Airport of Rodrigues Ltd

Proposed Expansion of Rodrigues Airport

APPENDICES 9.2 Specialists Reports

VOLUME 3 OF 4

Report Reference – 09053999

Prepared by

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- Specialist Report for Noise & Air Quality

Airport of Rodrigues Ltd

Proposed Expansion of Rodrigues Airport

Maritime Impacts Factual Report for the purpose of the Environmental and Social Impact Assessment Report

Report Reference – 09053999

Prepared by

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0 Non-Technical Executive Summary

0.1 Introduction

0.1.1 Geographical overview

Rodrigues is an island of volcanic origin belonging to the Mascarene Islands, located in the South Western Indian Ocean. It is 18 km long, 6.5 km wide and covers a surface area of 108 km².

The capital city is Port Mathurin, located on the opposite side of the island from Plaine Corail, in the northeast.

The island has a general mountainous topography with alluvial plains in the north and south. It is organized around a central ridge, from which steep ravines radiate. The valley bottoms usually remain dry and are only affected by torrential flows during heavy cyclonic rains.

However, the southwestern part of the island is dominated by a karst plain of coral sandstone over an area of about 10 km².

The island is surrounded by a large coral reef with several islets that emerge from it.

0.1.2 Marine conditions

The mean magnitude of current in deep water near Rodrigues is 0.17 m/s and most of the magnitude is inferior to 0.3 m/s, 89%. Directions vary with a predominance of South West – North East currents.

The reef lagoon's hydrodynamics are complex, although three lagoonal passes can be identified in the fringing reef around Rodrigues, none of them are in front of Plaine Corail.

Alongside the runway, currents are flowing from South-East to North-West throughout the duration of the year and fluctuate from almost no magnitude to 0.5 m/s with ebb and flow tide currents. They are tide-generated, the wave height inside the lagoon being very small. The current coefficient can briefly be reversed during light winds and strong tides.

Rodrigues' tides can be classified as meso-tidal due a tidal range inferior to 2 m. Sea level has risen by 6.7 cm between 1950 and 2001.

The coral reef fringing Rodrigues serves as a natural barrier that protects adjacent shorelines from offshore coastal hazards such as storms surges and waves. Plaine Corail is well protected from extreme waves due to the reef which is up to 8.3 km wide. In the canal between Crab Island and the runway, significant height reaches 45 cm when eastern wind blows with 10.5 m/s velocity (highest 10%) and 20 cm without wind.

Sea levels in the southwest Indian Ocean based on reconstructed tide gauge data and Topex/Poseiden altimeter for the period 1950-2001 shows a rise of around 1.5 mm/yr at Port Louis and 1.3 mm/yr at Rodrigues, (Church, et al., 2006). Analysis of Port Louis data for the period 1987-2007 gives a mean rise of 2.1 mm/yr for the last 10 years. This slightly higher rise is consistent with IPCC WGII AR4 conclusions, although longer period of measurements are necessary for reliable conclusions.

0.1.3 First approximation of storm water outlet flow in the sea

As a reminder, the study presented in this write-up is a first approximation of the stormwater flows going into the sea and cannot be taken as definitive for the project Proposed Expansion of Rodrigues Airport Environmental and Social Impact Assessment Report. This results will be consolidated during the second phase of the project after a more detailed study with the updated data of the project.

0.1.3.1 Statistical rainfall data

Because of the lack of statistical rainfall data on Rodrigues island, the ones at Vacoas (Mauritius main island) have been used. The latter maximize the generated water depth by the rain since the climate is dryer in Rodrigues than in Mauritius main island).

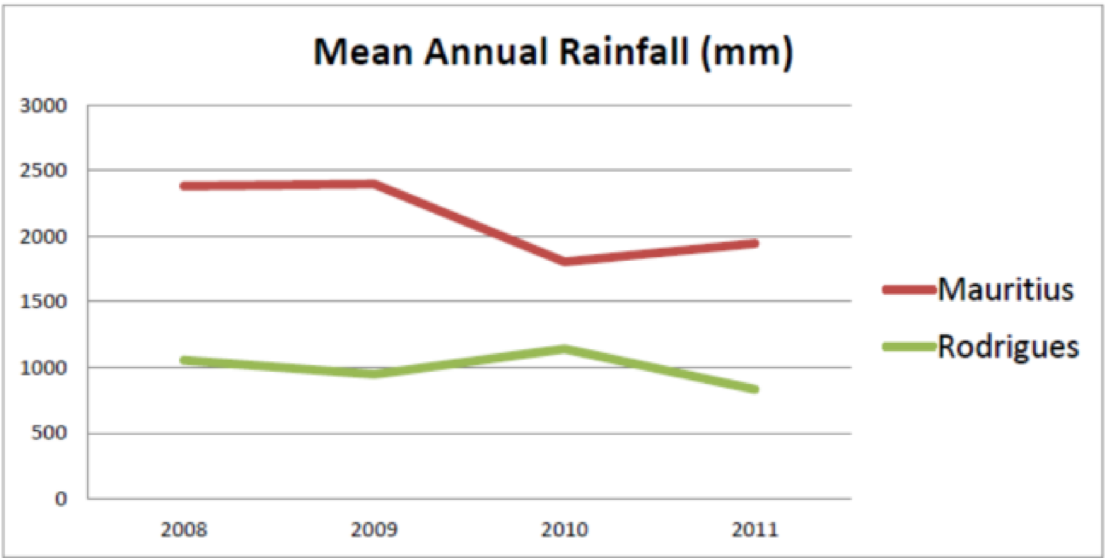


Figure 1: Mean Annual Rainfall (Island of Mauritius and Rodrigues)
(Source: National Climate Change Adaptation Policy Framework, 2012)

The statistical rainfall data at Vacoas are presented in the table below.

Table 1: Statistical rainfall data at Vacoas

Durée de l'épisode	Période de retour					
	2 ans	5 ans	10 ans	25 ans	50 ans	100 ans
	Quantités en mm					
6 min	6.4	10.3	12.9	17.5	21.6	27.3
15 min	12.3	19.8	24.7	33.6	41.5	52.3
30 min	20.2	32.4	40.3	55.0	67.9	85.6
1 h	33.0	53.0	66.0	90.0	111.0	140.0
2 h	47.0	75.5	94.0	128.2	158.1	199.4
3 h	57.8	92.8	115.6	157.6	194.4	245.2
6 h	82.3	132.2	164.6	224.4	276.8	349.1
12 h	117.2	188.2	234.4	319.6	394.2	497.2
24 h	166.9	268.0	333.8	455.1	561.3	708.0

The equations derived from the IDF curves for calculating intensity (mm/hr) are as follow:

For duration t < 1 hr $i = R\ x\ t^{-0.29}$

t > 1 hr $i = R\ x\ t^{-0.49}$

Where, for Return Period of 2 years, R = 33

5 years, R = 53

10 years, R = 66

25 years, R = 90

50 years, R = 111

100 years, R = 140

0.1.3.2 Watersheds split

The stormwater drainage system is to be divided into two distinct sub-networks due to the general topography of the project:

- the first one, to the South, is to manage stormwater from the new runway and its surroundings, with gravity outflows to the lagoon south of the runway,
- the second one, to the North, is to manage rainwater from buildings, stormwater from car parks, taxiways and their surroundings, with a natural outlet to the west, towards the existing boat house.

It is worth to note that the rain water storage for the water re-use process as explained in the Environmental and Social Impact Assessment Report of the project is not considered here to consider the worst case scenario (full tank when the event occurs).

The watersheds of the project whose outlet is the sea are displayed in the picture below.

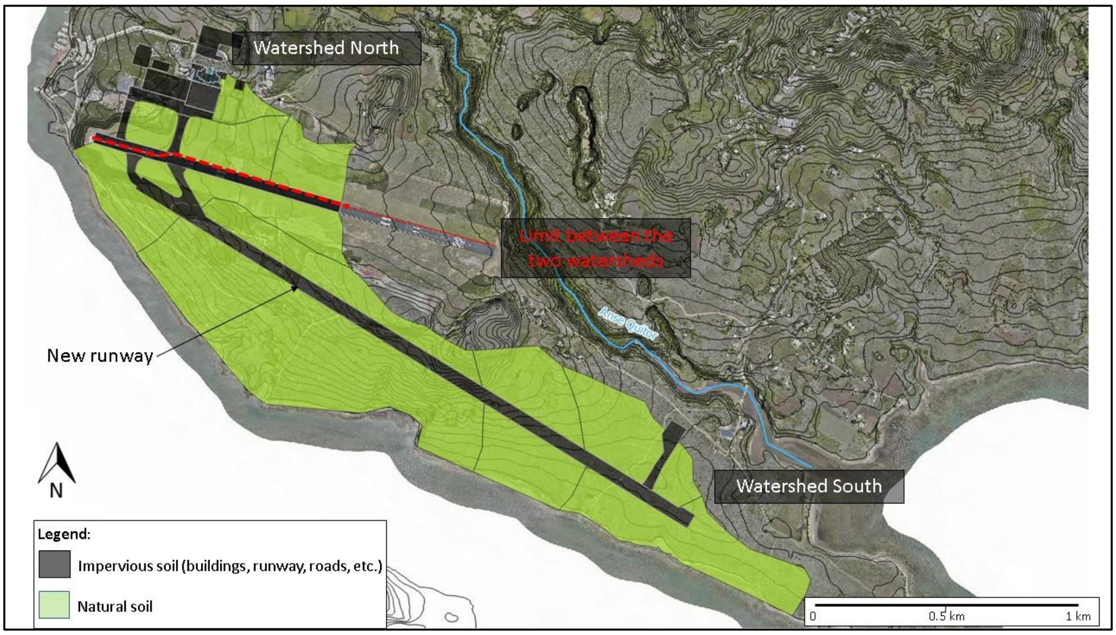


Figure 1: Watersheds of the study area whose outlet is the sea

0.1.3.3 Hydrograms generated by the watersheds

In this paragraph, we describe the construction process of hydrograms generated by the watersheds whose outlet is the sea.

0.1.3.3.1 Hydrological parameters

The hydrological parameters of each watersheds (North and South) are presented in the table below.

- The concentration times are calculated through the Kirpich formula:

$$t_c = \left[\frac{0.87 \times L^2}{1000 \times s}\right]^{0.385}$$

where t_c = time of concentration (hours)
L = longest flow path (km)
S = slope of L (m/m)

- The discharge peak flows are calculated through the rational formula:

$$Q_T = 0.278 \times C_T \times I_T \times (ARF \times A)$$

Q_T = Discharge (m^3/s) for return period T
C_T = runoff coefficient for return period T
I_T = intensity (mm/hr) for return period T
ARF = Area Reduction Factor
A = area (km^2)

Table 2: Hydrological parameters of the watersheds

	Unit	Watershed North	Watershed South
Surface	[ha]	19.7	115.1
Runoff coefficient T< 25 years	-	0.41	0.26
Runoff coefficient T> 25 years	-	0.45	0.31
Concentration time	[hour]	0.20	0.28
T= 2 years - Peak flow	[m^3/s]	1.19	3.91
T= 5 years - Peak flow	[m^3/s]	1.91	6.28
T= 10 years - Peak flow	[m^3/s]	2.37	7.82
T= 25 years - Peak flow	[m^3/s]	3.57	12.87
T= 50 years - Peak flow	[m^3/s]	4.40	15.87
T= 100 years - Peak flow	[m^3/s]	5.55	20.01

0.1.3.3.2 Hydrograms construction

Because of the lack of data (no measured hydrograms), the classical methods to build an hydrogram cannot be used here. We therefore defined the parameters of the hydrograms through the following method:

- The peak flow is the one calculated in the previous paragraph,

- The time of rise is equal of the concentration time,
- The duration of the hydrogram is equal to two times the concentration time.

The carried out hydrograms generated by the watersheds whose outlet is the sea are presented for each event below.

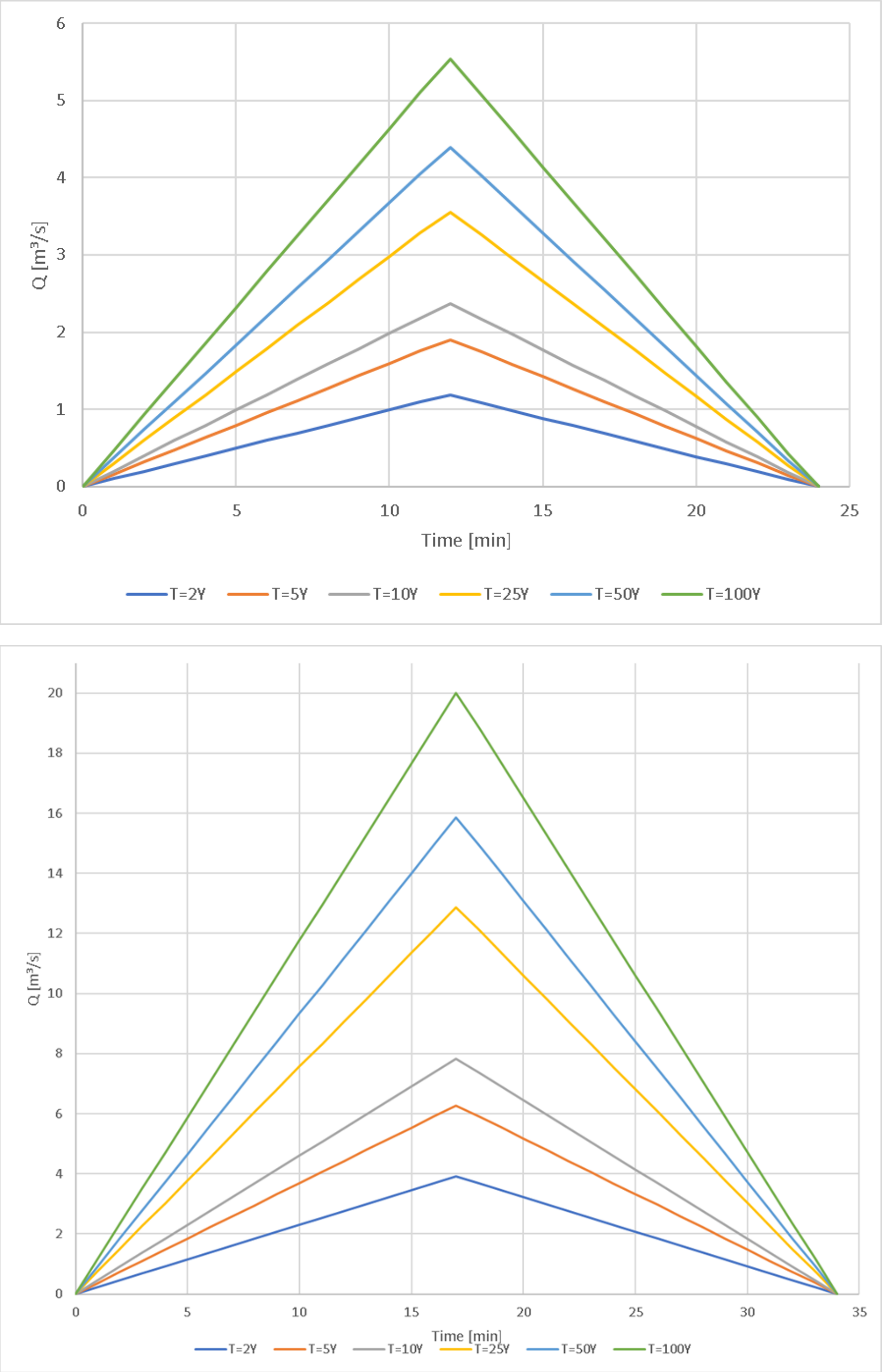


Figure 2: Hydrograms generated by the watershed North (top) and the watershed south (bottom)

0.1.4 Climate Change

0.1.4.1 Sea level rise

Sea level have started to rise under the impact of climate change. This increase is estimated by the IPCC for different parts of the world. For the South Indian Ocean, the estimates are as follows compared to the period 1995-2014 according to 2 scenarios:

Table 3 : Sea level rise

Period	Sea level rises	
	Scenario SSP2-4.5 *(middle-of-the-road development)*	**Scenario SSP5-8.5** *(Fossil-fuelled development)*
Near term (2021-2040)	+0,1m	+0,1m
Medium Term (2041-2060)	+0,2m	+0,3m
Long Term (2081-2100)	+0,6m	+0,7m

0.1.4.2 Tropical Cyclones

IPCC projections show medium confidence in evolution of tropical cyclones according to document: Climate Change 2021: The Physical Science Basis.

Projections for Madagascar (no projections for Indian Ocean) show medium confidence of decrease in frequency and increase in intensity. Cyclones will potentially be less numerous with more intense winds and rainfall. Lower minimum pressure and stronger winds may generate more significant surges. According to IPCC, "*The increase in global TC* [Tropical Storm] *maximum surface wind speeds is about 5% for a 2°C global warming across a number of high-resolution multi-decadal studies (Knutson et al., 2020)*" and "*A projected increase in global average TC* [Tropical Storm] *rain rates of about 12% for a 2°C global warming* […] *(Knutson et al., 2020)".*

0.1.5 Marine and shores geology and marine turbidity

The coastal zone is mostly surrounded by fringing coral reef enclosing a shallow lagoon area – 0.5 to 3m – with local deeper channels. A shallow channel also separates the location of the future airport runway from Crab Island. The width of lagoons varies from 4-8km from the shore (4,6km from the airport runway).

The coastline is about 67 km long and is composed of different shore types: rocky stretches alternating with sandy beaches and smaller stretches of rock boulders and pebble shores. Plaine Corail shore is mostly rocky.

The western coastal area of Rodrigues lagoon is characterized by a significant amount of medium sand and mud. The Northern part of the bay is composed of mud due to the very weak current and the important water runoff during heavy rains. Bed load and resuspension occurs within the lagoon during each tidal cycle. Sediment transport under the influence of the flow is mainly from South-East to North-West.

The sea water around Rodrigues is usually very clear. However, rivers carry large amounts of debris and soil into the lagoons during heavy rain, increasing the sea water turbidity. In some places, mangroves have been planted that stabilize the sediments and prevent the turbidity spreading into the lagoon. In Baie Topaze, the northern area of Plaine Corail Airport, natural turbid plume was identified in the past.

0.1.5.1 Physical environment sensitivity

The Physical Environment Sensitivity is summarised in Table 4 hereafter.

Table 4: Physical Environment Sensitivity

Sub-theme	Receptor	Sensitivity
Marine and shores geology and marine turbidity	Marine sediment quality: contamination of marine sediments	Medium
	Marine sediment dynamics: physical disturbance of marine sediments	Medium
	Seawater quality: temperature, salinity, concentration of contaminant	High
	Physical coastal processes: shoreline, morphology, wave, currents	Medium

0.2 Potential impacts and measures

Potential environmental impacts on the maritime and associated management measures are summarized in the next tables. Construction phase impacts which are temporary in nature are distinguished from the permanent impacts.

Impacts related to Operations are addressed in a third section.

0.2.1 Temporary impacts during works phase

Table 5: Summary of Temporary impacts during works phase

Context	Sub-context	Impact ID	Impact description	Positive / adverse	Impact rating before mitigation	Measure ID	Measure	Residual Impact rating
Physical	Marine	Phy-Mar-W-Temp-1	Increase in turbidity	Adverse	Major	Phy-Mar-Mit-1	Control of backfilling processes	High
						Phy-Mar-Mit-2	Optimisation of the location of discharges	
						Phy-Mar-Av-3	Optimisation of the discharges timetable to avoid times when currents reverse and/or already turbid condition	
						Phy-Mar-Mit-4	Silt curtain around discharges	
		Phy-Mar-W-Temp-2	Modification of the seabed	Adverse	Low	Phy-Mar-Mit-1	Control of backfilling processes	Low
						Phy-Mar-Mit-2	Optimisation of the location of discharges	
						Phy-Mar-Av-3	Optimisation of the discharges timetable to avoid times when currents reverse and/or already turbid condition	
						Phy-Mar-Mit-4	Mitigation - Silt curtain around discharges	
						Phy-Mar-Mit-5	Mitigation - Silt curtain around dredging area	
		Phy-Mar-W-Temp-3	Dredging in front of the boathouse	Adverse	Major	Phy-Mar-Av-3	Optimisation of the discharges timetable to avoid times when currents reverse and/or already turbid condition	High
						Phy-Mar-Mit-5	Mitigation - Silt curtain around dredging area	
		Phy-Mar-W-Temp-4	WWTP discharge	Adverse	Low	None	None	Low
		Phy-Mar-W-Temp-5	Desalination plant discharge	Adverse	Low	None	None	Low

0.2.2 Permanent and irreversible impacts during works phase

Table 6: Summary of Permanent and Irreversible Impacts during Works phase

Context	Sub-context	Impact ID	Impact description	Positive / adverse	Impact rating before mitigation	Measure ID	Measure	Residual Impact rating
Physical	Marine	Phy-Mar-W-Def-1	Alteration of the local bathymetry and shoreline	Adverse	Low	None	None	Low
		Phy-Mar-W-Def-2	Modification of the local hydrodynamic processes	Adverse	Negligible	None	None	Negligible
		Phy-Mar-W-Def-3	Modification of the sediment transit	Adverse	Low	None	None	Low
		Phy-Mar-W-Def-4	Modification of the bathymetry due to the dredging to access jetty facilities	Adverse	Low	None	None	Low
		Phy-Mar-W-Def-5	Remains of suspended particulate matter and sediment	Adverse	Low	None	None	Low

Note: When no impacts are foreseen, 'Impact ID' column is marked 'none' and the following columns are hence not populated and marked '-'

0.2.3 Permanent impacts during operation phase

Table 7: Summary of Permanent Impacts during Operation Phase

Context	Sub-context	Impact	Impact description	Positive / adverse	Impact rating before mitigation	Measure ID	Measure	Residual Impact rating
Physical	Marine	Phy-Mar-Op-1	Accidental spillage	Adverse	Major	Phy-Mar-Mit-6	Prevent spills and accidents: train staff to avoidance of spills.	Low
						Phy-Mar-Mit-7	Implementing methodologies for quick confining and treatment of pollutants and protocol for depollution in case of spill	
		Phy-Mar-Op-2	Uncontrolled waste water discharges	Adverse	Low	None	None	Low
		Phy-Mar-Op-3	WWTP discharge	Adverse	Low	Phy-Mar-Mit-8	Location of the outfall	Low
						Phy-Mar-Mit-9	Outfall sizing	
		Phy-Mar-Op-4	Desalination plant discharge	Adverse	Low	Phy-Mar-Mit-10	Location of the outfall	Low
						Phy-Mar-Mit-11	Outfall sizing (diffuser)	
		Phy-Mar-Op-5	Stormwater drainage	Adverse	Medium	Phy-Mar-Mit-12	Relocation of southern discharges	Low

Note: When no impacts are foreseen, 'Impact ID' column is marked 'none' and the following columns are hence not populated and marked '-'

0.3 Environment management plans for construction phase

Table 8 lists the plans to be developed and implemented to monitor the marine environmental measures in the impact study.

Specific guidelines for preparing plans are provided in Chapter 3.

Table 9 summarizes the marine environmental measures in the impact study.

The estimated cost associated with the marine environment management and monitoring are provided in Chapter 6. The costs are considered indicative at this stage and will be updated during the life cycle of the project.

Table 8: Marine Environment Management Plans for Construction Phase

Plan	Measures that the plan must allow to implement and monitor	Person in charge of implementation and control	Activity / Procedures to include
Marine environment monitoring plan	Phy-Mar-Mit-1 / 2 Phy-Mar-Av-3	External consultancy engineering Under ARL's control	- Current and turbidity monitoring plan
	Phy-Mar-Mit-4 / 5	Contractor Under ARL's control	- Marine Works monitoring plan
	BioM-Mit-1 / 2 BioM-Av-3	Shoals Rodrigues / SEMPA Under ARL's control	- Coral reef protection and monitoring

Table 9: Summary of Environmental Measures and Monitoring for Construction Phase

Theme / Issue	Title and ID of the measure		Complementary description	Period of performance / Corresponding plan	Performance monitoring system	Performance indicators	Corrective measures	Responsible managers for implementation
Marine environment	Phy-Mar-Mit-1	Control of backfilling processes	The construction processes must ensure a minimal volume of water in the low-lying embankment delimited area to insure the stability and sustainability of the runway.	Works phase and prior to the works **Marine environment monitoring plan**	Monitoring of turbidity level in the vicinity of the runway. Monitoring the water concentration in the embankment. Ensuring construction equipment are appropriate.	Compliance to water quality prevailing threshold.	Failure to meet the performance criteria shall be recorded as a non-conformance incident. In the case of structural failure or non-compliance turbidity level, works are to immediately cease. Incident has to be reported. Implementing protocol for depollution in case of spill.	External consultancy engineering Under ARL's control
	Phy-Mar-Mit-2	Optimisation of the location of discharges	The discharge should be located in order to promote a local settling of the inorganic matter. A hydrodynamic survey can be conducted to identify these optimal locations.	Works phase and prior to the works **Marine environment monitoring plan**	The discharge should be located in order to promote a local settling of the inorganic matter. A hydrodynamic survey can be conducted to identify these optimal locations.	Compliance for water quality prevailing threshold	Monitoring of turbidity levels.	External consultancy engineering Under ARL's control
	Phy-Mar-Av-3	Optimisation of the discharges timetable to avoid times when currents reverse and/or already turbid condition	In order to minimize the intensity and extent of the flume, discharge should occur with weak current and low level of turbidity.	Works phase and prior to the works **Marine environment monitoring plan**	Monitoring of turbidity levels in the vicinity of the runway. Monitoring of magnitude and direction of the current in the vicinity of the runway.	Compliance to water quality prevailing threshold. Compliance with current prevailing threshold.	Discharge to be stopped if non-compliance. Reducing the hydraulic flows of the deposited materials.	External consultancy engineering Under ARL's control
	Phy-Mar-Mit-4	Silt curtain around discharges	Silt curtains can be used to contain suspended sediments and to prevent sediment dispersal.	Works phase and prior to the works **Marine environment monitoring plan**	Monitoring of turbidity levels. Conducting daily visual inspection of the curtain.	Compliance to water quality prevailing threshold.	Failure to meet the performance criteria shall be recorded as a non-conformance incident. Discharge to be stopped if non-compliance. Verifying the operation of the equipment according to the manufacturer's specifications	Contractor Under ARL's control
	Phy-Mar-Mit-5	Silt curtain around dredging area	Silt curtain controls the suspended solids generated by the dredging and is placed around the excavation site.	Works phase and prior to the works **Marine environment monitoring plan**	Monitoring of turbidity levels. Monitoring of	Compliance to water quality prevailing threshold.	Dredging to be stopped if non-compliance. Verifying the operation of the equipment according to the	Contractor Under ARL's control

Theme / Issue	Title and ID of the measure		Complementary description	Period of performance / Corresponding plan	Performance monitoring system	Performance indicators	Corrective measures	Responsible managers for implementation
					contaminants in the water column.		manufacturer's specifications.	

0.4 Marine environment management plans for operation phase

Table 6 lists the plans to be prepared prior to start of operation and then implemented during operation to monitor the marine environmental measures in the impact study.

Specific guidelines for preparing plans are provided in Chapter 3.

Table 7 summarizes the marine environmental measures in the impact study.

The estimated cost associated with the marine environment management and monitoring are provided in Chapter 6. The costs are considered indicative at this stage and will be updated during the life cycle of the project.

Table 10: Marine Environment Management Plans for Operation Phase

Plan	Measures that the plan must allow to implement and monitor	Person in charge of implementation and control	Activity / Procedures to include
Marine biodiversity and habitats monitoring plan	-	To be implemented by ARL or an external specialist/ engineer Under ARL's control	- A monitoring procedure to implement by the person in charge for the monitoring - A follow-up plan to implement by ARL

Table 11: Summary of Environmental Measures and Monitoring during Operation Phase

Theme / Issue	Title and ID of the measure		Complementary description	Period of performance / Corresponding plan	Performance monitoring system	Performance indicators	Corrective measures	Responsible managers for implementation
Marine environment	Phy-Mar-Mit-6	Prevent spills and accidents: train staff to avoidance of spills.	-	Operational phase **Emergencies prevention and management plans**	Regular checking visits and tests	Zero spill	Improve training	ARL
	Phy-Mar-Mit-7	Implementing methodologies for quick confining and treatment of pollutants and protocol for depollution in case of spill	-	Operational phase In case of a spill **Emergencies prevention and management plans**	Monitoring of turbidity levels. Monitoring of contaminants in the water column.	Compliance to water quality prevailing threshold.	Informing of local authorities. The spill source will be immediately isolated, stopped and contained	ARL

1 Maritime baseline conditions

1.1 Scoping and methodology

The ESIA has been carried out in accordance with the Mauritius Environmental Protection Act 2002 and with the requirements of the World Bank Environmental and social Framework.

The purpose of the ESIA is to identify the environmental issues which could have been directly or indirectly impacted by the project. This methodology allows the study to focus on the effective potential impacts of such an airport project and helps to determinate the level of the investigations to carry out on the marine environment.

The following tasks have been undertaken:

- Desk review of available data,
- Site investigations,
- Consultations with interested parties,
- Consultations with specialists.

The island and coastal context of the project requires a specific focus on the natural and hydro-sedimentary marine environment and meteorological conditions.

In addition, the following subjects were the subject of campaigns to recognize the existing system:

- Marine natural environment (field investigation carried out in July 2019)
- Hydro-sedimentary context (field investigation carried out in July 2019)

The first step is a presentation of the general state of the island of Rodrigues. This global presentation aims to define the current state (baseline) of the island, before the potential implementation of the project. It is therefore a description that takes into account several themes (physical context elements, natural context elements...).

The final objective of this exercise is to highlight all the "receptors" which could be affected, directly or indirectly, by the implementation of the project.

For each of these receptors, sensitivity was assessed according to the importance of the issue and its vulnerability.

In the context of this social impact assessment, and in order to adapt as precisely as possible to the local context of Rodrigues Island, the sensitivity of the receptor was judged in particular on the basis of the results of consultation meetings with local stakeholders, taking into account the importance given to them by local communities and authorities.

Thus, at the end of each section of the initial state, the issues are listed and their sensitivity is assessed and rated using the following methodology: 1 "low", 2 "medium", 3 "high" or 4 "major". To make reading easier, a gradient of blue is associated with each score to make the report more readable.

The higher the importance of the issue, the more intense the shade of blue.

Table 12: Receptor sensitivity

Receptor sensitivity	Low	Medium	High	Major

1.2 Data Collection

The current compiled oceanographic data necessary to quantify the influence on the currents and sediment transport is summarized as follows:

- Bathymetry:
  The large scale model bathymetry data would be forced from the General Bathymetric Chart of the Oceans (GEBCO) with 0.5° resolution, approximately 430m.
  Closer to Rodrigues, the GEBCO bathymetry would be supplemented by a thinner data set close to the coast and inside the lagoon. Discussions are underway with the Hydrographic Section of the Ministry of Housing and Land of Mauritius to obtain accurate data both inside and outside the lagoon.
- Shoreline:
  The shoreline was defined using data obtained from the Database of Global Administrative Areas (GADM) with approximately a 30 m resolution and re-delineated if necessary.
- Hurricane tracks:
  The tracks of the Ocean Indian Hurricane were downloaded from the Joint Typhoon Warning Center (JTWC) website from 1986 to 2016. Trajectories are defined by 6 hours elapsed time points defined by its localization, intensity, maximum wind speed, and minimum SLP.
- Sea level:
  Port Mathurin tide gauge is part of the Global Sea Level Observing System (GLOSS). Controlled sea level data are checked and processed in order to establish sea level value more suitable for studies of long term sea-level change. Historical hourly level data are available at Rodrigues from 1986 to 2016.
- Tide Harmonic:
  The LEGOS[1] produced a global finite element solutions (FES) tidal atlases computed from the tidal hydrodynamic equations and data assimilation. Harmonic constants, amplitude and phase, are extracted in the surrounding of the island.
- Coral Reef:
  Coral reef distribution around the island is extracted from the global distribution of coral reefs in tropical and subtropical regions, version 4.0 of November 2018. The dataset[2] is compiled from various sources such as the UNEP World Conservation Monitoring Centre (UNEP-WCMC) and the WorldFish Centre, in collaboration with WRI (World Resources Institute) and TNC (The Nature Conservancy). The GIS layer has a consistent 30 m resolution and mostly originates from images acquired between 1999 and 2002.
- Climatology Statistics:
  An analysis was performed by MeteOcean to characterize the meteo-oceanic conditions in the vicinity of Rodrigues. Waves, winds, water height, salinity and

[1] Laboratoire d'Etude en Géophysique et Océanographie spatiales

[2] UNEP-WCMC, WorldFish Centre, WRI, TNC (2018). Global distribution of coral reefs, compiled from multiple sources including the Millennium Coral Reef Mapping Project. Version 4.0, updated by UNEP-WCMC. Includes contributions from IMaRSUSF and IRD (2005), IMaRS-USF (2005) and Spalding et al. (2001). Cambridge (UK): UNEP World Conservation Monitoring Centre. URL: http://data.unepwcmc.org/datasets/1

temperature statistics are available at a deep water point (2989m from the MSL) located at -63°12'E 20°S, in the South of the island.

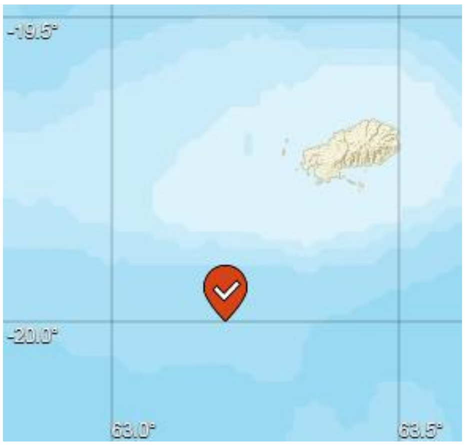


Figure 3 : Location of the analysis point: -63°12'E,20°S (WGS84)

At the present time, some data are still being gathering, they will be taken into account in the next version of the report. This is the case of bathymetry and sediment characteristics (granulometry) data.

1.3 Area of Influence

Several areas of influence (AoI) have been defined to establish the baseline of the project's site. Each component of the environment is contextualized at the scale of the Island or the Indian Ocean according to the themes, then examined at the scale of a "large area of influence" and finally, if necessary, at the scale of a "restricted area of influence".

The "large area" includes the airport and its remote surroundings, which are known to be influenced by the direct and indirect impacts of the airport. The "restricted area" is the project footprint's direct surroundings, which are considered potentially directly impacted by the project.

The project's footprint is included in the restricted area.

Specific areas of influence had to be defined for some of the baseline components:

- the areas of influence for the terrestrial and marine natural environment are designed to adapt to the targeted species and ecosystems,
- the socio-economic area of influence is designed to adapt to the boundaries of the villages and areas used by the affected inhabitants or for the resettlement of displaced populations.

At the beginning of each section, the area of influence applied is specified.

The area of influence for physical context is mapped in Figure 4.

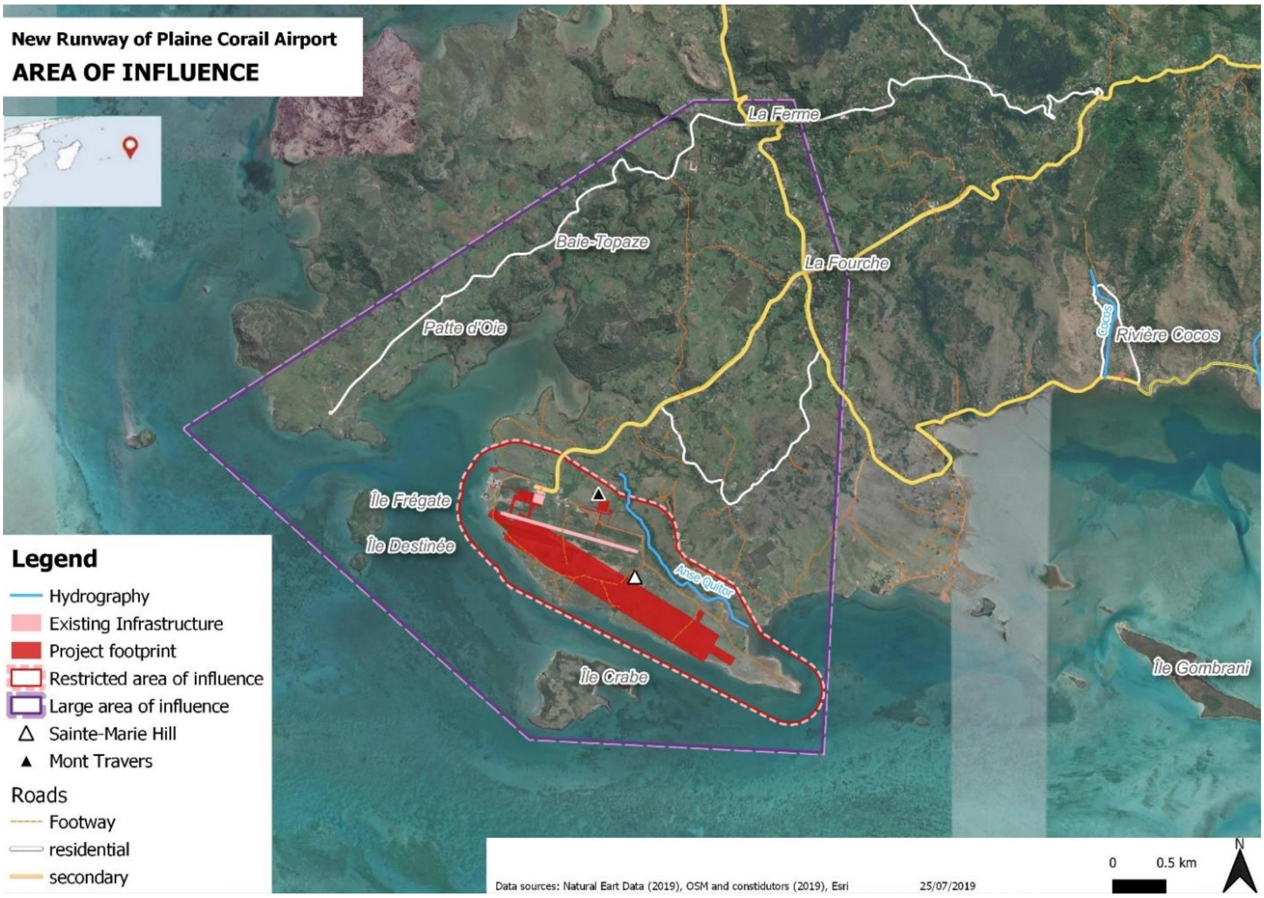


Figure 4: Area of influence

1.4 Marine environment

1.4.1 Geographical overview

Rodrigues, like Mauritius or La Réunion, is an island of volcanic origin belonging to the Mascarene Islands. Located in the South Western Indian Ocean near the southern end of the Mascarene Ridge, it is 18 km long, 6.5 km wide and covers a surface area of 108 km².

Rodrigues' capital city is Port Mathurin, located at the opposite corner of the island from Plaine Corail, in the northeast.

Rodrigues Island strikes E-W. Although of modest elevation (the highest peak, Mount Limon, rises to 398 metres), the island has a general mountainous topography. This mountain separates alluvial plains to the north and south. The island is organized around a central ridge in a west-southwest direction, from which steep ravines radiate. The valley bottoms usually remain dry and are only affected by torrential flows during heavy cyclonic rains.

However, the southwestern part of the island is dominated by a karst plain of coral sandstone over an area of about 10 km².

The island is surrounded by a large coral reef, located between 50 m and 8 km from the coastline. This immense lagoon is generally shallow. It is dotted with several islets which emerge from it.

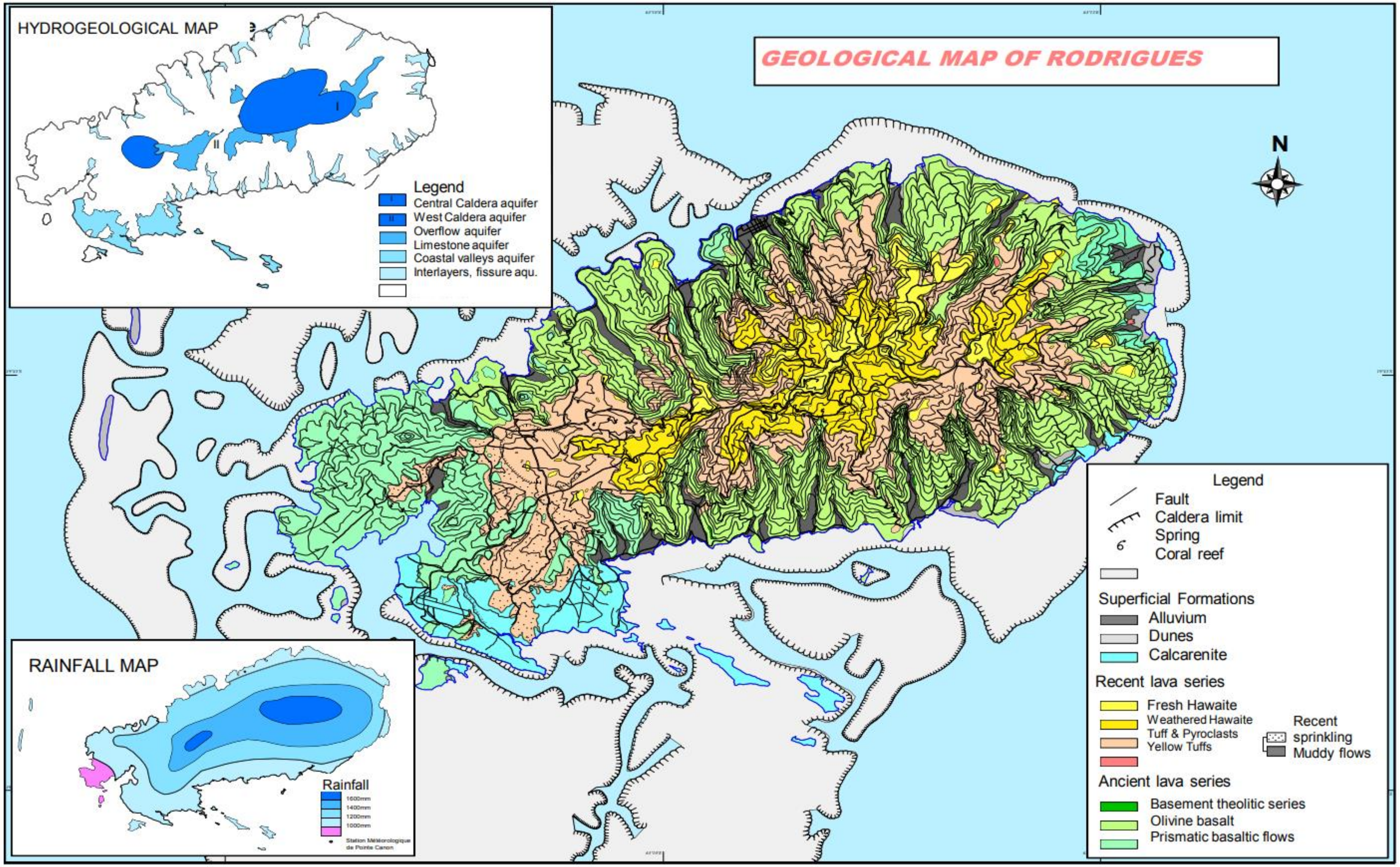


Figure 5: Geographical overview of Rodrigues Island

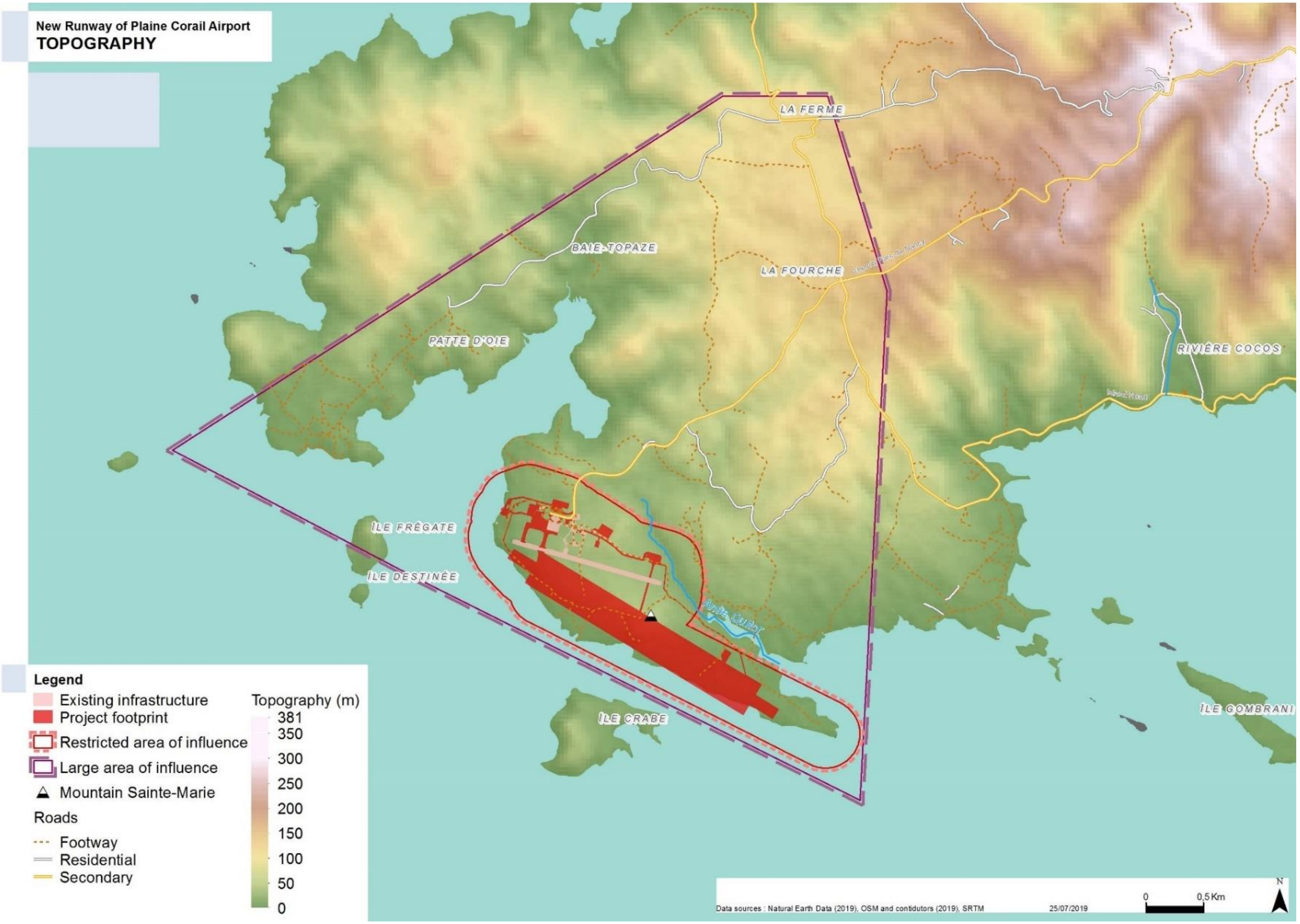


Figure 6: Topography of the area of influence

1.4.2 Climate and marine and terrestrial meteorological conditions

The purpose of this chapter is to present, in a traditional way, the particular climatic and meteorological conditions of the Island of Rodrigues linked to its geographical location. However, its purpose is also to present precisely the wind, current, swell, waves, and water level conditions, as well as the situation in terms of extreme events.

Indeed, since the project involves significant earthworks and a modification of the shoreline, it is important to be able to analyse its impacts on marine currents and sedimentation, as it may have impacts on the marine life of the reef and the balance of erosion phenomena.

This baseline is an input for the hydro-sedimentological modelling planned for impact analysis.

It is also important to analyse the risks associated with the arrival of large aircrafts on this island, which is sometimes subject to extreme weather conditions.

A numerical coupled wave–current–sediment transport model (horizontal two-dimensional approach, 2DH) is built and exploited in order to simulate flows, waves, sediment transport, winds and their mutual interaction with the reef; simulations are performed during its current state, considered as the baseline conditions.

1.4.2.1 Numerical hydrodynamic modelling

1.4.2.1.1 Hydrodynamic software

Delft3D suite is used to model hydrodynamics. Delft3D suite is a fully integrated computer software suite for a multi-disciplinary approach and 3D computations for coastal, river and estuarine areas. It can carry out simulations of flows, sediment transports, waves, water quality, morphological developments and ecology. It has been designed for experts and non-experts alike. The Delft3D suite is composed of several modules, grouped around a mutual interface, while being capable to interact with one another. Following molules are used in this study:

- Delft3D-FLOW: multi-dimensional (2D or 3D) hydrodynamic (and transport) simulation program which calculates non-steady flow and transport phenomena that result from tidal and meteorological forcing;
- Delft3D-WAVE: wave module of Delft3D computes wave propagation, wave generation by wind, non-linear wave-wave interactions and dissipation, for a given bottom topography, wind field, water level and current field in waters of deep, intermediate and finite depth.
- Delft3D-MORPHOOLOGY: sediment transport and morphology module supports both bedload and suspended load transport of non-cohesive sediments and suspended load of cohesive sediments due to waves and currents;
- D-Water Quality: this module simulates the far- and mid-field water and sediment quality due to a variety of transport and water quality processes.

1.4.2.1.2 Data input

The oceanographic data used in the DELFT-3D model is summarized as follows:

- The large-scale model bathymetry data would be forced from the General Bathymetric Chart of the Oceans (GEBCO) with 0.5° resolution, approximately 430m. Closer to Rodrigues, the GEBCO bathymetry would be supplemented by a thinner data set, approximately 200m, close to the coast and inside the lagoon furnished by the RRA.

- The LEGOS3 produced a global finite element solutions (FES) tidal atlases computed from the tidal hydrodynamic equations and data assimilation. Harmonic constants, amplitude and phase, are extracted in the surroundings of the island
- An analysis was performed by MeteOcean to characterize the meteo-oceanic conditions in the vicinity of Rodrigues. Waves, winds, water height, salinity and temperature statistics are available at a deep water point (2989m from the MSL) located at -63°12'E 20°S, in the South of the island.

-

1.4.2.1.3 Simulations carried out

To point out the impact of the structure, three types of simulation are carried out:

- The reference simulation. This is the current situation with no extension of the runway onto the ocean.
- The construction phase simulation. The runway is under construction hence the modified topography; turbid flumes are propagated during the construction work.
- The final phase construction. The runway is built, resulting in modified topography; new water discharges (brine or wastewater) are made.

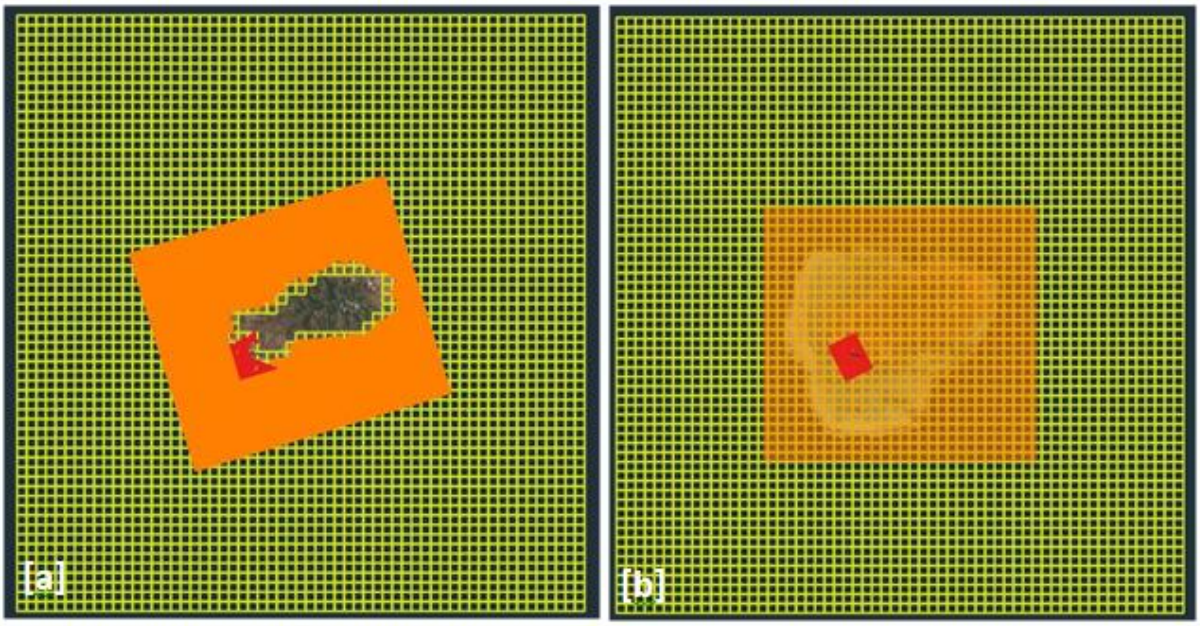


Figure 7: Flow [a] and Wave [b] computational grids

The computational domain of the model is about 42 km wide and 45km long centered on the coral reef fringing Rodrigues. The flow model consists of a 3 levels nested grid of 1000m, 50m and 10m resolution and the wave model is composed of another 3 levels nested grid of 1000m, 250m and 50m resolution.

1.4.2.2 General geographical and climatic considerations

Rodrigues, one of the three Mascarene Islands (the two others are Mauritius and La Réunion), lies near the edge of the southern tropical belt and is free from the influence of large land masses or continents. The climatological regime of the island, characterized as mild tropical maritime, is determined by the alternation of the two seasons: winter from May to October and summer from November to April.

[3] Laboratoire d'Etude en Géophysique et Océanographie spatiales

Summer is the rainier and warmer season, during which tropical cyclones occur. February is the wettest month. Winter is cooler and relatively drier. October is the driest month.

The average annual rainfall over Rodrigues is 1348 mm, which is equivalent to about 150 Mm^3/year for the whole island.

The rainfall increases from 800 mm on the coast to more than 1,600 mm on the summits.

The most frequent natural disasters faced by Rodrigues are cyclones and high intensity rainfall over short periods of time which lead to flash floods or water accumulation.

1.4.2.3 Winds

1.4.2.3.1 Wind pattern in the vicinity of the Mascarene Islands

The wave pattern on the coast of Rodrigues is influenced year-round by two types of persistent winds: south-easterly trade winds and Austral westerly ones; which is caused by the geographical location of the island being near to the Inter Tropical Convergence Zone (ITCZ). There are seasonal variations. The summer season experiences weaker trade winds when the subtropical anticyclones become less intense and migrate towards the pole. In winter, when strong anticyclones pass to the South and close to the Mascarene Islands, trades are stronger and more persistent as they are migrating equatorward and then moving eastwards along the southern high latitudes.

1.4.2.3.2 Wind statistics around Rodrigues

The following distribution rose chart shows the joint probability distribution of wind (magnitude and direction).

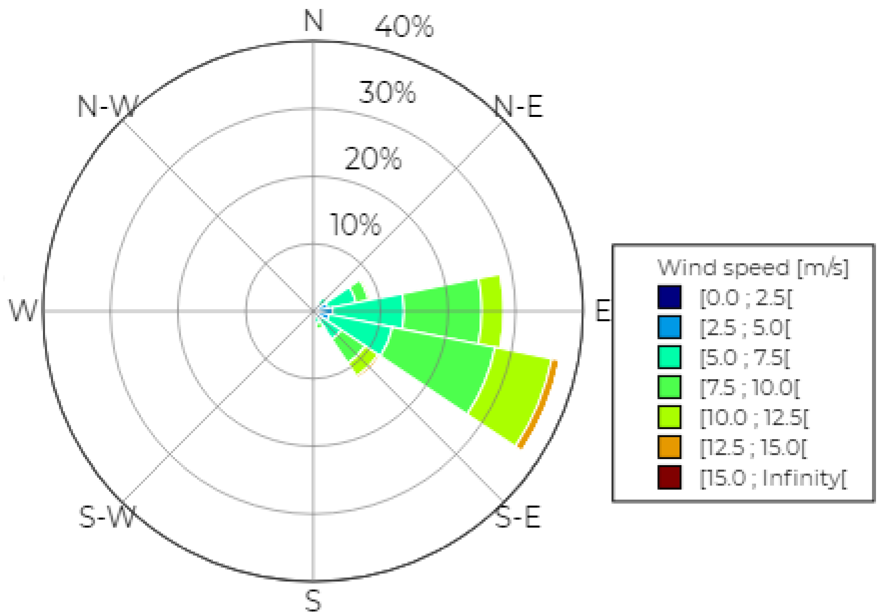


Figure 8: Wind distribution rose (coming from direction) at 10m at point (-63°12'E 20°S)

Most of the wind is coming from the East and South-Southeast directional sector with a mean velocity of 7.68 m/s. During extreme events, such as cyclones, wind gusts can reach a speed of up to 44.03m/s.

Plaine Corail's south side is sheltered from the dominant winds by its coast.

1.4.2.4 Current

1.4.2.4.1 Deep water offshore current

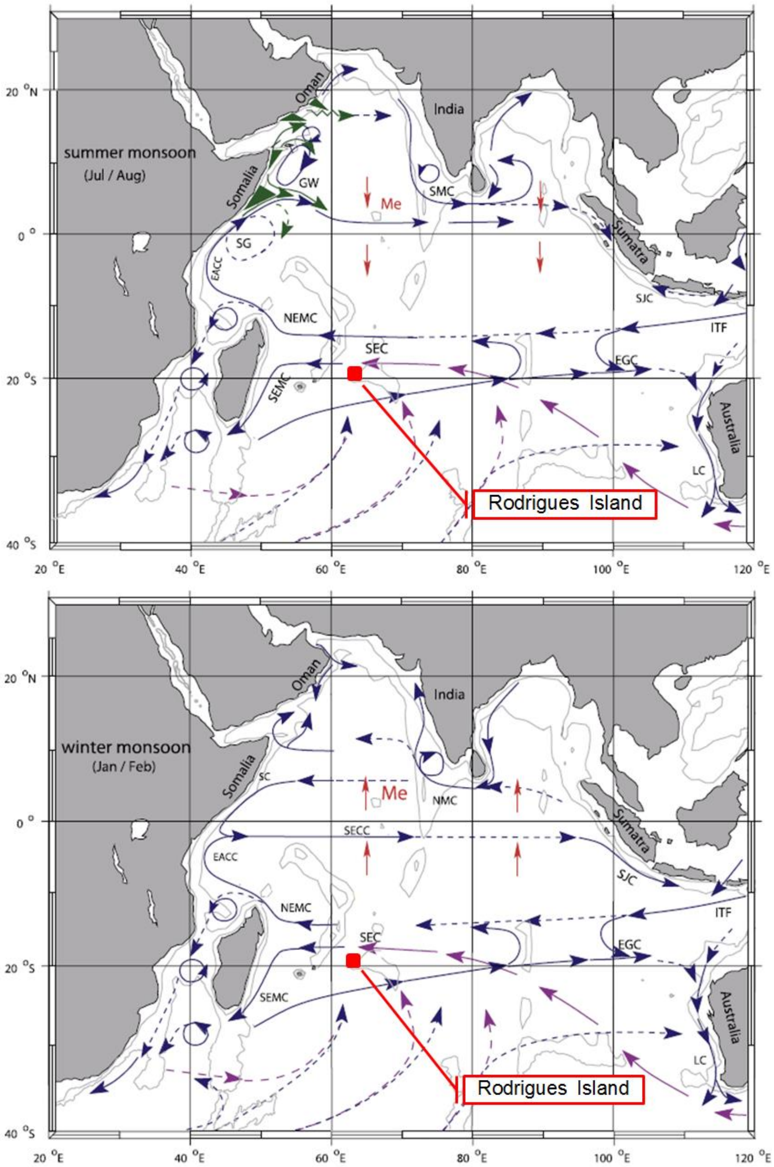


Figure 9: Schematic representations of identified current branches during summer and winter monsoons

The anticyclone winds influence the coastal hydrodynamics and offshore current systems of the island. The strong prevailing South Easterly trade winds increase the current magnitude of the South Equatorial Current (SEC) flowing from West to East throughout the duration of the year and fluctuate between 10 and 20°S in the Indian Ocean (see Figure 9). The speeds of the current increase as it passes through the channels situated within the Mascarene Plateau resulting in the formation of strong gyres on the leeward side. It splits when it reaches Madagascar: one part goes to the North to feed the current in the Mozambique Channel and the East Africa current as the other part flows southwards along the Madagascan coast.

1.4.2.4.2 Current near Rodrigues in deep water

The following distribution rose chart shows the joint probability distribution of the surface current (magnitude and direction).

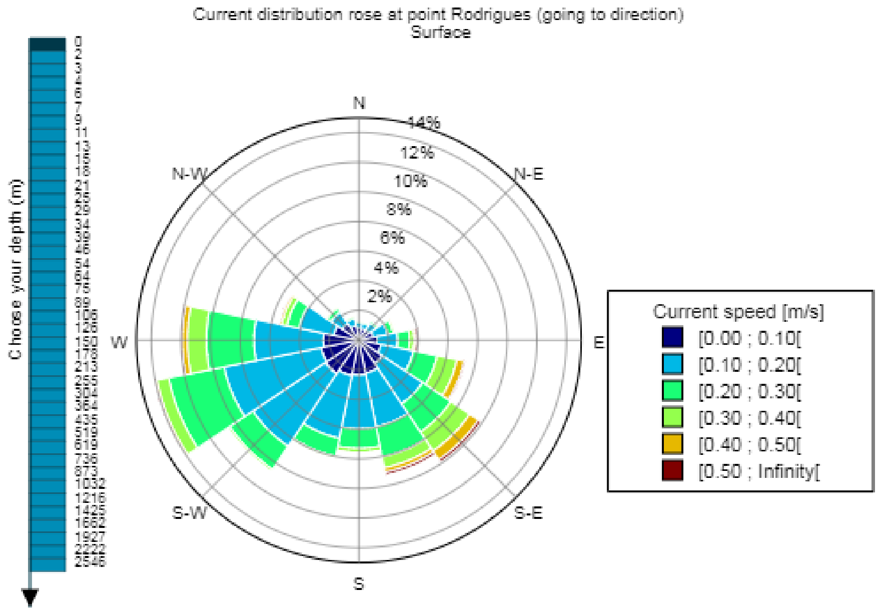


Figure 10: Annual current distribution rose (going to direction) in surface

The mean magnitude of current is 0.17 m/s and varies from 0 to 1.02 m/s. Currents of less than 0.3m/s are the most likely (89% frequency). Most of the magnitude is inferior to 0.3 m/s, 89%. The directional spreading is significant. Directions vary with a predominance of South West – North East currents.

1.4.2.4.3 Current inside the lagoon

The hydrodynamics of the reef lagoon are complex as it is exposed to a broad range of physical events such as tides, waves, winds, river discharge, rainfall, and evaporation.

Density-driven currents have been observed between the lagoon and ocean. Circulation patterns in a lagoon are mainly driven by spatiotemporal variations of hydrodynamic parameters: waves, winds and tides. Bathymetry pass dimensions and lagoonal width to length to depth ratios, as well as the reef structure (size, roughness), also have to be considered.

Tidal cycles have a direct effect on the lagoon water: the lagoon fills during the flow and empties during the ebb, inducing so called “tidal ellipses” (periodically rotating currents). This basic scheme can be significantly complicated by the presence of complex lagoon bathymetry with multiple openings and passages towards the open ocean and neighbouring lagoons. Around Rodrigues, at least three lagoonal passes can be identified in the fringing reef, none of them in front of Plaine Corail.

