Waterschap Rijn en IJssel

WATERBEHEER: VEILIG EN OP MAAT

INTEGRATED WATER MANAGEMENT ON BONAIRE

End report

FEBRUARY 2023

Thanks to:

hoogheemraadschap Hollands Noorderkwartier

waterschapsbedrijf limburg

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PREFACE

If anything should bring humanity closer together, it should be the climate crisis. The impact of the changes can be seen worldwide, and they are of unprecedented scale and intensity. There is no country that is not affected by it. Just hit the media, climate disruption is everywhere: historic droughts, unimaginable rainstorms, devastating storms. We, as humans, have entered unfamiliar territory. Nowhere does the climate still behave along predictable lines. We know it will change, but not really how. And to make it even more dramatic: it's happening much faster than expected. We are already in the midst of it, unfortunately, Bonaire can relate to that. So we are thinking about measures that can somewhat mitigate the worst consequences. This calls for joining forces. Available knowledge must be increased and shared. Experience gained elsewhere should be shared and applied with local knowledge.

The Netherlands has had water boards for almost 900 years. They ensure dry feet, clean and sufficient water in the Netherlands. They maintain the dikes, the watercourses, monitor the quantity and quality of the water, and process the wastewater. In recent years, climate adaptation has been added because many adaptation measures are related to water, but mainly because climate change has led to a completely different approach to water management. Delegations from all over the world come to the Netherlands to learn from the water boards. We also want to share this knowledge with the other parts of our kingdom, including Bonaire.

After the intense rain crisis/flooding in November 2022, Island Governor Rijna contacted me and through me asked the water boards for support and knowledge exchange. In early 2023, a delegation of water managers from various water boards visited Bonaire. For a week, we looked at the island's water infrastructure, talked to many officials to get a first impression of the situation. The report of these findings is here in front of you. It gives a picture of measures that can but especially must be taken in the short term. It is primarily and foremost a report of an exploration of what needs to be done, now, in the medium and long term.

Bonaire is a lively and friendly community. As a delegation we have also experienced this ourselves. However, it is also a small community that is overwhelmed by the quantity and complexity of assignments. Bonaire cannot and should not face these problems alone. Climate disruption is already overwhelming the organizations in the Netherlands, and that is why we are building national and international networks in the Netherlands to work together on solutions and answers. Bonaire must become a part of that network.

Climate adaptation is a global issue affecting all islands. Most islands lack sufficient knowledge, experience, resources, and implementation capacity. With an accelerated and combined approach (twinning), Bonaire could also be a pilot project for many other islands because we have little time. Knowledge gained and practical solutions implemented can be copied and adopted by other islands. A kind of testing ground for climate adaptation for islands.

Climate disruption requires an approach and commitment from everyone, from young to old, from student to entrepreneur, from retiree to churchgoer, no one can blame it on another. The future of humanity is at stake. We need to change our behavior and take responsibility. We must be good ancestors.

Hein Pieper
Chief Executive of the Rijn&IJssel Water Board

MANAGEMENT SUMMARY

MOTIVATION

On November 14, 2022, the Island Governor of Bonaire requested in a formal letter support from Rijn en IJssel Water Board to develop an integrated approach to water management. The immediate reason for this was the flooding caused by rainfall last year. For years Bonaire has been facing significant water challenges, including storage, transport, and wastewater management. No comprehensive plan has been developed for water management before, while the safety of the island's residents is increasingly under pressure due to, among other things, the overdue of maintenance of water dams and small streams, poor water drainage, and poorly maintained roads. Additionally, the coral reefs, which serve as natural barriers against rising sea levels and an important attraction for tourism, are also being affected.

CURRENT SITUATION

Bonaire is an island in the Caribbean part of the Netherlands that since 2010 has been administratively a special municipality as a Caribbean public body. It is part of the Dutch state system but has a different regime; for example, the islands are not part of a province or a water board.
It is located in the southern part of the Caribbean Sea, off the coast of Venezuela, and belongs to the ABC islands of the Lesser Antilles. The island was formed as a result of volcanic activity. The island was characterized by forests that were cut down for charcoal production. Until the desalination plant was built, Bonaire depended on rainwater for its water supply. This was made possible by a large and ingenious system of dams, basins, and saliñas where water was collected and stored. As the trees have disappeared, erosion by wind and especially rainwater has greatly increased; climate change reinforces this. The old system described above suddenly turned out to be a good measure to settle sediment and prevent it from polluting coral. Many of the proposed measures refer back to the old water system ('base in order').
When it comes to the wastewater chain, only a small part of the built-up area is equipped with sewers (about 10%) and that part is connected to the sewage treatment plant (RWZI) in Kralendijk. The remaining part, especially residential areas, is equipped with a cesspool or septic tank. These installations need to be emptied regularly. This is processed in a wastewater treatment plant (RWZI) located next to the STP in Kralendijk. The effluent from these plants is either reused as irrigation water or stored in one of the water basins from where it infiltrates into the soil or drains through the water system to the sea.
The island has no additional defenses other than natural protection against high water. Protection against sea storms is not yet required either. There are sea storms from the southwest that hit Bonaire's "soft belly" and cause flooding (water on the street). Based on our conversations, we have the impression that this is not yet perceived as problematic.

FUTURE SITUATION

The report as prepared by Wageningen University & Research, 'Bonaire 2050 - A nature inclusive vision', describes the developments the island will face. It is expected that the temperature on Bonaire will rise by 1.4 degrees Celsius, there will be an average of 5% less rainfall annually which will fall in shorter periods, and the sea level will rise by 60 cm. Reduced rainfall will reinforce the need for water retention. Because this amount of rain falls in shorter periods of time (peak rains), the required volume of basins and saliñas will have to increase so that flooding does not escalate. At the same time, the pressure on the island will increase due to population growth and increased tourism. The consequence is that Bonaire's natural treasure, the coral, is also coming under increasing pressure. And this is already vulnerable. On one hand measures are needed to preserve, strengthen and renew the natural capita land on the other hand, if the current policy is continued, there must be room to facilitate population growth and the increase in tourism.

The wastewater chain will have to grow along with the population growth. Additionally, Bonaire has the ambition to connect more plots to the sewage system. Both lead to the need to develop additional purification capacity. The question is whether this should be done at the current centralized location or with small, decentralized installations. The use of cesspools is no longer permitted, only septic tanks are allowed.

When it comes to protection from the sea, Bonaire will have to initiate a study, supported by a measurement program to identify the effects of sea level rise and sea storms. There is currently not enough data available on this subject. It is already clear that there will be an effect, and that it will be the greatest in the southern part and along the low-lying and built-up coastline.

SOLUTION OPTIONS

As described for the future situation, the storage capacity of the saliñas and basins will have to be increased to accommodate the peak rainfall. The volume can be increased by dredging the current basins to their original depth and by constructing more dams. However, to determine the appropriate intervention for each location, data must be collected. A good elevation map and data on flow rates and water quality are necessary.
The need to store water to prevent sedimentation in basins is a consequence of erosion due to the lack of trees and healthy soil. Combating erosion through reforestation and implementation of sustainable agriculture (including soil improvement by increasing organic matter content) is a significant transition to retaining water and preventing sediment runoff. This removes an important negative pressure on the coral. An additional benefit is that Bonaire will become less reliant on imported food due to agricultural practices.

