Potential Hydrogen Export Port in Río Negro

A Multi-Criteria Analysis on the Optimal Location for a Potential Hydrogen Export Port in the Province of Río Negro, Argentina

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Cover Image: The Jetty of the Punta Colorada Port; *picture taken by Marin Kok*

Preface

This report is the result of two months of work in Argentina. During these two months, detailed investigations in the province of Río Negro have been performed and many days at the office of Besna in Buenos Aires have been spent.

The goal of this report is to do a conceptual research on which location is the most optimal for a potential green hydrogen export port. This was possible due to the combination of extensive literature research, discussions with experienced professionals with different specialties, on-site surveys and a conceptual Multi-Criteria analysis. Being part of this Multidisciplinary Project was an intriguing and interesting process with very valuable results. Besides expanding our knowledge and interest on different domains of civil engineering, it was really interesting to work as a multidisciplinary team with different backgrounds and ideas.

This report is the outcome of close collaboration with many people. First, we would like to thank all the colleagues from Port Consultants Rotterdam for the friendly working environment and their support. Especially we would like to thank Ir. Pablo Arecco for being our supervisor in Argentina and for sharing, among others, his extensive knowledge, energy, passion and a typical Argentinian asado with us. Also, we would like also to thank Ir. Pedja Živojnović for his valuable input and advices. And Ir. Melisa Levington for her precious structural help, translation skills and for pushing us to learn to speak spanish.

Moreover, we would like to thank our weekly supervisors Dr. ir. Poonam Taneja and Dr. ir. Marian Bosch Rekveldt for their continuous guidance and encouragement. Their questions, comments, and suggestions were beneficial in order to present our valuable findings.

Furthermore, we would like to thank the governor of the Province of Río Negro, Arabela Carreras, for this opportunity to work on such an impressive and fascinating project. Additionally, we would like to thank Luis Giordano from the Northern Patagonian Logistics Corridor and Gonzalo Medina from the Investment Agency of the Government of the Province of Río Negro.

Finally, we would like to thank Mayra Morale and Nicolas Eortiz from INA for their great assistance during the bathymetry survey at Punta Colorada, Federico Migliora for his great support during the area survey and the Prefectura Naval Argentina for the navigation of the boat at Punta Colorada.

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Abstract

Over the last years, the urge to reduce the world's air pollutants is rapidly growing. New possibilities in order to replace fossil fuels have been explored and one of them is the usage of green hydrogen. The Argentinian, North Patagonian, province of Río Negro, has a great potential to generate green hydrogen on a large scale, due to the available natural resources. Therefore, the province is ambitious to contribute in the developing worldwide sustainable energy market by producing and exporting green hydrogen. Argentina is located at a large distance from the expected green hydrogen sales market in Europe and Asia. In order to reach competitiveness with respect to other future hydrogen ports, the use of a Free-Trade Zone (FTZ) is considered. This is a delimited territory within a country in which tax benefits can be enjoyed. The Province of Río Negro is considering three different locations for a potential green hydrogen export port:

- Punta Colorada Muelle, is an old iron ore export port that is out of operation since 2016. It is located within a FTZ. The deteriorated dry bulk jetty could potentially be reused by accommodating the liquid bulk loading infrastructure.
- Punta Colorada South, is a location roughly one kilometre south of old iron ore export port and is also located within a FTZ.
- Puerto Lobos, is located on the border of the provinces of Río Negro and Chubut. It has potentially favourable bathymetric and hydrodynamic characteristics.

The following main research question is formed: ”Which location between Punta Colorada Muelle, Punta Colorada South and Puerto Lobos is the most suitable for a potential hydrogen export port in Río Negro?” A conceptual qualitative Multi-Criteria Analysis is executed to compare the locations. In order to complete this analysis, firstly the hydrogen export port requirements and criteria are defined. Subsequently, primary and secondary data is collected. The primary data consists out of fieldwork surveys, including a topographic analysis, a hydraulic analysis and a structural analysis. The structural analysis is completed solely on the existing jetty at Punta Colorada Muelle, in order to create an understanding of the current state of the jetty. Furthermore, interviews are conducted with the director of the Maritime and Fluvial Research Center (CIEMF), the executive director of investment agency of the Government of Río Negro, and an ex-employee of the previous mining company at Punta Colorada Muelle. Secondary data on all locations is gathered through literature studies and presented documents from stakeholders.

With data from the field survey several detailed maps are made. A bathymetry map shows the sea bed profile from Punta Colorada Muelle until Punta Pórfido. A topographic map shows the ground level elevation for Punta Colorada Muelle. An interactive map of the jetty is made which contains all the gathered photographs of the structural components and indicates their level of corrosiveness. Next to that the stakeholders are displayed in a power-interest diagram.

Due to the limited information and the quality of the information that was gathered at Puerto Lobos no fair comparison between the locations can be made. Both locations at Punta Colorada have potential to construct a green hydrogen export port. The jetty at Punta Colorada Muelle has the potential to be used in the short-term if it is restored. Punta Colorada South has the advantage that potential future port operations will not depend on dated infrastructure. Next tot that there is no interference with the iron ore port authority. Puerto Lobos has the disadvantage that there is no FTZ and that is situated adjecent to a marine protected area.

To properly compare all three locations, bathymetric and aerial surveys that were completed at the Punta Colorada locations will need to be repeated at Puerto Lobos. To create a more definitive conclusion on any location, additional research like a CPT and an in depth analysis of the structural capacity of the jetty is required.

From the bathymetric surveys another potentially interesting location was found in Punto Pórfido. It is recommended this location is researched further.

Three alternative scenarios for phasing the port construction and operation are presented. These scenarios differ in permanent, temporary or no use of the current jetty at all.

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Acronyms

EIGA European Industrial Gases Association
FTZ Free-Trade Zone
LH2 Liquid Hydrogen
LNG Liquified Natural Gas
MCA Multi-Criteria Analysis
NH_3 Ammonia

1 Introduction

Over the last years, the urge to reduce the world's air pollutants is rapidly growing. New possibilities in order to replace fossil fuels have been explored and one of them is the usage of green hydrogen. Hydrogen is a zero-carbon fuel, which on combustion only emits water. When hydrogen is produced using renewable power such as sun and wind, it is labeled as green hydrogen.

Argentina, which is the second-largest country of South America, is split into twenty-three provinces. One of these provinces, the province of Río Negro, has shown great ambition and potential to generate green hydrogen on a large scale. Due to the strong and consistent wind-climate and fresh water availability in the province, Río Negro lends itself efficiently for the production of green hydrogen.

Fortescue, an Australian mining company and major supporter of green hydrogen, is planning to make a significant investment in green hydrogen in the province of Río Negro, in order to produce green hydrogen on an GigaWatt-scale. Marine export of this hydrogen is considered very plausible.

The province of Río Negro is situated at a relatively large distance from their expected green hydrogen consumers in Europe and Asia [16]. In order to be competitive with respect to other future hydrogen exporters, the use of a Free-Trade Zone (FTZ) is considered. FTZ, also known as Zonas Francas in Spanish, are delimited territories within a country in which tax benefits can be enjoyed in order to increase it's competing position [59]. In the past, Río Negro has had FTZs and the provincial government has created a new zone specifically dedicated for export of green hydrogen tax-free. This has made Rio Negro especially attractive for private investments into the production and export of green hydrogen. Also, the potential port can be established economically due to the fact that port construction resources can be imported tax-free.

The Province of Río Negro is considering three different locations for a potential green hydrogen export port. Two of them are located in or close-by an FTZ: 'Punta Colorada Muelle', which is an abandoned iron ore export port where a jetty is present, and a location situated approximately one kilometre to the South, which in this report has been named 'Punta Colorada South'. The third potential port location is 'Puerto Lobos', which is 30 kilometers to the South, located on the border between the provinces of Río Negro and Chubut, see Figure 1.1.

Figure 1.1: Three possible locations for the potential hydrogen port.

The goal of this report is to analyse the three locations in order to identify which of the three given locations is the most suitable for a potential hydrogen export port. Hence, the following main research question is formed:

”Which location between Punta Colorada Muelle, Punta Colorada South and Puerto Lobos is the most suitable for a potential hydrogen export port in Río Negro?”

To answer the main research question, the following sub-questions have been defined:

A *“Why does the Río Negro province want a hydrogen export port and what are its requirements?”*

B *“What influence and interests do the different stakeholders have within this project and how can they be engaged effectively?”*

C *“What are the topographic characteristics of the three locations that lend themselves for hydrogen export?”*

D *“What are the hydrometeorological, coastal and bathymetric characteristics of the three locations and how would they influence the potential hydrogen port?”*

E *“What are the structural assets of the Punta Colorada Muelle jetty and in what state are they?”*

The structure of this report follows the format of the above stated sub-questions. To begin, Chapter 2, is divided into sections in line with the five sub-questions of the report and it presents the methods used to answer these sub-questions. Next, Chapter 3, answers sub-question A by researching the ambitions and potential of the Province of Río Negro and the port requirements based on a literature and primary study. Following, Chapter 4 answers sub-question B by giving an overview on the influence and interests of the different stakeholders with the help of several interviews. Afterwards in Chapter 5, sub-question C is answered by analysing the surroundings with topographic elevations, visual inspections and satellite views. Subsequently, sub-question D is answered in Chapter 6, with literature research and primary data through land surveys. Consequently, Chapter 7, which answers sub-question E by an overview of the jetty with maps and descriptions. After having presented the results and answered the sub-questions, the results are discussed in Chapter 8. Chapter 9, presents the Multi-Criteria Analysis (MCA). In Chapter 10, conclusions are drawn. Finally, recommendations for future studies are given in Chapter 11.

2 Methodology

This research is based on information gathered through both primary and secondary research methods. Firstly, semi-structured interviews are used as a technique for qualitative primary research. These provide the input for the stakeholder analysis and background analyses. Furthermore, qualitative site and structure observations are made as well as quantitative data collection campaigns for the topographic and bathymetric characteristics of the three locations.

Secondary research contains the gathering of literature publications and shared documents obtained from stakeholders such as the province of Río Negro and mining company MCC. This includes both qualitative and quantitative data. A full overview of the methodology of this report is seen in Figure 2.1.

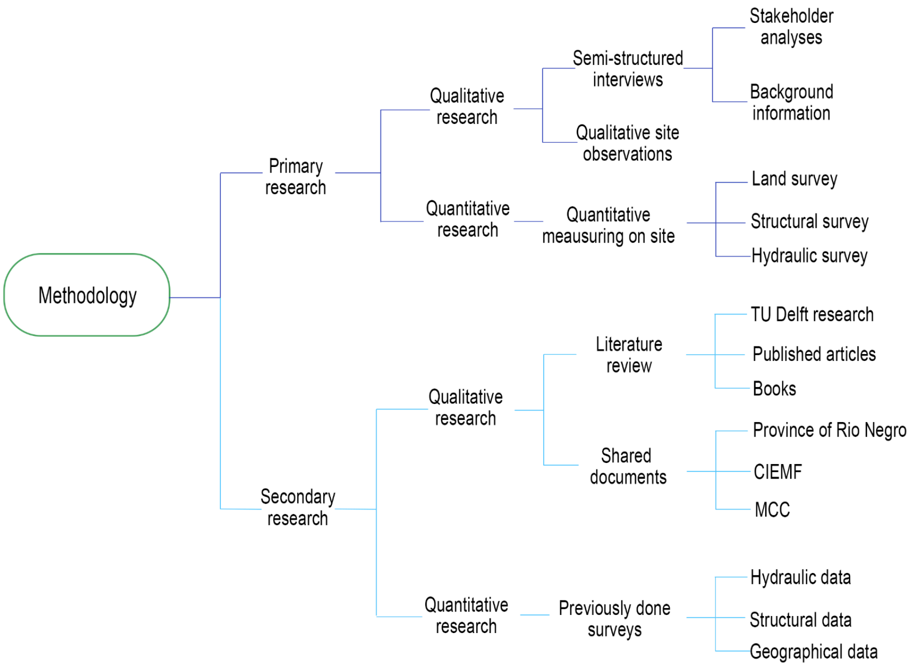


Figure 2.1: Structure for the methodology of the report.

2.1. Background Study

The background study is conducted in four parts: the plans and opportunities for hydrogen export in Río Negro, information on the proposed port locations, a review of the technical background of hydrogen export and the conceptual port requirements of an ammonia export port.

The majority of the research for the background study is done by means of a literature study. For the part of conceptual port requirements of an ammonia export port, the literature study is combined with discussions with experts on port requirements for the specific case of ammonia export. Multiple meetings were done to confirm the applicability of the requirements found in the literature study.

2.2. Interviews

Physical interviews are conducted with various stakeholders in order to get a thorough understanding of the role of the different parties as well as a complete gathering of data on the project.

In order to understand and compare the role of the stakeholders properly, the questions concerning their position within the project are always asked to same way for all interviewees. This allows them to interpret these questions according to their influence and interest in a parallel manner. Additionally, tailored questions are asked regarding their expertise on the project.

Interviews are conducted with the following stakeholders:

- Guillermo R. Delamer: Director of CIEMF, the Maritime and Fluvial Research and Training Center
- Gonzalo G. Medina: Executive Director of the Investment Agency of the Government of the Province of Río Negro
- Hugo O. Nicola: Ex-employee of the mining company MCC as operational manager at Punta Colorada Muelle

The interviews are conducted in the form of semi-structured interviews since this allows for a comfortable conversation in which the stakeholders are empowered to share information openly, whilst keeping a direction for the conversation with predetermined questions [2]. Seeing as all three interviewees have knowledge about the project as a whole, including crucial technical knowledge and procedural knowledge, it is chosen to keep the conversation quite open in order for the stakeholders to be able to share all insights that can be relevant. Furthermore, the aim of each interview is defined beforehand, in order for the output of the interview to be clear to all attendances. A complete overview of the interviews are found to be in Appendix A.

2.3. Stakeholder Analysis

The development of a hydrogen export port in the province of Río Negro comes with the involvement of various different stakeholders. Bryson [11] mentions the importance of analysing all potential stakeholders regarding projects. By understanding what added value and what opposing influence different parties can bring to the project, the stakeholders can be managed accordingly. Therefore, a stakeholder analysis is completed.

The technique used to analyse these stakeholders is by creating a power - interest grid. The stakeholders concerned by the development of a green hydrogen export port are displayed on the grid based on their power and interest. The required knowledge to fill in this power - interest grid is attained mainly through interviews with the stakeholders, as mentioned in Section 2.2.

Additionally, the role, the interest, and the attitude of the stakeholders towards the project is determined. This will give insight on how to strategically engage the different parties in the development of the potential green hydrogen export port. Stakeholders with a negative attitude towards the project, together with a large influence and interest, have high blocking power. Thus, these stakeholders need to be managed accordingly.

Additionally, stakeholders with a positive attitude, and high influence and interest, can be involved strategically to get the most out of their interest. The recommended strategy for the engagement of the stakeholders is included in the Figure 11.1.

2.4. Topographic Analysis

This section presents the methods used to answer the research sub-question C: ”What are the topographic characteristics of the three locations that lend themselves efficiently for hydrogen export?”.

The topographic analysis is completed in order to get a proper understanding of the topographic characteristics on the three distinct locations. The topographic characteristics of the locations are of high importance in order to evaluate the feasibility of building a hydrogen port. To properly consider the characteristics of the potential hydrogen export port areas, an analysis is made through a topographic elevation survey using the WingtraOne drone, which is designed primarily for use in precision agriculture and land surveying roles. Furthermore, satellite data retrieved from QGIS software and Google Earth is used to analyse the area, and a visual inspection is done on site for identifying existing structures (see Figure 2.2).

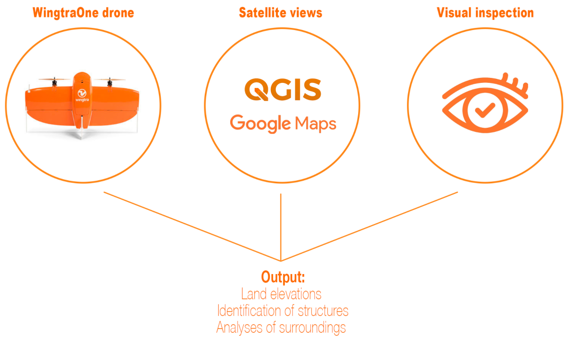


Figure 2.2: Land survey methods used.

2.4.1. WingtraOne Drone Analyses

The WingtraOne drone is used in order to identify the land elevations of the different areas, which can demonstrate the feasibility to build in the area. Larger differences in elevation will result in difficulties for the construction of large factories. The WingtraOne drone is used to measure the land elevations of Punta Colorada Muelle and Punta Colorada South areas. The following areas have been defined as flight zones for the drone (see Figure 2.3), for which the exact map coordinates can be found in Section C.2.The three zones are defined as the following:

- Zone survey area 1: the current location of Punta Colorada Muelle and existing port structures.
- Zone survey area 2: the existing jetty itself, on the ground of the Punta Colorada Muelle.
- Zone survey area 3: the complete Zona Franca area for Punta Colorada.

Figure 2.3: Identified zones for the WingtraOne Drone flight.

Figure 2.4: WingtraOne Drone at Punta Colorada Muelle.

This data collection provides an output in ArcGIS software, which demonstrates the elevations and slopes of the zones.

2.4.2. Satellite Data
The satellite data retrieved from Google Maps and GIS software demonstrate the locations of existing structures on the land, such as the old mining factory structures at the Punta Colorada Muelle. Furthermore, the satellite data is used to identify roads, other infrastructure assets and residential areas. For the areas where no drone flights could be made Digital Elevation Model data is used to estimate elevations.

2.4.3. Visual Inspection
The visual inspection is completed at the locations of Punta Colorada Muelle and Punta Colorada South. The visual inspection provides valuable insight of the existing structures on sight. Regarding the Punta Colorada Muelle, the area includes many structures which can be visually analysed to have a clearer understanding of the site. During the visual inspection, the structures are marked on a map whilst taking photographs.

2.5. Hydraulic Analysis
In this section the methods for the bathymetric survey and the bathymetric and hydrometereological analyses are described.

2.5.1. Hydrometeorological Conditions
A literature study is done to determine the hydrometeorological characteristics of the three proposed locations. Wind, wave, current and tidal conditions are very important factors regarding port performance and the overall feasibility of the project. The hydrometeorological conditions will eventually present an indication on the expected annual port downtime.

2.5.2. Bathymetry Survey
Desired output

A bathymetry survey is executed to map the profile of the seabed at the three locations. These bathymetric charts can later be used to compare the locations in the MCA. Bathymetric characteristics like slope of the foreshore and longshore uniformity can be useful to compare the locations.

Available bathymetry charts

Three different sources of bathymetric charts were analysed to get a complete overview, it should be mentioned that the level of detail and actuality differ. The different charts are used to get acquainted with the area and to compose a navigational grid for the bathymetry survey. The bathymetric charts are listed below and are shown in appendix D.

- Governmental bathymetry charts from 1970
- Bathymetry charts from a survey of 2013 at Punta Colorada
- Navionics

Measuring equipment and setup

The bathymetric survey is executed with a Rigid Inflatable Boat (RIB) provided by the local coastguards. The RIB is equipped with an echosounder. Next to the RIB a Wingtraone is available to map the topography of the intertidal zone. A sensor is mounted to the jetty which measures the tidal elevation. Knowing the tidal elevation during the measuring period, the depth measurements of the echosounder can be corrected to the MSL. Furthermore a Garmin GPS device is present on board to keep track of the exact location of the RIB. In figure 2.5 a the mounting of the echosounder to the RIB is shown. In figure 2.5 b it is shown how the water level sensor is mounted to the jetty.

(a) Setup of the echosounder **(b)** Installation of the water level sensor

Figure 2.5: Measuring equipment setup.

Maximum water depth of interest

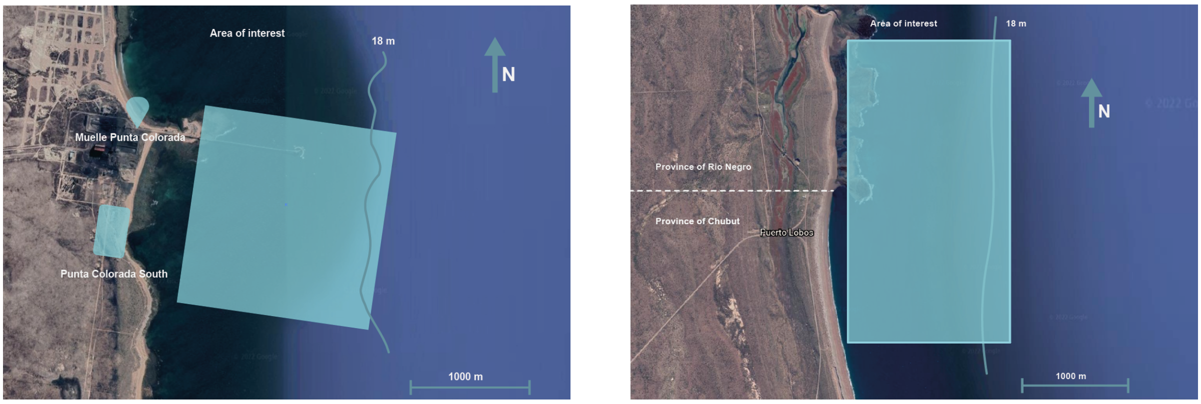
An approximate maximum water depth of interest is determined to demarcate the cross-shore distance of interest for the measuring campaign. This maximum water depth is based on the expected vessel draught, an assumed keel clearance and the tidal amplitude.

Average LNG tanker draught:	12.0 m
Keel clearance:	2.5 m
Tidal amplitude:	3.5 m
Water depth needed:	18.0 m

Area of interest

The area of interest at Punta Colorada Muelle and Punta Colorada South is shown in figure 2.6 a. The cross shore area of interest stretches from the nearshore towards an offshore water depth of 18 meters. The 18 meter depth line is sketched into the satellite image of Punta Colorada Muelle and South using the data from Navionics. The longshore area of interest stretches from the jetty until the trade free zone South of the jetty. A margin is taken of ± 250 meter north of the jetty and South of the trade free zone.

The area of interest at Puerto Lobos is shown in figure 2.6 b. The cross shore area of interest stretches from the nearshore towards an offshore water depth of 18 meters. The 18 meter depth line is sketched into the satellite image of Punta Colorada Muelle and South using the data from Navionics. The longshore area of interest is centered at the border between the province of Río Negro and the Province of Chubut. The longshore distance of interest is chosen to be ± 3 km.



(a) Punta Colorada

(b) Puerto Lobos

Figure 2.6: Areas of interest.

A further elaboration of the survey campaign is shown in appendix D.

2.5.3. Operational Port Downtime

Operational downtime of a port is undesirable because it influences the reliability and the competitiveness of the port. Downtime is defined as the time during the year that the hydrometeorological conditions exceed the operational limits of the port. The downtime for each of the locations should be assessed and compared to determine a prefered location.

2.5.4. Flood Safety

It is obvious that flooding of the port area is undesired as hydrogen is hazardous substance. It should be assessed if one of the potential locations has a considerable higher flood risk than others. For this a literature study has been done and is presented in Section 6.4.

2.6. Structural Analysis

From the three considered locations, Punta Colorada Muelle is the only one including an already existing structure. This port is an old mining port which has not been used for several years. Therefore, some damages are expected.

The purpose of this structural analysis is to examine the potential of reusing the old facility in order to export green hydrogen. This is done by providing an overview of the state of the jetty in the form of maps and qualitative descriptions.

The construction of a hydrogen export port by converting or reusing elements of the old facility will avoid heavy industrial processes. By reusing elements with little or no reprocessing, environmental benefits can be enjoyed through savings on energy and raw materials. Furthermore, potential cost-savings are an additional advantage. By reusing elements of the old facility a higher level in the waste management hierarchy will be reached, see Figure 2.7. Also, damaged elements could be repaired or replaced by new elements in order to increase the service lifetime and to be able to reuse the existing structure.

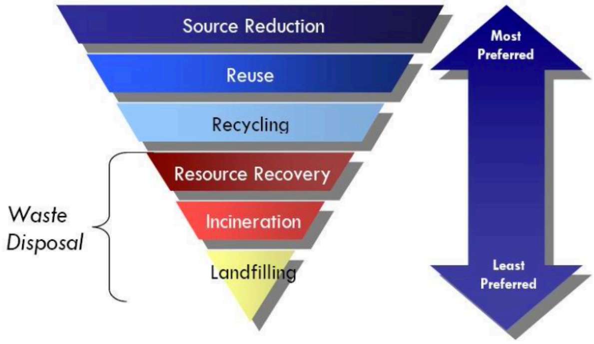


Figure 2.7: Waste management hierarchy [23].

According to the Stichting Koninklijk Nederlands Normalisatie Instituut (NEN), the steps in order to support the assessment of the possibility of the reuse of an existing structure are the following [38].

- Perform visual inspection and technical inspection.
- Whenever damage is detected, a good clarification must be given; the design calculations should be checked and all conditions under which the structure has functioned should be recorded. Relevant properties and loads should be determined and all relevant mechanisms should be checked.
- The current structural capacity needs to be determined as well as the reliability margins.
- Additional special inspections and calculations (finite element method, non linear, dynamic, probabilistic) should be performed if no sufficient safety has been proved.
- Decision making based on costs, for example, reparation or renovation, deconstruction or destruction and so on.

The structural analysis of this report consists of the visual inspection and the detection of the damages. The other steps are out of the scope of this report.

The state of the jetty is determined by carrying out the following on-site visual inspections:

- From the shore
- From a boat during low tide
- From the air using a drone
- On the structure itself.

During these global inspections, damages and flaws are noted and photographed.

In order to facilitate the structural analysis, we divide the port into several different components. Each component is analysed and the potential of its reuse is determined. We assume that if most of the components are in good state and suitable for reuse, then the whole existing structure is also suitable for reuse.

The process of reusing elements are quite similar when it comes to a steel or a reinforced concrete element. However, their damages are fairly different. The process for both materials are identified in the following paragraphs.

2.6.1. Steel Elements

The process of reusing steel elements depends on the size and complexity of the element that is being reused. Therefore, to facilitate the analysis, the steel elements are divided into different parts having the same form, size and original function [53].

Also, the damage level determines whether elements may be reused or not. For steel elements, if the corrosion process is not taken care of on time, the corrosion tends to build up in certain areas of the metal. There are many structural consequences of steel corrosion, such as loss of strength, fatigue, reduced bond strength, limited ductility and reduced shear capacity [18]. Steel corrosion constitutes the most important cause of premature aging and deterioration on reinforced-concrete structures [48]. In the Appendix E.1, examples of different types steel corrosion are given.

The Steel Construction Institute (SCI) has published a protocol, SCI P427: Structural Steel Reuse [10], in order to assess the materials characteristics of the reused steel elements. The protocol gives recommendations for data collection, inspection and testing to ensure that the steel elements can be reused with confidence. Also, further information on the dimensional and mechanical properties of the to-be reused steel elements could be obtain with further testing. However, steel elements with significant loss of section due to corrosion is out of the scope of the SCI protocol.

Since no standardised method for assessing the engineering properties of reused corroded steel is available, contractors need to obtain original design documentation or perform material tests in order to assess the potential of the reuse of elements. However, according to Walter P. Moore's Austin office [29], good practices in reuse of structural steel are:

- **Assessing the damage** - Elements with areas of high corrosion, localised section loss, or with existing holes in places where new holes are to be made should be avoided.
- **Focussing on connections** - Connections should be checked according to Table E.1 in Appendix E.1
- **Knowing the history** - Elements from dynamically loaded structures should be avoided due to for example fatigue damage. The temperature should also be considered as it could affect the steel properties.
- **Preparing the documentation** - The origin of the reused members should be known, as well as the section properties and material grade.

The steel structural analysis of this report consists of the assessment of the damage of the steel elements by visual inspections and pictures of the Punta Colorada Muelle. Also, the history and the documentation of jetty is intented to be obtained with literature, drawings and interviews at the location of the port.

In order to give an indication of the state of the jetty and of the damages, the steel elements of the jetty are graded according to the corrosiveness. Since these elements are not within reach for measurements or tests, we established the gradation of the corrosiveness according to the visuals. The assumption is made that for steel elements the length of the corrosion is the decisive factor [58]. The gradation goes from C1 (weak corrosion) to C5 (high corrosion) and each grade corresponds to a colour, see Table 2.1.

Corrosiveness	Corrosion Level
Weak	C1
Moderately Weak	C2
Medium	C3
Strong	C4
High	C5

Table 2.1: Classification of corrosiveness.

With the on-site visual inspections and the pictures, the steel elements are graded on basis of their corrosion level[1]. The gradation of each element is displayed on maps in Section 7.1.

2.6.2. Concrete Elements

The process of reusing concrete elements is quite complex. Normally, reinforced concrete elements are designed for a specific case with calculations according to design norms which define the amount of reinforcement. Now, if these reinforced concrete elements are to be reused, they must carry the loads demand according to the current design standards [29].

In order to assess old concrete structural members, the amount and situation of reinforcement need to be determined as well as some properties of this element. For this purpose, key information is needed.

[1] Grading is performed independently by three persons of the multidisciplinary project team and the average is taken.

Examples are: the function of the element, the exposure conditions, the remaining service life, the material properties, the reinforcement properties and the concrete strength [23] [26] [29].

Moreover, damage to concrete reduces its structural capacity. These damages may result in the concrete element to not be suitable for reusing. Elements with high corrosion or section loss should be avoided [29]. The different types of damage of concrete are mechanical, chemical, physical damage and reinforcement corrosion, see Figure E.2 in Appendix E.2 [15].

Examples of relevant damages which have to be noted during the visual inspections are for example honeycombs, carbonation, chloride ingress, corrosion, cracks and so on. These examples and some more are given in Appendix E.2. This appendix is also used in order to determine which damage is seen during the visual inspections.

Nowadays, no standardised technique for the reuse of concrete structures is available. However, good practices in the reuse of concrete elements was found [29]. Also, according to A. Glias[2], the reuse process of concrete elements consists of several different steps [23]. From these two sources, the following steps of the reuse process are established:

- **Create an inventory** - The inventory will contain all the relevant properties such as, the type and quantity of the elements, the location of the elements, old drawings and calculations sheets, the materials properties and so on. The following tables present the needed properties of columns for the inventory.
- **Quality Check** - Examine the quality and condition of the structural elements with visual inspections and specific testing. Members with areas of localised corrosion, frost damage or localised section loss should be avoided. Slabs with wide cracks or corroded steel should be avoided as well [29]. When focussing on connections, if wide cracks occur in the console area of a column, then this element should be avoided. A flowchart of the process of the quality check is presented in Appendix E.2 Figure E.4 [29].
- **Certification** - The results of the quality check, combined with the building inventory create the Element Identity (EID) of each element. An example of an Element Identity can be found in Appendix E.2 Figure E.5. This certifies whether the elements are suitable for reuse or not.

The concrete structural analysis of this report consists of the assessment of the damage of the concrete elements by visual inspections and pictures of the structure. Specific testing is out of the scope of this report. Also, any existing information in order to create the inventory of the concrete elements of the jetty is intented to be obtained with literature, old drawings and interviews at the location of the port.

The research and the review of any existing information as well as the creation of the inventory can be in the form of structural drawings, structural design calculations, materials specifications and standards codes [23]. However, little information on the jetty is available. Therefore, the required information has to be obtained with an on-site survey.

This survey consists of extended visual inspections of the jetty as mentioned earlier. During the visual inspections of the concrete elements, the damage is identified, located and the severity is reviewed.

The gathered information is displayed on maps and qualitative descriptions are given.

[2]A. Glias did his Master Thesis on the feasibility of reusing existing structural concrete elements of empty office buildings.

3
Background Study

This chapter aims to answer sub-question A: *''Why does the Río Negro province want a hydrogen export port and what are its requirements?''*.

3.1. Hydrogen Export in the Province of Río Negro

This section presents information regarding the motive of the Province of Río Negro to realise a hydrogen export port. This is done through providing insight into the ambitions of the province and the available assets that the Province of Río Negro has for producing green hydrogen. The ambitions are sub-divided into those of the province itself, and the potential investor of the project, which is stated in 3.1.1. Afterwards, the assets of Río Negro to produce green hydrogen are discussed. Natural assets such as wind, water and availability of land are presented, later financial and legal assets are mentioned in 3.1.2. The last section 3.2 includes the proposed project locations for the export port.

3.1.1. Project Ambitions

Province of Río Negro

Together with the research institute "Instituto Balseiro" located in Bariloche (Río Negro), alternatives have been analysed for the region to start producing green energy. This has resulted in the conceptual plan of using wind energy in combination with electrolysis to export green energy to customers in the Northern Hemisphere, see Section A.2.

Due to the unique natural conditions in the province of Río Negro there are huge opportunities to produce green hydrogen in a cost effective way. Producing green hydrogen in the province of Río Negro could economically boost the region. It is expected that the project will create more than 15000 direct jobs [3]. Argentina could also contribute in the global energy transition and participate in the international export market. The government of the province of Río Negro has recognised these possibilities and aims to become a front runner in the green hydrogen economy [16]. The government of Río Negro said that "It is expected to turn Río Negro into a global green hydrogen export hub by 2030".

The province of Río Negro is primarily interested in investments from the private sector for the realisation of this project A.2. This type of investment structure has the benefit of attracting larger investments while also benefiting from the private company's in-house expertise and technologies regarding hydrogen production. A private investment would imply the private company to build and operate the following assets; wind farm, electrolysis facilities and the export harbour. Río Negro stated that multiple parties have been interested in this type of project in the province. Currently, negotiations are present between Fortescue Future Industries (FFI) to determine the details of the this project.

Fortescue Future Industries

FFI is a Australian energy company, that develops, finances, operates and invests in zero-emission resources to produce renewable energy at a scale equal to the oil and gas super majors. Their aim is to make green hydrogen the most traded seaborne energy commodity in the world [31]. A news article from November 2021 from Reuters mentions that FFI, is willing to invest about $ 8 billion dollars to produce green hydrogen in the province of Río Negro [3].

In November 2021 a memorandum of understanding is signed by Fortescue Future Industries and the Government of Río Negro [3]. The 13th of January 2022 FFI presented its initiative to supply a green hydrogen production production plant and its derivatives to the province of Río Negro. Next to that the construction of 17 wind measurement masts in the region has been contracted. Currently the project is the pre-feasibility stage in which FFI defines the viability of the project [25]. It was mentioned in an interview with Gonzalo Medina that FFI aims for 2025 to start operating and exporting hydrogen, see Appendix A.2.

3.1.2. Assets in the Province

This section elaborates on the most essential elements needed for hydrogen production and their availability in the province of Río Negro. The production of green hydrogen needs wind and land for the generation of electricity, and fresh water for the conversion of electricity into hydrogen. These natural resources are introduced in the first sections. Thereafter, financial and legal assets are discussed.

Wind

As seen in figure 3.1, the availability of wind resources is abundant in the southern parts of Río Negro. The available energy from wind is proportional to the cube of its speed. To accurately portray the availability of wind resources it is expressed in wind power density (W/m^2). The relative proximity to the coast for these exceptionally windy areas make for great circumstances for clean energy generation and export.

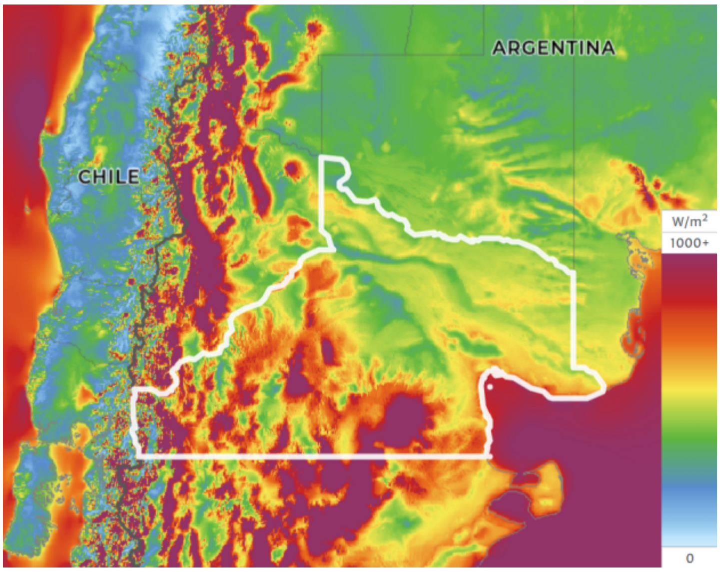


Figure 3.1: Wind power density in the province of Río Negro at a height of 100m.
[24]

Water

There is one source of fresh water in Río Negro, the river Río Negro itself. An artificial canal branching from Río Negro is available between General Conesa and San Antonio. The capacity of this canal is 500 l/s, [16]. Samples taken from the river have shown that water quality is sufficient for electrolysis purposes.

Interview A.2 has presented the intention of the Province and Fortescue to have a desalination plant to demineralise salt water for the electrolysers.

Both fresh- and salt water demineralisation are considered plausible for this project and will be discussed.

Financial and legal assets
The province of Río Negro is located quite far away from potential customers, which are predominantly located in the Northern Hemisphere [16]. Transport costs of hydrogen will thus be significant. In order to become a competitive supplier of green hydrogen, the province has applied a legal framework to the proposed export locations of green hydrogen, called; FTZ.

The FTZs will provide a tax-free environment for the private companies to construct facilities, produce and export commodities. This is attractive for both the construction of all facilities needed for the port, and for the export of green hydrogen.

The province will earn rent for the usage of the area within the FTZ, which is ultimately the source of income for the province.

The ownership of all infrastructure to be build by the private company is quite uncertain at this moment. It is most likely that partial ownership of the province and Fortescue will prevail. This is in line with previous agreements made between the province of Río Negro and the mining company 'MCC'.

3.2. Proposed Port Locations

In the South-East of Río Negro at the Gulf of San Matias, three locations have been identified suitable for the hydrogen export harbour. These locations are Punta Colorada Muelle, Punta Colorada South and Puerto Lobos, see figure 1.1.

3.2.1. Punta Colorada Muelle

The middle part of the deactivated FTZ of Punta Colorada, shown in figure 3.2, is proposed as potential location. A FTZ of 643 hectares adjacent to the coast was established at this location for the export of iron ore [36]. The FTZ is shown in figure 3.2 within the red frame. The port has been out of service since 2016 because of their poor competitive position in the iron ore market. In 2006 the province of Río Negro has contracted the Chinese mining company MCC Minera Sierra Grande to operate the port. The contract states an agreement of 99 years, starting in 2006, where MCC has the right to the use of the assets on the ground of the Punta Colorada area [57].

Figure 3.2: FTZ of Punta Colorada [36].

The most important characteristics of the location are listed:

- The FTZ has direct accessibility to ruta nacional 3 via the unpaved ruta provincial 9.
- The FTZ is connected to a high voltage grid of 132 KV from Puerto Madryn [36].
- The FTZ is connected to the water and gas supply infrastructure [36].

- The municipality of Sierra Grande, with 12000 inhabitants, is located about 25 km west of the FTZ [36].
- The developing touristic beach town Playas Doradas is located about 8 km North or the FTZ. Playas Doradas attracts lots of tourists during the summer season [36].
- In the interview with Hugo O. Nicola it was mentioned the port assets haven't had maintenance since the port went out of operation. The assets of the ports show clear signs of deferred maintenance.

In particular the existing jetty has been identified to be reused for the export of hydrogen. The jetty consists of a 1400 meter viaduct with a one meter wide conveyor belt. Originally it was designed to load dry bulk vessels up to 60000 tons and up to LOA 250m. The jetty used to have a capacity of 2000 tons per hour [36].At the mooring dolphins a depth of 12,70 meter has been reported during low water [46]. The current state of the jetty, and the lacking jetty assets to load liquid bulk are yet to be determined. The jetty is shown in figure 3.3

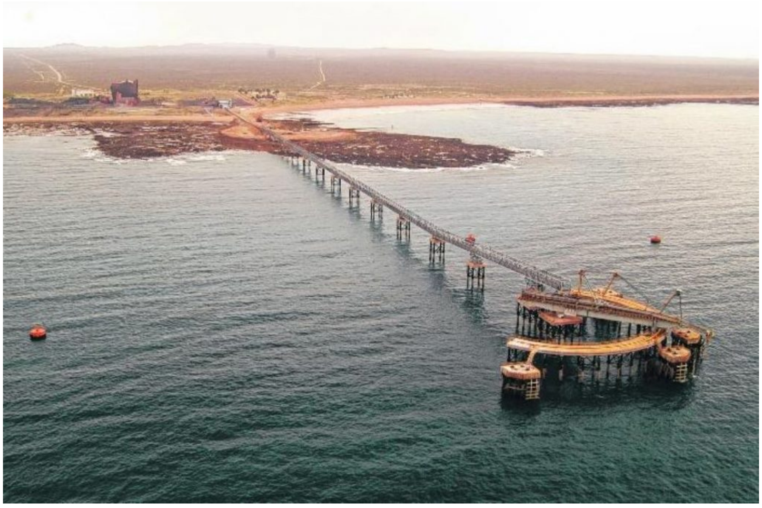


Figure 3.3: Port of Punta Colorada and the jetty.

3.2.2. Punta Colorada South

The next proposed location is the Southern part of the deactivated FTZ of Punta Colorada, shown in figure 3.2. This location is approximately 1 km South of the existing port. At this location the port would be established within the FTZ, without making use of the infrastructure of the old iron ore port. It is considered that the characteristics of Punta Colorada South are more or less the same as for Punta Colorada Muelle. Figure 3.4 gives an indication of the proposed location.

Figure 3.4: Punta Colorada South.

3.2.3. Puerto Lobos

The location at Puerto Lobos was identified and presented to the province of Río Negro by CIEMF, see Appendix A.1. It was proposed that the port should be established exactly at the border or the province of Río Negro and the province of Chubut. CIEMF envisions that both provinces could benefit from the port. In CIEMF's plans the port at Puerto Lobos would be used for multiple purposes, not just hydrogen export.

The most important characteristics of the proposed location are listed below:

- Puerto Lobos is an abandoned town, which currently only consists of ruins of old buildings [45].
- The nearest municipality is the municipality of Sierra Grande which is located about 60 km to the North-West.
- The area surrounding the proposed port location is currently publicly owned, easing the way for potential construction (see Appendix A.1).
- The touristic website patagonia.com.ar mentions that in the past there has been a FTZ [45] but no reliable sources were found to confirm this.

Figure 3.5 gives an indication of the proposed location.

Figure 3.5: Puerto Lobos.

3.3. Green Hydrogen Introduction

This section first elaborates on the applicability of hydrogen in the future energy market. Later it focuses on the basic physics of the electrolysis and the types of technologies used nowadays to produce hydrogen. The last sections briefly mention the different carrier types and their storage facilities.

3.3.1. Hydrogen Application

Green hydrogen has gained interest the past decades as it is a possible solution for large scale storage and transport of electrical energy. The application of hydrogen production using sustainable intermittent energy sources such as solar- and wind-energy seems to be an essential part of the global transition towards sustainable energy. Hydrogen is a carrier of energy that suffers from efficiency losses during conversion from and towards electricity. Thus, hydrogen becomes an interesting commodity in two situations; temporal and spatial inequalities of energy. Temporal inequalities originate when production and demand of energy are not equal at a certain time, which is the case when wind farms produce more energy (due to increased wind speeds for instance) than is demanded by the local consumers at that moment. With temporal inequality, hydrogen has a primary function as storage-commodity. Spatial inequalities originate when production and demand of energy are located far apart. The province of Río Negro has the potential to generate large amounts of sustainable energy using wind farms, but the demand for this energy is located mainly in the Northern Hemisphere. Thus, hydrogen is potentially interesting as a transport-commodity.

3.3.2. Hydrogen Production Technology

Electrochemical reaction

Hydrogen is obtained from splitting a water molecule (H2O) into hydrogen gas (H2) and oxygen gas (O2) under the supply of electricity, this electrochemical reaction is called electrolysis. When electrolysis is performed using sustainable energy, the hydrogen produced is labeled 'green hydrogen'. The electrolysis reaction needs to be performed at large scale to produce quantities interesting for maritime transport, which has become feasible with electrolysers nowadays. Electrolysers are basically large scale electrochemical factories that make use of the basic idea of electrolysis.

$$2H_2O + \textit{electricity} -> 2H_2 + O_2 \tag{3.1}$$

Using the chemical reaction above, and assuming an efficiency of the process of 100%, an overview can be made of the input and output quantities of any electrolyser, see figure 3.6.

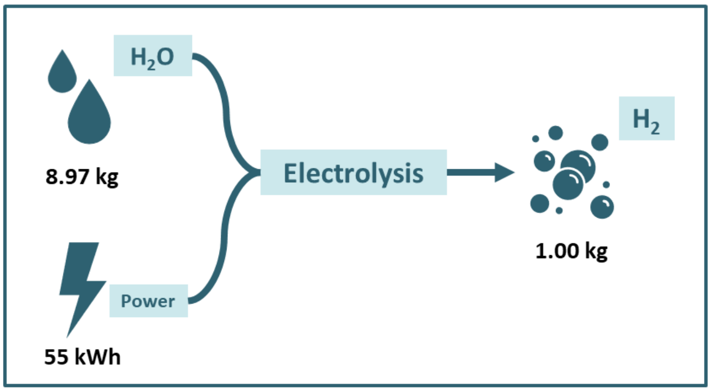


Figure 3.6: Schematic overview of input and output quantities of any electrolyser (assuming 100% efficiency).

Electrolysers generally follow a similar layout, a crude overview of electrolyser elements is added in the table in Appendix B table B.1.

While electrolysers generally are very efficient transforming electrical power into hydrogen (newest models attain almost 100% efficiency), some sub-functions mentioned above consume power (such as the water purification, cooling arrangement, and compressors) which reduces the net efficiency of the total process. The most used electrolyser types are compared in the table shown in Appendix B table B.2.

Assuming a suitable electrolyser type for the Río Negro project is difficult multiple aspects are of importance; capital costs, uncertainty regarding future costs and future performance. The majority of the experts in the field of electrolysis believe in future dominance of the PEM electrolyser type in combination with renewable energy sources [51], and as such, the **PEM technology is assumed most plausible for the Río Negro production of hydrogen**.

3.3.3. Hydrogen Carrier Technology

Hydrogen can be handled either in its pure form, liquid or compressed, or attached to a carrier such as ammonia, ethanol or dibenzyltoluene. Each way of handling has its advantages and disadvantages. The most plausible hydrogen carrier types are considered to be ammonia and LH_2 [7].

- Ammonia: most plausible for the pilot and mid-term planning
- Liquid hydrogen: plausible for long-term planning as the technique shows potential for higher energy density, but needs more innovation.

The characteristics of the considered hydrogen carriers are shown below.

Property	Liquid Hydrogen	Ammonia	Unit
Chemical Formula	H_2	NH_3	-
H %wt	100	17.6	%
Boiling Temperature (1 bar)	-253	-33.4	°C
Liquid Density (1 bar)	70.5	682	kg/m^3
Hydrogen Density (1 bar)	70.5	120	kg H_2/m^3
Energy Density	8460	14400	MJ/m^3
Flammability limits in air	4 - 74	14.8 - 33.5	%
Minimum ignition energy	0.02	680	mJ

Table 3.1: Overview of two hydrogen carriers assumed most plausible regarding the project ambitions derived from Appendix A.2, [7].

3.3.4. Hydrogen Storage

Liquid hydrogen storage

NASA has been storing Liquid Hydrogen (LH2) for decades now so the technology is more or less developed. A scale-up of existing tanks can be expected in the next decades leading to tanks with a capacity of 50,000 m3 [12]. In December 2020 Kawasaki announced the completion of the basic design of an 11,200 m3 spherical LH2 storage tank [30].

Storage is possibly the best regulated part of the liquid hydrogen value chain as the European Industrial Gases Association (EIGA), ISO and CEN have all published on the use of cryogenic tanks for liquid hydrogen storage. For example, EIGA document 06/19 gives specific guidance on the layout and locations of installations of LH2 terminals. However, most existing regulations and standards refer to small scale storage tanks.

Ammonia storage

Nowadays, Ammonia (NH_3) is already transported on a large scale, with well-established infrastructure for the handling and storage of it. Storage is done in two main ways depending on the volume of NH3 to be stored. Up till volumes of 5000 m3, the common technique is to store NH_3 pressurised at ambient temperature. Sea going tankers can either compress or refrigerate NH_3 or even a combination of the two to keep it in its liquid state. Cooling NH_3 down to -33°C allows the use of unpressurised containers [6]. The common practice for large volumes is to store as a liquid at ambient pressure and saturation temperature. To make sure that NH_3 is contained properly, double-walled tank systems are applied. Boil-off gas is also present in NH_3 storage. In this case, due to the fact that NH_3 is stored at a relatively high temperature (compared to LH2) and the boil-off rate of NH_3 is low [9], re-liquifying the gaseous NH_3 is the assumed process.

3.4. Conceptual Hydrogen Export Port Requirements in Río Negro

In this section the conceptual requirements for a hydrogen export port will be identified. Firstly, the boundary conditions for the Río Negro hydrogen port are listed. This will form the scope and basis of the port requirements determined later in this chapter. Secondly, the different assets of the port are described. In Figure 3.8 a schematic and preliminary layout on the port is shown. The figure shows the most essential required port assets. In the following sections an brief elaboration is given on each of the assets. The assets are divided into three categories. Part I: Hinterland, Part II: Production, Storage and Loading, Part III: Berthing and Mooring, Part IV: Safety requirements. When possible, a crude estimate is given on the spatial dimensions of the different assets.

3.4.1. Assumed Boundary Conditions

Hydrogen carrier

Resulting from the interview with Gonzalo Medina (see Appendix A.2), the hydrogen carrier used for export is assumed to be Ammonia. However, it is considered probable that the transport of liquid hydrogen will be common in the future.

Conceptual port layout

The ammonia port has distinct elements that each facilitate an essential function. The schematic overview below indicates the input, the processes, and the output of different elements, see Figure 3.7.

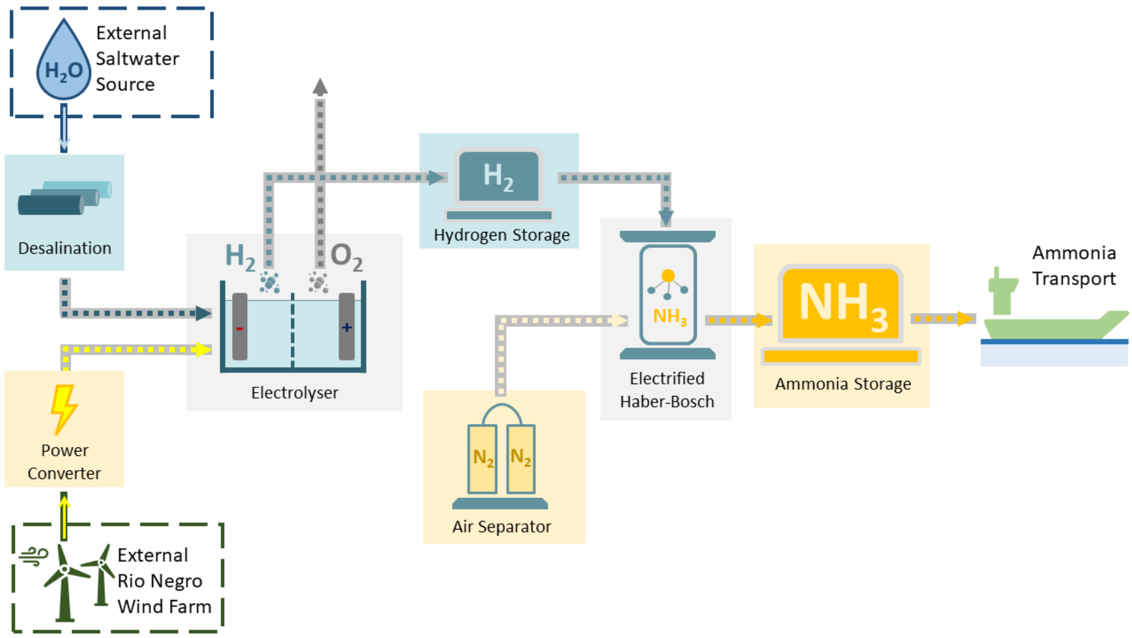


Figure 3.7: Flow diagram of port system.

Electricity entering the port area needs to be converted from alternating- to direct-current, and from high- to low-voltage with the usage of power conversion installations. The water source is expected to be salt water, which has to be demineralised. This is expected to be performed within a reverse osmosis installation. Both the converted electricity and the demineralised water are fed into the electrolyser, which produces low-density pure oxygen (O_2) and low-density pure hydrogen (H_2). The pure oxygen gas is a byproduct which could be stored and sold to various industries. For simplicity, oxygen gas is considered to be a waste product and is directly released into the atmosphere. The pure but low-density hydrogen is fed into a storage tank (possibly in compressed form). The electrified Haber-Bosch plant has two inputs, pure nitrogen gas and pure hydrogen gas. The pure nitrogen gas is collected from the local atmosphere using an air separator, after the nitrogen gas has been formed it is fed to a storage tank. The electrified Haber-Bosch plant retrieves the pure hydrogen and nitrogen gas from the storage tanks, which allow for some buffer when demand and production are not equal, and produces solely ammonia which is then fed into large storage tanks. These storage tanks store the produced volume of ammonia until it is retrieved by the Liquified Natural Gas (LNG) tanker that transports it to the client.

In Figure 3.8 a schematic and preliminary layout on the port is shown. The figure shows the most essential required port assets and the external conditions.

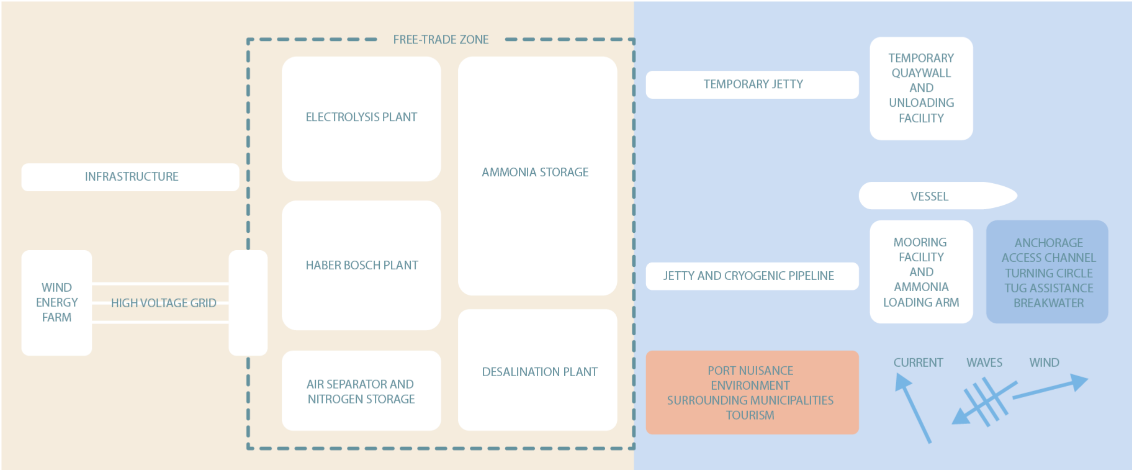


Figure 3.8: Conceptual port layout.

Port planning phases

Fortescue plans to increase energy production with 2GW each year until it reaches 15 GW [19]. With these conditions the following phases in the port planning shown in Table 3.2 are considered starting from the first year of operation. Due to the uncertainties of the global developing hydrogen market, the long-term planning phase kept out of the scope of this research.

Scenario	Horizon [years]	Changes	Capacity [GW]	Carrier
Short-term	2	Minor lay-out changes	2	NH_3
Medium-term	8	First phase of the masterplan	15	NH_3
Long-term	-	Port masterplan	-	NH_3 or H_2

Table 3.2: Port planning phases.

Expected vessels

Ammonia is transported in prismatic LNG carriers [28] at -34 °C [9]. The characteristics of these ships are given by Figure 3.9. Initially it is assumed that vessels with an approximate capacity of 75,000 m^3 will call at the port. These vessels are assumed of sufficient size for the short-term phase. The capacity of this type of vessel will result in around 17 annual port calls in the short-term phase, as can be seen in Table 3.4. In the medium term, using this vessel would result in an increase of the amount of calls to 123 calls annually. As this amount of calls is not favourable logistically and economically a larger vessel should be used in the medium-term planning. It is therefore assumed that all of the vessels shown in Figure 3.9 need to be able to call at the port. For calculation purposes regarding the medium term, a vessel with an approximate capacity of 218.000 m^3 is assumed.

DWT (t)	*Loa* (m)	*Lbp* (m)	*Beam* (m)	*Draught* (m)	Approx. Capacity (m^3)
LNG Carriers (Prismatic)					
125,000	345.0	333.0	55.0	12.0	267,000
97,000	315.0	303.0	50.0	12.0	218,000
90,000	298.0	285.0	46.0	11.8	177,000
80,000	280.0	268.8	43.4	11.4	140,000
52,000	247.3	231.0	34.8	9.5	75,000
27,000	207.8	196.0	29.3	9.2	40,000

Medium-term (125,000–80,000 DWT)
Short-term (52,000–27,000 DWT)

Figure 3.9: Characteristics of Prismatic LNG carriers [40].

Next to that, it is assumed Fortescue will want strict control over the availability of vessels for export. Either through acquisition of their own cargo fleet or strict contracts with an LNG chartering company. In this way the arrival of the vessels will be on-demand, instead of an uncertainty based on the availability of LNG carriers in the market.

Ammonia production

The total annual ammonia production is determined for the short- and medium term in order to get a first-order estimate of the total throughput of the Río Negro port. The calculation was based on certain efficiency rates presented in table 3.3.

Process	Factor
Wind turbine capacity	45%
Electrolysis efficiency	80%
Haber-Bosch efficiency	100%

Table 3.3: Assumed system efficiency [43][51].

Scenario	Capacity (GW)	Yearly Ammonia Production (m3/yr)	Design Vessel Storage (m3)	Calls per year
Short-term	2	$1.32*10^6$	75,000	17.6
Medium-term	15	$9.88*10^6$	220,000	44.9

Table 3.4: Annual ammonia production and corresponding calls.

3.4.2. Part I: Hinterland

High voltage power transmission

The production facilities need to be supplied with electric power to produce ammonia. To connect the production facilities to the future wind parks inland, a high voltage overhead power transmission line is required.

Hinterland accessibility

A connection with the hinterland by road is required for access to employees, construction materials and maintenance.

3.4.3. Part II: Production, Storage and Loading

This section gives a small overview of the different elements within port terminal needed for the production and storage.

Electrolyser facility

The electrolyser facility is build up of 3 sub-elements; the electrolyser itself, the reverse-osmosis facility, and the power conversion facility.

‘Hydrohub Innovation Program’ has presented a public report for a 1GW electrolyser facility which is taken as reference for this project (Hydrohub Innovation Program, 2020). The ”Hydrohub” electrolyser gives an impression of the size of the facilities for a 1GW (PEM) electrolyser. The design takes into account enough space for roads, accessibility of all facilities, maintenance, and pipe- and cable routing.

The electrolyser will require 2 GW of production capacity initially and grow with 2 GW each year until it reaches 15GW [19]. Sizes are assumed to increased proportionally. Proportional growth is assumed an upper-bound estimate of the actual size of the electrolyser facility since not all areas have to increase proportionally (roads, areas needed for maintenance, etc.)

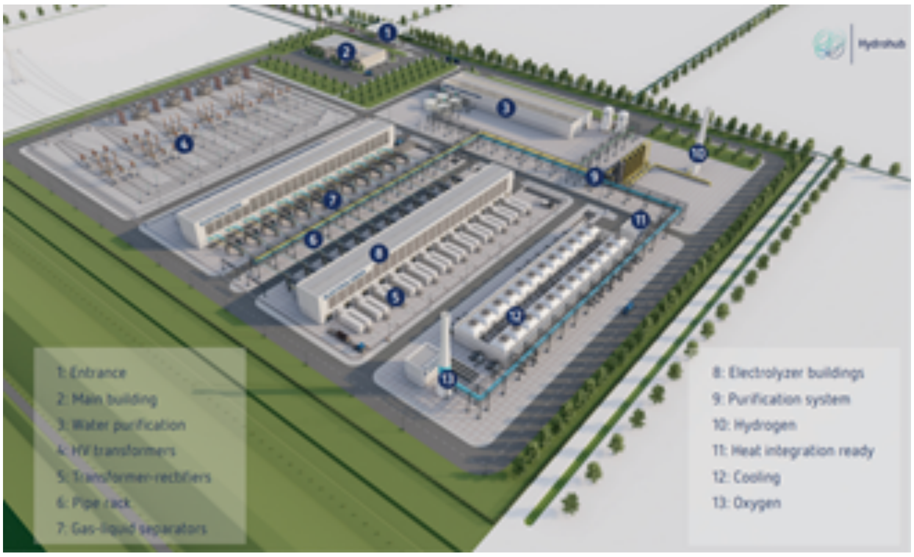


Figure 3.10: Reference 1GW electrolyser proposed by ”Hydrohub” [1].

Project	Technology	Capacity	Space Required
”Hydrohub design”	PEM	1 GW	10 ha
Río Negro Short-term	PEM	2 GW	20 ha
Río Negro Medium-term	PEM	15 GW	150 ha

Table 3.5: Size indication of total electrolyser facilities for the short- and medium term based on ”Hydrohub” 1GW electrolyser.

Ammonia Plant

Traditional ammonia production plants make use of the Haber-Bosch process. In order to make ammonia production a non-polluting industry, a modification of traditional the technology is needed, this is called the electrified Haber-Bosch process [52]. This novel technology only needs pure hydrogen- and pure nitrogen gas for producing ammonia.

Within this study, the electrified Haber-Bosch process is assumed feasible in the near future for large scale production and compatible with intermittent energy sources. The plant size of the green ammonia factory is assumed equal to modern traditional ammonia production plants of similar production capacity. The ammonia production plant in Pilbara, Australia, from the fertiliser company YARA is taken as a reference. This plant is one of the largest ammonia factories (850 Tons/y) and relatively modern (constructed in June 2006), the characteristics of the plant are added below and size indications are given for the short and medium term in Table 3.6.

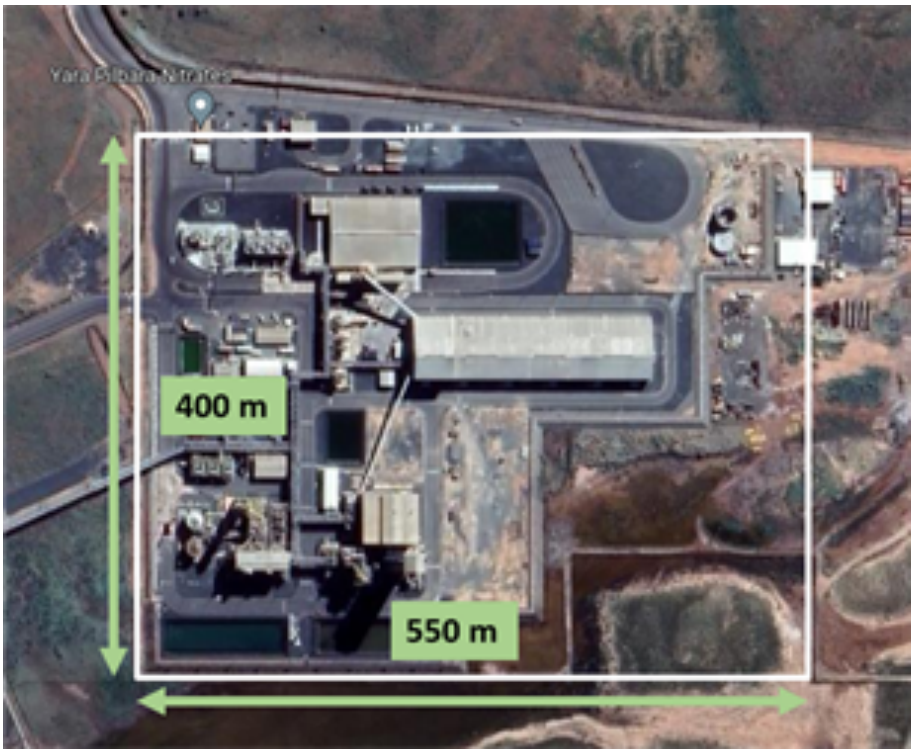


Figure 3.11: Pilbara ammonia plant, Australia.

Project	Technology	Capacity	Space Required
YARA Pilbara	Traditional Haber-Bosch	850,000 t/yr	22 ha
Río Negro Short-term	Electrified Haber-Bosch	900,000 t/yr	23 ha
Río Negro Medium-term	Electrified Haber-Bosch	6,300,000 t/yr	175 ha

Table 3.6: Size indication of total ammonia plant for the short- and medium term based on Pilbara ammonia plant.

Ammonia storage

For the Ammonia storage, several prismatic storage units are required. Presumably units that can store the ammonia at -34 ◦C. It is assumed that ammonia is exported on demand. Using this assumption, the time variability of the produced volume and the vessel arrival is excluded and the dimensions of the storage facility will only be based on the storage capacity of the expected vessel.

For the short-term, 75000 m^3 will be the minimum required storage volume, this volume . It is suggested that the dimensions of the storage facility should have a margin on the minimum required storage volume. This storage facility of twice minimum required storage volume is therefore proposed. This is 150000 m^3.

To accommodate storage of these enormous quantities of ammonia, the largest ammonia tanks existing today are taken as reference; the QAFCO storage tanks. These tanks are flat-bottomed, store up to 75.000 m^3 and have a diameter of 50 meters [47].

Figure 3.12: QAFCO storage tanks (75.000 m^3), Mesaieed.

Scenario	Storage Required	Number of Tanks	Space Required
Short-term	150,000 m3	2	1.5 ha
Medium-term	450,000 m3	6	4.5 ha

Table 3.7: Size indication of ammonia storage in flat-bottom tanks for the short- and medium term based on QAFCO storage tanks, mesaieed.

Loading infrastructure

For loading the ships three main components are required: cryogenic pipelines, LNG transfer systems and pumps. The length of the cryogenic pipelines should be as small as possible, as they are expensive and add heat to the transported ammonia. However, it is necessary to anticipate on sudden volume changes of the ammonia by constructing loops in the pipeline [21]. For the transfer system, either a marine loading arm or a flexible hose transfer system. Pumps could be placed on the jetty, or the vessels on board pumps could be used.

Jetty

A jetty is a shore-connected structure over water to which vessels can be moored. Such a structure is required to accommodate the ammonia loading infrastructure. The jetty should reach as far off-shore until the required water depth for the expected vessels. The length of the jetty is preferably as short a possible to reduce capital and maintenance costs of both the jetty and the loading infrastructure. The length of the jetty eventually depends on the local bathymetry and the required water depth.

An other jetty is required for unloading the port construction materials. Importing the construction materials within the FTZ is economically beneficial for the establishment of the port. It is expected that these construction materials will be unloaded at a quay wall with cranes and other necessary unloading infrastructure. Furthermore, it is mentioned that this secondary jetty might be temporary (see Appendix A.2.

If one jetty is able to facilitate both the import of construction materials and the export of ammonia, one jetty is preferred.