Figure 11: Passes and fringing reef enclosing Rodrigues

The flushing of the lagoon takes place in the pass n°3 causing high magnitude flow, up to 1.0 m/s, oriented to outside the coral reef. Bathymetry varies from 20 cm depth to 26.40 m and connects Anse Grand Var to the Ocean.

Another passe is located in the western part of the reef and participates, to a smaller extent, to the flushing of the lagoon.

Current magnitudes are under the influence of tidal cycles. The gravitational effects of the moon and the sun affect the Earth's tides on a monthly basis and are expressed under two configurations:

- When the sun, moon, and Earth are in alignment, the solar tide has an additive effect on the lunar tide, enhancing the tidal signal and generating extra-high high tides and very low low tides – known as spring tides.
- When the sun and moon are at a right angle to each other, the solar tide partially cancels out the lunar tide and produces moderate tides – known as neap tides.
- During each lunar month, two sets of spring tides and two sets of neap tides occur.

Spring currents exhibit the strongest velocities (see table below).

1.4.2.4.4 Current between Topaze Bay and Anse Quitor

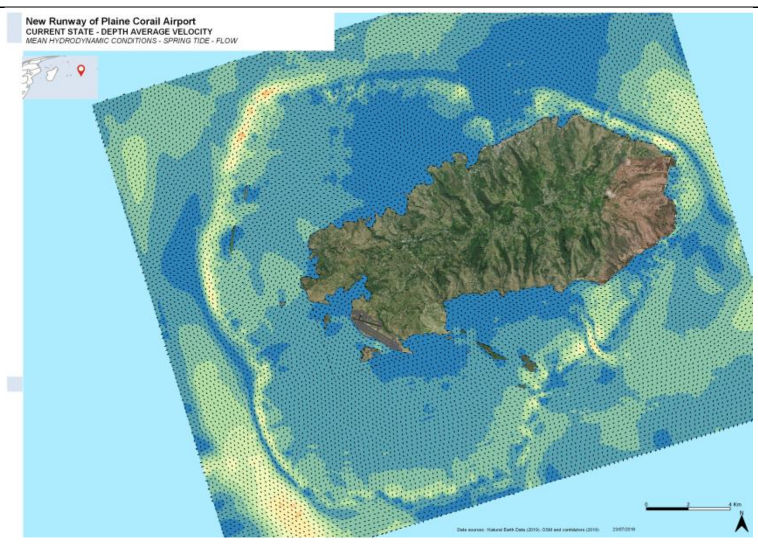
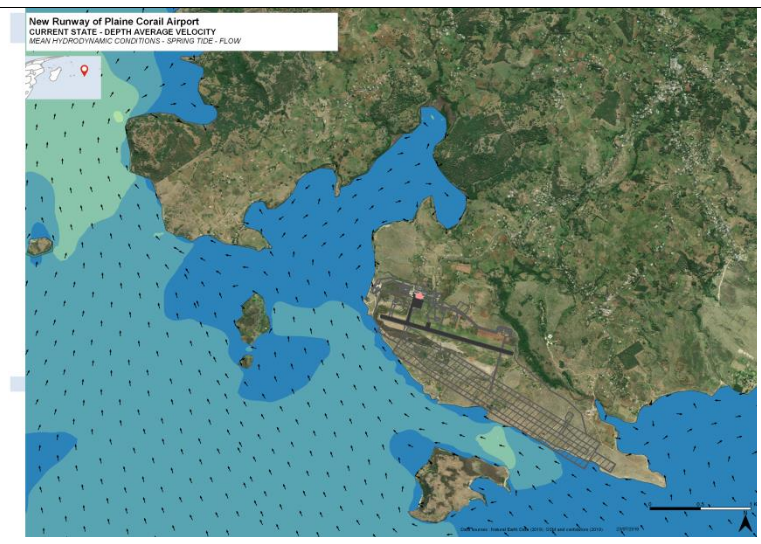
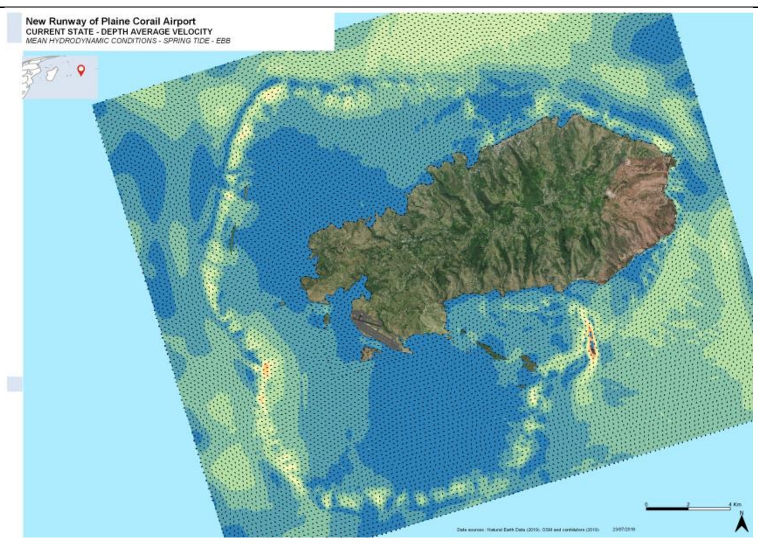
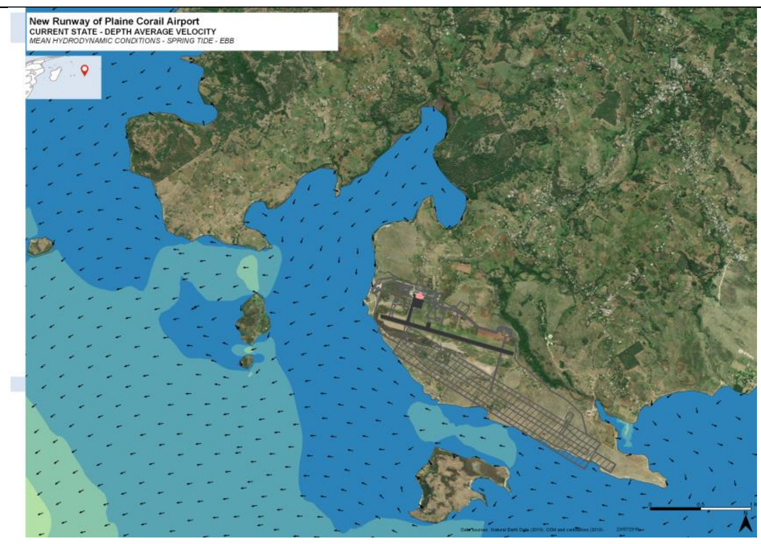
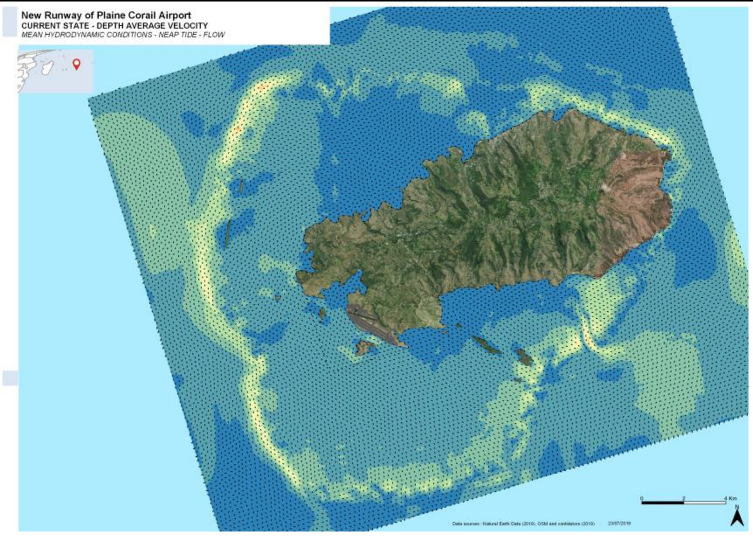
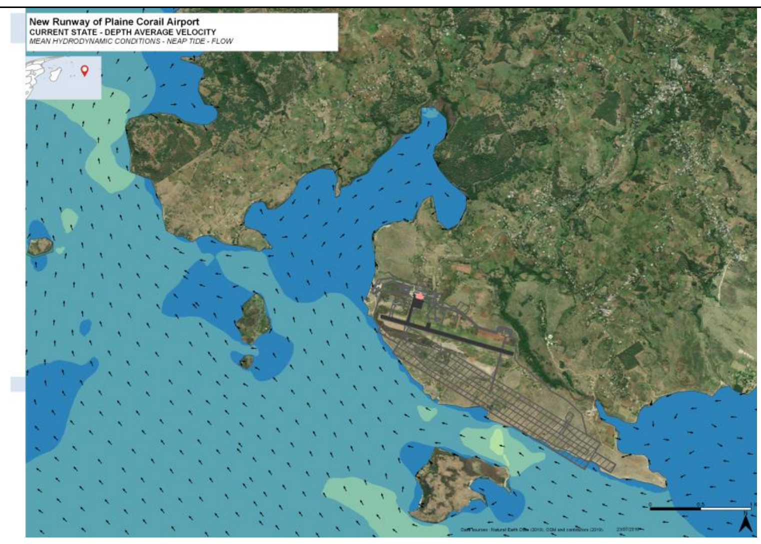
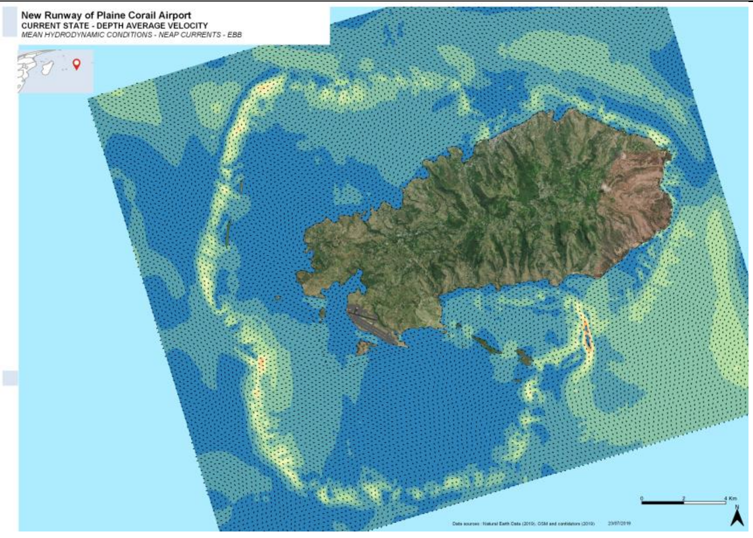
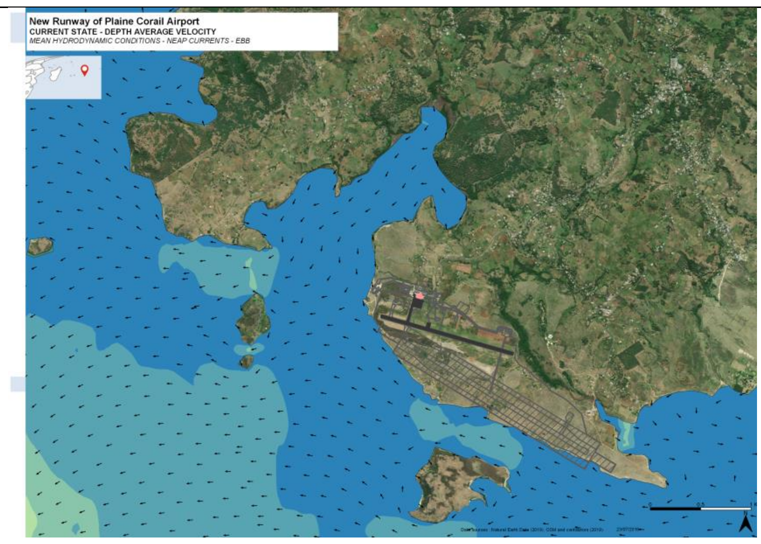
The channels between Crab Island and Plaine Corail, Fregate Island and Destinee Island, Fregate Island and the mainland are a bottleneck for current: the magnitude increases in this area.

Alongside the runway, currents are flowing from South-East to North-West throughout the duration of the year and fluctuate from almost no magnitude to 0.5 m/s with ebb and flow tide currents. They are tide generated, the wave height inside the laggon being very small. During light wind and strong tide coefficient the current can briefly reverse.

Topaze Bay is away from the main currents and relatively current free.

Southeast currents split when they reach Crab Island, its north western and south eastern fronts constitutes a calm sheltered area.

Table 13: Circulation pattern in the lagoon and at Plaine Corail

	RODRIGUES	PLAINE CORAIL
Spring tide – FLOW **Legend** Project runway,taxiway Existing apron, taxiway, runway Terminal Velocity < 0.1m/s 0.1 - 0.2m/s 0.2 - 0.3m/s 0.3 - 0.4m/s 0.4 - 0.5m/s 0.5 - 0.6m/s 0.6 - 0.7m/s 0.7 - 0.8m/s 0.8 - 0.9m/s 0.9 - 1.0m/s 1.0 - 1.2m/s > 1.5 m/s		
Spring tide - EBB **Legend** Project runway,taxiway Existing apron, taxiway, runway Terminal Velocity < 0.1m/s 0.1 - 0.2m/s 0.2 - 0.3m/s 0.3 - 0.4m/s 0.4 - 0.5m/s 0.5 - 0.6m/s 0.6 - 0.7m/s 0.7 - 0.8m/s 0.8 - 0.9m/s 0.9 - 1.0m/s 1.0 - 1.2m/s > 1.5 m/s		
Neap tide - FLOW **Legend** Project runway,taxiway Existing apron, taxiway, runway Terminal Velocity < 0.1m/s 0.1 - 0.2m/s 0.2 - 0.3m/s 0.3 - 0.4m/s 0.4 - 0.5m/s 0.5 - 0.6m/s 0.6 - 0.7m/s 0.7 - 0.8m/s 0.8 - 0.9m/s 0.9 - 1.0m/s 1.0 - 1.2m/s > 1.5 m/s		
Neap tide - EBB **Legend** Project runway,taxiway Existing apron, taxiway, runway Terminal Velocity < 0.1m/s 0.1 - 0.2m/s 0.2 - 0.3m/s 0.3 - 0.4m/s 0.4 - 0.5m/s 0.5 - 0.6m/s 0.6 - 0.7m/s 0.7 - 0.8m/s 0.8 - 0.9m/s 0.9 - 1.0m/s 1.0 - 1.2m/s > 1.5 m/s		

1.4.2.5 Waves

1.4.2.5.1 General information

Deep sea waves affecting Rodrigues's shores can be generated by the following three meteorological phenomena:

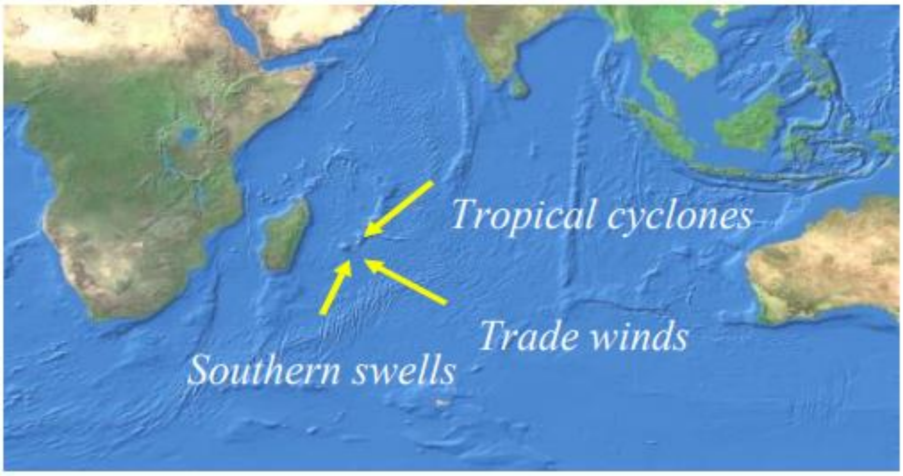


Figure 12: Type of Wave Generation Mechanisms in Mauritius and Rodrigues

- Local Generated Waves: waves generated by the south-eastern trade winds in the vicinity of Rodrigues, generally from the East to the South-east direction;
- Southern Hemisphere Swells: waves generated by distant storms, as extra-tropical cyclones, that can propagate thousands of kilometres across the ocean with little loss of energy. The swells typically approach Rodrigues from the southwest;
- Tropical Cyclones: waves due to tropical cyclones generated in the South Western part of the Indian Ocean. Tropical cyclones can have very high wind speeds and the waves generated can be extremely large. Their characteristics vary for each cyclone (wind speed and track). In general these waves approach the country predominantly from East to North. Also, the high wind speeds and low central depression of a tropical cyclone can induce large surges in coastal regions.

The following distribution rose chart shows the joint probability distribution of waves (magnitude and direction).

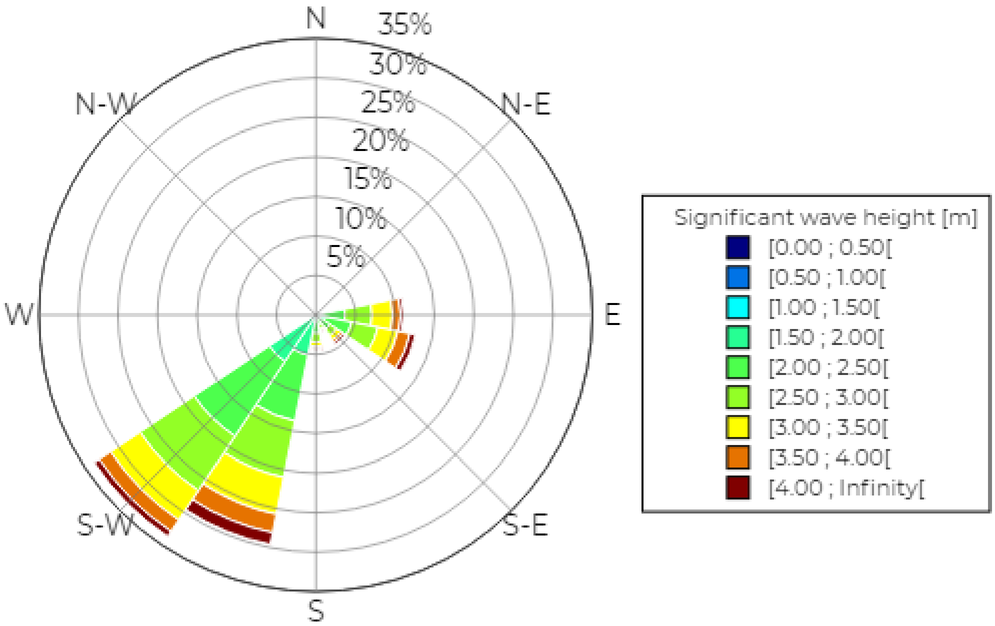


Figure 13: Annual wave distribution rose (peak direction) coming from direction at point (-63°12'E, 20°S)

Statistics computed during the period 10/01/1979 to 31/01/2019 show that the mean significant wave height is 2.66m and varies from 1.02 m to 12.95m. Most of them are coming from two directions:

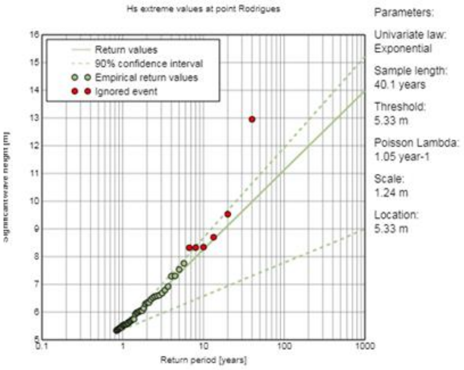
- 63.3% from the SW and SSW: these are the Southern swells;
- 25% from the E and ESE: these are waves generated by trade winds.

Wave spectral peak periods range between 6 and 22s, and the majority is included between 9 and 15.75s.

- Hydrodynamic mean annual conditions present the following wave characteristics:
- Trade winds (from East): Hs = 2.75m, Tp = 9.25s, Direction = 105°

Southern swells (from SW): Hs = 2.25m,Tp = 14.5s, Direction = 215°

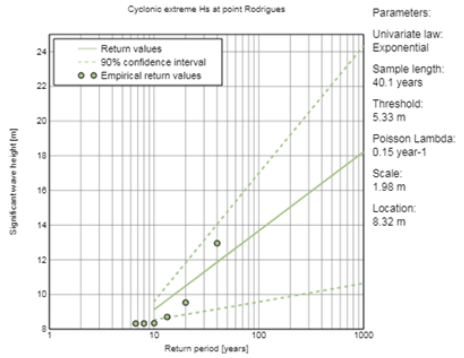
Extreme values are based on an Extreme Values Analysis, which uses probabilistic laws to predict extreme events over large return periods that usually exceed the duration of the data. Wave height extreme values in Rodrigues, for regular and for cyclonic waves, are the following:



Hs extreme values at point Rodrigues

Return period [years]	Hs [m]	Hs lower [m]	Hs upper [m]
1	5.39	5.37	5.41
5	7.39	6.21	7.69
10	8.26	6.57	8.69
50	10.26	7.43	10.96
100	11.12	7.79	11.92
500	13.12	8.61	14.23
1000	13.99	9.01	15.22

Figure 14: Hs extreme values at point (-63°12'E, 20°S)



Cyclonic extreme Hs at point Rodrigues

Return period [years]	Hs [m]	Hs lower [m]	Hs upper [m]
10	9.12	8.54	9.59
50	12.30	9.25	14.76
100	13.67	9.57	17.01
500	16.85	10.31	22.11
1000	18.22	10.64	24.34

Figure 15: Cyclonic extreme Hs values at point (-63°12'E, 20°S)

1.4.2.5.2 Inside the lagoon

The coral reef fringing Rodrigues serves as a natural barrier that protects adjacent shorelines from offshore coastal hazards such as storms surges and waves. As waves propagate towards Rodrigues, an important amount of energy is dissipated on the reef when the abrupt change of bathymetry causes a first depth limited wave breaking.

Waves breaking on the fringing reef create a radiation stress gradient that drives wave-induced current and wave set-up. Depending on the incident wave characteristics, the strongest generated current remains in the surrounding of the reef boundaries. The wave-induced velocity is less than 0.1m/s in the further area. In particular, Plaine Corail is well protected from extreme waves due to the reef, which is up to 8.3 km wide in this region, and Crab Island, which is located south of the area and can protect it from southwestern dominant waves.

The main physical processes during the wave propagation into the lagoon toward the shore include refraction, reflection and shoaling on the outside reef slope, bathymetric breaking occurring generally before the reef top, harmonic transfers toward infragravity (IG) waves, dissipation by friction, and interaction with co- or counter-currents. The relative importance of each process is controlled by the offshore wave features, the bathymetry, the mean water level and slope, and the reef roughness.

1.4.2.5.3 Between Topaze Bay and Anse Quitor

As most of the swell has broken on the reef or has been transformed during the propagation trough the lagoon, the most significant waves reaching the area of interest are wind waves. i.e waves generated and influenced by the local wind field.

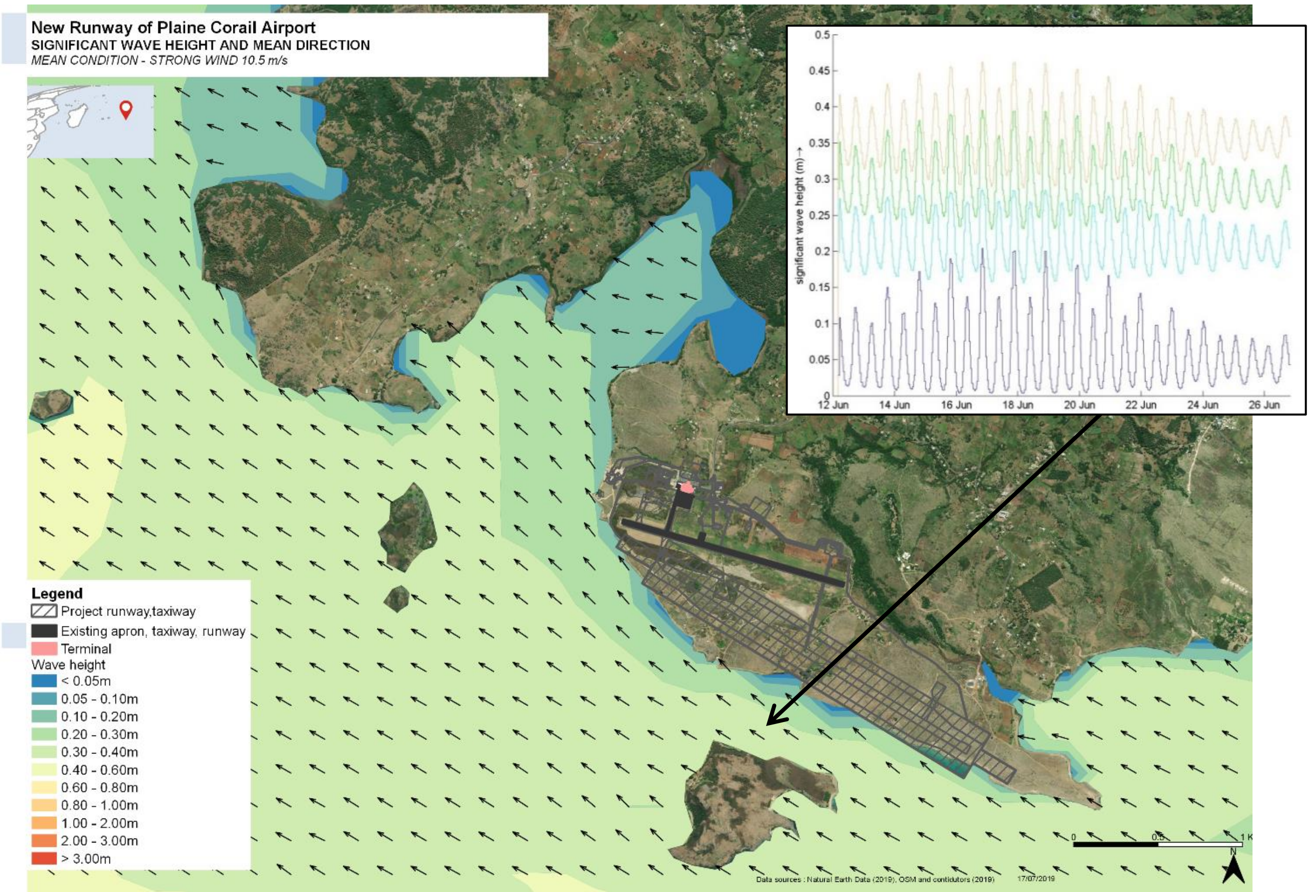


Figure 16: Significant wave height and mean direction under mean hydrodynamic conditions and wave significant height for nul (dark blue), light (blue), mean (green) and strong (yellow) wind

The comparison of nul, light, means and strong wind shows the impact of wind and tide onto wave height: the stronger the wind is, the higher is the wave, and the higher the sea level is, the higher is the wave.

In the canal between Crab Island and the runway, significant height reaches 45 cm when eastern wind blows with 10.5 m/s velocity (highest 10%) and 20 cm without wind.

1.4.2.6 Water level

1.4.2.6.1 General information

Tides are generated by the effect on the Earth's oceans of gravitational forces between the Earth, the Moon and the Sun, of centrifugal forces due to the Earth's rotation, and of centrifugal forces due to the Earth's solar orbit.

The tides with the largest range are called spring tides, and occur at a new moon and at a full moon. The tides with the smallest range are called neap tides, and occur at intermediate phases of the Moon, at seven and a quarter days after the new or full moon, in the first and last quarters.

1.4.2.6.2 Port Mathurin tide gauge

A tide gauge has been located at Port Mathurin since 1987.

Table 14: Characteristics of Rodrigues' tide gauge

Station Name	**Port Mathurin, Rodrigues (Indian Ocean)**
Gloss Station Number	19 (Operational since 1987)
Latitude	19°41'S
Longitude	63°25'E
Local Time	GMT + 4 hours
Type	Leupold and Steven's float/Stilling well
New Gauge	Real Time Satellite transmission
Authority Responsible	Mauritius Meteorological Services
Benchmarks	A bolt at the edge of the wharf of the tide gauge. Zero of tide staff tied to benchmark which is a point on beam adjacent to tide gauge station.
Auxiliary Benchmarks:	(a) Brass tube fixed on a wall in the marine services area about 200m from tide gauge. (b) One benchmark located near entrance of the Port
Tide predictions	Performed by the University of Hawaii
Data sent to	Permanent Service for Mean Sea Level (PSMSL), Hawaii
Other data available in vicinity	Sea Level Pressure, rainfall, winds

The maximum tidal range is approximately 1.90 m, and since the average water depth in the lagoon is less than 2 m, some areas are exposed during spring tides. Rodrigues' tides can be classified as meso-tidal due a tidal range inferior to 2 m.

The tide signal can be decomposed as elementary harmonic constants; the main ones are the following:

Table 15: Port Mathurin, Inner Harbour, Admiralty Tide Tables harmonic amplitudes and phases (2002 analyses)

Symbol	Constituent Name	Amplitude (cm)	Phase (°)
M2	Principal Lunar Semidiurnal	40.1	256.1
S2	Principal Solar Semidiurnal	25.55	282.0
K1	Luni-solar declinational diurnal	5.55	95.3

It is broadly representative of natural open-ocean as a consequence of the islands' limited continental shelf width.

The statistics of the sea level height are collected from the University of Hawaii Sea Level Center, computed from the period 09/11/1986 to 31/12/2018 and referred to as the zero point assigned to the tide gauge. The empirical probability distribution of total surface height at Port Mathurin is the following:

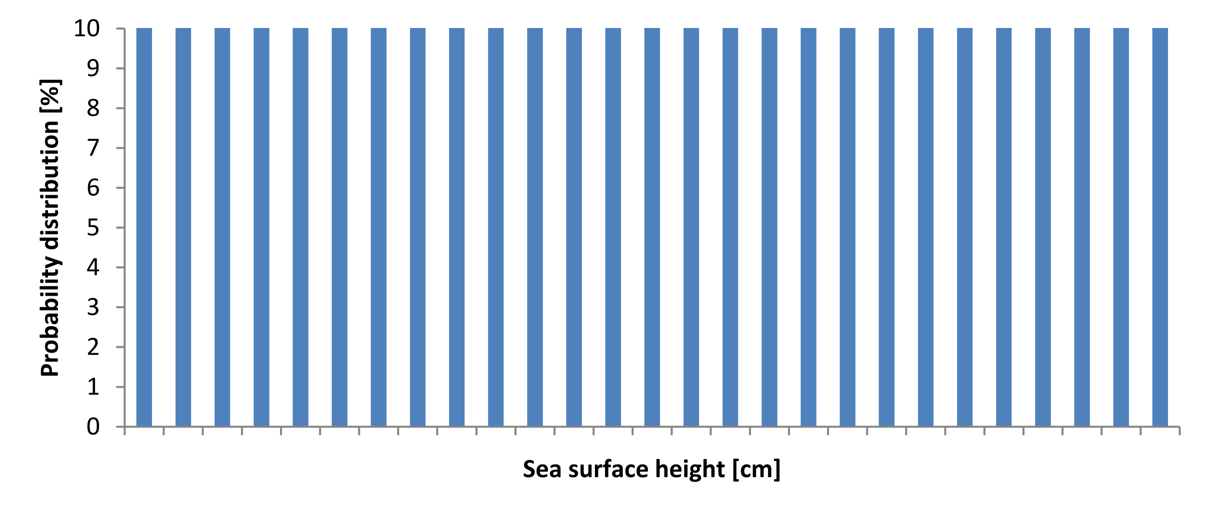


Figure 17: Empirical probability distribution of total sea surface height at Port Mathurin

Rodrigues is one of the islands being impacted by global climate change. From 1986 to 2003, sea level has decreased at a rate of -0.32 mm/year whereas between 2003 and 2009 an accelerated rise at a rate of 1.2 to 3 mm/year was observed.

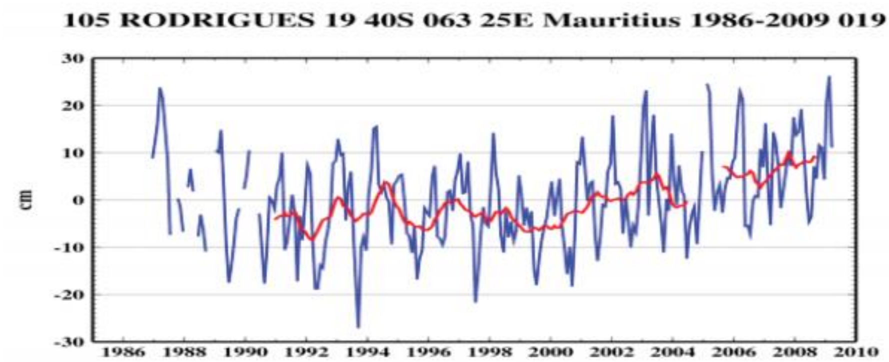


Figure 18: Sea level trend at Port Mathurin, Rodrigues [1986-2009]

According to the Acclimate study, sea level has already risen by 6.7 cm in Rodrigues between 1950 and 2001 representing an average +1.34 mm per year. Therefore, surveys showed occurrences of severe bleaching leading to the mortality of up to 75% of corals in some sites. The North and West of the island are particularly vulnerable.

1.4.2.6.3 Inside the lagoon

Of the processes linked to extreme sea levels in reef lagoon environments, wave setup has been found to be the largest component of extreme water levels for other island case studies with fringing reef morphology (e.g. Hoeke et al. 2015). Set-up at coasts has been regarded approximately as 10 to 20% of deep water wave height (e.g. WMO 1998; Holden 2008), with reefs potentially forcing higher set-up values, of up to a third of incident wave height (Munk and Sargent 1948; Hoeke et al. 2013).

The impacts of the reef on the still water level will be included in the model amongst others on the elevation caused by extreme wave breaking. Indeed, when waves are strong, water enters the lagoon faster than it can be flushed through reef passes. The sea level difference generates an elevation of the lagoon level and amplifies ebb tidal current.

Two different lagoon natural flushing processes are possible in lagoons exposed to wave and ocean tides. Their relative importance depends on the bathymetry of the lagoon and the local hydrodynamic climate. After studying the local bathymetry of the lagoon, it would be possible to determine the flushing process of Rodrigues.

The sea surface height alongside Plaine Corail could be impacted by this elevation and therefore is different from Port Mathurin's.

1.4.2.7 Tropical cyclones

As it is located in the cyclone belt, Rodrigues can be affected by hurricanes from the east from November to April. On average, ten named tropical depressions are tracked in the South-West Indian Ocean and of these, three reach tropical cyclone intensity.

These winds blow clockwise around the centre and generate very high waves. The cyclones often re-curve to the South and East prior to reaching the island of Rodrigues and the cyclone intensity typically diminishes with latitude.

Tropical disturbances are ranked according to their maximum of average sustained wind speed and which tropical cyclone basin they belong to. The Meteo France's Reunion Tropical Centre monitors the cyclonic activity of the South-West Indian Ocean, the basin where Rodrigues is located, and uses the following terminology to classify them:

Table 16: Tropical cyclone naming in the SW Indian Ocean (Mauritius Meteorological Service and Meteo France)

Tropical Disturbance Classification	Maximum of average 10-minute sustained wind speed		Beaufort Scale
	kt	km/h	
Very Intense Tropical Cyclone	> 115	> 212	Force 12 and +
Intense Tropical Cyclone	90 – 115	166 – 212	
Tropical Cyclone	64 – 89	118 – 165	
Severe Tropical Storm	48 – 63	89 – 165	Force 10 – 11
Moderate Tropical Storm	34 – 47	63 – 88	Force 8 – 9
Tropical Depression	28 - 33	51 – 62	Force 7
Tropical Disturbance	< 28	< 50	Force 0 – 6

Since the early 60's, 74 tropical disturbances have occurred in the vicinity of Rodrigues (refer table 32) which represent in average of 1.3 events per year. Most of them are qualified as Tropical Storm or Severe Tropical Storm. They usually present the same characteristics: they form in the eastern part of the Indian Ocean and migrate to the southwest following a parabolic trajectory. In the past few years, Hansella (1996), Kalunde (2003), Amara (2014), Bansi (2015) and Gelena (2019) were the most damaging cyclones. Cyclone Kalunde brought 3.4 million euros in damage to Rodrigues Island.

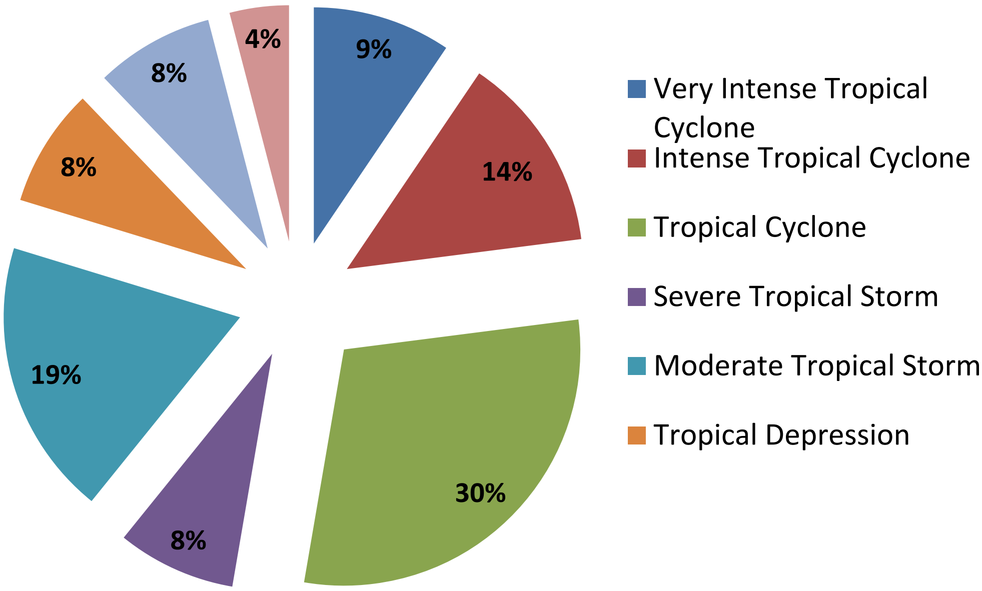


Figure 19: Distribution of Cyclone Types since 1962

The Cyclone Warning System of Mauritius and Rodrigues issues warnings to the population before a cyclonic disturbance is likely to affect its coast. Warning is ranked in 4 classes according to the remaining time before a 120 km/h gust hits:

- Class I: Issued 36 to 48 hours before Rodrigues is likely to be affected by gusts reaching 120 km/h;
- Class II: Issued so as to allow, as far as practicable, 12 hours of daylight before the occurrence of gusts of 120 km/h;
- Class III: Issued so as to allow, as far as practicable, 6 hours of daylight before the occurrence of gusts of 120 km/h;
- Class IV: Issued when gusts of 120 km/h have been recorded in some places and are expected to continue.

1.4.2.8 Tsunami

Minor floods were experienced as a result of the 26 December 2004 tsunami. So far there is no record of any significant tsunami that has affected Rodrigues but there is a possibility that a tsunami generated from either the Sumatra or the Makran source could affect the coasts of Rodrigues. The Tsunami Warning System of Mauritius considers a lead-time of 5-7 hours for a tsunami wave from Sumatra to reach its coast.

Table 17: Tropical disturbance events in the vicinity of Rodrigues Island [1962 - 2019]

Cyclone Season	Approaching date (UTC)	TC Name	Type	Intensity (kts) at nearest distance from Rodrigues Airport	Maximum intensity (kts) of the TC	Minimum sea level pressure (mb)	Code JTWC (Join Typhoon Warning Center)	Nearest distance form Rodrigues Airport	Wind speed at Plaine Corail (kts)	Direction in the vicinity of Rodrigues	Data Source	Cyclone Warning System (Mauritius Meteorological Services)
1962	06/04/1962	MAUD	Tropical Cyclone	64	-	-	-	-	_	Parabolic NE to SW	IBTrACS-NOAA	-
1963	19/02/1963	GRACE	Severe Tropical Storm	62	-	-	-	-	_	Parabolic NE to SW	IBTrACS-NOAA	-
1964	11/12/1963	AMANDA	Severe Tropical Storm	63	-	-	-	-	_	Parabolic NE to SW	IBTrACS-NOAA	-
1965	08/01/1965	FREDA	Tropical Cyclone	65	-	-	-	-	_	Parabolic NE to SW	IBTrACS-NOAA	-
1967	12/02/1967	HUGUETTE	Moderate Tropical Storm	35	-	-	-	-	-	NNW to SSE then E	IBTrACS-NOAA	-
1968	23/12/1967	CARMEN	Tropical Cyclone	70	-	-	-	-	-	N to S	IBTrACS-NOAA	-
1968	21/01/1968	HENRIETTE	Tropical Cyclone	80	-	-	-	-	_	NNE to SSW	IBTrACS-NOAA	-
1968	29/03/1968 00:00	MONIQUE	Tropical Cyclone	64	-	-	-	-	_	Parabolic NE to SW	Cycloneoi.com (NOAA, UNISYS, C.PEGOUD)	-
1970	19/02/1970 12:00	JANE	Very Intense Tropical Cyclone	140	-	900	-	305 km N		Parabolic NE to SW	FIRINGA/ - SA	-
1970	30/03/1970 00:00	LOUISE	Tropical Cyclone	80	-	910	-	210 km N	_	Atypical track	Cycloneoi.com (NOAA, UNISYS, C.PEGOUD)	-
1971	12/11/1970 00:00	CLAUDINE	Tropical Cyclone	70	-	970	-	160 km North	_	E to W	Cycloneoi.com (NOAA, UNISYS, C.PEGOUD)	-
1971	27/01/1971 00:00	GINETTE	Tropical Cyclone	81	-	938	-	55 km SE	_	-	Cycloneoi.com (NOAA, UNISYS, C.PEGOUD)	-
1971	26/02/1971 00:00	LISE/YVONNE	Tropical Cyclone	80	-	-	-	80 km	_	E to W then S	Cycloneoi.com (NOAA, UNISYS, C.PEGOUD)	-
1972	05/01/1972 00:00	BELLE	Moderate Tropical Storm	46	-	-	-	-	_	-	Cycloneoi.com (NOAA, UNISYS, C.PEGOUD)	-
1972	20/02/1972 00:00	FABIENNE	Very Intense Tropical Cyclone	135	-	-	-	120km W	_	From E	Cycloneoi.com (NOAA, UNISYS, C.PEGOUD)	-
1977	08/02/1977 09:00	GILDA	Moderate Tropical Storm	45	-	-	-	230 km	_	From E; Then N to S	FIRINGA	-
1977	24/02/1977 22:00	IO/JACK	-	-	-	-	-	300 km	_	-	FIRINGA/NOAA	-
1979	09/02/1979 00:00	CELINE	Very Intense Tropical Cyclone	116	-	-	-	-	_	-	FIRINGA/NOAA	-
1979	14/02/1979 11:00	ESTELLE	-	-	-	988	-	200 km W	_	Atypical track	FIRINGA/NOAA	-
1980	03/02/1980 16:00	JACINTHE	Tropical Cyclone	65	-	-	-	160 km NW	_	-	FIRINGA/NOAA	-
1982	31/01/1981 03:32	HEYLETTE	-	-	-	-	-	100 km N	_	-	FIRINGIA	-
1982	16/01/1982 12:00	DAMIA	Tropical Cyclone	80	120	-	TC 08S 1982	Over Rodrigues	_	-	JTWC	-
1984	22/01/1984 18:00	EDOARA	Tropical Depression	30	35	-	TC 15S 1984	40 km S	_	-	JTWC	-

1984	16/02/1984 06:00	HAJA	Tropical Depression	30	45	-	TC 20S 1984	155km S	_	-	JTWC	-
1985	02/12/1984 06:00	BOBALAHY	Tropical Disturbance	20	55	-	TC 02S 1985	130 km SE	_	From NE to SW	JTWC	-
1985	26/01/1985 00:00	DITRA	Tropical Cyclone	65	70	-	TC 16S 185	< 10km S	_	N the S	JTWC	-
1985	10/04/1985 12:00	HELISAONINA	Intense Tropical Cyclone	100	110	-	TC 33S 1985	110 km N	_	Loop. From N to W.	JTWC	-
1986	14/01/1986 06:00	COSTA	Tropical Cyclone	70	70	-	TC 06S 1986	130 km NE	-	NW to SE	JTWC	-
1987	06/02/1987 03:00	BEMAVAZA	Moderate Tropical Storm	35	-	-	-	-	-	-	FIRINGA	-
1989	05/04/1989 12:00	KRISSY	Tropical Cyclone	65	105	-	TC21S 1989	120km NW	-	NE to SW	JTWC	-
1989	22/03/1989 12:00	JINABO	Tropical Disturbance	25	65	-	TC19S 1989	190 km N		E to W and S	JTWC	-
1990	06/03/1990 00:00	EDISOANA	Intense Tropical Cyclone	95	100	-	TC18S 1990	210 km W	-	N to S	JTWC	-
1991	31/01/1991 06:00	BELLA	Intense Tropical Cyclone	100	130	-	TC08S 1991	25 km W	-	E to W and then to S	JTWC	Warning class IV (max)
1992	10/02/1992 00:00	CELESTA	Tropical Disturbance	25	45	-	TC 15S 1992	75 km N	-	NNW to SE	JTWC	-
1992	01/03/1992 00:00	GERDA	Tropical Depression	30	35	-	TC 24S 1192	150km NNW	-	-	JTWC	-
1994	15/02/1994 12:00	IVY	Severe Tropical Storm	50	100	-	TC 16S 1994	100 km W	-	NE to S	JTWC	-
1994	12/04/1994 12:00	ODILLE	Intense Tropical Cyclone	95	105	-	TC 26S 1994	150 km SW	-	NNW to SSE	JTWC	-
1995	30/11/1994 06:00	ALBERTINE	Tropical Cyclone	70	115	-	TC 02S 1995	105 km NW	-	NNE to SSW	JTWC	-
1995	27/01/1995 00:00	DORINA	Moderate Tropical Storm	45	100	-	TC08S 1995	150 km SE	-	ENE to WSW	JTWC	-
1995	09/02/1995 00:00	GAIL	Tropical Cyclone	70	75	-	TC 10S 1995	35 km NNW	-	NE to SW	JTWC	-
1996	24/02/1996 12:00	EDWIDGE	Tropical Depression	30	95	-	TC 16S 1996	15 km SW	-	SE to NW	JTWC	-
1996	29/02/1996 18:00	FLOSSY	Intense Tropical Cyclone	100	115	-	TC 17S 1996	100km NNW	-	NE to SW	JTWC	-
1996	06/04/1996 06:00	HANSELLA	Intense Tropical Cyclone	95	95	-	TC 24S 1996	30km NE	90	N to S	JTWC	Warning class IV (max)
1996	08/04/1996 18:00	HANSELLA	Severe Tropical Storm	60	95	-	TC 24S 1996	70km SW	-	E to W	JTWC	Warning class IV (max)
1997	21/02/1997 18:00	KARLETTE	Tropical Cyclone	65	65	-	TC 25S 1997	50 km S	-	NE to SW	JTWC	-
1999	03/02/1999 06:00	CHIKITA	Moderate Tropical Storm	35	40	-	TC 17S 1999	50 NE	-	ESE to WNW	JTWC	-
1999	08/03/1999 18:00	DAVINA	Intense Tropical Cyclone	100	110	-	TC 25S 1999	150 km N	-	NE to SW	JTWC	-
1999	07/04/1999 06:00	EVRINA /FREDERIC	Tropical Depression	30	140	-	TC 31 S 1999	30 km N	-	E to W	JTWC	-
2001	15/01/2001 18:00	BINDU	Moderate Tropical Storm	45	100	-	TC05S 2001	130 km SE	-	NE to SW	JTWC	-
2001	07/04/2001 00:00	EVARISTE	Severe Tropical Storm	55	75	-	TC 18S 2001	180 km W	-	NNW to SSE	JTWC	-
2002	20/01/2002 18:00	DI NA	Very Intense Tropical Cyclone	130	130	910	TC 10S 2002	180km NNW	-	ENE to WSW	JTWC	Warning class III

2003	12/03/2003 18:00	KALUNDE	Intense Tropical Cyclone	90	140	954	TC 23S 2003	60km SE	114	N to S	JTWC	Warning class IV
2005	02/02/2005 06:00	GERARD	Tropical Disturbance	15	60	1006	TC 14S 2005	30 km SE	-	NE to SW	JTWC	None
2005	10/04/2005 12:00	JULIET/ADELINE	Very Intense Tropical Cyclone	120	125	992	TC 26S 2005	130 km SE	-	NE to SSW	JTWC	Warning class III
2006	29/12/2005 00:00	-	Tropical Disturbance	25	35	1002	TC 04S 2006	200km NW	-	NE to SW	JTWC	-
2007	10/02/2007 18:00	ENOK	Moderate Tropical Storm	40	55	993	TC13S 2007	Over Rodrigues	-	NNW to SSE	JTWC	Warning class IV (max)
2007	15/02/2007 12:00	FAVIO	Moderate Tropical Storm	40	120	994	TC14S 2007	150 km NW	-	NE to SSW	JTWC	-
2007	06/02/2007 12:00	DORA	Severe Tropical Storm	50	115	985	TC10S 2007	130 km SE	-	NNE to SW	JTWC	Warning class II
2008	17/12/2007 06:00	CELINA	Moderate Tropical Storm	35	40	996	TC06S 2008	150 km WNW	-	NNE to SSW	JTWC	None
2008	19/02/2008 18:00	HONDO	Tropical Disturbance	25	130	1004	TC16S 2008	60 km N	-	E to NW	JTWC	None
2010	20/02/2010 18:00	GELANE	Tropical Cyclone	65	125	974	TC 16S 2010	180km W	-	N to S	JTWC	Warning class II
2011	19/03/2011 21:00	CHERONO	Moderate Tropical Storm	35	45	998	TC18S 2011	30 km S	-	E to SW	JTWC	Warning class I
2012	20/01/2012 18:00	ETHEL	Tropical Cyclone	70	70	970	TC07S 2012	90 km E	-	N to S	JTWC	Warning class IV
2012	21/02/2012 12:00	HILWA	Moderate Tropical Storm	40	40	993	TC13S 2012	75km ESE	-	NE to S	JTWC	None
2013	15/04/2013 12:00	IMELDA	Tropical Cyclone	70	85	970	TC21S 2013	110 km W	-	NE to SW then E	JTWC	Warning class IV
2014	21/12/2013 00:00	AMARA	Very Intense Tropical Cyclone	125	130	929	TC03S 2014	80 km E	73	Parabolic NE to SW	JTWC	Warning class IV (14h)
2015	09/01/2015 06:00	BANSI	Very Intense Tropical Cyclone	120	140	933	TC05S 2015	110 km NE	67	NE to SW	JTWC	Warning class IV (12h10)
2016	13/12/2015 00:00	BOHALE	Moderate Tropical Storm	35	35	996	TC 05S 2016	440 km E	-	NE to S	JTWC	
2017	12/03/2017 00:00	FERNANDO/ELEVEEN	Tropical Depression	30	45	1000	TC 11S 2017	100 km S	-	NE to WSW	JTWC	None
2018	13/01/2018 22:00	BERGUITTA	Moderate Tropical Storm	40	95	940	-	155 km N	-	E to W then SW	FIRINGA/MeteoFrance	Warning class III
2019	23/12/2018 07:00	CILIDA	Tropical Cyclone	85	95	945	-	310 km SW	-	NW to SE	FIRINGA/MeteoFrance	Warning class I
2019	06/02/2019 23:00	FUNI	Tropical Cyclone	85	100	940	-	220 km ENE	-	NNW to SSE	FIRINGA/MeteoFrance	Warning class II
2019	09/02/2019 23:00	GELENA	Intense Tropical Cyclone	95	100	942	-	50 kmSW	82	WNW to ESE	FIRINGA/MeteoFrance	Warning class IV (27 hours)
2019	26/03/2019 01:00	JOANINHA	Intense Tropical Cyclone	100	100	939	-	80 km NNE	96 (gusts > 54 kts during 33 hours)	-	FIRINGA/MeteoFrance	Warning class IV

Table 18: Sea level at Port Mathurin for the major cyclones impacting Rodrigues

Approaching date (UTC)	Name	Relative Sea Level [m]	Sea Level measured at Port Mathurin [cm]	Wind Speed at Plaine Corail
1/2/1991 6:00	BELLA	-0.37	1700	-
6/4/1996 6:00	HANSELLA	-0.10	1880	166 km/h (90kts)
8/4/1996 16:00	HANSELLA	-0.37	1549	-
12/3/2003 18:00	KALUNDE	0.21	2181	212 km/h (114kts)
15/4/2013 12:00	IMELDA	0.51	2428	-
21/12/2013 0:00	AMARA	0.51	2735	135 km/h (73kts)
9/1/2015 6:00	BANSI	-0.39	1878	124 km/h (67 kts)
13/1/2018 22:00	BERGUITTA	0.12	2373	-
23/12/2018 07:00	CILIDA	0.44	2629	-
06/02/2019 23:00	FUNANI	0.65	3150	-
09/02/2019 23:00	GELENA	1.04	3520	-
26/03/2019 01:00	JOANINHA	0.7	3030	178 km/h (gusts > 100 km/h during 33hours) (96 kts) (54kts)

1.4.3 Climate Change Projections

1.4.3.1 Sea Level Rise

Sea level have started to rise under the impact of climate change. This increase is estimated by the IPCC for different parts of the world. For the South Indian Ocean, the estimates are as follows compared to the period 1995-2014 according to 2 scenarios:

Period	Sea level rises	
	Scenario SSP2-4.5 *(middle-of-the-road development)*	Scenario SSP5-8.5 *(Fossil-fuelled development)*
Near term (2021-2040)	+0,1m	+0,1m
Medium Term (2041-2060)	+0,2m	+0,3m
Long Term (2081-2100)	+0,6m	+0,7m

1.4.3.2 Tropical Cyclones

IPCC projections show medium confidence in evolution of tropical cyclones according to document: Climate Change 2021: The Physical Science Basis.

Projections for Madagascar (no projections for Indian Ocean) show medium confidence of decrease in frequency and increase in intensity. Cyclones will potentially be less numerous with more intense winds and rainfall. Lower minimum pressure and stronger winds may generate more significant surges. According to IPCC, "*The increase in global TC* [Tropical Storm] *maximum surface wind speeds is about 5% for a 2°C global warming across a number of high-resolution multi-decadal studies (Knutson et al., 2020)*" and "*A projected increase in global average TC* [Tropical Storm] *rain rates of about 12% for a 2°C global warming* […] *(Knutson et al., 2020)".*

1.4.4 Marine and shores geology and marine turbidity

This chapter is the marine counterpart to the previous one, and is meant to base the assessment of the risks of impacts related to earthwork and shoreline work during the construction and then the consequences of the topography and shoreline modification.

1.4.4.1 Description of Rodrigues and Plaine Corail shorelines and reef

The coastal zone is mostly surrounded by fringing coral reef enclosing a shallow lagoon area – 0.5 to 3m – with deeper channels (to 40m in front of Port South-East). A shallow channel also separates the location of the future airport runway from Crab Island. The width of lagoons varies from place to place; along the West coast the reef lies 4-8km from the shore (4,6km from the airport runway). The reef platform and shallow lagoon around the island are more than twice the island's area. The bottom of the lagoon is composed of silty sand, the amount of silt being dependent on the distance from (temporary) rivulets. In general, the vast lagoon between the coastline and the reef is shallow, with sandbanks appearing at low tide and some deeper channels. At spring low tides, the intertidal zone locally extends several hundred meters.

Rodrigues Island was formed some ten million years ago from a crater of a sea-mount and consisted of theolitic lavas which have been observed as far as the eastern coast of the island. Subsequently, other eruptions consisting of pyroclasts and lavas (prismatic, hawaiites, etc.) contributed to the geomorphological features of the island.

The coastline is about 67 km long and is composed of different shore types: rocky stretches (especially at the headlands) alternating with sandy beaches (mainly in the bays) and smaller stretches of rock boulders and pebble shores. Locally, small (undercut) cliff walls (2–3 m high) occur, composed of eroded fossil coral reefs. In front of (temporary) rivulets, silty-sandy areas develop. Plaine Corail's shore is mostly rocky.

Because of late volcanic eruptions that occurred 1.3 to 1.5 million years ago, most of the shoreline is made of rocks and only 9% of the coastline are sandy beaches. Most are pocket beaches or small crescentic ones. They range from 2 to 25 m wide, some being very narrow as a consequence of the receding shoreline.

Table 19: General characteristics of beaches in Rodrigues

Island	Coastline (km)	Sandy coastline (km)	Number of beaches	Beaches seriously eroded
Rodrigues	67	6 (9%)	8	3

The eastern side of the island experiences greater exposure to the open ocean and prevailing wind and wave regime.

The southwestern area of Rodrigues Island is composed of thick eolian calcarenite deposits which contain a rich variety of limestone caves (Caverne Patate) and many karst features.

Plaine Corail, located in the South West, is an extensive area of low and flat land made of limestone, made up of solidified wind-blown sand.

Crab Island, which is southwest of mainland Rodrigues, is 1.1 km long in the east-west axis and 0.8 km wide in the north-south axis and lies some 350 m offshore of Plaine Corail at its nearest point to the mainland. The greater part of Crab Island consists of basaltic rock formed by volcanic activity probably over 1.3 million years ago (Upton et al., 1967). The summit of the islet rises to 45.5m above sea level at the highest point. The land slopes down rather steeply beyond the plateau except towards the NE where the gradient is much gentler. The islet has a rather open and shallow bay to the SW, fringed at places with some remnants of calcarenitic rocks consisting of wind-blown coralline sand probably deposited during the Pleistocene and thereafter cemented together (Mc Dougall et al., 1965). A more extensive calcarenitic area occurs along the Southern coast of the peninsula. The islet has three beaches of coralline sand: one in the southwest, and two on the eastern side, the larger of which occurs in the northeast portion of Crab Island. There is no river or fresh water body on Crab Island that could generate turbidity.

1.4.4.2 Marine sediment transport

The western coastal area of Rodrigues' lagoon is characterized by significant medium sand and mud.

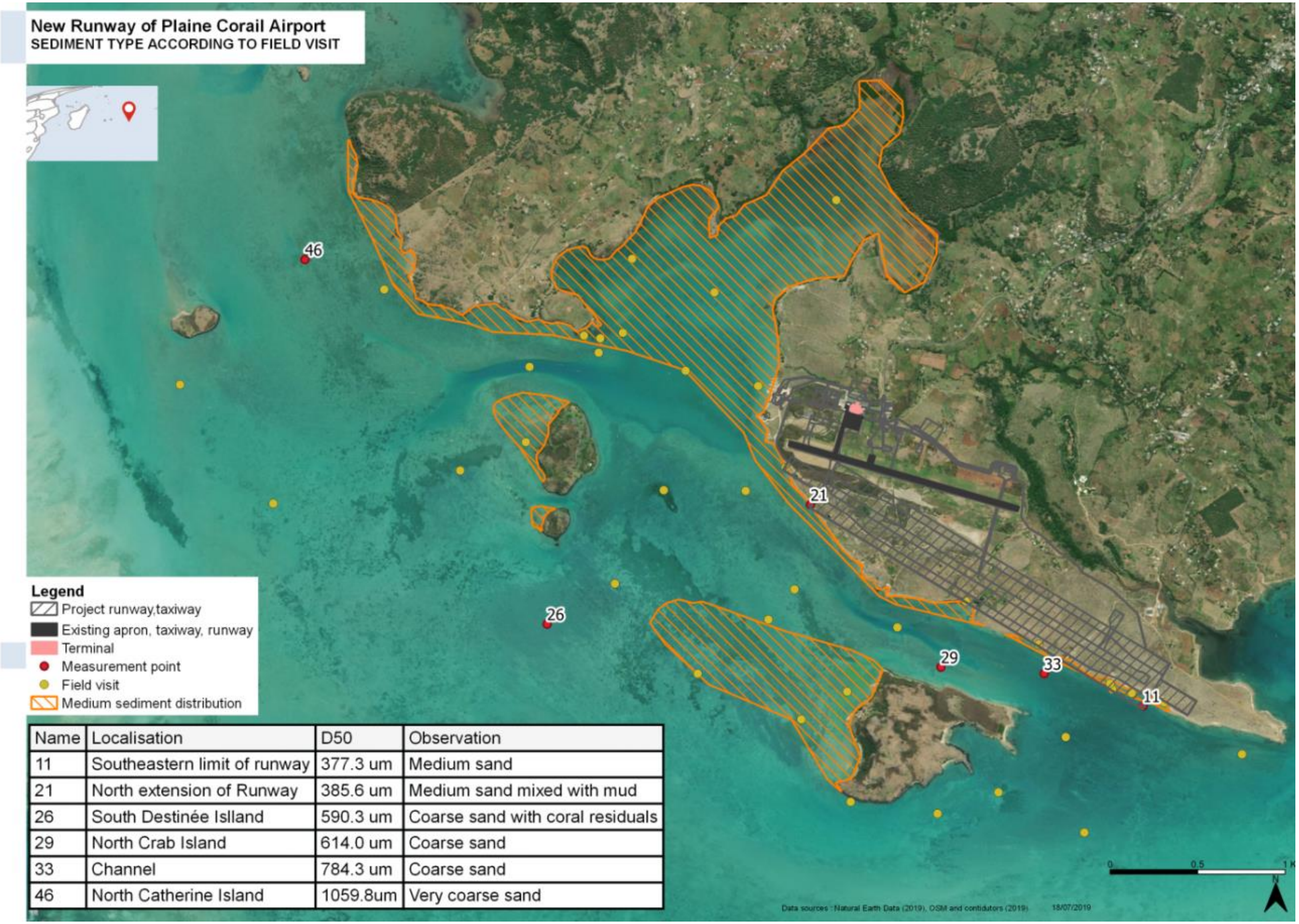
The grain size distribution of superficial distribution was conducted in July 2019. It shows sand is a more important component than silt and clays in the 6 samples collected and analysed (see figure below). These measurements showed a predominance of sand with a median diameter (d50) of 350 to 1060 µm.

Coarse sand stock exists in the inner part of the channel between Crab Island and the mainland, whereas finer sediments are located near the shore and in Topaze bay where current is weaker or almost non-existant. There, the portion of silt and clays is significant[4] (AFD, 2016).

The Northern part of the bay is composed of mud due to the very weak current and the important water runoff during heavy rains.

