Delft University of Technology

CEGM3000 Multidisciplinary Project

Preliminary design of a sustainable village in Patagonia, Argentina

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Abstract

This design report outlines a preliminary masterplan for developing a sustainable village in Patagonia, Argentina, addressing the unique challenges of remote living within a sensitive natural landscape. The project centres on creating a resilient, socially sustainable community that coexists harmoniously with its environment. A key objective is to assess multiple sustainable options for essential infrastructure, encompassing energy supply, accessibility, water and wastewater management, and other critical systems.

The report begins with an exploration of the site's distinctive environmental conditions, informed by a two-week site visit, as well as an analysis of key stakeholders, including residents, tourists, and potential investors. This groundwork establishes both community needs and environmental constraints, forming the guiding principles for the design. The preliminary masterplan then proposes practical solutions to meet these requirements, including infrastructure development such as jetties for enhanced accessibility, a hybrid renewable energy system to support off-grid living, and water and waste management systems that minimise ecological impact.

The proposed design is evaluated for economic feasibility, ensuring the village can support sustainable eco-tourism and community growth over the long term. This project could be used as an example for future developments in rural areas by prioritising sustainability for all social, environmental and economic aspects. This preliminary masterplan aims to contribute to ongoing research on environmentally conscious and socially inclusive development in challenging environments.

Preface

The following report presents the findings and outcomes of our multidisciplinary project. The team brings together expertise from diverse cultural and academic backgrounds within civil and environmental engineering. Margherita Fardelli specialises in building engineering, Katia Gatt and Federico Raimondi focus on dynamic engineering, and Barend Voogt studies geotechnical engineering. Sofia Piagnani and Julia van Witzenburg specialise in water quality within environmental engineering.

This project centres on developing a sustainable village at La Josefina, an estancia situated in Argentina's Santa Cruz region. Positioned strategically between two touristic routes, La Josefina has the potential to serve as a vital link between these destinations, enhancing connectivity and promoting eco-tourism in the area.

Sustainability is a core principle of our project, encompassing environmental, social, and economic aspects. Given the project's location in Patagonia, minimising environmental impact was of utmost importance. We prioritised preserving the natural landscape and ecosystems. Social sustainability was equally important, with the creation of a community as a foundation to encourage the sharing of environmental practice knowledge. Economically, a comprehensive financial plan was developed to ensure long-term viability and feasibility of development.

A key aspect of our project was the opportunity to conduct a two-week on-site visit, which provided us with invaluable, first-hand insights into the unique landscape of La Josefina. This experience was essential in shaping our understanding of the local culture and environment, allowing us to make more informed and sensitive decisions throughout the design process. This visit also allowed us to immerse ourselves in the stunning Patagonian environment and deepen our understanding of Argentine culture.

This multidisciplinary project (15 EC) was conducted as part of the second-year Master's program in Civil Engineering at TU Delft. We are grateful to our supervisors M.Z. Voorendt, M.D.M. Palmeros Parada, F. Kavoura, P.C. Meijers, P. Arecco, M. Goyeneche, and J.B. Saint Antonin, for their constant guidance and support throughout the project. We extend our gratitude to the Smart family, Besna, Port Consultancy Rotterdam, and UBA-FIUBA Facultad de Ingeniería for their hospitality and assistance during the project. Finally, we are thankful to Stichting Het Lamminga Fonds and Fast University Funds for their generous support in funding this project.

Buenos Aires, November 2024

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1 | Introduction

In this introduction, the motivation of the project is discussed in Chapter 1.1, explaining why the project is being undertaken. This is followed by a description of the project in Chapter 1.2 and an outline of its main goals, explaining what the project specifically aims to achieve. Finally, in Chapter 1.4 the methodology that will be used to achieve these objectives will be explained.

1.1 Project motivation

The development of a sustainable village at La Josefina represents a unique opportunity to create eco-tourism activity in the region while preserving the natural environment. La Josefina is located in between two important touristic routes: the Carretera Austral in Chile and the Ruta Nacional 40 in Argentina. Due to its strategic location, tourism is a key aspect in the development of the village. The land where La Josefina is located is planned to be sold by the current owner, and there is interest in such a development from people who want to relocate there. Additionally, its proximity to the Argentina-Chile border offers the potential to strengthen cross-border connections, addressing the current lack of infrastructure linking these countries, particularly in the southern regions of the continent.

This project could set an example for future developments by prioritizing sustainability in under the aspects of people, planet and profit. Moreover, since the estancia is located in an area of the region of Patagonia which was harshly damaged by cuttles, the design of the eco-village will prioritize minimizing both environmental and visual impacts, in order to preserve the natural landscape.

The core reasons for undertaking this project is the possibility to develop a village while restoring and preserving the natural landscape, providing economic opportunities for local communities in a way that aligns with sustainable principles, and promoting sustainable tourism in Patagonia.

1.2 Problem analysis

1.2.1 Project description

Estancia La Josefina is located in the Santa Cruz Province of Argentina. Within the province, the estancia is situated along the northern branch of Lake San Martín/O'Higgins, north of El Chaltén.

The following maps provide a comprehensive view of the estancia's location relative to the rest of Argentina.

First an overview of where the estancia is compared to the rest of Argentina and secondly to the province of Santa Cruz can be observed in Figure 1.1. The province of SantaCruz is the second largest province of Argentina, spanning an area of 243,943 km^2.

Figure 1.1: Location of La Josefina in Argentina and in the Province of Santa Cruz

In the following map a closer look is given to the location of the ranch. In Figure 1.2 is it possible to see on the left its position on Lake San Martín and on the right the property of Estancia La Josefina. The property spans 16,000 hectares of forests, mountains, glaciers, marshland, lagoons, and the Tucu-Tucu National Reserve and it has over 30 kilometres of shoreline along the northern branch of Lake San Martín/ O'Higgins, along the border between Argentina and Chile in Patagonia. Through the use of data obtained from the Instituto Geografico Nacional (Ministerio de Defensa Republica Argentina, n.d.) and the help of the manager of the ranch a detailed map with the outline of the ranch boundary was created.

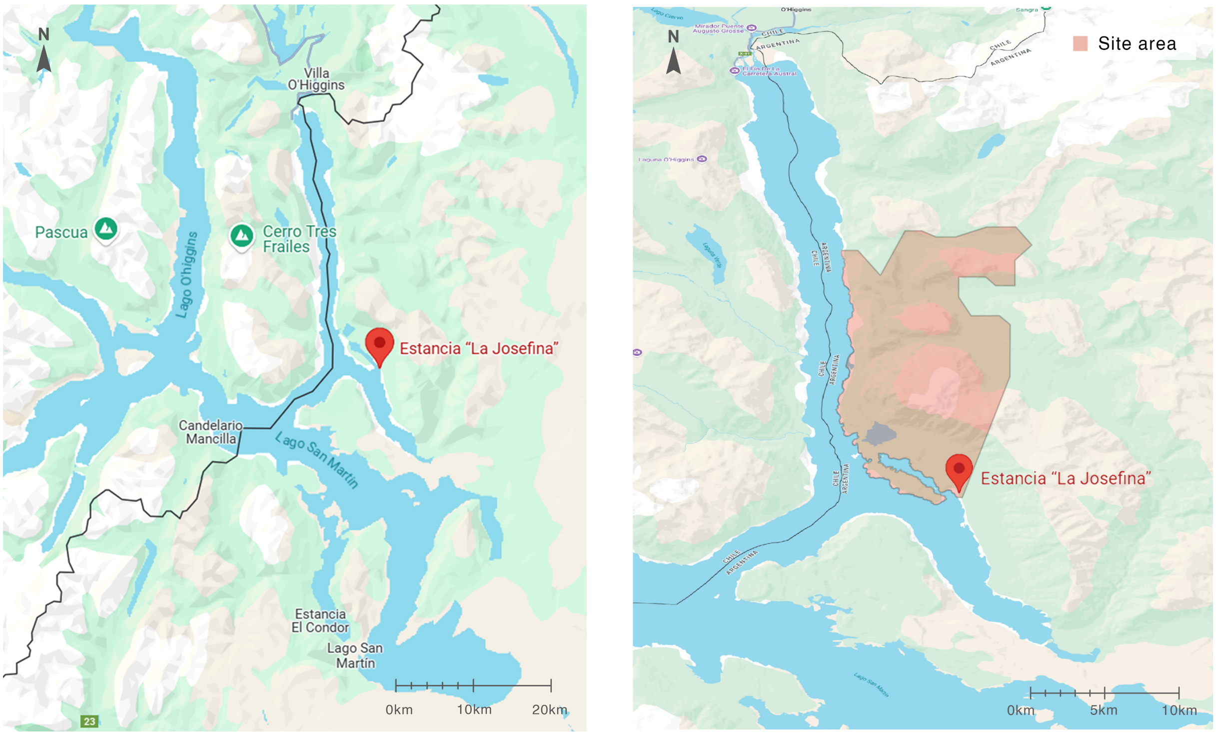


Figure 1.2: Location of La Josefina in Lake San Martín/O'Higgins

Currently, the ranch is rented by the Smart family to conduct a small-scale eco-tourism project. Due to its remote location a very unique travel experience is possible. Immersed in nature and remote from civilization, the ranch is a distinctive destination for those seeking an authentic Patagonian experience.

1.2.2 Analysis of the current situation

The problems this project aims to address involve several key challenges. First, the area's limited access to essential infrastructure and services represents the primary obstacle. Additionally, the current border crossing between Chile and Argentina in this region is difficult, which affects accessibility and complicates logistics. Another key point is developing the village in a way that minimizes environmental impact, requiring careful planning to avoid disrupting the landscape and ecosystems. These challenges will be addressed in the design.

1.3 Project goal

The goal of this project is to propose a preliminary masterplan design for the development of a sustainable village, including potential solutions for energy, accessibility, water and wastewater management, and other key aspects of sustainable infrastructure. This proposed preliminary masterplan must create a community for both ecotourists and permanent residents.

1.4 Methodology

The preliminary design of a sustainable eco-tourism village at Estancia La Josefina is structured through a systematic methodology that integrates research and design stages. This methodology builds on TU Delft's elementary design cycle (Figure 1.3) but adapts it to meet project-specific needs and the practical limitations of a large-scale development. The project unfolds in two main phases, Research phase and Design phase, each with feedback loops to incorporate emerging insights or address unforeseen conflicts.

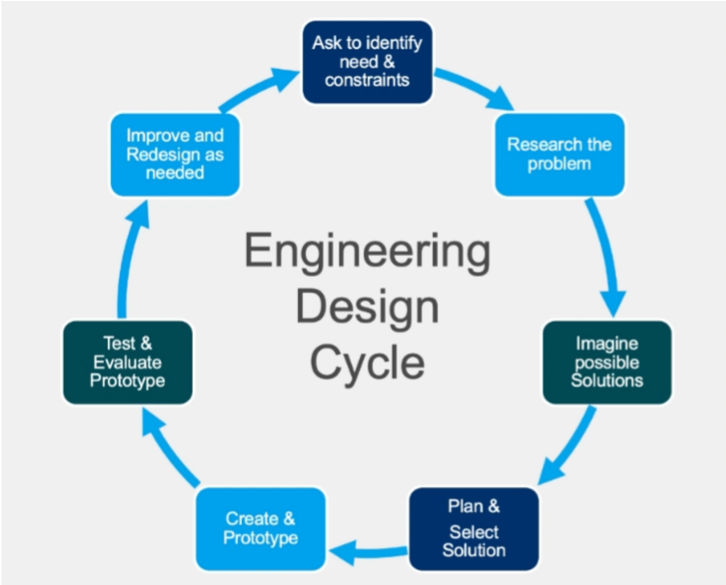


Figure 1.3: Elementary engineering design cycle (Saunders-Smits, 2021)

The flow chart in Figure 1.4 visually represents the approach of the project, providing an overview of the steps that will be outlined in detail in the following sections. This diagram illustrates the structured flow between stages, as well as the feedback loops used to refine the design.

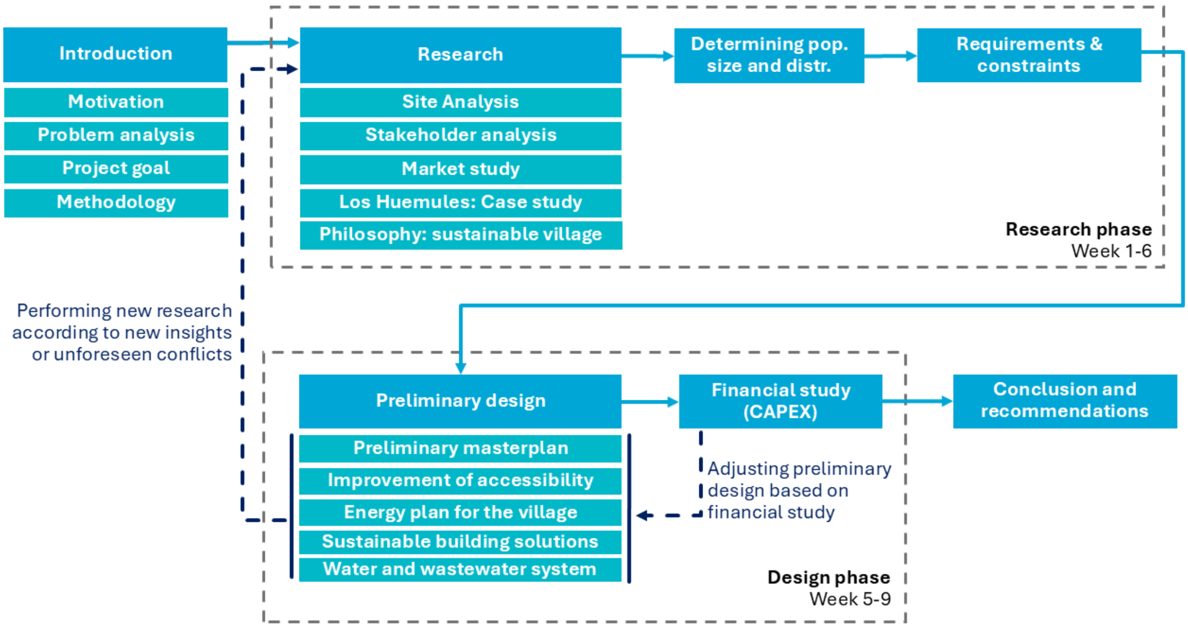


Figure 1.4: Flowchart of the project

1.4.1 Research phase

In the Research phase, an in-depth exploration of the project's context is performed, closely aligning with the steps *"ask to identify need and constraints"* and *"research the problem"* of the TU Delft design cycle. This phase focuses on developing a comprehensive understanding of the factors influencing the site and the needs of the eco-tourism village. By examining the following key aspects, a well-rounded foundation that informs the design stage is established.

Site analysis

Analysis of the site through a combination of both desk study and on-site research, conducted during a two-week site visit. This process includes a comprehensive review of the site's current situation, environmental and geographic conditions, available resources, and regulatory considerations.

Stakeholder analysis

Analysis of the key stakeholders involved in the project, including potential tourists and residents, government bodies, and potential investors. This section identifies and assesses the needs, interests, and concerns of these stakeholders, ensuring their perspectives are integrated into the project design.

Market study

Examination of the population's demographics. This includes identifying potential visitors and residents of the eco-tourism village, by investigating the patterns of tourism in this area, and understanding their preferences and needs to ensure the village is designed to accommodate and appeal to both these categories.

