure a barrier which prevents any Stormwater to reach the WRMS directly, by either capturing it, or draining it into the capturing zones.

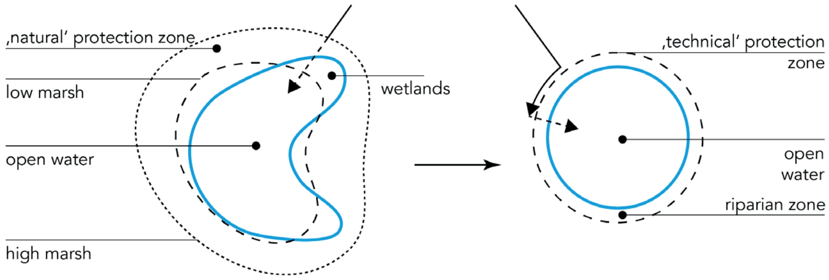


fig. 52:
Translating the natural environment into a technical Design.

2. Releasing the captured water to the lake

The outlets of these structures should be designed to slow down the stream and release the filtered water through this barrier into the WRMS, without producing shore erosion.

This can happen through physical outlet structures, like wetlands, gabbion walls, swales or other designed elements, which are subject to the designer. The use of bionengineered soils can prevent soil erosion and support the water conveyance.

3. The zone between barrier and lake system

The zone in-between the protection zone and the lake requires special attention and a proper design. This zone is the only one, which allows direct interactions with the WRMS. On the one hand, this zone has to handle the influences from the lake, i.e. different water levels, which might occur during one year, and/or days, on the other hand, this zone has major implications for the accessibility to the water from the urban context. Therefore this zone is from major importance for the perception, the design and the use for recreational activities. The design of the area and the used materials must ensure that the export activities are nearly zero, which includes bioengineered soils, and excludes the construction of lawns.

Vegetation can be a safe measure to avoid soil erosion, which leaches nutrients to the lake, as the roots can stabilize the soil. By assuming water level changes up to 1.5 m for the area of Ha Noi, the interaction between riparian zone and water is therefore from major importance and demands its protection. Zones, where wetlands cannot be installed, need further protection from soil erosion, like embankment walls or other engineered solutions.

7.3.2 The shape (IM2)

The structure of the lake is most important and has significant influence on the biological and chemical processes, which happens inside the lake. The literature review and the expert interviews give evidence, that the shape, the depth, the retention time, the shoreline and the structure are the most important aspects, by designing a WRMS.

Although the artificial lake is not mainly build to purify water, it has some similarities to polishing ponds in the context of its ecosystem. Stagnant waters can become a problem as the exchange of oxygen might be reduced. This might lead to areas, which are characterized by a permanent Oxygen depletion, which supports the nutrient release and can lead to blue green cynobacterias.
As terminal lakes, the storage basin doesn't have an outflow. It has a technical water intake, which reduces the water level from the monsoon season to the dry season. The inflow of the domestic streams and the intake for Tapwater are in their volume constant, while the inflow of the natural streams varies with the season. The In- and Outlet structures can be physically separated and divided in differently characterized zones. This differentiation can respond very precisely to different requirements. A diversion of the lake in different zones, might be able to react more precisely on the specific characteristics, especially when a manipulation is necessary to protect the system.

The shape of a lake is an important starting point and the movement of water has a great influence on its ecosystem. (see *Chapter 6*.3. technical measures: artificial circulation).
Wetlands, polishing ponds, even wastewater ponds are usually designed with a length to width ratio from at least 7:1 to support a current in the water, whereas the inflows

are on one side, and the intake on the other (USEPA 1999). The system can be designed to
produce a flow.

The wind fetch has a major influence on WRMS in terms of evaporation and wind inducing waves/mixing, as well as the water temperature, which indirectly stimulates the oxygen saturation. It is described in the literature, that the wind fetch in particular can be strong enough to distribute algae to one part of the lake, which leads to a concentration. Therefore, the typical wind direction of the area can be used as an additional element for the removal of algae, which can should be considered in the lakes design.

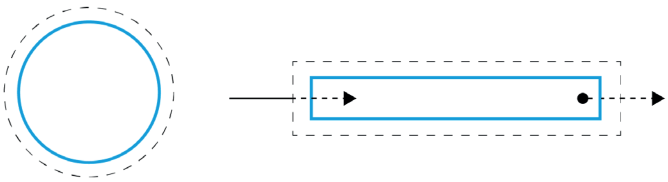


fig. 53:
To create a current, it is advisable to use a rectangle structure, instead a circle

7.3.3 Two water levels (IM3)

Due to different water levels in the monsoon and the dry season, the embankment walls can create cliffs, when the water level is low. The structure of the embankment has an influence on the lake structure as it controls the spatial variation of the water volume. The embankment structure can allow the expansion or resist to it. The overall design of the structure should be designed for two different water levels. To reduce the impacts of a system, which is either filled, or half-empty, the system can get expanded on the horizontal axis, which in consequence produces two different ecological states. Expanison zones can get used to influence the biological system, ans to reduce the impacts of falling water levels during the dry period (see *Design Solution 1*: Terraces).

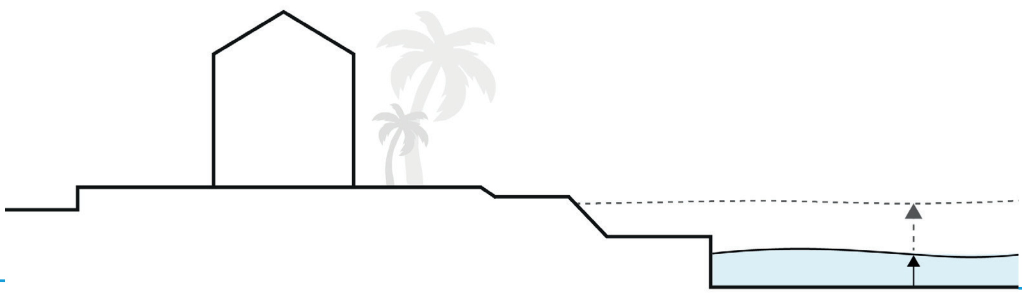


fig. 54:
The shoreline has to interact with changing water levels

7.3.4 The contact zone with groundwater (IM4)

Water exchange with groundwater can have a major impact on the lakes ecosystem. This interaction with the soil can bring freshwater, which has different characteristics, to the system and flush the nutrient rich water away. When the soil is sandy and the aquifers are deep, it is also possible that most of the waters get infiltrated to the ground, while the lake would not need any inflow from the urban context when the aquifers are near the bottom.

It is likely in case of Ha Noi that the soil is rich in iron, which in fact could lead to a protection of the lakes ecosystem, as Iron can immediately bound Phosphorous, which is than safely settled into the sediments. However, those processes are strongly dependent on the local context, and while in Vietnam the soil is partly saturated with iron, it is also enriched with Arsenic, which would be a danger to the human health and for the WRMS, or at least require aeration facilities, which has to be mananged very intensive.

A detailed analysis of the existing soils is hence necessary prior to any applied research.

Of course, this cannot be done within the framework of this doctorate. This research work is therefore based on the assumption that the WRMS which is designed for a northern Vietnamese context is isolated from the soil.

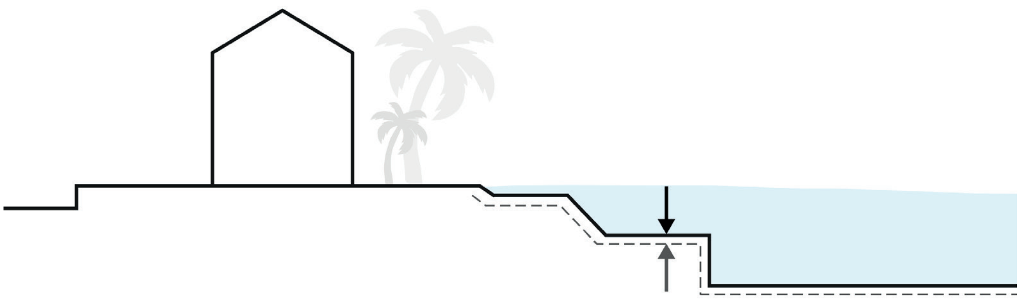


fig. 55:
Groundwater might be polluted with arsenic substances in northern Vietnam. Therefore the system has no interaction with groundwater

7.3.5 The Interaction with the atmosphere (IM5)

It was described in *Chapter 6*, that the lake is in a steady exchange with the atmosphere. One of the most important influence from the atmosphere is the Exposure to UV light, which is in fact the basis for every life within the lake. Without sunlight, any growth in the nature would be supressed. Light limitation can be a proper measure to control the biological system (see *Chapter 6*), but by designing a WRMS in tropical climates, like Vietnam, it must be considered that the WRMS answers with evaporating its water from the surface. This Evaporation to cools down the system by adiabatic cooling processes. The same processes happen with the Stormwater Runoff streams, and the retention zones, when they are not protected against the UV Exposure, e.g. by the use of trees or sewers. The amount of Evaporation, depends on several different factors, like the air humidity, the intensity of the solar radiation and the local wind speed. Evaporation is usually estimated in mm, and can therefore be seen as the opposite process to precipitation: Water is entering the atmosphere, instead of leaving. It is directly dependend on the surface area which is expose to the UV radiation. The bigger the area is, the bigger are the losses. This affects in particular retention zones and open water surfaces. The Evaporation losses during the rain event can be considered as relatively small, because during the rain, cloudy weather conditions are likely, which blocks the UV Light to enter. As soon as the sky becomes clear, they can be as high as 7.7 mm per/day, for Hanoi. The month Mai, can be seen as the beginning of the Monsoon season, and is characterized with 14 rainy days, with an overall amount of 188 mm. Under the assumption, that the average mm of rainfall can be set to 13mm every second day, the importantness of the right management becomes clear. The Evaporation from open water surfaces are among the biggest water losses within the system, and therefore the design of the surface area has significant impact on the overall water balance. Management involves a shading by trees or buildings, but as well the reduction of the surface area, which is exposed to UV. Due to this activities, the local climate can significantly influenced by adiabatic cooling. The lake surface must be designed as small as possible to minimize the water losses for the system, but as large as possible, to maximize adiabatic cooling issues.

Several methods are available to estimate, calculate, or measure the Evaporation, which is described in *Chapter 4*, and several methods are available to reduce the interactions with the environment by shading (*Design Solution 5: Shading and Design Solution 6: Floating structures*)

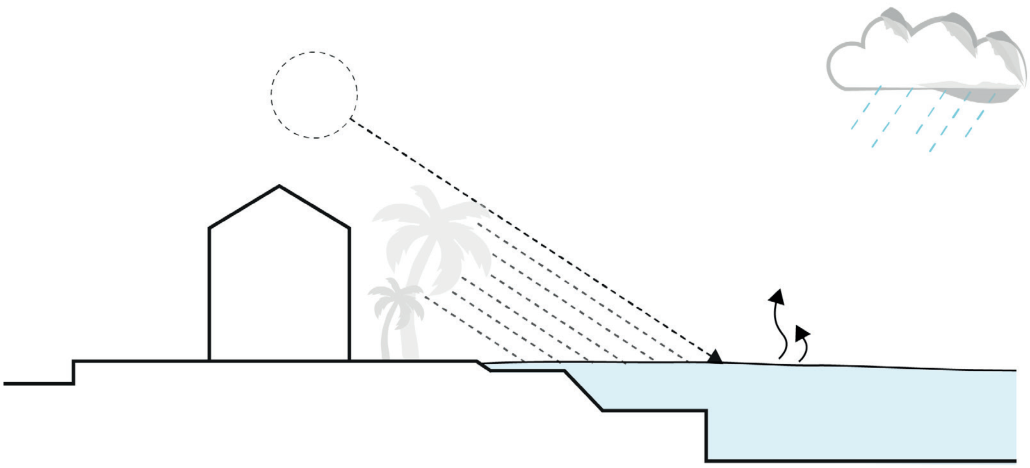


fig. 56:
UV Exposure of the water surface is the reason for Evaporation processes. Shading of the surface can reduce this.

7.3.6 The depth (IM6)

The depth of this WRMS should in general not exceed 3 m in order to prevent stratification, which results in a more complex ecosystem, which is less easier to control. Shallow lakes, allow submerged Macrophytes to grow, due to the relative good light availability, which is the desirable state of the lake, although the growth of them has to be controlled.

The internal loads of the lakes ecosystem (see *Chapter 6*), can be seen as key point. A depth of less than 3 m will lead to currents throughout the whole water column, which is from further importance for the sediments and its distribution and chemical reactions at the lakes bottom. *(Design Solution 8: Depressions)*

Oxygen Depletion usually occurs at the bottom of the lake, due to the subversion of biological materials. Although the storage lake is considered as shallow, which makes it less likely that oxygen depletion occurs, due to permanent mixing, the lower parts of the water are still critical, for example due to light limitiation during the monsoon season, or the chemical degradation processes. Therefore the removal of the lower waters, can stimulate the oxygen saturation. This can happens in combination with *Implication 10: Spillgates*.

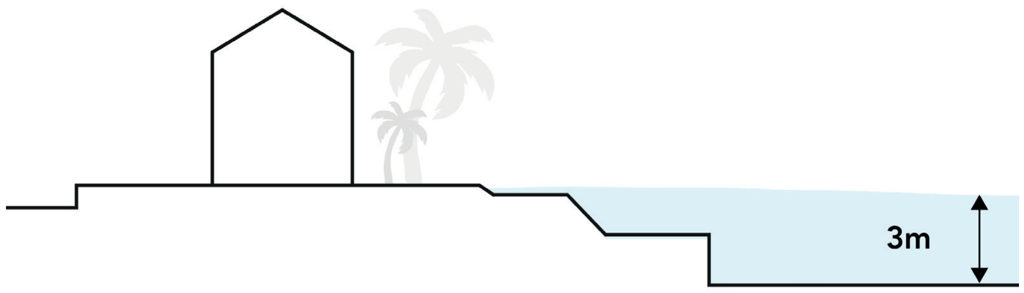


fig. 57:
A mean depth of not more than 3 m prevents the WRMS from stratification. The water column is ‚automatically mixed' all the time, by wind and waves.

7.3.7 The retention time (IM7)

The retention time is the time, that one drop of water needs to navigate through the entire system. It depends on the volume of the lake, the depth, and the structure, the wind fetch, currents, elevations etc. Retention times of less than 10 days prevent stratification as the water masses exchange is too fast. The retention time is mostly calculated by dividing the lakes volume, with its mean discharge.
Short residence times lead to a relative high 'flushing rate', which reduces sedimentation processes, and if the time is very short, they can suppress it completely which lead to an equalization of the nutrients availability to the inflow characteristics (Cooke et al. 2005). Small retention times furthermore suppress the growth of zooplankton, which feeds on phytoplankton (Jiang et al. 2010). According to Beklioglu et al. (2010) lakes with very short retention times (less than 3 days), tend to be clearer as expected from their nutrient balance by suppressing algal growth physically.

Submerged Macrophytes grow best at longer retention times (Barbourina and Rengel 2010), and it can be assumed that N removal efficiency in wetlands increased exponentially with increased retention time (Huang et al. 2000).

The retention time can be manipulated by dividing the system into several smaller systems, or physical barriers. In general, the retention during the monsoon season is higher, due to the higher volume of the lake in contrast to the constant water intake. The on the other side smaller retention time during the dry season, can be used to strengthen the ecosystem, due to higher flushing rate, although the nutrient load might be higher, when the domestic streams, are the major inflows.

The possibility of 'designing the retention time' is a chance to design areas which can answer more specific to specific characteristics:

A retention time of less than 3 days can be realized by designing riverine areas, which can protect the Tapwater intake, to suppress algal growth. Zones which are designed for a retention of 10 days, give the opportunity to react on system failures, or manipulate it when necessary, without influencing the whole system.

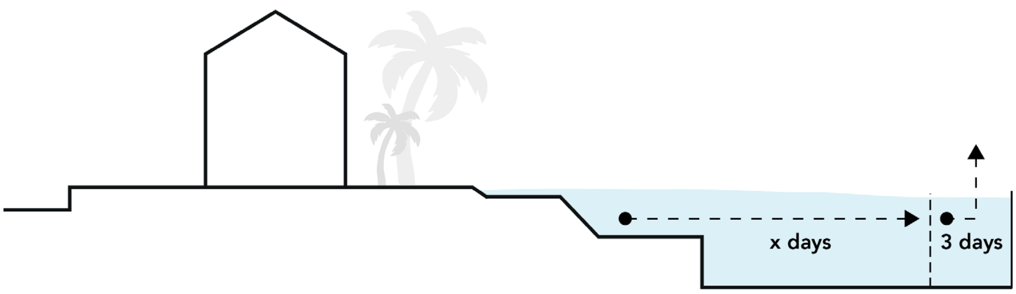


fig. 58:
Influencing the Retention time is a powerful measure to improve the ecological system.

7.3.8 Diversion of the lake system (IM8)

Dividing the lake in subsystems contributes to ecosystem on several ways. The above described different zones, as well as the design of retention times, are 'side effects', in consequence of a diversion, which is mainly applied under the assumption that, a smaller sub-lake has an own ecosystem, and can be influenced more efficient in case of uncontrolled eutrophication. It is widely used among lake managers and be found within lake restoration strategies. Several examples can be found in the literature, where diversion lead to successful results (Peimin 2005).
This can be of particular interest for the inflow streams, when they contain relatively high nutrients or for the areas with the water intake, like described above.

The possibility of a diversion, allows in a WRMS to adjust the system to the local context and to enhance the systems resiliency in case of failures. A physical separation allows to suppress or remove an upcoming algae bloom where it will occur, right before it affects the whole system.

Although it seems unlikely, that technical measures are not sufficient enough, it is possible to extend them with biological manipulation (fish stockings, controlled plant growth) or chemical treatments, which can be applied to designated areas and allow targeted manipulation.

Another benefit, which comes in their basis from the water reclamation technologies and which is applied in polishing and or water ponds, can be seen in the separation of different processes. In *Chapter 6*.3. was described, that aquatic plants, like duckweed, can successfully remove ammonium from polluted water, but as those plants tend to become a nuisance, it is not desirable to apply it to the whole lake. If applied to a separated area of the lake, it can be used as a design element, as they can develop a dense green surface, which shades the whole water and consumes nutrients until they are depleted. Similar approaches can be realized with the use of fish stockings or chemical treatment. Harvesting of these plants, can be done easily, when applied to designated areas, which allows the control and adjustment.

fig. 59:
Diversion of the WRMS gives the opportunity to react on malfunctions.

Diffrent zones, can develop different environments, which can be used to produce different conditions, which favor denitrificiation or nitrification.

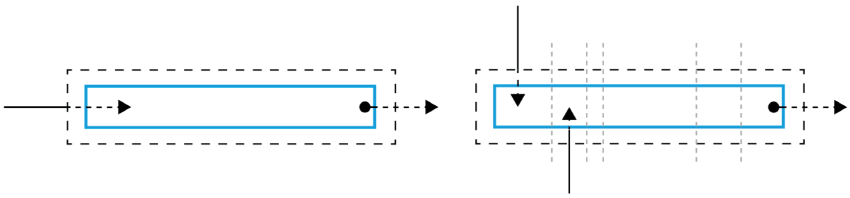


fig. 60:
‚Diverted areas' can get designed as attractive zones, while they rae equipped with dense floating Macrophytes, as it happens in Singapore in the upper Bishan Ang Mo Kio parc.

The kinetic energy of the 'water column pressure' allows the interconnections of different sub lakes without the use of electrical energy. As soon as two sub lakes are interconnected within a structure which allows water masses to exchange, both lakes will try to adjust their water level to each other until the pressure on both sides is balanced. This effect will occur as long as the structure is underneath the water surface in both lakes. As the water resource management system is characterized by a physical inflow and technical outflow, the water follows a flow direction. This effect can be used to control the water mass exchanges in their quality and quantity.

Therefore, an adjustable height of the out- and inlet structures gives the possibility to decide which waters can follow the flow, and enter the next basin. This is particular of interest during oxygen depletion where water from the bottom near zones can be withdrawn, to the surface layer of the next sublake, while the depleted waters can get aerated.

It gives furthermore the opportunity to prevent floating algal, to enter the following lake, as this structure is a physical barrier, when it is placed underneath the water surface. The same process can be found in water reclamation plants, to divide the treated waters, from the floating scum.

A common technique for manmade lakes, where this effect is applied, is the 'Teichmönch'. The system is usually designed to control the effluent of a lake and withdraw deep water or surface water. The adaption of those structures within this research is an important element to strengthen the ecosystem.

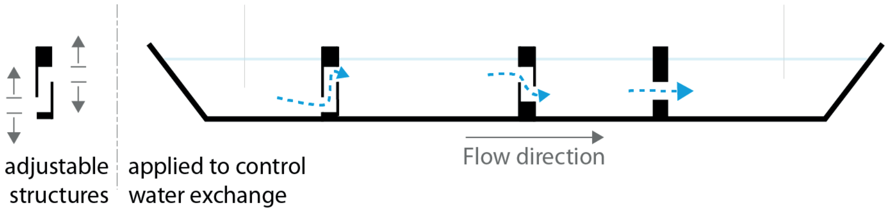


fig. 61:
The water masses which enter from one ‚subbasin' to the next one can be controlled

Those elements can be hidden with architectural elements like bridges walksways, barriers, gabion which are subject to the designer.

7.3.9 Cooling down the WRMS (IM9)

The main difference between (sub-)tropical lakes and reservoirs to their counterparts in the temperate climate, is the enhanced nutrient cycling, which is in its roots induced by the higher UV Exposure over the year. Furthermore, the missing winter season, doesn't cool down the system periodically, to limit the biological growth. The continously high UV Exposure heat up to water column, and the shallow character of the WRMS allows the penetration of the Water throughout the whole depth.
In Asia it is most common, to heat up the domestic waterstreams by the use of solar energy. For this purpose, most of the residential buildings are equipped with solar thermal panels on their roofs. The efficiency of those solar panels can be as high as 80% , but it is directly related to the available UV Exposure, which depends on the weather conditions. During periods of rain, where the sky is cloudy, the efficiency of these system drops down, and the system has to be supported by conventional methods, mostly gas or electricity (Semizentral, unpublished)
The temperature of a shallow water body reacts more slowly on changes in the weather period, due to its water volume. The energetic potential of this lake, by using the heat, which is induced by the climate and stored into the water, is huge. Capturing some amounts of this energy, by the use of heat exchanger, which are placed within the lake, will produce a constantly available heat flow towards the urban context, while cooling down the system. Under the assumption, that the water in the lake is 25

to 30 Centigrade it can be seen as feasible to use heat pumps, which use this water as input stream, to produce an output stream which has temperature from 40 to 50 degrees, by using electrical energy. Those heatpumps works most feasible, when the input energy is constantly available, without big changes. The heated water can get used for showering, or to provide warm water for laundry.

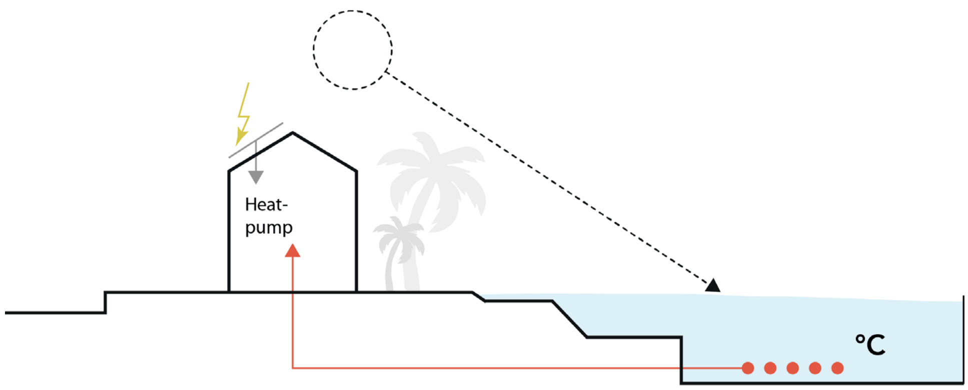
Beside heat pumps there a other concepts available, which can benefit from a constant energy flow in that dimension. Those concepts are highly dependent on the context, for example to the availability of public open spaces, which requires Air Conditioning. The use of adsorbtion or absorption Cooling machines can be discussed, and probably supported by the WRMS. Those machines need beside a hot water stream (90 centigrade), an middle temperature stream, which can be seen as a "cooling water" stream. This stream can be set to 30 Centigrade.

Several options are available to remove energy from the lake system, which in its consequence will cool, down the water. Cooling down a (sub--)tropical will at least increase the Oxygen capacity of the water and slow down the biological growth. Due to the constantly available energy, those streams should be considered at the interface form building service engineering.

Another factor, which influences the lakes temperature, is the effluent of the advanced membrane reactors. Capturing this heat, which means to control the temperature of the effluent, can also contribute to the biological system, by preventing energy to enter it.

A side effect of such as concept is furthermore, that roof areas, which are usually equipped with geothermal solar power, can be equipped with photocoltaic systems to produce electrical energy, thus contribute to a sustainable energy production. Capturing the energy of the domestic can also be feasible within the appartments on a decentralized scale and influence the effluent temperature.

fig. 62:
Cooling down the system with heat exchanger, can reduce the biological activities within the WRMS.



7.3.10 Spillgates (IM10)

To protect the WRMS system, and avoid disastrous floodings durinh the hoigh monsoon seasons, it is necessary to diver the surplus waters from the system. This can be done by Spillgates or emergency structures, which releases water when the maximum Capacity is reached. A Passive structures who divert the lower waters from the system is the previously described Olszecwski Tube (see *Chapter 6*, *Implication 6: The depth*), where the deeper layer of water are withdrawn due to the water pressure, after the water level exceeds a designed height.

This diversion or surplus water might lead to the indirect stimulation of the oxygen saturation, as the oxygen rich water from the surface has to replace the withdrawn water (*Chapter 6* see aeration, Sediment Oxygenation).
The withdrawn water can get released to a river, or infiltrated to the ground, or can get used for other purposes nearby. It is unlikely that these water has some toxic potentials, like it happens with deep stratified lakes, where the water is depleted completely and downstream effects may occur, by releasing these waters to a river. A careful design, of the WRMS volume, as well as the Olzeswski tube is therefore necessary. The use of a fountain, can enrich the spilled water with Oxygen.

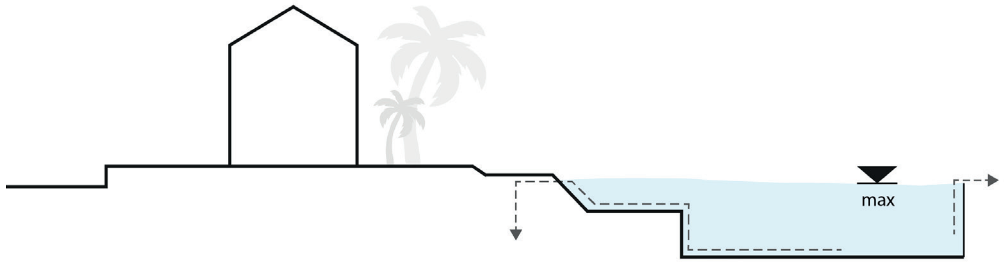


fig. 63:
Spillgates are neccessary to prevent the system from failing, in case thatbthe inflow streams, exyceed the capacity. of the wWRMS.

7.4. Storage water in the urban context

The previous described attributes have to be seen in the context of a water reservoir with a constant changing water volume. During the monsoon season, the reservoir has to collect as much Runoff as possible, to refill the evaporated waters in order to provide enough Tapwater or Service water during the dry season. The changes form dry to monsoon seasons, will produce a constantly increasing water volume followed by a constant decrease.

To store the water, the reservoir needs some expansion capacities, which affects vertical changes in the lakes structure, and horizontal.

Horizontal expansion means that the surfaces of these areas are exposed to water and air in a seasonal steady change. This has a strong influence on the whole ecosystem and the structure of this adaptive area. It is unlikely that any vegetation will survive when it is covered with 1 m of water for several months, but it is very likely that non vegetated soils will develop a sediment cover, due to sinking of biomasses, algae cells and/or particulate matter from the ecosystem, as well as degradation processes. Secondly, flooded biomass from vegetated soils will get degraded in the water which might increase the Oxygen demand, followed by its depletion, and therefore pose a major risk to the whole system. During high water the nutrients from the anthropogenic inputs, get mixed and diluted within the natural streams. At the end of the monsoon season, concurrent with falling water levels, the dilution effects, delivered by the natural streams in context of the expansion decrease, which leads to a more concentrated organic and nutrient load during the dry season.

The processes which happens within this cycle, can be explained with the processes during an artificial water level drawdown artificial dilution approaches, which are mainly used to tackle Macrophyte Nuisances (ref *Chapter 6*).

Under the Assumption, that a WRMS can develop a stable ecosystem, during the monsoon season, which means in that context when the temporarily zones are flooded, the drawdown can be a high risk to the ecosystem by concentrating the nutrients and organic matter. The continuous water intake, in combination with the reduced Stormwater inflow, leads to a successive lowering of the water level, which means that the biomass, which developed during the monsoon season, increases in relation to the available water. This is a particular problem when the remaining lake is relative small and can be often observed during the artificial drawdown of lakes (Cooke et al. 2005).

Oxygen Depletion and its harmful consequences, which include the release of P from the Sediments can occur. Therefore, biomass should be carefully monitored and removed during this phase and the remaining lakes ecosystem should have the possibility to get aerated (see *Chapter 6.3. technical measures*).

On the other hand, those expansion areas can have a positive dilution effect, at the beginning of the monsoon season. When those areas are free of Sediments. When they are getting flooded, the concentration of nutrients in the water will decrease immediately, as long as the external loads are lower than the internal loads, due to the spatial expansion, which leads to dilution.
Otherwise the dried sediments would immediately release the nutrients to the water.

The spatial expansion of the lake has a major influence to the structure of the ecosystem. As described previously, the lake should be designed as a shallow lake, with a mean depth, not more than 3m to avoid stratifications. The depth can be designed for the wet season to ensure, that it doesn't exceed this maximum value. In consequence the lake`s mean depth during the dry season decreases. It will lead to shallow zones (2m). Wetland Pond systems which have deeper zones and shallower ones, are more powerful than those, who have a fixed depth, as they attract a more diverse plant occurrence (USEPA 1993). A mean depth of 3 m can also be seen as a supporting aspect for the light availability throughout the whole water column.

Beside the use as a technical water reservoir, the lake has to provide a multifunctional space within a Community. Changing water levels and the lake expansion have a major influence of the surrounded areas, while they have to react on these changes. The technical measures, in combination with architectural elements can be seen as an additional toolbox to improve WRMS further.
Interfaces from design with the lake can be found at the shoreline, the surface, and by shifting the focus into an engineering context, also on the bottom. Architectural structures which are on the shoreline can either resist the floodings with the use of embankments, walls, walkways, wetlands, or they can expand the shore by flooding other structures, which lead to a change in their use.

7.5. Design Solutions

7.5.1 Terraces (DS1)

The zones, which can react to the changing water levels are limited by the above described protection zone, which can be seen in the authors understanding as the shoreline. This zone has to handle different water levels, provide surface extension and ensure its use as a cultural, recreational, multifunctional space during both seasons, wet and dry. While the basis for the lake design is the general structure, the expansion zones can be used as multifunctional spaces which contribute to the urban context to improve the livelihood.

Terraces are areas which can be accessible during the dry season, when the water level is low. They have the ability to change the architecture of the urban context periodically, while they furthermore gives the opportunity to manipulate the ecosystem of the Water Resource Managemt System, by using the change characteristics of dilution and concentration.

The effects which happens can be described in 4 phases, starting after the dry season, with Dilution, due to flooding (1), Sedimentation (2), Maintainance, and removal of the sediments (3), and finally the use as a public, multifunctional adaptive structure for the urban context (4), until it is flooded again.

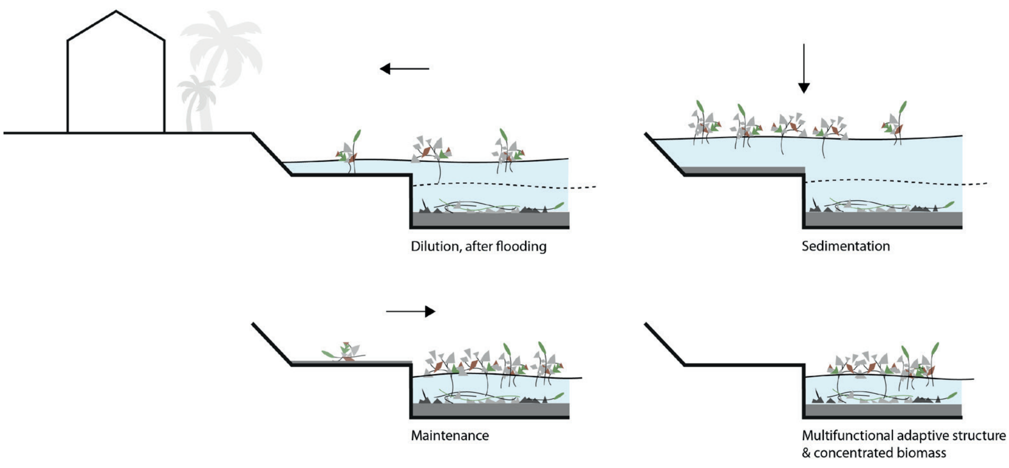


fig. 64:
The expansion zones can have a significant impact on the WRMS.

Designing the edge of this system, which is the boundary between flooded stage and dry stage, can improve the ecosystem, as powerful passive measure. A small parapet al.ong this edge will intensify the effect of dilution, and break the effect of concentration. As soon as the waterlevel reaches the height of the parapet, the water will flood the terrace. As the terrace is lower than the hight of the parapet, the structure will produce a current which distributes biomass and floating plants to the expansion zones. This promotes immediately the development of an ecosystem, which will grow further during the flooding phase, which will last for 6 to 8 months during the wet season. Although it is unlikely that rooted Macrophyte will emerge, as they grow relatively slow, floating plants might develop in those areas. When the water level declines, this small parapet cuts the ecological system of the WRMS into two parts as soon as the water level is lower than the parapet. The water which is on the adaptive structure can now drain through the parapet, which filters plant material, and solids, by the controlled release. The parapet can be designed as gabions, which are filled with fine gravel, to improve the filter capability. While the sediments and plant material, will get captured on the adaptive zones, the "treated water" will drain back to the core and promote dilution effects as it is free of biomass. The passive draining through gabions, will furthermore enrich the water with oxygen. As gabion constructions are accessible for the water from both sides, this effect will occur automatically with decreasing waters and improve the ecosystem, by reduction of nutrients, breaking the cycling and indirect aeration.

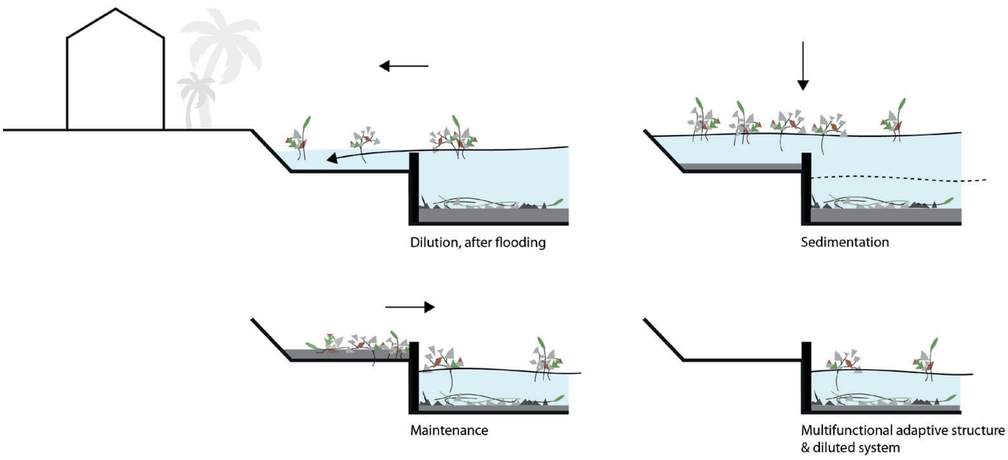


fig. 65:
The expansion zones, can get used to remove biomass from the WRMS.

The captured biomass has to be remowed by labour, before this space can be used by the public. This Design Solution can remove significant amounts of nutrient and floating plants from the system, and there several 'self-cleaning' measures available, which are commonly used to clean infrastructure elements of the Cities sewersystems.

Several solutions are available to design this process as an integrated part of the WRMS. It depends on the area, weather these concept is considered as terraces, steeps or sitting steps. They can be combined with sport fields or recreational zones. They can get designed to attract children to play, or promote other outside activities during the dry season, like sport games, or designated BBQ areas. The use as a multi-functional space in an urban context is unlimited and subject to the architect and the belongings of the inhabitants. The dilution effect for the WRMS works best, when the adaptive zones is clear and free of biomass, before the flooding occurs. Therefore, stoned surfaces which are protected against the soil, can be considered as applicable. The labour, which is necessary to maintain those zones produces furthermore jobs, which can be of interest in terms of the economical development. Examples for comparable structures can be found in the Netherlands (Water squares, Rotterdam.), although those zones are usually designed to get flooded during rain events.
They can get combined with other *Design Solutions*, floating elements, terraced shores, bridges, overhangs or bank steeps like described in the next parts.

7.5.2 Constructed Wetlands and Marshes (DS2)

Natural Wetlands are an essentiell part of the ecological system, as they act as a buffer- and protectionzone with significant influence to the water quality. Artificial constructed wetlands are an important technologie in water treatment, especially in rural areas, or countries of the global south, where technical treatment is not everwhere available. Constructed wetlands can either be designed as Free Water Surface flown (FWS), Horizontal Subsurface Flown (HWS), or Vertical Subsurface Flown (VSF). The FWS Wetlands are characterized by an open water surface, which is equipped with plants, while the HWS and VSF are characterized by drainage construction underneath the surface which drains the water along the roots of the plants. Although the environment in the subsurface versions is anaerobic, the plant roots release oxygen, which stimulate the biological degradation activites for aerobic bacterias. In general, the purifying capabilities of all systems are comparable, and when used as a second treatment option, the water can meet the requirements for field irrigation. Free surface wetlands require more space than subsurface flown constructions, because the use of technical filter medium in the subsurface flown Constructions provides a greater contact area for biological activities, than it happens in the open water versions.

fig. 66:
The constructed Wetlands in Singapore's Bishan-Ang Mo Kio parc create nice spots within recreational atmosphere

The plants which grow on the wetlands can be used as energy source. They require, like the expansion zones several labour activities, but they are highly resilient, and don't need any infrastructure.

The role of wetlands in natural systems are comparable, as they stabilize the water quality. Accoring to (Schueler 2000) Pond - Wetland systems, which are characterized by marshes and open water surfaces, are among the powerful natural systems, which can be translated to a hybridized design, which includes FWS and HWS/FWS features. The role of these wetlands as an element for the shoreline is particular of interest when it comes to Design Solutions for the Water Resource Management System.

The influences of aquatic vegetation to ecological system are described in *Chapter 6* in details. The same effects happens inside constructed wetlands, where those effects subvert the compounds of the water streams. Artificially constructed wetlands can be used in combination with a pondsystem to stabilize the water within a pond, while providing an accessible zone which fulfills aesthetiques as an designed Element. This system is used successfully in the Bishan Ang Mo Kio Parc in Singapore, to stabilize the water of the attached pond. Those wetlands significantly reduce phosphate and nitrogen, while they attract visitors in the parc and provide habitat.

fig. 67:
The marshes in Singapore's Alexandra canal, stabilize the water

In the context of WRMS they face challenges. The changing water levels, which can be up to 1.5 m have to be considered while designing those areas. Subsurface flown wetlands, are not constructed for changing hydrologic conditions, as this might be a danger for the wetland filter and the ecosystem. Therefore they cannot be applied at the riparian zones, which expose dry and wet cycles. They can be considered as zero resilient to waterlevel changes. Marshes and wetland plants, , have the ability to react on changing water levels, up to a certain degree. Those plants can be used to design Free Water surface flown parts, which are on the shore, and faeces some water level changes.

Pond systems, which can be naturally found in combination with natural wetlands, can be equipped with floating leafed rooted plants, which have the ability to react on changing water levels, as long as their roots are flexible enough. Those structure can be used to design the areas which are posed to the changes, whereas the rooted Macrophytes are more flexible than the Free Water Surface versions. By designing different areas of the riparian zone, ie. posed to seasonal floodings / to daily floodings / not posed to any floodings, it is possible to combine different wetlands with different characteristics, and creating a hybridized system. At least the lower areas can work without external pumping energy as pond or surface flown wetlands can reciev their waters directly from the open surface. In the case that the wetlands are used as a Designed Solution to protect the whole shore, they can either be attached to the outlet of the rainwater retention zones, or they can be run with lakes water which is pumped to the system. A combination of Stormwater Runoff and pumps thereby can ensure, that the constructed wetlands can be supplied with water during the dry season, and the wet seasosn.

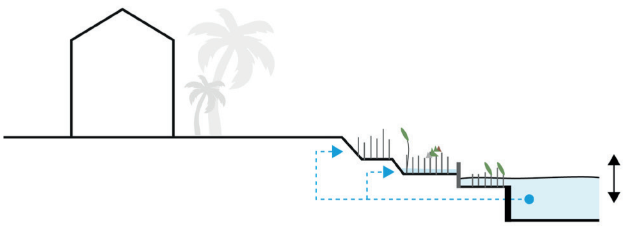


fig. 68:
Constructed wetlands and marshes can be used as a design element for the shorelines.

There are several ways to combine wetlands, with terraces (*Design Solution 2*), steep stones (Design Solution 4), which contributes to the WRMS, by improving the ecological system.

7.5.3 Gravel beds and beaches (DS3)

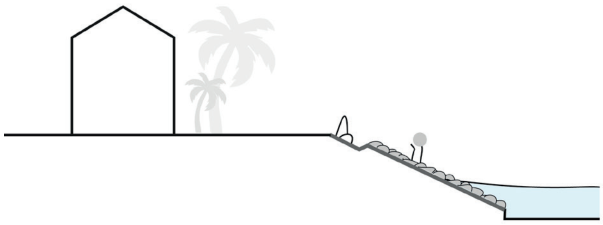


fig. 69:
Gravel beds can attract visitors to get in touch with the water. They are resilient to waterlevel changes.

In contrast to terraces and wetlands, which are characterized by horizontal and vertical surfaces, slopes can be used to give access to the water directly. Slopes which are equipped with gravel or stones, are highly flexible to changing water levels on a seasonal and daily change. When the water level rises, parts of the gravel become flooded, and when the water level decreases, the flooded parts are exposed to the air. It is observed, that those surfaces, which are facing those changes in the nature can develop a highly adaptive vegetation, which can react very quickly and/or resilient to those changes. Those vegetation might include some terrestrial and aquatic plants, like, and develop microorganism, which can support the ecological system.

The Development and Distribution of these plants can be controlled by the underneath structure, which can allow roots or suppress it. Those kind of gravel beds, can attract children to play or attract other visitors to enjoy the water, as this water becomes accessible for everyone. Such 'designed' slopes can be seen often at rivershores and have a strong influence on the perception of waters.
Sedimentation in these areas can occur, although it is unlikely that a gravelbed which is designed on a slope will accumulate significant amounts of it, as the structure is continuously exposed to waves and waters, which are induced by animals, visitors, waves, or other physical effects.

fig. 70:
Stones and gravel is used as a design element at the shore of Singapore's Upper Pierce Reservoir.

The combination of gravel beds with swales, can aerate the water, and it can be used to manage the inflow from the retention zones, to the WRMS, while improving the quality further. The contact with the gravel will aerate the water, before it enters the system, which contributes to the Oxygen Saturation for the ecosystem, especially to buffer the ecosystem after rainevents, where 'fresh' nutrients are entering the system. As the outflow of the retention area start with the rain event, but last longer, this stream can be attract visitors, urban public or children to play.

Gravelbeds and beaches can be seen as the ideal Design Solution, to promote access to the water.

7.5.4 Stepping stones and stairs (DS4)

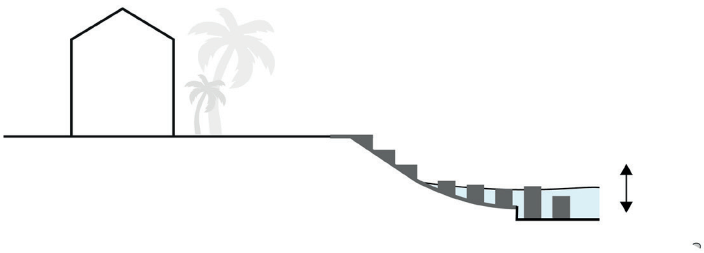


fig. 71:
The shoreline can be designed with stepping stones and stairs.

The shoreline of a WRMS can be designed with stairs and stepping stones, which allows and promotes the accessibility (like *Design Solution 3*) and therefore can be seen as a big potential to bring the people closer to water. It is in its construction comparable to terraces (*Design Solution 1*) and wetlands (*Design Solution 2*), and contribute to the ecological system, by dilution during the rise of the water level, and concentration, during the drawdown phase. Stairs can be used to protect and hide the embankement, they have high potential to invite people to sit along the water, and they can be used along with (*Design Impliction 8*) to capture Sediments.

When the lowest stairs are designed to get flooded seasonally and/or daily this feature is usable all over the year. Stairs which are constructed along the shore are exposed to seasonal or storm induced water level changes. The area which they use, is compared to the terraces relatively small, and it is likely that wind induced waves, will clean the stairs regularly.

The lowest stairs can get designed to be flooded. With the rising water level, 'just' more stairs are getting flooded, but the feature of accessing the water is still usable. Stars can be extended with stepping stones, which allow to crossover the WRMS for the designed water level. Crossing over a WRMS, without using a bridge, is perfect to discover the system and get close to it, as the inhabitants are directly over or at the water surface. The use of stepping stones within a system can be used to divide waters or encourage the water into a flow direction, or diverting the water during specified water levels. Stepping stones can act as a barrier, as long as the water level is lower than their height.

Riverrine areas of the system, which are equipped with stepping stones with very narrow gaps, can aerate the water ans act as a physical divertion of the system. This has to be designed in the context of the retention time, but can be a nice architectural feature. When the stepping stones are designed for the high water level it is particular of interest, how they behave during the low water level. They can be designed in Combination with Overhangs and bridges (*Design Solution 5*), to promote the accessibility of the water surface

fig. 72:
Stairs, which are floodable allows the contact to the water within the wetkands of Singapore's Ang Mo Kio parc.

fig. 73:
Stepping stones in Wipkingerpark, Zürich (CH)
Source: prominski et al. 2014

fig. 74:
Stepping stones in Zürich, CH
Source: https://www.stadt-zuerich.ch/ted/de/index/gsz/natur-_und_erlebnisraeume/park-_und_gruenanlagen/wipkingerpark.html

Crossing over via stepping stones might pose some risk, which makes further measure necessary, like the gap between the stone, or the water depth at this passage.
They can be combined with wetland plants to create micro biotopes as habitat and refugee for microorganism (Prominski et al. 2012). Areas which are exposed to changing water levels can furthermore develop microorganism Communities, which can adapt to those changes. This can be seen at the riparian zone of tropical lakes. The influence of these Communities to the WRMS are minimal, and therefore not considered, although they contribute to the ecological systemby increasing the contact zone between water and ripatrian zone, which provides habitat for biological bacterias.

7.5.5 Shading structures (DS5)

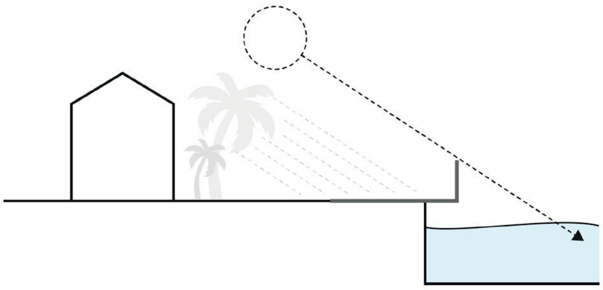


fig. 75:
Shading the water can reduce the biological growth

Overhangs and Balconies are designed elements, which can be used to shade the water which reduces the Availability of UV light on the water surface. It can be described therefore as a proper measurement to limit biological growth. Although it is must successful in the control of Macrophytes, it can have an impact on algae as well. The effects of shading the water surface can be seen in shallow lakes, which are characterized by a Clearwater, Macrophyte dominated state: Submerged Macrophytes stop until their biomass reaches areas, which is shaded by trees.