A second transition can be found in the wastewater system. It may be interesting to supplement the current centralized system with decentralized systems. These can improve the functional reuse of effluent because less water transport is needed. In addition, decentralized systems can make the replacement of purification by septic tanks interesting. Furthermore, sanitation of the still-existing cesspools can lead to an improvement in groundwater quality. In this domain, a monitoring program is necessary to map the impact of the effluent from the purification plant and septic tanks on the groundwater, and ultimately on the seawater. It is not known at this time what the impact of this is and whether this has a negative effect on the coral and the life around it.
Sea level rise will lead to a third transition. This will be experienced first in the southern part of the island and in the low-lying and built-up coastal areas. It is not yet clear which solutions are needed for this. Data collection and research are needed for this. This should be started as soon as possible. However, we do recommend not starting new developments in the low-lying coastal areas because these areas are already vulnerable to sea storms. A second argument is that the soil in this strip is porous so it is expected that a sea barrier cannot protect developments.
It is not possible for us to make a cost estimate for this transition. It is not clear whether the standard system applicable in the Netherlands also applies to Bonaire. An answer will have to be formulated in consultation with the Ministry of Infrastructure and Water Management to determine which norms system is applicable, whether the mainland needs to be protected, and what form of protection is necessary. If coastal defense is needed, this will require a large investment.

SHORT-TERM ACTIONS AND COST ESTIMATE

For the water system, we propose to take the following actions in the short term:

1. Putting the personnel capacity within the OLB in order for the purpose of managing and maintaining the water system.
2. Restoring the capacity and thus the functioning of the current water system.
3. Measuring the current water system and performing a soil profile measurement.
4. Drawing up and implementing a monitoring program to provide insight into the flow rates processed by the water system and the associated water quality data.
5. Implementing proper management and supervision around the water system.
6. Setting up and implementing an awareness campaign.

Cost estimate: $2,750,000 + TBD (to be determined)

For water safety, we propose to take the following actions in the short term:

1. The formulation of a standards system on the basis of which the required protection can be determined. This will have to be established in consultation with the Ministry of Infrastructure and Water Management.
2. Having an independent study conducted into the extent of sea level rise, the impact of sea storms on top of that and the potential consequences of these.

Cost estimate: $1,000,000 + PM.

For the wastewater chain, we propose to take the following actions in the short term:

1. Drawing up a future plan for the RWZI Kralendijk (sewage treatment plant) and possible decentralized solutions (including Rincon).
2. Adapting the Kralendijk UV installation.
3. Waterproofing the vacuum sewer system.
4. Examination of the water tightness of the return water line.
5. Development of a connection obligation ordinance and a prohibition of cesspools ordinance.
6. Developing a monitoring plan.
7. Establishing an awareness-raising campaign.

Cost estimate: $2,200,000

LONG-TERM ACTIONS

For the water system, we propose the following activity to be carried out in the longer term:

1. Counter erosion by planting trees and/or implementing sustainable agriculture including soil management.
2. Formulate policy so that water is used as a guiding principle in new spatial developments.
3. Develop the water system into a resilient system by, for example, allowing water to drain from basins in a controlled manner.
4. Strengthen the permitting and monitoring process through, for example, training
5. Enabling so-called small-scale solutions that make a positive contribution to water retention and reuse, such as storing water under homes.

Cost estimate: PM.

No activities can currently be identified for water safety because there is insufficient data and knowledge available.

Cost estimate: PM.

For the wastewater chain, we propose the following activity to be carried out in the longer term:
1. Modify the RWZI Kralendijk
2. Implementing the Future Plan.
3. Waterproofing of the return water pipeline.
4. Implementing the monitoring plan.
5. Make an inventory, prepare an implementation plan and clean up the remaining cesspools.
Integrate the personal capacity into one team for water.
Cost estimate: $5,100,000 + PM

CHAPTER 1: INTRODUCTION

MOTIVATION

On November 14, 2022, the Island Governor of Bonaire requested in a formal letter support from Rijn en IJssel Water Board to develop an integrated approach to water management. This is due to the floods caused by rainfall last year. Specific requests were made to develop a concrete plan around the following themes:

- Collection and transportation of water across the island (water dams/small streams/ wells)
- Wastewater; a wastewater vision is currently being developed in Bonaire;
- Saline cultivation;
- Climate adaptation; a climate table for Bonaire is currently being set up.

Based on this question, an exploratory mission took place from January 28 to February 5 where this plan is the final product. The content of this plan is based on the many policy documents that have already been written and discussions with local content experts. The resulting images were then tested against local situations.

The Dutch team consisted of the following members:
Hein Pieper Rijn en IJssel Water Board
David Koenders Dutch Noorderkwartier Water Board;
Jan Polman Rijn en IJssel Water Board;
Olaf Durlinger Water Board Company/Limburg Water Board;
René Eisenga Rijn en IJssel Water Board

BACKGROUND

As the Nature and Environment Policy Plan Caribbean Netherlands (NMBP-CN) states, “this area harbors a wealth of natural resources that provide the local population - but also the region and the rest of the world - with numerous ecological, cultural and economic services.” Bonaire adds beautiful coral reefs, foraging areas for flamingos, and stunning national parks to this list. These are important qualities for a healthy economy of the island; the well-being and prosperity depend heavily on the quality of the natural environment. However, these qualities, and thus well-being and prosperity, are under pressure. Important causes are the strong population growth, increase in tourism, erosion on the island, and climate change, to name a few. In the past fifteen years, the population has more than doubled from approximately 9,000 in 2010 to more than 22,000 in 2022. Regarding tourism, around 140,000 people visit the island annually, and this is not even counting those who visit via cruise ships.

For this plan, climate change and erosion are important topics. Climate change worldwide causes higher temperatures, sea level rise and longer periods of drought. At the same time, roughly the same amount of rainfall occurs in shorter periods of time, resulting in more flooding. In combination with the existing situation on Bonaire, where many trees have disappeared, this leads to significant erosion, with sedimentation in the sea, on the coral among other things. These events have led to the questions formulated above.

GOAL

The NMBP-CN has formulated a number of strategic goals that are partly applicable to this report. In the figure below, the goals of the NMBP-CN are shown. Of interest to us are, strategic goals 1 ‘Reverse coral reef degradation to enhance wellbeing in the CN’ and 4 ‘Create the local conditions to ensure sustainable results of nature policy in the CN’ are important. More specifically, 1.1 ‘Control erosion and runoff’, 1.2 ‘Effective waste and wastewater management’ and 4.1 ‘Create awareness through education and training’. We have tried to match these goals as much as possible.

Vision
A prosperous society and cultural identity in balance with a resilient and healthy natural environment

Strategic goal 1 Reverse coral reef degredation to enhance wellbeing in the CN	**Strategic goal 2** Restore and conserve the unique habitats and species in the CN	**Strategic goal 3** Sustainable use of land and water for the development of the local economy	**Strategic goal 4** Create the local conditions to ensure sustainble results of mature policy in the CN
1.1 Control erosion and runoff	2.1 Conservation and restoration of key habitats	3.1 Sustainable fisheries	4.1 Create awareness through education and training
1.2 Effective waste and wastewater management	2.2 Conservation of keystone and flag ship species	3.2 Tourism industry in balance with nature conservation	4.2 Create employment through inestments in nature
1.3 Coral reef restoration	2.3 Prevent new and control established invasive species	3.3 Invest in sustainable local food production	4.3 Develop a structural research agenda

READING GUIDE

The document is structured from the water system programs (Chapter 2), wastewater chain (Chapter 3), and water safety (Chapter 4). These are programs that are well-known in the Dutch water boards. All chapters have the same structure. The current situation is described first, followed by the bottlenecks of that system. Then the measures required to reduce or eliminate those bottlenecks are explained. Finally, an initial prioritization of the measures to be taken has been included, and the most important ones have been costed to the extend possible.