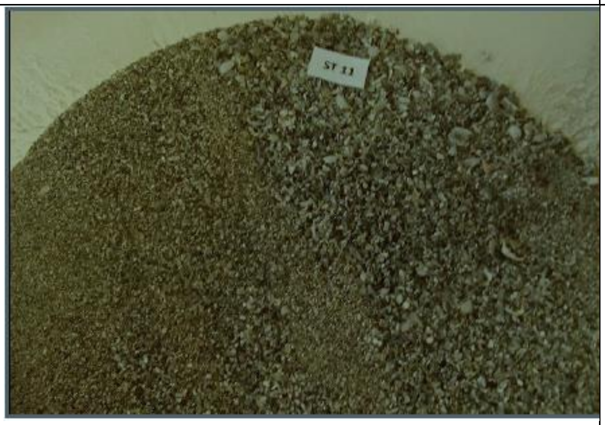
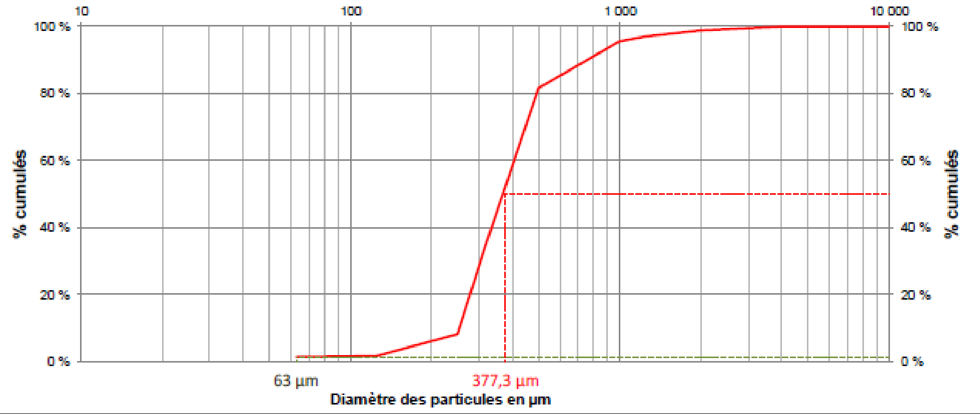
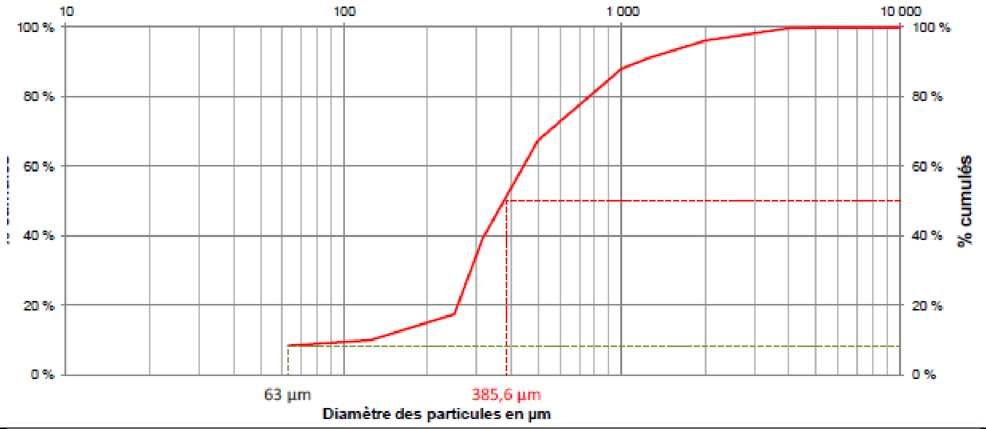
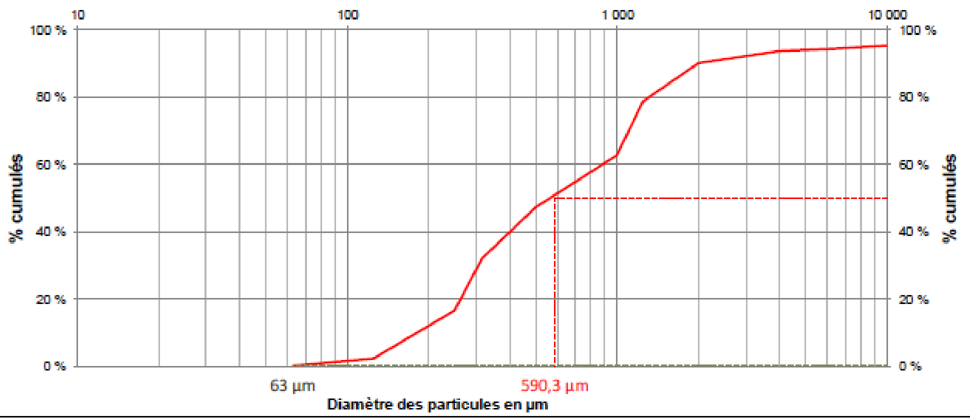
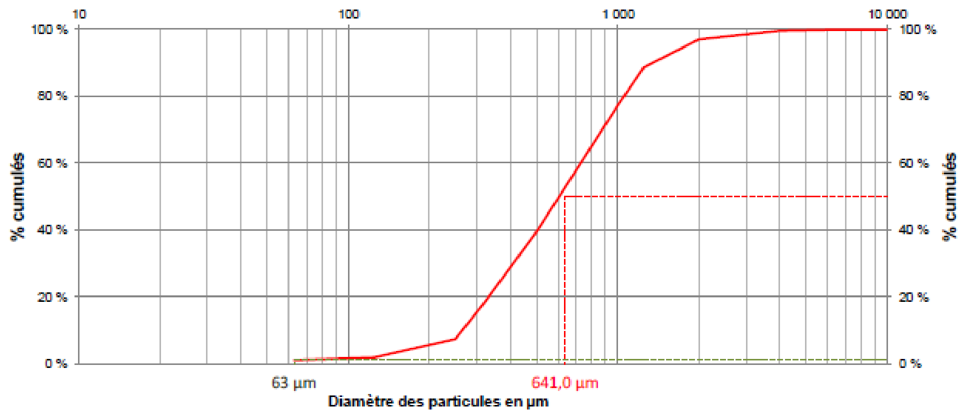
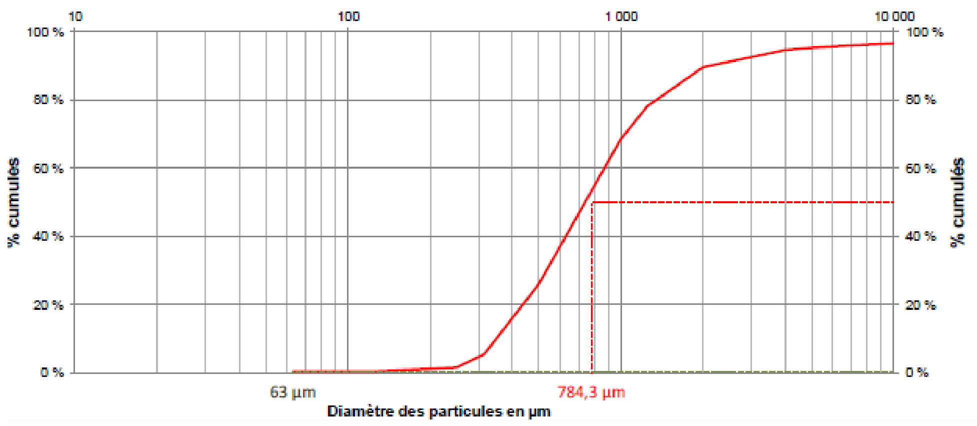
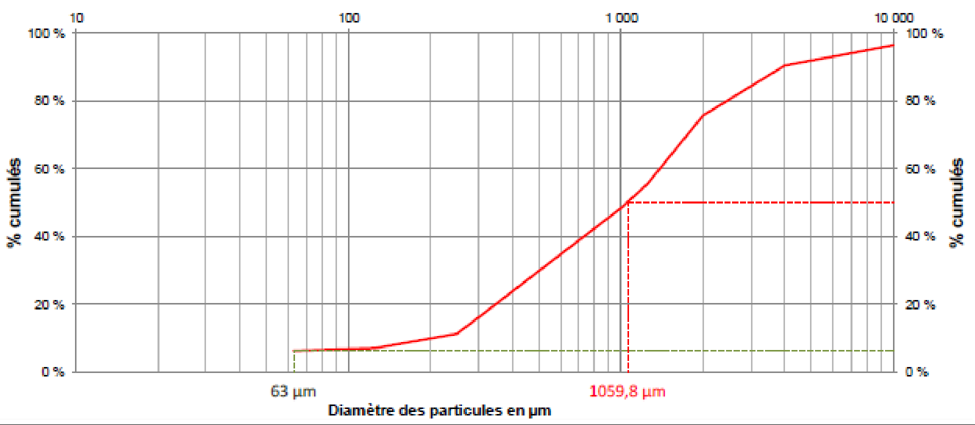
Bed load and resuspension occurs within the lagoon during each tidal cycle. Sediment transport under the influence of the flow is mainly from South-East to North-West. Resuspension is stronger when the current magnitude is important, the maximum is observed with ebb and flow current.

[4] AGENCE FRANCAISE DE DEVELOPPEMENT – Projet d'extension de l'aéroport de Rodrigues (Maurice): réalisation d'un diagnostic écologique / PHASE 1. BIOTOPE – Version finale - Juin 2016



Name	Localisation	D50	Observation
11	Southeastern limit of runway	377.3 um	Medium sand
21	North extension of Runway	385.6 um	Medium sand mixed with mud
26	South Destinée Islland	590.3 um	Coarse sand with coral residuals
29	North Crab Island	614.0 um	Coarse sand
33	Channel	784.3 um	Coarse sand
46	North Catherine Island	1059.8um	Very coarse sand

Figure 20: Marine sediment field measurement and grain size distribution.

SAMPLE	PHOTO	GRAIN SIZE DISTRIBUTION
11 Clean medium sand		
21 Silted medium sand		
26 Very coarse sand with coral residuals		
29 Coarse sand		
33 Coarse sand		
46 Very coarse sand		

1.4.4.3 Seawater turbidity

The sea water around Rodrigues is usually very clear. However, during heavy rain, along the North-Western and Western coasts, rivers carry large amounts of debris and soil into the lagoons, increasing the sea water turbidity. In some places, mangroves have been planted to stabilize the sediments and prevent the turbidity spreading into the lagoon.

In the northern area of Plaine Corail Airport, in Baie Topaze, natural turbid plume was identified in the past, see figure below.

Figure 21: Natural turbid plume in Baie Topaze (Google Earth, 25-05-2017)

Under common hydrodynamic conditions[5], inorganic matter levels are usually inferior to 20mg/L, rarely exceeding 30 mg/L in the Topaze bay. Turbidity is higher in the intertidal zone. The turbidity is homogenous in the water columns. Stronger winds increase sediment suspension, inorganic matter levels of 40-50 mg/L can be reached.

1.4.4.4 Marine environment issues

The studied area is characterized by a mild tropical maritime climate and influenced by south-easterly trade winds and Austral westerly ones. The coral reef fringing Rodrigues serves as a natural barrier that protects adjacent shorelines from offshore coastal hazards such as tropical cyclones approaching from the Northeast, southern hemisphere swells and local generated waves.

[5] Appendix Bc Consultation File (DCE) – Projet d'extension de l'aéroport de Rodrigues (Maurice) – Réalisation d'un diagnostic écologique – Phase 1 – Bibliographie, Agence Francaise de Développement (AFD), juin 2016

The coastal zone is surrounded by a shallow lagoon composed of silty sand and deeper channels. Usually crystal clear, the sea water around Plaine Corail can be very turbid after heavy rain.

Based on the description of the existing environment, the key marine receptors of concerns are the following:

- Marine receptor 1: Marine sediment quality: contamination of marine sediments.
- Marine receptor 2: Marine sediment dynamics: physical disturbance of marine sediments.
- Marine receptor 3: Seawater quality: temperature, salinity, concentration of contaminant.
- Marine receptor 4: Physical coastal processes: shoreline, morphology, wave, currents.

Even if the extension will change the shape of the island the area gained on the sea is minimal relative to the size of the channel between Crabe Island and Rodrigues, it would not change the wave dynamic. The receptor “Physical coastal processes” is therefore considered to be of low sensitivity.

“Seawater quality” is categorized as high because the project is located in a rather shallow area and pre-stresses. Natural turbid plumes have been identified in the past after heavy rain events.

The “Marine sediment quality” and “Marine sediment dynamic” receptors are considered to be of medium sensitivity because of the poor knowledge of sediment thickness and local granulometry, due to a lack of in situ data, as well as their temporal evolution.

1.4.5 Summary: Physical environment sensitivity

Table 20: Physical environment sensitivity

Theme	Sub-theme	Receptor	Sensitivity
Physical environment	Marine and shores geology and marine turbidity	Marine sediment quality: contamination of marine sediments	Medium
		Marine sediment dynamics: physical disturbance of marine sediments	Medium
		Seawater quality: temperature, salinity, concentration of contaminant	High
		Physical coastal processes: shoreline, morphology, wave, currents	Medium

1.5 Conclusion: main issues of the baseline

The main issues identified in the baseline assessment are the Marine reserves and habitats, and marine species such as *Acropora Formosa* and marine turtles,

2 Preliminary marine environmental and mitigation measures

2.1 Definitions and methodology

2.1.1 Project's phase considered in this study

This study is based on the preliminary design stage. During this first design phase, there is still a possibility to study several options. Therefore, the project is not confirmed, and some elements can be modified. However, all required field investigations have been carried out at this time and confirm that the project is feasible.

The next design step will be the detailed design, which consists of the final production detailed architectural and engineering drawings of the project's physical components. The detailed design also aims to ensure of the financial viability.

In order to consider all the potential consequences of the project, the impacts were studied with a broad vision. So, it is necessary to note that certain of these impacts will be avoided when the project is finalized.

For example, an impact of the project has been studied on the caves 'Grotte Fougère' and 'Grotte Petit Lac' which are in proximity of the new runway, even if the detailed design will avoid them.

2.1.2 Methodology for impact assessment and rating

In previous aspects of this study, receptors were defined and evaluated.

The chapter below aims to evaluate the consequences of the project (impacts), on all the receptors identified in the baseline.

The impacts are defined and classified according to whether they are:

- Temporary work impacts. These impacts are intended to appear during the project implementation phase, but to disappear once the works phase is completed (e.g. noise caused by the work equipment);
- Definitive work impacts. These impacts are intended to appear during the works phase, and to continue once the work is completed (e.g. destruction of habitat located in the project footprint);
- Operational impacts. These impacts are linked to the very existence and operation of the project (e.g. noise caused by the planes landing and taking off).

For each of these three types of large impacts, an assessment of the intensity was first conducted and rated on the basis of their severity (impact severity) as : 1 - not significant, 2 - low, 3 - medium, 4 - high, 5 - major.

Table 21: Impact severity

Impact severity	Not significant	Low	Medium	High	Major

The severity impacts were confronted with the sensitivity of the issues they affect. The evaluation of impact severity and receptors sensitivity is done regarding the previously described social impact assessment process and according to the various consultations and meetings with stakeholders during the field study. This provides the level of impact (impact magnitude). The severity of the social impacts and sensitivity of the receptors are then combined through a matrix to obtain the magnitude of the impact. This matrix applies both to adverse and positive impacts. The specific criteria used to assess the magnitude of each type of social impact are those defined in the assessment of impacts. The table below illustrates the magnitude matrix of social impacts:

Table 22: Magnitude matrix of social impacts

Impact severity	Not significant	Low	Medium	High	Major
Receptor sensitivity					
Low	Negligible	Low	Low	Low	Medium
Medium	Negligible	Low	Low	Medium	High
High	Negligible	Low	Medium	High	Major
Major	Low	Medium	High	Major	Major

- Following the identification and assessment of impacts, avoidance, reduction and impact compensation measures have been defined and numbered. The same measure can correspond to avoiding or mitigating several impacts.
- Finally, to correct previously identified impacts, these measures made it possible to carry out a new assessment of the impacts intensity. This is the mitigated impact or residual impact.

2.2 Temporary Impacts during Construction

2.2.1 Marine physical environment: shores, currents, turbidity and sedimentation

As approximately 2.7 ha of the new runway is built at sea, it is anticipated that seafloor will be disturbed as a sediment plume will be pumped from the backfilled area into the sea. It will increase turbidity and sedimentation while degrading the seawater quality. The dredging related to the construction of the boathouse will also generate a high level of turbidity.

Hence, the main potential temporary impacts on the marine physical environment are:

- Increase in turbidity;
- Modification of the seabed;
- Dredging at the boathouse.

2.2.2 Impact Phy-Mar-W-Temp-1: Increase in turbidity

2.2.2.1 Impact before mitigation

First of all, it is assumed that all equipment available for marine construction is land-based, no contamination from maritime equipment is considered.

Primary construction materials are dug out from the hill in the vicinity and used to backfill an enclosing structure, the newly reclaimed land from the sea founding the runway.

Filling the enclosing structure with sediment implies evacuating water once decantation is achieved. It is not recommended to reject it by overflow as there is no control of the process whatsoever. Doing so, important loads of fine particles can be released and impact receptors at significant distances from the work area. Local and temporal resuspension of those sediments can cause temporary increases in suspended particles concentration and turbidity that can lead to lethal stress for coral. It is recommended to pump water from the fenced area and discharge into the ocean in order to be able to regulate the flow rate and concentration of fine particles.

The extent, intensity and persistence of construction generated sediment plumes are determined by hydrodynamic and quality numerical models under main hydrodynamic condition with D-Water Quality module of Delft3D suite.

This module simulates the far- and mid-field water and sediment quality due to a variety of transport and water quality processes. To accommodate these, it includes several advection diffusion solvers and an extensive library of standardised process formulations with the user-selected substances. Default processes allow to simulate the deposition and resuspension of particles to and from the bed. The model used for the dispersion of sediment plume use the same grid as the current model and reuse the hydrodynamics results as input for the dispersion, deposal and resuspension of sediments.

The following hypotheses are taken into account:

- 5 discharges located in the vicinity of the reclaimed to the sea newly build area and near the boathouse (see location in Figure 22);
- A specific flow of 0.1 m^3/s for a 2000g/m^3 concentration;
- 14.5 days simulations to include one neap tide and one spring tide cycle;
- Non-concomitance of the discharge with a 3 days delay;
- Two wind conditions: 8.5 m/s mean wind and 5.5 m/s light wind;

Process parameters:

Table 23: Marine water quality model - Process parameters

Sedimentation velocity	Critical shear stress for sediment	Porosity of sediment layer	Zeroth-order resuspension flux	Critical shear stress for resuspension
0.0002 m/s	0.1 N/m²	0.35[-]	0.0001 kg/m²/s	0.2 N/m²

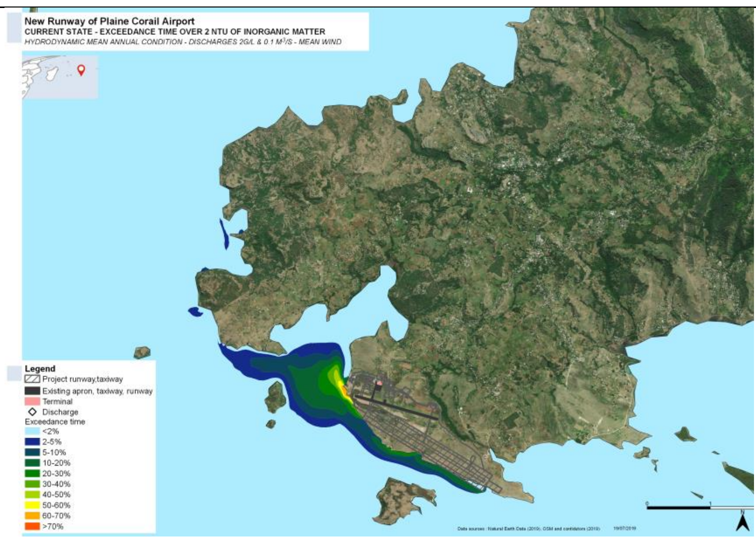
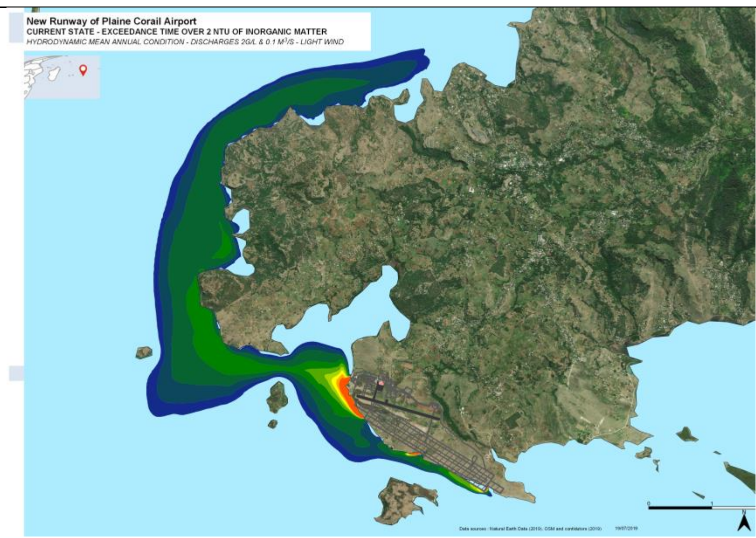
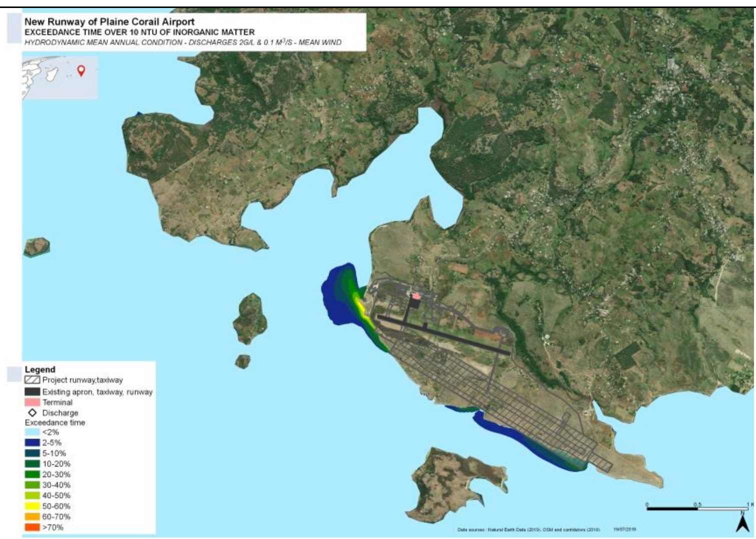
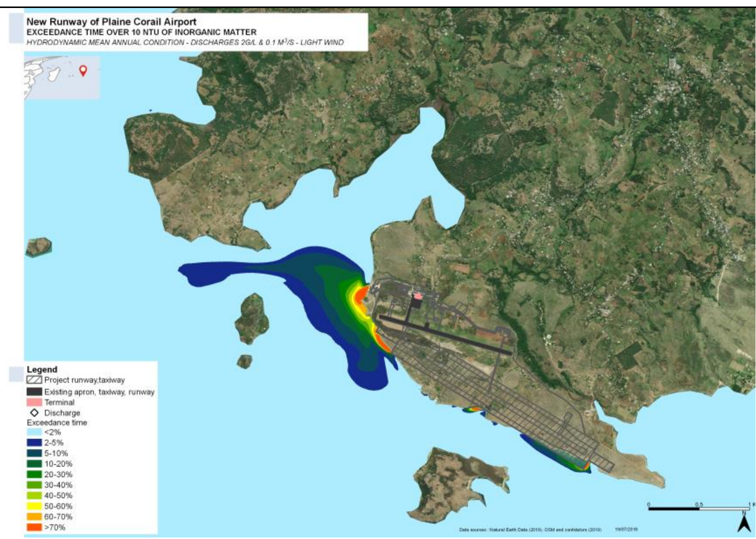
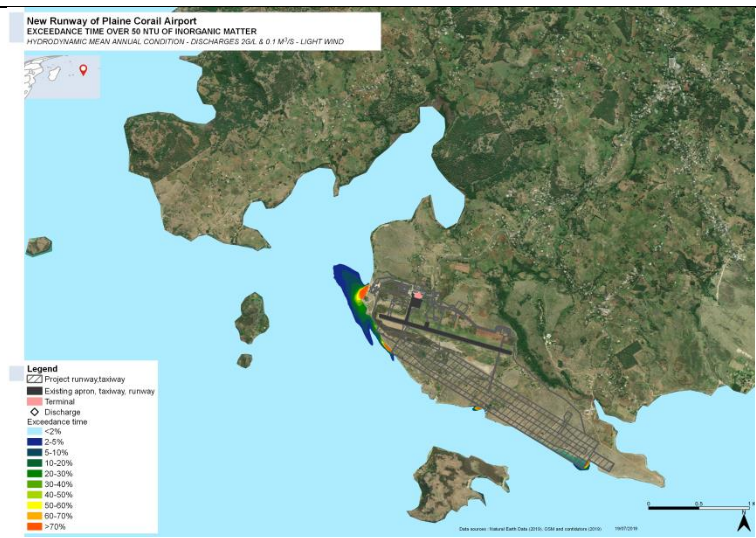
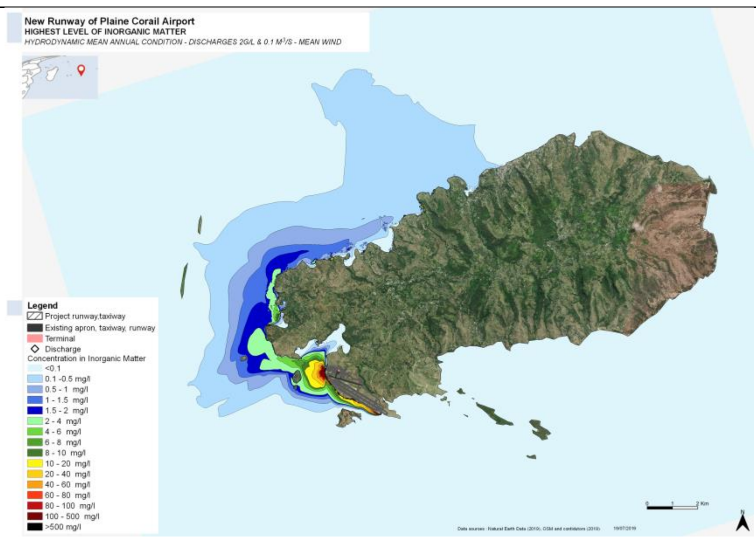
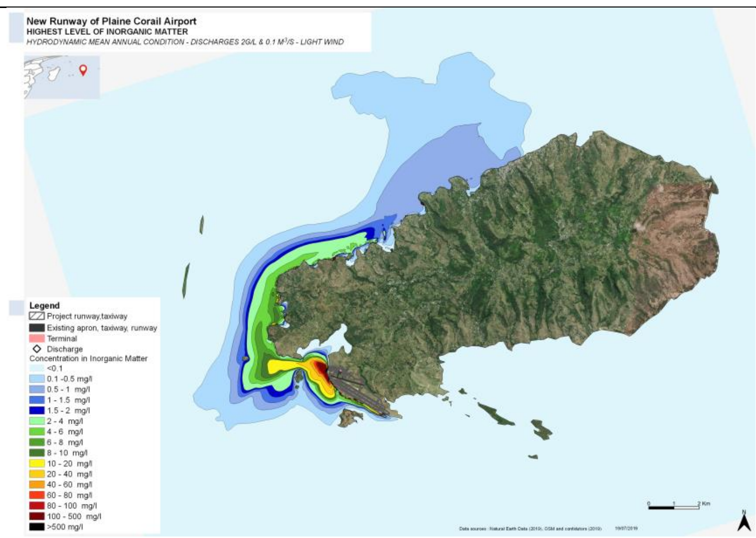
Main results such as exceedance time and maximum level are presented below.

An overall analysis of the temporal and special variability of the sediment plume highlights 4 main characteristics:

- The plume spreads in the same direction as the current (North-East);
- The level of inorganic matter is the highest at the West side of the new runway where the current is lower and so the dispersion is weaker;
- The inner and shallow part of Topaze Bay is not impacted which it consistent with the local circulation, almost non-existent in this area;
- Spatial variations in the lagoon are much greater with lighter wind. The plume reaches North Bay with light wind but barely passes Pointe Mapou when mean wind blows, respectfully at 9.9km and 4.4km of the boathouse. With lighter wind, the plume tends to go farther west, up to 2 km west from Fregate Island.
- The main receptor affected by this action may be the seawater quality.

The impact severity is major. Considering the receptor sensitivity assessed as high, **the impact magnitude is major**.

Table 24: Results from the marine water quality model

	MEAN WIND	LIGHT WIND
Exceedance Time over 2 NTU of Inorganic Matter Exceedance time <2% 2-5% 5-10% 10-20% 20-30% 30-40% 40-50% 50-60% 60-70% >70%		
Exceedance Time over 10 NTU of Inorganic Matter Exceedance time <2% 2-5% 5-10% 10-20% 20-30% 30-40% 40-50% 50-60% 60-70% >70%		
Exceedance Time over 50 NTU of Inorganic Matter Exceedance time <2% 2-5% 5-10% 10-20% 20-30% 30-40% 40-50% 50-60% 60-70% >70%		
Maximum Level of Inorganic Matter <0.1 0.1 -0.5 mg/l 0.5 - 1 mg/l 1 - 1.5 mg/l 1.5 - 2 mg/l 2 - 4 mg/l 4 - 6 mg/l 6 - 8 mg/l 8 - 10 mg/l 10 - 20 mg/l 20 - 40 mg/l 40 - 60 mg/l 60 - 80 mg/l 80 - 100 mg/l 100 - 500 mg/l >500 mg/l		

2.2.2.2 Mitigation measure and impact after mitigation

Phy-Mar-Mit-1

The construction processes must ensure a minimal volume of water in the low-lying embankment delimited area to insure the stability and sustainability of the runway. The connection between the seabed and the rocks is as watertight as possible to ensure the minimal infiltration volume. Extra water is carefully drained off to avoid the potential fine-sediment wash-out due to water pressure.

Phy-Mar-Mit-2

The discharge should be located in order to promote a local settling of the inorganic matter, i.e. away from the strongest current, and release a controlled level of fine particles.

A specific hydrodynamic survey should be conducted to optimize the position of each discharge in the vicinity of the build onto the sea part of the new runway using a representative local climate (wave, wind and water level). Several localizations for each discharge could be tested in order to choose which configuration minimizes the plume extent and/or does not reach sensitive areas such as corals.

The selected solution will have to be modelled over the entire discharge period to ensure that there is no impact by taking realistic conditions (representative local climate (wave, wind and water level) and tidal conditions).

Figure 22: Localization of the potential sediment discharges to the lagoon during works phase and current-meter

In order to determinate shutdown and warning thresholds, median value of turbidity in Topaze bay would need to be evaluated in a normal state, constituting an initial and reference state for the future turbidity in-situ measure to be compared to. At least three current meters and turbidimeters are installed to insure the construction follow-up (see map below) in the vicinity of the runway:

- In the channel between Crab Island and the mainland;
- South of Plaine Corail to monitor the entrance of Anse Quitor;
- Near the corals in the entrance of Topaze Bay.

Phy- Mar-Av-3

The extent of the plume is mitigated by selecting an adequate timetable. Discharges better not occurs during significate reverse of flows.

A specific hydrodynamic survey could be conducted to test the best time to release inorganic matter in the sea. The time of year, the tidal cycle and spring tide or neap tide period should be considered to determine the start of discharge. The duration of discharge and the time it occurs regarding the velocity and direction of current also affects the turbid flume extent and position.

The current and magnitude of current could be monitored by a current-meter in the channel between Crab Island and Plaine Corail where they are at their maximums. Construction would stop if the reversal lasted more than 3 hours and velocity higher than 0.2m/s.

Phy- Mar-Mit-4

Silt curtains can be used to contain suspended sediments during the working operation. This technique has been successfully used to prevent sediment dispersal in numerous projects from dredging to construction projects. It would be used around the 5 discharge points and in case of dredging in front of the jetty boathouse.

A silt curtain is a permeable or impervious structure that sits suspended in the water column to control migrating water borne sediment and silt. It contains sediment about one to two meters from the water surface where the turbidity is the most active. Silt curtains allow suspended sediment to settle and drop to the bottom within the water column by controlling dispersion. Water depth, quantity and type of material in suspension, hydrodynamic conditions and project duration have to be considered when designing and installing silt curtain. The curtain should remain clear from the sea bed at low tide, it should be free moving and not anchored under sand or dispersed mud.

The construction layout and the area expected to be potentially impacted are identified and surveyed after which the required length of the silt curtain is decided. Once the desired length of silt curtain is connected, anchors are fixed on the land and the furled curtains can be towed to site at a maximum two to three knot speed.

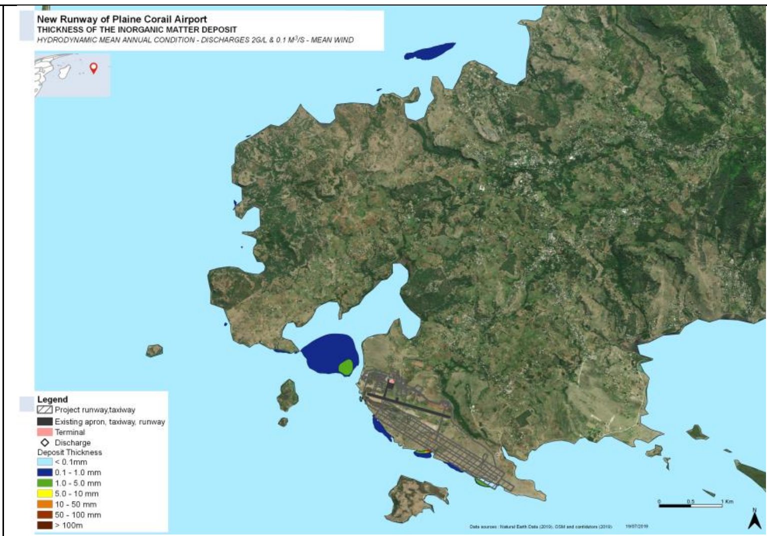
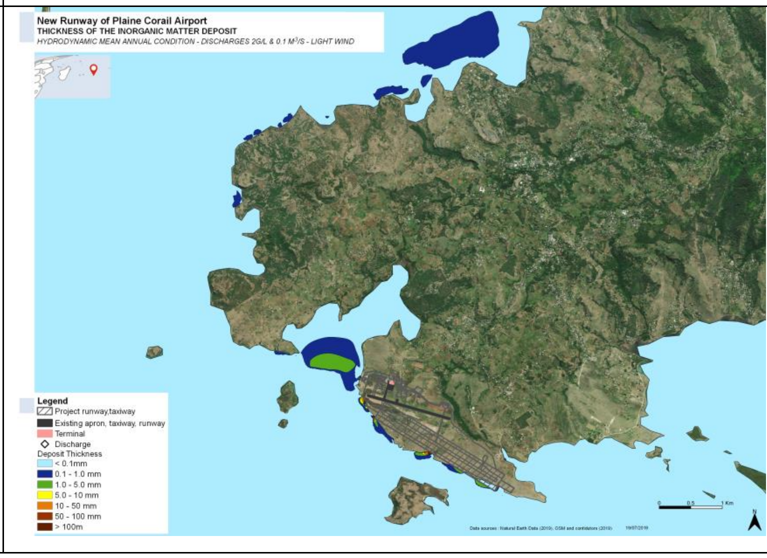
The proposed measures result in a high severity mitigated impact thus The residual impact is of **high magnitude**.

2.2.3 Impact Phy-Mar-W-Temp-2: Modification of the seabed

2.2.3.1 Impact before mitigation

The turbid plume also affects the seabed. Change in its composition might be detectable after the fine-sediment has settled down. Sediment thickness due to the suspended loaded water discharge is reported in the table below.

Table 25: Thickness of deposit due to the construction of the runway in the surrounding of Plaine Corail

Thickness of Inorganic Matter Deposit	
MEAN WIND Deposit Thickness < 0.1mm 0.1 - 1.0 mm 1.0 - 5.0 mm 5.0 - 10 mm 10 - 50 mm 50 - 100 mm > 100m	
LIGHT WIND Deposit Thickness < 0.1mm 0.1 - 1.0 mm 1.0 - 5.0 mm 5.0 - 10 mm 10 - 50 mm 50 - 100 mm > 100m	

Areas around the discharge location are the most impacted. The thickness of inorganic matter related to the construction can locally be larger than 10 cm. The extent is limited at the entrance of North Bay 9 km away from the first release point. Though the thickness is less than 1 mm.

Sediment deposits in the entrance of Bay Topaze reach a maximum of 5mm.

The main receptor affected by this action may be the marine sediment quality.

The impact severity is medium. Considering the receptor sensitivity assessed as medium, **the impact magnitude is low**.

2.2.3.2 Mitigation measure and impact after mitigation

The preceding mitigation measures can also be applied to limit the dispersion of the turbid plume and its effects on the marine sediment content.

The proposed measures result in low severity mitigated impact. The residual impact is of **low magnitude**

2.2.4 Impact Phy-Mar-W-Temp-3: Dredging in front of the boathouse

2.2.4.1 Impact before mitigation

Dredging may be carried out to deepen the access to the future jetty facilities and boathouse, in the North of the Airport, in order to allow larger ship access. This work is done by mechanical dredgers, this technic generates fine materials suspension that could increase the local turbidity and modify the sea-bed.

The main receptor affected by this action may be the seawater quality.

The impact severity is major. Considering the receptor sensitivity assessed as high, **the impact magnitude is major**.

2.2.4.2 Mitigation measure and impact after mitigation

The preceding mitigation measures can also be applied to limit the dispersion of the turbid plume and its effects on the marine sediment content. The relevant turbidimeter is the one located next to the corals.

Silt curtain is especially needed to control the suspended solids generated by the dredging. It will be placed around the excavation site.

The proposed measures result in a high severity mitigated impact. Thus the residual impact is of **high magnitude**.

2.2.5 Impact Phy-Mar-W-Temp-4: WWTP discharge

2.2.5.1 Impact before mitigation

Water supply needs during construction phase will logically lead to an increase in wastewater discharges. If discharges are made into the marine environment, it is necessary to know the extent of the plume. This area will then be used by the team in charge of marine biodiversity to determine its impact on marine flora and fauna.

Method used to assess the impact:

The extent, intensity and persistence of WWTP discharge plume are determined by hydrodynamic and quality numerical models under main hydrodynamic condition with D-Water Quality module of Delft3D suite.

This module simulates the far- and mid-field water quality due to a variety of transport and water quality processes. To accommodate these, it includes several advection diffusion solvers and an extensive library of standardised process formulations with the user-selected substances. Default processes allow to simulate the gradient density. The model used for the dispersion of WWTP plume use the same grid as the current model and reuse the hydrodynamics results as input for the dispersion.

Hypothesis considered will be the same as those used for the Phy-Mar-Op-3 impact, which corresponds to the operation of the WWTP at the operational stage. It is therefore assumed that WWTP discharges during the construction phase will be lower than during the operational phase:

- 1 discharge located in the vicinity of the WWTP, near the boathouse;
- An average flow of 21.5 m3/d. This flow is smoothed over 24 hours. This implies the presence of a storage tank to act as a buffer
- The discharge will have a BOD5 concentration of 250mg/l. This is the maximum concentration permitted for discharge into the sea according to local regulations
- 14.5 days simulations to include one neap tide and one spring tide cycle;
- An unfavorable wind condition in terms of plume dilution: a light wind of 5.5m/s

The maximum BOD5 concentration result is shown below.

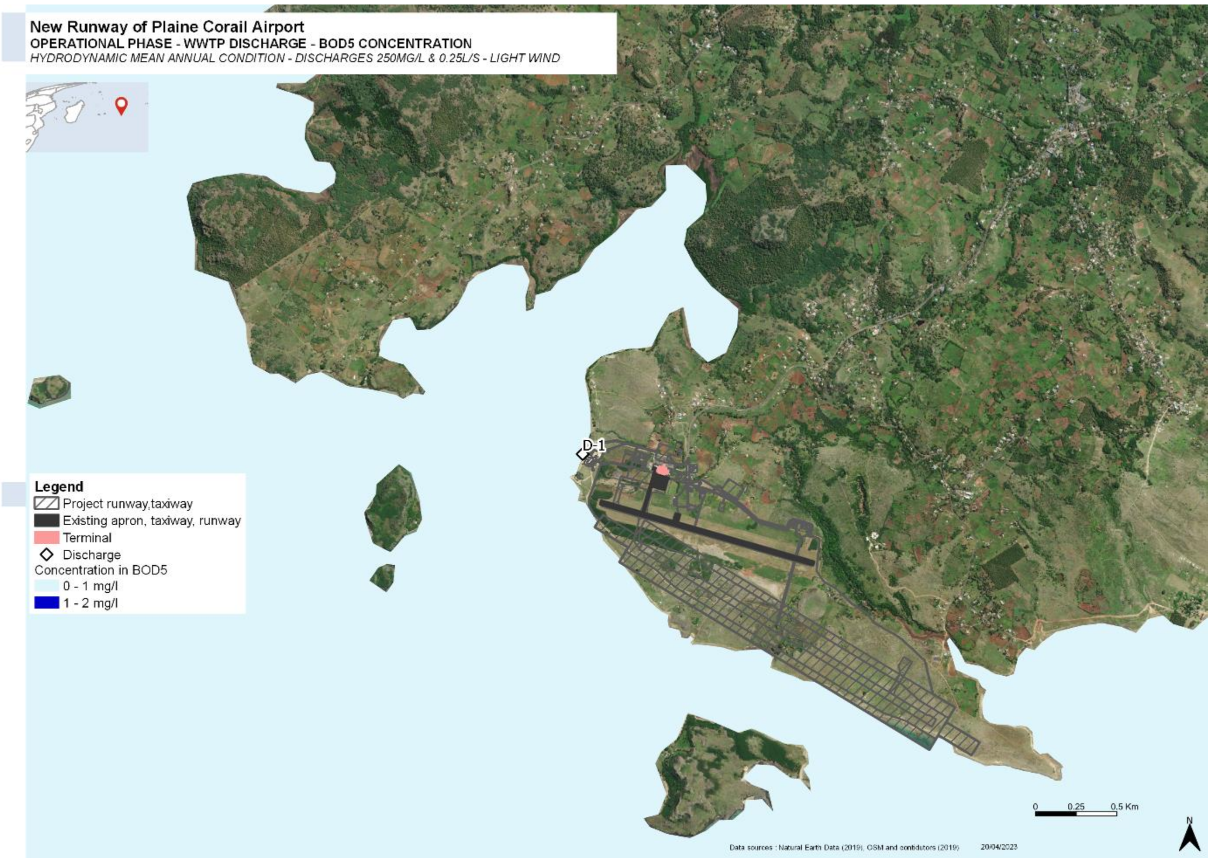


Figure 23: Maximum concentration of BOD5 due to WWTP discharge

This concentration is between 1 and 2mg/l around the discharge. It is less than 1mg/l over the rest of the area. These concentrations are anecdotal due to the very low flow of the discharge. Indeed, a flow of 21.5m3/d corresponds to an average flow of 0.25l/s. This value is minimal compared to the volume of water into which the water is discharged, approximately 20m3 (volume of water included in the model mesh).

The impact severity is not significant. Considering the receptor sensitivity assessed as high, **the impact magnitude is low**.

2.2.5.2 Mitigation measure and impact after mitigation

Despite not significant impact, mitigation measures are proposed for the operational phase.

2.2.6 Impact Phy-Mar-W-Temp-5: Desalination plant discharge

2.2.6.1 Impact before mitigation

Water supply needs require the potabilization of water. The desalination process is studied in this impact study. This process makes it possible to supply drinking water by pumping salt water and discharging brine. In the event of discharge into the sea, the discharge of brine may have a significant impact on marine fauna and flora. This area will then be used by the team in charge of marine biodiversity to determine its impact on marine flora and fauna.

Method used to assess the impact:

The extent, intensity, and persistence of the discharge plume from the desalination plant are determined by numerical modelling with the Delft3D suite. This module simulates in 3 dimensions the propagation of the brine plume (heavier than the ambient water) according to the tidal and wind conditions encountered on site.

The characteristics of the brine discharge (flow rate and salinity) are deduced from the consumption of drinking water and from our experience with other installations. Thus, for a consumption of 21m^3/d, rounded to 30m^3/d, the daily flow rate discharged is equal to 120m^3/d. By integrating a buffer tank, the smoothed hourly flow is equal to 5m^3/h.

Modelling hypotheses are listed below:

- 1 discharge located in the vicinity of the desalination plant, near the boathouse;
- Ambient salinity : 35ppm
- Salinity of discharge: 40ppm
- Average flow of 5m^3/h;
- 14.5 days simulations to include one neap tide and one spring tide cycle;
- Non-concomitance of the discharge with a 3 days delay;
- An unfavorable wind condition in terms of plume dilution: a light wind of 5.5m/s

The maximum salinity resulting from the entire simulation is shown below:

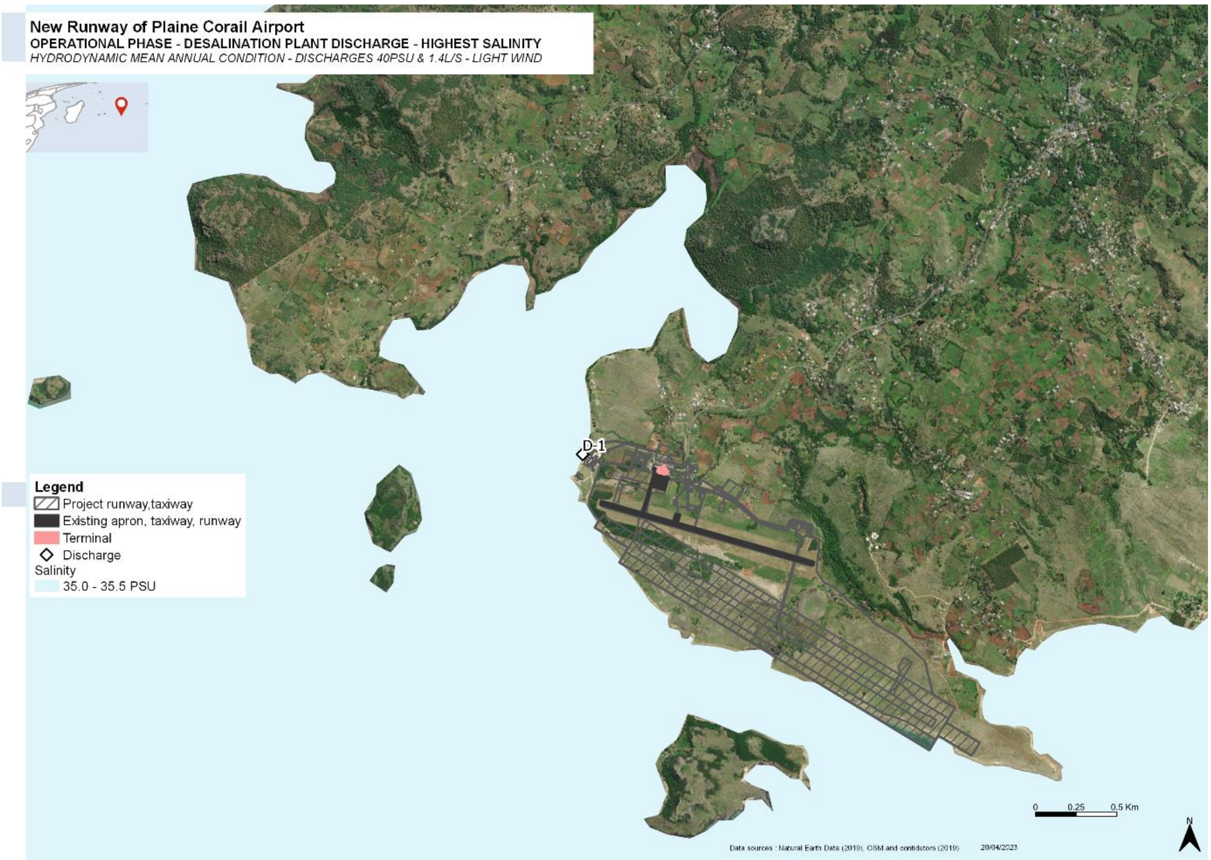


Figure 24: Maximum salinity desalination plant discharge

The main receptor affected by this action may be the seawater quality.

The impact severity is not significant. Considering the receptor sensitivity assessed as high, **the impact magnitude is low**.

2.2.6.2 Mitigation measure and impact after mitigation

Despite not significant impact, mitigation measures are proposed for the operational phase.

2.2.7 Summary

Table 26: Temporary Impact during Construction

Impact ID	Impact name	Direction	Impact magnitude mitigation	Measure ID	Avoidance / Mitigation / Compensation / Improvement Measures	Residual / improved impact magnitude
Phy-Mar-W-Temp-1	Increase in turbidity	Adverse	Major	Phy-Mar-Mit-1	Mitigation - Controlled backfilled processes	High
				Phy-Mar-Mit-2	Mitigation - Optimisation of the location of discharges	
				Phy-Mar-Av-3	Avoidance - Optimisation of the discharges timetable to avoid times when currents reverse and/or already turbid condition	
				Phy-Mar-Mit-4	Mitigation - Silt curtain around discharges	
Phy-Mar-W-Temp-2	Modification of the seabed	Adverse	Low	Phy-Mar-Mit-1	Mitigation - Controlled backfilled processes	Low
				Phy-Mar-Mit-2	Mitigation - Optimisation of the location of discharges	
				Phy-Mar-Av-3	Avoidance - Optimisation of the discharges timetable to avoid times when currents reverse and/or already turbid condition	
				Phy-Mar-Mit-4	Mitigation - Silt curtain around discharges	

Phy-Mar-W-Temp-3	Dredging in front of the boathouse	Adverse	Major	Phy-Mar-Av-3	Avoidance - Optimisation of the discharges timetable to avoid times when currents reverse and/or already turbid condition	High
				Phy-Mar-Mit-5	Mitigation - Silt curtain around dredging area	
Phy-Mar-W-Temp-4	WWTP discharge	Adverse	Low	None	-	Low
Phy-Mar-W-Temp-5	Desalination plant discharge	Adverse	Low	None	-	Low

2.3 Permanent and irreversible impacts during Construction Phase

2.3.1 Marine physical environment: shores, currents, turbidity and sedimentation

The main permanent impacts due to the construction on the marine physical environment are the:

- Modification of the local bathymetry and the shoreline;
- Modification of the hydrodynamic processes;
- Modification of the sediment transit;
- Modification of the bathymetry due to the dredging to access jetty facilities;
- Remains of suspended particulate matter and sediment.

2.3.2 Impact Phy-Mar-W-Def-1: Alteration of the local bathymetry and shoreline

2.3.2.1 Impact before mitigation

The action of changing the coastline and adding aggregate might alter the topography from which it existed previously.

The shoreline is modified by the extensions at 4 locations which represents more than 900m of new coastline, due to the extension of the runway and the vicinity of the jetty facilities. The constitution of the coastline is now partly artificial instead of being mainly composed of rock (see image below) interspersed with a few sandy beaches.

Figure 25: rocky coast in the west backfilled area

The impact severity is low. Considering the receptor sensitivity assessed as medium, **the impact magnitude is low**.

2.3.2.2 Mitigation measure and impact after mitigation

As the impact magnitude is low, no mitigation measure is necessary.

2.3.3 Impact Phy-Mar-W-Def-2: Modification of the local hydrodynamic processes

2.3.3.1 Impact before mitigation

Newly built areas will change the coastline geometry and seabed morphology leading to cause significant changes to the coastal hydrodynamics; it may redistribute wave energy, cause changes in wave propagation and change tidal current speed and direction especially in the channel between Crab Island and the mainland where the width is limited.

However, the dimensions of the constructed area are so secondary that the impact severity is low at Rodrigues's scale. Wave pattern does not experience significant changes, wave heights are restricted by the lagoon's restraining action, breaking on the reef barrier.

In Plaine Corail, flow magnitudes are higher, beyond 0.10 m/s behind the the construction. Flow locally changes direction to circumvent the new runway delineation, and resume its trajectory, see table below.

In Crab Island, the increase in flow magnitude remains below 0,01m/s at most in the extreme East of the island.

The hydrodynamic impact is no longer perceptible in front of the Destiny and Fregate islands.

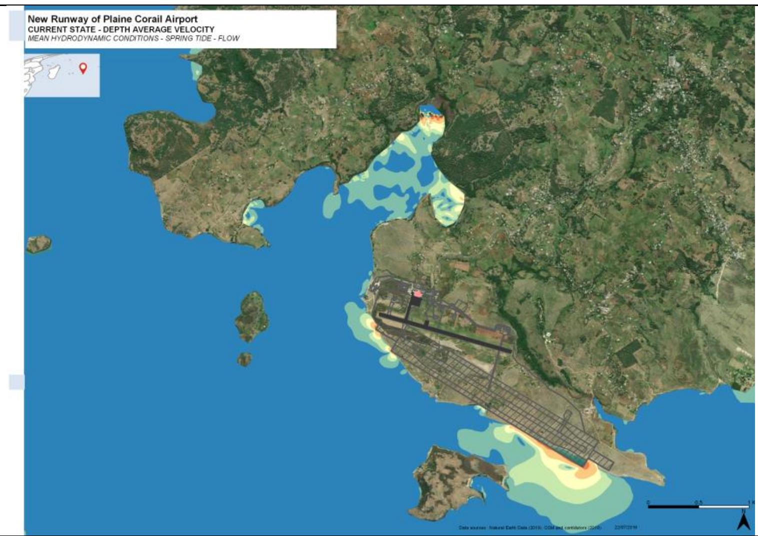
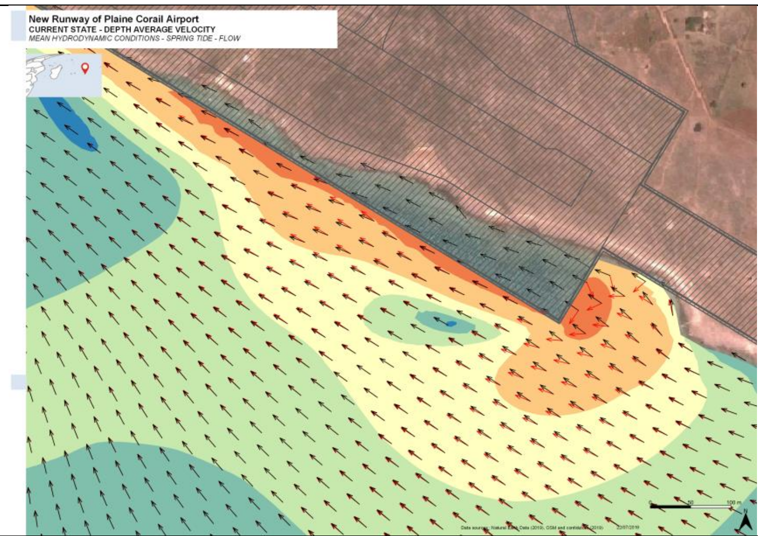
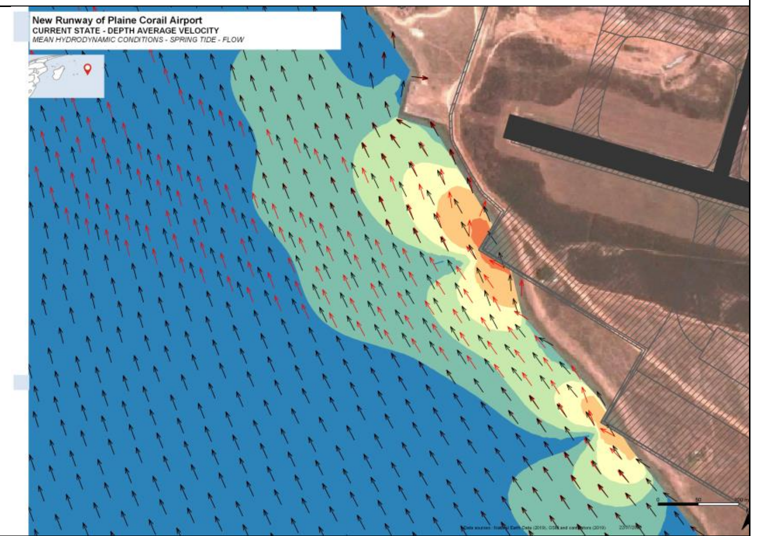
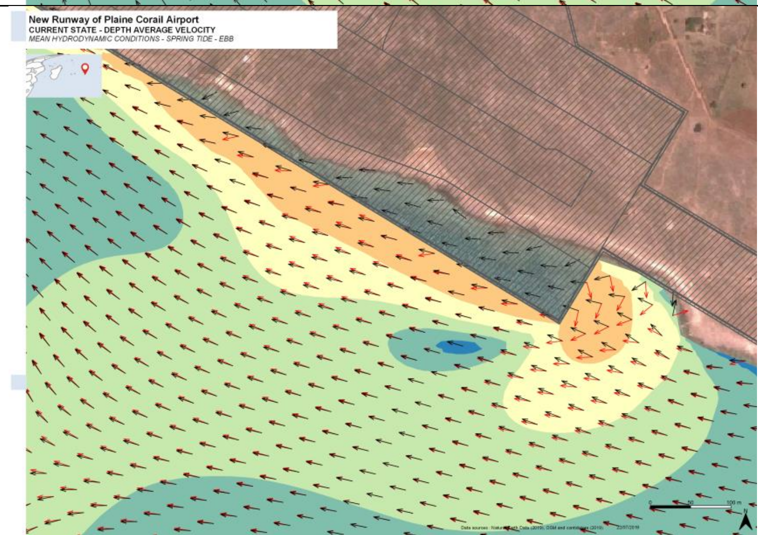
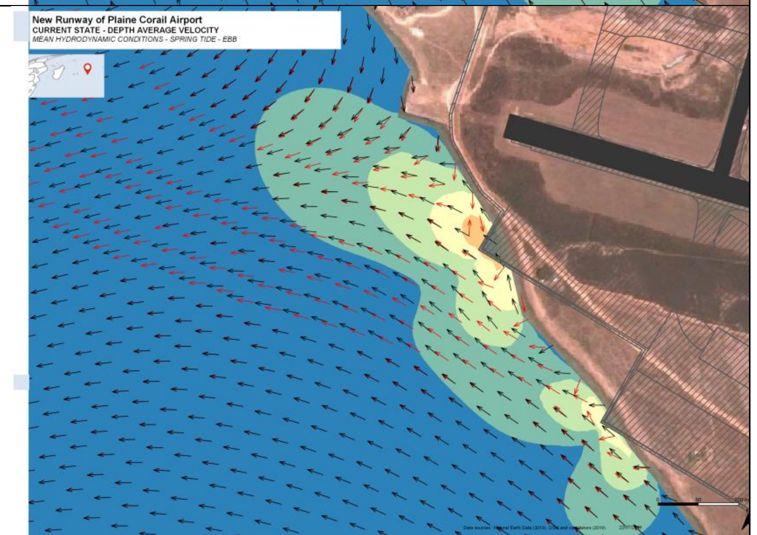
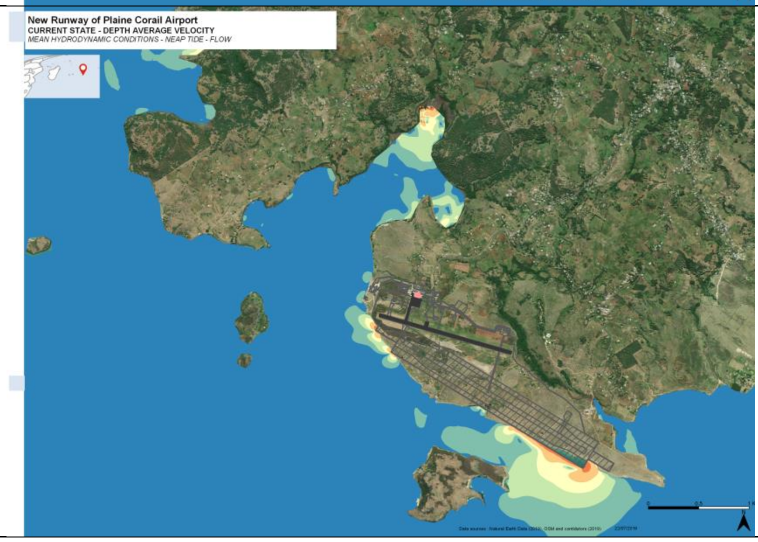
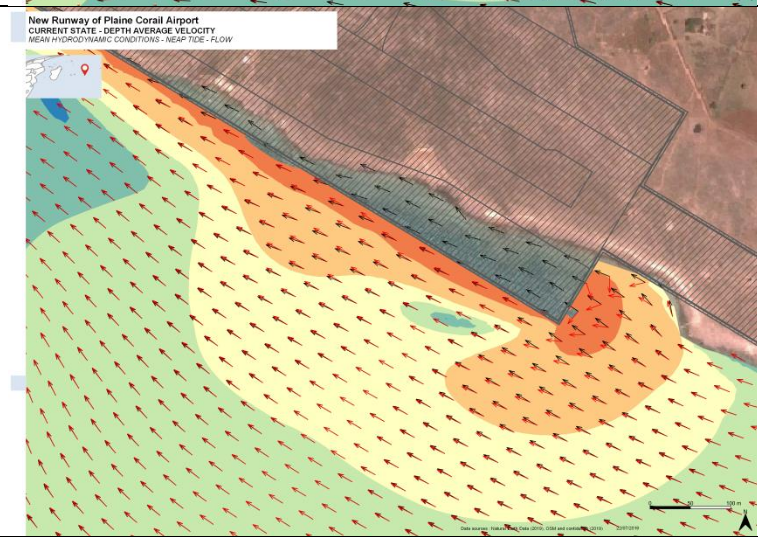
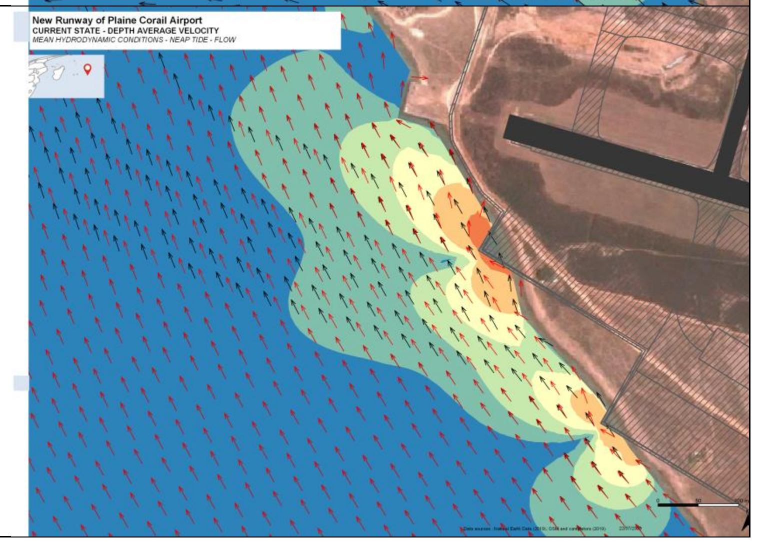
The main receptor affected by this action may be the physical coastal processes.

The impact severity is not significant. Considering the receptor sensitivity assessed as medium, **the impact magnitude is negligible**.

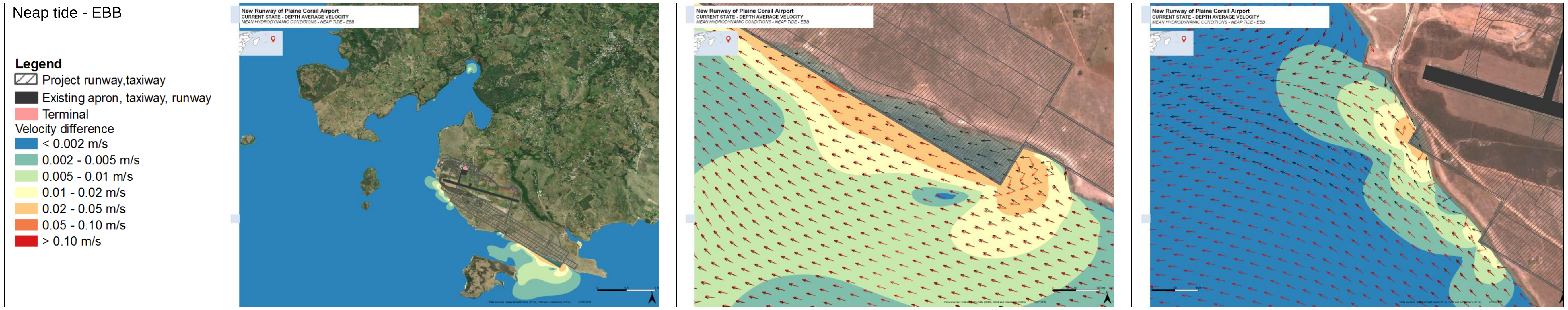
2.3.3.2 Mitigation measure and impact after mitigation

As the impact magnitude is negligible, no mitigation measure is necessary.