Case study

Analysis of an eco-tourism project located near the site, which shares similar objectives and context. This case study is examined to understand what strategies were successful and which challenges arose during implementation. Insights from this analysis inform the design and development of the eco-tourism village by highlighting best practices and potential obstacles to avoid. This case study is separated as it had aspects applicable to the entire design, additional case studies were researched relative to certain aspects of the proposed plan, but those will be explained in the respective sections.

Project philosophy

Formulation of guiding principles focused on creating a balanced and sustainable eco-tourism village. The core values emphasize the integration of social, economic, and environmental factors throughout the design process. This philosophy serves as a foundation for maintaining sustainability in all aspects of the project.

Determination of population size & distribution

Determination of the optimal population size and distribution based on stakeholder analysis and market study data through a Multi-Criteria Analysis (MCA). This element serves as a bridge, using findings from the Research stage to help define requirements and constraints.

Requirements & constraints

Translation of insights from the Research phase into clear functional requirements and constraints that will inform the development of the preliminary masterplan. These requirements and constraints are critical to the design process, as they ensure the project remains aligned with the needs of stakeholders and adheres to the project's sustainability and feasibility goals.

1.4.2 Design phase

The Design phase builds upon insights gathered during the Research phase to develop a comprehensive, stakeholder-informed preliminary masterplan, along with proposed solutions for critical site requirements.

This phase broadly follows the remaining five steps of the engineering design cycle: *"imagine possible solutions"* and *"plan and select solution"*, *"create and prototype"*, *"test and evaluate prototype"*, ensuring a structured approach throughout.

Preliminary masterplan

Development of a preliminary masterplan through close collaboration with potential investors, incorporating their feedback and discussing possible solutions. Given the project's large scale and time constraints, only one cohesive concept is developed to meet all requirements in advance. This section includes a design verification process to ensure that the proposed solution is feasible and aligns with the defined functional requirements and constraints, confirming the project's viability before moving forward.

Improvement of accessibility

Exploration of enhanced accessibility for the site through the development of key navigation routes to and from the eco-tourism village, alongside the strategic positioning of on-site jetties. Consideration is also given to the types of vessels that will be used in the village, ensuring compatibility with the site's logistics and environmental context. Additionally, the preliminary structural design of one proposed jetty is developed, accounting for both static and dynamic loading conditions. This design ensures that the jetty meets the site's relevant functional requirements, can withstand the local weather conditions, including waves and wind, and accommodates the identified vessel typologies.

Energy plan for the village

Development of a sustainable, off-grid energy system based on a hybrid model that considers the placement and balance of renewable energy resources. This is achieved through an analysis of available energy sources, followed by a phased approach that begins with an energy demand analysis to establish seasonal consumption profiles. The determination and optimization of technical specifications ensure the reliability and efficiency of the system, balancing energy supply throughout the year.

Sustainable building solutions

Selection of sustainable building typologies that meet the project's unique logistical and environmental challenges, guided by key criteria such as low carbon footprint, quick construction time, and sustainability. This is done through an evaluation of alternative construction methods for their suitability in addressing housing needs, and the assessment of location regulations for various construction methods, along with a review of relevant case studies. Additionally, this section includes the performance of a building physics analysis to examine the insulation properties of different wall materials, including the impact of additional layers for improved thermal performance.

Waste & water system

Analysis of sustainable options to provide water to all structures, follow key regulations, and manage wastewater. This chapter is divided into three phases of water design: first, the identification of current systems in practice on the property, then the exploration of various alternatives that could be implemented in the design, and lastly the explanation of a final design proposed for the preliminary masterplan. The development of this water plan ensures the feasibility of the design, providing a system that is functional in a rural environment while preventing negative environmental impact, and prioritising waste reuse.

Financial study

Assessment of the financial feasibility of the proposed preliminary designs through a capital expenditure analysis, in order to ensure that the village can be sustainably funded. Based on this evaluation, adjustments are made to the preliminary design if necessary.

1.4.3 Feedback loops

In the design process, feedback loops are critical to ensure that the final outcome meets all project requirements and adapts to emerging insights. These loops align with the *"improve and redesign as* *needed"* step of the engineering design cycle, allowing for adjustments based on ongoing evaluation and stakeholder input. The feedback loops in this project serve to refine and enhance the design in response to unforeseen challenges or new findings.

Feedback loop 1: Addressing unforeseen conflicts

As the development of the preliminary masterplan progresses, new research may be necessary to address any unforeseen conflicts or gaps in the design. This feedback loop allows for revisiting the project's assumptions, gathering additional data, and refining solutions to ensure the project remains feasible and aligned with stakeholder needs. This ongoing evaluation helps to optimise the design by incorporating new findings as the project progresses.

Feedback loop 2: Refining economic sustainability

After conducting a financial evaluation, the preliminary design may need to be refined to improve its economic sustainability. This feedback loop focuses on assessing the financial feasibility of the proposed solutions and adjusting them to ensure the project is economically feasible in the long term. This loop ensures that the project remains financially sustainable without compromising its core goals.

Both feedback loops ensure that the design adapts continuously, balancing stakeholder needs, environmental impact, and economic factors to create a robust, adaptable eco-tourism village.

2 | Site analysis

In the site analysis, information about the project site was gathered and analysed through both pre-site and on-site research methods. This comprehensive approach allowed for a detailed assessment of the location's characteristics, constraints, and possibilities, which will be particularly valuable during the design phase for zoning specific areas and determining the optimal placement of proposed developments.

2.1 Current conditions

This section provides a detailed overview of the current conditions of Estancia La Josefina, covering its accessibility, and available services, all of which contribute to the ranch's unique eco-tourism experience. Emphasizing its natural setting in southern Patagonia, the description of the site's current conditions will help assess its potential for integrating sustainable development with nature-based tourism opportunities.

2.1.1 Accessibility

Currently, the main way to reach Estancia La Josefina is via Provincial Route 31, which passes through the town of Tres Lagos, where visitors travel to from El Calafate - the village with the nearest airport. The access route by car concludes at the southern shore of Lago San Martín, to a bay within the estancia of Cancha Rayada. From this point, the ranch can be accessed by an hour-long boat ride across the lake or a five-hour hike.

The initial part of the journey by car involves navigating various roads, including unpaved tertiary roads, as shown in Figure 2.1. The yellow pathway below the site area on the map indicates the section that requires walking, requiring visitors to hike through uneven terrain. To illustrate the challenges of this hiking route, Figure A.5 depicts some of the types of terrain encountered along the way, which also involves a river crossing, emphasizing the physical difficulties that may arise. Additionally, another option for accessing the site on foot is through Villa O'Higgins in Chile, where travellers can cross the border by land at the northern border checkpoint depicted in Figure 2.1. This route requires a challenging three-day hike to reach La Josefina, navigating difficult terrain along the way.

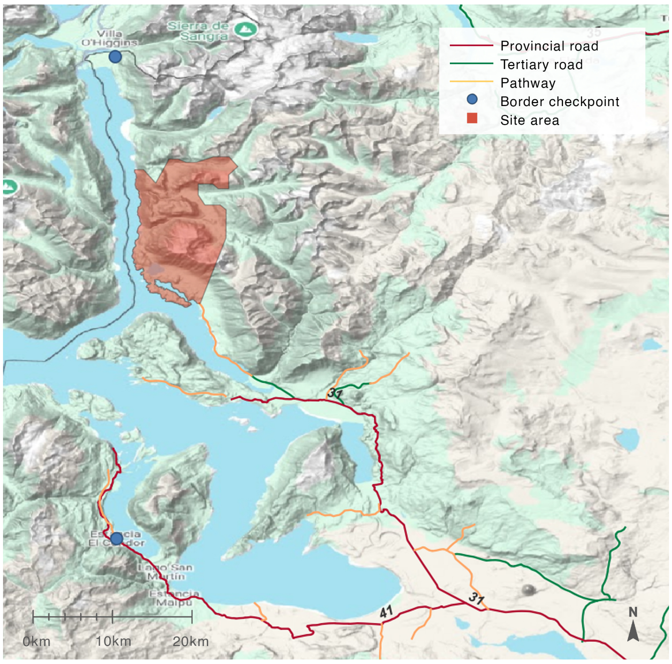


Figure 2.1: Map of current site accessibility

(a) River crossing

(b) Loose rock terrain

Figure 2.2: Terrain types of hiking access routes

In addition to the land routes, the boat route is another primary means of access, however the current boat access present is not ideal. The motorboat is stored on a trailer and launched into the lake without a proper ramp. The one-hour journey across the lake is often complicated by the region's unpredictable atmospheric conditions, making it a challenging and uncomfortable experience for visitors. Upon arrival, guests must disembark by jumping ashore, as the boat is beached on logs and secured with a steel rod and ropes. Given these limitations, the current boat access requires significant improvement. To ensure a more comfortable, efficient, and safe arrival experience, it is essential to enhance the boat access and docking infrastructure. This could be achieved by introducing a well-designed jetty and a proper ramp for launching and docking the boat.

Given the difficulties presented by both the land and boat access, it is clear that improving accessibility is essential to support the continued development and success of the estancia. Addressing these challenges will ensure smoother access for visitors and facilitate the transportation of materials for the development of the site.

2.1.2 Existing structures

To provide a comprehensive overview of the current conditions at Estancia La Josefina, Figure 2.3 presents a map indicating the shapes and locations of existing buildings.

An on-site survey was conducted to accurately position and size the structures currently present on the property. The existing buildings include four domes utilized as tourist accommodations and common spaces. Additionally, there is a cob house that serves as one of the accommodation options, along with cob bathrooms specifically for the Airbnb domes. The ranch manager's main house includes a kitchen, living area, three bedrooms, and two bathrooms, accommodating staff members during the Airbnb operation. The site owner's house is also located on the premises.

Other significant structures on the property include old gaucho houses, which have been damaged by previous landslides and are currently not in a usable state. Additional features include a waste collection area, a chicken coop, an electricity shed, an on-site wind turbine, and solar panels. The heating and warm water needs of the estancia are met through wood burning, emphasizing sustainability in its energy use. There is also a greenhouse for cultivating plants and a storage shed for equipment and supplies. Images of most of these structures can be found in Appendix A.1. These existing structures play a crucial role in the operation and sustainability of the estancia, enhancing the overall visitor experience.

Figure 2.3: Map of existing buildings

2.1.3 Services

Estancia La Josefina offers a variety of essential services designed to accommodate visitors while prioritizing sustainability and minimizing environmental impact. Current tourist accommodation options consist of three domes, each with a capacity for two guests. These domes are equipped with private bathrooms, hot water, and a wood-burning fireplace for heating, ensuring a comfortable stay. No cell phone service is available on site, and internet access is restricted to a designated area, encouraging guests to disconnect and fully engage with the natural surroundings.

A range of outdoor activities is available, including horseback riding, hiking, birdwatching, fishing, boat trips, and stargazing. These activities are intended to showcase the area's unique landscape and biodiversity, with excursions offered in durations from half-day to multi-day trips. In terms of food, meals are prepared with an emphasis on locally sourced ingredients, representing traditional Patagonian cuisine. A significant portion of the meals are cooked using a handmade mud oven, contributing to the authenticity of the culinary experience.

Overall, the services at Estancia La Josefina are focused on providing a low-impact, nature-centric experience, offering essential amenities alongside a diverse range of outdoor activities that encourage engagement with the local ecosystem.

2.2 Natural and physical site conditions

This section provides a comprehensive analysis of the site's environmental features and natural conditions, which are essential to understanding the unique characteristics of the landscape. Key elements examined include the topography and terrain, water systems, atmospheric conditions, geophysical activity, and biodiversity. Each of these aspects provides essential insights for the research and design phases, guiding the identification of site-specific requirements, environmental constraints, and opportunities for integration with the natural surroundings.

All maps in this section are illustrations created from modified QGIS basemaps, using data sourced from Instituto Geográfico Nacional (IGN) (Ministerio de Defensa Republica Argentina, n.d.).

2.2.1 Topography and terrain

Topography

The topography of the site is a critical factor in shaping the masterplan, as it helps identify the most suitable areas for development. The site features a varied landscape, ranging from low-lying areas near the lake at around 260 metres, to a mountain peak at around 1,780 metres. This variation provides distinct zones for different functions, with flat and gently sloping terrain offering prime locations for buildings, while steeper hills and mountainous regions may be better suited for conservation or recreational purposes.

To gain precise insights into the terrain, detailed topography maps were generated, as shown in the figure below. The map displays topography through contour lines, indicating elevation in metres relative to local mean sea level, allowing for a clear understanding of the land's gradient and elevation changes across the property. Through these contour lines, a 3D digital model was created to enhance visualization of the site's topography, enabling a more comprehensive understanding of the terrain and informing design decisions (Appendix A.2).

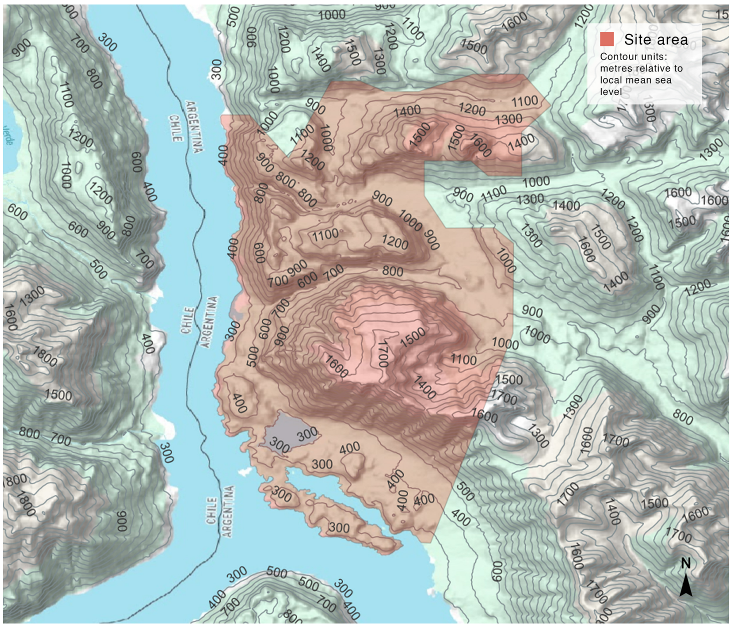


Figure 2.4: Topography

Geology

In addition to topography, it is essential to understand the geology of the area to identify the types of soils and rocks present on site. Lago San Martin is one of three large glacial lakes located in the province of Santa Cruz. The terrain of Estancia La Josefina is entirely characterized by glacial landscapes. The direction of the glacier's movement was from northwest to southeast (SegemAR, 2017).

Upon closer examination of the Estancia La Josefina area, one prominent geological formation can be identified: the 'Formación Río Lácteo' (number 1b in Figure 2.5). This formation comprises slates, schists, and phyllites and is predominantly found in the mountainous regions. Another significant geological feature is the 'El Quemado Complex' (numbers 3a and 3b in Figure 2.5), which consists of pyroclastic and sedimentary facies. At the base of the mountain range where the ranch is located, alluvial deposits (number 24 in Figure 2.5) are present. These deposits consist of gravels, sands, silts, and clays. While certain areas may show a predominance of one soil type, the deposits typically consist of a mix of at least two of the four soil types.