CHAPTER 2. WATER SYSTEM

2.1 Current/Future Water System

THE EXISTING WATER SYSTEM

Soil

The majority of Bonaire's subsoil consists of limestone, which was formed during the time when Bonaire was partially underwater. The other part of the island was formed as a result of volcanic activity. Only a portion of Bonaire's soil is fertile.

Water balance (Hydrological Research Bonaire, 2005)
On average, Bonaire receives 500 mm of rainfall per year. Of this, 85% evaporates, 5% infiltrates into groundwater, and 10% flows to lower areas and eventually into the sea.
It should be noted that precipitation amounts could vary greatly (between 200 and 1200 mm/year) from year to year. Due to climate change, it is expected that more rain will fall in shorter periods of time in the future putting more pressure on drainage systems.

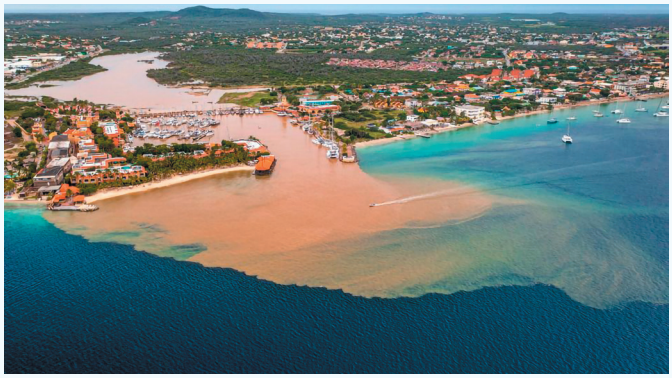
Surface water

On Bonaire, there is only very limited natural fresh surface water available. There is only one spring (Fontein) that drains water throughout the year. The amount of fresh water is entirely derived from infiltrating rainwater. Rain falls in very irregular showers in sometimes-large quantities and also irregularly distributed over the island. Due to the low infiltration capacity of the soil, heavy rainfall quickly leads to flooding. This mainly occurs in the center of Kralendijk and other low-lying areas. The increase in paved surface intensifies the occurring flooding.

In 2013, the watershed of Kralendijk was studied by the WUR (G. Koster, 2013). The surface water system consists of a network of small streams (natural streams that form during the rainy season) that end up in dams and saliñas. The Kralendijk watershed is by far the largest in terms of area and also the most complex. This is also where the biggest bottlenecks occur. Part of the surface water system is still natural; the dams were constructed based on expert judgment in the mid-20th century.

Saliñas are natural water storage areas that are fed with rainwater and seawater. They capture the rainwater with sediment that flows from higher areas to the sea. The sediment can settle in the saliñas, preventing it from flowing into the sea. Saliñas form a natural buffer for sediments and nutrients to protect the reefs.

In some parts of Kralendijk, a rainwater drainage system is present. These systems also drain into the saliñas. Saliñas attract many water birds, such as the flamingo. The storage capacity of the dams and saliñas has greatly decreased due to lack of maintenance. During heavy rainstorms, large scale flooding occurs in the lower areas of Kralendijk. Moreover, a lot of sediment and other pollution wash into the coral reef.
The most recent flooding occurred in November 2022, as shown in the photos below. There was also a lot of damage caused by flooding in 2004.



Heavy rainfall resulting in leaching to the sea and the coral.

Groundwater

The groundwater on Bonaire is generally brackish. The salinity of the groundwater varies greatly in time and place. In many places, the salinity of the groundwater is a major bottleneck for possible water use. Nitrate concentrations are generally low. There is a great knowledge gap regarding this part of the water system. Freshwater wells are present throughout the island, but there is a danger of salinization because excessive pumping of water.

2.2 Bottlenecks

The lack of sufficient storage capacity of the current drainage system is currently the biggest bottleneck. There are six reasons for this:

1. The basic information is not in order (basis in order): the location and dimensions of the original drainage system are not available. An accurate elevation map is also lacking. Parts of the water system in the field cannot be found or are difficult to locate. For further analysis, it is necessary to have the basic information in order.
2. Deferred maintenance of the drainage system (basis water system in order): current maintenance is carried out on an ad hoc basis. There is no plan for systematic maintenance; the basis system is not in order. Sedimentation occurs layer by layer, reducing the storage capacity. This increases the risk of failure of the water system and sediment leaching towards the coral.
3. Insufficient qualitative and quantitative measurement/monitoring (measurement is knowledge): there is no data available to evaluate the water system. Flow rate and water quality are not measured. Therefore, at the moment, no statement can be made about the proper functioning of the water system.
4. Lack of (legal) protection of the water system: there is insufficient protection within the instruments of spatial development, especially downstream where urbanization pressure is the greatest. As a result, new activities requiring a permit cannot be adequately tested for the water aspect. Spatial development in the downstream area puts extra pressure on the space occupied by the water system. Population growth and exponential increase in tourism on Bonaire are the main examples of this. In order to manage water sufficiently, it is important that there is, and remains, sufficient space for water. Due to climate change, the required space for water will become increasingly extensive and important.
5. Lack of awareness about the impact of the water system: water is related to numerous other topics on Bonaire. For example, outflow of sediment and pollution during heavy precipitation cause damage to the coral. Also, water is currently reused to a limited extent, while it can be an important link in building up the agricultural sector and thus becoming less dependent on imported food products from outside.
6. Water management is not specifically assigned within the organization. The activities related to the water aspect are fragmented and handled by different departments of the Department of Spatial Planning and Development (DRO) of the Public Entity Bonaire (OLB). Moreover, the OLB and DRO have limited expertise and capacity. Since external parties carry out a lot of work, there is no opportunity for knowledge building to take place within the organization.

2.3 Measures

The measures to improve the water system are divided according to the bottlenecks in the previous section.

1. BASIC INFORMATION IN ORDER (BASE IN ORDER)

In the past, fragmented field research has been conducted on the location of watersheds and the water system within them. The basic information is not up to date, reliable and complete. Good basic information is necessary for all kinds of processes, such as reviewing permits, making hydrological calculations and performing maintenance. The basic information should be collected and entered into a geographic information system (GIS system). This basic information is the framework for all kinds of policy themes, structural vision, zoning and implementation plans.

2. OVERDUE MAINTENANCE DRAINAGE SYSTEM (BASIC WATER SYSTEM IN ORDER)

Restore capacity of current drainage system

To restore and improve the functioning of the water system, it is important to eliminate the overdue maintenance (basic water system in order) and to conduct regular maintenance afterwards. Due to the inadequate functioning of the drainage system, heavy rainfall also causes damage to other infrastructure such as roads.

The elimination of overdue maintenance, in short term, mainly concerns the removal (dredging) of sediment from the basins and saliñas to the solid bottom. Released sediment can possibly be reused. This is already being done at the tree planting stage in quarries. Other possibilities should be explored.

Measurement of the drainage system

Immediately after eliminating the overdue maintenance, the drainage system must be measured and recorded in the GIS system. This makes it possible to test how much water can currently be collected in the system and determine whether that is sufficient. Based on this assessment, additional measures should be taken to increase capacity, if necessary.

Regular maintenance and supervision

After the overdue maintenance is done, the challenge is to keep the water system in good condition. This requires regular maintenance and supervision. Regular maintenance prevents decay. Supervision of the OLB employees on the state of the water system must be properly worked out. This starts with the development of a management and maintenance plan, its implementation, and periodic adjustment of this plan, if necessary.