The design of bridges and Overhangs, can be used to shade the water in critical areas, like the inlet structures of the MBR Effluent. It can furthermore reduce the losses through Evaporation form the open water surface, and it can be used to design or hide the shoreline of the WRMS. Due to the less intense UV Radiation underneath a shaded surface, the water changes in water temperature are less intense (Design *Implication 9: Cooling*). Shaded zones under Overhangs or bridges can be combined with aeration, which renders this technical process (see *Chapter 6*) unvisible for the public. The Changing water levels of the WRMS can educate the public as the same bridge can be constructed close to the water surface during the monsoon season, while it is 1 or 1.5 m over the water surface during the dry season. Bridges can be combined with floating structures (*Design Solution 6*).

fig. 76:
Shading walkways are used at the shore of the Alexandra Canal in Singapore

Shading the water is an opposite approach of the controlled growth of biomass, like duckweed or eichhornia crassipes (see *Chapter 6*), although they in consequence shade the water, too. Although a complete shading would suppress any growth, it is not considered as this doesn't follow the idea of a WRMS where the nature is in the focus. It gives the ability to limit an ecosystem by light, which can partly applied for specified areas.

Shading also comes from the urban context, as the structure of the buildings can contribute to the shading, the same effect can be achieved by planting trees around the lake.

Completely isolated water storage tanks, which doesnt allow any light penetration it give the possibility for a long term storage. Such systems can be used in Water Recycling projects, but as the core of this idea is, to create an urban environment, where water is one of the core elements, it is not considered.

People can come closer to the water and experience it immediately from the surface, which allows everybody to individually judge the system, which can be seen as key point of Community Involvement, and acceptance of a WRMS.

7.5.6 Floating structures (DS6)

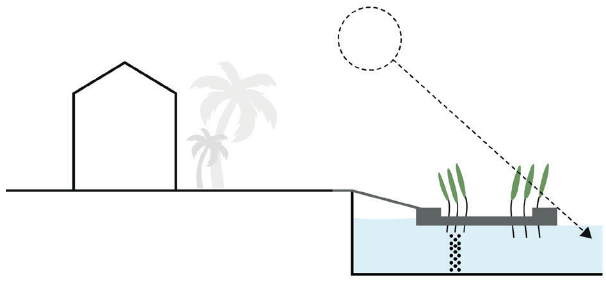


fig. 77:
Floating structures can be used to shade the water, while improving the water quality due to wetland plants.

Elements who float on the water, can fully adapt to changing water levels. The combination of floating elements with recreational issues can create a high quality space on the water, which fulfill both: Provide space for public and provide space for the water. By bringing the people on the water, the urban public can experience the WRMS directly. Floating structure can be place near the shore, or everywhere within the lake. A distance to Wetlands is necessary to protect them from physical damage (*Design Solution 2*)

fig. 78:
Floating structures at the Elster, Leipzig, DE
Source: Prominski et al. (2014)

Floating structures can be accessible by the use of ramps or bridges, which adapt to the changing water levels, with a change in the gradient. Floating structures shade the water underneath it completely, which doesn't allow any growth, despite terrestrial pants, which are planted on the floating desks and have their roots directly in the water column. Succesful experiments with them have shown, that significant reduction of nutrients and heavy metals can be achieved (Headley & Tanner 2007) as well as Denitirfication processes as described previously.. The maintainance of these plants is relatively easy, as it can happen from the floating deck. The performance of these floating structures can furthermore be improved in combination with aeration of the water column underneath, and the used plants can easily get adjusted to the local context. One side effect of these combination is, that the aeration is hidden and therefore unvisible for anybody. As they adapt to the water level, they can get used all over the year and therefore should be considered as an important element. Floating structures can be used furthermore in combination with Alum or Iron Treatment to provide a longterm Phosophorus protection.

The design of the floating structures is not limited to any public use. It can be designed in the context of the development and includes BBQ Areas, sitting banks or other recreational zones. Plants can provide habitat for insects, which contribute to the ecological system by grazing on algae and phytoplankton.

The relationship of a floating structure with the water surfaces differs from dry season, to the wet season, due to the different water levels, which increases the water surface. This can be used as an important element, during the dry season, where the inflow mainly consist of the effluent of the MBR, while support denitrification, which is particular of interest for this stream.

7.5.7 Depressions on the bottom, or dead zones in the flow (DS7)

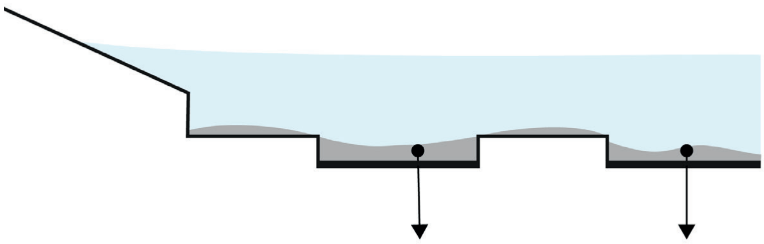


fig. 79:
Depressions on the lakes bottom can get used to accumulate the sediments

As the water in unstratified, shallow lakes has a steady movement, deep zones on the bottom/depressions can act as sediment traps, to control the Sedimentation of the system. By designing those areas with automatic dredging structures (see *Chapter 6*: *Sediment Removal*), it becomes possible to remove the Sediments easily from the system, without any negative side effects. It is likely, that submerged Macrophytes will grow roots to the sediments, therefore it might be necessary to combine it with cutting structures, which are commonly used in Lake restauration projects. Designated Areas which are not equipped with depressions can furthermore encourage Macrophytes to grow.

The WRMS system is characterized by a flow (*Implication 5:The shape*), which follows a current. Designing a WRMS will automatically lead to areas with less current activities, as the structure itself is not rivverrine. Those zones which can be found near the outlet structures, in 'dead edges' will accumulate more sediments, that other zones which are in the current. The use of automatic dredging structures in that zones, might remove more sediments, while reducing the impacts of this phenomena.
Depressions in combination with the above described sediment traps, can improve the effectiveness further.

7.5.8 Protected open water surface areas and enclosures (DS8)

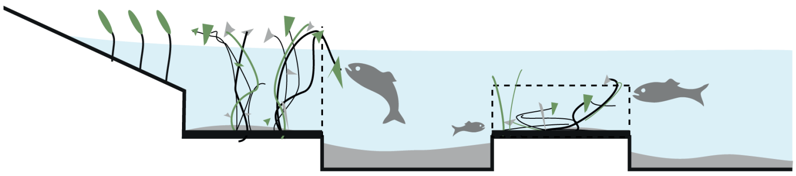


fig. 80:
The construction of enclosures or diverted areas can protect macrophytes from fish predation.

In General, open water surfaces are areas, which are not protected by shading structures (*Design Solution 5*), or floating elements (*Design Solution 6*). Open water surfaces can be seen as the key to design the system resilient to shocks and stresses, when they are planned in Combination with the structural *Implication 7: Retention time*, and the structural *Implication 8: Divertion*. Open water surface areas, are the perfect structure for any of the in *Chapter 6* described physical, technical, biological and chemical treatment opportunities. They can be integrated and designed with the use of bridges, step stone or other elements and can be developed as an additional layer, which covers the whole system.
They can play the key role in the system adjustments as those areas can receive a treatment, without affecting other areas. It is therefore necessary to include some of this *Design Solutions* into the system, to react on unwanted conditions. The combination of two or more of these open water surface areas, can lead to higly flexible systems. One can be used to reduce the Nitrogen by shading with plants (*Design Solution 5*), and the other is stocked with silver carp, to remove phytoplankton, before the water is released to other stages which are supported by other *Design Solutions*.

Protected open water surfaces areas can receive iron or alum treatment, which concentrates the flocculates, like it happens in Reclamation plants. If submerged Macrophytes are suppressed by fishgrazing or shading, these protected open water surface areas can be dredged automatically, before the water flow continous. There are several combinations which are powerful to improve the system. While the interaction between chemical treatments and floating structures, wetlands and/or fish stocking's might be difficult to control, it is important to separate those "Case-of" areas from the mainsystem, while they can be integrated into the holistic design. If the WRMS offers the opportunit to get manipulated in the case of failure, by designated areas, it is very likely that it is a question of adjustment and management, to produce sufficient water quality for the intake structure.

7.6. Conclusion

Designing a Water Resource Managing requires monitoring and adjustments. The *Implications* give the fundamental basis for constructing an artificial water reservoir in the context of an Water Resource Management System. The introduced *Implications* can be used to create a system, which is oriented at natural rivers or lakes, by creating an artificial Water system with a small, but steady current, to reduce the negative impacts of stagnant waters. Although it might not be possible to create a system without any stagnant areas in its flow, it is question of design, to turn the problem into a benefit, as those zones are characterized by higher sedimentation rates, and less oxygen, they can get used to divert water and nutrients from the system (*Design Solution 7*), or designed in combination with accessible wetlands (*Design Solution 2*), or introduced, protected Macrophytes (*Design Solution 8*) to get stabilized and adress social or cultural issues.

After the initial structure is build, it is a question of adjustment, to design this system, and it is very likely that the system need some time to develop the needed ecological system, and grow to a resilient structure. It might also be possible that some plant species wont grow, and that other plant species will become a nuisance. Both situations might differ from the expectations and need time to adjust.

Some of the technical solutions which are described in *Chapter 6*, can immediately improve the water quality, and when they are applied in Combination with matching *Implications* and *Design Solutions* they can be seen as the ultimate factors to prevent the system from failing. Those Combinations can be used during the Development phase, but also in case of failure in a later stage.

Extensive stocking of silver carps (*Chapter 6*) within a small protected zones of the system (*Design Solution 8*) will immediately remove any algae and aquatic plants, which eat the plant material, which leads to higher sediments, due to their metabolism. Dredging structures can remove the Sediments from the system automatically, and use them as a source for biogas, which is beyond the system boundary of this doctorate.

Alum Treatment (*Chapter 6*), can be described as the ultimate controlling mechanism, in case of failure. Applied Alum to the water column will immediately make the whole system P-limited, which can effectively limit the eutrophication, and therefore any aquatic growth. Due to the deposit effect of Alum, this treatment will last long, and protects the ecosystem from failing effectively. It can be applied in combination with Divertion (*Implication 8*), to produce a P-limited water stream, for the following zones of the system.
Those 'ultimate Combinations' can give the system a working guarantee, which is an important point for the feasibility of the whole concept.

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Chapter 8: The conceptual Design: Ha Noi

8.1. Ha noi

The case study of Ha Noi was selected as the Situation in Vietnam in the context of water and sanitation is challenging, especially in those areas, which are not equipped with centralized infrastructure in the outskirts of the City. The following case study aims for an explorative design of a conceptual scenario for a neighborhood in Ha Noi, which is independent from the urban water infrastructure, by a sustainable recycling and management of the available water streams.

77% of the urban population in Vietnam has access to a centralized water supply, while this number drops to 10% in rural areas, where people rely on own wells, which are management by provates. It is estimated, that by 2014, only 3 to 10% of the overall used waters of the Country, which includes domestic and industrial flows is treated in one of the 23 reclamation plants (Vietnam 2015).

Vietnam, in particular, experienced a fast growth of their economies which started in the 1980. Due to this rapid growth, the balance between water infrastrutcure and the Urban Development is not balanced, as these processes happened without any concern for the environment. The country focused on economical issues, without upgrading their infrastructure. By 2013. Vietnam had 283 industrial zones with 6800 factories, which mostly produce goods for the global markets. These industrial zones provide jobs for up to 4 million people (MPI 2012). Out of these 283 industrial zones, only 118 are equipped with treatment facilities. Those industrial zones produce more than 1 million m^3 heavily polluted wastewater per day. Most of these water flows are spilled directly to the river bodies, which results in an enormous pressure and pollution to it. At the same time, rivers corresponds to 30% of the Vietnamese water supply, while 70% are extracted from the aquifers.
Particular in the northern parts of Vietnam, arsenic substances are naturally available in the rivers and the aquifers, which requires high technologies treatment and intensive aeration, for it’s further use as Tapwater.

Beside the fact, that most of the water sources are polluted, either natural or through anthropogenic changes, the water supply grid in the city of Ha Noi is characterized by broken pipes and illegal connections. This affects the water quality as well as the pressure in the water supply network.

Furthermore, most of the areas in Ha Noi aren't equipped with proper infrastructure and the discharge of the domestic flows relies on septic tanks in bad maintainace due to financial, educational or technical problems, which prevent the effective use of this basic technology.

In recent years, housing developers started to construct residential areas mostly in the outskirts of Ha Noi following in their structure typical Asian housing developments. Although they are not as high and dense as in China or Hong Kong, they are visible in the skyline and 20 story's are more starting point than a limitation.
Several of these developments are under Construction in 2017. Those areas are usually equipped with green space, swimming pools, fitness clubs, parking decks and other facilities for the public.

A large real estate developer from Vietnam 'Vinhome' uses in its Television Commercials images of nature, animals and lakes, which are constructed in between buildings to attract the potential buyers. Butterflies who are flying everywhere, resting on the shoulders of the residents, while they enjoy the beauty of the nature, shall convince the audience of the highly livable environment, which they can purchase.
The reality in northern Vietnam is far more challenging as heavy rainfall, induced by typhoons during the monsoon season, happens several times a year and produces damages to the City, as well as danger for human life.
According to Gleick (2003) the twentieth century approach of designing water infrastructure is a hard path approach that addressed the issues of water demand only in terms of quantity, which answer water shortages only by exploiting new sources, than improving the management of the existing sources. He proposes the development of a softpath approach, which consist of carefully planned centralized structures which are complemented effectively by low cost community managed decentralized water management issues (Wong and Brown (2008)

Ha Noi is selected as a case study for this research, as the WRMS improves the urban water infrastructure, while creating a highly livable space for the residents and answers flood protection issues.

The assumptions made in the following section are based on the literature research of the previous Chapters and form the basis for the analytical consideration and development of an explorative case study in Ha Noi.

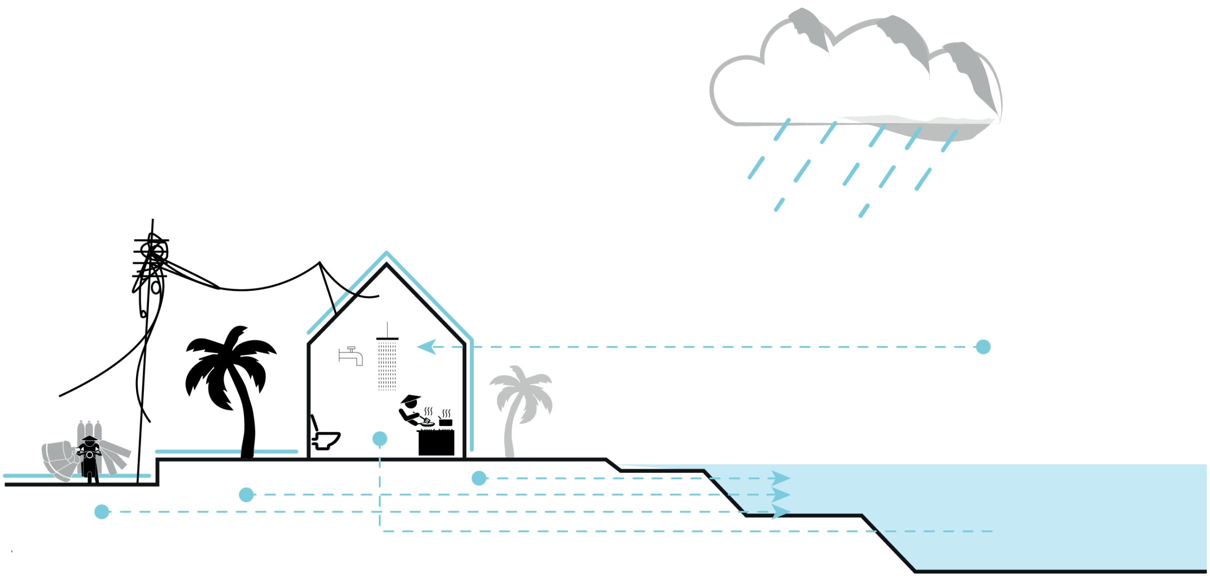


fig. 81:
A typical housing, somewhere in Vietnam

8.2. The reference residential district:

The conceptual design follows a medium dense development which consist of 6 buildings and provides space for 648 inhabitants. The 'reference building' design is oriented at available structures in Vietnam and China. It is designed with 9 Storey's, with 400 m^2 each, while producing a footprint of 10 m (width) to 40 m (length).

The buildings are equipped with four apartments on each story for three residents (mean calculation), with an average size of 85 m^2. excluding the access zones, which are located in-between the apartments. All Apartments are placed next to each other by using a "row house typologie", to provide a fully South – North orientation. The footprint of 400 m^2. equals the roof surface.

The building density index (GRZ) ranges around 0.3. while the floor area ration is considered as 1.6.

6 buildings produces an overall roof surface of 2400 m^2. According to the urban density index, the available open space in-between the buildings can be estimated to 5000 m^2. whereas 1000 m^2 of these are streets and traffic zones, which are not considered as catchment areas. This reduces the usable Catchment to 4000m2

8.3. Domestic flows (according to Chapter 5)

8.3.1 Greywater:

Each habitant produces 88 L greywater per day, which consists of 63 L personal hygiene, 15 L laundry, 7 L dishwashing and 3 L from the kitchen sink.

It has to be discussed, weather the water from the dishwasher and the kitchen sink should be included to the blackwater flow, due to the higher loads of organics and fatty substances. This is dependent on the engineering concept and the used membrane modules.

The treatment effectiveness of the MBR for greywater can be estimated to 95%.

The system will receive 54m^3 reclaimed greywater daily

8.3.2 Blackwater:

Each habitant produces additional 40 L blackwater per day, whereas 33 L are from toilet flushing and 7 L from household cleaning.

The treatment effectiveness of the MBR can be estimated to 90%, which is less in comparison of the greywater stream, as more substances will be removed, and more sludge will accumulate within the biological treatment.

The system will receive 23m³ reclaimed blackwater daily

8.4. The natural flows (according to Chapter 5)

The area of northern Vietnam, in particular Ha Noi receives an annual rainfall of 1676 mm. This corresponds to 1676 L/m².

The Distribution of the rainfall is characterized by a monsoon season, and a dry period. Most of the rainfall will occur during July and august, where the values range around 300 mm per month, which corresponds to 35 percent of the overall rainfall (for details refer to *Chapter 5*).

tab. 14:
Climate data of Ha Noi, for details see Appendix

	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec
rainfall [mm/m²]	18,6	26,2	43,8	90,1	188,5	240,0	290,0	265,0	130,0	43,9	23,4	
rainy days	9	12	15	13	14	15	16	17	14	9	5	4

8.4.1 Stream 3: Roof Runoff

2400 m² roof surface will flush 4022 m³ Runoff from the roof, annually to the system, while 10% are lost through evaporation and first flush diversion.
The system receives arithmetically around 10m3 daily.

8.4.2 Stream 4: Green spaces

4000 m² green space will flush 6704 m³ Runoff from the green spaces, annually to the system. 50% of these water are lost due to evaporation, transpiration and infiltration.
The system receives arithmetically around 9m3 daily.

8.4.3 Stream 5: streets, walkways

Due to chemical pollution and other particles like rubber, oil and petrol, the Runoff from streets and walkways is not considered within the catchment. In a zero Water City, this Runoff should receive a proper treatment, before it is discharged to the nature. For details refer to *Chapter 5*)

8.5. Evaporation and Infiltration:

Water losses by evaporation and infiltration are significant high. Therefore they must be taken into account, before the water masses can be calculated. *Implication 3: Evaporation* uses the Penman method to calculate the losses.

By using the weather data of Hanoi (table 14), the Evaporation from the open water surface can be estimated by the use of the Penman-Calculation:

tab. 15:
Expected Evaporation, according to Penman (1948)

Climate data, Hanoi

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
rainfall in mm/m2	18,6	26,2	43,8	90,1	188,5	240,0	290,0	318,0	265,0	130,0	43,9	23,4
Amount fo rainy days	9	12	15	13	14	15	16	17	14	9	5	4
Temperature, max	19,3	19,9	22,8	27	31,5	32,6	32,9	31,9	30,9	28,6	25,2	21,8
Temperature, min	13,7	15	18,1	21,4	24,3	25,8	26,1	25,7	24,7	21,9	18,5	15,3
Temperature, average	**16,5**	**17,45**	**20,45**	**24,2**	**27,9**	**29,2**	**29,5**	**28,8**	**27,8**	**25,25**	**21,85**	**18,55**
rel. air humidity	0,8	0,83	0,85	0,85	0,81	0,8	0,8	0,82	0,8	0,79	0,76	0,76
wind speed	2,2	2,4	2,3	2,2	2,1	2,1	2,1	1,8	2	2,3	2,2	2,1
sun in %	39,6	24,7	22	24,5	34,5	39	55,2	51,7	51,5	53,3	53	50,7
max sunduration	10,4	11,1	12	12,9	13,6	14	13,9	13,2	12,4	11,5	10,6	10,2
sunduration	**4,12**	**2,74**	**2,64**	**3,16**	**4,69**	**5,46**	**7,67**	**6,82**	**6,39**	**6,13**	**5,62**	**5,17**
extra-terrestric solar radiation	374	402	433	444	439	433	433	439	433	416	385	365

Penman Calculation

Constants														
Albedo constant			0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06
psychrometerkonstante			0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65
Sättigungsdampfdruck	es	[hPa]	6,00	19,91	24,00	30,13	37,48	40,41	41,12	39,49	37,27	32,08	26,15	21,33
Dampfdruck	ea	[hPa]	4,80	16,52	20,40	25,61	30,36	32,33	32,89	32,38	29,81	25,34	19,87	16,21
Globalstrahlung	RG	[W/m2]	152,52	130,99	134,66	144,19	166,71	175,15	213,73	208,24	204,92	200,99	185,38	171,13
Abstrahlung	I	[W/m2]	69,93	30,54	24,89	21,99	22,74	22,42	28,67	27,85	32,22	40,90	50,29	54,22
Strahlungsäquivalent	EH	[mm/d]	2,59	3,27	3,59	4,01	4,73	5,03	6,09	5,93	5,67	5,23	4,38	3,77
Windfunction	F(v)	[mm/d hPa]	0,44	0,47	0,45	0,44	0,42	0,42	0,42	0,38	0,41	0,45	0,44	0,42
d		[hPa/K]	0,38	1,24	1,46	1,78	2,15	2,30	2,33	2,25	2,14	1,88	1,57	1,32
Evaporation from the water surface (Lake)		**[mm/d]**	**4,15**	**4,75**	**4,97**	**5,38**	**6,30**	**6,64**	**7,71**	**7,37**	**7,24**	**6,93**	**6,17**	**5,49**

IM2: Groundwater describes the interactions between the system and the environment. As the WRMS is protected against the environment, the losses through infiltration can be neglected.

The losses through evaporation and infiltration for the natural flows are considered within the treatment effectiveness, which is set to 50%. As the subtropical climate is charcertizes by short rain events, with 'thick' raindrops, it is likely that the real losses are less than 50%, as the earth will get saturated with water immediately.

8.6. Tapwater

To fully serve the needs for Tapwater, each habitant is supplied with at least 125 L daily.
The treatment effectiveness can be set to 1.0.
The WRMS therefore has to supply 81 m^3 Tapwater daily.

The stored water in the WRMS is from high quality, as the domestic flows were treated by an MBR, and the natural ecosystem polishes the water further.
However, in the frame of this scenario, the Tapwater stream should fulfill the Vietnamese guidelines for Tapwater which requires further steps. Several technologies are available, which can get used for this purposes. The use of an MBR can ensure to produce a high quality water flow by the use of Ultra- or Nanofiltration, which are commonly used in the water supply utilities. Although the effluent of these MBR will be characterized by a quality which allows its use for Tapwater, a further treatment with active carbon, followed by a disinfection is required to enhance the resiliency of the system. This is particular from importance case of failure or malfunction, or adjustment processes of the MBR. It was described in *Chapter 5*, that chlorine is harmful for ecosystems in concentration above 0.05 mg/L, and therefore the Disinfection with UV Exposure was recommended for the domestic flows before they enter the WRMS. It can be discussed, if the use of chlorine disinfection is possible for this stream, as this stream doesn't enter the WRMS directly and is used in most countries of the world, for the disinfection of Tapwater. It provides a depot effect, which suppresses the development of any algae cells, viruses or bacterias which ensures the water quality

throughout the distribution grid. As soon as this chlorine gets in contact with pathogens, it starts to kill them by oxidation processes. It is very likely that the chlorine concentration is zero as soon as the domestic flows enters the reclamation technologies. In case that the domestic streams, still contain while the residual chlorine, it has to be be removed before the biological activation processes, as it would harm the treatment processes before the further filtration by the Membrane module. It should be however noted, that in European countries, the use of chlorine is strictly regulated for emergencies, and that the Tapwater usually doesn't contain chlorine.

The chlorine disinfection is required by the Vietnamese law for Tapwater and requires a concentration of 0.3mg/L. This concentration is designed for large scale water supply systems to ensure the quality. Considering that the Tapwater flow of the WRMS is compared to a large scale system relatively small, it might be possible to use concentration which are lower than 0.3 mg/L, as chlorine has already inhibitory effects starting at 0.05 mg/L.

The removal of the chlorine, before the flows enters the WRMS has to be ensured, even in case of malfunction of the MBR, to protect the Ecosystem of the WRMS. This can require an additional storage tank and / or diversion facilities.

8.7. Estimating the water masses

Before the sizing and design, as well the application of the *Implications* and *Design Solutions* which were described in *Chapter 7*, the water masses should be set in correlation to each other.

The system will receive rainwater and reclaimed water and loose water through the intake for Tapwater supply, as well as through evaporation from the lakes surface.

A daily breakdown of the monthly occurring rainwater (table 15) on randomized daily rain events is done by the use of an Excel balance sheet (Chapter 9.2; simplified in table 16).

The catchment of the Runoff, from the randomized daily rain events, is the first input flow to the WRMS. This flow is extended with the constant daily inflow of reclaimed grey and blackwater, and reduced by a constant intake. Furthermore the Penman Calculation reduces the water masses in the system by considering evaporation. The evaporation is equivalent to the surface area. Therefore, the system has to be developed in iterative steps, as the evaporation has to be adjusted with the design.

The theoretical water volume of this system in the context of Hanoi, by considering inflow, intake and losses is approximately 3700 m^3 during the rainy season in September, and 2200m^3 during the dry season in April. The months in-between are characterized by either a steady increasing or a steady decreasing volume. After the monsoon season, the relative influence of the domestic flows increases.

Water Resource Managemt System in the context of Hanoi
mothly chart, mean values

Start	1.1.	Jan	Feb	Mar	Apr	Mai	June
inflows:							
1: dom. flow Greywater	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6
2: dom. flow Blackwater	20736	20736	20736	20736	20736	20736	20736
3: nat. flow roof runoff	0,00	1296	2021	3052	6487	13134	17280
4: nat. flow green space	0,00	1440	2245,714286	3390,967742	7208	14593,54839	19200
5: direct Precipitation on the Lakes surface	0,00	1260,00	1965,00	2967,10	6307,00	12769,35	16800,00
Water in Lake	3.472.057,60	**3.167.525,70**	**2.666.924,96**	**2.259.711,94**	**2.139.389,55**	**2.343.118,12**	**3.169.781,83**
Lake surface area	**2100,00**	**1845,967742**	**1575**	**1575**	**1575**	**1575**	**1785**
outflows:							
Diversion by Spillgates	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Watervolume after spilling	3472057,60	3167525,70	2666924,96	2259711,94	2139389,55	2343118,12	3169781,83
Evaporation from the system	8719,94	7665,10	6539,95	6539,95	6539,95	6539,95	7411,95
Service water intake	87480	87480,00	87480,00	87480,00	87480,00	87480,00	87480,00
overall Watervolume	**3375857,66**	**3072380,59**	**2572905,01**	**2165691,99**	**2045369,60**	**2249098,17**	**3074889,88**
estimated Retention time	39,69	36,21	30,49	25,83	24,46	26,78	36,23

Start	Jul	Aug	Sep	Oct	Nov	Dec	31. Dez
inflows:							
1: dom. flow Greywater	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6
2: dom. flow Blackwater	20736	20736	20736	20736	20736	20736	20736
3: nat. flow roof runoff	20206	22157	19080	9058	3161	1630	0,00
4: nat. flow green space	22451,6129	24619,35484	21200	10064,51613	3512	1811,612903	0,00
5: direct Precipitation on the Lakes surface	19645,16	21541,94	18550,00	8806,45	3073,00	1585,16	0,00
Water in Lake	**4.256.842,35**	**4.767.244,10**	**4.772.672,63**	**4.604.604,36**	**4.381.142,86**	**3.878.219,33**	3.573.543,19
Lake surface area	**2100**	**2100**	**2100**	**2100**	**2100**	**2100**	**2100,00**
outflows:							
Diversion by Spillgates	4765,49	43663,40	38797,24	9025,53	0,00	0,00	0,00
Watervolume after spilling	3917530,36	4000000,00	4000000,00	4000000,00	4000000,00	3860931,67	3573543,19
Evaporation from the system	8719,94	8719,94	8719,94	8719,94	8719,94	8719,94	8719,94
Service water intake	87480,00	87480,00	87480,00	87480,00	87480,00	87480,00	87480
overall Watervolume	**3821330,43**	**3903800,06**	**3903800,06**	**3903800,06**	**3903800,06**	**3764731,73**	**3477343,26**
estimated Retention time	48,66	54,50	54,56	52,64	50,08	44,33	40,85

Overall Water spilling:	2945004,23
avergae daily:	**8068,50474**

tab. 16:
Monthly mean values of the Water Resource Management System

8.8. Translating the water masses into a WRMS

According to *Implication 2: Two water levels*, the system should be designed for different water levels. An inner lake for the dry period, where treatment can happen very effective, as well as the extended volume, which in fact is the additional storage capacity, to provide sufficient service water during the dry season.

The inner zone, and the extension zones can get designed in the context of the water masses. The inner lake provides the general storage area, while the second volume provides the extension.

Example, inner lake: 15 m width; 105 m length; 2 m depth

The inner zone is designed to handle 3150 m^3 of water, which is slightly more than the volume which occurs during the dry season, by considering the inflows.
The surface is 1575 m^2. which reduce the impacts of evaporation, compared to the overall size.

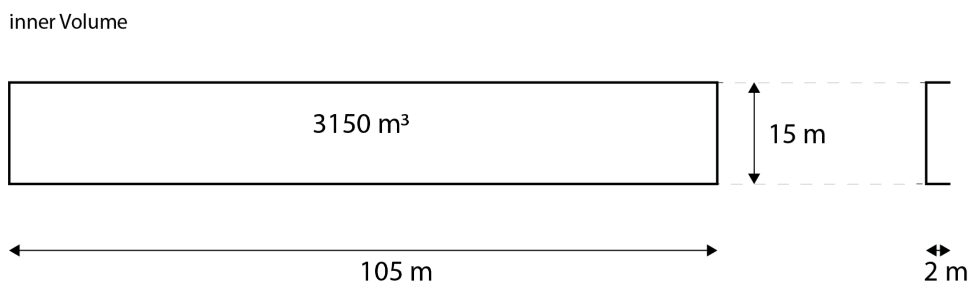


fig. 82:
Sizing the ‚inner structure' of the WRMS

The water level within the WRMS will stay below this point from February to Mai, which allows the use of the adaptive space by the residents.

8.8.1 The Expansion Zones, for storing the water.

According to *Implication 6: The depth*, changing water levels should ensure that the overall systems depth doesn't exceed 3 m. Therefore the space for expansion capacities is limited. The changing water levels are subject to the horizontal area which should be developed as adaptive zone, in the context of *Design Solution 1*: *Terraces*. An expansion zone of 5m will increase the water level up to 0.6 m.

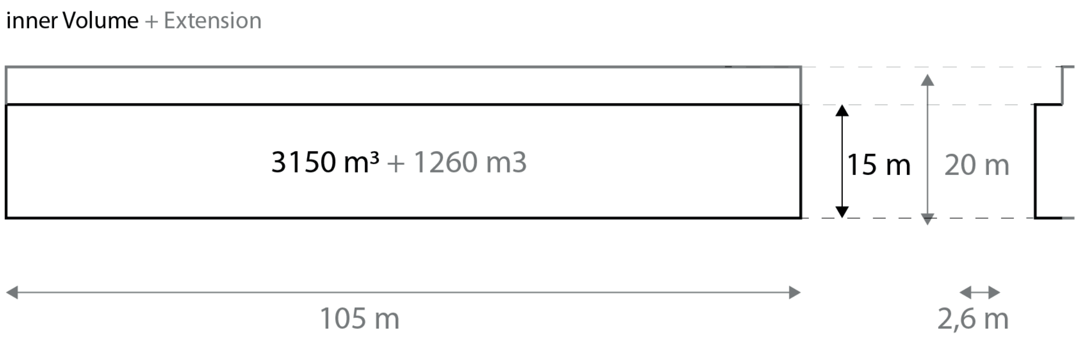


fig. 83:
Sizing the additional storage capacity

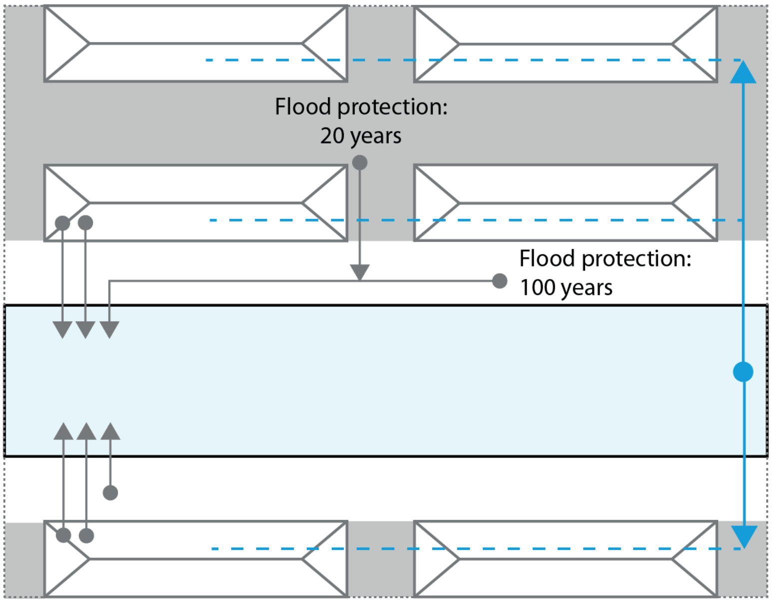
Note:
After designing the lakes volume, the Evaporation processes have to be adjusted.

8.8.2 Designing the inlet structure for the natural streams and the protection zone

After the basic structure of the lake system is adjusted, *Implication 1: Protection zone* should be used to define the inlet structure and flood protection for the natural streams. The protection zone must prevent Stormwater from entering the system by draining any drop to the 100 years retention zones. These retention zones, furthermore fulfill flood protection issues in case of a failure of the 20 years retention zones, which are designed for the areas near or in-between the residential buildings, as they receive the additional Runoff which can not be handled by the 20 years zones (for examples open channels or bioswales). Runoff, which is not captured by the 20 years retention zones, will get to the 100 years retention zones directly.

The Runoff from the retention zones near the residential building can enter the lake directly, after it passed the retention, by the use of underground Stormwater sewers. The Runoff from the roofs can enter the lake directly, except a passive first flush diversion, no further retention is necessary (See *Chapter 5*). They can be included to the Stormwater collection system.

All the inlet structures should be placed on one side of the WRMS, to ensure the current flow which is important in the context of *Implication 5: The shape*. The direct precipitation on the lake surface is the only inflow, which can't be included into this first zone.



Plot size: 100m x 78m = 8000 m²
Built-up area: 6 x 400 = 2400 m²
Density: 0,3
Floor area ratio: = 1,8

fig. 84:
Exemplary floor plan of the WRMS and the connected buildings

8.8.3 Designing the inlet structure of the MBR stream

The effluent of the domestic flows enters the WRMS system constantly. Their design is from further importance, as it should consider safety requirements, in case that the effluents contain high nutrients loads due to system maintenance, or other reasons, Rücksprache MW) which might happen. Therefore a protected area *Implication 8: Di-*

version can be used to extend the structure by increasing the vulnerability. *Implication 7: Retention time* describes the opportunity for effective manipulation by chemical, biological measures to enhance the vulnerability. An area which provides a retention time of several days can be divided into two or three subareas to allow an effective manipulation.

The domestic flows can be calculated to 75m³ daily. A retention time of 6 days requires therefore a storage basin of 450 m³. which can be realized by the diversion of 10 m of the WRMS, which corresponds to 430 m³ under the assumption that the general structure doesn't change.
This diversion will give the opportunity for managers to react on malfunctions of the MBR, before the water is released to the further system where is got mixed with the natural flows. The goal of this design is not to tackle security related issues, like broken membranes or pathogens in the water. These things have to be ensured within the reclamation facilities. The main goal is to tackle changing nutrient contents, due to adjustment at the membrane, or within the chemical P – precipitation, which might happen from time to time. Peak flows of nutrients to the WRMS should be prevented - the diversion can help to balance the nutrients.

Beside the active manipulation, a structure which is designed for a 3-days retention can be used for denitrification and P-uptake by duckweed or water hyacinth, which reduces the nutrients like described in (*Chapter 6*). The areas can be designed to be accessible. In the conceptual design, they are technical volumes. Fish stockings can also be used to reduce phytoplankton and aquatic plants, before the water is releases to the further system.

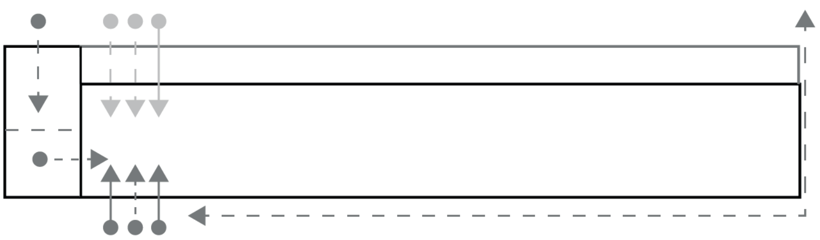


fig. 85:
A diversion of the ‚natural flows', from the ‚domestic flows', can increase the resiliency of the system.
A retention time of six days for the MBR Inflow, allows the manipulation of these streams in case of malfunction.

8.8.4 Security release of water

The theoretical technical volume of the above sized WRMS system is 4410 m^3. *Implication 10: Spillgates* describes the need to protect the system from surplus waters during the high monsoon season in September, by it's controlled release. Designing those spillgates must ensure, that the release rate doesn't exceed the refill rate. The spillgates are designed to 4000 m^3. which will lead to a couple of spilling events between July and October, while limiting the water storage of the WRMS to this value (see table 15). 4000 m^3 is enough water to overcome periods of droughts and provide fire extinguishing water, when neccessary.
The conceptual limitation of the systems design produces surplus water, which is particular of interest after the system lost water through a breakdown (see Vulnerability) for refilling purposes.

8.8.5 The further structure

Implication 7: Retention Time and *Implication 8: Diversion* should be used for the rest of the system, to increase vulnerability and creating the basis for long term adjustments.

The physical diversion of the area where the intake structure of the service water is installed, can be seen as an important security measure for the system. The service intake can be placed underneath a floating structure, or it can be withdrawn through shoreline filtration technologies, which filter the water before it receives the purifying facility. A relative short retention time in that area of less than 3 days can suppress algal growth. The size for this area, in this research scenario, should therefore not exceed a volume of 243 m^3. which corresponds to 81m^3 daily, while providing a retention time of 3 days.

To increase the overall resilience of the system, the WRMS is divided into several further subsystems for the zones in-between. The overall system is characterized by a retention time of 24 days in the dry season, and 54 days during the monsoon season (see figure 79). A diversion into six subsystems will lead to retention times of 4 to 9

days. A short retention of 4 days only can be considered as a riverine system, which tackles algae production during the dry season. Subsystems furthermore give the possibility to influence the system and tackle eutrophication or adjust it for long-term operation. Subsystems can be furthermore used to increase denitrification process, to reduce algae's and phytoplankton, to aerate the water or other improvements (see *Chapter 7*). The construction of 'pairs of zones' allows furthermore to enhance the effectiveness, as they can be adjusted to each other (see Implication 8: Diversion). The use of plants in the first section can be adjusted to reduce nutrients or stimulate denitirfication processes, while the second system can be used to aerate the water, after oxygen was reduced in the first system.
The consequent diversion of the system can enhance the effectiveness of biological and chemical treatments, like described in *Chapter 6*. Alum salts application in one of the subsystems will effectively reduce the biological growth in the following systems, while reducing the influences by this application in the other subsystems. If chemical Precipitation with Alum or Iron is applied, it must be done in Combination with dredging structures (see *Chapter 6*) and/or *Design Solution 8: Depressions* to ensure the possibility to control and/or remove the sediments automatically.

The diversion of the subsystem influences the adaptive spaces (*Design Solution 1*), as they can be sized and designed to be part of one or two subsystems only. This is dependent on the local context and the overall design and should be discussed in the context of the prospected use by the urban public or the residetns. If it is concentrated to one or two zones, the Retention time will locally increase in these parts, as well as the usable size. The Subsystems, which contains the adaptive spaces can be designed, with a continuously retention time during the dry period, when the water level is low and the adaptive spaces are not flooded. The retention time of the areas which are not equipped with adaptive spaces decreases and the differences between the dry and the wet season become more balanced. The shores of can get designed with steps, wetlands, gravel beaches *(Design Solution 2,3,4)*, which tolerate the changing water levels. The use of floating stuctures *(Design Solution 6)* can create recreational zones, upon the water, which can be an attractive landscape design.

8.8.6 Changing water levels on a daily base

A very heavy rain event, like it can happen during the monsoon season, can be estimated with the daily precipitation of 80 L/m^2. This corresponds to one fourth of the overall monthly rain, during a monsoon month. It corresponds roughly to the 100years rain event, which lasts one hour. Such a heavy rainfall would immediately increase the systems water level up to 0.384 m. Considering an evaporation of 0.007 m daily during the wet season, an the continuously service intake, the effective water level increase, can be estimated to 0.334 m within one rain event (0.384 - (0.007 + 0.043)).
It is particular important to protect the first section of the WRMS as this area has to buffer some of the fluctuations. If this rain event happens during the highest water level in September, the Spillgates must ensure the diversion of the surplus water, right at the beginning, to protect the further structure. The resiliency of the riparian zone is from importance, as soil erosion is particular an issue for wetlands or other aquatic or terrestrial vegetation. If *Design Solution 1: Terraces* or *Design Solution 2: Constructed Wetlands* are applied this must be taken into account. The use of gabion walls can protect the shoreline, while giving the possility to slow down and reduce the pressure the the system, when they are used as an inlet structure for the flows.

8.8.7 Flood Protection

Based on the data from the IDF Charts (Intensity-Duration-Frequency) for Ha Noi, a hydrological runoff model for a hypothetic area is created, which is used to simulate above-ground discharges. Details to this Calculation can be found in the Appendix *(Chapter 9.5: Flood Protection)*.

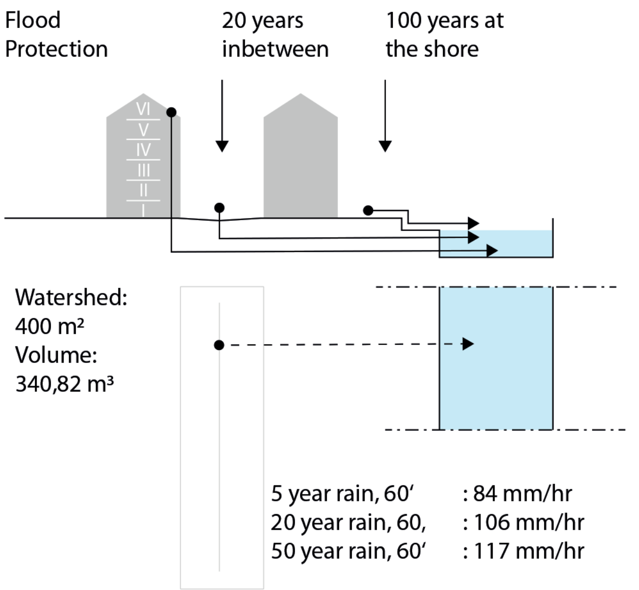


fig. 86:
The situation inbetween the buildings and the expected rainfall intensities for different designed storms in Ha Noi.

The 5 years rain event which last one hour will produce a runoff of 84 mm/h, which shows the pure effluent, because the losses of Interzeption and Infiltration is already integrated into the SCS- procedure. By using a DN 110 pipe to convey the runoff to the WRMS, this zone will not lead to any retention, as the water will passes the retention zone directly.

A designed storm which is estimated as a 20 years storm event, will produce a runoff of 106 mm/h. The same DN 110 pipe will lead to a retention of 29 minutes, which is less than the duration of the rainevent.

The DN 110 pipe, under a 50 years storm event, will lead to a retention of 32 min, which happend during the first half of the stormwevent, and therefore still not exceeding the designed capacity. However, the peak discharge of 0,0448 m^3/s can be harmful for the inlet structure, which requieres protection zones.
It must be noted, that the 50 years storm , will flush 35 m^3 per hour into the system, from the area in between two buildings. Under the Assumption of 6 buildings, the WRMS will receive 100 m^3 in one hour in the case of a 50 years strom event, which is unlikely to happen, but in the case of climate change possible. This will lead to a changing water level of more than 50 cm within one hour.

It is very likely that those rain event will occur only during the monsoon season, where the expansion zones are flooded. The right dimension of the Spillgates is from further importance. [1]

1 Details for the calculation are given in Appendix 9.5 : Flood protection:

8.9. The conceptual design of a WRMS

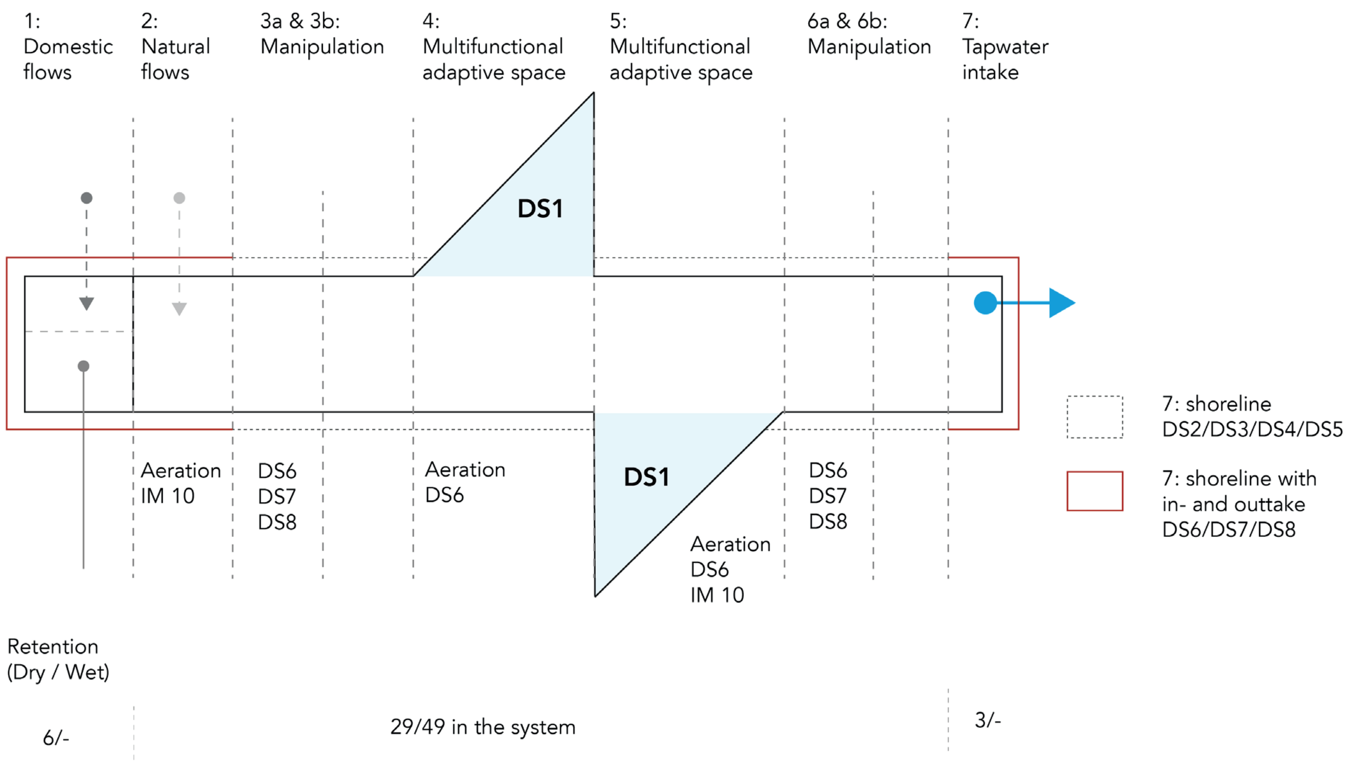


fig. 87:
The conceptual application of several Implications and Design Solutions

The conceptual design bases on the physical separation of the inlet structures of the domestic flows (1), and the natural flows (2) to have the possibility for adjustments. Furthermore the areas (3a&3b) can be seen as manipulation areas, which can be used in combination, or separatedly. After that, the water flows to the adaptive zones (4&5), which concentrate the expansion areas. Before the water is withdrawn as Tapwater, it has to pass another manipulation area (6a&6b) which can be used in combination or separated. The last stage is designed riverine with a retention time of less than 3 days to suppress algae growth.