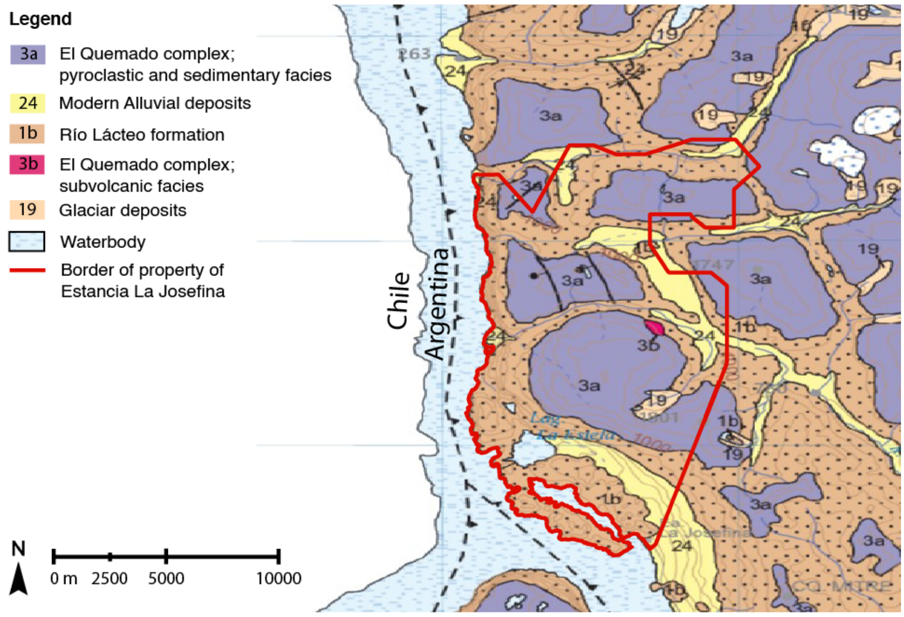


Figure 2.5: Geological map of the property of Estancia La Josefina. Modified from SegemAR (2017)

Soil and ground conditions

During the site visit several hikes were conducted to analyse the different types of soil in the area. Due to the remoteness of the area and the conceptual nature of the project, it was not feasible to conduct precise soil studies such as a cone penetration test (CPT) or a standard penetration test (SPT) to obtain specific soil parameters. However, during these hikes, a metal rod (1.5 meters in length) and a hammer were used to test the depth the rod could be driven into the different soils to give a first indication on the bearing capacity of the different soils. This is a critical first step in determining which areas may be suitable for construction without requiring major foundations.

From the initial observation it was possible to classify the soil into three categories: highly stable (a mix of stones, gravel and sand/clay), moderately stable (less gravel and more clay/sand) or unstable (mainly consists of clay or a soil containing more water such as peat). The soil tests were performed in areas of moderately stable soil and unstable soil, and the results were used to qualify other areas with similar soil types on its buildability.

In the unstable soils the rod could easily be driven its full length into the ground (and likely even further) while in the moderately stable soils, it could be driven anywhere from zero to forty centimetres deep. Because of this range and to be sure that the selected areas are suitable for constructions without major foundations, the moderately stable soils were also considered unstable. These unbuildable areas determined correspond to the 'marshland' areas depicted in Figure 2.11.

2.2.2 Water systems

Hydrological features

The site's location beside Lago San Martín provides access to various hydrological resources. A key aspect of the property is its long perimeter along the lake, which plays a dominant role in shaping the region's ecosystem, as well as offering potential use and accessibility for eco-tourism development. Additionally, a large lagoon, referred to as Laguna Estella, is located on the southwest side of the property, further enhancing the site's natural water resources.

In addition to the lake, Figure 2.6 highlights the presence of both perennial and intermittent watercourses. The perennial watercourses are consistently flowing, and are essential for maintaining year-round water availability. These can support wildlife, vegetation, and may contribute to hydro-power or other water-based activities. On the other hand, the intermittent watercourses flow only during certain times of the year, typically during wet seasons or after the melting of snow. These intermittent streams, while not reliable year-round, may offer support during certain seasons and help maintain the overall ecological balance.

The site's diverse hydrological system is further amplified by the varying altitudes and slopes present throughout the property. The presence of these water bodies, and the dynamic nature of water flow, are crucial factors for both the eco-tourism development and environmental conservation efforts, and therefore need to be carefully considered in terms of both resource management and sustainability.

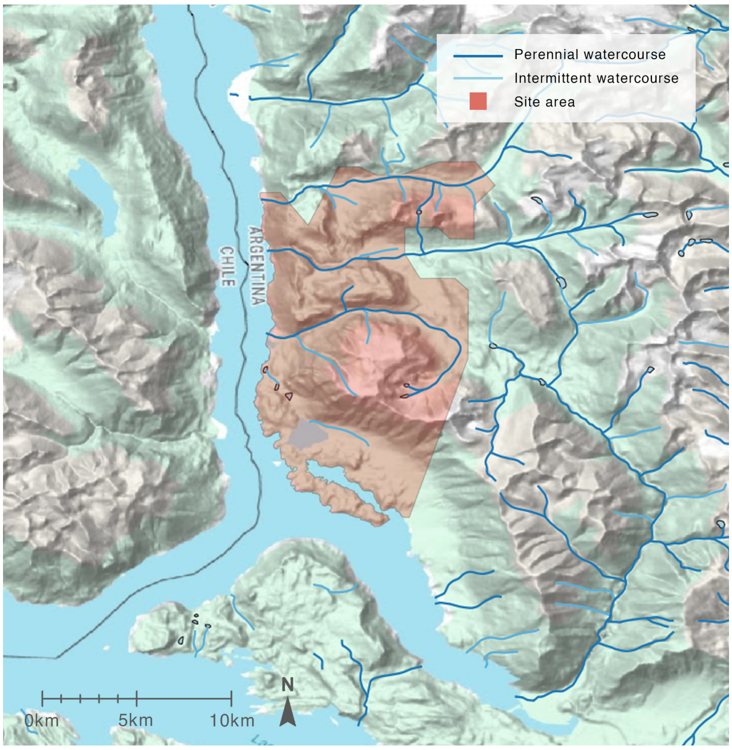


Figure 2.6: Map of the main watercourses present on site

From Figure 2.6, it is evident that there are no watercourses near the ranch. However, additional seasonal streams and water bodies were identified during on-site visits to the Estancia, including several located closer to the ranch area than shown on the map. These seasonal watercourses were observed particularly during excursions along the coastal region of the Estancia facing the peninsula. A considerable number of water bodies were also noted throughout the property, some of which were mapped using satellite imagery, with their placement visible in Figure 2.11.

Meteorological tidal waves

The analysis of meteorological tidal waves and wave behaviour is crucial for ensuring the long-term functionality and resilience of hydraulic structures at Lago San Martín. The hydrodynamic conditions, including meteorological tidal fluctuations, seiches, and wave activity driven by wind, directly impact the structural integrity and operational effectiveness of such structures. Understanding the range of tidal amplitudes and the oscillatory behaviour of the lake is essential for designing resilient infrastructure that can adapt to changing water levels and withstand periodic wave forces. Additionally, assessing wave behaviour helps identify the need for protective measures, such as windbreaks and wave-dampening structures, to safeguard any future development from high-velocity winds and significant wave action, ultimately contributing to the sustainable development of the eco-tourism village at Estancia La Josefina.

The meteorological tidal and wave behaviours observed in Lago San Martín, show significant similarities to those in Lago Argentino, located to the south of Lago San Martín (see Figure 2.7). Given their shared glacial-valley environments and proximity to the Southern Patagonian Icefield, Lago San Martín is expected to exhibit comparable meteorological tidal amplitudes and seiche dynamics (Richter et al., 2015). This allows us to use the well-documented hydrodynamic data from Lago Argentino to inform design strategies and planning at Estancia La Josefina.

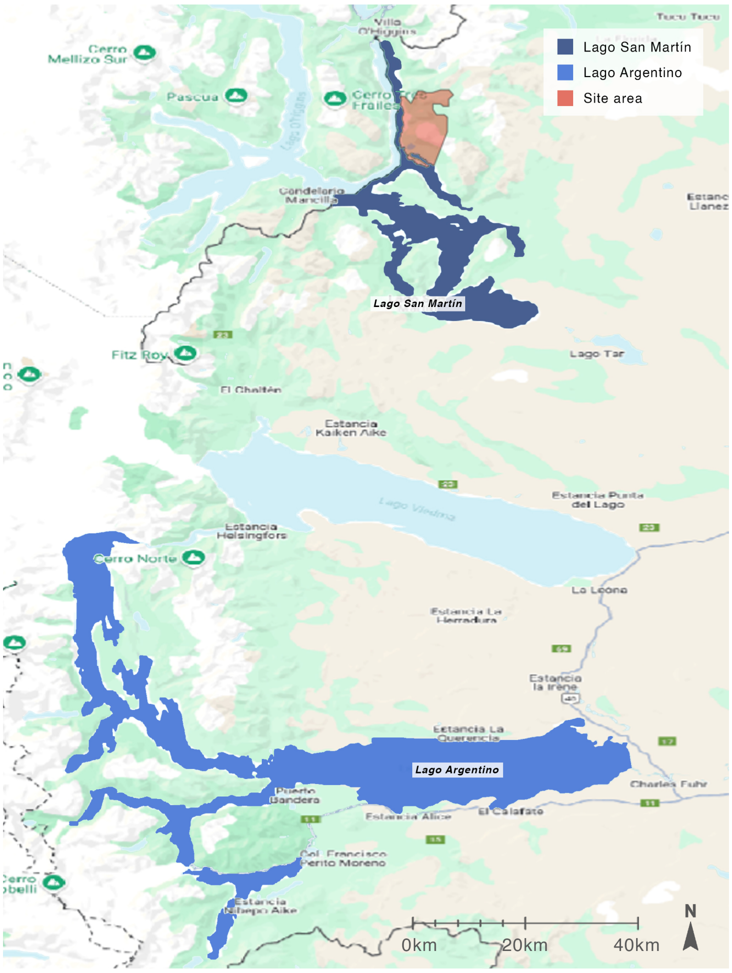


Figure 2.7: Map showing location of Lago Argentino relative to Lago San Martín

The shared glacial-valley environment of the two lakes is characterized by steep, glacier-carved shores and deep, narrow valleys. This morphology significantly impacts the meteorological tidal and wave behaviours in both lakes. In particular, the narrow valleys funnel winds and amplify wave action, while the steep shores reflect wave energy, contributing to seiche phenomena.

Proximity to the Southern Patagonian Icefield and the subsequent glacial melt-water inputs further contribution to the water level variations and hydrological characteristics of these lakes.

The meteorological tidal behaviour in Lago San Martín is expected to closely resemble that of Lago Argentino. For example, Lago Argentino experiences a significant annual meteorological tidal amplitude, with variations of up to 1.2 metres. On-site it was verified through empirical observations that Lake San Martin has comparable meteorological tidal ranges of up to 1.5 m A.3.

Predictions indicate that lake tides in San Martín could generate anti-clockwise gyres around an amphidrome near the centre of the lake, with maximum amplitudes located at points most distant from the amphidrome.

This pattern is characteristic of large, deep lakes in glacial environments and is consistent with behaviors modeled for Lago Argentino.

Surface seiches—oscillations in water levels caused by atmospheric pressure changes and wind are another key aspect of meteorological tidal variation. Lago Argentino exhibits prominent seiche modes, with a fundamental frequency of 17 cycles per day (approximately 85 minutes). Lago San Martín is expected to experience similar seiche behaviour, influenced by local wind patterns and the lake's bathymetry.

Wave behaviour in Lago San Martín is closely linked to its glacial-valley morphology and wind dynamics. Cold, fast-moving winds (katabatic winds), which are common in this region, are a major factor driving wave activity. These winds, descending from the Southern Patagonian Icefield, have a pronounced effect on both Lago Argentino and Lago San Martín, generating large waves and exciting seiches.

The narrow shape of Lago San Martín could amplify the seesaw-like tilting of the water surface, enhancing seiche activity in certain regions. Wind-generated waves can reach amplitudes of up to 2-3 meters listening to people of the area.

In addition to seiches, shallow-water barriers such as moraine ridges may influence wave patterns. These features, observed in Lago Argentino, are expected to affect wave dynamics in Lago San Martín as well, particularly by altering how waves propagate and dissipate within the lake's channels and basins (Pasquini et al., 2008).

2.2.3 Atmospheric conditions

Climate

Understanding the climate at Lago San Martín is essential for designing an eco-tourism village that is both sustainable and resilient. The local climate, shaped by geographical features and climate change, brings moderate seasonal variations in temperature and precipitation. Since we aim to mainly use site-sourced building materials, these must be able to endure the area's temperature extremes, precipitation patterns, and environmental challenges throughout the year. By accounting for these factors, we can ensure durable, efficient construction with minimal environmental impact. The graphs used to obtain the below data can be found in Appendix A.4.1.

The highest temperatures typically occur during the austral summer in January and February, with a mean daily maximum of 18°C, occasionally reaching up to 25°C on particularly hot days. In contrast, the coldest month is July, where the mean daily minimum is -6°C, with nighttime temperatures occasionally dropping to -16°C. These data are derived from MeteoBlue (2024) climate diagrams based on 30 years of hourly weather model simulations.

In terms of precipitation, April and May receive the highest rainfall, with around 42 mm per month, while January sees the lowest, with approximately 23 mm. The area is predominantly partly cloudy throughout the year, with occasional sunny days and fewer overcast days, particularly during the Argentinian winter months.

By analyzing data of Lago San Martín from MeteoBlue, including long-term records of precipitation and temperature in the area, an upward trend can be observed over the past 100 years due to the effects of climate change (MeteoBlue, 2024). This trend highlights the importance of designing structures and systems that are adaptable to ongoing environmental changes, ensuring both sustainability and resilience in the long term.

Wind

Estancia La Josefina, like the rest of the Patagonia region, is exposed to strong winds year-round. The prevailing winds come primarily from the north-west (see Annex A.7), driven by the shape of Lago San Martín and the ranch's location at the opening of a narrow channel, which creates a tunneling effect that amplifies the wind's intensity.

Unfortunately, due to the remote location of the site, no data collection stations are present and other alternatives were taken into account such as the weather stations of the closest towns and closest airports. Looking at the data of wind speed and wind gust gathered from the El Calafate Airport and Villa O'Higgins it can be said that during the Austral hemisphere winter months the intensity of wind speed is lower compared to the summer period.

Using weather model simulations from MeteoBlue (2024), the mean wind speed for locations near the northern arm of Lago San Martín were estimated, both in Argentina and Chile. In Argentina, the selected locations were Portezuelo Fósiles, Cerro Falucho, and Cerro Álvarez, while in Chile, the chosen sites were Villa O'Higgins Río Mayer private airport, and Cerro Taitao (Figure 2.8).