Preventing erosion

In the field of water management, the three-stage strategy ‘retain, store, drain’ should also be applied to combat erosion. Rainwater is first retained locally as much as possible, then stored in surface water or other storage facilities, and only if this is not possible, the rainwater is drained (in a controlled manner).

The leaching of sedimentation into the sea begins with erosion in upstream areas. Bonaire was a densely forested island centuries ago, where leaching of sedimentation barely occurred. Nowadays, trees are scarce on the island and vegetation remains one-sided due to the population of wild goats and donkeys.

By restoring the water-absorption capacity of the soil on Bonaire, leaching of sedimentation can be significantly reduced. This can be achieved by bringing back trees and implementing sustainable agriculture. In the latter, soil management and increasing organic matter should be an important item. As a result, less sediment will flow to the sea and the water system will have to be dredged less often. Removing the population of wild goats and donkeys is one of the necessary measures to restore the vegetation level. This is because the new plantings are eaten before they can mature.

Resilient water system
Spread out across the island, various basins can be found where rainwater collects. During periods of rainfall, these basins fill up and then slowly empty through evaporation and small-scale use by residents and local fauna. If a basin is filled during rainfall, the water flows over land towards lower-lying areas, where the water cascades towards the sea through basins.
By allowing filled basins to drain in a controlled manner through drainage works (culverts with valves), more capacity is made available for subsequent rainfall events. There is also less erosion of sediment, contributing to a robust water system. The water can be directed across the island and used for, for example, 'kunukus' or infiltration to increase the freshwater bubble under the island.

Creating space for water in downstream areas
The watershed around Kralendijk has four different drainage routes towards the sea. However, especially in the center, there is hardly any space for water. One of the outflow points on the boulevard is preceded by an 80-meter culvert, prone to clogging and unsuitable for sediment settling. By cleverly creating space for water in the center of Kralendijk, water can be given the necessary space to prevent adverse effects on the coral. These places can be multifunctional so that they provide tourist added value and can reduce heat stress.

3. MONITORING WATER SYSTEM
In order to determine what happens in the water system, a measurement plan needs to be developed, both quantitatively and qualitatively. For this, a measurement plan needs to be made first, after which the measurement points can be placed. By collecting and analyzing the quality and quantity of water, the behavior and functioning of the water system can be determined. This analysis is the basis for determining possible adjustments to the current policy. The monitoring system is also of great importance to test future policy for effectiveness.

4. (LEGAL) PROTECTION OF THE WATER SYSTEM
It needs to be examined which instruments and laws and regulations are best suited for protecting the water system. Is this in line with Spatial Planning through a zoning plan or under the Water Law through the Keur? There is a Spatial Development Plan for Bonaire (ROB). Functions have been assigned to areas within the ROB. However, not the entire water system has been included in the ROB as a water function. Furthermore, the ROB is not sufficiently taken into account when issuing permits. Better protection can lead to better enforcement in case unwanted activities occur that hinder the proper functioning of the water system. Especially the expected growth and expansion of paved surfaces will further burden the water system. By explicitly incorporating the aspect of rainwater into the design of new developments (for example, by requiring a mandatory water test), the negative consequences of expansion can be mitigated.

5. LACK OF AWARENESS ABOUT THE IMPACT OF THE WATER SYSTEM
Awareness campaign
To instill the great importance of sufficient and clean freshwater in everyone's mind, especially the intersections it has with other important themes (such as tourism, nature, agriculture, heat stress, public health), there needs to be support and awareness created. This is especially important given the impact of climate change. Everyone must understand what this potential could mean for him or her. This can be achieved by setting up an awareness campaign in which water-related themes are included.

6. WATER MANAGEMENT IS NOT SPECIFICALLY ASSIGNED WITHIN THE ORGANIZATION.
Approach the water aspect centrally and capacity building within the OLB
The expertise and capacity within the OLB is currently insufficient to adequately safeguard the water aspect. In the future, this pressure will increase further. There is a need for employees who can translate policy into tasks and then into the actual realization of those tasks. Due to the tight labor market, the ideal situation cannot be realized in the short term. The possible solution may lie in long-term intensive collaboration with partners (twinning).

2.4 Prioritization/costs

We have prioritized the following top three from the bottlenecks mentioned in paragraphs 2.2 and 2.3 and the associated measures:

- Establishing water management as a specific component within the organization and accelerating capacity building for this purpose.
- Getting the basics in order; eliminating overdue maintenance in the existing drainage system
- Developing a comprehensive monitoring plan (flow rates and water quality measurements).

Capacity Building Water Management

To solve/execute the aforementioned bottlenecks and measures, a results-oriented, competent group of people is required. Even necessary. Because this ideal situation is probably not achievable in the short term, an intensive collaboration with partners is necessary. The aforementioned bottlenecks in the field of having the basics (information) in order, the instruments for protecting the surface water system, and awareness can only be effectively dealt with once a well-equipped organization is in place.

Elimination of overdue maintenance drainage system

On Bonaire, several watersheds can be distinguished on Bonaire. Some of these have already undergone historical research, but the picture is far from complete. To effectively manage the (rain) water system on the entire island, more research and analysis is needed.

Due to the largest adverse effects of heavy rainfall occurring in the watershed around Kralendijk, it is proposed to give this area the highest priority in getting the water system in order, especially Saliña di Vlijt. Additionally, the water system in this watershed has been fairly well mapped and hydrologically assessed (WUR, G. Koster, 2013). The greatest problems occurred here during the floodings of November 2004 and 2022, and the impact on the coral reef was the greatest. Later in this section, an overall cost estimate has been made to achieve a well-functioning water system in this watershed. The experiences and learning points gained from the implementation of this sub-area can and should then be used again to further develop the next areas. This area can serve as a pilot project for the other areas on the island.

Based on data from the project plan 'Erosion Control and Nature Restoration Bonaire' drafted by DRO in 2015, it is estimated that clearing the overdue of maintenance of Saliña di Vlijt will cost $2,500,000. It is also necessary to take measures in the most upstream part of this watershed that focus on retaining rainwater (improving the water absorption capacity of the soil, reducing grazing pressure, restoring original vegetation, reusing rainwater, restoring/constructing small dams in the steepest areas). Additional data is still needed for these types of measures. The estimated cost for implementation is currently $250,000.

Developing an integrated monitoring plan for the surface water system (measuring is knowing)
In the previous paragraph, the importance of developing an integrated monitoring plan was already indicated. In addition to a hydrological monitoring network (precipitation, drain, evaporation) for the water balance, the water quality aspect should also be explicitly included. The development of such a monitoring plan primarily requires a commitment of time. The costs for installing the necessary measurement points and analyzing the data are not yet clear at this stage. This must first be determined once the plan is completed.

Dam upstream of Saliña di Vlijt and the saliña itself.