Table 27: Differential of circulation due to the constructed runway

	PLAINE CORAIL	SOUTH-EAST	NORTH-WEST
Spring tide - FLOW **Legend** Project runway,taxiway Existing apron, taxiway, runway Terminal Velocity difference < 0.002 m/s 0.002 - 0.005 m/s 0.005 - 0.01 m/s 0.01 - 0.02 m/s 0.02 - 0.05 m/s 0.05 - 0.10 m/s > 0.10 m/s			
Spring tide - EBB **Legend** Project runway,taxiway Existing apron, taxiway, runway Terminal Velocity difference < 0.002 m/s 0.002 - 0.005 m/s 0.005 - 0.01 m/s 0.01 - 0.02 m/s 0.02 - 0.05 m/s 0.05 - 0.10 m/s > 0.10 m/s			
Neap tide - FLOW **Legend** Project runway,taxiway Existing apron, taxiway, runway Terminal Velocity difference < 0.002 m/s 0.002 - 0.005 m/s 0.005 - 0.01 m/s 0.01 - 0.02 m/s 0.02 - 0.05 m/s 0.05 - 0.10 m/s > 0.10 m/s			

Neap tide - EBB



2.3.4 Impact Phy-Mar-W-Def-3: Modification of the sediment transit

2.3.4.1 Impact before mitigation

The extension of the airport will change the coastline geometry, seabed morphology and flow pattern leading to changes in sediment balance, transport and deposition regime.

Areas exposed to current and wave action are different from before the construction. The sedimentary composition of the seabed has changed: new sediments are available in the vicinity of the discharge and sediment that used to be on the area reclaimed from the sea has been replaced by artificial structure, non-erodible.

A numerical sediment transport model is constructed and exploited to identify deposit/erosion areas and sediment movement pattern in general. The model is forced by mean annual meteorological conditions, summarized in the table below, during a hydrodynamic period of 14.5 days (1 neap tide + 1 spring tide). As morphological changes take place over much longer periods than short-term hydrodynamics, a morphological acceleration factor is used in the model enabling a 3 months evolution simulation. A simulation is conducted with the runway extension achieved, another one in the current state.

Table 28: Marine sediment model inputs

Sediment transport model input (DELFT-3D)				
Winds conditions	Waves conditions		Sediment	Roughness
V = 8.5 m/s Dir = 105°	Hs = 2.25m Tp = 14.5s Dir = 215°	Hs = 2.75m Tp = 9.25s Dir = 105°	Specific density = 2650 kg/m^3 Dry bed density = 1600 kg/m^3	C = 40 $m^{1/2}/s$ in the lagoon C = 65 $m^{1/2}/s$ elsewhere

A movable sediment bed of 0.3m in thickness was assumed to exist everywhere from the seaward of the reef to the coast. Two types of sediments are used in the model, the grain size (750μm and 380μm) and special distribution is retrieved from analysis of the sample collected in the surroundings of Plaine Corail.

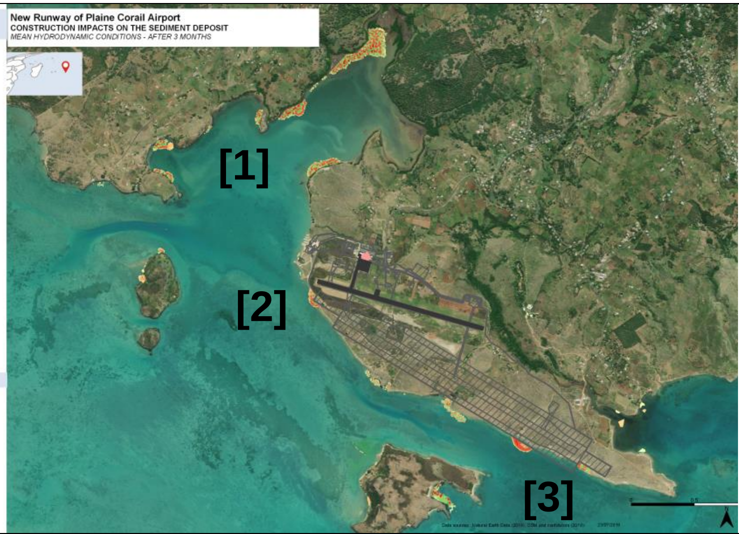
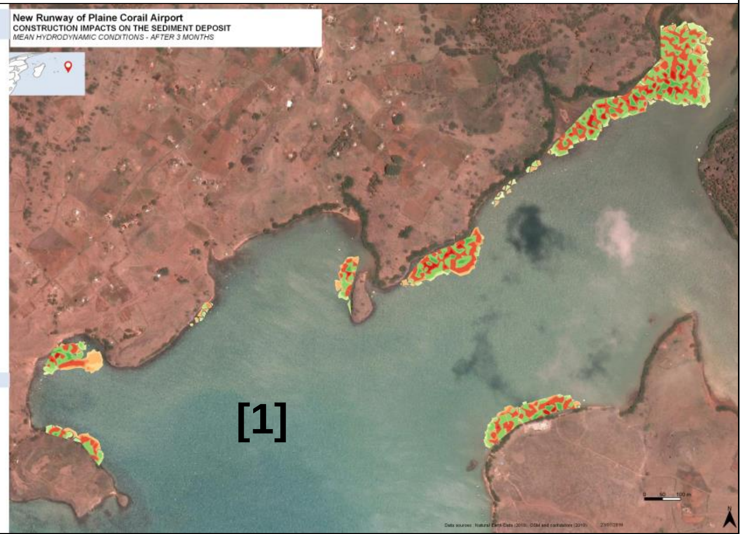
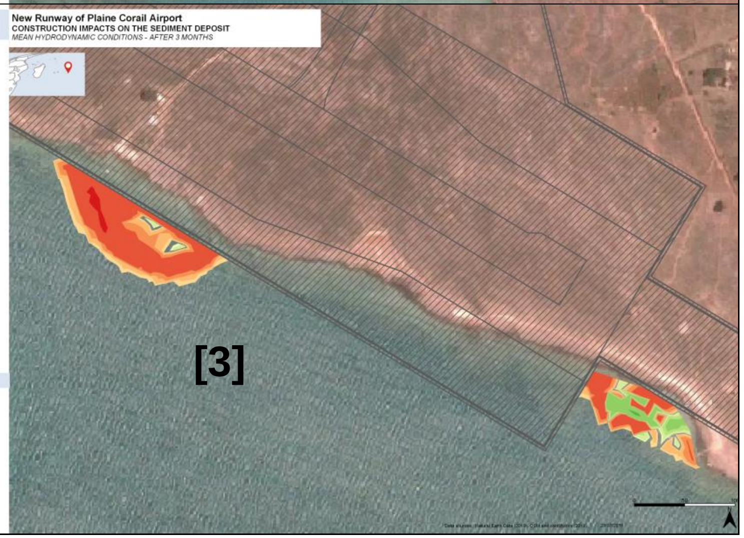
Outcomes are qualitative. The sediment accumulation/deposit result assessment will be analyzed to define whether or not the construction stage of the project will affect sensitive areas.

Three months after the constructions are achieved, two areas will be impacted:

- The shoreline of Topaze bay. However, values are so small that it may be residual numerical errors;
- The newly build area reclaimed from the sea and its immediate surroundings.

The general sediment flux has not been affected.

Table 29: Impact on sediment deposit due to the construction of the Runway

<table>
<tr><th></th><th colspan="2">Differential of cumulative erosion/sedimentation after 3 months</th></tr>
<tr><td rowspan="2">Legend
Project runway,taxiway
Existing apron, taxiway, runway
Terminal
Sediment deposit thickness
< 100 mm
-100 - -10 mmm
-10 - -5 mm
-5 - -2 mm
-2 - -1 mm
1 - 2 mm
2 - 5 mm
5 - 10 mm
10 - 100 mm
> 100 mm</td>
<td>
</td>
<td>
</td></tr>
<tr><td>
</td>
<td>
</td></tr>
</table>

The main receptor affected by this action may be the marine sediment dynamic.

The impact severity is low. Considering the receptor sensitivity assessed as medium, **the impact magnitude is low**.

2.3.4.2 Mitigation measure and impact after mitigation

As the impact magnitude is negligible, no mitigation measure is necessary.

2.3.5 Impact Phy-Mar-W-Def-4: Modification of the bathymetry due to the dredging to access jetty facilities

2.3.5.1 Impact before mitigation

The potential new dredge channel to access the jetty facilities and the boathouse changes the bathymetry of the area leading to modification in the sediment balance, transport and deposition regime.

The area is located away from main currents and thus from sediment transport. Impacts on those parameters are very small.

The impact severity is low. Considering the receptor sensitivity assessed as medium, **the impact magnitude is low**.

2.3.5.2 Mitigation measure and impact after mitigation

As the impact magnitude is low, no mitigation measure is necessary.

2.3.6 Impact Phy-Mar-W-Def-5: Remains of suspended particulate matter and sediment

2.3.6.1 Impact before mitigation

The land reclaimed by the ocean construction process and dredging near the jetty facilities generates a turbid flume and releases an important amount of suspended matter. Once the work is done, part of it still remains. It has not settled down to the seabed and has not been flown away with the ebb/flow currents.

Depending on the concentration of sediment released, remaining particles can stay for a long period but the turbidity will naturally decrease with time.

The main receptor affected by this action may be the marine sediment quality.

The impact severity is low. Considering the receptor sensitivity assessed as medium, **the impact magnitude is low**.

2.3.6.2 Mitigation measure and impact after mitigation

As the impact magnitude is low, no mitigation measure is necessary.

2.3.7 Summary

Table 30: Permanent Impact during Constructon - Physical Environment - Marine

Impact ID	Impact name	Direction	Impact magnitude mitigation	Measure ID	Avoidance / Mitigation / Compensation / Improvement Measures	Residual / improved impact magnitude
Phy-Mar-W-Def-1	Alteration of the local bathymetry and shoreline	Adverse	Low	None	-	Low
Phy-Mar-W-Def-2	Modification of the local hydrodynamic processes	Adverse	Negligible	None	-	Negligible
Phy-Mar-W-Def-3	Modification of the sediment transit	Adverse	Low	None	-	Low
Phy-Mar-W-Def-4	Modification of the bathymetry due to the dredging to access jetty facilities	Adverse	Low	None	-	Low
Phy-Mar-W-Def-5	Remains of suspended particulate matter and sediment	Adverse	Low	None	-	Low

2.4 Impacts during operation phase

The project aims to enable Rodrigues Island to develop tourism and aerial cargo. Tourism development might have significant impacts on the environment.

However, this ESIA only aims to address the impacts of the infrastructure. Thus, the so-cio-economic development and changes that could be expected due to the air access improvement are not part of this ESIA scope.

Impacts of the airport extension on tourism and socio-economics on an island scale are addressed in other studies carried out under RRA's control.

2.4.1 Marine physical environment: shores, currents, turbidity and sedimentation

The main impacts during operational phase on the marine physical environment are:

- Accidental spillage;
- Uncontrolled wastewater discharges.

2.4.2 Impact Phy-Mar-Op-1: Accidental spillage

2.4.2.1 Impact before mitigation

The activities of the airport and the jetty facilities will not impact the marine physical environment on their normal operational phase. However, airport operational activities use various chemicals and dangerous substances. Accidental spills or leaks of solid or liquid waste into the surroundings of the airplane or jetty during operations might occur and result in marine water contamination.

The main receptor affected by this action may be the seawater quality.

The impact severity is high. Considering the receptor sensitivity assessed as high, **the impact magnitude is high**

2.4.2.2 Mitigation measure and impact after mitigation

Mitigation measures to reduce adverseimpact of the spilling are:

- Prevent spills and accidents by training staff to avoidance of spills;
- Implementing a protocol for depollution in case of spill;
- Implementing methodologies for quick confining and treatment of pollutants.

The proposed measures result in a low severity mitigated impact. Thus, the residual impact is of **low magnitude**.

2.4.3 Impact Phy-Mar-Op-2: Uncontrolled waste water discharges

2.4.3.1 Impact before mitigation

Three discharge points are releasing collected rainwater from the runway and the upstream watershed. An extra release point is located North of the boathouse and is discharging treated used water and rainwater, previously transiting by an oil separator and a buffer storage unit, in case of water surplus during extreme event. (See Water Resource and Waste water management part.)

These discharges represent a small volume of fresh water input to the ocean compared to the water runoff naturally present due to the downward slope. Their impacts on the hydrodynamic circulation are marginal.

Treatment devices are, under normal circumstances, minimizing the level of contaminant in the water released into the ocean. During extreme events, pollution is diluted in large volumes of rainwater.

The main receptor affected by this action may be the seawater quality.

The impact severity is low. Considering the receptor sensitivity assessed as medium, **the impact magnitude is low**.

2.4.3.2 Mitigation measure and impact after mitigation

As the impact magnitude is low, no mitigation measure is necessary.

2.4.4 Impact Phy-Mar-Op-3: WWTP discharge

2.4.4.1 Impact before mitigation

Water supply needs during operation phase will logically lead to an increase in wastewater discharges. If discharges are made into the marine environment, it is necessary to know the extent of the plume. This area will then be used by the team in charge of marine biodiversity to determine its impact on marine flora and fauna.

Method used to assess the impact:

The modelling assumptions are the same as those used for the impact Phy-Mar-W-Temp-4, with the same results.

The results are not shown here. The conclusions are identical.

The impact severity is not significant. Considering the receptor sensitivity assessed as high, **the impact magnitude is low**.

2.4.4.2 Mitigation measure and impact after mitigation

Phy-Mar-Mit-8

The discharge should be located in such a way as to favour local dilution of the effluent, i.e. close to the strongest currents, while remaining as far away as possible from the issues.

A specific hydrodynamic study will be carried out to optimise the position of the WWTP discharge point using a representative local climate (wind and water level). Several locations for each discharge could be tested to choose the configuration that minimises the extent of the plume and/or does not reach sensitive areas such as corals.

The chosen solution will need to be modelled over a sufficiently long period of time to estimate the cumulative effects of the discharge.

Phy-Mar-Mit-9

The sizing of the outfall should consider the dilution of the effluent. Thus, the selected discharge structure should allow for optimal initial dilution (near field). The following aspects can be studied:

- outfall diameter and outlet velocity as a function of flow rate
- depth of the outfall;

The proposed measures result in a not significant impact. Thus, **the residual impact is low**.

2.4.5 Impact Phy- Mar-Op-4: Desalination plant discharge

2.4.5.1 Impact before mitigation

Water supply needs during operation phase require the potabilization of water. The desalination process is studied in this impact study. This process makes it possible to supply drinking water by pumping salt water and discharging brine. In the event of discharge into the sea, the discharge of brine may have a significant impact on marine fauna and flora. This area will then be used by the team in charge of marine biodiversity to determine its impact on marine flora and fauna.

Method used to assess the impact:

The modelling assumptions are the same as those used for the impact Phy-Mar-W-Temp-5, with the same results.

The results are not shown here. The conclusions are identical.

The impact severity is not significant. Considering the receptor sensitivity assessed as high, **the impact magnitude is low**.

2.4.5.2 Mitigation measure and impact after mitigation

Phy-Mar-Mit-10

The discharge should be located in such a way as to favour local dilution of the effluent, i.e. close to the strongest currents, while remaining as far away as possible from the issues.

A specific hydrodynamic study should be carried out to optimise the position of the discharge point and the desalination plant using a representative local climate (wind and water level). Several locations for each discharge could be tested in order to choose the configuration that minimises the extent of the plume and/or does not reach sensitive areas such as corals.

The chosen solution will need to be modelled over a sufficiently long period of time in order to estimate the cumulative effects of the discharge.

Phy-Mar-Mit-11

The design of the outfall should consider the dilution of the effluent. Thus, the selected discharge structure should allow for optimal initial dilution (near field). The following aspects can be studied

- outfall diameter and outlet velocity as a function of flow rate
- depth of the outfall;
- installation of a diffuser.

The installation of a diffuser is essential here, as the denser brine tends to spread over the bottom, and the diffuser selected should allow for a discharge towards the surface to increase dilution.

The proposed measures result in a not significant impact. Thus, **the residual impact is low**.

2.4.6 Impact Phy- Mar-Op-5: Stormwater drainage

2.4.6.1 Impact before mitigation

The implementation of the new runway will alter stormwater runoff and may increase freshwater input to some coastal areas. The magnitude of these potential freshwater plumes needs to be modelled to estimate their impact on marine life. This area will then be used by the team in charge of marine biodiversity to determine its impact on marine flora and fauna.

Method used to assess the impact:

The extent, intensity and persistence of storm water drainage plume are determined by numerical modelling of hydrodynamics with the Delft3D suite. This module simulates in 3 dimensions the propagation of the freshwater plume (lighter than the ambient water) in function of the tidal and wind conditions encountered on site.

The characteristics of the freshwater discharge (flow rate and duration) are calculated from the precipitation assumptions in our possession (see chapter X). The 2-year return period is used to identify the frequent impact of the development on the salinity of the water.

The modelled hydrographs are shown below:

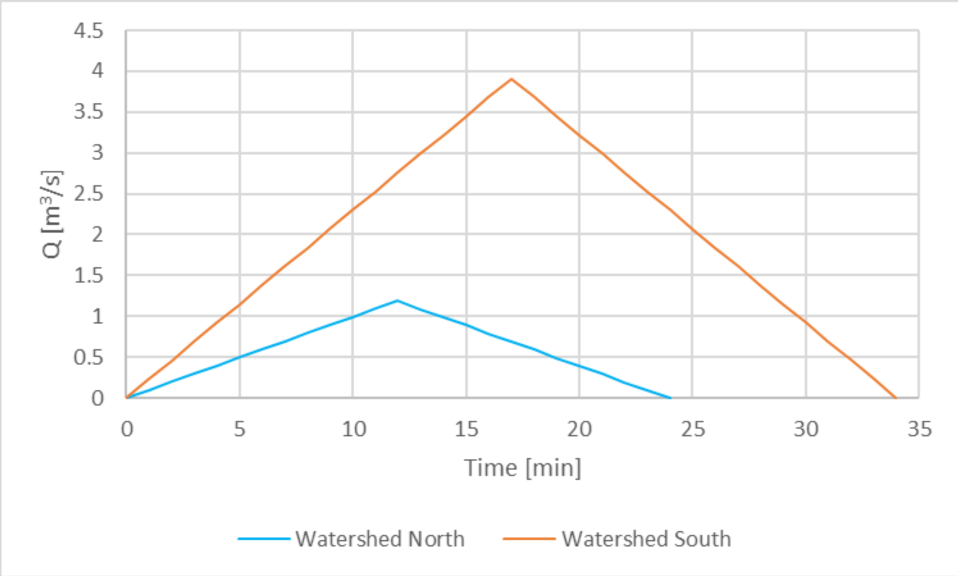
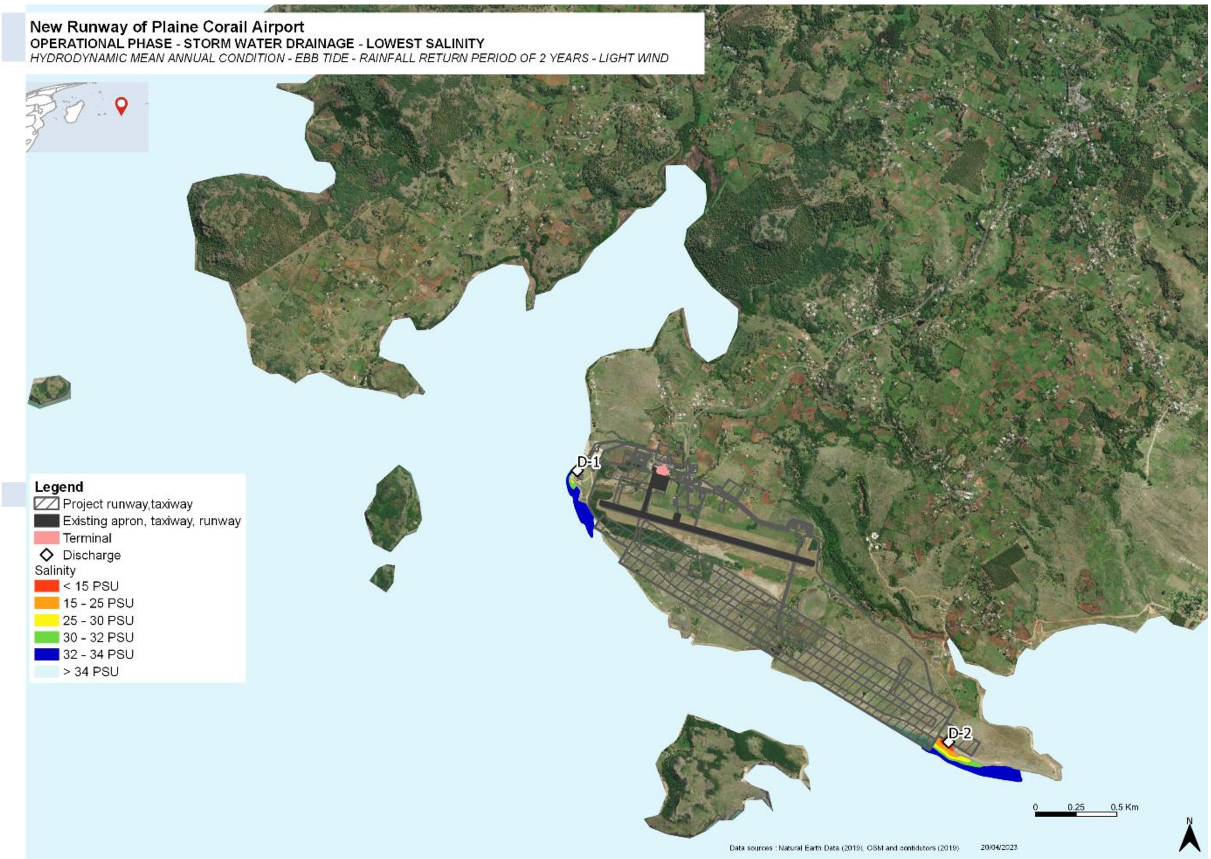


Figure 26: Hydrographs imposed on watersheds

Modelling assumptions are listed below:

- 2 discharges:
- 1 discharge located in the north of the new runway, near the boathouse;
- 1 discharge located in the south of the new runway.
- Ambient salinity: 35ppm;
- Flow and duration extracted from previous hydrographs
- Two simulations, one incorporating a discharge during the flood and the other during the ebb;
- 4 days simulations;
- An unfavorable wind condition in terms of plume dilution: a light wind of 5.5m/s ((A strong wind allows a strong dilution of the plume, thus strongly limiting its impact. Medium wind conditions and not the strong winds that can be associated with a cyclone are therefore chosen in order to remain in a unfavourable situation, limiting the dilution of the plume and increasing its concentration).

The following results show the minimum salinity over the entirety of each simulation.



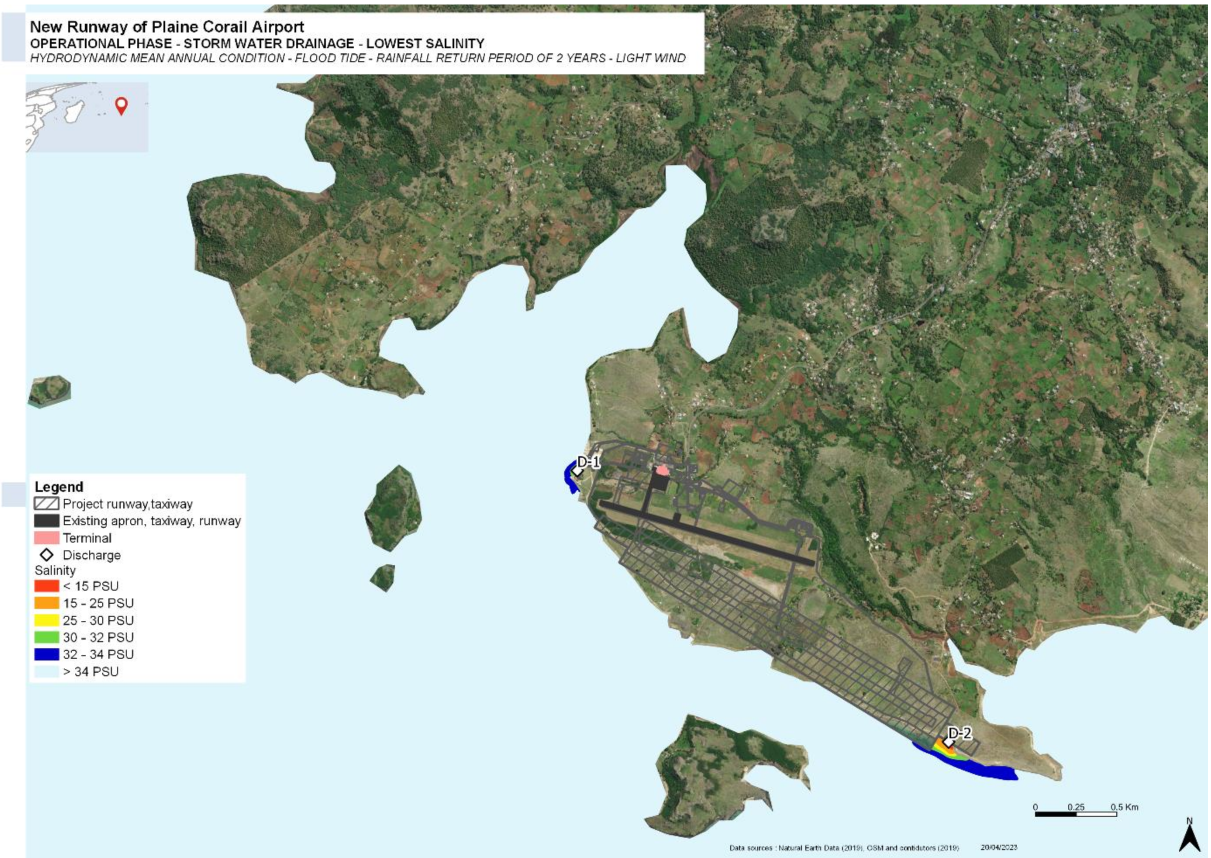


Figure 27: Salinity due to storm water drainage for ebb tide (top) and flood tide (bottom)

The plumes resulting from the discharges to the north and south are relatively small and remain close to the point of discharge. The freshwater plume does not reach the various islands in the vicinity. The discharge to the south, with the highest flows, generates the most extensive plume. Its location in a relatively confined area following the construction of the new runway contributes to limiting its dilution and thus increasing the concentration of freshwater. The discharge to the north, which is more exposed to currents and has lower flows, generates a very small plume.

The main receptor affected by this action may be the seawater salinity.

The impact severity is *medium*. Considering the receptor sensitivity assessed as high, **the impact magnitude is medium**.

2.4.6.2 Mitigation measure and impact after mitigation

Phy-Mar-Mit-12

As the impact of the northern discharge is low, the southern discharge should be optimised. This discharge, which drains a larger area, should be relocated to an area open to the currents to facilitate dilution.

It could also be divided into two separate discharges in order to distribute the freshwater and avoid too large a discharge in one area. The following locations can be proposed:

Figure 28: Proposed location of the southern outlets of the stormwater drainage system

The proposed measures result in a **low**. Thus, **the residual impact is low**.

2.4.7 Summary

Table 31: Impact during Operation - Physical Environment- Marine Environment

Impact ID	Impact name	Direction	Impact magnitude mitigation	Measure ID	Avoidance / Mitigation / Compensation / Improvement Measures	Residual / improved impact magnitude
Phy-Mar-Op-1	Accidental spillage	Adverse	Major	Phy-Mar-Mit-6	Prevent spills and accidents : train staff to avoidance of spills	Low
				Phy-Mar-Mit-7	Implementing methodologies for quick confining and treatment of pollutants and protocol for depollution in case of spill	
Phy-Mar-Op-2	Uncontrolled waste water discharges	Adverse	Low	None		-
Phy-Mar-Op- 3	WWTP discharge	Adverse	Low	Phy-Mar-Mit-8	Location of the outfall	Low
				Phy-Mar-Mit-9	Outfall sizing	
Phy-Mar-Op- 4	Desalination plant discharge	Adverse	Low	Phy-Mar-Mit-10	Location of the outfall	Low
				Phy-Mar-Mit-11	Outfall sizing (diffuser)	
Phy-Mar-Op-5	Stormwater drainage	Adverse	Medium	Phy-Mar-Mit-12	Relocation of southern discharges	Low

3 Preliminary Marine Environment Plan for the construction phase

The following chapters (3.1, 3.2, 3.3) aim to summarize and guide to implement all the marine environmental measures associated to the construction phase. Some measures don't directly address the works nor the operation phase but must be implemented as soon as possible, upstream of the works: these are the compensation measures and the more global measures accompanying the project, and they are also covered in this part.

The measures' descriptions should be read in section 2 as this chapter doesn't provide an exhaustive description of all measures.

The first paragraph is a table listing all the commitment and measures and indicating for each one:

- when and by whom it should be initiated and carried out,
- how it should be monitored,
- and which are the indicators of success, as well as the corrective measures to be taken if the performance objectives are not met.

The second paragraph is intended to guide stakeholders in the implementation of these measures monitoring, indicating which operational plans and procedures should be established to implement and monitor the measures, and the guidelines for the preparation of these plans.

The first paragraph refers to the plan that ensures each measure implementation. The second paragraph recalls for each plan which measures it addresses.

As part of the final EISA, an Environmental and Social Management Plan will be developed in accordance with the World Bank ESS1. An ESMP is an instrument that details (a) the measures to be taken during the implementation and operation of a project (in this case closure) to eliminate or offset adverse environmental and social impacts, or to reduce them to acceptable levels; and (b) the actions needed to implement these measures. The ESMP will include requirements for mitigation, monitoring, capacity development and training, implementation schedule and cost estimates, as well as integration with the Project.

The mitigation measures provided in the draft ESIA Report are by no means exhaustive, as detailed design and additional specialist studies including technical investigations still need to be completed to provide a sufficiently comprehensive list of mitigation measures.

Nonetheless, the mitigation measures included in this report aim to address some of the salient impacts that may be caused by the Project, albeit on a high level at this stage.

3.1 Marine Environment Management Plan for the construction phase

Table 32: Marine Environment Management Plan for the construction phase

Theme / Issue	Title and ID of the measure		Complementary description	Period of performance / Corresponding plan	Performance monitoring system	Performance indicators	Corrective measures	Responsible managers for implementation
Marine environment	Phy-Mar-Mit-1	Control of backfilling processes	The construction processes must ensure a minimal volume of water in the low-lying embankment delimited area to insure the stability and sustainability of the runway.	Works phase and prior to the works **Marine environment monitoring plan**	Monitoring of turbidity level in the vicinity of the runway. Monitoring the water concentration in the embankment. Ensuring construction equipment are appropriate.	Compliance to water quality prevailing threshold.	Failure to meet the performance criteria shall be recorded as a non-conformance incident. In the case of structural failure or non-compliance turbidity level, works are to immediately cease. Incident has to be reported. Implementing protocol for depollution in case of spill.	External consultancy engineering Under ARL's control
	Phy-Mar-Mit-2	Optimisation of the location of discharges	The discharge should be located in order to promote a local settling of the inorganic matter. A hydrodynamic survey can be conducted to identify these optimal locations.	Works phase and prior to the works **Marine environment monitoring plan**	The discharge should be located in order to promote a local settling of the inorganic matter. A hydrodynamic survey can be conducted to identify these optimal locations.	Compliance for water quality prevailing threshold	Monitoring of turbidity levels.	External consultancy engineering Under ARL's control
	Phy-Mar-Av-3	Optimisation of the discharges timetable to avoid times when currents reverse and/or already turbid condition	In order to minimize the intensity and extent of the flume, discharge should occur with weak current and low level of turbidity.	Works phase and prior to the works **Marine environment monitoring plan**	Monitoring of turbidity levels in the vicinity of the runway. Monitoring of magnitude and direction of the current in the vicinity of the runway.	Compliance to water quality prevailing threshold. Compliance with current prevailing threshold.	Discharge to be stopped if non-compliance. Reducing the hydraulic flows of the deposited materials.	External consultancy engineering Under ARL's control
	Phy-Mar-Mit-4	Silt curtain around discharges	Silt curtains can be used to contain suspended sediments and to prevent sediment dispersal.	Works phase and prior to the works **Marine environment monitoring plan**	Monitoring of turbidity levels. Conducting daily visual inspection of the curtain.	Compliance to water quality prevailing threshold.	Failure to meet the performance criteria shall be recorded as a non-conformance incident. Discharge to be stopped if non-compliance. Verifying the operation of the equipment according to the manufacturer's specifications	Contractor Under ARL's control

Theme / Issue	Title and ID of the measure		Complementary description	Period of performance / Corresponding plan	Performance monitoring system	Performance indicators	Corrective measures	Responsible managers for implementation
	Phy-Mar-Mit-5	Silt curtain around dredging area	Silt curtain controls the suspended solids generated by the dredging and is placed around the excavation site.	Works phase and prior to the works **Marine environment monitoring plan**	Monitoring of turbidity levels. Monitoring of contaminants in the water column.	Compliance to water quality prevailing threshold.	Dredging to be stopped if non-compliance. Verifying the operation of the equipment according to the manufacturer's specifications.	Contractor Under ARL's control

3.2 Marine environment monitoring plan

3.2.1 Provisions to be implemented

This plan should include all the provisions of the site to ensure that the measures regarding with the marine environment: turbidity and currents, but also marine biodiversity are implemented:

- “Phy-Mar-Mit-1 / 2 / 4 / 5” and “Phy-Mar-Av-3”,
- “BioM-Mit-1 / 2” and “BioM-Av-3”.

The measures’ descriptions should be read in section 2 as this chapter doesn’t provide an exhaustive description of all measures. The following sections guide the monitoring system to be set up.

3.2.2 Current and turbidity monitoring

The current affects the extent and the direction of the turbid plume while a high turbidity level endangers corals and natural fauna.

This plan must be implemented:

- Before the working phase to evaluate initial state conditions during dry and wet season (2 months minimum each) to determine alert and stop thresholds;
- During the works phase, and measurements should begin at least one day before commencement;
- A few months after the works phase is achieved until the turbidity has returned to its original value.
-

This plan consists in the:

- Installation of a current profiler ADCP (Acoustic Doppler Current profile) and a turbidimeter;
- Measure of turbidity and current every 3 hours in 3 locations:
- In the channel between Crab Island and the mainland;
- South of Plaine Corail to monitor the entrance of Anse Quitor;
- Near the corals at the entrance of Topaze Bay (Pointe Palmiste).

Figure 29 Localization of the potential sediment discharges to the lagoon during works phase and current-meter

The performance indicators are the following:

- Turbidity;
- Duration over an alert and a stop threshold;
- Number of exceedances over a threshold;
- Maximum concentration tolerated;
- Current magnitude (m/s) and direction (°):
- Duration of reverse current > 6 hours;
- Number of exceedances over a magnitude threshold;
- Maximum magnitude tolerated.

In case of insufficient performance, the corrective measures are the following:

- Decrease of the released flow;
- Temporary stop of the sediment discharge;
- Temporary stop of the dredging;
- Implementation of depollution protocol.
- Turbidity threshold will be fixed in consultation with stakeholders after the first result of the measurement campaign.

This plan should be implemented and managed by the following people:

- External Engineering consultancy will install and determine the initial state;
- Airport of Rodrigues insures the adequate state of the buoy;
- Construction and dredging company project managers for the works verify the performance indicator results in real time.
-

3.2.3 Coral Reef Protection and monitoring

This plan consists in implementing an ecological diagnosis and assessment of the health status of corals at Pointe Palmiste.

This plan must be implemented:

- Before the works phase (during 2 years)
- During the works

This plan consists in the:

- Installation of beaconing and prohibition of access + monitoring / restoration
- Communication on coral habitats and their fragility (effects of water heating, trampling, etc.) among the population and local stakeholders in order to raise awareness

The performance indicators are the following:

- Coral recovery rate;
- Algae recovery rate;
- Roughness;
- Study of coral reefs (specific richness, recovery rate, morphotypes);
- Study of fish populations (density, ecological structure, fisheries interest).

In case of insufficient performance, the corrective measures are the following:

- Decrease of the released flow;
- Temporary stop of the sediment discharge;
- Temporary stop of the dredging.

This plan should be implemented and managed by the following people:

- Shoals Rodrigues in partnership with SEMPA.

3.2.4 Marine works monitoring plan

This plan aims to ensure that the major marine biological issues in the project area are preserved (coral reef at Pointe Palmiste and marine turtles).

This plan must be implemented during the construction works.

This plan consists in:

- Visual surveillance by boat, on foot;
- Permanent exchange with the various stakeholders of the site;

The performance indicators are the following:

- Ensure that the floating boom is properly installed;
- Visual monitoring of corals at Pointe Palmiste in relation to the turbid plume;
- Monitoring of alert thresholds and work stoppage thresholds (turbidity monitoring);
- Visual surveillance of the maritime area, check for the absence of marine turtles.

In case of insufficient performance, the corrective measures are the following:

- Decrease of the released flow;
- Temporary stop of the sediment discharge;
- Temporary stop of the dredging;
- Implementation of depollution protocol;
- Ask for the optimal position of the floating boom;
- Stopping work if marine turtles are present and come to lay eggs on the beaches near the project.

This plan should be implemented and managed by the following people:

- Construction and dredging company project managers for the works verify the performance indicator results in real time.

3.3 Summary of plans to be drawn up for marine environment management during the construction phase

Table 33: Summary of Required ESMP– Marine Environmental Plans - Construction Phase

Plan	Measures that the plan must allow to implement and monitor	Person in charge of implementation and control	Activity / Procedures to include
Marine environment monitoring plan	Phy-Mar-Mit-1 / 2 Phy-Mar-Av-3	External consultancy engineering Under ARL's control	- Current and turbidity monitoring plan
	Phy-Mar-Mit-4 / 5	Contractor Under ARL's control	- Marine Works monitoring plan
	BioM-Mit-1 / 2 BioM-Av-3	Shoals Rodrigues / SEMPA Under ARL's control	- Coral reef protection and monitoring

4 Marine Environment Management Plan for the operational phase

The following chapters aim to summarize and guide to implement the marine environmental measures associated to the post-commissioning phase and the operational phase.

Some measures are part of the airport design and must be anticipated during the study phase.

Some other measures correspond to monitoring to be carried out after the end of the works for a few months, or to be permanently integrated into the airport's routine environmental management.

The measures' descriptions should be read in section 2 as this chapter doesn't provide an exhaustive description of all measures.

The first paragraph is a table listing all the commitment and measures and indicating for each one:

- when and by whom it should be initiated and carried out,
- how it should be monitored,
- and which are the indicators of success, as well as the corrective measures to be taken if the performance objectives are not met.

The following paragraphs are intended to guide stakeholders in the implementation of these measures monitoring, indicating which operational plans and procedures should be established to implement and monitor the measures, and the guidelines for the preparation of these plans.

The first paragraph refers to the plan that ensures each measure implementation. The second paragraph recalls for each plan which measures it addresses.

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4.1 Marine Environment Management Plan for operational phase

Table 34: Marine Environment Management Plan for operational phase

Theme / Issue	Title and ID of the measure		Complementary description	Period of performance / Corresponding plan	Performance monitoring system	Performance indicators	Corrective measures	Responsible managers for implementation
Marine environment	Phy-Mar-Mit-6	Prevent spills and accidents: train staff to avoidance of spills.	-	Operational phase **Emergencies prevention and management plans**	Regular checking visits and tests	Zero spill	Improve training	ARL
	Phy-Mar-Mit-7	Implementing methodologies for quick confining and treatment of pollutants and protocol for depollution in case of spill	-	Operational phase In case of a spill **Emergencies prevention and management plans**	Monitoring of turbidity levels. Monitoring of contaminants in the water column.	Compliance to water quality prevailing threshold.	Informing of local authorities. The spill source will be immediately isolated, stopped and contained	ARL
	Phy-Wat-Av-6	Integrated water management plan	Rainwater integrated management for the airport facilities: Implementation of a water treatment plant within an integrated water management plan including reuse / treatment of rainwater harvested for drinking water production.	Permanent as from the commissioning of the treatment facilities **Surface stormwater run-off, drinking and wastewater management and monitoring plan**	Monitoring of water quality at inlet and outlet of Treatment Plant; monitoring of water quality in rainwater storage and stored water quality is maintained including disinfection; regular manual sampling/analysis (once a week) and visual control; automatic real time monitoring on main parameters usually monitored for drinking water production (at least pH and turbidity)	Compliance with prevailing / target standards. Submission to local authorities once a month.	Reuse to be stopped if non-compliance. Informing of local authorities and implementation of remedial measures: confining / dedicated pumping for evacuation if deemed necessary.	To be implemented by the Detail Design Engineer Under ARL's control Operation Monitoring: ARL (or external specialist engineer under ARL and RRA's control)
	Phy-Wat-Mit-7	Water treatment plant	Drinking Water supply integrated management for the airport facilities: Implementation of a water treatment plant within an integrated water management plan including reuse / treatment of rainwater harvested for drinking water production. Reuse and treatment of wastewater / stormwater collected if necessary.	Permanent as from the commissioning of the treatment facilities **Surface stormwater run-off, drinking and wastewater management and monitoring plan**	Monitoring of water quality at inlet and outlet of Treatment Plant; monitoring of water quality in drinking water storage and stored drinking water quality is maintained including disinfection; regular manual sampling/analysis (once a week) and visual control; automatic real time monitoring of main parameters (at least pH, turbidity and residual free chlorine) on distribution line.	Compliance with prevailing / target standards. Submission to local authorities once a month.	Distribution to be stopped if non-compliance. Informing of local authorities and implementation of remedial measures: confining / dedicated pumping to empty drinking water storage if deemed necessary.	To be implemented by the Detail Design Engineer Under ARL's control Operation Monitoring: ARL (or external specialist engineer under ARL and RRA's control)

Theme / Issue	Title and ID of the measure		Complementary description	Period of performance / Corresponding plan	Performance monitoring system	Performance indicators	Corrective measures	Responsible managers for implementation
	Phy-Wat-Mit-8	Reuse water plan	Drinking Water supply integrated management for the airport facilities: Implementation of a water treatment plant within an integrated water management plan including reuse / treatment of rainwater harvested for drinking water production. Reuse and treatment of wastewater / stormwater collected if necessary.	Permanent as from the commissioning of the treatment facilities **Surface stormwater run-off, drinking and wastewater management and monitoring plan**	Monitoring of water quality at inlet and outlet of Treatment Plant; monitoring of water quality in drinking water storage and stored drinking water quality is maintained including disinfection; regular manual sampling/analysis (once a week) and visual control; automatic real time monitoring of main parameters (at least pH, turbidity and residual free chlorine) on distribution line.	Compliance with prevailing / target standards. Submission to local authorities once a month.	Distribution to be stopped if non-compliance. Informing of local authorities and implementation of remedial measures: confining / dedicated pumping to empty drinking water storage if deemed necessary.	To be implemented by the Detail Design Engineer Under ARL's control Operation Monitoring: ARL (or external specialist engineer under ARL and RRA's control)

4.2 Emergencies prevention and management plans - Marine contamination

4.2.1 Containment

Action should be taken as soon as possible to contain the spill in order to stop the material entering stormwater drains, contaminating soil or groundwater.

- Spills should be contained using absorbent material
- Any stormwater drain should be protected first by forming a "dam" of absorbent material around the drain
- Spilled material should then be contained by forming a "dam" of absorbent material around the spill
- Temporary floating barriers (booms) should be used to contain marine spills

4.2.2 Clean

Absorbent materials such as diatomaceous earth or polypropylene are the preferred products for the cleaning of any spills. These products absorb the spilt material leaving no residue and have no detrimental impact on the environment. A list of approved cleaning materials must be identified in the Emergency Response Plan.

All contaminated soil must be stored and disposed of in accordance with current environmental standards.

If groundwater is contaminated, decontamination measures must be taken immediately. The free phase of the hydrocarbons must be pumped as quickly and efficiently as possible. Depending on the direction of groundwater flow, underwater resurgences must be monitored and an emergency plan for the containment of contamination at sea must be implemented.

If sea water is contaminated, when the benefit of the clean-up is less than the potential harm caused to remove of the spill, spilled oil products are allowed to degrade naturally. A monitoring program is implemented to ensure there are no unforeseen threats to ecosystems.

In case of a large volume threatening spills into the sea, the use of dispersants could be considered. This chemical agent aids biodegrading by forming tiny oil droplets, making them more available for microbial degradation.

Tarred sand must be removed with appropriate equipment supplied by the state or contactors and transported to a secure disposal site.

Once clean-up operations are achieved, consideration will be given to restore areas identified as having high environmental sensitivity and value.

4.3 Summary of plans to be drawn up for marine environment management during the operational phase

Table 35: Summary of Environmental Management Plan for operational phase

Plan	Measures that the plan must allow to implement and monitor	Person in charge of implementation and control	Activity / Procedures to include
Marine biodiversity and habitats monitoring plan	-	To be implemented by ARL or an external specialist Under ARL's control	- A monitoring procedure to implement by the person in charge for the monitoring - A follow-up plan to implement by ARL

5 Cumulative Impact Assessment

5.1 Introduction

At this stage, the Cumulative Impact Assessment is only outlined and is of generic nature, based on bibliographic review and initial assessment from the ESIA undertaken and will be further assessed as part of the final ESIA based on the updated project information and strategic development plan for Rodrigues, currently being finalized .

It is proposed to use IFC's 'Good Practice Handbook - Cumulative Impact Assessment and Management: Guidance for the Private Sector in Emerging Markets' for the preparation of a Cumulative Impact Assessment.

Cumulative impacts are those that result from the successive, incremental, and/or combined effects of an action, project, or activity (collectively referred to in this document as "developments") when added to other existing, planned, and/or reasonably anticipated future ones. For practical reasons, the identification and management of cumulative impacts are limited to those effects generally recognized as important on the basis of scientific concerns and/or concerns of affected communities.

Multiple and successive environmental and social impacts from existing developments, combined with the potential incremental impacts resulting from proposed and/or anticipated future developments, may result in significant cumulative impacts that would not be expected in the case of a stand-alone development.

The expected outcomes of a good Cumulative Impact Assessment can be summarized as follows:

- Identification of all Valued Environmental and Social Components (VEC) that may be affected by the development under evaluation.
- In consultation with stakeholders, agreement on the selected VECs the assessment will focus on.
- Identification of all other existing and reasonably anticipated and/or planned and
- potentially induced developments, as well as natural environmental and external social drivers that could affect the selected VECs.
- Assessment and/or estimation of the future condition of selected VECs, as the result of the cumulative impacts that the development is expected to have, when combined with those of other reasonably predictable developments as well as those from natural environmental and external social drivers.
- Evaluation of the future condition of the VECs relative to established or estimated thresholds of VEC condition or to comparable benchmarks.
- Avoidance and minimization, in accordance with the mitigation hierarchy, of the development's impact on the VECs for the life of the development or for as long as the impacts continue to be present.
- Monitoring and management of risks to VEC viability or sustainability over the life span of either the development or its effects, whichever lasts longer.

- Provision of project-related monitoring data to governments and other stakeholders for the life of the development, and material support for the development of collaborative regional monitoring and resource management initiatives.
- Continuous engagement and participation of the affected communities in the decision-making process, VEC selection, impact identification and mitigation, and monitoring and supervision

5.2 Identification of Valued Environmental and Social Components

Valued environmental and Social components (VECs) are defined as fundamental elements of the physical, biological or socio-economic environment, including the air, water, soil, terrain, vegetation, wildlife, fish, birds and land use that may be affected by a proposed project.

The Draft ESIA has identified the preliminary VECs of concern both during construction and operation phases, as listed below. The final VECs will be assessed further during the finalization of the ESIA based on the revised designs and upon comprehensive consultation with stakeholders.

- Physical Environment (section 6.3)
  - Terrestrial geology and geotechnics
  - **Marine and shores geology and marine turbidity**
  - Hydrology
  - Hydrogeology
  - Water resource and waste water management

6 Estimated costs of the environmental management

The following table presents a cost estimate of the various environmental measures and management and monitoring plans previously presented.

Those costs are not to be considered as a project commitment, they are just indicative and will have to be revised afterwards.

6.1.1 Construction phase

Table 36: Cost Estimate Construction Phase – Marine Environmental Aspects

Theme / Issue	Title and ID of the measure / Plan		Implementation	Responsible for management and implementation	Estimated costs (EUR)	Comments
	Site and works facilities management and monitoring plan					
Marine environment including marine works monitoring (Marine environment monitoring plan)	Phy-Mar-Mit-1	Control of backfilling processes	Measurement campaign of turbidity and current	External consultancy engineering Under ARL's control	30000 + 10000/month	Transport: 30000 €. Installation of measure devices (buoy), measurement, and analysis: 10000 € per month.
	Marine environment monitoring plan for current and turbidity					
	Phy-Mar-Mit-2	Optimisation of the location of discharges	Specific hydrodynamic survey	External consultancy engineering Under ARL's control	60000	To limit the plume extent by choosing a sheltered release location.
	Phy-Mar-Av-3	Optimisation of the discharges timetable to avoid times when currents reverse and/or already turbid condition				To limit the plume extent by releasing at the appropriate time (weak current, initial low level of suspended particulate matter).
	Phy-Mar-Mit-4	Silt curtain around discharges	Placed around the discharge locations during the working phase.	Contractor Under ARL's control	15000	To contain suspended sediments and to prevent sediment dispersal.
	Phy-Mar-Mit-5	Silt curtain around dredging area	Placed around the excavation site during the dredging phase.	Contractor Under ARL's control	15000	To contain suspended sediments and to prevent sediment dispersal.

6.1.2 Operation phase

Table 37: Cost Estimate Operation Phase – Marine Environmental Aspects

Theme / Issue	Title and ID of the measure		Implementation	Responsible for management and implementation	Estimated costs (EUR)	Comments
Marine environment	Phy-Mar-Mit-6	Prevent spills and accidents : train staff to avoidance of spills.	-	ARL	-	Included in construction and exploitation costs
	Phy-Mar-Mit-7	Implementing methodologies for quick confining and treatment of pollutants and protocol for depollution in case of spill	-	ARL	-	Included in construction and exploitation costs

:

7 References

7.1.1 Climate and meteorological conditions

7.1.1.1 Current

- Schott, F. A., S.-P. Xie, and J. P. McCreary Jr. (2009), Indian Ocean circulation and climate variability, Rev. Geophys., 47, RG1002, doi:10.1029/2007RG000245.
- Assessment of the wave potential at selected hydrology and coastal environments around a tropical island, case study: Mauritius. Available from: https://www.researchgate.net/publication/322591524_Assessment_of_the_wave_potential_at_selected_hydrology_and_coastal_environments_around_a_tropical_island_case_study_Mauritius
- Wolanski et al., 1993; Kraines et al., 1998, 1999; 31 Tartinville and Rancher, 2000; Andréfouët et al., 2001; Kench and McLean, 2004; Angwenyi and Rydberg, 32 2005; Hench et al., 2008; Lowe et al., 2009; Taebi et al., 2011; Hoeke et al., 2013; Chevalier et al., 2014, 2015
- World Risk Report 2022; Bündnis Entwicklung HilftRuhr University Bochum – Institute for International Law ofPeace and Armed Conflict (IFHV); 2022

7.1.1.2 Wave

- Shoreline Change Detection Modelling for Le Morne Coast of Mauritius, Chapter VI, p. 118-158

7.1.1.3 Water level

- (Lynch et al. 2002)
- UNECO, Sea Level Measurement and Analysis in the Western Indian Ocean, National Report, Mauritius
- R. LOWRY ET Al., 2008, Observations of Seiching and Tides Around the Islands of Mauritius and Rodrigues, 28p.
- ASCLME 2012. National Marine Ecosystem Diagnostic Analysis. Mauritus. Contribution to the Agulhas and Somali Current Large Marine Ecosystems Project (supported by UNDP with GEF grant financing). Unpublished report.
- Acclimate project, 2011, Indian Ocean Comission (COI)
- Ministry of Environment, Sustainable Development, and Disaster and Beach Management – TNC Report 2016
- Tropical cyclones
- D.P. Callaghan et al., 2005, Atoll lagoon flushing forced by waves, / Coastal Engineering 53 (2006) 691–704
- IBTrACS - International Best Track Archive for Climate Stewardship, version 4, website: https://www.ncdc.noaa.gov/ibtracs/

7.1.2 Marine and shores geology and marine turbidity

7.1.2.1 Marine shores geology

- COPPEJANS E. and al., The Marine Green and Brown Algae of Rodrigues (Mauritius, Indian Ocean°, Journal of Natural History, 2004, 38, 2959-3020, ISSN 0022-2933 print/ISSN 1464-5262 online 2004 Taylor & Francis Ltd

- Beach Erosion management in Small Island Developing States: Indian Ocean case studies, WIT Transactiions on Ecology and the Environment, Vol 126, 2009, ISSN 1743-3541 (online)
- Final SIDPR, Rodrigues Regional Assembly, July 2009
- Ministry of Energy and Public Utilities, Hydrology Data Book 1999-2005, Chapter 7: Hydrology of Rodrigues and Agalega, Figure 7.3, p.7
- Mnistery of Agriculture, Food Technology & Natural Resources – Republic of Mauritius, Management Plan for Crab Island. Development of a Management Plan for the Conservation and Management of Offshore Islets for the Republic of Mauritius. 2004, Available from: https://www.researchgate.net/publication/269929648_Management_Plan_for_Crab_Island_Development_of_a_Management_Plan_for_the_Conservation_and_Management_of_Offshore_Islets_for_the_Republic_of_Mauritius

The current compiled oceanographic data necessary to quantify the influence on the currents and sediment transport is summarized as follows:

- <u>Bathymetry:</u>

  The large scale model bathymetry data would be forced from the General Bathymetric Chart of the Oceans (GEBCO) with 0.5° resolution, approximately 430m.
- Closer to Rodrigues, the GEBCO bathymetry would be supplemented by a thinner data set close to the coast and inside the lagoon. Discussions are underway with the Hydrographic Section of the Ministry of Housing and Land of Mauritius to obtain accurate data both inside and outside the lagoon.
- <u>Shoreline:</u>
- The shoreline was defined using data obtained from the Database of Global Administrative Areas (GADM) with approximately a 30 m resolution and re-delineated if necessary.
- <u>Hurricane tracks:</u>
- The tracks of the Indian Ocean Hurricane were downloaded from the Joint Typhoon Warning Center (JTWC) website from 1986 to 2016. Trajectories are defined by 6 hour elapsed time points defined by its localization, intensity, maximum wind speed, and minimum SLP.
- Sea level:
- Port Mathurin's tide gauge is part of the Global Sea Level Observing System (GLOSS). Controlled sea level data are checked and processed in order to establish sea level value more suitable for studies of long term sea-level change. Historical hourly level data are available in Rodrigues from 1986 to 2016.
- Tide Harmonic:
- The LEGOS[6] produced global finite element solutions (FES) tidal atlases computed from the tidal hydrodynamic equations and data assimilation. Harmonic constants, amplitude and phase, are extracted in the surrounding of the island.
- Coral Reef:
- Coral reef distribution around the island is extracted from the global distribution of coral reefs in tropical and subtropical regions, version 4.0 of November 2018. The dataset[7]

[6] Laboratoire d'Etude en Géophysique et Océanographie spatiales

[7] UNEP-WCMC, WorldFish Centre, WRI, TNC (2018). Global distribution of coral reefs, compiled from multiple sources including the Millennium Coral Reef Mapping Project. Version 4.0, updated by UNEP-WCMC. Includes contributions from IMaRSUSF and IRD (2005), IMaRS-USF (2005) and Spalding et al. (2001). Cambridge (UK): UNEP World Conservation Monitoring Centre. URL: http://data.unepwcmc.org/datasets/1

is compiled from various sources such as the UNEP World Conservation Monitoring Centre (UNEP-WCMC) and the WorldFish Centre, in collaboration with WRI (World Resources Institute) and TNC (The Nature Conservancy). The GIS layer has a consistent 30 m resolution and mostly originates from images acquired between 1999 and 2002.

- Climatology Statistics:
- An analysis was performed by MeteOcean to characterize the meteo-oceanic conditions in the vicinity of Rodrigues. Waves, winds, water height, salinity and temperature statistics are available at a deep water point (2989m from the MSL) located at -63°12'E 20°S, in the South of the island.

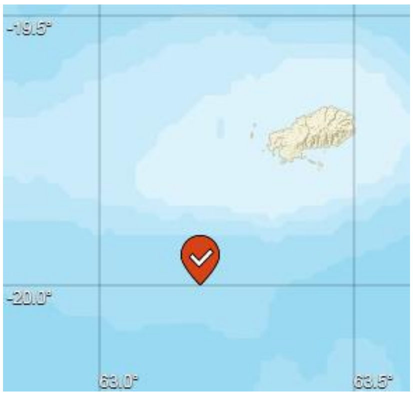

Figure 30: Location of the analysis point: -63°12'E,20°S (WGS84)

At the present time, some data are still being gathering, they will be taken into account in the next version of the report. This is the case of bathymetry and sediment characteristics (granulometry) data.

7.1.2.2 Seawater turbidity

- Final SIDPR, Rodrigues Regional Assembly, July 2009

Airport of Rodrigues Ltd

Proposed Expansion of Rodrigues Airport

Hydrogeological Impacts Factual Report for the purpose of the Environmental and Social Impact Assessment Report

Report Reference – 09053999

Prepared by

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02 April 2023

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0 Non-Technical Executive Summary

0.1 Environmental and social baseline conditions

0.1.1 Physical environment

0.1.1.1 Hydrogeology

The hydrogeological units of the Rodrigues Islands are formed on the coast by mainly volcanic rocks and a minority of limestone rocks (called calcarenite hereby).

Plaine Corail is characterized by two types of potentially aquiferous formation:

- Basalts which are weak and altered and are defined as a fractured aquifer with double porosity: matrix and fracture porosity.
- Karst calacarenites which represent highly complex aquifers since they combine three types of porosities that contribute to groundwater flow: the matrix, fracture and karst network porosities.

The epikarst in the project area is partially represented by sinkholes when visible but also by numerous non-observable dissolution structures below the soil deposit. The process of recharging can occur from different mechanisms:

- Direct infiltration through the soil;
- Streambed infiltration (sinking stream);
- Lateral recharge from basaltic material.

In terms of volume, usually, sinking streams represent the one mode of recharge for the underlying karst aquifers. Flood events may temporarily create an inflow to the cave network through riverbeds like the Anse Quitor River or through the large number of cave collapse sinkholes. In some areas, such as the Grande Cavern cave system's Canyon Tiyel section, the presence of an elongated collapsed depression could also act as preferential inflow during a rain event to the underground network. A considerable amount of water can circulate in the karstic network during rainstorms.

Basalt outcrops present in the new runway indicative of the potential presence of a basaltic fractured aquifer. This aquifer is probably in relation to the overall phreatic water in the Pointe Corail peninsula.

The three identified receiving environments are:

- Carbonate Karstic aquifer which has a consistent karst developed area with numerous open caves and gallery connections. The calcarenites in Plaine Corail are probably affected as well by karstic development and numerous entries of caves as identified. The cavities are mainly located below 10 m depth. This material seems to be relatively permeable.
- Basaltic aquifer which represents a small part of the geological material in the project area. No information on the groundwater level is available but probably lower than the deepest borehole that is to say 25m depth. Weathered basalt usually has high permeability compared to weathered basalt.
- Large caves and well-developed galleries. Three caves are located near Plaine Corail village, around the end of the projected runway's footprint (Cavern Bouteille, Cavern Petit Lac, Grotte Fougère).

There is no information regarding groundwater quality in the airport area. Water in the caves close to sea level is probably salty, at least in the tidal influence area. Stagnant freshwater ponds inside the caves are usually quickly invaded by biological elements and quickly become inappropriate for human consumption.

Topsoil has been encountered in most exploratory holes with an average thickness of 0.25m and it was generally described as gravelled, low plasticity sandy silt with roots. This description of topsoil corresponds to a thin layer of permeable material which is a “first barrier” to a potential contamination on the surface.

0.1.1.2 Physical environment sensitivity

The Physical Environment Sensitivity is summarised in Table 1 hereafter.

Table 1: Physical Environment Sensitivity

Sub-theme	Receptor	Sensitivity
Terrestrial geology and geotechnics and Hydrogeology Karstic environment	Carbonate Karstic aquifer	High
	Basaltic aquifer	Medium
	Caves (Plaine Corail)	Major
Water resource and wastewater management	Domestic wastewater management	High
	Water supply management	High

0.2 Potential impacts and measures

Potential environmental and social impacts and associated management measures are summarized in the next tables. Construction phase impacts which are temporary in nature are distinguished from the permanent impacts.

Impacts related to Operations are addressed in a third section.

0.2.1 Temporary impacts during construction phase

Table 2: Summary of Temporary impacts during construction phase

Context	Sub-context	Impact ID	Impact description	Positive / adverse	Impact rating before mitigation	Measure ID	Measure	Residual Impact rating
Physics	Hydrogeology and geotechnics	Phy-Kar-W-Temp-3	Erosion/Groundwater ingress	Adverse	High	Phy-Kar-Mit-5	Infilling of local erosion features and use of a drainage system to manage the rainwater responsible for local erosion	Low
						Phy-Kar-Mit-6	Open blasting and site excavation works to be done during dry season	
	Water resource and wastewater	Phy-Wat-W-Temp-2	Impact of works on water resource resulting from impact on karstic groundwater	Adverse	Major	Phy-Wat-Comp-2	Temporarily replace the Cavern Bouteille intake by a sea water pumping Upgrade Cavern Bouteille plant to enable it to provide drinking water from sea water Thus, temporarily provide drinking water from sea water to people currently connected to Cavern Bouteille plant Coordinate the water supply option according to Water Development Strategies of Rodrigues Island (updated in 2022 by BRL)	Negligible

0.2.2 Permanent and irreversible impacts during construction phase

Table 3: Summary of Permanent and Irreversible Impacts during construction phase

Context	Sub-context	Impact ID	Impact description	Positive / adverse	Impact rating before mitigation	Measure ID	Measure	Residual Impact rating
Physical	Hydrogeology and geotechnics	Phy-Kar-W-Def-3	Groundwater flow disturbance	Adverse	Low	-	-	Low
		Phy-Kar-W-Def-4	Pollution of groundwater	Adverse	Medium	Phy-Kar-Av/Mit-18	Daily maintenance and inspection of mobile construction equipment and plant	Low
						Phy-Kar-Av/Mit-19	No maintenance and refuelling on the construction site (or with specific waterproof delimited zone)	
						Phy-Kar-Mit-20	Establishment of a storage site for earthworks wastes, close to the project site, in order to reduce pollution induced by traffic from storage activity	
						Phy-Wat-Comp-5	Relocation of the intake of Cavern Bouteille (replacement by seawater).	
	Water resource and waste water	Phy-Wat-W-Def-1	Demolition of an unused reservoir	Adverse	Low	-	-	Low
		Phy-Wat-W-Def-2	Impact on water resource	Adverse	High	Phy-Wat-Av/Mit-4	Preventive measures to reduce risks during the construction phase - Risk management plan	Negligible
						Phy-Wat-Comp-5	Relocation of the intake of Cavern Bouteille (replacement by seawater).	