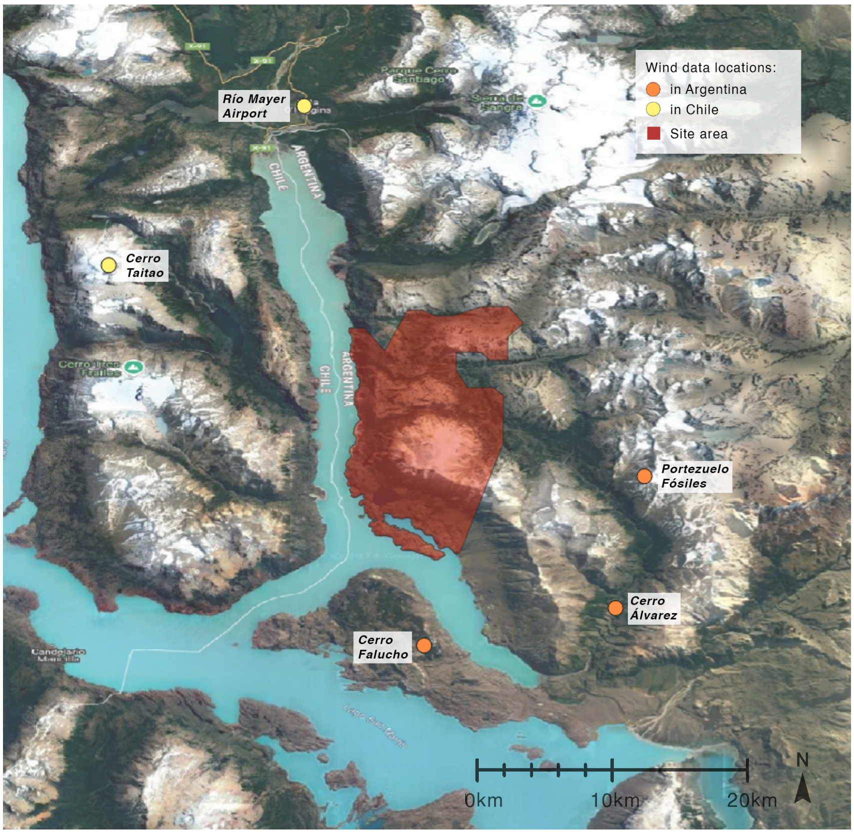


Figure 2.8: Wind data locations

The estimated mean wind speed across these locations range between 5 and 8 m/s, predominantly from the north-west. From the NASA (n.d.) data it was possible to notice a seasonality that suggests stronger winds in the summer season compared to winter (see Annex A.8). For design purposes, a mean wind speed of 10.786 obtained through a Extreme Value Analysis (see Annex A.9) will be considered.

2.2.4 Geophysical activity

Seismic activity

The site near Lago San Martín falls within seismic zone 1 according to the Argentinian Earthquake Code CIRSOC 103 (Instituto Nacional de Prevención Sísmica (INPRES), 2018)(Appendix A.5). This classification indicates a low seismic hazard in the region, though seismic considerations remain necessary due to the potential for minor quakes.

The Argentinian Earthquake Code emphasizes the need to assess soil properties and their response to seismic forces. Despite the low seismic hazard classification, it is crucial to evaluate the site's soil characteristics to ensure that building materials and construction methods can effectively withstand potential seismic events. This assessment should include factors such as soil stability, potential liquefaction, and the behaviour of various soil types under seismic stress, ensuring resilience of the eco-tourism village.

Additionally, while the region is not prone to significant volcanic activity, nearby volcanoes could contribute to occasional tremors. The closest active volcano is the Lautaro subglacial stratovolcano situatied in Chilean Patagonia, approximately 80 km away from the site. The last recorded eruption was in 1979, and its activity was largely confined beneath ice.

Landslides

When visiting the old gaucho houses located at the estancia, it became evident that the area had experienced a mudslide in the past. According to the ranch manager, this event occurred around 2005. The mudflow was reportedly slow enough for the ranch manager at the time to escape. Walking around the estancia, noticeable shifts in ground level further illustrated the mudslide's impact. There are very few trees in the area surrounding the current structures on the property. Discussions with the ranch manager revealed that many trees had been burned by former gauchos to clear land for cattle. The cattle have remained on the property and eat new tree sprouts, preventing regrowth.

Research, however, shows that trees play a critical role in reducing landslide risk through various mechanisms: their roots reinforce soil layers, they lower soil moisture, reduce soil erosion, and form barriers against rock, debris, and soil slides (RECOFTC, 2012). Although the trees currently present were insufficient to protect the house from damage, some of these stabilizing effects were observed on-site, as shown in Figure 2.9. It is likely that the mudslide was triggered by meltwater from snow and ice in the nearby mountains, mixing with loose gravel and sediment at the mountain base, which ultimately destroyed the gaucho houses. The lack of trees in the area may have contributed to the ranch's vulnerability during the event.

Figure 2.9: Trees partially withholding the mud slide

2.2.5 Biodiversity

Flora

The flora around Lago San Martín and the site of Estancia La Josefina is diverse and includes several key ecosystems, which are important to understand in order to promote conservation and sustainable use of natural resources. The steppe ecosystem features tussocks, short grasses and shrubs. In contrast, the native forest is dominated by three species of Nothofagus: *Nothofagus pumilio* (lenga), *Nothofagus* *antárctica* (ñire), and *Nothofagus betuloides* (guindo). The lenga forest is particularly significant, forming the main forest type and being crucial for the local huemul (refer to fauna), which relies on lenga for up to 50% of its diet. The guindo forest is limited to a narrow strip along Lago San Martín, covering 5.75 hectares and consisting of four distinct stands. This area has been impacted by the previously mentioned fires, leading to dense shrub growth in some regions. Ñire thrives mainly in the humid lowlands of La Josefina, forming even-aged stands and regenerating in rocky, moist environments near watercourses. This forest type is particularly resistant to grazing and supports high-value culinary mushrooms like the morel, offering potential for eco-tourism (Monelos, 2023).

Fauna

The terrestrial fauna of the region include a variety of native and introduced species. Historically, the landscape has been heavily influenced by domestic livestock grazing, which has modified the ecosystem and altered the original floristic patterns. Key species include the huemul, a critically endangered deer that is emblematic of the region's biodiversity conservation efforts. Other mammals like the guanaco and Patagonian rhea are commonly found in the steppe and forest ecosystems, alongside pumas, red foxes, and chinchillones. Wild cows, which have colonized the area after human arrival, are highly present in the landscape and contribute to the overgrazing problem, aggravating the degradation of native vegetation and altering the balance of the ecosystem. Avian species which can be found in the area include the Andean condor, torrent duck, and Patagonian eagle. In aquatic environments, fish species like trout and perch are commonly found in the lakes and rivers. This fauna, both endangered and thriving, offers opportunities for eco-tourism while highlighting the importance of sustainable practices to protect vulnerable species like the huemul and maintain the ecological balance of the region.

2.3 Site resources

Evaluating natural resources available on site encourages that the development aligns with sustainable practices, minimizes environmental impact, and effectively utilizes the site's inherent resources. This section addresses key aspects such as the waste produced, the availability and use of local materials, and water resources.

2.3.1 Waste produced

Waste at the site is carefully managed and reused wherever possible. Waste generated is collected, sorted, and repurposed, contributing to sustainable practices. For example, the cob house on the property reused waste materials for insulation, and wine bottles are repurposed into drinking glasses. Combustible waste is burned in wood stoves to heat the houses, helping to minimize waste output and make practical use of available resources. Human waste on the other hand, is treated with biodigestors. There are three of them in the area of the houses and the domes that treat toilet waste. The black water, once treated with the biodigestor is discharged about 20 meters from the house.

2.3.2 Local materials

Timber

Native tree species outlined in the biodiversity section of the site analysis provide valuable timber resources for construction, as well as for fuel. Most Lenga forests, which are the primary native forests on-site, currently produce low timber yields due to the health limitations of wild species. However, effective silvicultural management, such as regular thinning, can significantly improve both the quality and growth rates of these trees—from 1.5-2 mm/year to approximately 4 mm/year—thereby boosting timber yield (CONICET, 2020). Managed Lenga forests can exhibit substantial volume growth, making them a valuable and sustainable construction resource. Additionally, wood from these forests can be used as a renewable fuel source for heating, as it is currently utilized on the site, supporting a self-sufficient energy system in colder months.

Earth and adobe

In the context of vernacular architecture in Patagonia, rammed earth and adobe construction methods are viable and sustainable options, particularly due to the availability of suitable local materials. The site offers abundant clay-rich soils that are ideal for creating adobe bricks. These bricks are made by mixing the local soil with organic materials such as straw or grass, which are readily available from the steppe areas on-site. The combination of these materials provides a sustainable approach to construction, using what the land offers without the need for external resources. Two huts on-site have already been constructed using these materials, showcasing the practicality and effectiveness of rammed earth and adobe in this environment.

2.3.3 Water resources

Water for the property is sourced from an upstream flowing stream. A simple yet effective system channels the naturally flowing water through a filter before entering a pipe that supplies the property, providing drinking water without the need for pumping. The presence of numerous streams across the site, especially along the coast, provides an opportunity to extend this system to the proposed eco-tourism village, ensuring a sustainable water supply with minimal environmental impact.

2.4 Laws and regulations framework

To ensure the successful transformation of Estancia La Josefina into a sustainable ecotourism destination, adherence to a comprehensive set of regulations is critical. This section outlines some of the key laws and regulations affecting various aspects of the project, categorized into land use and environmental protection, construction codes and standards, vegetation and soil management, fauna and water management, air quality and cultural heritage, path construction and fire prevention, waste management, and environmental insurance. The data and regulations referenced in this framework are sourced from national and provincial legal systems, ensuring compliance with Argentine environmental standards (Argentina.gob.ar, 2024).

2.4.1 Land use and environmental protection

The development of Estancia La Josefina is subject to rigorous environmental regulations due to its location within the Tucu Tucu Reserve, an area of high conservation value (Figure 2.10). The reserve is home to endangered species such as the huemul, making adherence to environmental protection laws critical.

- **Ley 2658/03 - Procedimiento de Evaluación de Impacto Ambiental**: Establishes the procedures for conducting Environmental Impact Assessments (EIAs) in the province of Santa Cruz. Key components include the scope of assessment, public participation, and mitigation measures.
- **Ley 1451/82 - Uso y Preservación de las Aguas Públicas**: Governs the study, use, and preservation of non-marine public water resources in the province. This law establishes water quality standards and prohibits pollution, ensuring sustainable water resource management.
- **Ley 229/61 - Ley de Conservación de Suelos**: Focuses on the conservation of soil resources and sustainable management practices, providing guidelines for soil protection and promoting sustainable land use.
- **Ley 26331/07 - Ley de Protección de Bosques Nativos**: Requires a Forest Management Plan for developments affecting native forests, aimed at conserving biodiversity.
- **Provincial Law 2373/94**: Governs the protection of wildlife, ensuring all species within the reserve are safeguarded.
- **Ley 26331/07**: Outlines minimum standards for the protection and conservation of native forests, mandating a Forest Management Plan for any development impacting native forests.

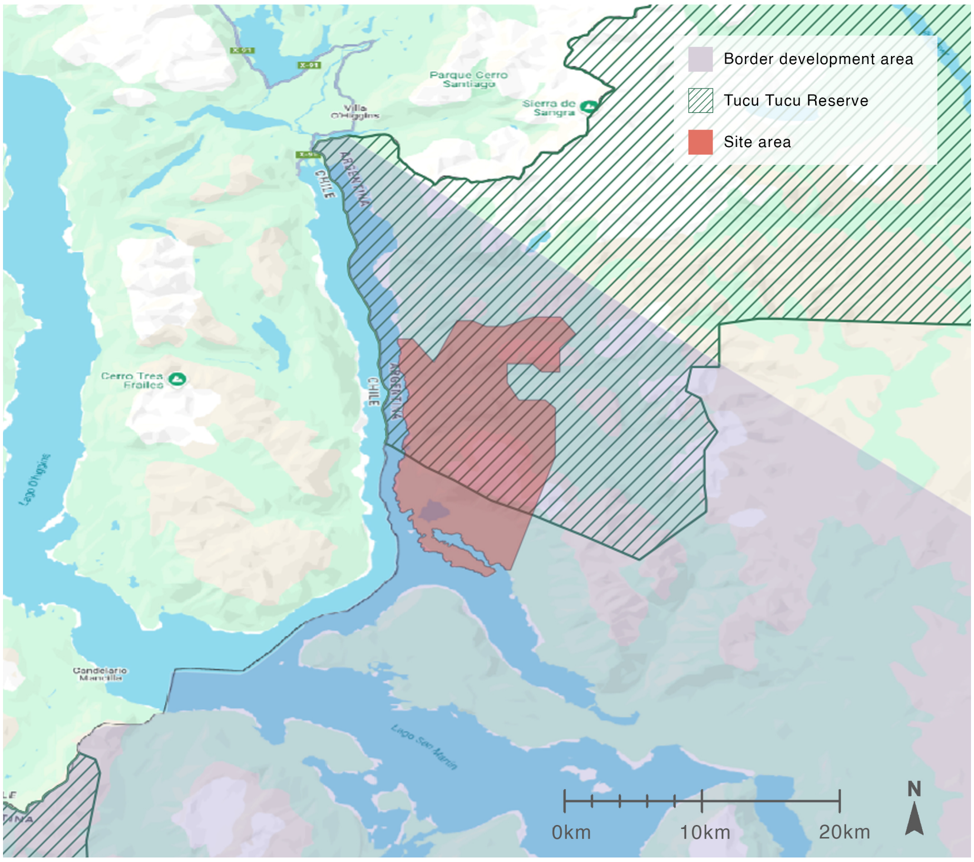


Figure 2.10: Limitations

2.4.2 Water and waste management

Effective management of water and waste is essential for maintaining sustainability within the ecotourism village. Relevant regulations include:

- **Ley 25688/03 - Environmental Water Management Regime**: Governs the sustainable use and protection of water resources, ensuring wastewater treatment and water conservation practices.
- **Ley 26221/07 - Drinking Water Supply and Sewage Services**: Ensures the provision of safe drinking water and effective sewage treatment in compliance with health and environmental standards.
- **Ley 25916/04 - Household Waste Management**: Establishes regulations for waste collection, treatment, and disposal, promoting recycling and sustainable waste management.
- **Ley 2829/05 - Tratamiento y Disposición Final de Residuos Sólidos Urbanos**: Focuses on the treatment and disposal of urban solid waste, with a strong emphasis on recycling and minimizing waste production.

2.4.3 Codes and standards

All construction within the ecotourism site must comply with safety and durability standards, as defined by national and international regulations:

- **CIRSOC Codes** are pivotal:
  - CIRSOC 101: Structural safety for buildings
  - CIRSOC 102: Structural design loads

- CIRSOC 301: Steel structures
- CIRSOC 601: Timber structures

- **PIANC (International Navigation Association) Codes**: These codes are essential for designing and building infrastructure related to water accessibility:
  - PIANC 126: Guidelines for the design and construction of jetties and mooring facilities.
  - PIANC 115: Guidelines for waterway and port projects.

2.4.4 Infrastructure safety and community Engagement

To ensure the safety of both infrastructure and the environment, as well as to promote active community involvement, adherence to relevant regulations is essential.

- **Pathway Construction and Fire Prevention**:
  - Trails should be carefully designed to follow natural contours to minimize environmental disturbance. In sensitive areas, wooden walkways will help preserve vegetation and prevent soil erosion.
  - To mitigate wildfire risk, firebreaks and proper clearance around the development will be incorporated into the design, adhering to local fire safety regulations.
- **Public Participation in Environmental Decision-Making**:
  - The **Escazú Agreement** (Ley 27566) promotes public access to environmental information and encourages community involvement in environmental decision-making processes. This ensures transparency and local stakeholder engagement in the planning and management of the ecotourism site.