CHAPTER 3: WASTEWATER CHAIN

3.1 Current wastewater system

GENERAL

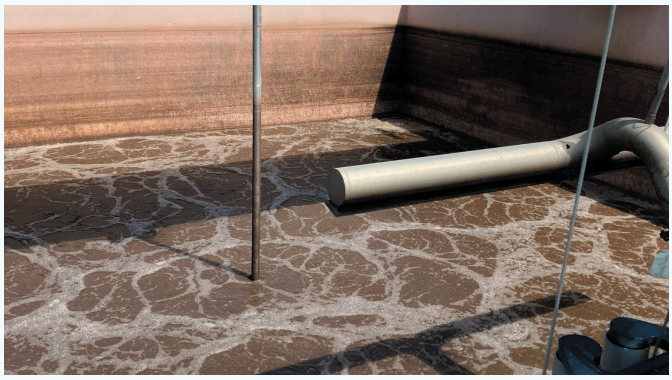
This paragraph provides a brief description of the wastewater infrastructure present on Bonaire, consisting of a sewer system (only partly in Kralendijk), a system of cesspools and septic tanks, and two wastewater treatment plants (RWZIs), both located in Kralendijk. After visiting several sites, it can be concluded that the existing RWZIs and transport pipelines are generally functioning properly. Regarding the sewer system, renovation work still needs to be carried out.

Various discussions with stakeholders have revealed that clarity will be provided in the short term regarding the separation of tasks and responsibilities related to the operation, management, and maintenance of the wastewater infrastructure between, on one hand, the Public Entity Bonaire (OLB), and the Water and Energy Company Bonaire (WEB), on the other hand.

TECHNICAL

Vacuum Sewer System Kralendijk

In Kralendijk, a coastal strip with a width of 500 meters was planned to be equipped with a (vacuum) sewer system. The first phase, with a width of 200 meters, has now been almost entirely completed. Due to the high costs (approximately 40 million for the first phase), it is still unclear whether the expansion to 500 meters will be executed. It is currently unclear whether there is a formal obligation to connect (new) house connections to the central sewer system. The vacuum pump stations transport the collected wastewater to a central booster pump station.



New vacuum station Belhem and the aeration of WWTP Kralendijk.

RWZI Kralendijk including transport system
The collected wastewater is transported via the central booster pump station to the RWZI Kralendijk, located at Kaminda Laguna. The RWZI is located at a considerable distance from the built-up area of Kralendijk. In the past, this location was chosen because it provided the possibility of infiltrating the effluent (treated wastewater) into the ground.
The RWZI consists of the following units:
• Mechanical treatment (for removal of coarse, dirt, and grease/oil);
• Activated sludge plant (SBR);
• Post-filtration using sand filters;
• UV post-treatment;
• Effluent pump;
• Sludge thickener and sludge drying beds.

The RWZI Kralendijk was put into operation in 2014. In the context of operating the RWZI Kralendijk, WEB is supported by RHDHV. Monthly result sheets are discussed. WEB can also rely on the knowledge of RHDHV in the field of maintenance of the installations.

Cesspools and septic tanks
For the other buildings (outside the aforementioned coastal strip), wastewater is discharged into cesspools and septic tanks. Although the construction is clearly different, the operation of cesspools and septic tanks is comparable. Both facilities consist of an underground system that receives household wastewater. In the septic tank, this water is partially purified after which it is often used by the user/owner as spray/irrigation water. In a cesspool, the liquid fraction often infiltrates into the soil. The breakdown of oxygen-binding substances varies from 30-40% for septic tanks to almost 0% for cesspools. The use of cesspools is prohibited and is being replaced by the use of septic tanks or connection to the sewage system (in the coastal strip). Given the (very) low level of purification, both systems lead to contamination of groundwater and ultimately to contamination of seawater. These facilities need to be emptied periodically. The extracted wastewater, including the captured sludge fraction, is transported by truck to the kAWZI Kralendijk.

kAWZI for wastewater from septic tanks (salt problem)
The kAWZI has been in operation since 2011 for the wastewater extracted from septic tanks.
The septic tanks are scattered across the entire island. The kAWZI is located next to the RWZI Kralendijk. A separate purification system was chosen because the water from the septic tanks is "contaminated" with incoming seawater. The salt fraction is harmful to the biological process of the RWZI Kralendijk. The kAWZI consists of:
- Receiving station for trucks;
- Buffer tank;
- Activated sludge system;
- Disinfection by chlorine dosing;
- Sludge buffer.

Effluent return
The effluent of the RWZI Kralendijk is used, among other things, for irrigation water and serves as a substitute for drinking water (approximately 4 $/m3). For this purpose, an effluent pipeline has been installed to Kralendijk, with which in particular the hotels and resorts can be served against payment (1.5 $/m3). Currently, 10 hotels are using this service (100 m3/day); there are approximately 30 connection possibilities have been realized which are not yet in use.
A second recipient is the LVV, located next to the RWZI Kralendijk. The costs (1.5 $/m3) prevent large-scale use of effluent for irrigation.
Individuals can obtain effluent at the same rate (1.5 $/m3), but they must pay for the transportation costs themselves. Taking into account these transportation costs, the price comes to approximately 10 $/m3 obtained. As a result, very few individuals use this service. Therefore, (unintended)

prioritization for reuse has been made due to the pricing:
- Hotels/resorts;
- Agriculture excluding LVV;
- Residents.

The indicated costs of effluent reuse for residents (10 $/m3) and for agriculture (1.5 $/m3) are strong obstacles to large-scale use of this. Given the general aim of reducing the sharply increasing drinking water consumption (5%/year over the past 10 years), the pricing would require differentiation.

Sludge processing
One of the waste products of the treatment process is sewage sludge. The sludge is currently deposited in landfill. During rainfall, precipitation will seep through the waste pile (leachate) and transport hazardous substances to groundwater streams. This eventually ends up in the sea.

ORGANIZATIONAL

Ownership situation wastewater infrastructure
The ownership of the entire wastewater infrastructure (vacuum sewer, supply line, RWZI, kAWZI, return line) lies with OLB. WEB, a governmental limited liability company of the OLB, provides the operation and maintenance of the entire infrastructure. In the short term, a management agreement will be concluded between OLB and WEB. This agreement will have to include matters such as:
- Performance of the infrastructure (availability, effluent requirements), including the method of monitoring;
- Financing of the services to be provided by WEB;
- Responsibility for calamities caused by errors and design and/or construction

Staffing for wastewater treatment plants (RWZI) and combined sewer systems (kAWZI)
Currently, 16 full-time employees are deployed for the operation and maintenance of both installations together. Under the manager, there are two working groups, “infrastructure” (sewerage and supply/return pipeline with 6 ftes) and the “RWZI” working group (RWZI and kAWZI) with 9 ftes.

Reuse of effluent
There is uncertainty about the possibility of using the treated effluent from the RWZI Kralendijk. The Nature and Environment Policy Plan - Caribbean Netherlands (NMBP-CN) states that from 2024, a ban will apply on irrigation with treated wastewater within a certain distance from the high-water mark. This would therefore apply to hotels and resorts that are interested in reusing the effluent as irrigation water.
In the Netherlands, this effluent irrigation ban has already existed for a long time partly because of the presence of heavy metals, medicine residues, hormone-disrupting substances, etc. Normal biological treatment plants only remove these substances to a very limited extent. The effluent from the wastewater treatment plant and the kAWZI are currently not sampled for the presence of these substances.
Within the OLB, it is stated that the ban only applies if the treated wastewater would be used for irrigation at the end user’s location, due to the presence and release of aerosols. Reuse in the form of (drip) irrigation would be allowed. It is unclear whether the spray ban will also apply to individuals.

A second discharge route for the effluent consists of transporting it by axle to individuals. A problem in this route is the use of trucks. Trucks that have transported (treated) wastewater cannot be used for transporting other liquids without thorough cleaning. It is currently unclear where this (logical) restriction is documented. Monitoring of truck usage is not currently taking place.