3.4.4. Part III: Berthing and Mooring

Required depths

The minimum required depth is defined as the depth that must be implemented for the approach channel, manoeuvring spaces and berthing position.This depth is based on the deterministic planning stage formula for the access channel. This formula is given below [32]

$$d = D_s - T + s_{max} + r + m \tag{3.2}$$

In this equation:

- D_s is the draught of the design vessel.
- T is the tidal restriction.
- s_{max} is the sinkage. As a rule of thumb s_{max} = 0.5 m.
- r is the response to waves. This is $H_s/2(m)$
- m is a safety margin. This is 0.3 m for soft mud and 1.0 m for rock [32].

The loading time of a vessel of 140000 m^3 is approximately 12 hours [33]. Therefore, it is expected that for the vessels that are expected in the short-term, a tidal window can be implemented. However, in the long-term, due to the time required for loading of the vessel, no tidal window can be implemented effectively.

Fenders & breasting dolphins

The following relevant considerations are mentioned in PIANC 153[41].

- Fender systems and breasting dolphins should be positioned along the parallel body of the vessel when berthed
- The spacing of primary fenders should consider the geometry of the range of vessels to be berthed
- A minimum of two breasting dolphins should be provided, although four dolphins may be required to accommodate the range of vessels
- At least two fenders (one at either side of the platform) should make full-face contact with the parallel body of the vessel. The spacing between outer breasting dolphins should be between 0.25 and 0.40 length overall (LOA) of the maximum sized vessel expected to call at the port. The spacing between the inner breasting dolphins should be approximately 0.25 to 0.40 LOA of the minimum sized vessel expected to call at the port per OCIMF [39]. See figure 3.13

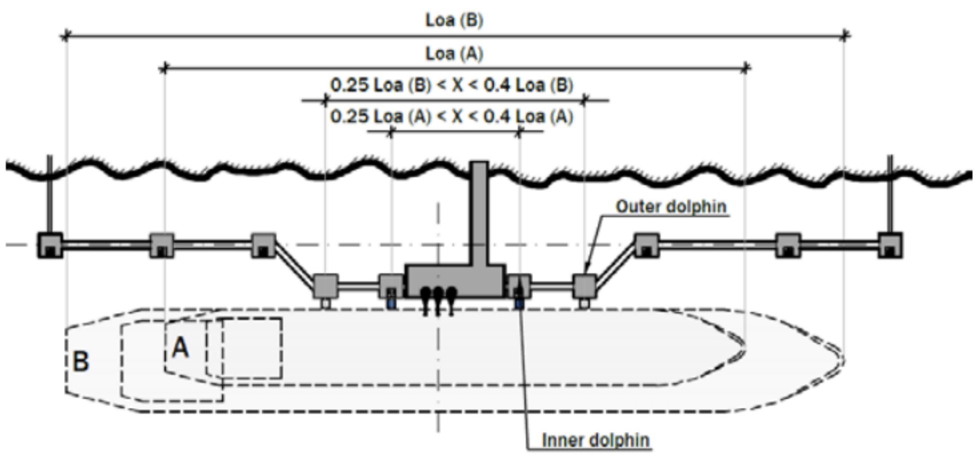


Figure 3.13: Visualisation of required fender spacing [41].

Mooring
A mooring arrangement needs to be made for the port. An idealised mooring arrangement for a multi-directional environment is shown in Figure 3.14. A mooring arrangement could also consist of existing mooring buoys instead of the mooring dolphins shown in the figure. The mooring arrangement should be equipped with a quick release system to allow for quick exit of vessels in emergency situations and safe line handling.

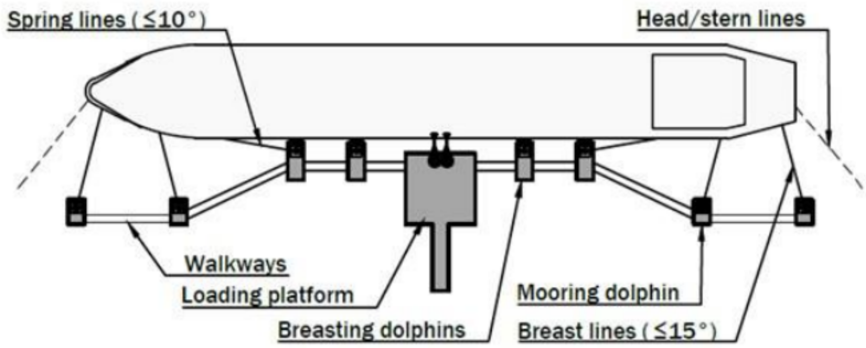


Figure 3.14: Ideal mooring arrangement for a multi-directional environment [42].

Tugboat assistance
Berthing LNG vessels requires the assistance of multiple tugboats. Depending on the regulations of the Prefectura, possibly three or four tugboats are required. Initially with a limited amount of calls these tugboats could come from another port like San Antonio as was done in the past (see Appendix A.3). When the amount of calls increases it might be better to accommodate permanent tugboats at the port itself.

Operating limits
In terms of nautical safety, liquid hydrogen is not expected to be more dangerous than LNG. However, exporting NH3 is considered to be more challenging. In the first applications strict rules can be expected which will probably be relaxed when experience is gained [7]. To make a first estimate of the nautical safety requirements and operating limits for marine oil and petrochemical terminals export are used shown in figure 3.15. For these limits it is conservatively assumed that the different environmental limits act simultaneously. Any location considered must not exceed these values regularly, or the various areas need to be protected.

Description	$V_{wind,1\,min}$	$V_{current,1\,min}$	H_s
Turning areas			
• Without tug assistance	< 10 m/s	0.5 m/s	< 2.0-3.0 m
• With tug assistance	< 10 m/s	0.1 m/s	< 1.5-2.0 m
Vessel berthing			
• Forces longitudinal to berth	17.0 m/s	1.0 m/s	2.0 m
• Forces transverse to berth	10.0 m/s	0.1 m/s	1.5 m
Loading/unloading operations stoppage			
• Forces longitudinal to berth			
– < 30,000 DWT	22 m/s	1.5 m/s	1.5 m
– 30,000 DWT – 200,000 DWT	22 m/s	1.5 m/s	2.0 m
– > 200,000 DWT	22 m/s	1.5 m/s	2.5 m
• Forces transverse to berth			
– < 30,000 DWT	20 m/s	0.7 m/s	1.0 m
– 30,000 DWT – 200,000 DWT	20 m/s	0.7 m/s	1.2 m
– > 200,000 DWT	20 m/s	0.7 m/s	1.5 m
Vessel at the berth			
• Forces longitudinal to berth	30.0 m/s	2.0 m/s	3.0 m
• Forces transverse to berth	25.0 m/s	1.0 m/s	2.0 m

Notes:

1. *When vessel manoeuvring/turning areas are located in zones with no geometrical restriction in one direction (e.g. in some river ports), the operational limits in the longitudinal direction (river) can be higher, in accordance with the particular conditions of the project.*
2. *Longitudinal = wind, current or waves taken as acting longitudinally when their direction lies in the sector of ±45° relative to the vessel's longitudinal axis.*
3. *Transverse = wind, current or waves taken as acting transversally when their direction lies in the sector of ±45° relative to the vessel's transverse axis.*
4. *Specifically for waves, the wave period can have a significant impact on the limitations and, often, a (dynamic) mooring analysis is needed to assess the limitations in more detail.*

Figure 3.15: Indicative operating limits by PIANC 153 [41].

3.4.5. Part IV: Safety Requirements

Risks of handling ammonia

Ammonia has a high toxicity-level. If liquid ammonia is leaked from storage units or from transport pipelines, a dense cloud will be formed in the atmosphere which will propagate close to the ground surface because of its relative density [7]. At very high concentrations, ammonia can get into the deeper airways causing damage to the lungs and possible death [17]. Next to the health risks for staff and local inhabitants, ammonia leakage causes severe damage to nature.

Ammonia is not easily flammable. In comparison with natural gas or gasoline vapour, very high concentrations of ammonia are needed for an explosion to occur [7]. "A possible ammonia fire gives only a limited hazard, because only very little heat radiation occurs from the fire to the environment. The probability of a fire or explosion arising exists almost exclusively in poorly ventilated spaces. The minimum ignition energy is 680 mJ (this is approximately 10,000 times as large as for hydrogen)." [17].

Practical requirements

The Department of Labor of the United States has published the Safety and Health Standards for storage and handling of anhydrous ammonia. The most important safety standards are listed below to get a preliminary understanding of the port layout requirements.

- Cylinders shall be stored in such manner as to protect them from moving vehicles or external damage.
- Storage areas shall be kept free of readily ignitable materials such as waste, weeds, and long dry grass.
- Permanent storage containers shall be located at least 50 feet from a dug well or other sources of potable water supply, unless the container is a part of a water-treatment installation.
- Secure anchorage or adequate pier height shall be provided against container flotation wherever sufficiently high flood water might occur [54].

The Port of Amsterdam has executed a study on external safety aspects when bunkering alternative marine fuel for seagoing vessels. In this study the minimum required distance from the ammonia storage to vulnerable areas, such as residential areas and hospitals, are calculated. This distance is based on the dutch safety standards for toxic clouds, an 1 % probability of dead of and unprotected exposed person and the probability of occurrence of a certain size of toxic clouds. For liquid ammonia flow rates up to 400 m^3/s a distance of 1446 meter is required and for flow rates up to 1000 m^3/s a distance of 2624 meter is required. Minimum required distances for fire and explosion hazards are not taken into account for ammonia because the relatively low flammability [17].

4

Stakeholder Analysis Results

This chapter aims to answer sub-question B: *''What influence and interests do the different stakeholders have within this project and how can they be engaged effectively?''*.

As mentioned in Section 2.2, the stakeholder analysis is an important part of the realisation of the green hydrogen port export. According to the Province of Río Negro, the green hydrogen port in Río Negro built by Fortescue will transport the first ship of ammonia to Europe in 2025 (see Appendix A.2). Furthermore, the province of Río Negro desires to be a facilitator in the creation of this project in the private sector, and is interested in building a green hydrogen export port for own public use. These large ambitions by the province and Fortescue require strategic management of the stakeholders who play a role in the realisation of this project. Depending on their level of support, their needs and their expectations on the project, they can be involved appropriately.

Figure 4.1 demonstrates the power and interest grid for the main stakeholders involved within the project.

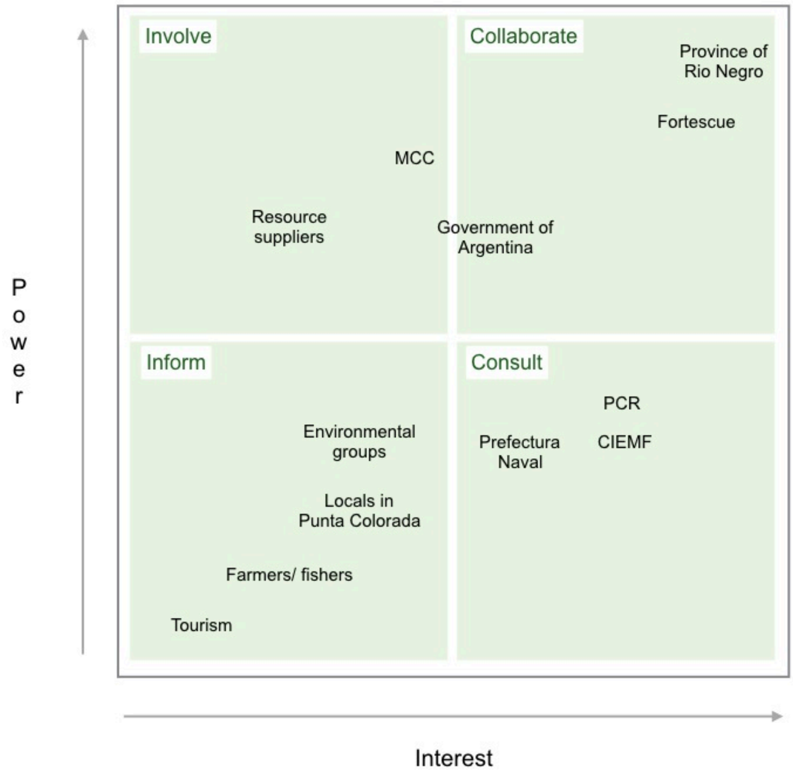


Figure 4.1: Stakeholder Power - Interest grid for the realisation of the green hydrogen export port.

4.1. Description of Stakeholders

Additionally, a detailed understanding of the stakeholders and their roles is provided.

The province of Río Negro

The Province of Río Negro, in which the project is situated, has extremely high influence and interest in the project. The addition of a green hydrogen export port in the province creates an immense economic benefit for the region, and allows them to compete on a worldwide scale. Their high interest in the project is demonstrated in their ambitions for the hydrogen potential in their province, which is visible through their publications [49]. Additionally, the Province of Río Negro holds high blocking power. The provinces in Argentina are fully autonomous; they own and manage their natural and financial resources [4]. This results in their power to block or advance the process of the project.

Fortescue

Fortescue is the developer and investor of the hydrogen port at Punta Colorada Muelle. Fortescue is investing 8.4 billion dollars for the green hydrogen plan [35]. This leaves the party with a high level of power regarding the development of the project. The Province of Río Negro is supporting their plans [20]. Furthermore, Fortescue is completing their own analyses of the different possible port designs. Their interest is very high seeing as this project brings large economic benefits to the company.

PCR

The Port Consultancy of Rotterdam functions in a consulting role within the project. PCR provides the Province of Río Negro with advice and recommendations regarding the project. They maintain relatively high interest in the project, however, their power remains quite low.

MCC Minera Sierra Grande SA

Since 2006, the Chinese mining company MCC Minera Sierra Grande SA has a concession for maintaining and operating the mining port and all the assets located on the Punta Colorada Muelle (see Appendix C. According to Hugo O. Nicola [Appendix A.3], an ex-employee of MCC and the operational manager of the port until 2016, the contract states an agreement of 99 years, starting in 2006, where MCC has the right to the use of the assets on the ground of the Punta Colorada Muelle [57]. These include the mining processing structures and machines, as well as the use of the jetty itself. Due to their long-term contract regarding the usage of the Punta Colorada Muelle, MCC holds relatively high power. If the Punta Colorada Muelle is to be reconstructed for hydrogen export, they remain in decision making power. Their interest in the project also remains high, seeing as rebuilding the existing port into a hydrogen export port would create many economic opportunities for MCC.

Government of Argentina
The government of Argentina only intervenes whenever a province acts against the Constitution [4]. Their power is high, yet for the present case, the Government of Argentina agrees to the hydrogen development project and therefore the government of Argentina has no further large influence. The decision making power now lays more in the hands of the province itself. The interest of the government, however, is moderately high since a hydrogen export port is beneficial for the economy of the entire country.

CIEMF
The Centro de Investigación y Entrenamiento Marítimo y Fluvial is a centre for the training of pilots and research through simulation into port design. The CIEMF has identified a location for a potential hub port at Puerto Lobos. The port would be used to welcome large ships with destinations in Europe or Asia. CIEMF envisions the export of the full oil and gas fields of Argentina. CIEMF also sees potential in the location for transport of containers or other goods, as mentioned in the interview with CIEMF (see Section A.1). The result of a port at Puerto Lobos would be local economic growth and an increase in people settling down locally, according to CIEMF. CIEMF has high interest in the project, seeing as they are interested to stay aboard on the project and be involved in the implementation of the port. According to Guillermo Delarmo, the director of CIEMF, they have economic as well as research interest in this project. Regarding their power, it remains quite low. The party does not play a crucial for the realisation of the hydrogen port in Río Negro, especially when Puerto Lobos location is not chosen as a valuable location. They could have an advising role, however do not how high decision power.

Prefectura Naval
The Prefectura Naval, the Argentinian coast guard authority, is responsible for the security of the port area and makes usage of the jetty area for their coastal operations. The Prefectura has medium to high interest in the project, seeing as it is based on the land for which they have coastal safety responsibility. However, their power remains low since they have no deciding power in the project.

Resource suppliers
The resources needed for the re-purposing of the port will be supplied by different parties, located in different countries. These involve construction material suppliers as well as the wind farm elements. The suppliers have a relatively high interest due to the potential of work availability, however their influence can be regarded as medium to high since the construction depends on resource availability. However, there is a possibility to change to different suppliers when needed.

Locals in Punta Colorada
The area of Punta Colorada is relatively deserted, with potential upcoming residential developments. This results in little influence of locals on the project since they are with such little representatives. Along with this, their interest is medium regarding the project, as they will not be in direct contact with the project. There is one private house situated directly next to the Punta Colorada Muelle (see building 11 in Appendix C), which will be influenced by the works of the port mostly by nuisance of the constructions, as well as the actual operations of the port. Living close to an ammonia factory comes with dangerous living circumstances. On the other hand, the hydrogen export will provide locals with potential employment opportunities, thus creating economic benefits in the area. The power of locals will remain relatively low in the process, since they are such a small player.

Tourists in Playa Dorada
The region of Punta Colorada is a deserted area, where tourism plays little to no role. However, Playas Doradas can be found about 10 kilometres north of Punta Colorada, and is a popular touristic destination, offering many recreational possibilities. Tourists in this area have none to little interest in the

project, seeing as they can be minimally effected by the constructions. Apart from that, a well functioning hydrogen port will create extra traffic on and to the coast, which could have limited influence on the attractiveness of the location. These stakeholders have low interest and extremely low power.

Environmental groups
There are two main environmental organizations based in Argentina: the Climate Action Network Latin America and the Fundación Vida Silvestre Argentina. The former represents Latin America at UN climate conferences and links over 30 non-governmental organisations, which are engaged in climate justice issues and active against climate change [13]. The latter represents in Argentina the World Wildlife Fund (WWF). Regarding the locations, Puerto Lobos poses a risk for environmental groups. Puerto Lobos falls within the Argentinian natural protected areas, which is located on the border between the provinces of Chubut and Río Negro [44]. This is definitely a sensitive area for environmental groups to get involved. However, their power remains quite low in Argentina. Furthermore, the Climate Action Network Latin America is fighting climate change, which could cause their support for the green hydrogen export. The other two potential locations, namely Muelle de Punta Colorada Muelle and Punta Colorada South are neither located in a preserved nature area.

Farmers / Fishers who depend on the Río Negro
Seeing as Punta Colorada is located along the Golfo San Matias, it is a region which can be used for farming and fishing. As the region develops into an active port usage, this will have influence on the farmers and fishers who depend on this source of water. Therefore, their interest is regarded as medium, however seeing as the harbour does not attract many farmers and fishers, their power remains low.

4.2. Stakeholder Overview

Stakeholder characteristics				
Stakeholder	Role	Interest	Influence level	Attitude
Province of Río Negro	The initiator of the project and decision making power.	Aiming to make the Province of Río Negro a greener province, whilst creating an economic benefit for Argentina as a whole.	Extremely high influence	Positive attitude
Fortescue	The investor of the project.	Gain economic profit from the export of hydrogen in Argentina.	Extremely high influence	Positive attitude
PCR	Advising role.	Providing the province of Río Negro with valuable advise regarding the technical issues for the production and export of hydrogen.	Medium to low influence	Positive attitude
MCC Minera Sierra Grande	The contractual owner of the assets located on the Punta Colorada Muelle location.	Interest in the economic benefit MCC can gain from the production and export of green hydrogen on their property.	Potential high influence	Neutral attitude
Government of Argentina	Approving factor and decision making power.	Economic growth for Argentina, by becoming a key world-wide player in the hydrogen production and export sector.	High influence	Positive attitude
CIEMF	Advising role regarding Puerto Lobos.	Possibility to provide data and research on the Puerto Lobos port, and ultimately being a key player in the process of realising this port.	Low influence	Positive attitude

Stakeholder characteristics				
Stakeholder	Role	Interest	Influence level	Attitude
Prefectura Naval	The coast guards of Punta Colorada Muelle.	Interest in the collaboration between Prefectura Naval and the port.	Low influence	Neutral attitude
Resource suppliers	Supply of goods needed for the construction of the green hydrogen export port.	Financial interest in the selling of their goods and services.	Medium influence	Positive attitude
Locals in Punta Colorada	Living in the area of Punta Colorada.	Locals have an interest in the development of their region and employment opportunities, as well as that they do not want to be bothered by nuisance or sound pollution due to constructions in the area.	Very low influence	Negative attitude
Tourists in Playas Doradas	Creating economic activity in the area of Playas Doradas	Enjoying the coast of Playas Doradas. Their interest is not found in the production of ammonia in the area. The tourist sector in the area is interested in a safe and clean zone.	Extremely low influence	Neutral attitude
Argentinian environmental groups	Providing opinions on the purpose and usage of land in Argentina, from the perspective of preserving the environment.	Striving for sustainability and biodiversity in the port locations, and the production of green energy	Medium to low	Neutral: Negative attitude regarding the constructions, however positive attitude towards green hydrogen production.
Fishers/ farmers	Fishing and farming in the province of Río Negro.	Their interest in the project is related to the fact that the constructions might negatively influence their ability to fish and farm in the area.	Very low influence	Negative attitude

The stakeholder analyses provides valuable input for the final recommendation and the effective realisation of this project. The recommended engagement strategies are provided in Section 11.1.

5 Topographic Analysis Results

This section demonstrates the results regarding the topographic analyses of the three different potential hydrogen export locations and aims to answer sub-question C *"What are the topographic characteristics of the three locations that lend themselves for hydrogen export?"*. The visual inspection of structures, the topographic elevations, the satellite surroundings and the free-trade zones and marine protected areas are identified and explained for the locations. The results are collected through primary and secondary research, as mentioned in Section 2.4.

5.1. Visual inspection of structures

The visual inspection of structures entails the identification of all physical structures located on the areas.

5.1.1. Punta Colorada Muelle

A visual land inspection of the Punta Colorada Muelle, around the shoreside of the jetty was completed to identify any assets and structures in the area. The soil is contaminated with waste produced by the previous mining production. The soil in the whole area is covered in fine black granular material mixed with iron ore pellets. Figure 5.1 demonstrates the location of the detected structures in the area. A complete overview of photos of the structures detected can be found in Appendix C. At location 15, old corroded barrels are found, labelled as organic waste. Old bulldozers, trucks and other vehicles are left all over the compound. The area is full of abandoned structures (locations 1, 2, 3, 6, 9,10) that were previously used to process iron ore for export. The buildings are generally in bad shape, seemingly not ready for direct use. Most windows are broken and the interiors in bad shape, however, the main structures seem in acceptable state. According to a guard of MCC the buildings could be taken back in to use. There are several empty storage pits at 4, 5 and 12. At location 7 there is a working transformer building with unknown characteristics which seems to be in a good shape. Location 14 seems to be a designated area for bulky waste. The dirt road at location 8 is used for transportation from and to the facilities.

Figure 5.1: Visual analyses on Punta Colorada Muelle.

5.1.2. Punta Colorada South

The area of Punta Colorada South is mainly characterised by empty space. There are a few dirt roads that are seemingly rarely used. Furthermore there are some foundations of structures that were never completed.

5.1.3. Puerto Lobos

The Puerto Lobos location could not be visually inspected due to unforeseen circumstances. From Google Earth, three structures can be identified in the area. One of these structures is clearly abandoned.

5.2. Topographic Elevations

The topographic elevations have been detected through the WingtraOne drone. The drone data of the free-trade zone is incomplete due to technical difficulties. The data is missing the area of approximately 1 km north of the border shown in Figure 5.2.

5.2.1. Slopes in the Free-Trade Zone: Punta Colorada Muelle and Punta Colorada South

The construction of large ammonia production facilities can be completed more efficiently when there is little change in land elevation. Therefore the slopes in the free-trade zone are identified using interpolation with ArcGIS. Based on the different heights in the area, which is visible in Section C.3 from Appendix C, the slopes can be identified. An arbitrary limiting slope of 5° is assumed, in order to designate locations for the necessary factories. Figure 5.2 visualises the slopes for the entire region. Three locations with slopes exceeding the construction limit can be identified. The first location is typified by the dried up river bed. The banks of this dried up river bed exceed the construction limit of 5°. The second area is located in the south of the Free-Trade zone, where there are two small slopes that exceed 5°. The third location is at the shoreline, where it can be reasonably assumed the factory will not be built.

The slopes in the northern zone can not be determined using the drone footage. Using visual inspection and comparing satellite images to the areas that are well known there is no reason to assume any significant slopes in this area.

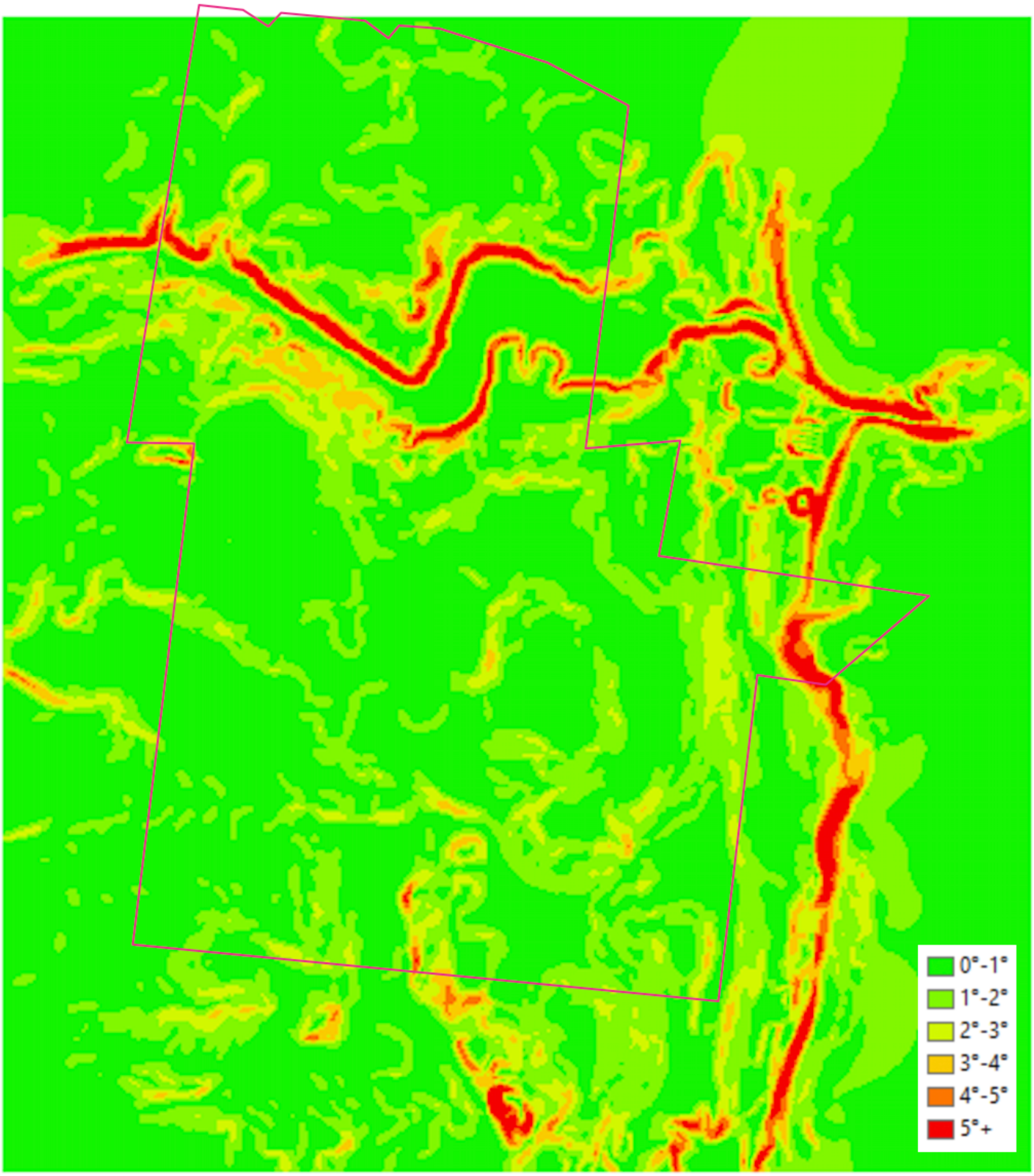


Figure 5.2: Slopes in the free-trade zone, limiting slope of 5°.

5.2.2. Digital Elevation Map and Interpolated Slopes: Puerto Lobos

As no drone data was acquired at the location of Puerto Lobos, the Digital Elevation Model SRTM (Shuttle Radar Topographic Mission) 1-ArcSecond global was used. This is elevation data acquired in the year 2000 by the Shuttle Radar Topography Mission. Some changes to the elevations might have occured in this time, however the assumption is made that these changes are negligible. SRTM has a very course resolution of about 30m. This is a clear asymmetry of information with the extremely precise drone data. The slopes in the area are interpolated using ArcGIS. The slopes exceeding 5° are coloured red in Figure 5.3. The only significant areas exceeding 5° found in the direct vicinity of Puerto Lobos are on the coastline.

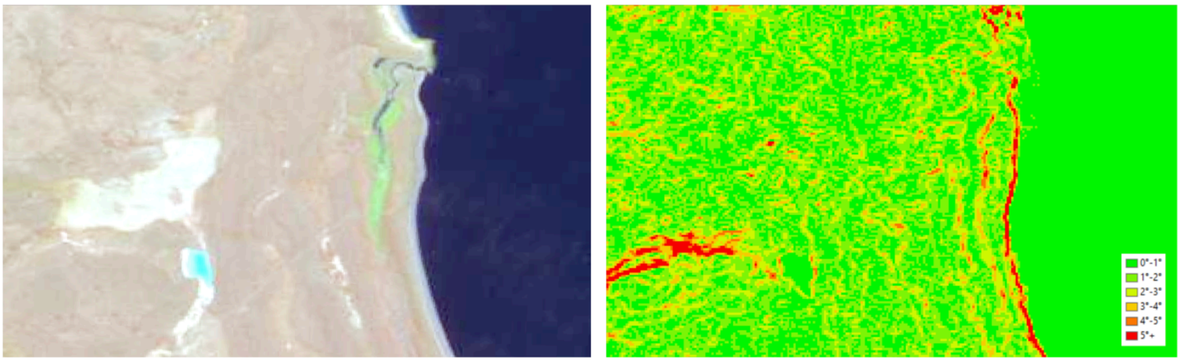


Figure 5.3: Elevation slopes of Puerto Lobos.

5.3. Satellite View of Surroundings

The satellite images of the surroundings of the three locations demonstrate the existence of residential areas nearby the potential ammonia export locations, and the geographical accessibility through roads and infrastructure leading to the locations.

5.3.1. Punta Colorada Muelle and Punta Colorada South

The Punta Colorada Muelle and Punta Colorada South are located around 31 km from Sierra Grande, and around 7 km from Playas Doradas, a village and municipality in Río Negro which attracts many tourists due to the coastal beaches of the San Matias Gulf. Furthermore, the orange highlight in Figure 5.4 demonstrates an area of 820 m^2, containing defined street blocks, which have been constructed for use of real estate and housing. The plans for the urbanisation of this area include both residential and touristic purposes [55]. The construction of an ammonia export port definitely influences the possibilities of constructing housing in the area.

Figure 5.4: Satellite view of surroundings in Punta Colorada Muelle and South.

Punta Colorada Muelle and Punta Colorada South are accessible through the main National Route RN3, a highway crossing from the eastern side of the country in Buenos Aires, through the provinces of Buenos Aires, Río Negro, Chubut Province, Santa Cruz and Tierra del Fuego. Furthermore, the Provincial Routes PR5 followed by PR9 allow for access to the Punta Colorada construction site.

5.3.2. Puerto Lobos

Puerto Lobos is accessible through the main National Route RN3, towards the province of Chubut, following by the Provincial Route RP60. The location is located about 60 km from the municipality of

Sierra Grande. No residential areas are located near Puerto Lobos. There is no evidence of any supply of fresh water, gas or electricity.

Puerto Lobos is located directly on the border of the province of Río Negro and Chubut, as visible in Figure 5.5.

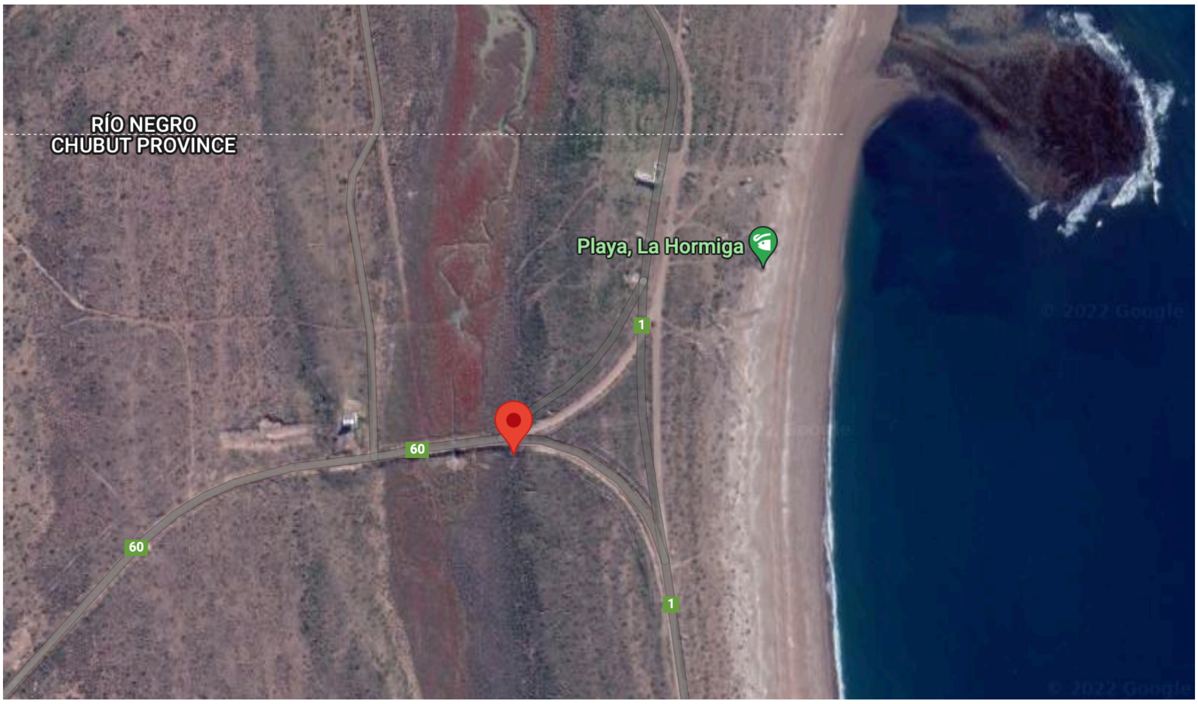


Figure 5.5: Satellite view of Puerto Lobos.

5.4. Free-trade Zones and Marine Protected Areas

This section looks into the potential of free-trade zones in the three locations, as well as the presence of marine protected areas in the off-shore and on-shore zones of the locations.

5.4.1. Punta Colorada Muelle and Punta Colorada South

Both the potential location of Punta Colorada Muelle and Punta Colorada South allow for the construction of the ammonia export port in the free-trade zone, which comes with many advantages, as explained in Section 3.1.2. Furthermore, the area is not located within a marine protected area, allowing for construction to occur without area protection issues.

5.4.2. Puerto Lobos

As mentioned in Section 3.2.3, patagonia.com.ar claims that there was once a Free-Trade zone at Puerto Lobos which could be reactivated [45]. On the Río Negro side of Puerto Lobos, a provincial marine protected area is located. The protected area ranges from 500m inland to 12 miles offshore. On the Chubut side of the border, there is a marine protected area ”Peninsula Valdes” that only covers the sea side of the shoreline.

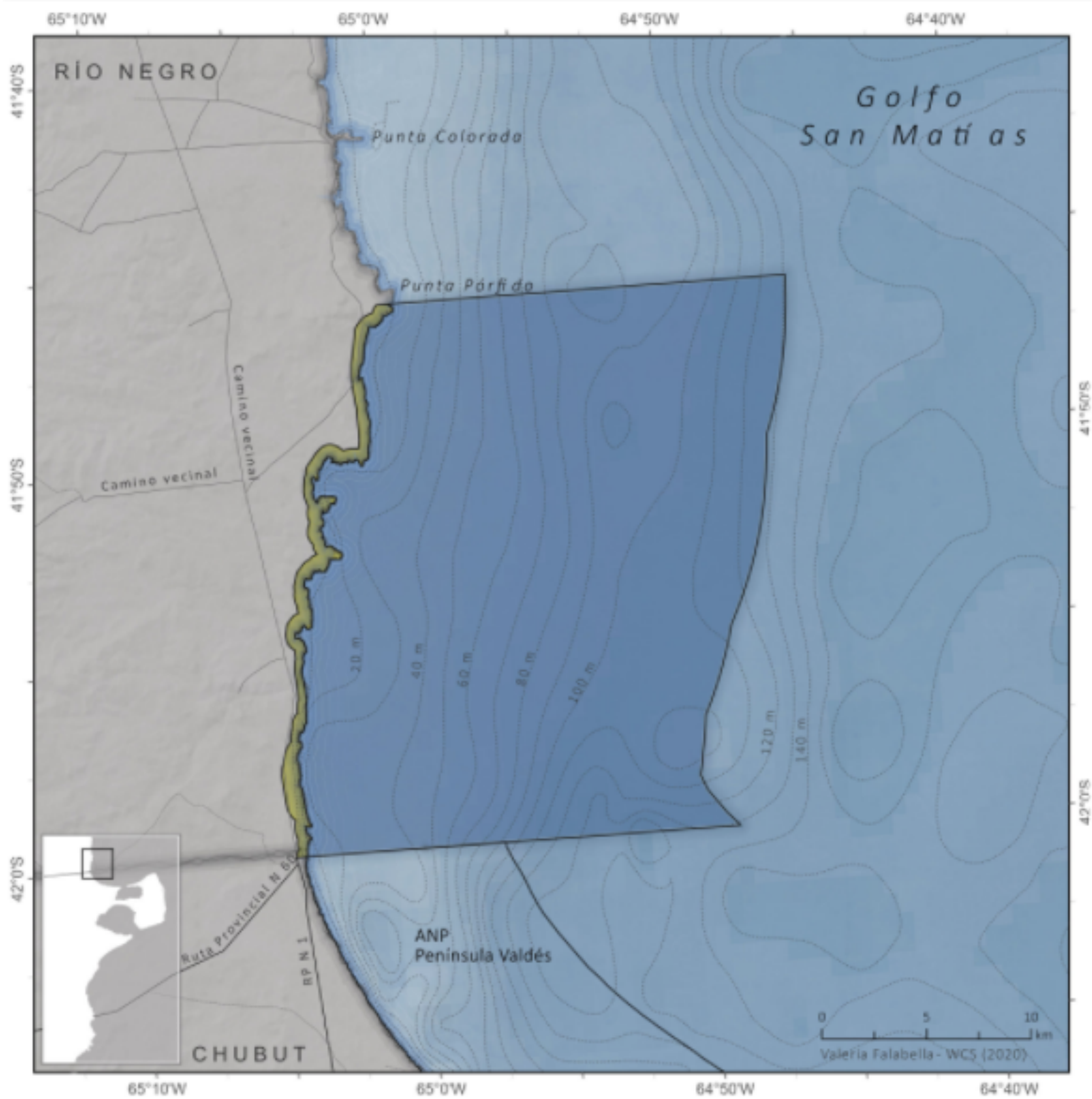


Figure 5.6: Marine protected area at Puerto Lobos and Peninsula Valdes [44].

6

Hydraulic Analysis Results

This chapter aims to answer sub-question D: *"What are the hydrometeorological, coastal and bathymetric characteristics of the three locations and how would they influence the potential hydrogen port?"*.

6.1. Hydrometeorological conditions

In this section the results of the analysis of the wind, waves and tidal characteristics are presented.

6.1.1. Wind

All three locations of Punta Colorada Muelle, Punta Colorada South and Puerto Lobos are located at an approximate latitude of 42°. At these latitudes strong westerly trade winds are present. These trade winds generally blow in the same direction throughout the year and they can vary spatially and temporally with the seasons [8].

This is confirmed by the operational manual of the jetty which mentions, the strongest winds are from the North-West (NW), South-West (SW) and South (S) direction. Under the strong wind conditions from NW and SW direction, there is only a small influence on the sea-state and the waves as the fetch is limited, especially near the coast. The annual wind conditions are indicated by the wind rose shown in Figure 6.1 [37]. It should be noted that there is no information provided on the location where the data of the wind rose data was gathered, nor the measuring period. As data is lacking for the Puerto Lobos location is missing, it is assumed that the same wind conditions hold for Puerto Lobos as it is located relatively close-by, only 30 km south of both Punta Colorada locations.

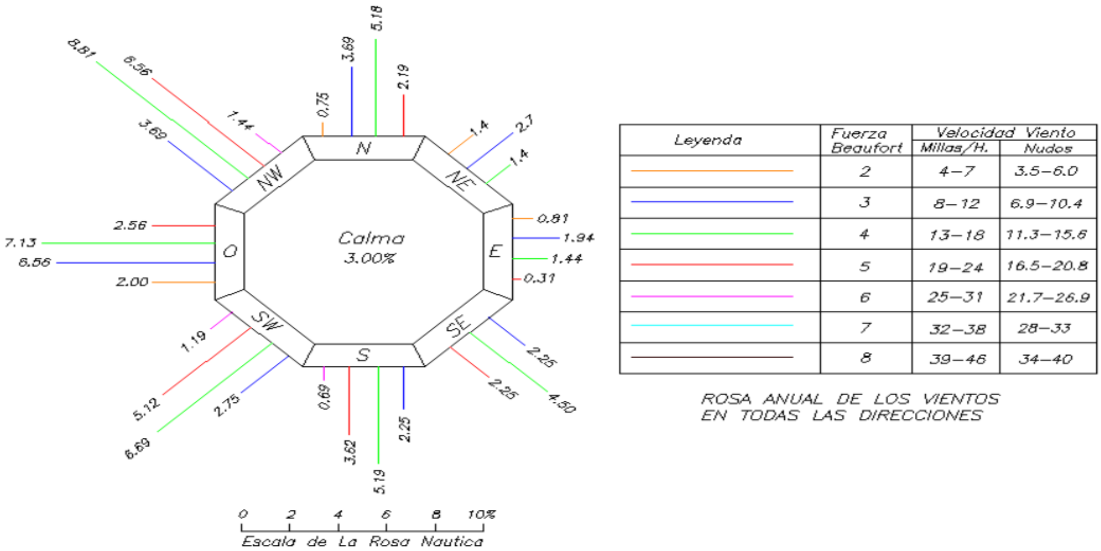


Figure 6.1: Annual wind rose [37].

6.1.2. Waves

Wave climate is expected to be mild in the area as the dominant wind direction is directed offshore and the locations of Punta Colorada Muelle, Punta Colorada South and Puerto Lobos are semi-sheltered due to the geographic position within the Gulf of San Matias. This is confirmed by the wave rose provided by the MCC operating manual shown in Figure 6.2. The bars of the wave rose add up to 35.6 %. Normally a wave rose shows waves from all direction and the percentages add up to 100 %. As the waves in offshore direction have been omitted in the wave rose, it is assumed that the missing 64.4 % of waves were directed in offshore direction (NW, W and SW). This assumption can partly be substantiated from the wind rose in which 58.3 % of the year, offshore winds are present. It should again be noted that there is no information provided on which location the wave rose data is gathered, nor the measuring period. However, as the operating manual was specifically made for the Punta Colorada Muelle, it is assumed the measurements were conducted locally at the port.

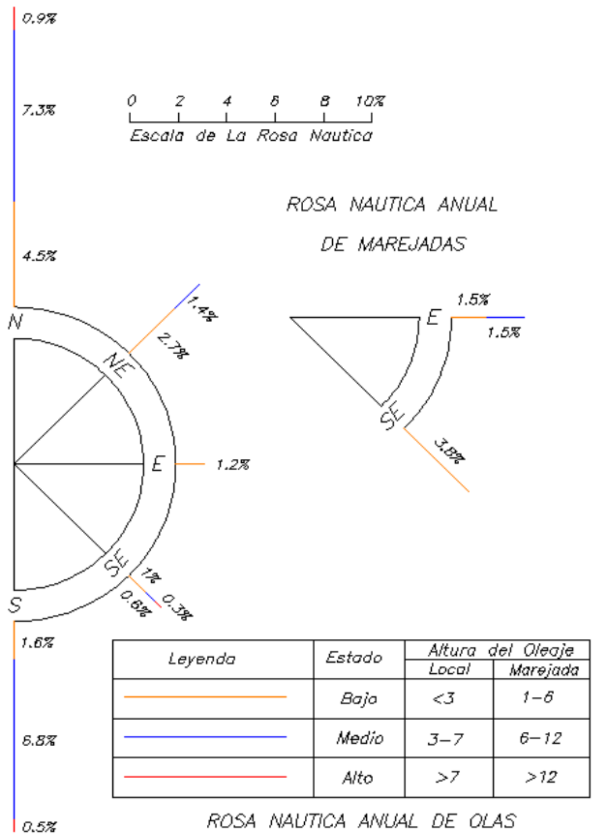


Figure 6.2: Annual wave rose [37].

Waves originating from N to E to S need to be considered. Wind waves (Olas local) waves rarely exceed 2.13 m. Swell waves (Marejada) rarely originate from NE. Usually swell originates from E to SE, the swell does not exceed 3.66m. The operational manual of the jetty also provides information on the annual exceedance percentage of wave heights. The annual wave height exceedance percentages are shown in Figure 6.3. The manual does not mention whether these are significant wave heights or any other wave height characteristic. The wave measuring method and statistical wave processing method are not mentioned either.

Wave height equal to or greater than (feet)	Wave height equal to or greater than (m)	Occurrence percentage (%)
0	0	100
0.5	0.1524	38
1.5	0.4572	35
2	0.6096	33
2.5	0.762	30
3.2	0.97536	25
3.7	1.12776	20
4	1.2192	15
4.6	1.40208	10
5.3	1.61544	5.8
6	1.8288	4.8
8	2.4384	3.2
10	3.048	1.8
12	3.6576	0

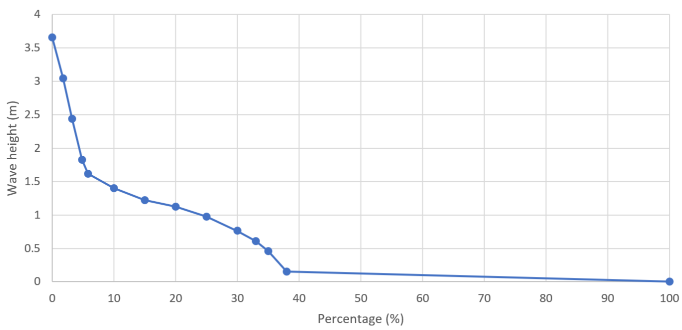


Figure 6.3: Annual wave height exceedance percentages.

6.1.3. Tidal Amplitude and Currents

In 2011 the Argentinian Coastal Education and Research Foundation (CERF) has published a study in which the tidal currents in the North Patagonian gulfs were modelled. The model was validated with data from several current meters and tidal gauges that where deployed around the gulf of San

Matías. A tidal gauge and a current meter were deployed at Punta Colorada Muelle. Unfortunattely no measurements were done at Puerto Lobos or any location near Puerto Lobos. Measuring periods of the instruments ranged from 25 days to 271 days. In general the model outcomes seem to correspond well with the measurements.

The left panel of Figure 6.4 shows one of the model outcomes. The tidal current is shown by tidal ellipses in the bay. The scale of an tidal ellipse is shown at the bottom of the figure. It can be seen that nearshore and at the southern part of the bay, approximately at Puerto Lobos, tidal currents are relatively weak. The figure shows that the nearshore currents intensifies slightly from South to North. In the North a maximal tidal current of 0.65 m/s at San Antonio is reported.

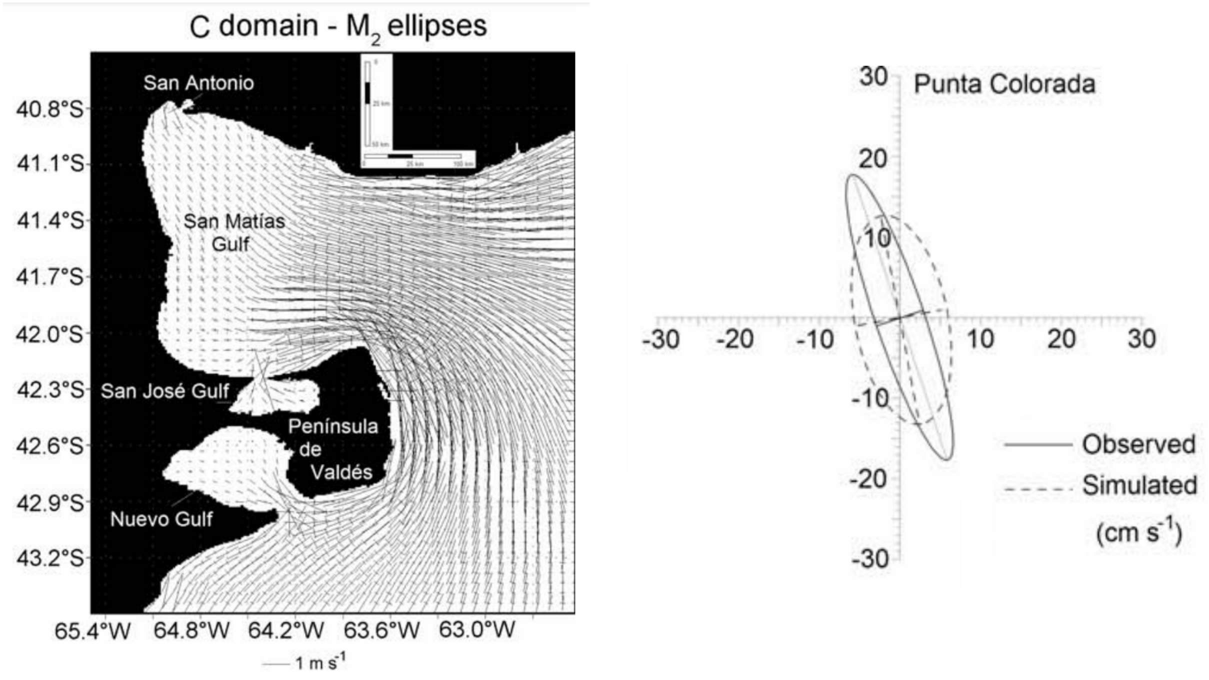


Figure 6.4: Tidal ellipse at Punta Colorada [14].

At Punta Colorada Muelle, a tidal gauge has been installed over a period of 271 days to measure the tidal amplitude. A mean observed amplitude of 2.84 m and a semi-diurnal period have been reported [14]. MCC mentions a spring tidal amplitude of 4.38 m. Next to that a current meter has been installed over a period of 58 days. The mean current direction and velocity at Punta Colorada Muelle is displayed in the tidal ellipse in Figure 6.4 on the right. The solid line indicates the observations by the current meter. The dashed line shows the current simulation. It can be concluded that the maximum absolute observed current velocity is approximately 0.2 m/s and is directed either to the NNW and the SSE [14]. The current directions are confirmed by the operation manual of the Jetty. However, the reported current intensities do not correspond. The operational manual reports that the current intensities can reach up to 0.5 m/s at the ship loader and 1 m/s offshore offshore [37]. The operation manual does not report any sources of the data nor elaborates on the how these values were found.

6.2. Operational Downtime of the Port

The operation limits distinguish forces longitudinal and transverse to the berth. First, the preferred berthing position is determined. It is mentioned in Section 3.4.4 that no tidal window can be implemented because the long time required for loading. Thus, during loading, the vessel will be subject to the maximum tidal current. The maximum tidal current reported by the MCC is 1 knot (± 0.51 m/s) in NNW and SSE direction at the ship loader. The operating limits for berthing transverse to the current is 0.7 m/s and for berthing longitudinal to the current 1.5 m/s. Therefore, vessel berthing is preferred longitudinal to the main current direction. This means that the longitudinal axis of the vessel is oriented long-shore parallel (to the north). This also means that the vessel will be subject to wind and waves from their dominant direction. This can be seen in the wave rose and the wind rose in Figure 6.2 and Figure 6.1.

Next, the governing activity with its operating limits should be chosen. When conditions exceed the limits for the berthing of the vessel, the vessel will just wait at the anchorage. When the conditions exceed the operation limits for loading and unloading, the loading and unloading will be stopped. But when the limits for the vessel at the berth are exceeded, the vessel needs to leave and sail to the anchorage. This is considered very inconvenient and is therefore chosen to be the governing limit. These limits are winds of 25 m/s transverse to the berth and significant waves of 2 m transverse to the berth.

From the wind rose in Figure 6.1, it can be concluded that these wind speeds barely are exceeded yearly. From Figure 6.3 it can be seen that waves of 2 meter are exceeded 4 % of the year.

6.3. Bathymetry

This section gives an overview of the bathymetry on each of the three project locations. The bathymetry is an important aspect for port construction as a certain minimal depth must be guaranteed for ships to berth, load and leave the port safely at all times. An elaboration on the required minimal depth was given in Section 3.4. With this formula, figure 3.9 on the expected vessels and information about the tide and waves in the section above, the minimum required depth is determined for the short-term and medium-term. This is shown in table 6.1.

	Short-term	Medium-term
Draught of design vessel	9.5 m	12 m
Tidal restriction	0 m	2.84
Sinkage	0.5 m	0.5 m
Response to waves (For H_s = 2m)	1 m	1 m
Underkeel clearance (For rock)	1 m	1 m
Minimum required depth	12 (m+MSL)	17.34 (m+MSL)

Table 6.1: Minimum required depth short-term and medium-term.

The distance from shore to the required nautical depth is important for the jetty length or for the amount of capital- and maintenance dredging, if possible. Other aspects that play an important role is the longshore uniformity of depth contours as this can hinder ship manoeuvrability. LNG tankers need to be able to depart at any time due to the hazardous nature of Ammonia loading/unloading, navigability around the port is therefore of great importance.

In this chapter, two data sources are used. The first data source is the data obtained from the field survey. This data was recently collected and thus gives an overview of the current bathymetry. A disadvantage of this data source is that it only includes the bathymetries at Punta Colorada Muelle and Punta Colorada South.

The second source will be bathymetry charts from Navionics. These charts are available at all three locations and can thus be used for a much courser, but complete assessment. The level of detail differs within these charts, which is qualitatively indicated in Table 6.2 and is seen in the charts due to a low number of depth measurements, see chart type B.

Location	Chart	Level of Detail	Year
Punta Colorada Muelle	Bathymetry Survey Navionics	Very high Moderate	2022 Unknown
Punta Colorada South	Bathymetry Survey Navionics	High Moderate/Low	2022 Unknown
Puerto Lobos	- Navionics	- Low	- Unknown

Table 6.2: Indication of the quality of different charts.

6.3.1. Punta Colorada Muelle

The relatively straight depth contours indicate an alongshore uniform coastline where only minor depth changes are present. These minor depth changes do not pose large challenges for vessel manoeuvrability. The existing jetty extends 900 meters towards the offshore and has a local depth near the ship loader of 11 (m+MSL) for the 'N-S' berthing position and 11.25 (m+MSL) for the 'W-E' berthing position.

Distances to required depth are given for the Punta Colorada Muelle location from the most offshore point of the land-head where the current jetty is present.

	Short-term (12 m+MSL)	Medium-term (17.34 m+MSL)
Distance to required depth	990m	1510m
Uniformity of bathymetry at required depth	+	+

Table 6.3: Distance from Punta Colorada Muelle land-head to minimum required depth for the short- and medium-term.

6.3.2. Punta Colorada South

The depth contours are quite straight and alongshore parallel. The largest variations occur just south of the FTZ and vary 1 meter. If this poses serious concerns for vessel berthing, the jetty might need to be be located more to the North or to the South. This location does not have a land-head as can be seen at Punta Colorada Muelle, causing distances to required depth to be lengthier in general. The distance to the required depth is presented from shoreline and from the end of the inter tidal zone and is presented in Table 6.4. The bathymetry map can be found in Figure D.10 in the appendix.

Table 6.4: Distances from Punta Colorada South to minimum required depth for the short- and medium-term.

	Short-term (12 m+MSL)	Medium-term (17.34 m+MSL)
Distance to required depth	1350m	2100m
Distance from end of intertidal zone	900m	1650m
Uniformity of bathymetry at required depth	+	+

6.3.3. Puerto Lobos

Data for bathymetric analysis is collected from Navionics and presented in Figure D.14 in the appendix, as it is not known when this data was gathered and what the precision is, this section presents only a rough indication of the Puerto Lobos location. The Puerto Lobos location has favourable distances to required depth. Furthermore, this location shows an alongshore uniform coast, but due to low-quality resolution of the bathymetry data, this might not be an accurate representation. This is mainly because Navionics has an interpolation algorithm for locations with low availability of measurements.

	Short-term (12 m+MSL)	Medium-term (17.34 m+MSL)
Distance to required depth	1000m	2000m
Distance from end of intertidal zone	750m	1750m
Uniformity of bathymetry at required depth	+	+

Table 6.5: Distances from Puerto Lobos to minimum required depth for the short- and medium-term.

6.4. Flood Safety

The flood safety is divided into two parts, the local coastal vulnerability and the general tsunami risk in the Gulf of San Matías. The results are presented in this section.

6.4.1. Coastal Vulnerability

The Argentinian Geological Association has studied the vulnerability to sea level rise of the coastal areas of Río Negro. The coastline has been divided into 43 zones. The Coastal Vulnerability index for each zone has been determined with the method of Gornitz. This index can be used to identify areas of geological hazard related to permanent and/or episodic floods. The index is based on several components that describe the characteristics of a coastal zone. Components such as: topography, geomorphology, tidal range, maximum wave height and a moderate sea level rise of 2 mm/year. In Figure 6.5 the coastal vulnerability indices are shown. The coastal vulnerability of Punta Colorada Muelle and Punta Colorada South are considered high with an index of 24. The coastal vulnerability of Puerto Lobos is considered moderate with an index of 19 [50]. It should be noted that the zones in between both locations are considered to have a low vulnerability. It should be noted that the paper does not elaborate on which score was given to the different components of the coastal zones.

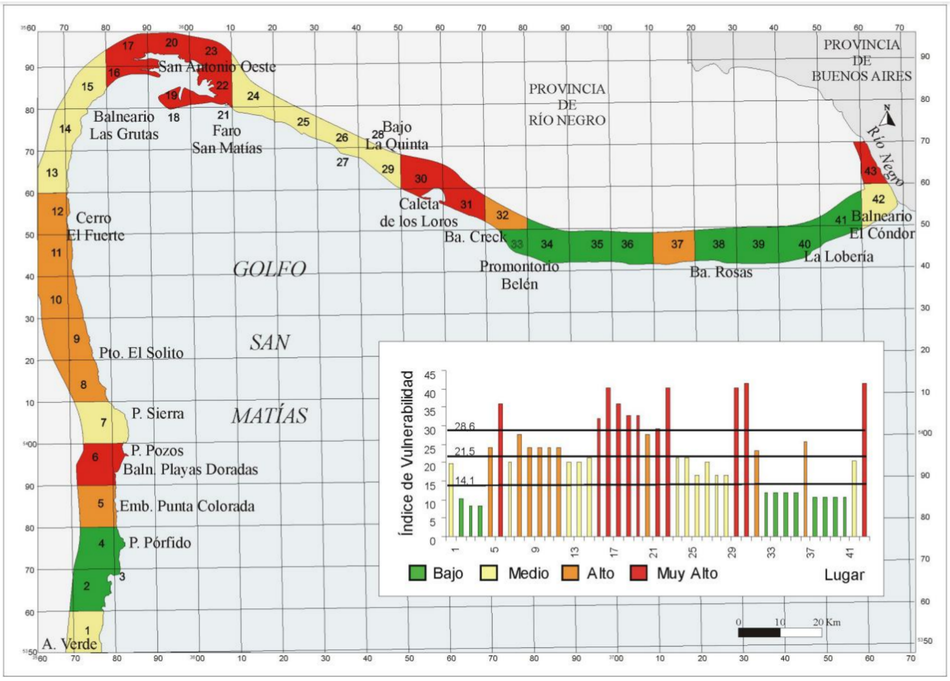


Figure 6.5: Coastal vulnerability map of the province of Río Negro [50].

6.4.2. Tsunamis

The Global Facility of Disaster Reduction and Recovery has developed an online tool with information on disaster risk on a global and local scale. They defined the hazard on tsunamis in the Gulf of San Matías to be low. This is based on the study of Davies et al. (2017) in which the global probabilistic tsunami hazard was assessed from earthquake sources. GFDRR reports that there is more than a 2 % chance that a potentially damaging tsunami will occur in the next 50 years [22].

7

Structural Analysis Results for Punta Colorada Muelle

In this chapter, the results of the structural survey are presented. The results aims to answer sub-question E: *“What are the structural assets of the Punta Colorada Muelle jetty and in what state are they?”*.

Ideally, much documentation such as old drawings, calculations sheets or records would have been gathered. However, little to no information was found in the literature or archives besides satellite pictures of Google Maps. All the results and gathered information rely on the survey.

The survey consists of visual inspections of the jetty structure of the Punta Colorada Muelle, which is a structure of approximately 1.5 kilometres. The structure is divided into different elements in order to facilitate the structural analysis: the column groups, the trusses, the ship loading structure, the mooring dolphins and the buoys.

Figure 7.1: The jetty seen from the ship loading structure.

Firstly, an overview of the different components of the column groups is given followed by the gradation of the state of these components. Secondly, the layout and the condition of the trusses are described. Thirdly, a description on the state of the ship loading structure is given. Next, the mooring dolphins are evaluated. Finally, the condition of the buoys are portrayed.

The results are displayed into maps and extended descriptions. Furthermore, an interactive map on Google My Maps is made, where you can click on an icon to let corresponding photographs pop up [1].

7.1. Column Groups

The column groups are complex structures which need to be further divided to obtain smaller, simpler elements. Therefore, it was decided that a column group consists of a concrete platform, steel or concrete columns and steel platform joints. There are in total 25 column groups which are numbered in order to be able to recognise them more easily, see Figure 7.2.

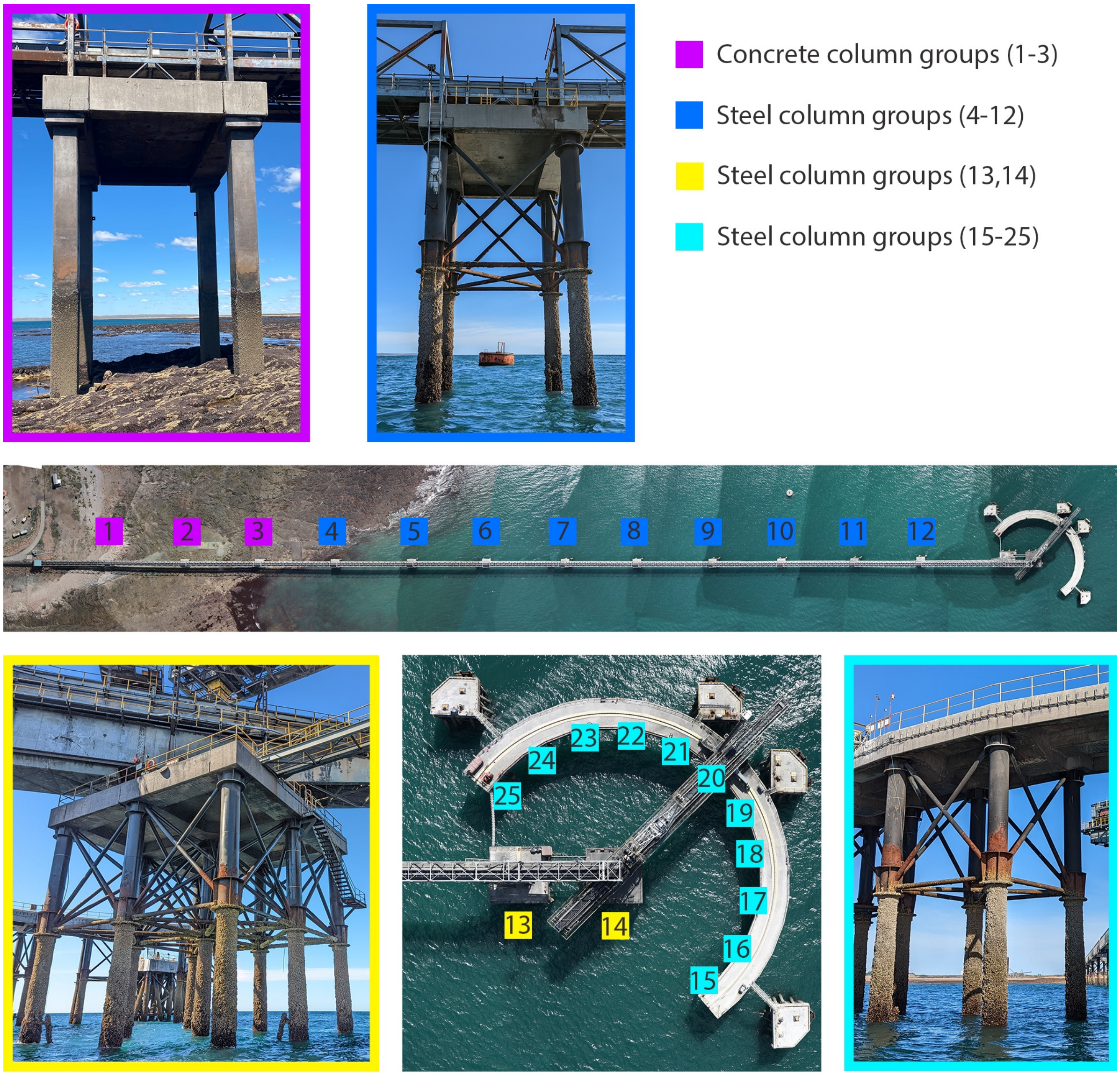


Figure 7.2: Column group types and numbering.

As mentioned in Section 2.6, steel and concrete elements do not have the same reuse process, therefore, the 25 column groups are separated based on the material of the columns.

Column groups number 1, 2 and 3 are made of concrete columns, see Figure 7.2. All three column groups have four concrete columns attached to a concrete platform. On this platform, bolted steel joints are placed in order to connect the platform with the trusses.

[1] Link to interactive map: `https://www.google.com/maps/d/u/0/edit?mid=1DbKPQ6_SlcOixza4Ki9jL37oBh4Htx43&ll=-41.69403415262085%2C-65.01845355742495&z=16`

The following 22 column groups are made of steel columns, see Figure 7.2. Two of the steel column groups have nine columns whereas the other 20 steel column groups have four columns. Just as the concrete column groups, the columns are connected to a concrete platform which is connected to the trusses with bolted steel joints. However, the steel column groups are somewhat more complex than the concrete column groups. Indeed, the steel column groups have extra elements: the steel crosses and two types of steel joints. The former connects diagonally the columns to each other with welded connections and the latter is located at the middle of the steel column splitting the column in two and at the top of the column connecting it to the concrete platform.

Additionally, to clarify which elements of the column groups are damaged, the columns are also numbered, see Figure F.1 in the appendix. The numbering for the columns of column groups 1 to 10 follows the numbering of the columns of the column groups 11 and 12. Also as mentioned earlier, the column groups 13 and 14 consist out of nine steel columns, yet the middle column is not numbered as it is hardly visible and thus too difficult to analyse.