2.5 Determination of buildable land

Combining insights from each section of the site analysis, areas unsuitable for development were identified, including marshlands, mountainous terrain, water bodies, and the protected Tucu Tucu Reserve, all of which were marked on a constraint map (Figure 2.11). This map defines the non-buildable areas, leaving unshaded regions as potential development zones for the preliminary masterplan design. Additionally, an unexplored area shaded in grey represents a section that could not be assessed due to adverse weather during the site visit. Further research is recommended to determine whether this area holds potential for development.

This analysis outcome is essential as it sets the foundation for the design phase, guiding zoning considerations and helping to align land use with ecological preservation and project goals.

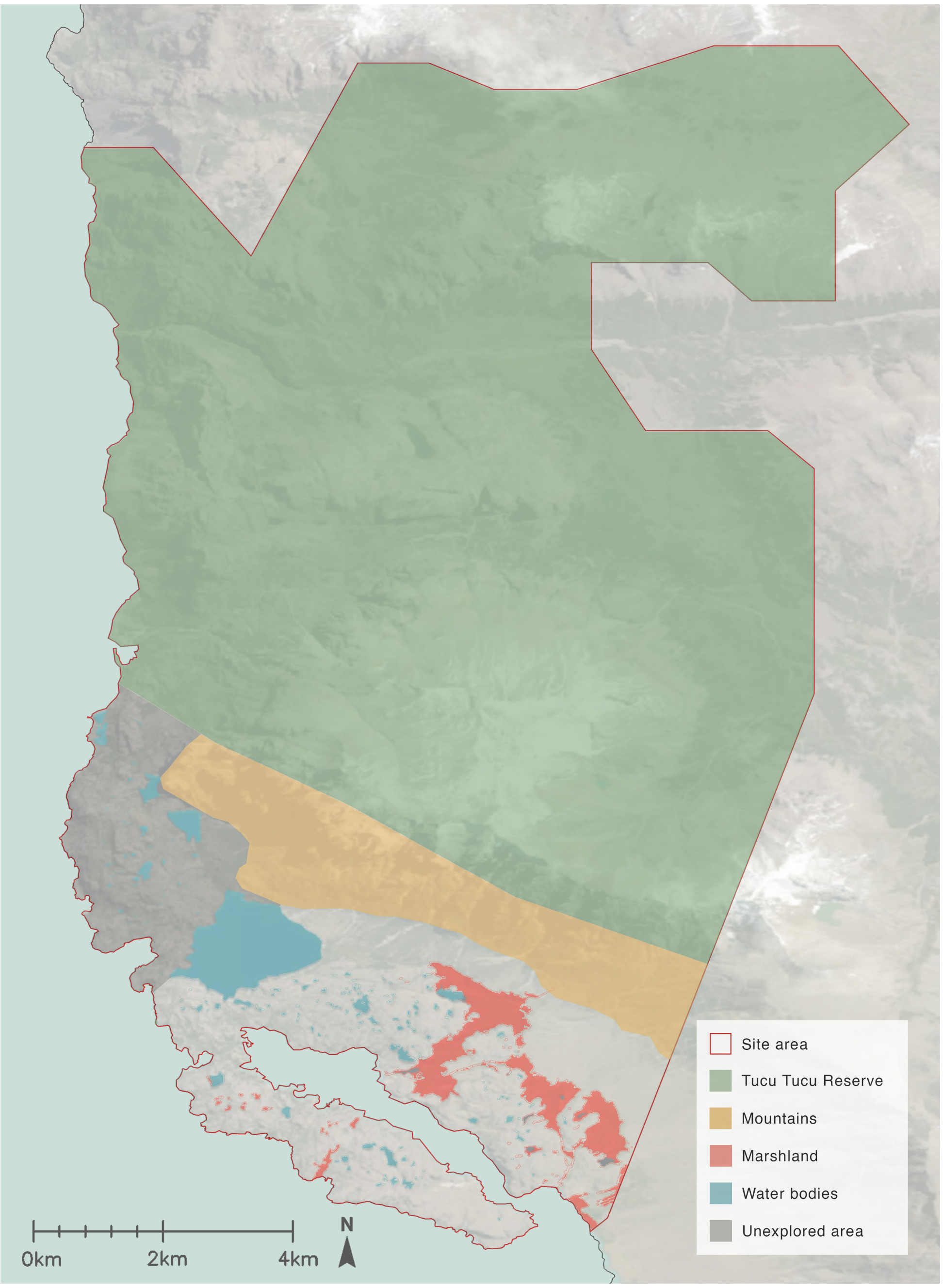


Figure 2.11: Non-buildable zones

2.6 Conclusion

The site analysis provides essential insights that will guide the preliminary masterplan for the eco-tourism village at Estancia La Josefina. The identification of potential development areas, combined with constraints posed by sensitive environmental zones, lays a foundation for responsible planning. Improving accessibility and conducting further on-site surveys, particularly in areas currently unexamined, are recommended next steps to refine land-use decisions and infrastructure placement. These findings establish a solid basis for land-use planning, helping to ensure that development aligns with both visitor needs and environmental preservation.

3 | Stakeholder analysis

In this section a stakeholder analysis is performed with the purpose of identifying, assessing and understanding the stakeholders that might have an influence on or interest in creating a sustainable village in Estancia La Josefina. The interests of various stakeholders have become clear through a desk study and interviews. This section will start with the identification and description of the stakeholders and their interests in Chapter 3.1, followed by a stakeholder assessment in Chapter 3.1 and a conclusion on the most important stakeholders and their interests that will be used as requirements and evaluation criteria in the design phase.

3.1 Stakeholder identification and description

UNASUR

Argentina and Chile are members of the 'la Unión de Naciones Suramericanas (UNASUR) which translates to Union of South American Nations. Within this union, there is a strategic discussion body for planning and implementing the integration of South American infrastructure (COSIPLAN), in commitment to social economic and environmental development. This body is made up of the local Ministers of infrastructure and planning of the different regions. (COSIPLAN, n.d.-a). COSIPLAN aims to implement methodologies and tools to carry out and complete projects, incorporate social participation mechanisms, address the financing of projects with a high socioeconomic impact on the region, improve monitoring and assessment tools, and make headway with the harmonization of the regulatory and institutional frameworks, according to COSIPLAN (n.d.-b). This body might be interested in a new link between Carretera Austral (Chile) and Route Nacional 40 (Argentina) since these are two major roads in both countries with major touristic activity. Connecting these roads can bring a lot of economic growth in the area and better connection between both countries which aligns with the goals of this board. However, the project itself is small but might be a accelerator for the development. That is why UNASUR is expected to have medium interest, but low influence on the project.

Government of Chile

The northern part of Lago San Martín, where the ranch is located, is near the border with Chile. The creation of a sustainable village at Estancia La Josefina has a potential impact on the region's economic and geopolitical dynamics. Because of the border, Chile has an interest in how increased activity in the area could affect trade, tourism, infrastructure and border security. Since the Chilean government is part of COSIPLAN (COSIPLAN, n.d.-a), it is one of their interest to improve connectivity between Chile and Argentina. The creation of a sustainable village on a new possible route between Carretera Austral and Route Nacional 40 could accelerate the improvement of the connectivity between the two countries. This connection could facilitate trade, tourism and economic growth in both countries, as well as strengthen the ties between the two nations. Moreover, the Chilean government is responsible for maintaining security and managing border activities along Lake San Martin. As tourism activity increases due to the development of the village, the government needs to ensure that border patrols and security measures are ready to facilitate this growth. Although the project might accelerate a new connection between the two countries, it is a rather small project. The interest compared to the other stakeholders is considered rather low, but the influence moderate, because the border is very close to the property.

Government of Argentina

The development of a sustainable village at Estancia La Josefina is interesting for the government of Argentina for the same reasons as it is for Chile. Moreover, the ranch is located within a border development zone. A border development zone is a selected area along a border with a neighbouring country. The potential economic growth of the area due to the development of the village aligns with the country's broader goals to promote regional growth, improve infrastructure and encourage settlement in remote areas (G. Argentina, n.d.). The property of the ranch is also a strategic location near the lake, in terms of border security and controlling border activities, because there is a good view of the three arms of the lake. However, the project is very small in scale, so it will not draw the attention of the government in short notice. Following discussions with stakeholders, it has become evident that the government is unlikely to show strong interest in the project. Assistance from governmental bodies should not be anticipated due to the current economic challenges and limited bureaucratic capacity. The government of Argentina thus has a low interest, but a slightly higher than moderate influence.

Province of Santa Cruz, Argentina

A significant part of Estancia La Josefina is located within the boundaries of Provincial Park Tucu Tucu. One of the key priorities is to protect the sustainable use of the natural resources of this park. Therefore it is not allowed to construct any buildings in the Provincial Park. At the same time, the province recognizes the potential for eco-tourism as a major driver for economic growth. This has already been proven in for example El Calafate and El Chaltén. In addition to tourism, the province is interested in integrating eco-tourism with sustainable agriculture and livestock production, allowing local producers to benefit from increased demand (Malatesta, 2020). The province is a more local institution and so the project is relatively of a higher interest than for the government. Their power is considered slightly higher than the power of the government of Argentina, because their bureaucracy is closer to the project and they regulate local development.

Ranch owner

The ranch owner is one of the important stakeholders of the project as he is the current owner of the property and has the wish to sell the land for 4,5 million USD. He has no further interest in developing a sustainable project. His influence is however moderate as he still has to sell the property.

Potential investors

To develop the project, the involvement of investors is essential to make its financial aspects feasible. That makes the power of the potential investors very high. Consequently, potential investors are regarded as the client, including the current ranch manager, who has shown interest in investing. Interviews with multiple potential investors revealed their priorities, emphasizing the preservation of the natural environment and a commitment to sustainable development. Therefore, many potential investors prefer that no more than 5% of the land will be allocated for infrastructure and housing necessary for eco-tourism and future inhabitants (see Appendix C).

Sustainability is so vital to these investors that profitability takes a secondary role. However, most of them do expect a return on their investment. They have highlighted that any future investors should also be selected based on shared sustainability values, as they believe the project would fail if profit-driven investors that do not have a sustainable view are involved.

Additionally, a key consideration influencing their investment is the opening of the water border with Chile. Some potential investors consider the project unfeasible if this border remains closed, which would deter their commitment to invest. Many potential investors also expressed a desire for a plot of land where they could build a residence to live in during a part of the year. The anticipated return on investment time frame varies, with some aiming for a 6-10 year return, while others are comfortable with a 15-year horizon. Both interest and power of the potential investors are very high, making it the key stakeholder in the project.

Environment

The environment plays a crucial role as a stakeholder in the project. Although the environment is not a traditional stakeholder and does not have a voice, it holds intrinsic value and directly influences the success of the project. The prestine Patagonian landscapes and its vulnerable ecosystems define the identity of the region and are therefore a key aspect in the design of a sustainable village. Moreover, the project also influences the environment as stakeholder, especially when the environment is not taken care of. The environment as a stakeholder thus demands that the balance between human development and natural preservation is maintained to ensure that flora, fauna and the ecosystems remain healthy. Any disruption of the natural landscape could have a long term influence on the ecosystem, possibly decreasing the natural, but also economic value of the area. The influence of the environment as a stakeholder on the project is strengthened by the sustainable view of other stakeholders, such as potential investors and future inhabitants. Consequently, the influence of the environment is not low, but slightly lower than moderate. Their interest is, however, very high. The interest of the environment is reflected in the goal of ecological balance and preservation of nature.

Future inhabitants

Future inhabitants of the sustainable village play a central role in establishing and maintaining a cohesive community. Two primary types of future residents have been identified: temporary and permanent. Temporary residents mainly include staff who work at the ranch, supporting eco-tourism activities, while permanent residents may consist of investors who receive a plot through their investment, or individuals who have independently purchased a plot.

Both types of residents share a common vision for a high quality of life that harmonizes the natural environment with essential community amenities. Preserving the surrounding ecosystem is one of their core values, and they advocate for sustainable infrastructure that meets basic needs in an environmentally responsible way. That is the reason why they work and/or live in this area instead of in a more developed environment. Key elements of this infrastructure include a reliable energy system, internet connectivity, waste and wastewater reuse, access to basic healthcare and education, clean drinking water, and locally grown food.

While future inhabitants may have only moderate influence on initial project decisions, their needs and preferences are fundamental to the village's design and functionality. Creating a strong community is especially important for future inhabitants due to the site's remote location. This is why the interest of the future inhabitants is very high. It is even higher to that of the investors, considering that part of the future inhabitants are also investors that actually live on the property. The influence of the future inhabitants is higher than moderate, since they make the community and they are key to the success of the village.

Eco-tourists

Eco-tourists represent one of the key stakeholder groups in the project, as they are primarily interested in experiencing pristine natural landscapes while minimizing their environmental impact. This group includes a range of tourists, from hikers and backpackers to high-budget travellers. Common values among eco-tourists include a strong preference for sustainable practices and a desire for tourism infrastructure that has minimal impact on the surrounding ecosystem.

For eco-tourists, the preservation of local flora and fauna is crucial, as is the protection of the area's cultural integrity. They prefer low levels of human interaction during their visits, seeking remote and tranquil environments that allow them to disconnect from city life. In addition, eco-tourists place significant importance on the availability of on-site activities that align with their values, as well as access to local food.

Although eco-tourists have limited influence on the project's development, their preferences can affect operational decisions, particularly in terms of the types of activities and amenities offered. Their satisfaction plays a vital role in the village's long-term success, as positive experiences can lead to word-of-mouth promotion, helping to raise the village's reputation as a destination for responsible eco-tourism. This, in turn, can foster steady visitation and support the financial viability of the project over time. The influence of the tourists is therefore higher than moderate. Their interest is higher than moderate, but lower than for example future inhabitants or investors. Their interest has a limit, since tourists only stay for a short period of time at the ranch.

Surrounding ranches

The surrounding ranches are important stakeholders in the development of a sustainable village at Estancia La Josefina. Located nearby, these ranches have both direct and indirect interests in the project, including considerations around access, infrastructure, and potential economic benefits. Currently, accessing Estancia La Josefina requires crossing land owned by neighbouring ranches. According to Argentine law, landowners must permit traffic through their property if no public road provides access to the destination property ("Código Civil y Comercial de la Nación, Libro III, Título XIII", n.d.). However, these ranches retain the right to determine the quality and condition of the road.

A sustainable village at La Josefina would increase traffic through these properties, potentially impacting the ranches. For example, during an interview with Estancia Cancha Rayada (see Appendix C.3), concerns were raised about the potential increase in touristic traffic through their land. Although they see potential economic advantages from a sustainable village near the lake, they are in doubt whether they like the added traffic.

Another consideration for these ranches is wildlife management, specifically the presence of pumas. Ranches in the area often hunt pumas to protect their cattle, a practice that conflicts with the conservation goals of other stakeholders interested in sustainable living and eco-tourism in the proposed village.

As Estancia La Josefina is a privately-owned property, the surrounding ranches have limited influence over the project. However, they can still complicate development by restricting access or engaging in practices that may impact the local environment at La Josefina. Therefore, their influence is considered slightly lower than moderate. Their interest is higher than moderate, since the project could have a direct influence on their property and operation in the area. Their cooperation, or lack thereof, could therefore play a crucial role in the success of the project.