Note: When no impacts are foreseen, 'Impact ID' column is marked 'none' and the following columns are hence not populated and marked '-'

0.2.3 Permanent impacts during operation phase

Table 4: Summary of Permanent Impacts during Operation Phase

Context	Sub-context	Impact	Impact description	Positive / adverse	Impact rating before mitigation	Measure ID	Measure	Residual Impact rating
Physical	Hydrogeology and geotechnics	Phy-Kar-Op-3	Pollution of groundwater	Adverse	Medium	Phy-Kar-Av-25	All operations involving hydrocarbons must comply with current standards to prevent spills and, if necessary, implement emergency measures	Low
						Phy-Kar-Mit-26	Do not allow groundwater to be used for drinking water supply downstream of airport infrastructure	

Note: When no impacts are foreseen, 'Impact ID' column is marked 'none' and the following columns are hence not populated and marked '-'

0.3 Environmental management plan for construction phase

Table 5 below lists the plans to be developed and implemented to monitor all the environmental measures in the impact study.

Specific guides for preparing plans are provided in Chapters 3.1.1, 3.1.2 and 3.1.3.

Table 6 summarizes all the environmental measures in the impact study. The precise description of the measures is given in the impact study, in Chapter 8 of the ESIA.

Table 5: Environmental Management Plans for Construction Phase

Plan	Measures that the plan must allow to implement and monitor	Person in charge of implementation and control	Activity / Procedures to include
Karst monitoring plan	Phy-Kar-Mit-5 / 7 / 18	To be implemented by the Contractor Under RRA and ARL's control	- Groundwater monitoring plan - Caves monitoring plan
	Phy-Kar-Comp-17	External specialist Under ARL's control	- A plan to follow the sediments moving and storage

Table 6: Summary of Environmental Measures and Monitoring for Construction Phase

Theme / Issue	Title and ID of the measure	Complementary description	Period of performance / Corresponding plan	Performance monitoring system	Performance indicators	Corrective measures	Responsible managers for implementation
Karst	Phy-Kar-Mit-20	Establishment of a storage site for earthworks wastes (wood from formwork, material and equipment wrappings, unusable cement / grouting mixes, damaged or contaminated construction material), close to the project site, in order to reduce pollution induced by traffic from storage activity	Works phase **Site and works facilities management and monitoring plan**	Installation of a network of observation wells upstream and downstream of the facilities to allow, on the one hand, sampling and analysis of groundwater to define reference values and, on the other hand, to establish a groundwater quality monitoring program (and levels) during the project development phases (construction and operation phases)	Number and intensity of accidental spills of hydrocarbons and other chemicals	In the event of a surface spill, the environmental response plan must be implemented immediately. In the event that there is a significant change in groundwater quality and/or a contaminant is detected, the environmental management plan will also have to be put in place to contain the contamination.	To be implemented by the Contractor Under ARL's control
	Phy-Kar-Av-21	Proceed to an impact assessment of the extraction site and have the material origin validate priori the works phase	Prior to the works phase **Site and works facilities management and monitoring plan**		-	-	- To be implemented by the Contractor Under ARL's control

0.4 Environmental management plans for operation phase

No management plan here.

1 Environmental and social baseline conditions

1.1 Physical environment

1.1.1 Hydrogeology

This chapter tends to define the hydrogeological context and focuses on the karstic calcarenites formation on the restricted area of influence. It aims to describe how groundwater flows in the hydrostratigraphic units and to analyse the current quality of groundwater. It also seeks to identify the points of vulnerability and contamination of groundwater, as well as the current use of groundwater. The goal is to base the project impact assessment on the groundwater: risks of chronic or accidental pollution, flow modification and supply to wells, boreholes or springs due to karstic voids consolidation or filling in the project footprint area.

This subject is particularly sensitive on an island such as Rodrigues where fresh water is a scarce resource.

1.1.1.1 Hydrogeological setting

1.1.1.1.1 General considerations and definitions

The hydrogeological context is closely linked to geology. The hydrogeological units of the Rodrigues Islands are formed mainly by volcanic rocks and by a minority (in terms of coverage) of limestone (called calcarenite hereby) on the coast. The reader is asked to refer to the chapter on geology for more details.

The Figure 1 below shows the main hydrogeological units on Rodrigues Island.

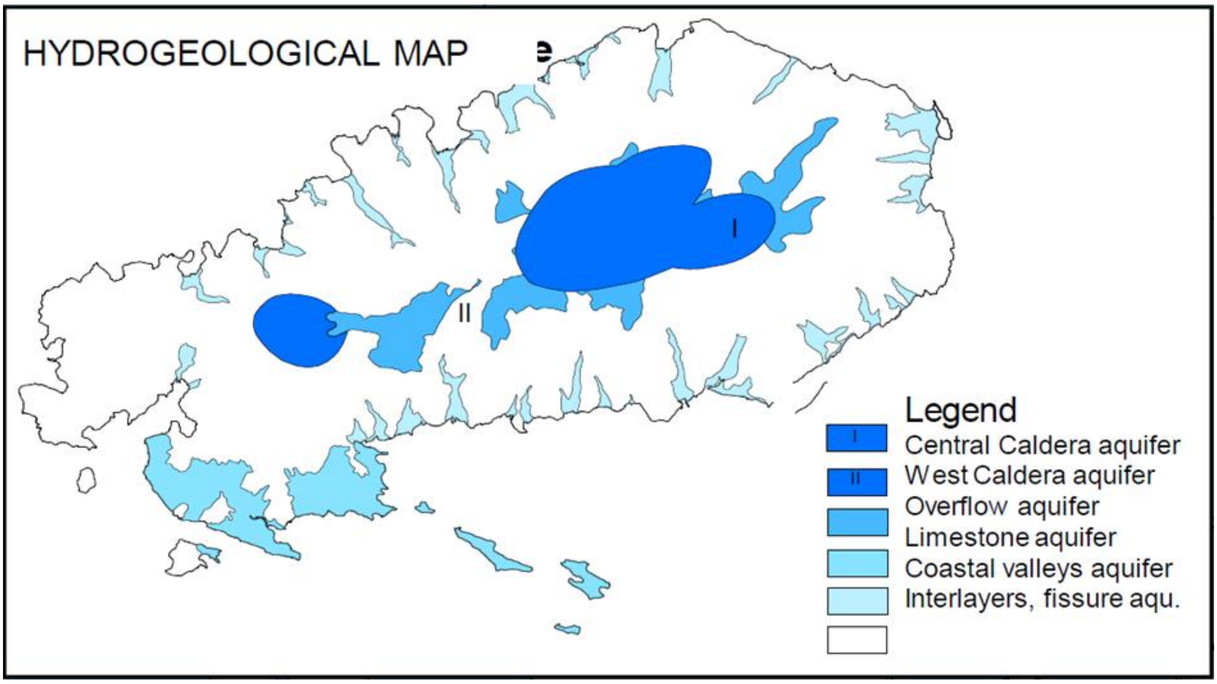

Figure 1: Hydrogeological map (from WRU of Mauritius)

According to surface observations and the interpretation of borehole data, Plaine Corail is characterized by two types of potentially aquiferous formations: basalts and karst calcarenites.

The basalts identified in the project area are weak, altered, and are defined as a fractured aquifer with double porosity: the matrix and the fracture porosity. These two types of porosities define the aquifer properties and contribute to groundwater flow. Karst calacarenites represent very complex aquifers since they combine three types of porosities that contribute to groundwater flow: the matrix, fracture and karst network porosities.

1.1.1.1.2 Particularities of karst carbonate aquifers

The restricted study area has elements typical of karst landforms: caves, doline, karren, lapiaz, sink holes, pinnacle, etc. closely linked to groundwater flow paths. Karst aquifers are the most heterogenic and anisotropic type of aquifer. The secondary porosity, as fracture in fractured aquifer, comes from dissolution conduct networks (sometimes also called tertiary porosity).

This section aims to help with the understanding of groundwater movement in carbonate aquifer with well-developed karstic network. Figure 2 below shows a general conceptual model of a karst system called "double continuum", where water flows into voids (fast flow) and through porosity of the rock (slow flow).

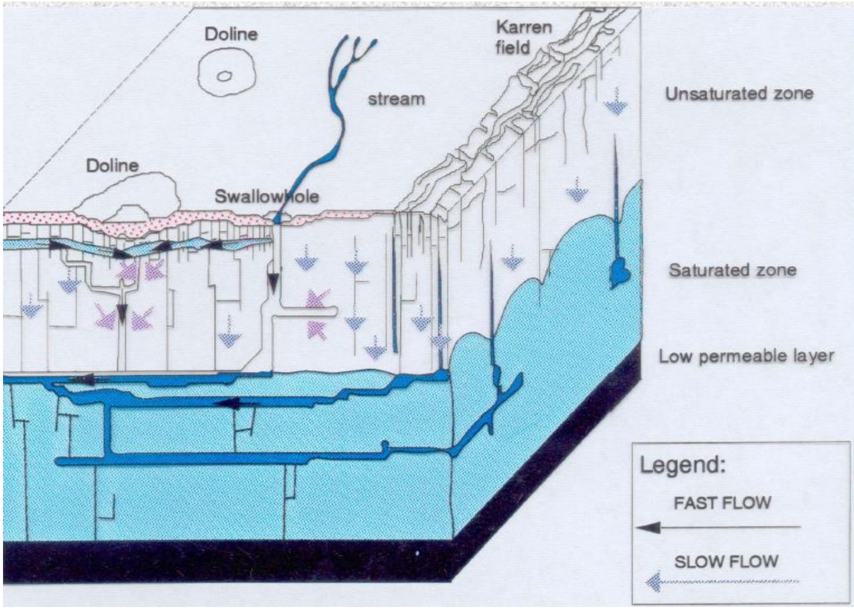

Figure 2: Karstic system conceptual model (modified from M. Bakalowicz, hydrosciences Montpellier 2002)

Hydrodynamically speaking (rapid variation in water conditions over time), the karst network is the most influential because it has a high capacity to transmit water between infiltration and discharge. A well-developed karst network will react very quickly to precipitation, resulting in a sudden and significant variation in the groundwater flow regime.

The result of this particularity is that the aquifer reacts quickly to heavy precipitation and the direction of flow may be totally erratic. That is, groundwater flow does not correspond to a conventional pattern related to topography and geological structure. This makes it very difficult to develop a groundwater flow map that is representative of a seasonal period.

The epikarst, the upper part of the karst in which water is stored before it percolates to underlying aquifers, has a considerable importance to karst hydrogeology. The conceptual model above graphically shows how surface water from a stream flows, or direct infiltration from rain reaches first the unsaturated zone and then the saturated zone.

The concept of “elementary representative volume” is important in karst hydrogeology because local and regional groundwater flows can have very different behaviours and directions. The phreatic surface can be extremely variable in karst, due to high permeability contrasts.

1.1.1.1.3 Local considerations

1.1.1.1.3.1 Recharge process

The epikarst in the project area is partially represented by sinkholes when visible but also by numerous non-observable dissolution structures below the soil deposit. The process of recharge can occur by different mechanisms:

- Direct infiltration through the soil;
- Streambed infiltration (sinking stream);
- Lateral recharge from basaltic material.

In terms of volume, usually, sinking streams represent the one mode of recharge for the underlying karst aquifers. Floods may temporarily create an inflow to the cave network through riverbeds like the Anse Quitor River or through the large number of cave collapse sinkholes. In some areas, such as the Grande Cavern cave system’s Canyon Tiyel section, the presence of an elongated collapsed depression could also act as preferential inflow during rain to the underground network. A considerable amount of water can circulate in the karstic network during rainstorms.

Basaltic outcrops are present in the new runway area indicating the presence of a potential basaltic fractured aquifer. This aquifer is probably in relation to the overall phreatic water in the Pointe Corail peninsula but there is no evidence of this connectivity.

1.1.1.1.3.2 Hydraulic properties

There is not sufficient information to provide hydraulic properties of the potential basaltic or karstic aquifer. Due to the high hydraulic anisotropy of the Karst aquifer, for the local scale of Plaine Corail, there is no practical reason to provide any range of permeability or transmissivity value. This agrees with the elementary representative volume concept discussed in the previous section. Indeed, the volume represented by the Plaine Coral Peninsula is too small to identify a flow pattern with certainty. Therefore, only an estimate based on a few observations will allow a conceptual model of groundwater flow to be presented in the following section.

1.1.1.2 Groundwater flow

Geotechnical investigations (2018 and 2019) for the new runway extension highlighted groundwater level in 55 rotary coring boreholes out of 111 in total. There is new geotechnical investigation in progress and geotechnical interpretative report still pending in the present time.

From the existing information, water level depths were converted to water elevation using borehole’s ground elevation references. The groundwater level in Phase B boreholes (south of the projected runway) is between 1.2 and 12.8 m deep below the ground surface.

Figure 3 below shows the groundwater elevation curves (isopiestic line) and the arrows indicate the hypothetical groundwater flow direction. Natural groundwater flow is relatively consistent with topography, but saturated karst features probably disturb the local groundwater flow. At this time, the only information about groundwater level mapping could be interpreted as above the level of tide influence. The groundwater level between 3 and 13 m AMSL on the map is consistent with topographic elevation in the area.

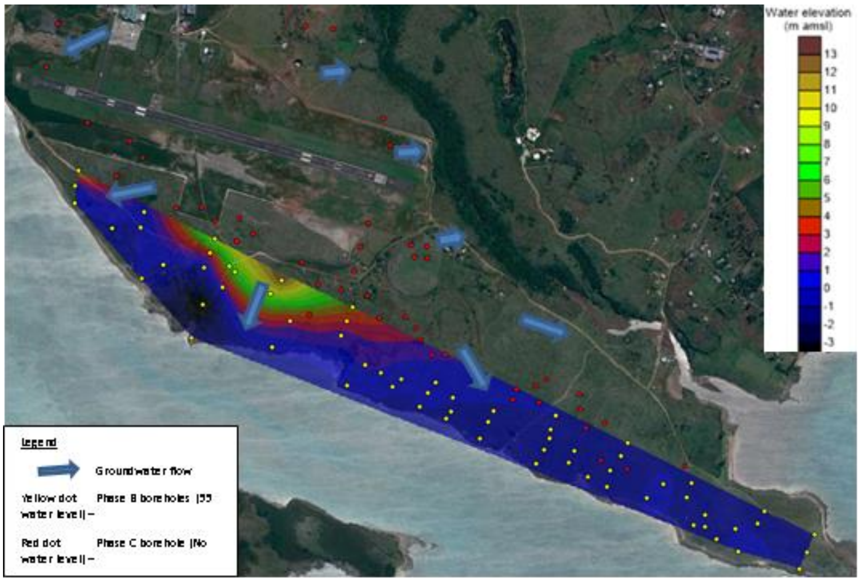

Figure 3: Location of two drilling campaign data sets and groundwater map contour

Negative groundwater elevation seems not to have any coherent signification. Tidal influence may affect consistence between values, as expressed in the geotechnical report. For example, based on the tidal prediction chart of May and June in 2016 (information on hand), the highest tide was 2.77 m. Spatial distribution of groundwater level is therefore probably not representative of a specific time. Unless a groundwater monitoring program with a datalogger is performed, no realistic groundwater level could be graphically produced at an exact representative time. At the present time, no monitoring program of the groundwater level has been implemented yet.

In the second geotechnical drilling campaign (Phase C), no groundwater was encountered in any boreholes. The red dots in Figure 3 show the locations of the phase C borehole campaign, while the yellow dots indicate the locations of the first (Phase B) borehole drilling campaign. The groundwater level from the Phase C geotechnical investigations does not appear to be reliable because the bottoms of 11 of the 47 boreholes drilled during phase C of the field work are under the sea level, with no groundwater level report. So, the dry conditions of these boreholes are incoherent.

Figure 4 below shows a vertical profile of ground surface and groundwater levels (isopiestic lines in previous figure) from a section (red line) on both levels data. The solid blue line represents the measured groundwater level and the dashed blue line represents the projected water level.

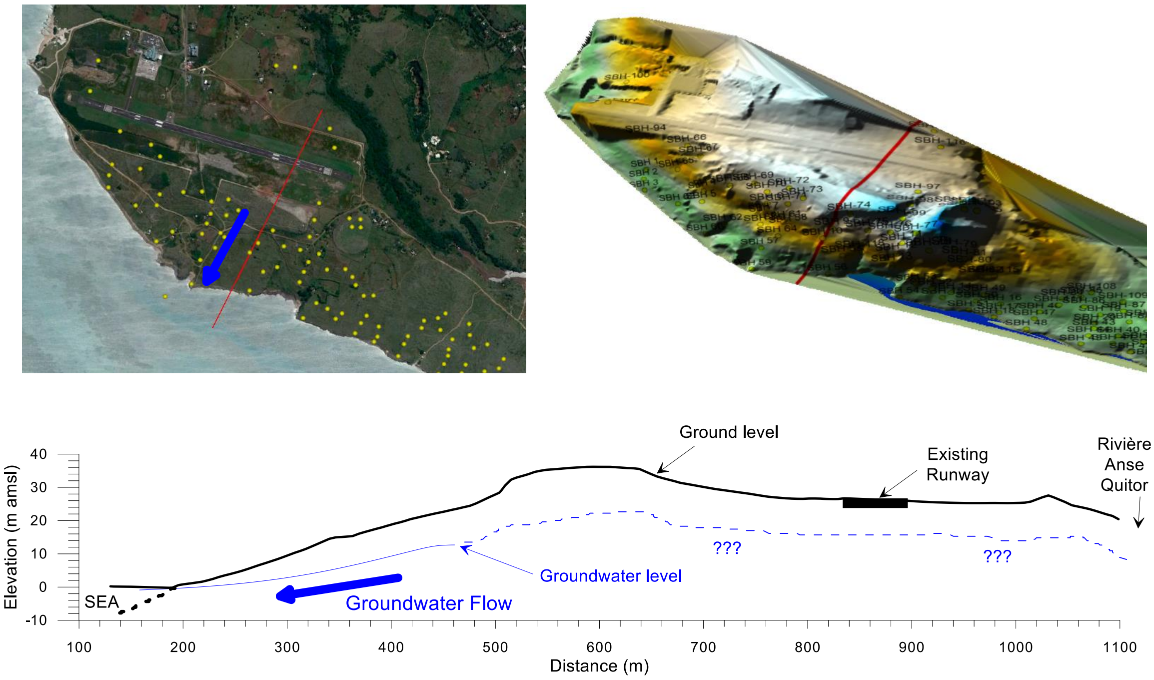

Figure 4: Vertical section of topographic and groundwater level

In conventional porous medium, groundwater is naturally flowing from a high land elevation to the sea, relatively associated to the landform. In a karstic medium, flow path is probably completely disturbed by saturated or partially saturated karstic networks and flow direction is probably not landform dependent.

Apparently, there are springs in the lower topographic part of the airport area because groundwater elevation is already close to sea level below the inland. There is not enough information to identify local groundwater patterns associated with all caves already identified in the airport area. However, there appears to be no groundwater use on the south side of Plaine Corail. Therefore, a change in groundwater flow regime in this specific area is not expected to affect any users.

1.1.1.3 Hydrogeological receptors identification

The three receiving environments identified in the project area that are related to the hydrogeological context are as follows:

1. Receptor #1: Carbonate Karstic aquifer
2. Receptor #2: Basaltic aquifer
3. Receptor #3: Caves (in carbonate formation)

1.1.1.3.1 Carbonate Karstic aquifer

The carbonate eolian calcarenites aquifer on the left bank of the Rivière Anse Quitor (northern side) has a consistent karst developed area with numerous opened caves and gallery connections. The calcarenites in Plaine Corail are probably affected as well by karstic development and numerous entries of caves have been identified.

There is calcarenites outcrop in most of Plaine Corail site but it is also covered by mainly topsoil in the western part of the area. The geotechnical description of the topsoil is a very weak orangish cream coral with frequent seams of black silt and frequent rootlets. The average thickness of the topsoil in the area of borehole investigation is about 0.3 m and up to a maximum of 1 meter. This material does not represent an aquifer in the footprint area. A infiltration test will have to be performed in further investigations.

Based on the geotechnical and geophysical investigations, cavities appear to be scattered in calcarenite formation all over the study area, except in areas where the basaltic substratum outcrops to the surface. The cavities are mainly located below a 10 m depth. No cavity has been identified at 0 to 5m deep and laboratory tests indicate an average porosity of 33.8% for the weathered calcarenite in the first 5m of depth. This material seems to be relatively permeable (hydrogeologically speaking) and is probably part of the epikarst that contributes to surface water infiltration into the weathered and non-weathered calcarenite aquifer. The numerous cavities identified in the calcarenite below 5m depth consist of the karstic network up and below the groundwater level.

1.1.1.3.2 Basaltic aquifer

The basaltic aquifer represents a small part of the geological material in the project area because it is mostly covered by calcarenite materials. The Mont Sainte-Marie is the main outcrop of the basalt and no information on the groundwater level is available but probably lower than the deepest borehole, that is to say 25 m deep. Weathered basalt has usually high permeability compared to unweathered basalt. Geotechnical investigations identified mostly weathered basalt in most of the boreholes.

1.1.1.3.3 Caves

In the project area, caves are karst features expression as a dissolution of carbonate rock. Based on the observations of the Riviere Anse Quitor’s left bank, there are large caves and well-developed galleries of pluri-metric size and up to 500m (Grande Cavern) and 1 km long. (i.e. Cavern Patate in the vicinity of the project: Plaine Cavern). Several speleological and karst studies have identified interconnections between caves.

The right bank of Rivière Anse Quitor did not benefit from as many studies and galleries development and interconnections are only considered as a similar development. However, there are a few visible caves or sinkholes in Plaine Corail calcarenite that confirm the presence of potential large-scale karstic development. Geotechnical investigations also identified over 500 cavities (or drilling anomalies) in around 140 boreholes located mainly in the footprint of the projected runway.

Three caves are located near Plaine Corail village, around the end of the footprint of the projected runway (Figure 5). Evidence of paleontological materials were identified in one of them.

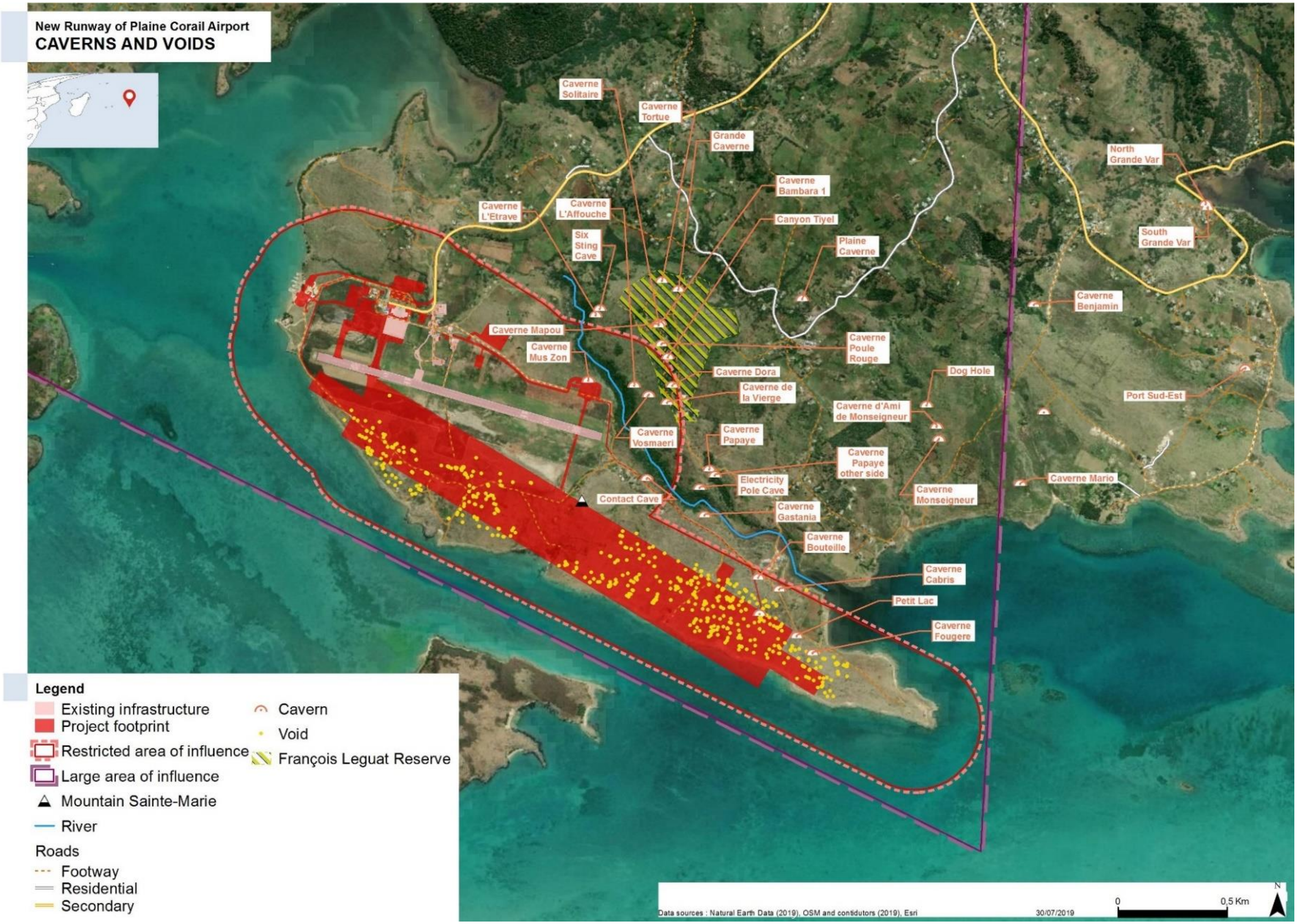

Figure 5: Caves location of the Plaine Corail area

Cavern Bouteille is a small opening that gives access to a water filled chamber that was used for pumping water for the desalination plant. In April 2018, a 315 mm diameter borehole was drilled to a depth of 20 m. The well is equipped with a 250 mm diameter PVC pipe whose section between 3 and 20 m depth corresponds to a screen (slotted casing). The drilling crossed a small cavity of 30 cm thickness, which indicates that despite the proximity of the Bouteille cave, it was not encountered at the drilling site. The productivity of the well was evaluated by air-lift at 36 m^3/h. The second intake borehole close to the first one is not described in documents. The figure 6 shows the location of the intakes boreholes of the Cavern Bouteille. The previous drilling information does not specify whether the borehole identified as Osmosun or Conventional borehole.

Figure 6: Location of Cavern Bouteille catchments

Groundwater quality is brackish probably mixed with fresh groundwater. Information on the quality of the water pumped to the Bottle Cave suggests that the supply of fresh water is significant. Indeed, the average electrical conductivity and salinity of the pumped water are respectively 25 000 us/cm and 15.4 ppt. However, the typical conductivity and salinity values of seawater are respectively 55000 us/cm and 35 ppt. As the value of these upstream groundwater parameters is unknown, the ratio of fresh water to seawater cannot be determined, but according to standard values for groundwater, this should be close to 1/1 for the current operating flow rate. Any change in the operating rate may affect this ratio in the same location of extraction. Water quality parameter of borehole intake of Cavern Bouteille is presented in the section Water Quality hereafter.

Cavern Bouteille has galleries that reach a maximum length of 25 m, a maximum depth of 8.5m. The small underground lake that occupies part of the cave reaches 2.5 m in depth. Figure 7 shows Cavern Bouteille orifice and the borehole abstraction.

Figure 7: Cavern Bouteille orifice and one of the two borehole abstraction

Cavern Petit Lac is a small pond in a natural depression in the surficial calcarenite. This pond contains no significant sediment accumulation (Figure 8). There is no evidence of interconnectivity with a deeper karst developed galleries.

Figure 8: The pound of Cavern Petit-Lac

<u>Grotte Fougère</u> is a collapse feature (sinkhole) with an anchialine pond (a landlocked body of water with a subterranean connection to the ocean that is also under slight tidal influence) as it shows variations over 30 cm during the tidal cycle. Fine organic sediment has accumulated inside the small cave. The sediments contain over 3000 years of well-preserved bones, terrestrial and freshwater gastropod shells, and microfossils that include pollen, spores, and algal skeletons. For scientists and cave specialists, Grotte Fougère sediments represent an important paleoenvironmental site to preserve on the island. However, the fossiliferous sediments are probably already affected by sheep excrements and need immediate protection. Figure 9 shows the sinkhole – Grotte Fougère – and the presence of livestock (sheep).

Burney et al (2015) mapped the Grotte Fougère, which is estimated to have a development of about 25 m. Figure 9 shows the topography of the Grotte Fougère

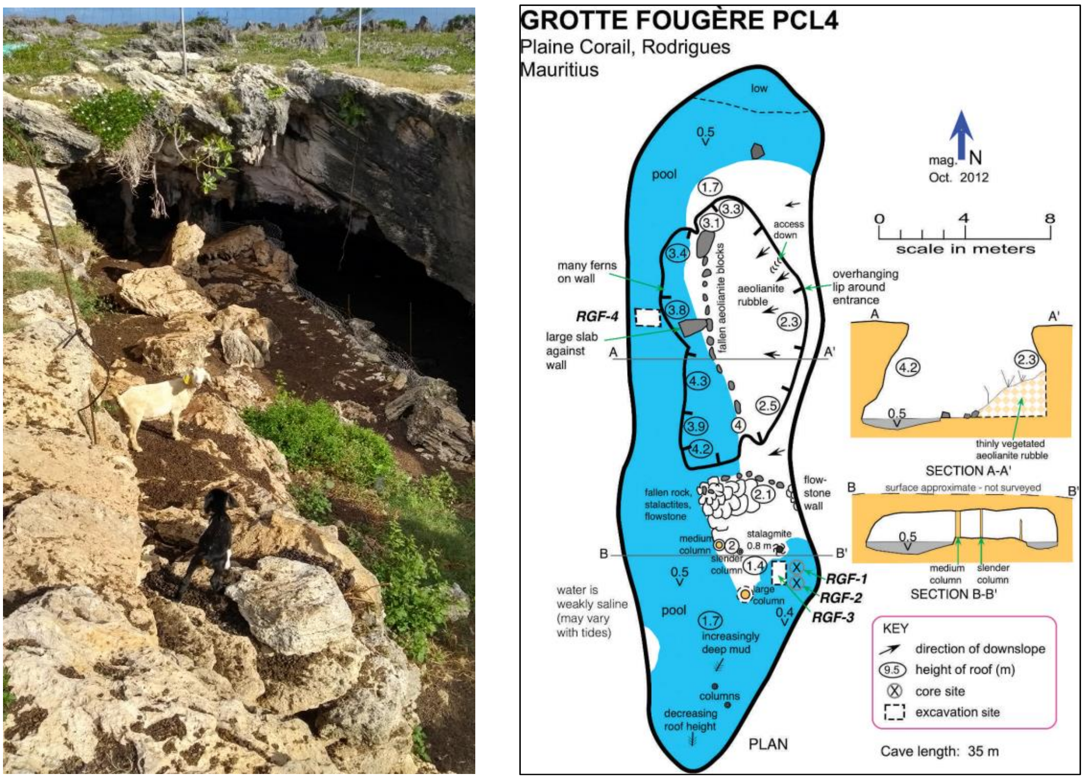

Figure 9: Grotte Fougère sinkhole view (left picture) and topography (right picture) from Burney and al. (2015)

Two other caverns also situated on the Rivière Anse Quitor's right bank and close to the project, include Cavern Gastonia and Cavern Cabris:

Cavern Gastonia has an explored length of 142 m. Its floor varies between 8 to 12 m AMSL. The larger cavities may have headroom of 12 m. Cavern Gastonia contains an underground lake in which there are several large cones composed of white calcite flakes. This phenomenon is rare in the world and may be the only occurrence in the southern hemisphere.

Cavern Cabris runs over 68 m of galleries. There is no more available information about this cavern.

1.1.1.4 Water quality, vulnerability and contamination

1.1.1.4.1 Groundwater quality

At present time, the only available information on water quality is from partial analysis from borehole intake of Cavern Bouteille catchment site.

There is no more information about groundwater quality in the area of the airport. Water in the caves close to sea level is probably salted, at least in the tidal influence area. Salted intrusions in land are not documented in Rodrigues (so far, the information where collected). Stagnant freshwater ponds inside the caves are usually quickly invaded by biological elements and quickly become inappropriate for human consumption. Water inflow from storms probably “flush” or dilute the stagnant water in the cave’s pond changing the water quality for a relatively short term.

The water pumped into Cavern Bouteille borehole is brackish and probably results from a mixture of tide influenced seawater and fresh water from the karst aquifer but definitively closed to seawater quality. The results of laboratory analyses of water from the borehole intake are presented in Table 9 below.

Table 7: Cavern Bouteille Borehole intake quality

Parameters	**Concentration (mg/L)**	
Sample date	19 – 03 - 2018	15 - 07 - 2020
Chloride	10170	13162
Sulphate	1560	1974
Copper	<0.005	-
Chromium	<0.01	-
Potassium	136.64	285.40
Sodium	5128	7923
Nitrogen Nitrate	<0.01	<0.01
Nitrate as NO3-	<0.04	<0.04

Sodium, Chloride, Sulphate and Potassium concentration increased significatively between 2018 and 2020 sampling. Nevertheless, one must be cautious on the interpretation since the two samples were not taken during the same period of the year and there is no information about precipitation events during or before the sampling.

1.1.1.4.2 Vulnerability

Generally, when there is groundwater use for drinking water, the vulnerability of an aquifer becomes a main issue.

The concept of vulnerability is strong considering the nature of the superficial material as a “first barrier” to a potential contamination event from the surface. Topsoil has been encountered in most exploratory holes with an average thickness of 0.25 m and it was generally described as gravelled, low plasticity sandy silt with roots (from Geotechnical investigation report phase C). This description of topsoil corresponds to a thin layer of non-impermeable material.

However, most of the material will probably be removed for the new airport infrastructure development. Vulnerability analysis on existing conditions will not reflect the vulnerability of the groundwater after the new installations are built. Nevertheless, the information available on soil type and rock formation characteristics would indicate that the aquifers identified so far on the Plaine Corail site would be highly vulnerable. However, the only known use of groundwater potentially connected with the karstic network of carbonate rocks of Plaine Corail is the Cavern Bouteille catchment.

1.1.1.4.3 Potential sources of contamination

Potential sources of groundwater contamination must be identified in the airport area. The usual contaminant vectors in the airport are:

- Fuel storage and operation (Kerosene, diesel and gas);
- Firefighting foam;
- Industrial waste water;
- Sanitary waste water;
- Any chemical liquid or highly soluble material;
- Contact rainwater, runoff water and infiltration.

To our knowledge, there is no groundwater monitoring history at Plaine Corail Airport.

1.1.1.5 Groundwater uses in the Island

In 2009, KMPG indicated about 62% of water is captured by surfaces and 38% by boreholes. In 2009 the groundwater extraction from the boreholes was about 3780 and 2670 m^3/d respectively during the wet and dry season. It is to be noted that all boreholes are persistently over-utilized. The limit for borehole water has long been reached. Production is at maximum capacity and falling year after year. Based on the existing information review, no borehole is extracting groundwater in the vicinity of the airport.

The extraction of brackish water from Cavern Bouteille is not really considered a groundwater use in the same way as inland drilling. Nevertheless, the dissolution of seawater in Cavern Bouteille is indeed provided by a groundwater supply of karstic origin.

1.1.1.6 Hydrogeological receptors sensitivity

The hydrogeological issues mainly concern change in groundwater quality and quantity, no matter the nature of the aquifer. The change in water quality infiltrating the environment can then affect the physicochemical processes that naturally occur in the saturated or unsaturated levels of aquifer formations.

Caves are particular receptors that may or may not be part of the aquifer system. A karst network that is no longer active nevertheless plays a decisive role, especially during heavy precipitation. The interconnection of the cavities then transforms the underground regime for more or less short periods of time. Changing the recharge of these cavities or networks will therefore influence the natural temporary or permanent groundwater flow.

1.1.1.6.1 Carbonate aquifer

The hydraulic conductivity of karst aquifers is mainly ensured by the saturated or unsaturated gallery network. Aquifer recharge can be achieved both by infiltration through the ground and the epikarst and laterally by depending on the connectivity of the karst network.

Implementing an impermeable layer over the surface can therefore affect the recharge rate and therefore the groundwater flow regime. This aquifer is therefore considered sensitive to surface changes.

On the other hand, in Plaine Corail, the only use of groundwater from these cavities has been identified at Cavern Bouteille.

1.1.1.6.2 Basalt aquifer

There are groundwater users from this formation on the left bank (north) of the Anse Quitor River but no users have been identified in the Plaine Corail area. According to available information, there are no groundwater quality references for this formation on Plaine Corail.

1.1.1.6.3 Caves

Caves are partially part of carbonate aquifers when they contribute temporarily or permanently to the control of groundwater flow.

The sensitivity of caves is mainly associated with their palaeontological content present in sediments accumulated at the bottom of the caves for nearly 3000 years. The interest is therefore mainly scientific knowledge rather than environmental concern since some of these caves have already been affected by the presence of humans and livestock.

Table 8: Hydrogeological receptors sensitivity

Receptors identification	Receptors description	Sensitivity	Justification
Hydrogeology 1	Carbonate Karstic aquifer	High	Only one catchment structure has been identified in the nearby area (Cavern Bouteille). The water collected is already unsuitable for consumption due to its high salinity. Nevertheless, a change in water quality could lead to changes in the karst dissolution regime and affect the structure of the underground cavity network.
Hydrogeology 2	Basaltic aquifer	Medium	There are no catchment points in this aquifer on the Plaine Corail. There are no water quality references. The basaltic formation outcrops on two areas that are precisely on the path of the new track.
Hydrogeology 3	Caves (Plaine Corail)	Major	Some caves (Cavern Fougère and Cavern Cabris) represent a fairly considerable scientific interest for the paleoenvironmental material in the sediments.

1.1.2 Summary: Physical environment sensitivity

Table 9: Physical environment sensitivity

Theme	Sub-theme	Receptor	Sensitivity
Physical environment	Terrestrial geology and geotechnics and Hydrogeology	Carbonate Karstic aquifer	High
		Basaltic aquifer	Medium
	Karstic environment	Caves (Plaine Corail)	Major

1.2 Conclusion: main issues of the baseline (hydrogeology)

The main issues identified in the baseline assessment are:

- The karstic system, involving a risky geology and a high sensitivity of groundwater, to be put into perspective of the scarcity of fresh water;
- The high sensitivity of the Cavern Bouteille pumping station due to the proximity of new infrastructures;
- All considerations considered, Cavern Bouteille represents the only groundwater collection site for drinking water supply on Plaine Corail.

2 Preliminary environmental, social impacts and mitigation measures

2.1 Temporary Impacts during Construction

2.1.1 Physical environment

2.1.1.1 Water resource and waste water management

2.1.1.1.1 Impact Phy-Wat-W-Temp-2: Impact of works on water resource due to impact on karstic groundwater

2.1.1.1.1.1 Impact before mitigation

The vibrations associated with the stripping of natural surface materials can increase the transport of fine particles in groundwater. The karst network of aquifers contributes to the transport of these particles without filtering them. The groundwater component that feeds the Cavern Bouteille intake could then have an increase in turbidity. This change in turbidity could affect the pumping system. Most of all, it would then influence the reverse osmosis treatment process (saturation of the micro-membranes) so the Cavern Bouteille desalination plant could be affected to.

The impact severity is major. Considering the receptor sensitivity assessed as major, **the impact magnitude is major**.

2.1.1.1.1.2 Mitigation measure and impact after mitigation

To mitigate this impact, the temporary or permanent relocation of the water abstraction at Cavern Bouteille has to be planned. A feasibility study for an alternative source out of the area of influence must be completed before work begins. As it is likely that another intake in the groundwater will be difficult to find, it is proposed to replace Cavern Bouteille intake by a sea water pumping. The Cavern Bouteille desalination plant should be upgraded in order to enable it to treat seawater and provide drinking water. The current capacity of 1000 m^3/day must be maintained. (Phy-Wat-Comp-2)

The proposed measures result in a not significant severity mitigated impact. Thus, the residual impact is of **negligible magnitude**

2.1.1.1.2 Impact Phy-Wat-W-Temp-4: Risks of accidental pollution

2.1.1.1.2.1 Impact before mitigation

Potential sources of accidental contamination are presented in section – Geotechnics and Hydrogeology of the karstic system

The impact severity is high. Considering the receptor sensitivity assessed as high, **the impact magnitude is high**.

2.1.1.1.2.2 Mitigation measure and impact after mitigation

The mitigation of a contamination event consists mainly in the implementation of preventive measures to reduce risks during the construction phase. Below is a short list of prevention measures for construction-on-construction sites:

- Provide sealed vats for polluting products stored in drums, tanks or cisterns in order to recover any spills.
- Avoid buried deposits of pollutants. If this is not possible, provide a system to quickly detect a possible leak.
- Provide a waterproof floor where harmful products are handled or delivered.
- Use the best technologies to limit the release of hazardous products.
- In the event of accidents, have an "intervention kit" at your disposal (absorbent products, etc.)

Development of a Risk Management Plan (RMP): a definition of RMP could be “*The RMP will describe existing and proposed risk management measures that are to either continue or to be put in place to provide confidence that the identified threat activity will cease to be or not become a significant threat to drinking water*”. (Phy-Wat-Av/Mit-4)

The proposed measures result in low severity mitigated impact. Thus, the residual impact is of **negligible magnitude.**

2.1.1.1.3 Summary

Table 10: Temporary Impact during Construction – Physical Environment - Water & wastewater

Impact ID	Impact name	Direction	Impact magnitude mitigation	Measure ID	Avoidance / Mitigation / Compensation / Improvement Measures	Residual / improved impact magnitude
Phy-Wat-W-Temp-2	Impact of works on water resource resulting from impact on karstic groundwater	Adverse	Major	Phy-Wat-Comp-2	Temporarily replace the Cavern Bouteille intake by a sea water pumping Upgrade Cavern Bouteille plant to enable it to provide drinking water from sea water Thus, temporarily provide drinking water from sea water to people currently connected to Cavern Bouteille plant Refer to BRL 2022 Water resources strategy action plan to estimate the volume of water requirement to replace.	Negligible

2.2 Permanent and irreversible impacts during Construction Phase

2.2.1 Physical environment

2.2.1.1 Geotechnics and Hydrogeology

2.2.1.1.1 Impact Phy-Kar-W-Def-3: Groundwater flow disturbances

2.2.1.1.1.1 Impact before mitigation

The nature of the impacts on the groundwater flow will focus mainly on changing surface coverage. Indeed, the excavation of the topsoil and the removal of geological material, such as basalt from Mont Sainte-Marie, will change the vertical recharge regime and thus the groundwater flow regime. Replacing these natural materials with an impermeable cover, as it is the case with the airstrip and its drainage system, will reduce recharge and therefore, depending on the contribution of this component to the total recharge of aquifers, will decrease the volume of groundwater in the Plaine Corail. The hydraulic gradient and direction of groundwater flow may therefore be subject to local changes. However, it is not possible at this stage of knowledge to quantify the impact on groundwater flow. The impact magnitude of ground water flow is considered low because the runway is located close to the shoreline which corresponds to the outlet of the groundwater.

The impact severity is medium. Considering the receptor sensitivity assessed as high, **the impact magnitude is low**.

2.2.1.1.1.2 Mitigation measure and impact after mitigation

There are no possible mitigation measures during the works because the groundwater regime is locally linked to the recharge rate, which is mainly associated with precipitation, soil type and topography. Where the nature of the soil and topography change, the recharge rate will inevitably change.

The proposed measures result in a medium severity mitigated impact. Thus, the residual impact is of **low magnitude**.

2.2.1.1.2 Impact Phy-Kar-W-Def-4: Pollution of groundwater

2.2.1.1.2.1 Impact before mitigation

The flow of any foreign liquid on the ground and indirectly into aquifers through the unsaturated part will modify groundwater quality in the more or less long term depending on the percolation rate and underground transport process. The water quality of the only water catchment structure (Cavern Bouteille) is therefore threatened in quantity and quality during the construction phase.

Groundwater contamination can therefore be considered permanent following the construction phase since unsaturated cavities in the karst network can contain this contamination for a very long time.

The impact severity is high. Considering the receptor sensitivity assessed as high, **the impact magnitude is high**.

2.2.1.1.2.2 Mitigation measure and impact after mitigation

The mitigation of a contamination event consists mainly in the implementation of preventive measures to reduce risks during the construction phase.

The proposed measures result in a not significant severity mitigated impact. Thus, the residual impact is of **negligible magnitude.**

2.2.1.1.3 Summary

Table 11: Permanent Impact during Construction - Physical Environment - Karstic Environment

Impact ID	Impact name	Direction	Impact magnitude mitigation	Measure ID	Avoidance / Mitigation / Compensation / Improvement Measures	Residual / improved impact magnitude
Phy-Kar-W-Def-3	Groundwater flow disturbances	Adverse	Low	-	-	Low
Phy-Kar-W-Def-4	Pollution of groundwater	Adverse	Medium	Phy-Kar-Av/Mit-18	Daily maintenance and inspection of mobile construction equipment and plant	Low
				Phy-Kar-Av/Mit-19	No maintenance and refuelling on the construction site (or with specific waterproof delimited zone)	
				Phy-Kar-Mit-20	Establishment of a storage site for earthworks wastes (wood from formwork, material and equipment wrappings, unusable cement / grouting mixes, damaged or contaminated construction material), close to the project site, in order to reduce pollution induced by traffic from storage activity	
				Phy-Wat-Comp-5	Relocation of the intake of Cavern Bouteille (replacement by seawater).	

2.3 Impacts during operation phase

The project aims to enable Rodrigues Island to develop tourism and aerial cargo. Tourism development might have significant impacts on the environment.

However, this ESIA only aims to address the impacts of the infrastructure. Thus, the socio-economic development and changes that could be expected due to the air access improvement are not part of this ESIA scope.

Impacts of the airport extension on tourism and socio-economics on an island scale are addressed in other studies carried out under RRA's control.

2.3.1 Physical environment

2.3.1.1 Geotechnics and Hydrogeology

2.3.1.1.1 Phy-Kar-Op-3: Pollution of groundwater

2.3.1.1.1.1 Impact before mitigation

Potential impacts on groundwater contamination have been addressed in sections: - Geotechnics and Hydrogeology of the karstic system, Water resource and waste water management, for the construction phase.

During the airport's operating period, it is the fuel filling operations of aircraft and other service vehicles that present the greatest risk of contamination. These operations must therefore take place in specially developed sites with appropriate means of restraint in the event of a spill.

At this stage of the study, there is not enough data to assess groundwater quality. Therefore, when the airport is operational, a network of observation wells will have to be installed and a water quality monitoring program will have to be implemented.

According to the possible construction options, there is no catchment work planned downstream of the airport infrastructure. There are therefore no specific measures to be implemented at this level.

The impact severity is high. Considering the receptor sensitivity assessed as high, **the impact magnitude is medium**.

2.3.1.1.1.2 Mitigation measure and impact after mitigation

Impact mitigation consists mainly of the application of an emergency plan in the event of a spill of hydrocarbons or other liquids presenting a risk of a change in the quality of groundwater in Plaine Corail.

The proposed measures result in low severity mitigated impact. Thus, the residual impact is of **low magnitude**.

2.3.1.1.2 Summary

Table 12: Impact during Operation - Physical Environment- Karstic Environment

Impact ID	Impact name	Direction	Impact magnitude mitigation	Measure ID	Avoidance / Mitigation / Compensation / Improvement Measures	Residual / improved impact magnitude
Phy-Kar-Op-4	Pollution of groundwater	Adverse	Medium	Phy-Kar-Av-25	All operations involving hydrocarbons must comply with current standards to prevent spills and, if necessary, implement emergency measures.	Low
				Phy-Kar-Mit-26	Do not allow groundwater to be used for drinking water supply downstream of airport infrastructure	

3 Preliminary Environmental and Social Management Plan (ESMP) for the construction phase

3.1 Preliminary Environment Management Plan for the construction phase

3.1.1 Environmental Management Plan for the construction phase

Table 13: Overall Environmental Management Plan for the construction phase

Theme / Issue	Title and ID of the measure		Complementary description	Period of performance / Corresponding plan	Performance monitoring system	Performance indicators	Corrective measures	Responsible managers for implementation
Karst	Phy-Kar-Mit-20	Establishment of a storage site for earthworks wastes (wood from formwork, material and equipment wrappings, unusable cement / grouting mixes, damaged or contaminated construction material), close to the project site, in order to reduce pollution induced by traffic from storage activity	-	Works phase **Site and works facilities management and monitoring plan**	Installation of a network of observation wells upstream and downstream of the facilities to allow, on the one hand, sampling and analysis of groundwater to define reference values and, on the other hand, to establish a groundwater quality monitoring program (and levels) during the project development phases (construction and operation phases)	Number and intensity of accidental spills of hydrocarbons and other chemicals	In the event of a surface spill, the environmental response plan must be implemented immediately. In the event that there is a significant change in groundwater quality and/or a contaminant is detected, the environmental management plan will also have to be put in place to contain the contamination.	To be implemented by the Contractor Under ARL's control

3.1.2 Environment Management Plans to be implemented for the construction phase

3.1.2.1.1 Groundwater quality monitoring plan

This plan consists of identify changes in groundwater quality and flow regime during working and operation phases.

This plan must be implemented:

- Before the working phase to define reference values of water quality and groundwater levels;
- During the working and operation phases to identify any changes of indicators.

This plan consists in:

- Installation of a network of observation wells:
  - Upstream (minimum of 3 observation wells; depth up to 5 meters below groundwater level).
  - Downstream – between facilities and shoreline - (minimum 5 observation wells; depth up to 2 meters below groundwater level). Multi-piezometers must be considered to be installed in each downstream borehole: The deeper must be installed below zero mean sea level and the other between the groundwater level and the zero level.
- Implementation of monitoring program:
  - Groundwater level measurement;
  - Groundwater sampling and in-situ parameters analysis;
  - Sampling frequencies: A first sampling campaign must be carried out in all observation wells before work begins. Downstream well sampling should be conducted on a monthly basis during the construction phase and semi-annually during operations;
  - Parameters analysis of groundwater: The first samples will be fully analysed according to current national water quality standards (number of parameters and threshold values). At a minimum, the Dissolved Priority Pollutant Metals (see note) should be analysed as well as petroleum hydrocarbons.

Note: According to US EPA the 13 Dissolved Priority Pollutant Metals are : Arsenic, barium, cadmium, chromium, Lead, mercury, selenium, Silver, copper, Iron, manganese, Zinc and Sodium.

The groundwater quality monitoring program will be adjusted based on the results of the first analyses.

The performance indicators are the following:

- Groundwater level: Drastic change of initial groundwater levels.
- Groundwater quality:

  - Detection of hydrocarbons in a sample;
  - Dissolved Priority Pollutant Metals: Change of more than 20% of threshold values.
- Abnormal odour of kerosene, diesel, gasoline or other products used on the site.

In case of insufficient performance, the corrective measures are the following:

- Identification of the source of contamination;
- Stop the source of contamination if it is properly identified;
- In the case of an oil spill: activate the oil spill contingency plan.
- Implementation of depollution protocol and set up a contaminant recovery system depending on the nature of the contaminant.

3.1.3 Emergencies management plans

Provision for Emergency Preparedness and Response is a prerequisite under section 19 of the ESS4: Community Health and Safety.

3.1.3.1 Oil spill or accidental pollution management

In the event of an oil spill on the ground, two scenarios are possible:

- The oil is contained in the topsoil;
- Oil seeps into the groundwater until it reaches the groundwater and ca flow to the sea.

The karstic aquifer in Plaine Corail is very vulnerable to surface discharge (direct access to groundwater through surface cavities). Any hydrocarbon spill should be reported directly to ARL for a decision on whether to initiate the emergency plan depending on the volume of oil spilled and the nature of the surrounding soil.

The practical thresholds for significant (reportable) spills of petroleum products are usually as follows:

- Land-based spills: 70 L;
- Spills directly on water: Any amount.

In the event of an accidental spill of contaminant on the soil, if it has been able to infiltrate deeper layers, changes in groundwater quality should be monitored through monitor well network. An Oil Spill Emergency Plan must be implemented in detail before the initial earthwork phase.

The objectives of an Oil Spill Emergency Plan are:

- To minimize the risk of spills or unplanned situations that might cause environmental harm;
- To ensure that contingency measures are in place and implemented in the event of such spills or unplanned situations.

3.1.3.1.1 Groundwater contamination

In the most unfavourable case where the contamination reaches the karst aquifer of the Plaine Corail, the following particularities of contaminant transport must be considered:

- The transport of the contaminant to the sea could be very fast
- The exact underground flow path is generally not known

3.1.3.1.1.1 Groundwater sampling

As soon as a major spill likely to reach groundwater occurs, groundwater sampling in the downstream observation wells should be implemented. The analyses will focus specifically on the nature of the contaminant.

3.1.3.1.1.2 Groundwater decontamination

A company specializing in soil and groundwater remediation should be contacted immediately to assess the situation and propose appropriate measures to address it:

- Assess the nature and extent of the contamination
- Contain contamination
- Recover the contaminant and decontaminate the aquifer
- Treat contaminated water
- Dispose of contaminated materials (soil and water)

The free phase of the hydrocarbons must be pumped as quickly and efficiently as possible by the contractor. Depending on the direction of groundwater flow, underwater resurgences must be monitored, and a Maritime Oil Spill Response Plan must be implemented.

3.1.4 Summary of plans to be drawn up for environmental management during the construction phase

Table 14: Summary of Required ESMP– Environmental Plans - Construction Phase

Plan	Measures that the plan must allow to implement and monitor	Person in charge of implementation and control	Activity / Procedures to include
Karst monitoring plan	Phy-Kar-Mit-5 / 7 / 18	To be implemented by the Contractor Under RRA and ARL's control	- Groundwater monitoring plan - Caves monitoring plan
	Phy-Kar-Comp-17	External specialist Under ARL's control	- A plan to follow the sediments moving and storage

4 Environmental and Social Management Plan (ESMP) for the operational phase

4.1 Environment Management Plan for operational phase

4.1.1 Environmental Management Plan for operational phase

Table 15: Overall Environmental Management Plan for operational phase

<table>
<tr><th>Theme / Issue</th><th colspan="2">Title and ID of the measure</th><th>Complementary description</th><th>Period of performance /
Corresponding plan</th><th>Performance monitoring system</th><th>Performance indicators</th><th>Corrective measures</th><th>Responsible managers for implementation</th></tr>
<tr><td rowspan="5">Karst</td><td>Phy-Kar-Av-25</td><td>All operations involving hydrocarbons must comply with current standards to prevent spills and, if necessary, implement emergency measures</td><td>-</td><td>Operational phase

Emergencies prevention and management plans</td><td rowspan="2">Installation of a network of observation wells upstream and downstream of the facilities to allow, on the one hand, sampling and analysis of groundwater to define reference values and, on the other hand, to establish a groundwater quality monitoring program (and levels) during the project development phases (construction and operation phases)</td><td rowspan="2">Number and intensity of accidental spills of hydrocarbons and other chemicals</td><td rowspan="2">In the event of a surface spill, the environmental response plan must be implemented immediately. In the event that there is a significant change in groundwater quality and/or a contaminant is detected, the environmental management plan will also have to be put in place to contain the contamination.</td><td>ARL</td></tr>
<tr><td>Phy-Kar-Mit-26</td><td>Do not allow groundwater use downstream of airport infrastructure</td><td>-</td><td>Operational phase

Karst monitoring plan</td><td>To be implemented by the Detail Design Engineer

Under ARL's control

Operation Monitoring: ARL (or external specialist engineer under ARL control)</td></tr>
<tr><td>Phy-Kar-Av-22</td><td>Supplementary geotechnical and geophysical investigations to characterize karstic network (caves and voids)</td><td>-</td><td>Operational phase

Karst monitoring plan</td><td>Periodic topographic surveys</td><td>Non-compliance with the leveling tolerances</td><td>Geophysical and/or ground investigation launching</td><td rowspan="3">To be implemented by ARL or an external specialist Contractor (as part of the 10-year guarantee)

Under ARL's control</td></tr>
<tr><td>Phy-Kar-Mit/Comp-23</td><td>In situ investigation diagnostic of infilled cavities (televisual cavity inspections)</td><td>-</td><td>Operational phase

Karst monitoring plan</td><td>Geophysical/geotechnical detection of underground cavity(ies)</td><td>Borehole log anomaly vertical to a levelling defect</td><td>Repair works as cavity filling/grouting</td></tr>
<tr><td>Phy-Kar-Mit/Comp-24</td><td>Additional laboratory testings (Aggregate testings) to characterize erosive potential of in situ geological formations</td><td>-</td><td>Operational phase

Karst monitoring plan</td><td>Detection of gully development as part of site visits</td><td>Slope instability, defect on drainage device</td><td>Slope reconstruction with coarse granular materials/Drainage system improvement works</td></tr>
</table>

4.1.2 Environment Management Plans to be drawn up in operational phase

4.1.2.1 Karst monitoring plan

4.1.2.1.1 Operational phase groundwater quality monitoring plan

This plan consists in keeping monitoring the network of observation wells upstream and downstream of the facilities to allow sampling and analysis of groundwater to define reference values and then to establish a groundwater quality monitoring program (and levels).

The installation of observation wells and water analyses will have been carried out before the work begins. The water quality monitoring program will have begun during the construction phase.

During the airport's operational phase, semi-annual monitoring should be carried out under normal circumstances or more frequently in the event of a spill incident. This should be included in the routine inspection program of the airport. In the event of a surface spill, the environmental response plan must be implemented immediately. In the event that there is a significant change in groundwater quality and/or that a contaminant is detected, the environmental management plan will also have to be put in place to contain the contamination.

This plan should be implemented and managed by the following people:

- ARL;
- Project managers;
- Mauritius authorities:
  - Environmental Assessment Division;
  - Pollution Prevention and Control Division;
- (WRU) Water Resources Unit.

The following plans and procedures should be implemented:

- A monitoring procedure to implement by the person in charge for the monitoring and to be integrated to the current routine inspections of the airport,
- A follow-up plan to implement by ARL.

4.1.3 Emergencies prevention and management plans

4.1.3.1 Oil spill prevention prevention plan

An oil spill prevention plan should be implemented describing all the precautions, procedures, tools, actions of training, awareness-raising and check-up routine that should be scheduled in order to prevent oil spills and other pollutions, with reference to measures “Phy-Mar-Mit-6 / 7”, “Phy-Hyd-Mit-5” and “Phy-Kar-Av-25”.

4.1.3.2 Oil spill management plan

4.1.3.2.1 Groundwater contamination

In the most unfavourable case where the contamination reaches the karst aquifer of the Plaine Corail, the following particularities of contaminant transport must be considered:

- The transport of the contaminant to the sea could be very fast
- The exact underground flow path is generally not known

4.1.3.2.1.1 Groundwater sampling

As soon as a major spill likely to reach groundwater occurs, groundwater sampling in the downstream observation wells should be implemented. The analyses will focus specifically on the nature of the contaminant.

4.1.3.2.1.2 Groundwater decontamination

A company specializing in soil and groundwater remediation should be contacted immediately to assess the situation and propose appropriate measures to address it:

- Assess the nature and extent of the contamination
- Contain contamination
- Recover the contaminant and decontaminate the aquifer
- Treat contaminated water
- Dispose of contaminated materials (soil and water)

The free phase of the hydrocarbons must be pumped as quickly and efficiently as possible by the contractor. Depending on the direction of groundwater flow, underwater resurgences must be monitored, and a Maritime Oil Spill Response Plan must be implemented.

4.1.4 Summary of plans to be drawn up for environmental management during the operational phase

Table 16: Summary of Environmental Management Plan for operational phase

Plan	Measures that the plan must allow to implement and monitor	Person in charge of implementation and control	Activity / Procedures to include
Karst monitoring plan	<u>Design – groundwater</u> Phy-Kar-Mit-26	To be implemented by the Detail Design Engineer Under ARL's control	- Sizing note and plans - A follow-up plan to implement by ARL
	<u>Operation monitoring – groundwater</u> Phy-Kar-Mit-26	To be implemented by ARL or an external specialist Under ARL's control	- A monitoring procedure to implement by the person in charge for the monitoring - A follow-up plan to implement by ARL
	<u>Operation monitoring – caves</u> Phy-Kar-Av-22 Phy-Kar-Mit/Comp-23 Phy-Kar-Mit/Comp-24	To be implemented by ARL or an external specialist Contractor (as part of the 10-year guarantee) Under ARL's control	

5 References

5.1 Physical environment

5.1.1 Geology and geotechnics

- Stratagem974 (2018). New runway – Sir Gaëtan Duval Airport, Plaine Corail Geophysical survey, Rodrigues Island (February 2018), 45p.
- GIBB (Mauritius) Ltd (2018). Extension of Runway at Plaine Corail Airport – Rodrigues Geotechnical Interpretative Report (September 2018), 119p.
- Water Research Co Limited (2018). Factual Report - Geotechnical investigation for Extension of Runway at Sir Gaetan Duval Airport – Phase B (April 2018), 365p.

5.1.2 Hydrogeology

5.1.2.1 Ground water

The list of reviewed documents is shown below:

- Factual Report Geotechnical Investigation For Extension Of Runway At Sir Gaetan Duval Airport- Phase B April 2018 OPG 17067 ROD
- Factual Report Geotechnical Investigation For Extension Of Runway At Sir Gaetan Duval Airport- Phase C September 2018 OPG 17067 ROD
- Extension of Runway at Plaine Corail Airport Rodrigues Geotechnical Interpretative Report for preliminary design phase Report No: M019/031
- Stratigraphy and chronology of karst Features on Rodrigues island, southwestern Indian ocean Karst Geotechnical investigation
- Gregory J. Middleton and David A. Burney, May 2013. Rodrigues – An Indian Ocean Island Calcarenite: Its History, Study and Management
- John Mylroie, Joan Mylroie and Greg Middleton. Rodrigues Island: carbonate deposition and karst processes as indicators of platform stability. Carbonates Evaporites, Springers.
- Feasibility study new runway at Sir Gaëtan Duval Airport, Rodrigues Final Report Ref. CCO 15 of 2010 Client: Rodrigues Regional Assembly Rotterdam/London/Mauritius, 28 October 2011
- KPMG 2009. Final SIDPR Sustainable Integrated Development Plan for Rodrigues “Plan de Développement Durable et Integré de Rodrigues”. 453 p.
- BRL 2022. Consultancy services for the development of rodrigues water resources strategy and the definition of priority action plan. Water Development Strategies (revised version).

Other references:

- Petar T.Milanović, 2004. Water Resources Engineering In Karst. CRC Press LLC 340 p.
- M. Bakalowicz. Cours DEA HHGG Université Paris-6. Hydrogéologie karstique. Caractéristiques et concepts. Méthodes d’exploration, d’exploitation et de gestion active. Déc. 2002.
- Williams P.W. 2008. The role of the epikarst in karst and cave hydrogeology: a review. International Journal of Speleology, 37 (1), 1-10. Bologna (Italy)
- U.S. Environmental Protection Agency (EPA). 2002. Lexicon Of Cave And Karst Terminology With Special Reference To Environmental Karst Hydrology. 121 p.