It might be possible due to the used technologies, that the system can develop a stable ecological state right away, which can handle the nutrient loads - with or without

the Application of some minor *Design Solutions* in Combination with technical aeration and/or automatic sediment removal. However, it is likely that the system need some adjustments, as it can also happen that the system will develop algae blooms, or Macrophyte Nuisances or Oxygen Depletion, especially during the first filling phases, where it is not resilient.
In this case, the *Design Solutions* and their application have to get adjusted to the location. This can require some maintenance efforts, labour and temporal failing of the system, but as some Solutions can be seen as the ultimate tool, it is likely that the system will work.
A reduction of the UV Exposure will reduce the biological growth within the WRMS.
Therefore shading structures, like floating wetlands can be used to increase the system purifying capabilities. Those structures are adaptive, shade the water, provide habitat for terrestrial pants, which can contribute significantly to the water quality. Other shading structures can be applied, like trees at the shoreline . Areas which are not shaded can be equipped with submersed Macrophytes, which can be introduced to the system. The use of fish stockings can suppress algae blooms, while the interactions with plants have to be discussed, this measure might require some protective structures for the plants.
Alum Treatment, or the stocking of silver carp in combination with dredging can improve the systems quality immediately, when applied properly.

Those measures can be applied in the beginning, to support the Development of the ecosystem and their influence can be successive lowered.

8.9.1 The balance between the domestic streams, and the natural streams

The WRMS receives domestic flows and natural flows. Without considering the diversion of the surplus water, the system would receive 61 % of its water from the natural flows, and 39% from the domestic flows, in an annual mean calculation. The diversion during the high monsoon from (july to October), which is induces by high amounts of rainwater which counts for 70% to the inflows, removes in consequence more natural water from the system in relation to the natural streams. The effect of diversion is huge, and changes the relation between both streams in an anuual mean calculation

towards the domestic flows, which counts 70%. Designing the System, to store more volume, wil redcue this effect significantly.
It must be however considered, that more volume requires either more space in the horizontal axis, which has influences on the Urban Density index and the structure of the area, or it has to be adjusted in the lake depth, which might produce deeper zones, which tend to stratisfy.
A technical diversion of the domestic flows during the high monsoon season, before they enter the WRMS could reduce the spilling events and increase the relation of the natural waters within the System. It could get realized by bypassing the WRMS and releasing the reclaimed water directly, or using this stream for other purposes, like nearby aquacultures, or support neighbour communities.

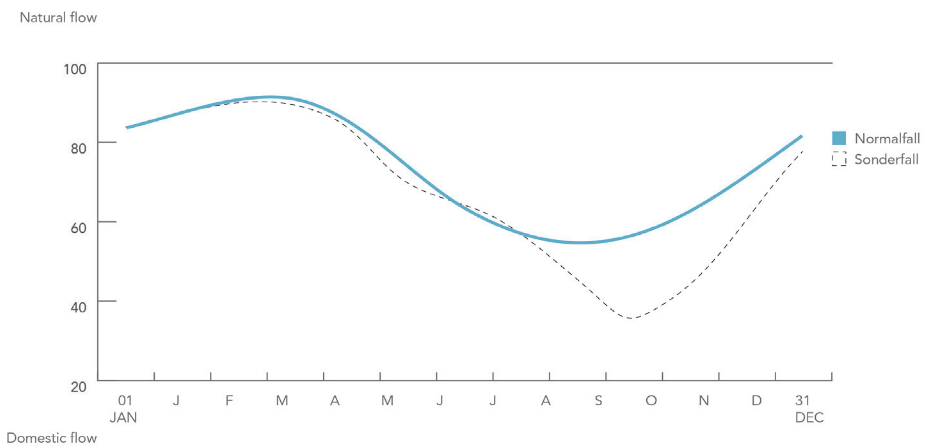


fig. 88:
The relation between the watervolumes, which come from the domestic flows and the natrual flows.

In this scenario, the contribution to the WRMS by natural streams is huge The constant available domestic streams, would not delivery sufficient amounts of water, to supply this WRMS. Each resident contributes 115 liter per day to the system, and the daily losses through evaporation, and Tapwater intake can be estimated to 147 liters, per resident. The gap of 32 liters daily must be closed by the natural streams, otherwise the system would not be able to work.

The Urban Density index

The system is designed with an urban density index of 0.3 and an FAR of 1.8
An increase of the building structure to 9 storey's, without changing the other values, would increase the FAR to 2.6, under the assumption that all other factors are remaining constant. It woud increase the density.

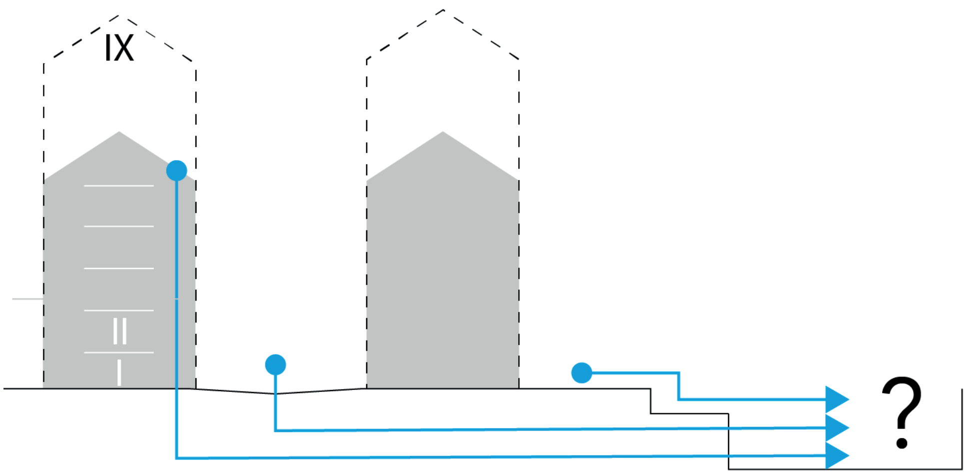


fig. 89:
An increase of 3 Storey would increase the floor area ratio to 2.6

n increase of 50 residents, which contribute to the system, and receive Tapwater from the system, would in consequence reduce the water volume to less than 2000 m^3. which means a decrease in the volume of 0.8 m. 1000 residents would reduce the water volume to 1.000 m^3. which means that the system already fails and 1300 residents, would empty the WRMS.

Redesigning the system, by applying those implications which doesn't affect the density *Implication 10: Spillgates*, *Implication 6: The depth*), shows that the system would also be emptied, one month later, due to the bigger storage capacity.

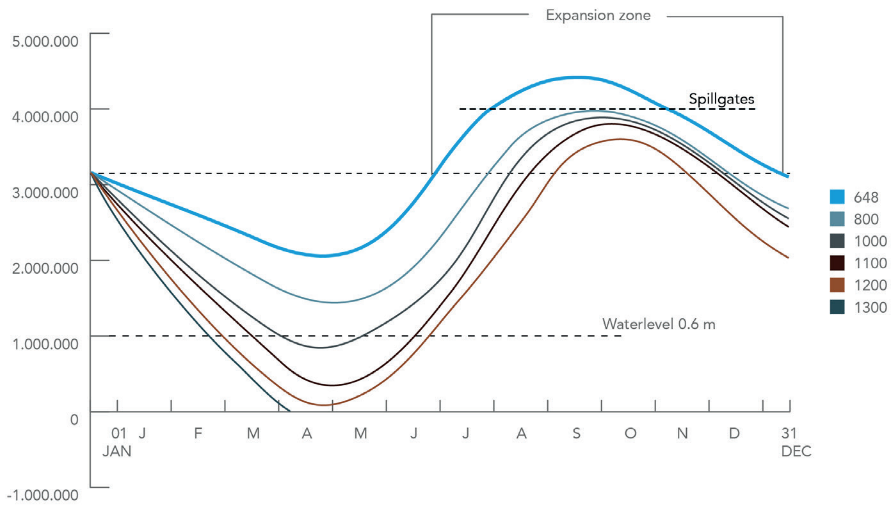


fig. 90:
Comparison of different densities. The system will fall dry, when more than 1000 inhabitants are connected

The comparison between different densities, shows that the system, according to its design in this scenario, is dependent on the connected inhabitants and limited to medium dense areas. The intake of Tapwater counts in this scenario to 90% of the overall losses, while Evapoartion can be estimated to 10%. A reduction of the water intake, in areas where only 'service' water (for toilet flushing + laundry) is needed can decrease the water losses and therefore be applied in more dense structures.

8.10. Vulnerability

Phases without rainfall can occur and it is likely that this happens regularly in the dry season, where the rainfall is generally very low. The WRMS is designed to provide enough Tapwater throughout the year, by considering evaporation and the intake of Tapwater. In this conceptual design, the water volume will reach its lowest level during the dry operiod with 2000m3. which is below the designed volume of the expansion structures.

A system breakdown of both domestic flows, during the dry season, will lead to a consequent water level drawdown of the system. An intake 81m^3 daily, will decrease the water level up to 0.056 m daily. By considering an additional Evaporation of 0.004 m daily, the water level decreases everyday 0.06 m, which results to 30 cm after after 5 days.

In the case of a breakdown of one treatment facility, either the greywater flow, or the blackwater flow, the water level drawdown is reduced, which can be estimated from table 1.

As the water from the membrane modules is characterized by a quality, which fits the characeristics of Runoff streams, it is unlikely that a temporal breakdown will have influence on the ecological system. The unexpected lowering of the water level, can however deplete oxygen due to the higher concentration of biomasses. The possibility to aerate the system (*Chapter 6*) is therefore important. This can happen in combination with several *Design Solutions*, as described in *Chapter 7*.

In General, the WRMS is designed to store and handle water from one season to the other.

This allows that unexpected water losses can be balanced by the surplus water of the wet season. In this scenario, the surplus volume, which is spilled through the spillgates can be estimated to 3000 m^3. However, when the WRMS will not receive the domestic flows, the system should be refilled or at least supported artificially. During the monsoon season, failures of the system can be buffered, as the natural flows are higher than the domestic flows (see table 1).

A temporary breakdown of the MBR treatment, must ensure that the occurring water masses from the domestic flows, can either be stored, bypassed to other MBR (e.g. Greywater to Blackwater, or Blackwater to Greywater) or diverted from the system, to avoid damages. While storage capacities require a lot of space, within the system, the emergency connection to a sewer network can get used to reduce the pressure.

Although a complete failure of the system is extremely difficult and unlikely it must be considered as a scenario. In the complete failing of the WRMS, the designed structures can be covered by concrete to become a ‘technical’ storage area which collects natural and domestic streams. As the system in the above described scenario is insulated from the environment, and the bottom of the structure probably artificially constructed, it is relatively easy to achieve.

Covering this area, suppress any UV penetration of the water, which in consequence doesn’t allow any light to stimulate biological growth and to suppress anaerobic processes, chlorine can be added to the water. The area can be redesigned to a water storage facility which can serve the connected buildings with service- or Tapwater.

Less intense changes might contain the adjustment of the treatment technologies or the diversion of water flows, when the reasons for the failure can be identified. Adjustment of the technology might contain the use of other membrane modules, like Nanofiltration.

The use of reverse osmosis will produce absolute nutrient free water, which will have dilution effects on the other water flows. Reverse Osmosis, which is commonly used in seawater desalination, will increase the operational costs up to 5 times (Tolkdsorf 2018), in contrast to Nano filtration, and the economical feasibility must be discussed, especially within the use in small scale projects.

The interactions between the ecological system, with partly / fully desalinated water, like it is the case with Nanofiltration (NF) / Reverse Osmosis (RO), must be discussed, and requires further treatment steps.

8.11. The role of the local context

8.11.1 Example 1: Hilly terrains

The local context of the WRMS has a significant influence on the structure. Especially the interactions with the soil, as well as the geological environment can bring benefits to the system. When the area is hilly, and characterized by different elevations, the system can be designed with cascading areas, which are placed on different elevation levels. This can stimulate the curretns and flows from one basin into another, and by the integration of fountains or waterfalls, the water receives a lot of oxygen. Although those systems might require pumping energy at the end to pump the water 'back' to the households, it can reduce the energy which is needed for artificial aeration.

8.11.2 Example 2: Mountains

Areas which are designed in hilly areas or mountainous regions, can be designed to capture additional Runoff streams. When the plot is connected to a mountain, or a slope, the occurring Runoff from the slope can be used within the WRMS. Hong Kong gives good Examples of buildings which are designed near or at or with mountains. Those mountains are usually protected from erosion with a concrete layer, which produce a clear Runoff, which is comparable to the Runoff from roofs.

8.11.3 Example 3: Iron rich soils

Iron rich soils can be used to bound Phosphorous. A WRMS system which is designed within an iron rich environment, can be designed to allow interactions with the soil, if the water losses through infiltration are not an obstacle. Iron rich soils, will immediately bound Phosphorous which is freely available in the water, which will decrease the biological productivity of the lake.

8.11.4 Example 4: Additional water streams

Additional water streams, like springs, creeks or rivers, can be used as an additional water source for the WRMS. They can influence the System by chemical processes, or dilute the water constantly, or they can be used cool the system down.

8.12. Conclusion: Ha Noi

The conceptual case study proves that it is possible to create zero water Cities in (sub-) tropical Asia, but it is subject to their density and the number of residents. The water reuse in this research based in Ha Noi considers domestic water flows, natural flows and losses through evaporation, infiltration, and the tap water intake.

The system has surplus water in the monsoon season which is roughly 3000 cubic meters, that is released through spilling facilities to fulfil security issues. 3000 cubic meters is a relatively low volume in comparison to the water volume which pass the system throughout the year or even on a daily basis.

The surplus can be used to balance unexpected losses which occur during the year. In addition, a diversion of the domestic flows was also discussed to increase the concentration of the natural flows, which might further increase user acceptance. In areas characterized by water scarcity, it can be researched further if the surplus water could contribute to the water supply for the neighbourhood, especially with regards to the 3000 m^3 , which corresponds to the daily water needs of 60 people.

Moreover, the construction and use of a WRMS requires space within an urban context. The denser the area, the less is the number of green spaces that are available. Additionally, the influence of the domestic flows has gained more prominence than the influence of the natural flows. The manipulation of the scenario regarding the attached residents showed, that highly dense urban areas require adjustments of this concept. Those adjustments could include a reduction of the importance of ecosystem services, specifically to reduce losses through evaporation and biomass growth. Besides the tap water which is used for the residents, a WRMS described and designed, has to supply the attached ecosystem services with water. This includes any evapotranspiration processes in the designed zones. The evapotranspiration activities of the wetlands (*Design Solution 2*) weren't calculated, as they are included in the water losses during storm water flows, which are 50%; a relatively high amount. According to the excel sheets of the above designed scenario, the system has significant losses through these processes, and without capturing the runoff, those losses would draw down the system immediately.

Furthermore, some highly dense residential areas can be found in Hong Kong, which are constructed near or at least close to high mountains, which are covered by man-made concrete slopes to deter erosion and to protect the constructed buildings. These 'slopes' which are in fact part of these developments, can produce high masses of runoff during a rain event. Henceforth, if these areas are integrated into a design, they can be used to increase the relative influence of the natural streams, while the quality of these streams can be comparable to the high-quality roof Runoff, by taking into consideration the First Flush Diversion. However, it might not be possible to create zero water cities in highly dense urban areas, either due to physical limitation of space, land use conflicts or the limitation of the capture-able water masses.

8.13. Conclusion: Water Based Urban Design

The design of an integrated Water Resource Management System, can attract people for water recycling, which can change the perception of water recycling projects as natural ecosystems are the interface with the urban public, instead of technical invisible reclamation technologies.

A WRMS can also be designed for smaller volumes, without considering 100 percent water recycling. A water localized 'recycling' of 30%, 50% or 70% can also significantly reduce the dependency on external water supply, by saving enormous amounts of water. These systems can thus, get designed to recycle the available flows partly, either with a focus on natural or domestic flows dependant on the location or they can get connected to the urban infrastructure.

Any reduction of the water use contributes to the planet's water balance and especially in Asia, where many parts are characterized by a mismanagement of water sources. These concepts can help improve the situation on a smaller scale, while reducing the dependency on the centralized infrastructure, which in consequence protects the natural water sources. In the theoretical frame, Water Sensitive Urban Design considers any water flow, as a valuable good, including the domestic flows. WSUD Projects which recycle water flows, are usually embedded into a design which improves the livelihood, faces climate change and saves water, which is particularly important for water scarce areas. However, those projects usually focus on the natural flows, without considering the domestic flows.

Additionally, hydrologic issues become more and more integrated into concepts like the Chinese Sponge City, which tackles flood protection. This is a major challenge in many parts of China, which faces heavy rainfall. These rain events are further expected to happen more often due to the intensification of the hydrological cycle, which is related to the climate change. Moreover, modern technologies can filtrate any kind of water to a 'fit for purpose' quality and can easily reach tap water qualities. Recycling of domestic flows is 5 to 10 times cheaper than seawater desalination and water reclamation of the domestic flows is therefore, at present the focus of several research projects.

The combination of hydrology, engineering solutions and Water Sensitive Urban Design can create urban areas which contribute to their own water balance, by recycling of their own flows. Working with the nature means to include the nature into the water cycles, which reduces on the one hand the available water due to Evaporation and Transpiration, but also creates highly liveable spaces on the other hand.

The role of evaporation and the losses through infiltration have been discussed within this doctorate and they are immense. However, as soon as water and nature start becoming an integrated part of the environment of the inhabitants; investors, developers and the urban public might shift their perception towards a more nature-based water source, instead of a water stream which has to be treated technically. The use of ecosystem services, and the attached evaporation processes will improve the local climate, by adiabatic cooling effects. The local climate can differ up to 20 centigrade from dense urban concrete dominated structures, to green, vegetated areas which can improve livelihood. Green vegetated areas also possess the ability to filter particulate matter from the air, which important in the context of Asian Megacities, in terms of a healthy environment. Therefore, the water losses—despite being high—have significant positive impacts on the local structure. Urban planners should not create cities which are 'sensitive' to water, they should rather go a step further to create cities which are 'based' on water.

Outlook

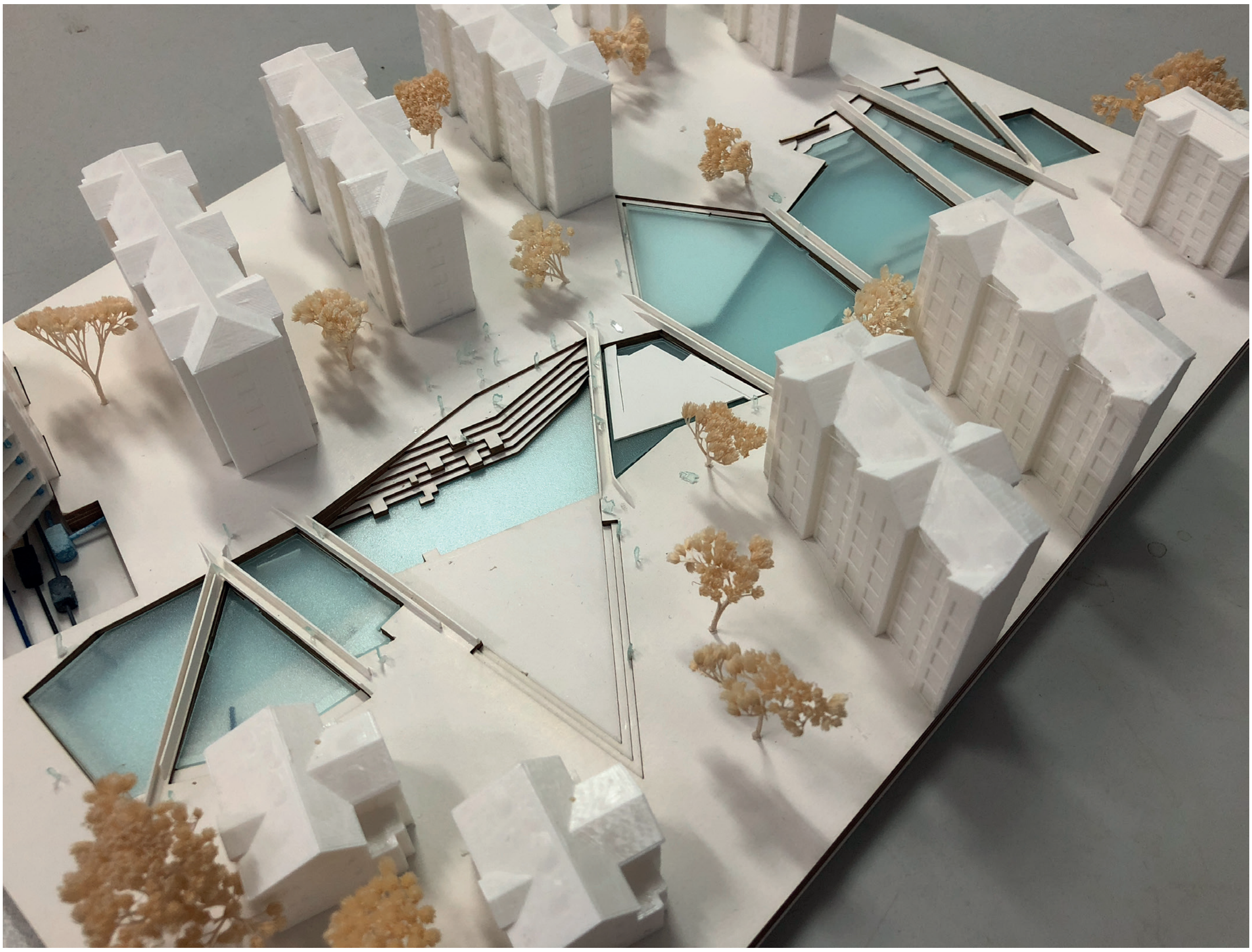
This research project combines different disciplines into a holistic approach towards zero Water Cities, by designing a Water Resource Management System. Although projects are available which recycle water, they are mostly technically driven and applied to other scales. The effects of ecosystem services and their contribution to the water cycles in the context of this research, have yet to be estimated along with a deeper understaing of limnology.

A pilot project, which is based within the subtropical or tropical areas of Asia, can further help in determining the effects of physical, biological, chemical and technical manipulation or improvement of a Water Resource Management System, and the benefits of design solutions and implications to the urban landscape in particular.

Chapter X: to be continued...

This model was created (2017) by the Author, as part of the doctorate for illustration purposes.
The size of this area doesn't fit to the above described scenario, as the basis are the housing units from the ‚Semizentral' project.

fig. 91:
Illustration of the application of ReSource Water in Qingdao, China



9.1. Climate data of Ha Noi

1. Climate data, Hanoi														
source: http://www.geo.de/reisen/community/reisen/hanoi/klima, visited: 07 July 2017			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
rainfall in mm/m²			18,6	26,2	43,8	90,1	188,5	240,0	290,0	318,0	265,0	130,0	43,9	23,4
rainy days per month			9	12	15	13	14	15	16	17	14	9	5	4
Temperature, max			19,3	19,9	22,8	27	31,5	32,6	32,9	31,9	30,9	28,6	25,2	21,8
Temperature, min			13,7	15	18,1	21,4	24,3	25,8	26,1	25,7	24,7	21,9	18,5	15,3
Temperature, average			16,5	17,45	20,45	24,2	27,9	29,2	29,5	28,8	27,8	25,25	21,85	18,55
rel. air humidity			0,8	0,83	0,85	0,85	0,81	0,8	0,8	0,82	0,8	0,79	0,76	0,76
wind speed			2,2	2,4	2,3	2,2	2,1	2,1	2,1	1,8	2	2,3	2,2	2,1
sun in %			39,6	24,7	22	24,5	34,5	39	55,2	51,7	51,5	53,3	53	50,7
max sunduration			10,4	11,1	12	12,9	13,6	14	13,9	13,2	12,4	11,5	10,6	10,2
sunduration			4,12	2,74	2,64	3,16	4,69	5,46	7,67	6,82	6,39	6,13	5,62	5,17
extra-terrestric solar radiat.			374	402	433	444	439	433	433	439	433	416	385	365
2. Evaporation, Lake Surface														
using the Penman Calculation Penman (1948)														
Albedo constant			0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06
psychrometerkonstante			0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65
saturation vapor pressure	es	[hPa]	6,00	19,91	24,00	30,13	37,48	40,41	41,12	39,49	37,27	32,08	26,15	21,33
vapor pressure	ea	[hPa]	4,80	16,52	20,40	25,61	30,36	32,33	32,89	32,38	29,81	25,34	19,87	16,21
global radiation	RG	[W/m²]	152,52	130,99	134,66	144,19	166,71	175,15	213,73	208,24	204,92	200,99	185,38	171,13
Irradiation	I	[W/m²]	69,93	30,54	24,89	21,99	22,74	22,42	28,67	27,85	32,22	40,90	50,29	54,22
radiation equivalent	EH	[mm/d]	2,59	3,27	3,59	4,01	4,73	5,03	6,09	5,93	5,67	5,23	4,38	3,77
Windfunction	F(v)	[mm/d hPa]	0,44	0,47	0,45	0,44	0,42	0,42	0,42	0,38	0,41	0,45	0,44	0,42
d		[hPa/K]	0,38	1,24	1,46	1,78	2,15	2,30	2,33	2,25	2,14	1,88	1,57	1,32
Result:		**[mm/d]**	**4,15**	**4,75**	**4,97**	**5,38**	**6,30**	**6,64**	**7,71**	**7,37**	**7,24**	**6,93**	**6,17**	**5,49**

9.2. Rainfall pattern of randomized rainevents in Ha Noi

Month	Amount	rainy Days	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
January	18,6	9	0	2,4	0	0	0	1,7	0	1,7	0	0	0	0	2,3	3,2	0	1,3	0	0	0	0	0,6	0	0	3,5	0	0	0	0	1,9	0	0
February	26,2	12	2,0	0	2,5	0	0	3,7	0	0,6	2,9	0	0	0	3,2	1,9	1,0	0	0	0	0	3,4	1,5	0	2,7	0	0	0	0	0,8			
March	43,8	15	0	0	0	2,7	1,5	0	2,2	0	0	4,8	0,7	0	0	0	0	0	4,4	0,6	0	0,3	3,2	4,0	1,9	0	0	3,5	0	4,4	0	4,8	4,8
April	90,1	13	0	7,3	3,4	0	5,1	8,1	0	0	0	11,7	2,4	0	0	0	0	0	12,3	0	0	0	0	0	13,2	10,9	0	2,3	0,6	7,3	0	5,6	
Mai	188,5	14	0	0	0	0	15,2	10,2	0	0	0	0	0	0	19,7	15,6	25,2	13,7	15,0	0	0	3,9	14,4	7,8	11,9	0	23,5	1,6	10,9	0	0	0	0
Juni	240	15	0	17,0	0	0	23,2	2,1	17,4	12,2	0	13,8	20,6	0	28,6	0	0	0	0	0	18,7	6,2	28,4	0	19,6	0	0	0	5,4	2,3	24,6	0	
Juli	290	16	0	0	8,3	23,3	0	9,0	0	26,6	0	0	17,5	29,4	3,1	14,7	18,0	0	0	29,1	0	16,7	0	27,5	20,0	9,1	22,7	0	0	0	0	15,0	0
August	318	17	14,0	0	0	4,2	23,9	3,1	12,5	0	31,7	0	7,2	24,0	22,5	30,0	28,0	0	0	16,0	0	0	0	0	0	16,8	25,2	0	27,7	20,9	10,3	0	0
September	265	14	7,3	13,2	0	23,8	0	0	0	11,4	0	0	16,2	27,0	24,7	15,9	0	31,3	0	12,3	11,9	18,4	0	23,7	0	28,0	0	0	0	0	0	0	
Oktober	130	9	18,0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,3	0	0	21,7	0	20,2	0	17,0	16,6	0	11,5	0	0	9,8	0	13,1	0
November	43,9	5	10,5	0	0	13,1	0	0	0	0	0	0	3,3	0	0	0	0	0	0	0	0	0	6,1	0	0	0	0	0	0	0	10,8	0	
Dezember	23,4	4	0	0	0	0	5,2	0	0	0	0	0	5,6	0	0	0	0	0	8,5	0	0	0	4,0	0	0	0	0	0	0	0	0	0	0

Jan:	18,6
Feb:	26,2
Mar:	43,8
Apr:	90,1
Mai:	188,5
Jun:	240,0
Jul:	290,0
Aug:	318,0
Sep:	265,0
Oct:	130,0
Nov:	43,9
Dec:	23,4
Total	1677,5

9.3. Scenario Ha Noi

Building Type:

width	[m]		10
length	[m]		40
height	[m]		30
floors:			8
roof surface:	[m2]		400
1 pers. HH		pers	0
2 pers. HH		pers	0
3 pers. HH		pers	72
4 pers. HH		pers	0
residents:		pers	108
number of buildings:		pcs.	6
overall residents:		pers.	648

structural Attributes

Overall plot			10200
	streets/parking	[m2]	5000
	roof	[m2]	2400
	green space	[m2]	4800

daily Waterflows:

Water demand	[l/p]	128
food prep. / cooking		*3*
dishwashing		*7*
laundry		*15*
pers. Hygiene		*63*
toilet		*33*
HH cleaning		*7*
occ. greywater	[l/p]	88
occ. blackwater	[l/p]	40
needed Servicewater		125
needed Water for irrigation		10
needed Servicewater		135

9.4. The Water Masses of the WRMS

Water Resource Managemt System in the context of Hanoi
daily chart

		Start	1	2	3	4	5	6	7	8	9	10	11	12	13
1: dom. flow Greywater	Eff.	0,9	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024
tr. Greywater	[l/d]		51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6
2: dom. flow Blackwater	Eff.	0,9	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920
tr. Blackwater	[l/d]		23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328
3: nat. flow roof runoff	Eff.	0,95	0	9120	1440	0	2640	7920	6960	0	0	0	0	0	0
Stormwater receiving the lake	[l/d]		0,00	8664,00	1368,00	0,00	2508,00	7524,00	6612,00	0,00	0,00	0,00	0,00	0,00	0,00
4: nat. flow green space	loss. Evap.	0,2	0												
	loss. Infiltr.	0,3	0	18240	2880	0	5280	15840	13920	0	0	0	0	0	0
Stormwater receiving the lake			0,00	9120,00	1440,00	0,00	2640,00	7920,00	6960,00	0,00	0,00	0,00	0,00	0,00	0,00
5: direct Precipitation on the Lakes surface															
precipitation on the lake			0,00	7980,00	1260,00	0,00	2310,00	6930,00	6090,00	0,00	0,00	0,00	0,00	0,00	0,00
daily Input to the Lake			74649,60	92433,60	77457,60	74649,60	79797,60	90093,60	88221,60	74649,60	74649,60	74649,60	74649,60	74649,60	74649,60
Water in WRMS															
overall		0,00 3.105.000,00	**3.179.649,60**	**3.183.863,26**	**3.166.380,93**	**3.144.830,59**	**3.132.918,24**	**3.135.921,89**	**3.136.213,54**	**3.116.843,19**	**3.097.472,83**	**3.078.102,48**	**3.058.732,13**	**3.039.361,78**	**3.019.991,43**
treated Greywater	[l]	1800000,00	1851321,60	1846631,68	1842157,59	1837511,37	1833897,50	1830183,21	1826632,99	1823194,30	1819519,03	1815611,38	1811475,54	1807115,62	1802535,71
treated Blackwater	[l]	800000,00	823328,00	821746,31	820245,37	818652,95	817505,95	816300,32	815154,33	814044,97	812817,21	811473,15	810014,88	808444,47	806763,96
treated Storm, roof	[l]	150000,00	150000,00	154125,77	150836,88	146254,20	144389,69	147580,51	149767,81	145277,95	140895,62	136618,91	132445,91	128374,76	124403,60
treated Stom, green	[l]	150000,00	150000,00	154581,77	151351,10	146752,80	145005,38	148573,72	151079,25	146550,07	142129,37	137815,21	133605,67	129498,87	125492,94
rainwater		205000,00	205000,00	206777,75	201789,99	195659,27	192119,71	193284,14	193579,17	187775,89	182111,61	176583,84	171190,13	165928,05	160795,21
Total	[l]		**3179649,60**	**3183863,26**	**3166380,93**	**3144830,59**	**3132918,24**	**3135921,89**	**3136213,54**	**3116843,19**	**3097472,83**	**3078102,48**	**3058732,13**	**3039361,78**	**3019991,43**
Lake surface area, accord. to the structure			*2100,00*	*2100,00*	*2100,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*
Spilling of Surplus water	[l]		**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**
treated Greywater			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
treated Blackwater			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
treated Storm, roof			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
treated Stom, green			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
rainwater			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
WRMS, after spilling			**3179649,60**	**3183863,26**	**3166380,93**	**3144830,59**	**3132918,24**	**3135921,89**	**3136213,54**	**3116843,19**	**3097472,83**	**3078102,48**	**3058732,13**	**3039361,78**	**3019991,43**
treated Greywater	[l]		1851321,60	1846631,68	1842157,59	1837511,37	1833897,50	1830183,21	1826632,99	1823194,30	1819519,03	1815611,38	1811475,54	1807115,62	1802535,71
treated Blackwater	[l]		823328,00	821746,31	820245,37	818652,95	817505,95	816300,32	815154,33	814044,97	812817,21	811473,15	810014,88	808444,47	806763,96
treated Storm, roof	[l]		150000,00	154125,77	150836,88	146254,20	144389,69	147580,51	149767,81	145277,95	140895,62	136618,91	132445,91	128374,76	124403,60
treated Stom, green	[l]		150000,00	154581,77	151351,10	146752,80	145005,38	148573,72	151079,25	146550,07	142129,37	137815,21	133605,67	129498,87	125492,94
rainwater			205000,00	206777,75	201789,99	195659,27	192119,71	193284,14	193579,17	187775,89	182111,61	176583,84	171190,13	165928,05	160795,21
Intake for Servicewater															
overall	**[l]**		**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**
treated Greywater	[l]		50934,42	50738,15	50894,68	51114,20	51207,64	51054,98	50951,20	51171,34	51387,54	51599,87	51808,35	52013,05	52214,00
treated Blackwater	[l]		22651,78	22578,35	22661,54	22772,53	22827,09	22771,60	22737,51	22847,69	22955,89	23062,15	23166,49	23268,94	23369,51
treated Storm, roof	[l]		4126,87	4234,77	4167,28	4068,36	4031,77	4116,92	4177,55	4077,50	3979,23	3882,72	3787,96	3694,93	3603,60
treated Stom, green	[l]		4126,87	4247,30	4181,49	4082,23	4048,96	4144,63	4214,13	4113,20	4014,07	3916,72	3821,13	3727,28	3635,15
rainwater			5640,06	5681,44	5575,00	5442,67	5364,53	5391,87	5399,60	5270,28	5143,27	5018,53	4896,05	4775,80	4657,75
Evaporation nach Penman															
overall	**[l]**		**8719,94**	**8719,94**	**8719,94**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**
treated Greywater			5077,10	5057,54	5073,14	3821,27	3828,25	3816,84	3809,08	3825,54	3841,70	3857,57	3873,16	3888,46	3903,49
treated Blackwater			2257,91	2250,59	2258,88	1702,46	1706,54	1702,39	1699,84	1708,08	1716,17	1724,11	1731,91	1739,57	1747,09
treated Storm, roof			411,36	422,12	415,39	304,15	301,41	307,78	312,31	304,83	297,48	290,27	283,19	276,23	269,40
treated Stom, green			411,36	423,37	416,81	305,19	302,70	309,85	315,05	307,50	300,09	292,81	285,67	278,65	271,76
rainwater			562,20	566,32	555,71	406,89	401,05	403,09	403,67	394,00	384,51	375,18	366,03	357,04	348,21
WRMS, after intake															
overall			**3083449,66**	**3087663,33**	**3070180,99**	**3050810,64**	**3038898,29**	**3041901,94**	**3042193,59**	**3022823,23**	**3003452,88**	**2984082,53**	**2964712,18**	**2945341,83**	**2925971,48**
treated Greywater	[l]		1795310,08	1790835,99	1786189,77	1782575,90	1778861,61	1775311,39	1771872,70	1768197,43	1764289,78	1760153,94	1755794,02	1751214,11	1746418,22
treated Blackwater	[l]		798418,31	796917,37	795324,95	794177,95	792972,32	791826,33	790716,97	789489,21	788145,15	786686,88	785116,47	783435,96	781647,37
treated Storm, roof	[l]		145461,77	149468,88	146254,20	141881,69	140056,51	143155,81	145277,95	140895,62	136618,91	132445,91	128374,76	124403,60	120530,61
treated Stom, green	[l]		145461,77	149911,10	146752,80	142365,38	140653,72	144119,25	146550,07	142129,37	137815,21	133605,67	129498,87	125492,94	121586,03
rainwater	[l]		198797,75	200529,99	195659,27	189809,71	186354,14	187489,17	187775,89	182111,61	176583,84	171190,13	165928,05	160795,21	155789,25
treated Greywater	%		58,22%	58,00%	58,18%	58,43%	58,54%	58,36%	58,24%	58,49%	58,74%	58,98%	59,22%	59,46%	59,69%
treated Blackwater	%		25,89%	25,81%	25,90%	26,03%	26,09%	26,03%	25,99%	26,12%	26,24%	26,36%	26,48%	26,60%	26,71%
treated Storm, roof	%		4,72%	4,84%	4,76%	4,65%	4,61%	4,71%	4,78%	4,66%	4,55%	4,44%	4,33%	4,22%	4,12%
treated Stom, green	%		4,72%	4,86%	4,78%	4,67%	4,63%	4,74%	4,82%	4,70%	4,59%	4,48%	4,37%	4,26%	4,16%
rainwater	%		6,45%	6,49%	6,37%	6,22%	6,13%	6,16%	6,17%	6,02%	5,88%	5,74%	5,60%	5,46%	5,32%
estimated retention time			36,35	36,40	36,20	35,95	35,81	35,85	35,85	35,63	35,41	35,19	34,96	34,74	34,52
size of inner Lake	width	15													
	length	105													
	depth	2													
	Volume 1:	3150													
	surface 1:	1575													
size of extension Arwa	width	20													
	length	105													
	depth	1													
	Volume	2100													
	surface 2	2100													
Total		5250													
Spilllevel		4000000													

		Jan															
14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024
51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6
25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920
23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328
0	0	0	0	6960	0	0	0	0	0	0	0	0	0	5040	0	4560	0
0,00	0,00	0,00	0,00	6612,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	4788,00	0,00	4332,00	0,00
0	0	0	0	13920	0	0	0	0	0	0	0	0	0	10080	0	9120	0
0,00	0,00	0,00	0,00	6960,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	5040,00	0,00	4560,00	0,00
0,00	0,00	0,00	0,00	6090,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	4410,00	0,00	3990,00	0,00
74649,60	74649,60	74649,60	74649,60	88221,60	74649,60	74649,60	74649,60	74649,60	74649,60	74649,60	74649,60	74649,60	74649,60	84477,60	74649,60	83541,60	74649,60
3.000.621,08	**2.981.250,72**	**2.961.880,37**	**2.942.510,02**	**2.942.801,67**	**2.923.431,32**	**2.904.060,97**	**2.884.690,61**	**2.865.320,26**	**2.845.949,91**	**2.826.579,56**	**2.807.209,21**	**2.787.838,86**	**2.768.468,50**	**2.763.336,15**	**2.743.965,80**	**2.737.477,45**	**2.718.107,10**
1797739,82	1792731,95	1787516,01	1782095,90	1776475,44	1771040,20	1765403,69	1759569,75	1753542,16	1747324,66	1740920,94	1734334,63	1727569,34	1720628,61	1713515,95	1706536,76	1699385,14	1692340,56
804975,37	803080,67	801081,85	798980,84	796779,57	794651,16	792422,52	790095,58	787672,20	785154,26	782543,59	779842,00	777051,28	774173,20	771209,50	768297,82	765300,66	762344,05
120530,61	116753,96	113071,88	109482,60	112596,38	108999,03	105493,53	102078,14	98751,13	95510,81	92355,47	89283,47	86293,16	83382,92	85339,15	82435,57	83942,97	81059,91
121586,03	117776,31	114061,99	110441,28	113872,43	110234,31	106689,08	103234,99	99870,28	96593,23	93402,13	90295,32	87271,12	84327,90	86504,04	83560,82	85257,67	82329,45
155789,25	150907,83	146148,64	141509,39	143077,84	138506,63	134052,14	129712,16	125484,48	121366,95	117357,43	113453,79	109653,96	105955,88	106767,51	103134,84	103591,00	100033,12
3000621,08	**2981250,72**	**2961880,37**	**2942510,02**	**2942801,67**	**2923431,32**	**2904060,97**	**2884690,61**	**2865320,26**	**2845949,91**	**2826579,56**	**2807209,21**	**2787838,86**	**2768468,50**	**2763336,15**	**2743965,80**	**2737477,45**	**2718107,10**
1575,00	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*
0,00	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
3000621,08	**2981250,72**	**2961880,37**	**2942510,02**	**2942801,67**	**2923431,32**	**2904060,97**	**2884690,61**	**2865320,26**	**2845949,91**	**2826579,56**	**2807209,21**	**2787838,86**	**2768468,50**	**2763336,15**	**2743965,80**	**2737477,45**	**2718107,10**
1797739,82	1792731,95	1787516,01	1782095,90	1776475,44	1771040,20	1765403,69	1759569,75	1753542,16	1747324,66	1740920,94	1734334,63	1727569,34	1720628,61	1713515,95	1706536,76	1699385,14	1692340,56
804975,37	803080,67	801081,85	798980,84	796779,57	794651,16	792422,52	790095,58	787672,20	785154,26	782543,59	779842,00	777051,28	774173,20	771209,50	768297,82	765300,66	762344,05
120530,61	116753,96	113071,88	109482,60	112596,38	108999,03	105493,53	102078,14	98751,13	95510,81	92355,47	89283,47	86293,16	83382,92	85339,15	82435,57	83942,97	81059,91
121586,03	117776,31	114061,99	110441,28	113872,43	110234,31	106689,08	103234,99	99870,28	96593,23	93402,13	90295,32	87271,12	84327,90	86504,04	83560,82	85257,67	82329,45
155789,25	150907,83	146148,64	141509,39	143077,84	138506,63	134052,14	129712,16	125484,48	121366,95	117357,43	113453,79	109653,96	105955,88	106767,51	103134,84	103591,00	100033,12
87480	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**
52411,24	52604,83	52794,81	52981,21	52808,88	52996,15	53179,85	53360,02	53536,73	53710,00	53879,88	54046,42	54209,65	54369,62	54245,44	54405,87	54306,28	54466,56
23468,22	23565,11	23660,19	23753,48	23685,69	23778,93	23870,41	23960,13	24048,12	24134,40	24218,99	24301,92	24383,20	24462,87	24414,48	24494,00	24456,28	24535,40
3513,95	3425,96	3339,61	3254,89	3347,13	3261,66	3177,82	3095,58	3014,93	2935,85	2858,32	2782,31	2707,81	2634,79	2701,61	2628,12	2682,52	2608,85
3544,71	3455,96	3368,85	3283,39	3385,06	3298,62	3213,83	3130,66	3049,10	2969,12	2890,71	2813,84	2738,49	2664,65	2738,49	2663,99	2724,53	2649,70
4541,87	4428,15	4316,54	4207,03	4253,24	4144,64	4038,10	3933,60	3831,12	3730,63	3632,10	3535,52	3440,85	3348,07	3379,98	3288,03	3310,40	3219,48
6539,95	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**
3918,23	3932,71	3946,91	3960,84	3947,96	3961,96	3975,69	3989,16	4002,37	4015,33	4028,03	4040,48	4052,68	4064,64	4055,36	4067,35	4059,90	4071,89
1754,47	1761,71	1768,82	1775,80	1770,73	1777,70	1784,54	1791,24	1797,82	1804,27	1810,60	1816,80	1822,87	1828,83	1825,21	1831,16	1828,34	1834,25
262,70	256,12	249,67	243,33	250,23	243,84	237,57	231,42	225,39	219,48	213,69	208,00	202,43	196,98	201,97	196,48	200,54	195,04
265,00	258,37	251,85	245,46	253,07	246,60	240,26	234,05	227,95	221,97	216,11	210,36	204,73	199,21	204,73	199,16	203,68	198,09
339,55	331,05	322,70	314,52	317,97	309,85	301,89	294,07	286,41	278,90	271,53	264,31	257,24	250,30	252,69	245,81	247,48	240,69
2906601,12	**2887230,77**	**2867860,42**	**2848490,07**	**2848781,72**	**2829411,37**	**2810041,01**	**2790670,66**	**2771300,31**	**2751929,96**	**2732559,61**	**2713189,26**	**2693818,90**	**2674448,55**	**2669316,20**	**2649945,85**	**2643457,50**	**2624087,14**
1741410,35	1736194,41	1730774,30	1725153,84	1719718,60	1714082,09	1708248,15	1702220,56	1696003,06	1689599,34	1683013,03	1676247,74	1669307,01	1662194,35	1655215,16	1648063,54	1641018,96	1633802,11
779752,67	777753,85	775652,84	773451,57	771323,16	769094,52	766767,58	764344,20	761826,26	759215,59	756514,00	753723,28	750845,20	747881,50	744969,82	741972,66	739016,05	735974,39
116753,96	113071,88	109482,60	105984,38	108999,03	105493,53	102078,14	98751,13	95510,81	92355,47	89283,47	86293,16	83382,92	80551,15	82435,57	79610,97	81059,91	78256,03
117776,31	114061,99	110441,28	106912,43	110234,31	106689,08	103234,99	99870,28	96593,23	93402,13	90295,32	87271,12	84327,90	81464,04	83560,82	80697,67	82329,45	79481,66
150907,83	146148,64	141509,39	136987,84	138506,63	134052,14	129712,16	125484,48	121366,95	117357,43	113453,79	109653,96	105955,88	102357,51	103134,84	99601,00	100033,12	96572,95
59,91%	60,13%	60,35%	60,56%	60,37%	60,58%	60,79%	61,00%	61,20%	61,40%	61,59%	61,78%	61,97%	62,15%	62,01%	62,19%	62,08%	62,26%
26,83%	26,94%	27,05%	27,15%	27,08%	27,18%	27,29%	27,39%	27,49%	27,59%	27,69%	27,78%	27,87%	27,96%	27,91%	28,00%	27,96%	28,05%
4,02%	3,92%	3,82%	3,72%	3,83%	3,73%	3,63%	3,54%	3,45%	3,36%	3,27%	3,18%	3,10%	3,01%	3,09%	3,00%	3,07%	2,98%
4,05%	3,95%	3,85%	3,75%	3,87%	3,77%	3,67%	3,58%	3,49%	3,39%	3,30%	3,22%	3,13%	3,05%	3,13%	3,05%	3,11%	3,03%
5,19%	5,06%	4,93%	4,81%	4,86%	4,74%	4,62%	4,50%	4,38%	4,26%	4,15%	4,04%	3,93%	3,83%	3,86%	3,76%	3,78%	3,68%
34,30	34,08	33,86	33,64	33,64	33,42	33,20	32,98	32,75	32,53	32,31	32,09	31,87	31,65	31,59	31,37	31,29	31,07