Town of Villa O 'Higgins

Villa O'Higgins, a small town north of Estancia La Josefina and connected to the ranch by Lago San Martín, could benefit from an increase in tourist activity in the region. As Chile's Carretera Austral terminates in Villa O'Higgins, it is the end of the route for many travellers. Once they reach the town, tourists have limited options: they can either explore the local surroundings, travel further by ferry, or return north along the highway.

For Villa O'Higgins, increased tourism activity around Lake San Martín and Estancia La Josefina could bring more visitors into the town, boosting demand for local businesses and services, such as accommodations, restaurants, and guided tours. Additionally, the town has an interest in improving transportation links, particularly with Argentina's Route Nacional 40, which would provide a more direct connection across the border. This potential cross-border link could transform Villa O'Higgins into a key gateway between Chile and Argentina, attracting more visitors and supporting the town's economic growth. Villa O'Higgins does not have a direct influence on the project in Estancia La Josefina. Their influence is therefore considered lower than moderate. Since Villa O'Higgins is across the border in Argentina, and considering the small scale of the project, their interest (compared to the other stakeholders) is expected to be lower than moderate.

Tourist companies

Tourist companies, including renowned hotel operators like Explora (Explora, 2024) and Eolo (Patagonia, 2024), along with ferry companies serving other Argentine lakes, represent important stakeholders with significant interests in the sustainable village project at Estancia La Josefina. These companies could benefit from new eco-tourism opportunities in the region, as their guests seek high-quality, immersive experiences in remote and pristine natural settings.

Explora and Eolo, for example, are known for offering luxury eco-tourism packages in Patagonia, catering to tourists who are interested in nature-focused travel without compromising on comfort. They have a vision on sustainable tourism, and partnering with a new sustainable village development could open avenues for unique guest itineraries that include guided hikes, wildlife viewing, and exclusive cultural experiences. These operators would likely be interested in collaborating to design experiences that align with their own sustainability and conservation goals. Their support could also bring financial resources and credibility to the project, as they are well-regarded within the eco-tourism industry.

Ferry operators on nearby Argentine lakes, which currently transport tourists across remote stretches of Patagonia, also stand to gain from the development. Increased tourism around Lake San Martín could justify expanding ferry services, allowing for new routes and even additional vessels to handle higher tourist numbers. However, these operators would need reassurance that the growth in tourism will be managed sustainably to protect the delicate ecosystem, as they too depend on maintaining Patagonia's natural beauty as a central attraction for their clients. Therefore, their interest is high. Their influence is considered rather low, because they only exploit activity on the property based on their view and the wishes of their guests (the tourists).

Fundación Rewilding Argentina

Fundación Rewilding Argentina is a foundation that aims to recover complete and functional ecosystems through rewilding, guided by the respect for the intrinsic value for species and by the goal of establishing development models that allow rural communities to live in harmony with the natural world. They promote the creation of new 'nature destinations' through experiences offered by local guides and other entrepreneurs and businesses who value wildlife and regional culture (F. R. Argentina, n.d.). It is thus in their interest to regulate the livestock in the area to give more space to the wild animals in the area such as the guanaco and the puma. The interest of this foundation is therefore very high, but influence very low.

Access fund

The Access fund is an American organisation that comes up for the climbing community, focusing on protecting and promoting access to climbing areas. Since 96% of the land in Argentina is privately owned (Lavagna, 2021)(including the property Estancia La Josefina), it is not allowed for climbers to enter the terrain without permission. Since climbers are part of the tourists that visit this area, they play an important role in the business opportunity. The Access fund desires that the climbing community is integrated in the design of the sustainable village. Their interest is considered very high, but influence low.

3.2 Stakeholder assessment

In the previous chapter, the stakeholders are identified and their interests and possible influence on the project are described. To assess the stakeholders, an power-interest stakeholder matrix is made. This matrix has four quadrants, with on the vertical axis the power, and on the horizontal axis the interest. Power is defined as the stakeholder's 'influence to change the projects decisions or outcomes'. Interest is defined by 'how much the stakeholders care about the project's success or failure' (Engr, 2024). The stakeholders with high power and high interest are placed in the upper right quadrant and are in the category 'key players'. They need to be managed closely. The stakeholders with high power and low interest are placed in the upper left quadrant and are in the category 'keep satisfied'. They have no interest, but are very powerful and could be a risk for the project if they are not taken care off. The stakeholders with high interest and low power are placed in the lower right quadrant and are in the category 'keep informed'. This category could add value to the project, but does not have a lot of power. The stakeholders with low power and low interest are placed in the lower left quadrant and are in the category 'monitor' (Engr, 2024). In Figure 3.1 the stakeholder matrix is shown. The placement of the stakeholders is discussed in previous Chapter 3.1.

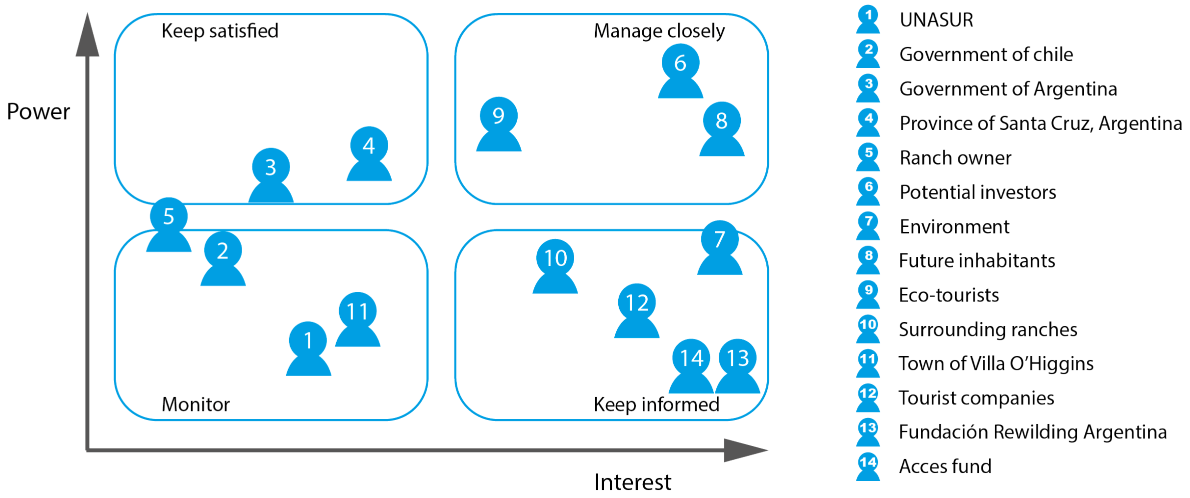


Figure 3.1: Power-interest stakeholder matrix of the project

The stakeholders in the upper right quadrant are most critical for the development of the project, because they have a high power and high interest in the project. These are potential investors, eco-tourist, and future inhabitants, which are called key stakeholders. The second most important stakeholders are located in the lower right 'keep informed' quadrant. Although the upper left 'keep satisfied' quadrant has stakeholders with more power, they care less about the project. As long as these stakeholders are satisfied, they will not interfere with the project. The stakeholders in the lower right quadrant that are positioned close to the upper right quadrant are therefore the second most important stakeholders in the project. Of these stakeholders, the environment is the stakeholder with most interest in and influence on the project and is thus considered a key stakeholder.

3.3 Conclusion

From the stakeholder assessment it became clear that there are four key stakeholders. These are the potential investors, eco-tourists, future inhabitants and the environment.

Potential investors are driven by a strong commitment to sustainability, seeing profitability as secondary to ecological preservation. Their high influence over the project emphasizes their desire to limit infrastructure to a maximum of 5% of the land area, ensuring minimal environmental impact while allowing for necessary amenities.

The environment holds intrinsic value and significantly influences the project's design although it is not a conventional stakeholder. Protecting the unique Patagonian ecosystems is important, as any disruption could harm both the natural and economic value of the area. Environmental preservation is a priority for investors, future inhabitants, and eco-tourists, reinforcing the need for a balanced approach to development.

Future inhabitants seek a high quality of life that aligns with ecological sustainability. They emphasize the importance environmentally friendly infrastructure and are deeply committed to the village's long-term success as a community.

Eco-tourists seek to experience pristine natural landscapes and want to minimize the impact on nature with their visit. Their preferences influence the types of activities and amenities offered and contribute to the village's reputation as an eco-friendly destination, which is critical for long-term financial viability.

4 | Market study

This chapter presents an analysis of the market study. Firstly, the market gap and consequently the business target are studied, to evaluate La Josefina's potential as a tourist destination in the area. The purpose of this chapter is to establish, also through interviews, the profiles of the expected population of the village.

4.1 Market gap

To identify the market gap that this project could address, an analysis of the area's population was conducted in order to explore the demographics and behaviours of the individuals who will either reside in or visit the sustainable village.

The unique location of the estancia offers an extraordinary blend of natural beauty, isolation, and cultural heritage. Nestled near National Parks and glaciers with minimal human impact, it allows visitors to disconnect from the modern world.

The tourists examined in this research are those travelling along two major routes: the Carretera Austral in Chile and Ruta Nacional 40 in Argentina. Currently, there is no direct connection between these routes near La Josefina. Establishing a link between them would create a new tourist corridor, allowing travelers to pass through La Josefina. Therefore, it is essential to understand who these tourists are, the nature of their journeys, and, most importantly, the facilities and amenities they would require at La Josefina.

Carretera Austral
La Carretera Austral, or Route 7, is a Chilean road located in the southernmost region of Chile. It is the main land transportation route in the Aysén Region and the Palena Province in the Los Lagos Region, connecting these areas with the rest of the country by traversing Chilean Patagonia. As of 2014, the road spanned 1,240 kilometers, linking Puerto Montt with Villa O'Higgins. However, the long-term project aims for the road to eventually reach Puerto Williams. In the North it is connected to the Carretera Panamericana (Patagonline, 2024). The Carretera Austral can be traveled in regular vehicles along its entire length, though it includes both paved sections and gravel sections.

Ruta National 40
La Ruta National 40, built in 1935 and also known as RN40 or "Ruta 40," is a route in western Argentina, extending from Cabo Vírgenes near Río Gallegos in the Santa Cruz Province in the south to La Quiaca in the Jujuy Province in the north, with a total length of approximately 5,194 kilometers. The route runs parallel to the Andes mountains. The southern part of the route, which is now largely paved, has become a well-known journey for adventure tourism, and there are plans to pave the entire road. RN40 is the longest route in South America and one of the longest in the world. At its traditional southern end near the city of Río Gallegos, it starts at sea level. The road crosses 20 national parks, 18 major rivers, and 27 passes in the Andes. The highest point of Route 40 is 5,000 meters (16,404 feet) at Abra del Acay in Salta Province. The route traverses the provinces of Santa Cruz, Chubut, Río Negro, Neuquén, Mendoza, San Juan, La Rioja, Catamarca, Tucumán, Salta, and Jujuy (Turismo Ruta 40, 2024).

In Figure 4.1 it is possible to observe La Josefina's location and its proximity to these two routes.

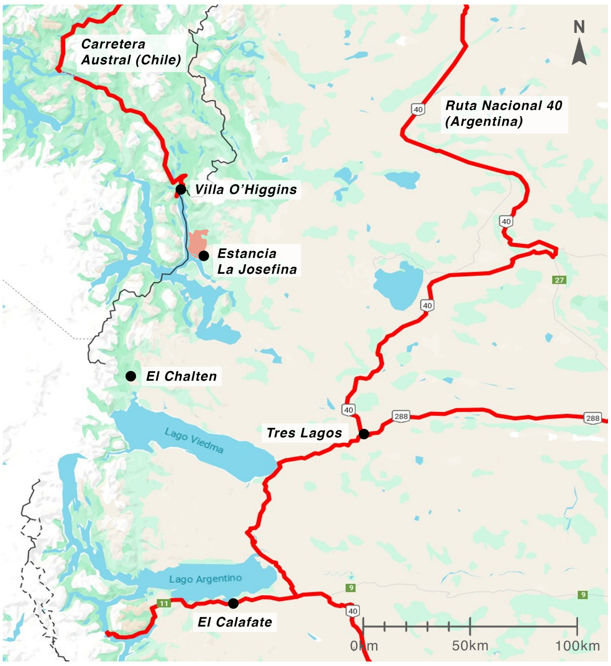


Figure 4.1: Carretera Austral and Ruta Nacional 40

The specific route that this research is focused on is the one between El Chaltén (Argentina) and Villa O'Higgins (Chile). The current way to arrive from one place to the other is long, complicated, and adventurous (LaidBack Trip, 2024). From Villa O'Higgins to arrive at El Chaltén the route is the following:

1. Take a bus from Villa O'Higgins to Puerto Bahamondes.
2. Take a ferry (around 3 hours) from Puerto Bahamondes to Candelario Mancilla.
3. Walk or bike from Candelario Mancilla to the Border (1 km).
4. Walk or bike from the Border to Lago Desierto (22 km).
5. Cross Lago Desierto by boat or on foot.
6. Take a bus or hitchhike from Lago Desierto to El Chaltén.

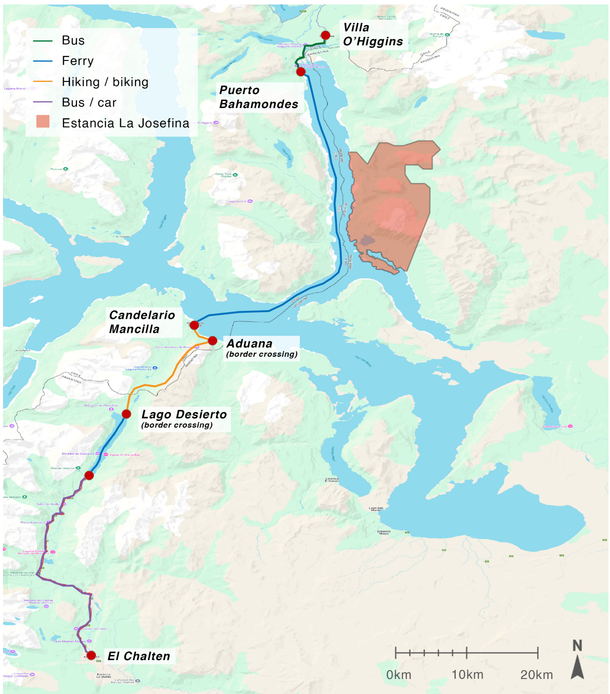


Figure 4.2: Current Route

4.2 Business target

The goal of this research is to determine the business target, in terms of profiles of people who will form the core population of the village and the activities that could attract tourism in the area. Once the profiles are worked out, the planning for housing, utilities, and amenities will be discussed in Chapter 9. For this reason this part of the research is divided into two main categories: population, which was further subdivided into tourists and inhabitants, and activities.

4.2.1 Population: Tourists

The tourist analysis was made to develop a tourist profile and to understand the number of tourists visiting these areas every year.

The tourists' of interest are the ones who visit the villages of Villa O'Higgins, El Chaltén and El Calafate. In the analysis, a closer look is done at the tourists crossing the border from Villa O'Higgins, Chile, to El Chaltén, Argentina, since La Josefina could be potentially included in this route.

Data collection

To have a more detailed overview of the tourists in the area, different entities were contacted, such as:

- Border crossing points
- Tourist information centres
- Local municipalities

Villa O'Higgins

Villa O'Higgins is a village in Chile's Aysén region and the endpoint of the Carretera Austral. Located north of Lake San Martín, it serves as the primary crossing point from Chile to Argentina via the lake, making it a key location for this analysis.