No integral policy various departments OLB on wastewater policy
Various conversations with different individuals within the OLB have shown that there is no integral policy and prioritization. This leads to uncertainties in the area of desires and requirements regarding the (future) use of the wastewater infrastructure.

Awareness
As with all matters that relate to the experiences of residents, involved officials and directors, all parties should be involved in the process of adapting the wastewater infrastructure in order to achieve a more sustainable solution.
There is an impression that the awareness is sufficiently present among the involved officials. It is unclear to what extent this also applies to residents in word and deed.

3.2 Bottlenecks

GENERAL

This paragraph provides an overview of the bottlenecks associated with the wastewater infrastructure present on Bonaire, which consists of a sewer system (only partially in Kralendijk), a system of cesspools and septic tanks, and two treatment plants, both located in Kralendijk. Various discussions and field visits have led to the indicated current and future bottlenecks, both technical and organizational. Various conversations with stakeholders have shown that clarity will soon be provided on the separation of tasks and responsibilities concerning the operation, management, and maintenance of the wastewater infrastructure between OLB and WEB.

TECHNICAL

Overloading RWZI Kralendijk

Due to increase in Bonaire's population and the number of tourists on the one hand, and the increase in the island's sewage rate on the other hand, the biological and hydraulic load on the RWZI Kralendijk will increase. Information from WEB indicates that the RWZI Kralendijk will reach its maximum design capacity within 5 years. Due to the nature of the RWZI being SBR, the installation can be expanded quite 'easily'. The UV installation is already in dire need of expansion. Currently, treatment takes place with one UV lamp, while at least four lamps are needed for environmentally safe operation. WEB has informed OLB about the need for expanding the UV installation, but the timing of execution is unknown.

Due to the upcoming ban on cesspools as stated in the NMBP, and therefore a likely increase in the number of septic tanks, combined with the population growth of Bonaire, not all of whom will be connected to the sewer system, the burden on the kAWZI Kralendijk will also increase. However, information from WEB indicates that the kAWZI Kralendijk will not be overloaded in the short term. For both treatment plants, however, there is no sufficient backup in case of large-scale breakdowns.

The vacuum sewer system does not meet waterproofing requirements.

During the extreme high water level in November 2022, it was found that the installed vacuum sewer system in Kralendijk is not 100% leak-proof. Because of the design principle, the pipeline should also function at high water. The observed backflow from toilets and floor drains in connected buildings indicates that the sewer system is not leak-proof. During the 2022 high water level, a large-scale use of vacuum trucks was necessary to minimize the inconvenience caused by the system's failure.

Untreated wastewater flows through the supply system to the RWZI. Leaks in the feeder system and impoundment at high water (caused by leaks) will lead to contamination of the soil that will eventually drain to the ocean through runoff over the impermeable basalt substrate.

The return pipeline is not optimal

Commissioning of the return pipeline revealed that it was not constructed in accordance with the applicable standards. Couplings between pipe lengths were missing in several places. It is uncertain if all leaks have been resolved. The return pipeline carries (treated) wastewater, which still contains (residues) of medications, hormone-disrupting substances, heavy metals, and nutrients. Leaks in the return pipeline will lead to soil contamination that, through runoff over the impermeable basalt substrate, will eventually flow into the ocean.

The use of cesspools

Cesspools are simple pits where feces, urine, and possibly flush water are collected without further treatment. If the pit is not watertight (which is often the case), the watery fraction leaks partially into the soil. Some of the organic material is biologically degraded. Organic material accumulates as sludge at the bottom of the pit. Over time, a cesspool becomes full and needs to be emptied. The sludge (the 'beer') was traditionally used as fertilizer in agriculture. To prevent the need for frequent emptying, some cesspools have an overflow for the water fraction. Cesspools require a certain level

of maintenance. Although it is a fairly robust system, emptying is necessary. The associated costs may be a reason for owners/users to neglect this maintenance. The use and lack of maintenance lead to contamination of the soil and groundwater. Eventually, the contamination will end up in the ocean.

Improper use of septic tanks
Septic tanks are a greatly improved form of a cesspool. Nutrients are reduced. The removal rate of about 30-40%. Septic tanks have an overflow for the wet (contaminated) fraction. They require a certain degree of maintenance. Although it is a robust system, emptying and a certain level of operation are necessary. The costs associated with emptying (60-150 $/m3) may be a reason for owners/users to neglect this maintenance. The operation of the facilities then decline even further. The users of septic tanks also need to be "trained" in the use and maintenance of the septic tank. The use and lack of maintenance lead to contamination of the soil and groundwater. Eventually, the contamination will end up in the ocean. Due to the construction of the septic tanks, there is a possibility of subsidence/leaks.

Discrepancy between drinking water use and total influent
It was indicated that there is a large discrepancy in the quantity of drinking water delivered and the quantity of wastewater offered. This can have various causes:
- Leaks in pipes (transport pipes, sewage pipes).
- Use of treated wastewater, originating from e.g. septic tanks, for other purposes, such as irrigation.
- Sampling errors.

Impact of sludge on solid waste landfill
Undesirable substances such as heavy metals, residues of medications, and hormone-disrupting substances are present in the sewage sludge. Dumping the sewage sludge on the landfill poses the danger of leaching these substances and contaminating the groundwater and ultimately endangering the aquatic environment.
In this context, attention is also drawn to the current situation in which the waste landfill is unprotected. There is no top cover or impermeable layer under the landfill.
Influence/contamination of groundwater streams and ultimately the aquatic marine environment are real threats.

Waste processing of Bonaire.

ORGANIZATIONAL

Lack of SLA between OLB and WEB regarding infrastructure goals and financing

OLB has financed the wastewater infrastructure (sewers, pipelines, and RWZI/kAWZI) and transferred the operation, management, and maintenance to WEB. No SLA has been established to regulate the goals of the infrastructure.

This SLA should regulate the following matters:

- Objectives (what do we want to achieve);
- Monitoring of results (are we achieving what we want);
- Financing (who pays what, who collects the levy).

Lack of maintenance plan/asset management plan

A solid maintenance plan is lacking, which limits asset management to corrective maintenance. Periodic maintenance hardly takes place. It is known that lack of periodic maintenance increases costs and increases the chances of unwanted breakdowns. Breakdowns will lead to unwanted discharges of untreated wastewater, pipeline breaks, which will cause environmental damage. Also, the lack of a suitable Management & Maintenance plan will lead to financial uncertainty. It is unclear what the costs will be for managing and maintaining the wastewater infrastructure.

Note: During the visit to Bonaire, WEB indicated that a management agreement, including the Service Level Agreement (SLA), would be signed in the short term between WEB and OLB. As part of the SLA, it is necessary to incorporate a maintenance plan along with a summary of the present state of affairs.

Lack of regulations on the use of cesspools

The NMBP-CN provides for a ban on the use of cesspools. However, there is no legal framework to which this ban applies.

Following this, an inventory will have to be made to determine where cesspools are still in use, after which a remediation plan must be developed and introduced.

Unclear ownership within OLB of wastewater infrastructure

Various departments/persons within OLB are involved in the wastewater infrastructure, leading to uncertainties about desires/competencies within OLB. These are the following examples:

- The obligation to connect to the existing sewerage system versus allowing the use of septic tanks;
- Uncertainty about the status of treated wastewater in terms of reusing this effluent. The NMBP-CN states that reuse within the coastal zone is not allowed, while within some departments of the OLB drip irrigation with effluent is allowed;
- Divided opinion on the damage caused by infiltration of (untreated) wastewater to the (aquatic) environment.