- Evans, David; Henri Letient; and Aley, Thomas. 2005 Aquifer vulnerability mapping in karstic terrain Antamina Mine, Peru. Proc. Annual Mtng. Society for Mining, Metallurgy, and Exploration. 13p.
- Dörfliger, Nathalie & Jeannin, P.-Y & Zwahlen, F. (1999). Water vulnerability assessment in karst environments: A new method of defining protection areas using a multi-attribute approach and GIS tools (EPIK method). Environmental Geology. 39. 165-176
- Mylroie, Mylroie & Middleton 2016. Rodrigues Island: cabonate deposition and karst processes as indicator of platform stability. Carbonates and evaporites, 31(4): 421-435
- Société D’études Scientifiques des Caverns de la Réunion, 1997. Expédition Rodrigues 97.Bulletin no 2. Numéro Spécial.
- L. Ferry, 1995. Hydroconsult International (GIE ORSTOM-EDF) Evaluation et Mise en Valeur Des Ressources en Eau ee L'ile Rodrigues (projet FAO TPCIMARl4451)
- Virendra PROAG (date inconnue) La Distribution D’eau Potable à Maurice et à Rodrigues. Département de Génie Civil, Université de Maurice, Réduit, île Maurice. 16 p.
- JAN SVOMA and VLADIMiR HOUZIM, 1984. Protection of Groundwater from Oil Pollution in the Vicinity of Airports. Environ Geol Water Sci Vol 6, No 1, 21-30
- M.J. Lace and J.E. Mylroie (eds.), Coastal Karst Landforms, Coastal Research Library 5, DOI 10.1007/978-94-007-5016-6 4, © Springer ScienceCBusiness Media Dordrecht 2013
- Enrique Fernandez y Ramon Peiro, 1995. Introducción a la geología kárstica. Federación Española de Espeleología. 205 p.

5.1.2.2 Water quality, vulnerability and contamination

- GOD (Foster, 1987), DRASTIC (Aller et al., 1987), SINTACS (Civita and De Maio,1997), EPIK (Doerfliger and Zwahlen, 1997), PI (Goldscheider et al., 2000), and COP, based on the European approach (COST, 2003), COPK (Daly et al.,2002; Zwahlen, 2003
- Dörfliger, 1999
- KMPG (2009
- (Source: UNDESA 29 June 2009)

Airport of Rodrigues Ltd

Proposed Expansion of Rodrigues Airport

Water Management Factual Report for the purpose of the Environmental and Social Impact Assessment Report

Report Reference – 09053999

Prepared by

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1 Non-Technical Executive Summary – Water management

1.1 Hydrology

Rodrigues Island is divided into 38 major river basins. The low permeability of soils generated by alteration of basalt suggests a generally low infiltration capacity, which is sometimes increased locally by the presence of fracture zones. Also, a significant proportion of surface run off water returns to the sea.

A geographical gradient is observed for the annual rainfall between coastal areas (less than 1000 mm) and the central plateau (more than 1,600 mm).

The airport is located near the Anse Quitor River which is quite deep near the actual airport runway, although as a result there is no potential flooding expected.

Runoff from the current runway flows to the shoulders and into the natural drains, thus directly discharged into the natural environment.

1.2 Water resource and wastewater management

Drinking and fresh water needs and resource

Construction

The water requirement during construction is both for potable and non-potable use. The water demand is not known at this stage and shall be calculated by the contractor.

Given the water scarcity, it is proposed that a built in temporary containerised-type desalination plant be set up by the contractor, with all precautions taken to minimize the impact on the environment. Since only 20 feet containers can be unloaded at Port Mathurin Harbour, no 40 feet containers will be considered.

Operation

The daily water demand for Rodrigues is estimated to be 11,000 to 12,000 m^3/day, satisfied by rainwater harvested by private individuals and by water provided by the public services. The daily freshwater production is provided by surface water harvesting, boreholes, and desalination of sea marine water.

The airport's water usages are identified at the passenger terminal building and for firefighting.

During November and December (highest passenger traffic period due to school holidays) the average daily water consumption reaches an average of 12.5 m^3 per day. During the rest of year, when traffic is at its lowest, the airport's average minimum daily water consumption is 3.6 m^3 per day (rising over 12.5 in November-December).

Wastewater management

The existing airport has its own on-site wastewater treatment system consisting of a septic tank and a leaching field; which corresponds to a primary treatment. The overflow from the septic tank is released to a leaching field. However, currently regular pumping of the overflow from the septic tank is done because the system does not work properly and the leaching field is not permeable enough. This pre-treated wastewater is transported to the municipal wastewater treatment plant of Grenade.

A wastewater treatment plant of capacity 50 m3 has just been constructed at Grenade. It is in the handing over phase and will be in operation shortly. In the meantime waste water is being disposed in a leaching field at Grenade itself.

The existing wastewater treatment plant will be dismantled once the new wastewater treatment plant is operational.

Stormwater management

Stormwater on the project site is drained naturally towards the sea, without any specific pre-treatment, via the existing slope and natural drains on the site.

The fuel depot is equipped with a retention capacity (equipped with a disconnection valve) to collect stormwater generated therein. The loading / unloading platform is equipped with a disconnecting valve in order to direct the stormwater from the platform towards an open-air oil separator during "off duty" periods and to isolate the platform during fuel loading / unloading operations.

1.2.1 Water sensitivity

The Water Sensitivity is summarised in Table 1 hereafter.

Table 1: Water Sensitivity

Sub-theme	Receptor	Sensitivity
Hydrology	Stormwater management	Major
	Flooding of issues downstream of facilities	Low
	Transfer of pollution to the natural environment	Major
	Transfer of sediments to the lagoon	Major
Water resource and wastewater management	Domestic wastewater management	High
	Water supply management	High

1.3 Potential impacts and measures

1.3.1 Temporary impacts during works phase

Table 2: Summary of Temporary impacts during works phase

Context	Sub-context	Impact ID	Impact description	Positive / adverse	Impact rating before mitigation	Measure ID	Measure	Residual Impact rating
Physical	Hydrology	None	-	-	-	-	-	-
	Water resource and wastewater	Phy-Wat-W-Temp-1	Impact of water resource resulting from works' water supply	Adverse	Major	Phy-Wat-Mit-1	Install a desalination plant to supply drinking water to the workers' camp by sea water pumping	Negligible
		Phy-Wat-W-Temp-2	Impact of works on water resource resulting from impact on karstic groundwater	Adverse	Major	Phy-Wat-Comp-2	Temporarily replace the Caverne Bouteille intake by a sea water pumping Upgrade Caverne Bouteille plant to enable it to provide drinking water from sea water Thus, temporarily provide drinking water from sea water to people currently connected to Caverne Bouteille plant	Negligible
		Phy-Wat-W-Temp-3	Works wastewater	Adverse	Major	Phy-Wat-Av-3	Works wastewater treatment plant	Negligible
		Phy-Wat-W-Temp-4	Risk of accidental pollution	Adverse	High	Phy-Wat-Av/Mit-4	Preventive measures to reduce risks during the construction phase - Risk management plan	Negligible
		Phy-Wat-W-Temp-5	Desalination plant	Adverse	High	Phy-Wat-Av/Mit-5	Good engineering design and best site practices to reduce the impacts Importance of ESMP & ESCP in the contractor's contract	Negligible to low

Note: when no impacts are foreseen, 'Impact ID' column is marked 'none' and the following columns are hence not populated and marked '-'

1.3.2 Permanent and irreversible impacts during works phase

Table 3: Summary of Permanent and Irreversible Impacts during Works phase

Context	Sub-context	Impact ID	Impact description	Positive / adverse	Impact rating before mitigation	Measure ID	Measure	Residual Impact rating
Physical	Hydrology	Phy-Hyd-W-Def-1	Transfer of sediments to the lagoon	Adverse	Major	Phy-Hyd-Mit-1	Temporary sedimentation capacities	Low
	Water resource and waste water	Phy-Wat-W-Def-1	Demolition of an unused reservoir	Adverse	Low	-	-	Low
		Phy-Wat-W-Def-2	Impact on water resource	Adverse	High	Phy-Wat-Av/Mit-4	Preventive measures to reduce risks during the construction phase - Risk management plan	Negligible
						Phy-Wat-Comp-5	Carry out measurements on Caverne Bouteille intake Go on supplying inhabitants from water supply during analysis and measurements According to measurements results, keep using seawater in a definitive manner or get back to the initial situation, pumping underground water in Caverne Bouteille intake	

Note: when no impacts are foreseen, 'Impact ID' column is marked 'none' and the following columns are hence not populated and marked '-'

1.3.3 Permanent impacts during operation phase

Table 4: Summary of Permanent Impacts during Operation Phase

Context	Sub-context	Impact	Impact description	Positive / adverse	Impact rating before mitigation	Measure ID	Measure	Residual Impact rating
Physical	Hydrology	Phy-Hyd-Op-1	Stormwater management	Adverse	Major	Phy-Hyd-Mit-2	Stormwater network	Low
		Phy-Hyd-Op-2	Flooding issues downstream of airport facilities	Adverse	Low	Phy-Hyd-Mit-3	Stormwater ditch located to restore the watershed boundary	Negligible
		Phy-Hyd-Op-3	Transfer of pollution to the natural environment	Adverse	Major	Phy-Hyd-Mit-5	Treat chronic or accidental sources of pollution	Low
		Phy-Hyd-Op-4	Increase in supply of materials to the lagoon	Adverse	Major	Phy-Hyd-Mit-6	Vegetation of slopes and ditches and collection of infrastructures runoff	Low
	Water resource and waste water	Phy-Hyd-Op-4	Increase in supply of materials to the lagoon	Adverse	Major	Phy-Hyd-Mit-6	Vegetation of slopes and ditches and collection of infrastructures runoff	Low
		Phy-Wat-Op-2	Peak flows resulting in increasing soil erosion	Adverse	Major	Phy-Wat-Av-6	Integrated water management plan	Negligible
		Phy-Wat-Op-3	Pollution of marine water	Adverse	Low	Phy-Wat-Mit-7	Water treatment plant	Negligible
		Phy-Wat-Op-4	Extra burden on the water supply public network	Adverse	High	Phy-Wat-Mit-8	Reuse water plan	Low

Note: when no impacts are foreseen, 'Impact ID' column is marked 'none' and the following columns are hence not populated and marked '-'

1.4 Summary for the water management plan for construction phase

Table 5 lists the plans to be developed and implemented to monitor water management measures in the impact study.

Specific guides for preparing plans are provided in Chapter **Erreur ! Source du renvoi introuvable.**.

Table 6 summarizes water management measures in the impact study.

The estimated cost associated with the water management and monitoring are provided in Chapter 9. The costs are considered indicative at this stage and will be updated during the life cycle of the project.

Table 5: Summary of Water Management Plans for Construction Phase

Plan	Measures that the plan must allow to implement and monitor	Person in charge of implementation and control	Activity / Procedures to include
Surface stormwater run-off, drinking and wastewater management and monitoring plan	Phy-Wat-Mit-1 Phy-Wat-Comp-2 Phy-Wat-Av-3 Phy-Hyd-Mit-1	To be implemented by the Contractor Under RRA and ARL's control	- A water management plan - A desalination skid, wastewater treatment plant and buffer storage monitoring - A water quality monitoring

Table 6: Summary of Water Measures and Monitoring during Construction Phase

Theme / Issue	Title and ID of the measure		Complementary description	Period of performance / Corresponding plan	Performance monitoring system	Performance indicators	Corrective measures	Responsible managers for implementation
Hydrology - Stormwater management Waste water management / Water resource and water supply	Phy-Hyd-Mit-1	Temporary sedimentation capacities	Stormwater management from the modified natural watersheds: During the construction works, excavation of the terrain will facilitate transfer of sediments to the lagoon. => Implementation of specific temporary drains and buffer storage/sedimentation capacities	Works phase **Surface stormwater run-off, drinking and wastewater management and monitoring plan**	Monitoring of water quality at discharge; visual control.	Compliance with prevailing / target standards. Submission to local authorities once a month.	Discharge to be stopped if non-compliance. Informing of local authorities/client for remedial measures.	To be implemented by the Contractor Under RRA and ARL's control
	Phy-Wat-Mit-1	Install a desalination plant to supply drinking water to the workers' camp	Water supply for workers' site facilities and construction facilities: The construction works cannot create a burden on the existing water supply already suffering a severe deficiency Specific desalination skid for the water supply of the workers' site facilities and construction facilities	Works phase **Surface stormwater run-off, drinking and wastewater management and monitoring plan**	Monitoring of water quality at inlet and outlet of Treatment Plant; monitoring of water quality on distribution line; regular manual sampling/analysis (once a week) and visual control; automatic real time monitoring of main parameters (at least pH, turbidity and residual free chlorine) on distribution line.	Compliance with prevailing / target standards. Submission to local authorities once a month.	Water production to be stopped if non-compliance. Informing of local authorities/client for remedial measures.	To be implemented by the Contractor Under RRA and ARL's control

Theme / Issue	Title and ID of the measure		Complementary description	Period of performance / Corresponding plan	Performance monitoring system	Performance indicators	Corrective measures	Responsible managers for implementation
	Phy-Wat-Comp-2	Temporary or permanent relocation of the captation of actual Caverne Bouteille	Propose a new location for Caverne Bouteille, including a seawater pumping, settle a new pumping system and upgrade the existing treatment plant to provide water to the people currently supplied by Caverne Bouteille plant	Works phase and prior to the works **Surface stormwater run-off, drinking and wastewater management and monitoring plan**	Monitoring of water quality at inlet and outlet of Treatment Plant; monitoring of water quality on distribution line; regular manual sampling/analysis (once a week) and visual control; automatic real time monitoring of main parameters (at least pH, turbidity, salinity, temperature, TDS, electrical conductivity and residual free chlorine) on distribution line.	Compliance with prevailing / target standards. Submission to local authorities once a month. Significant change in the value of the measured parameters (e. g. +/-20%) depending on the tolerance of the treatment system.	Water production to be stopped if non-compliance. Informing of local authorities/client for remedial measures. Temporary stop of pumping Identification of the source/cause of the water quality change Relocation of the catchment	To be implemented by the Contractor Under RRA and ARL's control
	Phy-Wat-Av-3	Works wastewater treatment plant	Wastewater management for the existing airport facilities and workers' site facilities: During the construction works, the existing wastewater treatment facilities will be dismantled. The sewage from the airport facilities will need to be treated to avoid direct discharge into the environment => Wastewater treatment skid of adequate capacity for both the airport facilities and for the workers' site facilities	Works phase **Surface stormwater run-off, drinking and wastewater management and monitoring plan**	Monitoring of water quality at inlet and outlet of Treatment Plant; monitoring of water quality at discharge; regular manual sampling/analysis (once a week) and visual control; automatic real time monitoring on main parameters usually monitored.	Compliance with prevailing / target standards. Submission to local authorities once a month.	Discharge to be stopped if non-compliance. Informing of local authorities/client for remedial measures.	To be implemented by the Contractor Under RRA and ARL's control
	Phy-Wat-Av/Mit-4	Preventive measures to reduce risks during the construction phase - Risk management plan	Oil and other spills related to chemical products used during construction =>Implementation of specific retention / confining zones for storage and use Identification of threat activity that will cease to be or not become a significant threat to drinking water	Works phase **Site and works facilities management and monitoring plan**	Monitoring of any leakage from the specific retention zones Ensure that all site managers are aware of the RMP and are able to apply it Verify that the resources to apply the RMP are present on the site	Zero leakage observed Regular meetings between the project manager, the contracting authority and all site managers	Implementation of remedial confining procedure Training workshops for all site managers	To be implemented by the Contractor Under ARL's control

1.5 Summary for the water management plan for operation phase

Table 7 lists the plans to be prepared prior to start of operation and then implemented during operation to monitor water management measures in the impact study.

Specific guides for preparing plans are provided in Chapter **Erreur ! Source du renvoi introuvable.**.

Table 8 summarizes the water management measures in the impact study.

The estimated cost associated with the water management and monitoring are provided in Chapter 9. The costs are considered indicative at this stage and will be updated during the life cycle of the project.

Table 7: Summary of Water Management Plans for Operation Phase

Plan	Measures that the plan must allow to implement and monitor	Person in charge of implementation and control	Activity / Procedures to include
Surface stormwater run-off, drinking and wastewater management and monitoring plan	<u>Design</u> Phy-Hyd-Mit-2 / 3 / 4 / 6 Phy-Wat-Av-6 Phy-Wat-Mit-7 / 8	To be implemented by ARL or an external specialist/ engineer Under ARL's control	- A water management plan
	<u>Operation monitoring of measures</u> Phy-Hyd-Mit-2 / 3 / 4 / 6 Phy-Wat-Av-6 Phy-Wat-Mit-7 / 8	To be implemented by ARL or an external specialist/ engineer Under ARL's control	- A desalination plant, wastewater treatment plant and storm water management system monitoring - A water quality monitoring plan

Table 8: Summary of Water management Measures and Monitoring during Operation Phase – Water management

Theme / Issue	Title and ID of the measure		Complementary description	Period of performance / Corresponding plan	Performance monitoring system	Performance indicators	Corrective measures	Responsible managers for implementation
Hydrology - Stormwater management Wastewater management / Water resource and water supply	Phy-Hyd-Mit-2 Phy-Hyd-Mit-3 Phy-Hyd-Mit-4 Phy-Hyd-Mit-6	Stormwater network Stormwater ditch located to restore the watershed boundary Climate change adaptation: buffering storage and works facilitating infiltration Vegetation of slopes and ditches and collection of infrastructures runoff	Stormwater management for the runway before discharge at sea: Implementation of oil separator/sedimentation works on outlet	Permanent as from the commissioning of the runway **Surface stormwater run-off, drinking and wastewater management and monitoring plan**	The oil separator on the discharge point at sea will be equipped with an alarm to order a maintenance before leakage; monitoring of water quality at discharge at sea; regular manual sampling/analysis of outlet during discharge at sea and visual control.	Compliance with prevailing / target standards. Submission to local authorities once a month.	Discharge to be stopped if non-compliance. Informing of local authorities and implementation of remedial measures: confining / dedicated pumping for evacuation if deemed necessary.	To be implemented by the Detail Design Engineer Under ARL's control Operation Monitoring: ARL (or external specialist engineer under ARL and RRA's control)
			Stormwater management and collection in a buffer storage to reduce peak flows before discharge at sea: Implementation of oil separator/sedimentation works before outlet into the buffer storage. Stormwater collection in a buffer storage. Implementation of a water treatment plant within an	Permanent as from the commissioning of the new runway facilities **Surface stormwater run-off, drinking and wastewater management and monitoring plan**	The oil separator on the inlet of the buffer storage will be equipped with an alarm to order a maintenance before leakage; monitoring of water quality at discharge at sea, regular manual sampling/analysis of outlet during discharge at sea and visual control.	Compliance with prevailing / target standards. Submission to local authorities once a month.	Discharge / reuse to be stopped if non-compliance. Informing of local authorities and implementation of remedial measures: confining / dedicated pumping for evacuation if deemed necessary.	To be implemented by the Detail Design Engineer Under ARL's control Operation Monitoring: ARL (or external specialist engineer under ARL and RRA's control)

Theme / Issue	Title and ID of the measure		Complementary description	Period of performance / Corresponding plan	Performance monitoring system	Performance indicators	Corrective measures	Responsible managers for implementation
			integrated water management plan including reuse of treated stormwater collected.					
	Phy-Wat-Av-6 Phy-Wat-Mit-7 Phy-Wat-Mit-8	Integrated water management plan Water treatment plant Reuse water plan	Wastewater management for the airport facilities before discharge at sea Wastewater integrated management for the airport facilities =>Implementation of a water treatment plant within an integrated water management plan including reuse of treated wastewater.	Permanent as from the commissioning of the treatment facilities **Surface stormwater run-off, drinking and wastewater management and monitoring plan**	Monitoring of water quality at inlet and outlet of Treatment Plant; monitoring of water quality in industrial water storage and stored water quality is maintained including disinfection; regular manual sampling/analysis (once a week) and visual control; automatic real time monitoring on main parameters usually monitored.	Compliance with prevailing / target standards. Submission to local authorities once a month.	Discharge / reuse to be stopped if non-compliance. Informing of local authorities and implementation of remedial measures: confining / dedicated pumping for evacuation if deemed necessary.	To be implemented by the Detail Design Engineer Under ARL's control Operation Monitoring: ARL (or external specialist engineer under ARL and RRA's control)
			Rainwater integrated management for the airport facilities: Implementation of a water treatment plant within an integrated water management plan including reuse / treatment of rainwater harvested for drinking water production.	Permanent as from the commissioning of the treatment facilities **Surface stormwater run-off, drinking and wastewater management and monitoring plan**	Monitoring of water quality at inlet and outlet of Treatment Plant; monitoring of water quality in rainwater storage and stored water quality is maintained including disinfection; regular manual sampling/analysis (once a week) and visual control; automatic real time monitoring on main parameters usually monitored for drinking water production (at least pH and turbidity)	Compliance with prevailing / target standards. Submission to local authorities once a month.	Reuse to be stopped if non-compliance. Informing of local authorities and implementation of remedial measures: confining / dedicated pumping for evacuation if deemed necessary.	To be implemented by the Detail Design Engineer Under ARL's control Operation Monitoring: ARL (or external specialist engineer under ARL and RRA's control)
			Drinking Water supply integrated management for the airport facilities: Implementation of a water treatment plant within an integrated water management plan including reuse / treatment of rainwater harvested for drinking water production. Reuse and treatment of wastewater / stormwater collected if necessary.	Permanent as from the commissioning of the treatment facilities **Surface stormwater run-off, drinking and wastewater management and monitoring plan**	Monitoring of water quality at inlet and outlet of Treatment Plant; monitoring of water quality in drinking water storage and stored drinking water quality is maintained including disinfection; regular manual sampling/analysis (once a week) and visual control; automatic real time monitoring of main parameters (at least pH, turbidity and residual free chlorine) on distribution line.	Compliance with prevailing / target standards. Submission to local authorities once a month.	Distribution to be stopped if non-compliance. Informing of local authorities and implementation of remedial measures: confining / dedicated pumping to empty drinking water storage if deemed necessary.	To be implemented by the Detail Design Engineer Under ARL's control Operation Monitoring: ARL (or external specialist engineer under ARL and RRA's control)

2 Legal and institutional framework applicable to the Water Component

2.1 Main regulations under the Environment Protection Act 2002

Water pollution (effluent discharge)

Standards for discharge on land/underground and to surface water courses are set under the Environment Protection (Standards for effluent discharge) Regulations 2003.

The water treatment plant proposed for the project complies with the Environmental Guideline No. 16 for Wastewater Treatment Plant published by the Ministry of Environment.

2.1.1 Effluent Discharge Standards

Standards for discharge on land/underground and to surface water courses are set under the Environment Protection (Standards for effluent discharge) Regulations 2003.

Table 9 below reproduces the Second Schedule (Regulation 4): Effluent discharge Standards

Table 9 - Environment Protection (Standards for effluent discharge) - Maximum permissible limit

Parameter	***Unit***	***Maximum permissible limit***	
		Land/Underground	***Surface water courses***
Total coliforms	MPN per 100 ml	-	<400
E. Coli	MPN per 100 ml mg/1	<1000	<200
Free Chlorine	mg/1	-	0.5
Total Suspended Solids (TSS)	mg/1	45	35
Reactive Phosphorus		10	1
Colour	-	Not objectionable	
Temperature	°C	40	
pH	-	5 – 9	
Chemical Oxygen Demand (COD)	mg/1	120	
Biochemical Oxygen Demand (BOD5)	mg/1	40	
Chloride	mg/1	750	
Sulphate	mg/1	750	
Sulphide	mg/1	0.002	
Ammoniacal Nitrogen	mg/1	1	
Nitrate as N	mg/1	10	
Total Kjeldahl Nittogen (TKN)	mg/1	25	
Nitrite as N	mg/1	1	
Aluminium	mg/1	5	
Arsenic	mg/1	0.1	
Berylium	mg/1	0.1	
Boron	mg/1	0.75	
Cadmium	mg/1	0.01	
Cobalt	mg/1	0.05	
Copper	mg/1	0.5	
Iron	mg/1	2.0	
Lead	mg/1	0.05	
Lithium	mg/1	2.5	
Manganese	mg/1	0.2	
Mercury	mg/1	0.005	
Molybdenum	mg/1	0.01	
Nickel	mg/1	0.1	
Selenium	mg/1	0.02	
Sodium	mg/1	200	
Total Chromium	mg/1	0.05	
Vanadium	mg/1	0.1	
Zinc	mg/1	2	
Oil & Grease	mg/1	10	
Total Pesticides	mg/1	0.025	
Total organic halides	mg/1	1	
Cyanide (as CN)	mg/1	0.1	
Phenols	mg/1	0.5	
Detergents (as LAS*)	mg/1	15	
(* Linear Alkylate Sulphonate)			

Standards for discharge into the ocean are set under the Environment Protection (Standards for effluent discharge into the ocean) Regulations 2003.

Table 9 below reproduces the Schedule (Regulation 3): Effluent discharge Standards into the ocean being permissible limits or range for the corresponding parameters.

Table 10 - Environment Protection (Standards for effluent discharge into the ocean) - Maximum permissible limit

Parameter	***Unit***	***Permissible limits***
Temperature	**°C**	**40**
PH	*-*	*5 – 9*
Floatables	*mm*	*6*
Biochemical Oxygen Demand (BOD5)	**mg/l**	**250**
Chemical Oxygen Demand (COD)	*mg/l*	*750*
Suspended Solids	*mg/l*	*300*
Cadmium	*µg/l*	**20**
Chromium (VI)	*µg/l*	*100*
Chromium, Total	*µg/l*	*500*
Cyanides (as CN-)	*µg/l*	*100*
Lead	*µg/l*	*2*
Nickel	*µg/l*	*2*
Zinc	*µg/l*	*2*
Total Mercury	*µg/l*	*10*
Arsenic	*µg/l*	*200*
Total pesticides	**mg/l**	**1**
Oil & Grease	*mg/l*	*20*

Standards of effluent for use in irrigation are set under the Environment Protection (Standards for effluent for use in irrigation) Regulations 2003.

Table 11 below reproduces the Schedule (Regulation 3(1)): Effluent discharge Standards for use in irrigation being maximum limits for the corresponding parameters except where an upper and a lower limit are specified.

Table 11 - Environment Protection (Standards for effluent for use in irrigation) - Maximum permissible limit

List	Parameter[1]	Unit	Standards
A	pH	-	5 – 9
	Colour	-	not objectionable
B	Biochemical Oxygen Demand (BOD_5)	mg/l	40
	Chemical Oxygen Demand (COD)	mg/l	120
	Suspended Solids	mg/l	45
	Chloride	mg/l	250
	Sulphate	mg/l	500
	Nitrate N	mg/l	20
	Total Dissolved Solids	mg/l	2000
	Sodium Adsorption Ratio (SAR)	-	<6
C	Aluminium	mg/l	5
	Arsenic	mg/l	0.10
	Beryllium	mg/l	0.10
	Boron	mg/l	0.75
	Cadmium	mg/l	0.01
	Chromate chromium	mg/l	0.10
	Cobalt	mg/l	0.05
	Copper	mg/l	0.20
	Fluorine	mg/l	1
	Iron	mg/l	5
	Lead	mg/l	2
	Lithium	mg/l	2.5
	Manganese	mg/l	0.2
	Molybdenum	mg/l	0.01
	Nickel	mg/l	0.20
	Mercury	mg/l	0.02
	Selenium	mg/l	0.02
	Vanadium	mg/l	0.10
	Zinc	mg/l	2
D	Total Pesticides	mg/l	0.025
	Oil & Grease	mg/l	10
	Detergents)	mg/l	5
E	Faecal coliforms[2]	MPN per 100 ML	1000[3]
	Intestinal nematodes[2]	Arithmetic mean no. of eggs per Litre	≤1

Notes: -

(a) [1]A 95% compliance limit will be accepted based on the series of samples taken in a year

(b) [2]Prohibited for crops to be eaten raw

(c) [3]200 faecal coliforms MPN/100 ml for public lawns such as hotel lawns, with which the public may have direct contact

2.1.2 Drinking Water Standards

Drinking Water Standards are set under the Environment Protection (Drinking Water Standards) Regulations 1996.

Table 12 below reproduces the Second Schedule (Regulation 3): Drinking Water Standards being maximum limits for the corresponding parameters except where an upper and a lower limit are specified.

Table 12 - Environment Protection (Drinking Water Standards) - Maximum permissible limit

Parameter	***Standards***
Microbial	
E. coli	must not be detectable in any l00ml sample
Coliform Organisms	0 in 95% of samples examined throughout the year. In the case of quantities of water needed for distribution throughout the year, when not less than 50 samples are examined for each period of 30 days, 3 in an occasional sample, but not consecutive samples
Physico-chemical	
pH	6.5-8.5
Total dissolved solids	1000mg/l
Turbidity	5 NTU
Organoleptic	
Colour	20 Pt-Co
Taste and odour	not objectionable
Trace metals	
Aluminium	0.2 mg/l
Arsenic	0.01 mg/l
Cadmium	0.003 mg/l
Copper	1 mg/l
Lead	0.01 mg/l
Mercury	0.001 mg/l
Total chromium	0.05 mg/l
Zinc	3.0 mg/l
Nickel	0.02 mg/l
Anions	
Chloride	250mg/l
Fluoride	1.5 mg/l
Sulphate	250mg/l
Nitrate	50 mg/l(as No3)
Nitrite	3 mg/1(as No2)
Pesticides	
Aldrin and Dieldrin	0.03 microgram/l
DDT	2 microgram/l
HCB	1 microgram/l
Methoxychlor	20 microgram/l
Heptachlor and Heptachlor Oxide	0.03 microgram/l

2.2 Water Development Strategies

A consultancy for the Development of Rodrigues Water Resources Strategy and the Definition of Priority Action Plan was commissioned and the revised version was issued in May 2022.

The main objective expressed by the Rodrigues Regional Assembly is to ‘Secure a regular access for all at least one day out of the week’, and also to ‘Ensure and secure the quality of the water distributed to the consumers’

3 Project description and justification

3.1 Introduction to the project and background information

3.1.1 Ancillary Facilities within the Scope of Works under Phase 1 of the Airport Expansion

3.1.2 Water tower

New water storage will need to be provided near the fire station to safeguard water supplies during emergency situations. The water will be supplied from the integrated water system proposed and detailed hereinafter. The capacity of the new water storage tanks will need to cater for the enhanced service requirements and it will be determined in the detailed design phase. For fighting purposes, the water tower will need to have a minimum volume of 30 m^3 as per firefighting guidelines.

3.1.3 Stormwater drainage and domestic wastewater management facilities

The project includes an appropriate **stormwater drainage network** ensuring that stormwater is adequately captured and disposed of in an environmentally safe manner. The possibility of reuse of stormwater in an effective manner has been considered in an "integrated" water management scheme.

The project includes a **new sewer network with an associated wastewater treatment plant** to cater for the new control tower and Rescue and Fire Fighting Station, together with the existing passenger terminal building. These facilities should also include a provision for the new buildings of the airport expansion project, if deemed necessary.

3.1.3.1 Main Concept Design considerations

The general principle proposed is presented in the figures hereinafter, based on the following concept design considerations:

Stormwater drainage and management

Collection, pre-treatment and disposal or reuse.

Use of the stormwater drainage facilities to confine the effluents generated by chronic pollution and any eventual firefighting on the runway and preserve the environment, in particular the 2 caverns (Caverne Petit Lac and Grotte Fougère) near Anse Quitor, but also potentially Caverne Bouteille in the same zone where drinking water is currently being produced by desalination.

Use the opportunity of gravity stormwater drainage for stormwater harvesting to reuse it after an adequate treatment for the water supply requirements of the airport (reuse of stormwater preferably dedicated to "non-drinking" uses).

Assess, on the one hand, the water needs for the airport, and on the other hand, assess the volume of wastewater to be produced and the volume of stormwater to be collected in order to determine the zones of the airport that can be drained effectively towards the buffer storage capacity and the Water Treatment Plant for reuse. This is to relax as far as possible the constraints induced by the topographical characteristics of the new runway which tends to slope down towards Anse Quitor.

The stormwater harvesting on the impermeable zones (namely taxiways, aprons, roads) will come in addition to the rainwater harvesting from the roofs of the passenger terminal building for reuse.

The stormwater drainage network (including the runway) needs to be non-infiltrating to convey the first runoff flow with the highest pollutant loadings to a buffer storage through an oil separator / primary sedimentation equipment.

The stormwater management including a buffer storage and / or works facilitating infiltration eventually and reducing soil erosion, enables to address climate change adaptation for disaster risk reduction. In fact, reduction of peak flows, run off and soil erosion lead to reduced sedimentation of water bodies including lagoons, thus protecting biodiversity, corals and white sandy beaches.

However, according to the recommendations of Gregory MIDDLETON in his email dated 10th April 2019 to Aurele Anquetil ANDRE, “The stormwater drainage system must be properly constructed to carry water far away from the runway, as excessive infiltration of concentrated runoff from infrastructure has been identified as a major cause of sinkhole collapse in the young limestones of Florida. Water and sewer systems in karst areas are prone to failure caused by small leaks that create minor subsidence, which then leads to major pipe failure”.

The buffer storage capacity for reuse, is to be emptied within a small lapse of time so as to be made available for the next eventual rain event. A monitoring is to be carried out for maintenance purposes.

A sea outfall is to be implemented for discharging at sea the excess water that cannot be reused. The sea outfall for excess stormwater is to be implemented tentatively in the zone of the existing boat house and new sea rescue facility, in common with the sea outfall of the Waste Water Treatment Plant.

The water to be reused is to be conveyed by pumping towards the Water Treatment Plant (WTP 1 on the General Principle diagram Figure 1, consisting tentatively of a sand filtration, activated carbon and ozonation) before being stored in an industrial water storage tank after proper treatment and adequate treated water quality monitoring.

An industrial water storage is envisaged with a capacity of 400 m^3 to reuse treated waste water or treated stormwater. This capacity can be backed up if required by rainwater harvesting from roofs of buildings.

Domestic wastewater management

Having a new Waste Water Treatment Plant on site gives the opportunity to implement an “Integrated” Water Management associating both stormwater and sewage water as sources of raw water for the common uses of the airport, after an adequate treatment.

The considered sewage water has to be strictly domestic wastewater. Any non-domestic wastewater shall be evacuated specifically by pumping via a dedicated carrier. In fact, domestic wastewater is generally free of pollutants like heavy metals and therefore can be treated using biological techniques with regard to toxicity towards bio-organisms.

The Wastewater Treatment Plant shall be of modular type to cater for future extensions if required and of “package plant” type, including UV disinfection and water quality monitoring at the outlet. A dedicated inlet lift pumping station shall be implemented at the inlet of the Water Treatment Plant.

The sludge produced shall be reused in agriculture and therefore shall require a minimum level of dryness.

A sea outfall is to be implemented for discharging at sea the excess treated water that cannot be reused, even if the objective is zero discharge as far as wastewater is concerned.

This sea outfall is to be implemented tentatively in the zone of the existing boat house and new sea rescue facility, in common with the sea outfall of the buffer storage tank described above.

The gravity sewer networks to be implemented to convey the domestic wastewater to the Water Treatment Plant shall be of uPVC type, with intermediate lift pumping stations if required. The pumping networks shall be of HDPE type.

The treated wastewater will be stored in a dedicated 400 m^3 water tank; note that this figure may be reviewed at detailed design stage.

Water supply

- The Integrated Water Management gives the opportunity to have enough raw water for reuse after an adequate treatment and water quality monitoring.
- The treated water from the outlet of the water treatment plant (WTP 2 on the General Principle diagram Figure 1) will be used for drinking water purposes provided the level of treatment can be made compliant with the drinking water standards and correctly monitored at the outlet of the treatment. Only the fraction dedicated to drinking water purposes has to be disinfected thoroughly. The treatment will be ensured by a specific Reverse Osmosis treatment stage (WTP 2 on the General Principle diagram Figure 1).
- The water to be used is to be conveyed by pumping from the Water Treatment Plant outlet towards the corresponding storage tank after adequate water quality monitoring.
- It is proposed that this storage tank be the existing storage capacity of 400 m^3 since it is already connected to the distribution network and to the drinking water supply from the public network, to be maintained as back-up. The existing rainwater harvesting will be disconnected from the storage tank and connected to a new storage of 400 m^3 to be implemented and dedicated to rainwater storage. In fact, at the moment, the drinking water from the public network is connected to the same storage tank used for rainwater harvesting from the roofs of the passenger terminal building. The drinking water is thus contaminated on the bacteriological point of view. It is therefore proposed to have a storage dedicated to drinking water uses at the airport.
- The specific storage tank for drinking water purposes shall be equipped with a disinfection facility using controlled chlorination towards the passenger terminal building.
- A desalination plant is envisaged to supply water for the construction phase. The same is planned to be used as water supply facility, after the construction, for the operation phase, to supply both the airport and the public network, as far as possible.

Determination of the storage capacity for treated water to be potentially reused

The storage capacity determined for rainwater, industrial water and drinking water is based on a compromise considering namely:

- a water demand of around 21 m^3/d
- a storage of 1 month considering a period of no rain for around 21 days
- the existing storage capacity of 400 m^3 taking into account an existing volume reserved for fire fighting (volume considered of 120 m^3).

A dedicated separate storage tank for rainwater harvesting, industrial water and drinking water for distribution, is proposed with a capacity of 400 m^3 each.

In fact, the new capacity envisaged is arbitrarily fixed for the moment to 400 m^3 like the existing water storage on site.

Determination of treatment capacity for reuse

- WWTP to produce industrial water = around 21 m^3/d (estimated water demand)
- Rainwater to produce drinking water (WTP 2) = around 21 m^3/d (estimated water demand)
- Stormwater to produce industrial water (WTP 1) = up to 100 m^3/d (estimated stormwater collected during the month of least rainfall forecast: October)

Estimate of the total footprint for the whole water treatment plant

- Approximate total surface area (including land area, building footprint, road access, industrial water buffer storage) = 850 m^2
- Approximate height of buildings = 5 m.

The figures 1 and 2 hereinafter illustrates the general principle proposed for the integrated water management.

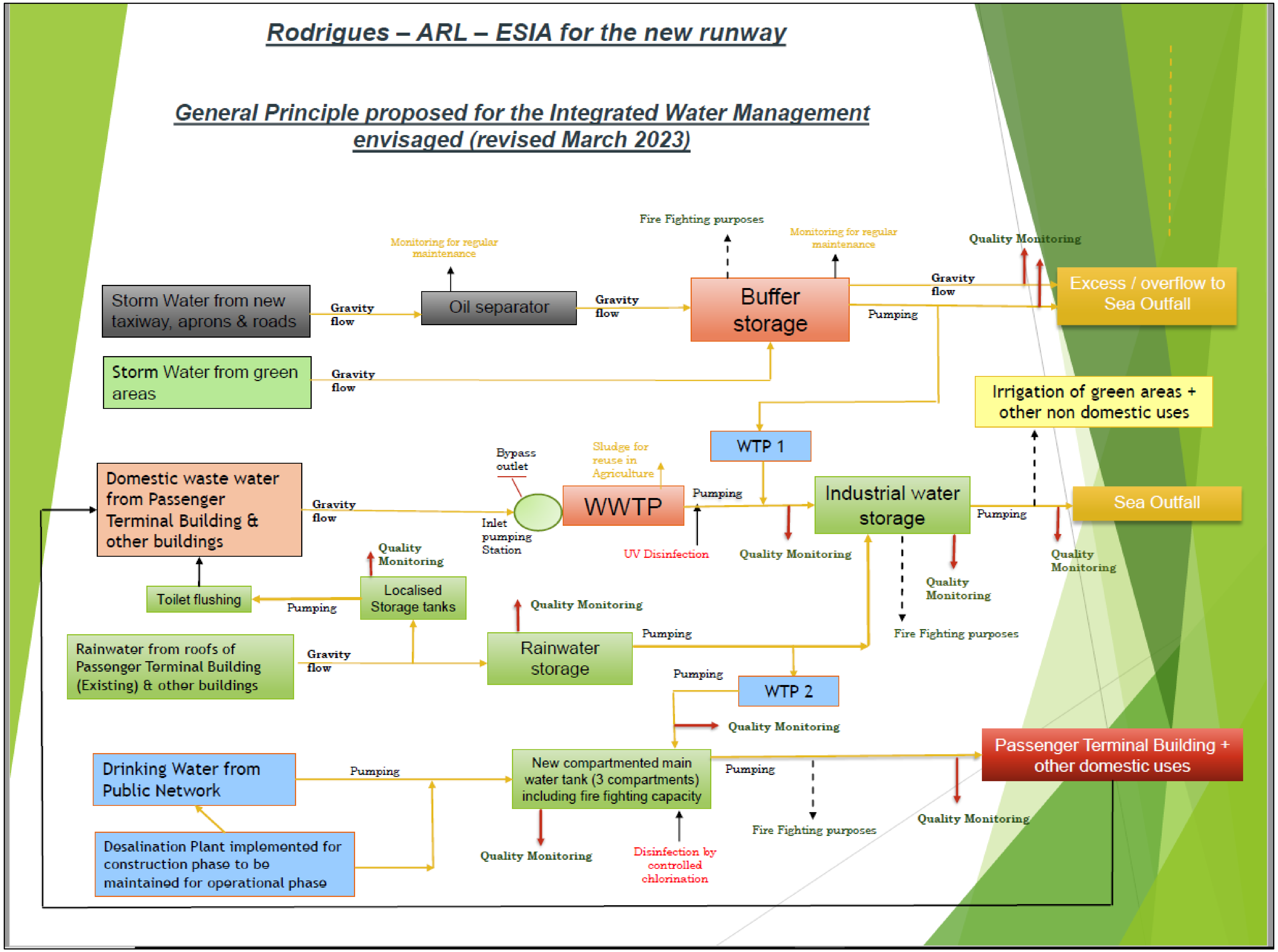


Figure 1: General principle proposed for the integrated water management envisaged

Figure 2: Tentative location of the buffer storage for the stormwater management

The location of the buffer storage envisaged, as indicated in the figure above, has been chosen in order to benefit from the existing topography in the specific zones

Moreover, the location of the new Wastewater Treatment Plant (in the Preliminary Design) (location in **Erreur ! Source du renvoi introuvable.** above) and the location of the existing water facilities for reuse in the passenger terminal building (zone of existing terminal building in **Erreur ! Source du renvoi introuvable.** above), make it easier to handle the water transfer among the corresponding water facilities and for easy access for maintenance purposes as well.

3.1.3.2 Main Concept Design numerical assumptions and applicable standards

The main assumptions made at this prior stage are namely:

Air passenger volume projected / year :	100 000
Air passenger volume projected / day :	274
Number of employees projected :	170
Ratio L / employee per day :*	75
Ratio L / passenger from terminal per day :*	30
* source : INFRATA June 2014	
Ratio L / passenger from planes per day	2

The flow of wastewater produced at this prior stage is thus estimated to:

	Number	Ratio L/d	Volume (m3/d)
Passengers	274	30	8.2
Employees	170	75	12.8
Passengers from planes	274	2	0.5
Total			**21.5**

According to EPA Guidelines, the design assumptions are the following:

Parameters	Units	Design
Hydraulic flows		
Average flows	m3/d	21.5
Peak flows	m3/h	5.8
Pollution Flows		
BOD5	kg/d	5.4
COD	kg/d	8.6
Total Suspended Solids (TSS)	kg/d	6.5
NK	kg/d	2.2
Pt	kg/d	0.4
Bacteriological proprieties		
Faecal coliforms	U/100mL	1.00E+05
Physico-chemical proprieties		
Wastewater temperature	°C	20
pH range		7 to 8
Minimum hardness		5
Minimum K Acid buffer capacity	mmol/L	8

The standards to be complied with are according to Chapter 2 of the present document (*Legal and Institutional Framework applicable to the Water Component*).

The discharge limits will also include reference to the WBG EHS discharge limits, namely the following table extracted from the General EHS Guidelines: Environmental Wastewater and Ambient Water Quality.

Table 1.3.1 Indicative Values for Treated Sanitary Sewage Discharges[a]

Pollutants	Units	Guideline Value
pH	pH	6 – 9
BOD	mg/l	30
COD	mg/l	125
Total nitrogen	mg/l	10
Total phosphorus	mg/l	2
Oil and grease	mg/l	10
Total suspended solids	mg/l	50
Total coliform bacteria	MPN[b] / 100 ml	400[a]

Notes:
[a] Not applicable to centralized, municipal, wastewater treatment systems which are included in EHS Guidelines for Water and Sanitation.
[b] MPN = Most Probable Number

However, for reuse, we propose the following standards according to local (Mauritian) wastewater regulations:

Parameter	Unit	Land/ Underground	Surface water courses	REUSE in irrigtion
Total coliforms	MPN per 100 ml	-	400	-
Faecal coliforms	MPN per 100 ml	-	-	1000
E. Coli	MPN per 100 ml	<1000	<200	-
Free Chlorine	mg/l	-	0.5	-
Total Suspended Solids (TSS)	mg/l	45	35	45
Total Dissolved Solids	mg/l	-	-	2000
Sodium Adsorption Ratio (SAR)	-	-	-	<6
Reactive Phosphorus	mg/l	10	1	-
Color	-	Not objectionable	Not objectionable	Not objectionable
Temperature	degree C	40	40	-
pH	-	5 - 9	5 - 9	5 - 9
Chemical Oxygen Demand (COD)	mg/l	120	120	120
Biochemical Oxygen Demand (BOD5)	mg/l	40	40	40
Chloride	mg/l	750	750	250
Sulphate	mg/l	750	750	500
Sulphide	mg/l	0.002	0.002	-
Ammoniacal Nitrogen	mg/l	1	1	-
Nitrate as N	mg/l	10	10	20
Total Kjeldahl Nitrogen (TKN)	mg/l	25	25	-
Nitrite as N	mg/l	1	1	-
Aluminium	mg/l	5	5	5
Arsenic	mg/l	0.1	0.1	0.1
Beryllium	mg/l	0.1	0.1	0.1
Boron	mg/l	0.75	0.75	0.75
Cadmium	mg/l	0.01	0.01	0.01
Cobalt	mg/l	0.05	0.05	0.05
Copper	mg/l	0.5	0.5	0.2
Chromate chromium	mg/l	-	-	0.1
Fluorine	mg/l	-	-	1
Iron	mg/l	2	2	-
Lead	mg/l	0.05	0.05	2
Lithium	mg/l	2.5	2.5	2.5
Manganese	mg/l	0.2	0.2	0.2
Mercury	mg/l	0.005	0.005	0.02
Molybdenum	mg/l	0.01	0.01	0.01
Nickel	mg/l	0.1	0.1	0.2
Selenium	mg/l	0.02	0.02	0.02
Sodium	mg/l	200	200	-
Total Chromium	mg/l	0.05	0.05	-
Vanadium	mg/l	0.1	0.1	0.1
Zinc	mg/l	2	2	2
Oil & Grease	mg/l	10	10	10
Total Pesticides	mg/l	0.025	0.025	0.025
Total organic halides	mg/l	1	1	-
Cyanide (as CN -) or Free cyanide	mg/l	0.1	0.1	-
Phenols	mg/l	0.5	0.5	-
Detergents (as LAS*) * Linear Alkylate Sulphonate	mg/l	15	15	-
Detergents	mg/l	-	-	5
Intestinal nematodes	Arithmetic mean no. of eggs per litre	-	-	<1

For drinking water uses, the following local (Mauritian) standards are commonly used. However, we propose that the Treated Water be monitored in compliance with the EC Drinking Water Directive 98/83/EC and the Drinking Water Standards (GN n°55 of 1996 below), whichever is more strict.

Parameter	*Standards*
Microbial	
E. *coli*	must not be detectable in any 100ml sample
Coliform Organisms	0 in 95% of samples examined throughout the year. In the case of quantities of water needed for distribution throughout the year, when not less than 50 samples are examined for each period of 30 days, 3 in an occasional sample , but not in consecutive samples
Physico-chemical	
pH	6.5-8.5
Total dissolved solids	1000 mg/l
Turbidity	5 NTU
Organoleptic	
Colour	20 Pt-Co
Taste and Odour	not objectionable
Trace metals	
Aluminium	0.2 mg/l
Arsenic	0.01 mg/l
Cadmium	0.003 mg/l
Copper	1 mg/l
Lead	0.01mg/l
Mercury	0.001 mg/l
Total chromium	0.05 mg/l
Zinc	3.0 mg/l
Nickel	0.02 mg/l
Anions	
Chloride	250mg/l
Fluoride	1.5 mg/l
Sulphate	250 mg/l
Nitrate	50 mg/l (as NO_3)
Nitrite	3 mg/l (as NO_2)
Pesticides	
Aldrin and dieldrin	0.03 microgram/l
DDT	2 microgram/l
Lindane	2 microgram/l
HCB	1 microgram/l
Methoxychlor	20 microgram/l
Heptachlor and Heptachlor oxide	0.03 microgram/l

3.1.3.3 Main Concept Design working principle (Wastewater Treatment for discharge or reuse)

The figure below illustrates the general working principle envisaged and proposed for the Waste Water Treatment Plant.

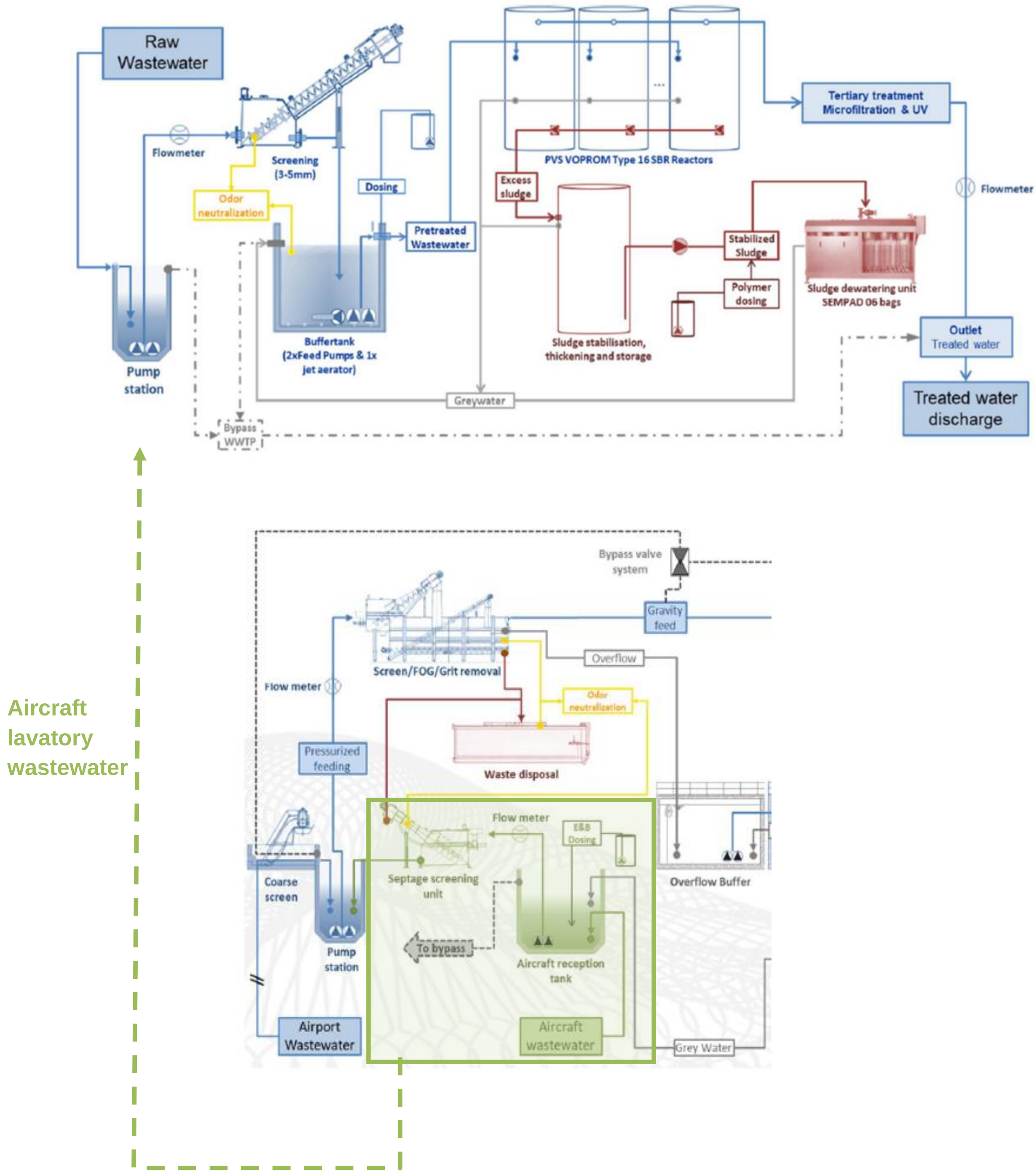


Figure 3: General principle proposed for the wastewater treatment plant

3.1.3.3.1 Pre-treatment of the wastewater from the Aircraft infrastructures

The wastewater from the aircrafts will first enter a receiving tank with a storage capacity of 2 days. This receiving tank will be equipped with special aerators and a dosing station which will add specific reagents in order to render the aircraft wastewater treatable.

A pair of clog free pumps will enable to feed the pre-treatment unit.

A flowmeter will count the flow of aircraft wastewater sent to the pre-treatment unit.

A special pre-treatment unit, developed and engineered in order to handle septic and highly concentrated wastewater from aircrafts will press and remove the suspended solids and sediment in order to obtain a wastewater quality adapted to the domestic wastewater flows coming from the airport infrastructures.

The pre-treated aircraft wastewater will be added to the general inlet pump station of the WWTP.

3.1.3.3.2 Pre-treatment of the domestic wastewater from the Airport infrastructures

The water will be lifted up by the pump station and the incoming flows counted with a flowmeter.

In addition, the pump station will be equipped with an overflow/bypass system. But this is to be used in a very exceptional situation.

The lifting station will send the wastewater to a screening unit in order to remove a maximum of suspended solids.

The waste removed by this primary step will be stored in dedicated waste disposal containers.

The primary treatment unit and the waste containers will be treated by an activated carbon for odour removal in order to avoid the spreading of unwanted gases.

In addition, the primary treatment will be equipped with an overflow sending the wastewaters to a buffer tank and a by-pass system in order to be able to by-pass the biological treatment for maintenance purposes.

After pre-treatment, the wastewater will be sent by gravity to a buffer tank.

3.1.3.3.3 Buffering of the screened wastewater

The wastewater will enter a buffer tank. This receiving tank will be equipped with jet mixing aerator and a dosing station which will add specific reagents depending on the quality of the wastewater.

A pair of clog free pumps will enable to feed the pre-treatment unit.

A flowmeter will count the flow sent to the SBR Cells.

The buffer tank will be designed in order to handle the overflows and return of greywaters.

3.1.3.3.4 Biological treatment with treatment modules.

After buffering, the wastewater will be sent to the biological reactors. There will be unit reactor cells and 1 stabilisation cell with a modular scalability. This means that each cell can be activated, put on hold or completely off-line from the process.

Therefore, the plant will be capable of adapting the treatment in regard to the influent loads giving the possibility to start with smaller amounts of wastewater and grow in regard to the airport growth itself.

The process is designed here in order to handle 15 to 20 m³/d of wastewater per reactor cell. It includes carbon, nitrogen and phosphorus treatment.

The biological system is also paired with the buffer tank, designed to handle all overflows from the reactors.

The excess sludge will be sent to an aerated stabilization sludge storage.

The treated water will be sent by gravity to a tertiary disinfection unit before sea outfall pumping via a specific pumping station.

3.1.3.3.5 Sludge treatment: stabilization, thickening, storage and dehydration

The generated excess sludge coming from the biological reactors will be treated within a dedicated sludge stabilization tank. This reactor will have following properties:

- Aerated storage of the sludge in order to avoid fermentation and odours
- Thickening of the sludge up to five times higher than in the biological SBR reactors
- Storage of the sludge in a liquid form

The stabilized sludge will be pumped out and sent to a sludge dehydration unit with capacity of 70% dry content. In order to reach this high dryness, the unit used will be the filtration bag technology. The sludge will enter the unit, the bags will hold up the sludge and the water will pass through the bags. Once the bags are full, they will be stored outside in order to dry out up to 70% of dryness.

The filtration bag technology is the best known on the market in order to reach high dryness capabilities and is suitable for installations handling up to 200 m³/d of domestic wastewater. An illustration is given below.

Figure 4: Example of the filtration bag technology proposed for the sludge treatment on site

3.1.3.3.6 Tertiary treatment of treated water

The treated effluents from the biological reactors will be polished with a microfilter unit in order to remove the last suspended particulate matter. This prior step is important in order to provide high efficiency for the bacterial removal.

After microfiltration the effluents will pass through a UV disinfection system in order to destroy bacteria, eggs and viruses.

Once the water is disinfected, it can be released to the sea according to the local regulations or reused as proposed either as industrial water or, if really necessary, to produce drinking water through the specific Reverse Osmosis treatment units.

The industrial water storage envisaged is of 400 m^3.

3.1.3.4 Main Concept Design working principle (Rainwater/Stormwater Treatment for reuse or discharge)

The stormwater to be treated and reused will be collected from the zones illustrated below, which exclude the new runway due to topographical constraints.

In accordance with the General Principle diagram (Figure 1), rainwater harvested from the roofs of buildings will be treated for reuse in priority to produce drinking water for the airport. This rainwater will be supported by the stormwater collected in the buffer storage for the drinking water production. However, stormwater reuse is preferably dedicated to “non-drinking” purposes.

For the drinking water production, it is envisaged the implementation of 2 reverse osmosis units after an adequate pre-treatment consisting tentatively of at least a drum filtration and a sand filtration.

The drinking water produced will be stored in the existing storage of 400 m^3 already connected to the water distribution facilities of the passenger terminal building.

The stormwater collected in the buffer storage will top up the rainwater harvested, if necessary, for drinking water production. Otherwise, it will be used for industrial water production. The excess will be discharged at sea. Stormwater is to be used preferably for “non-drinking” purposes.

The rainwater storage envisaged is of 400 m^3 (refer to the General Principle diagram - Figure 1).

Figure 5 below shows the catchment areas according to the topography.

Note: The stormwater collected from the green area along the runway could also be conveyed towards a buffer storage for reuse, as illustrated in Figure 2 above.

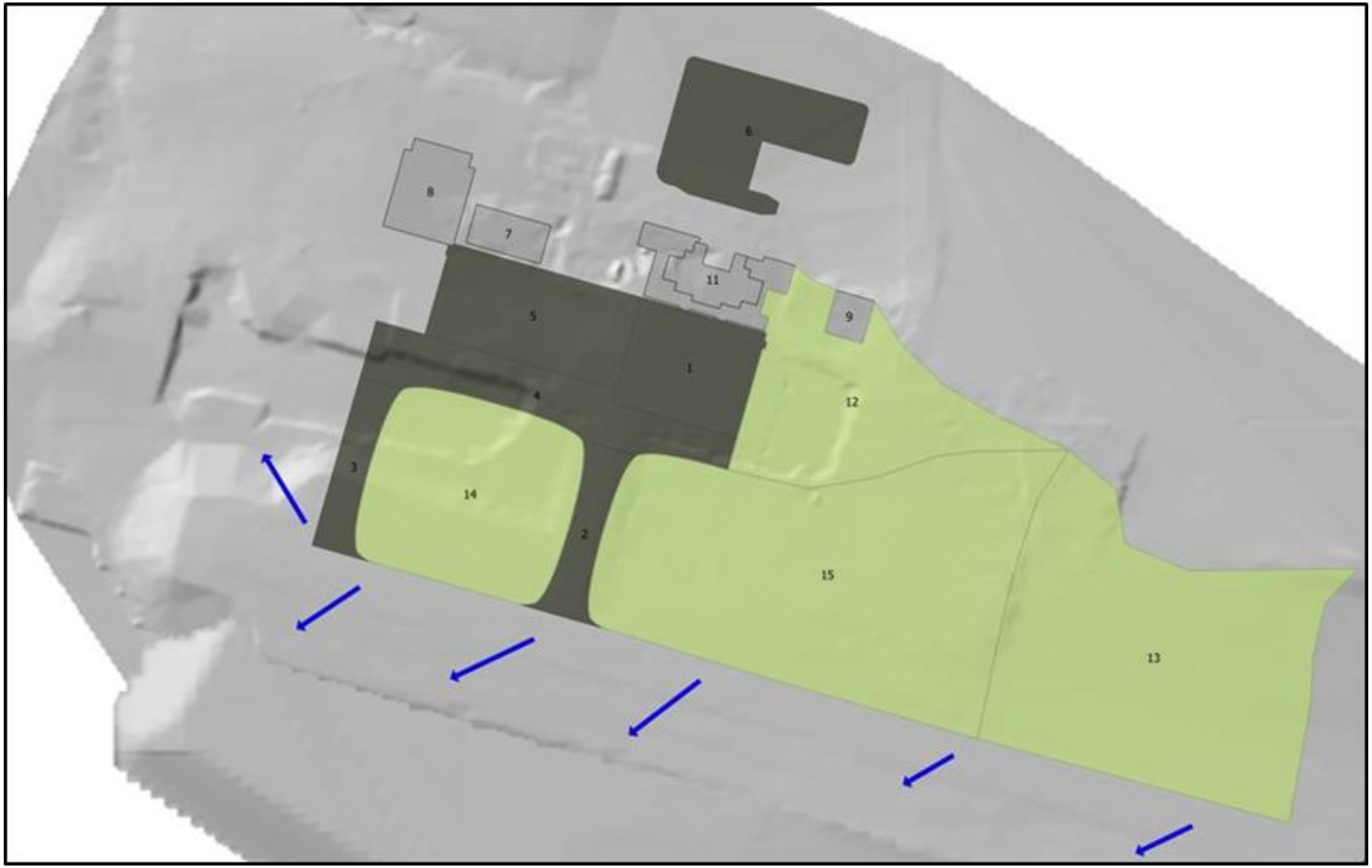


Figure 5: Zones for rainwater/stormwater collection for treatment and reuse

3.1.3.5 Main Concept Design assumptions and characteristics for the stormwater drainage management on the new runway towards Anse Quitor

The drainage system defined in the impact study replaces those proposed in the preliminary design in order to better take into account the issues associated with potential impacts on the natural environment and the reuse water network.

The design of the stormwater drainage system covers both quantitative (flows and volumes of water flowing on site and discharged to the natural environment) and qualitative (quality of water discharged to the natural environment) aspects.

On the quantitative side, the main issue is to protect the facilities against flooding. Since runoff is ultimately discharged into the ocean, and in the absence of issues vulnerable to downstream flooding, reducing the volumes of discharged water is not that essential. However, a particular attention is paid to the choice of final outlets in order to limit the concentration of the volumes of discharged water and to keep them away from sensitive sites, particularly the identified caves.

The main issue is therefore based on the quality of the discharged water, which is likely to have a strong impact on the end receiving environment (the lagoon). The aim is to treat chronic or accidental sources of pollution and to limit the supply of materials resulting from the erosion of drained catchment areas.

The stormwater drainage system is to be divided into two distinct sub-networks due to the general topography of the project:

- the first one, to the South, is to manage stormwater from the new runway and its surroundings, with gravity outflows to the lagoon south of the runway and Anse Quitor,
- the second one, to the North, is to manage rainwater from buildings, stormwater from car parks, taxiways and their surroundings, with a natural outlet to the west, towards the existing boat house. This drainage system will feed the water re-use process as indicated in the above scheme.

3.1.3.5.1 Stormwater drainage of the airport installation, to the North of the new runway

To the North of the future runway, stormwater from the airport facilities (including collecting roofs, roads, parkings, taxiways and part of the existing runway and the natural watersheds overhanging) is collected to a retention basin to buffer peak flows and supply the stormwater reuse network.