Data provided by the Municipality of Villa O'Higgins (Turismo Villa O'Higgins, 2024) includes the names and nationalities of tourists for each month of 2023 and 2024, along with details on tourist types and modes of transport. Additionally, the Tourist Information Center reported that around 3,000 people cross the border annually during the open season.

In total, 6,772 tourists were recorded in 2023, while the 2024 count (from January to July) stands at 5,859. A detailed breakdown of this data can be found in Appendix C.

El Chaltén

El Chaltén is a small village in the Santa Cruz Region in Argentina. It is known as the Trekking Capital of Argentina and it's located in the Parque National Los Galciares. Since it is a destination known worldwide for trekking, it consequently attracts many tourists. Data were collected there to gain insights about the main attractions that interest tourists and the type of accommodation they choose.

An insight regarding the type of tourists that travel to this are was obtained by interviewing Rolando Garibotti, an alpine guide that worked in the region for many years and knows the area very well. According to him, tourism in El Chaltén has shifted significantly, and it is now facing challenges related to over-tourism. Daily visitors at popular sites like Laguna de Los Tres range from 2,000 to 2,500. The population in El Chaltén almost quadruples during the summer. The majority of tourists (90-95%) tend to engage in short walks within the valley, opting not to explore more adventurous routes or backpacking opportunities. This has led to a decline in the village's appeal as a destination for backpackers. The complete interview can be found in Appendix C.2.1 .

El Calafate

El Calafate is a city of around six thousand inhabitants located in the Southern Patagonia and as El Chaltén it belongs to the province of Santa Cruz. It represents a significant tourist destination not only due to its airport, but also because it is the starting point for many tourists visiting various points of interest in Los Glaciares National Park, including the Perito Moreno Glacier (one of the most visited in the world), Cerro Chaltén, and Cerro Torre.

The data was found on the Santa Cruz Patagonia Tourism Observatory website (Turismo Santa Cruz, 2018). They distributed surveys to tourists arriving at El Calafate airport, to investigate their accommodation preferences. This data offered insights into visitor numbers and their choices of where to stay, revealing approximately 20,000 visitors during the winter season and 50,000 in summer. Their preferred types of accommodations are luxury hotels (4-5 stars) and hostels.

Overview of tourist types

By understanding the current route, it is possible to identify the types of tourists who would be inclined to explore a new route that includes La Josefina as a destination. The profiles of potential tourists in the area, based on their types and interests, are:

- **Backpackers**: Adventurous travellers seeking affordable accommodations and immersive experiences, who are interested in either camping or staying in a hostel. They would consider staying at La Josefina as an intermediate step of their journey.
- **High-Income Tourists**: Visitors looking for luxury accommodations and exclusive activities, such as private fishing or guided tours.
- **Climbers and hikers**: Outdoor adventurers seeking scenic trekking routes and challenging climbs.

4.2.2 Population: Inhabitants

The different types of inhabitants of the village that were identified are divided in the following two categories:

- **Permanent residents**

- **Temporary residents**

Each group will have different needs for housing, amenities, and communal spaces.

Permanent residents
This category consists of three types of people:

- Plot owners
- Investors
- Working staff

The first category would be interested in buying a plot of land in the area and relocating there by building their permanent house. The investors, that are essential for the realisation of the project, by investing on the project will have a plot of land. Their interest in having a plot of land in the area was assessed with the interviews that were held and that can be found in Appendix C. The last category of permanent residents includes the staff, essential for the daily operations of the eco-tourism village. The workforce will be determined based on the current staffing ratio practised at the estancia, which requires staff to number approximately 40% of the total tourist population during the tourism season.

Plot owners are not only investing in a place to live but are also dedicating themselves to contributing to the village's growth and daily operations. Their involvement goes beyond simply residing in the area, as they will take on permanent roles in various aspects of the village's functioning, such as managing facilities, participating in sustainable farming practices, or supporting local eco-tourism initiatives.

Investors, on the other hand, are essential in every stage of the project. They are people interested in the development and long-term success of the sustainable village. Their financial contributions will be critical to achieving the realization of the project, from the initial construction phases to the full realization of the village's sustainable infrastructures. In return for their investment, these stakeholders will receive a plot within the sustainable village, enabling them to have a personal involvement in the community's growth and evolution.

Potential investors were interviewed during the weeks spent at the estancia to gain a deeper insight into their vision of the project and the interviews that were held can be found in Appendix C. It is highlighted in the interviews the necessity for health and education accessibility, and a good internet connection.

This category is considered a type of inhabitants since these investors will have the opportunity to settle in their plots.

Temporary residents
Temporary residents were identified as people who would come to the village for a limited amount of time. The temporary residents of the village are identified in two main categories:

- Digital nomads
- Temporary workers

The first category consists of remote workers who usually travel to different locations.
According to (Cook, 2023) *'Digital nomads use digital technologies to work remotely, they have the ability to work and travel simultaneously, have autonomy over frequency and choice of location, and visit at least three locations a year that are not their own or a friend's or family home'*.
These remote workers would spend some months at La Josefina while continuing to do their jobs online.

To have insights about the life and the work of a digital nomad, as well as the aspects they usually take into account while choosing a place to live for a few months, a questionnaire was prepared and given to digital nomads met in the city of Buenos Aires, which results can be found in Appendix C.1.2.

The second category of temporary residents was identified with people who would come here for a Workaway experience. This would be possible by establishing a Workaway on the site.

The concept behind a Workaway relies on putting your own time at the service of your host (the one who hosts you) who in return guarantees you food and accommodation. The agreement with the host consists of working for 4-5 hours a day (excluding weekends) and in exchange the host offers you free accommodation and free meals. The most important aspect of the WorkAway platform is the money saved by both the volunteer and the host. The volunteer will have free food and accommodation, while the host will have someone enthusiast about the project to help.

Offering a Workaway program at the village was considered a valuable option that could benefit both parties: the locals and the volunteers. The locals would gain the advantage of having volunteers working for them, going from assisting with tasks such as organizing activities like hikes, yoga classes, and workshops in ceramics and photography, but also cleaning the rooms of the guests and preparing food for them, while volunteers would have the opportunity to have a unique experience in Patagonia, the chance to explore it and the possibility to connect with local people at a very reasonable cost.

To have a better insight into the experience of a Workaway and discover what are the main aspects that need to be taken into consideration for organizing one, two people were interviewed and they can be found in Appendix C.1.1.

4.2.3 Activities

A wide array of activities were identified as suitable for the area. These are a combination of activities already offered by the estancia and others that are considered appealing for both tourists and inhabitants.

- **Trekking on the Argentine side of Lake San Martín**: Explore diverse trails that showcase the area's untouched beauty.
- **Fishing on Lake San Martín**: Exceptional fishing opportunities for both casual and experienced fishermen. Also includes fly-fishing tours for experts or with a guide.
- **Star gazing and night photography**: Patagonia is one of the areas with the lowest light pollution in the world, making it the perfect place for astronomy lovers.
- **Horse riding**: Guided horseback rides through the Patagonian landscape, offering an authentic Gaucho experience.
- **Edible forests and sustainable gardening workshop**: Learn about and engage with sustainable food forests that grow edible plants in harmony with the environment, and learn how to grow food through special techniques such as permaculture.
- **Animal safari and bird-watching**: Wildlife observation opportunities to see iconic Patagonian species such as the huemul, puma, and condors.
- **Glacier excursions**: Potential trips to explore nearby glaciers, allowing visitors to witness Patagonia's majestic ice formations up close if border crossings are made available.
- **Boat trips on Lake San Martín**: Scenic boat tours offering breathtaking views of the lake and its surrounding wilderness.
- **Workshops**: Engaging activities such as ceramics, cooking classes, yoga, photography, painting, and more, catering to tourists seeking creative and mindful experiences.
- **Winter activities**: The location of the village offers opportunities to practice winter sports and activities such as cross-country skiing, sledding, and snowshoeing.

4.3 Conclusion

The purpose of the market study was to identify the potential population of the village, categorized into two groups: tourists and inhabitants. It also helped define their needs through interviews that were conducted. Additionally, the study explored the potential of tourism at Estancia La Josefina to facilitate the accessibility in the region of Lago San Martin/O'Higgins. These insights will guide the development of a sustainable ecotourism village at La Josefina.

5 | Case study: Los Huemules

5.1 Los Huemules introduction

The most critical case study is Los Huemules, located near the town of El Chalten within the Santa Cruz region of Argentina. Additional case studies are used for specific aspects of the design and will described in their respective sections. The community is located on 5,800 hectares and is the most developed ecotourist village in the Santa Cruz region. Within the property there is a large river called Rio Diablo, a lake called Lago Azul, housing communities, and a nature reserve. The river on the property can be seen below in Figure 5.1. The housing of Los Huemules consists of 91 one hectare plots for permanent residents and two hotels in the North and South parts of the property. The building's footprint of the total property is 3.5% and the remaining land is a protected nature reserve. Additionally, Los Huemules has a published environmental assessment of the area referencing all crucial laws that must be followed, most of which have minimal enforcement as the development is on private property. As a result most construction on the property followed European codes and laws for construction codes.

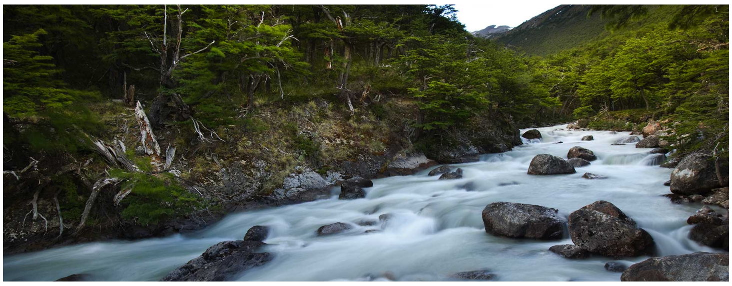


Figure 5.1: Rio Diablo in Los Huemules (RANCH, n.d.)

5.2 Existing building codes

The environmental impact report of Los Huemules detailed the building codes for the area within their environmental assessment, mandating all homes must be built at least 30 m from the nearest water source to prevent pollution. All pipes must be buried at least one meter below the ground to prevent pipe freezing, and the proposed pipe material is HDPE. This pipe material allows for the contraction and freezing of pipes during winter without bursting. In addition to the building codes, there is detailed information regarding fire precautions, safety structures, and regulations housing during emergencies. Regarding fire safety, fire hydrants must be located every 100 meters along the roads of the property, and a fire protection room must be located on the premises with firefighter gear and extinguishers. Lastly, there is an additional requirement to have enough possible housing for all staff and visitors in case of severe inclement weather and people being unable to leave (**Martinez2001**).

5.3 Current water and wastewater system

Los Huemules details their water treatment and sewage system as well. With potable water being collected from the river on the property at an upstream point to prevent pollution. At the intake point there is a water storage tank large enough to supply water to the village for up to twelve hours. Sewage treatment on the property is maintained individually on each plot of land with a reed filtering system below the homes. The effluent is then dispersed to various parts of the river to increase the dilution of possible pathogens. This would be a useful wastewater treatment method to apply to La Josefina if urine diverting toilets are found infeasible. However, a large difference between the two properties is the lack of running water through La Josefina compared to Los Huemules. A new wastewater method is offered for recently built homes in the form of individual anaerobic digester tanks. However, these tanks just process the waste, and do not collect the biogas released. Due to neither of their current solutions reusing any waste products they will not be applied to the final proposed design.

Regarding the fresh water used on the Los Huemules property, all water is taken from Lago Azul on the property. The lake can be seen in Figure 5.2 below. The water is tested annually for pH, conductivity, hardness, certain ions, turbidity, bacteria, nitrogen, COD, and fluoride. Initial tests found levels of pH, hardness, COD, conductivity, calcium, magnesium, and fluoride the levels proved to be safe and sufficient to be drunken straight from the river. However, the initial turbidity, nitrogen levels, and faecal coliforms levels were too high for direct human consumption and require some treatment prior to consumption. Regarding turbidity, the levels were high most likely due to flowing from the glaciers to the lake, this is treated with a fine filter. The nitrogen levels are a bit lower than expected, however it is assumed this is a result of sample contamination rather than the water itself, later tests found it is not hazardous to human health. Lastly, high traces of faecal coliforms and bacteria were found in the water most likely as a result of the large animal population in the area and the faeces entering the water. The wild cow population from the property was removed to prevent the need for a disinfection treatment. As a result the only existing treatment on the property is filtration, and since the initial development in 2000, all water tests have complied with quality regulations.

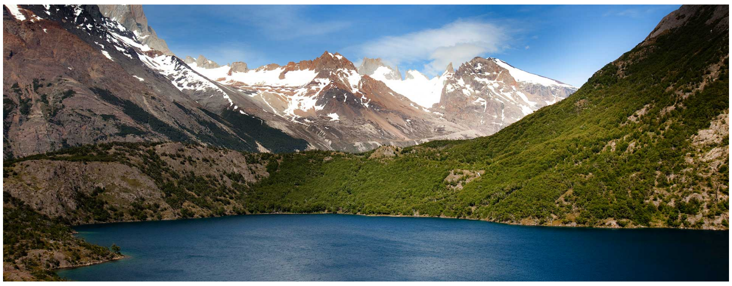


Figure 5.2: Lago Azul in Los Huemules (RANCH, n.d.)

5.4 Healthcare

Regarding health care, the property includes a facility for basic medical needs and maintenance where one of the working staff members can assist the guests or other staff members. However, for any larger medical emergencies the property has two off-roading ambulances to be able to rush the patient to the nearest hospital in El Calafate. An incorporation of some vehicle to transport people in case of emergencies is necessary in the final design proposal of the village. In the case of the village without having direct road access, constructing a helicopter pad could be the best alternative.

5.5 Energy

For the selection of energy sources on the property, an assessment was conducted to determine the best source of energy between hydraulic, wind, and diesel. Diesel was selected as the best option for the property, and five generators are also on the property in case of an outage. Los Huemules recently installed a small hydroelectric turbine to power the street lights around the property as well to promote green energy. After discussing the energy alternatives with the property manager, the wind levels on site are lower than La Josefina, so wind energy could not support the entire community.

5.6 Community support

Lastly, Los Huemules conducted an impact study relative to how the sustainable village will impact the community of Santa Cruz as well as its acceptance. The study found that many people felt positively about the increase in jobs for the area, but expressed concerns about the commercialization of the region and increased pollution. To minimize the concerns Los Huemules created an in depth environmental analysis to show all the efforts in place to have as minimal of an impact as possible. During the introduction of the eco-tourist village locals were invited to the property for a forum. During this forum the locals had a voice to express their concerns and the owners of the property remained very transparent about all actions and stages of the development. their main concern was for a similar thing to occur as it has in Bariloche and diminish its natural beauty. Where the town was developed quicker than the infrastructure could support, and negatively impacting the environment. It is important to not that most of the jobs are seasonal to support the increased tourism during the summer months, and many of the staffers travel from Chile for the peak season. Regarding providing education for children that would live on the property, they must travel to the schools in the town of El Chaltén.