The workload within the OLB regarding the (re) development of the wastewater infrastructure is too extensive
Bonaire (OLB) faces a huge task in terms of (re) designing its wastewater infrastructure.

- The first phase of constructing the sewage system along the coastal strip has cost millions of dollars. A similar task will be required for the expansion of the sewage system.
- Furthermore, the future expansion of the RWZI will also put pressure on the existing staff members with expertise in wastewater.
- Efforts will also have to be made regarding monitoring the operation of the infrastructure, monitoring the effect of use on groundwater and the aquatic environment, among other things.
- Connecting to the sewer system and/or monitoring the operation of other systems (such as septic tanks) must be carried out.
- Finally, consideration will have to be given to the financial consequences of having the population of Bonaire use the wastewater infrastructure. Think about setting up and implementing a levy decision.
- Without a communication plan (awareness), many uncertainties will arise, which could lead to additional human resources being needed.

Some of the described tasks may be transferred (should be transferred?) to partner organizations. This could include WEB or external (consultancy) companies. However, even in that case, OLB must have a certain level of basic knowledge. Expansion of the workforce with competent employees is necessary. These employees must be willing to commit themselves to Bonaire for a longer period of time to ensure continuity.

Monitoring is lacking
Bonaire lacks a monitoring system that indicates the consequences/effects of the efficient use of wastewater (treatment) on groundwater flows and/or the aquatic marine environment. The following examples are:

- Impact of the use of cesspools;
- Impact of improper use of septic tanks;
- Impact of effluent reuse on the subsurface;
- Impact of effluent discharge into the quarry;
- Impact of seepage of precipitation on landfill.

3.3 Measures

GENERAL

In this paragraph, the measures are described that can solve the bottlenecks, as identified in paragraph 3.2.

TECHNICAL/ORGANIZATIONAL

Integrated solution for the expansion of the RWZI Kralendijk

Due to the increase in supply to the RWZI Kralendijk, this treatment plant will need to be expanded within a period of 2-5 years. Based on the principle of "asset base in order," the structural and electromechanical condition of the installation components must be checked. An asset management system must be established. The performance of the RWZI is currently being measured with the support of RHDHV. The RWZI currently meets the design requirements.

Load and maintenance condition studies will need to be included in an integrated study. Emphasis will also have to be placed on the future expectation of inputs to the RWZI:

- Increase in Bonaire's population.
- Increase in tourism. In this context, the wastewater from the marina is also included.
- Increase in the number of connections to the sewage system.
- Ban on the use of cesspools. All cesspools will eventually need to be remediated and replaced by septic tanks or connections to the sewage system. (The NMBP-CN states that regulations regarding a ban on cesspools will be provided by 2030.)

The possibility of modular construction should be included in this study. This makes it possible to achieve a flexible, future-proof solution without making large-scale investments too early or unnecessarily. The Verdygo construction technique can be considered in this context.
A study of resident hotspots, such as Rincon but also large-scale new construction plans, will need to consider the possibility of decentralized treatment plants.
For the "larger" resident hotspots, a value case should be written, which not only considers environmental security and sustainable use of energy (such as transportation), but also an integral concept of wastewater treatment of the buildings and the reuse of effluent.

A study has been conducted by RHDHV, called the "Integrated vision wastewater Bonaire 2023-2030". This study can be used as a good guide.
In the short term, the UV treatment of the RWZI Kralendijk needs to be adjusted for the removal of pathogenic bacteria.
Action 1: Execute future plan for RWZI Kralendijk.
Action 2: Integral study large resident hotspots.
Action 3: Adjust UV filtration.

Waterproofing chambers of vacuum sewage system It has been found that the collection chambers of the recently installed vacuum sewer system in Kralendijk were not constructed to be waterproof. In case of heavy rainfall (such as November 2022), rainwater can intrude, which can lead to severe flooding in the house sewerage of the connected residences.

Action 4: Waterproofing of collection chambers of vacuum sewage system

Water tightness of return water line
There is uncertainty about the water tightness of the return water line (effluent). By means of pressure testing this pipe and possibly implementing water-tightness measures (including replacement), certainty about the water-tightness can be obtained.

Action 5: Conduct research and actions on water tightness return line.

Regulation for connecting to sewer system
Expanding the area in which a sewer system is installed, will lead to a more environmentally secure solution for the wastewater problem in Kralendijk. A regulation that establishes the obligation to connect to a sewer system (within a certain number of meters from an existing sewer system) instead of allowing the use of septic tanks will result in an environmentally secure solution. This connection regulation is missing.

Action 6: Sewer connection requirement regulation.

Establishing an integrated monitoring system regarding the water system, including the wastewater chain.
The island of Bonaire faces a significant challenge in protecting the coral reef from the dangers posed by the wastewater chain. It is essential to know how the wastewater infrastructure, in the broadest sense, functions. Therefore, it is necessary to establish a monitoring system. This means that not only the direct parameters of the wastewater infrastructure need to be monitored, but also the issues that are influenced by the operation of the wastewater infrastructure. This includes the quality of the groundwater and seawater.

There is currently insufficient monitoring of the impact of such things as:
- Leaking sewage systems;
- Discharge of (un) treated wastewater;
- Reuse of effluent;
- The reuse of purified wastewater can be technically improved by monitoring the purified water.
- Dumping sewage sludge;
- In order to determine the effects of the “unprotected” dumping of sewage sludge on waste disposal, a monitoring system should be set up. Depending on the results of the monitoring, measures should be drawn up. In this context, the effects of the years of unprotected solid waste dumping can also be included.
- Transport of influent/effluent by axle.

Action 7: Setting up and installing a monitoring system for the wastewater chain as part of the water system.

Ban on the use of cesspools
The NMBP-CN includes a ban on the use of cesspools. A legal framework overseeing this prohibition is lacking. Following this, an inventory must be made of where cesspools are still in use, after which a remediation plan (septic tank or sewerage) can be made and introduced.

Action 8: Drawing up a regulation banning, listing, and sanitizing cesspools.

SLA for the wastewater infrastructure
WEB and OLB should draw up a Service Level Agreement (SLA) regarding the operation, management, and maintenance of the wastewater infrastructure on Bonaire. This will provide clarity for both parties on their responsibilities. The financial settlement of services will also provide more certainty in the future and ultimately lead to a healthier and more environmentally secure future for the wastewater infrastructure. The SLA can also regulate matters such as an asset

management system to reduce the number of unforeseen failures that may result in environmental damage.

Note: During the visit to Bonaire, WEB indicated that a management agreement, including the SLA, would be signed in the short term between WEB and SLA.

Action 9: Check if the management agreement pays sufficient attention to a maintenance plan.

Integral approach within OLB
In order to avoid that the deposition of responsibilities related to wastewater issues may lead to conflicts of interest between different departments/teams within OLB, it is preferable to give the responsibility over the operation of wastewater infrastructure unambiguously within one team. Given the high correlation with water system and groundwater issues, it is strongly preferred to establish a "Water" team within OLB. Considering the importance and scale of the wastewater problem, this is not an illogical choice. This does not mean that projects should be placed within this new department, but ultimate responsibility is.
A separate water department also strengthens the involvement of employees, as there will be a priority answer (it does not have to be "added"). There will also be a knowledgeable spokesperson in conversations with third parties, including WEB.
Creating a separate water organization will also facilitate twinning with a Dutch partner (such as a water board). The cooperation with the city of Breda is portrayed by OLB as a workable and positive example.
The current gap in required knowledge, capacity, and willingness/interest can can thus be closed.