To sum up, there are many distinct elements composing the column groups which need to be evaluated in order to determine the potential of the reuse of the structure namely:

- the concrete columns
- the upper and lower steel columns
- the upper and lower steel column joints
- the steel crosses
- the concrete platforms
- the steel platform joints

The state of these column group elements is described in the following paragraphs.

7.1.1. Concrete Columns (Column Group 1 - 3)

In the methodology, it has been presented which properties are needed for the inventory of the concrete columns. The most relevant ones are the damages on the elements. These are presented in the following paragraphs.

At the first column group, some small damages are noticed. The crowns of column 1-2 and column 1-3[2] both experience corrosion which exposes a part of the reinforcement of the crowns, see Figure F.2 in the appendix.

At the second column group, damage is noticed as well, see Figure F.3 in the appendix. Column 2-3 has two large areas of honeycombs and one area of localised corrosion. Also, the crown of the column experiences reinforcement corrosion. At column 2-4, a large section loss is detected at the middle of the column, as well as a localised reinforcement corrosion close to the top of the column.

The damage of the last concrete column group is shown in Figure F.4 in the appendix. Column 3-2 has large areas of corrosion where the steel ladder connections are located. At column 3-3, a man-made rectangular hole is detected. Its edges are damaged and some corrosion is noticed below the hole. It is not determined what is the depth or the cause of this rectangular hole.

7.1.2. Steel Columns (Column Group 4 - 25)

As explained earlier, the steel columns are separated by steel column joints. Therefore, we distinguish two elements of the steel columns, namely one above the steel joint and the other one below the joint.

At all steel column groups, the lower steel columns are fully covered by roughly the same amount marine growth, see Figure F.1 in the appendix. In short, marine growth causes extra static loading to the structure due to its mass and causes extra hydrodynamic loading due to the increase of its column diameter [27]. However, the thickness is small compared to the column diameters. Therefore, it is assumed that the marine growth has a very limited negative effect on the structural capacity of the columns.

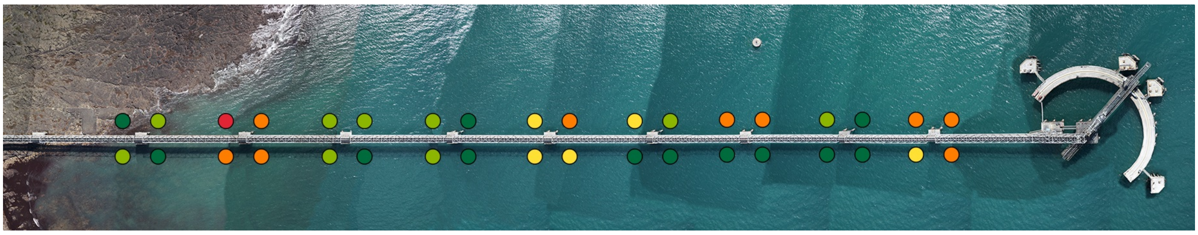
[2] The first number corresponds to the column group and the second number corresponds to the column

Most of the steel columns above the joint are affected by general corrosion, characterised by the uniform loss of material over the surface, see Appendix E.1 for different types of corrosion. The severity of the corrosion varies between the elements. In Section 2.6, a gradation for the steel elements according to the corrosion level has been provided, see Table 2.1. The decisive factor for the corrosion level is taken as the area of the corrosion [58]. After comparison of the steel columns, it is established that the least corroded steel column corresponds to lowest corrosion level (C1) and the most corroded column corresponds to highest corrosion level (C5), see Figure 7.3.

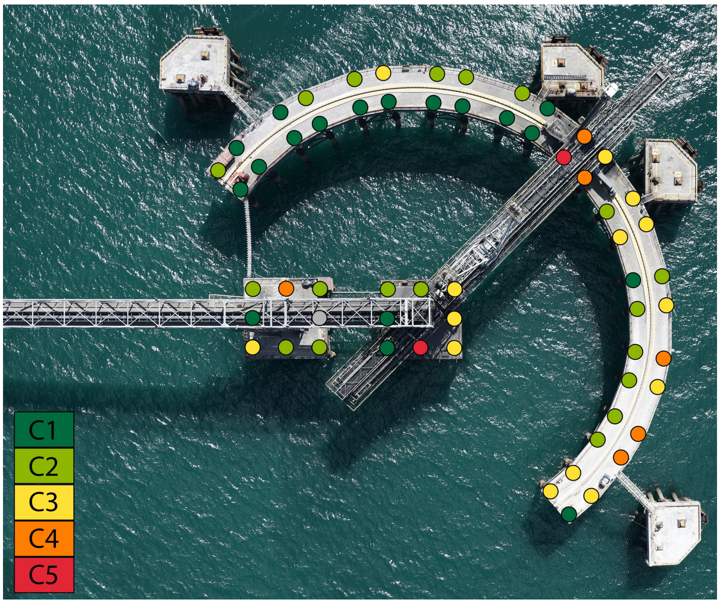
(a) C1. **(b)** C2. **(c)** C3. **(d)** C4. **(e)** C5.

Figure 7.3: Corrosion levels: steel columns.

As stated in Section 2.6.1, there are various negative consequences of steel corrosion to the structural capacity of steel elements. Typically, the structural capacity depends primarily on the cross-sectional dimensions of a structural member. For an axial member as the columns are, the cross-sectional loss of steel is governing for calculating the loss of structural capacity [34]. The loss of steel is difficult to determine from the images and therefore, the decrease of structural capacity cannot be quantified. However, the columns that suffer the most from corrosion can be identified in the maps, see Figure 7.4.



(a) Grades of steel column groups 4-12.



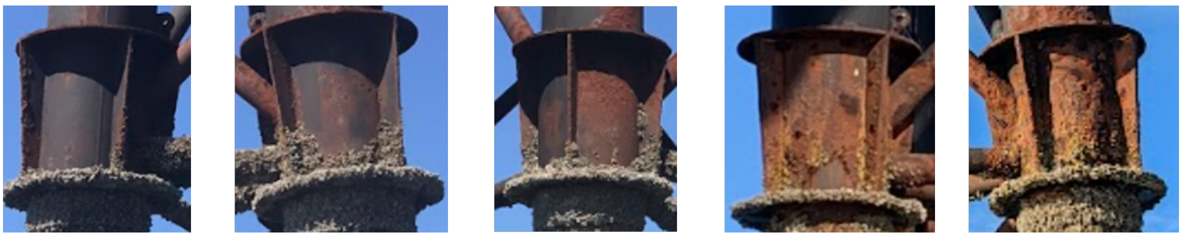
(b) Grades of steel column groups 13-25.

Figure 7.4: Corrosion grades of the steel columns.

7.1.3. Steel Column Joints

As explained earlier, there are two types of joints at the steel columns: in the middle and at the top of the columns. The upper joints, which connect the concrete platform, the columns and the crosses to each other, are all in similar state; they do not experience noticeable corrosion. Therefore, these joints are not further compared or evaluated.

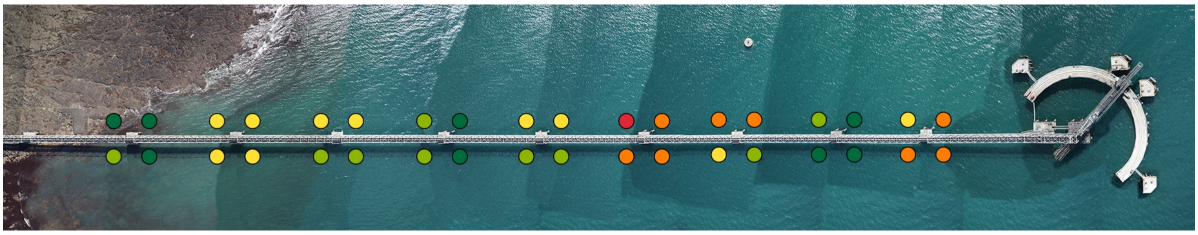
The lower joints which split the column steels in two are labeled as the steel column joints. The numbering of the joints follows the numbering of the columns, see F.1 Figure F.1. These joints are welded joints which connect the crosses to the columns. Unlike the upper steel joints, these steel column joints are corroded and the severity of the corrosion varies between the joints. Just like the upper steel columns, the length of the corrosion is the decisive factor. The gradation of the corrosion level goes from the lowest level (C1) corresponding to the least corroded joint to the the highest level (C5) corresponding to the most corroded joint, see Figure 7.5.



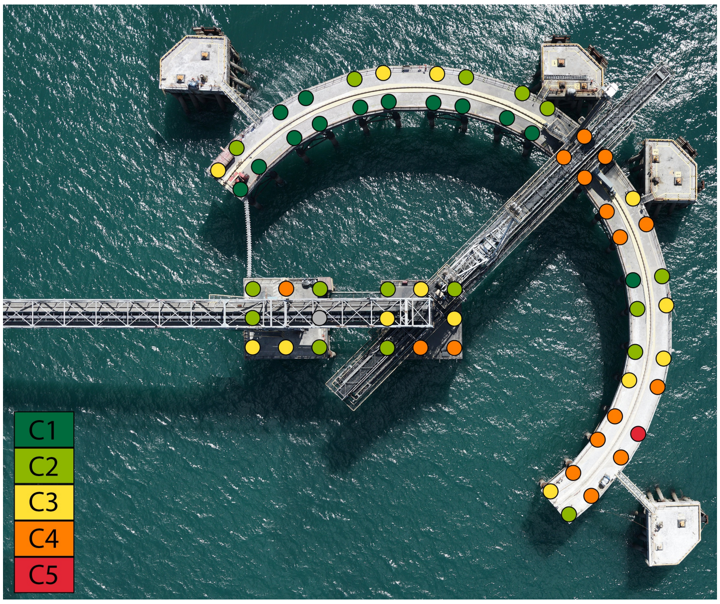
(a) C1. **(b)** C2. **(c)** C3. **(d)** C4. **(e)** C5.

Figure 7.5: Corrosion levels: steel column joints.

For plates in bending, like parts of the joints, the loss of thickness is governing for calculating the loss of structural capacity [34]. As for the columns, the loss of steel is difficult to determine from the images and therefore, the decrease of structural capacity cannot be quantified. However, the joints that suffer the most from corrosion can be identified the map, see Figure 7.6.



(a) Grades of the column groups 4-12.



(b) Grades of the column groups 13-25.

Figure 7.6: Corrosion grades of the steel column joints.

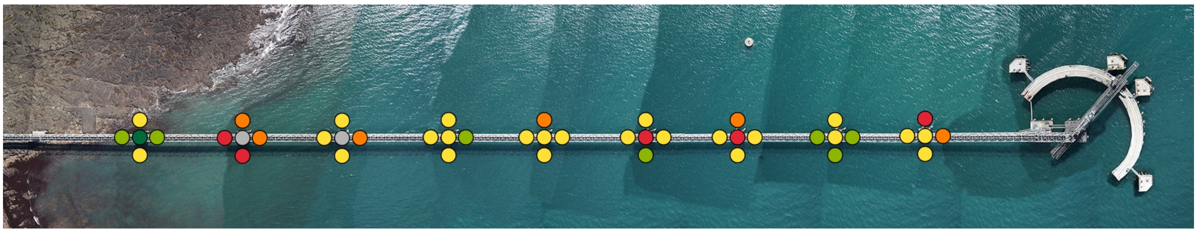
7.1.4. Steel Crosses

The steel crosses connect the steel columns to each other and are welded to the columns at the location of the steel column joints. Just as the steel columns and the steel column joints, the steel crosses suffer from general corrosion. We distinguish two types of set of crosses: vertical and horizontal. The former consists of three steel bars in the same vertical plane and the latter of two bars in the horizontal plane. Like the steel columns and the joints, the severity of corrosion differs from one set to another and the gradation is characterised as shown in Figure 7.7.

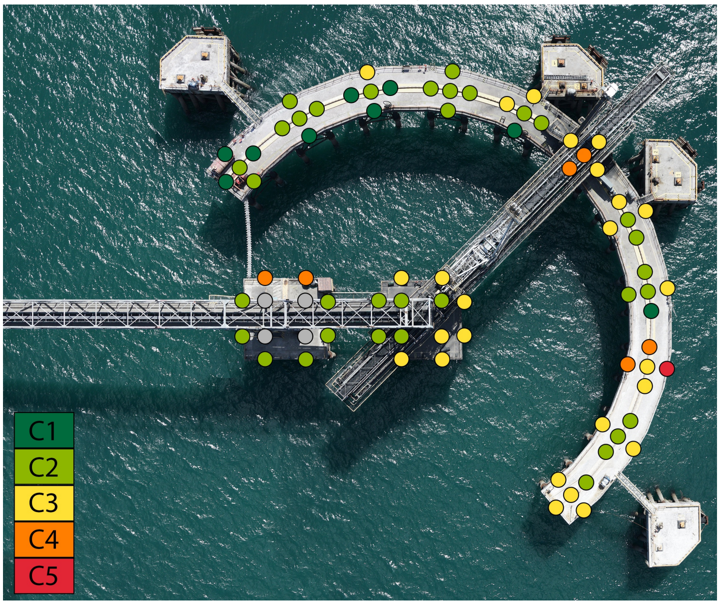
(a) C1. **(b)** C2. **(c)** C3. **(d)** C4. **(e)** C5.

Figure 7.7: Corrosion levels: steel crosses.

The results of the grading are to be found in Figure 7.8.



(a) Grades of the column groups 4-12.



(b) Grades of the column groups 13-25.

Figure 7.8: Corrosion grades of the steel crosses.

7.1.5. Concrete Platform

The concrete platforms consist of a squared reinforced concrete platform which is placed on top of the columns. It is noticed that all platforms have cracks, however, some are more severe than others, see Figure F.6 in the appendix. The crack occurring at column group 2 is considered the worst, see Figure F.6c in the appendix. According to [23], when it is believed that the crack influences structural integrity of the element then extra testing is needed.

The damage of the concrete platform of column group 11 is different from the damages of the other concrete platforms. Many years ago, a vessel collided with the jetty at the location of the column group 11. Consequently, one of the corners is severely damaged, see Figure F.7 in the appendix.

7.1.6. Steel Platform Joints

On top of each concrete platform of the column groups 1 to 11, four steel joints are located. These joints connect the concrete platforms with the steel trusses. The joints are numbered in the same way as the columns and column joints are. They consist of a steel plate which is bolted to the concrete platform. The corrosion level is established based on the area of corrosion. Again, the least corroded joint corresponds to the lowest corrosion level C1 and the most corroded joint corresponds to the highest level of corrosion C5, see Figure 7.9.

(a) C1. (b) C2. (c) C3. (d) C4. (e) C5.

Figure 7.9: Corrosion levels: steel platform joints.

The results of the grading are presented below in Figure 7.10.

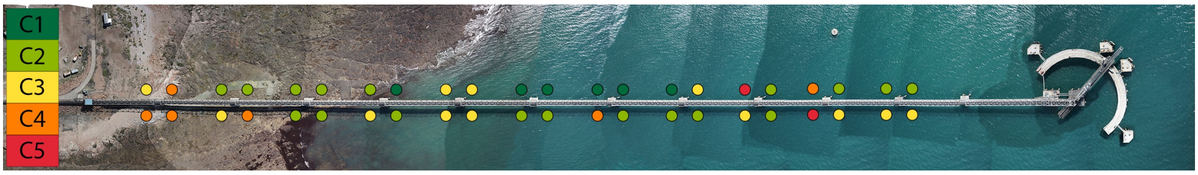


Figure 7.10: Platform joint grades of the column groups 1-11.

The constructions above the column groups 12, 13 and 14 that connect the column groups to the trusses and ship loading structure, are more complex. Due to their complexity, these structures are not elaborated descriptively. However, images of the structures are presented below in Figure F.8 in the appendix. Not much damages are observed, besides some mild general and pitting corrosion.

7.2. Trusses

The trusses support the conveyor belt from the shore to the ship loading facility and are supported by the column groups 1 to 14. There are thirteen trusses in total, the first twelve consisting of twelve squares of 5 metres per side[3]. This makes a total length of 60 metres per truss. The thirteenth truss is longer. The composition of the trusses consist of a horizontal roof with two diagonals and at the sides vertical squares with one larger diagonal. An example of one truss is shown in Figure F.9 in the appendix.

Some parts of the trusses are corroded. However, the difference in the severity of corrosion is small and therefore, no grading is performed. Figure F.10 in the appendix shows some examples of parts of the trusses.

To be noted are some deflections at the 12th truss, being the truss in between column groups 11 and 12, see Figure F.11 in the appendix. A vessel crashed into the construction many years ago, as mentioned in Section 7.1.5. Despite the damage, no reparations were performed. The damage was declared to be of no harm to the structural function of the truss, see Appendix A.3.

7.3. Ship Loading Structure

On site, there is a large construction in order to connect the conveyor belt from the last truss to the funnel, which leads the dry bulk to a moored vessel. The construction is mainly made of concrete and has a steel framework present at the top. Some corrosion is visible on the back side of the concrete structure, nonetheless the overall structure has little damage.

[3]Measured on site.

Figure 7.11: Image of the ship loading structure.

7.4. Mooring Dolphins

At the port four mooring dolphins are present. The foundation exists out of many steel columns, on top of that a reinforced block of concrete is placed. On each dolphin two mooring bollards are present. These three components will be elaborated independently. See Figure 7.12 for two examples.

(a) Mooring dolphin 1 **(b)** Mooring dolphin 2.

Figure 7.12: Examples of mooring dolphins.

The mooring dolphins are numbered according to Figure F.12 in the appendix.

7.4.1. Steel Columns

At the seaside the columns are protected by a wooden structure. Both the wooden structure and the steel columns are mostly covered by marine growth. Some parts that are not covered by marine growth are heavily corroded, as can be seen in Figure F.13 in the appendix.

7.4.2. Concrete Platform

The concrete platform of all four dolphins are heavily damaged. A lot of corrosion has occurred, which has caused the reinforcement bars to be visible in a lot of places. This can be seen in Figure F.13 and Figure F.14 in the appendix.

7.4.3. Mooring Bollards

On each mooring dolphin, two mooring bollards are located. Two types of mooring bollards are present, type 1 and type 2, based on their corrosion level. Type 1 is severely corroded and type 2 is slightly damaged, see Figure F.15 in the appendix.

Mooring dolphins 1 and 4 both have two type 1 bollards, mooring dolphins 2 and 3 both have one of both types present.

7.5. Buoys

Originally six buoys were present, named as shown in Figure F.16 in the appendix. However, at the moment of inspection the two northern buoys were missing offshore, leaving the port with only four buoys. One of the buoys was lost during a storm and high tide, as the chain that connects the buoy to ground, broke [Hugo O. Nicola, Appendix A.3]. The cause for the absence of the other buoy is unknown. Also, there are two buoys on the land, one which is in a good state and the other which has a lot of corrosion, see Figure F.17 in the appendix. The four remaining buoys are subjected to a lot of corrosion, as shown in Figure 7.13.

(a) Buoy 'Suroeste' (SW). **(b)** Buoy 'Sureste' (SE). **(c)** Buoy 'Este' (E). **(d)** Buoy 'Oeste' (W).

Figure 7.13: Buoys.

7.6. Pipeline in Jetty

As stated in Section 3.4.3 of the background study, a (cryogenic) pipeline will be needed to transport ammonia to the ship loading facility. The interview with the former operational manager of the port mentioned the presence of earlier intentions to construct a pipeline in the jetty, as stated in Appendix A.3. Plans of exporting iron in a liquid state were already in an advanced phase, as drawings with a pipeline in the truss structure were already made. Unfortunately, those drawing have not been retrieved.

8

Discussion

In order to draw a conclusion, the potential problems with the results have to be discussed. In this chapter the potential inaccuracies or other problems with the results are discussed.

8.1. Background Study

All technology concerned with hydrogen production, storage and transport is subject to vast amounts of research since technological challenges need to be vanquished before it will become a commercially trade-able commodity. The uncertainties listed below have been mentioned in the report but have been dealt with by making assumptions of feasibility, scale and safety requirements for the different elements. Most assumptions on sizes of different elements within the port were upper bound in order to accommodate for some variation. Furthermore, regarding the feasibility of different technologies, it has been assumed that most technologies will become available at the desired scale in the future.

Production

Different technologies currently exist for producing hydrogen, but electrolyser installations are currently significantly expensive regarding CAPEX and OPEX. Furthermore, the compatibility with intermittent energy sources and efficiency of the total installations are still a point of improvement. As of now, it is not clear which technology is going to be most suitable for GW-scale electrolyser facilities which poses an uncertainty in the estimation of costs, area needed and safety requirements.

Carrier

Hydrogen storage and transport faces technical challenges since it has to be either cooled or compressed extensively for it to become efficient. Storage tanks and vessels need to be able to hold hydrogen compressed and cooled for longer time-periods safely. To overcome difficulties in storage and transport, carriers of hydrogen pose an outcome. These carriers are often chemical compositions containing hydrogen. Hydrogen needs to be added to the carrier after production and subtracted from the carrier before usage. This requires enormous chemical plants and efficiency losses are also evident in the conversion processes. For ammonia in specific, the process to convert hydrogen and nitrogen gas into ammonia is still a novel technology that is only performed at small scale. Which carrier will turn out to be favourable for hydrogen transport in the end is thus undecided at the moment, which again poses uncertainties on estimation of costs, area needed and safety requirements within the port terminal area.

8.2. Stakeholder Analysis

The stakeholder analysis was completed through primary research, collected by conducting semi-structured interviews with stakeholders as well as literature sources found on the different parties (see Figure 2.1). When analysing the data that was acquired for the stakeholder analyses, it is important to note the potential subjective nature of the data. The interviews may provide subjective information regarding the positions and roles of the different stakeholders, as it is the perspective of the interviewee regarding the subject. The opinion about one's power, interest, and attitude towards the project is very much influenced by the person's objectives and wishes regarding the subject, and is prone to alterations in interpretation of the interviewer.

Furthermore, to some extend the interviews that were conducted have been recorded by writing down verbatim someone's oral language. According to Weber [56], this method of recording sometimes ”transforms that language, robbing it at times of its power, clarity, and depth, even its meaning”. The verbatim transcription can cause for the differences in tones, voices and styles to be left out, whilst this can definitely have an impact on the message which is trying to be brought across. This is a realisation which should be kept mind whilst processing and understanding the interview data.

Additionally, most stakeholders have not been interviewed directly due to lack in available contact. The analysis on these stakeholders has been completed through information attained from other stakeholders and literature resources. For example, the investor Fortescue, one of the key players in the project, has not been interviewed directly. The opinions and perspectives of Fortescue regarding this project is valuable information for the success of this project, however, this information has been gathered through second-hand information, leaving room for misinterpretations and misunderstandings. Therefore, the data should always be interpreted with a critical eye.

8.3. Topographic Analysis

The topographic data for Puerto Lobos was not collected with the same technology as the data from Punta Colorada Muelle and Punta Colorada South. Therefore, there is a difference in the accuracy of the data. To verify the results of the topographic analysis for Puerto Lobos, which was done with SRTM data, the same type of data was acquired for both locations of Punta Colorada. The data interpolated from the contour lines supplied by the drone data are more accurate. Due to the courser resolution in the SRTM data, slopes are reduced overall. This can be seen in Figure 8.1 and Figure 8.2. There are much less red areas in Figure 8.2 than in Figure 8.1. Therefore any conclusions drawn from the SRTM data are of diminished value.

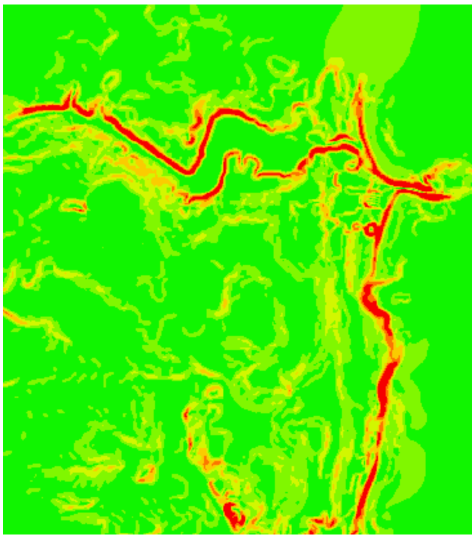


Figure 8.1: Interpolated slopes from contour lines.

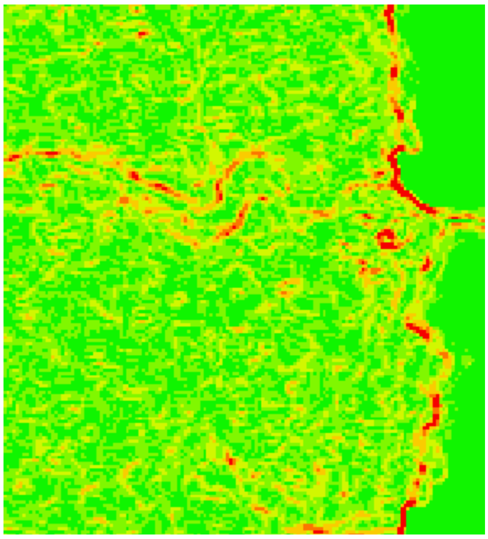


Figure 8.2: Interpolated slopes from SRTM.

8.4. Hydraulic Analysis

Quality of hydrometeorologic data

The gathered data of the hydrometeorologics are mostly retrieved from the operational manual of the jetty. In this document, data on wind, waves, currents and the tide was given without any metadata. The data would have been considered more reliable if information on measuring method, measuring equipment, measuring period, was provided as well. Next to that, the operational manual only provides data for Punta Colorada Muelle. No data on Puerto Lobos was found. A comparison between both locations is therefore considered to be unfair. Moreover, the estimated operational downtime might inaccurate because the reliability of the available hydrometeorological data is questioned.

Coarser bathymetry data at Puerto Lobos
The bathymetric data for Puerto Lobos was not collected with the same technology as the data from Punta Colorada Muelle and Punta Colorada South. At the Punta Colorada locations a bathymetry survey with an echo sounder has generated accurate and reliable data. At Puerto Lobos the only available data was obtained from Navionics. Looking at **??**B, it can be seen that the resolution of this bathymetry map is very coarse. A comparison between the bathymetry maps of both locations is therefore considered to be inaccurate.

8.5. Structural Analysis Punta Colorada Muelle

The results of the structural analysis can be divided into two main aspects: the overview of the structural elements of the jetty and the review on the state of those elements. Both aspects are briefly discussed in this section.

The structural elements of the jetty are presented in several maps, pictures and accompanying explanations. This gives much additional information on the scarce available data. However, still many more details on the structure can be provided. For example the steel and concrete types, the original structural drawings, the design calculations and a 3D model of the jetty. This information would be of great value in order to further assess the potential of the redesign of the jetty for ammonia export.

The structural elements of the jetty have either been graded based on the amount of corrosion or reviewed qualitatively. These grades and reviews give a good idea of the state of the structure. However, important to note is that level of experience of the reviewers[1] in inspecting damaged structures is very limited. This makes the overall review rather superficial, even though the reviews are supported by literature research.

[1] Three members of the multidisciplinary team.

9

Multi-Criteria Analysis

In order to draw a conclusion of the most relevant aspects in constructing the hydrogen export port, a qualitative MCA is conducted. The criteria for the MCA are based on the domains already discussed in this report: topographics, hydraulic conditions, the potential reuse of the structure and the political environment. The criteria are defined and their importance is established. This is done quantitatively by comparing each criterion with the other criteria and determining which one is most important. This quantitative weighting of the criteria is determined for fifty percent by the authors of this report, the other fifty percent by two consultants of Ports Consultants Rotterdam (PCR) Pablo Arrecco and Pedja Živojnović.

However, the data gathered on all three locations is not equally accurate. Therefore, no grades for the criteria are given. Instead, the locations are qualitatively compared and evaluated based on the results and the significance of each criterion.

Also, a complete overview of the three different locations is given, by explaining the advantages and disadvantages of each location.

All criteria contain a definition which is provided in *italic*.

9.1. Topographic Analysis

The characteristics of the land and location determine the feasibility of building a potential jetty in the area. These characteristics are based on the following factors:

9.1.1. Geographical Accessibility

The accessibility of the locations is based on the presence of roads and infrastructure to and from the location. This influences the feasibility to transport goods and services to the locations. This is relevant in the construction phase of the project, as well as the operations of the hydrogen export port.

Due to the previously used mining export infrastructure at the location of Punta Colorada, this location is accessible by already existing roads. The RN3 allows for accessibility through a highway, which can be used effectively for the transport of the construction materials. However, PR5 and PR9 are dirt-roads, resulting in serious accessibility difficulty when there is rainfall. Therefore, if the Punta Colorada location is chosen for the hydrogen export port, it is advised to place paved roads from RN3 to the port location. This road is a total of 28 km from West to East.

Regarding Puerto Lobos, there is the same challenge. The highway RN3 is accessible, however RP60 is a dirt-road, creating difficulties for transportation in rainy weather circumstances. It is also recommended to replace the dirt-road with a paved road for efficient transportation of materials. This road is a total of 20 km.

9.1.2. Presence of Residential Areas

The residential areas surrounding or located in the potential hydrogen export port areas influence the feasibility of building in the area. The construction of an ammonia factory close to a residential area comes with serious safety issues. Furthermore, the construction and operation of the port will cause noise and air pollution for the residential areas.

At Punta Colorada there are two main residential areas, the first being Playa Doradas, 5 km north of the Punta Colorada Jetty. The conflicts with this residential area should be quite limited as the distance is quite large. The second residential area is located right next to the FTZ. This residential area is still in an early stage of development. The residential and tourism under development area right next to the potential ammonia production facilities will raise some serious safety concerns. The properties in this residential area will also suffer from devaluation, creating more conflict between the province, a potential operator of the ammonia plant and the owners of the plots in the residential area.

As there are no residential areas near Puerto Lobos, none of these issues should occur in this location.

9.1.3. Presence of Existing Inland Structures

The presence of existing structures on site means that these structures can be reused, recycled, or need to be demolished. These existing structures include structures such as old factory elements and houses.

Existing structures are mostly prominent in the Punta Colorada location, where the old ore mining production and export structures can still be found (see Appendix C). These will either be re-used or demolished. However, issues regarding these buildings can occur due to the contractual rights of MCC on this locations. As MCC has the right to operate and maintain these structures, they might cause difficulties with building and re-building.

On the other hand, the locations of Punta Colorada South and Puerto Lobos do not contain note worthy structures in the area.

9.1.4. Available Land for Construction

The area required for all of the different facilities have been determined in Section 3.4. The area available is mainly influenced by the presence of existing structures and slopes in land elevation. Large differences in land elevations on the potential locations can create difficult building conditions for the port. The land elevations therefore demonstrate the feasibility of construction on the area.

The land available for construction of the ammonia export port is based on the two main aspects: the free-trade zone allocation in Punta Colorada, and the differences in land elevation which make the construction either feasible or inefficient. The boundary of land elevations in order to build is set at 5%, as shown in the Section 5.2. The required area for construction of all of the production facilities is given in Section 3.4 and shown in Table 9.1. The total estimated area required for the production facilities and storage is 329.5 ha.

	Electrolyser	Ammonia plant	Storage	Total
Short-Term	20 ha	23 ha	1.5 ha	44.5 ha
Medium-Term	150 ha	175 ha	4.5 ha	329.5 ha

Table 9.1: Area required for production and storage facilities.

The available area for construction results from Section 5.2 and are shown in Figure 9.1. As the most northern area was not surveyed by the drone, no substantial conclusions can be drawn on this 116 ha area, except from the fact that it is positioned in the FTZ. The rest of the 570 ha area is more than sufficient for the 329.5 ha of space required for the construction of the production facilities and storage. The constraint of the FTZ will not be a limiting factor in the short and medium term plans for the ammonia export port. Figure 9.1 demonstrates the three zones in which construction based on the FTZ and differences in land elevations is feasible.

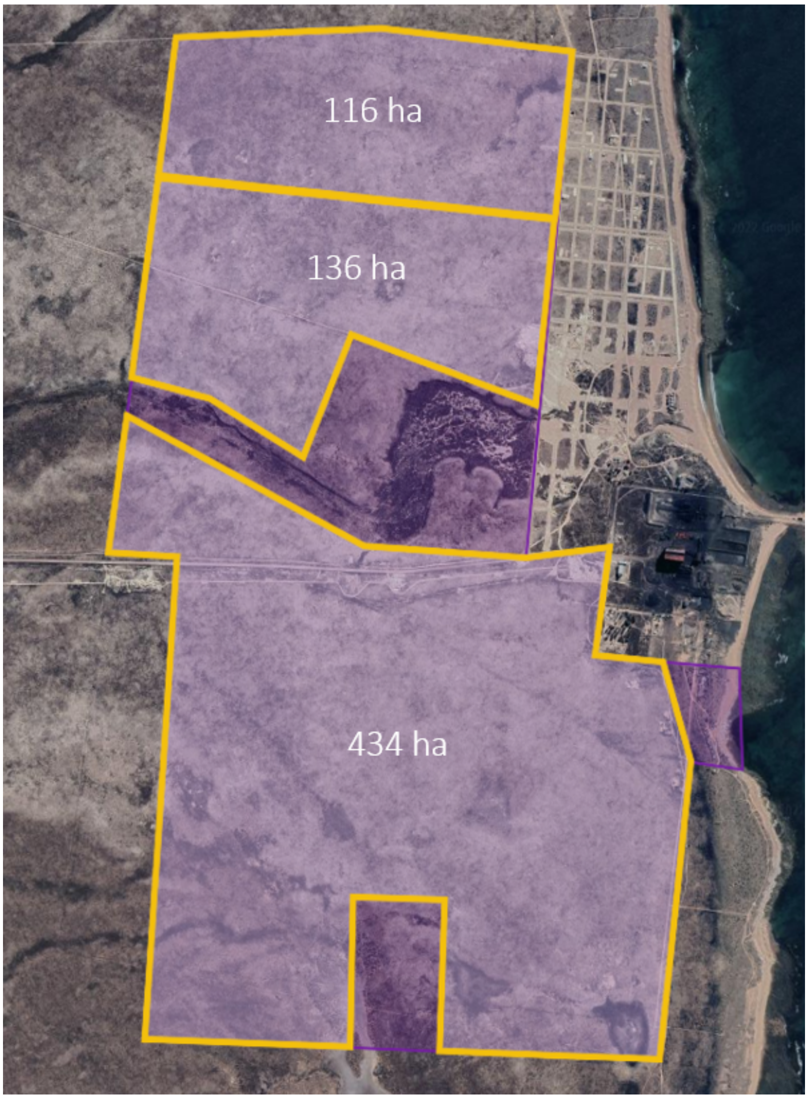


Figure 9.1: Estimated area available for construction in the Free-Trade zone at Punta Colorada.

At Puerto Lobos no restriction due to any FTZ is present. Therefore the available area for construction is only based on the slopes in land elevation. As the slopes behind the beachfront at Puerto Lobos are very limited, there is more than sufficient area available for construction of the ammonia production facilities.

9.2. Hydraulic Conditions

The the hydraulic conditions determine the length and important factors regarding the operation of a jetty.

9.2.1. Distance From Shore to Required Depth

The required length of a new or existing jetty is based on the distance from shore to a required depth of for vessel berthing. These required depths have been split into a short-term required depth of 12 m+MSL and a medium-term required depth of 17.34 m+MSL (see Port Requirements Section 3.4). The required depth is determined through minimal required depth of the design vessel, and the tidal characteristics or tidal window.

For the short-term the minimum required depth for vessel manoeuvring and berthing is 12 m+MSL. For the medium-term the minimum required depth is 17.34 m+MSL. The distance from the shore to the required depth for berthing is different for each location because it depends on the local bathymetry. The table below gives an approximation of the general distance to required depth of all locations and the data source used for the approximation.

Location	Short-term distance to required depth	Medium-term distance to required depth	Source	Quality
Punta Colorada Muelle	990m	1510m	2022 Bathymetry Survey	Good & recent
Punta Colorada South	1390m	2750m	2022 Bathymetry Survey	Good & recent
Puerto Lobos	1000m	2000m	Navionics	Poor & no information on date of measurement

Table 9.2: Overview of the different lengths to required depth and the data sources used for approximation.

The results indicate the most favourable location to start operation based on distance to required depth and therefore jetty length to be Punta Colorada Muelle. Due to the availability of a land-head the distances to required depth are generally smaller, for both the short-term and long-term. Also, the possible re-usage of the existing iron ore jetty provides possibilities for decreased investments to be made for the short-term. The depth at the end of the jetty (11 m+MSL) is not sufficient for the short-term design vessel (12 m+MSL). Causing the need for either dredging activities or extension of the jetty and another 90 meters and building new berthing structures.

Puerto Lobos has a relatively steep foreshore and also has reduced distance to required depth. Bear in mind that the source is questionable and bathymetry surveys should be performed to create a clear image.

9.2.2. Long-shore Uniformity of Bathymetry

Loading of ammonia to vessels at berth is a critical moment due to the hazardous nature of the substance. The loading time is expected to be 12 hours for vessels with a capacity of 140000 m^3. During loading, the ship must have the possibility to decouple berth and leave within minutes if the hydrometeorologic conditions exceed the operation limits. A long-shore uniform depth contours are beneficial for ship manoeuvrability and would thus ease operations. In the table below the long-shore uniformity of the bathymetry is classified for each location.

The bathymetry charts shown in 6.3 were analysed. For each location, the long-shore profile looks uniform on a scale (100 m) that is important for the navigability of vessels. On larger scale (1000 m) the long-shore profile varies gradual. It is considered that this scale does not negatively influence the navigability of the area. Furthermore, no notable anomalies in bathymetry such as sandbanks were found.

9.2.3. Hydrometeorological Conditions

The hydrometeorological conditions greatly influence the annual expected downtime the port. Loading and mooring could be interrupted if the operating limits discussed in the port requirements are exceeded.

The operational manual of the jetty reports data on wind, waves and currents in Punta Colorada. Metadata on these findings such as, measuring method and location of measurement, was not reported. Further literature study did not yield use full data on the hydrometeorologic conditions at Puerto Lobos.

The semi-diurnal tide at the gulf of San Matías is has a rather large tidal amplitude nearshore. At Punta Colorada a tidal amplitude is reported of 2.84 m [14]. The same order of magnitude is expected at Puerto Lobos.

A study from CERF has modelled the tidal currents in the gulf of San Matías. Concluding from Figure 6.4, the nearshore currents seem to intensify slightly from South to North in the gulf of San Matías [14]. The maximum tidal current is expected to be slightly larger at Punta Colorada. For both locations these tidal currents are not expected to exceed the operational limits.

The operational downtime of the port is estimated with the operating limits for handling marine oil and petrochemicals shown in Figure 3.15 and the hydrometeorological conditions of Punta Colorada shown in Section 6.1. Following the reasoning in Section 6.2, the estimated downtime at Punta Colorada is 4 % of the year, which amounts to 14 days. In this reasoning operational downtime was mainly due to exceeding waveheights. It is not expected that the operational downtime would differ a lot at Puerto Lobos.

9.2.4. Flood Safety

Due to the handling of toxic chemicals, damage to any of assets of the port is undesired. Therefore, flood safety and possible coast erosion should be evaluated. It should be assessed if any of the locations is more prone to be flooded with respect to the others.

The Argentinian Geological Association has classified the coast of Río Negro with Gornitz coastal vulnerability indices. The coastal vulnerability of Punta Colorada was classified high with an index of approximately 24. The coastal vulnerability of Puerto lobos was classified moderate with an index of approximately 19 [50]. The paper is not clear about what components of the indices were governing in this difference.

Next to that, the GFDRR reports that there is more than a 2 % chance that a potentially damaging tsunami will occur in the next 50 years in the gulf of San Matías [22].

9.3. Potential Reuse of Jetty

This criteria is not applicable for the locations of Punta Colorada South and Puerto Lobos, since these do not involve existing structures.

At Muelle Punta Colorada, there is an already existing jetty structure. At the other locations, namely, Punta Colorada South and Puerto Lobos, a structure will have to be constructed from scratch.

Reusing an existing structure can have many advantages on many fields.

Firstly, the sustainability of the port. By constructing a new port, the Muelle Punta Colorada will be left unused. Also, raw materials will be needed, these will need to be transported to the construction site and again processed. This costs a lot of time, energy and materials. By converting and reusing the old facility, a lot of energy, waste and raw materials will be saved.

Secondly, the costs of the export port. On the one hand, the current state of the jetty is not determined so, more testing is needed. This could bring potential costs if every elements would to be tested. Also, the possible costs of repair or replacement of many elements is present. Finally, the facility is quite old so, recurrent maintenance could occur, which will bring extra costs. However, on the other hand, reusing the old facility will save time and the much higher costs of the construction of a new structure.

Finally, the current jetty at Punta Colorada is designed for transportation of dry bulk. Even if the structural elements of the jetty were to be in perfect condition, undoubtedly many adaptations would need to be made. Therefore, it is important to assess the compatibility of this dry bulk jetty, considered in perfect state, with ammonia transport. If a whole new structure would to be constructed, then you would have the freedom to construct the port the way you want it. The pipelines would be on the right place, the mooring arrangements would be optimal and you could build a construction which would be ready to use on the short term and afterwards extended for the medium term, for example.

9.4. Political Environment

The political environment at each of the locations could greatly influence the feasibility of a hydrogen export project.

9.4.1. Existing Free-Trade Zones

To make a more attractive business case for foreign parties, Argentinian law allows for the creation of a free-trade zone. The availability of such a zone could be very influential to the attractiveness of the project.

As explained in Section 3.1.2, the free-trade zone provides a huge financial benefit regarding the production and export of hydrogen. Punta Colorada and Punta Colorada South are provided with the benefit of building in the FTZ. On the other hand, Puerto Lobos cannot benefit from this tax-free region. This brings a definite advantage to the locations of Punta Colorada compared to Puerto Lobos. According to Guillermo (see Appendix A.1), there is a possibility for a new FTZ to be allocated in Puerto Lobos, since in the 30's a FTZ was actually operating. However, research does not provide any more proof of this. Therefore, this statement is not considered for the MCA.

9.4.2. Presence of Marine Protected Area

Argentina identifies different marine protected areas in the country, in which their objective is to protect and conserve the unique existing ecosystem, rich in wildlife as well as paleontological and archaeological research potential. Building on or close to marine protected areas comes with certain challenges.

At Punta Colorada, no marine protected area is present.

There is a marine protected area just north and south of the border between Río Negro and Chubut. Construction of an export facility at this location would mean changing the boundaries of at least one of the marine protected areas. This would be met with political resistance. Changing the boundary of a marine protected area defeats the purpose of creating the area in the first place and environmental groups will protest. Legislation might not even allow moving the boundary for economic purposes.

9.4.3. Interfering Governmental Managements

Issues with the local government(s) can arise in any way, shape or form. Potential collaborations or internal struggles of governmental institutions can effect the process. It is important to assess the dangers of these issues to the project.

The governmental provinces in Argentina work autonomously leading to the fact that governments have own decision making power. Punta Colorada, placed in the province of Río Negro, results in the decision making power of one province regarding the construction of the green hydrogen export port.

However, as Puerto Lobos is located on the border of two provinces, namely Río Negro and Chubut, the construction of the hydrogen port will result in two provinces being involved in the project. The collaboration of two provinces could potentially result in a stronger position in this project, since it can be valuable to share knowledge and expertise on the export of hydrogen and allow for more financial input. However, this depends on the willingness and openness of the provinces to collaborate. On the other hand, may the location on the border of the provinces cause political conflicts as different provincial municipalities have different objectives and perspectives on this project. Political conflicts during these large complex projects are very costly and time inefficient.

9.5. Overview

	Punta Colorada Muelle	Punta Colorada South	Puerto Lobos
Geographical accessibility	Advised pavement of 28 km existing dirt road	Advised pavement of 28 km existing dirt road	Advised pavement of 20 km existing dirt road
Presence of residential areas	Playas Doradas at 5 km, potential adjacent residential area	Playas Doradas at 6 km, potential residential area at 1 km	No near residential areas
Presence of existing inland structures	Potential practical and contractual issues on ore mining structures	No nearby structures	No nearby structures
Available land for construction	Enough suitable area available for short- and medium-term ammonia production and storage within FTZ	Enough suitable area available for short- and medium-term ammonia production and storage within FTZ	No potential FTZ, limited amount of slopes provide plenty area suitable for construction
Distance from shore to required depth	990 m - 1510 m	1390 m - 2750 m	100 - 2000 m
Uniformity of bathymetry	Uniform	Uniform	Uniform
Flood safety	High vulnerability	High vulnerability	Moderate vulnerability
Potential reuse of jetty	Additional research on current structural capacity needed, reuse of jetty potentially saves a lot of costs and time, and is preferred from a sustainable point of view	Advantage of designing ammonia export facility without restrictions of an existing structure	Advantage of designing ammonia export facility without restrictions of an existing structure
Existing free-trade zones	Financial benefits due to existing FTZ	Financial benefits due to existing FTZ	No FTZ present
Presence of marine protected area	No marine protected area present	No marine protected area present	Conflicting marine protected area present
Interfering governmental managements	No interfering provincial governments	No interfering provincial governments	Location at border of provinces Río Negro and Chubut, potential cooperative advantage or political conflicts

Table 9.3: Overview of Multi-Criteria Analysis.

10 Conclusion

The goal of this research was to analyse three proposed locations and determine the most suitable location for the construction of a hydrogen export port. This chapter compiles the most essential information from the MCA based on the weighting of the criteria. These criteria together determine the suitability of different locations through their specific advantages and disadvantages. Information is split up between the three proposed locations to create a clear image per location and together, they serve to answer the main research question.

“Which location between Punta Colorada Muelle, Punta Colorada South and Puerto Lobos is the most suitable for a potential hydrogen export port in Río Negro?”

Bear in mind that the conclusion presented in this report is made with limited availability of information. Therefore, it should be stressed that the conclusion presented in this report gives an overview of the characteristics of all locations, but more data and research is needed to reach a definitive conclusion on the research question, for recommendations on future research, see Chapter 9.

10.1. Punta Colorada Muelle

The Punta Colorada Muelle location is considered to have high potential for a hydrogen export port. The existing jetty creates possibilities for a cost-efficient and rapidly realisable export of hydrogen in the form of ammonia. These characteristics are unique in this area and the potential is advised to be further explored with future research.

Previous plans of the mining company MCC indicate construction of a pipeline within the jetty was plausible. This enforces the idea that the current jetty is feasible to be repurposed for hydrogen export. However, maintenance has been lacking, damage was noted especially for the berthing structures and mooring buoys. These structures need to be revised or completely renewed. It should be noted that these results have been derived from visual observations, to make a conclusive statement on the repurposing of this jetty, structural samples should be analysed to determine the lifetime and suitability of certain elements, a design study should clarify if it is possible to incorporate a cryogenic pipeline. The presence of the mining company MCC, who still have right to use the existing infrastructure for iron ore export, might pose problems during construction and operation of the port, as the hydrogen infrastructure to be build within the jetty may not limit the functionality of the iron ore infrastructure. Cooperation with the mining company is considered plausible and should be explored.

The Punta Colorada Muelle is not directly bordering marine protected areas which simplifies construction and operation of a harbour with respect to the Puerto Lobos location. Furthermore, the FTZ bordering Punta Colorada Muelle and Punta Colorada South have ample space to facilitate electrolysers, an ammonia production plant, and storage facilities. The short term facilities will take up approximately 7% of the total FTZ area, in the medium term the facilities will take up approximately 51% of the total FTZ area, leaving ample room for more expansion if needed.

10.2. Punta Colorada South

Punta Colorada South has approximately the same land- and hydraulic characteristics as Punta Colorada Muelle. The only difference would be the absence of the existing jetty. Distance to required depth for berthing of vessels is somewhat larger due to absence of a land-head, making a new jetty somewhat more costly. An advantage however, is that design and realisation of the hydrogen port is not restricted in any way by the existing infrastructure or the mining company MCC. A new jetty also has the advantage that lifetime of the structure is well known and certain, and the jetty can be dedicated to the export of ammonia solely, in contrast to the Punta Colorada Muelle location. Lastly, Punta Colorada South also has direct access to the Zona Franca. This location is considered potentially valuable for building a new jetty.

10.3. Puerto Lobos

Puerto Lobos shows deficiencies on certain very important criteria. Firstly, Puerto Lobos is located on the border of two marine protected areas, one in the Province of Río Negro, the other in Chubut. The marine protected areas have the objective maintain terrestrial, coastal, and marine ecosystems. The specific laws and regulations of these marine protected areas might make it very difficult to construct and operate a port. Furthermore, the presence of a harbour will most likely disturb natural processes. Secondly, Puerto Lobos has no existing port infrastructure, which has the disadvantage that a new jetty is to be build from scratch, requiring larger initial investments and extra time to start the export of ammonia. An advantage on the other side is that there are no restrictions applied to the design of an ammonia export facility due to already existing buildings and infrastructure. In addition, there is not an FTZ at the moment. The legal procedures to construct a FTZ are extensive and need to be realised in Río Negro as well as in Chubut. This might turn out to be a bottleneck in the project.

Due to low availability of the specific site conditions (hydraulic, topographic, and political), no fair conclusive results can be shared on this location and recommendations go out to future research in order to be able to still include it in the MCA presented in Chapter 9.

11 Recommendations

11.1. Stakeholder Analyses

This section dives into sub-question B, and gives a recommendation on how stakeholders can be engaged efficiently in order to use their expertise and value to the fullest extend in this project. Figure 11.1 demonstrates an overview of increasing level of engagement per stakeholder group, and advises a certain approach towards these stakeholders.

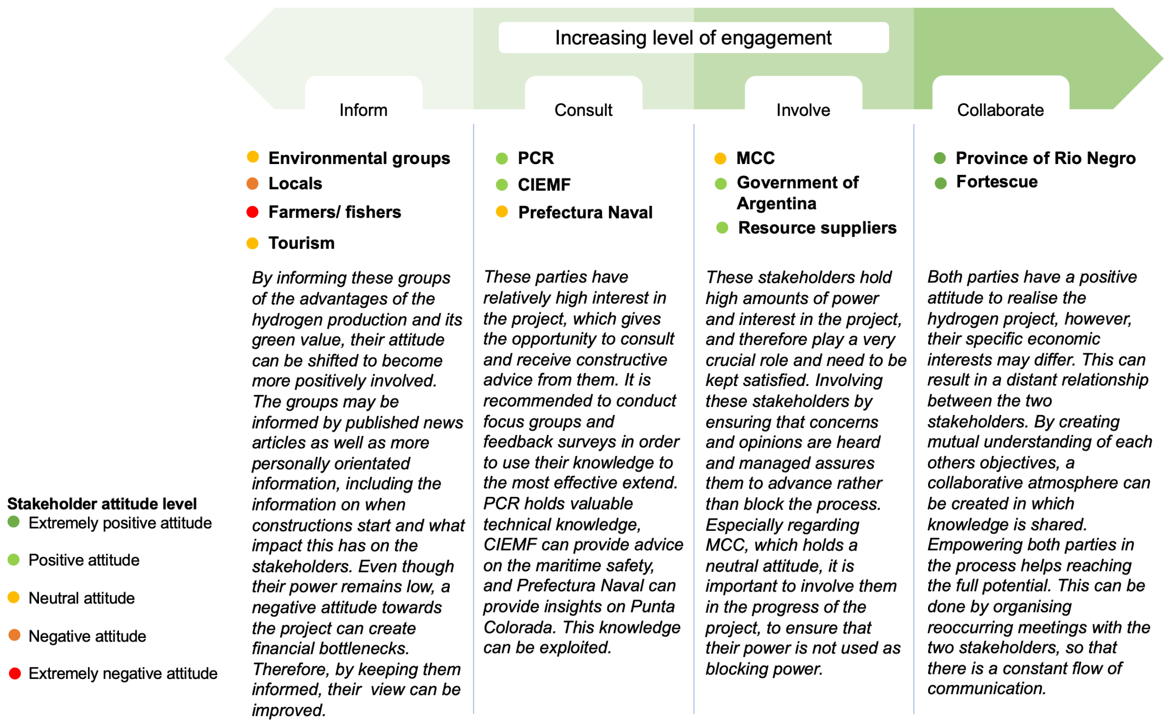


Figure 11.1: Stakeholder engagement strategy.

Research demonstrates that the stakeholder analysis is a dynamic process, in which the existing stakeholder networks are constantly shifting and create for a challenge in stakeholder management [5]. This dynamic nature calls for a dynamic approach in the stakeholder analyses. As the project progresses, relationships and attitudes of stakeholders towards the project change. If the engagement strategy is implemented correctly, certain attitudes and interests may shift to become more positive regarding the project, which consequently calls for a different stakeholder engagement approach. Apart from this, the allocation of power between the different stakeholders will change as different decisions regarding the project have been made. For instance, when the final decision has been made regarding the location of the hydrogen export port, it may result in a less powerful role of CIEMF if Puerto Lobos is disregarded. On the other hand, when the location of the current jetty at Punta Colorada Muelle is chosen to be reused, the power of MCC may increase due to their operational contract on the land.

Therefore, it is advised that the stakeholder network is revised continuously, and critically re-examined during the entire project life cycle. Different parties may come into play, and communication streams as well as influences of parties may start shifting. The stakeholder network is recommended to be updated regularly, especially at moments when the project enters into the next project stage or when the stakeholder network changes.

11.2. Topographic Analysis

The topographic analysis focuses on the feasibility of building a hydrogen export port on the three different locations. This was completed with the use of the WingtraOne drone elevation data, the satellite views and the visual inspection, as demonstrated in Section 2.4.

11.2.1. Additional Aerial Data

The aerial elevation data was collected within the FTZ, covering the locations of Punta Colorada Muelle and Punta Colorada South. However, this data was not able to be collected at Puerto Lobos due to weather circumstances. As the currently used elevation data on Puerto Lobos lacks detail, it is recommended to obtain the land elevation levels in Puerto Lobos in the same detail as the collected data at both locations of Punta Colorada. Additionally, the WingtraOne data was not accurately saved regarding the zone covering the jetty of Punta Colorada Muelle. It is recommended that this zone is included in a future survey.

11.2.2. Inland Visual Inspection

The visual inspection regarding the Punta Colorada Muelle has been done through identifying the structures on the land. The next step regarding this visual inspection is creating an understanding of the current state of the structures. This will allow an opinion on whether or not these structures are reusable for the hydrogen port.

11.2.3. Additional Measures

To further analyse the potential of the area for construction of the ammonia production facilities, the soil characteristics should be measured. A CPT should be done to identify and verify the locations for these large facilities.

11.3. Structural Assessment of Existing Jetty

The structural analysis of this report researched the potential of the reuse of the jetty into a hydrogen export port by visual inspections. In Section 2.6, the steps to assess the possibility of the reuse of an existing structure were presented. The first step is completed: visual inspections were performed and during these inspections damages were detected and reported. For following studies, further elaborated assessment of the damage is needed as well as the completion of the last steps from Section 2.6.

11.3.1. Damage Assessment

For the complete assessment of the damage, further investigation is needed. The concrete elements suffered of different damages, namely reinforcement corrosion and cracks. Since it is not known in what extend the cracks and deterioration are decreasing the structural integrity of the element, they need to be tested. In addition, deterioration is caused due to the environment of the jetty, so extra testing is required, such as the carbonation depth, chloride ingress and corrosion potential [23].

As for damage on steel elements, a gradation of the corrosion level has been determined based on the area of corrosion. However, as stated in Section 7.1.2, the cross-sectional area loss should be determined to obtain the decrease of structural capacity of the corroded elements

11.3.2. Determination of the Current Structural Capacity

Next, as explained in the methodology, it is important to gather information on the elements. Some of these information have been obtained, however a few are missing. For example, the dimensions of the elements, the reinforcement properties of the concrete elements, the concrete strength, the yield and tensile strength of the steel as well as the loads on the elements. Some of these can be obtained with a ferroscan or a ground-penetrating radar [23]. These are non-destructive tests and therefore very interesting for the jetty. These tests will verify the location, diameter, cover, spacing and number of steel reinforcing bars. The strength of the steel is also important. Furthermore, in order to determine the concrete properties, different methods are available. Core drilling is the most accurate. With this method, the compressive strength is determined as well as the elasticity modulus, the bending strength and the tensile strength [23]. It is preferable to conduct the tests in specific critical spots, as these are the places where the chance for failure are the highest.

After these tests, drawings of the structure should be made with the gathered information as well as an inventory with the properties of the concrete and steel elements. Consequently the structural capacity of the partial structures can be calculated, for example for a column groups or truss as whole.

11.3.3. Detailed Calculations

After having determined the partial structural capacity of larger elements, detailed calculations should be performed on the governing joints and elements to determine their structural capacity. For this matter, the use of finite element method driven software is advised [38].

11.3.4. Decision Making

Finally, the decision making will be based on the costs. Depending on the outcome of the calculations and the structural design requirements of the repurposed port design, a cost estimation should be made. It is advised to take in consideration the expected life time of the possibly repaired jetty, when comparing the costs to a completely new jetty.

11.4. Reuse of Current Jetty

Using the location of Punta Colorada can be favourable in the case that the existing jetty can be used. It has access to the FTZ which is large enough for the production of ammonia for short and medium-term export. The distance from shore to the required depth of 990m for the short-term and 1510m for the medium term is adequate.

11.5. Hydraulic Analysis

To make a more complete analysis of the hydraulic conditions, the following measures could be taken.

11.5.1. Hydrodynamic Measuring Stations at Locations of Interest

To get more exact information of the hydrometeorological conditions at the locations, a measuring station for currents and wave data should be installed at Puerto Lobos, Punta Colorada Muelle and Punta Colorada South. If these measuring stations are on location for a longer period of time, a more insightful conclusion on the downtime of a potential port can be given for all locations.

11.5.2. Bathymetry Survey at Puerto Lobos

To make an educated decision on which location to be advantageous for hydrogen port construction and operation, the bathymetry near Puerto Lobos is recommended to be surveyed in the same fashion as was done for the Punta Colorada Muelle. Puerto Lobos shows a steep foreshore that varies significantly in alongshore direction. This means there are possibilities to have a very short distance from shore to required depth, which makes the construction of a jetty cost-effective. It is proposed to perform a exploratory and a in depth bathymetry survey that could be performed in two to three days. The exploratory survey should primarily be focused on finding locations of specific interest where great depths are found near the coast. Once these regions have been located, a more detailed survey is to be performed on these locations of interest.

11.5.3. Soil Investigation of Sea-Bottom near Existing Jetty

Dredging could pose an advantageous solution especially when reusing the existing jetty. The local depth near the existing jetty is not sufficient for short and medium-term vessels to manoeuvre to berthing positions, even when time-restriction are made by implementing a tidal window. Capital dredging an access channel and space for maneuvering into berthing position is a solution if the soil is able to be dredged. During the field survey it became clear that the sea bottom is mainly made up of rock and patches of sand on top. Furthermore, from an interview with Hugo from the MCC, it became clear that dredging was considered difficult if not impossible. Therefore, a soil investigation is recommended to explore the possibility of dredging the soil to required depth in specific locations.

11.6. Investigate Locations for Cargo Jetty

The hydrogen port will need a cargo jetty to facilitate the import of all materials needed for the construction of the hydrogen port. Electrolyser components, ammonia production components, general construction materials, etc. This cargo berth will be in use for many years, as their will be a gradual expansion of the hydrogen port to meet it's projected maximum production capacity of 15GW over the years. The cargo berth would require a smaller depth than the ammonia export berth. This berth would preferably be as close to the FTZ as possible for logistical reasons. Furthermore, location of the cargo berth should be selected with care so that the infrastructure might also serve various other functions, such as serving as tug-boat harbour and or facilitating small fishing vessels to unload. Preferential locations for such a multi purpose port can be derived from the detailed data from the bathymetry survey performed within this research.

11.7. Investigate Punto Pórfido

When reviewing the results of the bathymetry surveys, a fourth interesting location was found at Punto Pórfido. This location is characterised by a very steep bottom profile close to shore. This means a shorter jetty could be build at this location. One of the disadvantages of this location is that it is located approximately 7.5 kilometers to the south of the FTZ. constructing such a lengthy cryogenic pipeline brings extra challenges of it's own. Therefore, it should be determined if it is possible to either relocate the FTZ to a location nearer to Punto Pórfido. If this is not possible, an investigation should be started in order to consider if the advantageous of the shorter jetty weigh up to the disadvantages of a longer cryogenic pipeline. No further research was performed on the Punta Pórfido location. The opportunities at this location are recommended to be researched in more detail.

11.8. Potential Future Port Scenarios

Three possible port alternatives are presented in this section. The scenarios are based on pending further expert research into the structural integrity of the jetty. These alternatives are an indication of the possibilities at the locations of Punta Colorada Muelle and Punta Colorada South.

11.8.1. Short-term Use of Jetty

After expert assessment on the loss of structural integrity of the elements and a potential positive verdict on the structural usability of the jetty, there is a possibility to reuse the existing jetty. To accommodate the short-term design vessel at the head of the jetty, tidal restrictions will have to be implemented along with the dredging of a small berthing pocket. Tidal restrictions are acceptable for the smaller vessels used in the short-term scenario as loading takes significantly shorter than it takes for the medium-term vessels as explained in Section 3.4.4.

11.8.2. Medium-term Use of Jetty

In the medium-term scenario, the depth at the shiploader is insufficient for the required vessels with a draught of 12m. The jetty can not be used in its current form. As a larger depth will need to be reached, a 700m longer jetty is required.

11.8.3. Scenario 1: Port Phasing Using the Existing Jetty and Building a New Jetty

To quickly advance to a stage in the project where export of ammonia can commence, it is recommended to investigate the possibilities for the phasing of the project.

Assuming a positive expert verdict on the structural integrity, the current jetty could potentially be used for the short-term scenario. This would only require design and construction works on the repurposing of the jetty itself. In this design, shown in Figure 11.2, the previous function of the shiploader could be retained or lost, this is a decision that would need to be made in discussion with MCC. This could be completed relatively quickly when compared to the design and construction of an entire new jetty. To satisfy the needs for the medium-term phase of the project, additional arrangements will need to be made. Parallel to the repurposing of the existing jetty, a new jetty with a length of 2200m would be built at the location of Punta Colorada South. Alternatively, depending on the outcomes of future research, potentially a jetty with a much shorter length could be built at Punto Pórfido. This jetty would reach the required depths for the medium-term scenario and be designed to accommodate the largest LNG carriers in the world.

An advantage of this scenario compared to scenario 2, is that the lifetime of the reused jetty is of little importance for the medium-term phase of the project. In addition, the operations of the reused jetty are not disturbed due to the construction of the second jetty. Compared to scenario 3 there will be more costs, however, these costs could be compensated by the potential benefit of starting to export ammonia in a shorter time span.

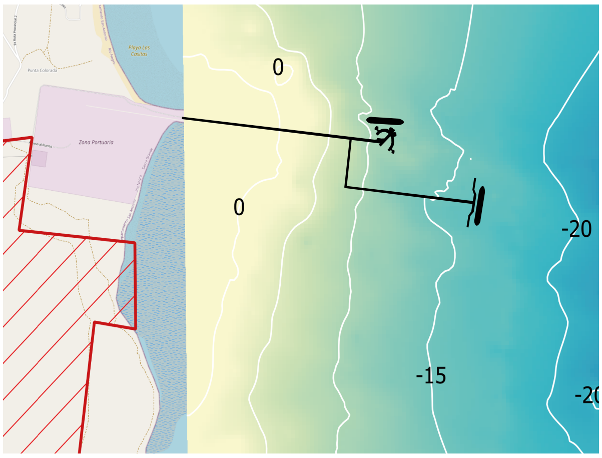


Figure 11.2: Visualisation of scenario 1.

11.8.4. Scenario 2: Port Phasing Using and Extending the Existing Jetty

In this scenario, shown in Figure 11.3, the existing jetty would be reused in the same way as the scenario above. To meet the demands of the medium-term phase the jetty would then be branched to the side to extend the jetty another 850m offshore to the required depth without halting short-term operations at the existing head of the jetty.

For this scenario, the expected lifetime of the reused jetty structure is an important parameter to determine and could cause complications for medium- or a possible long-term use. An advantage compared to Scenario 1 is the big potential cost savings due to the minimization of new constructions. Compared to scenario 3 there are as well potential cost savings, furthermore there is the potential benefit of starting export ammonia in a shorter time span.

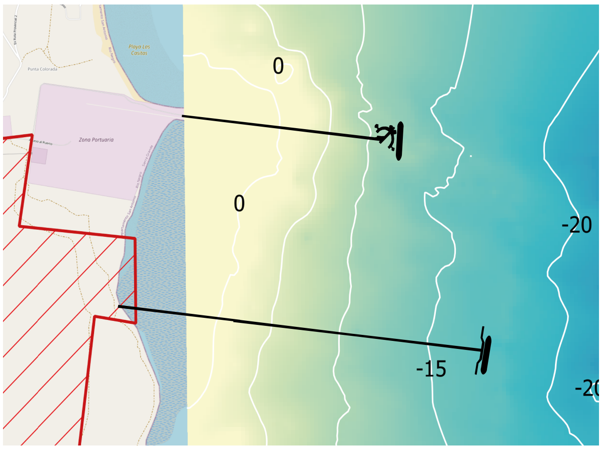


Figure 11.3: Visualisation of scenario 2.

11.8.5. Scenario 3: Construction of a New Jetty Without Reusing the Current Jetty

Construction of a new jetty at the location of Punta Colorada South, as seen in Figure 11.4 or, pending more investigation into the area, Punto Porfido, without reusing the current jetty at Punta Colorada Muelle could be an option if the jetty is not found to be structurally sound. Another reason to only build a new jetty could be that after more in depth investigation into the construction costs it is deemed inefficient to repurpose the existing jetty. When building a new jetty, phasing can also be applied to commence short-term export as quickly as possible. This would be done by creating an additional berth partway of the design length of the full jetty. The partially built jetty could then be extended to full design length at any time.

By creating an additional berth to accommodate the short-term export of ammonia, it is expected that more time is needed compared to re-using the existing jetty. In addition, the time span between the completion of the short-term berthing location and the medium-term berthing location is expected to be relatively small. Therefore, it is questionable if the advantage of exporting ammonia in a shortly earlier stage outweighs the costs of the extra berth. Compared to scenario 1 and 2, the main advantage is having no complications or restrictions due to the use of the existing jetty. Especially compared to scenario 2, where the whole port structure is reliant on the existing jetty.

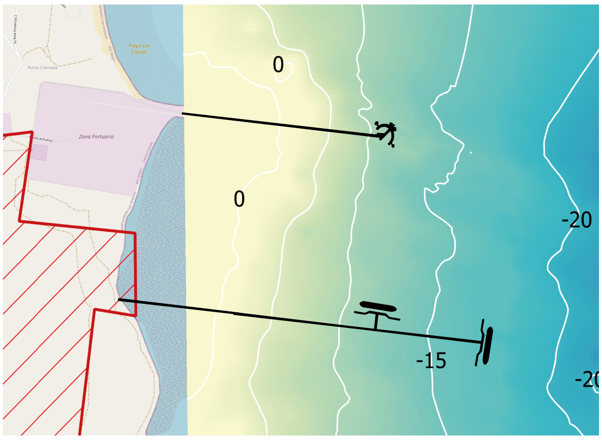


Figure 11.4: Visualisation of scenario 3.