The outlet of the roads, parkings and taxiways stormwater network will be equipped with an oil separator designed to collect and treat up to 20% of the flow generated by a 2-year return period rainfall. The outlet of this network is also equipped with a first storage works associated with a valve to isolate the flow from the natural environment in the event of a pollution (leakage of polluting liquids, water from fire fighting, etc.).

As no risk of flooding associated with rainwater discharge has been identified, the main objective of the buffer tank is to reduce pollution and sedimentation to the lagoon, thus protecting biodiversity, corals and white sandy beaches.

The buffer tank is therefore to be sized to contain a 2-year return period rainfall with a leakage rate of 10L/s/ha of drainage area. If the soil allows it, infiltration can be preferred. A sea outfall is to be implemented for discharging at sea the excess water that cannot be reused. The sea outfall for excess stormwater is to be implemented tentatively in the zone of the existing boat house and new sea rescue facility, in common with the sea outfall of the WasteWater Treatment Plant.

However, the sizing of the collection system and of the buffer tank will have to take into account the evolution of rainfalls associated with the climate change. A higher intensity of the 2-year event obtained by the current rain data of Rodrigues is to be considered in the detailed design phase depending on the climate change prediction in the region.

3.1.3.5.2 Stormwater drainage of the **new runway** and associated taxiways

The stormwater drainage of the **new runway** and associated taxiways is to be designed to collect the first flows of runoff loaded with potential pollutants in a watertight network, connected with oil separators and sedimentation works. The outlet of this network is also to be equipped with a storage capacity associated with a valve to isolate the flow from the natural environment in the event of a pollution (leakage of polluting liquids, water from firefighting, etc.). All these structures will be designed to collect and treat up to 20% of the flow generated by a 2-year return period rainfall.

Over and above these first flows, the water is to be evacuated away from the runway to avoid any risk of flooding.

To the North of the runway, a large ditch will collect its flows. It will also collect runoff from the excavated hillside created by the project that could flow to the runway in the absence of such existing works (cut-off drain). The ditch will be vegetated, wide and shallow, in order to reduce flow velocities and spread water; this will allow to:

- facilitate the natural infiltration of water if the soil allows it,
- reduce transfer times to the natural outlet,
- reduce the risk of erosion and the transfer of materials to the lagoon.

This ditch will be divided into several linear sections to create different evacuation points to the ocean, to the South of the runway, via structures passing under the runway, if necessary. All these works will be sized at least for a 50 year return period rain event.

The sizing of the leak-tight collectors could be increased over 20% of the 2-year event rainfall, if necessary, in the detailed design phase in order to limit the use of the infiltration system which can be subject to failures and sinkhole collapse if used too frequently. Indeed, water and sewer systems in karst areas are prone to failure caused by small leaks that create minor subsidence, which then leads to major drainage system failure.

Moreover, as for the stormwater drainage of the airport installation, the sizing of the collection system and of the buffer tank will have to take into account the evolution of rainfall associated with the climate change. A higher intensity of the synthetical rainfall events obtained by the current rain data of Rodrigues will be considered in the detailed design phase depending on the climate change prediction in the region.

On the southern part of the runway, flows will be in free runoff over the grassed shoulders and will flow to the ocean.

The project has been designed to evacuate the stormwater avoiding the sensitive points of caves and favouring multiple discharge points to the ocean to avoid concentration effects in the receiving environment. In addition, the first runoff is collected in leak-tight collectors and pre-treated before discharge.

Note: We do not know yet the sensitivity of the receiving environment (Marine Impacts) which will be assessed in April 2023. The impacts and the corresponding mitigation will be determined soon afterwards.

These principles are presented on the illustrating figures hereinafter.

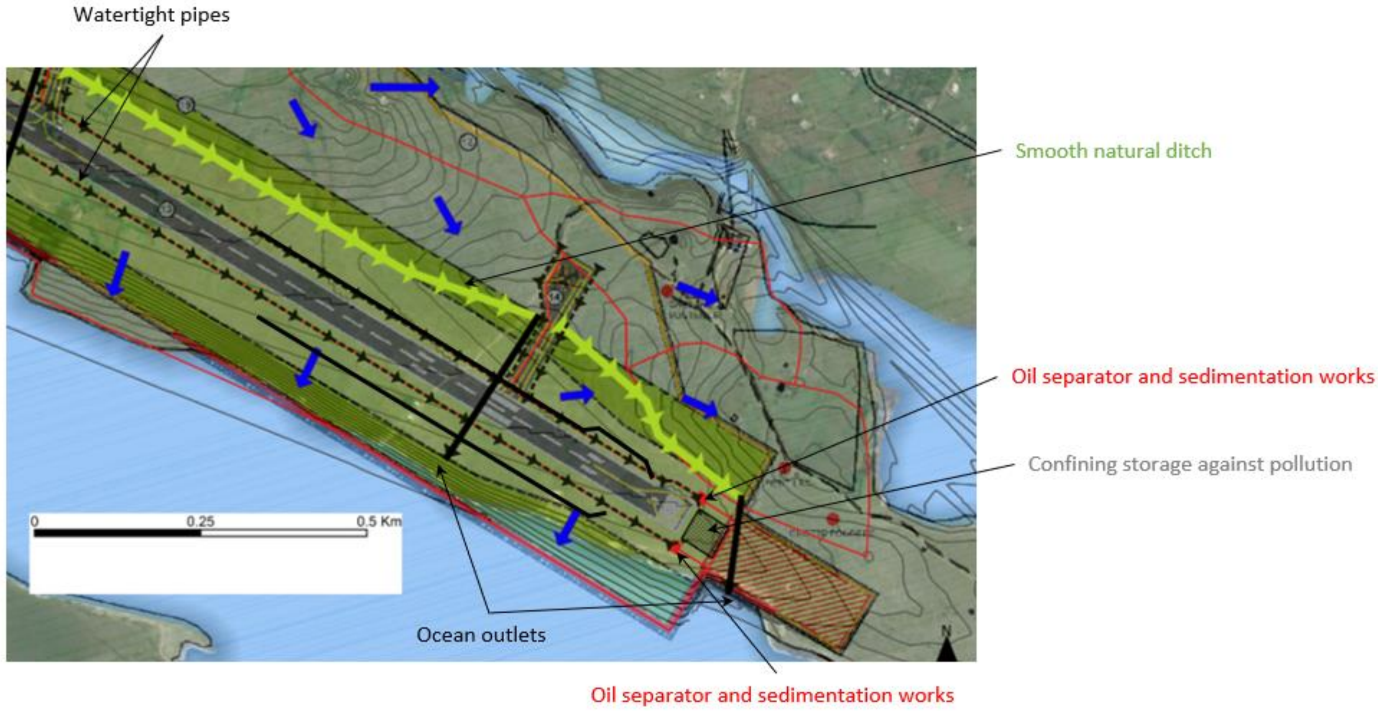
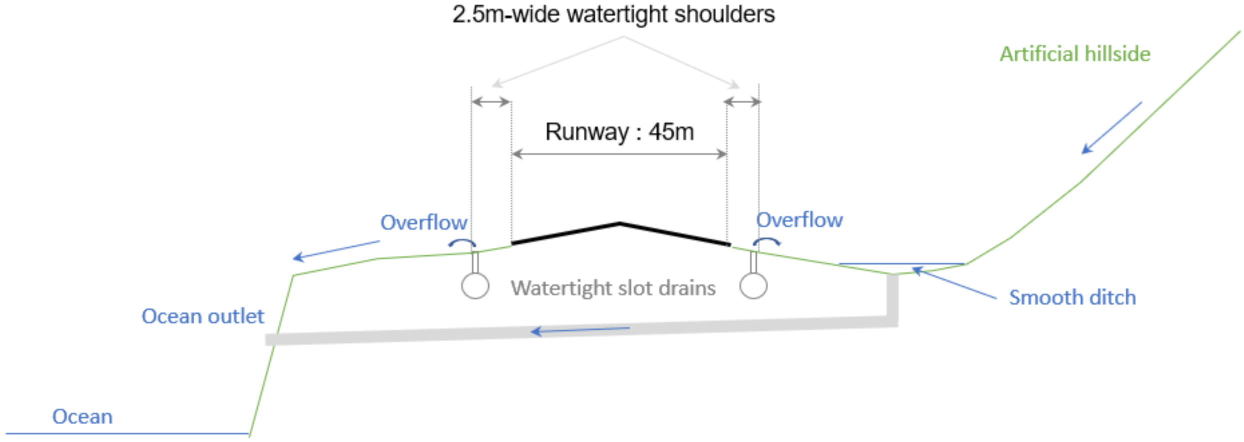


Figure 6: Schematic diagram of the stormwater network



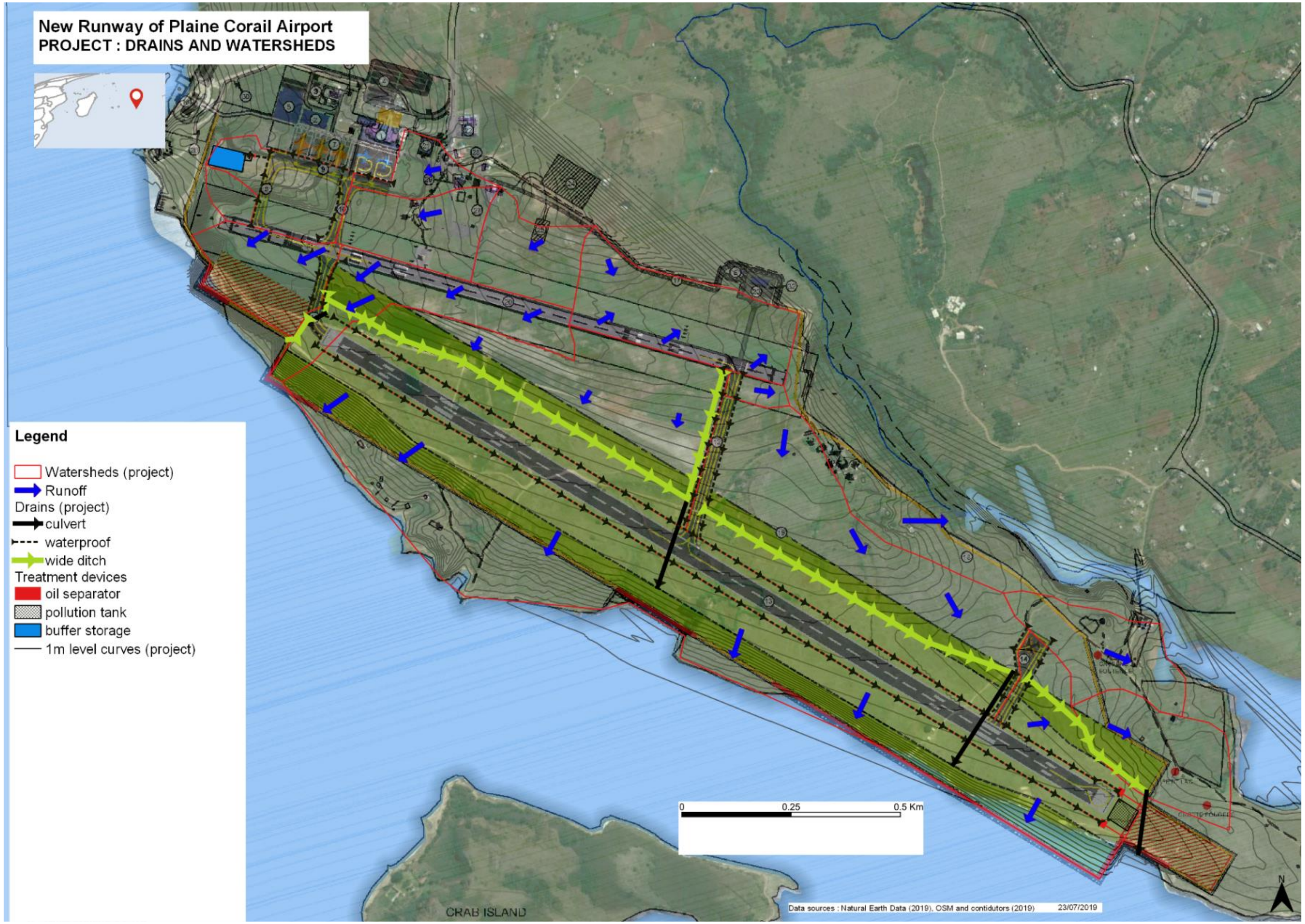


Figure 7: Projected watershed and stormwater network

3.2 Construction Activities

As the project is only at the Preliminary Design stage, the construction phase has not been described yet in details. Only some principles are known.

Precise methods, phases and organizations will be described in the Detailed Design, following the recommendations of the Environmental and Social Management Plan provided as a last chapter of this ESIA Report.

3.2.1 Worker's installation

As about 400 workers will be needed for the works and a part of them will come from Mauritius or other countries, a **workers' camp** will be erected for the workers.

The location of the site establishment and workers' camp is recently known and given on Drawing No M243/DD/CE/SK/07 below. The impact assessment of such facilities will be discussed with the Consultant responsible for drafting the Terms of Reference for the Tender for construction.

Figure 8: Temporary facilities associated with the construction phase

3.2.2 Work site supply - water

Water supply, estimated to be around 40 m^3 per day, might not be possible from the public reservoir if the works' needs are too important. Therefore, the Terms of Reference for the contractor will include the provision of a desalination plant and the minimum measures that will need to be complied with will be stipulated in the final ESIA and ESMP.

The following assumptions are made regarding the anticipated temporary desalination plant that is required during the construction phase:

The water desalination plant will be a pre-fabricated and pre-tested reverse osmosis unit designed to produce 20 m^3/day. To date, assumptions have been made on the water characteristics which will be confirmed at the end of the detailed design. The desalination plant may be constituted of:

- A prefiltration system equipped with:
  - a pump
  - a sand filter to remove particles up to 80 µm.
  - a microfiltration system to remove particles up to 5 µm
  - an anti-fouling dosing to prevent co-precipitation on the membrane surfaces
- A reverse osmosis system equipped with an energy recovery system with pressure exchanger that does not require any electric energy, working at an efficiency of about 95 percent and practically maintenance free.

A 35 percent recovery rate is expected.

Special attention will be put on the brine discharge and disposal. One recommendation, at his early stage, in the Terms of Reference for the provision of the desalination plant could be a zero liquid discharge of the brine, which will potentially allow for the production of salt on site. As such brine could be treated through an evapo-concentrator-condenser-crystallizer instead of being diluted and rejected in the natural environment.

This is fully in line with the integrated management plan that aims at optimizing the different water uses.

The potential impacts associated with the desalination plant and potential mitigation and management measures will be further assessed as part of the final ESIA and ESMP, namely with respect to the final configuration retained for the brine discharge and towards the marine environment impacted.

4 Water management baseline conditions

4.1 Hydrology

This chapter describes the rivers and surface water characteristics of the stormwater system. It indicates how the storm water is managed in the project area, depending on the geology, soil properties, and topography. The goal is to base the assessment of the project and earthwork impact on the river flows and floods on it.

The chapter also presents the hypotheses considered in the conception of the stormwater management system of the project.

4.1.1 Water catchment physical characteristics

The Island of Rodrigues is divided into 38 major river basins. Their catchment areas vary between 0.35 Km^2 and 7.02 Km^2 as shown in the figure below.

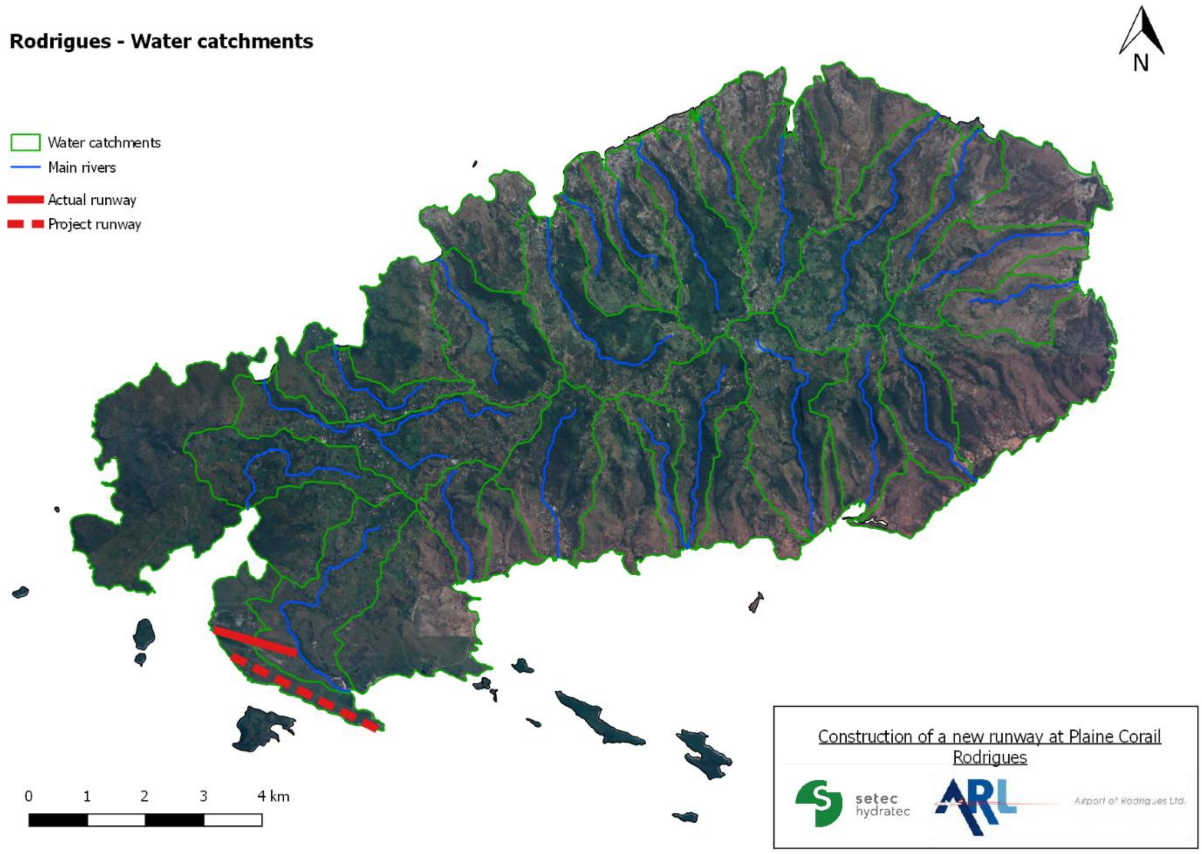


Figure 9: Water catchments

In most water basins, the low permeability of soils generated by alteration of basalt suggests a generally low infiltration capacity, which is sometimes increased locally by the presence of fracture zones.

As for most volcanic islands of comparable geological structure and topography, a proportion of the amount of water infiltrated during rainy episodes is returned to the sea. This part can represent a significant fraction of the water balance of a watershed.

The rivers that lead to the North, East and South coasts of the island have watersheds of similar morphology. Watershed heads are characterized by soft-shaped hills (slopes of 10 to 20%). Further downstream, the rivers have cut into very small valleys. The slopes that generate the flow are then very steep (30 to 100%), with frequent waterfalls in the beds and cliffs on the top of the slopes. Transfer times of the flow generating zones are very short as a result.

Therefore, although the main watersheds are usually relatively elongated, their concentration times are very short: around 15 to 30 minutes at their mouth into the sea, for the most abundant. Response times are extremely short and hydrological regimes are a succession of fast and short-lived floods separated by dry periods of varying lengths.

The deep cut valleys with steep gradients and the absence of impounding reservoirs in Rodrigues result in most of the rainfall over the island being lost to the sea as high velocity runoff. Due to negligible infiltration to groundwater, base flow of rivers is very low. The flows range from 1.4 l/s in Riv. Grenade to 56.9 l/s in Riv. Baie aux Huîtres.

4.1.2 Rainfall analysis

The definition of the hydrology scope depends upon territorial and climatic data, including rainfall data. Rainfall is the main input data for flood estimations (with sea level when it comes to coastal area), due to the availability of historical records and the presence of measuring stations throughout the island.

The main issue for rainfall assessment is the definition of statistical intensities and their spatial repartition on the territory for intense events, which can generate flood events. Indeed, a geographical gradient is observed for the annual rainfall between coastal areas (less than 1,000 mm) and the central plateau (over 1,600 mm).

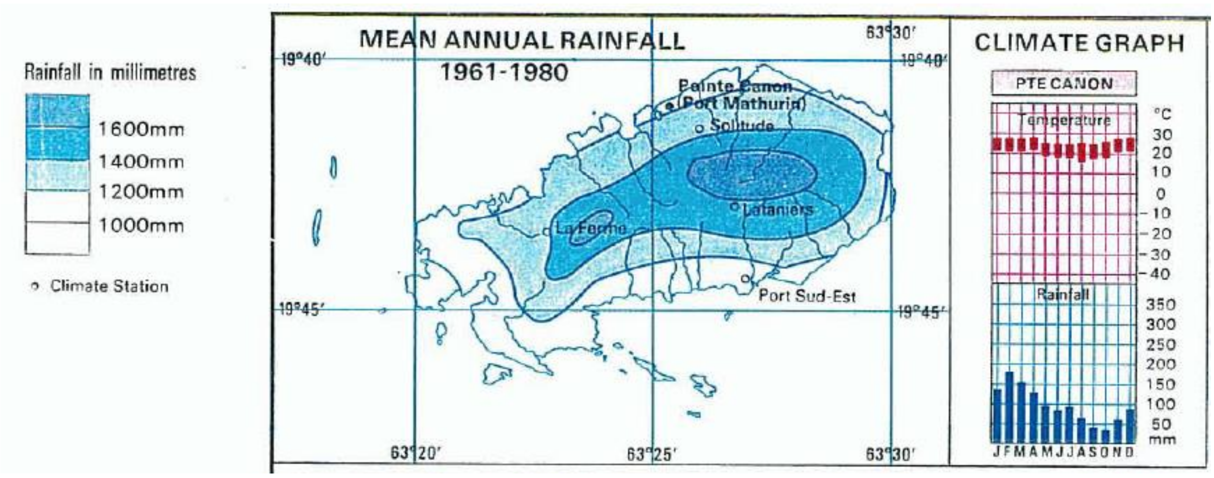


Figure 10: Mean annual rainfall – Rodrigues ("Etude d'un programme de lutte contre l'érosion à Rodrigues", BRGM, ONF, Impact, December 1996)

4.1.2.1 Rainfall stations, available data

Mauritius Meteorological Services (MMS) is collecting data from its own recording systems, and from private ones. The existing rainfall stations network (the only automatic weather stations) for Rodrigues Island is shown on the map below.

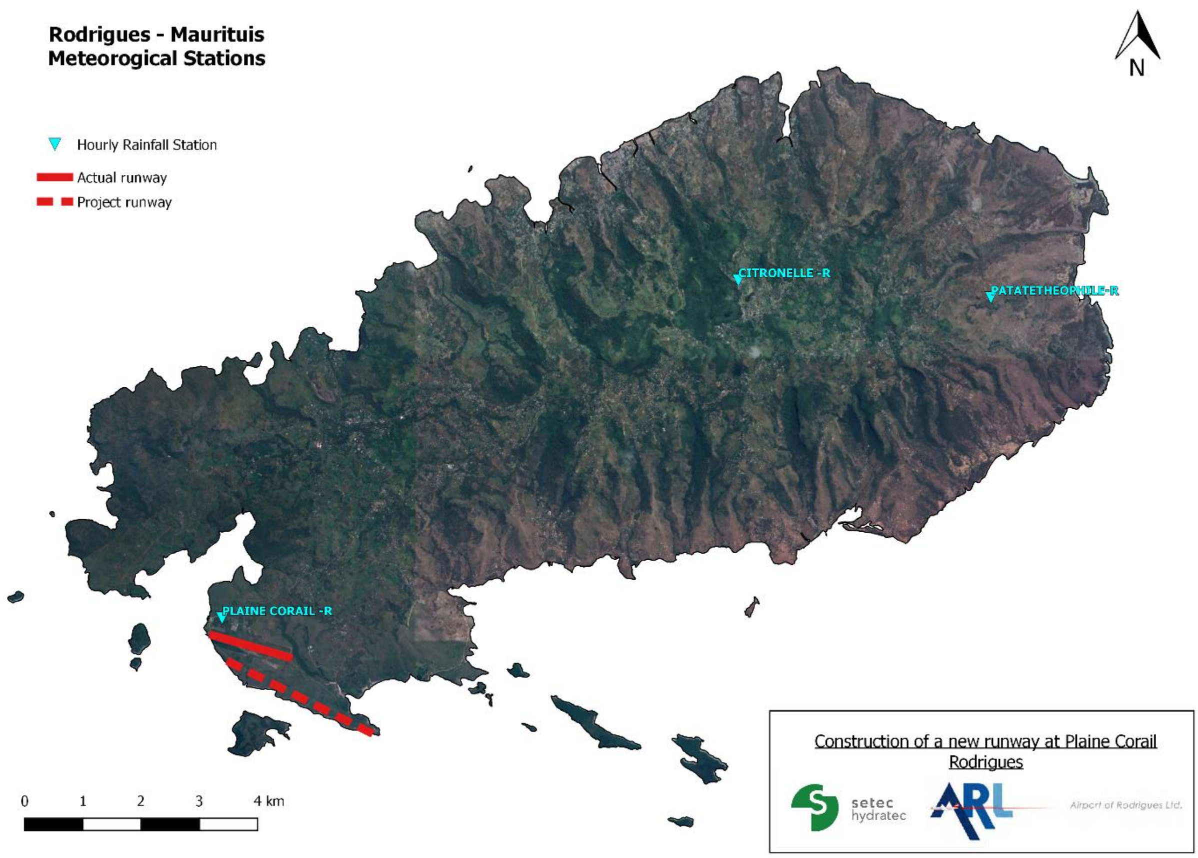


Figure 11: Rainfall stations. Note: The station "Plaine Corail – R" corresponds to the study area

4.1.2.2 Statistical analysis

Rainfall statistical analysis can be synthetized in Intensity – Duration – Frequency (IDF) curves.

Hydrological studies for statistical discharge estimation are based on IDF curves established from storm rainfall data across the island.

Note: Rainfall data specific to the Rodrigues Airport platform is not available since they do not exist. Therefore, as in the Preliminary Design, the rainfall data to be considered is the one used for Mauritius and based on the same IDF curves as Mauritius.

4.1.3 Runoff, rivers and flooding

The airport is located near the Anse Quitor River. The river is quite deep near the actual airport runway, and there is no potential flooding expected as a result.

The illustration below shows the Digital Elevation Model (DEM) of Rodrigues. This DEM was made from level curves of 10 m. The next figure shows a zoomed-in view of the DEM on the project area with level curves and flood areas for a 100-year return period.

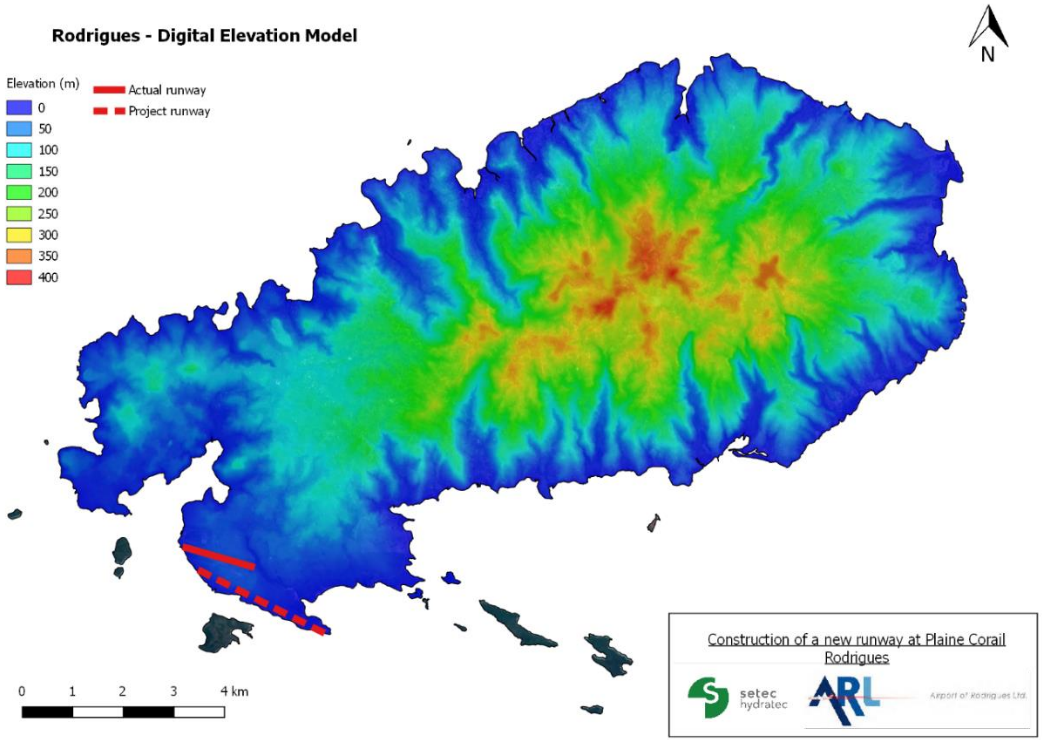


Figure 12: DEM of Rodrigues

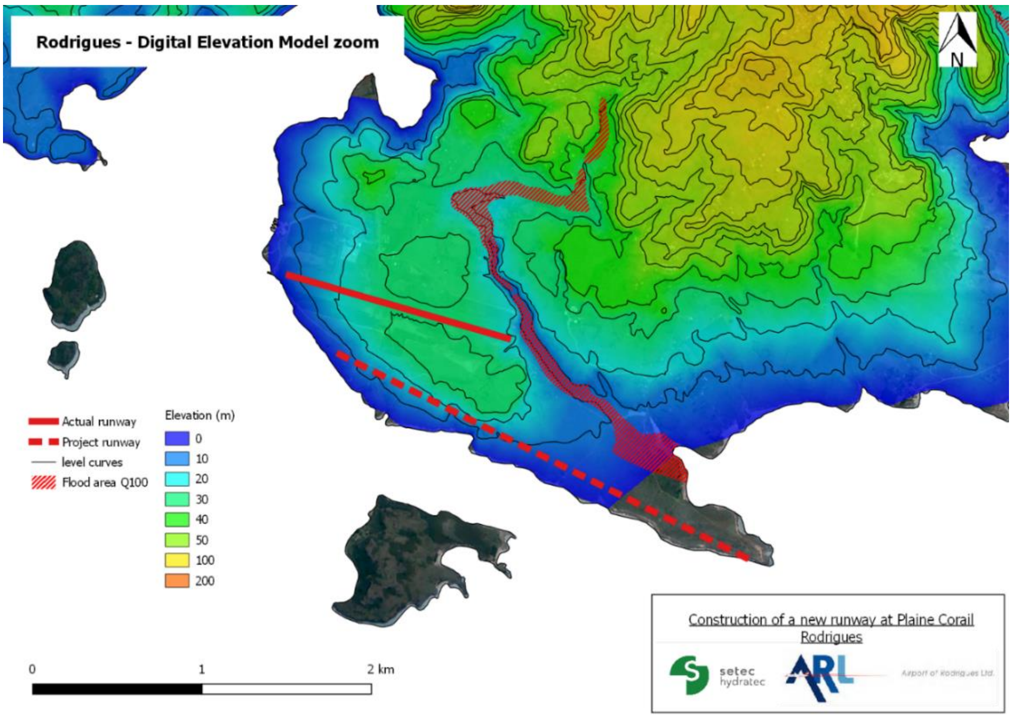


Figure 13: DEM of Rodrigues (zoom) and flood area for Q100

The map below shows a detailed view of the topography of the site from a 2m planimetric resolution point seedling.

On the basis of this topographical data, existing maps and observations made on site during the first field visit carried out at the beginning of April 2019, the sub-watersheds as well as the main runoff and rainwater drains could be specified:

- Artificial ditches. During the second site visit carried out with ARL at the beginning of May 2019, a drain was observed only around the existing apron and along the taxiway in front of the passenger terminal building, which passes under the existing taxiway and discharges the stormwater into the natural environment nearby as illustrated hereinafter.
- Natural low points of runoff concentration; however, no ditches are marked.

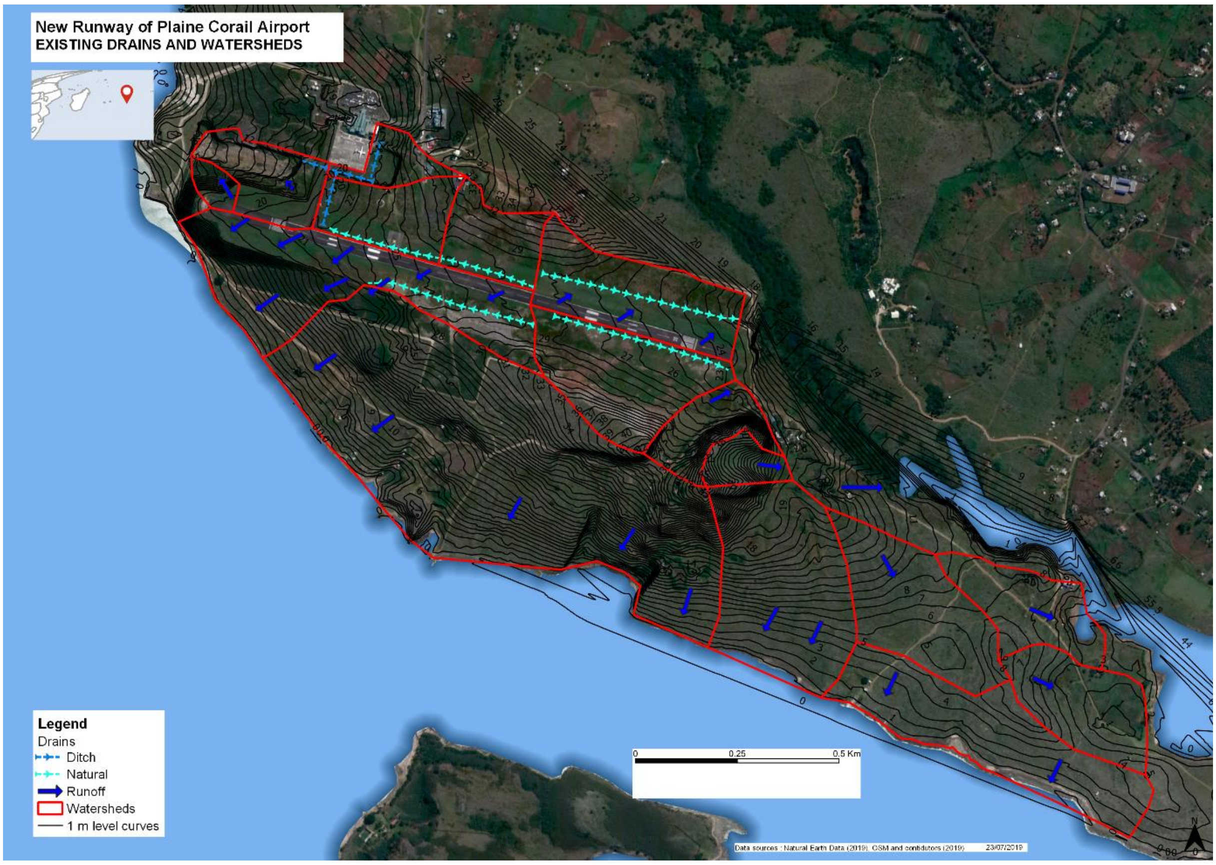


Figure 14: Detailed view of the watersheds and drains of the existing site (topography 2 m planimetric resolution)

Runoff from the current runway flows diffusely to the shoulders and into the natural drains. These runoffs are thus directly discharged into the natural environment.
The topography of the current track makes it possible to manage current rains without damage:

- slightly elevated topography compared to the low drainage points of natural watersheds,
- slight lateral slope allowing a regular drainage of water to the shoulders.

Figure 15: View south / north of the current runway – April 2019 field visit

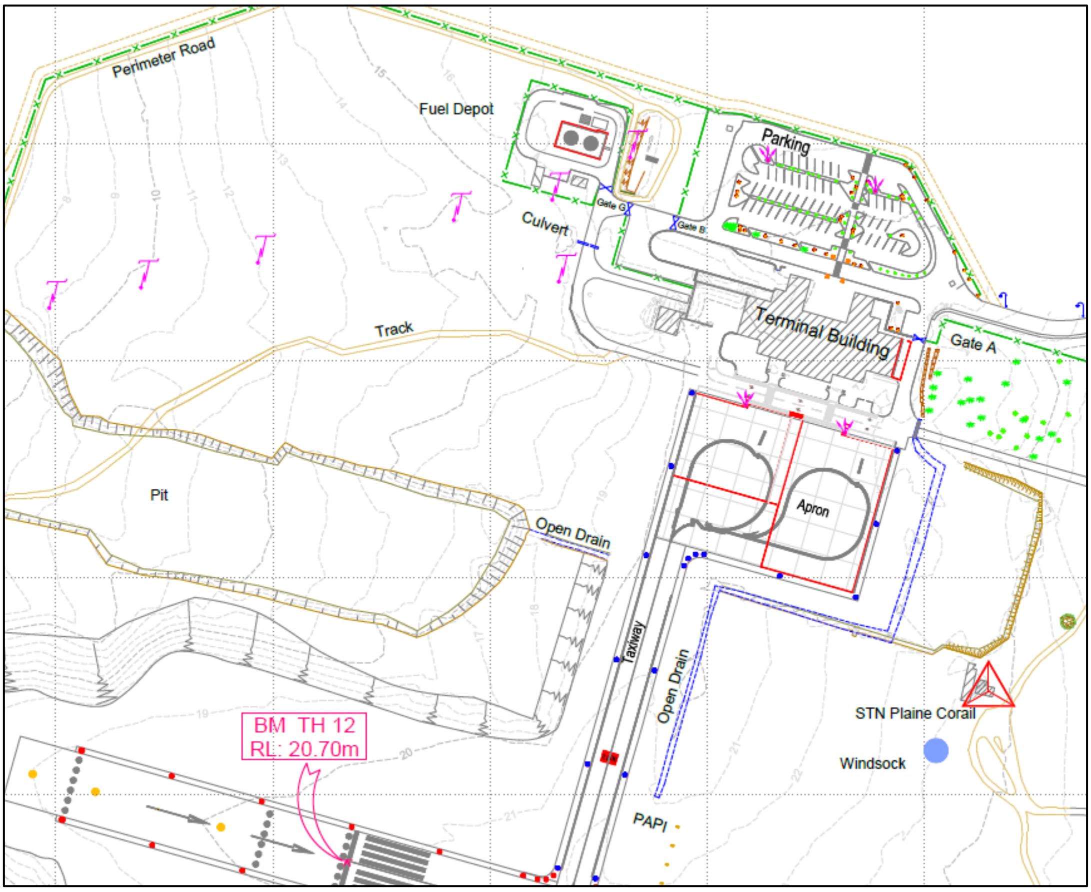


Figure 16: Extract of the general layout drawing showing the existing drains observed around the apron in front of the passenger terminal building

Figure 17: View of the existing drains observed around the apron in front of the passenger terminal building

Figure 18: View of the existing drains observed around the apron in front of the passenger terminal building

An uncertainty still remains on the accuracy of the flood zone observed on the previous map, particularly at the mouth of the Anse Quitor River illustrated below:

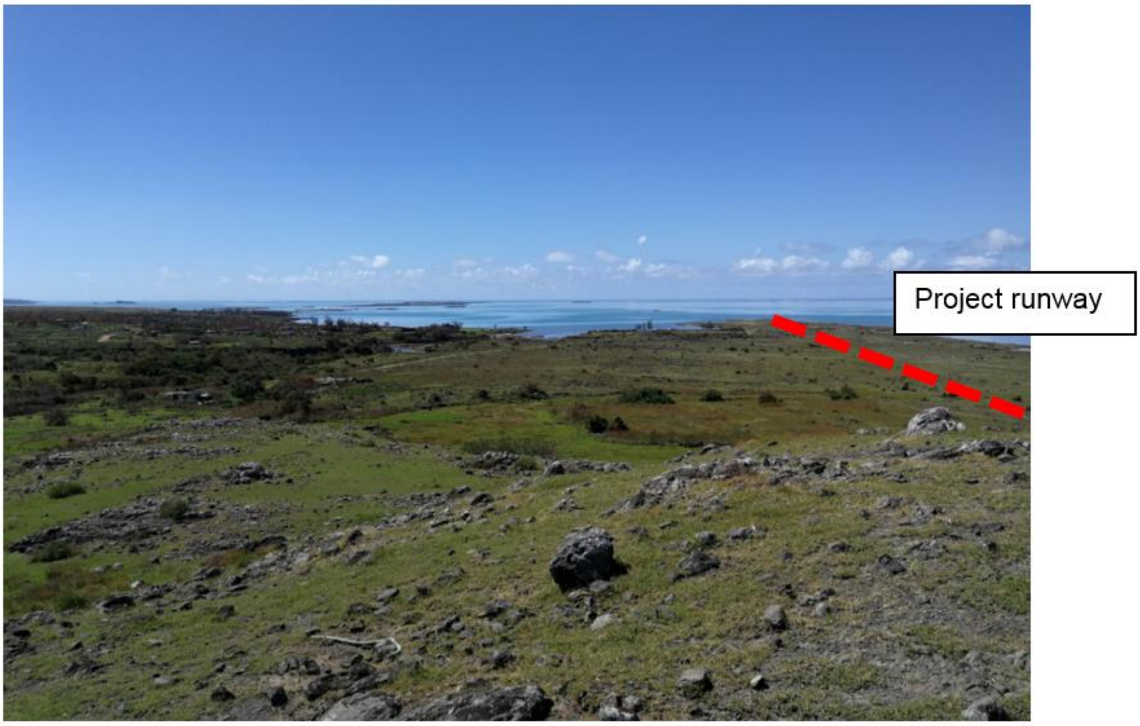


Figure 19: View north/south of the site of the project runway – April 2019 field visit

The first field visit highlighted a flat outlet of the Anse Quitor River, which is probably a flood-prone area.

Even if the boundaries of the project runway are probably in the flood area, the installations on fill above the original ground level will not be concerned by flooding and run-off.

The position on a watershed with no other built-up issues also limits the risks associated with stormwater run-off.

Thus, in light of the above, we can observe that the problem of stormwater run-off only concerns the drainage of the various platforms that will be managed and equipped with drains. In case of extreme events and overflowing of the drainage systems, stormwater will be discharged to the sea in gullies without impacting issues.

4.1.4 Hydrology issues

4.1.4.1 Stormwater management

Stormwater management is an issue regarding the new runway and its proper drainage is therefore important in order not to disturb the operation of the runway during landing and take-off of airplanes. Furthermore, its proper pre-treatment, with respect to oil, grease and suspended solids in our case, is also important before its discharge in the environment or at sea.

This issue sensitivity is of a major level.

4.1.4.2 Flooding of issues downstream of facilities

The development is likely to change the downstream flows. As no watercourses cross the project and all stormwater runoff discharges flow directly to the sea, no built environment issues are likely to be affected by this risk.

This issue sensitivity is of a low level.

4.1.4.3 Transfer of pollution to the natural environment

Transfer of possible pollution from the runway by stormwater runoff directly to the natural environment, including effluents generated by a fire fighting operation on the runway.

This issue sensitivity is of a major level.

4.1.4.4 Transfer of sediments to the lagoon

Stormwater management including a buffering storage and / or other works facilitating infiltration and reducing soil erosion enables to address climate change adaptation for disaster risk reduction. In fact, reduction of peak flows, run off and soil erosion leads to reduced sedimentation of water bodies including lagoons, thus protecting biodiversity, corals and white sandy beaches. The buffering storage offers an opportunity of confining any pollution generated by an eventual firefighting on the runway.

This issue sensitivity is of a major level.

4.2 Water resource and waste water management

4.2.1 Water supply in Rodrigues

4.2.1.1 Current water supply

As Rodrigues is a small island, fresh water is a scarce resource. It comes from dams built on rivers, but also many boreholes and springs that are typical of karst areas.

The daily **water demand** for Rodrigues is estimated to be 11.000 to 12.000 m³/day.

This demand is satisfied by rainwater harvested by private individuals in private reservoirs and by water provided by the public services.

The production of water varies depending on rainfall intensity and frequency. The daily fresh water production is provided by surface water harvesting, boreholes, and desalination of marine water, in the following proportions:

Table 13: Water production for 2017/ 2022

Serial No.	Sources	2017	2019	2020	2021	2022
1	Surface water	1273	3000	3404	3033	2887
2	Boreholes	2529	3148	3510	1899	1878
3	Desalination	628	1200	1677	1805	1135
	Total	**4430**	**7348**	**8591**	**6737**	**5900**

Two desalination plants are already operational in Rodrigues:

- Songe, with a capacity of 500 m³/day;
- Caverne Bouteille, partially powered by solar energy and located close to the project area, with a capacity of .
  - Solar hybrid plant : 240 m³/day of potable water
  - Electricity plant : 300 m³/day of potable water
  - A project is currently under consideration to rise the capacity of the electric plant up to 1000 m3/ day.
- Caverne Bouteille plant'spotable water is distributed to about 1 500 families in :
  - Vangassailles
  - Anse Quitor/Corail
  - Cascade Jean Louis
  - Petite Butte
  - Grand Var
  - Plaine Corail/Airport
  - Grand La Fouche Corail
  - Mt Cabris
  - Camp Pintade
  - Citadelle
  - Pistaches
  - Piment/ Reposoire
  - Baie Topaze
  - La Ferme.
- The capacity of extraction of salty water is about 3 200 m³/day.

Here are the water quality results according to analysis carried out in Caverne Bouteille intake:

1.0 Intake Borehole water (before treatment)
2.0

Frequency	Parameters	Range of results
Daily	pH	6.2 – 8.4
	Cond	20100 - 29900
	TDS	10300 - 17900
	Salinity	12.2 - 18.6
Monthly	Chloride	10997 - 12876
	Sulphate	1602 - 2370
	Potassium	152.77 – 234.61
	Sodium	5119 - 6485
	Nitrate	<0.04

2.0 Desalinated Water (after treatment)

Frequency	Parameter	Range of results
Daily	pH	6.52 - 8.45
	Conductivity	119 - 550
	TDS	59 - 280
	Salinity	0.06 - 0.26
Monthly	pH	6.5 – 6.9
	Conductivity	511 - 561
	TDS	343 - 389
	Salinity	0
	Hardness	42 - 59
	CaCO3(alkalinity)	16.9 – 19.8
	Chloride	209 - 232
	Sulphate	9.67 – 12.89

Water distribution is managed by the water resources, water is collected from dams, boreholes and desalination plants, pumped uphill for storage into reservoirs prior to distribution by gravity on the network.

Water is treated prior to distribution on the network, the water from boreholes is not necessarily treated prior to storage into distribution reservoirs.

The map below shows the water network in Rodrigues.
A reservoir is located in the project area, named Bangelique reservoir, but it's not used anymore. A spring used for fresh water is located north of the project area, very close to the restricted area.

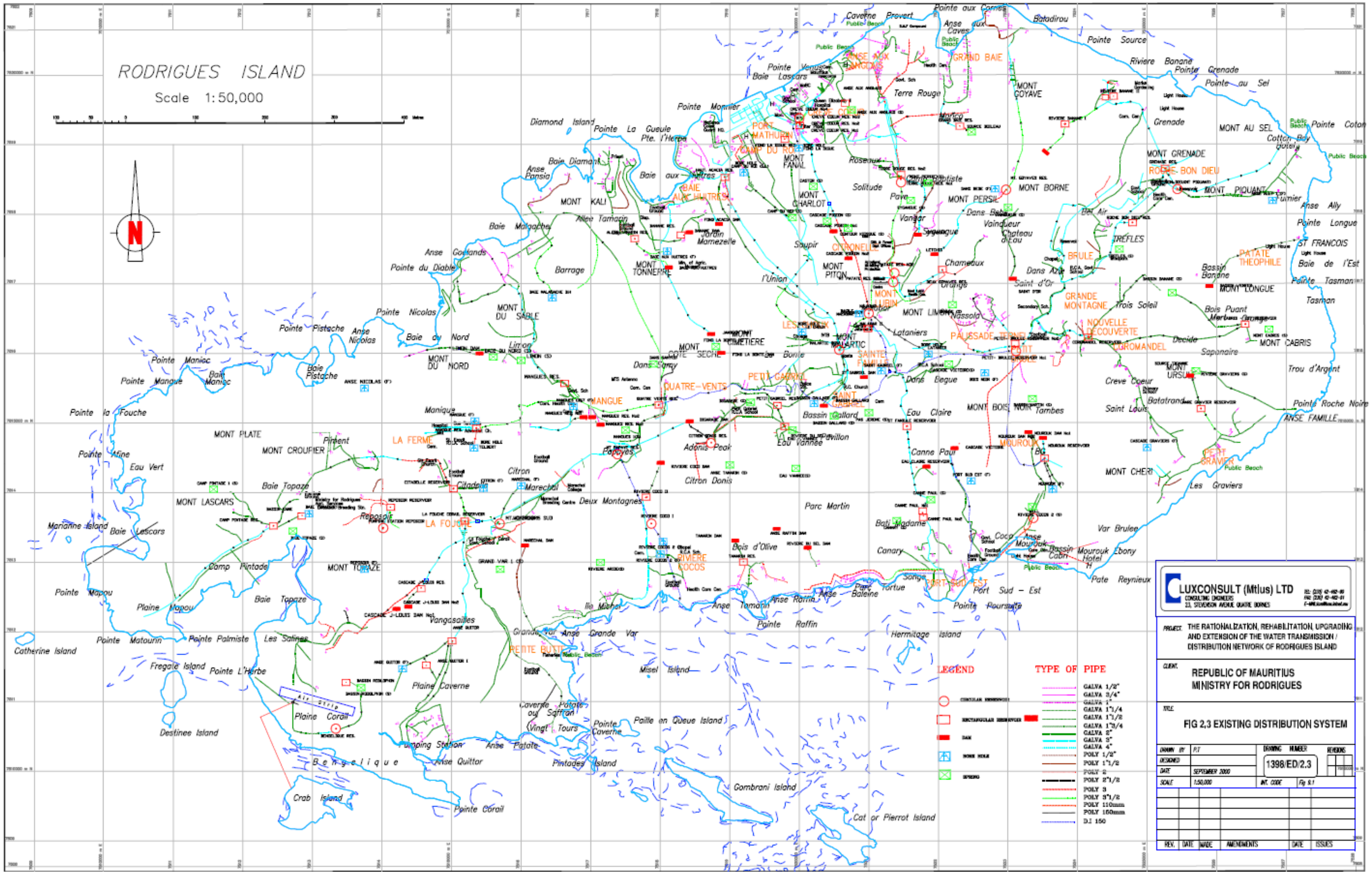


Figure 20: Water network of the island

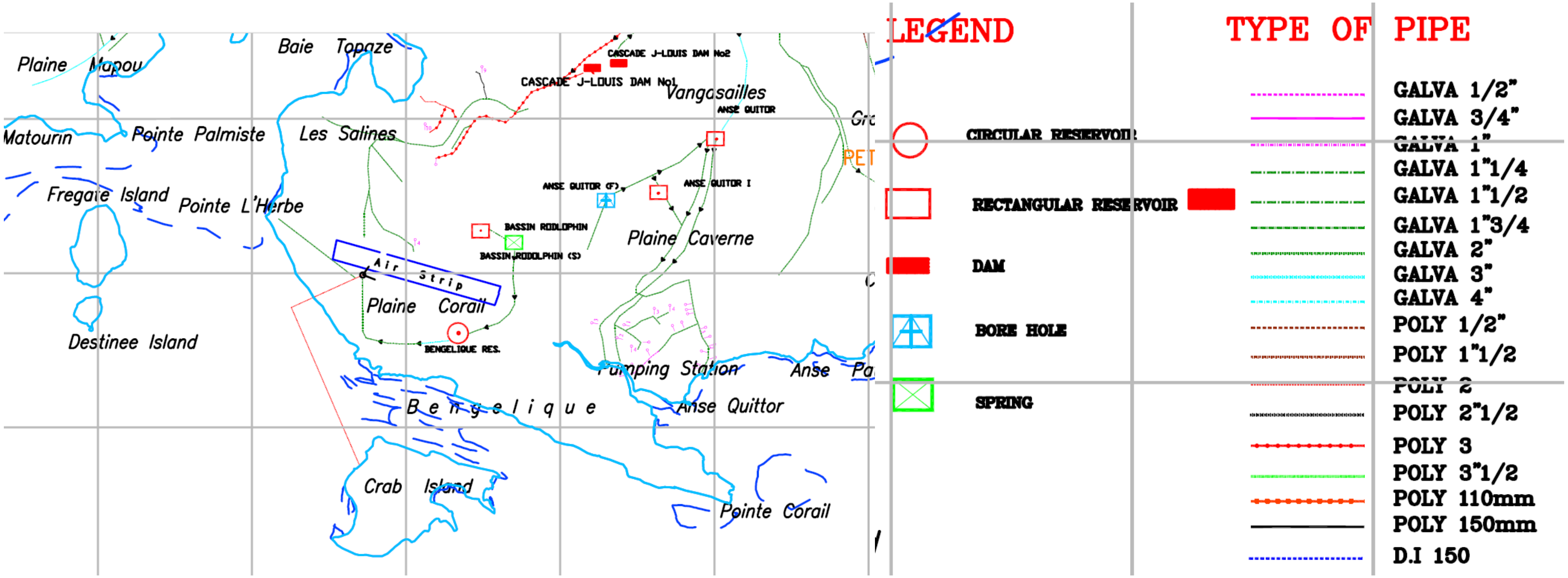


Figure 21: Water network in Plain Corail and the restricted area

4.2.1.2 Project for increasing water production

Two new desalination plants are to be commissioned:

- Pointe cotton;
- Baie malgache.

There is also a project of construction of a dam at Pave la Bonte or Anse Baleine, still under study. New boreholes could be projected, not precisely defined.

There is currently no master plan available for the water development at the commission for water resources. A consultation with the Government of India is currently ongoing to master and control the development of Rodrigues up to 2045.

4.2.1.3 Water supply and consumption in Plaine Corail Airport

The airport platform is connected to the public water supply distribution network. However, due to the erratic water supply from the public water network, the airport of Rodrigues relies mainly on rainwater harvesting to meet its daily water requirements.

The water collected from the roof of the terminal building is not treated and is used mainly for sanitary purposes and general maintenance and cleaning of the facilities at the passenger terminal building at Plaine Corail Airport.

The airport has a total storage capacity of 400 m^3 plus 2 additional individual tanks for rainwater harvesting. The main storage of 400 m^3, comprising 2 compartments in connection with each other (isolation of any one compartment possible) caters for a reserved volume for firefighting. The storage is also supplied by drinking water from the public water network. The water is used at the passenger terminal building and for firefighting (fuel depot) purposes using booster pumps installed in a room behind the storage concrete tank, as illustrated below.


Figure 22: Water storage and distribution facilities at the airport passenger terminal building

The graph below, provided by ARL, shows the water consumption of the airport for the year 2017. It can be observed that the water demand is highest during the months of October, November and December, which corresponds to Rodrigues' highest passenger traffic period, coinciding with school holidays in the Mauritius and Rodrigues Islands. During this period, the average daily water consumption reaches an average of 12.5 m^3 per day. For the rest of the year when traffic is at its lowest, the minimum average daily water consumption is 3.6 m^3 per day. The average daily water consumption is estimated to 5.6 m^3 per day irrespective of the time of the year. This amount is expected to increase proportionally with the increase in passenger traffic at Plaine Corail Airport.

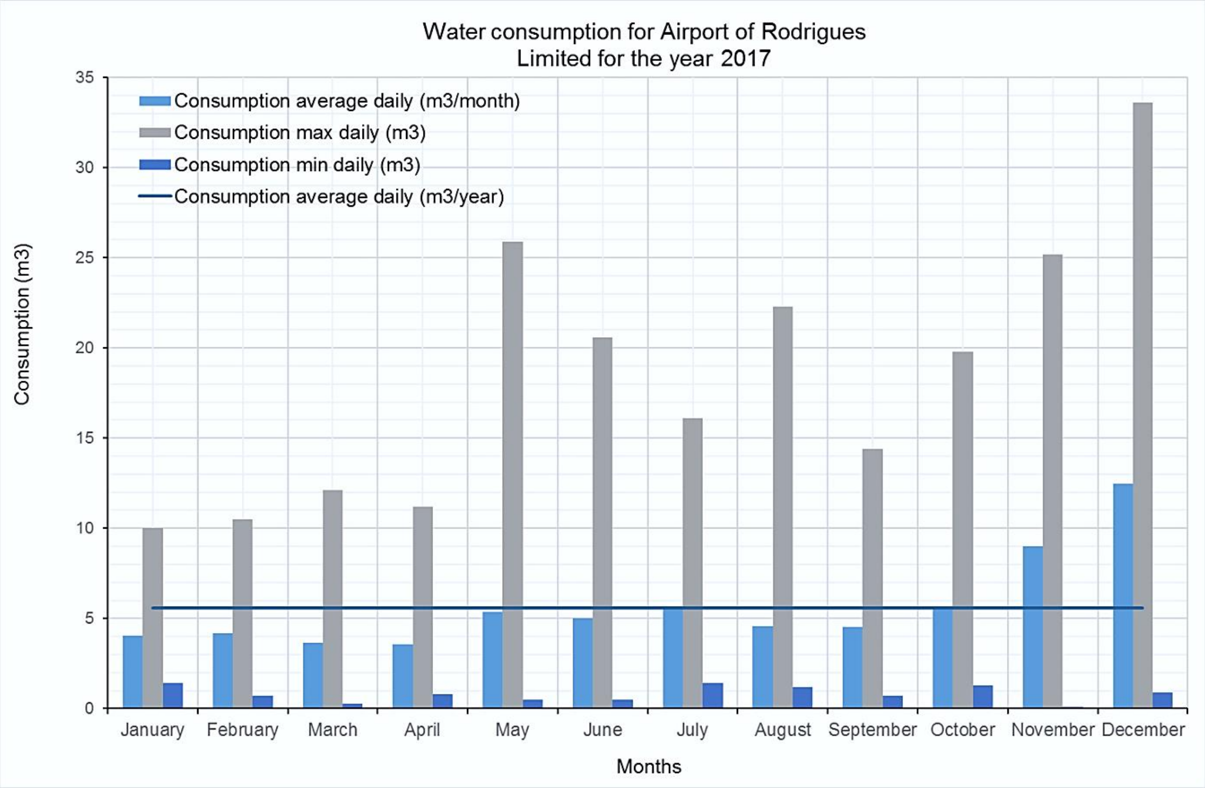


Figure 23: Graph of the water consumption for Airport of Rodrigues Limited for the year 2017

Table 14: Data table of the water consumption for Airport of Rodrigues Limited for the year 2017

Months	**January**	**February**	**March**	**April**	**May**	**June**
Consumption average daily (m3/month)	4.0	4.2	3.6	3.6	5.4	5.0
Consumption max daily (m3)	10.0	10.5	12.1	11.2	25.9	20.6
Consumption min daily (m3)	1.4	0.7	0.3	0.8	0.5	0.5
Months	**July**	**August**	**September**	**October**	**November**	**December**
Consumption average daily (m3/month)	5.5	4.6	4.5	5.5	9.0	12.5
Consumption max daily (m3)	16.1	22.3	14.4	19.8	25.2	33.6
Consumption min daily (m3)	1.4	1.2	0.7	1.3	0.1	0.9

The figure below illustrates an extract of the existing rainwater harvesting network from the roof of the passenger terminal building to the dedicated storage site.

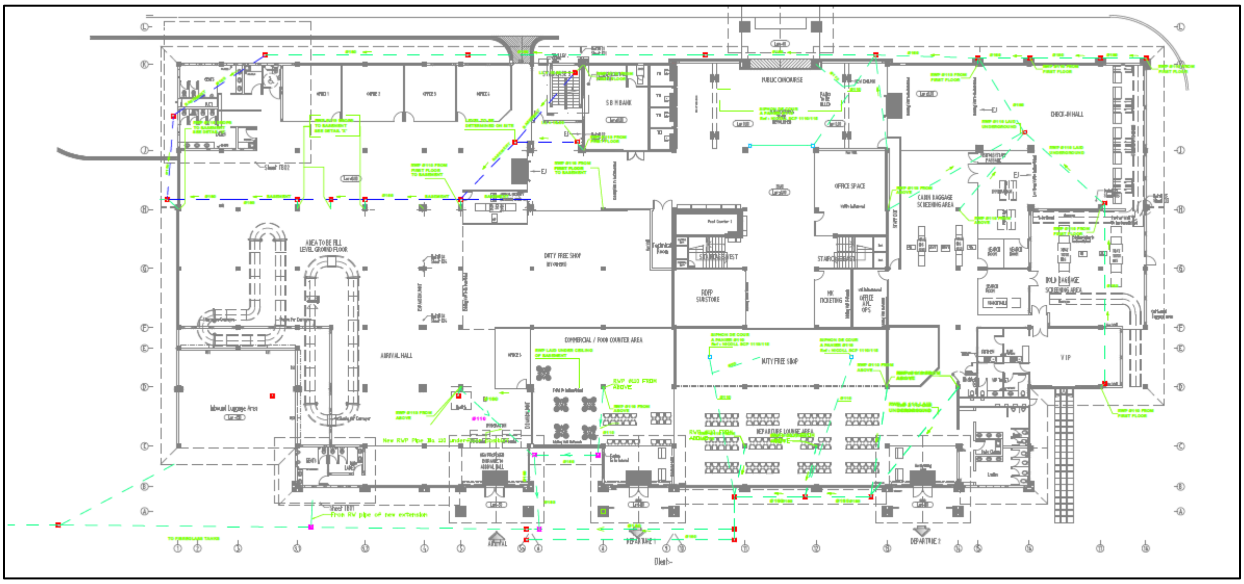


Figure 24: Extract of the existing rainwater harvesting network

Note: This principle will be included in the "integrated" water management plan, potentially envisaged at this stage, together with the overall wastewater and stormwater management of the whole airport platform.

4.2.2 Waste water management

4.2.2.1.1 Waste water management in Rodrigues Island

Rainwater is collected into drains and discharged into the sea.

There is no network of wastewater treatment on the island; most buildings have pit latrines. The existing airport has its own treatment system. Over 90% of households are owners of their dwellings, of these, 94% had access to sanitation facilities in 2000 (either flush toilets or pit latrines) (KPMG, July 2009). The existing airport has its own treatment system.

There is an underway water management plan for Rodrigues

4.2.2.1.2 Waste water management in Plaine Corail airport

The airport is currently equipped with a leaching field instead of the usual infiltration field. The leaching dates back to 2003, coinciding with the construction of the passenger terminal building and has been selected due the impermeability of the coral substrate at the airport.

The wastewater produced by the airport is directed to its own on-site wastewater treatment system consisting of a sceptic tank and a leaching field; which corresponds roughly to a primary treatment. The overflow from the septic tank is released to a leaching field. However, currently regular pumping of the overflow from the septic tank is done because the system does not work properly and the leaching field is not permeable enough. This pre-treated wastewater is carted away to the municipal wastewater treatment plant of Grenade.

The aircraft lavatory wastewater is not unloaded from the plane and is taken to Mauritius for disposal. No facilities are currently available in Rodrigues to handle it.

No heavy maintenance/repair activities are carried out on site at the moment. However, small maintenance operations can be done if necessary. The real extent of this activity cannot currently be estimated.

Note: In the framework of the “integrated” water management plan potentially envisaged, the specific effluents generated by maintenance/repair operations must be specifically collected and evacuated separately.

The figure below illustrates an extract of the sewerage network from the different collection points of the passenger terminal building to the dedicated septic tank.