Action 10: reorganization of activities within OLB so that all water-related matters are placed within one department.

Guaranteeing the operation of septic tanks
The impact of septic tank use on the environment is determined to a significant extent by the operation and maintenance of septic tanks. When leaving the septic tanks under the ownership of users, a training program will have to be set up, followed by a monitoring and enforcement program. An alternative solution is to equalize the Management and Maintenance of septic tanks with the intake system to the RWZI. WEB would then have a role in the management and maintenance of the septic tanks.

Action 11: If the ownership of the septic tank lies with the user, write a proper operation plan.

Awareness
Changes and adjustments to the wastewater infrastructure will have an impact on residents, involved officials, and administrators. Perhaps in the technical sense, because the use of the cesspool will be prohibited or a decentralized treatment plant will be built in the immediate residential area, or in the financial sense because it will be necessary to pay for wastewater treatment in the form of a levy.
Therefore, it is very important to include everyone in the project of wastewater treatment from the very first moment, including the preservation of the coral, should be explicitly mentioned.

Action 12: Setting up an awareness program

3.4 Prioritization/costs

In this paragraph, the measures as presented in paragraph 3.3 have been prioritized and costed.

Nr.	Action	Priority		T/O	Costs [$]
1.a	Future plan RWZI Kralendijk	A		T	300.000
1.b	Adjustment RWZI Kralendijk		B	T	5.000.000
2.a	Future plan for building hotspots (including Rincon)	A		T	500.000
2.b	Execution Future Plan		B	T	Note (depending on 2a).
3.	Adjusting UV installation in Kralendijk	A		T	200.000
4.	Making vacuum sewerage system waterproof	A		T	800.000
5.a	Research water tightness return water line	A		T	100.000
5.b	Waterproofing return water line		B	T	Note (depending on 6a).
6.	Regulation connection requirement	A		O	50.000
7.a	Setting up a monitoring system plan	A		T/O	100.000
7.b	Setting up a monitoring system.		B	T/O	Note (depending on 5a).
8.a	Regulation banning cesspools	A		O	50.000
8.b	Inventory/execution plan		B	O	100.000
8.c	Sanitizing cesspools		B	T	Note. (depending on 7b).
9.	Including asset management in SLA WEB-OLB	A		O	--
10.	Reorganizing OLB: one water department		B	O	Note
11.	Septic tank operation plan	A		O	10.000
12.	Communication trajectory	A		O	100.000

Priority:
A: 0-2 years
B: 2-5 years

CHAPTER 4. WATER SAFETY

4.1 Current and future situation

The protection against flooding from the sea is currently provided by the natural defense of the island. The island is mostly situated above sea level. Especially the southern part (salt pans, etc.), parts of Kralendijk, and Klein Bonaire, are low-lying and vulnerable to flooding from the sea. There are no dikes or other man-made defenses for protection against the sea. Currently, this is not seen as a major problem, although in some parts of Kralendijk, water may stand on the streets during strong storms (southwester).
Storms on the north and east sides of the island are halted by a relatively high and undeveloped coastline. Storms from the south and west sides of the island pose a greater problem because the island is lower on these sides. A large salt mine is active in the southern part of the island, and much of Kralendijk is situated in the low-lying western part of the island.

The soil of Bonaire around the coastal area is composed of limestone up to several tens of meters from the coastline. Limestone is porous, which makes mitigating sea level rise difficult. If dikes are placed around the coast, water simply penetrates under the dike through the limestone.

On behalf of Greenpeace, the Vrije Universiteit Amsterdam conducted research on the effects of climate change on Bonaire (IVM & VU, 2022). Different scenarios were considered, including the potential impact on different themes. The VU concludes in its research that sea level rise will drastically change the coastline of Bonaire (including the island of Klein Bonaire). Furthermore, the situation in the scenario of sea level rise combined with a severe storm is exacerbated due to surge and wave overtopping.

The ecologically and touristically important ecosystems of mangrove forests and coral reefs also play a crucial role in water safety. Both ecosystems act as a natural barrier against waves and can adapt to a rising sea level through gradual changes. Therefore, preserving and expanding these types of ecosystems is essential. Various organizations on Bonaire are involved in this. It is expected that the natural coastal defense is not sufficient to protect the residents of Bonaire. A comprehensive package of adaptation measures needs to be developed in the coming years. Creating support among the residents and politicians of Bonaire is essential in this regard.

Currently, there is not enough data available to develop a well-founded plan on this topic. Based on data from Puerto Rico, sea level at Bonaire is rising at a rate of 3.4 mm/year (source KNMI). It is expected that sea level around Bonaire will have risen by 30 to 120 cm in 2100 (source KNMI). However, the implications of this for the situation on Bonaire have not been studied yet. This means that nothing can be said yet about the necessary measures and associated costs. However, we can conclude that the effects of sea level rise in combination with sea storms will have a significant impact on the southern part of the island, on the western coastline, and on the free drainage of the water system.

4.2 Bottlenecks

Since 2017, all dike bodies in the Netherlands have been designed and tested according to new standards. These standards are based on, among other things, the consequential damage and the risk of victims in case of flooding. It is unclear whether this system also applies to Bonaire when drafting this report. Having a system in place is necessary to determine whether an area requires protection and, if so, how it should be implemented. The standardization system will need to be determined and established in consultation with the Ministry of Infrastructure and Water Management.

The expected height and exact consequences of sea level rise are still unknown. This knowledge gap results in a lack of ability to develop policies on this topic and for new developments in spatial planning. However, it can be established that the effect of sea level rise on Bonaire is significant, with major consequences for densely populated areas and/or areas with significant economic interests. Apart from the knowledge gap on water safety, it is useful to impose restrictions on new developments around the coastal area of Kralendijk in anticipation of research results.

Slave houses on the southern tip and boulevard of Kralendijk.

4.3 Measures

Firstly, a discussion needs to be held with the ministry regarding the norm system that should be applied for Bonaire.

To fill the knowledge gap regarding the effects of sea level rise, it is recommended to have it investigated by an independent, scientific institute. Questions that should at least be addressed are:

- What level of sea level rise can Bonaire expect?
    - o Additional: what is the effect of storms on this?
- What is the effect of this level of sea level rise on the water safety of the island, particularly on the south and west sides? To answer this question, a detailed, reliable altitude map is needed. This is currently not available. There is an altitude map. However, manual measurements suggest that these measurements are 1.20 meters too high (IVM & VU, 2022).
- What is the effect on the mangrove forests on the east side of the island and the reef that partially protects them?
- What is the effect on saltwater intrusion into the groundwater?
- What are possible solutions for the expected effects of sea level rise in the different areas of the island?

The theme of water safety needs to be better integrated in new developments. In the current situation, this is insufficient. Therefore, it is recommended not to allow new developments in risk areas along the coast or to demand additional measures. Subsequently, the consequences of sea level rise for the coast of Bonaire need to be investigated. Based on this research, a policy can be developed to allow new developments along the coast again. OLB staff should also be trained to consider water safety in new developments. A (variant of the) water test, as used in the Netherlands, can also be a useful tool for this topic. By constructing new developments at higher levels or otherwise protecting them against rising sea levels, the island is better equipped for climate change.

4.4 Prioritization/Costs

To establish and implement effective policies regarding sea level rise, more information is needed about the degree and consequences of the rise for Bonaire. Conducting a study should be outsourced. Based on the results, the water safety theme can be developed further. The cost of such a study is estimated at $1,000,000.