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A

Semi-Structured Interviews

Interviews have been conducted for primary research. These interviews were all in the format of semi-structured interviews, for which an open interview approach was used. The three conducted interviews are presented below.

A.1. Interview: Guillermo R. Delamer

Interviewee: Guillermo R. Delamer
Function: Director of CIEMF, el Centro de Investigaciones y Entrenamiento Marítimo y Fluvial
Date: 17-02-022
Language: English

Attending:
Guillermo R. Delamer
Melissa Levington
MDP team

Aim: to get a better understanding of the role of CIEMF and share knowledge on specifically the characteristics of the Puerto Lobos location.

Questions and answers:

Notes on CIEMF background information

- Guillermo is the director of maritime and riverine research and training centre
- Only private company who is allowed to give navigation course
- Simulations are used for research, teaching and training
- The admiral gives us an example of a harbour at Rosario that they have developed for the transport of aceite. His company is provided with the initial drawings of the port. With their simulation they try to find practical bottlenecks in the initial design of the port from the nautical side such as navigatiability.
- The admiral shows us different bridge setups for simulations they use for their courses. The simulation has all the equipment a normal vessel has.
- Every 4 month new software is tested. The company is provided with the newest software to test it so that permanent improvent is established.
- They develop their own scenarios, ships, bathymetry for the simulation.

Interview questions:

Q1: What is the exact location of the port in Puerto Lobos?

A1: Precise coordination given in file

Q2: Why was the location at Puerto Lobos considered initially?

A2: According to Guillermo, Puerto Lobos is the best proposed location for the port. The location is on the border of two provinces, which will help make the project succeed. Frontier of the two provinces is a strategic location, beneficial for two parties. There are also many resources on land. There are no civilized locations any where near, so no people to disturb. The land is state-owned, not private yet. Also the bathymetric characteristics of Puerto lobos are good, directly deep water.

Q3: What are the advantages of this location after research?

A3: The region touches two provinces and has good bathymetry characteristics.

Q4: What are the disadvantages of this location after research?

A4: Nothing

Q5: What research have you done on the location at Puerto Lobos?

A5: Nautical aspects were researched.

Q6: What are the (beneficial) characteristics of the proposed port location?

A6: There are many positive characteristics of the location:

1. Ruta numero 3 (access)
2. We have to build everything new
3. Building new infrastructure is easier in an empty space (Puerto lobos)
4. A lot of gas is present in the mountains near chile
5. Wind and water resources
6. Rain is coming more to the south
7. For the region it is going to bring an ecnomic boost and people will move to the south where there is more space
8. Argentina is seen as the center of Argentina for habitants/economy but beneficial to have more population to the south (decentralization)
9. Gas pipelines can be built
10. Different parties have different ideas and it is hard to get everybody thinking in the same direction
11. Puerto Lobos protected areas for nature (beneficial)
12. Government area
13. Huge reserves of oil and gas surrounding the location of San Matias

Q7: What is the next step for CIEMF considering this project?

A7: The view of CIEMF on the optimal location has been presented to the Province, the next step is with the Provinces. Deciding which location is best needs our support.

Q8: Could you give a brief explanation of CIEMF's goals with regards to the Río Negro hydrogen project?

A8: CIEMF's goal is mainly to provide insights on the Puerto Lobos location, as well as simulation of the area. Their aim is to convince Río Negro to chose Puerto Lobos as the location for the hydrogen export port.

Q9: How would you define your position in the Punta Colorada hydrogen export project?

A9: CIEMF gives advice on the location and provides simulations of the area. They can also develop the port but is not per se necessary. CIEMF is only location for ship simulation so they will play a role in this part.

Q10: To what extent does CIEMF have an influence on the decision-making process?

A10: The CIEMF acts as an advising institution, they give advice on the Puerto Lobos location.

Q11: How is this in consultation with the Province of Río Negro and other stakeholders?

A11: CIEMF has meetings with the Province of Río Negro in order to present and consult about the Puerto Lobos location.

Q12: Which parties are you most in contact with regarding this project?

A12: Province of Río Negro in order to discuss the proposed location.

A.2. Interview: Gonzalo G. Medina

Interviewee: Gonzalo G Medina
Function: Executive Director of the Investment Agency of the Government of the Province of Río Negro
Date: 21-02-22
Language: English and Spanish

Attending:
Gonzalo G. Medina
Luise Giordano
Melisa Levington
MDP team

Aim: to get a better understanding of the role of Fortescue and the province of Río Negro in the green hydrogen port project.

Questions and answers:

Information on the port

Q1: Which characteristics does the Province of Río Negro see as most relevant for the port?

A1: There will be a desalinization plant, which means that there is no fresh water needed. The electrolyser and ammonium plants are separated.

Q2: How important is the Zona Franca in your decision-making for the location?

A2: Punta Colorada is a free zone, providing many economic opportunities. Puerto Lobos however, is not located in a free zone, therefore this location is not considered by Fortescue. There will potentially be a new free zone in San Antonio. Punta Colorada provides the benefits of the Zona Franca.

Q3: Does the Province of Río Negro have a most preferred hydrogen carrier for the port design? And what is the expected throughput?

A3: Fortescue needs to develop a port, with 2 GW growth per year. They will use ammonia and Fortescue will bring all of their own materials. Fortescue provides the province with little information, and they have no iidea how they will develop their port. Everything is still being developed and negotiated. Both sides are still speculating. Fortescue is developing green H2 all over the world.

The role of Río Negro

Q4: Could you give a brief explanation of your goals regarding the hydrogen export port?

A4: Fortescue will transport their first ship of Amonia in 2025. Río Negro should be developed into the international agenda, since this project will play an international role. Argentinian green hydrogen will become a large player. Argentina's economy is very fragile, but they want to attract private investors and projects. The province will become a facilitator to create projects for the private sector. They have started a scientific partnership with Fraunhofer, a public German company. The province wants to start a public green hydrogen plant, to enable the opportunity for other companies who would like to invest in green hydrogen of Río Negro.

Q5: What challenges do you see regarding this project?

A5: Río Negro has an important scientific community in Bariloche, where they have been studying green hydrogen for 20 years. There is a lot of knowledge, but it is a challenge to develop green hydrogen in Argentina with all its political barriers. They are not used to working with these professional companies, such as Fortescue, and furthermore they are not used to technical developments. However, they are excited to be able to say, ''this green h2 came from patagonia, Argentina''.

Q6: Which of the three locations do you think has the most potential and why?

A6: Gonzalo is only interested in Punta Colorada, and is scared of reaction of Fortescue when mentioning Puerto Lobos option. Puerto Lobos is not in the free-trade zone, making it much less interesting.

Q7: Which parties are you most in contact with regarding this project? And what is this collaboration like?

A7: A lot of contact is going on between Province of Río Negro and Fortescue. Everything is still being developed and negotiated, whilst both sides are still speculating. Fortescue is currently developing green h2 all over the world. It is still a bit uncertain if Fortescue will share their knowledge with the provincial. They say they're the best in the world, and supply little information about their plans. This is why the relationship is difficult. Probably they want to keep their technology secret from competition.

Q8: What is the structure for ownership in the project?

A8: All infrastructure will be property of Río Negro. Private company will build it, and have a contract to use it for limited time. Fortescue will develop the port and operate it.

Q9: How will the Province of Río Negro be influenced by this project?

A9: This project will bring many economic benefits to the province.

A.3. Interview: Hugo O. Nicola

Interviewee: Hugo Omar Nicola
Function: Ex-employee of MCC as operational manager at Muelle Punta Colorada
Date: 24-02-022
Language: Spanish

Attending:
Hugo Omar Nicola
Pablo Arreco
Luise Giordano
Melissa Levington
MDP team

Aim: to get a better understanding of characteristics of the jetty and the responsibilities of MCC in the operations.

Questions and answers:

About MCC

Q1: What role did you have on this port? ¿Qué estaban tu trabajo en este puerto?

A1: Operational manager, security and operation, chauffeur of the port within MCC.

Q2: Are you still involved in the port? ¿Ahora tu estas activo en el puerto? Tienes tareas?

A2: The works have been stopped completely, so he has retired.

Q3: Do you think the port will be used for iron export in the future? ¿Cree que el puerto se utilizará para la exportación de hierro en el futuro?

A3: The iron ores in the region contain fosfor which makes it expensive to harvest and process. They are not able to compete with Australia and Brazil.

Q4: What is MCC's idea of the rebuilding of the port? ¿Que piensas MCC sobre la reconstrucción del puerto?

A4: MCC is interested in the project, economical interest in hydrogen. The contract is for 99 years, and hes not sure why the chinese are staying whilst they can leave.

Technical questions

Q5: Do you have the technical drawings of the port? ¿Tienes los planos técnicos del puerto?

A5: He will ask for the structural drawings, he says they should be available and he will try his best.

Q6: Do you have maintenance records for the port? ¿Cuenta con registros de mantenimiento del puerto?

A6: Last shipment was in 2016, since then there was no maintenance. The chinese company who took over the port in 2006 upgraded the mooring system so that vessels of 30,000 to 60,000 dwt could moor. Conveyor belt needs full maintenance. Protective paint on trusses, dolphins and piles is from 2010.

Q7: What is your opinion on the maintenance needed at the port?

A7: In his eyes, the mooring buoys should be assessed firstly, the chains and the anchors of the mooring buoys with divers to make sure that ships can berth. He thinks that we should review the mooring dolphins and berthing places.

Q8: Do the steel columns have concrete inside? ¿Las columnas de acero tienen hormigón en su interior?

A8: The steel columns have concrete inside.

Q9: Do you know the technical aspects of the boys, bridge and the jetty in general?

A9: Mooring boys have a capacity of 230 tons. With low tide the depth of the northern berth is 11 meters. Different mooring bouyes were used depending on the wind conditions when berthing. Mooring bouyes were anchored to the ocean bottom and anchored with anchors of 200 meter. A cap of 2000 tons per hour, the bridge can take up loads of 240 tons. A design already exists of a pipeline in the jetty for the export of liquid iron. Design drawings were already made which showed a feasible option to construct a pipeline in the jetty.

Q10: Was it difficult for ships to moor at the jetty? ¿Fue difícil para los barcos amarrar en el embarcadero?

A10: Vessels needed two tugboats for operation, one always stayed at the berth, one in the small basin.

Q11: What is the current like?

A11: The current is mostly north-east.

Q12: Do you know if the conveyor belt is still functioning? ¿Sabes si la cinta transportadora sigue funcionando?

A12: Yes it is still functioning.

Q13: Do you know anything about local sedimentation and dredging activities? ¿Sabe algo sobre las actividades locales de sedimentación y dragado?

A13: The whole soil consist of rock and therefore no dredging.

Q14: How often were ships mooring at the port? ¿Con qué frecuencia atracaban los barcos en el puerto?

A14: From 2009 tilll 2015 one vessel per month.

Q15: Did ships have to wait often? ¿Tuvieron los barcos que esperar a menudo?

A15: Normally boats could enter directly but there was a max of 1 day waiting. The mooring is only allowed during daylight. However, loading was possible all day (also during night) and the same holds for leaving the port by the vessel.

Q16: Around how large were the vessels entering the port?

A16: Vessels with 14 meters draft entered the port during the last years.

Q17: What have been the worst conditions you experienced in your years working for MCC?

A17: The worst meteorological conditions he has experienced were large tidal amplitude, 3 meters of waves, and hard winds. The anchor of a mooring buoy snapped. During 10 years only one time the loading of a vessel needed to stop due to weather conditions, the vessel could stay moored.

B

Hydrogen technology

Element	Description	Input	Output
Power converter	This station is needed to convert the electricity from the wind farm to be applicable for the electrolyser.	High voltage alternating current electricity	Low voltage direct current
Water purification installation	The water needed for electrolysis is demineralised, as natural water contains minerals such as salt and calcium, a purification installation is needed.	River or sea water and electricity	Demi-water
Electrolyser cell	This is the heart of the electrolyser where the electrolysis reaction happens at large scale. The cell consist of a positively charged plate (Anode), a negatively charged plate (Cathode), and the electrolyte.	Demi-water and electricity (DC, low voltage)	Low pressure hydrogen and oxygen gas
Compressor	Hydrogen gas coming out of the electrolyser cell has a very low density and in order to store the hydrogen gas efficiently, it has to be compressed using the compressor.	Low density hydrogen gas and electricity	High density hydrogen gas
Cooling arrangement	Some electrolyser cells produce waste heat, as electrolyser should not become overheated, the need for a cooling arrangement is present.	Electricity	-

Table B.1: Electrolyser elements.

Type	Description	Efficiency (%)	Purity (%)	*Technology Maturity Level
Alkaline Electrolysis Technology (AE)	Electrolyser cell consists of an anode, cathode and an aqueous solution. Relatively cheap and mature technology. AE is not very suitable for varying supply, although research aims to improve this aspect.	62-82	...	9-10
Proton Exchange Membrane (PEM)	Electrolyser cell consists of an anode, cathode and a proton exchange membrane. The membrane is relatively expensive and research aims to find new, cheaper materials to replace membrane. PEM is very suitable to varying electricity supply.	67-84	...	7-9
Solid Oxide Electrolysis (SOE)	Uses solid oxide and ceramic electrolyte to produce hydrogen gas. Operates at very high temperatures (500-650 °C), causing start up times to be relatively large making it less suitable for varying electricity supply	75-90	...	3-5

Table B.2: Electrolyser type comparison.

C

Area Surveys

C.1. Visual Survey

Figure C.1 shows the identified structures which were discovered on the location of Punta Colorada Muelle. These structures were part of the old iron ore port, which was managed bij MCC.

Figure C.1: Overview of structures on Area 1.

C.2. Drone survey area coordinates

The WingtraOne drone was used to gather data for the FTZ. The coordinates shown in Figure C.2 were identified as a boundary for the drone flight area.

Figure C.2: Areas to be surveyed by drone.

Location	Coordinates
Area 1 NW	-41.6916107, -65.032444
Area 1 NE	-41.6935459, -65.026515
Area 1 SE	-41.7014564, -65.0228623
Area 1 S	-41.6995155, -65.0299406
Area 1 SW	-41.6974676, -65.0325078
Area 2 SW	-41.7116524, -65.0370152
Area 2 SE	-41.713173, -65.0218712
IT NE	-41.6956162,-65.0148089
IT Jetty	-41.698171, -65.0117658
IT SE	-41.7080124, -65.0177816
IT SW	-41.7082524, -65.0216628
IT Beach 1	-41.7036014, -65.020413
IT Beach 2	-41.7000306, -65.0196251
IT Beach 3	-41.6936128, -65.020361
IT Beach 4	-41.6936128, -65.020361
Jetty NE	-41.6974786, -65.006077
Jetty SE	-41.6986296, -65.0060135
Jetty SW	-41.6962559, -65.0281282
Jetty NW	-41.6938205, -65.0282967

Figure C.3: Coordinates of the areas surveyed by drone.

C.3. Topographic map of Free-Trade Zone: Punta Colorada Muelle and Punta Colorada South

The WingtraOne drone identified the levels of elevation in the free-trade zone. In Figure C.4 the different heights of the area, in meters, are visible, together with the free-trade zone marked in pink. Both the Punta Colorada Muelle and Punta Colorada South areas have access to this free-trade zone. The different heights illustrate the changes in topography, which is valuable information for the construction and realisation of the hydrogen port. The heights are transferred into slopes in the following section.

Figure C.4: Topographic map analyses of the Free-Trade Zone.

D

Bathymetry survey

In this section a further elaboration is given on the bathymetry survey.

D.1. Measuring period

The RIB will be available for three days from Thursday the 24th of February. During the entire tidal cycle the RIB will be sailing and gathering bathymetry data.

D.2. Expert assistance

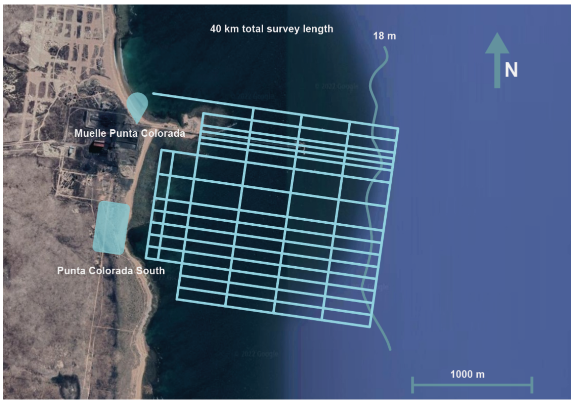
A team of two experts from Instituto Nacional del Agua will supervise and manage the survey. The team has very extensive knowledge and expertise on executing bathymetry surveys and processing the data.

D.3. Conceptual survey grid

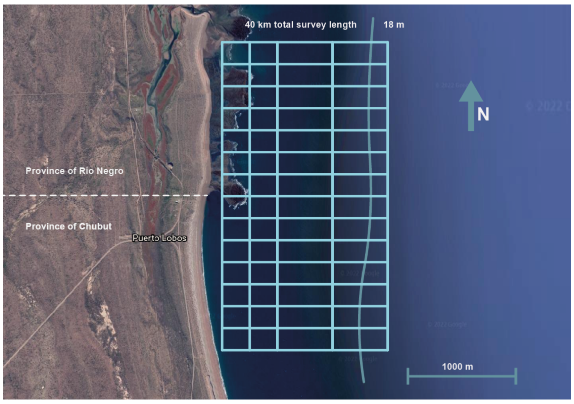
The survey grid is used as a guideline for the route of the survey. The total measuring distance is based on the distance which can be covered during a working day. This is calculated with the assumptions below.

Average sailing speed	5 km/h
Operational time	10 h/day
Operational down time	2 h/day
Measuring time	8 h/day
Total measuring distance	40 km/day

Next, the conceptual survey grids have been composed within both areas of interest. Both grids are approximately 40 km long. The grid is fine at the locations where larger detail is desired and coarse at the locations where a lower spatial resolution is allowed. The conceptual grids are shown in figure D.1 a and b.



(a) Survey grid at Punta Colorada

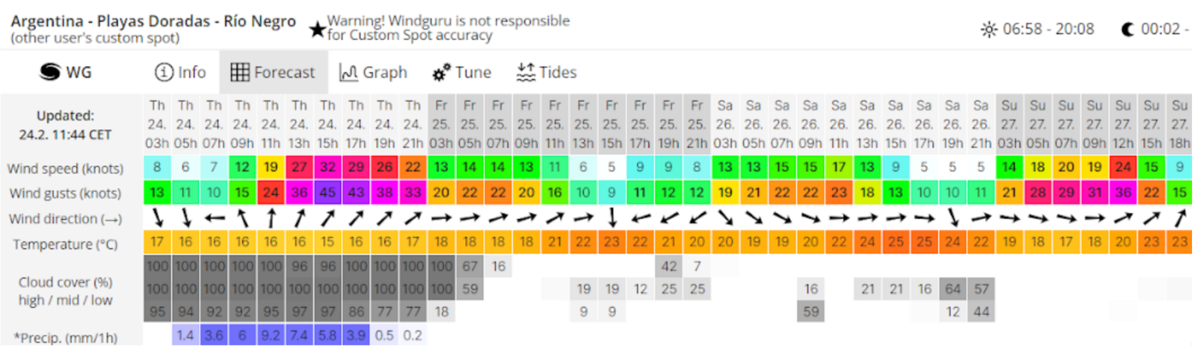


(b) Survey grid at Puerto lobos

Figure D.1: Areas of interest.

D.4. Meteorological conditions

The meteorological conditions during the measuring campaign are shown in figure D.2. The conditions on Thursday and Saturday are considered too rough to set sail. It is expected that the survey can only take place on Friday 24 February and Saturday 25 February.



Updated: 24.2. 11:44 CET	Th 24. 03h	Th 24. 05h	Th 24. 07h	Th 24. 09h	Th 24. 11h	Th 24. 13h	Th 24. 15h	Th 24. 17h	Th 24. 19h	Th 24. 21h
Wind speed (knots)	8	6	7	12	19	27	32	29	26	22
Wind gusts (knots)	13	11	10	15	24	36	45	43	38	33
Wind direction (→)	↘	↘	←	↖	↑	↗	↗	↗	↗	↗
Temperature (°C)	17	16	16	16	16	16	15	16	16	17
Cloud cover (%) high	100	100	100	100	100	96	96	100	100	100
Cloud cover (%) mid	100	100	100	100	100	100	100	100	100	100
Cloud cover (%) low	95	94	92	92	95	97	97	86	77	77
*Precip. (mm/1h)		1.4	3.6	6	9.2	7.4	5.8	3.9	0.5	0.2

Updated: 24.2. 11:44 CET	Fr 25. 03h	Fr 25. 05h	Fr 25. 07h	Fr 25. 09h	Fr 25. 11h	Fr 25. 13h	Fr 25. 15h	Fr 25. 17h	Fr 25. 19h	Fr 25. 21h
Wind speed (knots)	13	14	14	13	11	6	5	9	9	8
Wind gusts (knots)	20	22	22	20	16	10	9	11	12	12
Wind direction (→)	→	→	→	→	↗	→	↓	↙	↙	↙
Temperature (°C)	18	18	18	18	21	22	23	22	21	20
Cloud cover (%) high	100	67	16						42	7
Cloud cover (%) mid	100	59				19	19	12	25	25
Cloud cover (%) low	18					9	9			
*Precip. (mm/1h)										

Updated: 24.2. 11:44 CET	Sa 26. 03h	Sa 26. 05h	Sa 26. 07h	Sa 26. 09h	Sa 26. 11h	Sa 26. 13h	Sa 26. 15h	Sa 26. 17h	Sa 26. 19h	Sa 26. 21h
Wind speed (knots)	13	13	15	15	17	13	9	5	5	5
Wind gusts (knots)	19	21	22	22	23	18	13	10	10	11
Wind direction (→)	↘	↘	↘	↘	→	→	→	→	↓	→
Temperature (°C)	20	19	19	20	22	24	25	25	24	22
Cloud cover (%) high										
Cloud cover (%) mid				16		21	21	16	64	57
Cloud cover (%) low				59					12	44
*Precip. (mm/1h)										

Updated: 24.2. 11:44 CET	Su 27. 03h	Su 27. 05h	Su 27. 07h	Su 27. 09h	Su 27. 12h	Su 27. 15h	Su 27. 18h
Wind speed (knots)	14	18	20	19	24	15	9
Wind gusts (knots)	21	28	29	31	36	22	15
Wind direction (→)	→	→	→	→	↗	↗	↗
Temperature (°C)	19	18	17	18	20	23	23
Cloud cover (%) high							
Cloud cover (%) mid							
Cloud cover (%) low							
*Precip. (mm/1h)							

Figure D.2: Meteorological conditions during planned survey period (Data retrieved from Windguru.)

D.5. Other practicalities

For the survey at Puerto Lobos the measuring equipment needs to be transported from Punta Colorada to Puerto Lobos. The RIB can either sail to the location or be transported with a trailer. Because of the rough weather conditions, sailing to Puerto Lobos is considered to be irresponsible. Transporting the RIB to Puerto Lobos is considered to be inefficient and time consuming (1,5 hours over dirt roads). Next to that it is not known if the RIB can even launch at the Puerto Lobos. Therefore it is chosen to shift the focus of the bathymetry survey to Punta Colorada as it has been considered not feasible to execute the survey at Puerto Lobos.

D.6. Final survey campaign

As mentioned before, due to the weather forecast and practical considerations the focus for the bathymetry survey has shifted towards the locations at Punta Colorada. It is now intended to gather as much information as possible at Punta Colorada. The final proposed survey grid is divided in three stages. The consecutive stages will explore a larger part of the area of interest if the weather conditions allow it.

Stage 1 focuses on mapping the area around the ship loader and the potential sandbanks indicated by navionics. The RIB will navigate along a fine grid, with a spacing of approximately 25 m, such that the bathymetry can be mapped with a high spatial resolution. The grid is shown in figure D.3.

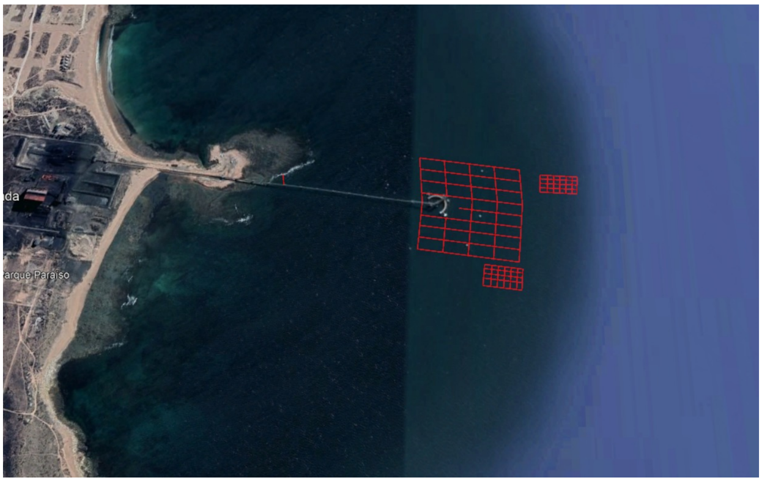


Figure D.3: Survey stage 1.

Stage 2 focuses on mapping the bathymetry between the jetty and the southern Punta Colorada location. A fine grid is chosen near the jetty so that a map with a high spatial resolution can be obtained. When going more south the grid gets more course so that a larger area can be surveyed. The grid of stage 2 is shown in figures D.4.

Figure D.4: Survey stage 2.

In stage 3 it is intended to extend the survey as far as possible to the south. The available time that is left will determine the extent of the survey. The survey is shown in figure D.5.

Figure D.5: Survey stage 3.

D.7. Available Bathymetry charts

A Governmental bathymetry chart from 1970 shows the entire gulf of San Matias. The chart was updated in 2000. The chart is shown in figure D.6 and is considered not very accurate with a low spatial resolution.

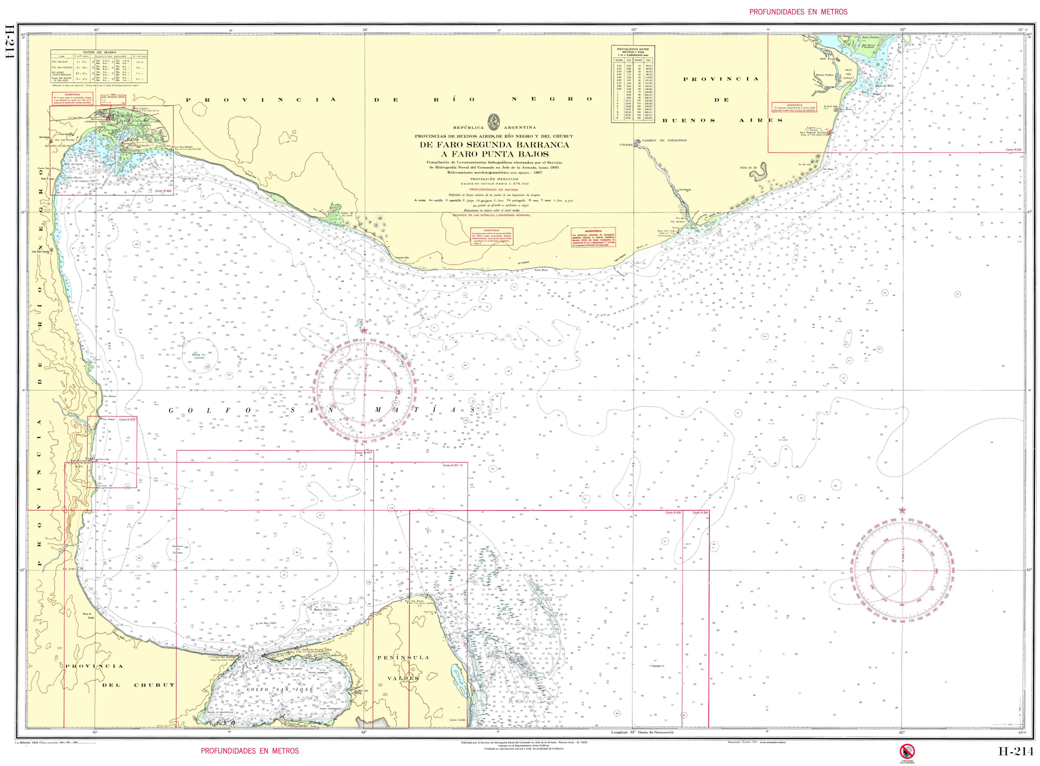


Figure D.6: Governmental bathymetry chart.

The bathymetry map shown in figure D.7 is from a survey executed in 2013 at Punta Colorada is available. In this survey the bathymetry around the jetty was mapped with a relatively fine grid. Comparing this map with the new bathymetric survey, an understanding about the morphodynamics of the region can be retrieved.

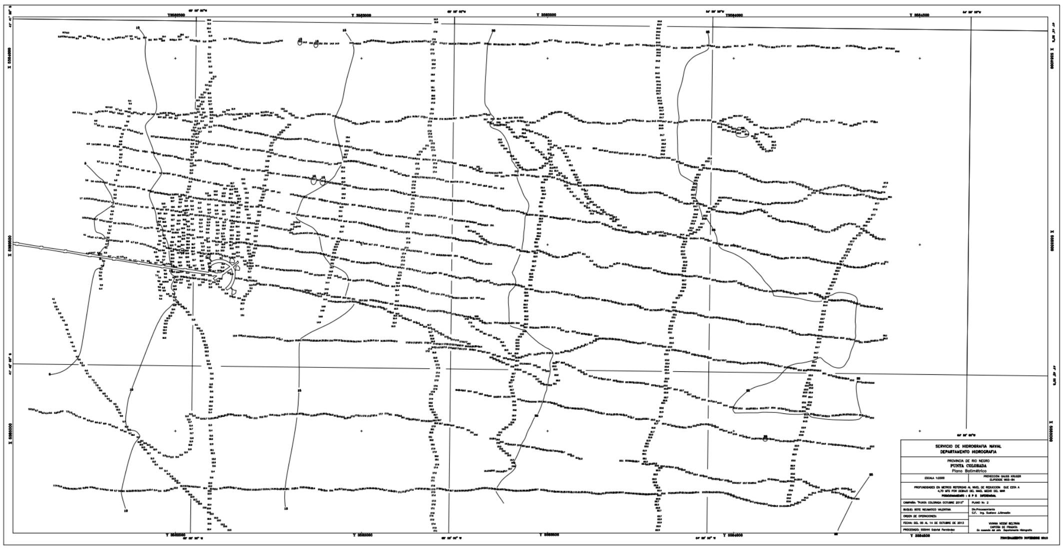


Figure D.7: Bathymetry chart from 2013 survey.

Navionics has mapped the area surrounding the jetty as well. Accurate Navionics data south of the jetty is however missing.

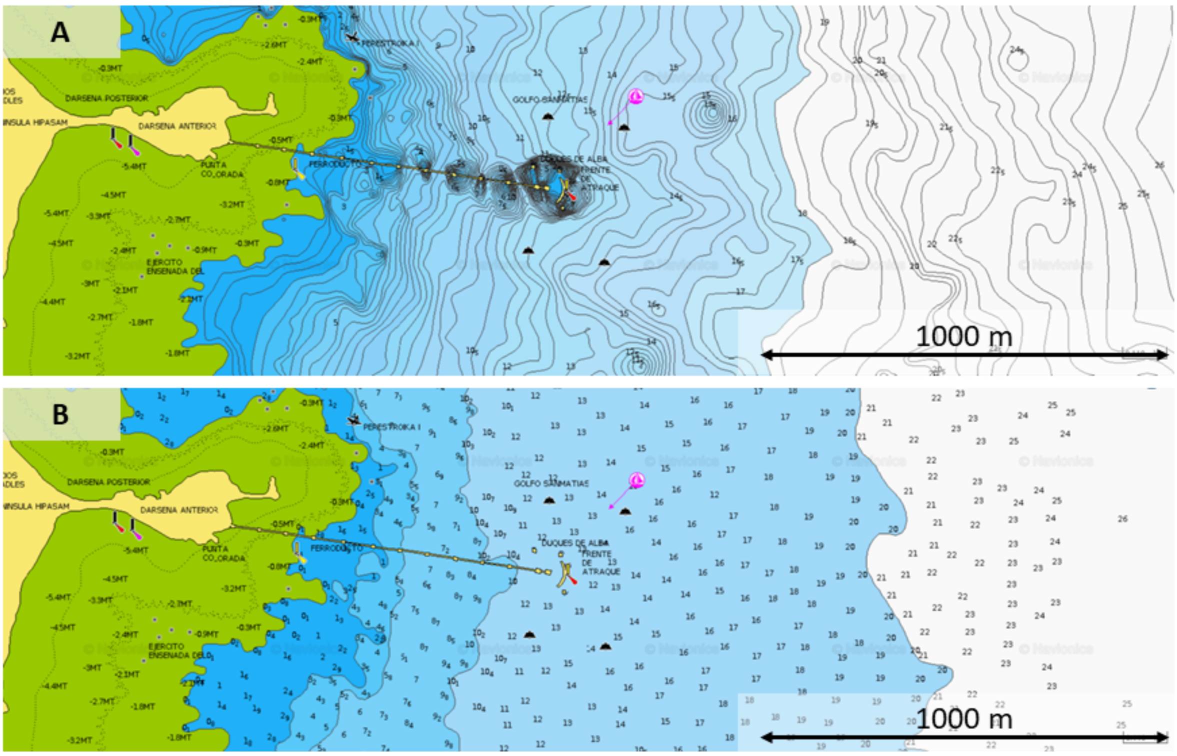


Figure D.8: Navionics charts of Punta Colorada Muelle in Navionics view (A) and Sonar view (B).

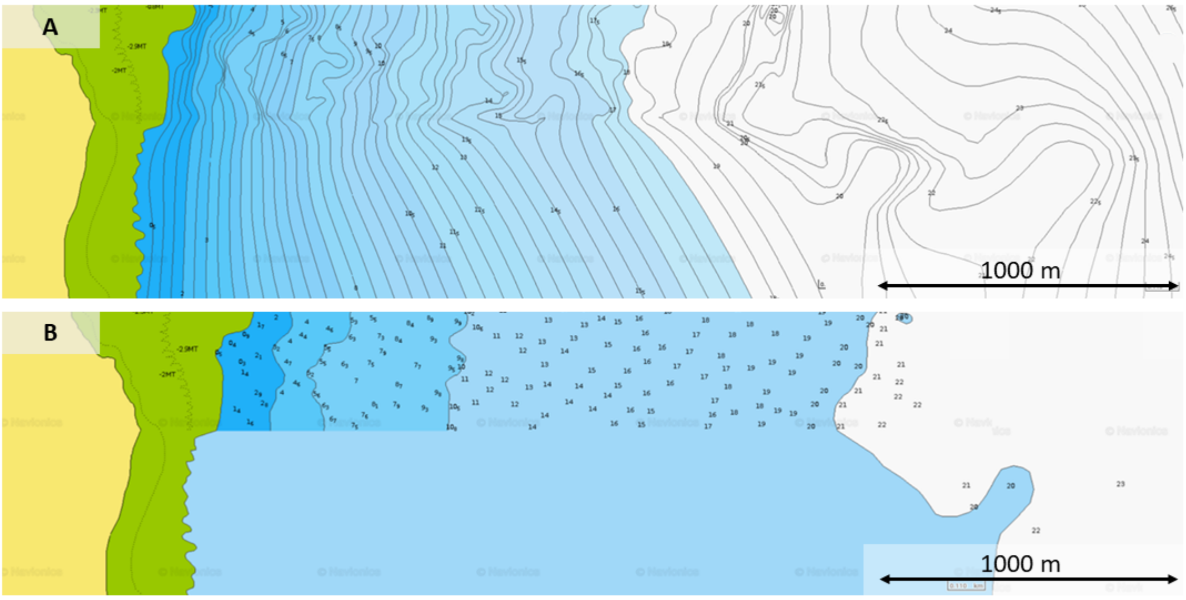


Figure D.9: Navionics charts of Punta Colorada South in Navionics view (A) and Sonar view (B).

D.8. Field Survey Data on Punta Colorada Muelle and Punta Colorada South

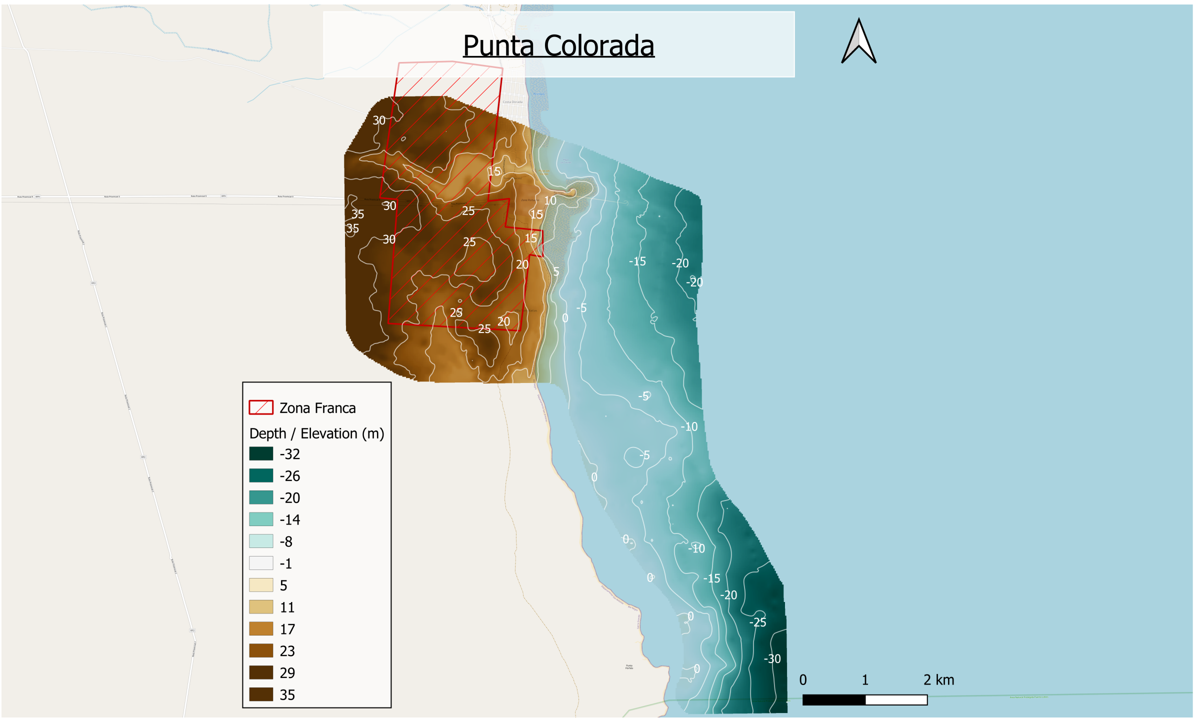


Figure D.10: Total output of Bathymetry and Topography Survey, 2022.

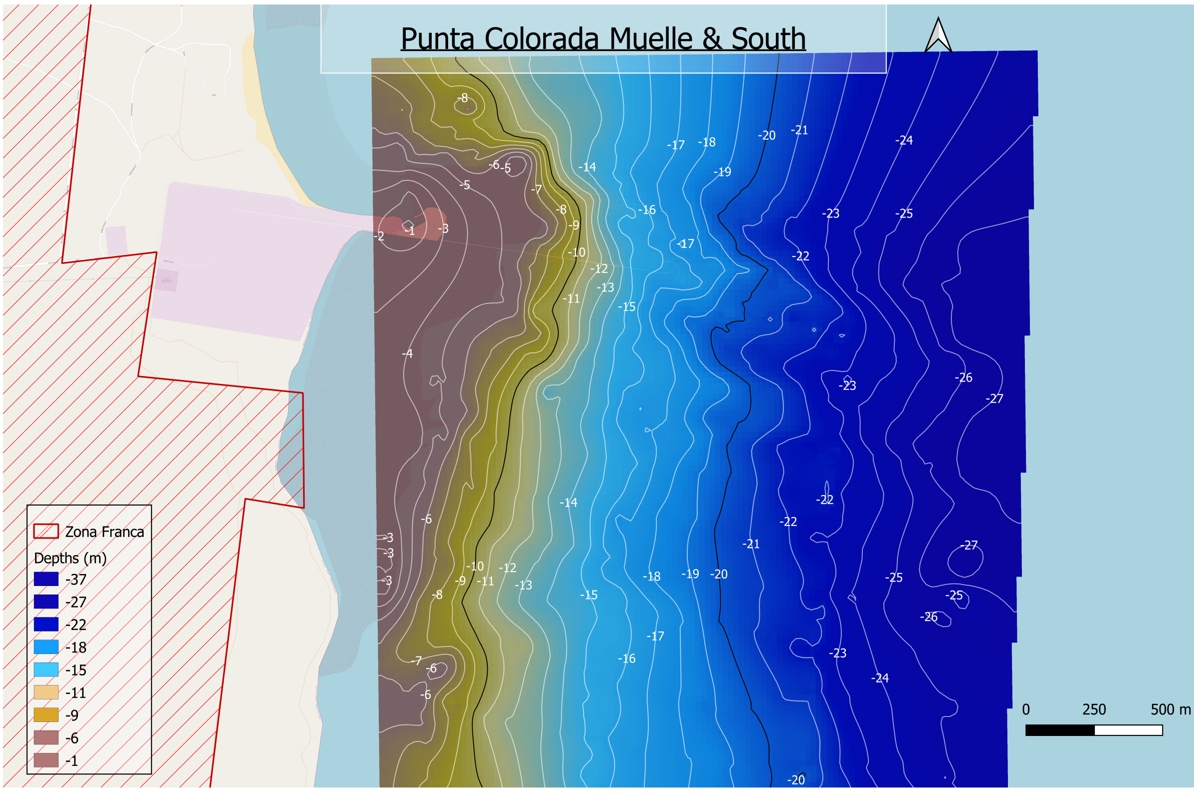


Figure D.11: Bathymetry survey, 2022, zoomed in on Punta Colorada Muelle and Punta Colorada South.

D.9. Distances From Shore to Required Depth

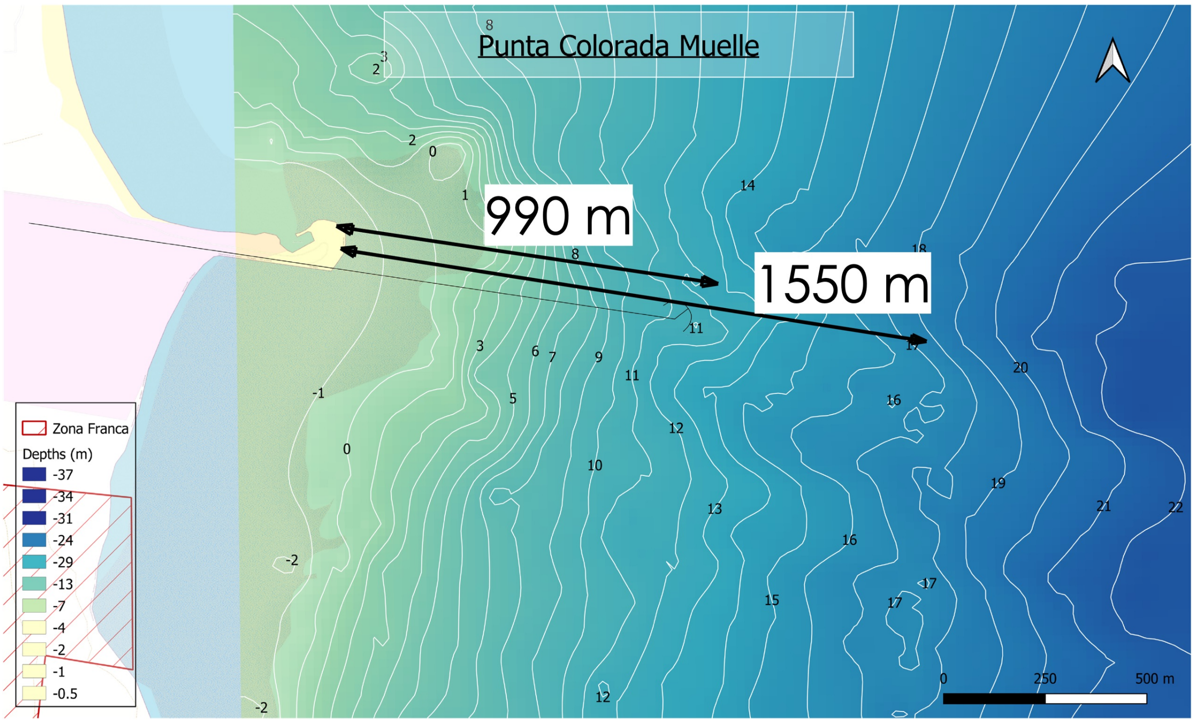


Figure D.12: Distances from shore to required depth (short- and medium-term) for Punta Colorada Muelle bathymetry map (field measurements from Feb 2022).

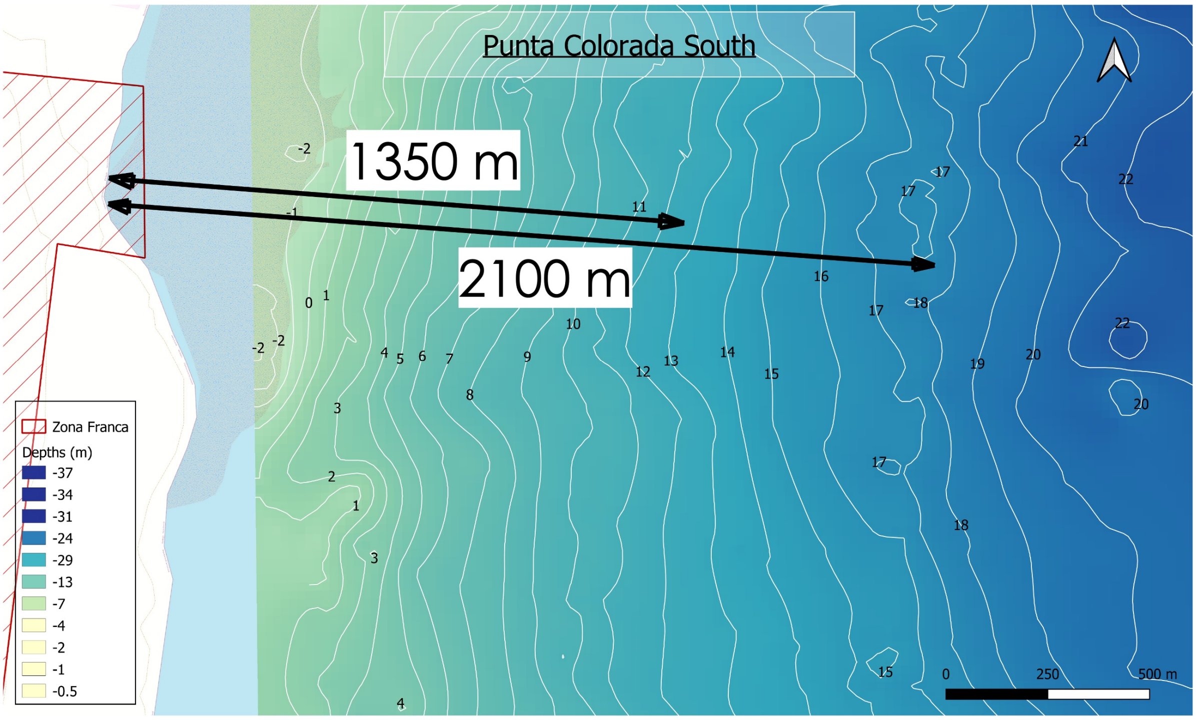


Figure D.13: Punta Colorada South bathymetry map, made with field measurements performed in 2022.

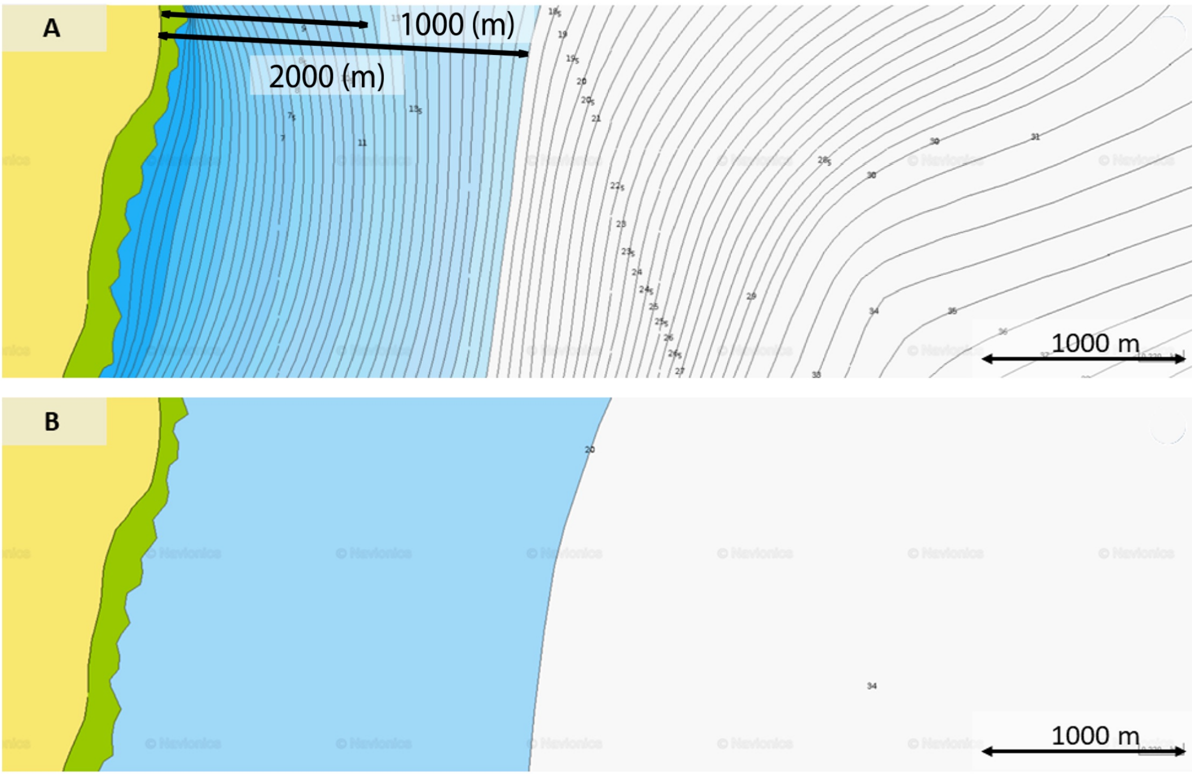


Figure D.14: Navionics charts of Puerto Lobos in Navionics view (A) and Sonar view showing the interpolation points (B).

E

Structural Survey

E.1. Examples Steel Corrosion

General Corrosion	Uniform loss of material over surface.	 
Galvanic Corrosion	Occurs due to two dissimilar materials connecting.	 
Stress Corrosion	This occurs under the simultaneous influence of static tensile stress and a specific corrosive environment.	 

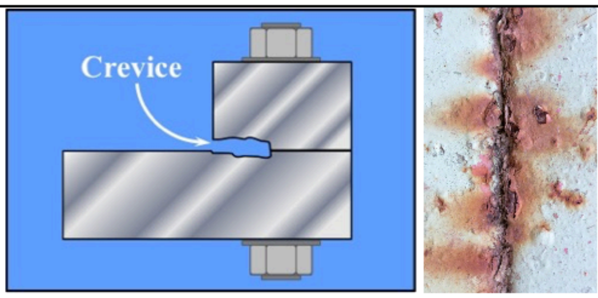
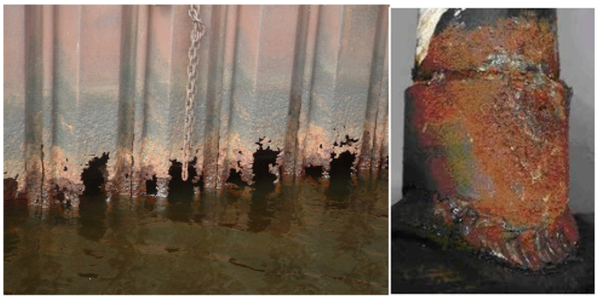
Pitting Corrosion	Very localized corrosion which leads to cavities or holes.	
Crevice Corrosion	Occurs on a metal surface that is shielded from full exposure to the environment because of the close proximity of another material that forms a narrow gap between them.	
Microbial Corrosion	Occurs in soils and water as a result of microbiological activity.	

Figure E.1: Example Steel Corrosion.

Connections	Suitability	Note
Welds	not suitable	Cannot be separated without damaging the elements
Rivets	sometimes suitable	Difficult to separate without damaging the elements
Standard bolts and screws	mostly suitable	Bolt hole can already be damaged
Slip-resistant bolts	suitable	

Table E.1: Connections in steel structures [29].

E.2. Examples Concrete Damage

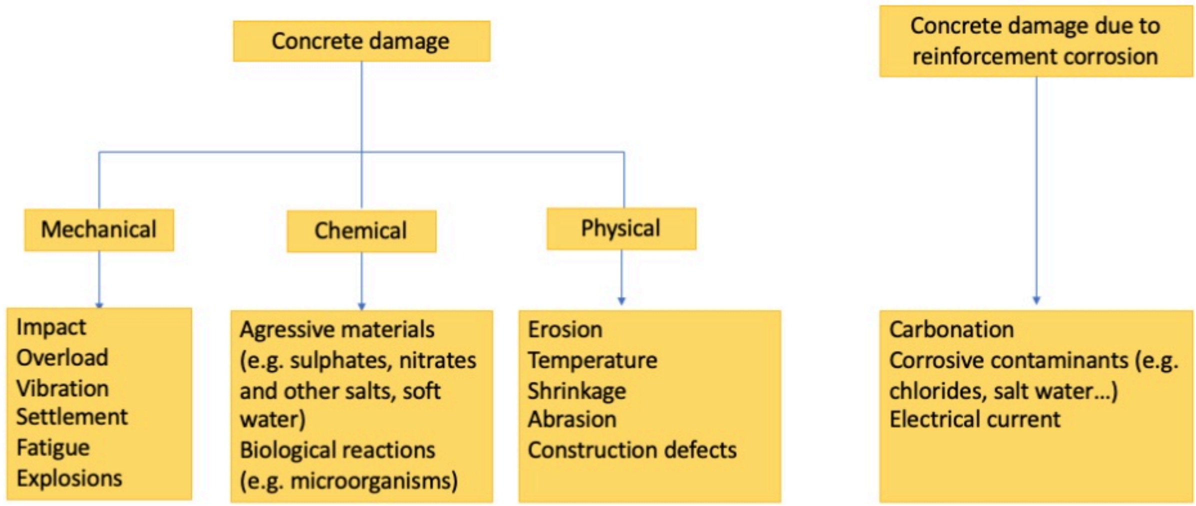


Figure E.2: Overview Concrete Damage.

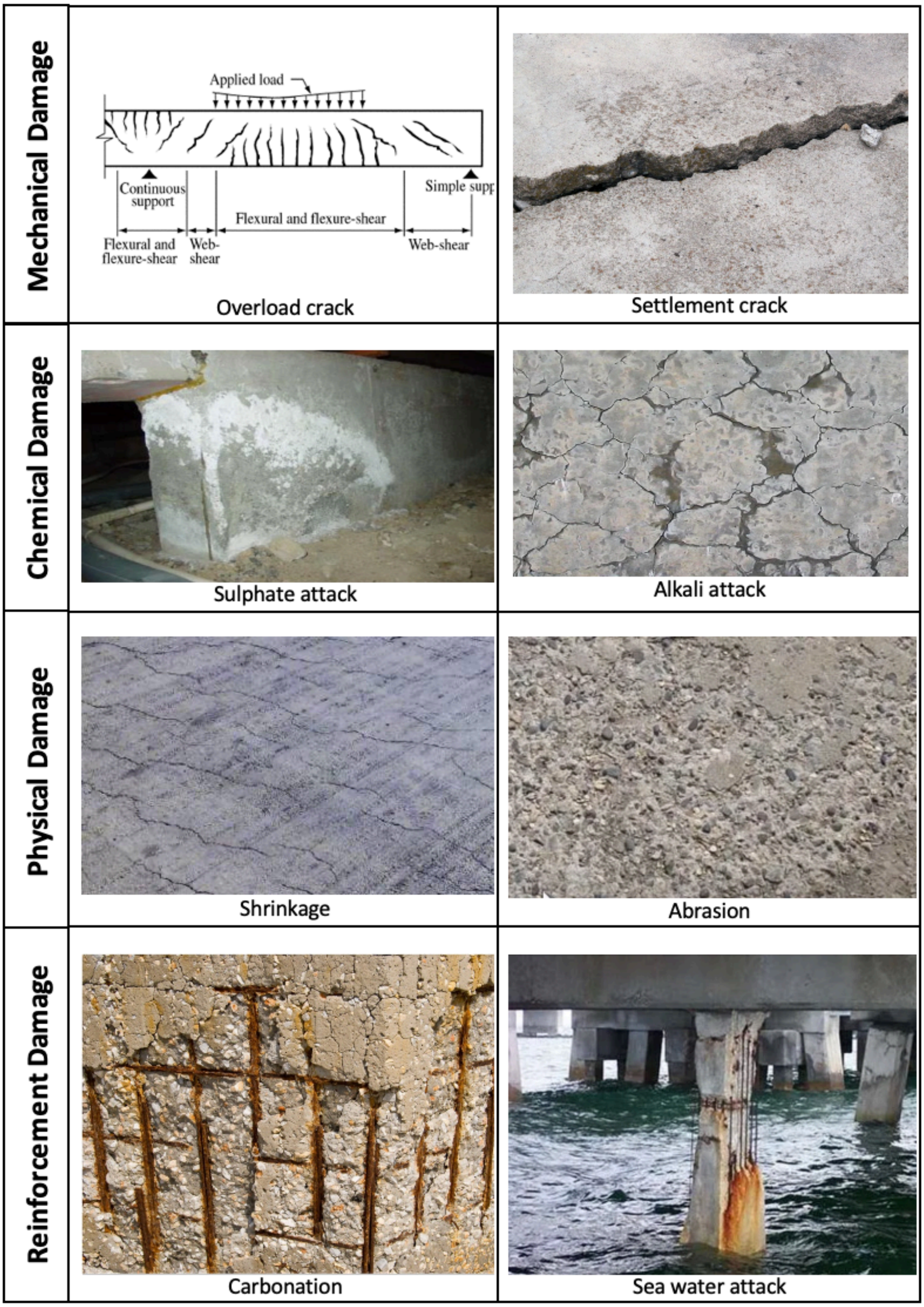


Figure E.3: Examples Concrete Damage.

General	Material	Type	Section	Dimensions
Address Construction year Label Quantity Level	Type of concrete Type of steel (reinforcement)	Precast Pre-stressed Post-tensed Cast-in-situ	Rectangular Round	Clear height Section height Width

Table E.2: Inventory properties for columns [23].

Reinforcement	Section	Damages	Load	Modifications	Properties
Amount Area Location	Effective depth Cover Area	Location Type Severity	Max. Axial	Sawing Drilling	Weight Volume

Table E.3: Element Identity properties for columns [23].

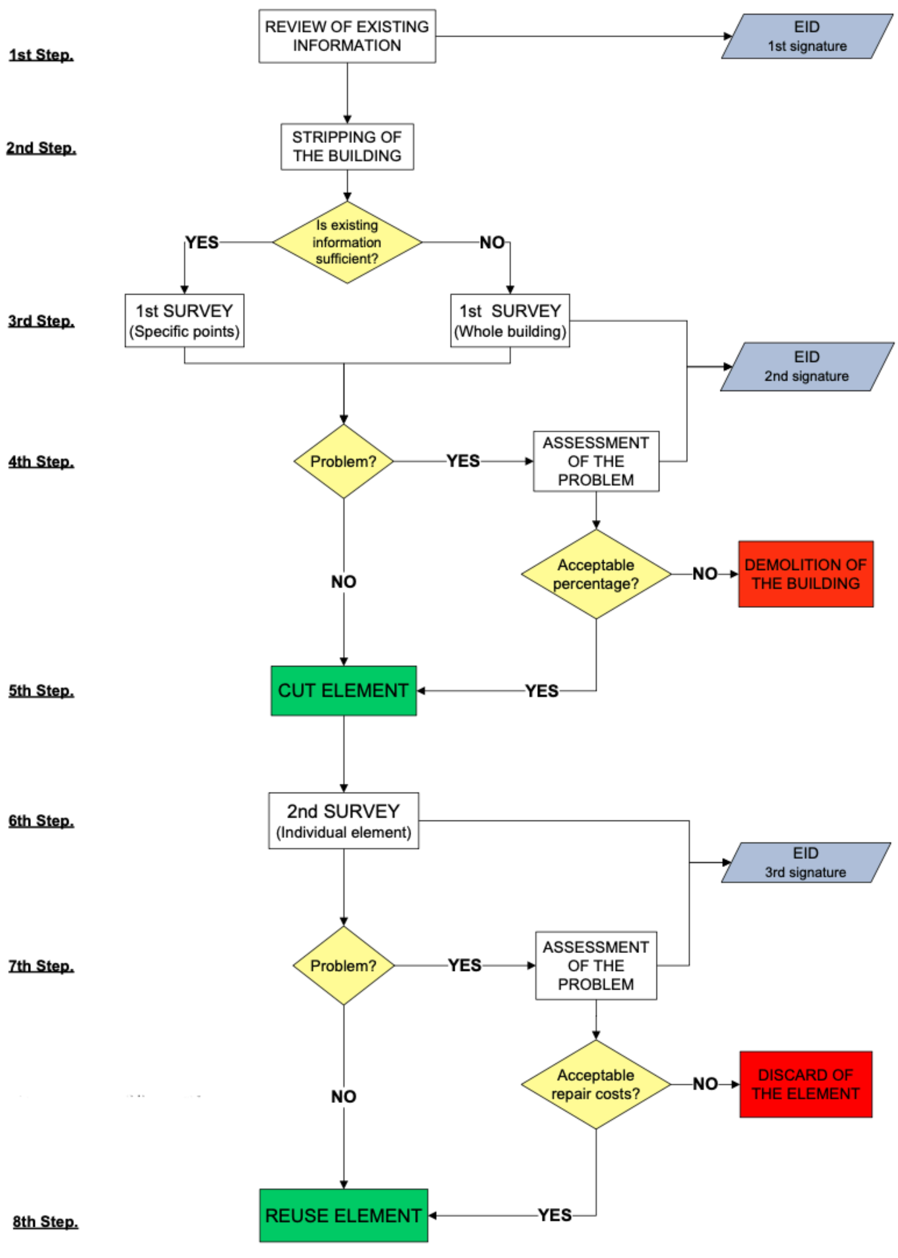


Figure E.4: Quality check flowchart [23].

ELEMENT IDENTITY (EID)

BUILDING
Name:
Address:
Year (drawing):
Function:
Location of the element:
Structural system:

PICTURE OF THE ELEMENT

MATERIAL PROPERTIES
Concrete (f_{ck}):
Steel (f_{yk}):

DIMENSIONS
Height:
Length:
Width:
Type:
Effective depth:

REINFORCEMENT
Main rebars:
Stirrups:
Cover:

LOADS
Maximum moment:
Maximum shear:
Maximum load:

OTHER CHARACTERISTICS
Openings:
Damages:
Environmental conditions:
Type:
Quantity:
Price:
Possible use:
LCA:

1)Existing information	2) 1st Survey	3)2nd Survey
(Signature)	*(Signature)*	*(Signature)*

Figure E.5: Element Identity [23].

F

Visuals Muelle Punta Colorada

In this appendix, supporting pictures and overviews of the Muelle Punta Colorada will be presented.

F.1. Column groups

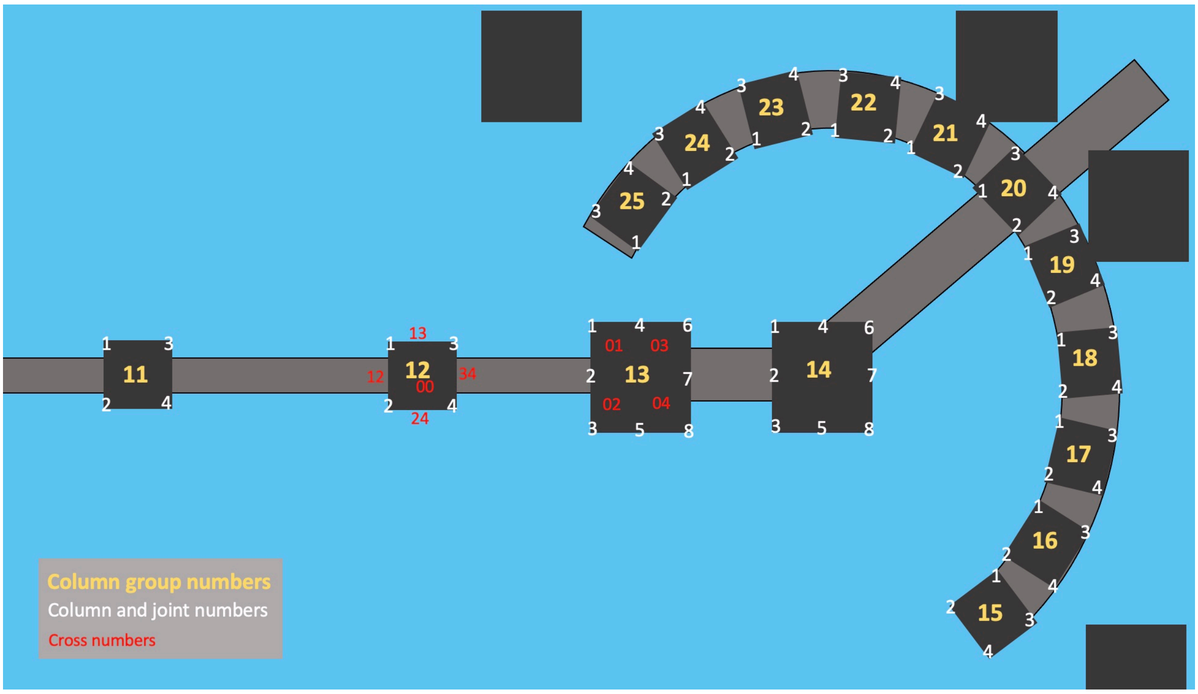


Figure F.1: Column group element numbers.

(a) Column 1-2.

(b) Column 1-3.

Figure F.2: Damages at the first column group.

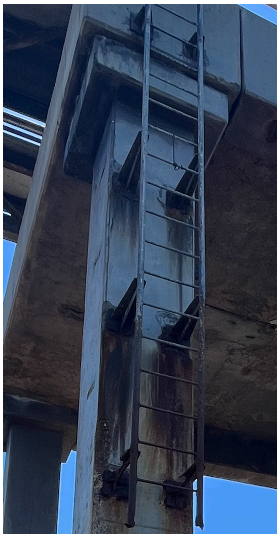
(a) Column 2-3.

(b) Column 2-3.