Water Resource Managemt System in the context of Hanoi
daily chart

			Start	1,00	2,00	3,00	4,00	5,00	6,00	7,00	8,00	9,00	10,00	11,00	12,00
1: dom. flow Greywater	Eff.		0,9	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024
tr. Greywater	[l/d]			51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6
2: dom. flow Blackwater	Eff.		0,9	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920
tr. Blackwater	[l/d]			23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328
3: nat. flow roof runoff	Eff.		0,95	0,00	0,00	960,00	0,00	0,00	0,00	8.400,00	0,00	0,00	1.200,00	5.280,00	7.920,00
Stormwater receiving the lake	[l/d]			0,00	0,00	912,00	0,00	0,00	0,00	7980,00	0,00	0,00	1140,00	5016,00	7524,00
4: nat. flow green space	loss. Evap.		0,2												
	loss. Infiltr.		0,3	0,00	0,00	1.920,00	0,00	0,00	0,00	16.800,00	0,00	0,00	2.400,00	10.560,00	15.840,00
Stormwater receiving the lake				0,00	0,00	960,00	0,00	0,00	0,00	8400,00	0,00	0,00	1200,00	5280,00	7920,00
5: direct Precipitation on the Lakes surface															
precipitation on the lake				0,00	0,00	840,00	0,00	0,00	0,00	7350,00	0,00	0,00	1050,00	4620,00	6930,00
daily Input to the Lake				74649,60	74649,60	76521,60	74649,60	74649,60	74649,60	91029,60	74649,60	74649,60	76989,60	84945,60	90093,60
Water in WRMS															
overall		0,00	3.105.000,00	**2.698.736,74**	**2.679.366,39**	**2.662.708,04**	**2.643.337,69**	**2.623.967,34**	**2.604.596,99**	**2.608.956,63**	**2.589.586,28**	**2.570.215,93**	**2.554.235,58**	**2.549.781,23**	**2.552.784,88**
treated Greywater	[l]		1800000,00	1.685.123,71	1.677.738,12	1.670.187,27	1.662.534,73	1.654.722,21	1.646.753,10	1.638.630,70	1.630.900,35	1.623.008,95	1.614.959,97	1.606.835,81	1.598.907,38
treated Blackwater	[l]		800000,00	759.302,39	756.177,43	752.970,89	749.711,56	746.373,34	742.957,87	739.466,80	736.146,36	732.747,14	729.270,83	725.754,79	722.321,50
treated Storm, roof	[l]		150000,00	78.256,03	75.529,71	73.791,34	71.185,78	68.653,80	66.193,85	71.784,40	69.197,48	66.685,13	65.385,75	67.994,94	73.011,71
treated Stom, green	[l]		150000,00	79.481,66	76.712,64	74.980,76	72.333,20	69.760,40	67.260,80	73.232,84	70.593,72	68.030,68	66.742,08	69.565,34	74.920,21
rainwater			205000,00	96572,95	93208,50	90777,78	87572,42	84457,59	81431,37	85841,89	82748,37	79744,03	77876,95	79630,34	83624,07
Total	[l]			**2698736,74**	**2679366,39**	**2662708,04**	**2643337,69**	**2623967,34**	**2604596,99**	**2608956,63**	**2589586,28**	**2570215,93**	**2554235,58**	**2549781,23**	**2552784,88**
Lake surface area, accord. to the structure				*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*
Spilling of Surplus water	[l]			**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**
treated Greywater				*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
treated Blackwater				*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
treated Storm, roof				*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
treated Stom, green				*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
rainwater				*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
WRMS, after spilling				**2.698.736,74**	**2.679.366,39**	**2.662.708,04**	**2.643.337,69**	**2.623.967,34**	**2.604.596,99**	**2.608.956,63**	**2.589.586,28**	**2.570.215,93**	**2.554.235,58**	**2.549.781,23**	**2.552.784,88**
treated Greywater	[l]			1.685.123,71	1.677.738,12	1.670.187,27	1.662.534,73	1.654.722,21	1.646.753,10	1.638.630,70	1.630.900,35	1.623.008,95	1.614.959,97	1.606.835,81	1.598.907,38
treated Blackwater	[l]			759.302,39	756.177,43	752.970,89	749.711,56	746.373,34	742.957,87	739.466,80	736.146,36	732.747,14	729.270,83	725.754,79	722.321,50
treated Storm, roof	[l]			78.256,03	75.529,71	73.791,34	71.185,78	68.653,80	66.193,85	71.784,40	69.197,48	66.685,13	65.385,75	67.994,94	73.011,71
treated Stom, green	[l]			79.481,66	76.712,64	74.980,76	72.333,20	69.760,40	67.260,80	73.232,84	70.593,72	68.030,68	66.742,08	69.565,34	74.920,21
rainwater				96572,95	93208,50	90777,78	87572,42	84457,59	81431,37	85841,89	82748,37	79744,03	77876,95	79630,34	83624,07
Intake for Servicewater															
overall	**[l]**			**87.480,00**	**87.480,00**	**87.480,00**	**87.480,00**	**87.480,00**	**87.480,00**	**87.480,00**	**87.480,00**	**87.480,00**	**87.480,00**	**87.480,00**	**87.480,00**
treated Greywater	[l]			54.623,56	54.777,33	54.871,95	55.020,79	55.166,50	55.309,12	54.944,35	55.094,19	55.240,82	55.310,75	55.128,65	54.792,09
treated Blackwater	[l]			24.612,91	24.688,82	24.737,93	24.811,35	24.883,21	24.953,56	24.794,80	24.868,10	24.939,82	24.976,79	24.899,79	24.752,84
treated Storm, roof	[l]			2.536,68	2.466,01	2.424,32	2.355,86	2.288,84	2.223,24	2.406,98	2.337,59	2.269,70	2.239,40	2.332,83	2.502,00
treated Stom, green	[l]			2.576,41	2.504,63	2.463,40	2.393,83	2.325,73	2.259,07	2.455,54	2.384,76	2.315,50	2.285,85	2.386,71	2.567,40
rainwater				3130,43	3043,21	2982,39	2898,17	2815,72	2735,02	2878,33	2795,36	2714,17	2667,21	2732,02	2865,67
Evaporation nach Penman															
overall	**[l]**			**6.539,95**	**6.539,95**	**6.539,95**	**6.539,95**	**6.539,95**	**6.539,95**	**6.539,95**	**6.539,95**	**6.539,95**	**6.539,95**	**6.539,95**	**6.539,95**
treated Greywater				4.083,62	4.095,12	4.102,19	4.113,32	4.124,21	4.134,88	4.107,61	4.118,81	4.129,77	4.135,00	4.121,38	4.096,22
treated Blackwater				1.840,05	1.845,72	1.849,39	1.854,88	1.860,25	1.865,51	1.853,64	1.859,12	1.864,49	1.867,25	1.861,49	1.850,51
treated Storm, roof				189,64	184,36	181,24	176,12	171,11	166,21	179,94	174,76	169,68	167,42	174,40	187,05
treated Stom, green				192,61	187,24	184,16	178,96	173,87	168,89	183,58	178,28	173,11	170,89	178,43	191,94
rainwater				234,03	227,51	222,96	216,67	210,50	204,47	215,18	208,98	202,91	199,40	204,24	214,24
WRMS, after intake															
overall				**2.604.716,79**	**2.585.346,44**	**2.568.688,09**	**2.549.317,74**	**2.529.947,39**	**2.510.577,03**	**2.514.936,68**	**2.495.566,33**	**2.476.195,98**	**2.460.215,63**	**2.455.761,28**	**2.458.764,92**
treated Greywater	[l]			1.626.416,52	1.618.865,67	1.611.213,13	1.603.400,61	1.595.431,50	1.587.309,10	1.579.578,75	1.571.687,35	1.563.638,37	1.555.514,21	1.547.585,78	1.540.019,07
treated Blackwater	[l]			732.849,43	729.642,89	726.383,56	723.045,34	719.629,87	716.138,80	712.818,36	709.419,14	705.942,83	702.426,79	698.993,50	695.718,15
treated Storm, roof	[l]			75.529,71	72.879,34	71.185,78	68.653,80	66.193,85	63.804,40	69.197,48	66.685,13	64.245,75	62.978,94	65.487,71	70.322,67
treated Stom, green	[l]			76.712,64	74.020,76	72.333,20	69.760,40	67.260,80	64.832,84	70.593,72	68.030,68	65.542,08	64.285,34	67.000,21	72.160,87
rainwater	[l]			93208,50	89937,78	87572,42	84457,59	81431,37	78491,89	82748,37	79744,03	76826,95	75010,34	76694,07	80544,17
treated Greywater	%			0,62	0,63	0,63	0,63	0,63	0,63	0,63	0,63	0,63	0,63	0,63	0,63
treated Blackwater	%			0,28	0,28	0,28	0,28	0,28	0,29	0,28	0,28	0,29	0,29	0,28	0,28
treated Storm, roof	%			0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03
treated Stom, green	%			0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03
rainwater	%			3,58%	3,48%	3,41%	3,31%	3,22%	3,13%	3,29%	3,20%	3,10%	3,05%	3,12%	3,28%
estimated retention time				30,85	30,63	30,44	30,22	30,00	29,77	29,82	29,60	29,38	29,20	29,15	29,18

size of inner Lake	width	15
	length	105
	depth	2
	Volume 1:	3150
	surface 1:	1575
size of extension Arwa	width	20
	length	105
	depth	1
	Volume	2100
	surface 2	2100
Total		5250
Spilllevel		4000000

	Feb														
13,00	14,00	15,00	16,00	17,00	18,00	19,00	20,00	21,00	22,00	23,00	24,00	25,00	26,00	27,00	28,00
57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024
51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6
25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920
23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328
0,00	5.520,00	0,00	4.320,00	0,00	0,00	5.520,00	0,00	0,00	0,00	0,00	3.840,00	2.880,00	8.400,00	0,00	8.640,00
0,00	5244,00	0,00	4104,00	0,00	0,00	5244,00	0,00	0,00	0,00	0,00	3648,00	2736,00	7980,00	0,00	8208,00
0,00	11.040,00	0,00	8.640,00	0,00	0,00	11.040,00	0,00	0,00	0,00	0,00	7.680,00	5.760,00	16.800,00	0,00	17.280,00
0,00	5520,00	0,00	4320,00	0,00	0,00	5520,00	0,00	0,00	0,00	0,00	3840,00	2880,00	8400,00	0,00	8640,00
0,00	4830,00	0,00	3780,00	0,00	0,00	4830,00	0,00	0,00	0,00	0,00	3360,00	2520,00	7350,00	0,00	7560,00
74649,60	85413,60	74649,60	83073,60	74649,60	74649,60	85413,60	74649,60	74649,60	74649,60	74649,60	82137,60	80265,60	91029,60	74649,60	91497,60
2.533.414,52	**2.529.638,17**	**2.510.267,82**	**2.503.101,47**	**2.483.731,12**	**2.464.360,77**	**2.460.584,41**	**2.441.214,06**	**2.421.843,71**	**2.402.473,36**	**2.383.103,01**	**2.374.580,65**	**2.363.346,30**	**2.367.705,95**	**2.348.335,60**	**2.353.373,25**
1.591.340,67	1.583.604,51	1.576.067,73	1.568.359,05	1.560.770,91	1.553.010,59	1.545.081,95	1.537.365,32	1.529.477,44	1.521.422,22	1.513.203,49	1.504.825,06	1.496.564,11	1.488.348,57	1.480.568,88	1.472.613,17
719.046,15	715.688,95	712.416,68	709.061,72	705.756,38	702.368,45	698.899,79	695.522,54	692.063,46	688.524,42	684.907,26	681.213,79	677.569,58	673.942,13	670.508,36	666.991,32
70.322,67	72.956,86	70.245,24	71.718,27	69.024,43	66.411,56	69.121,83	66.480,66	63.920,25	61.438,76	59.034,37	60.353,31	60.699,66	66.264,87	63.633,54	69.293,85
72.160,87	75.002,84	72.215,18	73.830,43	71.057,25	68.367,43	71.279,08	68.555,48	65.915,16	63.356,23	60.876,80	62.315,05	62.727,72	68.632,25	65.906,92	71.908,21
80544,17	82385,02	79322,99	80132,01	77122,14	74202,74	76201,76	73290,06	70467,40	67731,74	65081,08	65873,45	65785,24	70518,13	67717,91	72566,69
2533414,52	**2529638,17**	**2510267,82**	**2503101,47**	**2483731,12**	**2464360,77**	**2460584,41**	**2441214,06**	**2421843,71**	**2402473,36**	**2383103,01**	**2374580,65**	**2363346,30**	**2367705,95**	**2348335,60**	**2353373,25**
1575,00	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*
0,00	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
2.533.414,52	**2.529.638,17**	**2.510.267,82**	**2.503.101,47**	**2.483.731,12**	**2.464.360,77**	**2.460.584,41**	**2.441.214,06**	**2.421.843,71**	**2.402.473,36**	**2.383.103,01**	**2.374.580,65**	**2.363.346,30**	**2.367.705,95**	**2.348.335,60**	**2.353.373,25**
1.591.340,67	1.583.604,51	1.576.067,73	1.568.359,05	1.560.770,91	1.553.010,59	1.545.081,95	1.537.365,32	1.529.477,44	1.521.422,22	1.513.203,49	1.504.825,06	1.496.564,11	1.488.348,57	1.480.568,88	1.472.613,17
719.046,15	715.688,95	712.416,68	709.061,72	705.756,38	702.368,45	698.899,79	695.522,54	692.063,46	688.524,42	684.907,26	681.213,79	677.569,58	673.942,13	670.508,36	666.991,32
70.322,67	72.956,86	70.245,24	71.718,27	69.024,43	66.411,56	69.121,83	66.480,66	63.920,25	61.438,76	59.034,37	60.353,31	60.699,66	66.264,87	63.633,54	69.293,85
72.160,87	75.002,84	72.215,18	73.830,43	71.057,25	68.367,43	71.279,08	68.555,48	65.915,16	63.356,23	60.876,80	62.315,05	62.727,72	68.632,25	65.906,92	71.908,21
80544,17	82385,02	79322,99	80132,01	77122,14	74202,74	76201,76	73290,06	70467,40	67731,74	65081,08	65873,45	65785,24	70518,13	67717,91	72566,69
87.480,00	**87.480,00**	**87.480,00**	**87.480,00**	**87.480,00**	**87.480,00**	**87.480,00**	**87.480,00**	**87.480,00**	**87.480,00**	**87.480,00**	**87.480,00**	**87.480,00**	**87.480,00**	**87.480,00**	**87.480,00**
54.949,74	54.764,24	54.924,18	54.812,02	54.972,23	55.128,85	54.931,57	55.090,92	55.246,62	55.398,75	55.547,34	55.438,04	55.395,79	54.990,25	55.154,03	54.740,23
24.829,00	24.749,97	24.826,92	24.780,75	24.857,59	24.932,71	24.847,66	24.923,79	24.998,19	25.070,88	25.141,88	25.096,04	25.080,45	24.900,24	24.977,72	24.793,52
2.428,27	2.523,00	2.447,97	2.506,46	2.431,12	2.357,48	2.457,46	2.382,31	2.308,88	2.237,14	2.167,06	2.223,43	2.246,82	2.448,30	2.370,47	2.575,80
2.491,75	2.593,75	2.516,62	2.580,27	2.502,72	2.426,91	2.534,15	2.456,66	2.380,94	2.306,96	2.234,69	2.295,70	2.321,89	2.535,77	2.455,16	2.672,98
2781,23	2849,04	2764,32	2800,51	2716,33	2634,05	2709,17	2626,32	2545,37	2466,28	2389,03	2426,79	2435,06	2605,44	2522,62	2697,46
6.539,95	**6.539,95**	**6.539,95**	**6.539,95**	**6.539,95**	**6.539,95**	**6.539,95**	**6.539,95**	**6.539,95**	**6.539,95**	**6.539,95**	**6.539,95**	**6.539,95**	**6.539,95**	**6.539,95**	**6.539,95**
4.108,01	4.094,14	4.106,10	4.097,71	4.109,69	4.121,40	4.106,65	4.118,56	4.130,20	4.141,58	4.152,69	4.144,51	4.141,36	4.111,04	4.123,28	4.092,35
1.856,20	1.850,29	1.856,05	1.852,59	1.858,34	1.863,95	1.857,60	1.863,29	1.868,85	1.874,28	1.879,59	1.876,17	1.875,00	1.861,53	1.867,32	1.853,55
181,54	188,62	183,01	187,38	181,75	176,24	183,72	178,10	172,61	167,25	162,01	166,22	167,97	183,03	177,21	192,57
186,28	193,91	188,14	192,90	187,10	181,43	189,45	183,66	178,00	172,47	167,06	171,62	173,58	189,57	183,55	199,83
207,92	212,99	206,66	209,36	203,07	196,92	202,54	196,34	190,29	184,38	178,60	181,43	182,04	194,78	188,59	201,66
2.439.394,57	**2.435.618,22**	**2.416.247,87**	**2.409.081,52**	**2.389.711,17**	**2.370.340,81**	**2.366.564,46**	**2.347.194,11**	**2.327.823,76**	**2.308.453,41**	**2.289.083,05**	**2.280.560,70**	**2.269.326,35**	**2.273.686,00**	**2.254.315,65**	**2.259.353,30**
1.532.282,91	1.524.746,13	1.517.037,45	1.509.449,31	1.501.688,99	1.493.760,35	1.486.043,72	1.478.155,84	1.470.100,62	1.461.881,89	1.453.503,46	1.445.242,51	1.437.026,97	1.429.247,28	1.421.291,57	1.413.780,59
692.360,95	689.088,68	685.733,72	682.428,38	679.040,45	675.571,79	672.194,54	668.735,46	665.196,42	661.579,26	657.885,79	654.241,58	650.614,13	647.180,36	643.663,32	640.344,25
67.712,86	70.245,24	67.614,27	69.024,43	66.411,56	63.877,83	66.480,66	63.920,25	61.438,76	59.034,37	56.705,31	57.963,66	58.284,87	63.633,54	61.085,85	66.525,48
69.482,84	72.215,18	69.510,43	71.057,25	68.367,43	65.759,08	68.555,48	65.915,16	63.356,23	60.876,80	58.475,05	59.847,72	60.232,25	65.906,92	63.268,21	69.035,40
77555,02	79322,99	76352,01	77122,14	74202,74	71371,76	73290,06	70467,40	67731,74	65081,08	62513,45	63265,24	63168,13	67717,91	65006,69	69667,57
0,63	0,63	0,63	0,63	0,63	0,63	0,63	0,63	0,63	0,63	0,63	0,63	0,63	0,63	0,63	0,63
0,28	0,28	0,28	0,28	0,28	0,29	0,28	0,28	0,29	0,29	0,29	0,29	0,29	0,28	0,29	0,28
0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,02	0,03	0,03	0,03	0,03	0,03
0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03
3,18%	3,26%	3,16%	3,20%	3,11%	3,01%	3,10%	3,00%	2,91%	2,82%	2,73%	2,77%	2,78%	2,98%	2,88%	3,08%
28,96	28,92	28,70	28,61	28,39	28,17	28,13	27,91	27,68	27,46	27,24	27,14	27,02	27,07	26,84	26,90

Water Resource Managemt System in the context of Hanoi
daily chart

		Start	1	2	3	4	5	6	7	8	9	10	11	12
1: dom. flow Greywater	Eff.	0,9	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024
tr. Greywater	[l/d]		51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6
2: dom. flow Blackwater	Eff.	0,9	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920
tr. Blackwater	[l/d]		23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328
3: nat. flow roof runoff	Eff.	0,95	12240	9360	0	12720	480	0	6720	9600	0	9360	960	0
Stormwater receiving the lake	[l/d]		11628,00	8892,00	0,00	12084,00	456,00	0,00	6384,00	9120,00	0,00	8892,00	912,00	0,00
4: nat. flow green space	loss. Evap.	0,2												
	loss. Infiltr.	0,3	24480	18720	0	25440	960	0	13440	19200	0	18720	1920	0
Stormwater receiving the lake			12240,00	9360,00	0,00	12720,00	480,00	0,00	6720,00	9600,00	0,00	9360,00	960,00	0,00
5: direct Precipitation on the Lakes surface														
precipitation on the lake			10710,00	8190,00	0,00	11130,00	420,00	0,00	5880,00	8400,00	0,00	8190,00	840,00	0,00
daily Input to the Lake			98517,60	92901,60	74649,60	99453,60	75585,60	74649,60	87753,60	93369,60	74649,60	92901,60	76521,60	74649,60
Water in WRMS														
overall	0,00	3.105.000,00	**2.368.580,90**	**2.375.652,54**	**2.356.282,19**	**2.372.845,84**	**2.354.831,49**	**2.335.461,14**	**2.335.074,79**	**2.342.824,43**	**2.323.454,08**	**2.330.525,73**	**2.313.867,38**	**2.294.497,03**
treated Greywater	[l]	1800000,00	1465102,19	1458267,10	1451875,63	1445264,75	1439320,21	1433174,93	1426800,41	1420673,01	1414981,55	1409045,08	1403521,84	1397813,79
treated Blackwater	[l]	800000,00	663672,25	660656,02	657837,59	654916,67	652294,72	649578,94	646756,48	644043,34	641525,22	638893,52	636446,76	633913,86
treated Storm, roof	[l]	150000,00	78153,48	83943,21	80621,03	89488,11	86398,29	82948,72	85993,41	91650,95	87972,90	93305,03	90452,84	86777,45
treated Stom, green	[l]	150000,00	81275,40	87409,20	83949,85	93320,10	90102,45	86504,98	89742,50	95729,09	91887,39	97529,11	94554,51	90712,45
rainwater		205000,00	80377,57	85377,01	81998,09	89856,22	86715,82	83253,57	85781,98	90728,04	87087,03	91753,00	88891,43	85279,48
Total	[l]		**2368580,90**	**2375652,54**	**2356282,19**	**2372845,84**	**2354831,49**	**2335461,14**	**2335074,79**	**2342824,43**	**2323454,08**	**2330525,73**	**2313867,38**	**2294497,03**
Lake surface area, accord. to the structure			*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*
Spilling of Surplus water	[l]		**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**
treated Greywater			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
treated Blackwater			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
treated Storm, roof			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
treated Stom, green			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
rainwater			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
WRMS, after spilling			**2368580,90**	**2375652,54**	**2356282,19**	**2372845,84**	**2354831,49**	**2335461,14**	**2335074,79**	**2342824,43**	**2323454,08**	**2330525,73**	**2313867,38**	**2294497,03**
treated Greywater	[l]		1465102,19	1458267,10	1451875,63	1445264,75	1439320,21	1433174,93	1426800,41	1420673,01	1414981,55	1409045,08	1403521,84	1397813,79
treated Blackwater	[l]		663672,25	660656,02	657837,59	654916,67	652294,72	649578,94	646756,48	644043,34	641525,22	638893,52	636446,76	633913,86
treated Storm, roof	[l]		78153,48	83943,21	80621,03	89488,11	86398,29	82948,72	85993,41	91650,95	87972,90	93305,03	90452,84	86777,45
treated Stom, green	[l]		81275,40	87409,20	83949,85	93320,10	90102,45	86504,98	89742,50	95729,09	91887,39	97529,11	94554,51	90712,45
rainwater			80377,57	85377,01	81998,09	89856,22	86715,82	83253,57	85781,98	90728,04	87087,03	91753,00	88891,43	85279,48
Intake for Servicewater														
overall	**[l]**		**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**
treated Greywater	[l]		54111,36	53698,60	53902,75	53282,75	53469,53	53682,82	53452,89	53047,28	53275,25	52890,75	53062,72	53293,05
treated Blackwater	[l]		24511,74	24327,71	24423,06	24144,89	24232,20	24331,45	24229,74	24048,29	24153,96	23981,89	24062,04	24168,60
treated Storm, roof	[l]		2886,48	3091,09	2993,16	3299,17	3209,62	3107,03	3221,61	3422,20	3312,25	3502,35	3419,74	3308,48
treated Stom, green	[l]		3001,79	3218,72	3116,75	3440,44	3347,23	3240,24	3362,07	3574,48	3459,64	3660,91	3574,81	3458,50
rainwater			2968,63	3143,89	3044,28	3312,74	3221,42	3118,45	3213,69	3387,74	3278,90	3444,10	3360,70	3251,37
Evaporation nach Penman														
overall	**[l]**		**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**
treated Greywater			4045,33	4014,47	4029,74	3983,39	3997,35	4013,30	3996,11	3965,78	3982,83	3954,08	3966,94	3984,16
treated Blackwater			1832,48	1818,72	1825,85	1805,06	1811,58	1819,00	1811,40	1797,84	1805,74	1792,87	1798,86	1806,83
treated Storm, roof			215,79	231,09	223,77	246,64	239,95	232,28	240,85	255,84	247,62	261,83	255,66	247,34
treated Stom, green			224,41	240,63	233,01	257,21	250,24	242,24	251,35	267,23	258,64	273,69	267,25	258,56
rainwater			221,93	235,04	227,59	247,66	240,83	233,13	240,25	253,27	245,13	257,48	251,24	243,07
WRMS, after intake														
overall			**2274560,94**	**2281632,59**	**2262262,24**	**2278825,89**	**2260811,54**	**2241441,19**	**2241054,83**	**2248804,48**	**2229434,13**	**2236505,78**	**2219847,43**	**2200477,08**
treated Greywater	[l]		1406945,50	1400554,03	1393943,15	1387998,61	1381853,33	1375478,81	1369351,41	1363659,95	1357723,48	1352200,24	1346492,19	1340536,58
treated Blackwater	[l]		637328,02	634509,59	631588,67	628966,72	626250,94	623428,48	620715,34	618197,22	615565,52	613118,76	610585,86	607938,43
treated Storm, roof	[l]		75051,21	80621,03	77404,11	85942,29	82948,72	79609,41	82530,95	87972,90	84413,03	89540,84	86777,45	83221,63
treated Stom, green	[l]		78049,20	83949,85	80600,10	89622,45	86504,98	83022,50	86129,09	91887,39	88169,11	93594,51	90712,45	86995,39
rainwater	[l]		77187,01	81998,09	78726,22	86295,82	83253,57	79901,98	82328,04	87087,03	83563,00	88051,43	85279,48	81785,05
treated Greywater	%		61,86%	61,38%	61,62%	60,91%	61,12%	61,37%	61,10%	60,64%	60,90%	60,46%	60,66%	60,92%
treated Blackwater	%		28,02%	27,81%	27,92%	27,60%	27,70%	27,81%	27,70%	27,49%	27,61%	27,41%	27,51%	27,63%
treated Storm, roof	%		3,30%	3,53%	3,42%	3,77%	3,67%	3,55%	3,68%	3,91%	3,79%	4,00%	3,91%	3,78%
treated Stom, green	%		3,43%	3,68%	3,56%	3,93%	3,83%	3,70%	3,84%	4,09%	3,95%	4,18%	4,09%	3,95%
rainwater	%		3,39%	3,59%	3,48%	3,79%	3,68%	3,56%	3,67%	3,87%	3,75%	3,94%	3,84%	3,72%
estimated retention time			27,08	27,16	26,94	27,12	26,92	26,70	26,69	26,78	26,56	26,64	26,45	26,23

size of inner Lake	width	15
	length	105
	depth	2
	Volume 1:	3150
	surface 1:	1575
size of extension Arwa	width	20
	length	105
	depth	1
	Volume	2100
	surface 2	2100
Total		5250
Spilllevel		4000000

		Mar																
13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024
51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6
25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920
23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328
0	0	7680	12000	1440	0	10800	0	1440	0	0	7200	0	0	0	0	3360	0	0
0,00	0,00	7296,00	11400,00	1368,00	0,00	10260,00	0,00	1368,00	0,00	0,00	6840,00	0,00	0,00	0,00	0,00	3192,00	0,00	0,00
0	0	15360	24000	2880	0	21600	0	2880	0	0	14400	0	0	0	0	6720	0	0
0,00	0,00	7680,00	12000,00	1440,00	0,00	10800,00	0,00	1440,00	0,00	0,00	7200,00	0,00	0,00	0,00	0,00	3360,00	0,00	0,00
0,00	0,00	6720,00	10500,00	1260,00	0,00	9450,00	0,00	1260,00	0,00	0,00	6300,00	0,00	0,00	0,00	0,00	2940,00	0,00	0,00
74649,60	74649,60	89625,60	98049,60	77457,60	74649,60	95709,60	74649,60	77457,60	74649,60	74649,60	88689,60	74649,60	74649,60	74649,60	74649,60	81201,60	74649,60	74649,60
2.275.126,68	**2.255.756,32**	**2.258.081,97**	**2.272.611,62**	**2.257.309,27**	**2.237.938,92**	**2.249.078,57**	**2.229.708,21**	**2.214.405,86**	**2.195.035,51**	**2.175.665,16**	**2.176.634,81**	**2.157.264,45**	**2.137.894,10**	**2.118.523,75**	**2.099.153,40**	**2.089.275,05**	**2.069.904,70**	**2.050.534,34**
1391858,18	1385661,03	1379228,26	1373122,82	1367637,11	1361994,80	1356096,48	1350728,14	1345093,68	1339304,86	1333260,02	1326965,66	1320968,85	1314718,72	1308221,84	1301484,64	1294513,44	1287580,34	1280417,01
631266,43	628507,25	625639,06	622917,27	620474,63	617959,03	615325,43	612930,51	610413,11	607824,00	605117,07	602295,33	599607,13	596802,48	593884,40	590855,85	587719,73	584599,62	581373,73
83221,63	79782,49	83753,15	91665,91	89241,61	85524,58	92191,54	88337,58	85980,66	82330,06	78803,62	82238,17	78685,89	75256,52	71946,90	68753,91	68866,45	65767,38	62780,07
86995,39	83400,30	87604,17	95956,59	93426,78	89535,43	96573,88	92536,73	90074,74	86250,32	82555,96	86188,36	82465,44	78871,35	75402,76	72056,39	72189,03	68940,43	65808,99
81785,05	78405,27	81857,33	88949,03	86529,13	82925,08	88891,24	85175,25	82843,67	79326,27	75928,49	78947,29	75537,15	72245,02	69067,84	66002,62	65986,39	63016,92	60154,55
2275126,68	**2255756,32**	**2258081,97**	**2272611,62**	**2257309,27**	**2237938,92**	**2249078,57**	**2229708,21**	**2214405,86**	**2195035,51**	**2175665,16**	**2176634,81**	**2157264,45**	**2137894,10**	**2118523,75**	**2099153,40**	**2089275,05**	**2069904,70**	**2050534,34**
1575,00	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*
0,00	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
2275126,68	**2255756,32**	**2258081,97**	**2272611,62**	**2257309,27**	**2237938,92**	**2249078,57**	**2229708,21**	**2214405,86**	**2195035,51**	**2175665,16**	**2176634,81**	**2157264,45**	**2137894,10**	**2118523,75**	**2099153,40**	**2089275,05**	**2069904,70**	**2050534,34**
1391858,18	1385661,03	1379228,26	1373122,82	1367637,11	1361994,80	1356096,48	1350728,14	1345093,68	1339304,86	1333260,02	1326965,66	1320968,85	1314718,72	1308221,84	1301484,64	1294513,44	1287580,34	1280417,01
631266,43	628507,25	625639,06	622917,27	620474,63	617959,03	615325,43	612930,51	610413,11	607824,00	605117,07	602295,33	599607,13	596802,48	593884,40	590855,85	587719,73	584599,62	581373,73
83221,63	79782,49	83753,15	91665,91	89241,61	85524,58	92191,54	88337,58	85980,66	82330,06	78803,62	82238,17	78685,89	75256,52	71946,90	68753,91	68866,45	65767,38	62780,07
86995,39	83400,30	87604,17	95956,59	93426,78	89535,43	96573,88	92536,73	90074,74	86250,32	82555,96	86188,36	82465,44	78871,35	75402,76	72056,39	72189,03	68940,43	65808,99
81785,05	78405,27	81857,33	88949,03	86529,13	82925,08	88891,24	85175,25	82843,67	79326,27	75928,49	78947,29	75537,15	72245,02	69067,84	66002,62	65986,39	63016,92	60154,55
87480	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**
53517,79	53737,02	53432,47	52855,83	53001,55	53239,75	52746,63	52994,24	53137,86	53376,08	53608,24	53331,39	53567,08	53796,67	54020,28	54238,00	54202,55	54416,77	54625,22
24272,58	24374,00	24237,78	23978,05	24045,94	24155,73	23933,65	24047,61	24114,34	24223,96	24330,79	24206,54	24314,88	24420,42	24523,21	24623,29	24608,40	24706,83	24802,60
3199,92	3094,03	3244,67	3528,51	3458,48	3343,12	3585,88	3465,82	3396,66	3281,15	3168,57	3305,19	3190,82	3079,40	2970,90	2865,25	2883,51	2779,51	2678,33
3345,03	3234,33	3393,86	3693,67	3620,67	3499,90	3756,33	3630,57	3558,40	3437,38	3319,44	3463,95	3344,09	3227,32	3113,60	3002,87	3022,63	2913,62	2807,55
3144,68	3040,62	3171,22	3423,93	3353,36	3241,50	3457,51	3341,75	3272,74	3161,44	3052,96	3172,93	3063,13	2956,18	2852,01	2750,59	2762,92	2663,27	2566,32
6539,95	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**
4000,96	4017,35	3994,58	3951,47	3962,36	3980,17	3943,31	3961,82	3972,55	3990,36	4007,72	3987,02	4004,64	4021,81	4038,52	4054,80	4052,15	4068,16	4083,75
1814,60	1822,19	1812,00	1792,58	1797,66	1805,87	1789,27	1797,78	1802,77	1810,97	1818,95	1809,67	1817,77	1825,66	1833,34	1840,82	1839,71	1847,07	1854,23
239,22	231,31	242,57	263,79	258,55	249,93	268,08	259,10	253,93	245,30	236,88	247,09	238,54	230,21	222,10	214,20	215,57	207,79	200,23
250,07	241,80	253,72	276,14	270,68	261,65	280,82	271,42	266,02	256,98	248,16	258,96	250,00	241,27	232,77	224,49	225,97	217,82	209,89
235,09	227,31	237,08	255,97	250,70	242,33	258,48	249,83	244,67	236,35	228,24	237,21	229,00	221,00	213,21	205,63	206,55	199,10	191,86
2181106,72	**2161736,37**	**2164062,02**	**2178591,67**	**2163289,32**	**2143918,97**	**2155058,61**	**2135688,26**	**2120385,91**	**2101015,56**	**2081645,21**	**2082614,85**	**2063244,50**	**2043874,15**	**2024503,80**	**2005133,45**	**1995255,10**	**1975884,74**	**1956514,39**
1334339,43	1327906,66	1321801,22	1316315,51	1310673,20	1304774,88	1299406,54	1293772,08	1287983,26	1281938,42	1275644,06	1269647,25	1263397,12	1256900,24	1250163,04	1243191,84	1236258,74	1229095,41	1221708,04
605179,25	602311,06	599589,27	597146,63	594631,03	591997,43	589602,51	587085,11	584496,00	581789,07	578967,33	576279,13	573474,48	570556,40	567527,85	564391,73	561271,62	558045,73	554716,90
79782,49	76457,15	80265,91	87873,61	85524,58	81931,54	88337,58	84612,66	82330,06	78803,62	75398,17	78685,89	75256,52	71946,90	68753,91	65674,45	65767,38	62780,07	59901,51
83400,30	79924,17	83956,59	91986,78	89535,43	85773,88	92536,73	88634,74	86250,32	82555,96	78988,36	82465,44	78871,35	75402,76	72056,39	68829,03	68940,43	65808,99	62791,56
78405,27	75137,33	78449,03	85269,13	82925,08	79441,24	85175,25	81583,67	79326,27	75928,49	72647,29	75537,15	72245,02	69067,84	66002,62	63046,39	63016,92	60154,55	57396,37
61,18%	61,43%	61,08%	60,42%	60,59%	60,86%	60,30%	60,58%	60,74%	61,02%	61,28%	60,96%	61,23%	61,50%	61,75%	62,00%	61,96%	62,20%	62,44%
27,75%	27,86%	27,71%	27,41%	27,49%	27,61%	27,36%	27,49%	27,57%	27,69%	27,81%	27,67%	27,79%	27,92%	28,03%	28,15%	28,13%	28,24%	28,35%
3,66%	3,54%	3,71%	4,03%	3,95%	3,82%	4,10%	3,96%	3,88%	3,75%	3,62%	3,78%	3,65%	3,52%	3,40%	3,28%	3,30%	3,18%	3,06%
3,82%	3,70%	3,88%	4,22%	4,14%	4,00%	4,29%	4,15%	4,07%	3,93%	3,79%	3,96%	3,82%	3,69%	3,56%	3,43%	3,46%	3,33%	3,21%
3,59%	3,48%	3,63%	3,91%	3,83%	3,71%	3,95%	3,82%	3,74%	3,61%	3,49%	3,63%	3,50%	3,38%	3,26%	3,14%	3,16%	3,04%	2,93%
26,01	25,79	25,81	25,98	25,80	25,58	25,71	25,49	25,31	25,09	24,87	24,88	24,66	24,44	24,22	24,00	23,88	23,66	23,44

Water Resource Managemt System in the context of Hanoi
daily chart

			Start	1	2	3	4	5	6	7	8	9	10	11	12	13
1: dom. flow Greywater	Eff.		0,9	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024
tr. Greywater	[l/d]			51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6
2: dom. flow Blackwater	Eff.		0,9	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920
tr. Blackwater	[l/d]			23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328
3: nat. flow roof runoff	Eff.		0,95	0	32400	6000	0	0	0	0	0	18240	35040	28080	0	0
Stormwater receiving the lake	[l/d]			0,00	30780,00	5700,00	0,00	0,00	0,00	0,00	0,00	17328,00	33288,00	26676,00	0,00	0,00
4: nat. flow green space	loss. Evap.		0,2													
	loss. Infiltr.		0,3	0	64800	12000	0	0	0	0	0	36480	70080	56160	0	0
Stormwater receiving the lake				0,00	32400,00	6000,00	0,00	0,00	0,00	0,00	0,00	18240,00	35040,00	28080,00	0,00	0,00
5: direct Precipitation on the Lakes surface																
precipitation on the lake				0,00	28350,00	5250,00	0,00	0,00	0,00	0,00	0,00	15960,00	30660,00	24570,00	0,00	0,00
daily Input to the Lake				74649,60	137829,60	86349,60	74649,60	74649,60	74649,60	74649,60	74649,60	110217,60	142977,60	129405,60	74649,60	74649,60
Water in WRMS																
overall		0,00	3.105.000,00	**2.031.163,99**	**2.103.323,64**	**2.100.903,29**	**2.081.532,94**	**2.062.162,59**	**2.042.792,23**	**2.023.421,88**	**2.004.051,53**	**2.036.209,18**	**2.115.826,83**	**2.175.782,48**	**2.156.412,12**	**2.137.041,77**
treated Greywater	[l]		1800000,00	1273029,64	1265424,35	1260180,65	1255106,45	1249736,63	1244079,13	1238141,72	1231932,05	1225457,64	1220194,94	1217295,34	1216015,15	1214318,27
treated Blackwater	[l]		800000,00	578044,90	574615,95	572258,24	569976,45	567559,41	565010,73	562333,99	559532,68	556610,24	554237,31	552936,94	552371,42	551615,93
treated Storm, roof	[l]		150000,00	59901,51	87908,75	89679,17	85665,83	81796,43	78067,09	74474,04	71013,54	85009,94	114372,69	135966,37	130090,99	124419,00
treated Stom, green	[l]		150000,00	62791,56	92285,02	94159,82	89945,96	85883,23	81967,56	78194,99	74561,59	89303,54	120220,04	142957,88	136780,38	130816,73
rainwater			205000,00	57396,37	83089,57	84625,41	80838,24	77186,89	73667,72	70277,15	67011,66	79827,81	106801,84	126625,94	121154,18	115871,84
Total	[l]			**2031163,99**	**2103323,64**	**2100903,29**	**2081532,94**	**2062162,59**	**2042792,23**	**2023421,88**	**2004051,53**	**2036209,18**	**2115826,83**	**2175782,48**	**2156412,12**	**2137041,77**
Lake surface area, accord. to the structure				*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*
Spilling of Surplus water	[l]			**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**
treated Greywater				*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
treated Blackwater				*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
treated Storm, roof				*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
treated Stom, green				*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
rainwater				*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
WRMS, after spilling				**2031163,99**	**2103323,64**	**2100903,29**	**2081532,94**	**2062162,59**	**2042792,23**	**2023421,88**	**2004051,53**	**2036209,18**	**2115826,83**	**2175782,48**	**2156412,12**	**2137041,77**
treated Greywater	[l]			1273029,64	1265424,35	1260180,65	1255106,45	1249736,63	1244079,13	1238141,72	1231932,05	1225457,64	1220194,94	1217295,34	1216015,15	1214318,27
treated Blackwater	[l]			578044,90	574615,95	572258,24	569976,45	567559,41	565010,73	562333,99	559532,68	556610,24	554237,31	552936,94	552371,42	551615,93
treated Storm, roof	[l]			59901,51	87908,75	89679,17	85665,83	81796,43	78067,09	74474,04	71013,54	85009,94	114372,69	135966,37	130090,99	124419,00
treated Stom, green	[l]			62791,56	92285,02	94159,82	89945,96	85883,23	81967,56	78194,99	74561,59	89303,54	120220,04	142957,88	136780,38	130816,73
rainwater				57396,37	83089,57	84625,41	80838,24	77186,89	73667,72	70277,15	67011,66	79827,81	106801,84	126625,94	121154,18	115871,84
Intake for Servicewater																
overall	**[l]**			**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**
treated Greywater	[l]			54827,99	52630,67	52472,95	52748,01	53015,68	53276,12	53529,44	53775,77	52648,34	50449,62	48942,85	49330,55	49708,23
treated Blackwater	[l]			24895,76	23899,03	23828,39	23954,24	24076,71	24195,87	24311,78	24424,48	23913,19	22915,24	22231,51	22408,26	22580,45
treated Storm, roof	[l]			2579,89	3656,24	3734,17	3600,25	3469,93	3343,12	3219,79	3099,85	3652,21	4728,80	5466,69	5277,45	5093,10
treated Stom, green	[l]			2704,36	3838,26	3920,74	3780,13	3643,29	3510,16	3380,66	3254,73	3836,68	4970,56	5747,80	5548,82	5354,99
rainwater				2472,00	3455,80	3523,74	3397,37	3274,38	3154,73	3038,34	2925,16	3429,58	4415,78	5091,15	4914,91	4743,22
Evaporation nach Penman																
overall	**[l]**			**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**
treated Greywater				4098,91	3934,64	3922,85	3943,41	3963,42	3982,89	4001,83	4020,24	3935,96	3771,58	3658,94	3687,92	3716,16
treated Blackwater				1861,19	1786,68	1781,40	1790,80	1799,96	1808,87	1817,53	1825,96	1787,74	1713,13	1662,01	1675,23	1688,10
treated Storm, roof				192,87	273,34	279,16	269,15	259,41	249,93	240,71	231,74	273,04	353,52	408,69	394,54	380,76
treated Stom, green				202,18	286,95	293,11	282,60	272,37	262,42	252,74	243,32	286,83	371,60	429,70	414,83	400,34
rainwater				184,81	258,35	263,43	253,99	244,79	235,85	227,14	218,68	256,39	330,12	380,61	367,44	354,60
WRMS, after intake																
overall				**1937144,04**	**2009303,69**	**2006883,34**	**1987512,99**	**1968142,63**	**1948772,28**	**1929401,93**	**1910031,58**	**1942189,23**	**2021806,88**	**2081762,52**	**2062392,17**	**2043021,82**
treated Greywater	[l]			1214102,75	1208859,05	1203784,85	1198415,03	1192757,53	1186820,12	1180610,45	1174136,04	1168873,34	1165973,74	1164693,55	1162996,67	1160893,89
treated Blackwater	[l]			551287,95	548930,24	546648,45	544231,41	541682,73	539005,99	536204,68	533282,24	530909,31	529608,94	529043,42	528287,93	527347,38
treated Storm, roof	[l]			57128,75	83979,17	85665,83	81796,43	78067,09	74474,04	71013,54	67681,94	81084,69	109290,37	130090,99	124419,00	118945,14
treated Stom, green	[l]			59885,02	88159,82	89945,96	85883,23	81967,56	78194,99	74561,59	71063,54	85180,04	114877,88	136780,38	130816,73	125061,40
rainwater	[l]			54739,57	79375,41	80838,24	77186,89	73667,72	70277,15	67011,66	63867,81	76141,84	102055,94	121154,18	115871,84	110774,01
treated Greywater	%			62,67%	60,16%	59,98%	60,30%	60,60%	60,90%	61,19%	61,47%	60,18%	57,67%	55,95%	56,39%	56,82%
treated Blackwater	%			28,46%	27,32%	27,24%	27,38%	27,52%	27,66%	27,79%	27,92%	27,34%	26,19%	25,41%	25,62%	25,81%
treated Storm, roof	%			2,95%	4,18%	4,27%	4,12%	3,97%	3,82%	3,68%	3,54%	4,17%	5,41%	6,25%	6,03%	5,82%
treated Stom, green	%			3,09%	4,39%	4,48%	4,32%	4,16%	4,01%	3,86%	3,72%	4,39%	5,68%	6,57%	6,34%	6,12%
rainwater	%			2,83%	3,95%	4,03%	3,88%	3,74%	3,61%	3,47%	3,34%	3,92%	5,05%	5,82%	5,62%	5,42%
estimated retention time				23,22	24,04	24,02	23,79	23,57	23,35	23,13	22,91	23,28	24,19	24,87	24,65	24,43
size of inner Lake	width		15													
	length		105													
	depth		2													
	Volume 1:		3150													
	surface 1:		1575													
size of extension Arwa	width		20													
	length		105													
	depth		1													
	Volume		2100													
	surface 2		2100													
Total			5250													
Spilllevel			4000000													