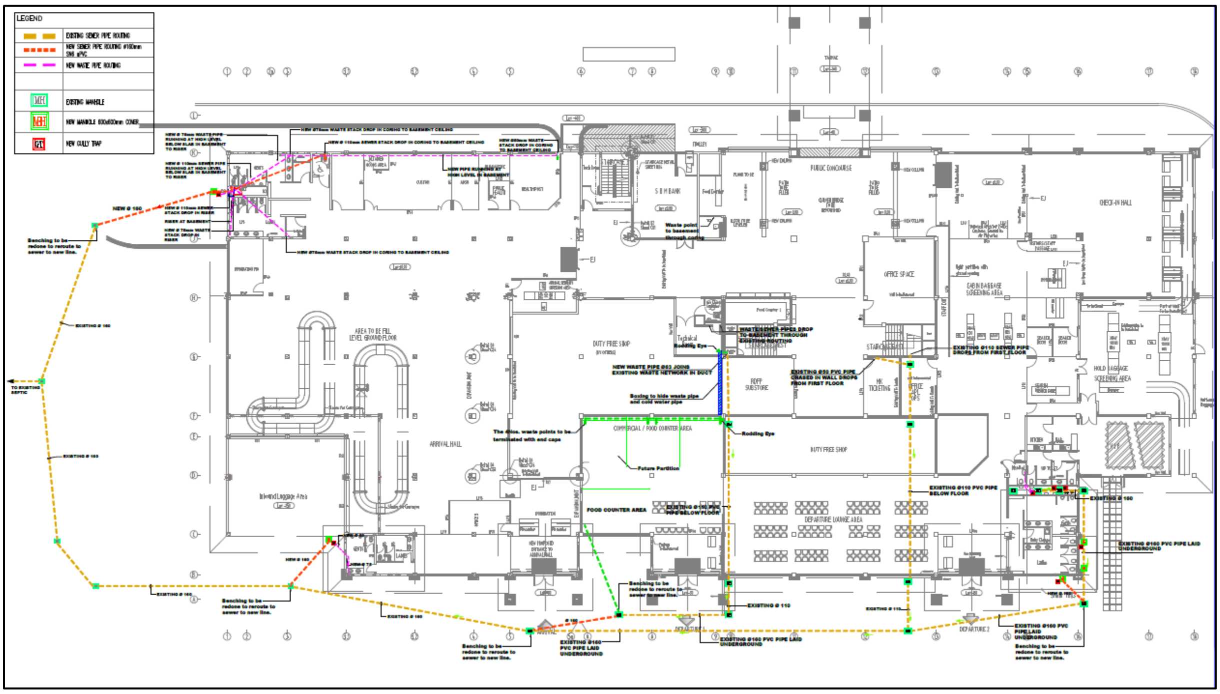


Figure 25: Extract of the existing wastewater network provided

4.2.3 Stormwater

As described above, only natural drains enable the stormwater drainage on the site, in addition to the natural slope of the existing runway which helps to drain the stormwater towards the sea, without any specific pre-treatment such as an oil and grease separator. An existing natural drain can be observed only around the apron and along the taxiway in front of the passenger terminal building, which passes under the taxiway and discharges the stormwater into the natural environment nearby.
The fuel depot is equipped with a retention capacity (equipped with a disconnection valve) to collect stormwater generated therein. Collected stormwater is then pumped for evacuation by dedicated wastewater tankers. The loading / unloading platform is equipped with a disconnecting valve in order to direct the stormwater from the platform towards an open-air oil separator (visual control for maintenance) during “off duty” periods and to isolate the platform during fuel loading / unloading operations. However, the disconnection valves are rusty and therefore show that they have not been used for a long time and further need a replacement, as illustrated below, as observed during our last site visit in May 2019.

<u>Note</u>: As indicated in the Preliminary Design Study, the new runway will be equipped with stormwater drains and oil and grease separators for pre-treatment purposes. However, due to the impermeability of the coral substratum, unlike what is mentioned in the Preliminary Design Study, infiltration will be difficult unless the infiltration drains and trenches are deep enough to go beyond the coral layer.
Anyway, in order to collect the storm water and pre-treat it on oil separators, the drains have to be impermeable to convey all the stormwater to be pre-treated. Therefore, it is expected that the stormwater be collected, pre-treated and managed within the framework of the "integrated" water management plan envisaged away from the runway. The impermeable drains are further required to collect and confine effluents generated by an eventual fire fighting operation on the runway.

Figure 26: View of the Fuel depot and associated facilities to prevent environmental accidental pollution

4.2.4 Water resource and waste water issues

4.2.4.1 Domestic wastewater management

Domestic wastewater management is an issue regarding the preservation of the surrounding receiving environment with the increasing number of passengers. Its proper treatment / management is therefore important before discharge in the environment or at sea.

This issue sensitivity is of a high level.

4.2.4.2 Water supply management

Water supply management is an issue regarding the sufficiency and availability of water at the airport for the different basic uses. Drinking water supply is very irregular and therefore alternatives have to be implemented. An integrated water management combining reuse of treated wastewater and stormwater, together with rainwater harvesting, is thus important and necessary. This can reduce the burden on the existing public water supply network. Given the island context and the limitation of freshwater resources and the potential relocation of one of the supply sources (Caverne Bouteille), the sensitivity of the drinking water supply is considered high.

This issue sensitivity is of a high level.

4.3 Summary: Water sensitivity

Table 15: Water sensitivity

Theme	Sub-theme	Receptor	Sensitivity
Physical environment	Hydrology	Stormwater management	Major
		Flooding of issues downstream of facilities	Low
		Transfer of pollution to the natural environment	Major
		Transfer of sediments to the lagoon	Major
	Water resource and wastewater management	Domestic wastewater management	High
		Water supply management	High

5 Preliminary environmental impacts and mitigation measures

5.1 Definitions and methodology

5.1.1 Project's phase considered in this study

This study is based on the preliminary design stage. During this first design phase, there is still a possibility to study several options. Therefore, the project is not confirmed, and some elements can be modified. However, all required field investigations have been carried out at this time and confirm that the project is feasible.

The next design step will be the detailed design, which consists of the final production detailed architectural and engineering drawings of the project's physical components. The detailed design also aims to ensure of the financial viability.

In order to consider all the potential consequences of the project, the impacts were studied with a broad vision. So, it is necessary to note that certain of these impacts will be avoided when the project is finalized.

Note: An option of shifting the runway to the East by 75 m is ongoing. An update of some impacts might be necessary.

5.1.2 Methodology for impact assessment and rating

In previous aspects of this study, receptors were defined and evaluated.

The chapter below aims to evaluate the consequences of the project (impacts), on all the receptors identified in the baseline.

For each theme, the impacts are defined and classified according to whether they are:

- Temporary work impacts. These impacts are intended to appear during the project implementation phase, but to disappear once the works phase is completed (e.g. noise caused by the work equipment);
- Definitive work impacts. These impacts are intended to appear during the works phase, and to continue once the work is completed (e.g. destruction of habitat located in the project footprint);
- Operational impacts. These impacts are linked to the very existence and operation of the project (e.g. noise caused by the planes landing and taking off).

Each identified impact was numbered, then the following protocol was carried out:

- For each of these three types of large impacts, an assessment of the intensity was first conducted and rated on the basis of their severity (impact severity) as : 1 - not significant, 2 - low, 3 - medium, 4 - high, 5 - major.

Table 16: Impact severity

Impact severity	Not significant	Low	Medium	High	Major

The severity impacts were confronted with the sensitivity of the issues they affect. The evaluation of impact severity and receptors sensitivity is done regarding the previously described social impact assessment process and according to the various consultations and meetings with stakeholders during the field study. This provides the level of impact (impact magnitude). The severity of the social impacts and sensitivity of the receptors are then combined through a matrix to obtain the magnitude of the impact. This matrix applies both to adverse and positive impacts. The specific criteria used to assess the magnitude of each type of social impact are those defined in the assessment of impacts. The table below illustrates the magnitude matrix of social impacts:

Table 17: Magnitude matrix of social impacts

Impact severity	Not significant	Low	Medium	High	Major
Receptor sensitivity					
Low	Negligible	Low	Low	Low	Medium
Medium	Negligible	Low	Low	Medium	High
High	Negligible	Low	Medium	High	Major
Major	Low	Medium	High	Major	Major

- Following the identification and assessment of impacts, avoidance, reduction and impact compensation measures have been defined and numbered. The same measure can correspond to avoiding or mitigating several impacts.
- Finally, to correct previously identified impacts, these measures made it possible to carry out a new assessment of the impacts intensity. This is the mitigated impact or residual impact.

5.2 Temporary Impacts during Construction

Physical environment - Hydrology

No temporary impact.

Physical environment - Water resource and waste water management

5.2.1.1.1 Impact Phy-Wat-W-Temp-1: impact of water resource due to work water supply

5.2.1.1.1.1 Impact before mitigation

The supply of water (drinking and non-drinking water, intended for watering the tracks, for supplying processes such as concrete manufacturing, washing machinery, etc.) is likely to weigh on the already very tight public water supply network.

The impact severity is high. Considering the receptor sensitivity assessed as major, **the impact magnitude is major**.

5.2.1.1.1.2 Mitigation measure and impact after mitigation

It is proposed to install a desalination plant for the water supply during the works, producing water for the works needs including drinking water for the workers. This plant should pump water from the sea (eventually via a borehole) and provide fresh water and drinking water. (Phy-Wat-Mit-1)

The proposed measures result in a not significant severity mitigated impact. Thus, the residual impact is of **negligible magnitude.**

5.2.1.1.2 Impact Phy-Wat-W-Temp-2: impact of works on water resource due to impact on karstic groundwater

5.2.1.1.2.1 Impact before mitigation

The vibrations associated with the stripping of natural surface materials can increase the transport of fine particles in groundwater. The karst network of aquifers contributes to the transport of these particles without filtering them. The groundwater component that feeds the Caverne Bouteille intake could then have an increase in turbidity. This change in turbidity could affect the pumping system. Most of all, it would then influence the reverse osmosis treatment process (saturation of the micro-membranes) so the Caverne Bouteille desalination plant could be affected too.

The impact severity is major. Considering the receptor sensitivity assessed as major, **the impact magnitude is major**.

5.2.1.1.2.2 Mitigation measure and impact after mitigation

To mitigate this impact, the temporary or permanent relocation of the water abstraction at Caverne Bouteille has to be planned. A feasibility study for an alternative source out of the area of influence must be completed before the works begin. As it is likely that another intake in the groundwater will be difficult to find, it is proposed to replace Caverne Bouteille intake by a sea water pumping. The Caverne Bouteille desalination plant should be upgraded in order to enable it to treat seawater and provide drinking water. The current capacity of 1000 m³/day must be maintained. An alternative can be found and discussed with the Rodrigues Regional Assembly and the Rodrigues Public Utilities Corporation within the framework of the water supply improvement programme in Rodrigues.

(Phy-Wat-Comp-2)

The proposed measures result in a not significant severity mitigated impact. Thus, the residual impact is of **negligible magnitude.**

5.2.1.1.3 Impact Phy-Wat-W-Temp-3: impact of works waste water

5.2.1.1.3.1 Impact before mitigation

The construction activities and processes and the workers living on the site during the works will generate waste water which, if discharged into the natural environment without treatment, would cause unacceptable pollution. However, the existing water treatment system is not large enough to take this into account.

The impact severity is major. Considering the receptor sensitivity assessed as high, **the impact magnitude is major**.

5.2.1.1.3.2 Mitigation measure and impact after mitigation

It is proposed to provide a temporary wastewater treatment plant dedicated to the construction site. (Phy-Wat-Av-3)

The proposed measures result in a not significant severity mitigated impact. Thus, The residual impact is of **negligible magnitude**

5.2.1.1.4 Impact Phy-Wat-W-Temp-4: Risks of accidental pollution

5.2.1.1.4.1 Impact before mitigation

Potential sources of accidental contamination are possible related to Geotechnics and Hydrogeology of the karstic system.

The impact severity is high. Considering the receptor sensitivity assessed as high, **the impact magnitude is high**.

5.2.1.1.4.2 Mitigation measure and impact after mitigation

The mitigation of a contamination event consists mainly in the implementation of preventive measures to reduce risks during the construction phase.

Below is a short list of prevention measures for construction on the construction sites:
- Provide sealed vats for polluting products stored in drums, tanks or cisterns in order to recover any spills.
- Avoid buried deposits of pollutants. If this is not possible, provide a system to quickly detect a possible leak.
- Provide a waterproof floor where harmful products are handled or delivered.

- Use the best technologies to limit the release of hazardous products.
- In the event of accidents, have an "intervention kit" at your disposal (absorbent products, etc.)

Development of a Risk Management Plan (RMP): a definition of RMP could be “*The RMP will describe existing and proposed risk management measures that are to either continue or to be put in place to provide confidence that the identified threat activity will cease to be or not become a significant threat to drinking water*”. (Phy-Wat-Av/Mit-4)

The proposed measures result in low severity mitigated impact. Thus, The residual impact is of **negligible magnitude.**

5.2.1.1.5 Impact Phy-Wat-W-Temp-5: Risks associated with the desalination plant

5.2.1.1.5.1 Impact before mitigation

The following are assumptions given that the location, type and specifications of the desalination plant are not clearly known to date.

Construction and operation activities could result in a variety of coastal zone impacts including impacts to water quality, to marine life, disturbance of ecological important ecosystems (sand-dunes, seagrass beds and other important habitats by the siting of pipelines route). The most significant of these impacts are to water quality, which subsequently has adverse impacts on marine life and ecosystems[1]

The impact severity is high. Considering the receptor sensitivity assessed as high, **the impact magnitude is high**.

5.2.1.1.5.2 Mitigation measures and impact after mitigation

The mitigation measures are in the form of best engineering design /selection of appropriate SWRO desalination plant and good site practices/ Operation & Maintenance during operation.

Below is an overview of the possible mitigation measures:

- Adequate siting of the plant to minimize disturbance of the natural environment
- Reduce construction activity by preferring containerized units
- Adequate mode of sea water abstract to avoid/reduce Impingement and Entrainment of marine organisms through boreholes/beach wells
- Desalination method: a reverse osmosis plant is to be considered
- Optimize the use of chemicals for pre-treatment, post-treatment, maintenance and cleaning
- Adequate mode of brine management. As mentioned previously, a zero liquid discharge of the brine should be favoured, through the installation of an evapo-concentrator-condenser-crystallizer instead of rejecting the diluted brine in the natural environment

An assessment of the potential impacts associated with a desalination plant will be carried out in the final ESIA and provide adequate mitigation measures as part of the ESMP.

[1] UNEP – Sea Water Desalination in the Mediterranean – Assessment and Guidelines - 2033

The tender documents for construction will incorporate all relevant aspects of the ESMP; the contractor will contractually be required to apply all relevant aspects of the ESMP.

The proposed measures result in low severity mitigated impact. Thus, the residual impact is of **negligible to low magnitude.**

5.2.1.1.6 Summary

Table 18: Temporary Impact during Construction – Physical Environment - Water & wastewater

Impact ID	Impact name	Direction	Impact magnitude mitigation	Measure ID	Avoidance / Mitigation / Compensation / Improvement Measures	Residual / improved impact magnitude
Phy-Wat-W-Temp-1	Impact of water resource resulting from works water supply	Adverse	Major	Phy-Wat-Mit-1	Install a desalination plant to supply drinking water to the workers' camp	Negligible
Phy-Wat-W-Temp-2	Impact of works on water resource resulting from impact on karstic groundwater	Adverse	Major	Phy-Wat-Comp-2	Temporarily replace the Caverne Bouteille intake by a sea water pumping Upgrade Caverne Bouteille plant to enable it to provide drinking water from sea water Thus, temporarily provide drinking water from sea water to people currently connected to Caverne Bouteille plant	Negligible
Phy-Wat-W-Temp-3	Works waste water	Adverse	Major	Phy-Wat-Av-3	Works wastewater treatment plant	Negligible
Phy-Wat-W-Temp-4	Risk of accidental pollution	Adverse	High	Phy-Wat-Av/Mit-4	Preventive measures to reduce risks during the construction phase - Risk management plan	Negligible
Phy-Wat-W-Temp-5	Desalination plant	Adverse	High	Phy-Wat-Av/Mit-5	Good engineering design and best site practices to reduce the impacts Importance of ESMP & ESCP in the contractor's contract	Negligible to low

5.3 Permanent and irreversible impacts during Construction Phase

5.3.1 Physical environment - Hydrology

5.3.1.1.1 Impact Phy-Hyd-W-Def-1: Transfer of sediments to the lagoon

5.3.1.1.1.1 Impact before mitigation

Excavation and remodeling of the natural terrain will facilitate soil erosion in the event of a heavy rainfall during the construction phase, increasing the supply of materials to the lagoon and destabilizing the ecosystem.

The impact severity is high. Considering the receptor sensitivity assessed as major, **the impact magnitude is major**.

5.3.1.1.1.2 Mitigation measure and impact after mitigation

The aim of the proposed mitigation measures is to avoid erosion during the works. Temporary sedimentation capacities downstream of the construction sites will be implemented. These capacities may be made of materials available on site; particular attention must be paid to the stability of the structures thus created.

The proposed measures result in a low severity mitigated impact. Thus, **The residual impact is of low magnitude**.

5.3.1.1.2 Summary

Table 19: Permanent Impact during Construction - Physical Environment - Hydrology

Impact ID	Impact name	Direction	Impact magnitude mitigation	Measure ID	Avoidance / Mitigation / Compensation / Improvement Measures	Residual / improved impact magnitude
Phy-Hyd-W-Def-1	Transfer of sediments to the lagoon	Adverse	Major	Phy-Hyd-Mit-1	Temporary sedimentation capacities	Low

5.3.2 Physical environment - Water resource and waste water management

5.3.2.1.1 Impact Phy-Wat-W-Def-1: Demolition of Bangelique reservoir

5.3.2.1.1.1 Impact before mitigation

The reservoir of Bangélique is located within the project footprint, close to Sainte Marie Hill. It's to be demolished by the project. However, this tank is not used anymore.

The impact severity is low. Considering the receptor sensitivity assessed as low, **the impact magnitude is low** .

5.3.2.1.1.2 Mitigation measure and impact after mitigation

No measure is proposed as the tank is not used anymore.

5.3.2.1.2 Impact Phy-Wat-W-Def-2: impact of works on water resource supply

5.3.2.1.2.1 Impact before mitigation

The temporary impacts identified on the groundwater resource (increased groundwater turbidity and impact on the pumping system and on the reverse osmosis process) may become permanent if they are not controlled and corrected in time.

Furthermore, the groundwater flow disturbance could result in a decrease of Caverne bouteille flow rate.

The impact severity is high. Considering the receptor sensitivity assessed as high, **the impact magnitude is high**.

5.3.2.1.2.2 Mitigation measure and impact after mitigation

Risk prevention measures and an action plan in the event of an accident are the best means of minimizing the risk of contamination and controlling and cleaning up the receiving environment. (Phy-Wat-Av/Mit-4)

After the construction works, the supply of seawater (or relocated intake) to the upgraded Caverne Bouteille plant must be maintained, long enough to carry out measurements and analyzis on Caverne Bouteille underground water intake.

In case of a decrease of Caverne Bouteille's supply by underground water, or persistent impact on the pumping or desalination system, the temporary solution (relocation or supply by seawater pumping) should become definitive. (Phy-Wat-Comp-5)

The proposed measures result in a low severity mitigated impact. Thus, the residual impact is of **low magnitude**.

5.3.2.1.3 Summary

Table 20: Permanent Impact during Construction - Physical Environment - Water & Wastewater

Impact ID	Impact name	Direction	Impact magnitude mitigation	Measure ID	Avoidance / Mitigation / Compensation / Improvement Measures	Residual / improved impact magnitude
Phy-Wat-W-Def-1	Demolition of Bangelic reservoir	Adverse	Low	-	-	Low
Phy-Wat-W-Def-2	Impact on Caverne Bouteille's supply	Adverse	High	Phy-Wat-Comp-5	Carry out measurements on Caverne Bouteille intake Go on supplying inhabitants from water supply during analyzis and measurements According to measurements results, keep using seawater in a definitive manner or get back to the initial situation, pumping underground water in Caverne Bouteille intake	Low
				Phy-Wat-Av/Mit-4	Preventive measures to reduce risks during the construction phase - Risk management plan	

5.4 Impacts during operation phase

The project aims to enable Rodrigues Island to develop tourism and aerial cargo. Tourism development might have significant impacts on the environment.

However, this ESIA only aims to address the impacts of the infrastructure. Thus, the socio-economic development and changes that could be expected due to the air access improvement are not part of this ESIA scope.

Impacts of the airport extension on tourism and socio-economics on an island scale are addressed in other studies carried out under RRA's control.

5.4.1 Physical environment - Hydrology

The project involves significant movement of excavated soil and fill, significantly altering the natural watersheds on the southern part of the existing facilities. The map below shows the current and post-development sub-watersheds and highlights the right-of-way of the modified watersheds and runoff axes.

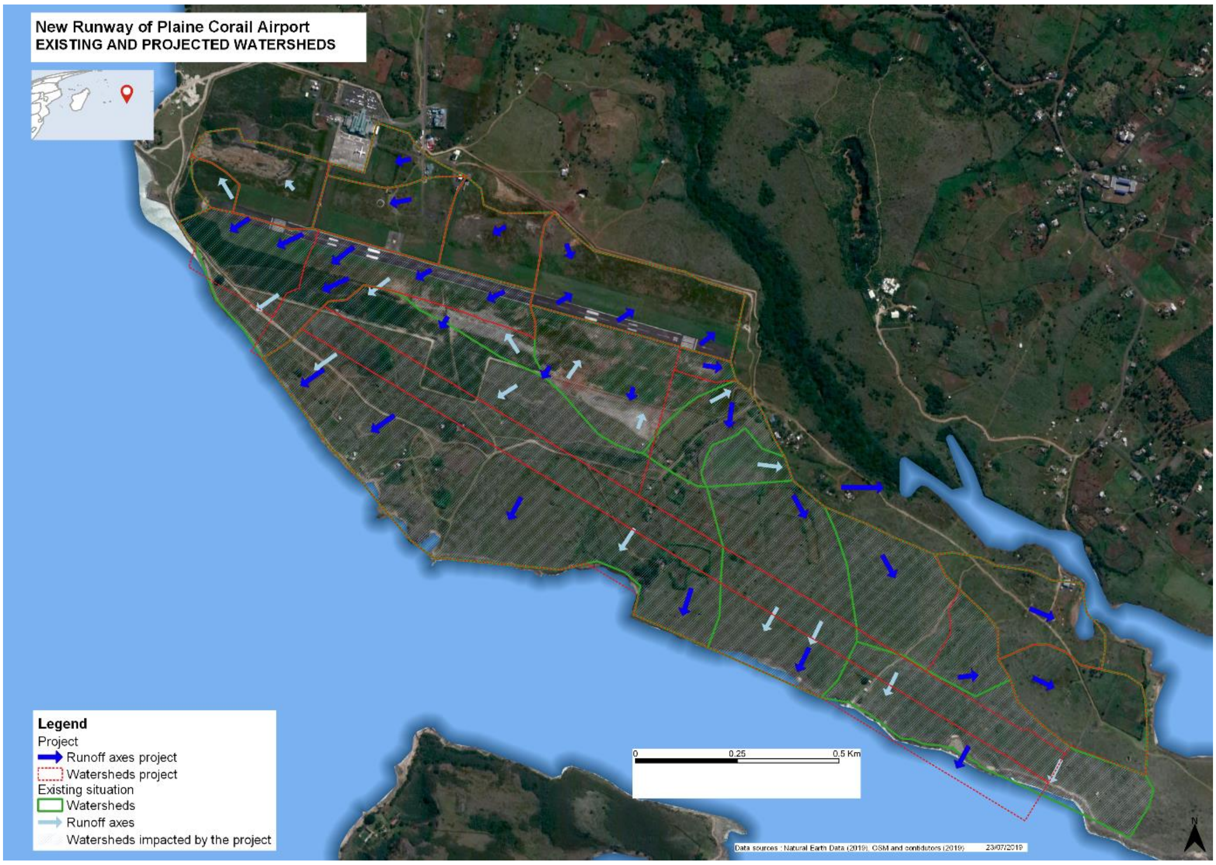


Figure 27: Evolution of the catchment areas after development

The main potential impacts of the project on hydrology are the following:

- Changes in the general topography of the site can result in changes in runoff flow dynamics and threaten to flood the airport facilities themselves or downstream issues.

- Resloping and flow concentration can increase soil erosion in non-sealed watersheds and increase the transfer of materials to the lagoon.
- Leaching of runways, car parks and taxiways by stormwater creates chronic pollution towards the surrounding natural environment. In addition to this risk of chronic pollution, there is also a risk of accidental pollution created by the discharge of pollutants or water from firefighting.

5.4.1.1.1 Impact Phy-Hyd-Op-1: Stormwater management

5.4.1.1.1.1 Impact before mitigation

Sources of permanent impact of the project include flooding of facilities that could interrupt the proper functioning of the airport: buildings, technical installations and runway.

The construction of the runway requires the creation of a large excavation to the North of the runway. The water flowing on this artificial hillside flows by gravity towards the runway, creating a risk of flooding the runway. On the southern part of the runway, the topography slopes down towards the ocean, thus allowing gravitational water runoff without impacting the runway.

The impact severity is major. Considering the receptor sensitivity assessed as major, **the impact magnitude is major**.

5.4.1.1.1.2 Mitigation measure and impact after mitigation

To mitigate these impacts, the stormwater networks will be sized to collect at least the flows generated by a 50-year return rainfall period:

- Runway: a large ditch located at the bottom of the artificial hillside and below the runway will allow the drainage of hillside runoff (cut-off drain) and runway water over and above the capacity of the network collecting the first runoff water,
- Extension of the existing airport facilities, to the North of the new runway: the networks will collect the runoff to the new buffer storage.

The proposed measures result in a not significant severity mitigated impact. Thus, the residual impact is of **low magnitude**.

5.4.1.1.2 Impact Phy-Hyd-Op-2: Flooding of issues downstream of airport facilities

5.4.1.1.2.1 Impact before mitigation

<u>Mitigation measure Phy-Hyd-Mit-1</u>

Soil sealing (extension of existing buildings, new buildings, car parks, taxiways and runways) and to a lesser extent the modification of the topography of the natural terrain (with a local increase in flow slopes) lead to an increase in the runoff flows on the site and discharged downstream.

Since discharge is done directly into the sea, the increase in runoff flows does not threaten any built environment.

However, the earthworks slightly modify the watershed draining the water towards the cave of Petit Lac, above Anse Quitor. However, the change in flow rates induced to this site remains unsignificant.

The impact severity is not significant. Considering the receptor sensitivity assessed as low, **the impact magnitude is low**.

5.4.1.1.2.2 Mitigation measure and impact after mitigation

Mitigation measure Phy-Hyd-Mit-2

To mitigate the impact on the caves, the stormwater ditch located north of the runway is positioned to restore the boundary of the existing watershed draining water to the cave of Petit Lac.

Mitigation measure Phy-Hyd-Mit-3

To address climate change adaptation for the reduction of peak flows and run off, mitigation measures include:

- A buffering storage at the outlet of the drainage network located north of the runway, sized for a 2-year return rainfall period,
- Works facilitating infiltration: large vegetated ditch to reduce flow speed, hillside vegetation.

The proposed measures result in a not significant severity mitigated impact. Thus, the residual impact is of **negligible magnitude**.

5.4.1.1.1 Impact Phy-Hyd-Op-3: Transfer of pollution to the natural environment

5.4.1.1.1.1 Impact before mitigation

The leaching of runways, car parks and taxiways by rainwater creates chronic pollution towards the surrounding natural environment. In addition to this risk of chronic pollution, there is also a risk of accidental pollution created by the discharge of pollutants or water from firefighting.

The impact severity is major. Considering the receptor sensitivity assessed as major, **the impact magnitude is major**.

5.4.1.1.1.2 Mitigation measure and impact after mitigation

Mitigation measure Phy-Hyd-Mit-4

The aim of the proposed mitigation measures is to treat chronic or accidental sources of pollution before release into the natural environment. They include:

- To the North of the new runway, the outlet of the roads, parkings and taxiways watertight stormwater network will be equipped with an oil separator and sedimentation works designed to collect and treat up to 20% of the flow generated by a 2-year return period rainfall. The outlet of this network is also to be equipped with initial storage works associated with a valve to isolate the flow from the natural environment in the event of accidental pollution (leakage of polluting liquids, fire fighting, etc.).
- The stormwater drainage of the **new runway** and associated taxiways is designed to collect the first flows of runoff loaded with potential pollutants in a watertight network, connected with oil separators and sedimentation works. The outlet of this network is also equipped with storage works associated with a valve to isolate the flow to the natural environment in the event of pollution (leakage of polluting liquids, water from fire fighting, etc.). All these structures will be designed to collect and treat up to 20% of the flow generated by a 2-year return period rainfall.

  Over and above these first flows, the water is to be evacuated away from the runway to avoid any risk of flooding.

The proposed measures result in a low severity mitigated impact. Thus, the residual impact is of **low magnitude**.

5.4.1.1.2 Impact Phy-Hyd-Op-4: Transfer of sediments to the lagoon

5.4.1.1.2.1 Impact before mitigation

The project can increase the supply of materials to the lagoon, destabilizing the ecosystem:

- Changing the topography of the site associated with the concentration of flows can create erosion of the natural terrain,
- Leaching of artificial soils may result in the discharge of more or less polluting suspended solids.

The impact severity is high. Considering the receptor sensitivity assessed as major, **the impact magnitude is major**.

5.4.1.1.2.2 Mitigation measure and impact after mitigation

Mitigation measure Phy-Hyd-Mit-5

The aim of the proposed mitigation measures is to avoid erosion on hillsides and drains concentrating the collected flows, and the discharge of suspended solids from the runway, taxiways and parking. They include:

- Vegetation of slopes and ditches,
- Collection of runway, taxiway and parking runoff in watertight networks equipped with sedimentation works at their outlets.

The proposed measures result in a low severity mitigated impact. Thus, The residual impact is of **low magnitude**.

5.4.1.1.3 Summary

Table 21: Impact during Operation - Physical Environment- Hydrology

Impact ID	Impact name	Direction	Impact magnitude mitigation	Measure ID	Avoidance / Mitigation / Compensation / Improvement Measures	Residual / improved impact magnitude
Phy-Hyd-Op-2	Flooding of issues downstream of airport facilities	Adverse	Major	Phy-Hyd-Mit-2	Stormwater network sized to collect at least the flows generated by a 50-year return rainfall period	Low
Phy-Hyd-Op-2	Transfer of pollution to the natural environment	Adverse	Low	Phy-Hyd-Mit-3	Restore the boundary of the existing watershed draining water to the cave of Petit Lac	Negligible
				Phy-Hyd-Mit-4	Creation of buffering storage and works facilitating infiltration	
Phy-Hyd-Op-3	Increase of the supply of materials to the lagoon	Adverse	Major	Phy-Hyd-Mit-5	Watertight stormwater network equipped with: - Oil separator and sedimentation works designed to collect and treat up to 20% of the flow generated by a 2-year return period rainfall. Gates and tanks to isolate accidental pollution, including water from firefighting.	Low
Phy-Hyd-Op-4	Flooding of issues downstream of airport facilities	Adverse	Major	Phy-Hyd-Mit-6	- Vegetation of slopes and ditches, Collection of runway, taxiway and parking runoff in watertight networks equipped with sedimentation works at their outlets.	Low

5.4.2 Physical environment - Water resource and domestic waste water

5.4.2.1.1 Impacts Phy-Wat-Op-1 and Phy-Wat-Op-2 associated to stormwater drainage

5.4.2.1.1.1 Impact before mitigation

This project of a new runway, at the Preliminary Design stage, includes an infiltration drainage network along the runway to address the stormwater issue, associated with oil separators before discharge into the environment. However, no buffering is included to reduce the peak flows. The Preliminary Design does not propose the reuse of the stormwater collected and pre-treated. The resulting potential environmental impacts are:

Major impact due to:

- Pollution of the soil due to direct infiltration of stormwater without prior oil separation.
- Pollution also due to an eventual firefighting operation on the runway with no possibility of confining the effluents generated.

Major impact due to no reduction of peak flow, runoff and soil erosion, leading to increasing sedimentation of water bodies including lagoons, thus threatening biodiversity, corals and white sandy beaches.

The impact severity is high. Considering the receptor sensitivity assessed as major, **the impact magnitude is major**.

5.4.2.1.1.2 Mitigation measure and impact after mitigation

A non infiltrating drainage network will be implemented to convey the stormwater to oil separators for pre-treatment and then to a buffer storage for reuse within the framework of an integrated water management plan. This will enable to address and **avoid** the above mentioned impacts, bringing them to **negligible**.

The proposed measures result in a not significant mitigated impact. Thus, The residual impact is of **negligible magnitude**.

5.4.2.1.2 Impact Phy-Wat-Op-3 associated to the waste water management

5.4.2.1.2.1 Impact before mitigation

This project of a new runway, at the Preliminary Design stage, includes a new sewer network associated with a Water Treatment Plant to cater for the domestic wastewater of the airport, including the new control tower and the fire and rescue services. The treated wastewater is to be discharged at sea after proper treatment to the required corresponding standards. The Preliminary Design does not propose the reuse of the treated wastewater which will then require a higher level of treatment. The resulting potential environmental impact is a **low impact** on the environment (sea) in which the treated water is discharged according to basic minimum standards.

The impact severity is low. Considering the receptor sensitivity assessed as high, **the impact magnitude is low**.

5.4.2.1.2.2 Mitigation measure and impact after mitigation

The implementation of a Water Treatment Plant within the framework of an integrated water management plan with the reuse of the treated wastewater, and with an objective of zero discharge, leads to a higher level of treatment. This will enable to address and **mitigate** the above mentioned impact, bringing it to **negligible**.

The proposed measures result in a low severity mitigated impact. Thus, The residual impact is of **negligible magnitude**.

5.4.2.1.3 Impact Phy-Wat-Op-4 : Water supply management

5.4.2.1.3.1 Impact before mitigation

This project of a new runway, at the Preliminary Design stage, includes a Water supply network associated with water tanks connected to the existing public network which is non performant. No alternative proposed. The resulting potential environmental impact is:

High impact due to an extra burden on the water supply public network requirements due to an increased volume required.

The impact severity is major. Considering the receptor sensitivity assessed as medium, **the impact magnitude is high**.

5.4.2.1.3.2 Mitigation measure proposed and attenuated impact after mitigation

The implementation of an integrated water management plan with the reuse of the treated wastewater and stormwater collected, leads to the **mitigation** of the above mentioned impact, bringing it to **low**.

The proposed measures result in a high severity mitigated impact. Thus, the residual impact is of **low magnitude**.

5.4.2.1.4 Summary

Table 22: Impact during Operation - Physical Environment- Water & Wastewater

Impact ID	Impact name	Direction	Impact magnitude mitigation	Measure ID	Avoidance / Mitigation / Compensation / Improvement Measures	Residual / improved impact magnitude
Phy-Wat-W-Def-1	Pollution of soil and surface water	Adverse	Major	Phy-Wat-Av-6	Integrated water management plan	Negligible
Phy-Wat-W-Def-2	Peak flows resulting in increasing soil erosion	Adverse	Major	Phy-Wat-Av-6	Integrated water management plan	Negligible
Phy-Wat-W-Def-3	Pollution of marine water	Adverse	Low	Phy-Wat-Mit-7	Water treatment plant	Negligible
Phy-Wat-W-Def-4	Extra burden on the water supply public network	Adverse	High	Phy-Wat-Mit-8	Reuse water plan	Low

6 Preliminary Water Management Plan for the construction phase

The following chapters (6.1, 6.2, 6.3) aim to summarize and guide to implement the water management measures associated to the construction phase. Some measures don't directly address the works nor the operation phase but must be implemented as soon as possible, upstream of the works: these are the compensation measures and the more global measures accompanying the project, and they are also covered in this part.

The measures' descriptions should be read in section 5 as this chapter doesn't provide an exhaustive description of all measures.

The first paragraph is a table listing all the commitment and measures and indicating for each one:

- when and by whom it should be initiated and carried out,
- how it should be monitored,
- and which are the indicators of success, as well as the corrective measures to be taken if the performance objectives are not met.

The second paragraph is intended to guide stakeholders in the implementation of these measures monitoring, indicating which operational plans and procedures should be established to implement and monitor the measures, and the guidelines for the preparation of these plans.

The first paragraph refers to the plan that ensures each measure implementation. The second paragraph recalls for each plan which measures it addresses.

As part of the final ESIA, an Environmental and Social Management Plan will be developed in accordance with the World Bank ESS1. An ESMP is an instrument that details (a) the measures to be taken during the implementation and operation of a project (in this case closure) to eliminate or offset adverse environmental and social impacts, or to reduce them to acceptable levels; and (b) the actions needed to implement these measures. The ESMP will include requirements for mitigation, monitoring, capacity development and training, implementation schedule and cost estimates, as well as integration with the Project.

The mitigation measures provided in the draft ESIA Report are by no means exhaustive, as detailed design and additional specialist studies including technical investigations still need to be completed to provide a sufficiently comprehensive list of mitigation measures.

Nonetheless, the mitigation measures included in this report aim to address some of the salient impacts that may be caused by the Project, albeit on a high level at this stage.

6.1 Water Management Plan for the construction phase

Table 23: Overall Water Management Plan for the construction phase

Theme / Issue	Title and ID of the measure		Complementary description	Period of performance / Corresponding plan	Performance monitoring system	Performance indicators	Corrective measures	Responsible managers for implementation
Hydrology - Stormwater management Waste water management / Water resource and water supply	Phy-Hyd-Mit-1	Temporary sedimentation capacities	Stormwater management from the modified natural watersheds: During the construction works, excavation of the terrain will facilitate transfer of sediments to the lagoon. => Implementation of specific temporary drains and buffer storage/sedimentation capacities	Works phase **Surface stormwater run-off, drinking and wastewater management and monitoring plan**	Monitoring of water quality at discharge; visual control.	Compliance with prevailing / target standards. Submission to local authorities once a month.	Discharge to be stopped if non-compliance. Informing of local authorities/client for remedial measures.	To be implemented by the Contractor Under RRA and ARL's control
	Phy-Wat-Mit-1	Install a desalination plant to supply drinking water to the workers' camp	Water supply for workers' site facilities and construction facilities: The construction works cannot create a burden on the existing water supply already suffering a severe deficiency Specific desalination skid for the water supply of the workers' site facilities and construction facilities	Works phase **Surface stormwater run-off, drinking and wastewater management and monitoring plan**	Monitoring of water quality at inlet and outlet of Treatment Plant; monitoring of water quality on distribution line; regular manual sampling/analysis (once a week) and visual control; automatic real time monitoring of main parameters (at least pH, turbidity and residual free chlorine) on distribution line.	Compliance with prevailing / target standards. Submission to local authorities once a month.	Water production to be stopped if non-compliance. Informing of local authorities/client for remedial measures.	To be implemented by the Contractor Under RRA and ARL's control
	Phy-Wat-Comp-2	Temporary or permanent relocation of the captation of actual Caverne Bouteille	Propose a new location for Caverne Bouteille, including a seawater pumping, settle a new pumping system and upgrade the existing treatment plant to provide water to the people currently supplied by Caverne Bouteille plant	Works phase and prior to the works **Surface stormwater run-off, drinking and wastewater management and monitoring plan**	Monitoring of water quality at inlet and outlet of Treatment Plant; monitoring of water quality on distribution line; regular manual sampling/analysis (once a week) and visual control; automatic real time monitoring of main parameters (at least pH, turbidity, salinity, temperature, TDS, electrical conductivity and residual free chlorine) on distribution line.	Compliance with prevailing / target standards. Submission to local authorities once a month. Significant change in the value of the measured parameters (e. g. +/- 20%) depending on the tolerance of the treatment system.	Water production to be stopped if non-compliance. Informing of local authorities/client for remedial measures. Temporary stop of pumping Identification of the source/cause of the water quality change Relocation of the catchment	To be implemented by the Contractor Under RRA and ARL's control
	Phy-Wat-Av-3	Works wastewater treatment plant	Wastewater management for the existing airport facilities and workers' site facilities: During the construction works, the existing wastewater treatment facilities will be dismantled. The sewage from the airport facilities will need to be treated to avoid direct	Works phase **Surface stormwater run-off, drinking and wastewater management and monitoring plan**	Monitoring of water quality at inlet and outlet of Treatment Plant; monitoring of water quality at discharge; regular manual sampling/analysis (once a week) and visual control; automatic real time	Compliance with prevailing / target standards. Submission to local authorities once a month.	Discharge to be stopped if non-compliance. Informing of local authorities/client for remedial measures.	To be implemented by the Contractor Under RRA and ARL's control

Theme / Issue	Title and ID of the measure		Complementary description	Period of performance / Corresponding plan	Performance monitoring system	Performance indicators	Corrective measures	Responsible managers for implementation
			discharge into the environment => Wastewater treatment skid of adequate capacity for both the airport facilities and for the workers' site facilities		monitoring on main parameters usually monitored.			
	Phy-Wat-Av/Mit-4	Preventive measures to reduce risks during the construction phase - Risk management plan	Oil and other spills related to chemical products used during construction =>Implementation of specific retention / confining zones for storage and use Identification of threat activity that will cease to be or not become a significant threat to drinking water	Works phase **Site and works facilities management and monitoring plan**	Monitoring of any leakage from the specific retention zones Ensure that all site managers are aware of the RMP and are able to apply it Verify that the resources to apply the RMP are present on the site	Zero leakage observed Regular meetings between the project manager, the contracting authority and all site managers	Implementation of remedial confining procedure Training workshops for all site managers	To be implemented by the Contractor Under ARL's control

6.2 Environment Management Plans to be implemented for the construction phase

6.2.1 Site and works facilities management and monitoring plan

6.2.1.1 Environmental provisions and procedures to be implemented for the site and works facilities

This plan should include all the provisions of the site to ensure that the following measures are implemented:

- "Wor-Fac",
- all the measures for infrastructures and solid waste management: "Inf-Mit-1 to 6",
- the measures targeting the earthworks methods and the works schedule and phasing ("Phy-Kar-Mit-3 / 4 / 6 / 8 / 10 / 11 / 14 / 20 / 21", "Land-Mit-7 / 8"),
- the measures targeting the engine and people circulation rules inside the works site ("Phy-Kar-Mit-1 / 2 / 10 / 12 / 13 / 15 / 16"),
- the measures "Phy-Wat-Av/Mit-4" and "Phy-Kar-Mit-19".

This plan should be implemented by the contractor and follow the following guidelines. It should include the following procedures:

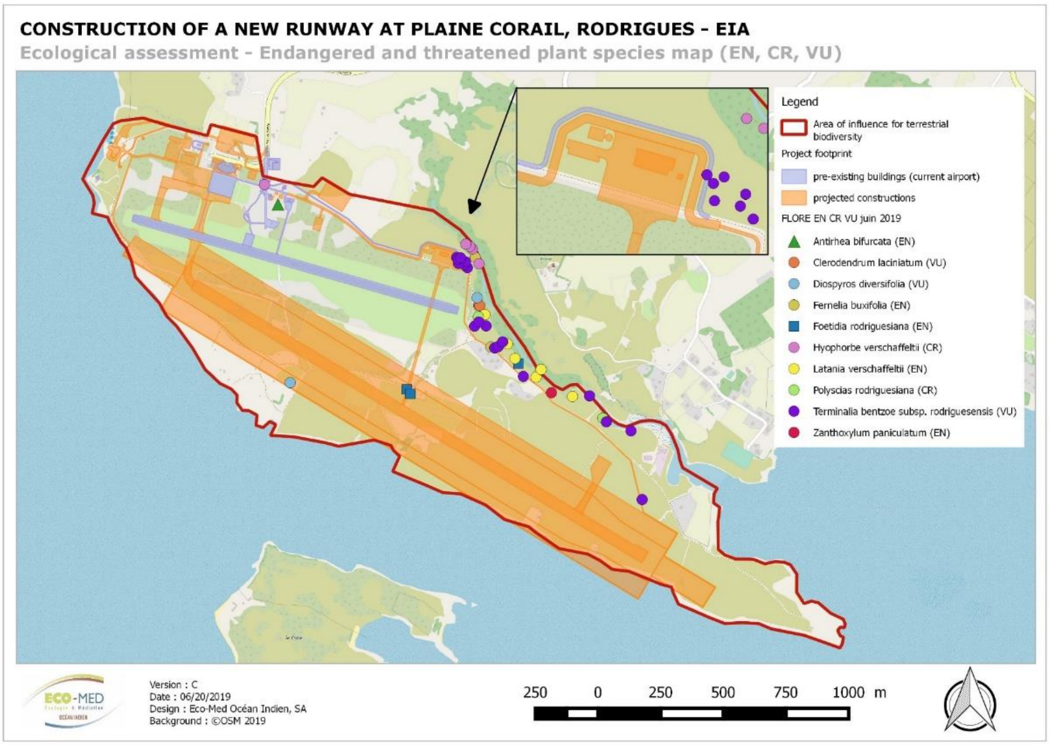
- A waste management and monitoring plan,
- An excavated soil management and monitoring plan,
- A hazardous material management plan,
- A spill risk management plan (Phy-Wat-Av/Mit-4),
- A works traffic inside and outside the works site management plan,
- A fencing plan and procedure,
- A plants monitoring plan.

6.2.1.2 Plants and facilities

The main site facilities to be provided for the construction of the new runway and other airport project components are as follows:

- Base camp,
- Wastewater treatment plant,
- Desalination plant,
- Asphalt plant,
- Concrete plant,
- Storage and maintenance sheds and hangars,
- Crane,
- Incinerator.

These facilities should not be located at the level of protected species designated as to be avoided by the project.



6.2.2 Surface stormwater run-off, drinking and wastewater management and monitoring plan

6.2.2.1 Environmental provisions to be implemented

This plan should include all the provisions of the site to ensure that the measures regarding stormwater, wastewater and drinking water resources are implemented : « Phy-Wat-Mit-1 », « Phy-Wat-Comp-2 », « Phy-Wat-Av-3 » et « Phy-Hyd-Mit-1 ».

Refer to section 5 where the detailed measures are described.

A water management plan should be provided by the contractor describing the works facilities envisaged to implement these measures.

The following sections guide the monitoring system to be set up.

6.2.2.2 Facilities monitoring and survey

The measures implemented during the works phase will require a monitoring plan of:

- the water quality at the inlet and the outlet of the Water Treatment Plants (both for Drinking Water via the Reverse Osmosis installations and the Sewage Treatment Plant);
- of the stormwater quality at the discharge points at sea.

Therefore, a regular manual sampling/analysis (tentatively once a week) and visual controls of the different works implemented (buffer storage and associated equipment: valves and automatic real time monitoring instrumentation on main parameters usually monitored) will be necessary.

Regarding the water quality, the analysis results shall be compliant with the standards promulgated under the Environment Protection Act, and will be submitted to local authorities once a month. In case of non-compliance, for each installation, the outlet should be stopped and information conveyed to relevant local authorities/client for remedial measures. The remedial measures include direct pumping of non-compliant water/effluents for proper evacuation and elimination.

However, regarding the treatment works, adequate Operation & Maintenance tasks, under the supervision of the Client, should enable to avoid the risks mentioned above. These include the following specific tasks for operation and maintenance of the treatment plant:

- Water analyses = 4h per week
- Electromechanical tasks = 4h per week per Treatment Plant + 2h per month per pumping station
- Current O&M tasks = 10h per week per treatment Plant + 2h per week per pumping station
- Oversight 24h/24h = intervention whenever required (alarm, breakdown), with remote information available, considering the implementation of a minimum remote operation monitoring equipment.

Regarding the buffer storage works and oil separators for stormwater run-off, following regular visual controls, maintenance tasks shall be required and carried out, including mainly pumping of sedimentation materials and floats (oil spills), or replacement of monitoring instrumentation if deemed necessary.

6.2.2.3 Person in charge

This plan should be prepared, managed and implemented by the contractor, under ARL's and RRA's relevant commissioners' control.

The basic monitoring tasks should be carried out by a qualified technical worker.

The specific operation and maintenance tasks for the treatment plants should be carried out by 2 skilled technicians + 1 on stand-by whenever required. The skills required include:

- A technician with good qualifications in water analysis.
- A technician with good qualifications in electromechanics.
- All O&M personnel shall have good Computer skills.

6.3 Summary of plans to be drawn up for water management during the construction phase

Table 24: Summary of Required ESMP– Water Management Plans - Construction Phase

Plan	Measures that the plan must allow to implement and monitor	Person in charge of implementation and control	Activity / Procedures to include
Surface stormwater run-off, drinking and wastewater management and monitoring plan	Phy-Wat-Mit-1 Phy-Wat-Comp-2 Phy-Wat-Av-3 Phy-Hyd-Mit-1	To be implemented by the Contractor Under RRA and ARL's control	- A water management plan - A desalination skid, wastewater treatment plant and buffer storage monitoring - A water quality monitoring

7 Environment Management Plan for operational phase

7.1 Water Management Plan for operational phase

The following chapters aim to summarize and guide to implement the water management measures associated to the post-commissioning phase and the operational phase.

Some measures are part of the airport design and must be anticipated during the study phase.

Some other measures correspond to monitoring to be carried out after the end of the works for a few months, or to be permanently integrated into the airport's routine environmental management.

The measures' descriptions should be read in section 5 as this chapter doesn't provide an exhaustive description of all measures.

The first paragraph is a table listing all the commitment and measures and indicating for each one:

- when and by whom it should be initiated and carried out,
- how it should be monitored,
- and which are the indicators of success, as well as the corrective measures to be taken if the performance objectives are not met.

The second paragraph is intended to guide stakeholders in the implementation of these measures monitoring, indicating which operational plans and procedures should be established to implement and monitor the measures, and the guidelines for the preparation of these plans.

The first paragraph refers to the plan that ensures each measure implementation. The second paragraph recalls for each plan which measures it addresses.

Table 25: Overall Water Management Plan for operational phase

Theme / Issue	Title and ID of the measure		Complementary description	Period of performance / Corresponding plan	Performance monitoring system	Performance indicators	Corrective measures	Responsible managers for implementation
Hydrology - Stormwater management Wastewater management / Water resource and water supply	Phy-Hyd-Mit-5	Treat chronic or accidental sources of pollution	Prevention / management of accidental pollution / water from firefighting Confining any accidental pollution / water from firefighting	Operational phase In case of a spill **Emergencies prevention and management plans**	Monitoring of water quality at stormwater outlet and nearby aquifer (control piezometer)	Compliance with prevailing / target standards.	Information of local authorities and implementation of remedial measures / dedicated pumping for evacuation if deemed necessary.	ARL
	Phy-Hyd-Mit-2 Phy-Hyd-Mit-3 Phy-Hyd-Mit-4 Phy-Hyd-Mit-6	Stormwater network Stormwater ditch located to restore the watershed boundary Climate change adaptation: buffering storage and works facilitating infiltration Vegetation of slopes and ditches and collection of infrastructures runoff	Stormwater management for the runway before discharge at sea: Implementation of oil separator/sedimentation works on outlet	Permanent as from the commissioning of the runway **Surface stormwater run-off, drinking and wastewater management and monitoring plan**	The oil separator on the discharge point at sea will be equipped with an alarm to order a maintenance before leakage; monitoring of water quality at discharge at sea; regular manual sampling/analysis of outlet during discharge at sea and visual control.	Compliance with prevailing / target standards. Submission to local authorities once a month.	Discharge to be stopped if non-compliance. Informing of local authorities and implementation of remedial measures: confining / dedicated pumping for evacuation if deemed necessary.	To be implemented by the Detail Design Engineer Under ARL's control Operation Monitoring: ARL (or external specialist engineer under ARL and RRA's control)
			Stormwater management and collection in a buffer storage to reduce peak flows before discharge at sea: Implementation of oil separator/sedimentation works before outlet into the buffer storage. Stormwater collection in a buffer storage. Implementation of a water treatment plant within an integrated water management plan including reuse of treated stormwater collected.	Permanent as from the commissioning of the new runway facilities **Surface stormwater run-off, drinking and wastewater management and monitoring plan**	The oil separator on the inlet of the buffer storage will be equipped with an alarm to order a maintenance before leakage; monitoring of water quality at discharge at sea, regular manual sampling/analysis of outlet during discharge at sea and visual control.	Compliance with prevailing / target standards. Submission to local authorities once a month.	Discharge / reuse to be stopped if non-compliance. Informing of local authorities and implementation of remedial measures: confining / dedicated pumping for evacuation if deemed necessary.	To be implemented by the Detail Design Engineer Under ARL's control Operation Monitoring: ARL (or external specialist engineer under ARL and RRA's control)
	Phy-Wat-Av-6 Phy-Wat-Mit-7 Phy-Wat-Mit-8	Integrated water management plan Water treatment plant Reuse water plan	Wastewater management for the airport facilities before discharge at sea Wastewater integrated management for the airport facilities =>Implementation of a water treatment plant within an integrated water management plan including reuse of treated wastewater.	Permanent as from the commissioning of the treatment facilities **Surface stormwater run-off, drinking and wastewater management and monitoring plan**	Monitoring of water quality at inlet and outlet of Treatment Plant; monitoring of water quality in industrial water storage and stored water quality is maintained including disinfection; regular manual sampling/analysis (once a week) and visual control; automatic real time monitoring on main parameters usually monitored.	Compliance with prevailing / target standards. Submission to local authorities once a month.	Discharge / reuse to be stopped if non-compliance. Informing of local authorities and implementation of remedial measures: confining / dedicated pumping for evacuation if deemed necessary.	To be implemented by the Detail Design Engineer Under ARL's control Operation Monitoring: ARL (or external specialist engineer under ARL and RRA's control)

Theme / Issue	Title and ID of the measure		Complementary description	Period of performance / Corresponding plan	Performance monitoring system	Performance indicators	Corrective measures	Responsible managers for implementation
			Rainwater integrated management for the airport facilities: Implementation of a water treatment plant within an integrated water management plan including reuse / treatment of rainwater harvested for drinking water production.	Permanent as from the commissioning of the treatment facilities **Surface stormwater run-off, drinking and wastewater management and monitoring plan**	Monitoring of water quality at inlet and outlet of Treatment Plant; monitoring of water quality in rainwater storage and stored water quality is maintained including disinfection; regular manual sampling/analysis (once a week) and visual control; automatic real time monitoring on main parameters usually monitored for drinking water production (at least pH and turbidity)	Compliance with prevailing / target standards. Submission to local authorities once a month.	Reuse to be stopped if non-compliance. Informing of local authorities and implementation of remedial measures: confining / dedicated pumping for evacuation if deemed necessary.	To be implemented by the Detail Design Engineer Under ARL's control Operation Monitoring: ARL (or external specialist engineer under ARL and RRA's control)
			Drinking Water supply integrated management for the airport facilities: Implementation of a water treatment plant within an integrated water management plan including reuse / treatment of rainwater harvested for drinking water production. Reuse and treatment of wastewater / stormwater collected if necessary.	Permanent as from the commissioning of the treatment facilities **Surface stormwater run-off, drinking and wastewater management and monitoring plan**	Monitoring of water quality at inlet and outlet of Treatment Plant; monitoring of water quality in drinking water storage and stored drinking water quality is maintained including disinfection; regular manual sampling/analysis (once a week) and visual control; automatic real time monitoring of main parameters (at least pH, turbidity and residual free chlorine) on distribution line.	Compliance with prevailing / target standards. Submission to local authorities once a month.	Distribution to be stopped if non-compliance. Informing of local authorities and implementation of remedial measures: confining / dedicated pumping to empty drinking water storage if deemed necessary.	To be implemented by the Detail Design Engineer Under ARL's control Operation Monitoring: ARL (or external specialist engineer under ARL and RRA's control)

7.2 Water Management Plans to be drawn up in operational phase

7.2.1 Surface stormwater run-off, drinking and wastewater management and monitoring plan

7.2.1.1 Design

The detailed design implemented during the construction should comply with the Environmental impact objectives set out in sections 3.1.3 and in section 54.1.2 where measures "Phy-Hyd-Mit-2 / 3 / 4 / 6", "Phy-Wat-Av-6" and "Phy-Wat-Mit-7 / 8" are described.

7.2.1.2 Operation monitoring of measures

A monitoring system should be set up in the operational phase and integrated into the current routine inspections of the airport, with reference to the following measures described in section 7.1 : "Phy-Hyd-Mit-2 / 3 / 4 / 6", "Phy-Wat-Av-6", "Phy-Wat-Mit-7 / 8".

The following specific tasks for operation and maintenance of the treatment plant should be included:

- Water analyses = 4h per week
- Electromechanical tasks = 4h per week per Treatment Plant + 2h per month per pumping station
- Current operation and maintenance tasks = 10h per week per treatment Plant + 2h per week per pumping station
- Oversight 24h/24h = intervention whenever required (alarm, breakdown), with remote information available, considering the implementation of a minimum remote operation monitoring equipment.

7.2.1.3 Persons in charge and document to provide and implement

Design measures should be designed and sized in the detailed design and implemented during the operation and followed-up by ARL. A water management plan should be provided.

Operation monitoring measures should be implemented by ARL or by an external specialist sub-consultant. This one should implement:

- A desalination plant, wastewater treatment plant and storm water management system monitoring procedure including namely regular manual sampling/analysis and visual controls.
- A water quality monitoring plan including namely regular manual sampling/analysis and visual controls.

The basic monitoring tasks should be carried out by a qualified technical worker. The specific operation and maintenance tasks for the treatment plants should be carried out by 2 skilled technicians + 1 on stand-by whenever required. The skills required include:

- A technician with good qualifications in water analysis.
- A technician with good qualifications in electromechanics.
- All O&M personnel shall have good Computer skills.

7.2.2 Summary of plans to be drawn up for water management during the operational phase

Table 26: Summary of Water Management Plan for operational phase

Plan	Measures that the plan must allow to implement and monitor	Person in charge of implementation and control	Activity / Procedures to include
Surface stormwater run-off, drinking and wastewater management and monitoring plan	Design Phy-Hyd-Mit-2 / 3 / 4 / 6 Phy-Wat-Av-6 Phy-Wat-Mit-7 / 8	To be implemented by the Detail Design Engineer Under ARL's control	- A water management plan
	Operation monitoring of measures Phy-Hyd-Mit-2 / 3 / 4 / 6 Phy-Wat-Av-6 Phy-Wat-Mit-7 / 8	To be implemented by ARL or external specialist engineer Under ARL and RRA's control	- A desalination plant, wastewater treatment plant and storm water management system monitoring - A water quality monitoring plan

8 Estimated costs of the water management

The following table presents a cost estimate of the various water management measures and monitoring plans previously presented.

Those costs are not to be considered as a project commitment, they are just indicative and will have to be revised afterwards.

8.1 Construction phase

Table 27: ESMP Cost Estimate Construction Phase - Water Aspects

Theme / Issue	Title and ID of the measure / Plan		Implementation	Responsible for management and implementation	Estimated costs (EUR)	Comments
Hydrology - Stormwater management Wastewater management / Water resource and water supply	Phy-Hyd-Mit-1	Temporary sedimentation capacities	-	To be implemented by the Contractor Under RRA and ARL's control	-	Included in construction costs
	Phy-Wat-Mit-1	Install a desalination plant to supply drinking water to the workers' camp	Specific desalination skid for the workers' site facilities and construction facilities during the construction phase	To be implemented by the Contractor Under RRA and ARL's control	200 000 €	Estimated cost for a 60 m3/d desalination plant
	Phy-Wat-Comp-2	Temporary or permanent replacement of current Caverne Bouteille plant supply by seawater and plant upgrading in order to enable it to treat sea water In case of no possible upgrading, a new mobile treatment plant would would be necessary	Research for a new catchment site with construction of a structure and installation of pumps Caverne Bouteille existing plant upgrading	To be implemented by the Contractor Under RRA and ARL's control	Upgrading and new pumping system: to be sized and estimated by contractor In case of a new mobile treatment plant: 1.5 M€	Relocation in the sea or in Plaine Caverne area out of the zone of influence *30 000 €/month in a leasing solution is chosen*
	Phy-Wat-Av-3	Works wastewater treatment plant	Wastewater treatment skid of adequate capacity for both the airport facilities and for the workers' site facilities during the construction phase	To be implemented by the Contractor Under RRA and ARL's control	700 000 €	For 400 workers, and 100 l/d
	Surface stormwater run-off, drinking and wastewater management and monitoring plan		Controls and analysis	To be implemented by the Contractor Under RRA and ARL's control	67 000€/year	Basic monitoring tasks & survey = 12,000 €/y Specific O&M tasks on the Treatment Plants: - Sewage Treatment Plant (50 m3/d) = 90 € / day, i.e. around 25,000 € per year. - Drinking Water Treatment Plant (60 m3/d) = 110 €/day, i.e. around 30,000 € per year.
	Phy-Wat-Av/Mit-4	Preventive measures to reduce risks during the construction phase - Risk management plan	-	To be implemented by the Contractor Under ARL's control	-	Included in construction costs

8.2 Operation phase

Table 28: ESMP Cost Estimate Operation Phase – Water Aspects

<table>
<tr><th>Theme / Issue</th><th colspan="2">Title and ID of the measure</th><th>Implementation</th><th>Responsible for management and implementation</th><th>Estimated costs (EUR)</th><th>Comments</th></tr>
<tr><td rowspan="10">Hydrology - Stormwater management
Waste water management
/
Water resource and water supply</td><td>Phy-Hyd-Mit-5</td><td>Treat chronic or accidental sources of pollution</td><td>-</td><td>ARL</td><td>-</td><td>Included in construction and exploitation costs</td></tr>
<tr><td>Phy-Hyd-Mit-2</td><td>Stormwater network</td><td rowspan="8">Water treatment plant within an integrated water management plan for the airport facilities at operational phase</td><td rowspan="8">To be implemented by the Detail Design Engineer

Under ARL’s control</td><td rowspan="8">1,75 M</td><td rowspan="8">All included: Water treatment plant, buffer storage for stormwater, storage capacities for rainwater, industrial water, drinking water before distribution, connecting pipelines and discharge lines at sea, ancillaries including building, access roads</td></tr>
<tr><td>Phy-Hyd-Mit-3</td><td>Stormwater ditch located to restore the watershed boundary</td></tr>
<tr><td>Phy-Hyd-Mit-4</td><td>Climate change adaptation: buffering storage and works facilitating infiltration</td></tr>
<tr><td>Phy-Hyd-Mit-6</td><td>Vegetation of slopes and ditches and collection of infrastructure runoff</td></tr>
<tr><td>Phy-Wat-Av-6</td><td>Integrated water management plan</td></tr>
<tr><td>Phy-Wat-Mit-7</td><td>Water treatment plant</td></tr>
<tr><td>Phy-Wat-Mit-8</td><td>Reuse water plan</td></tr>
<tr style="display:none"></tr>
<tr><td colspan="2">Surface stormwater run-off, drinking and wastewater management and monitoring plan</td><td>Operation Monitoring</td><td>ARL (or external specialist engineer under ARL and RRA’s control)</td><td>67 000€/year</td><td>Basic monitoring tasks & survey = 12,000 €/y

Specific O&M tasks on the Treatment Plants:

- Sewage Treatment Plant (50 m3/d) = 90 € / day, i.e. around 25,000 € per year.

- Drinking Water Treatment Plant (60 m3/d) = 110 €/day, i.e. around 30,000 € per year.</td></tr>
</table>

9 References

9.1 Hydrology

- (M. Bakalowicz 2002)
- (Milanović, 2004)
- (Williams, 2008).
- (Evans, 2005)
- (ADP, December 2000).