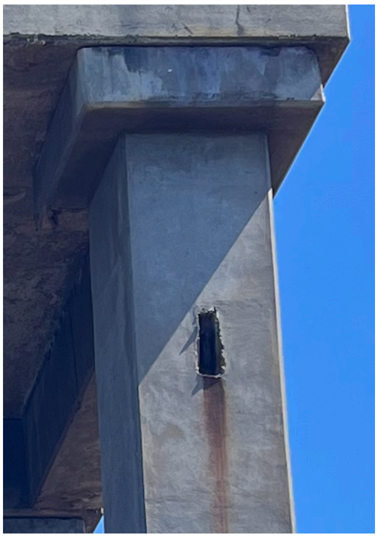
(c) Column 2-4.

(d) Column 2-4.

Figure F.3: Damages at the second column group.



(a) Column 3-2.



(b) Column 3-3.

Figure F.4: Damages at the third column group.

Figure F.5: Example of marine growth on lower steel columns.

(a) Limited amount of cracks.

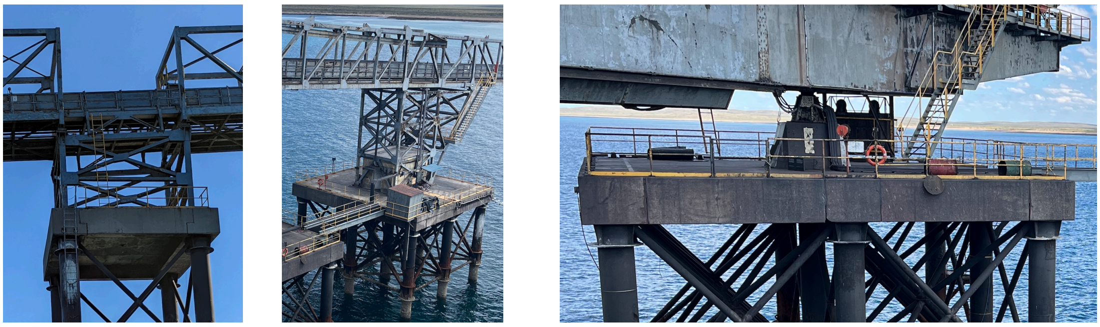
(b) Limited amount of cracks.

(c) Cracks column group 2.

Figure F.6: Concrete platform examples.

(a) (b)

Figure F.7: Damage of the concrete platform at the column group 11.



(a) Column group 12. **(b)** Column group 13. **(c)** Column group 14.

Figure F.8: Connecting structures above column group 12, 13 and 14.

F.2. Trusses

Figure F.9: An example of a truss.

(a) Corroded end of truss.

(b) Middle truss part in good state.

(c) Bottom part of truss.

(d) End of truss in good state.

Figure F.10: Pictures of parts of the trusses.

(a) Deformation seen from sea.

(b) Deformation seen from jetty.

(c) Deformation seen from jetty.

Figure F.11: Deformation of twelfth truss element due to vessel crash.

F.3. Mooring dolphins

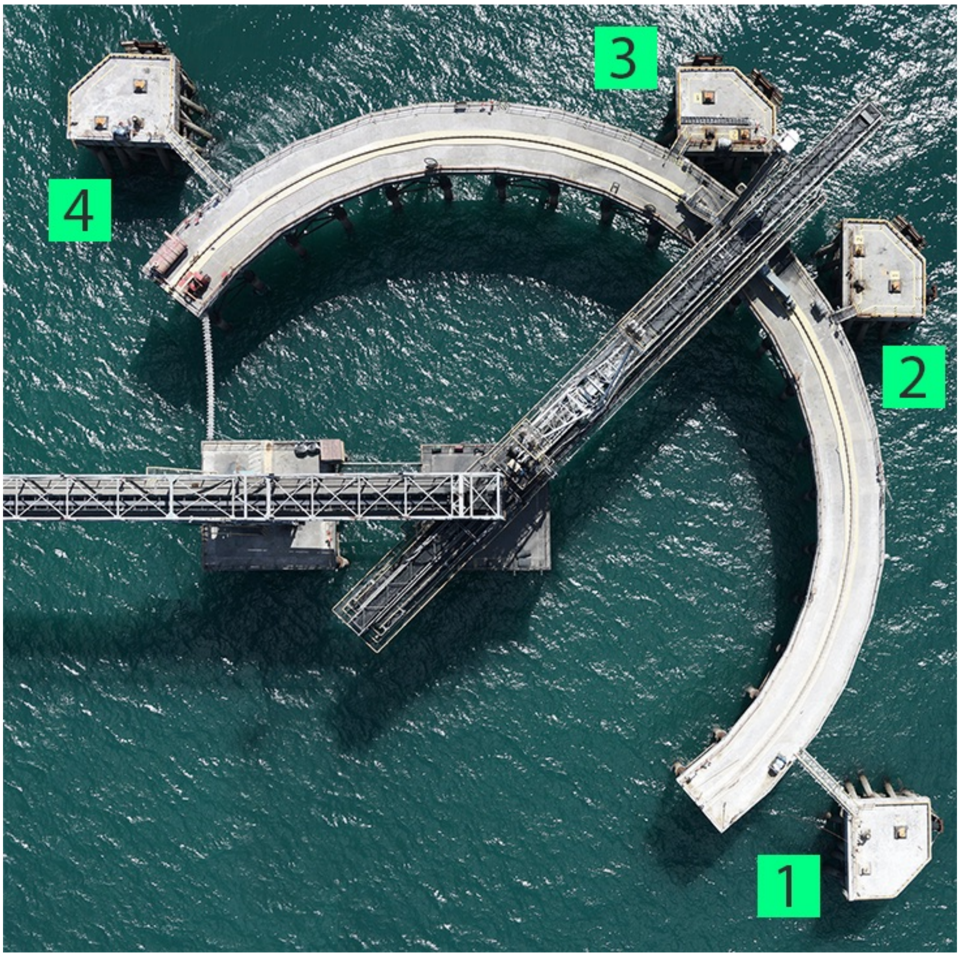


Figure F.12: Numbering of the mooring dolphins.

(a) Mooring dolphin 2 (left) and 3 (right).

(b) Mooring dolphin 1.

(c) Mooring dolphin 4.

Figure F.13: Examples of mooring dolphins.

(a) Concrete platform at mooring dolphin 2.

(b) Concrete platform at mooring dolphin 4.

Figure F.14: Examples of mooring dolphins.

(a) Type 1.

(b) Type 2.

Figure F.15: Examples of the mooring bollard types.

F.4. Buoys

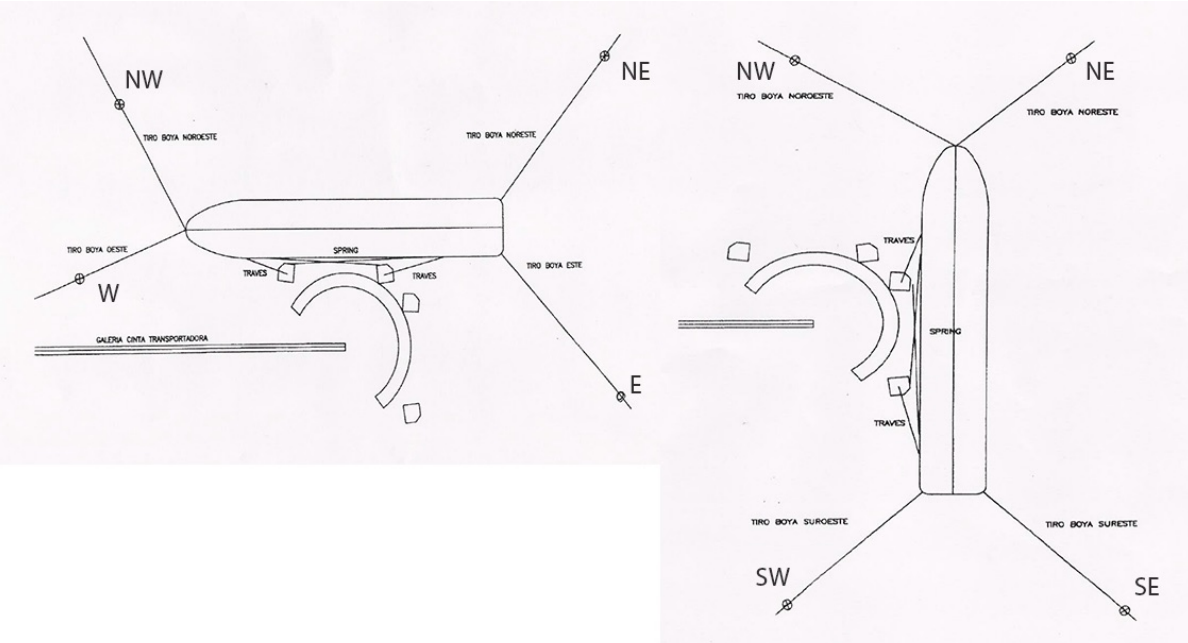


Figure F.16: Overview of the original buoys present (NW, NE, E, SE, SW, W) including the possible mooring positions at the jetty [37].

(a) The buoy in a good state.

(b) The buoy in a bad state.

Figure F.17: Buoys on land.

G

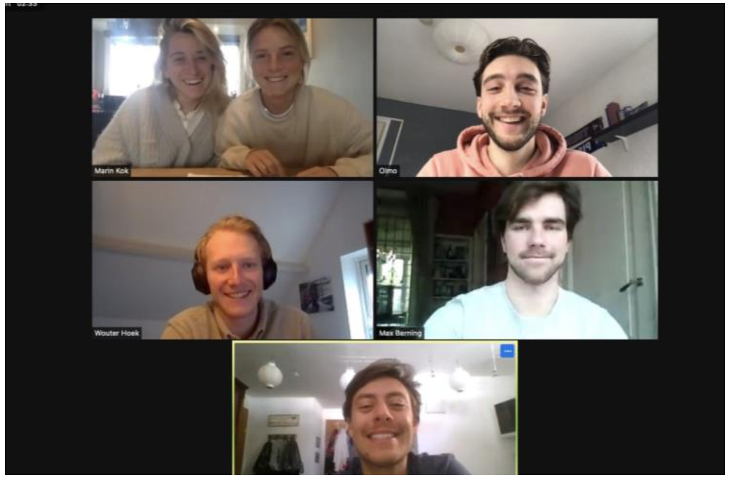
Presentation Slides

G.1. English Presentation

3 POTENTIAL LOCATIONS FOR HYDROGEN EXPORT IN RÍO NEGRO ARGENTINA

OUR MULTI-DISCIPLINARY GROUP

COVID START



OFFICE IN BUENOS AIRES

ARRIVAL IN BUENOS AIRES

TABLE OF CONTENTS

1. PROJECT AMBITIONS & POTENTIAL

1. PROJECT AMBITIONS
& POTENTIAL

*"It is expected to turn **Río Negro** into a **global green hydrogen** export hub by **2030**".*

1
ENERGY SECURITY

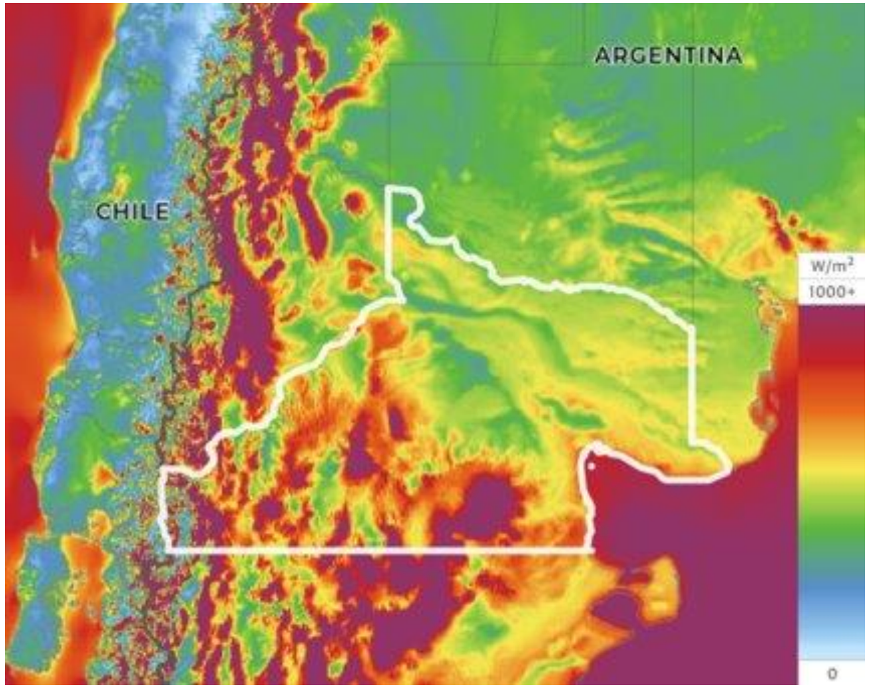
2
ENVIRONM. SUSTAINABILITY

3
EFFICIENCY AND COMPETENCE

4
SOCIAL INCLUSION AND EMPLOYMENT

1. PROJECT AMBITIONS
& POTENTIAL

WIND



WATER

1. PROJECT AMBITIONS **& POTENTIAL**

FREE-TRADE ZONE

2. RESEARCH QUESTION

*"Which **location** between*
Punta Colorada Muelle**, **Punta Colorada South
*and **Puerto Lobos** is the most suitable for*
*a **hydrogen export port** in Río Negro?"*

Port Requirements | Stakeholders | Topography | Hydraulic | Structural

3. SCOPE

Santiago
Mendoza
Rosario
Uruguay
Buenos Aires
Argentina
Concepción
Temuco
Neuquen
Mar del Plata
San Carlos de Bariloche
Puerto Montt
Golfo San Matias
Sierra Grande
3
Playas Doradas
Punta Colorada
Punta Colorada Muelle
Punta Colorada South
Puerto Lobos
Puerto Lobos

3. SCOPE

1 PUNTA COLORADA MUELLE
2 PUNTA COLORADA SOUTH
3 PUERTO LOBOS

3. SCOPE

PUNTA COLORADA MUELLE

3. SCOPE

PUNTA COLORADA MUELLE

3. SCOPE

PUNTA COLORADA SOUTH

3. SCOPE
PUERTO LOBOS

4. METHODOLOGY

DEFINING PORT REQUIREMENTS, CRITERIA AND STAKEHOLDERS

GATHERING DATA PER LOCATION

ANALYSING LOCATIONS BASED ON REQUIREMENTS AND CRITERIA

PROPOSING RECOMMENDATION FOR RIO NEGRO

4. METHODOLOGY

1. STAKEHOLDER IDENTIFICATION
2. TOPOGRAPHIC SURVEY
2. HYDRAULIC SURVEY
3. STRUCTURAL SURVEY

4. METHODOLOGY
STAKEHOLDER IDENTIFACTION

SEMI-STRUCTURED INTERVIEWS

- Guillermo R. Delamer
- Gonzalo G. Medina
- Hugo O. Nicola

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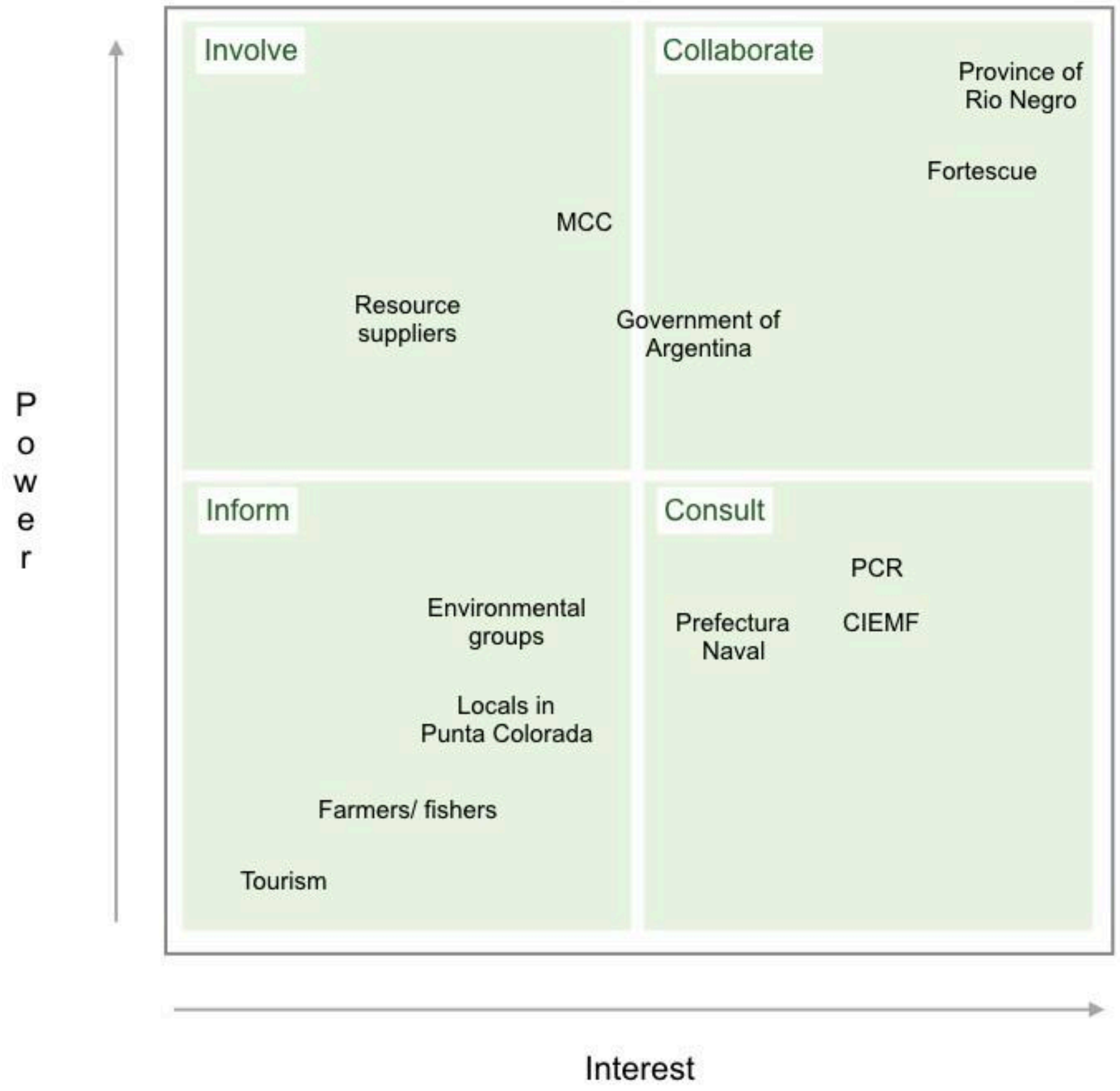
4. METHODOLOGY
STAKEHOLDER IDENTIFACTION



4. METHODOLOGY
TOPOGRAPHIC SURVEY

PUNTA COLORADA MUELLE	Elevation analysis with WingtraOne Visual inspection Satellite data
PUNTA COLORADA SOUTH	Elevation analysis with WingtraOne Satellite data
PUERTO LOBOS	Satellite data

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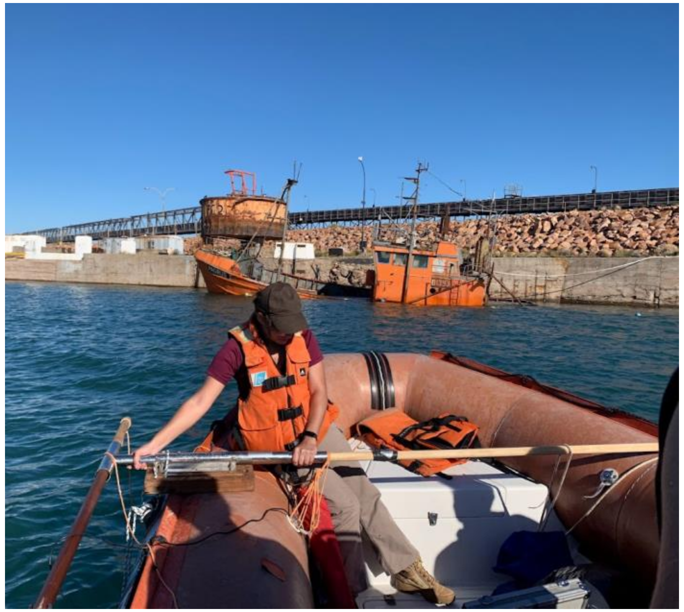
4. METHODOLOGY
HYDRAULIC SURVEY



PUNTA COLORADA MUELLE	Bathymetry data Hydrometeorological analysis
PUNTA COLORADA SOUTH	Bathymetry data Hydrometeorological analysis
PUERTO LOBOS	Hydrometeorological analysis

INA Instituto Nacional del Agua

PREFECTURA NAVAL ARGENTINA

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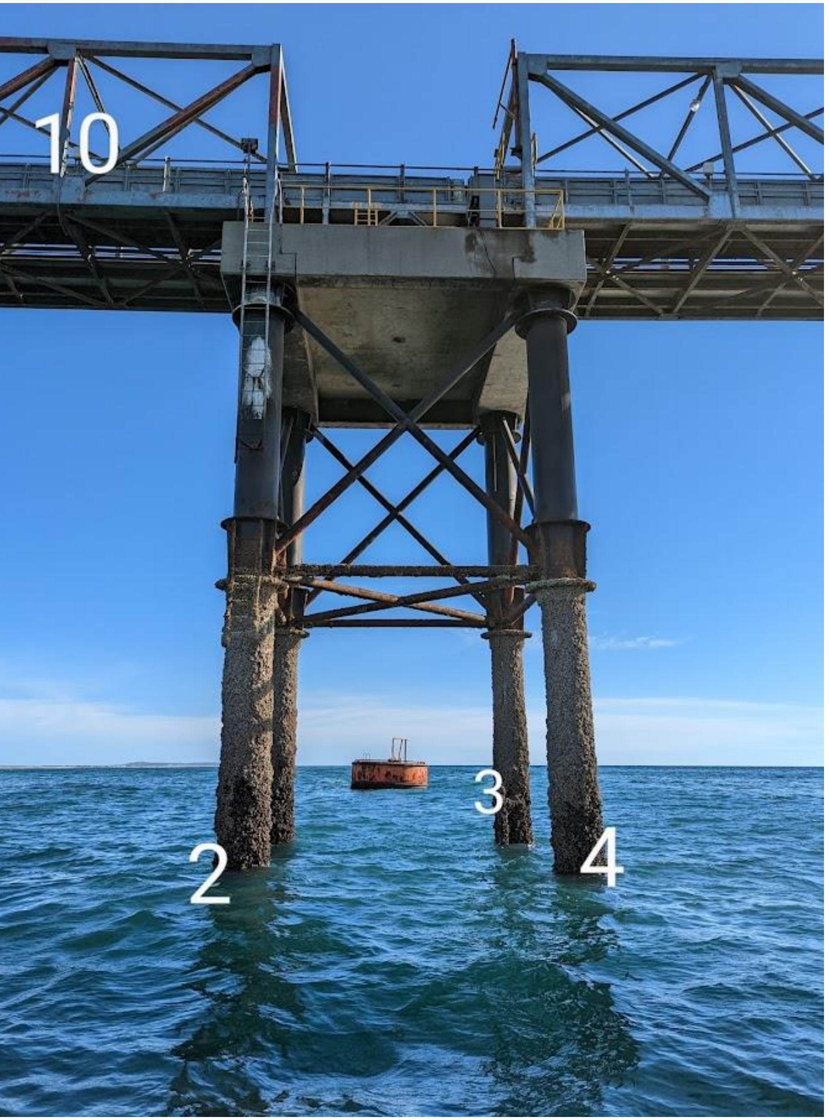
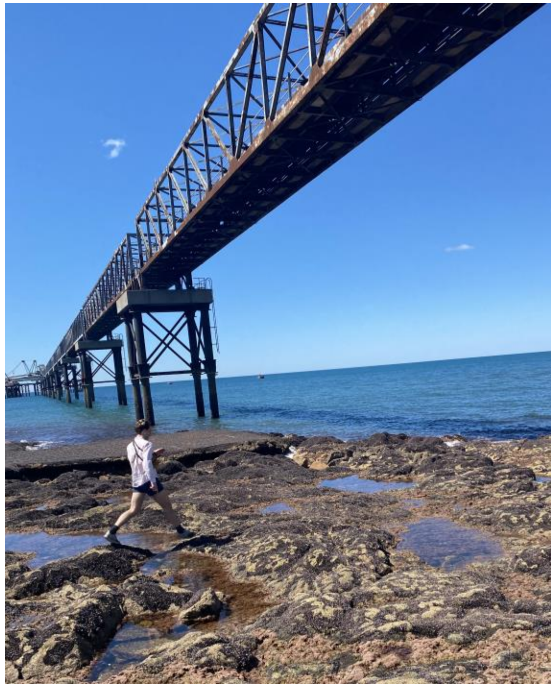
4. METHODOLOGY
STRUCTURAL SURVEY





PUNTA COLORADA MUELLE	Visual inspection Examination of structural elements
PUNTA COLORADA SOUTH	-
PUERTO LOBOS	-

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5. BACKGROUND STUDY

1 PRIMARY ASSUMPTIONS

2 CONCEPTUAL MAP

3 PORT TERMINAL

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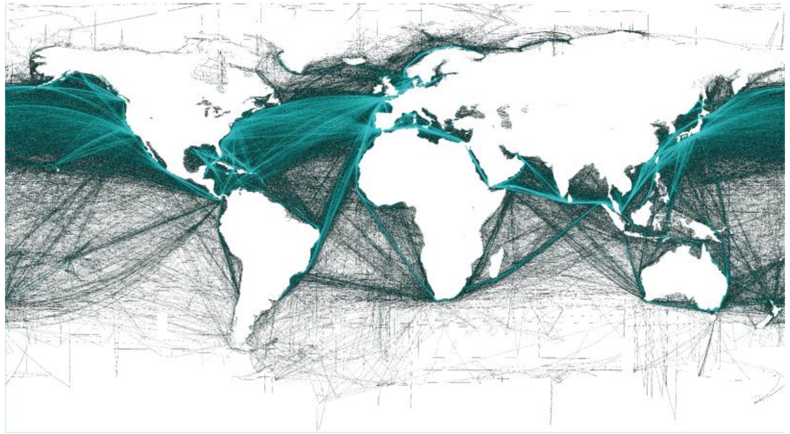
5. BACKGROUND STUDY
FUTURE SCENARIOS

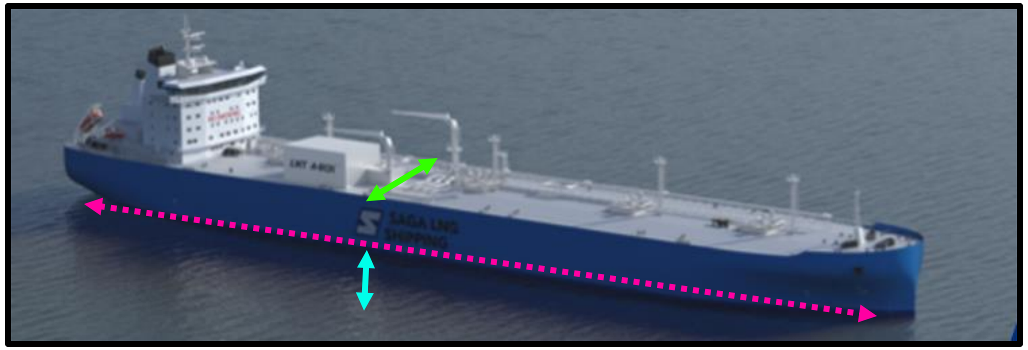


TERM	HORIZONTE	CAPACITY	MEANS OF EXPORT
Short	2 years	2 GW	NH_3
Medium	8 years	15 GW	NH_3
Long	-	-	NH_3 or LH_2

5. BACKGROUND STUDY
EXPECTED VESSELS

SHORT TERM

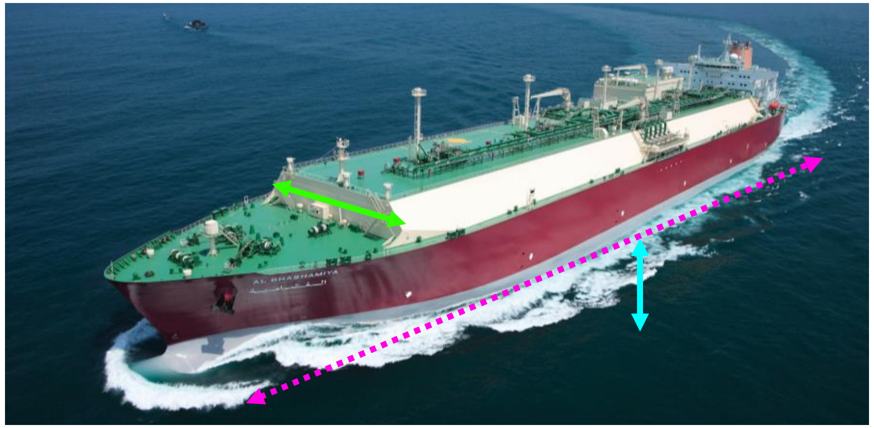
75.000 m³



- LENGTH 230 m
- REQUIRED DEPTH 12 m
- WIDTH 35 m

MEDIUM TERM

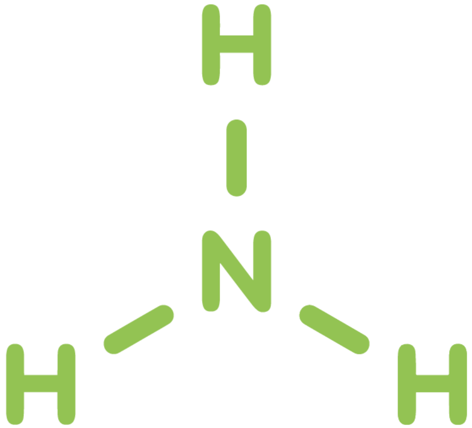
220.000 m³



- LENGTH 300 m
- REQUIRED DEPTH 17.3 m
- WIDTH 50 m

5. BACKGROUND STUDY
AMMONIA MANAGEMENT

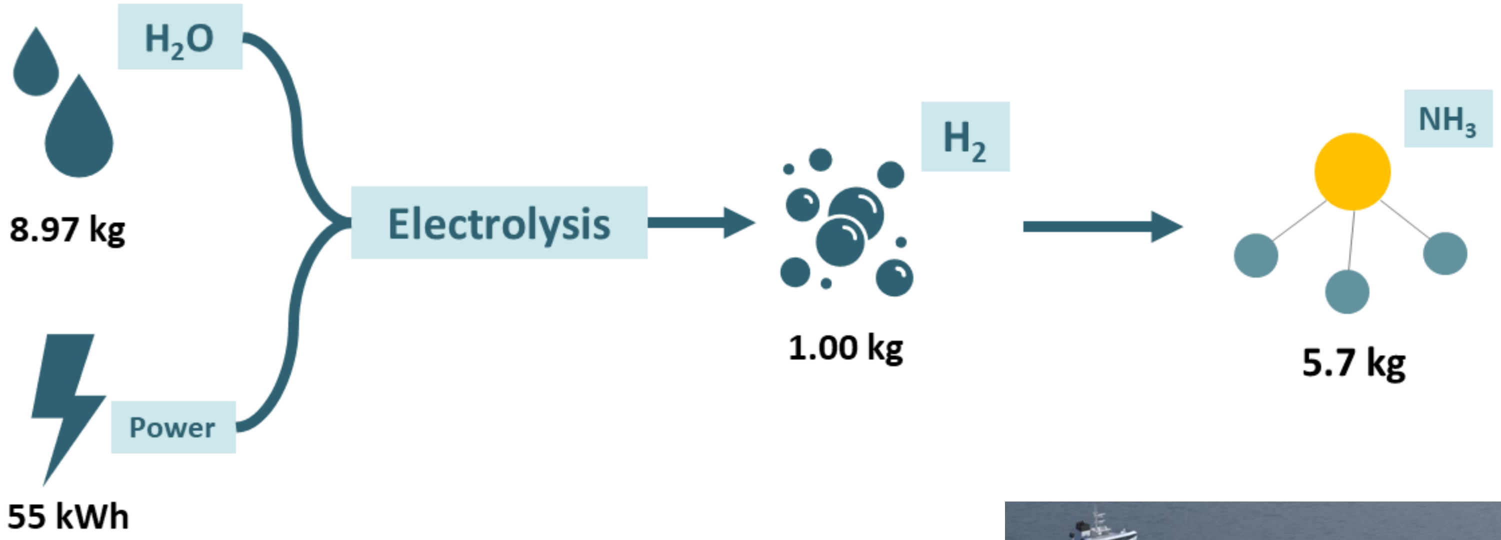
- **Storage and Transport**
  - High Pressure
  - Low Temperature –34 °C



- **Inflamable in High Concentrations**

- **Leakage**
  - Toxic Clouds

5. BACKGROUND STUDY
AMMONIA PRODUCTION



Short Term	1.320.000 m^3 / year
Medium Term	9.880.000 m^3 / year

17.5 times a year

44.9 times a year

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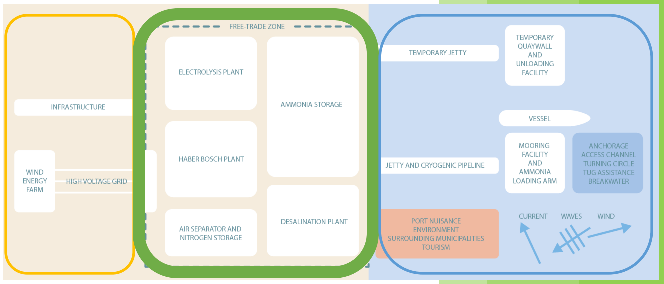
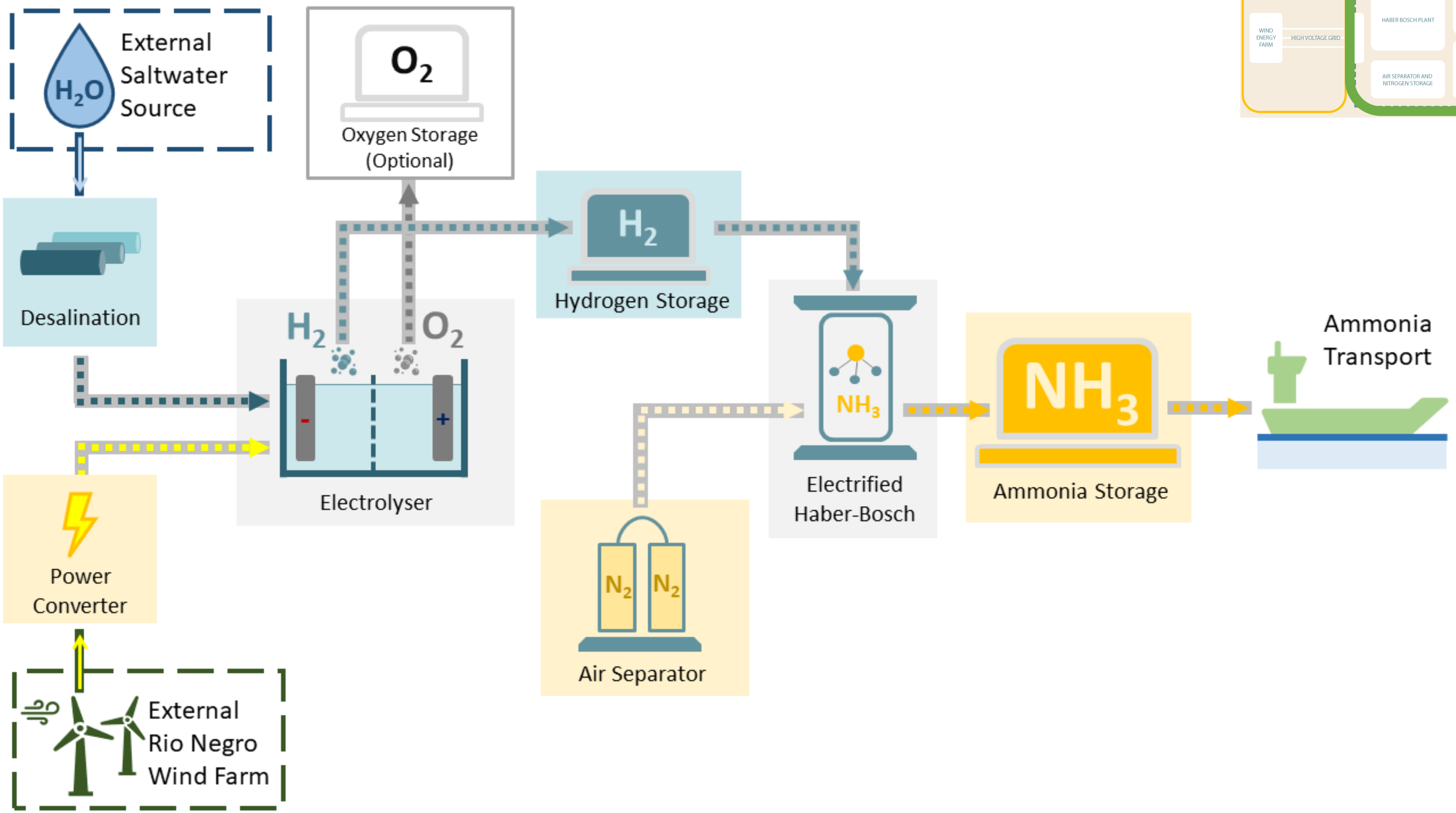
5. BACKGROUND STUDY
PORT TERMINAL

2. Port Terminal





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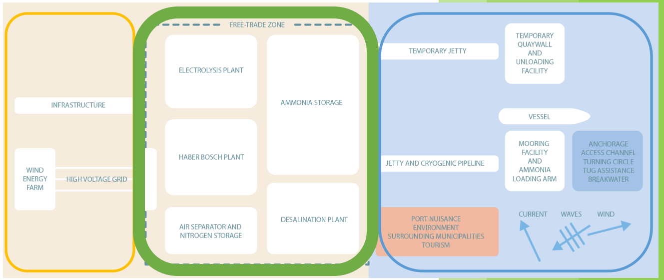
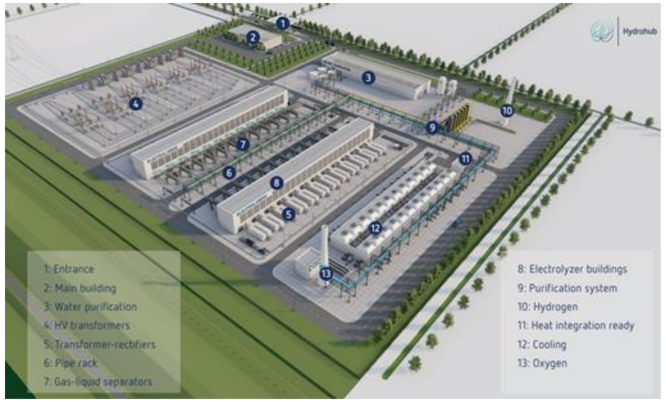
TU Delft

5. BACKGROUND STUDY
REQUIRED AREA

2. Port Terminal



ELECTROLYSER



AMMONIA PLANT

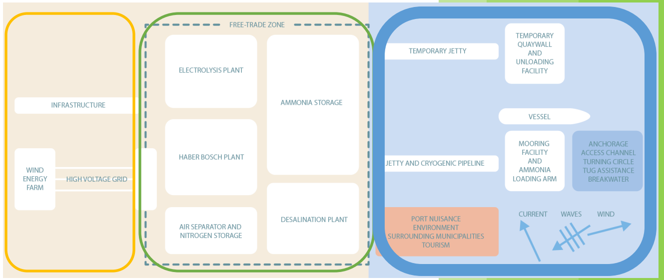
AMMONIA STORAGE

Short Term	44.5 ha
Medium Term	329.5 ha

5. BACKGROUND STUDY

JETTY AND MOORING INFRASTRUCTURE

3. Hydraulic



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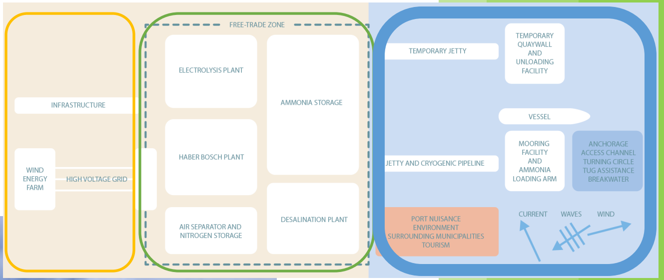
5. BACKGROUND STUDY
LOADING INFRASTRUCTURE

3. Hydraulic



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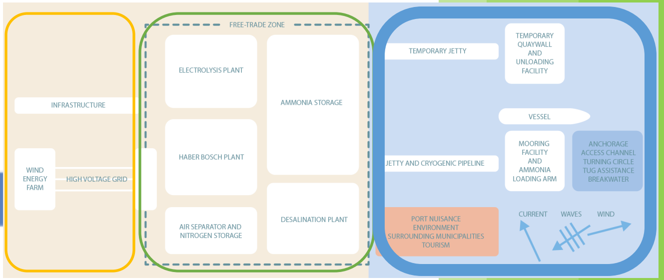
5. BACKGROUND STUDY
OPERATING LIMITS

3. Hydraulic



Description	$V_{wind,1\ min}$	$V_{current,1\ min}$	H_s
Turning areas			
• Without tug assistance	< 10 m/s	0.5 m/s	< 2.0-3.0 m
• With tug assistance	< 10 m/s	0.1 m/s	< 1.5-2.0 m
Vessel berthing			
• Forces longitudinal to berth	17.0 m/s	1.0 m/s	2.0 m
• Forces transverse to berth	10.0 m/s	0.1 m/s	1.5 m
Loading/unloading operations stoppage			
• Forces longitudinal to berth			
– < 30,000 DWT	22 m/s	1.5 m/s	1.5 m
– 30,000 DWT – 200,000 DWT	22 m/s	1.5 m/s	2.0 m
– > 200,000 DWT	22 m/s	1.5 m/s	2.5 m
• Forces transverse to berth			
– < 30,000 DWT	20 m/s	0.7 m/s	1.0 m
– 30,000 DWT – 200,000 DWT	20 m/s	0.7 m/s	1.2 m
– > 200,000 DWT	20 m/s	0.7 m/s	1.5 m
Vessel at the berth			
• Forces longitudinal to berth	30.0 m/s	2.0 m/s	3.0 m
• Forces transverse to berth	25.0 m/s	1.0 m/s	2.0 m

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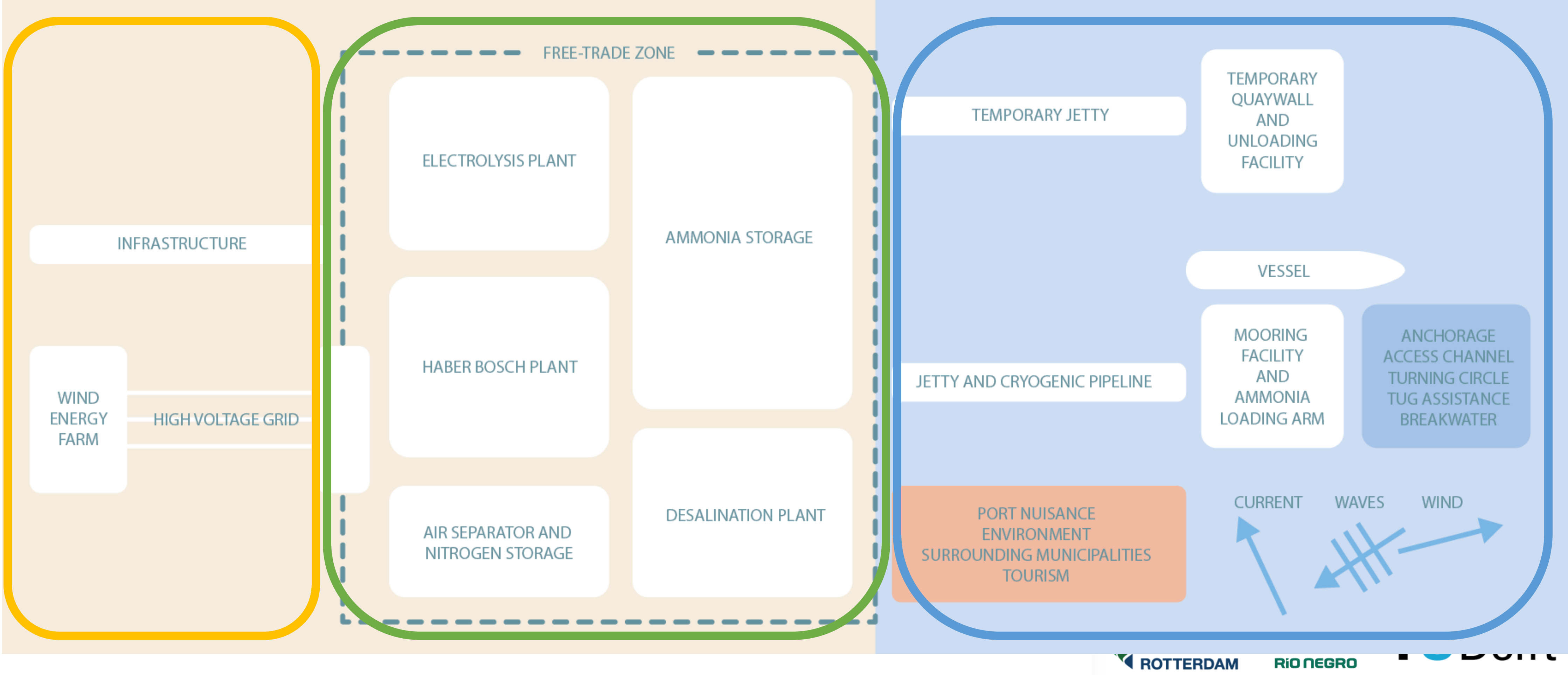
5. BACKGROUND STUDY

1. Hinterland

2. Port Terminal

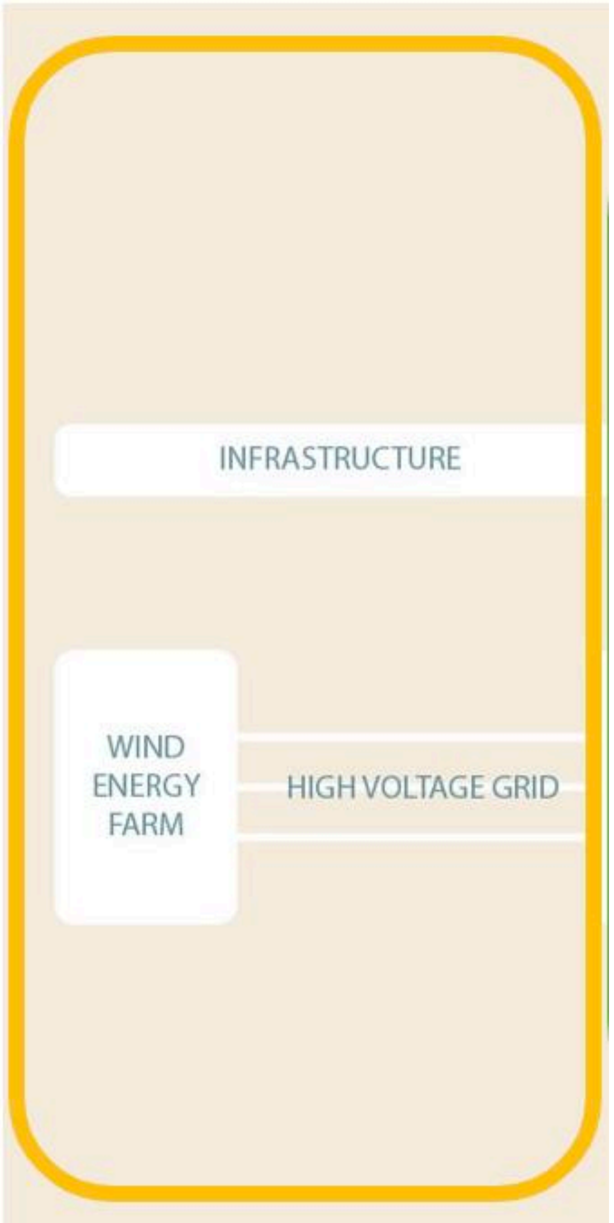
3. Hydraulic



5. BACKGROUND STUDY

1. Hinterland

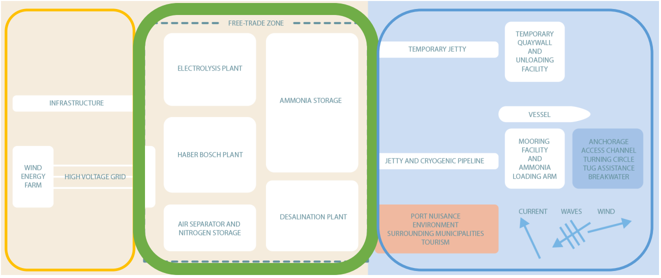
- High Voltage Power Transmission
- Good Accessibility

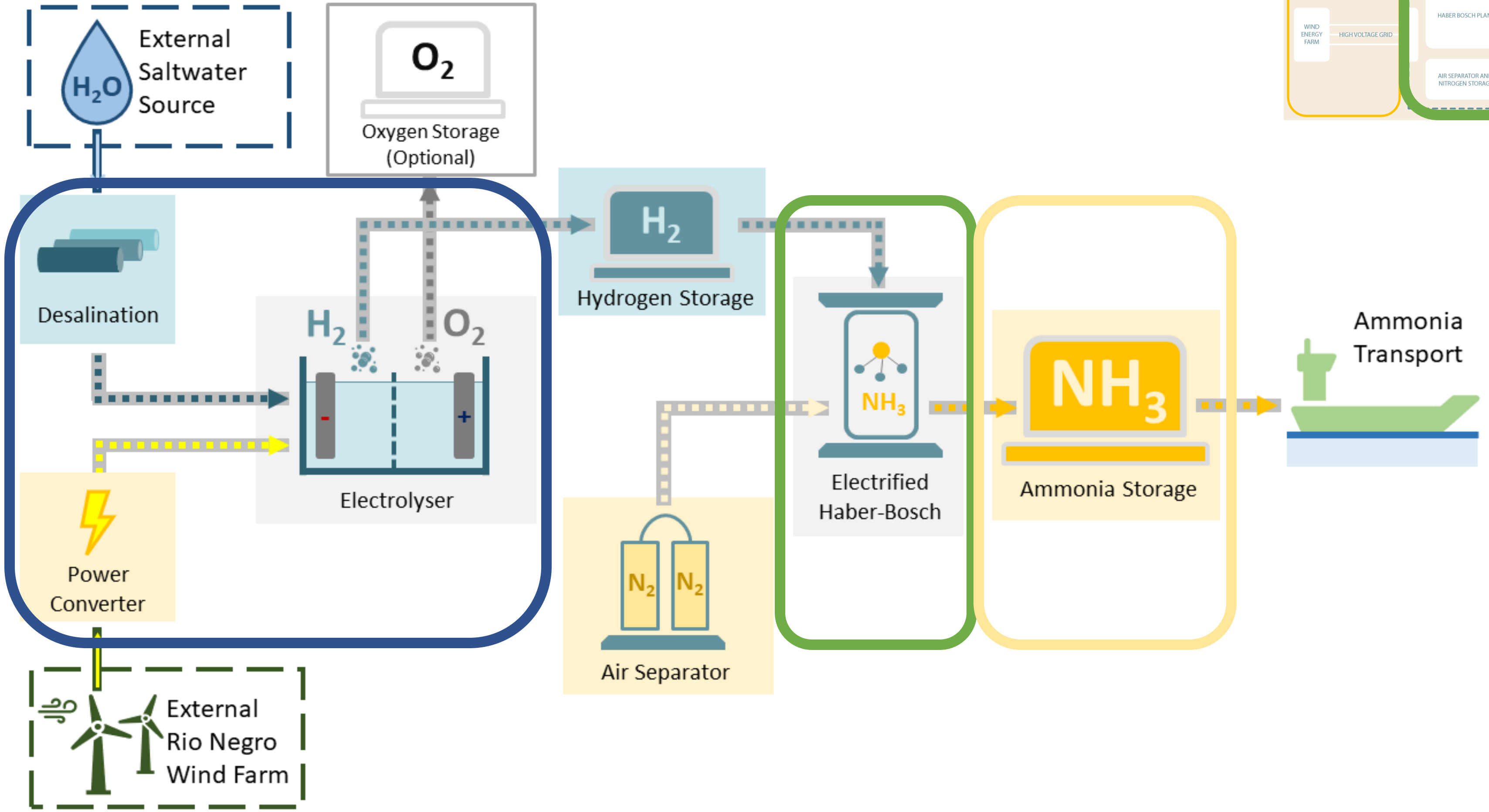


ROTTERDAM RIO NEGRO

5. BACKGROUND STUDY

2. Port Terminal





Electrolyser Facility | Ammonia Production | Ammonia Storage

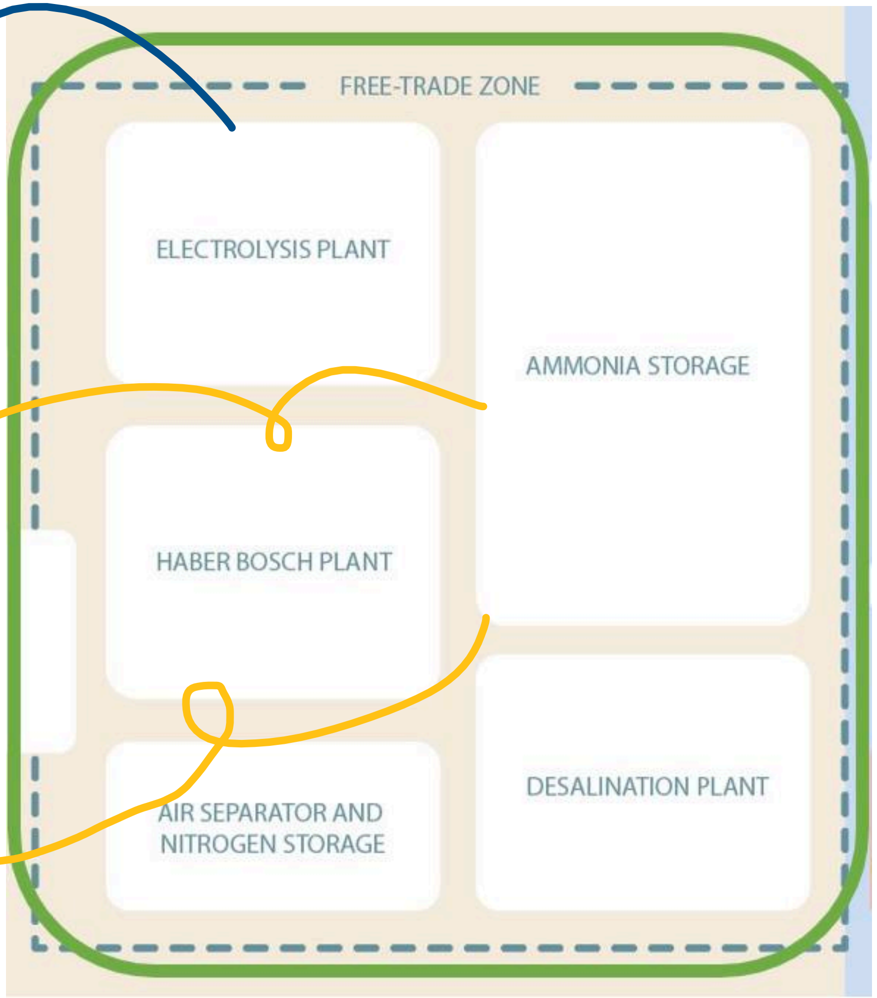
5. BACKGROUND STUDY

2. Port Terminal

Planning type	Electrolyser capacity	Total space required
Short-term Year 1-2	2 GW	20 ha
Mid-term Year 8	15 GW	150 ha

Planning type	Weight of total volume	Total space required
Short-term Year 1-2	105.000 (Tons)	2 (Ha)
Medium-term Year 8	315.000 (Tons)	6 (Ha)

Planning type	Ammonia Production (Tons/y)	Space needed	Staff needed
Short-term Year 1-2	840.000 (Tons/y)	22 (Ha)	100
Mid-term Year 8	6.300.000 (Tons/y)	165 (Ha)	750



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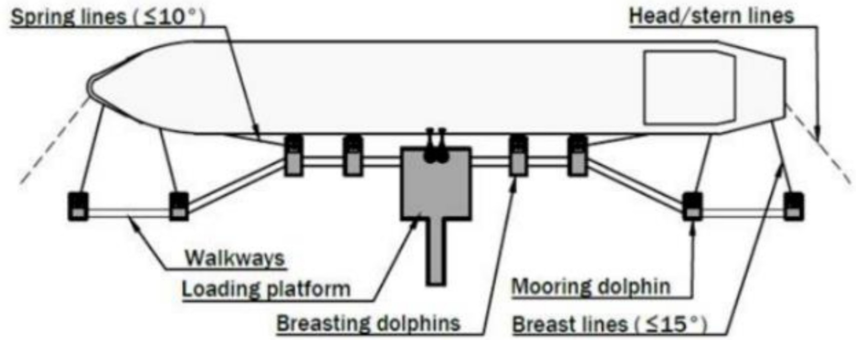
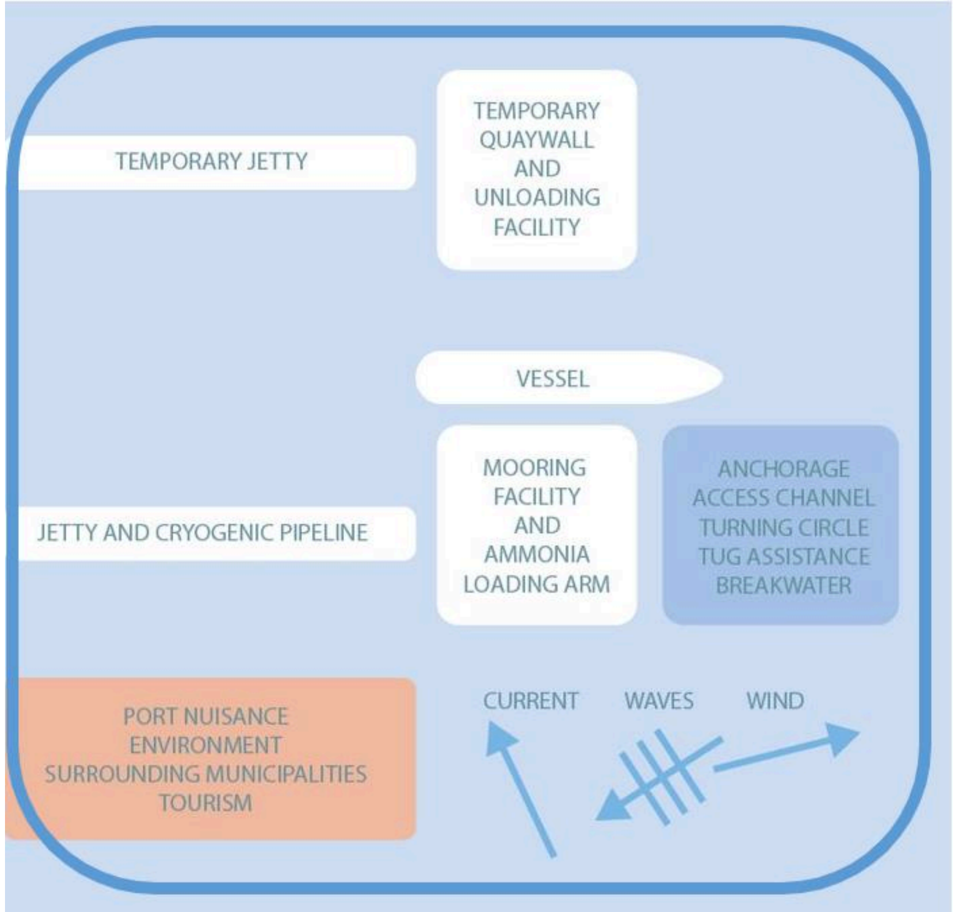
5. BACKGROUND STUDY

3. Hydraulic

	Depth
Nautical depth for design vessel	16.8 (m)
Spring tidal amplitude	4.38 (m)
Total required depth	21.18 (m +MSL)



Type	Vessel Size	Draught	Calls per year
Short-term Year 1-2	75.000 (m^3)	9.5 m	17
Short-term Year 8	200.000 (m^3)	12 m	45



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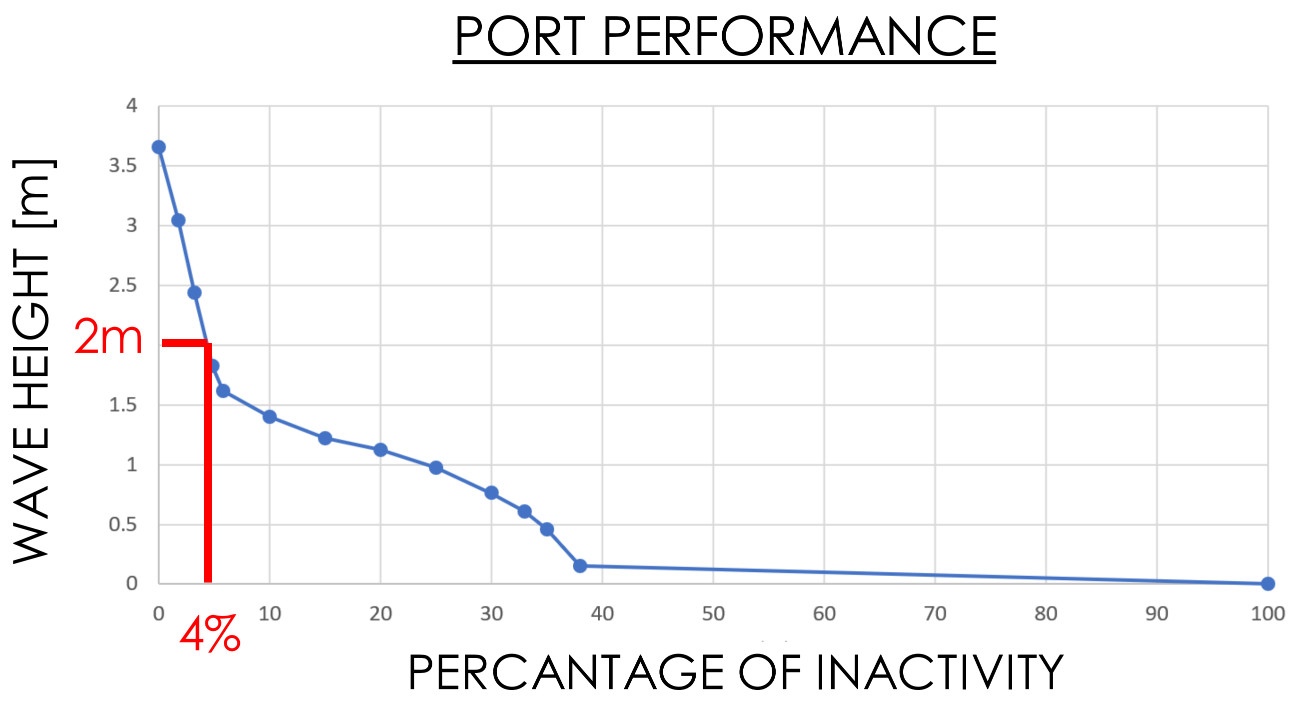
5. BACKGROUND STUDY
PORT PERFORMANCE

Description	$V_{wind,1\ min}$	$V_{current,1\ min}$	H_s
Vessel berthing			
• Forces longitudinal to berth	17.0 m/s	1.0 m/s	2.0 m



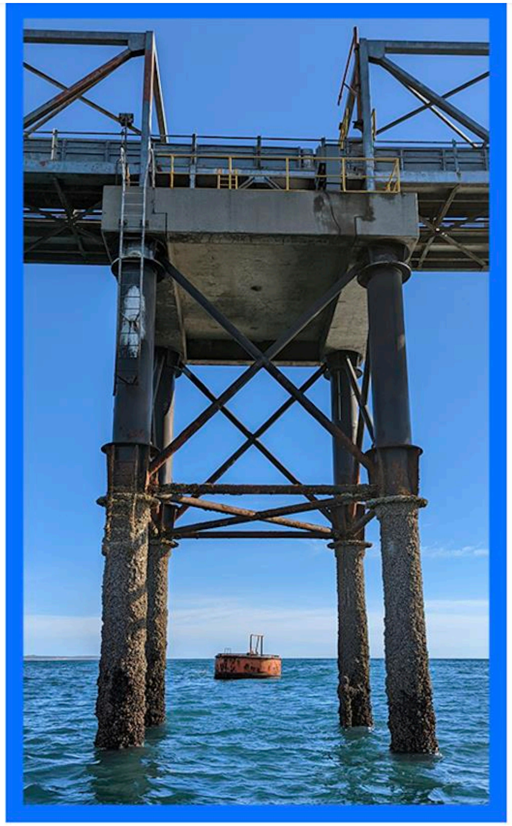
Annual Amount of Time of Inactivity of the Port:
Approx. 14 days per year

6. RESULTS

1 PUNTA COLORADA MUELLE
2 PUNTA COLORADA SOUTH
3 PUERTO LOBOS

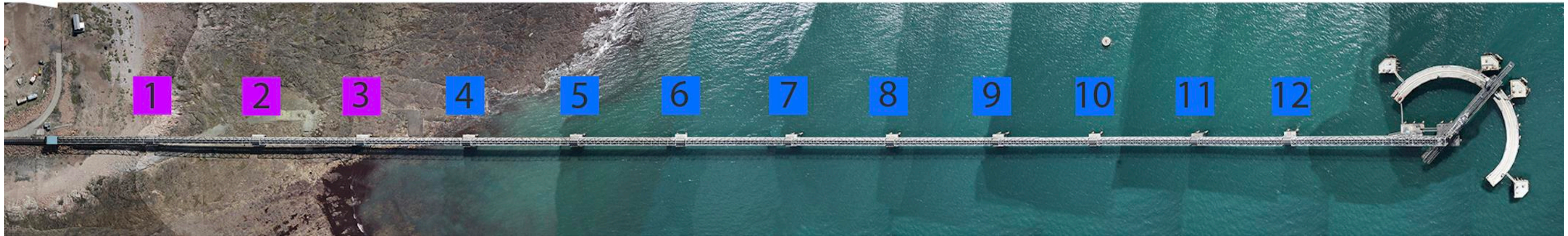
6. RESULTS – STRUCTURAL
PUNTA COLORADA MUELLE