	Apr															
14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024
51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6
25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920
23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328
240	0	0	0	0	10320	0	0	20640	35280	8880	7920	0	0	2640	0	10800
228,00	0,00	0,00	0,00	0,00	9804,00	0,00	0,00	19608,00	33516,00	8436,00	7524,00	0,00	0,00	2508,00	0,00	10260,00
480	0	0	0	0	20640	0	0	41280	70560	17760	15840	0	0	5280	0	21600
240,00	0,00	0,00	0,00	0,00	10320,00	0,00	0,00	20640,00	35280,00	8880,00	7920,00	0,00	0,00	2640,00	0,00	10800,00
210,00	0,00	0,00	0,00	0,00	9030,00	0,00	0,00	18060,00	30870,00	7770,00	6930,00	0,00	0,00	2310,00	0,00	9450,00
75117,60	74649,60	74649,60	74649,60	74649,60	94773,60	74649,60	74649,60	114897,60	143445,60	91965,60	90093,60	74649,60	74649,60	79797,60	74649,60	95709,60
2.118.349,42	**2.098.979,07**	**2.079.608,72**	**2.060.238,36**	**2.040.868,01**	**2.050.651,66**	**2.031.281,31**	**2.011.910,96**	**2.050.848,61**	**2.131.144,25**	**2.136.859,90**	**2.139.863,55**	**2.120.493,20**	**2.101.122,85**	**2.089.210,50**	**2.069.840,14**	**2.080.979,79**
1212215,49	1209734,61	1206868,35	1203626,94	1200020,46	1196058,78	1192542,50	1188666,04	1184439,30	1181460,97	1180659,92	1180033,52	1179507,56	1178531,31	1177116,60	1175464,87	1173392,42
550675,38	549562,43	548273,78	546814,10	545187,98	543399,93	541813,69	540063,28	538153,22	536809,90	536455,40	536179,83	535949,51	535514,19	534879,28	534136,31	533201,82
119173,14	113883,81	108782,59	103864,48	99124,58	104362,05	99577,17	94968,14	110138,12	138604,90	140926,05	142249,43	135999,37	129969,33	126661,53	120961,43	125726,90
125301,40	119740,07	114376,54	109205,53	104221,88	109740,52	104709,05	99862,48	115835,74	145805,32	148252,81	149649,82	143074,60	136730,86	133252,49	127255,78	132275,34
110984,01	106058,14	101307,46	96727,31	92313,11	97090,38	92638,90	88351,01	102282,22	128463,15	130565,73	131750,95	125962,16	120377,16	117300,59	112021,75	116383,30
2118349,42	**2098979,07**	**2079608,72**	**2060238,36**	**2040868,01**	**2050651,66**	**2031281,31**	**2011910,96**	**2050848,61**	**2131144,25**	**2136859,90**	**2139863,55**	**2120493,20**	**2101122,85**	**2089210,50**	**2069840,14**	**2080979,79**
1575,00	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*
0,00	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
2118349,42	**2098979,07**	**2079608,72**	**2060238,36**	**2040868,01**	**2050651,66**	**2031281,31**	**2011910,96**	**2050848,61**	**2131144,25**	**2136859,90**	**2139863,55**	**2120493,20**	**2101122,85**	**2089210,50**	**2069840,14**	**2080979,79**
1212215,49	1209734,61	1206868,35	1203626,94	1200020,46	1196058,78	1192542,50	1188666,04	1184439,30	1181460,97	1180659,92	1180033,52	1179507,56	1178531,31	1177116,60	1175464,87	1173392,42
550675,38	549562,43	548273,78	546814,10	545187,98	543399,93	541813,69	540063,28	538153,22	536809,90	536455,40	536179,83	535949,51	535514,19	534879,28	534136,31	533201,82
119173,14	113883,81	108782,59	103864,48	99124,58	104362,05	99577,17	94968,14	110138,12	138604,90	140926,05	142249,43	135999,37	129969,33	126661,53	120961,43	125726,90
125301,40	119740,07	114376,54	109205,53	104221,88	109740,52	104709,05	99862,48	115835,74	145805,32	148252,81	149649,82	143074,60	136730,86	133252,49	127255,78	132275,34
110984,01	106058,14	101307,46	96727,31	92313,11	97090,38	92638,90	88351,01	102282,22	128463,15	130565,73	131750,95	125962,16	120377,16	117300,59	112021,75	116383,30
87480	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**
50060,02	50418,60	50767,65	51107,33	51437,81	51023,40	51358,53	51684,45	50522,87	48497,05	48334,53	48241,08	48660,06	49068,01	49288,55	49680,00	49326,94
22740,86	22904,34	23063,47	23218,33	23369,00	23181,23	23333,97	23482,52	22955,20	22035,17	21961,72	21919,63	22110,36	22296,07	22396,61	22574,81	22414,68
4921,41	4746,38	4576,01	4410,20	4248,89	4452,04	4288,43	4129,31	4698,00	5689,51	5769,31	5815,31	5610,59	5411,26	5303,61	5112,33	5285,29
5174,48	4990,46	4811,32	4636,99	4467,38	4681,49	4509,44	4342,13	4941,03	5985,07	6069,26	6117,85	5902,48	5692,77	5579,59	5378,36	5560,58
4583,23	4420,23	4261,56	4107,15	3956,92	4141,84	3989,62	3841,59	4362,90	5273,20	5345,17	5386,13	5196,51	5011,89	4911,64	4734,50	4892,51
6539,95	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**
3742,46	3769,26	3795,36	3820,75	3845,46	3814,48	3839,53	3863,90	3777,06	3625,61	3613,46	3606,47	3637,80	3668,29	3684,78	3714,05	3687,65
1700,09	1712,31	1724,21	1735,79	1747,05	1733,01	1744,43	1755,54	1716,12	1647,34	1641,84	1638,70	1652,96	1666,84	1674,36	1687,68	1675,71
367,92	354,84	342,10	329,70	317,64	332,83	320,60	308,71	351,22	425,34	431,31	434,75	419,44	404,54	396,49	382,19	395,13
386,84	373,08	359,69	346,66	333,98	349,99	337,12	324,61	369,39	447,44	453,73	457,37	441,27	425,59	417,13	402,08	415,71
342,64	330,45	318,59	307,05	295,82	309,64	298,26	287,20	326,17	394,22	399,60	402,66	388,49	374,69	367,19	353,95	365,76
2024329,47	**2004959,12**	**1985588,76**	**1966218,41**	**1946848,06**	**1956631,71**	**1937261,36**	**1917891,01**	**1956828,65**	**2037124,30**	**2042839,95**	**2045843,60**	**2026473,25**	**2007102,90**	**1995190,54**	**1975820,19**	**1986959,84**
1158413,01	1155546,75	1152305,34	1148698,86	1144737,18	1141220,90	1137344,44	1133117,70	1130139,37	1129338,32	1128711,92	1128185,96	1127209,71	1125795,00	1124143,27	1122070,82	1120377,82
526234,43	524945,78	523486,10	521859,98	520071,93	518485,69	516735,28	514825,22	513481,90	513127,40	512851,83	512621,51	512186,19	511551,28	510808,31	509873,82	509111,44
113883,81	108782,59	103864,48	99124,58	94558,05	99577,17	94968,14	90530,12	105088,90	132490,05	134725,43	135999,37	129969,33	124153,53	120961,43	115466,90	120046,48
119740,07	114376,54	109205,53	104221,88	99420,52	104709,05	99862,48	95195,74	110525,32	139372,81	141729,82	143074,60	136730,86	130612,49	127255,78	121475,34	126299,06
106058,14	101307,46	96727,31	92313,11	88060,38	92638,90	88351,01	84222,22	97593,15	122795,73	124820,95	125962,16	120377,16	114990,59	112021,75	106933,30	111125,03
57,22%	57,63%	58,03%	58,42%	58,80%	58,33%	58,71%	59,08%	57,75%	55,44%	55,25%	55,15%	55,62%	56,09%	56,34%	56,79%	56,39%
26,00%	26,18%	26,36%	26,54%	26,71%	26,50%	26,67%	26,84%	26,24%	25,19%	25,10%	25,06%	25,27%	25,49%	25,60%	25,81%	25,62%
5,63%	5,43%	5,23%	5,04%	4,86%	5,09%	4,90%	4,72%	5,37%	6,50%	6,60%	6,65%	6,41%	6,19%	6,06%	5,84%	6,04%
5,92%	5,70%	5,50%	5,30%	5,11%	5,35%	5,15%	4,96%	5,65%	6,84%	6,94%	6,99%	6,75%	6,51%	6,38%	6,15%	6,36%
5,24%	5,05%	4,87%	4,69%	4,52%	4,73%	4,56%	4,39%	4,99%	6,03%	6,11%	6,16%	5,94%	5,73%	5,61%	5,41%	5,59%
24,22	23,99	23,77	23,55	23,33	23,44	23,22	23,00	23,44	24,36	24,43	24,46	24,24	24,02	23,88	23,66	23,79

Water Resource Managemt System in the context of Hanoi
daily chart

		Start	1	2	3	4	5	6	7	8	9	10	11	12
1: dom. flow Greywater	Eff.	0,9	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024
tr. Greywater	[l/d]		51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6
2: dom. flow Blackwater	Eff.	0,9	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920
tr. Blackwater	[l/d]		23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328
3: nat. flow roof runoff	Eff.	0,95	45600	46800	40800	0	0	33840	0	21600	0	0	0	0
Stormwater receiving the lake	[l/d]		43320,00	44460,00	38760,00	0,00	0,00	32148,00	0,00	20520,00	0,00	0,00	0,00	0,00
4: nat. flow green space	loss. Evap.	0,2												
	loss. Infiltr.	0,3	91200	93600	81600	0	0	67680	0	43200	0	0	0	0
Stormwater receiving the lake			45600,00	46800,00	40800,00	0,00	0,00	33840,00	0,00	21600,00	0,00	0,00	0,00	0,00
5: direct Precipitation on the Lakes surface														
precipitation on the lake			39900,00	40950,00	35700,00	0,00	0,00	29610,00	0,00	18900,00	0,00	0,00	0,00	0,00
daily Input to the Lake			163569,60	165909,60	154209,60	74649,60	74649,60	140637,60	74649,60	116769,60	74649,60	74649,60	74649,60	74649,60
Water in WRMS														
overall		0,00 3.105.000,00	**2.190.429,44**	**2.303.269,09**	**2.399.158,74**	**2.379.788,39**	**2.360.418,03**	**2.436.645,68**	**2.417.275,33**	**2.458.924,98**	**2.439.554,63**	**2.420.184,28**	**2.400.813,92**	**2.381.443,57**
treated Greywater	[l]	1800000,00	1171699,42	1172728,09	1176178,67	1181407,34	1186054,26	1190133,06	1195532,41	1200353,76	1205778,39	1210629,53	1214920,28	1218663,54
treated Blackwater	[l]	800000,00	532439,44	532913,50	534487,86	536869,96	538987,47	540846,57	543305,57	545501,69	547971,78	550181,05	552135,48	553840,91
treated Storm, roof	[l]	150000,00	163366,48	200814,29	231377,01	222309,64	213526,70	237169,53	228018,15	239669,38	230505,33	221621,70	213012,08	204670,17
treated Stom, green	[l]	150000,00	171899,06	211320,63	243494,47	233952,24	224709,32	249598,72	239967,75	252234,21	242589,73	233240,37	224179,38	215400,14
rainwater		205000,00	151025,03	185492,57	213620,73	205249,20	197140,28	218897,81	210451,46	221165,95	212709,40	204511,62	196566,70	188868,82
Total	[l]		**2190429,44**	**2303269,09**	**2399158,74**	**2379788,39**	**2360418,03**	**2436645,68**	**2417275,33**	**2458924,98**	**2439554,63**	**2420184,28**	**2400813,92**	**2381443,57**
Lake surface area, accord. to the structure			*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*
Spilling of Surplus water	[l]		**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**
treated Greywater			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
treated Blackwater			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
treated Storm, roof			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
treated Stom, green			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
rainwater			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
WRMS, after spilling			**2190429,44**	**2303269,09**	**2399158,74**	**2379788,39**	**2360418,03**	**2436645,68**	**2417275,33**	**2458924,98**	**2439554,63**	**2420184,28**	**2400813,92**	**2381443,57**
treated Greywater	[l]		1171699,42	1172728,09	1176178,67	1181407,34	1186054,26	1190133,06	1195532,41	1200353,76	1205778,39	1210629,53	1214920,28	1218663,54
treated Blackwater	[l]		532439,44	532913,50	534487,86	536869,96	538987,47	540846,57	543305,57	545501,69	547971,78	550181,05	552135,48	553840,91
treated Storm, roof	[l]		163366,48	200814,29	231377,01	222309,64	213526,70	237169,53	228018,15	239669,38	230505,33	221621,70	213012,08	204670,17
treated Stom, green	[l]		171899,06	211320,63	243494,47	233952,24	224709,32	249598,72	239967,75	252234,21	242589,73	233240,37	224179,38	215400,14
rainwater			151025,03	185492,57	213620,73	205249,20	197140,28	218897,81	210451,46	221165,95	212709,40	204511,62	196566,70	188868,82
Intake for Servicewater														
overall	**[l]**		**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**
treated Greywater	[l]		46794,60	44541,15	42886,75	43428,03	43956,63	42727,94	43265,73	42704,41	43238,01	43759,42	44268,83	44766,41
treated Blackwater	[l]		21264,23	20240,48	19488,91	19735,11	19975,54	19417,37	19661,96	19407,05	19649,72	19886,85	20118,52	20344,80
treated Storm, roof	[l]		6524,43	7627,09	8436,65	8172,01	7913,56	8514,82	8251,86	8526,60	8265,69	8010,74	7761,66	7518,36
treated Stom, green	[l]		6865,20	8026,13	8878,49	8599,98	8328,00	8961,05	8684,31	8973,62	8699,03	8430,71	8168,57	7912,51
rainwater			6031,54	7045,16	7789,21	7544,87	7306,26	7858,83	7616,13	7868,32	7627,55	7392,28	7162,43	6937,91
Evaporation nach Penman														
overall	**[l]**		**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**
treated Greywater			3498,34	3329,87	3206,19	3246,65	3286,17	3194,31	3234,52	3192,56	3232,45	3271,43	3309,51	3346,71
treated Blackwater			1589,70	1513,17	1456,98	1475,38	1493,36	1451,63	1469,92	1450,86	1469,00	1486,73	1504,05	1520,97
treated Storm, roof			487,76	570,20	630,72	610,93	591,61	636,56	616,90	637,44	617,94	598,88	580,26	562,07
treated Stom, green			513,24	600,03	663,75	642,93	622,60	669,92	649,23	670,86	650,33	630,27	610,68	591,53
rainwater			450,91	526,69	582,32	564,05	546,21	587,52	569,38	588,23	570,23	552,64	535,46	518,67
WRMS, after intake														
overall			**2096409,49**	**2209249,14**	**2305138,79**	**2285768,43**	**2266398,08**	**2342625,73**	**2323255,38**	**2364905,03**	**2345534,68**	**2326164,32**	**2306793,97**	**2287423,62**
treated Greywater	[l]		1121406,49	1124857,07	1130085,74	1134732,66	1138811,46	1144210,81	1149032,16	1154456,79	1159307,93	1163598,68	1167341,94	1170550,41
treated Blackwater	[l]		509585,50	511159,86	513541,96	515659,47	517518,57	519977,57	522173,69	524643,78	526853,05	528807,48	530512,91	531975,14
treated Storm, roof	[l]		156354,29	192617,01	222309,64	213526,70	205021,53	228018,15	219149,38	230505,33	221621,70	213012,08	204670,17	196589,74
treated Stom, green	[l]		164520,63	202694,47	233952,24	224709,32	215758,72	239967,75	230634,21	242589,73	233240,37	224179,38	215400,14	206896,09
rainwater	[l]		144542,57	177920,73	205249,20	197140,28	189287,81	210451,46	202265,95	212709,40	204511,62	196566,70	188868,82	181412,23
treated Greywater	%		53,49%	50,92%	49,02%	49,64%	50,25%	48,84%	49,46%	48,82%	49,43%	50,02%	50,60%	51,17%
treated Blackwater	%		24,31%	23,14%	22,28%	22,56%	22,83%	22,20%	22,48%	22,18%	22,46%	22,73%	23,00%	23,26%
treated Storm, roof	%		7,46%	8,72%	9,64%	9,34%	9,05%	9,73%	9,43%	9,75%	9,45%	9,16%	8,87%	8,59%
treated Stom, green	%		7,85%	9,17%	10,15%	9,83%	9,52%	10,24%	9,93%	10,26%	9,94%	9,64%	9,34%	9,04%
rainwater	%		6,89%	8,05%	8,90%	8,62%	8,35%	8,98%	8,71%	8,99%	8,72%	8,45%	8,19%	7,93%
estimated retention time			25,04	26,33	27,43	27,20	26,98	27,85	27,63	28,11	27,89	27,67	27,44	27,22
size of inner Lake	width	15												
	length	105												
	depth	2												
	Volume 1:	3150												
	surface 1:	1575												
size of extension Arwa	width	20												
	length	105												
	depth	1												
	Volume	2100												
	surface 2	2100												
Total		5250												
Spilllevel		4000000												

		Mai																
13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024
51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6
25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920
23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328
39600	10080	0	42480	0	15120	8880	0	0	0	36720	0	0	0	0	0	12240	32160	66720
37620,00	9576,00	0,00	40356,00	0,00	14364,00	8436,00	0,00	0,00	0,00	34884,00	0,00	0,00	0,00	0,00	0,00	11628,00	30552,00	63384,00
79200	20160	0	84960	0	30240	17760	0	0	0	73440	0	0	0	0	0	24480	64320	133440
39600,00	10080,00	0,00	42480,00	0,00	15120,00	8880,00	0,00	0,00	0,00	36720,00	0,00	0,00	0,00	0,00	0,00	12240,00	32160,00	66720,00
34650,00	8820,00	0,00	37170,00	0,00	13230,00	7770,00	0,00	0,00	0,00	32130,00	0,00	0,00	0,00	0,00	0,00	10710,00	28140,00	58380,00
151869,60	94305,60	74649,60	157485,60	74649,60	104133,60	91965,60	74649,60	74649,60	74649,60	146253,60	74649,60	74649,60	74649,60	74649,60	74649,60	98517,60	137361,60	204753,60
2.473.943,22	**2.483.048,87**	**2.463.678,52**	**2.564.314,16**	**2.544.943,81**	**2.568.287,46**	**2.574.003,11**	**2.554.632,76**	**2.535.262,41**	**2.515.892,05**	**2.600.255,70**	**2.580.885,35**	**2.561.515,00**	**2.542.144,65**	**2.522.774,30**	**2.503.403,94**	**2.518.611,59**	**2.590.093,24**	**2.759.206,89**
1221872,01	1226757,48	1231628,25	1235947,93	1241953,80	1247392,88	1253049,88	1258601,65	1263602,05	1268063,09	1271996,64	1277325,43	1282114,90	1286376,71	1290122,30	1293363,01	1296109,98	1299047,70	1303214,09
555303,14	557527,35	559744,74	561711,52	564444,50	566919,77	569493,95	572020,19	574295,73	576326,03	578116,48	580540,96	582720,24	584659,60	586364,25	587839,35	589089,96	590427,19	592322,78
234209,74	234884,81	225990,97	257722,60	248273,27	253465,10	252622,24	243394,78	234436,95	225742,88	252190,77	243072,06	234217,11	225620,21	217275,76	209178,23	212950,15	235552,71	290386,18
246496,09	247208,23	237847,76	271250,91	261305,57	266771,94	265885,94	256174,00	246745,84	237595,30	265436,26	255838,63	246518,59	237470,17	228687,46	220164,62	224135,94	247928,93	305649,15
216062,23	216670,98	208466,80	237681,20	228966,67	233737,77	232951,09	224442,15	216181,84	208164,76	232515,56	224108,27	215944,15	208017,96	200324,52	192858,73	196325,56	217136,72	267634,69
2473943,22	**2483048,87**	**2463678,52**	**2564314,16**	**2544943,81**	**2568287,46**	**2574003,11**	**2554632,76**	**2535262,41**	**2515892,05**	**2600255,70**	**2580885,35**	**2561515,00**	**2542144,65**	**2522774,30**	**2503403,94**	**2518611,59**	**2590093,24**	**2759206,89**
1575,00	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*
0,00	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
2473943,22	**2483048,87**	**2463678,52**	**2564314,16**	**2544943,81**	**2568287,46**	**2574003,11**	**2554632,76**	**2535262,41**	**2515892,05**	**2600255,70**	**2580885,35**	**2561515,00**	**2542144,65**	**2522774,30**	**2503403,94**	**2518611,59**	**2590093,24**	**2759206,89**
1221872,01	1226757,48	1231628,25	1235947,93	1241953,80	1247392,88	1253049,88	1258601,65	1263602,05	1268063,09	1271996,64	1277325,43	1282114,90	1286376,71	1290122,30	1293363,01	1296109,98	1299047,70	1303214,09
555303,14	557527,35	559744,74	561711,52	564444,50	566919,77	569493,95	572020,19	574295,73	576326,03	578116,48	580540,96	582720,24	584659,60	586364,25	587839,35	589089,96	590427,19	592322,78
234209,74	234884,81	225990,97	257722,60	248273,27	253465,10	252622,24	243394,78	234436,95	225742,88	252190,77	243072,06	234217,11	225620,21	217275,76	209178,23	212950,15	235552,71	290386,18
246496,09	247208,23	237847,76	271250,91	261305,57	266771,94	265885,94	256174,00	246745,84	237595,30	265436,26	255838,63	246518,59	237470,17	228687,46	220164,62	224135,94	247928,93	305649,15
216062,23	216670,98	208466,80	237681,20	228966,67	233737,77	232951,09	224442,15	216181,84	208164,76	232515,56	224108,27	215944,15	208017,96	200324,52	192858,73	196325,56	217136,72	267634,69
87480	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**
43206,07	43219,75	43732,51	42163,60	42690,97	42488,21	42586,12	43099,14	43600,97	44091,78	42793,59	43295,39	43786,36	44266,65	44736,42	45195,82	45018,34	43875,14	41318,09
19635,83	19642,18	19875,35	19162,44	19402,24	19310,20	19354,81	19588,07	19816,25	20039,41	19449,48	19677,64	19900,87	20119,24	20332,83	20541,71	20461,11	19941,59	18779,45
8281,79	8275,20	8024,46	8792,05	8534,16	8633,43	8585,61	8334,73	8089,32	7849,30	8484,42	8239,01	7998,90	7764,02	7534,28	7309,61	7396,49	7955,76	9206,63
8716,24	8709,36	8445,47	9253,56	8982,13	9086,68	9036,39	8772,34	8514,04	8261,42	8930,03	8671,74	8419,02	8171,80	7929,99	7693,53	7785,01	8373,76	9690,53
7640,08	7633,51	7402,21	8108,35	7870,51	7961,48	7917,07	7685,72	7459,42	7238,09	7822,48	7596,23	7374,85	7158,29	6946,48	6739,34	6819,06	7333,76	8485,29
6539,95	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**
3230,06	3231,08	3269,42	3152,13	3191,55	3176,39	3183,71	3222,07	3259,58	3296,27	3199,22	3236,74	3273,44	3309,35	3344,47	3378,81	3365,54	3280,08	3088,92
1467,96	1468,44	1485,87	1432,57	1450,50	1443,62	1446,95	1464,39	1481,45	1498,13	1454,03	1471,09	1487,78	1504,10	1520,07	1535,69	1529,66	1490,82	1403,94
619,14	618,65	599,90	657,29	638,01	645,43	641,86	623,10	604,75	586,81	634,29	615,94	597,99	580,43	563,26	546,46	552,96	594,77	688,28
651,62	651,11	631,38	691,79	671,50	679,31	675,56	655,81	636,50	617,62	667,60	648,29	629,40	610,92	592,84	575,16	582,00	626,02	724,46
571,17	570,68	553,39	606,18	588,39	595,20	591,88	574,58	557,66	541,12	584,80	567,89	551,34	535,15	519,31	503,83	509,79	548,27	634,36
2379923,27	**2389028,92**	**2369658,56**	**2470294,21**	**2450923,86**	**2474267,51**	**2479983,16**	**2460612,81**	**2441242,45**	**2421872,10**	**2506235,75**	**2486865,40**	**2467495,05**	**2448124,70**	**2428754,34**	**2409383,99**	**2424591,64**	**2496073,29**	**2665186,94**
1175435,88	1180306,65	1184626,33	1190632,20	1196071,28	1201728,28	1207280,05	1212280,45	1216741,49	1220675,04	1226003,83	1230793,30	1235055,11	1238800,70	1242041,41	1244788,38	1247726,10	1251892,49	1258807,08
534199,35	536416,74	538383,52	541116,50	543591,77	546165,95	548692,19	550967,73	552998,03	554788,48	557212,96	559392,24	561331,60	563036,25	564511,35	565761,96	567099,19	568994,78	572139,39
225308,81	225990,97	217366,60	248273,27	239101,10	244186,24	243394,78	234436,95	225742,88	217306,77	243072,06	234217,11	225620,21	217275,76	209178,23	201322,15	205000,71	227002,18	280491,28
237128,23	237847,76	228770,91	261305,57	251651,94	257005,94	256174,00	246745,84	237595,30	228716,26	255838,63	246518,59	237470,17	228687,46	220164,62	211895,94	215768,93	238929,15	295234,15
207850,98	208466,80	200511,20	228966,67	220507,77	225181,09	224442,15	216181,84	208164,76	200385,56	224108,27	215944,15	208017,96	200324,52	192858,73	185615,56	188996,72	209254,69	258515,04
49,39%	49,41%	49,99%	48,20%	48,80%	48,57%	48,68%	49,27%	49,84%	50,40%	48,92%	49,49%	50,05%	50,60%	51,14%	51,66%	51,46%	50,15%	47,23%
22,45%	22,45%	22,72%	21,90%	22,18%	22,07%	22,12%	22,39%	22,65%	22,91%	22,23%	22,49%	22,75%	23,00%	23,24%	23,48%	23,39%	22,80%	21,47%
9,47%	9,46%	9,17%	10,05%	9,76%	9,87%	9,81%	9,53%	9,25%	8,97%	9,70%	9,42%	9,14%	8,88%	8,61%	8,36%	8,46%	9,09%	10,52%
9,96%	9,96%	9,65%	10,58%	10,27%	10,39%	10,33%	10,03%	9,73%	9,44%	10,21%	9,91%	9,62%	9,34%	9,06%	8,79%	8,90%	9,57%	11,08%
8,73%	8,73%	8,46%	9,27%	9,00%	9,10%	9,05%	8,79%	8,53%	8,27%	8,94%	8,68%	8,43%	8,18%	7,94%	7,70%	7,79%	8,38%	9,70%
28,28	28,38	28,16	29,31	29,09	29,36	29,42	29,20	28,98	28,76	29,72	29,50	29,28	29,06	28,84	28,62	28,79	29,61	31,54

Water Resource Managemt System in the context of Hanoi
daily chart

		Start	1	2	3	4	5	6	7	8	9	10	11	12	13
1: dom. flow Greywater	Eff.	0,9	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024
tr. Greywater	[l/d]		51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6
2: dom. flow Blackwater	Eff.	0,9	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920
tr. Blackwater	[l/d]		23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328
3: nat. flow roof runoff	Eff.	0,95	35040	0	8400	0	76560	0	32640	0	6720	25200	0	3600	0
Stormwater receiving the lake	[l/d]		33288,00	0,00	7980,00	0,00	72732,00	0,00	31008,00	0,00	6384,00	23940,00	0,00	3420,00	0,00
4: nat. flow green space	loss. Evap.	0,2													
	loss. Infiltr.	0,3	70080	0	16800	0	153120	0	65280	0	13440	50400	0	7200	0
Stormwater receiving the lake			35040,00	0,00	8400,00	0,00	76560,00	0,00	32640,00	0,00	6720,00	25200,00	0,00	3600,00	0,00
5: direct Precipitation on the Lakes surface															
precipitation on the lake			30660,00	0,00	7350,00	0,00	66990,00	0,00	28560,00	0,00	5880,00	22050,00	0,00	3150,00	0,00
daily Input to the Lake			142977,60	74649,60	91029,60	74649,60	223941,60	74649,60	138297,60	74649,60	87753,60	123789,60	74649,60	81669,60	74649,60
Water in WRMS															
overall	0,00	3.105.000,00	**2.838.824,54**	**2.819.454,19**	**2.823.813,83**	**2.804.443,48**	**3.001.355,13**	**2.981.984,78**	**3.054.822,43**	**3.035.452,07**	**3.035.065,72**	**3.086.885,37**	**3.067.515,02**	**3.058.314,67**	**3.038.944,32**
treated Greywater	[l]	1800000,00	1310128,68	1318059,70	1325428,14	1332619,11	1339264,19	1348632,22	1357432,37	1366975,52	1375956,49	1384653,85	1393801,84	1402403,14	1410611,49
treated Blackwater	[l]	800000,00	595467,39	599073,91	602424,68	605694,72	608716,59	612976,03	616977,32	621316,27	625399,65	629354,08	633513,30	637423,99	641156,04
treated Storm, roof	[l]	150000,00	313779,28	303387,12	301250,11	291219,87	354188,62	343093,37	363283,87	352102,88	347580,86	360753,54	349765,76	342465,37	331937,16
treated Stom, green	[l]	150000,00	330274,15	319335,70	317086,85	306529,33	372812,82	361134,15	382387,84	370618,88	365859,34	379725,79	368160,15	360475,97	349394,07
rainwater		205000,00	289175,04	279597,76	277624,05	268380,45	326372,90	316149,00	334741,04	324438,53	320269,38	332398,11	322273,97	315546,21	305845,56
Total	[l]		**2838824,54**	**2819454,19**	**2823813,83**	**2804443,48**	**3001355,13**	**2981984,78**	**3054822,43**	**3035452,07**	**3035065,72**	**3086885,37**	**3067515,02**	**3058314,67**	**3038944,32**
Lake surface area, accord. to the structure			*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*
Spilling of Surplus water	[l]		**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**
treated Greywater			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
treated Blackwater			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
treated Storm, roof			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
treated Stom, green			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
rainwater			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
WRMS, after spilling			**2838824,54**	**2819454,19**	**2823813,83**	**2804443,48**	**3001355,13**	**2981984,78**	**3054822,43**	**3035452,07**	**3035065,72**	**3086885,37**	**3067515,02**	**3058314,67**	**3038944,32**
treated Greywater	[l]		1310128,68	1318059,70	1325428,14	1332619,11	1339264,19	1348632,22	1357432,37	1366975,52	1375956,49	1384653,85	1393801,84	1402403,14	1410611,49
treated Blackwater	[l]		595467,39	599073,91	602424,68	605694,72	608716,59	612976,03	616977,32	621316,27	625399,65	629354,08	633513,30	637423,99	641156,04
treated Storm, roof	[l]		313779,28	303387,12	301250,11	291219,87	354188,62	343093,37	363283,87	352102,88	347580,86	360753,54	349765,76	342465,37	331937,16
treated Stom, green	[l]		330274,15	319335,70	317086,85	306529,33	372812,82	361134,15	382387,84	370618,88	365859,34	379725,79	368160,15	360475,97	349394,07
rainwater			289175,04	279597,76	277624,05	268380,45	326372,90	316149,00	334741,04	324438,53	320269,38	332398,11	322273,97	315546,21	305845,56
Intake for Servicewater															
overall	**[l]**		**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**
treated Greywater	[l]		40372,36	40895,81	41060,94	41568,86	39035,31	39563,70	38872,37	39395,46	39659,33	39240,04	39748,72	40114,32	40606,30
treated Blackwater	[l]		18349,67	18587,64	18662,74	18893,65	17742,16	17982,37	17668,19	17905,98	18025,96	17835,42	18066,66	18232,87	18456,52
treated Storm, roof	[l]		9669,29	9413,28	9332,54	9084,12	10323,48	10065,04	10403,25	10147,40	10018,36	10223,48	9974,69	9795,88	9555,25
treated Stom, green	[l]		10177,59	9908,12	9823,15	9561,68	10866,31	10594,29	10950,32	10681,02	10545,20	10761,14	10499,26	10311,05	10057,77
rainwater			8911,09	8675,16	8600,62	8371,69	9512,74	9274,60	9585,87	9350,13	9231,16	9419,91	9190,67	9025,88	8804,17
Evaporation nach Penman															
overall	**[l]**		**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**
treated Greywater			3018,21	3057,35	3069,69	3107,66	2918,26	2957,76	2906,07	2945,18	2964,91	2933,56	2971,59	2998,92	3035,70
treated Blackwater			1371,81	1389,60	1395,22	1412,48	1326,39	1344,35	1320,86	1338,64	1347,61	1333,37	1350,65	1363,08	1379,80
treated Storm, roof			722,87	703,73	697,70	679,12	771,78	752,46	777,74	758,61	748,97	764,30	745,70	732,33	714,34
treated Stom, green			760,87	740,72	734,37	714,83	812,36	792,02	818,64	798,51	788,35	804,50	784,92	770,85	751,91
rainwater			666,19	648,55	642,98	625,86	711,17	693,36	716,63	699,01	690,12	704,23	687,09	674,77	658,19
WRMS, after intake															
overall			**2744804,59**	**2725434,23**	**2729793,88**	**2710423,53**	**2907335,18**	**2887964,83**	**2960802,47**	**2941432,12**	**2941045,77**	**2992865,42**	**2973495,07**	**2964294,72**	**2944924,36**
treated Greywater	[l]		1266738,10	1274106,54	1281297,51	1287942,59	1297310,62	1306110,77	1315653,92	1324634,89	1333332,25	1342480,24	1351081,54	1359289,89	1366969,48
treated Blackwater	[l]		575745,91	579096,68	582366,72	585388,59	589648,03	593649,32	597988,27	602071,65	606026,08	610185,30	614095,99	617828,04	621319,72
treated Storm, roof	[l]		303387,12	293270,11	291219,87	281456,62	343093,37	332275,87	352102,88	341196,86	336813,54	349765,76	339045,37	331937,16	321667,56
treated Stom, green	[l]		319335,70	308686,85	306529,33	296252,82	361134,15	349747,84	370618,88	359139,34	354525,79	368160,15	356875,97	349394,07	338584,39
rainwater	[l]		279597,76	270274,05	268380,45	259382,90	316149,00	306181,04	324438,53	314389,38	310348,11	322273,97	312396,21	305845,56	296383,20
treated Greywater	%		46,15%	46,75%	46,94%	47,52%	44,62%	45,23%	44,44%	45,03%	45,34%	44,86%	45,44%	45,86%	46,42%
treated Blackwater	%		20,98%	21,25%	21,33%	21,60%	20,28%	20,56%	20,20%	20,47%	20,61%	20,39%	20,65%	20,84%	21,10%
treated Storm, roof	%		11,05%	10,76%	10,67%	10,38%	11,80%	11,51%	11,89%	11,60%	11,45%	11,69%	11,40%	11,20%	10,92%
treated Stom, green	%		11,63%	11,33%	11,23%	10,93%	12,42%	12,11%	12,52%	12,21%	12,05%	12,30%	12,00%	11,79%	11,50%
rainwater	%		10,19%	9,92%	9,83%	9,57%	10,87%	10,60%	10,96%	10,69%	10,55%	10,77%	10,51%	10,32%	10,06%
estimated retention time			32,45	32,23	32,28	32,06	34,31	34,09	34,92	34,70	34,69	35,29	35,07	34,96	34,74
size of inner Lake	width	15													
	length	105													
	depth	2													
	Volume 1:	3150													
	surface 1:	1575													
size of extension Arwa	width	20													
	length	105													
	depth	1													
	Volume	2100													
	surface 2	2100													
Total		5250													
Spilllevel		4000000													

	Juni															
14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024
51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6
25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920
23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328
31200	76320	0	44400	79200	0	18480	53040	19680	0	0	0	0	65280	0	0	0
29640,00	72504,00	0,00	42180,00	75240,00	0,00	17556,00	50388,00	18696,00	0,00	0,00	0,00	0,00	62016,00	0,00	0,00	0,00
62400	152640	0	88800	158400	0	36960	106080	39360	0	0	0	0	130560	0	0	0
31200,00	76320,00	0,00	44400,00	79200,00	0,00	18480,00	53040,00	19680,00	0,00	0,00	0,00	0,00	65280,00	0,00	0,00	0,00
27300,00	66780,00	0,00	38850,00	69300,00	0,00	16170,00	46410,00	17220,00	0,00	0,00	0,00	0,00	57120,00	0,00	0,00	0,00
135489,60	223473,60	74649,60	161229,60	229089,60	74649,60	110685,60	178077,60	113025,60	74649,60	74649,60	74649,60	74649,60	201945,60	74649,60	74649,60	74649,60
3.107.713,96	**3.303.947,61**	**3.282.397,28**	**3.386.276,94**	**3.588.466,61**	**3.566.916,27**	**3.597.571,93**	**3.725.859,60**	**3.759.905,26**	**3.738.354,93**	**3.716.804,59**	**3.695.254,26**	**3.673.703,92**	**3.836.569,59**	**3.815.019,25**	**3.793.468,91**	**3.771.918,58**
1418291,08	1426704,08	1436484,82	1445706,17	1455957,04	1468247,22	1479970,11	1491716,95	1504523,12	1517350,39	1529625,67	1541356,84	1552551,72	1563218,07	1575342,81	1586940,39	1598018,21
644647,72	648472,72	652919,36	657111,71	661771,98	667359,14	672688,42	678028,57	683850,20	689681,39	695261,66	700594,60	705683,76	710532,66	716044,43	721316,58	726352,45
351307,56	413183,20	401152,68	431575,77	494555,24	481297,15	485872,54	523268,19	528453,66	514932,78	501681,90	488697,15	475974,72	525526,80	512349,50	499430,04	486764,81
369784,39	434917,03	422253,70	454278,36	520572,87	506617,31	511433,81	550797,95	556256,61	542024,37	528076,34	514408,44	501016,65	553176,98	539306,37	525707,16	512375,56
323683,20	380670,58	369586,72	397604,93	455609,47	443395,45	447607,05	482047,93	486821,68	474365,99	462159,02	450197,22	438477,07	484115,07	471976,15	460074,74	448407,54
3107713,96	**3303947,61**	**3282397,28**	**3386276,94**	**3588466,61**	**3566916,27**	**3597571,93**	**3725859,60**	**3759905,26**	**3738354,93**	**3716804,59**	**3695254,26**	**3673703,92**	**3836569,59**	**3815019,25**	**3793468,91**	**3771918,58**
1575,00	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*
0,00	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
3107713,96	**3303947,61**	**3282397,28**	**3386276,94**	**3588466,61**	**3566916,27**	**3597571,93**	**3725859,60**	**3759905,26**	**3738354,93**	**3716804,59**	**3695254,26**	**3673703,92**	**3836569,59**	**3815019,25**	**3793468,91**	**3771918,58**
1418291,08	1426704,08	1436484,82	1445706,17	1455957,04	1468247,22	1479970,11	1491716,95	1504523,12	1517350,39	1529625,67	1541356,84	1552551,72	1563218,07	1575342,81	1586940,39	1598018,21
644647,72	648472,72	652919,36	657111,71	661771,98	667359,14	672688,42	678028,57	683850,20	689681,39	695261,66	700594,60	705683,76	710532,66	716044,43	721316,58	726352,45
351307,56	413183,20	401152,68	431575,77	494555,24	481297,15	485872,54	523268,19	528453,66	514932,78	501681,90	488697,15	475974,72	525526,80	512349,50	499430,04	486764,81
369784,39	434917,03	422253,70	454278,36	520572,87	506617,31	511433,81	550797,95	556256,61	542024,37	528076,34	514408,44	501016,65	553176,98	539306,37	525707,16	512375,56
323683,20	380670,58	369586,72	397604,93	455609,47	443395,45	447607,05	482047,93	486821,68	474365,99	462159,02	450197,22	438477,07	484115,07	471976,15	460074,74	448407,54
87480	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**
39923,91	37775,44	38284,12	37347,91	35493,47	36009,33	35987,55	35024,24	35005,05	35507,01	36001,80	36489,48	36970,11	35643,90	36123,27	36595,94	37061,94
18146,39	17169,88	17401,12	16975,61	16132,74	16367,24	16357,36	15919,53	15910,83	16139,00	16363,92	16585,60	16804,08	16201,30	16419,20	16634,06	16845,89
9889,07	10940,02	10691,22	11149,19	12056,32	11804,00	11814,67	12285,89	12295,29	12049,77	11807,76	11569,22	11334,14	11982,86	11748,39	11517,20	11289,26
10409,18	11515,48	11253,59	11735,68	12690,58	12424,99	12436,23	12932,27	12942,17	12683,73	12428,99	12177,90	11930,45	12613,33	12366,52	12123,17	11883,24
9111,46	10079,17	9849,95	10271,60	11106,89	10874,44	10884,19	11318,07	11326,66	11100,48	10877,53	10657,79	10441,23	11038,61	10822,61	10609,64	10399,67
6539,95	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**
2984,69	3765,43	3816,13	3722,81	3537,96	3589,38	3587,21	3491,19	3489,28	3539,31	3588,63	3637,24	3685,15	3552,96	3600,74	3647,85	3694,30
1356,61	1711,48	1734,53	1692,12	1608,10	1631,47	1630,49	1586,85	1585,98	1608,72	1631,14	1653,24	1675,02	1614,93	1636,65	1658,07	1679,18
739,30	1090,49	1065,69	1111,34	1201,76	1176,61	1177,68	1224,65	1225,58	1201,11	1176,99	1153,21	1129,78	1194,44	1171,07	1148,03	1125,30
778,18	1147,85	1121,75	1169,80	1264,99	1238,51	1239,63	1289,08	1290,06	1264,30	1238,91	1213,88	1189,22	1257,29	1232,68	1208,43	1184,51
681,17	1004,68	981,83	1023,86	1107,13	1083,96	1084,93	1128,18	1129,03	1106,49	1084,26	1062,36	1040,77	1100,32	1078,79	1057,56	1036,63
3013694,01	**3207747,68**	**3186197,34**	**3290077,01**	**3492266,67**	**3470716,33**	**3501372,00**	**3629659,66**	**3663705,33**	**3642154,99**	**3620604,66**	**3599054,32**	**3577503,99**	**3740369,65**	**3718819,31**	**3697268,98**	**3675718,64**
1375382,48	1385163,22	1394384,57	1404635,44	1416925,62	1428648,51	1440395,35	1453201,52	1466028,79	1478304,07	1490035,24	1501230,12	1511896,47	1524021,21	1535618,79	1546696,61	1557261,96
625144,72	629591,36	633783,71	638443,98	644031,14	649360,42	654700,57	660522,20	666353,39	671933,66	677266,60	682355,76	687204,66	692716,43	697988,58	703024,45	707827,38
340679,20	401152,68	389395,77	419315,24	481297,15	468316,54	472880,19	509757,66	514932,78	501681,90	488697,15	475974,72	463510,80	512349,50	499430,04	486764,81	474350,24
358597,03	422253,70	409878,36	441372,87	506617,31	492953,81	497757,95	536576,61	542024,37	528076,34	514408,44	501016,65	487896,98	539306,37	525707,16	512375,56	499307,81
313890,58	369586,72	358754,93	386309,47	443395,45	431437,05	435637,93	469601,68	474365,99	462159,02	450197,22	438477,07	426995,07	471976,15	460074,74	448407,54	436971,25
45,64%	43,18%	43,76%	42,69%	40,57%	41,16%	41,14%	40,04%	40,01%	40,59%	41,15%	41,71%	42,26%	40,75%	41,29%	41,83%	42,37%
20,74%	19,63%	19,89%	19,41%	18,44%	18,71%	18,70%	18,20%	18,19%	18,45%	18,71%	18,96%	19,21%	18,52%	18,77%	19,01%	19,26%
11,30%	12,51%	12,22%	12,74%	13,78%	13,49%	13,51%	14,04%	14,05%	13,77%	13,50%	13,22%	12,96%	13,70%	13,43%	13,17%	12,90%
11,90%	13,16%	12,86%	13,42%	14,51%	14,20%	14,22%	14,78%	14,79%	14,50%	14,21%	13,92%	13,64%	14,42%	14,14%	13,86%	13,58%
10,42%	11,52%	11,26%	11,74%	12,70%	12,43%	12,44%	12,94%	12,95%	12,69%	12,43%	12,18%	11,94%	12,62%	12,37%	12,13%	11,89%
35,52	37,77	37,52	38,71	41,02	40,77	41,12	42,59	42,98	42,73	42,49	42,24	41,99	43,86	43,61	43,36	43,12

Water Resource Managemt System in the context of Hanoi
daily chart

		Start	1	2	3	4	5	6	7	8	9	10	11	12	
1: dom. flow Greywater	Eff.	0,9	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	
tr. Greywater	[l/d]		51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	
2: dom. flow Blackwater	Eff.	0,9	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	
tr. Blackwater	[l/d]		23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	
3: nat. flow roof runoff	Eff.	0,95	0	0	76560	0	0	0	13200	80400	0	0	0	49200	
Stormwater receiving the lake	[l/d]		0,00	0,00	72732,00	0,00	0,00	0,00	12540,00	76380,00	0,00	0,00	0,00	46740,00	
4: nat. flow green space	loss. Evap.	0,2													
	loss. Infiltr.	0,3	0	0	153120	0	0	0	26400	160800	0	0	0	98400	
Stormwater receiving the lake			0,00	0,00	76560,00	0,00	0,00	0,00	13200,00	80400,00	0,00	0,00	0,00	49200,00	
5: direct Precipitation on the Lakes surface															
precipitation on the lake			0,00	0,00	66990,00	0,00	0,00	0,00	11550,00	70350,00	0,00	0,00	0,00	43050,00	
daily Input to the Lake			74649,60	74649,60	223941,60	74649,60	74649,60	74649,60	100389,60	231429,60	74649,60	74649,60	74649,60	170589,60	
Water in WRMS															
overall	0,00	3.105.000,00	**3.750.368,24**	**3.728.817,91**	**3.923.549,57**	**3.901.999,24**	**3.880.448,90**	**3.858.898,56**	**3.874.638,23**	**4.080.217,89**	**3.980.340,97**	**3.958.790,64**	**3.937.240,30**	**4.054.679,97**	**4**
treated Greywater	[l]	1800000,00	1608583,56	1618643,71	1628205,85	1639606,12	1650504,85	1660908,90	1670825,08	1680663,25	1660096,46	1671295,58	1682004,14	1692228,75	
treated Blackwater	[l]	800000,00	731155,38	735728,66	740075,57	745257,95	750212,35	754941,89	759449,66	763921,96	754574,10	759664,97	764532,86	769180,77	
treated Storm, roof	[l]	150000,00	474350,24	462182,78	522990,91	510167,90	497590,22	485254,49	485697,40	550018,45	526492,06	513767,40	501282,68	535774,67	
treated Stom, green	[l]	150000,00	499307,81	486500,17	550508,93	537011,22	523771,74	510786,95	511253,35	578959,90	554195,57	540801,35	527659,69	563967,20	
rainwater		205000,00	436971,25	425762,59	481768,32	469956,04	458369,73	447006,32	447412,73	506654,32	484982,78	473261,34	461760,93	493528,57	
Total	[l]		**3750368,24**	**3728817,91**	**3923549,57**	**3901999,24**	**3880448,90**	**3858898,56**	**3874638,23**	**4080217,89**	**3980340,97**	**3958790,64**	**3937240,30**	**4054679,97**	
Lake surface area, accord. to the structure			*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	
Spilling of Surplus water	[l]		**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**80217,89**	**0,00**	**0,00**	**0,00**	**54679,97**	
treated Greywater			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*33042,17*	*0,00*	*0,00*	*0,00*	*22820,79*	
treated Blackwater			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*15018,86*	*0,00*	*0,00*	*0,00*	*10372,90*	
treated Storm, roof			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*10813,47*	*0,00*	*0,00*	*0,00*	*7225,27*	
treated Stom, green			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*11382,47*	*0,00*	*0,00*	*0,00*	*7605,46*	
rainwater			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*9960,92*	*0,00*	*0,00*	*0,00*	*6655,55*	
WRMS, after spilling			3750368,24	3728817,91	3923549,57	3901999,24	3880448,90	3858898,56	3874638,23	4000000,00	3980340,97	3958790,64	3937240,30	4000000,00	
treated Greywater	[l]		1608583,56	1618643,71	1628205,85	1639606,12	1650504,85	1660908,90	1670825,08	1647621,08	1660096,46	1671295,58	1682004,14	1669407,96	
treated Blackwater	[l]		731155,38	735728,66	740075,57	745257,95	750212,35	754941,89	759449,66	748903,11	754574,10	759664,97	764532,86	758807,87	
treated Storm, roof	[l]		474350,24	462182,78	522990,91	510167,90	497590,22	485254,49	485697,40	539204,98	526492,06	513767,40	501282,68	528549,40	
treated Stom, green	[l]		499307,81	486500,17	550508,93	537011,22	523771,74	510786,95	511253,35	567577,43	554195,57	540801,35	527659,69	556361,74	
rainwater			436971,25	425762,59	481768,32	469956,04	458369,73	447006,32	447412,73	496693,40	484982,78	473261,34	461760,93	486873,02	
Intake for Servicewater															
overall	**[l]**		**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	
treated Greywater	[l]		37521,35	37974,22	36302,70	36758,78	37208,62	37652,28	37723,21	35325,05	36485,63	36931,72	37371,79	36017,59	
treated Blackwater	[l]		17054,72	17260,58	16500,83	16708,14	16912,62	17114,29	17146,54	16056,51	16584,04	16786,82	16986,86	16371,33	
treated Storm, roof	[l]		11064,56	10843,05	11660,68	11437,60	11217,57	11000,56	10965,88	11560,57	11571,25	11353,06	11137,80	11403,49	
treated Stom, green	[l]		11646,71	11413,55	12274,22	12039,40	11807,80	11579,38	11542,87	12168,88	12180,12	11950,44	11723,86	12003,54	
rainwater			10192,66	9988,61	10741,57	10536,07	10333,39	10133,49	10101,50	10649,12	10658,96	10457,97	10259,69	10504,32	
Evaporation nach Penman															
overall	**[l]**		**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	
treated Greywater			3740,10	3785,24	3618,62	3664,09	3708,93	3753,15	3760,22	3521,17	3636,86	3681,32	3725,19	3590,20	
treated Blackwater			1700,00	1720,52	1644,79	1665,45	1685,84	1705,94	1709,15	1600,50	1653,08	1673,30	1693,24	1631,88	
treated Storm, roof			1102,91	1080,83	1162,33	1140,09	1118,16	1096,53	1093,07	1152,35	1153,41	1131,66	1110,21	1136,69	
treated Stom, green			1160,93	1137,69	1223,48	1200,08	1176,99	1154,22	1150,58	1212,98	1214,10	1191,21	1168,63	1196,50	
rainwater			1016,00	995,66	1070,71	1050,23	1030,02	1010,10	1006,91	1061,50	1062,48	1042,44	1022,68	1047,06	
WRMS, after intake															
overall			**3654168,31**	**3632617,97**	**3827349,64**	**3805799,30**	**3784248,96**	**3762698,63**	**3778438,29**	**3903800,06**	**3884141,04**	**3862590,70**	**3841040,37**	**3903800,06**	
treated Greywater	[l]		1567322,11	1576884,25	1588284,52	1599183,25	1609587,30	1619503,48	1629341,65	1608774,86	1619973,98	1630682,54	1640907,15	1629800,16	
treated Blackwater	[l]		712400,66	716747,57	721929,95	726884,35	731613,89	736121,66	740593,96	731246,10	736336,97	741204,86	745852,77	740804,66	
treated Storm, roof	[l]		462182,78	450258,91	510167,90	497590,22	485254,49	473157,40	473638,45	526492,06	513767,40	501282,68	489034,67	516009,22	
treated Stom, green	[l]		486500,17	473948,93	537011,22	523771,74	510786,95	498053,35	498559,90	554195,57	540801,35	527659,69	514767,20	543161,70	
rainwater	[l]		425762,59	414778,32	469956,04	458369,73	447006,32	435862,73	436304,32	484982,78	473261,34	461760,93	450478,57	475321,64	
treated Greywater	%		42,89%	43,41%	41,50%	42,02%	42,53%	43,04%	43,12%	41,21%	41,71%	42,22%	42,72%	41,75%	
treated Blackwater	%		19,50%	19,73%	18,86%	19,10%	19,33%	19,56%	19,60%	18,73%	18,96%	19,19%	19,42%	18,98%	
treated Storm, roof	%		12,65%	12,39%	13,33%	13,07%	12,82%	12,57%	12,54%	13,49%	13,23%	12,98%	12,73%	13,22%	
treated Stom, green	%		13,31%	13,05%	14,03%	13,76%	13,50%	13,24%	13,19%	14,20%	13,92%	13,66%	13,40%	13,91%	
rainwater	%		11,65%	11,42%	12,28%	12,04%	11,81%	11,58%	11,55%	12,42%	12,18%	11,95%	11,73%	12,18%	
estimated retention time			42,87	42,62	44,85	44,60	44,36	44,11	44,29	46,64	45,50	45,25	45,01	46,35	
size of inner Lake	width	15											100,00%	100,03%	
	length	105													
	depth	2													
	Volume 1:	3150													
	surface 1:	1575													
size of extension Arwa	width	20													
	length	105													
	depth	1													
	Volume	2100													
	surface 2	2100													
Total		5250													
Spilllevel		4000000													