6. RESULTS – STRUCTURAL
PUNTA COLORADA MUELLE

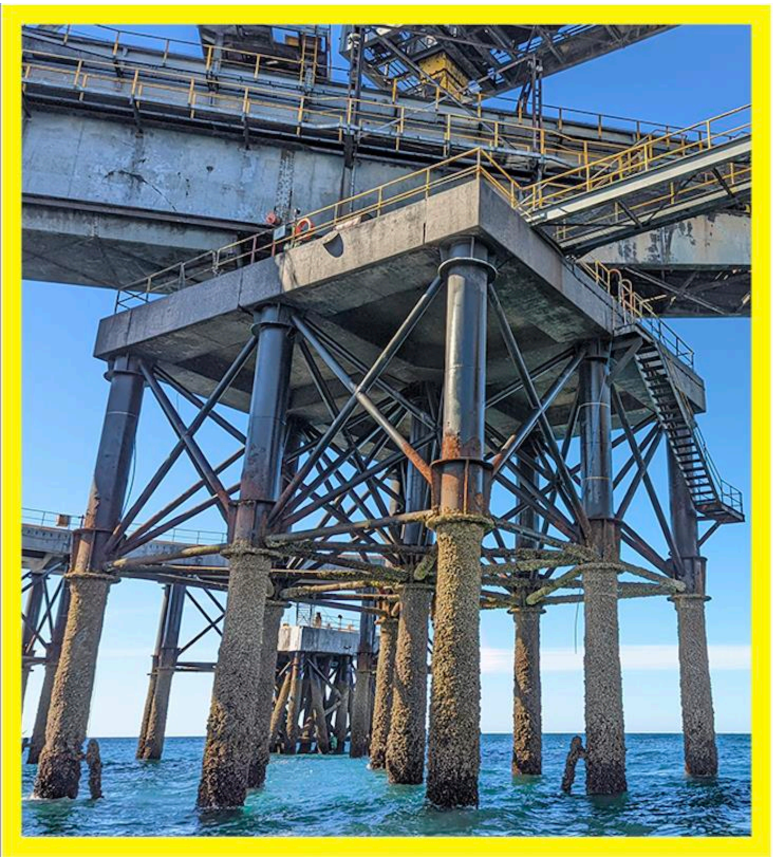


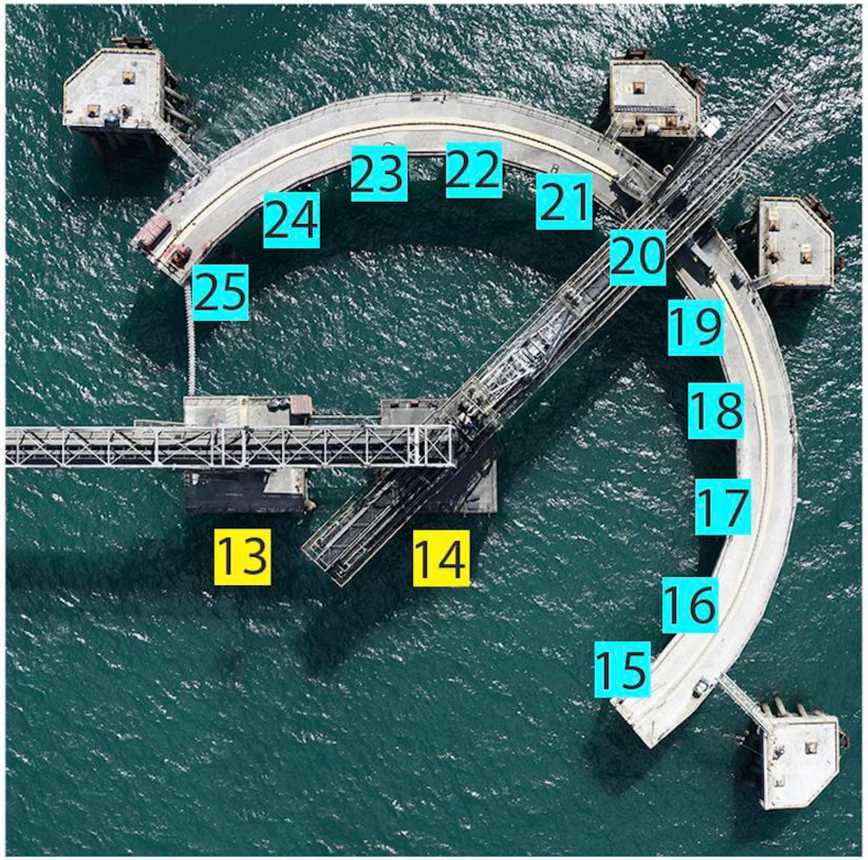
COLUMN GROUPS

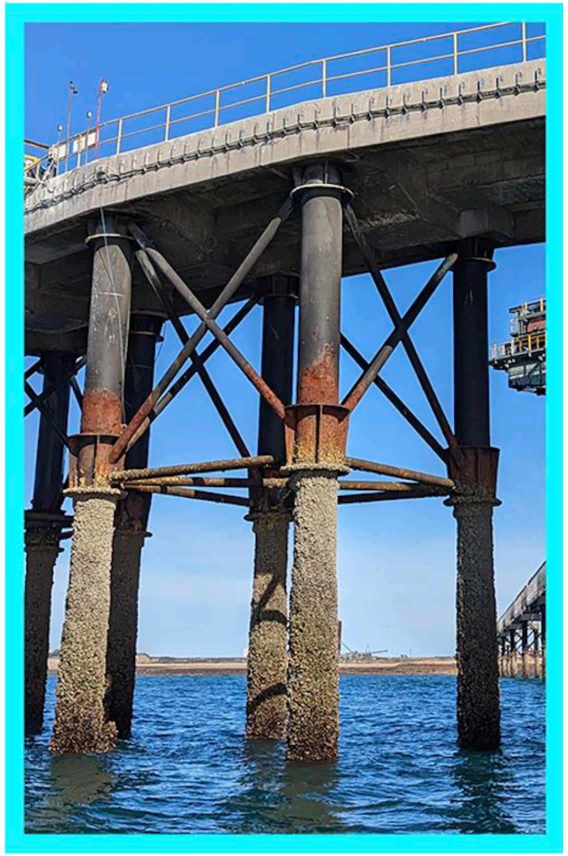
- Concrete Column Groups (1-3)
- Steel Column Groups (4-12)



6. RESULTS – STRUCTURAL
PUNTA COLORADA MUELLE







- Large Steel Column Groups (13,14)
- Steel Column Groups (15-25)

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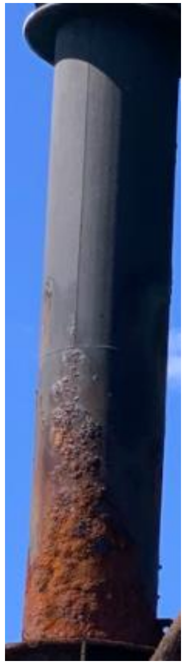
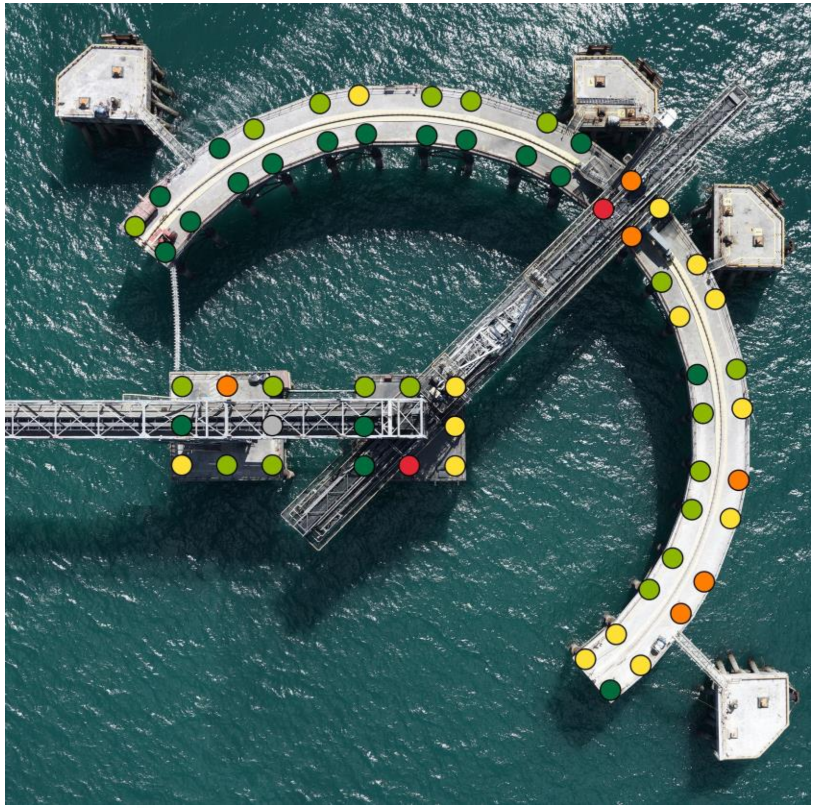
6. RESULTS – STRUCTURAL

PUNTA COLORADA MUELLE





C1 C2 C3 C4 C5

6. RESULTS – STRUCTURAL
PUNTA COLORADA MUELLE

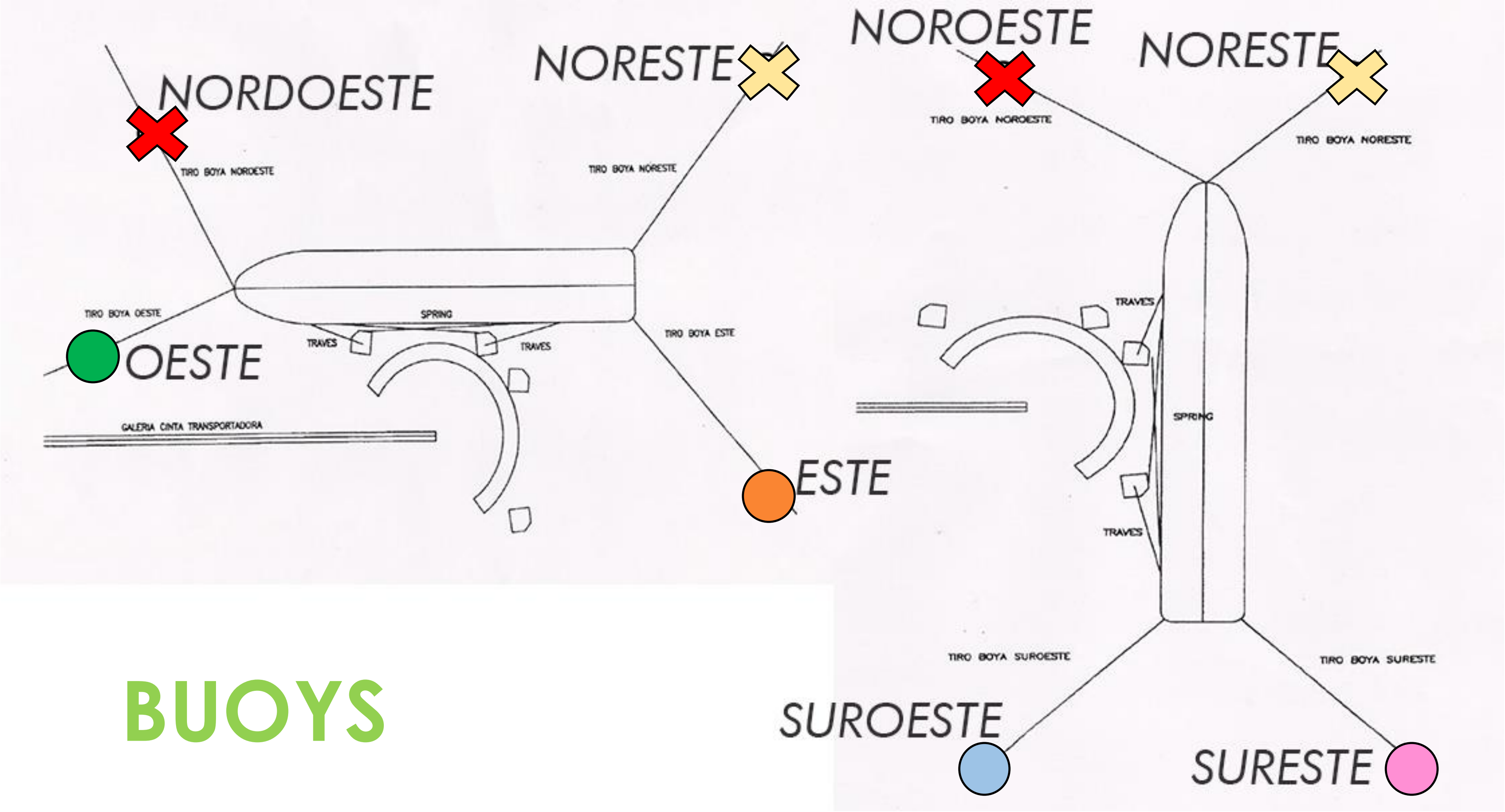
TRUSSES

6. RESULTS – STRUCTURAL
PUNTA COLORADA MUELLE

SHIP LOADER

PORT CONSULTANTS ROTTERDAM RN RIO NEGRO TU Delft

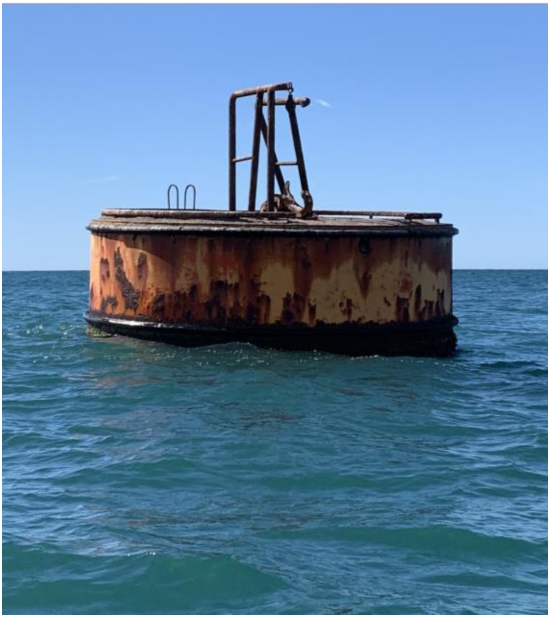
6. RESULTS – STRUCTURAL
PUNTA COLORADA MUELLE



BUOYS

6. RESULTS – STRUCTURAL
PUNTA COLORADA MUELLE

SUROESTE



SURESTE

ESTE

OESTE

BUOYS

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TU Delft

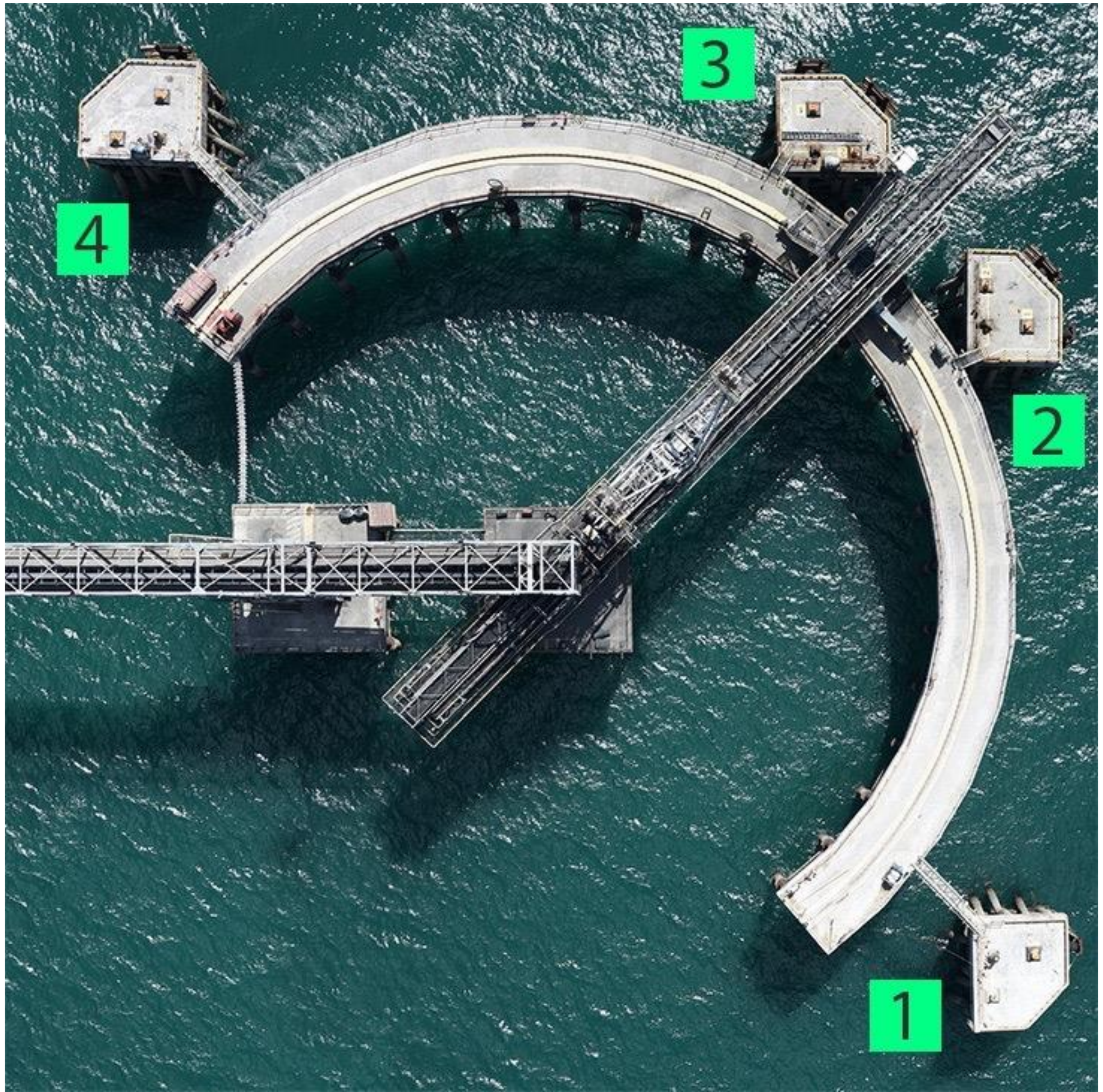
6. RESULTS – STRUCTURAL
PUNTA COLORADA MUELLE

BUOYS

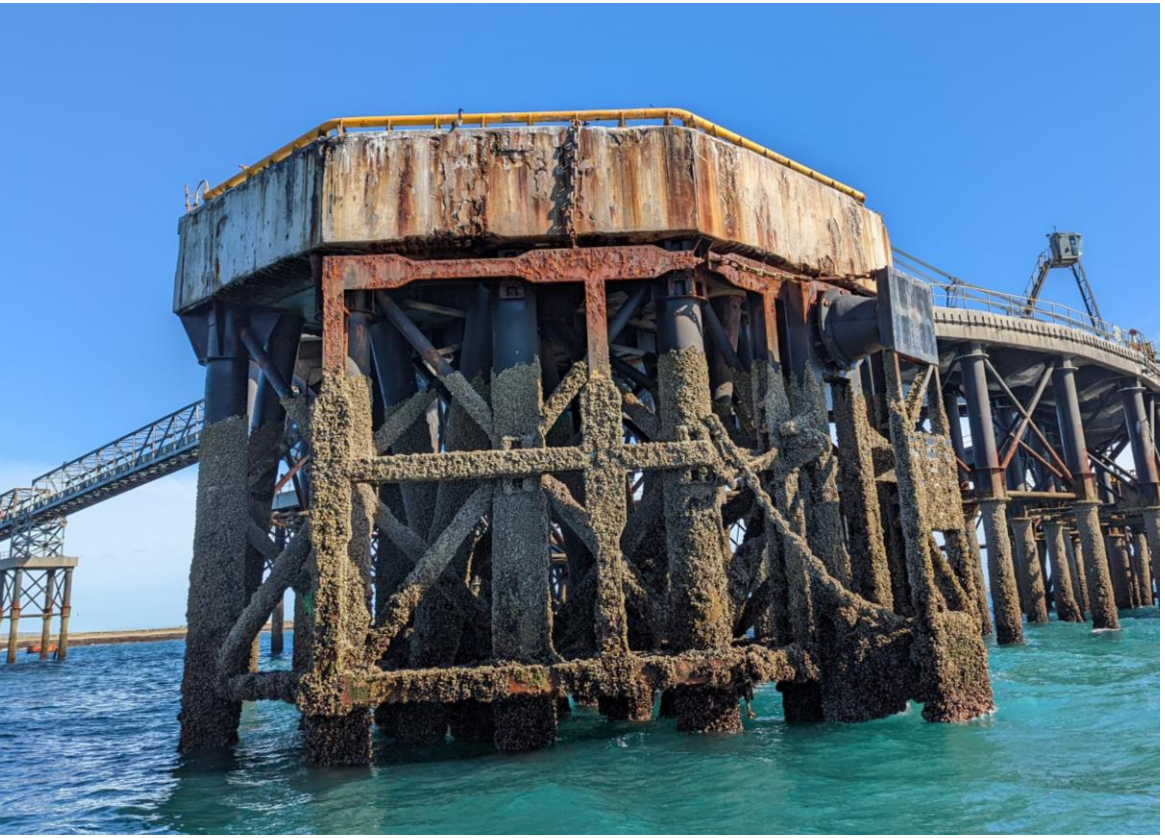
PORT CONSULTANTS ROTTERDAM
RN RíO NEGRO
TU Delft

6. RESULTS – STRUCTURAL
PUNTA COLORADA MUELLE

MOORING DOLPHINS



6. RESULTS – STRUCTURAL
PUNTA COLORADA MUELLE



MOORING DOLPHINS

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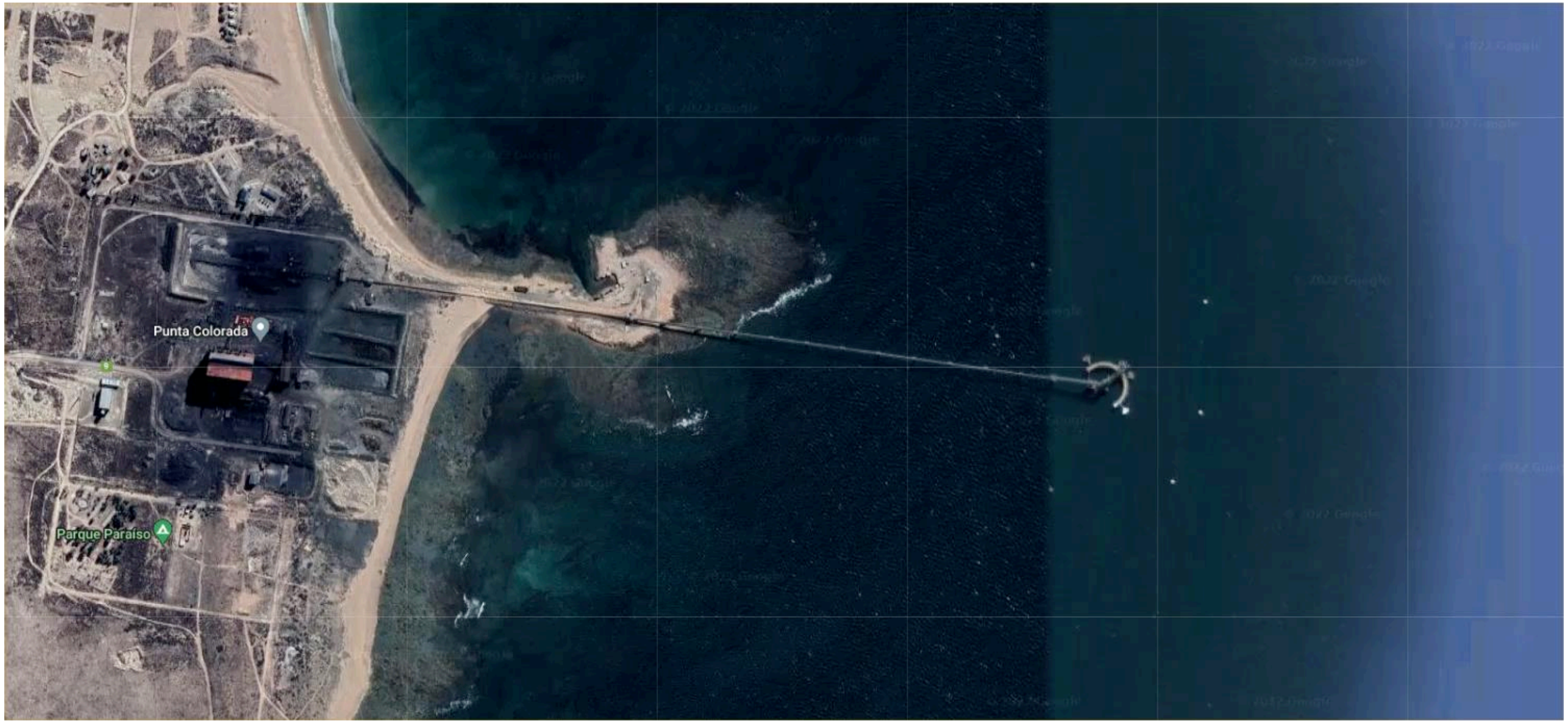
6. RESULTS – STRUCTURAL

PUNTA COLORADA MUELLE

MOORING DOLPHINS

PORT CONSULTANTS ROTTERDAM
RN RÍO NEGRO
TU Delft

6. RESULTS – STRUCTURAL
PUNTA COLORADA MUELLE



INTERACTIVE MAP WITH PHOTOS

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6. RESULTS – TOPOGRAPHY
PUNTA COLORADA MUELLE

WINGTRAONE DRONE VIDEO

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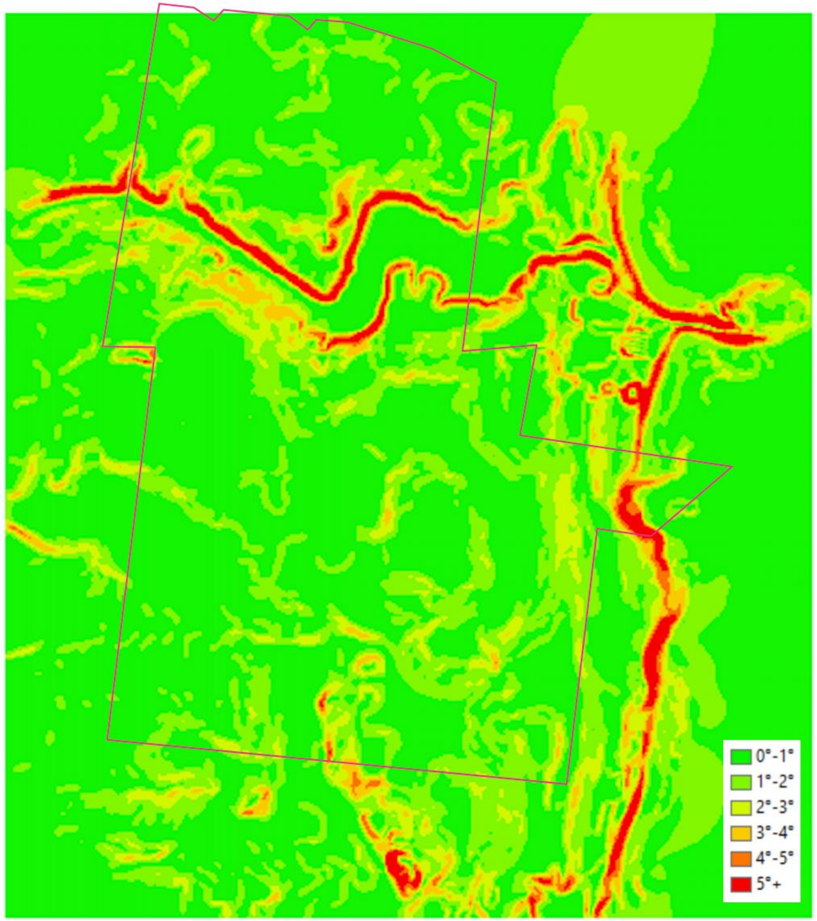
6. RESULTS – TOPOGRAPHY
PUNTA COLORADA MUELLE



ELEVATION

AVAILABLE AREA

SHORT TERM
44.5 ha

MEDIUM TERM
329.5 ha

REQUIRED AREA

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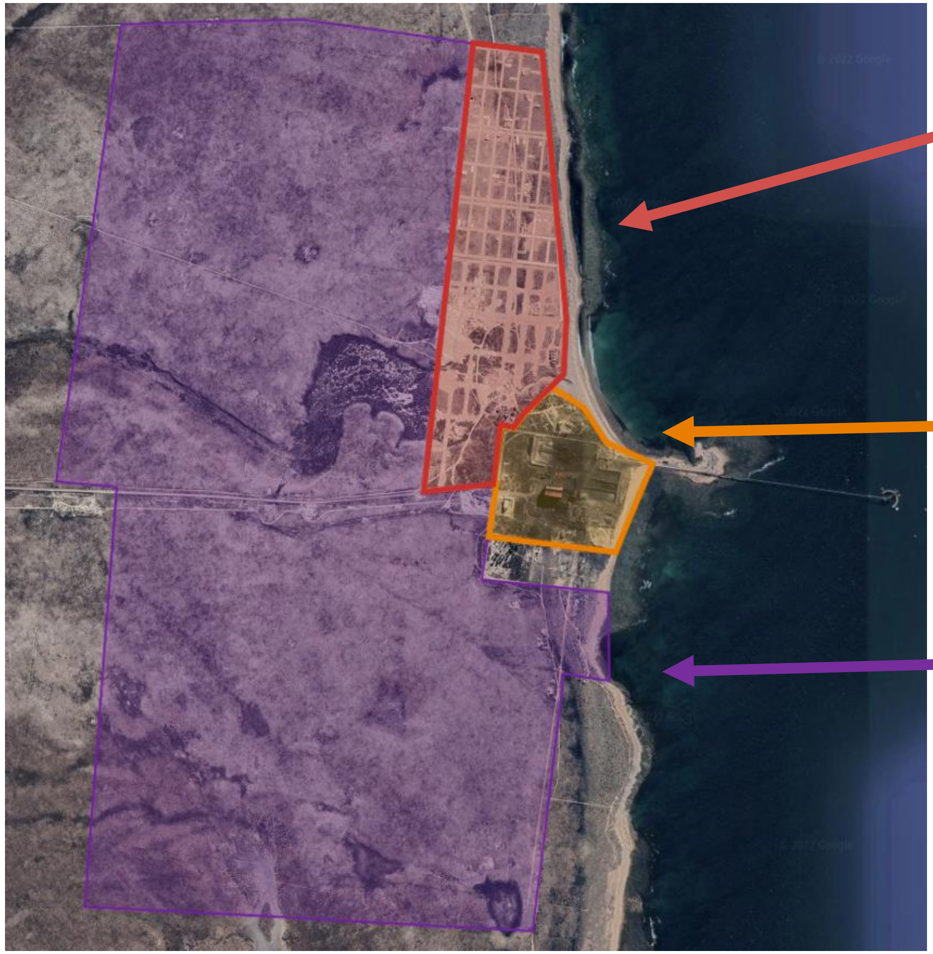
RN RíO NEGRO
TU Delft

6. RESULTS – TOPOGRAPHY
PUNTA COLORADA MUELLE

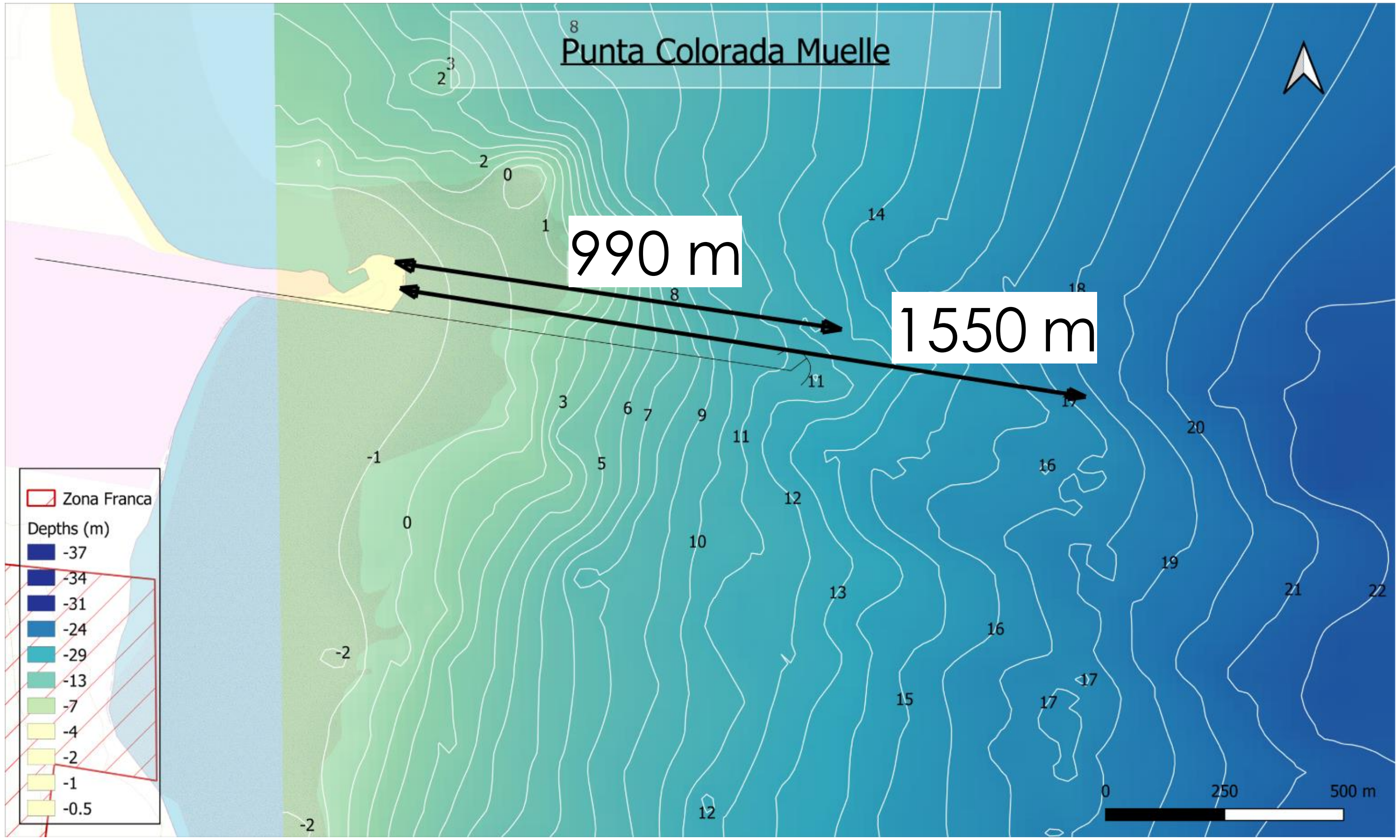


Urbanisation Project “Costa Doradas”

Infrastructure of MCC

Free-Trade Zone

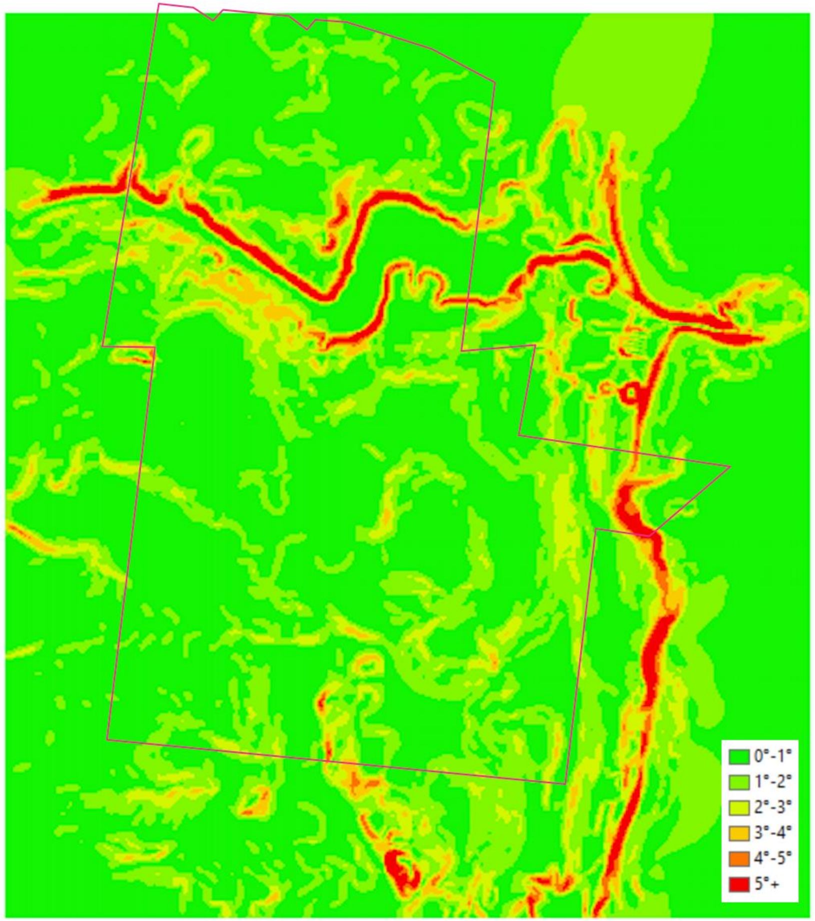
6. RESULTS – BATHYMETRY
PUNTA COLORADA MUELLE



DISTANCE FROM SHORE TO REQUIRED DEPTH

6. RESULTS
PUNTA COLORADA SOUTH

6. RESULTS – TOPOGRAPHY
PUNTA COLORADA SOUTH



ELEVATION

DIFFERENT ZONES

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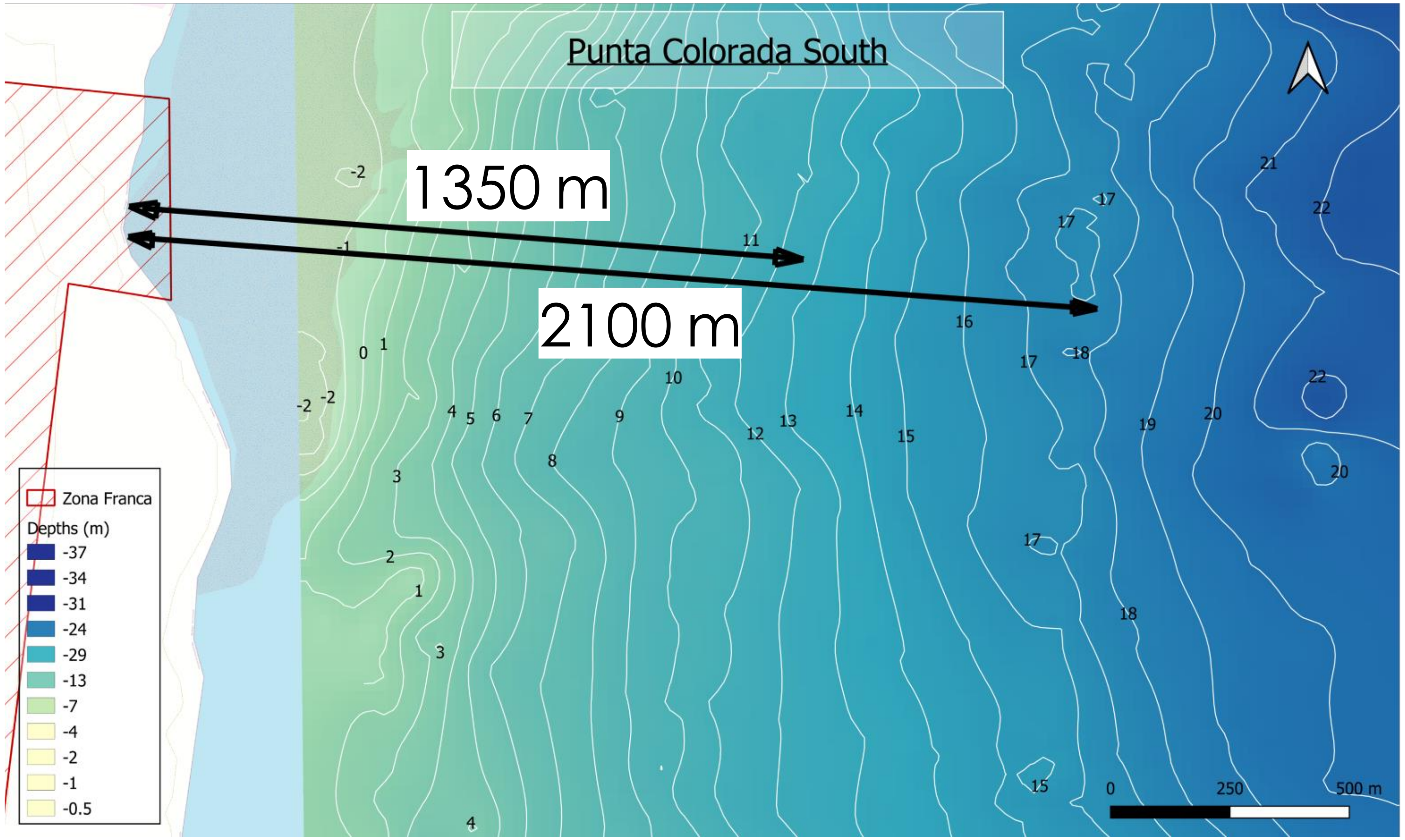
6. RESULTS – BATHYMETRY
PUNTA COLORADA SOUTH

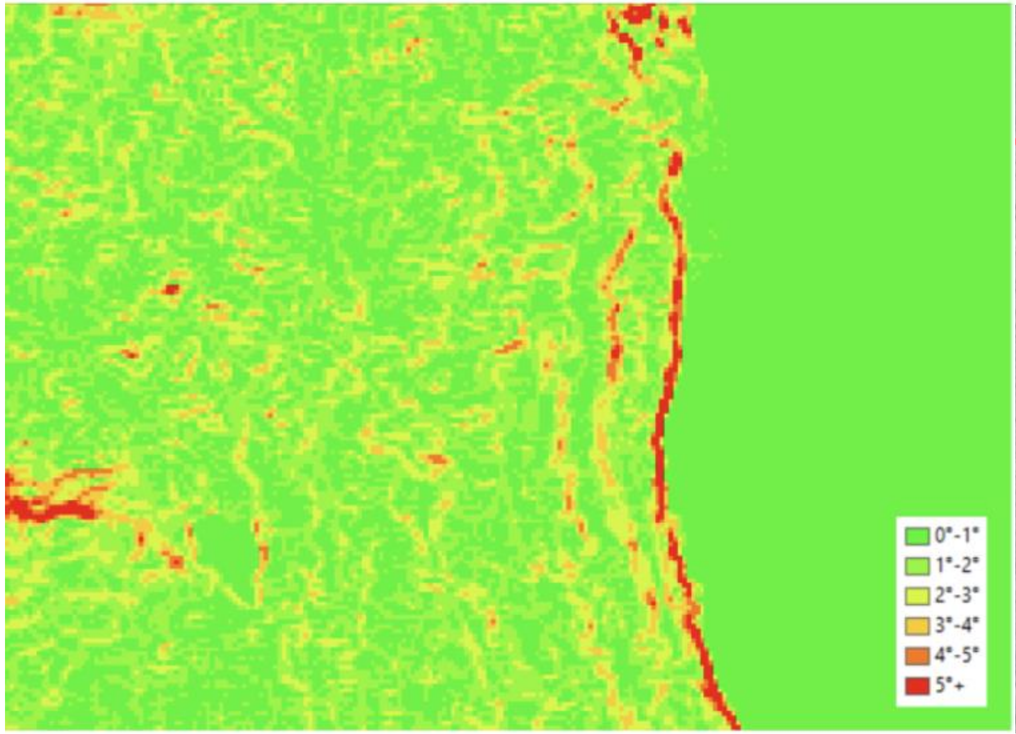


DISTANCE FROM SHORE TO REQUIRED DEPTH

PORT CONSULTANTS ROTTERDAM RN RiO NEGRO TUDelft

6. RESULTS
PUERTO LOBOS

6. RESULTS – TOPOGRAPHY
PUERTO LOBOS



ELEVATION

BORDER PROVINCE OF RÍO NEGRO / PROVINCE OF CHUBUT

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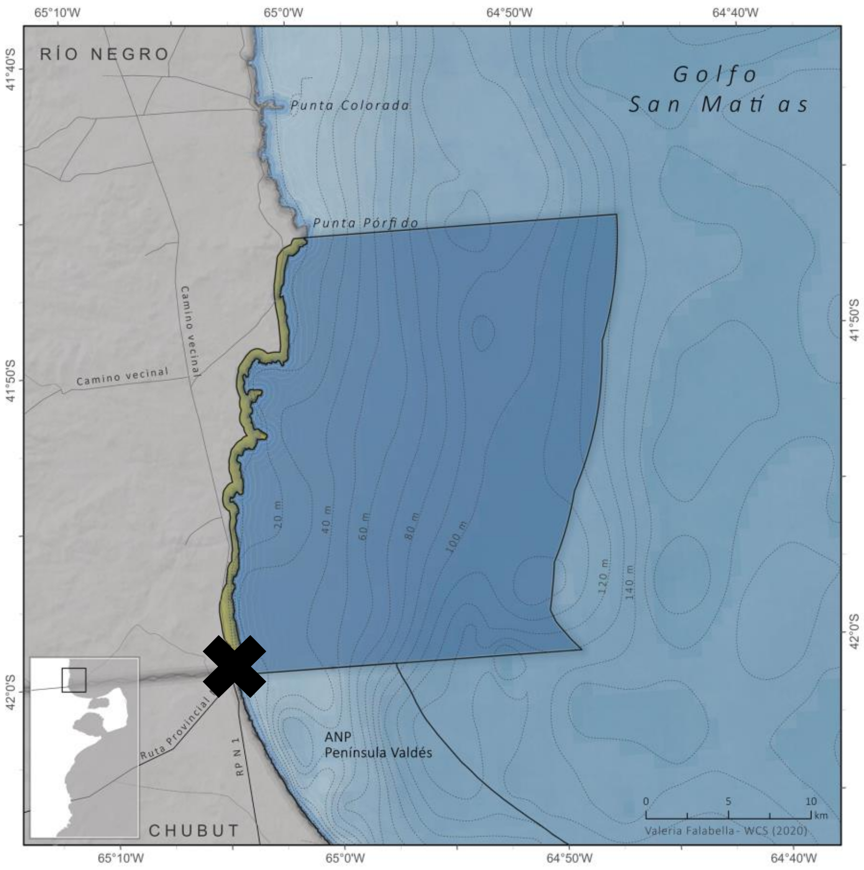
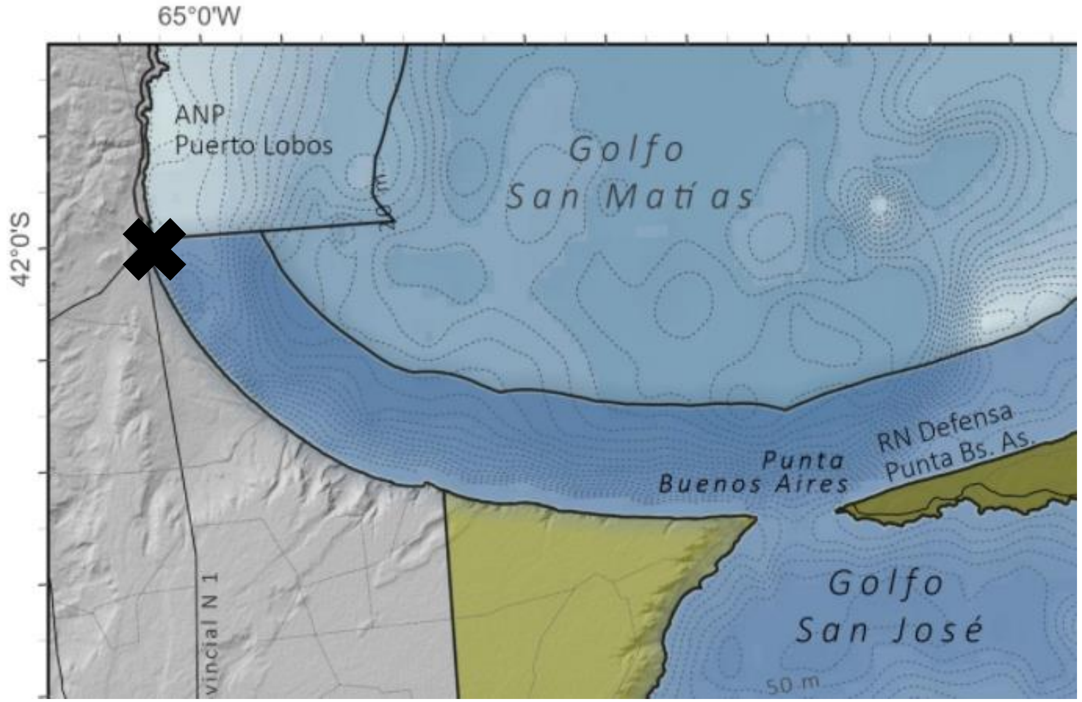
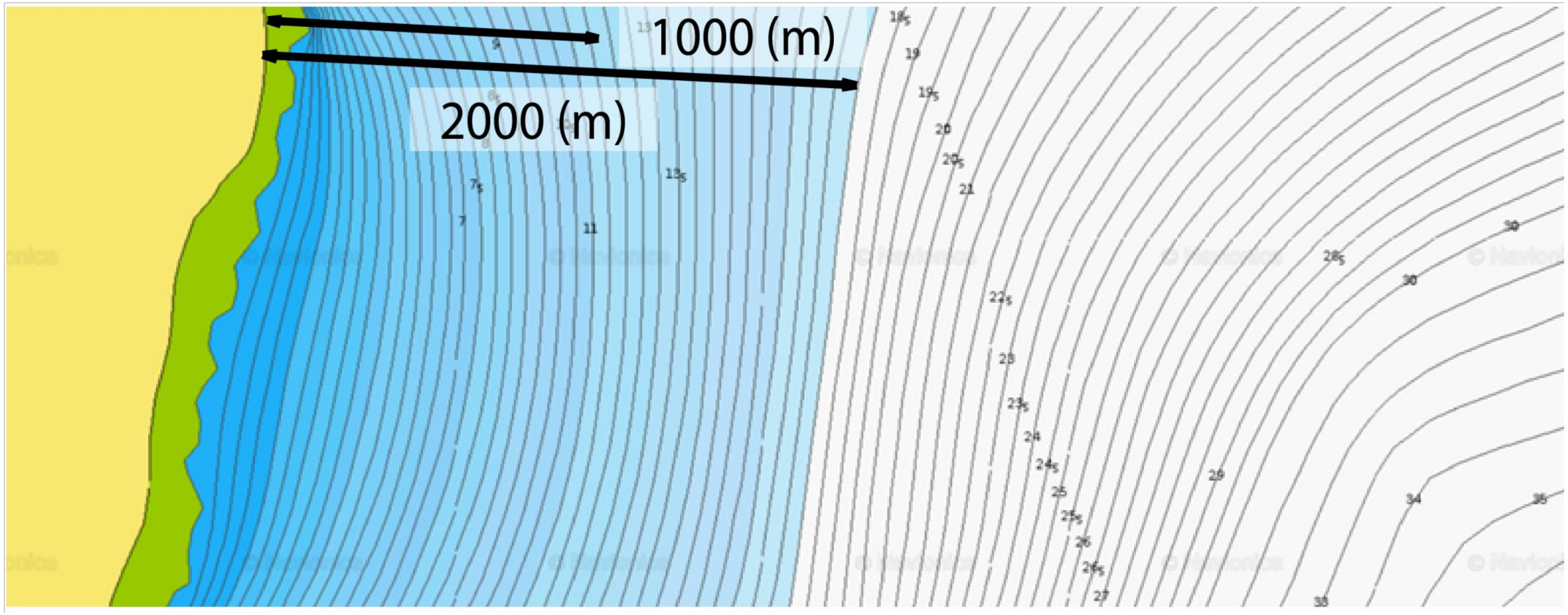
6. RESULTS – TOPOGRAPHY
PUERTO LOBOS

MARINE PROTECTED AREAS AROUND PUERTO LOBOS





6. RESULTS – BATHYMETRY PUERTO LOBOS

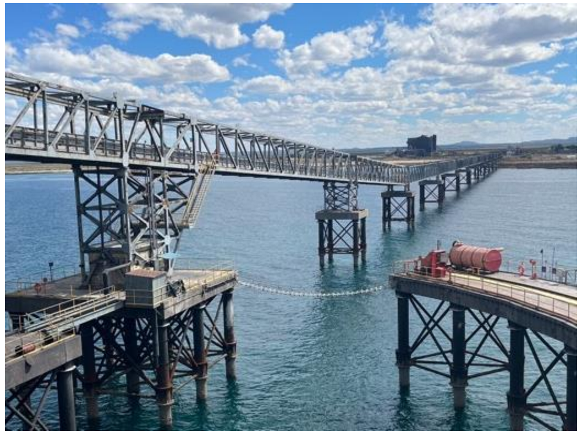


DISTANCE FROM SHORE TO REQUIRED DEPTH

7. SUMMARY OF THE LOCATIONS

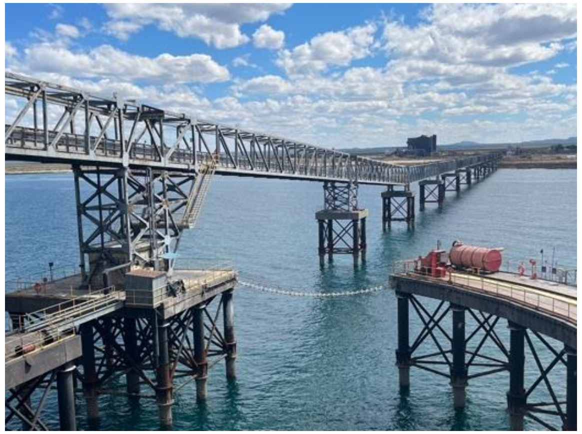
1 PUNTA COLORADA MUELLE
2 PUNTA COLORADA SOUTH
3 PUERTO LOBOS

7. SUMMARY OF THE LOCATIONS
PROTECTED MARINE AREA



	Punta Colorada Muelle	Punta Colorada South	Puerto Lobos
Presence of marine protected area	No protected marine area	No protected marine area	Presence of protected marine area

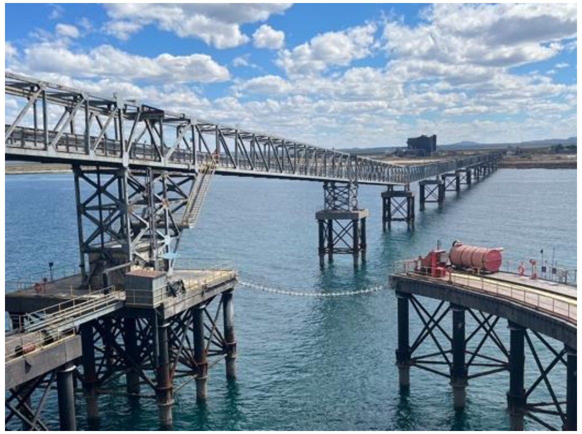
7. SUMMARY OF THE LOCATIONS
POTENTIAL REUSE OF JETTY



	Punta Colorada Muelle	Punta Colorada South	Puerto Lobos
Potential reuse of existing jetty	Yes, however further structural investigation needed.	No	No

7. SUMMARY OF THE LOCATIONS

AREA FOR CONSTRUCTION



	Punta Colorada Muelle	Punta Colorada South	Puerto Lobos
Available area for construction	Sufficient area, however, existing infrastructures present	Sufficient area and no existing infrastructure	Sufficient area and no existing infrastructure

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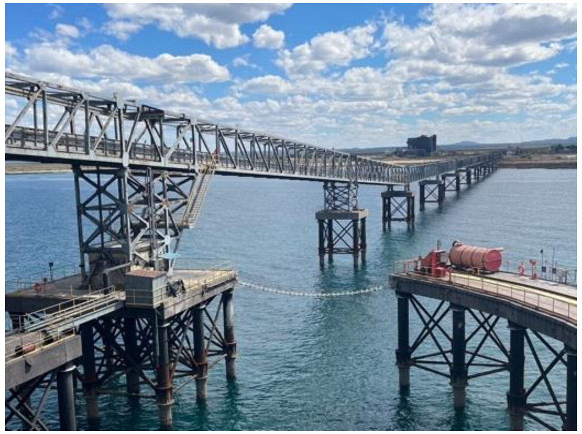
7. SUMMARY OF THE LOCATIONS
FREE-TRADE ZONE



	Punta Colorada Muelle	Punta Colorada South	Puerto Lobos
Presence of a Free-Trade Zone	Financial benefits due to the Free-Trade Zone	Financial benefits due to the Free-Trade Zone	No presence of a Free-Trade Zone

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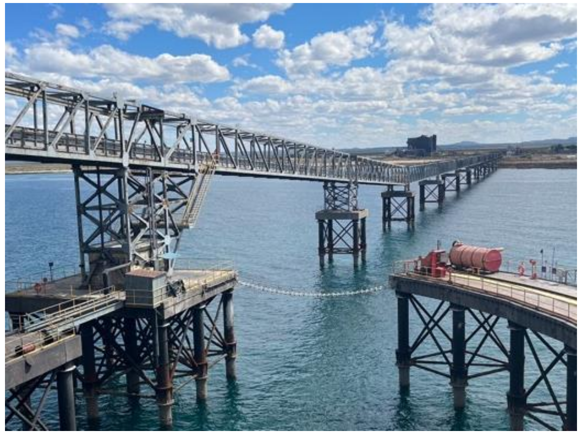
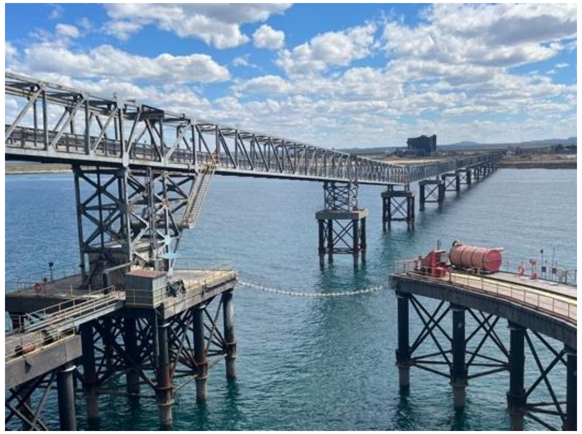
7. SUMMARY OF THE LOCATIONS
DISTANCE FROM SHORE



	Punta Colorada Muelle	Punta Colorada South	Puerto Lobos
Distance from shore to required depth	990m / 1510m	1390m/ 2750m	1000m / 2000m (no reliable data)

7. SUMMARY OF THE LOCATIONS
PRESENCE RESIDENTIAL AREAS



	Punta Colorada Muelle	Punta Colorada South	Puerto Lobos
Presence of residential areas	Playas Doradas at 5 km, potential adjacent residential area	Playas Doradas at 6 km, potential adjacent residential area	No near residential areas

7. SUMMARY OF THE THREE LOCATIONS

	Punta Colorada Muelle	Punta Colorada Sur	Puerto Lobos
Presence of marine protected area	No protected marine area	No protected marine area	Presence of protected marine area
Potential reuse of existing jetty	Yes, however further structural investig ation needed.	No	No
Available area for construction	Sufficient area, however, existing infrastructures present	Sufficient area and no existing infrastructure	Sufficient area and no existing infrastructure
Presence of a Free-Trade Zone	Financial benefits due to the Free-Trade Zone	Financial benefits due to the Free-Trade Zone	No presence of a Free-Trade Zone
Distance from shore to required depth	990m / 1510m	1390m/ 2750m	1000m / 2000m (no reliable data)
Presence of residential areas	Playas Doradas at 5 km, potential adjacent residential area	Playas Doradas at 6 km, potential adjacent residential area	No near residential areas

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8. CONCLUSIONS

Locations of Punta Colorada

- Both Punta Colorada locations show potential to build a hydrogen export port.
- They have similar characteristics: absence of marine protected areas and the presence of a Free-Trade Zone.
- The existing jetty at Punta Colorada Muelle has potential in the short-term for a cost-effective hydrogen port design. However, further structural investigation is required.
- Punta Colorada South has no interference from MCC and no design restrictions due to an existing jetty infrastructure.

8. CONCLUSIONS

Puerto Lobos

- Puerto Lobos shows disadvantages in some very important criteria, such as the presence of a marine protected area and the fact that no Free-Trade Zone is present.
- There is little information available on this location, therefore, a complete conclusion cannot be reached.

9. RECOMMENDATIONS

Further investigation on the existing jetty

- Retrieve the design calculations sheets and drawings
- Determine the actual capacity of the structure
- Repair or replace the mooring infrastructure (the mooring dolphins and the buoys)

To complete the comparison between the locations

- Puerto Lobos – determine the flexibility of the area of the protected marine and the possibility of a Free-Trade Zone
- Complete the survey – bathymetry and topography

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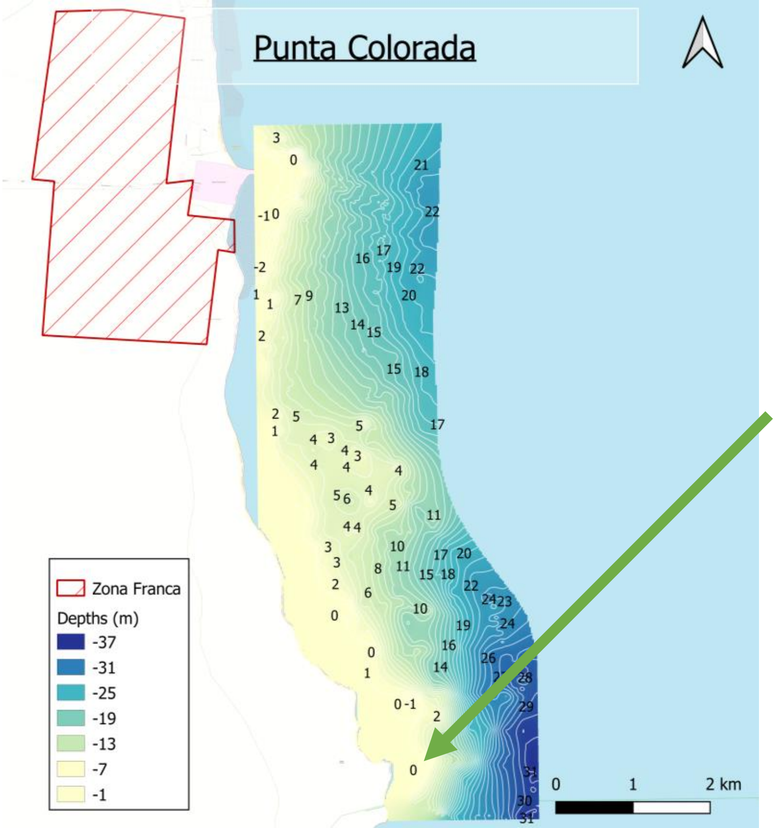
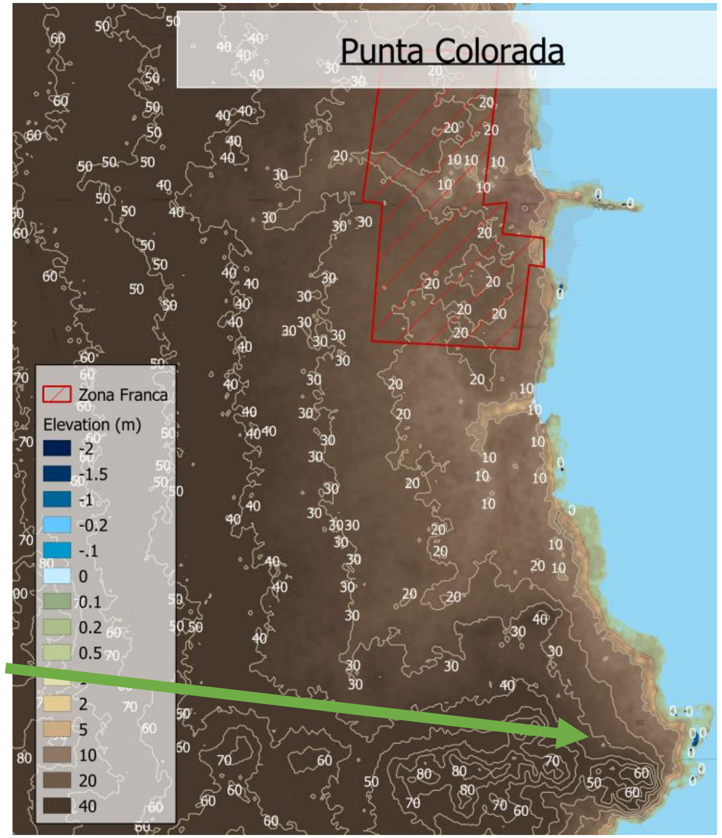
9. RECOMMENDATIONS
INVESTIGATE PUNTA PÓRFIDO



Favourable bathymetry

Challenging terrain elevations



9. RECOMMENDATIONS
STAKEHOLDER ANALYSES

Informing to create improved attitude
- news articles
- focus groups

Consulting to receive constructive advice
- focus groups
- feedback surveys

Involving to use their power in your advantage
- regular meetings
- feedback sessions

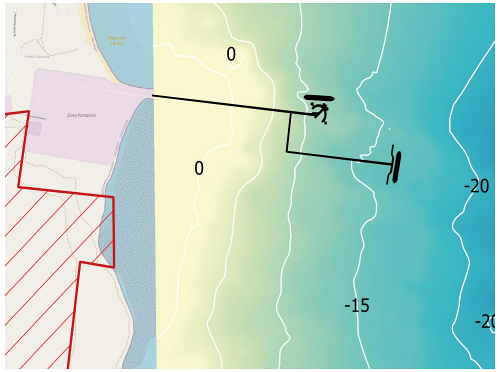
Collaborating to reach full potential of project
- regular meetings
- feedback sessions

Increasing level of engagement

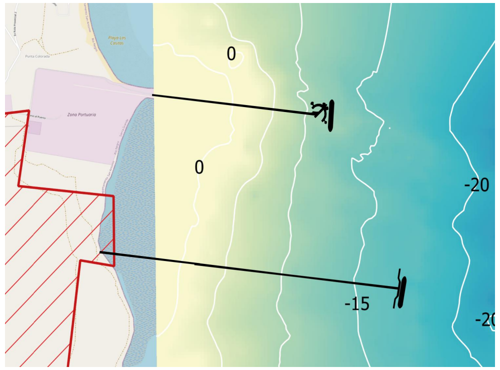
Inform	Consult	Involve	Collaborate
Environmental groups	**PCR**	**MCC**	**Province of Rio Negro**
Locals	**CIEMF**	**Government of Argentina**	**Fortescue**
Farmers/ fishers	**Prefectura Naval**	**Resource suppliers**	
Tourism			

10. CONCEPTUAL PORT SCENARIOS

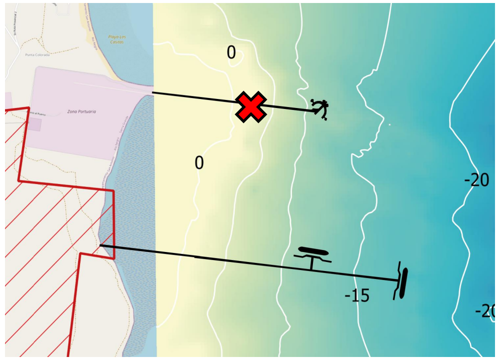
ALTERNATIVES



Alternative 1
- Short Term - Reuse existing jetty
- Long Term – Extend jetty to deeper water



Alternative 2
- Short Term - Reuse existing jetty
- Long Term – New jetty to deeper water



Alternative 3
- Short Term - Build new jetty to shallow depth
- Long Term – Extend new jetty to deeper water

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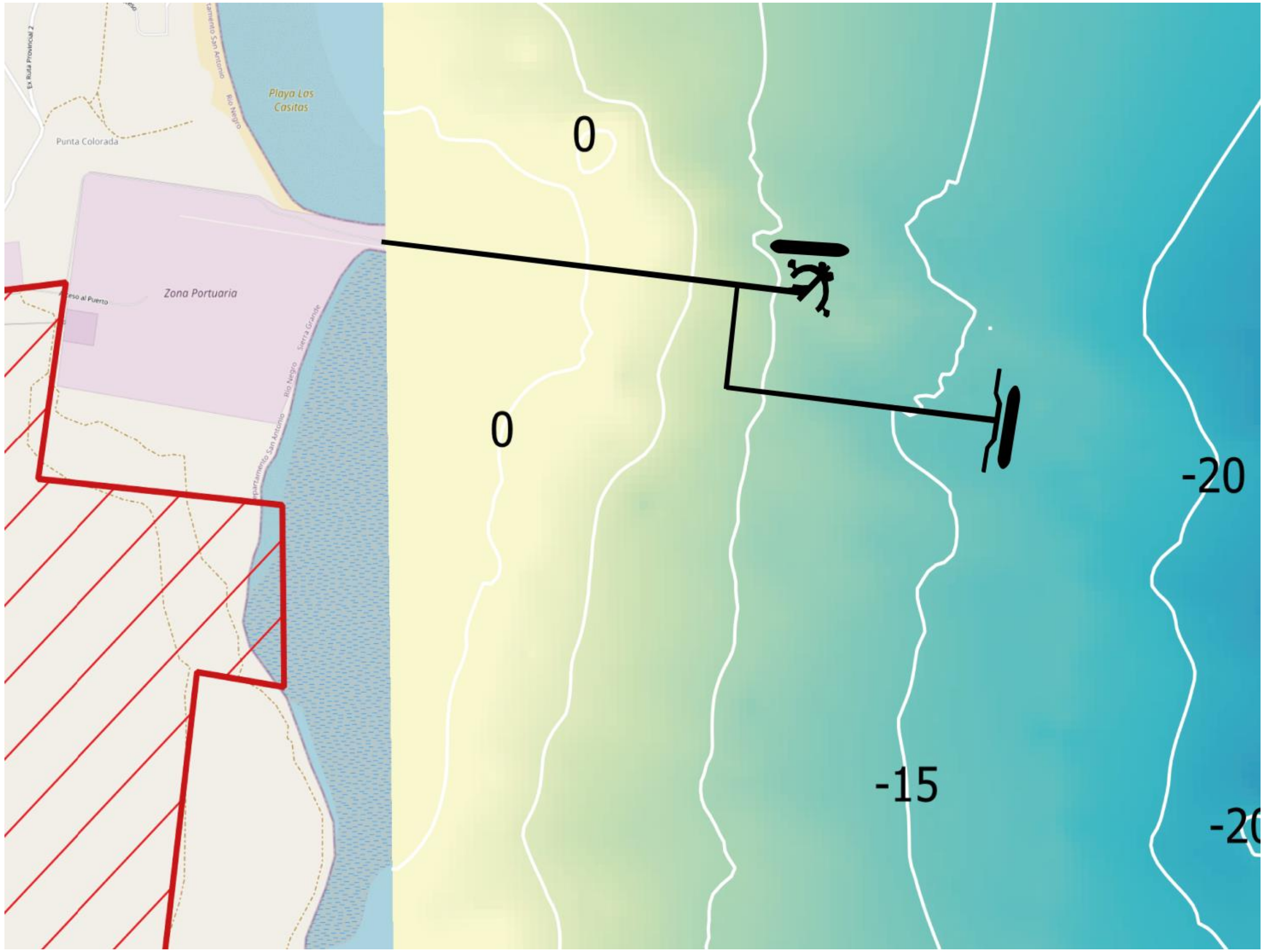
10. CONCEPTUAL PORT SCENARIOS

ALTERNATIVE 1



- Quick start of export operations
- Huge cut in investments
- Sustainable

- Long term operations dependent on the lifetime of the current jetty
- Possible conflicts with MCC

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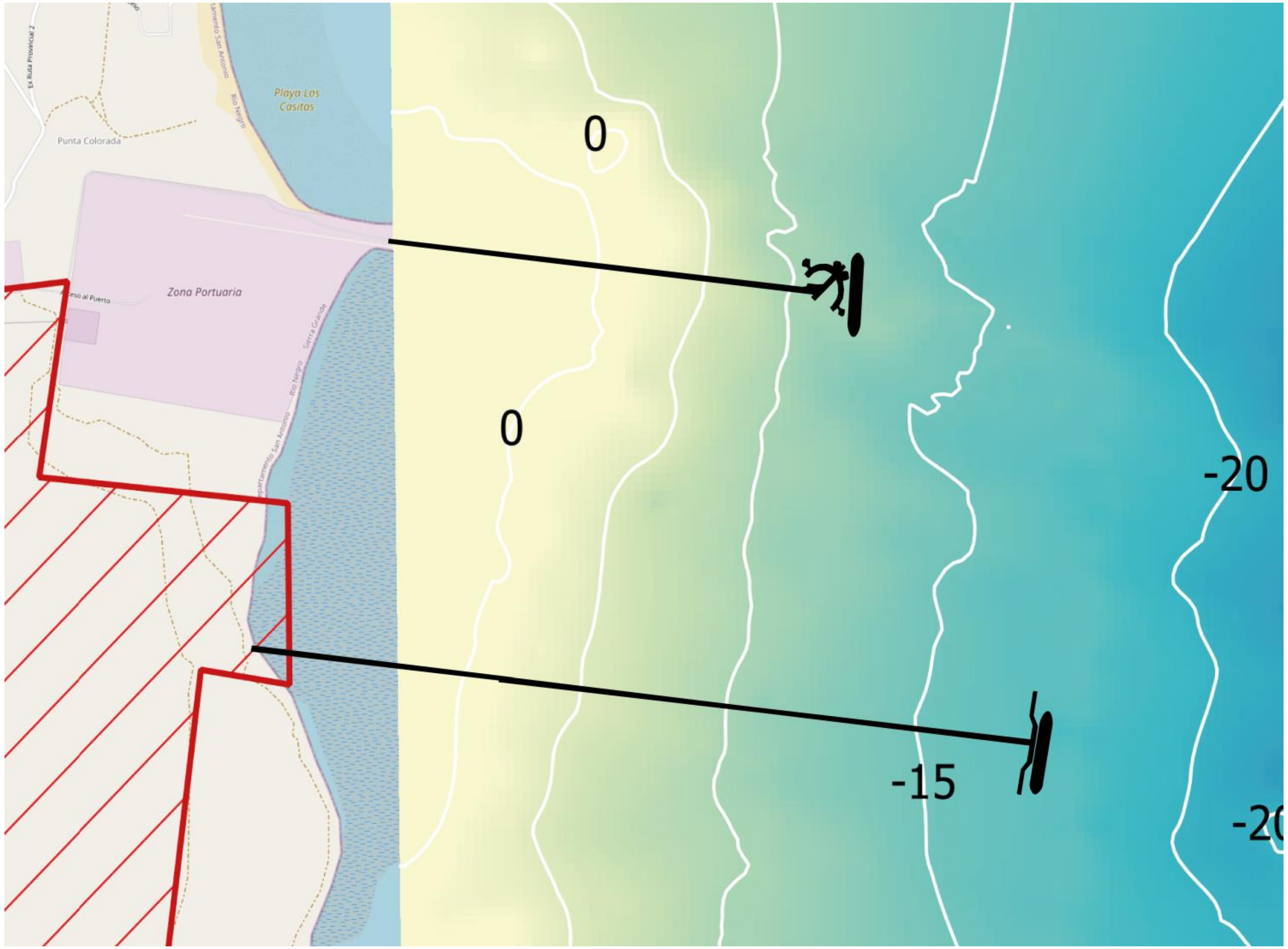
10. CONCEPTUAL PORT SCENARIOS

ALTERNATIVE 2



- Quick start export operations
- Lifetime of reused jetty does not influence the long-term port operations

- Large total investment
- Possible conflicts with MCC

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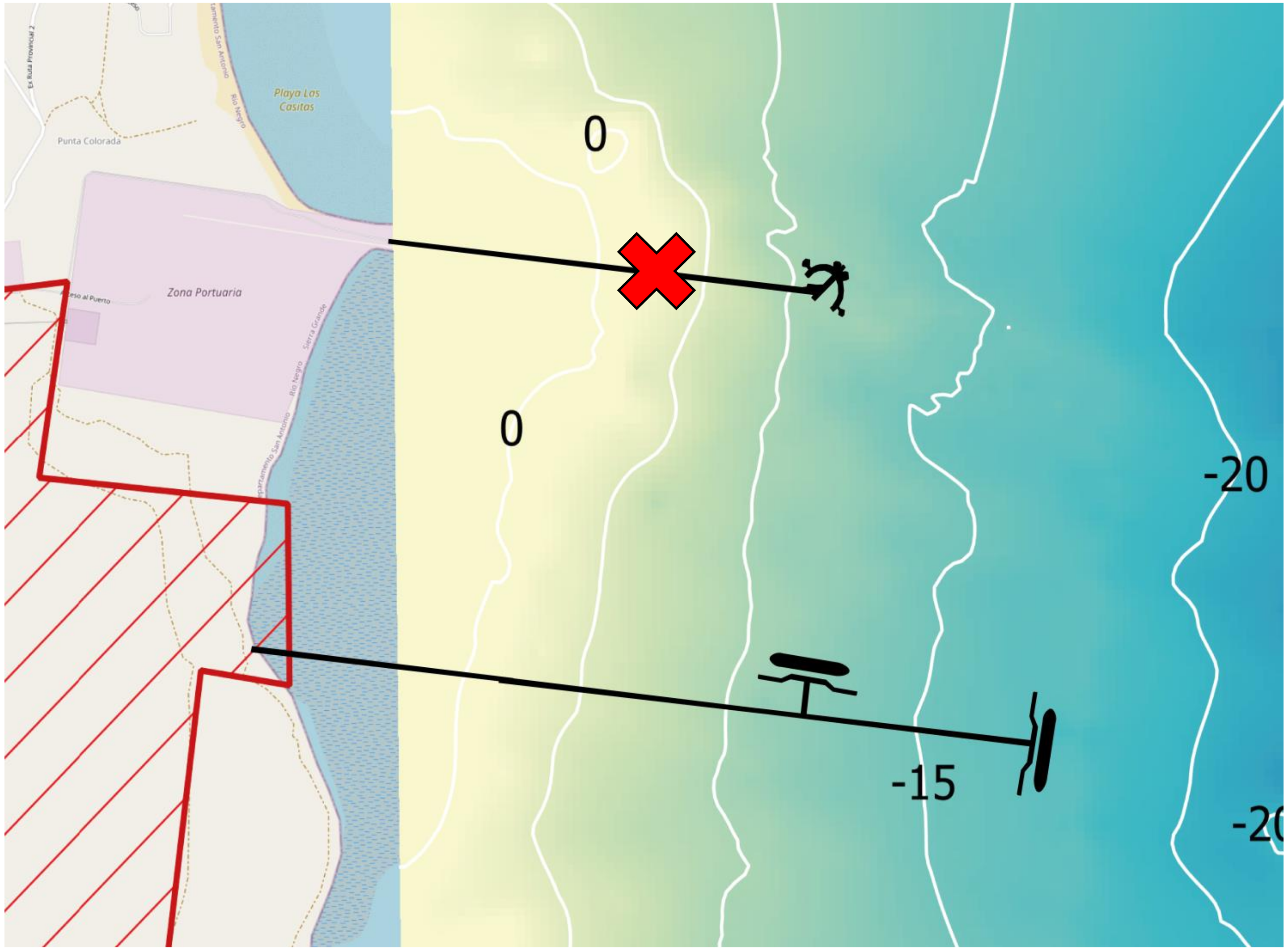
10. CONCEPTUAL PORT SCENARIOS

ALTERNATIVE 3



- No dependencies on the state of current jetty
- No dependencies/ conflicts on MCC

- Moderate total investment
- Long time needed to start export operations

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RN RÍO NEGRO
TU Delft

PRESENTATION FOR THE CLIENT

Gobierno de Río Negro

Inicio | Institucional | Acerca de Río Negro | Transparencia | Buscar en el sitio...

Gobierno de Río Negro / Hidrógeno verde: estudiantes holandeses presentaron su investigación para el desarrollo portuario en Punta Colorada

HIDRÓGENO VERDE

Hidrógeno verde: estudiantes holandeses presentaron su investigación para el desarrollo portuario en Punta Colorada

¡GRACIAS!

G.2. Spanish Presentation

TRES UBICACIONES POTENCIALES PARA EXPORTAR HIDRÓGENO VERDE EN RÍO NEGRO

¿QUIENES SOMOS NOSOTROS?

SE = ENGENIERÍA ESTRUCTURAL

HE = INGENIERÍA HIDRÁULICA

CME = INGENIERÍA DE GESTIÓN DE LA CONSTRUCCIÓN

PORT CONSULTANTS ROTTERDAM RN RíO NEGRO TU Delft

CONTENIDO

PORT CONSULTANTS ROTTERDAM RN RiO NEGRO TUDelft

1. OBJETIVOS & OPORTUNIDADES

1. OBJETIVOS
& OPORTUNIDADES

"*Se espera que* ***Río Negro*** *se convierta en un* ***centro mundial*** *de exportación de* ***hidrógeno verde*** *para* ***2030***"

1
SEGURIDAD ENERGÉTICA

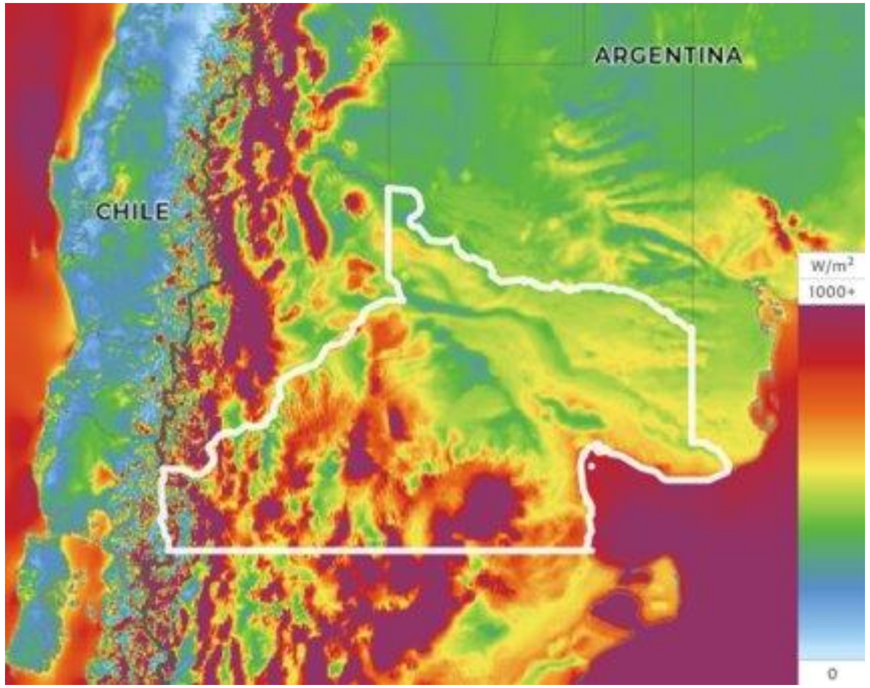
2
SOSTENIBILIDAD AMBIENTAL

3
EFICIENCIA Y COMPETENCIA

4
INCLUSION SOCIAL Y EMPLEO

1. OBJETIVOS
& OPORTUNIDADES

VIENTO



AGUA

1. OBJETIVOS
& OPORTUNIDADES

ZONA FRANCA

2. PREGUNTA PRINCIPAL

*"Que **ubicación** entre Punta Colorada Muelle, Punta Colorada Sur y Puerto Lobos es el mas **apropiado** para realizar un **puerto** para producir **hidrógeno verde**?''*

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3. ALCANCE

PORT CONSULTANTS ROTTERDAM RN RíO NEGRO TU Delft

3. ALCANCE

1 PUNTA COLORADA MUELLE
2 PUNTA COLORADA SUR
3 PUERTO LOBOS

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3. ALCANCE

PUNTA COLORADA MUELLE

3. ALCANCE
PUNTA COLORADA MUELLE

- VIEJO MUELLE DE HIERRO
- CARGA SECA A GRANEL - NO SE UTILIZA HACE 6 AÑOS
- CERCA DE LA ZONA FRANCA
- PROPUESTA POR LA PROVINCIA RÍO NEGRO

3. ALCANCE
PUNTA COLORADA SUR

3. ALCANCE
PUNTA COLORADA SUR

- PROPUESTA PARA INVESORES POTENCIALES
- ACCESO DIRECTO A LA ZONA FRANCA

3. ALCANCE
PUERTO LOBOS

3. ALCANCE PUERTO LOBOS

- EL CENTRO DE INVESTIGACIÓN Y ENTRENAMIENTO MARÍTIMO Y FLUVIAL (CIEMF) INICIÓ EL ESTUDIO CONCEPTUAL
- COOPERACION DE LA PROVINCIA RIO NEGRO Y LA PROVINCIA DE CHUBUT
- SE ENCONTRARIA UNA MAYOR PROFUNDIDAD CERCANA A LA COSTA

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4. METODOLOGÍA

DEFINING PORT REQUIREMENTS AND CRITERIA

GATHERING DATA PER LOCATION

ANALYSING LOCATIONS BASED ON REQUIREMENTS AND CRITERIA

PROPOSING RECOMMENDATION FOR RIO NEGRO

PORT CONSULTANTS ROTTERDAM RN RIO NEGRO TU Delft

4. METODOLOGÍA

1 INVESTIGACIÓN TOPOGRÁFICO
2 INVESTIGACIÓN HIDRÁULICA
3 INVESTIGACIÓN ESTRUCTURAL

4. METODOLOGÍA
INVESTIGACIÓN TOPOGRÁFICO

PUNTA COLORADA MUELLE	Elevación de la tierra con WintraOne Inspección visual Datos satelitales
PUNTA COLORADA SUR	Elevación de la tierra con WintraOne Datos satelitales
PUERTO LOBOS	Datos satelitales

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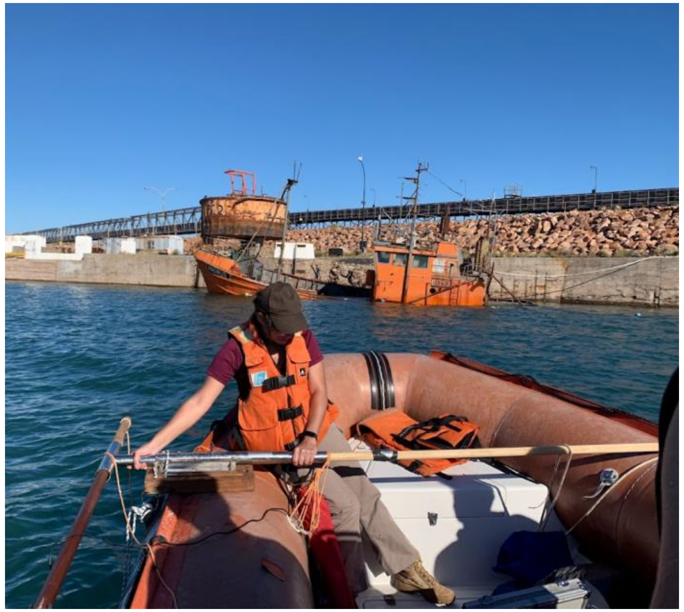
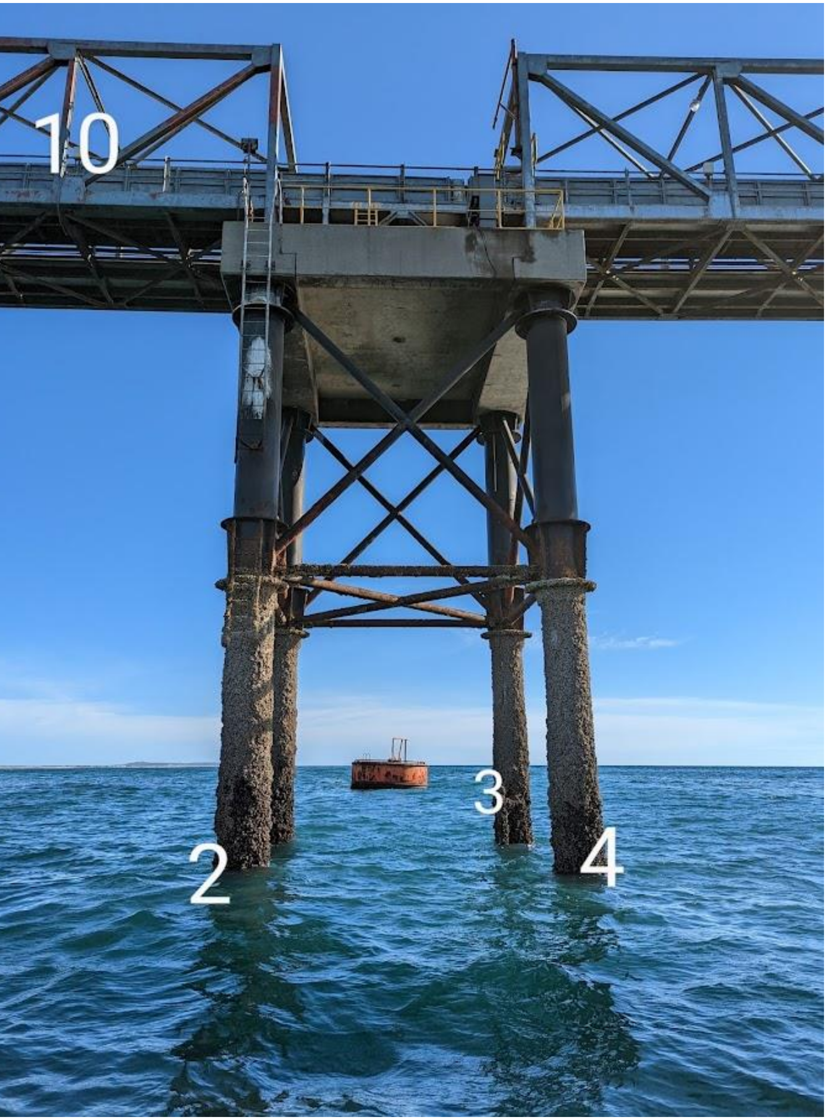
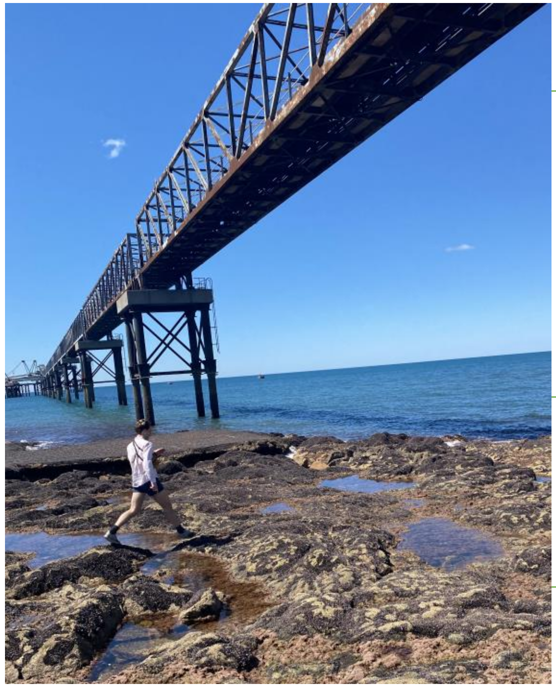
4. METODOLOGÍA
INVESTIGACIÓN HIDRÁULICA



PUNTA COLORADA MUELLE	Datos batimétricos Análisis hidrometeorológico
PUNTA COLORADA SUR	Datos batimétricos Análisis hidrometeorológico
PUERTO LOBOS	Análisis hidrometeorológico

4. METODOLOGÍA
INVESTIGACIÓN ESTRUCTURAL





PUNTA COLORADA MUELLE	Inspección visual Revisión de elementos estructurales
PUNTA COLORADA SOUTH	-
PUERTO LOBOS	-

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RN RíO NEGRO
TUDelft

5. ESTUDIO PRELIMINAR

1 SUPUESTOS PRIMARIOS
2 MAPA CONCEPTUAL
3 SISTEMA DE LA TERMINAL

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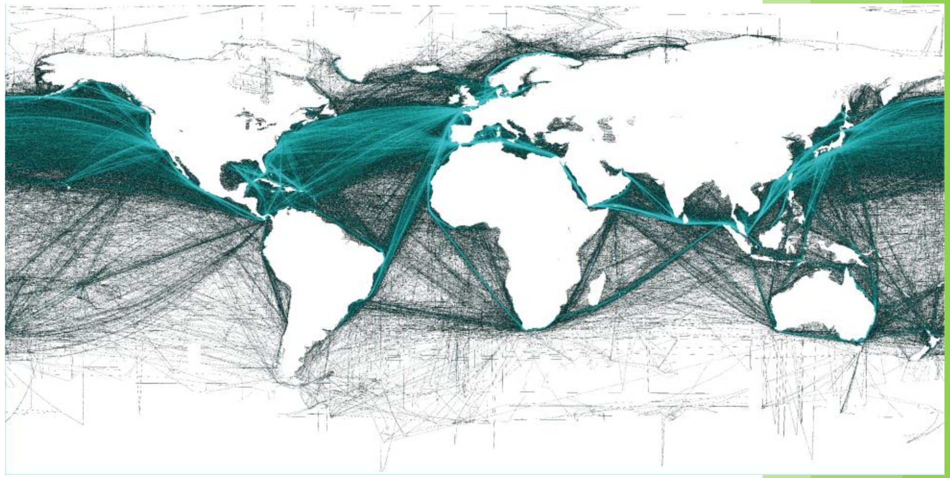
5. ESTUDIO PRELIMINAR
ESCENARIO A FUTURO



PLAZO	HORIZONTE	CAPACIDAD	MANERA DE EXPORTACIÓN
Corto	Año 2	2 GW	NH_3
Intermedio	Año 8	15 GW	NH_3
Largo	-	-	NH_3 or LH_2

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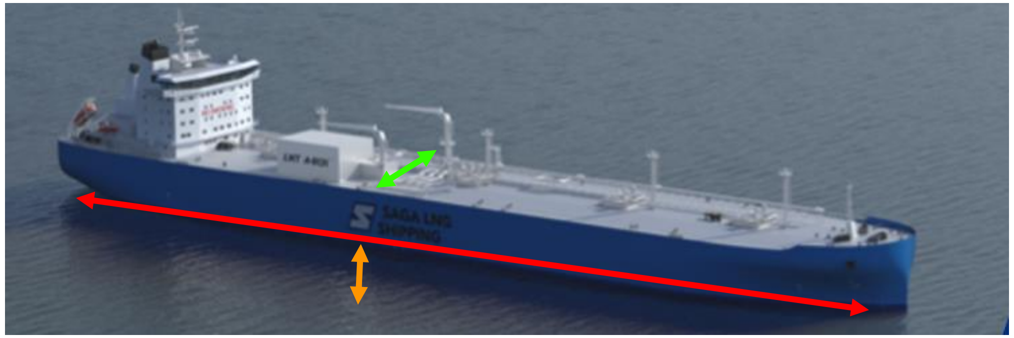
5. ESTUDIO PRELIMINAR
BARCOS ESPERADOS

Corto Plazo

75.000 m3



- Longitud: 230 m
- Profundidad requerida: 12 m
- Ancho: 35 m

Plazo Intermedio

220.000 m^3

- Longitud: 300 m
- Produndidad requerida: 17.3 m
- Ancho: 50 m

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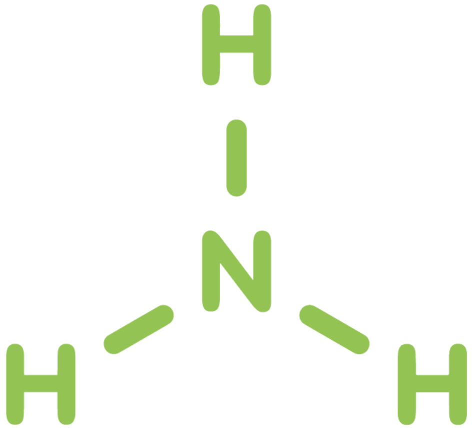
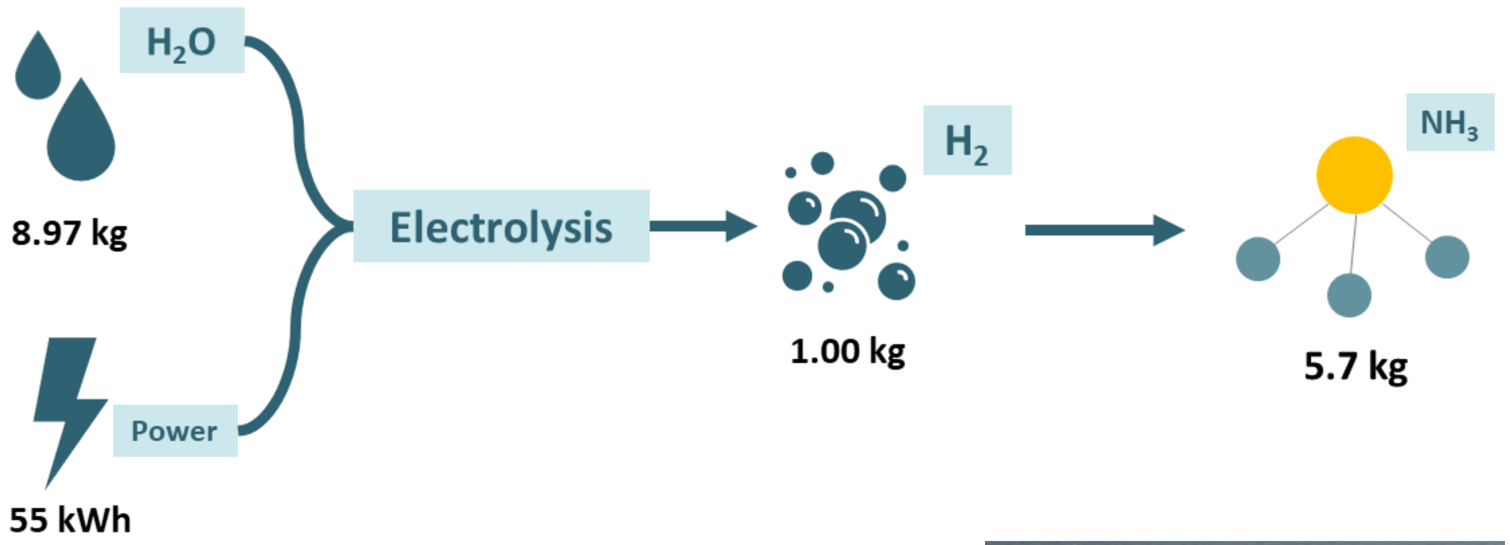
5. ESTUDIO PRELIMINAR
MANEJO DE AMMONIA

- Almacenar y transportar
  - Alta presión
  - Baja temperatura –34 °C



- Inflamable en alta concentracion
- En caso de derrame: Nube Toxica

5. ESTUDIO PRELIMINAR
PRODUCCIÓN DE AMMONIA

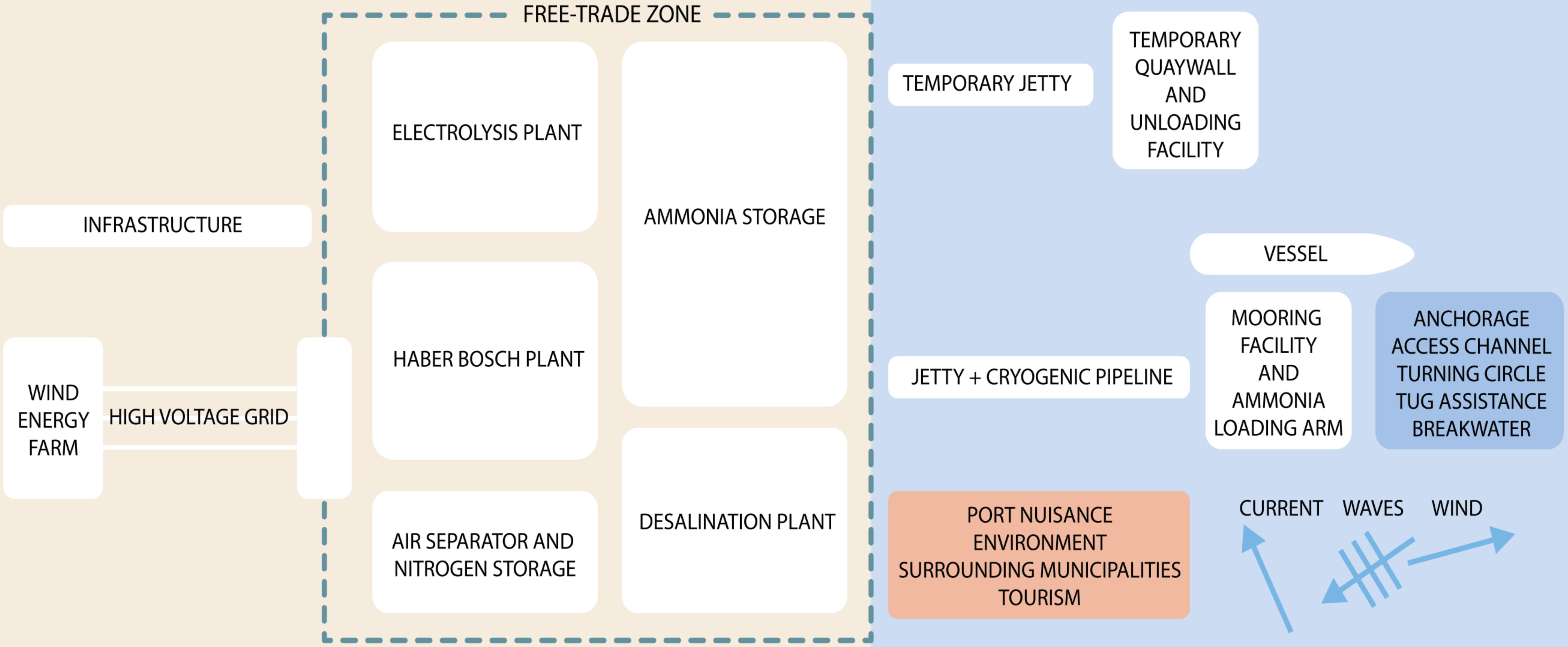


Corto Plazo	1.320.000 m^3 / año
Plazo Medio	9.880.000 m^3 / año

17.5 veces / año

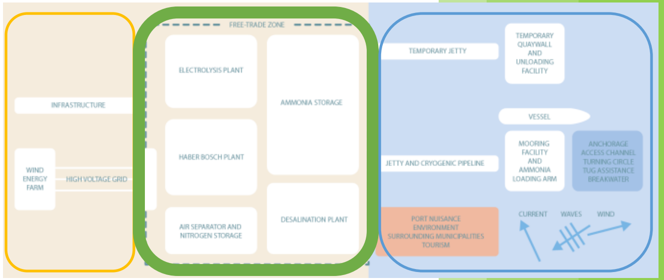
44.9 veces / año

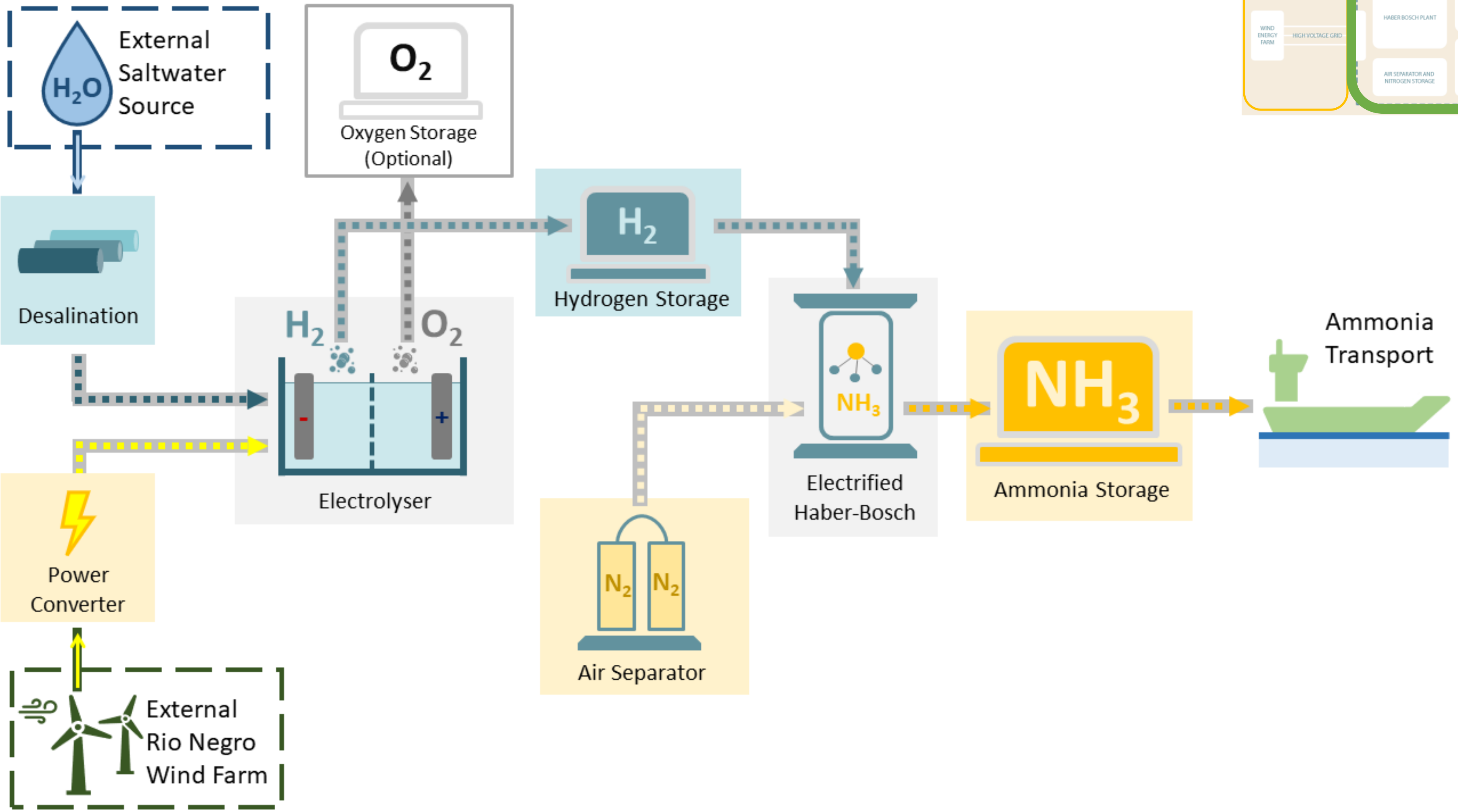
5. ESTUDIO PRELIMINAR
MAPA CONCEPTUAL



5. ESTUDIO PRELIMINAR
SISTEMA DE LA TERMINAL

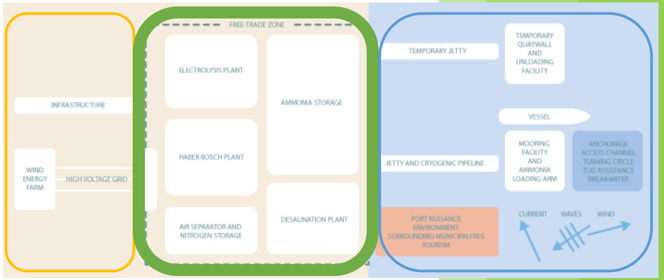
2. Port Terminal



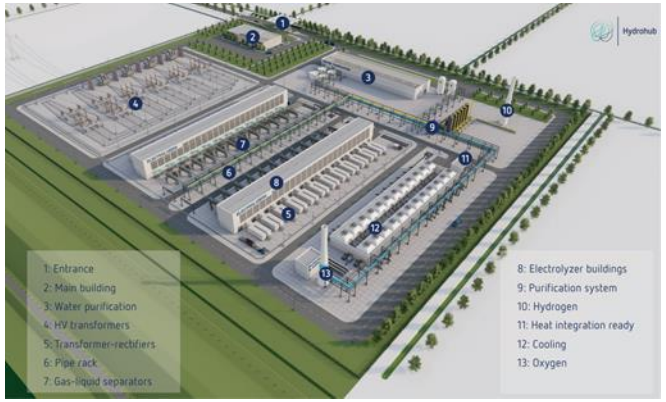


5. ESTUDIO PRELIMINAR ÁREA REQUIRIDA

2. Port Terminal



Electrolizador



Planta de amoníaco

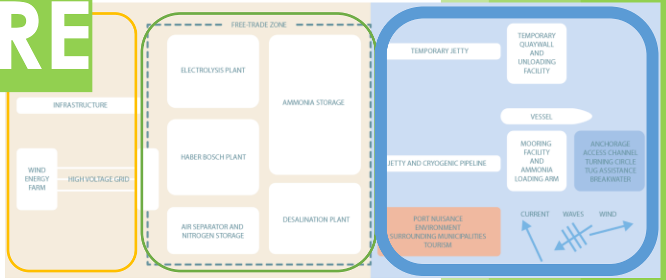
Almacenamiento de amoníaco

Corto Plazo	44.5 ha
Plazo Medio	329.5 ha

5. ESTUDIO PRELIMINAR

MUELLE Y INFRAESTRUCTURA DE AMARRE

3. Hydraulic



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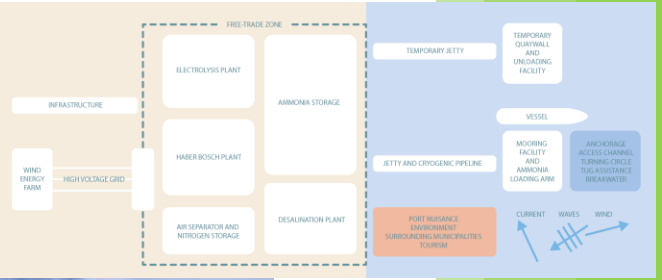
5. ESTUDIO PRELIMINAR
UNIDADES DE CARGA

3. Hydraulic



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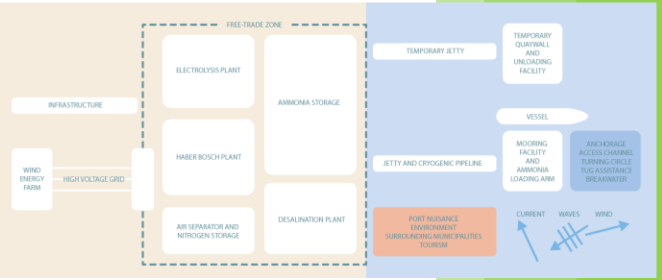
5. ESTUDIO PRELIMINAR
LÍMITES DE OPERACIÓN

3. Hydraulic



Description	$V_{wind,1\,min}$	$V_{current,1\,min}$	H_s
Turning areas			
• Without tug assistance	< 10 m/s	0.5 m/s	< 2.0-3.0 m
• With tug assistance	< 10 m/s	0.1 m/s	< 1.5-2.0 m
Vessel berthing			
• Forces longitudinal to berth	17.0 m/s	1.0 m/s	2.0 m
• Forces transverse to berth	10.0 m/s	0.1 m/s	1.5 m
Loading/unloading operations stoppage			
• Forces longitudinal to berth			
– < 30,000 DWT	22 m/s	1.5 m/s	1.5 m
– 30,000 DWT – 200,000 DWT	22 m/s	1.5 m/s	2.0 m
– > 200,000 DWT	22 m/s	1.5 m/s	2.5 m
• Forces transverse to berth			
– < 30,000 DWT	20 m/s	0.7 m/s	1.0 m
– 30,000 DWT – 200,000 DWT	20 m/s	0.7 m/s	1.2 m
– > 200,000 DWT	20 m/s	0.7 m/s	1.5 m
Vessel at the berth			
• Forces longitudinal to berth	30.0 m/s	2.0 m/s	3.0 m
• Forces transverse to berth	25.0 m/s	1.0 m/s	2.0 m

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6. RESULTADOS

1 PUNTA COLORADA MUELLE
2 PUNTA COLORADA SUR
3 PUERTO LOBOS

6. RESULTADOS: ESTRUCTURAL

PUNTA COLORADA MUELLE

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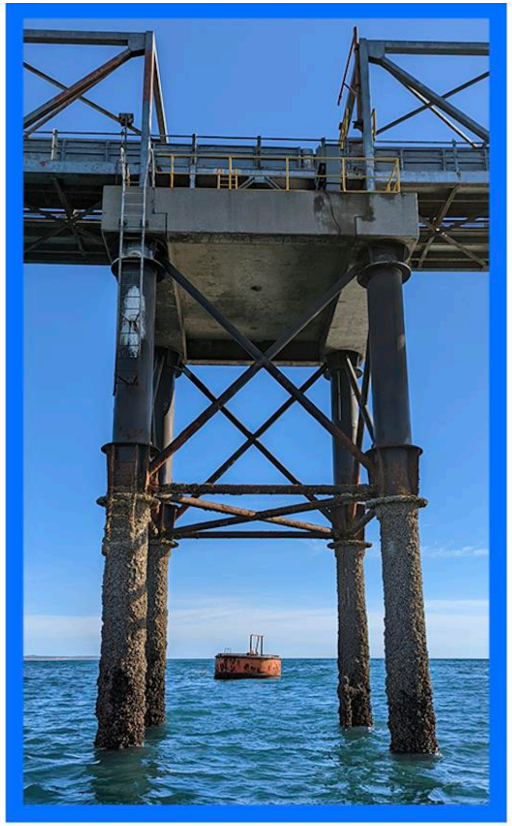
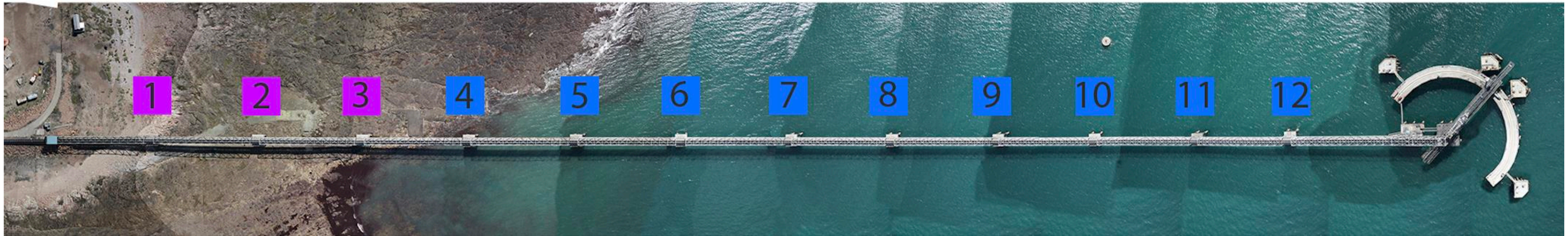
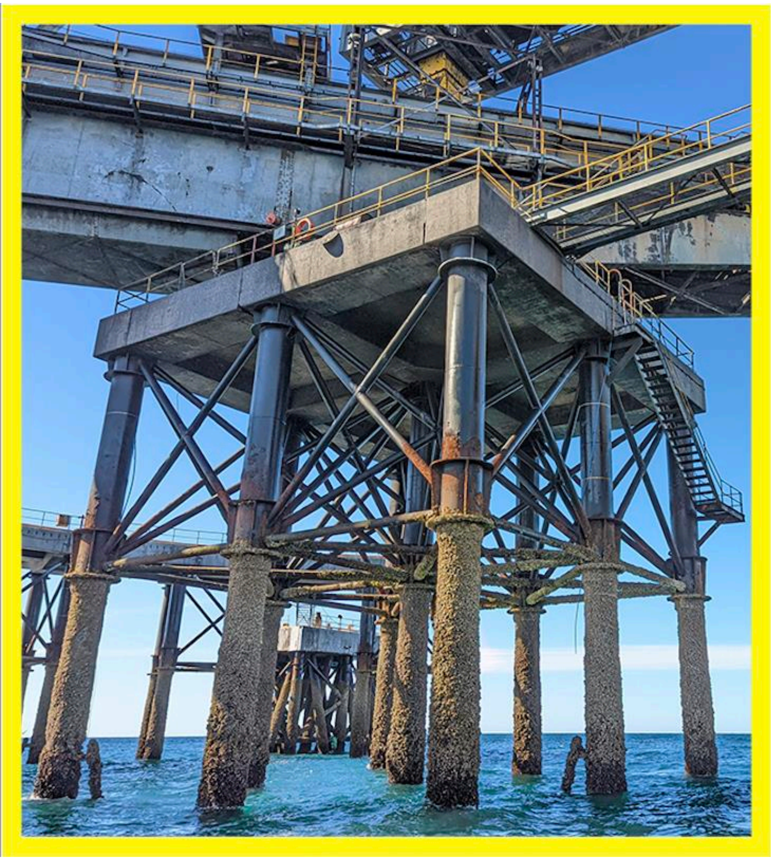
6. RESULTADOS: ESTRUCTURAL
PUNTA COLORADA MUELLE

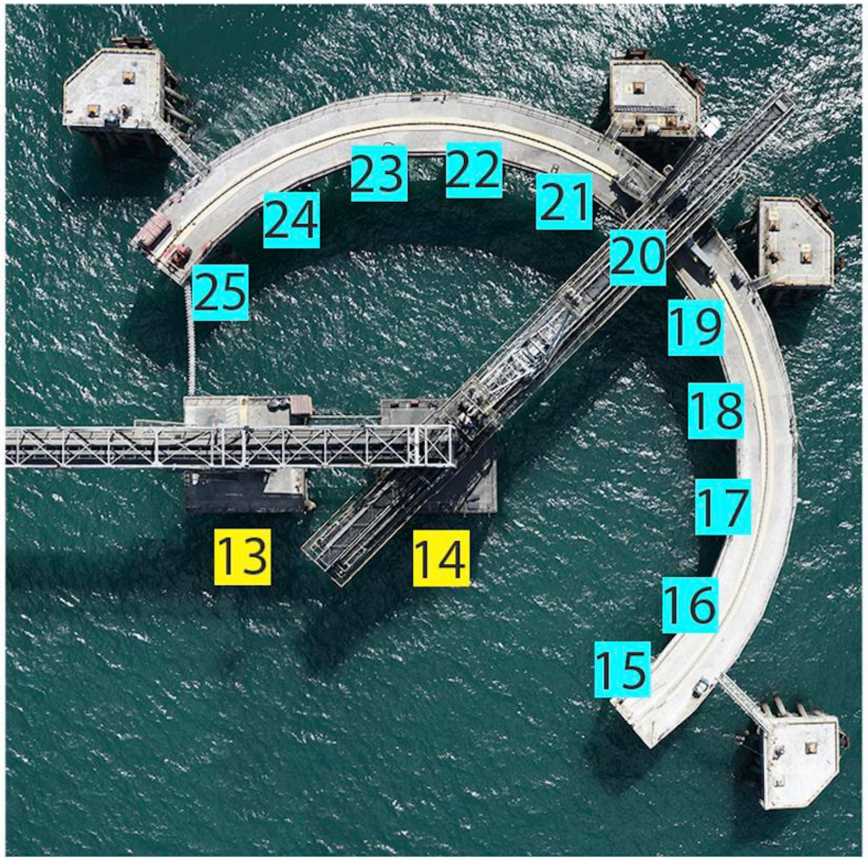


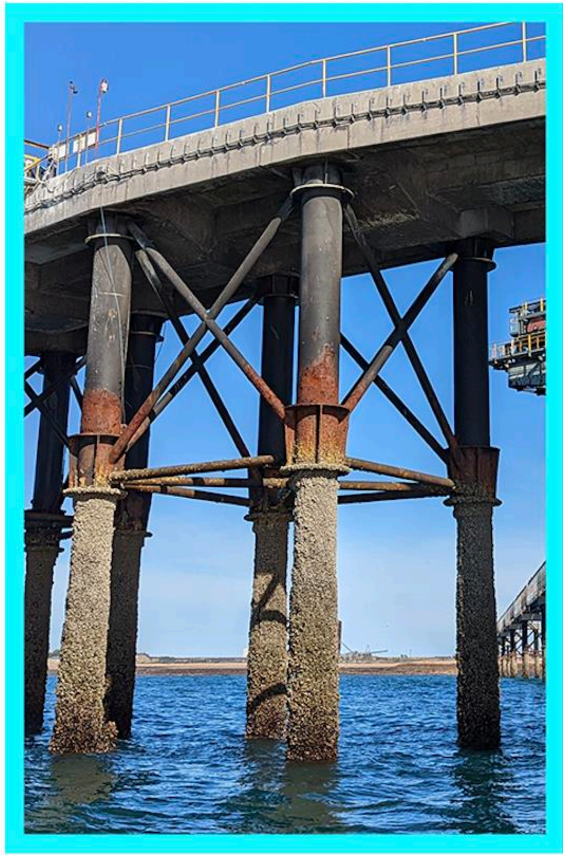
- Grupos de columnas hormigón (1-3)
- Grupos de columnas acero (4-12)



6. RESULTADOS: ESTRUCTURAL
PUNTA COLORADA MUELLE







- Grupos de columnas grandes acero (13,14)
- Grupos de columnas acero (15-25)

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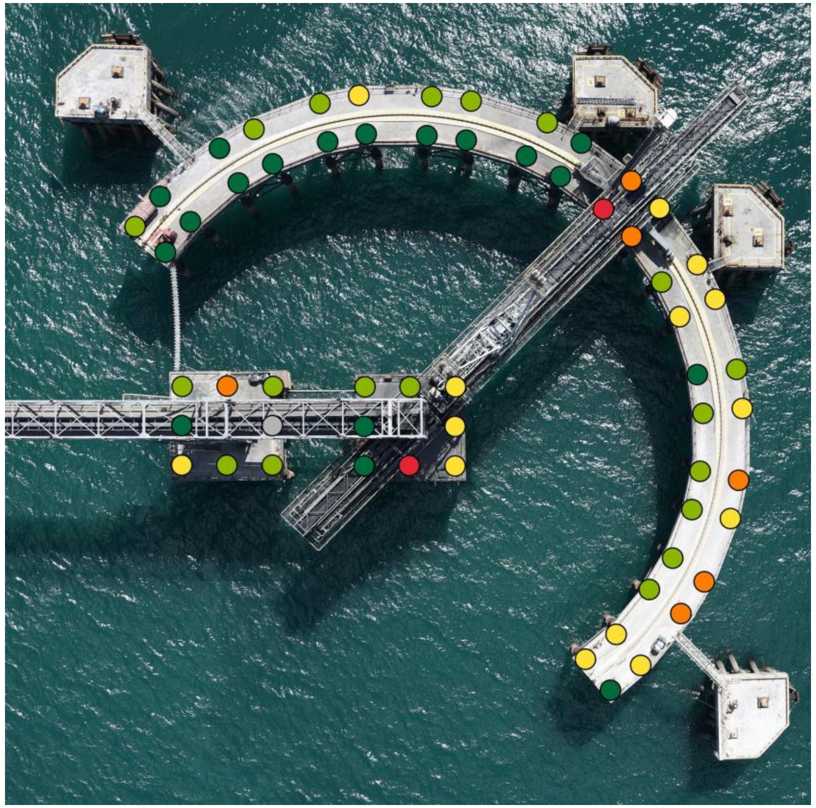
6. RESULTADOS: ESTRUCTURAL
PUNTA COLORADA MUELLE

C1 C2 C3 C4 C5



6. RESULTADOS: ESTRUCTURAL
PUNTA COLORADA MUELLE

PASARELA

6. RESULTADOS: ESTRUCTURAL
PUNTA COLORADA MUELLE

Cargador de barcos

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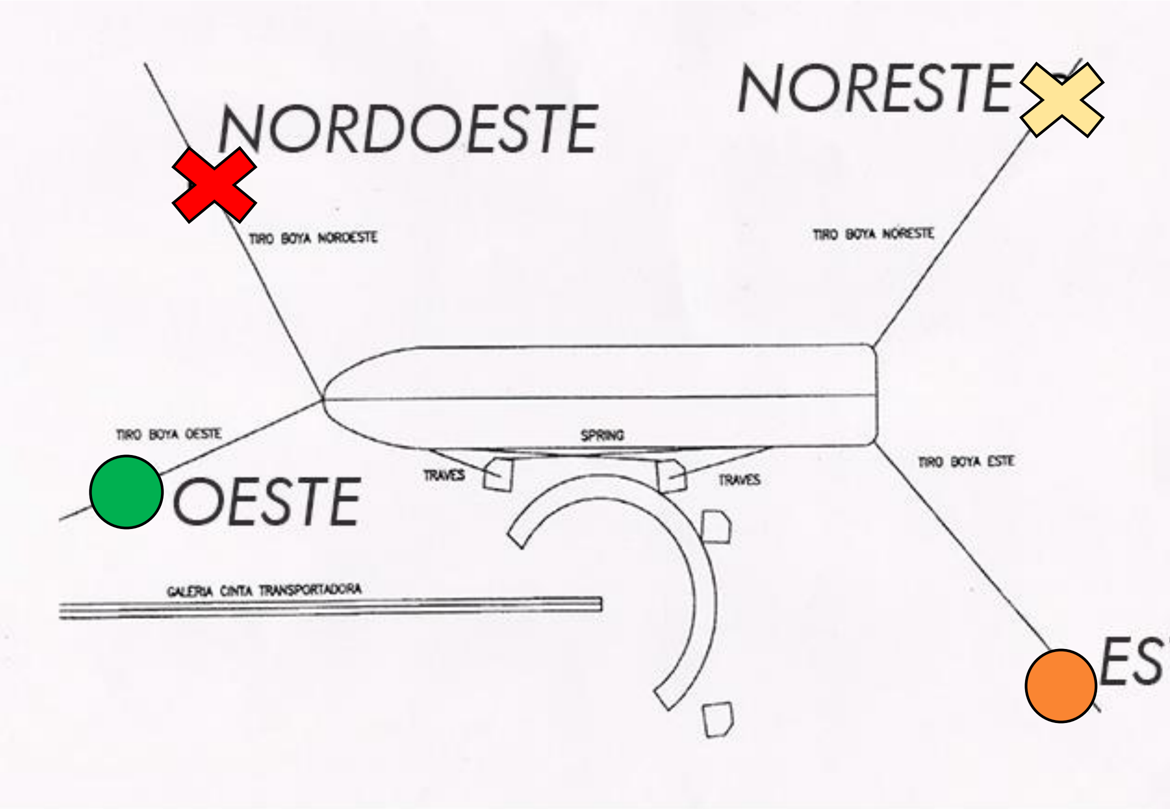
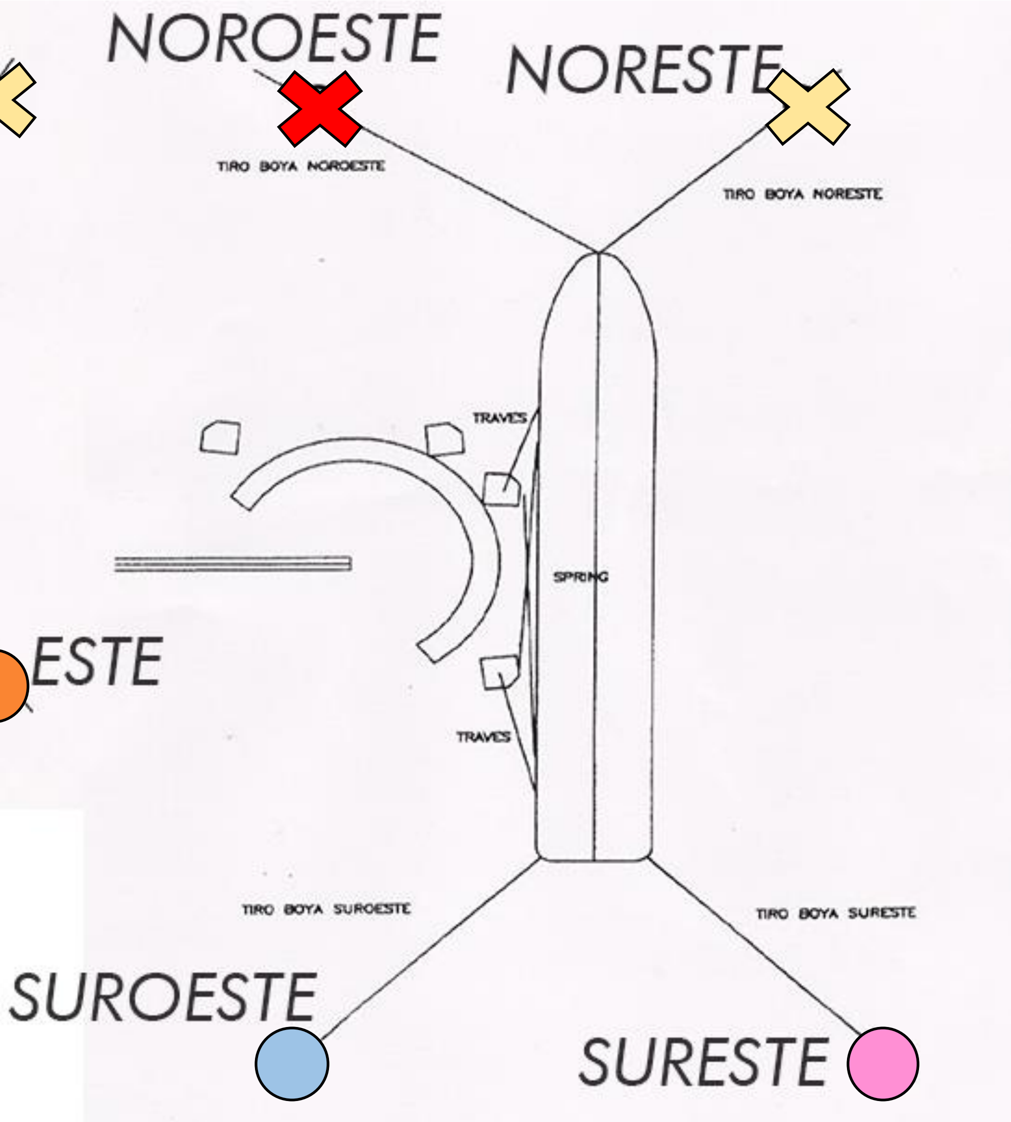
6. RESULTADOS: ESTRUCTURAL
PUNTA COLORADA MUELLE

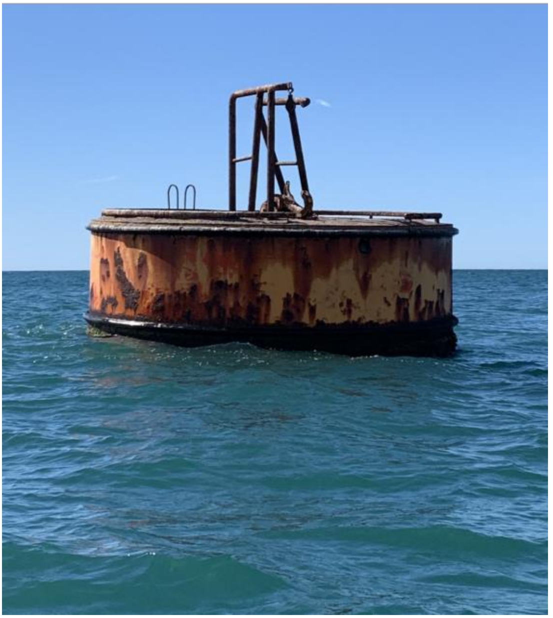




BOYAS

6. RESULTADOS: ESTRUCTURAL PUNTA COLORADA MUELLE

SUROESTE | SURESTE | ESTE | OESTE



BOYAS

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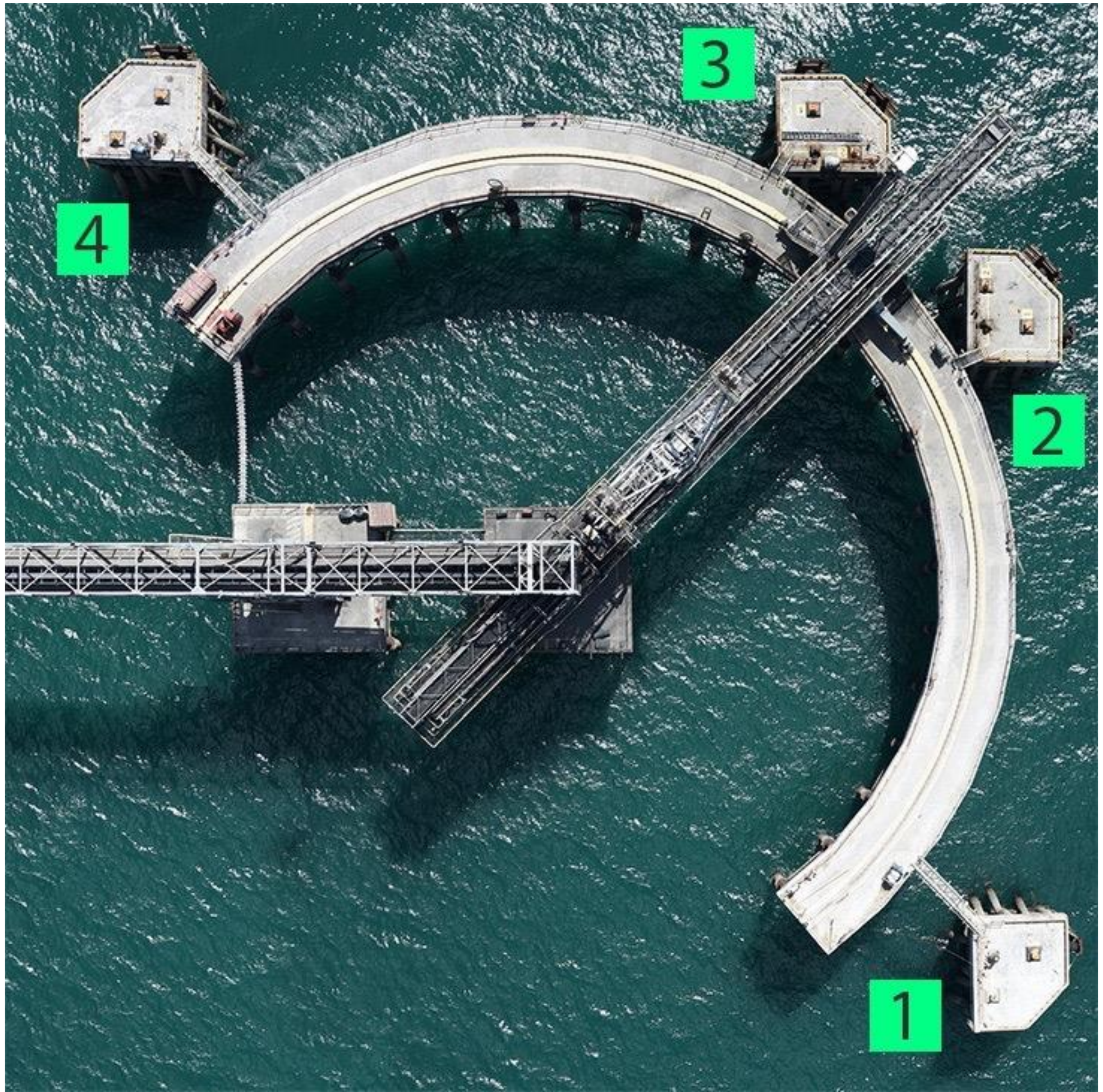
6. RESULTADOS: ESTRUCTURAL
PUNTA COLORADA MUELLE