	Juli																	
13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	#	31
57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	##	#	57024
51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	##	#	51321,6
25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	##	#	25920
23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	##	#	23328
27840	240	0	58800	60720	8880	27600	0	0	0	93360	0	87120	0	7680	25680	##	#	0
26448,00	228,00	0,00	55860,00	57684,00	8436,00	26220,00	0,00	0,00	0,00	88692,00	0,00	82764,00	0,00	7296,00	24396,00	##	#	0,00
55680	480	0	117600	121440	17760	55200	0	0	0	186720	0	174240	0	15360	51360	##	#	0
27840,00	240,00	0,00	58800,00	60720,00	8880,00	27600,00	0,00	0,00	0,00	93360,00	0,00	87120,00	0,00	7680,00	25680,00	##	#	0,00
24360,00	210,00	0,00	51450,00	53130,00	7770,00	24150,00	0,00	0,00	0,00	81690,00	0,00	76230,00	0,00	6720,00	22470,00	##	#	0,00
128937,60	75117,60	74649,60	189309,60	193053,60	91965,60	128469,60	74649,60	74649,60	74649,60	256701,60	74649,60	244533,60	74649,60	89625,60	124725,60	##	#	74649,60
4.058.394,98	3.980.511,86	3.958.961,52	4.103.521,18	4.152.410,54	4.007.066,60	4.056.589,32	3.979.791,65	3.958.241,32	3.936.690,98	4.178.882,64	3.982.567,63	4.207.131,30	3.983.185,91	3.983.331,58	4.034.327,24	##	#	3.978.853,68
1681121,76	1668978,40	1679964,58	1690464,24	1660509,58	1613826,20	1623626,04	1614331,76	1626631,57	1638419,99	1649703,93	1594056,41	1606873,17	1544149,30	1558177,37	1571868,02	##	#	1534815,77
764132,66	758613,46	763607,50	768380,38	754765,22	733546,20	738000,96	733776,70	739367,77	744726,39	749855,70	724562,01	730388,03	701877,81	708254,40	714477,62	##	#	697636,61
542457,22	522206,62	509586,07	553063,49	584156,61	558115,09	569975,47	548696,21	535433,07	522420,06	598345,81	559548,23	628796,20	584168,31	577355,77	587808,27	##	#	587277,84
571001,70	549685,49	536400,84	582166,69	614896,55	587484,72	599969,46	577570,41	563609,32	549911,53	629833,48	588994,19	661886,89	614910,43	607739,42	618742,14	##	#	618184,20
499681,64	481027,88	469402,53	509446,38	538082,58	514094,39	525017,38	505416,57	493199,58	481213,01	551143,72	515406,79	579187,01	538080,06	531804,62	541431,20	##	#	540939,26
4058394,98	3980511,86	3958961,52	4103521,18	4152410,54	4007066,60	4056589,32	3979791,65	3958241,32	3936690,98	4178882,64	3982567,63	4207131,30	3983185,91	3983331,58	4034327,24	##	#	3978853,68
2100,00	2100,00	2100,00	2100,00	2100,00	2100,00	2100,00	2100,00	2100,00	2100,00	2100,00	2100,00	2100,00	2100,00	2100,00	2100,00	##	#	2100,00
58394,98	0,00	0,00	103521,18	152410,54	7066,60	56589,32	0,00	0,00	0,00	178882,64	0,00	207131,30	0,00	0,00	34327,24	##	#	0,00
24189,14	0,00	0,00	42646,02	60947,53	2846,04	22649,54	0,00	0,00	0,00	70617,78	0,00	79111,80	0,00	0,00	13374,69	##	#	0,00
10994,87	0,00	0,00	19384,24	27702,99	1293,63	10295,09	0,00	0,00	0,00	32098,57	0,00	35959,47	0,00	0,00	6079,34	##	#	0,00
7805,25	0,00	0,00	13952,36	21440,95	984,25	7951,14	0,00	0,00	0,00	25612,99	0,00	30957,76	0,00	0,00	5001,54	##	#	0,00
8215,97	0,00	0,00	14686,55	22569,23	1036,05	8369,56	0,00	0,00	0,00	26960,86	0,00	32586,93	0,00	0,00	5264,75	##	#	0,00
7189,76	0,00	0,00	12852,01	19749,84	906,62	7323,98	0,00	0,00	0,00	23592,44	0,00	28515,33	0,00	0,00	4606,92	##	#	0,00
4000000,00	3980511,86	3958961,52	4000000,00	4000000,00	4000000,00	4000000,00	3979791,65	3958241,32	3936690,98	4000000,00	3982567,63	4000000,00	3983185,91	3983331,58	4000000,00	##	#	3978853,68
1656932,63	1668978,40	1679964,58	1647818,22	1599562,05	1610980,16	1600976,50	1614331,76	1626631,57	1638419,99	1579086,15	1594056,41	1527761,38	1544149,30	1558177,37	1558493,33	##	#	1534815,77
753137,79	758613,46	763607,50	748996,14	727062,24	732252,57	727705,87	733776,70	739367,77	744726,39	717757,13	724562,01	694428,55	701877,81	708254,40	708398,28	##	#	697636,61
534651,97	522206,62	509586,07	539111,14	562715,66	557130,83	562024,33	548696,21	535433,07	522420,06	572732,82	559548,23	597838,44	584168,31	577355,77	582806,73	##	#	587277,84
562785,73	549685,49	536400,84	567480,13	592327,31	586448,67	591599,90	577570,41	563609,32	549911,53	602872,61	588994,19	629299,96	614910,43	607739,42	613477,39	##	#	618184,20
492491,88	481027,88	469402,53	496594,37	518332,74	513187,77	517693,40	505416,57	493199,58	481213,01	527551,28	515406,79	550671,67	538080,06	531804,62	536824,28	##	#	540939,26
87480	87480	87480	87480	87480	87480	87480	87480	87480	87480	87480	87480	87480	87480	87480	87480	##	#	87480
35715,71	36679,26	37121,68	35128,64	33698,42	35170,00	34524,92	35484,71	35949,74	36408,49	33056,31	35014,61	31767,15	33913,10	34219,94	33794,23	##	#	33744,82
16234,13	16672,10	16873,21	15967,31	15317,22	15986,12	15692,91	16129,18	16340,56	16549,09	15025,40	15915,53	14439,44	15414,86	15554,34	15360,85	##	#	15338,40
11524,59	11476,57	11260,17	11492,92	11854,89	12162,96	12120,01	12060,92	11833,46	11609,07	11989,49	12290,88	12431,01	12829,69	12679,61	12637,53	##	#	12912,03
12131,03	12080,48	11852,69	12097,70	12478,73	12803,01	12757,80	12695,60	12456,17	12219,97	12620,43	12937,69	13085,20	13504,86	13346,88	13302,59	##	#	13591,54
10615,82	10571,58	10372,25	10586,54	10919,86	11203,62	11164,01	11109,59	10900,07	10693,38	11043,67	11321,29	11450,26	11817,49	11679,24	11640,45	##	#	11893,22
8719,94	8719,94	8719,94	8719,94	8719,94	8719,94	8719,94	8719,94	8719,94	8719,94	8719,94	8719,94	8719,94	8719,94	8719,94	8719,94	##	#	8719,94
3560,11	3656,16	3700,26	3501,59	3359,03	3505,72	3441,42	3537,09	3583,44	3629,17	3295,03	3490,23	3166,52	3380,43	3411,02	3368,58	##	#	3363,66
1618,20	1661,86	1681,91	1591,61	1526,81	1593,48	1564,26	1607,74	1628,81	1649,60	1497,72	1586,45	1439,31	1536,54	1550,44	1531,16	##	#	1528,92
1148,76	1143,98	1122,40	1145,61	1181,69	1212,39	1208,11	1202,22	1179,55	1157,18	1195,10	1225,15	1239,11	1278,85	1263,89	1259,70	##	#	1287,06
1209,21	1204,17	1181,47	1205,89	1243,87	1276,19	1271,69	1265,49	1241,62	1218,08	1257,99	1289,62	1304,32	1346,15	1330,41	1325,99	##	#	1354,79
1058,18	1053,77	1033,90	1055,26	1088,48	1116,77	1112,82	1107,39	1086,51	1065,91	1100,82	1128,50	1141,35	1177,96	1164,18	1160,31	##	#	1185,51
3903800,06	3884311,92	3862761,58	3903800,06	3903800,06	3903800,06	3903800,06	3883591,72	3862041,38	3840491,04	3903800,06	3886367,70	3903800,06	3886985,98	3887131,64	3903800,06	##	#	3882653,74
1617656,80	1628642,98	1639142,64	1609187,98	1562504,60	1572344,44	1563010,16	1575309,97	1587098,39	1598382,33	1542734,81	1555551,57	1492827,70	1506855,77	1520546,42	1521330,51	##	#	1497707,30
735285,46	740279,50	745052,38	731437,22	710218,20	714672,96	710448,70	716039,77	721398,39	726527,70	701234,01	707060,03	678549,81	684926,40	691149,62	691506,27	##	#	680769,29
521978,62	509586,07	497203,49	526472,61	549679,09	543755,47	548696,21	535433,07	522420,06	509653,81	559548,23	546032,20	584168,31	570059,77	563412,27	568909,50	##	#	573078,76
549445,49	536400,84	523366,69	554176,55	578604,72	572369,46	577570,41	563609,32	549911,53	536473,48	588994,19	574766,89	614910,43	600059,42	593062,14	598848,81	##	#	603237,86
480817,88	469402,53	457996,38	484952,58	506324,39	500867,38	505416,57	493199,58	481213,01	469453,72	515406,79	502957,01	538080,06	525084,62	518961,20	524023,52	##	#	527860,54
41,44%	41,93%	42,43%	41,22%	40,03%	40,28%	40,04%	40,56%	41,09%	41,62%	39,52%	40,03%	38,24%	38,77%	39,12%	38,97%	##	#	38,57%
18,84%	19,06%	19,29%	18,74%	18,19%	18,31%	18,20%	18,44%	18,68%	18,92%	17,96%	18,19%	17,38%	17,62%	17,78%	17,71%	##	#	17,53%
13,37%	13,12%	12,87%	13,49%	14,08%	13,93%	14,06%	13,79%	13,53%	13,27%	14,33%	14,05%	14,96%	14,67%	14,49%	14,57%	##	#	14,76%
14,07%	13,81%	13,55%	14,20%	14,82%	14,66%	14,80%	14,51%	14,24%	13,97%	15,09%	14,79%	15,75%	15,44%	15,26%	15,34%	##	#	15,54%
12,32%	12,08%	11,86%	12,42%	12,97%	12,83%	12,95%	12,70%	12,46%	12,22%	13,20%	12,94%	13,78%	13,51%	13,35%	13,42%	##	#	13,60%
46,39	45,50	45,26	46,91	47,47	45,81	46,37	45,49	45,25	45,00	47,77	45,53	48,09	45,53	45,53	46,12	##	#	45,48
100,04%	100,00%	100,00%	100,06%	100,09%	100,00%	100,03%	100,00%	100,00%	100,00%	100,11%	100,00%	100,12%						

Water Resource Managemt System in the context of Hanoi
daily chart

			Start	1	2	3	4	5	6	7	8	9	10	11	12
1: dom. flow Greywater	Eff.		0,9	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024
tr. Greywater	[l/d]			51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6
2: dom. flow Blackwater	Eff.		0,9	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920
tr. Blackwater	[l/d]			23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328
3: nat. flow roof runoff	Eff.		0,95	0	54240	99360	37680	0	120000	960	38400	0	8400	0	0
Stormwater receiving the lake	[l/d]			0,00	51528,00	94392,00	35796,00	0,00	114000,00	912,00	36480,00	0,00	7980,00	0,00	0,00
4: nat. flow green space	loss. Evap.		0,2												
	loss. Infiltr.		0,3	0	108480	198720	75360	0	240000	1920	76800	0	16800	0	0
Stormwater receiving the lake				0,00	54240,00	99360,00	37680,00	0,00	120000,00	960,00	38400,00	0,00	8400,00	0,00	0,00
5: direct Precipitation on the Lakes surface															
precipitation on the lake				0,00	47460,00	86940,00	32970,00	0,00	105000,00	840,00	33600,00	0,00	7350,00	0,00	0,00
daily Input to the Lake				74649,60	180417,60	268401,60	148125,60	74649,60	308649,60	76521,60	149529,60	74649,60	91029,60	74649,60	74649,60
Water in WRMS															
overall		0,00	3.105.000,00	**3.957.303,34**	**4.088.981,00**	**4.261.235,09**	**4.090.793,20**	**3.980.584,78**	**4.298.034,44**	**3.987.832,36**	**4.074.762,03**	**3.980.214,70**	**3.982.394,36**	**3.960.844,03**	**3.939.293,69**
treated Greywater	[l]		1800000,00	1549028,90	1562694,43	1544045,09	1467988,19	1452973,17	1469180,35	1388022,57	1405860,40	1398806,25	1416319,36	1433427,91	1449934,80
treated Blackwater	[l]		800000,00	704097,29	710309,06	701832,38	667261,58	660436,83	667803,87	630914,45	639022,67	635816,44	643777,06	651553,78	659057,01
treated Storm, roof	[l]		150000,00	573078,76	610675,52	677724,01	657610,07	627893,47	726718,98	662101,06	682608,95	654264,88	646431,60	630816,21	615495,11
treated Stom, green	[l]		150000,00	603237,86	642813,47	713390,96	692218,62	660938,09	764965,01	696946,35	718533,66	688697,89	680452,38	664015,16	647887,74
rainwater			205000,00	527860,54	562488,53	624242,64	605714,73	578343,21	669366,22	609847,93	628736,34	602629,23	595413,97	581030,97	566919,04
Total	[l]			**3957303,34**	**4088981,00**	**4261235,09**	**4090793,20**	**3980584,78**	**4298034,44**	**3987832,36**	**4074762,03**	**3980214,70**	**3982394,36**	**3960844,03**	**3939293,69**
Lake surface area, accord. to the structure				*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*
Spilling of Surplus water	[l]			**0,00**	**88981,00**	**261235,09**	**90793,20**	**0,00**	**298034,44**	**0,00**	**74762,03**	**0,00**	**0,00**	**0,00**	**0,00**
treated Greywater				*0,00*	*34006,06*	*94657,71*	*32581,30*	*0,00*	*101875,95*	*0,00*	*25794,14*	*0,00*	*0,00*	*0,00*	*0,00*
treated Blackwater				*0,00*	*15457,16*	*43025,85*	*14809,55*	*0,00*	*46306,88*	*0,00*	*11724,52*	*0,00*	*0,00*	*0,00*	*0,00*
treated Storm, roof				*0,00*	*13289,01*	*41547,88*	*14595,34*	*0,00*	*50392,17*	*0,00*	*12524,22*	*0,00*	*0,00*	*0,00*	*0,00*
treated Stom, green				*0,00*	*13988,37*	*43734,44*	*15363,46*	*0,00*	*53044,23*	*0,00*	*13183,35*	*0,00*	*0,00*	*0,00*	*0,00*
rainwater				*0,00*	*12240,41*	*38269,21*	*13443,55*	*0,00*	*46415,21*	*0,00*	*11535,79*	*0,00*	*0,00*	*0,00*	*0,00*
WRMS, after spilling				**3957303,34**	**4000000,00**	**4000000,00**	**4000000,00**	**3980584,78**	**4000000,00**	**3987832,36**	**4000000,00**	**3980214,70**	**3982394,36**	**3960844,03**	**3939293,69**
treated Greywater	[l]			1549028,90	1528688,38	1449387,38	1435406,90	1452973,17	1367304,40	1388022,57	1380066,26	1398806,25	1416319,36	1433427,91	1449934,80
treated Blackwater	[l]			704097,29	694851,90	658806,53	652452,03	660436,83	621496,99	630914,45	627298,15	635816,44	643777,06	651553,78	659057,01
treated Storm, roof	[l]			573078,76	597386,50	636176,13	643014,73	627893,47	676326,81	662101,06	670084,73	654264,88	646431,60	630816,21	615495,11
treated Stom, green	[l]			603237,86	628825,10	669656,52	676855,16	660938,09	711920,79	696946,35	705350,31	688697,89	680452,38	664015,16	647887,74
rainwater				527860,54	550248,12	585973,43	592271,18	578343,21	622951,01	609847,93	617200,55	602629,23	595413,97	581030,97	566919,04
Intake for Servicewater															
overall	**[l]**			**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**
treated Greywater	[l]			34242,78	32704,89	29754,85	30695,61	31931,51	27829,42	30448,68	29628,28	30743,96	31111,84	31658,98	32198,74
treated Blackwater	[l]			15564,75	14865,72	13524,81	13952,43	14514,20	12649,63	13840,20	13467,30	13974,43	14141,65	14390,35	14635,70
treated Storm, roof	[l]			12668,46	12780,54	13060,22	13750,62	13799,01	13765,61	14524,33	14385,87	14379,90	14199,96	13932,33	13668,32
treated Stom, green	[l]			13335,15	13453,14	13747,55	14474,28	14525,22	14490,07	15288,72	15142,98	15136,69	14947,28	14665,57	14387,66
rainwater				11668,87	11772,05	12029,60	12665,49	12710,06	12679,23	13378,07	13250,52	13245,02	13079,27	12832,77	12589,59
Evaporation nach Penman															
overall	**[l]**			**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**
treated Greywater				3413,29	3260,00	2965,94	3059,71	3182,91	2774,01	3035,10	2953,32	3064,53	3101,20	3155,74	3209,54
treated Blackwater				1551,48	1481,80	1348,14	1390,77	1446,76	1260,91	1379,58	1342,41	1392,96	1409,63	1434,42	1458,87
treated Storm, roof				1262,78	1273,95	1301,83	1370,65	1375,47	1372,14	1447,77	1433,97	1433,38	1415,44	1388,76	1362,45
treated Stom, green				1329,24	1341,00	1370,34	1442,78	1447,86	1444,36	1523,97	1509,44	1508,81	1489,93	1461,85	1434,15
rainwater				1163,14	1173,43	1199,10	1262,49	1266,93	1263,86	1333,52	1320,80	1320,25	1303,73	1279,16	1254,92
WRMS, after intake															
overall				**3861103,40**	**3903800,06**	**3903800,06**	**3903800,06**	**3884384,84**	**3903800,06**	**3891632,43**	**3903800,06**	**3884014,76**	**3886194,43**	**3864644,09**	**3843093,76**
treated Greywater	[l]			1511372,83	1492723,49	1416666,59	1401651,57	1417858,75	1336700,97	1354538,80	1347484,65	1364997,76	1382106,31	1398613,20	1414526,51
treated Blackwater	[l]			686981,06	678504,38	643933,58	637108,83	644475,87	607586,45	615694,67	612488,44	620449,06	628225,78	635729,01	642962,44
treated Storm, roof	[l]			559147,52	583332,01	621814,07	627893,47	612718,98	661189,06	646128,95	654264,88	638451,60	630816,21	615495,11	600464,34
treated Stom, green	[l]			588573,47	614030,96	654538,62	660938,09	644965,01	695986,35	680133,66	688697,89	672052,38	664015,16	647887,74	632065,93
rainwater	[l]			515028,53	537302,64	572744,73	578343,21	564366,22	609007,93	595136,34	602629,23	588063,97	581030,97	566919,04	553074,53
treated Greywater	%			39,14%	38,24%	36,29%	35,90%	36,50%	34,24%	34,81%	34,52%	35,14%	35,56%	36,19%	36,81%
treated Blackwater	%			17,79%	17,38%	16,50%	16,32%	16,59%	15,56%	15,82%	15,69%	15,97%	16,17%	16,45%	16,73%
treated Storm, roof	%			14,48%	14,94%	15,93%	16,08%	15,77%	16,94%	16,60%	16,76%	16,44%	16,23%	15,93%	15,62%
treated Stom, green	%			15,24%	15,73%	16,77%	16,93%	16,60%	17,83%	17,48%	17,64%	17,30%	17,09%	16,76%	16,45%
rainwater	%			13,34%	13,76%	14,67%	14,81%	14,53%	15,60%	15,29%	15,44%	15,14%	14,95%	14,67%	14,39%
estimated retention time				45,24	46,74	48,71	46,76	45,50	49,13	45,59	46,58	45,50	45,52	45,28	45,03

size of inner Lake	width	15
	length	105
	depth	2
	Volume 1:	3150
	surface 1:	1575
size of extension Arwa	width	20
	length	105
	depth	1
	Volume	2100
	surface 2	2100
Total		5250
Spilllevel		4000000

		August																
13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024
51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6
25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920
23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328
59520	0	0	60000	0	42000	39600	0	0	0	0	0	91920	32880	58560	2160	0	17520	0
56544,00	0,00	0,00	57000,00	0,00	39900,00	37620,00	0,00	0,00	0,00	0,00	0,00	87324,00	31236,00	55632,00	2052,00	0,00	16644,00	0,00
119040	0	0	120000	0	84000	79200	0	0	0	0	0	183840	65760	117120	4320	0	35040	0
59520,00	0,00	0,00	60000,00	0,00	42000,00	39600,00	0,00	0,00	0,00	0,00	0,00	91920,00	32880,00	58560,00	2160,00	0,00	17520,00	0,00
52080,00	0,00	0,00	52500,00	0,00	36750,00	34650,00	0,00	0,00	0,00	0,00	0,00	80430,00	28770,00	51240,00	1890,00	0,00	15330,00	0,00
190713,60	74649,60	74649,60	191649,60	74649,60	156549,60	151869,60	74649,60	74649,60	74649,60	74649,60	74649,60	253893,60	138765,60	188841,60	78861,60	74649,60	108813,60	74649,60
4.085.887,36	**3.980.471,83**	**3.958.921,50**	**4.106.871,16**	**3.980.953,03**	**4.078.052,69**	**4.092.160,90**	**3.980.616,21**	**3.959.065,88**	**3.937.515,54**	**3.915.965,21**	**3.894.414,87**	**4.132.538,54**	**4.074.420,98**	**4.145.638,80**	**3.987.931,23**	**3.966.380,89**	**3.994.324,55**	**3.972.774,22**
1465848,11	1452569,76	1468785,69	1484416,49	1463243,47	1479205,72	1467989,65	1452517,37	1468735,85	1484369,15	1499425,19	1513911,78	1527836,70	1495732,29	1485063,49	1450963,51	1467283,85	1483018,20	1498622,56
666290,44	660255,01	667625,99	674730,99	665107,07	672362,73	667264,66	660231,96	667604,07	674710,20	681553,93	688138,81	694468,39	679875,64	675026,29	659526,45	666944,84	674096,88	681189,82
657008,34	628053,98	612875,18	654982,60	622995,15	647840,44	658071,12	628128,73	612948,68	598054,86	583443,40	569110,48	642376,30	638535,98	667703,95	631349,29	616119,40	617820,14	602940,47
691585,93	661107,72	645130,09	689453,73	655782,80	681935,78	692704,98	661186,74	645207,78	629530,10	614149,66	599062,40	676184,35	672141,97	702845,15	664577,15	648545,71	650335,99	634673,20
605154,53	578485,36	564504,54	603287,35	573824,54	596708,04	606130,49	578551,41	564569,50	550851,23	537393,03	524191,39	591672,80	588135,10	614999,92	581514,83	567487,08	569053,34	555348,17
4085887,36	**3980471,83**	**3958921,50**	**4106871,16**	**3980953,03**	**4078052,69**	**4092160,90**	**3980616,21**	**3959065,88**	**3937515,54**	**3915965,21**	**3894414,87**	**4132538,54**	**4074420,98**	**4145638,80**	**3987931,23**	**3966380,89**	**3994324,55**	**3972774,22**
2100,00	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*
85887,36	0,00	0,00	106871,16	0,00	78052,69	92160,90	0,00	0,00	0,00	0,00	0,00	132538,54	74420,98	145638,80	0,00	0,00	0,00	0,00
30812,85	*0,00*	*0,00*	*38628,27*	*0,00*	*28311,55*	*33061,08*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*49000,69*	*27320,17*	*52171,18*	*0,00*	*0,00*	*0,00*	*0,00*
14005,75	*0,00*	*0,00*	*17558,20*	*0,00*	*12868,82*	*15027,69*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*22272,95*	*12418,21*	*23714,08*	*0,00*	*0,00*	*0,00*	*0,00*
13810,64	*0,00*	*0,00*	*17044,30*	*0,00*	*12399,47*	*14820,64*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*20602,26*	*11663,12*	*23456,84*	*0,00*	*0,00*	*0,00*	*0,00*
14537,48	*0,00*	*0,00*	*17941,33*	*0,00*	*13052,04*	*15600,64*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*21686,55*	*12276,95*	*24691,37*	*0,00*	*0,00*	*0,00*	*0,00*
12720,65	*0,00*	*0,00*	*15699,06*	*0,00*	*11420,81*	*13650,86*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*18976,10*	*10742,53*	*21605,32*	*0,00*	*0,00*	*0,00*	*0,00*
4000000,00	3980471,83	3958921,50	4000000,00	3980953,03	4000000,00	4000000,00	3980616,21	3959065,88	3937515,54	3915965,21	3894414,87	4000000,00	4000000,00	4000000,00	3987931,23	3966380,89	3994324,55	3972774,22
1435035,26	1452569,76	1468785,69	1445788,22	1463243,47	1450894,17	1434928,57	1452517,37	1468735,85	1484369,15	1499425,19	1513911,78	1478836,01	1468412,13	1432892,31	1450963,51	1467283,85	1483018,20	1498622,56
652284,69	660255,01	667625,99	657172,78	665107,07	659493,91	652236,97	660231,96	667604,07	674710,20	681553,93	688138,81	672195,44	667457,43	651312,21	659526,45	666944,84	674096,88	681189,82
643197,71	628053,98	612875,18	637938,30	622995,15	635440,97	643250,48	628128,73	612948,68	598054,86	583443,40	569110,48	621774,04	626872,86	644247,11	631349,29	616119,40	617820,14	602940,47
677048,45	661107,72	645130,09	671512,40	655782,80	668883,73	677104,35	661186,74	645207,78	629530,10	614149,66	599062,40	654497,80	659865,02	678153,77	664577,15	648545,71	650335,99	634673,20
592433,89	578485,36	564504,54	587588,29	573824,54	585287,22	592479,63	578551,41	564569,50	550851,23	537393,03	524191,39	572696,70	577392,57	593394,60	581514,83	567487,08	569053,34	555348,17
87480	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**
30724,51	31923,55	32455,65	30796,57	32154,24	31123,73	30675,13	31921,24	32453,37	32978,31	33496,14	34006,91	31304,87	31527,59	30236,45	31828,61	32361,49	32479,69	32999,48
13965,60	14510,62	14752,48	13998,36	14615,49	14147,08	13943,17	14509,59	14751,46	14990,07	15225,45	15457,62	14229,43	14330,67	13743,79	14467,49	14709,72	14763,45	14999,72
13771,04	13802,93	13542,66	13588,65	13690,09	13631,11	13751,06	13804,07	13543,79	13287,02	13033,73	12783,89	13162,08	13459,30	13594,71	13849,40	13588,74	13530,93	13276,67
14495,80	14529,36	14255,39	14303,81	14410,59	14348,50	14474,77	14530,57	14256,59	13986,31	13719,69	13456,70	13854,79	14167,66	14310,19	14578,29	14303,92	14243,06	13975,43
12684,18	12713,54	12473,82	12516,15	12609,59	12555,24	12665,71	12714,53	12474,80	12238,29	12004,99	11774,88	12123,18	12396,93	12521,63	12756,22	12516,14	12462,88	12228,70
8719,94	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**
3062,59	3182,11	3235,15	3069,78	3205,11	3102,39	3057,67	3181,88	3234,93	3287,25	3338,87	3389,78	3120,44	3142,65	3013,95	3172,65	3225,77	3237,55	3289,36
1392,08	1446,41	1470,52	1395,35	1456,86	1410,17	1389,84	1446,30	1470,41	1494,20	1517,66	1540,80	1418,38	1428,47	1369,97	1442,11	1466,25	1471,61	1495,16
1372,69	1375,86	1349,92	1354,51	1364,62	1358,74	1370,69	1375,98	1350,03	1324,44	1299,19	1274,29	1311,99	1341,61	1355,11	1380,50	1354,51	1348,75	1323,41
1444,93	1448,27	1420,97	1425,79	1436,44	1430,25	1442,83	1448,40	1421,09	1394,14	1367,57	1341,35	1381,03	1412,22	1426,43	1453,15	1425,80	1419,74	1393,06
1264,35	1267,28	1243,38	1247,60	1256,91	1251,50	1262,51	1267,37	1243,48	1219,90	1196,65	1173,71	1208,43	1235,72	1248,15	1271,53	1247,60	1242,29	1218,95
3903800,06	**3884271,90**	**3862721,56**	**3903800,06**	**3884753,09**	**3903800,06**	**3903800,06**	**3884416,28**	**3862865,94**	**3841315,61**	**3819765,27**	**3798214,94**	**3903800,06**	**3903800,06**	**3903800,06**	**3891731,29**	**3870180,95**	**3898124,62**	**3876574,28**
1401248,16	1417464,09	1433094,89	1411921,87	1427884,12	1416668,05	1401195,77	1417414,25	1433047,55	1448103,59	1462590,18	1476515,10	1444410,69	1433741,89	1399641,91	1415962,25	1431696,60	1447300,96	1462333,71
636927,01	644297,99	651402,99	641779,07	649034,73	643936,66	636903,96	644276,07	651382,20	658225,93	664810,81	671140,39	656547,64	651698,29	636198,45	643616,84	650768,88	657861,82	664694,95
628053,98	612875,18	597982,60	622995,15	607940,44	620451,12	628128,73	612948,68	598054,86	583443,40	569110,48	555052,30	607299,98	612071,95	629297,29	616119,40	601176,14	602940,47	588340,38
661107,72	645130,09	629453,73	655782,80	639935,78	653104,98	661186,74	645207,78	629530,10	614149,66	599062,40	584264,35	639261,97	644285,15	662417,15	648545,71	632815,99	634673,20	619304,71
578485,36	564504,54	550787,35	573824,54	559958,04	571480,49	578551,41	564569,50	550851,23	537393,03	524191,39	511242,80	559365,10	563759,92	579624,83	567487,08	553723,34	555348,17	541900,53
35,89%	36,49%	37,10%	36,17%	36,76%	36,29%	35,89%	36,49%	37,10%	37,70%	38,29%	38,87%	37,00%	36,73%	35,85%	36,38%	36,99%	37,13%	37,72%
16,32%	16,59%	16,86%	16,44%	16,71%	16,50%	16,31%	16,59%	16,86%	17,14%	17,40%	17,67%	16,82%	16,69%	16,30%	16,54%	16,81%	16,88%	17,15%
16,09%	15,78%	15,48%	15,96%	15,65%	15,89%	16,09%	15,78%	15,48%	15,19%	14,90%	14,61%	15,56%	15,68%	16,12%	15,83%	15,53%	15,47%	15,18%
16,93%	16,61%	16,30%	16,80%	16,47%	16,73%	16,94%	16,61%	16,30%	15,99%	15,68%	15,38%	16,38%	16,50%	16,97%	16,66%	16,35%	16,28%	15,98%
14,82%	14,53%	14,26%	14,70%	14,41%	14,64%	14,82%	14,53%	14,26%	13,99%	13,72%	13,46%	14,33%	14,44%	14,85%	14,58%	14,31%	14,25%	13,98%
46,71	45,50	45,26	46,95	45,51	46,62	46,78	45,50	45,26	45,01	44,76	44,52	47,24	46,58	47,39	45,59	45,34	45,66	45,41

Water Resource Managemt System in the context of Hanoi
daily chart

		Start	1	2	3	4	5	6	7	8	9	10	11	12
1: dom. flow Greywater	Eff.	0,9	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024
tr. Greywater	[l/d]		51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6
2: dom. flow Blackwater	Eff.	0,9	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920
tr. Blackwater	[l/d]		23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328
3: nat. flow roof runoff	Eff.	0,95	0	0	0	54960	54720	65760	74880	0	480	42960	0	0
Stormwater receiving the lake	[l/d]		0,00	0,00	0,00	52212,00	51984,00	62472,00	71136,00	0,00	456,00	40812,00	0,00	0,00
4: nat. flow green space	loss. Evap.	0,2												
	loss. Infiltr.	0,3	0	0	0	109920	109440	131520	149760	0	960	85920	0	0
Stormwater receiving the lake			0,00	0,00	0,00	54960,00	54720,00	65760,00	74880,00	0,00	480,00	42960,00	0,00	0,00
5: direct Precipitation on the Lakes surface														
precipitation on the lake			0,00	0,00	0,00	48090,00	47880,00	57540,00	65520,00	0,00	420,00	37590,00	0,00	0,00
daily Input to the Lake			74649,60	74649,60	74649,60	181821,60	181353,60	202881,60	220665,60	74649,60	75585,60	158421,60	74649,60	74649,60
Water in WRMS														
overall	0,00	3.105.000,00	**3.951.223,88**	**3.929.673,55**	**3.908.123,21**	**4.041.834,88**	**4.134.029,38**	**4.167.340,56**	**4.193.848,60**	**3.982.896,23**	**3.962.701,89**	**4.062.513,56**	**3.979.929,98**	**3.958.379,64**
treated Greywater	[l]	1800000,00	1513655,31	1528124,14	1542036,67	1555400,45	1553985,93	1519936,49	1476546,99	1427315,43	1444162,71	1460425,31	1455223,45	1471370,46
treated Blackwater	[l]	800000,00	688022,95	694599,74	700923,67	706998,17	706355,27	690878,36	671155,98	648778,12	656436,01	663828,14	661463,72	668803,30
treated Storm, roof	[l]	150000,00	588340,38	574016,14	559964,00	598392,27	630087,68	657944,67	688082,47	641223,91	626192,26	651802,60	626575,61	611430,48
treated Stom, green	[l]	150000,00	619304,71	604226,58	589434,88	629885,72	663249,34	692572,53	724296,58	674971,83	659149,06	686107,32	659552,62	643610,40
rainwater		205000,00	541900,53	528706,95	515763,99	551158,27	580351,15	606008,51	633766,58	590606,94	576761,86	600350,19	577114,58	563164,99
Total	[l]		**3951223,88**	**3929673,55**	**3908123,21**	**4041834,88**	**4134029,38**	**4167340,56**	**4193848,60**	**3982896,23**	**3962701,89**	**4062513,56**	**3979929,98**	**3958379,64**
Lake surface area, accord. to the structure			*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*
Spilling of Surplus water	[l]		**0,00**	**0,00**	**0,00**	**41834,88**	**134029,38**	**167340,56**	**193848,60**	**0,00**	**0,00**	**62513,56**	**0,00**	**0,00**
treated Greywater			*0,00*	*0,00*	*0,00*	*16099,12*	*50381,78*	*61033,42*	*68249,14*	*0,00*	*0,00*	*22472,88*	*0,00*	*0,00*
treated Blackwater			*0,00*	*0,00*	*0,00*	*7317,76*	*22900,75*	*27742,39*	*31022,26*	*0,00*	*0,00*	*10214,92*	*0,00*	*0,00*
treated Storm, roof			*0,00*	*0,00*	*0,00*	*6193,64*	*20428,07*	*26419,93*	*31804,63*	*0,00*	*0,00*	*10029,87*	*0,00*	*0,00*
treated Stom, green			*0,00*	*0,00*	*0,00*	*6519,61*	*21503,21*	*27810,42*	*33478,53*	*0,00*	*0,00*	*10557,75*	*0,00*	*0,00*
rainwater			*0,00*	*0,00*	*0,00*	*5704,75*	*18815,57*	*24334,42*	*29294,04*	*0,00*	*0,00*	*9238,13*	*0,00*	*0,00*
WRMS, after spilling			**3951223,88**	**3929673,55**	**3908123,21**	**4000000,00**	**4000000,00**	**4000000,00**	**4000000,00**	**3982896,23**	**3962701,89**	**4000000,00**	**3979929,98**	**3958379,64**
treated Greywater	[l]		1513655,31	1528124,14	1542036,67	1539301,33	1503604,15	1458903,08	1408297,85	1427315,43	1444162,71	1437952,43	1455223,45	1471370,46
treated Blackwater	[l]		688022,95	694599,74	700923,67	699680,41	683454,53	663135,98	640133,72	648778,12	656436,01	653613,22	661463,72	668803,30
treated Storm, roof	[l]		588340,38	574016,14	559964,00	592198,63	609659,61	631524,74	656277,83	641223,91	626192,26	641772,72	626575,61	611430,48
treated Stom, green	[l]		619304,71	604226,58	589434,88	623366,11	641746,13	664762,11	690818,05	674971,83	659149,06	675549,57	659552,62	643610,40
rainwater			541900,53	528706,95	515763,99	545453,52	561535,59	581674,09	604472,54	590606,94	576761,86	591112,06	577114,58	563164,99
Intake for Servicewater														
overall	**[l]**		**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**
treated Greywater	[l]		33512,29	34018,17	34517,17	33316,08	31817,70	30625,01	29375,86	31349,44	31881,11	30964,10	31986,23	32517,22
treated Blackwater	[l]		15232,81	15462,76	15689,58	15143,63	14462,55	13920,42	13352,63	14249,71	14491,38	14074,56	14539,16	14780,52
treated Storm, roof	[l]		13025,84	12778,40	12534,32	12817,33	12900,98	13256,84	13689,38	14083,79	13823,72	13819,59	13772,31	13512,58
treated Stom, green	[l]		13711,39	13450,92	13194,00	13491,91	13579,96	13954,56	14409,86	14825,02	14551,27	14546,92	14497,16	14223,76
rainwater			11997,66	11769,75	11544,94	11805,60	11882,63	12210,39	12608,77	12972,04	12732,51	12728,69	12685,14	12445,92
Evaporation nach Penman														
overall	**[l]**		**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**
treated Greywater			3340,48	3390,90	3440,64	3320,92	3171,56	3052,68	2928,16	3124,89	3177,88	3086,48	3188,36	3241,29
treated Blackwater			1518,39	1541,32	1563,92	1509,50	1441,62	1387,58	1330,98	1420,40	1444,49	1402,94	1449,25	1473,31
treated Storm, roof			1298,41	1273,74	1249,41	1277,62	1285,96	1321,43	1364,55	1403,86	1377,94	1377,53	1372,81	1346,92
treated Stom, green			1366,74	1340,78	1315,17	1344,86	1353,64	1390,98	1436,36	1477,75	1450,46	1450,03	1445,06	1417,81
rainwater			1195,92	1173,20	1150,79	1176,77	1184,45	1217,12	1256,83	1293,04	1269,17	1268,79	1264,44	1240,60
WRMS, after intake														
overall			**3855023,95**	**3833473,61**	**3811923,28**	**3903800,06**	**3903800,06**	**3903800,06**	**3903800,06**	**3886696,29**	**3866501,96**	**3903800,06**	**3883730,04**	**3862179,71**
treated Greywater	[l]		1476802,54	1490715,07	1504078,85	1502664,33	1468614,89	1425225,39	1375993,83	1392841,11	1409103,71	1403901,85	1420048,86	1435611,96
treated Blackwater	[l]		671271,74	677595,67	683670,17	683027,27	667550,36	647827,98	625450,12	633108,01	640500,14	638135,72	645475,30	652549,47
treated Storm, roof	[l]		574016,14	559964,00	546180,27	578103,68	595472,67	616946,47	641223,91	625736,26	610990,60	626575,61	611430,48	596570,97
treated Stom, green	[l]		604226,58	589434,88	574925,72	608529,34	626812,53	649416,58	674971,83	658669,06	643147,32	659552,62	643610,40	627968,83
rainwater	[l]		528706,95	515763,99	503068,27	532471,15	548468,51	568246,58	590606,94	576341,86	562760,19	577114,58	563164,99	549478,47
treated Greywater	%		38,31%	38,89%	39,46%	38,49%	37,62%	36,51%	35,25%	35,84%	36,44%	35,96%	36,56%	37,17%
treated Blackwater	%		17,41%	17,68%	17,94%	17,50%	17,10%	16,59%	16,02%	16,29%	16,57%	16,35%	16,62%	16,90%
treated Storm, roof	%		14,89%	14,61%	14,33%	14,81%	15,25%	15,80%	16,43%	16,10%	15,80%	16,05%	15,74%	15,45%
treated Stom, green	%		15,67%	15,38%	15,08%	15,59%	16,06%	16,64%	17,29%	16,95%	16,63%	16,90%	16,57%	16,26%
rainwater	%		13,71%	13,45%	13,20%	13,64%	14,05%	14,56%	15,13%	14,83%	14,55%	14,78%	14,50%	14,23%
estimated retention time			45,17	44,92	44,67	46,20	47,26	47,64	47,94	45,53	45,30	46,44	45,50	45,25

size of inner Lake	width	15
	length	105
	depth	2
	Volume 1:	3150
	surface 1:	1575
size of extension Arwa	width	20
	length	105
	depth	1
	Volume	2100
	surface 2	2100
Total		5250
Spilllevel		4000000

	September																
13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024
51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6
25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920
23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328
0	54720	0	58560	0	0	49200	0	0	13920	41280	36000	0	62400	0	0	26160	0
0,00	51984,00	0,00	55632,00	0,00	0,00	46740,00	0,00	0,00	13224,00	39216,00	34200,00	0,00	59280,00	0,00	0,00	24852,00	0,00
0	109440	0	117120	0	0	98400	0	0	27840	82560	72000	0	124800	0	0	52320	0
0,00	54720,00	0,00	58560,00	0,00	0,00	49200,00	0,00	0,00	13920,00	41280,00	36000,00	0,00	62400,00	0,00	0,00	26160,00	0,00
0,00	47880,00	0,00	51240,00	0,00	0,00	43050,00	0,00	0,00	12180,00	36120,00	31500,00	0,00	54600,00	0,00	0,00	22890,00	0,00
74649,60	181353,60	74649,60	188841,60	74649,60	74649,60	170589,60	74649,60	74649,60	101793,60	155145,60	144849,60	74649,60	196329,60	74649,60	74649,60	125661,60	74649,60
3.936.829,31	**4.069.862,97**	**3.980.101,03**	**4.123.982,69**	**3.981.341,80**	**3.959.791,47**	**4.077.231,13**	**3.980.271,89**	**3.958.721,55**	**3.976.495,22**	**4.071.560,88**	**4.081.840,45**	**3.980.378,46**	**4.135.108,13**	**3.981.592,85**	**3.960.042,51**	**4.012.394,17**	**3.978.746,82**
1486933,56	1501920,61	1492568,65	1507814,53	1479690,17	1495258,47	1510253,97	1498009,66	1513125,58	1527677,08	1542040,90	1530466,04	1515755,46	1530443,47	1497319,04	1512463,66	1527043,51	1537149,28
675877,47	682689,80	678438,97	685368,95	672585,21	679661,75	686477,91	680912,36	687783,26	694397,61	700926,64	695665,39	688978,80	695655,19	680598,68	687482,63	694109,85	698703,40
596570,97	633977,23	608366,25	649293,90	615082,95	600220,89	632379,00	605762,45	591121,67	589980,96	614924,06	624042,66	597118,25	641966,77	606544,66	591889,83	602363,26	586105,11
627968,83	667343,85	640384,95	683466,70	647455,20	631810,94	665661,60	637644,20	622232,86	621032,13	647288,03	656886,58	628545,11	675754,09	638467,68	623041,55	634066,22	616952,39
549478,47	583931,48	560342,21	598038,61	566528,27	552839,42	582458,64	557943,21	544458,18	543407,43	566381,24	574779,80	549980,84	591288,61	558662,78	545164,84	554811,34	539836,64
3936829,31	**4069862,97**	**3980101,03**	**4123982,69**	**3981341,80**	**3959791,47**	**4077231,13**	**3980271,89**	**3958721,55**	**3976495,22**	**4071560,88**	**4081840,45**	**3980378,46**	**4135108,13**	**3981592,85**	**3960042,51**	**4012394,17**	**3978746,82**
2100,00	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*
0,00	69862,97	0,00	123982,69	0,00	0,00	77231,13	0,00	0,00	0,00	71560,88	81840,45	0,00	135108,13	0,00	0,00	12394,17	0,00
0,00	*25781,86*	*0,00*	*45330,67*	*0,00*	*0,00*	*28607,31*	*0,00*	*0,00*	*0,00*	*27102,58*	*30685,68*	*0,00*	*50004,82*	*0,00*	*0,00*	*4716,99*	*0,00*
0,00	*11719,00*	*0,00*	*20604,81*	*0,00*	*0,00*	*13003,30*	*0,00*	*0,00*	*0,00*	*12319,34*	*13948,01*	*0,00*	*22729,43*	*0,00*	*0,00*	*2144,09*	*0,00*
0,00	*10882,81*	*0,00*	*19520,26*	*0,00*	*0,00*	*11978,56*	*0,00*	*0,00*	*0,00*	*10807,77*	*12511,99*	*0,00*	*20975,25*	*0,00*	*0,00*	*1860,68*	*0,00*
0,00	*11455,58*	*0,00*	*20547,62*	*0,00*	*0,00*	*12609,00*	*0,00*	*0,00*	*0,00*	*11376,60*	*13170,50*	*0,00*	*22079,20*	*0,00*	*0,00*	*1958,61*	*0,00*
0,00	*10023,73*	*0,00*	*17979,33*	*0,00*	*0,00*	*11032,96*	*0,00*	*0,00*	*0,00*	*9954,60*	*11524,27*	*0,00*	*19319,42*	*0,00*	*0,00*	*1713,80*	*0,00*
3936829,31	4000000,00	3980101,03	4000000,00	3981341,80	3959791,47	4000000,00	3980271,89	3958721,55	3976495,22	4000000,00	4000000,00	3980378,46	4000000,00	3981592,85	3960042,51	4000000,00	3978746,82
1486933,56	1476138,75	1492568,65	1462483,86	1479690,17	1495258,47	1481646,66	1498009,66	1513125,58	1527677,08	1514938,32	1499780,36	1515755,46	1480438,64	1497319,04	1512463,66	1522326,51	1537149,28
675877,47	670970,80	678438,97	664764,13	672585,21	679661,75	673474,61	680912,36	687783,26	694397,61	688607,31	681717,37	688978,80	672925,76	680598,68	687482,63	691965,76	698703,40
596570,97	623094,42	608366,25	629773,64	615082,95	600220,89	620400,45	605762,45	591121,67	589980,96	604116,29	611530,67	597118,25	620991,52	606544,66	591889,83	600502,57	586105,11
627968,83	655888,28	640384,95	662919,08	647455,20	631810,94	653052,61	637644,20	622232,86	621032,13	635911,44	643716,07	628545,11	653674,89	638467,68	623041,55	632107,61	616952,39
549478,47	573907,75	560342,21	580059,29	566528,27	552839,42	571425,67	557943,21	544458,18	543407,43	556426,65	563255,52	549980,84	571969,18	558662,78	545164,84	553097,54	539836,64
87480	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**
33041,04	31728,98	32805,68	31022,94	32512,48	33033,36	31789,82	32923,85	33437,11	33607,78	32549,39	32142,56	33312,98	31319,32	32897,76	33411,34	33190,44	33797,03
15018,62	14422,24	14911,64	14101,31	14778,37	15015,14	14449,89	14965,36	15198,66	15276,24	14795,15	14610,23	15142,24	14236,04	14953,51	15186,95	15086,54	15362,27
13256,36	13393,15	13371,49	13359,08	13514,90	13260,12	13311,15	13313,69	13062,63	12979,15	12979,81	13106,03	13123,35	13137,34	13326,46	13075,24	13092,42	12886,59
13954,05	14098,04	14075,24	14062,17	14226,20	13958,01	14011,73	14014,40	13750,13	13662,25	13662,95	13795,81	13814,04	13828,77	14027,84	13763,41	13781,49	13564,82
12209,92	12335,91	12315,95	12304,51	12448,04	12213,37	12260,36	12262,70	12031,46	11954,57	11955,17	12071,42	12087,37	12100,26	12274,44	12043,06	12058,88	11869,29
8719,94	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**
3293,50	3162,72	3270,04	3092,34	3240,82	3292,74	3168,78	3281,82	3332,98	3350,00	3244,50	3203,94	3320,61	3121,88	3279,22	3330,42	3308,40	3368,86
1497,04	1437,60	1486,38	1405,61	1473,10	1496,70	1440,35	1491,74	1514,99	1522,72	1474,77	1456,34	1509,37	1419,04	1490,55	1513,82	1503,81	1531,30
1321,38	1335,02	1332,86	1331,62	1347,15	1321,76	1326,84	1327,10	1302,07	1293,75	1293,82	1306,40	1308,13	1309,52	1328,37	1303,33	1305,04	1284,52
1390,93	1405,28	1403,01	1401,71	1418,06	1391,32	1396,68	1396,94	1370,60	1361,84	1361,91	1375,15	1376,97	1378,44	1398,28	1371,93	1373,73	1352,13
1217,08	1229,63	1227,64	1226,50	1240,81	1217,42	1222,10	1222,34	1199,29	1191,62	1191,68	1203,27	1204,86	1206,14	1223,51	1200,44	1202,02	1183,12
3840629,37	**3903800,06**	**3883901,09**	**3903800,06**	**3885141,87**	**3863591,53**	**3903800,06**	**3884071,95**	**3862521,62**	**3880295,28**	**3903800,06**	**3903800,06**	**3884178,53**	**3903800,06**	**3885392,91**	**3863842,57**	**3903800,06**	**3882546,89**
1450599,01	1441247,05	1456492,93	1428368,57	1443936,87	1458932,37	1446688,06	1461803,98	1476355,48	1490719,30	1479144,44	1464433,86	1479121,87	1445997,44	1461142,06	1475721,91	1485827,68	1499983,39
659361,80	655110,97	662040,95	649257,21	656333,75	663149,91	657584,36	664455,26	671069,61	677598,64	672337,39	665650,80	672327,19	657270,68	664154,63	670781,85	675375,40	681809,84
581993,23	608366,25	593661,90	615082,95	600220,89	585639,00	605762,45	591121,67	576756,96	575708,06	589842,66	597118,25	582686,77	606544,66	591889,83	577511,26	586105,11	571933,99
612623,85	640384,95	624906,70	647455,20	631810,94	616461,60	637644,20	622232,86	607112,13	606008,03	620886,58	628545,11	613354,09	638467,68	623041,55	607906,22	616952,39	602035,44
536051,48	560342,21	546798,61	566528,27	552839,42	539408,64	557943,21	544458,18	531227,43	530261,24	543279,80	549980,84	536688,61	558662,78	545164,84	531921,34	539836,64	526784,23
37,77%	36,92%	37,50%	36,59%	37,17%	37,76%	37,06%	37,64%	38,22%	38,42%	37,89%	37,51%	38,08%	37,04%	37,61%	38,19%	38,06%	38,63%
17,17%	16,78%	17,05%	16,63%	16,89%	17,16%	16,84%	17,11%	17,37%	17,46%	17,22%	17,05%	17,31%	16,84%	17,09%	17,36%	17,30%	17,56%
15,15%	15,58%	15,29%	15,76%	15,45%	15,16%	15,52%	15,22%	14,93%	14,84%	15,11%	15,30%	15,00%	15,54%	15,23%	14,95%	15,01%	14,73%
15,95%	16,40%	16,09%	16,59%	16,26%	15,96%	16,33%	16,02%	15,72%	15,62%	15,90%	16,10%	15,79%	16,36%	16,04%	15,73%	15,80%	15,51%
13,96%	14,35%	14,08%	14,51%	14,23%	13,96%	14,29%	14,02%	13,75%	13,67%	13,92%	14,09%	13,82%	14,31%	14,03%	13,77%	13,83%	13,57%
45,00	46,52	45,50	47,14	45,51	45,27	46,61	45,50	45,25	45,46	46,54	46,66	45,50	47,27	45,51	45,27	45,87	45,48

Water Resource Managemt System in the context of Hanoi
daily chart

		Start	1	2	3	4	5	6	7	8	9	10	11
1: dom. flow Greywater	Eff.	0,9	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024
tr. Greywater	[l/d]		51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6
2: dom. flow Blackwater	Eff.	0,9	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920
tr. Blackwater	[l/d]		23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328
3: nat. flow roof runoff	Eff.	0,95	39360	0	0	0	0	0	0	0	36480	48240	0
Stormwater receiving the lake	[l/d]		37392,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	34656,00	45828,00	0,00
4: nat. flow green space	loss. Evap.	0,2											
	loss. Infiltr.	0,3	78720	0	0	0	0	0	0	0	72960	96480	0
Stormwater receiving the lake			39360,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	36480,00	48240,00	0,00
5: direct Precipitation on the Lakes surface													
precipitation on the lake			34440,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	31920,00	42210,00	0,00
daily Input to the Lake			151401,60	74649,60	74649,60	74649,60	74649,60	74649,60	74649,60	74649,60	145785,60	168717,60	74649,60
Water in WRMS													
overall	0,00	3.105.000,00	**4.068.388,49**	**3.980.066,76**	**3.958.516,42**	**3.936.966,09**	**3.915.415,75**	**3.893.865,42**	**3.872.315,08**	**3.850.764,74**	**3.932.270,41**	**4.046.998,07**	**3.979.566,84**
treated Greywater	[l]	1800000,00	1551304,99	1540484,48	1554571,91	1568114,27	1581118,93	1593593,18	1605544,24	1616979,30	1627905,47	1639401,63	1633167,60
treated Blackwater	[l]	800000,00	705137,84	700219,46	706622,85	712778,49	718689,72	724359,84	729792,16	734989,94	739956,39	745181,93	742348,30
treated Storm, roof	[l]	150000,00	609325,99	584917,64	570779,93	556908,82	543300,73	529952,09	516859,35	504019,01	526083,59	559041,37	539414,70
treated Stom, green	[l]	150000,00	641395,44	615702,45	600820,65	586219,50	571895,20	557844,00	544062,18	530546,04	553771,92	588464,32	567804,69
rainwater		205000,00	561224,23	538742,74	525721,09	512945,01	500411,17	488116,30	476057,14	464230,45	484553,03	514908,82	496831,55
Total	[l]		**4068388,49**	**3980066,76**	**3958516,42**	**3936966,09**	**3915415,75**	**3893865,42**	**3872315,08**	**3850764,74**	**3932270,41**	**4046998,07**	**3979566,84**
Lake surface area, accord. to the structure			*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*
Spilling of Surplus water	[l]		**68388,49**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**46998,07**	**0,00**
treated Greywater			*26077,01*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*19038,49*	*0,00*
treated Blackwater			*11853,17*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*8653,85*	*0,00*
treated Storm, roof			*10242,60*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*6492,19*	*0,00*
treated Stom, green			*10781,68*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*6833,88*	*0,00*
rainwater			*9434,02*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*5979,67*	*0,00*
WRMS, after spilling			**4000000,00**	**3980066,76**	**3958516,42**	**3936966,09**	**3915415,75**	**3893865,42**	**3872315,08**	**3850764,74**	**3932270,41**	**4000000,00**	**3979566,84**
treated Greywater	[l]		1525227,98	1540484,48	1554571,91	1568114,27	1581118,93	1593593,18	1605544,24	1616979,30	1627905,47	1620363,15	1633167,60
treated Blackwater	[l]		693284,66	700219,46	706622,85	712778,49	718689,72	724359,84	729792,16	734989,94	739956,39	736528,08	742348,30
treated Storm, roof	[l]		599083,39	584917,64	570779,93	556908,82	543300,73	529952,09	516859,35	504019,01	526083,59	552549,18	539414,70
treated Stom, green	[l]		630613,76	615702,45	600820,65	586219,50	571895,20	557844,00	544062,18	530546,04	553771,92	581630,45	567804,69
rainwater			551790,21	538742,74	525721,09	512945,01	500411,17	488116,30	476057,14	464230,45	484553,03	508929,15	496831,55
Intake for Servicewater													
overall	**[l]**		**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**
treated Greywater	[l]		32796,02	33859,13	34354,78	34843,74	35326,08	35801,84	36271,07	36733,83	36215,51	35025,81	35900,77
treated Blackwater	[l]		14907,26	15390,50	15615,79	15838,05	16057,29	16273,55	16486,83	16697,18	16461,58	15920,81	16318,52
treated Storm, roof	[l]		12881,71	12856,22	12613,77	12374,60	12138,67	11905,96	11676,44	11450,08	11703,62	11943,92	11857,57
treated Stom, green	[l]		13559,69	13532,85	13277,65	13025,89	12777,54	12532,58	12290,98	12052,71	12319,59	12572,54	12481,65
rainwater			11864,80	11841,31	11618,01	11397,72	11180,41	10966,07	10754,67	10546,19	10779,70	11001,02	10921,50
Evaporation nach Penman													
overall	**[l]**		**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**
treated Greywater			3269,08	3375,05	3424,46	3473,20	3521,27	3568,70	3615,47	3661,60	3609,93	3491,34	3578,56
treated Blackwater			1485,94	1534,11	1556,57	1578,72	1600,58	1622,13	1643,39	1664,36	1640,88	1586,97	1626,62
treated Storm, roof			1284,04	1281,50	1257,33	1233,49	1209,97	1186,78	1163,90	1141,34	1166,61	1190,56	1181,95
treated Stom, green			1351,62	1348,94	1323,51	1298,41	1273,66	1249,24	1225,16	1201,40	1228,01	1253,22	1244,16
rainwater			1182,67	1180,33	1158,07	1136,12	1114,45	1093,09	1072,02	1051,24	1074,51	1096,57	1088,65
WRMS, after intake													
overall			**3903800,06**	**3883866,82**	**3862316,49**	**3840766,15**	**3819215,82**	**3797665,48**	**3776115,14**	**3754564,81**	**3836070,47**	**3903800,06**	**3883366,91**
treated Greywater	[l]		1489162,88	1503250,31	1516792,67	1529797,33	1542271,58	1554222,64	1565657,70	1576583,87	1588080,03	1581846,00	1593688,27
treated Blackwater	[l]		676891,46	683294,85	689450,49	695361,72	701031,84	706464,16	711661,94	716628,39	721853,93	719020,30	724403,17
treated Storm, roof	[l]		584917,64	570779,93	556908,82	543300,73	529952,09	516859,35	504019,01	491427,59	513213,37	539414,70	526375,18
treated Stom, green	[l]		615702,45	600820,65	586219,50	571895,20	557844,00	544062,18	530546,04	517291,92	540224,32	567804,69	554078,88
rainwater	[l]		538742,74	525721,09	512945,01	500411,17	488116,30	476057,14	464230,45	452633,03	472698,82	496831,55	484821,41
treated Greywater	%		38,15%	38,70%	39,27%	39,83%	40,38%	40,93%	41,46%	41,99%	41,40%	40,52%	41,04%
treated Blackwater	%		17,34%	17,59%	17,85%	18,10%	18,36%	18,60%	18,85%	19,09%	18,82%	18,42%	18,65%
treated Storm, roof	%		14,98%	14,70%	14,42%	14,15%	13,88%	13,61%	13,35%	13,09%	13,38%	13,82%	13,55%
treated Stom, green	%		15,77%	15,47%	15,18%	14,89%	14,61%	14,33%	14,05%	13,78%	14,08%	14,54%	14,27%
rainwater	%		13,80%	13,54%	13,28%	13,03%	12,78%	12,54%	12,29%	12,06%	12,32%	12,73%	12,48%
estimated retention time			46,51	45,50	45,25	45,00	44,76	44,51	44,27	44,02	44,95	46,26	45,49

size of inner Lake	width	15
	length	105
	depth	2
	Volume 1:	3150
	surface 1:	1575
size of extension Arwa	width	20
	length	105
	depth	1
	Volume	2100
	surface 2	2100
Total		5250
Spilllevel		4000000

Oktober

12	13	14	15	16	17	18	19	20	21
57024	57024	57024	57024	57024	57024	57024	57024	57024	57024
51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6
25920	25920	25920	25920	25920	25920	25920	25920	25920	25920
23328	23328	23328	23328	23328	23328	23328	23328	23328	23328
0	0	25920	0	39360	20160	40800	0	0	0
0,00	0,00	24624,00	0,00	37392,00	19152,00	38760,00	0,00	0,00	0,00
0	0	51840	0	78720	40320	81600	0	0	0
0,00	0,00	25920,00	0,00	39360,00	20160,00	40800,00	0,00	0,00	0,00
0,00	0,00	22680,00	0,00	34440,00	17640,00	35700,00	0,00	0,00	0,00
74649,60	74649,60	125193,60	74649,60	151401,60	113961,60	154209,60	74649,60	74649,60	74649,60
3.958.016,51	**3.936.466,17**	**3.988.139,83**	**3.966.589,50**	**4.056.231,16**	**4.036.735,28**	**4.094.585,11**	**3.980.671,89**	**3.959.121,55**	**3.937.571,22**
1645009,87	1656349,36	1667192,85	1678299,25	1688917,81	1677326,02	1673774,74	1648016,08	1659510,47	1670508,79
747731,17	752885,50	757814,37	762862,75	767689,38	762420,40	760806,20	749097,74	754322,48	759321,72
526375,18	513581,58	525654,60	512975,02	537926,07	537039,94	558230,95	532523,43	519654,07	507027,36
554078,88	540611,94	553320,39	539973,47	566237,73	565304,98	587611,31	560550,78	547004,08	533712,81
484821,41	473037,78	484157,61	472479,00	495460,18	494643,94	514161,91	490483,85	478630,45	467000,54
3958016,51	**3936466,17**	**3988139,83**	**3966589,50**	**4056231,16**	**4036735,28**	**4094585,11**	**3980671,89**	**3959121,55**	**3937571,22**
2100,00	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*
0,00	**0,00**	**0,00**	**0,00**	**56231,16**	**36735,28**	**94585,11**	**0,00**	**0,00**	**0,00**
0,00	*0,00*	*0,00*	*0,00*	*23413,31*	*15264,08*	*38664,27*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*10642,41*	*6938,21*	*17574,66*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*7457,22*	*4887,19*	*12895,16*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*7849,70*	*5144,41*	*13573,85*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*6868,52*	*4501,38*	*11877,16*	*0,00*	*0,00*	*0,00*
3958016,51	**3936466,17**	**3988139,83**	**3966589,50**	**4000000,00**	**4000000,00**	**4000000,00**	**3980671,89**	**3959121,55**	**3937571,22**
1645009,87	1656349,36	1667192,85	1678299,25	1665504,49	1662061,94	1635110,47	1648016,08	1659510,47	1670508,79
747731,17	752885,50	757814,37	762862,75	757046,97	755482,19	743231,54	749097,74	754322,48	759321,72
526375,18	513581,58	525654,60	512975,02	530468,85	532152,74	545335,79	532523,43	519654,07	507027,36
554078,88	540611,94	553320,39	539973,47	558388,03	560160,56	574037,46	560550,78	547004,08	533712,81
484821,41	473037,78	484157,61	472479,00	488591,66	490142,56	502284,75	490483,85	478630,45	467000,54
87480	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**
36357,97	36809,01	36569,94	37013,57	35919,63	36018,51	34933,81	36217,11	36668,23	37113,26
16526,34	16731,36	16622,69	16824,34	16327,09	16372,04	15878,99	16462,31	16667,37	16869,65
11633,93	11413,31	11530,25	11313,26	11440,53	11532,27	11650,99	11702,84	11482,18	11264,50
12246,24	12014,01	12137,10	11908,69	12042,65	12139,23	12264,20	12318,77	12086,50	11857,36
10715,51	10512,31	10620,02	10420,15	10537,37	10621,87	10731,21	10778,97	10575,73	10375,23
8719,94	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**
3624,13	3669,09	3645,26	3689,48	3580,44	3590,30	3482,17	3610,09	3655,06	3699,42
1647,33	1667,77	1656,94	1677,04	1627,47	1631,95	1582,81	1640,95	1661,39	1681,55
1159,66	1137,67	1149,33	1127,70	1140,38	1149,53	1161,36	1166,53	1144,53	1122,84
1220,70	1197,55	1209,82	1187,05	1200,40	1210,03	1222,49	1227,93	1204,77	1181,93
1068,11	1047,86	1058,59	1038,67	1050,36	1058,78	1069,68	1074,44	1054,18	1034,19
3861816,57	**3840266,23**	**3891939,90**	**3870389,56**	**3903800,06**	**3903800,06**	**3903800,06**	**3884471,95**	**3862921,62**	**3841371,28**
1605027,76	1615871,25	1626977,65	1637596,21	1626004,42	1622453,14	1596694,48	1608188,87	1619187,19	1629696,10
729557,50	734486,37	739534,75	744361,38	739092,40	737478,20	725769,74	730994,48	735993,72	740770,52
513581,58	501030,60	512975,02	500534,07	517887,94	519470,95	532523,43	519654,07	507027,36	494640,02
540611,94	527400,39	539973,47	526877,73	545144,98	546811,31	560550,78	547004,08	533712,81	520673,52
473037,78	461477,61	472479,00	461020,18	477003,94	478461,91	490483,85	478630,45	467000,54	455591,12
41,56%	42,08%	41,80%	42,31%	41,65%	41,56%	40,90%	41,40%	41,92%	42,42%
18,89%	19,13%	19,00%	19,23%	18,93%	18,89%	18,59%	18,82%	19,05%	19,28%
13,30%	13,05%	13,18%	12,93%	13,27%	13,31%	13,64%	13,38%	13,13%	12,88%
14,00%	13,73%	13,87%	13,61%	13,96%	14,01%	14,36%	14,08%	13,82%	13,55%
12,25%	12,02%	12,14%	11,91%	12,22%	12,26%	12,56%	12,32%	12,09%	11,86%
45,24	45,00	45,59	45,34	46,37	46,14	46,81	45,50	45,26	45,01

22	23	24	25	26	27	28	29	30	31
57024	57024	57024	57024	57024	57024	57024	57024	57024	57024
51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6
25920	25920	25920	25920	25920	25920	25920	25920	25920	25920
23328	23328	23328	23328	23328	23328	23328	23328	23328	23328
0	0	36000	0	0	0	0	25680	0	0
0,00	0,00	34200,00	0,00	0,00	0,00	0,00	24396,00	0,00	0,00
0	0	72000	0	0	0	0	51360	0	0
0,00	0,00	36000,00	0,00	0,00	0,00	0,00	25680,00	0,00	0,00
0,00	0,00	31500,00	0,00	0,00	0,00	0,00	22470,00	0,00	0,00
74649,60	74649,60	144849,60	74649,60	74649,60	74649,60	74649,60	124725,60	74649,60	74649,60
3.916.020,88	**3.894.470,54**	**3.974.620,21**	**3.953.069,87**	**3.931.519,54**	**3.909.969,20**	**3.888.418,87**	**3.939.414,53**	**3.917.864,20**	**3.896.313,86**
1681017,70	1691043,87	1700593,86	1710755,04	1720444,56	1729668,78	1738434,03	1746746,57	1755412,87	1763631,75
764098,52	768655,87	772996,79	777615,52	782019,86	786212,69	790196,91	793975,34	797914,58	801650,44
494640,02	482488,83	504770,55	492553,31	480566,77	468807,84	457273,40	470356,41	458870,37	447603,19
520673,52	507882,79	531337,24	518476,99	505859,59	493481,77	481340,26	495111,85	483021,29	471161,09
455591,12	444399,18	464921,78	453669,02	442628,76	431798,12	421174,27	433224,37	422645,09	412267,39
3916020,88	**3894470,54**	**3974620,21**	**3953069,87**	**3931519,54**	**3909969,20**	**3888418,87**	**3939414,53**	**3917864,20**	**3896313,86**
2100,00	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*
0,00	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
3916020,88	**3894470,54**	**3974620,21**	**3953069,87**	**3931519,54**	**3909969,20**	**3888418,87**	**3939414,53**	**3917864,20**	**3896313,86**
1681017,70	1691043,87	1700593,86	1710755,04	1720444,56	1729668,78	1738434,03	1746746,57	1755412,87	1763631,75
764098,52	768655,87	772996,79	777615,52	782019,86	786212,69	790196,91	793975,34	797914,58	801650,44
494640,02	482488,83	504770,55	492553,31	480566,77	468807,84	457273,40	470356,41	458870,37	447603,19
520673,52	507882,79	531337,24	518476,99	505859,59	493481,77	481340,26	495111,85	483021,29	471161,09
455591,12	444399,18	464921,78	453669,02	442628,76	431798,12	421174,27	433224,37	422645,09	412267,39
87480	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**
37552,26	37985,27	37429,48	37858,39	38281,51	38698,88	39110,55	38788,86	39195,72	39597,04
17069,20	17266,02	17013,39	17208,35	17400,68	17590,39	17777,52	17631,29	17816,23	17998,65
11049,76	10837,96	11109,82	10900,03	10693,06	10488,91	10287,54	10444,90	10245,88	10049,58
11631,33	11408,38	11694,55	11473,71	11255,85	11040,95	10828,99	10994,62	10785,14	10578,50
10177,45	9982,37	10232,77	10039,53	9848,91	9660,87	9475,40	9620,33	9437,03	9256,22
8719,94	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**
3743,18	3786,34	3730,94	3773,69	3815,87	3857,47	3898,51	3866,44	3907,00	3947,00
1701,44	1721,06	1695,88	1715,31	1734,49	1753,40	1772,05	1757,47	1775,91	1794,09
1101,43	1080,32	1107,42	1086,51	1065,88	1045,53	1025,45	1041,14	1021,30	1001,73
1159,40	1137,18	1165,70	1143,69	1121,97	1100,55	1079,42	1095,94	1075,05	1054,46
1014,48	995,03	1019,99	1000,73	981,73	962,99	944,50	958,95	940,68	922,65
3819820,94	**3798270,61**	**3878420,27**	**3856869,94**	**3835319,60**	**3813769,27**	**3792218,93**	**3843214,60**	**3821664,26**	**3800113,92**
1639722,27	1649272,26	1659433,44	1669122,96	1678347,18	1687112,43	1695424,97	1704091,27	1712310,15	1720087,71
745327,87	749668,79	754287,52	758691,86	762884,69	766868,91	770647,34	774586,58	778322,44	781857,71
482488,83	470570,55	492553,31	480566,77	468807,84	457273,40	445960,41	458870,37	447603,19	436551,87
507882,79	495337,24	518476,99	505859,59	493481,77	481340,26	469431,85	483021,29	471161,09	459528,13
444399,18	433421,78	453669,02	442628,76	431798,12	421174,27	410754,37	422645,09	412267,39	402088,51
42,93%	43,42%	42,79%	43,28%	43,76%	44,24%	44,71%	44,34%	44,81%	45,26%
19,51%	19,74%	19,45%	19,67%	19,89%	20,11%	20,32%	20,15%	20,37%	20,57%
12,63%	12,39%	12,70%	12,46%	12,22%	11,99%	11,76%	11,94%	11,71%	11,49%
13,30%	13,04%	13,37%	13,12%	12,87%	12,62%	12,38%	12,57%	12,33%	12,09%
11,63%	11,41%	11,70%	11,48%	11,26%	11,04%	10,83%	11,00%	10,79%	10,58%
44,76	44,52	45,43	45,19	44,94	44,70	44,45	45,03	44,79	44,54

Water Resource Managemt System in the context of Hanoi
daily chart

		Start	1	2	3	4	5	6	7	8	9	10	11	12	13
1: dom. flow Greywater	Eff.	0,9	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024
tr. Greywater	[l/d]		51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6
2: dom. flow Blackwater	Eff.	0,9	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920
tr. Blackwater	[l/d]		23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328
3: nat. flow roof runoff	Eff.	0,95	0	0	0	0	0	0	0	0	0	17280	29280	0	0
Stormwater receiving the lake	[l/d]		0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	16416,00	27816,00	0,00	0,00
4: nat. flow green space	loss. Evap.	0,2													
	loss. Infiltr.	0,3	0	0	0	0	0	0	0	0	0	34560	58560	0	0
Stormwater receiving the lake			0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	17280,00	29280,00	0,00	0,00
5: direct Precipitation on the Lakes surface															
precipitation on the lake			0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	15120,00	25620,00	0,00	0,00
daily Input to the Lake			74649,60	74649,60	74649,60	74649,60	74649,60	74649,60	74649,60	74649,60	74649,60	108345,60	131745,60	74649,60	74649,60
Water in WRMS															
overall	0,00	3.105.000,00	**3.874.763,52**	**3.853.213,19**	**3.831.662,85**	**3.810.112,52**	**3.788.562,18**	**3.767.011,85**	**3.745.461,51**	**3.723.911,17**	**3.702.360,84**	**3.729.626,50**	**3.790.792,17**	**3.769.241,83**	**3.747.691,50**
treated Greywater	[l]	1800000,00	1771409,31	1778751,59	1785664,59	1792154,27	1798226,51	1803887,18	1809142,08	1813996,95	1818457,50	1822529,38	1826841,66	1831803,02	1836372,69
treated Blackwater	[l]	800000,00	805185,71	808523,11	811665,40	814615,26	817375,38	819948,42	822337,01	824543,78	826571,31	828422,17	830382,31	832637,48	834714,60
treated Storm, roof	[l]	150000,00	436551,87	425713,46	415085,03	404663,67	394446,48	384430,62	374613,24	364991,52	355562,68	362739,95	381199,64	371525,83	362043,62
treated Stom, green	[l]	150000,00	459528,13	448119,29	436931,47	425961,62	415206,69	404663,68	394329,59	384201,47	374276,38	381831,41	401262,66	391079,71	381098,44
rainwater		205000,00	402088,51	392105,74	382316,36	372717,71	363307,11	354081,95	345039,59	336177,46	327492,97	334103,59	351105,90	342195,80	333462,15
Total	[l]		**3874763,52**	**3853213,19**	**3831662,85**	**3810112,52**	**3788562,18**	**3767011,85**	**3745461,51**	**3723911,17**	**3702360,84**	**3729626,50**	**3790792,17**	**3769241,83**	**3747691,50**
Lake surface area, accord. to the structure			*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*
Spilling of Surplus water	[l]		**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**
treated Greywater			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
treated Blackwater			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
treated Storm, roof			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
treated Stom, green			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
rainwater			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
WRMS, after spilling			**3874763,52**	**3853213,19**	**3831662,85**	**3810112,52**	**3788562,18**	**3767011,85**	**3745461,51**	**3723911,17**	**3702360,84**	**3729626,50**	**3790792,17**	**3769241,83**	**3747691,50**
treated Greywater	[l]		1771409,31	1778751,59	1785664,59	1792154,27	1798226,51	1803887,18	1809142,08	1813996,95	1818457,50	1822529,38	1826841,66	1831803,02	1836372,69
treated Blackwater	[l]		805185,71	808523,11	811665,40	814615,26	817375,38	819948,42	822337,01	824543,78	826571,31	828422,17	830382,31	832637,48	834714,60
treated Storm, roof	[l]		436551,87	425713,46	415085,03	404663,67	394446,48	384430,62	374613,24	364991,52	355562,68	362739,95	381199,64	371525,83	362043,62
treated Stom, green	[l]		459528,13	448119,29	436931,47	425961,62	415206,69	404663,68	394329,59	384201,47	374276,38	381831,41	401262,66	391079,71	381098,44
rainwater			402088,51	392105,74	382316,36	372717,71	363307,11	354081,95	345039,59	336177,46	327492,97	334103,59	351105,90	342195,80	333462,15
Intake for Servicewater															
overall	**[l]**		**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**
treated Greywater	[l]		39992,86	40383,23	40768,18	41147,78	41522,05	41891,04	42254,81	42613,38	42966,82	42748,21	42157,97	42514,15	42865,29
treated Blackwater	[l]		18178,57	18356,01	18530,99	18703,53	18873,65	19041,38	19206,72	19369,71	19530,36	19431,00	19162,71	19324,61	19484,22
treated Storm, roof	[l]		9855,97	9665,03	9476,73	9291,06	9107,99	8927,50	8749,57	8574,17	8401,29	8508,22	8796,93	8622,71	8450,96
treated Stom, green	[l]		10374,70	10173,71	9975,50	9780,06	9587,35	9397,36	9210,07	9025,44	8843,46	8956,02	9259,93	9076,53	8895,74
rainwater			9077,90	8902,03	8728,60	8557,58	8388,96	8222,72	8058,84	7897,29	7738,06	7836,54	8102,46	7941,99	7783,80
Evaporation nach Penman															
overall	**[l]**		**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**
treated Greywater			3986,46	4025,37	4063,74	4101,58	4138,88	4175,67	4211,92	4247,67	4282,90	4261,11	4202,27	4237,78	4272,78
treated Blackwater			1812,02	1829,71	1847,15	1864,35	1881,31	1898,03	1914,51	1930,76	1946,77	1936,87	1910,12	1926,26	1942,17
treated Storm, roof			982,44	963,40	944,63	926,13	907,88	889,89	872,15	854,67	837,43	848,09	876,87	859,50	842,38
treated Stom, green			1034,14	1014,11	994,35	974,87	955,66	936,72	918,05	899,65	881,51	892,73	923,02	904,74	886,72
rainwater			904,88	887,35	870,06	853,01	836,21	819,63	803,30	787,20	771,32	781,14	807,65	791,65	775,88
WRMS, after intake															
overall			**3778563,59**	**3757013,25**	**3735462,92**	**3713912,58**	**3692362,25**	**3670811,91**	**3649261,57**	**3627711,24**	**3606160,90**	**3633426,57**	**3694592,23**	**3673041,90**	**3651491,56**
treated Greywater	[l]		1727429,99	1734342,99	1740832,67	1746904,91	1752565,58	1757820,48	1762675,35	1767135,90	1771207,78	1775520,06	1780481,42	1785051,09	1789234,62
treated Blackwater	[l]		785195,11	788337,40	791287,26	794047,38	796620,42	799009,01	801215,78	803243,31	805094,17	807054,31	809309,48	811386,60	813288,22
treated Storm, roof	[l]		425713,46	415085,03	404663,67	394446,48	384430,62	374613,24	364991,52	355562,68	346323,95	353383,64	371525,83	362043,62	352750,28
treated Stom, green	[l]		448119,29	436931,47	425961,62	415206,69	404663,68	394329,59	384201,47	374276,38	364551,41	371982,66	391079,71	381098,44	371315,97
rainwater	[l]		392105,74	382316,36	372717,71	363307,11	354081,95	345039,59	336177,46	327492,97	318983,59	325485,90	342195,80	333462,15	324902,47
treated Greywater	%		45,72%	46,16%	46,60%	47,04%	47,46%	47,89%	48,30%	48,71%	49,12%	48,87%	48,19%	48,60%	49,00%
treated Blackwater	%		20,78%	20,98%	21,18%	21,38%	21,57%	21,77%	21,96%	22,14%	22,33%	22,21%	21,91%	22,09%	22,27%
treated Storm, roof	%		11,27%	11,05%	10,83%	10,62%	10,41%	10,21%	10,00%	9,80%	9,60%	9,73%	10,06%	9,86%	9,66%
treated Stom, green	%		11,86%	11,63%	11,40%	11,18%	10,96%	10,74%	10,53%	10,32%	10,11%	10,24%	10,59%	10,38%	10,17%
rainwater	%		10,38%	10,18%	9,98%	9,78%	9,59%	9,40%	9,21%	9,03%	8,85%	8,96%	9,26%	9,08%	8,90%
estimated retention time			44,29	44,05	43,80	43,55	43,31	43,06	42,82	42,57	42,32	42,63	43,33	43,09	42,84

size of inner Lake	width	15
	length	105
	depth	2
	Volume 1:	3150
	surface 1:	1575
size of extension Arwa	width	20
	length	105
	depth	1
	Volume	2100
	surface 2	2100
Total		5250
Spilllevel		4000000

November																
14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	###	57024
51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	###	51321,6
25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	###	25920
23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	###	23328
0	3360	33120	0	0	0	0	0	22320	0	0	0	0	0	0	0	0
0,00	3192,00	31464,00	0,00	0,00	0,00	0,00	0,00	21204,00	0,00	0,00	0,00	0,00	0,00	0,00	###	0,00
0	6720	66240	0	0	0	0	0	44640	0	0	0	0	0	0	0	0
0,00	3360,00	33120,00	0,00	0,00	0,00	0,00	0,00	22320,00	0,00	0,00	0,00	0,00	0,00	0,00	###	0,00
0,00	2940,00	28980,00	0,00	0,00	0,00	0,00	0,00	19530,00	0,00	0,00	0,00	0,00	0,00	0,00	###	0,00
74649,60	81201,60	139233,60	74649,60	74649,60	74649,60	74649,60	74649,60	118173,60	74649,60	74649,60	74649,60	74649,60	74649,60	74649,60	###	74649,60
3.726.141,16	**3.714.082,83**	**3.786.096,49**	**3.764.546,15**	**3.742.995,82**	**3.721.445,48**	**3.699.895,15**	**3.678.344,81**	**3.719.848,48**	**3.698.298,14**	**3.676.747,80**	**3.655.197,47**	**3.633.647,13**	**3.612.096,80**	**3.590.546,46**	**###**	**3.547.445,79**
1840556,22	1844359,12	1847909,24	1852277,80	1856265,93	1859879,05	1863122,49	1866001,56	1868521,53	1871520,83	1874160,53	1876445,82	1878381,86	1879973,76	1881226,55	###	1882734,89
836616,22	838344,81	839958,51	841944,23	843757,02	845399,35	846873,65	848182,32	849327,77	850691,09	851890,96	852929,74	853809,76	854533,35	855102,81	###	855788,43
352750,28	346835,12	369315,61	359931,76	350734,00	341719,67	332886,16	324230,88	336955,26	328241,17	319702,98	311338,14	303144,14	295118,47	287258,66	###	272026,85
371315,97	365089,50	388753,17	378875,44	369193,58	359704,82	350406,40	341295,58	354689,66	345516,94	336529,37	327724,28	319099,01	310650,94	302377,46	###	286343,98
324902,47	319454,28	340159,97	331516,93	323045,28	314742,59	306606,45	298634,46	310354,26	302328,11	294463,97	286759,49	279212,36	271820,28	264580,97	###	250551,64
3726141,16	**3714082,83**	**3786096,49**	**3764546,15**	**3742995,82**	**3721445,48**	**3699895,15**	**3678344,81**	**3719848,48**	**3698298,14**	**3676747,80**	**3655197,47**	**3633647,13**	**3612096,80**	**3590546,46**	**###**	**3547445,79**
2100,00	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	###	*2100,00*
0,00	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**###**	**0,00**
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	###	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	###	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	###	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	###	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	###	*0,00*
3726141,16	**3714082,83**	**3786096,49**	**3764546,15**	**3742995,82**	**3721445,48**	**3699895,15**	**3678344,81**	**3719848,48**	**3698298,14**	**3676747,80**	**3655197,47**	**3633647,13**	**3612096,80**	**3590546,46**	**###**	**3547445,79**
1840556,22	1844359,12	1847909,24	1852277,80	1856265,93	1859879,05	1863122,49	1866001,56	1868521,53	1871520,83	1874160,53	1876445,82	1878381,86	1879973,76	1881226,55	###	1882734,89
836616,22	838344,81	839958,51	841944,23	843757,02	845399,35	846873,65	848182,32	849327,77	850691,09	851890,96	852929,74	853809,76	854533,35	855102,81	###	855788,43
352750,28	346835,12	369315,61	359931,76	350734,00	341719,67	332886,16	324230,88	336955,26	328241,17	319702,98	311338,14	303144,14	295118,47	287258,66	###	272026,85
371315,97	365089,50	388753,17	378875,44	369193,58	359704,82	350406,40	341295,58	354689,66	345516,94	336529,37	327724,28	319099,01	310650,94	302377,46	###	286343,98
324902,47	319454,28	340159,97	331516,93	323045,28	314742,59	306606,45	298634,46	310354,26	302328,11	294463,97	286759,49	279212,36	271820,28	264580,97	###	250551,64
87480	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**###**	**87480**
43211,42	43441,29	42697,04	43042,97	43384,00	43720,17	44051,51	44378,06	43942,18	44269,18	44591,46	44909,06	45222,02	45530,37	45834,17	###	46428,24
19641,55	19746,03	19407,74	19564,98	19720,00	19872,80	20023,41	20171,84	19973,71	20122,35	20268,84	20413,20	20555,46	20695,62	20833,71	###	21103,74
8281,65	8169,21	8533,26	8364,04	8197,23	8032,80	7870,73	7711,00	7924,21	7764,26	7606,62	7451,27	7298,19	7147,36	6998,76	###	6708,18
8717,52	8599,17	8982,37	8804,25	8628,66	8455,58	8284,98	8116,84	8341,27	8172,90	8006,96	7843,44	7682,30	7523,54	7367,12	###	7061,24
7627,86	7524,30	7859,60	7703,74	7550,10	7398,65	7249,38	7102,25	7298,63	7151,31	7006,11	6863,03	6722,03	6583,11	6446,25	###	6178,60
8719,94	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**###**	**8719,94**
4307,28	4330,19	4256,01	4290,49	4324,48	4357,99	4391,02	4423,57	4380,12	4412,72	4444,84	4476,50	4507,69	4538,43	4568,71	###	4627,93
1957,85	1968,27	1934,55	1950,22	1965,67	1980,90	1995,92	2010,71	1990,96	2005,78	2020,38	2034,77	2048,95	2062,92	2076,69	###	2103,60
825,51	814,30	850,59	833,72	817,09	800,70	784,55	768,63	789,88	773,93	758,22	742,74	727,48	712,44	697,63	###	668,67
868,96	857,16	895,36	877,60	860,10	842,85	825,84	809,08	831,45	814,67	798,13	781,83	765,77	749,94	734,35	###	703,86
760,34	750,02	783,44	767,90	752,59	737,49	722,61	707,95	727,52	712,84	698,36	684,10	670,05	656,20	642,56	###	615,88
3629941,23	**3617882,89**	**3689896,55**	**3668346,22**	**3646795,88**	**3625245,55**	**3603695,21**	**3582144,88**	**3623648,54**	**3602098,20**	**3580547,87**	**3558997,53**	**3537447,20**	**3515896,86**	**3494346,53**	**###**	**3451245,85**
1793037,52	1796587,64	1800956,20	1804944,33	1808557,45	1811800,89	1814679,96	1817199,93	1820199,23	1822838,93	1825124,22	1827060,26	1828652,16	1829904,95	1830823,68	###	1831678,73
815016,81	816630,51	818616,23	820429,02	822071,35	823545,65	824854,32	825999,77	827363,09	828562,96	829601,74	830481,76	831205,35	831774,81	832192,42	###	832581,08
343643,12	337851,61	359931,76	350734,00	341719,67	332886,16	324230,88	315751,26	328241,17	319702,98	311338,14	303144,14	295118,47	287258,66	279562,27	###	264650,00
361729,50	355633,17	378875,44	369193,58	359704,82	350406,40	341295,58	332369,66	345516,94	336529,37	327724,28	319099,01	310650,94	302377,46	294276,00	###	278578,88
316514,28	311179,97	331516,93	323045,28	314742,59	306606,45	298634,46	290824,26	302328,11	294463,97	286759,49	279212,36	271820,28	264580,97	257492,17	###	243757,16
49,40%	49,66%	48,81%	49,20%	49,59%	49,98%	50,36%	50,73%	50,23%	50,60%	50,97%	51,34%	51,69%	52,05%	52,39%	###	53,07%
22,45%	22,57%	22,19%	22,37%	22,54%	22,72%	22,89%	23,06%	22,83%	23,00%	23,17%	23,33%	23,50%	23,66%	23,82%	###	24,12%
9,47%	9,34%	9,75%	9,56%	9,37%	9,18%	9,00%	8,81%	9,06%	8,88%	8,70%	8,52%	8,34%	8,17%	8,00%	###	7,67%
9,97%	9,83%	10,27%	10,06%	9,86%	9,67%	9,47%	9,28%	9,54%	9,34%	9,15%	8,97%	8,78%	8,60%	8,42%	###	8,07%
8,72%	8,60%	8,98%	8,81%	8,63%	8,46%	8,29%	8,12%	8,34%	8,17%	8,01%	7,85%	7,68%	7,53%	7,37%	###	7,06%
42,59	42,46	43,28	43,03	42,79	42,54	42,29	42,05	42,52	42,28	42,03	41,78	41,54	41,29	41,04	###	40,55

Water Resource Managemt System in the context of Hanoi
daily chart

		Start	1	2	3	4	5	6	7	8	9	10	11	12
1: dom. flow Greywater	Eff.	0,9	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024
tr. Greywater	[l/d]		51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6
2: dom. flow Blackwater	Eff.	0,9	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920
tr. Blackwater	[l/d]		23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328
3: nat. flow roof runoff	Eff.	0,95	0	0	0	0	0	0	0	0	0	0	0	0
Stormwater receiving the lake	[l/d]		0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
4: nat. flow green space	loss. Evap.	0,2												
	loss. Infiltr.	0,3	0	0	0	0	0	0	0	0	0	0	0	0
Stormwater receiving the lake			0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
5: direct Precipitation on the Lakes surface														
precipitation on the lake			0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
daily Input to the Lake			74649,60	74649,60	74649,60	74649,60	74649,60	74649,60	74649,60	74649,60	74649,60	74649,60	74649,60	74649,60
Water in WRMS														
overall	0,00	3.105.000,00	**3.525.895,45**	**3.504.345,12**	**3.482.794,78**	**3.461.244,45**	**3.439.694,11**	**3.418.143,78**	**3.396.593,44**	**3.375.043,11**	**3.353.492,77**	**3.331.942,43**	**3.310.392,10**	**3.288.841,76**
treated Greywater	[l]	1800000,00	1883000,33	1882946,47	1882578,14	1881900,15	1880917,25	1879634,14	1878055,48	1876185,90	1874029,97	1871592,23	1868877,17	1865889,23
treated Blackwater	[l]	800000,00	855909,08	855884,60	855717,19	855409,02	854962,25	854379,02	853661,45	852811,64	851831,68	850723,62	849489,50	848131,35
treated Storm, roof	[l]	150000,00	264650,00	257429,34	250362,49	243447,10	236680,87	230061,48	223586,65	217254,12	211061,66	205007,04	199088,07	193302,57
treated Stom, green	[l]	150000,00	278578,88	270978,18	263539,39	256260,05	249137,70	242169,92	235354,31	228688,49	222170,11	215796,83	209566,34	203476,34
rainwater		205000,00	243757,16	237106,53	230597,57	224228,13	217996,05	211899,23	205935,56	200102,95	194399,35	188822,72	183371,02	178042,26
Total	[l]		**3525895,45**	**3504345,12**	**3482794,78**	**3461244,45**	**3439694,11**	**3418143,78**	**3396593,44**	**3375043,11**	**3353492,77**	**3331942,43**	**3310392,10**	**3288841,76**
Lake surface area, accord. to the structure			*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*
Spilling of Surplus water	[l]		**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**
treated Greywater			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
treated Blackwater			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
treated Storm, roof			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
treated Stom, green			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
rainwater			*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
WRMS, after spilling			**3525895,45**	**3504345,12**	**3482794,78**	**3461244,45**	**3439694,11**	**3418143,78**	**3396593,44**	**3375043,11**	**3353492,77**	**3331942,43**	**3310392,10**	**3288841,76**
treated Greywater	[l]		1883000,33	1882946,47	1882578,14	1881900,15	1880917,25	1879634,14	1878055,48	1876185,90	1874029,97	1871592,23	1868877,17	1865889,23
treated Blackwater	[l]		855909,08	855884,60	855717,19	855409,02	854962,25	854379,02	853661,45	852811,64	851831,68	850723,62	849489,50	848131,35
treated Storm, roof	[l]		264650,00	257429,34	250362,49	243447,10	236680,87	230061,48	223586,65	217254,12	211061,66	205007,04	199088,07	193302,57
treated Stom, green	[l]		278578,88	270978,18	263539,39	256260,05	249137,70	242169,92	235354,31	228688,49	222170,11	215796,83	209566,34	203476,34
rainwater			243757,16	237106,53	230597,57	224228,13	217996,05	211899,23	205935,56	200102,95	194399,35	188822,72	183371,02	178042,26
Intake for Servicewater														
overall	**[l]**		**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**
treated Greywater	[l]		46718,59	47004,55	47286,14	47563,42	47836,42	48105,17	48369,73	48630,12	48886,39	49138,57	49386,71	49630,84
treated Blackwater	[l]		21235,72	21365,70	21493,70	21619,73	21743,82	21865,98	21986,24	22104,60	22221,08	22335,71	22448,50	22559,47
treated Storm, roof	[l]		6566,16	6426,28	6288,54	6152,92	6019,38	5887,93	5758,52	5631,15	5505,80	5382,45	5261,08	5141,66
treated Stom, green	[l]		6911,74	6764,51	6619,52	6476,75	6336,19	6197,82	6061,60	5927,53	5795,58	5665,74	5537,97	5412,27
rainwater			6047,79	5918,96	5792,09	5667,17	5544,18	5423,10	5303,91	5186,60	5071,15	4957,53	4845,74	4735,75
Evaporation nach Penman														
overall	**[l]**		**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**
treated Greywater			4656,87	4685,38	4713,44	4741,08	4768,30	4795,08	4821,46	4847,41	4872,96	4898,09	4922,83	4947,16
treated Blackwater			2116,76	2129,72	2142,47	2155,04	2167,41	2179,58	2191,57	2203,37	2214,98	2226,41	2237,65	2248,71
treated Storm, roof			654,51	640,57	626,84	613,32	600,01	586,90	574,00	561,31	548,81	536,52	524,42	512,52
treated Stom, green			688,96	674,28	659,83	645,60	631,59	617,79	604,22	590,85	577,70	564,76	552,02	539,49
rainwater			602,84	590,00	577,35	564,90	552,64	540,57	528,69	517,00	505,49	494,16	483,02	472,06
WRMS, after intake														
overall			**3429695,52**	**3408145,18**	**3386594,85**	**3365044,51**	**3343494,18**	**3321943,84**	**3300393,51**	**3278843,17**	**3257292,83**	**3235742,50**	**3214192,16**	**3192641,83**
treated Greywater	[l]		1831624,87	1831256,54	1830578,55	1829595,65	1828312,54	1826733,88	1824864,30	1822708,37	1820270,63	1817555,57	1814567,63	1811311,22
treated Blackwater	[l]		832556,60	832389,19	832081,02	831634,25	831051,02	830333,45	829483,64	828503,68	827395,62	826161,50	824803,35	823323,17
treated Storm, roof	[l]		257429,34	250362,49	243447,10	236680,87	230061,48	223586,65	217254,12	211061,66	205007,04	199088,07	193302,57	187648,40
treated Stom, green	[l]		270978,18	263539,39	256260,05	249137,70	242169,92	235354,31	228688,49	222170,11	215796,83	209566,34	203476,34	197524,58
rainwater	[l]		237106,53	230597,57	224228,13	217996,05	211899,23	205935,56	200102,95	194399,35	188822,72	183371,02	178042,26	172834,46
treated Greywater	%		53,40%	53,73%	54,05%	54,37%	54,68%	54,99%	55,29%	55,59%	55,88%	56,17%	56,45%	56,73%
treated Blackwater	%		24,27%	24,42%	24,57%	24,71%	24,86%	25,00%	25,13%	25,27%	25,40%	25,53%	25,66%	25,79%
treated Storm, roof	%		7,51%	7,35%	7,19%	7,03%	6,88%	6,73%	6,58%	6,44%	6,29%	6,15%	6,01%	5,88%
treated Stom, green	%		7,90%	7,73%	7,57%	7,40%	7,24%	7,08%	6,93%	6,78%	6,63%	6,48%	6,33%	6,19%
rainwater	%		6,91%	6,77%	6,62%	6,48%	6,34%	6,20%	6,06%	5,93%	5,80%	5,67%	5,54%	5,41%
estimated retention time			40,31	40,06	39,81	39,57	39,32	39,07	38,83	38,58	38,33	38,09	37,84	37,60
size of inner Lake	width	15												
	length	105												
	depth	2	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%
	Volume 1:	3150												
	surface 1:	1575												
size of extension Arwa	width	20												
	length	105												
	depth	1												
	Volume	2100												
	surface 2	2100												
Total		5250												
Spilllevel		4000000												