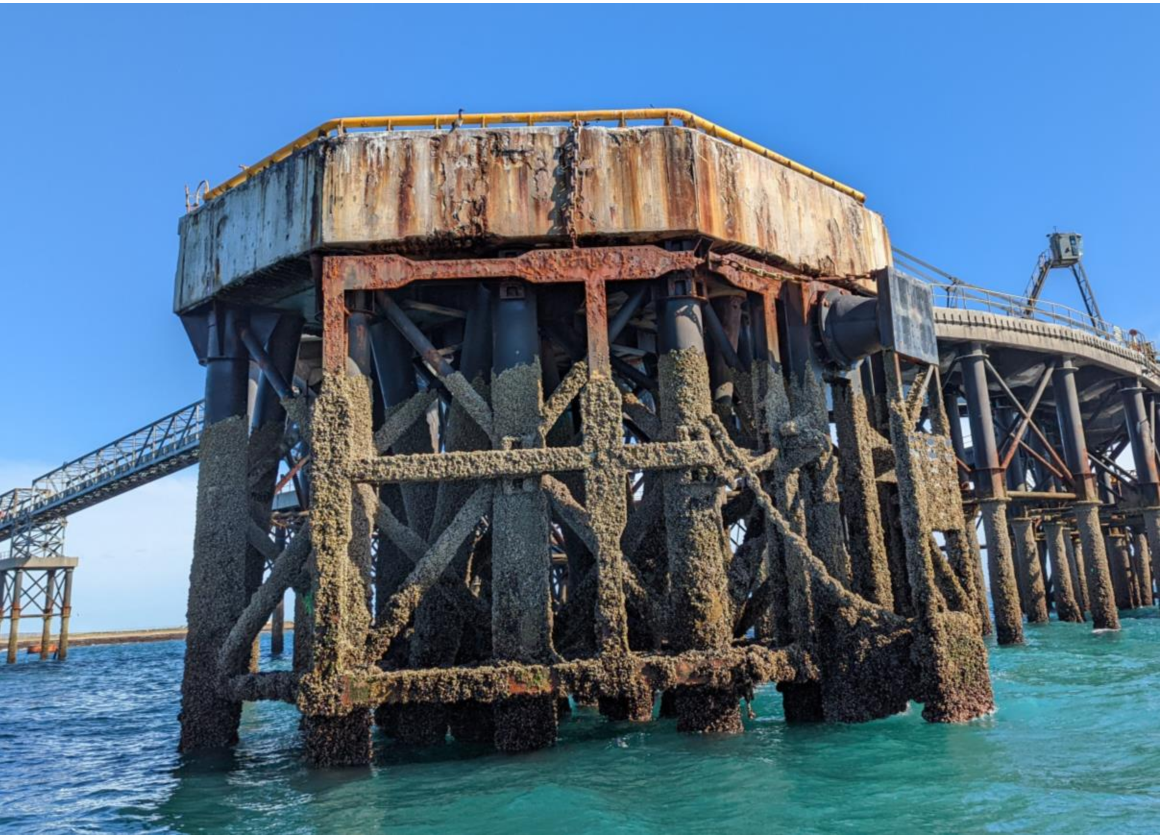
BOYAS

6. RESULTADOS: ESTRUCTURAL PUNTA COLORADA MUELLE

DUQUES DE ALBA



6. RESULTADOS: ESTRUCTURAL
PUNTA COLORADA MUELLE



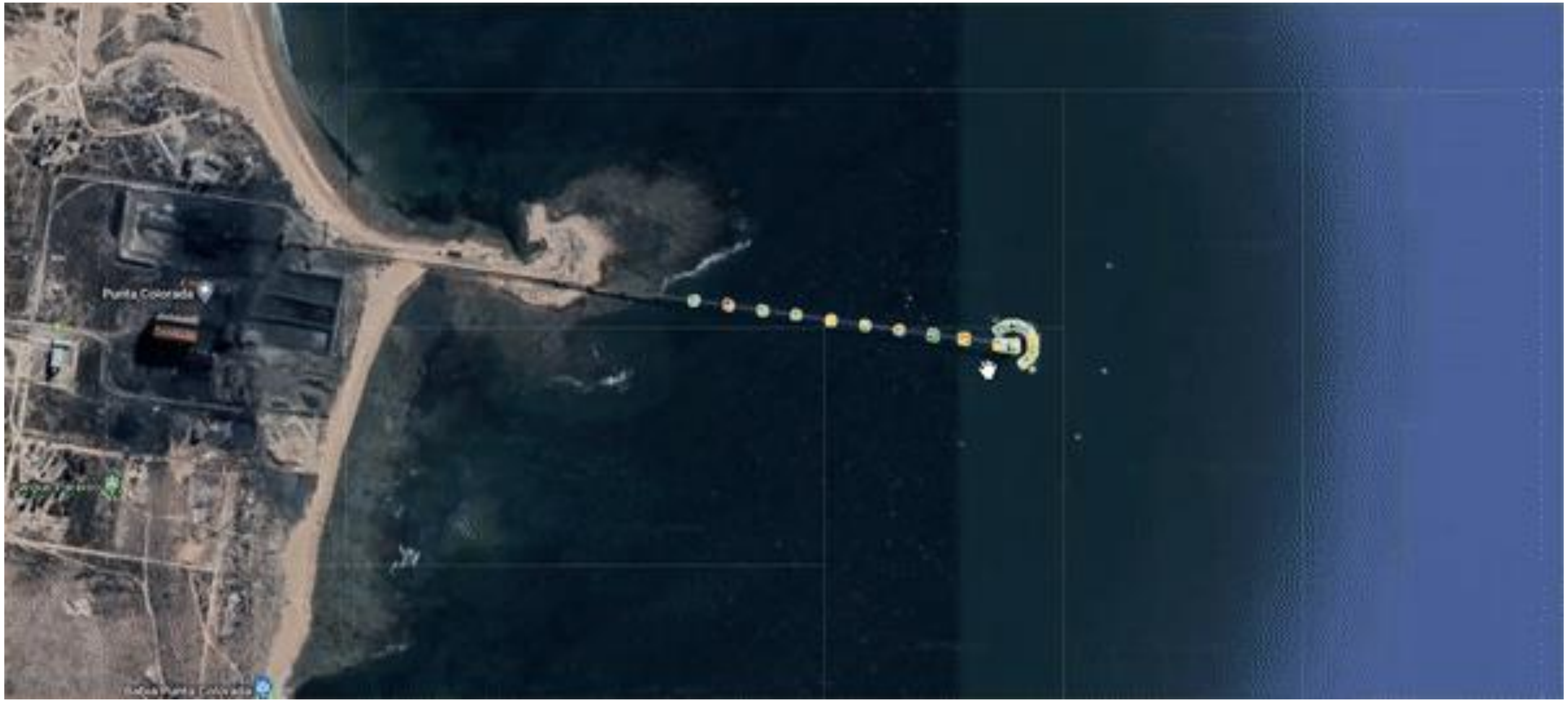
DUQUES DE ALBA

PORT CONSULTANTS ROTTERDAM RN RÍO NEGRO TU Delft

6. RESULTADOS: ESTRUCTURAL
PUNTA COLORADA MUELLE

DUQUES DE ALBA

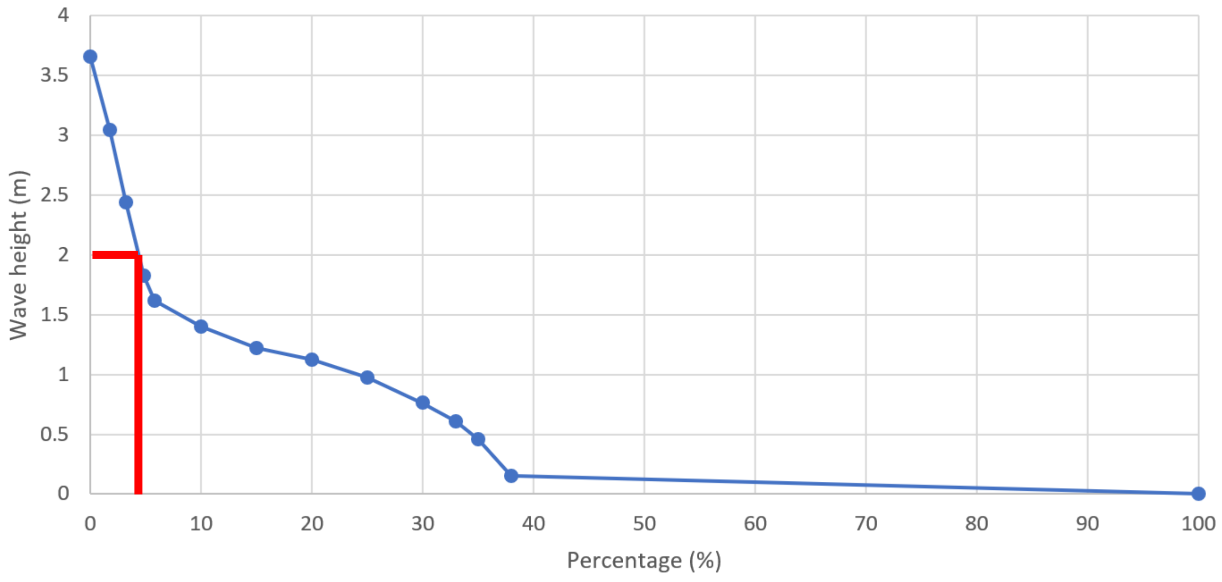
6. RESULTADOS: ESTRUCTURAL
PUNTA COLORADA MUELLE



6. RESULTADOS: INACTIVIDAD PUNTA COLORADA MUELLE

Description	$V_{wind,1\ min}$	$V_{current,1\ min}$	H_s
Vessel berthing			
• Forces longitudinal to berth	17.0 m/s	1.0 m/s	2.0 m

Altura del oleaje igual o mayor que



Tiempo de inactividad anual del puerto: Aprox. 14 días al año

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6. RESULTADOS: TOPOGRAFÍA
PUNTA COLORADA MUELLE

WINGTRAONE DRONE VÍDEO

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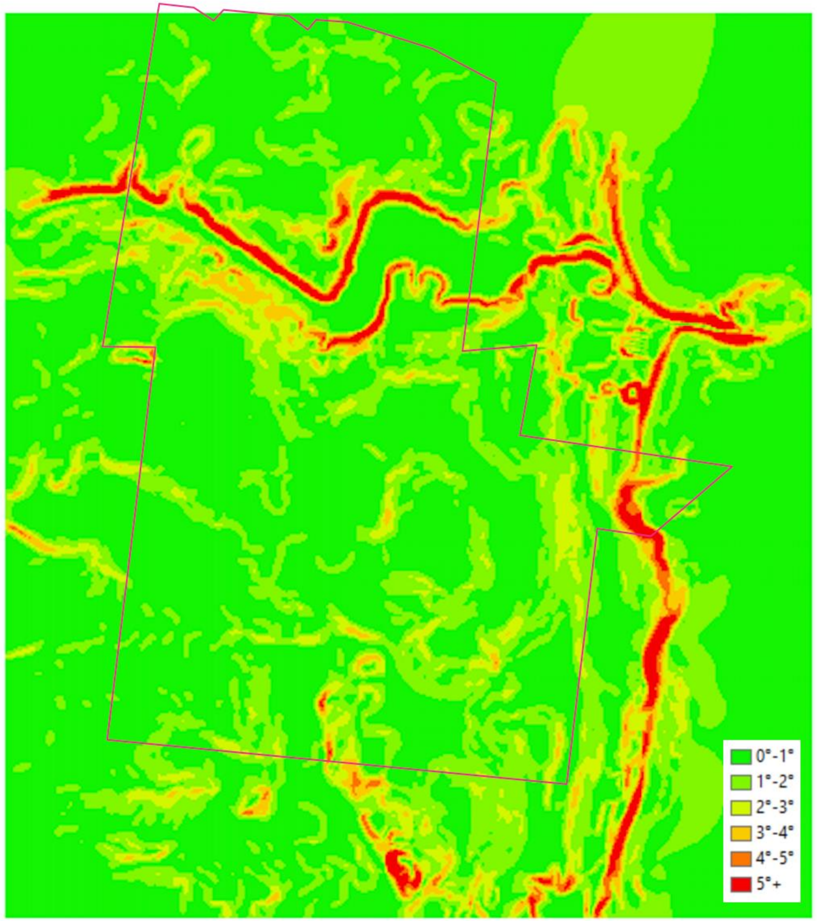
6. RESULTADOS: TOPOGRAFÍA

PUNTA COLORADA MUELLE



ELEVACIÓN

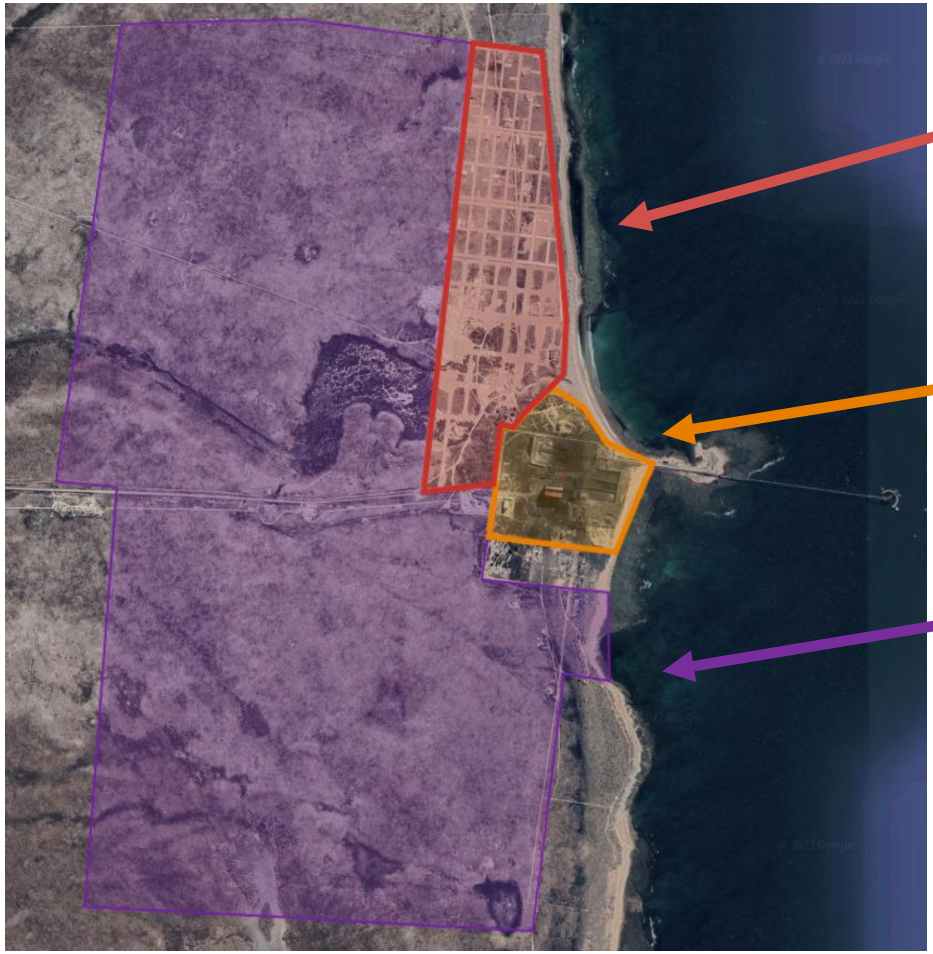
TERRENO DISPONIBLE

Corto Plazo
44.5 ha

Plazo Medio
329.5 ha

TERRENO NECESARIO

6. RESULTADOS: TOPOGRAFÍA PUNTA COLORADA MUELLE

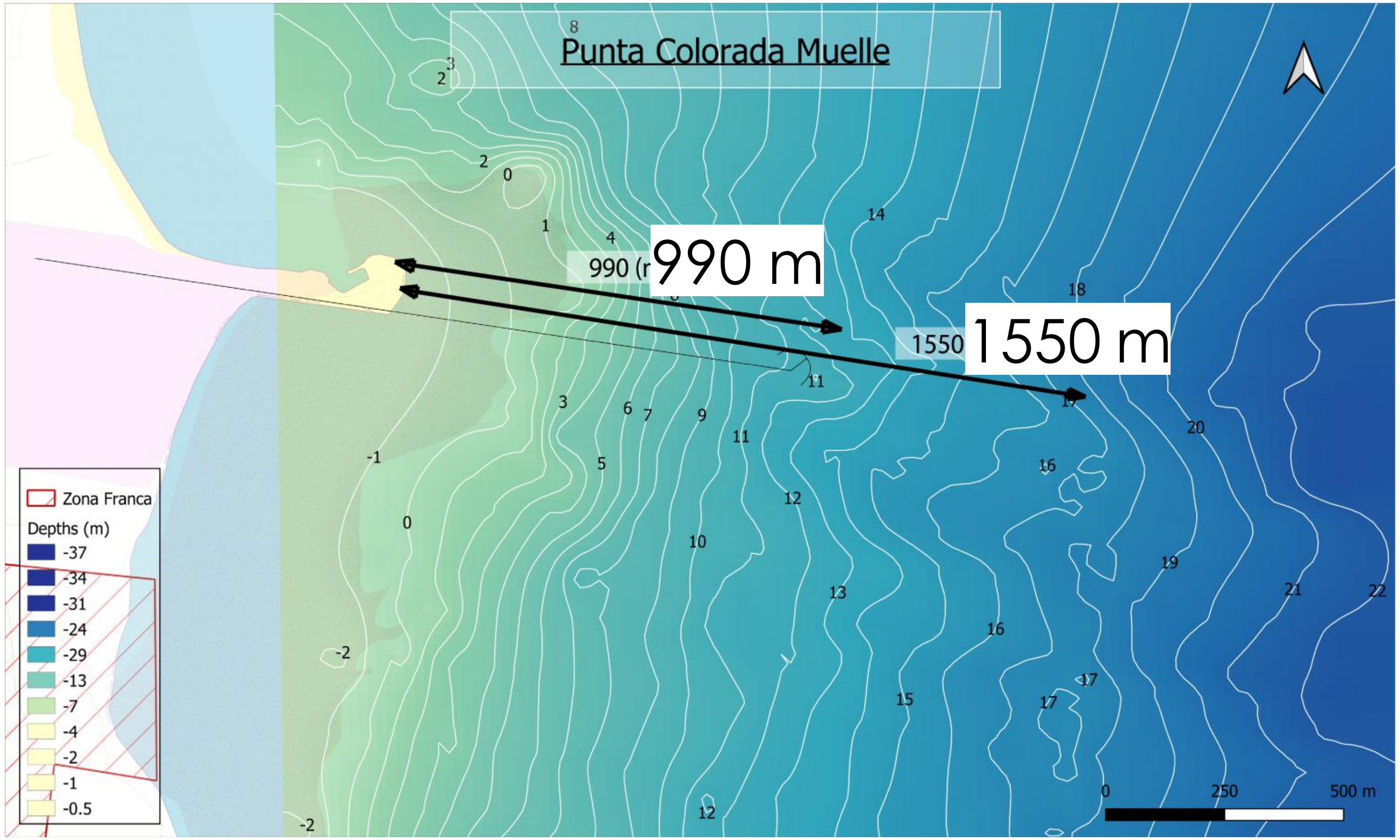


Proyecto de urbanización “Costa Doradas”

Estructuras de MCC

Zona Franca

6. RESULTADOS: BATIMETRÍA
PUNTA COLORADA MUELLE

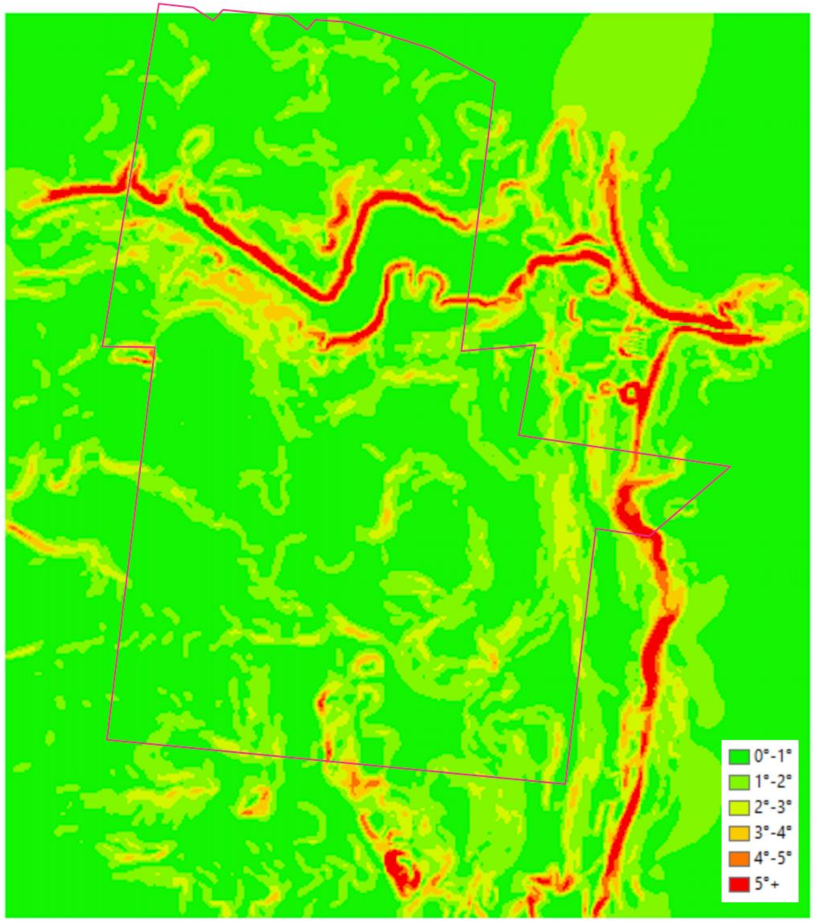


DISTANCIA DE LA ORILLA A LA PROFUNDIDAD REQUERIDA

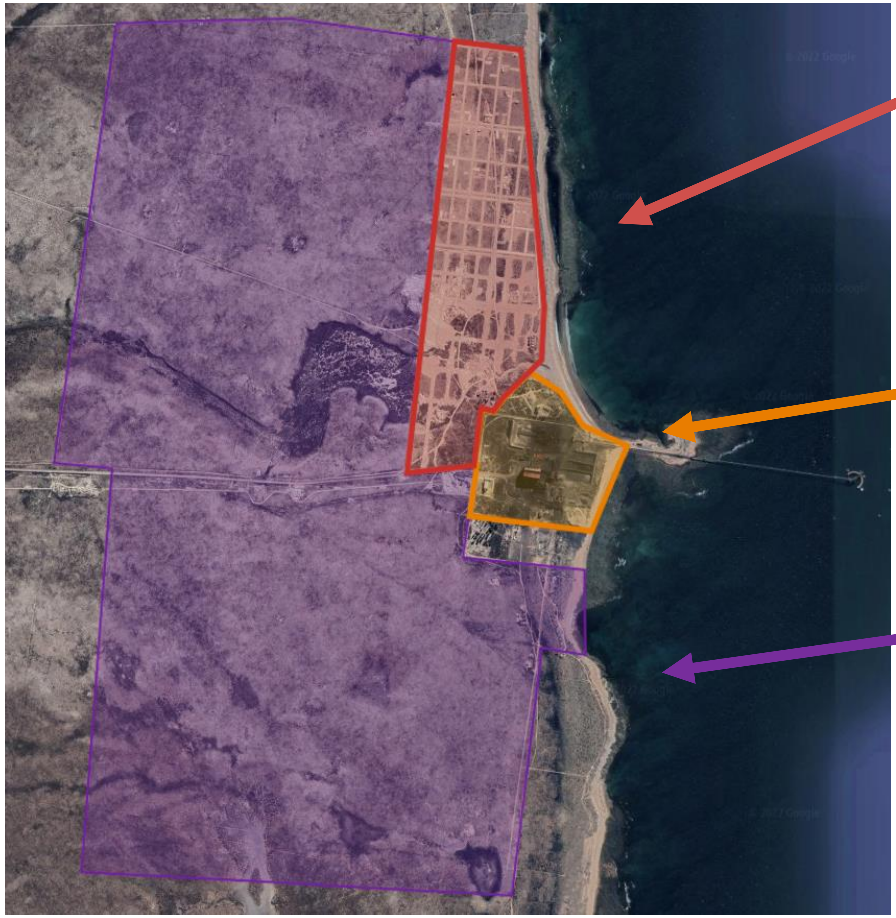
6. RESULTADOS

PUNTA COLORADA SUR

6. RESULTADOS: TOPOGRAFÍA PUNTA COLORADA SUR



ELEVACIÓN



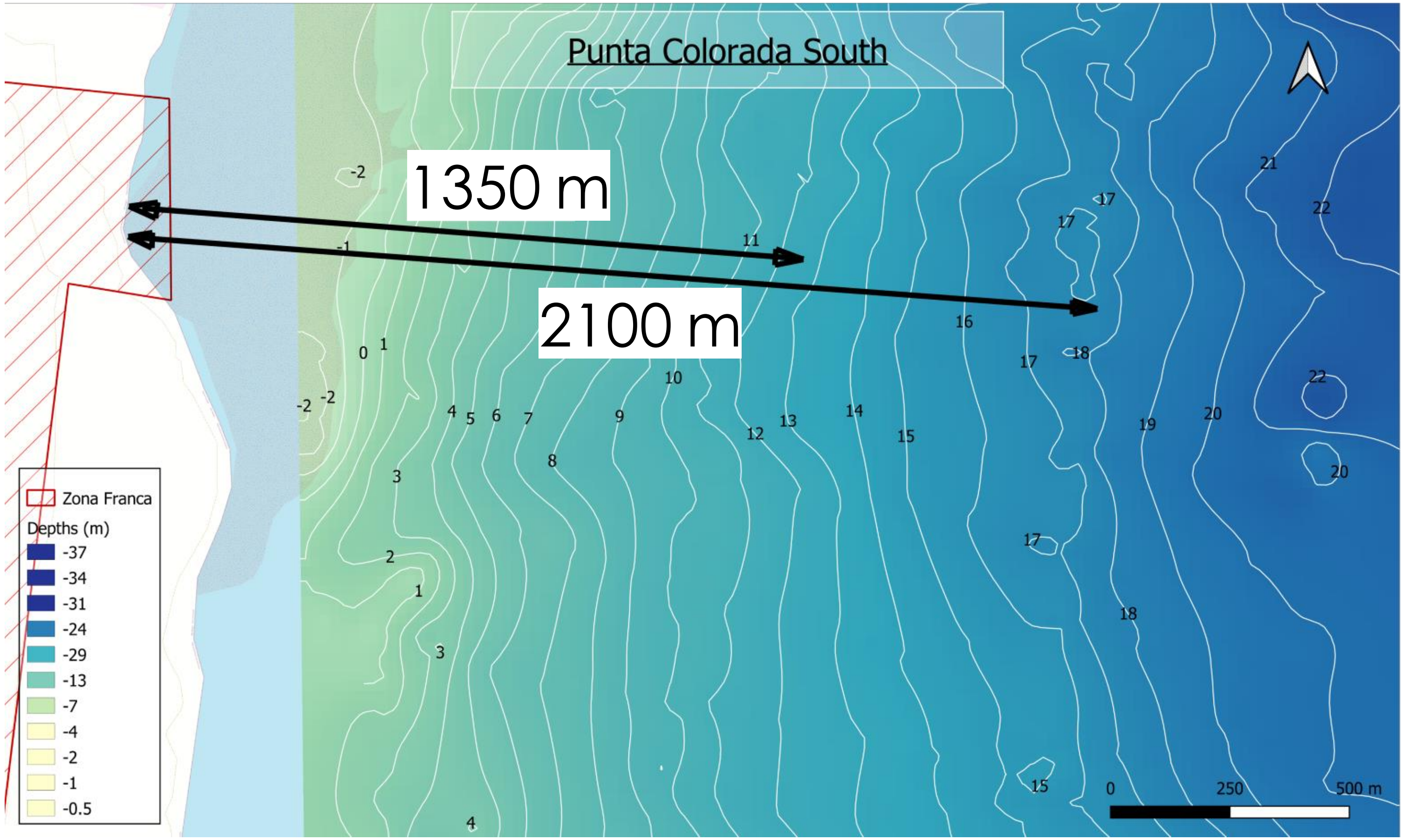
ZONAS DIFFERENTES

Proyecto de urbanización "Costa Doradas"

Estructuras de MCC

Zona Franca

6. RESULTADOS: BATIMETRÍA
PUNTA COLORADA SUR

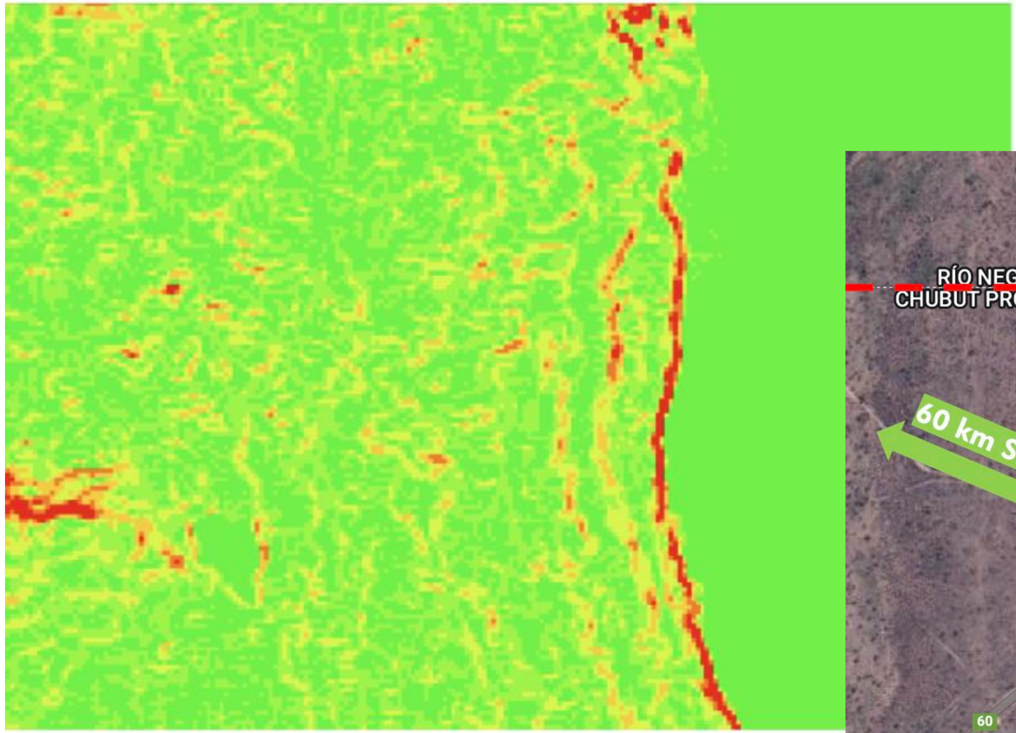


DISTANCIA DE LA ORILLA A LA PROFUNDIDAD REQUERIDA

6. RESULTADOS

PUERTO LOBOS

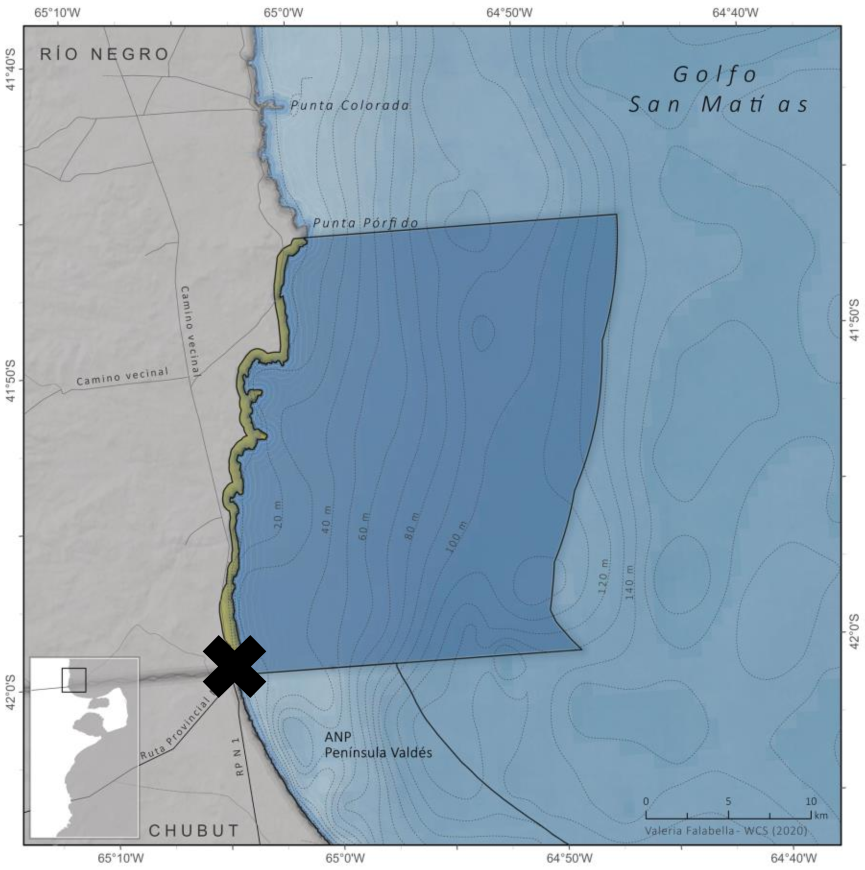
6. RESULTADOS: TOPOGRAFÍA
PUERTO LOBOS

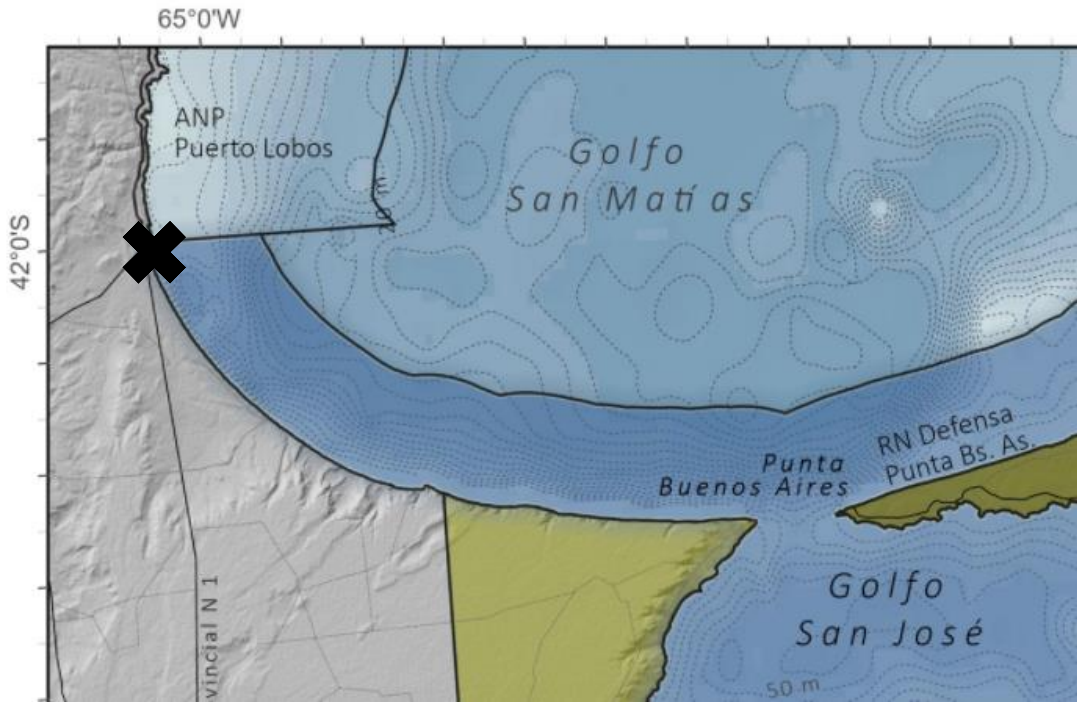


ELEVACIÓN

6. RESULTADOS: TOPOGRAFÍA
PUERTO LOBOS

ÁREAS NATURALES PROTEGIDAS PUERTO LOBOS Y PENINSULA VALDES





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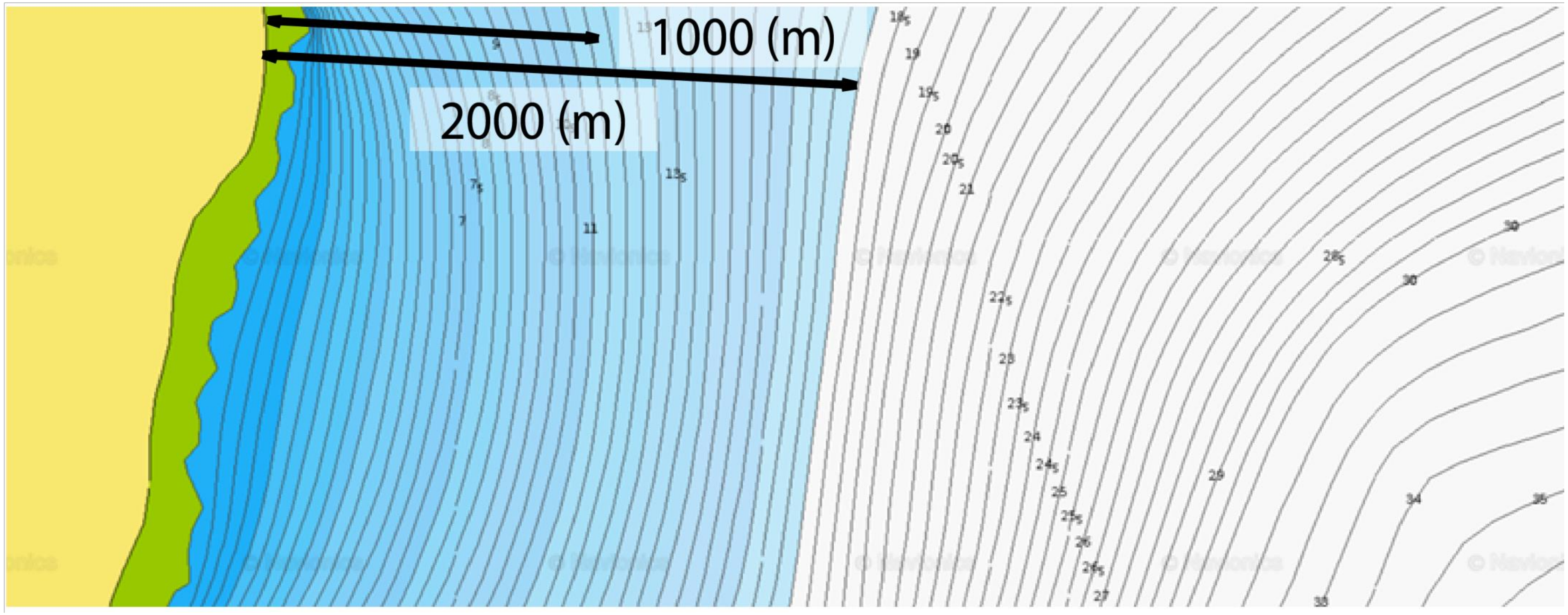
6. RESULTADOS: BATIMETRÍA
PUERTO LOBOS



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7. RESUMEN TRES UBICACIÓNES

1 PUNTA COLORADA MUELLE
2 PUNTA COLORADA SUR
3 PUERTO LOBOS

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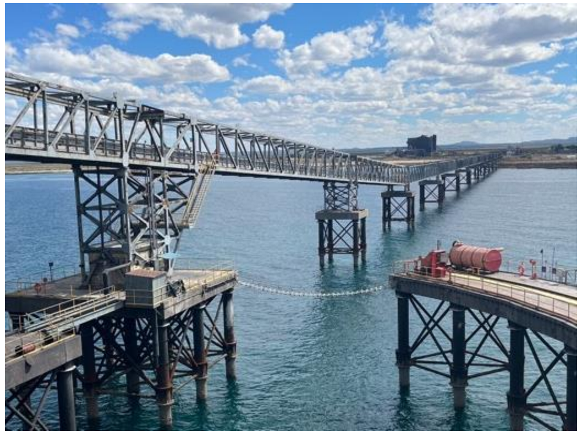
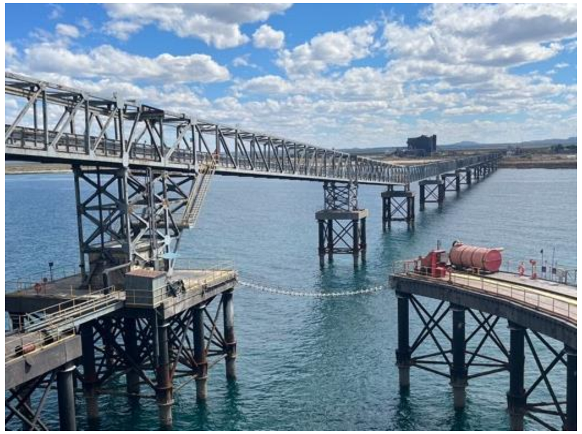
7. RESUMEN TRES UBICACIÓNES
MARINA PROTEGIDA



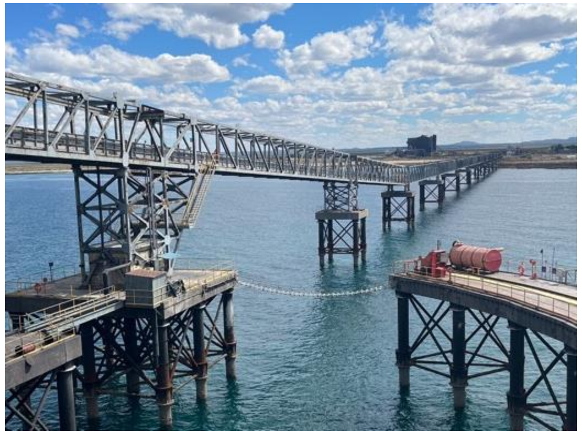
	Punta Colorada Muelle	Punta Colorada Sur	Puerto Lobos
Presencia de área marina protegida	No área de marina protegida	No área de marina protegida	Presencia de áreas marinas protegidas

7. RESUMEN TRES UBICACIÓNES
REUTILIZACIÓN MUELLE



	Punta Colorada Muelle	Punta Colorada Sur	Puerto Lobos
Reutilización potencial del muelle	Si, aunque es necesario profundizar la investigación estructural	No	No

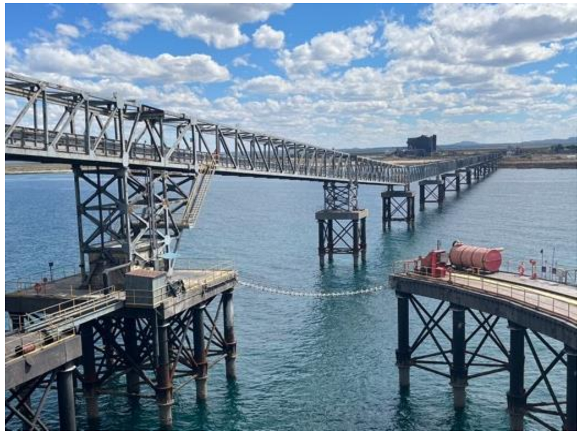
7. RESUMEN TRES UBICACIÓNES
TERRENO DISPONIBLE



	Punta Colorada Muelle	Punta Colorada Sur	Puerto Lobos
Terreno disponible para construcción	Área suficiente, aunque con estructuras existentes	Área suficiente y no hay estructuras existentes cercanas	Área suficiente y no hay estructuras existentes cercanas

7. RESUMEN TRES UBICACIÓNES

ZONA FRANCA



	Punta Colorada Muelle	Punta Colorada Sur	Puerto Lobos
Presencia de zona franca	Beneficios financieros debido a la zona franca	Beneficios financieros debido a la zona franca	No presencia de una zona franca

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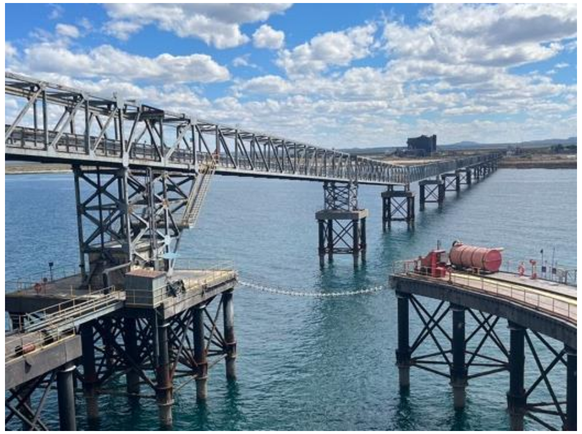
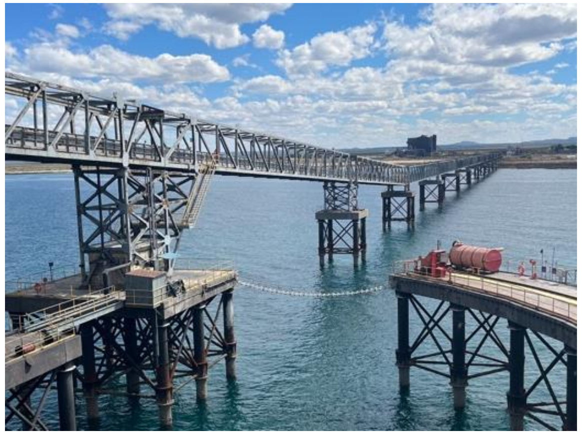
7. RESUMEN TRES UBICACIÓNES
DISTANCIA COSTA - PROFUNDIDAD



	Punta Colorada Muelle	Punta Colorada Sur	Puerto Lobos
Distancia desde la costa hasta la profundidad requerida	990m / 1510m	1390m/ 2750m	1000m / 2000m (datos poco fiables)

7. RESUMEN TRES UBICACIÓNES
PRESENCIA AREAS RESIDENCIAL



	Punta Colorada Muelle	**Punta Colorada Sur**	**Puerto Lobos**
Presencia de áreas residencial	Playas Doradas a 5 km, potencial área residencial adyacente	Playas Doradas a 6 km, potencial área residencial adyacente	No áreas residenciales cercanos

7. RESUMEN TRES UBICACIÓNES

	Punta Colorada Muelle	Punta Colorada Sur	Puerto Lobos
Presencia de área marina protegida	No hay área de marina protegida	No hay área de marina protegida	**Presencia de áreas marinas protegidas**
Reutilización potencial del muelle	Si, aunque es necesario profundizar la investigación estructural	**No**	**No**
Terreno disponible para construcción	Área suficiente, aunque con estructuras existentes	Área suficiente y no hay estructuras existentes cercanas	Área suficiente y no hay estructuras existentes cercanas
Presencia de zona franca	Beneficios financieros debido a la zona franca	Beneficios financieros debido a la zona franca	**No presencia de una zona franca**
Distancia desde la costa hasta la profundidad requerida	990m / 1510m	1390m/ 2750m	1000m / 2000m (datos poco fiables)
Presencia de áreas residencial	Playas Doradas a 5 km, potencial área residencial adyacente	Playas Doradas a 6 km, potencial área residencial adyacente	No hay áreas residenciales cercanas

8. CONCLUSIONES

Ubicaciones de Punta Colorada

- Ambas ubicaciones de Punta Colorada muestran potencial para construir un puerto de exportación de hidrógeno y tienen características similares; ausencia de áreas marinas protegidas y disponibilidad de zonas francas.
- El muelle existente tiene potencial para un diseño de un puerto de hidrógeno rentable a corto plazo
- Punta Colorada Sur no tiene interferencia de MCC y no tiene restricciones de diseño debido a la infraestructura existente

8. CONCLUSIONES

Puerto Lobos

- Puerto Lobos muestra desventajas en ciertos criterios muy importantes como áreas marinas protegidas y zona franca.
- Poca información, por lo tanto, no se llego a una conclusión completa sobre esta ubicación

9. RECOMENDACIONES

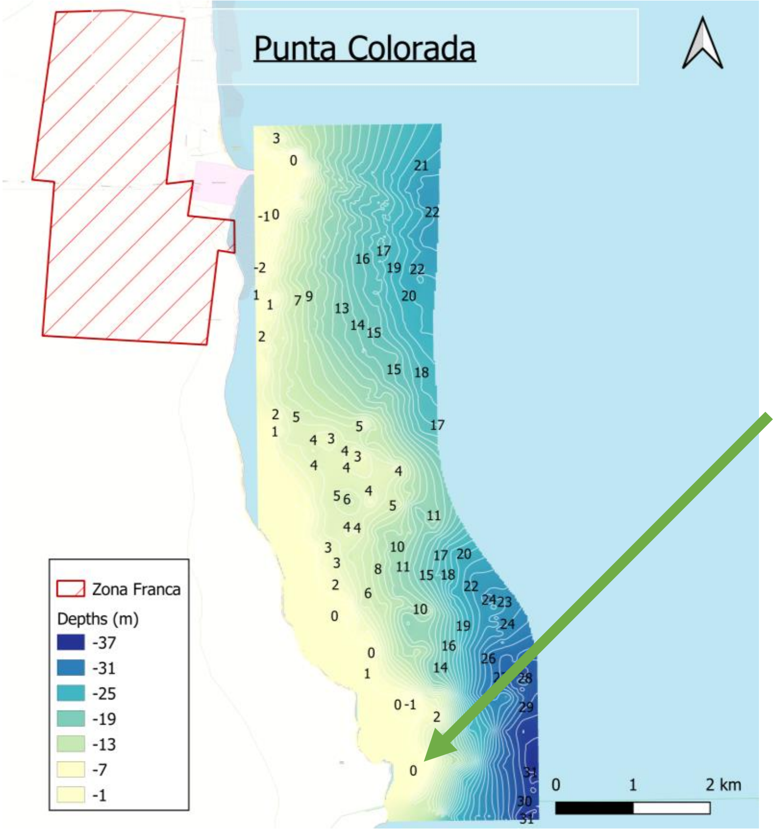
Mas investigación sobre el muelle existente

- Recuperar cálculos y planos de diseño
- Determinar la capacidad estructural actual
- Posible reparación o reemplazo de la infraestructura de amarre (duques de alba y boyas)

Para completar comparación de ubicaciones:

- Puerto Lobos: determinar flexibilidad del área marina protegida y posibilidad de una zona franca
- Completar relevamiento: batimetría y topografía

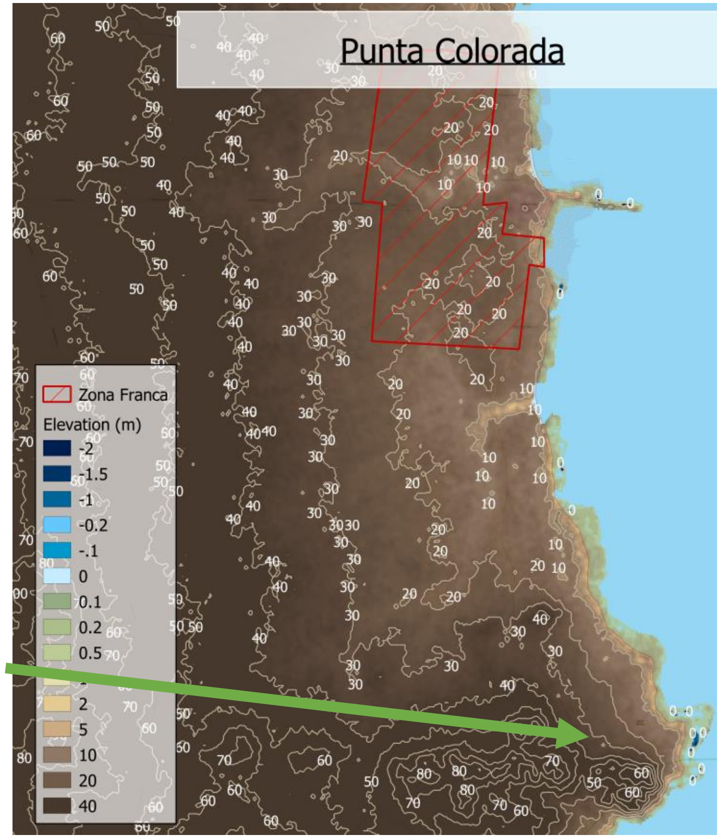
9. RECOMENDACIONES



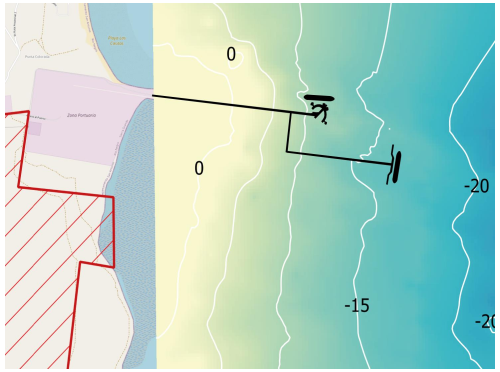
Investigar Punta Pórfido

Batimetría favorable

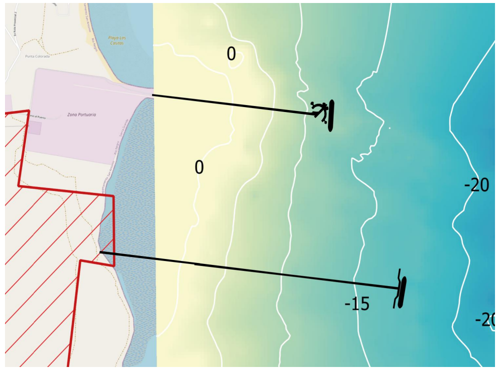
Características en tierra



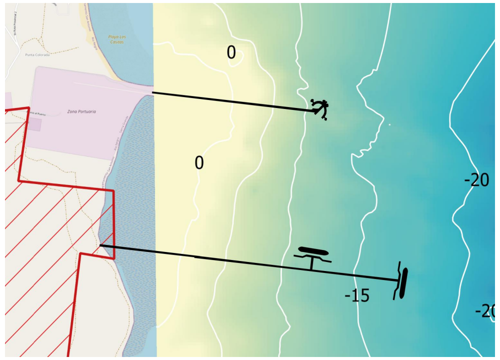
10. ESCENARIO POTENCIAL DEL PUERTO
ALTERNATIVAS



Alternativa 1:
- Corto plazo: Reutilizar muelle existente
- Intermedio plazo: Extender el muelle existente a profundidad mayor



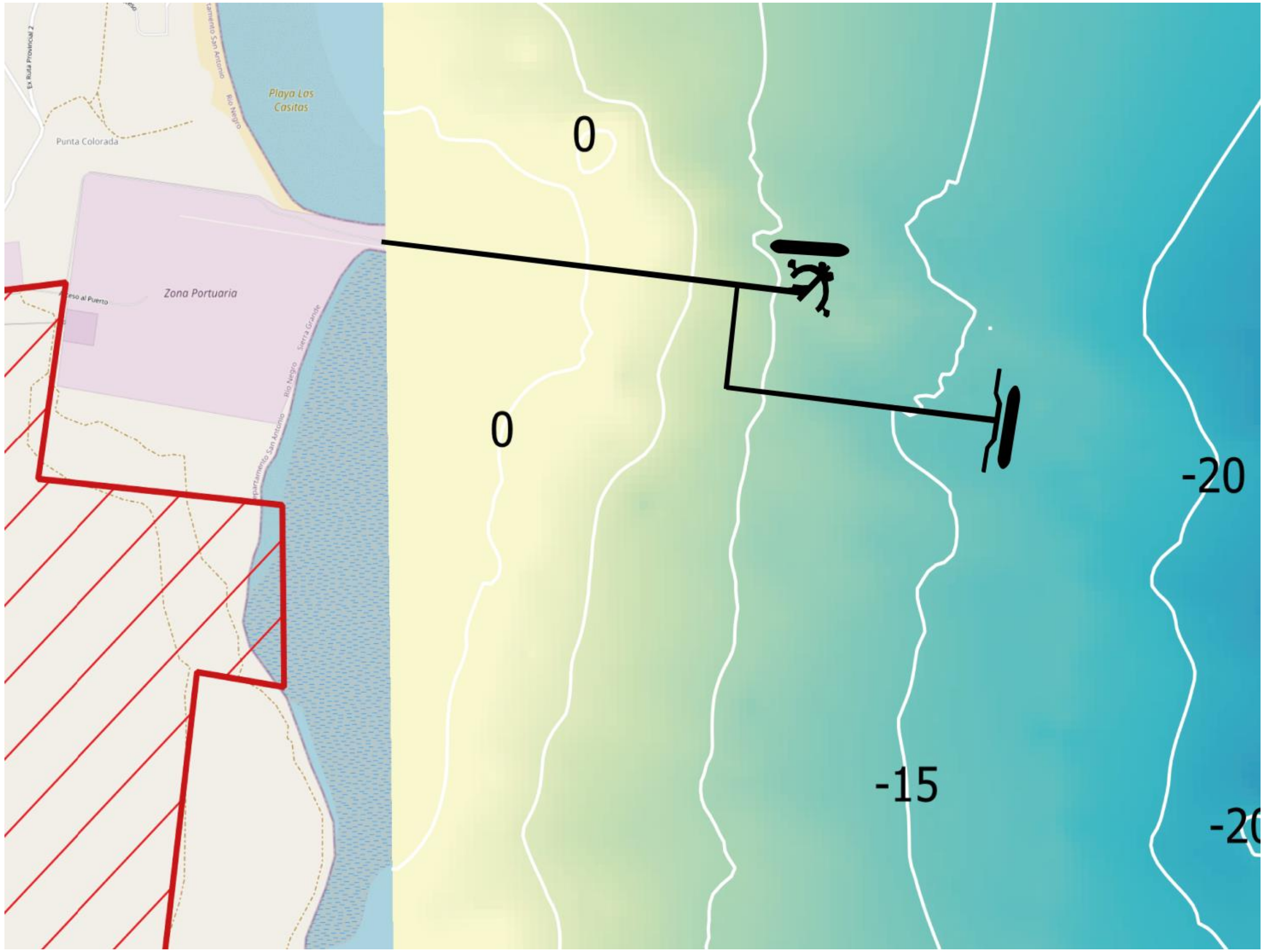
Alternativa 2:
- Corto plazo: Reutilisar muelle existente
- Intermedio plazo: Construir un nuevo muelle a profundidad mayor



Alternativa 3:
- Corto plazo: Construir un nuevo muelle a poca profundidad
- Intermedio plazo: Construir el nuevo muelle a profundidad mayor

10. ESCENARIO POTENCIAL DEL PUERTO

ALTERNATIVA 1

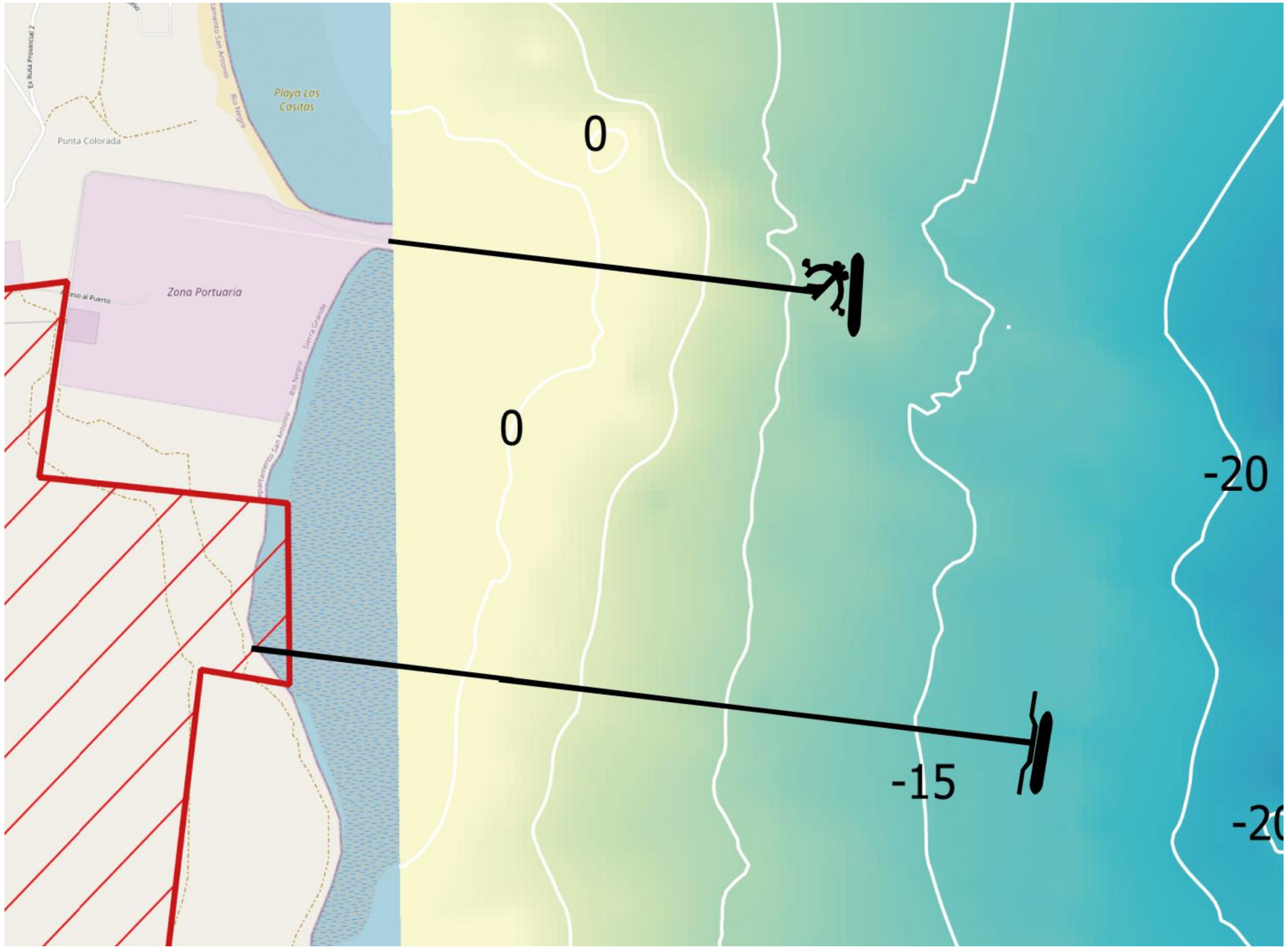


- Inicio rapido de las operaciones de exportacion
- Reduccion potential de inversion
- sostenible

- Las operaciones a largo plazo dependen de la vida util del muelle existente
- Posible conflicto con MCC

10. ESCENARIO POTENCIAL DEL PUERTO

ALTERNATIVA 2



- Inicio rapido de las operaciones de exportacion
- Vida util del muelle existente no influencer operaciones de exportacion
- Acceso directo a la Zona Franca

- Inversion total mas grande
- Posible conflict0 con MCC

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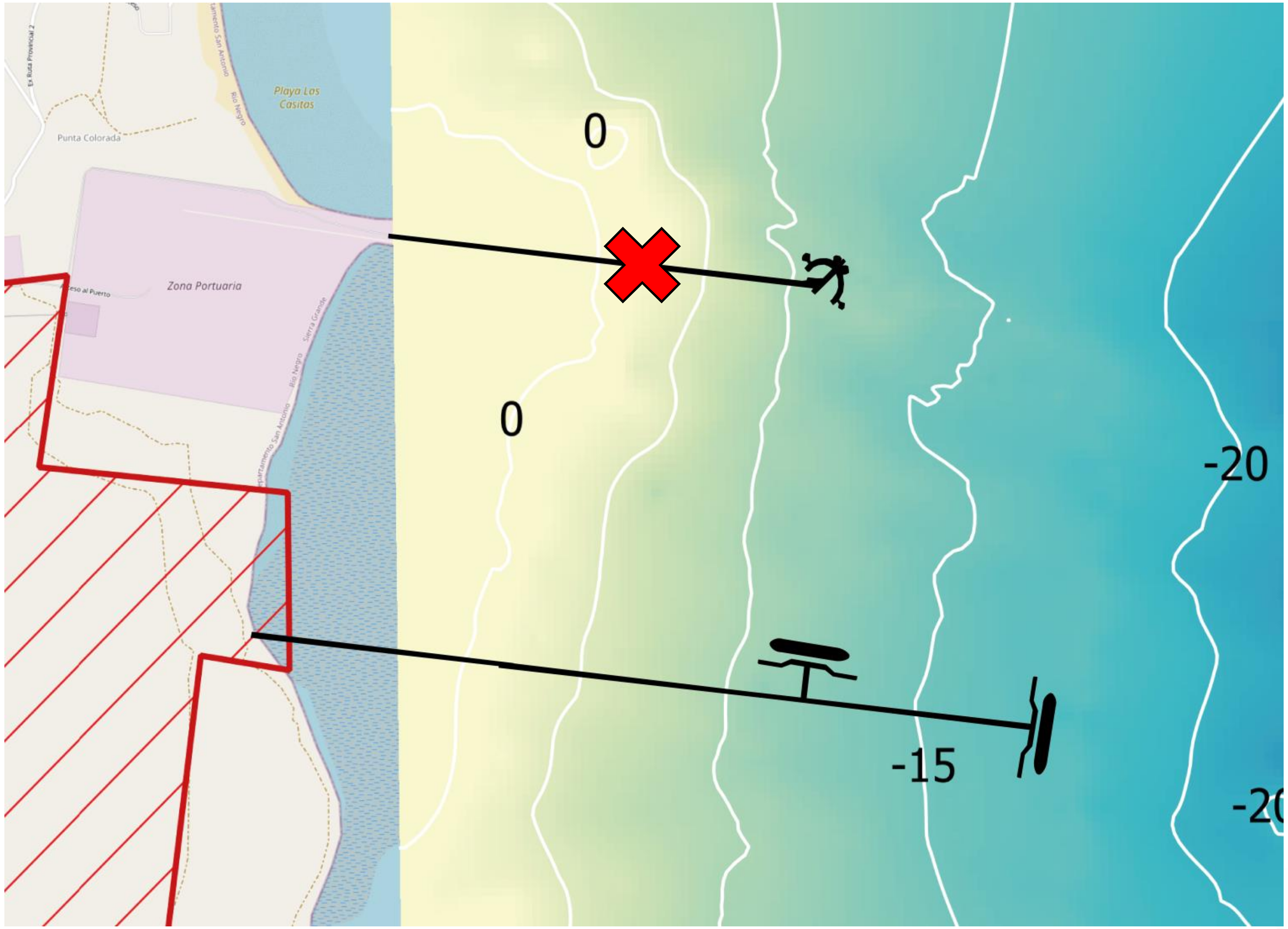
10. ESCENARIO POTENCIAL DEL PUERTO

ALTERNATIVA 3



- Operaciones de exporter no dependente del estado actual del muelle existente
- Acceso directo a la Zona Franca
- Sin dependencias ni conflictos con MCC

- Inversion total moderada
- El tiempo mas largo necesario para el inicio de las operaciones de exportacion

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¡GRACIAS!

DANKJEWEL!