		Dezember																
13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024	57024
51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6	51321,6
25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920	25920
23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328	23328
0	0	0	0	0	19680	23520	0	0	0	8400	0	0	0	0	0	4560	0	0
0,00	0,00	0,00	0,00	0,00	18696,00	22344,00	0,00	0,00	0,00	7980,00	0,00	0,00	0,00	0,00	0,00	4332,00	0,00	0,00
0	0	0	0	0	39360	47040	0	0	0	16800	0	0	0	0	0	9120	0	0
0,00	0,00	0,00	0,00	0,00	19680,00	23520,00	0,00	0,00	0,00	8400,00	0,00	0,00	0,00	0,00	0,00	4560,00	0,00	0,00
0,00	0,00	0,00	0,00	0,00	17220,00	20580,00	0,00	0,00	0,00	7350,00	0,00	0,00	0,00	0,00	0,00	3990,00	0,00	0,00
74649,60	74649,60	74649,60	74649,60	74649,60	113025,60	120513,60	74649,60	74649,60	74649,60	91029,60	74649,60	74649,60	74649,60	74649,60	74649,60	83541,60	74649,60	74649,60
3.267.291,43	**3.245.741,09**	**3.224.190,76**	**3.202.640,42**	**3.181.090,08**	**3.215.135,75**	**3.260.029,41**	**3.238.479,08**	**3.216.928,74**	**3.195.378,41**	**3.197.558,07**	**3.176.007,74**	**3.154.457,40**	**3.132.907,06**	**3.113.536,71**	**3.094.166,36**	**3.087.678,01**	**3.068.307,66**	**3.048.937,31**
1862632,82	1859112,31	1855332,02	1851296,22	1847009,15	1842475,00	1838667,99	1835732,49	1832523,14	1829044,45	1825300,91	1821707,53	1817850,38	1813733,89	1810624,52	1807270,41	1803675,93	1800075,51	1796238,69
846651,17	845050,94	843332,63	841498,18	839549,51	837488,54	835758,08	834423,77	832964,97	831383,76	829682,15	828048,80	826295,55	824424,42	823011,07	821486,48	819852,63	818216,08	816472,07
187648,40	182123,40	176725,48	171452,53	166302,50	179969,31	196928,46	191117,31	185440,12	179894,66	182458,76	176969,41	171609,08	166375,60	161382,60	156509,30	156085,58	151332,77	146695,58
197524,58	191708,80	186026,77	180476,31	175055,22	189441,34	207293,07	201176,08	195200,09	189362,77	192061,82	186283,56	180641,11	175132,18	169876,39	164746,60	164300,58	159297,62	154416,38
172834,46	167745,63	162773,85	157917,18	153173,71	165761,56	181381,81	176029,43	170800,43	165692,77	168054,43	162998,43	158061,28	153240,96	148642,13	144153,56	143763,28	139385,69	135114,59
3267291,43	**3245741,09**	**3224190,76**	**3202640,42**	**3181090,08**	**3215135,75**	**3260029,41**	**3238479,08**	**3216928,74**	**3195378,41**	**3197558,07**	**3176007,74**	**3154457,40**	**3132907,06**	**3113536,71**	**3094166,36**	**3087678,01**	**3068307,66**	**3048937,31**
2100,00	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*2100,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*	*1575,00*
0,00	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
0,00	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
3267291,43	**3245741,09**	**3224190,76**	**3202640,42**	**3181090,08**	**3215135,75**	**3260029,41**	**3238479,08**	**3216928,74**	**3195378,41**	**3197558,07**	**3176007,74**	**3154457,40**	**3132907,06**	**3113536,71**	**3094166,36**	**3087678,01**	**3068307,66**	**3048937,31**
1862632,82	1859112,31	1855332,02	1851296,22	1847009,15	1842475,00	1838667,99	1835732,49	1832523,14	1829044,45	1825300,91	1821707,53	1817850,38	1813733,89	1810624,52	1807270,41	1803675,93	1800075,51	1796238,69
846651,17	845050,94	843332,63	841498,18	839549,51	837488,54	835758,08	834423,77	832964,97	831383,76	829682,15	828048,80	826295,55	824424,42	823011,07	821486,48	819852,63	818216,08	816472,07
187648,40	182123,40	176725,48	171452,53	166302,50	179969,31	196928,46	191117,31	185440,12	179894,66	182458,76	176969,41	171609,08	166375,60	161382,60	156509,30	156085,58	151332,77	146695,58
197524,58	191708,80	186026,77	180476,31	175055,22	189441,34	207293,07	201176,08	195200,09	189362,77	192061,82	186283,56	180641,11	175132,18	169876,39	164746,60	164300,58	159297,62	154416,38
172834,46	167745,63	162773,85	157917,18	153173,71	165761,56	181381,81	176029,43	170800,43	165692,77	168054,43	162998,43	158061,28	153240,96	148642,13	144153,56	143763,28	139385,69	135114,59
87480	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**	**87480**
49871,01	50107,25	50339,59	50568,09	50792,76	50131,54	49339,03	49588,05	49832,97	50073,82	49937,27	50177,14	50412,97	50644,80	50872,51	51096,16	51101,69	51321,65	51537,62
22668,64	22776,02	22881,63	22985,49	23087,62	22787,06	22426,83	22540,02	22651,35	22760,83	22698,76	22807,79	22914,98	23020,36	23123,87	23225,52	23228,04	23328,02	23426,19
5024,19	4908,63	4794,98	4683,22	4573,32	4896,75	5284,40	5162,59	5042,79	4924,98	4991,78	4874,45	4759,10	4645,70	4534,31	4424,92	4422,21	4314,62	4208,98
5288,62	5166,98	5047,35	4929,70	4814,02	5154,47	5562,53	5434,31	5308,20	5184,19	5254,50	5131,00	5009,57	4890,21	4772,96	4657,81	4654,96	4541,71	4430,51
4627,55	4521,12	4416,44	4313,50	4212,28	4510,17	4867,22	4755,03	4644,69	4536,18	4597,70	4489,63	4383,38	4278,94	4176,35	4075,59	4073,10	3974,00	3876,70
8719,94	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**8719,94**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**	**6539,95**
4971,10	4994,65	5017,81	5040,59	5062,98	4997,07	4918,07	4942,90	4967,31	4991,32	4977,71	5001,62	5025,12	3786,17	3803,20	3819,92	3820,33	3836,78	3852,92
2259,59	2270,30	2280,82	2291,18	2301,36	2271,40	2235,49	2246,77	2257,87	2268,78	2262,59	2273,46	2284,15	1720,99	1728,73	1736,33	1736,51	1743,99	1751,33
500,81	489,29	477,96	466,82	455,86	488,10	526,74	514,60	502,66	490,92	497,58	485,88	474,38	347,31	338,98	330,80	330,60	322,56	314,66
527,16	515,04	503,12	491,39	479,86	513,79	554,47	541,69	529,12	516,76	523,76	511,45	499,35	365,59	356,82	348,21	348,00	339,54	331,22
461,27	450,66	440,23	429,97	419,88	449,57	485,16	473,98	462,98	452,16	458,29	447,52	436,93	319,89	312,22	304,69	304,50	297,09	289,82
3171091,49	**3149541,16**	**3127990,82**	**3106440,48**	**3084890,15**	**3118935,81**	**3163829,48**	**3142279,14**	**3120728,81**	**3099178,47**	**3101358,14**	**3079807,80**	**3058257,46**	**3038887,11**	**3019516,76**	**3000146,41**	**2993658,06**	**2974287,71**	**2954917,35**
1807790,71	1804010,42	1799974,62	1795687,55	1791153,40	1787346,39	1784410,89	1781201,54	1777722,85	1773979,31	1770385,93	1766528,78	1762412,29	1759302,92	1755948,81	1752354,33	1748753,91	1744917,09	1740848,15
821722,94	820004,63	818170,18	816221,51	814160,54	812430,08	811095,77	809636,97	808055,76	806354,15	804720,80	802967,55	801096,42	799683,07	798158,48	796524,63	794888,08	793144,07	791294,55
182123,40	176725,48	171452,53	166302,50	161273,31	174584,46	191117,31	185440,12	179894,66	174478,76	176969,41	171609,08	166375,60	161382,60	156509,30	151753,58	151332,77	146695,58	142171,94
191708,80	186026,77	180476,31	175055,22	169761,34	183773,07	201176,08	195200,09	189362,77	183661,82	186283,56	180641,11	175132,18	169876,39	164746,60	159740,58	159297,62	154416,38	149654,65
167745,63	162773,85	157917,18	153173,71	148541,56	160801,81	176029,43	170800,43	165692,77	160704,43	162998,43	158061,28	153240,96	148642,13	144153,56	139773,28	139385,69	135114,59	130948,07
57,01%	57,28%	57,54%	57,81%	58,06%	57,31%	56,40%	56,69%	56,96%	57,24%	57,08%	57,36%	57,63%	57,89%	58,15%	58,41%	58,42%	58,67%	58,91%
25,91%	26,04%	26,16%	26,28%	26,39%	26,05%	25,64%	25,77%	25,89%	26,02%	25,95%	26,07%	26,19%	26,31%	26,43%	26,55%	26,55%	26,67%	26,78%
5,74%	5,61%	5,48%	5,35%	5,23%	5,60%	6,04%	5,90%	5,76%	5,63%	5,71%	5,57%	5,44%	5,31%	5,18%	5,06%	5,06%	4,93%	4,81%
6,05%	5,91%	5,77%	5,64%	5,50%	5,89%	6,36%	6,21%	6,07%	5,93%	6,01%	5,87%	5,73%	5,59%	5,46%	5,32%	5,32%	5,19%	5,06%
5,29%	5,17%	5,05%	4,93%	4,82%	5,16%	5,56%	5,44%	5,31%	5,19%	5,26%	5,13%	5,01%	4,89%	4,77%	4,66%	4,66%	4,54%	4,43%
37,35	37,10	36,86	36,61	36,36	36,75	37,27	37,02	36,77	36,53	36,55	36,31	36,06	35,81	35,59	35,37	35,30	35,07	34,85
100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%

9.5. Flood protection

The following paragraphs are part of a conceptual consideration of the extent to which hydrological calculations can be simplified in order to undertake an initial potential assessment with regard to flood protection in the context of WSUD, ie. in the context of the described scenario in chapter 8. They have no claim to a complete hydrological calculation and serve only as a sketch, which shows complex procedures in a simplified way.

It should give an idea of what a precipitation-discharge ratio can look like in the case of defined heavy rainfall with a duration of 1 hour on very small areas, with reference to the area between the buildings according to Chapter 8. Furthermore, it shows the amount of Runoff that is produced and the time the Runoff needs to drain to the Reservoir (i.e. WRMS).

The calculations were divided into several sub-processes. It is assumed, that a ‚designed Storm', precipitates on the defined surface (Input), while the Precipitation becomes Runoff in dependancy of the soil and the structure of the collection area (System), and drains through a pipe or an open sewer to the WRMS (Output):

I Runoff Formation (Input), *Assuming a desigend Precipitation*
Assumption of the precipitation by simulation of an Euler model rainfall type 2 from measured precipitation values of the IDF charts for Ha Noi. The one hour rain events were divided into 5 min intervals via a typical growth function.

II Runoff Concentration (System), *Designing a Runoff*
Creation of a Runoff by using the SCS method for very small areas with the aid of the hydrological software ‚HEC-Hms' „to simulate the complete hydrologic processes of dendritic watershed systems".

III Dewatering Calculation (Output), *Bioswale & Drainage Pipe*
The calculation of the open channels was calculated by using the Maning-Strickler formula and an online calculation Tool for Channel Hydraulics.

http://www.peacesoftware.de/einigewerte/gerinnehydraulik.html

The Calculation of the dewatering processes under the assumption of an DN-110 KG drainage pipe is performed in iterative steps, second per second:
$\sum$ t= 0 to 3600 for (Q_z-Q_a) dt = Ret(t) +(Q_z-Q_a) dt.

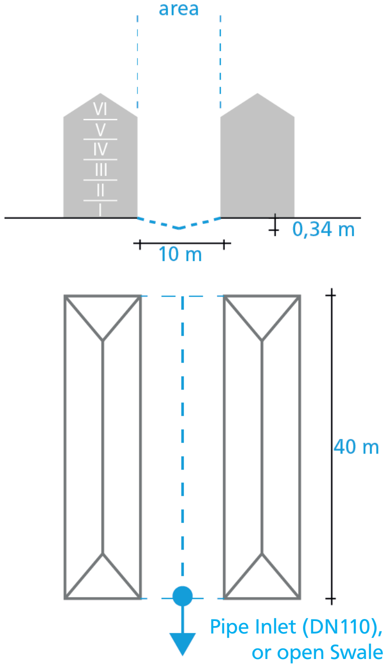
Furthermore, the Toricelli Equation was used to calculate the the the water pressure at the pipe inlet and the velocity of the waterstream, as well as the remaining water level in the Watershed, inbetween the buildings.

additional Assumptions/Simplifications:

- *the precipation on the area is evenly distributed over the whole surface*
- *The system input and output is charcterised by linearity*
- *The catchment area is time invariant*
- *The rain event is comparable with the rain model Euler type II*
- *The inreasing Water saturation of the soil and further influences on the infiltration capacity are not considered.*

The designed rainfall has been chosen for 5, 20, and 50 years, with a duration of one hour, to allow a first conclusion about the expected water quantities. However, a precise hydrological investigation includes further rain events of varying durations.

Systemativ Illustration of the Watershed:



9.5.1 Evaluation & Summary of the Results

The equations and results from the dewatering calculation are based on the following assumption:

effective precipitation [1h] :

$N_{eff,5}$ = 59.18 mm (N_5 = 84.95mm)

$N_{eff,20}$ = 79.48 mm (N_{20} =106.42mm)

$N_{eff,50}$ = 89.98 mm (N_{50} =117.38mm)

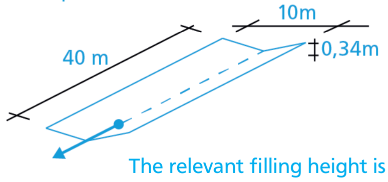
volume flow (peak) of the rainevent:

$Q_{5;1h}$ = 0.03020 m³/s

$Q_{20;1h}$ = 0.03971 m³/s

$Q_{50;1h}$ = 0.04487 m³/s

schematic simplification



The relevant filling height is considered as: h_b=0,297 m, (h_G = 0,34 m)

fig. 92:
Simplified Illustration of the relevant Watershed inbetween the buildings

cross section surface area:	A_G =	$G*h/2 = 1.485\ m^2$; $h_B = 0.297$ m
cross section surface:	$A_{R/K}$ =	$Pi*r^2 = 0.0085\ m^2$
volume area:	V_B =	$59{,}4m^3$ (= A_G * 40m)

9.5.2 Results

Under the assumptions described above, the 5-year rain event will not lead to any significant retention due to insufficient water masses.

Open drainage channel for 20 years rainfall event:

Runoff open channel:	$Q_K = v_m * A_K = 3.38 m/s * 0.0085\ m^2$	$=0.0287 m^3/s$
Retention open channel:	Ret(t) =	$= 3.3\ m^3$
Duration of Runoff retention:	Ret(t)= 0 between t = 901s - 1560s	**= 11 min**

Open drainage channel for 50 years rainfall event:

Runoff open channel:	$Q_K = v_m * A_K = 3.38\ m/s * 0.0085\ m^2$	$=0.0304\ m^3/s$
Retention open channel:	Ret(t) =	$= 4.81 m^3$
Duration of Runoff retention:	Ret(t)= 0 between t = 901s - 1688s	**= 14 min**

Closed pipe channel for 20 years rainfall event:

moment t [s]	Water depth	Runoff	Retention
1	0.000 m	$0.0092\ m^3/s$	$0.00\ m^3$
600	0.034m	$0.0071\ m^3/s$	$0.022\ m^3$
1500	0.27 m	$0.0194\ m^3/s$	$9.19\ m^3$
2335	0.023m	$0.0057 m^3/s$	$0.0027 m^3$

Duration of runoff : T_A = 15 + 14 = **29 min**.

Closed pipe channel for 50 years rainfall event:

moment t [s]	Water depth	Runoff	Retention
1	0.000 m	$0.0099\ m^3/s$	$0.000\ m^3$
600	0.036 m	$0.0071\ m^3/s$	$0.028\ m^3$
1500	0.289 m	$0.0203\ m^3/s$	$11.73\ m^3$
2498	0.0143m	$0.0045\ m^3/s$	$0.016\ m^3$

Duration of runoff : T_A = 15 + 17 = **32 min**.

9.5.3 Runoff Formation (Input):

parameter Index

N_{eff}	effective precipitation	[mm]
N	precipitation	[mm]
Ψ	runoff coefficient	[-]
S	stored contet	[in]
I_a	initial loss	[in]

The choice of the soil humidity type 3, referred to the soil type D for a permenant meadow results in a value of *CN2 = 78*

CN2 = 78.   CN3 = CN2 / (0.4036*0.0059*CN2) = 90.3

The effective precipitation, N_{eff} resulting from the existing precipitation, which is declared in the IDF-Chart, as well as considering losses, due to infiltration and evaporation.

N_{eff} = [N - 25.4 * (200 / CN - 2)]2 / [N + 25.4 * (800 / CN – 8)]

refer at the SCS table appendix 9.5.7.

For further details see link collection L24

territorial retention CS Values S:

S = (25400 / CN) – 25)) = 10 in

Initial loss (20%) by Maniak of the territorial retention S --> I_a=a*S (for a = -0.2):

I_a= 2 in

For further details see link collection L21

The data from the IDF Charts showing singular rainevents with a defined duration.

To subdivide the 1h rainevent in 5min intervales, the following functions are created for thje 20 years rainevent:

$$F(t) = 10.86*e^{(-0.102t))}$$

The Integrals from t=0 to t=X define steps to develope the Euler distribution II - a model rain .

The results of the values which were calculated for t are to be found at the Euler distribution table, and are analog valid for the 50 years rainevent:

$$F(t) = 11.99*e^{(-0.102t)}$$

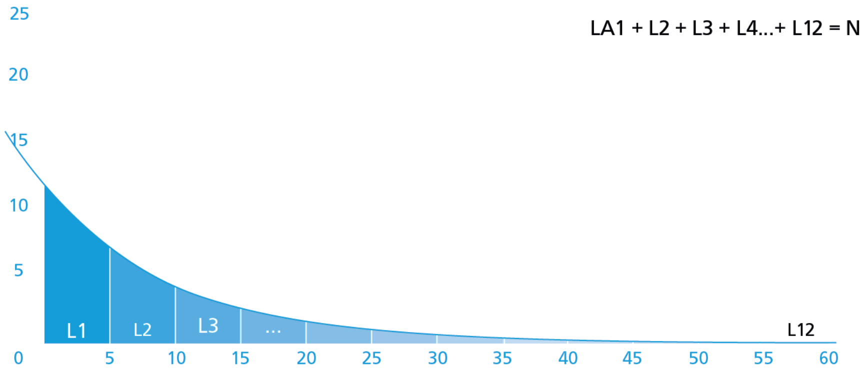


fig. 93:
Division of a typical rainevent into 5 min steps

Intervale	Precipitation 5	Precipitation 20	Precipitation 50	Euler-D 5	Euler-D 20	Euler-D 50
0-5	33.91	42.54	46.96	7.34	9.21	7.34
5-10	20.36	20.36	28.20	12.23	15.34	16.93
10-15	12.23	15.34	16.93	20.36	20.36	28.20
15-20	7.34	9.21	10.16	33.91	42.54	46.96
20-25	4.41	5.53	6.10	4.41	5.53	6.10
25-30	2.64	3.32	3.66	2.64	3.32	3.66
30-35	1.59	1.99	2.20	1.59	1.99	2.20
35-40	0.95	1.19	1.32	0.95	1.19	1.32
40-45	0.57	0.72	0.79	0.57	0.72	0.79
45-50	0.34	0.43	0.47	0.34	0.43	0.47
50-55	0.20	0.25	0.29	0.20	0.25	0.29
55-60	0.12	0.15	0.17	0.12	0.15	0.17

Considering the previous introduced function and the Rainfall values, the rainfall event shows the following character:

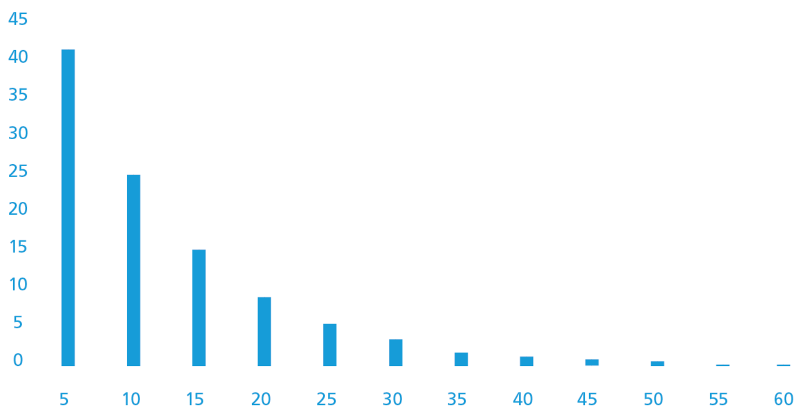


fig. 94:
Distribution of rainfall

Considering the Euler type II Rainfall pattern, it changes the distribution of rain:

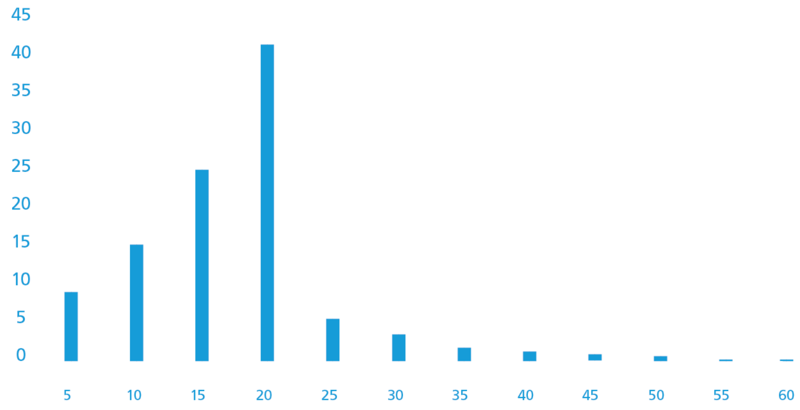


fig. 95:
Distribution of rainfall, according to Euler type II

9.5.4 Runoff Concentration (System) :

Parameter Index

T_c	concentration time	[h]
L	flow length	[ft]
J	slope	[%]
T_{lag}	delay time	[h]
T_a	time to peak	[h]
Q_{max}	maximal runoff value	[m³/s]
U_{max}	value of the peak	[m³]
A	area	[km²]

$$T_c = 0.0523 \text{ [h] } (=(L^{0.8}*(S+1)^{0.7})/(1140*J^{0.5}))$$

L=132.2 ft; S=10 in; J= 6 %

The concentration time correspond to the time range, which is needed for the water to flow from the highest point to the areas Outlet.

$$T_{lag} = 0.0313\ [h] = 1.8\ min$$

T_{lag} is the time range between main focus of the effective precipitation and the peak (0.6*T_c).

$$T_a = T_{lag} + \Delta T / 2 = 0.5313\ [h]$$

T_a indicates the rise time of the hydrographic curve until the maximum of the peak outflow is reached Q_{max}.

The hydrographic curve corresponds approximately to the time distribution of the runoff:

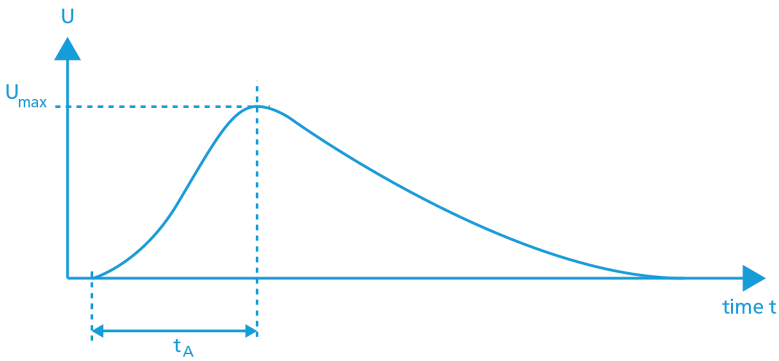


fig. 96:
A typical hyrographic curve, with the peak flow

After the necessary values had been defined, the datas were implement in the Hec-HMS (Hydrologic Modeling System) which calculated the total Runoff, considering the diversion into 5 min intervals.

9.5.5 Results of Hec-HMS

5 years Rainevent, 1 hour

Time	Precipitation [mm]	Loss [mm]	Excess [mm]	direct flow [m³/s]
5 min	7.36	7.24	0.0124	0.0001
10min	12.27	7.55	4.72	0.00386
15min	20.42	5.93	14.50	0.01357
20 min	34.02	4.26	29.76	0.0302
25min	4.42	0.34	4.08	0.0166
30min	2.64	0.19	2.45	0.00697
35min	1.59	0.11	1.48	0.00343
40min	0.95	0.064	0.88	0.00185
45min	0.57	0.038	0.53	0.00102
50min	0.34	0.022	0.31	0.00061
55min	0.20	0.013	0.18	0.00036
60min	0.12	0.0078	0.112	0.00022

Peak Discharge	**0.0302 (m³ / s)**
Precipitation Volume	**84.95 (mm)**
Loss Volume	**25.77 (mm)**
Excess Volume	**59.18 (mm)**

20 years Rainevent, 1 hour

Time	Precipitation [mm]	Loss [mm]	Excess [mm]	direct flow [m³/s]
5 min	9.275	8.81	0.46	0.00038
10min	15.44	7.94	7.51	0.00624
15min	25.72	5.69	20.02	0.01916
20 min	42.29	3.81	38.49	0.03971
25min	5.56	0.30	5.27	0.02165
30min	3.34	0.16	3.17	0.00905
35min	2.01	0.096	1.91	0.00443
40min	1.19	0.056	1.14	0.00238
45min	0.72	0.033	0.69	0.00132
50min	0.433	0.019	0.41	0.00079
55min	0.25	0.011	0.245	0.00047
60min	0.15	0.0068	0.144	0.00028

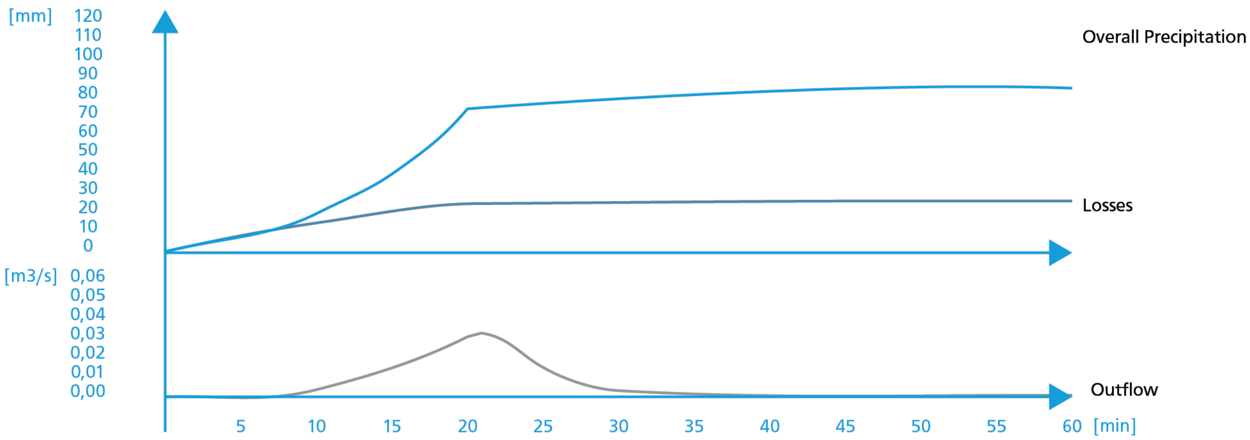
Peak Discharge	**0.03971 (m³ / s)**
Precipitation Volume	**106.42 (mm)**
Loss Volume	**26.936 (mm)**
Excess Volume	**79.483 (mm)**

50-years Rainevent, 1 hour

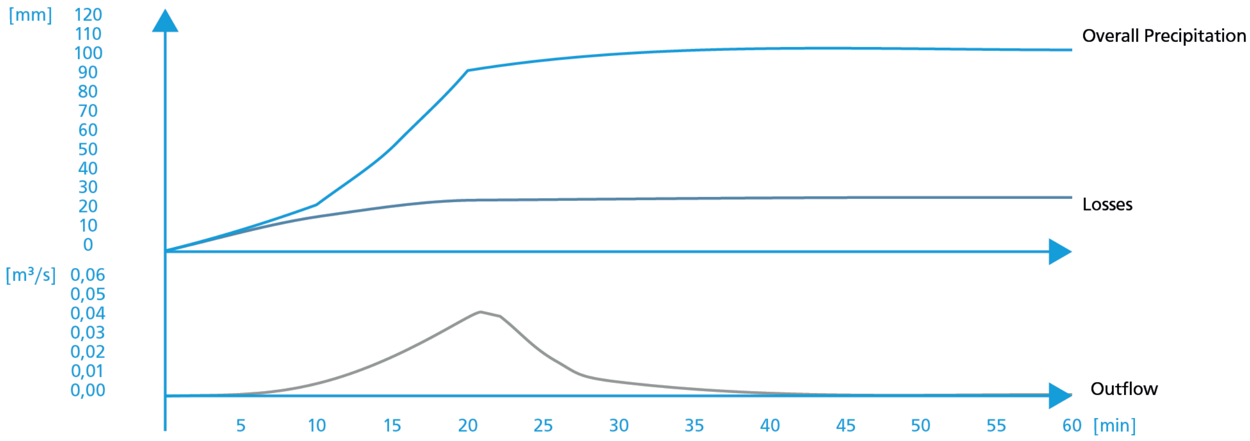
Time	Precipitation [mm]	Loss [mm]	Excess [mm]	direct flow [m³/s]
5 min	10.17	9.476	0.695	0.00056
10min	16.95	8.05	8.89	0.00744
15min	28.23	5.56	22.67	0.02187
20 min	47.01	3.65	43.35	0.0448
25min	6.112	0.28	5.83	0.0243
30min	3.66	0.156	3.50	0.0101
35min	2.21	0.089	2.11	0.00492
40min	1.32	0.052	1.27	0.00265
45min	0.79	0.030	0.75	0.00145
50min	0.47	0.018	0.45	0.00087
55min	0.28	0.011	0.276	0.00052
60min	0.17	0.0066	0.166	0.00023

Peak Discharge	**0.0448 (m^3 / s)**
Precipitation Volume	**117.38 (mm)**
Loss Volume	**27.394 (mm)**
Excess Volume	**89.813 (mm)**

Hydrographic Chart of the 5 years rainevent (1 hour)



Hydrographic Chart of the 20 years rainevent (1 hour)



Hydrographic Chart of the 50 years rainevent (1 hour)

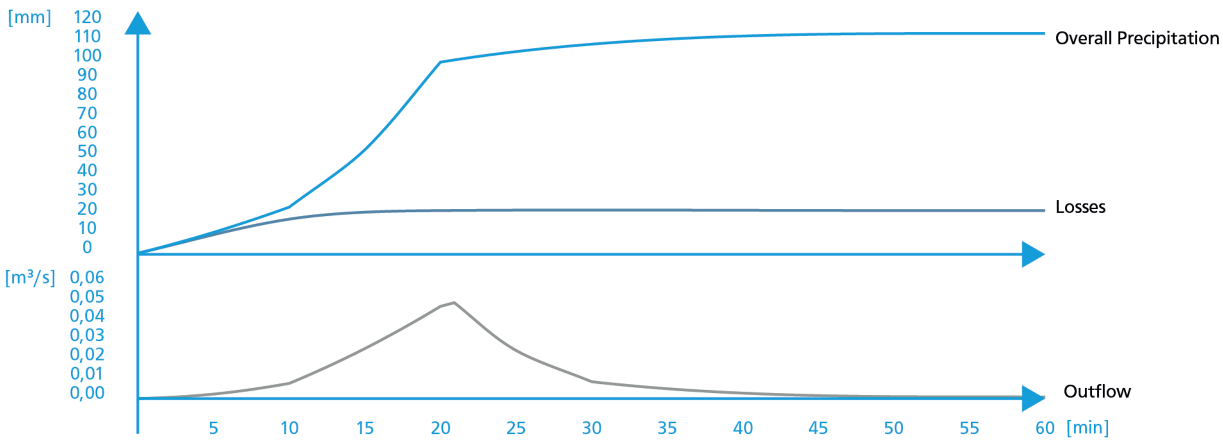


fig. 97:
Results of the simulation by Hec-HMS for a 5, 20 & 50 years rainevent, under conditions described above
Source: Hec-HMS, Illustration modified by the author

9.5.6 Dewatering Calculation (Output):

Parameter Index:

v_m	flow velocity	[m/s]
kst	Strickler-coefficient	[-]
$r^{2/3}$	hydrological cross section	[mm]
I_o	soil slope	[1/m]
Q_K	volume flow channel	[m³/s]
A_K	cross section channel	[mm]
$Q_{5;1h}$	volume flow 5 years event for 1h	[m³/s]
$Q_{20;1h}$	volume flow 20 years event for 1h	[m³/s]
$Q_{50;1h}$	volume flow 50 years event for 1h	[m³/s]
V_B	volume basin	[m³]
V_N	volume precipitation	[m³]
k	filling height quotient for $0 < k$	[-]
h_N	filling height basin	[m]
h_B	filling height area	[m]
h_P	filling height Pipe	[m]
h_G	total filling height	[m]
g	gravity	[m/s²]
v_r	flow velocity of the pipe	[m/s]
A_R	cross section of the pipe	[m²]
Q_z	inlet flow = $Q_{20;1}$	[m³/s]
Q_a	runoff flow = Q_R	[m³/s]
Ret(t)	summed retention over t seconds	[m³]
dh_N	alteration of the water level	

With the usual sequence of an hydrological runoff model the runoff routing would be the next step to define a representative cross-section of the runoff channel, but in this case due to the very small size of the system, the retention of the runoff depends mostly on the channel pipe, which carries the water to the WRMS.

Therefore the focus is set to the dimenson of the channel pipe:

It is assumed that the basin that represents the area, is a triangle in cross section. The area is 40 m wide and forms the hypothetic retention basin.

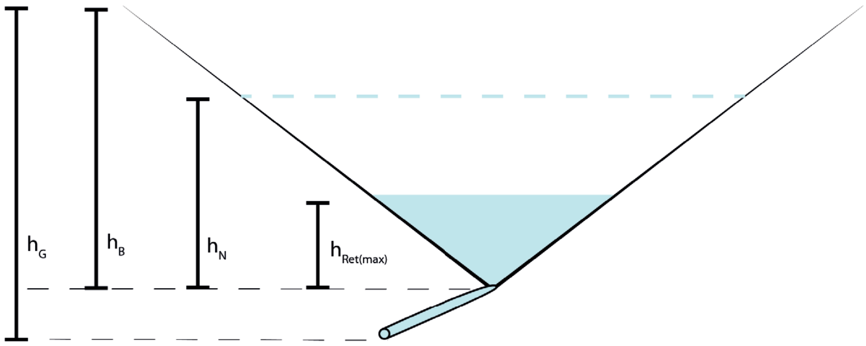


fig. 98:
Schematic illustration of the system

Dewatering Calculation, Bioswale

Runoff for an open channel during 5, 20, 50 years rainevent, with a duration of 1 hour (Manning-Strickler) :

To ensure that the channel is responsible to hold the total dewatering, the implementation of a choke would be necessary.

The mean flow velocity for an open drainage channel is calculated according to the Manning-Strickler-flow formula: $v_m = kst * r^{2/3} * I^{1/2}$

With:

Coefficient pipe, smooth steel	$kst = 90\ m^{(1/3)}/s$
hydraulic cross section DN 110	$R_h = 0.0265\ m$
with *nearly* 100% filling and bottom slopes	$I_o = 1:100 = 1\%$

For further details see link collection L1

Due to the small retention of the 5 years rain event, the focus is on the 20 and 50 years event.

The outflow channel which is requiered for the scenario has a volume flow of:

$$Q_K = 0.0287\ m^3/s$$

20 years rainfall event volume flow of the peak for open channel:

$Q_K = v_m * A_K$

$Q_K = 3.38$ m/s * 0.0085 m² = 0.0287 m³/s

$Q_K = 0.0287$ m³/s < $Q_{20;1h} = 0.03971$ m³/s peak

The difference of the calculated runoff of the pipe $Q_K = 0.0287$ m³/s combined with the inlet flow $Q_{20;1} = 0.03971$ m³/s :

Arising retention of **0.0011 m³/s** corresponds to an impoundment of **11.01 l/s**.

For $Q_z = 0.03577$m³/s Inlet and $Q_a = 0.0304$ m³/s runoff corresponds to following calculation:

$$Ret(t) = Ret(t-1)+Q_z-Q_a$$

The contemplation of this calculation means, over a time range of one hour at the 20 years rain event, a retention amount of **3.29 m³** Water arises at the peak of the rain event.

After t=1200 seconds, the inlet gets smaller and the arisen retention drains of.

$Ret(t)= Ret(t-1)-Q_a$ means in this case:

for Ret(t)= 0 - 900s the constant runoff is higher than the inlet
for Ret(t)= 900 - 1200s the Inlet arises to the peak.
for Ret(t)= 1200 - 1560s the arisen retention drains off.
for Ret(t)= 1560 - 3600s the constant runoff is higher than the inlet again.

The retention under given conditions takes **5 min** to be dammed up and another **6 min** until it drains off.

50 years rainfall event volume flow of the peak for open channel:

$Q_K = v_m * A_K$

Q_K= 3.38 m/s * 0.0085 m² = 0.0287 m³/s

Q_K=0.0287 m³/s < $Q_{20;1h}$=0.0448 m³/s peak

The difference of the calculated runoff of the pipe Q_K= 0.0287 m³/s combined with the inlet flow $Q_{20;1}$=0.0448 m³/s :

Arising retention of **0.016 m³/s** corresponds to an impoundment of **16.10 l/s**.

For Q_z = 0.0448 m³/s Inlet and Q_a = 0.0287 m³/s runoff corresponds to following calculation:

$$Ret(t) = Ret(t-1)+Q_z-Q_a$$

The contemplation of this calculation means, over a time range of one hour at the 20 years rain event, a retention amount of **4.83 m³** Water arises at the peak of the rain event.

After t=1200 seconds, the inlet gets smaller and the arisen retention drains of.

$Ret(t)= Ret(t-1)+Q_z-Q_a$ means in this case:

for Ret(t)= 0 - 900s the constant runoff is higher than the inlet
for Ret(t)= 900 - 1200s the Inlet arises to the peak.
for Ret(t)= 1200 - 1688s the arisen retention drains off.
for Ret(t)= 1688 - 3600s the constant runoff is higher than the inlet again.

The retention under given conditions takes **5** min to be dammed up and another **8.2 min** until it drains off.

Dewatering Calculation for a DN110 drainage pipe:

Runoff retention for a closed channel during 20 years rain event, using iterative steps in relation to the water volume and pressure.

20 years rainfall event volume flow of the peak for closed channel:

In this case a drain pipe is used for the drainage of the retention basin which means that the run off depends directly on the water level in the basin.

The cross section surface of the area is defined as:

$$A_G = G*h/2 = 1.485m^2 \ \ (h_G = 0.297 \text{ m})$$

It is assumed that the pipe has a length of 20 m, which results in a slope height of 0.2 m.

The pipe is a DN110 has a diameter of 104mm and a cross section of:

$$A_R = 0.0085m^2$$

The area between the buldings, has a theoretical holding Capacity of:

V_B= **59.4 m³** for the retention basin .

The total runoff amount of an hour is variable and depends on the interval strength-ness of the rainevent .

The total precipitation event ends up in a total Volume :

$$V_N = \mathbf{31.765m^3}$$

The maximal filling height is calculated by the ratio between volume and height :

$$V_N = k * V_B => V_N/V_B = k$$

$$k = {}^3\sqrt{}k * h_G = h_N$$

That means for every second, during the draining process, the height of the waterlevel depends on the ratio between inlet and outflow.
With the filling height of the basin compared with the total height of the pipe the drainage velocity can be calculated with the Toricelli-equation ($v= \sqrt{2*g*h_G}$), and results in a velocity for the peak of 2.28 m/s.

The height of the water level within the basin, influences the pressure and therefore the flow velocity.

The calculation for the peak is:

$$Q_{R,max}= v_R*A_R= 0.00198\ m^3/s$$

After 600 s, the diachrage to the pipe can be considered as relevant $Q_Z > Q_A$.
t=601 results in a volume flow at the pipe inlet of: t=0.00192 m/s, which result to a filling height of 0.024 m. At this Volume of water the flow velocity reducing itself to 0.81 m/s. This results into the following Runoff:

$$Q_R(t=1)= v_R*A_R = 0.007\ m^3/s$$

The resulting retention is Ret(t=601)= Q_z-Q_a = 0.0192 – 0.007 = 0.0122 m³/s

After a calculation of ∑ t=0 to 3600 for (Q_z-Q_a) dt is valid:
A retention of 9.18 m³ Water arises between t = 601 and t = 1500. While the inlet decreases according to the rainevent, the retention drains of between
t = 1500 and t = 2335.

After 885 seconds = 14.75 min the retention is drained completely.

The 20 years rain event will lead to a retention of 9.2 m³, which is is dammed up over 15 min. This needs another 14 min to be drained.

The total event takes about 15 + 14 = 29 **minutes**
and the basin would not be filled more than 16%.

Runoff retention for a closed channel during 50 years rain event, using iterative steps in relation to the water volume and pressure.

50 years rainfall event volume flow of the peak for closed channel:

The difference of the 20 to 50 years rain event, with a duration of 1 hour, can be seen in the overall volume of the event:

$$V_N = \mathbf{35.925m^3}$$

If the moment is t=601, the inlet of the volume is 0.00219 m/s , which results in a filling height of 0.036 m. At this amount of water the flow velocity reducing itself to 0.83 m/s . That means a runoff amount of :

$$Q_R(t=1) = v_R * A_R = 0.0071\ m^3/s$$

The resulting retention is Ret(t=601)= Q_z-Q_a = 0.0219 – 0.0071 = 0.0148 m^3/s.

After a calculation of ∑ t=0 to 3600 for (Q_z-Q_a) dt is valid:
A retetion of 11.73 m^3 Water arising between t=601 and t=1500. While the inlet decreases according to the rainevent, the retention drains of between

t = 1500 and t = 2498 .

After 998 seconds = 16.63 min the retention is drained completely.

At the 20 years rain event will lead to a retention of 11.73 m^3, which is dammed up over 16 min. This needs another 17 min to be drained.

The total event takes about 15 + 17 = 32 **minutes**
and the basin would not be filled more than 20%.

9.5.7 Discussion of the results

Due to the relatively small catchment area to be drained, which covers exactly the area between two houses with 400 m^2, the water masses to be dewatered are relatively small, so that flood protection can be ensured without issues, at least in the previous described examples.
In this illustration, the 50 year rain event with a duration of 60 min leads to a retention of 32 min and results in a damming height of approx. 30 cm. The maximum damming height has a great influence on the design of the open areas, as it can be assumed that all installations below this mark will be flooded during such a rain event. The damming height depends largely on the pipe used (DN110), which throttles the drain. The use of a DN150 pipe may no longer lead to impoundment, the use of a DN80 pipe would increase this due to the higher throttling. In general, the larger the pipe, the less build-up, but the greater the effort involved in installing it.

This damming level should be further validated in further simulation with various rain events. Here also the 100-year rain event would be particularly interesting, or the 50 year, assuming that the duration is 2, 5 or 10 hours.

The used drainage pipe is therefore more relevant for the roof dewatering than for the open areas, where drainage could also be designed as open bioswales, as overflow should be prevented in any case.

In the event that the areas to be drained become larger, as outlined in *Chapter 8*.11, the water masses will increase and the use of open channels such as bioswales is preferable due to their more flexible character and higher removal capacity.

9.5.8 **SCS Table** (see L24)

Cover			Hydrologic soil group			
Land Use	**Treatment Practice**	**Hydrologic Condition**	**A**	**B**	**C**	**D**
Fallow Row crops	Straight row	-	77	86	91	94
	Straight row	Poor	72	81	88	91
	Straight row	Good	67	78	85	89
	Contoured	Poor	70	79	84	88
	Contoured	Good	65	75	82	86
	Contoured & terraced	Poor	66	74	80	82
	Contoured & terraced	Good	62	71	78	81
Small grain	Straight row	Poor	65	76	84	88
	Straight row	Good	63	75	83	87
	Contoured	Poor	63	74	82	85
	Contoured	Good	61	73	81	84
	Contoured & terraced	Poor	61	72	79	82
	Contoured & terraced	Good	59	70	78	81
Closed-seeded Legumes or rotation meadow	Straight row	Poor	66	77	85	89
	Straight row	Good	58	72	81	85
	Contoured	Poor	64	75	83	85
	Contoured	Good	55	69	78	83
	Contoured & terraced	Poor	63	73	80	83
	Contoured & terraced	Good	51	67	76	80
Pasture or rage		Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80
	Contoured	Poor	47	67	81	88
	Contoured	Fair	25	59	75	83
	Contoured	Good	6	35	70	79
Meadow Woods		Good	30	58	71	78
		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	25	55	70	77
Farmsteads			59	74	82	86
Road (dirt)			72	82	87	89
(hard surface)			74	84	90	92

9.5.9 Used references, in the context of this research

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Vergleich unterschiedlicher Ansätze zur Simulation der Abflussprozesse in HEC-HMS am Beispiel des Sachenbachgebiets, Bachelorarbeit (see Appendix Link collection L22)

9.5.10 Internet sources

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