5.7 Site visit

After having the opportunity to visit Los Huemules and meet with the property manager, the successes of the property were discussed, as well as what could be changed. The main successes were its ability to surround its residents with nature while protecting the environment, and all of the plots on the property were sold within ten years of breaking ground. However, after 25 years of development only 14 of the 91 plots have built homes.The owners of the undeveloped plots are planning to resell the plots for a return on investment. This creates a lack of community in the area, leading to a proposal for the La Josefina development to include strict plot purchasing regulations with a clause stating within five years of purchasing the plot construction of a home must begin. Part of the plot owner regulations can be seen in Figure 5.3. These same regulations will also include types and restrictions of homes the purchasers can built to minimize the environmental impact. Another important addition to the final design after the site visit is the addition of a small road or path for all-terrain vehicles to facilitate easy passage between different development zones for the transport of staff and goods. During the visit it was also noted the importance of all water and wastewater systems to be individual for each structure to reduce large investments at the beginning of the project. Lastly, an important aspect needed for the proposed development will be a fire protection plan as in summer months the vegetation is very arid. Currently, a fire protection plan is out of the scope of the proposed master plan but it will be necessary prior to beginning further development of the design.

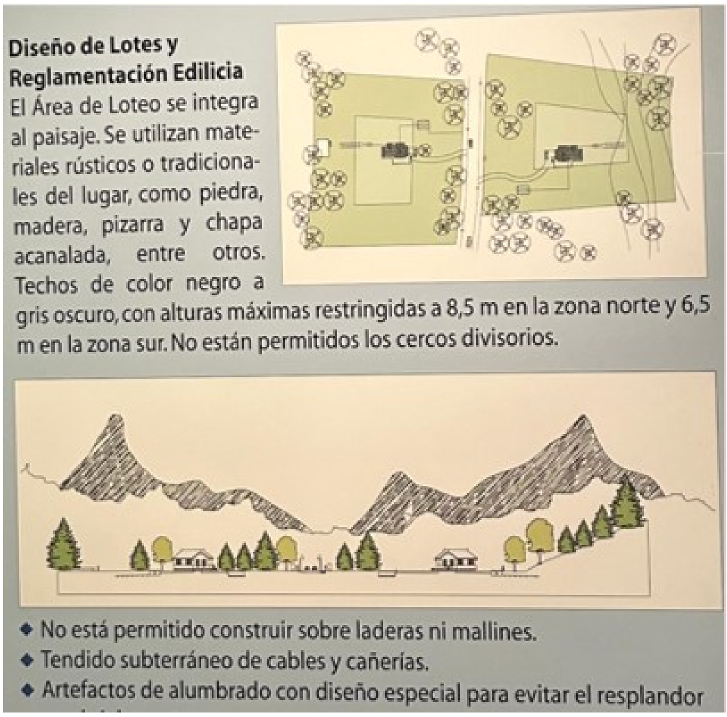


Figure 5.3: Plot construction restrictions

5.8 Conclusion

The most relevant information found from Los Huemules are their successes and failures. This analysis helped identify essential features for this project and the issues that need to be addressed. Ultimately used to help create the foundation of our requirements and limitations for our project. Additionally, these outcomes helped mould our philosophy to create a better society with better environmental protection.

6 | Philosophy: Creating a sustainable village

The proposed project aims to balance the social, economic, and environmental aspects of the design. Socially the design is intended to create a community, that educates the visitors and permanent residents about sustainable options. Economically, the goal is for the project to be profitable in a sustainable way while still protecting the environment. Lastly, the whole project is intended to provide a space for humans to interact with an incredibly beautiful and uninhabited part of the world. All social, economic, and environmental factors help lead to the final goal of increasing the current value of the property by being able to share it with many more people. It is important to note that the social and environmental aspects are values intended for the project being balanced with the economic conditions of the project to be successful and possible.

6.1 Social sustainability | People

The primary social goal is to create an open and educational community based on the desire to enjoy and protect the natural beauty on the existing estancia. To support this, the proposed design includes steps and precautions aimed at fostering a strong sense of community and avoiding issues seen in the Los Huemules case study. Below the many proposed ways to create a successful community are listed.

- Providing two staff residence options to cater to two different audiences. The first being individual dorm housing for single "workaway" type staff that want to help with the creation of the estancia for the experience. Within this housing type multiple shared spaces such as kitchens and common spaces are providing to foster this community. The second type of staff housing option is targeting at young families wanting to settle down without having the burden of a mortgage. The second staff housing type is a home for a family with 3/4 of a hectare of property given to the staff to work off over a certain amount of years. This allows families to be rooted on the estancia and increase the amount of permanent residences rather than only temporary tourists.
- The common spaces for the hostel and campsite are shared to allow both groups of tourists to interact and create a welcoming atmosphere. Shared spaces will be a common priority in all tourist and staff structures to help create a more welcoming community.
- As previously mentioned part of the way of creating a community is through the concept of education, particularly regarding sustainable education. All proposed sustainable practices will be used as an opportunity to teach guests about better practices to implement in daily life that can help reduce negative environmental impact. Some examples could be explanations about energy consumption, and green energy alternatives. Another crucial educational purpose will be on educating Argentinians on reducing water consumption. Excessive water consumption is a large problem the country currently faces, so using the beautiful back drop with very detail water reducing measures implemented, it provides a great opportunity to share this information with the guests and residents. Lastly, there is a large educational opportunity to explain the impacts climate change will have on the world if it continues at its current rate based on the melting of the glaciers. This provides a visual representation of climate change's impacts.

6.2 Environmental sustainability | Planet

When designing an eco-tourism village the environment of course will hold a very large role in the overall design, the main goal being to avoid green washing and encourage genuine environmental protection. This task is very difficult to balance, and remained an ethical dilemma for the group, by determining how much development would diminish some of the uninhabited beauty of Patagonia. Environmental protection is much easier to maintain on a smaller scale as seen by the concepts and beliefs conducted by Earthship Biotecture. The design created by Earthship Biotecture is a general concept for a circular home that can be located around the world, a more detailed explanation is in Appendix 6 However, in the case of this project in order for the project to break even or make a profit, the capacity had to be increased than what was originally hoped for to minimize environmental impact. As a whole conceptually the idea of creating an economy as circular as possible in a rural location is ideal, to avoid depending on alternative sources for basic needs, but this also must be balanced with the toll that this can have on nature. Below many environmental protection provisions are listed.

- All of the food, or as much as possible will be grown on site, educating the visitors about the benefits of eating locally, while also being able to learn traditional recipes.
- Utilizing local materials for construction like clay and straw, not only is economically beneficial, it also is energy efficient and minimizes the amount of goods needed to be transported to the site.
- Creating a green energy system that can support a capacity of 300 people.
- Reuse of waste materials for a circular economy. Using PET plastic for home insulation, feces for compost, and urine to be used as fertilizer.
- Not allowing cars on the property will be greatly beneficial for the environment removing the chance of emissions, while also encouraging a social walking community.

6.3 Economical sustainability | Profit

As all projects must be profitable, this project is no different than any others in that sense. However, with an environmentally focused project and in such a rural location a profit can be difficult to make. In the case of this project, profitability is mostly addressed by increasing accessibility, and thus allowing more visitors of the estancia and increasing revenue. In addition to having complex economics from the project being remote and sustainable, the current economic situation in Argentina is very tumultuous with high inflation rates, requiring a need for a quick return on investments. Typically the quicker the return on investment the less environmentally friendly a project is. This project aims to balance these conflicting ideals by targeting investors wanted to join the community resulting in a more delayed need for a return on investments. The main proposals to tackle the economic balance are listed below.

- As much individualized initial developments such as water tanks and sewage systems in order to help reduce overall initial investment, and spread it over many years.
- Targeting clients that are not as eager for a quick return in investment, by creating a 20 year development plan with four, five year phases. This prolonged developed time allows for a more gradually and less severe environmental impact.
- Prioritizing accessibility before other steps in the phases are complete. This combined with the first and second proposal allow some of the estancia to be occupational during the 20 year construction project, allowing some incoming income to be able to offset initial investments.
- On property growth of food in greenhouses and usage of cob materials on-site helps prevent the large costs of transporting goods to this remote place.
- Catering to a large range of tourist types allow an income to be made while still remaining accessible for people of all financial classes.

6.4 Conclusion

The philosophies listed above encompass the overall goal of the project while also detailing the intricacies between the social, economic, and environmental ideals. The listed examples in each section are a few of the many detailed examples provided in each of the following report sections. Throughout the following sections each of these philosophies are kept in mind consistently for each design choice made.

7 | Determination of the population size and distribution

This chapter establishes the population-related functional requirements and constraints, which are essential for the preliminary masterplan. Through two multi-criteria analyses (MCA), it determines the optimal population size based on stakeholder preferences and defines how this population should be distributed across various accommodation types.

7.1 Objectives

Building upon insights from the stakeholder analysis (Chapter 3) and market study (Chapter 4), which provide general direction regarding population size and distribution, this chapter aims to refine and specify these requirements and constraints in greater detail. The stakeholder analysis established a maximum population of 500 people as an upper limit, while the market study identified various demographic groups with unique accommodation needs. The objective now is to make these broad guidelines more precise by defining the optimal population size and its distribution across the different accommodation types.

To achieve this, two distinct multi-criteria analyses (MCA) are performed, each focused on a different objective:

- **Optimal population size MCA**
  Optimisation of the population capacity for the sizing of the preliminary masterplan.
- **Population distribution MCA**
  Proportional distribution of the population number within the different demographics catered for in the preliminary masterplan.

The multi-criteria analysis method is chosen because guarantees results that align with the stakeholders' preferences on the selected factors, based on a set of predefined criteria. This approach allows to easily obtain outcomes that try to satisfy every party involved in the project.

Due to the different goals of the two MCA analysed in this chapter, two methods of rating are used. For the purpose of the population distribution MCA, the preferences of the stakeholders are achieved by rating the importance of each criterion for all stakeholders on a scale from 0 to 10. In cases where a stakeholder views a criterion as having a negative impact on their decision, a negative score is assigned. A large scale is chosen since it allows to have a detailed distribution of the options due to the broad score availability. On the other hand, for the purpose of the optimal population size MCA, the preferences of the stakeholders were achieved by rating on a scale from 0 to 3. A more compact scale is chosen since it is not necessary to ensure a distribution of the options but rather clear final results. This scoring avoids neutral ratings ensuring that the final result stands out from the other options.

7.2 Criteria

Criteria are established to evaluate and compare the alternatives of each multi-criteria analysis. Below, the five criteria chosen for the MCAs are outlined. Each of them encompasses various sub-criteria which are categorised for simplicity and clarity.

1. **Environmental impact**

   Due to the importance of sustainability in the project as a whole, environmental impact is a necessary criterion to include. This category considers factors such as energy efficiency, carbon emissions and visual impact. A high score indicates a low environmental impact.

2. **Affordability**

   This criterion is defined as the spending costs of the tourists staying at the eco-tourism village, as well as the cost of living for the permanent inhabitants. This is an important criterion to consider as it directly affects the target audience which the village is being designed for. A high score reflects a high affordability.

3. **Business growth**

   Business growth considers both income and revenue, focusing on the resulting growth after factoring the two. This criterion also considers the scalability and adaptability of the options being analysed. Including this category promotes long-term business development which is necessary for a project of this nature. A high score indicates high business growth.

4. **Technical difficulty**

   Technical difficulty is especially important to consider as its own criteria due to the current limited accessibility to the site location. This category includes the sub-criteria of feasibility, maintenance and construction time, with a high score reflecting low technical difficulty.

5. **User comfort**

   The final criteria is that of user comfort, which considers amenities available and the quality of stay provided by the options being evaluated. This criteria is essential in order to create a positive experience for the first-hand users of the village. A high score reflects high user comfort.

For a better understanding of what each score represents for the different criteria in the two MCAs, refer to the Tables B.1 and B.2 in Appendix B.1. These tables provide detailed explanations of the scoring system explained in Chapter 7.1.

7.3 Stakeholders

After defining the criteria, the main stakeholders are identified, as their preferences dictate the scoring system used in the multi-criteria analysis. As discussed Chapter 3, the primary stakeholders are the following:

- Investors
- Tourists
- Environment
- Inhabitants

Each stakeholder was given equal weighting no matter the influence of their preference on the final decision to assure the alignment of the final decision on the population size and of the population distribution with the requirements of all the stakeholders.
In addition, the analyses are also performed with the stakeholders having different weightings, in order to investigate the sensitivity of the outcome. The sensitivity analysis can be found in the Appendix B.4.
Having defined the main stakeholders, the scoring and the descriptions of their preferences on the importance of the different criteria are obtained. Through surveys, that were given to the different types of stakeholders, and guided by the philosophy of the project (Chapter 6) the rating for stakeholder preferences for both the MCAs were decided and can be found in the Appendix B.2
With the main stakeholders identified, the scoring and descriptions of their preferences regarding the importance of the different criteria are obtained. Surveys were conducted among each stakeholder group (Annex C), and the project philosophy outlined in Chapter 6 guided the assessment of these preferences. The final ratings, reflecting stakeholder priorities for both MCAs, are provided in Appendix B.

7.4 Optimal population size MCA

Drawing from the stakeholder analysis (Chapter 3), a maximum population of 500 people was defined as an upper limit. Here, we seek to refine this figure to determine an optimal population size tailored to the primary needs of our four main stakeholder groups. To achieve this, an MCA was conducted, evaluating the increasing population sizes of 50, 100, 300, and 500 people.

7.4.1 Factors

As done with the stakeholder preference, also the criteria for the optimal population size are rated following the more compact scale as explained in Chapter 7.1. The scores, based on interviews (see Annex C) and the project philosophy (Chapter 6), are summarised as follows:

The environmental impact rating decreases as the population rises, reflecting increasing damage. In smaller populations, the impact is low due to fewer resources consumed and less infrastructure required. As the population approaches and supersedes 300, the increased demand for resources significantly amplifies the strain on the environment, bringing greater disruption and hence leading to lower ratings.

The affordability rating increases as the population rises, reflecting reduced prices. At smaller population sizes, the remote and exclusive nature of the site results in higher costs. As population increases and accessibility improves, the exclusivity reduces and as a result the price also decreases. After reaching 300, the prices stabilise since the main infrastructure is established, despite the demand for higher amenities.

Business growth improves drastically with population increase. A small population limits economic activity due to fewer tourists and residents. As the population grows, the significant influx of more visitors and demand for services generate the local business and encourage revenue generation. Beyond 300 people, the business increases further however it is less drastic compared to earlier stages since the foundation for business growth is already well-established.

The rating for technical difficulty decreases as population increases, reflecting higher technical difficulty. Small populations allow for simpler construction and fewer facilities, leading to less technical complexity and faster construction. As population rises, the need for more infrastructure and amenities increase the technical difficulty.

User comfort improves with larger populations due to the presence of more extensive facilities and better amenities. In smaller populations, fewer services are available, limiting the overall user experience. By 300 people, comfort levels significantly increase as a wider range of amenities are present. Beyond this point, user comfort increases minimally since most services and amenities are already in place.

Criteria	**50**	**100**	**300**	**500**
Environmental impact	3	2	1	0
Affordability	0	1	3	3
Business growth	0	1	3	3
Technical difficulty	3	2	1	0
User comfort	1	2	3	3

Table 7.1: Optimal population size criteria ratings

7.4.2 Results

The results obtained from the population sizing MCA are presented in Figure 7.2, in terms of its respective percentage preference. Based on the results, the optimal population number based on stakeholder preferences is 300. More detailed results can be found in Appendix B.3.

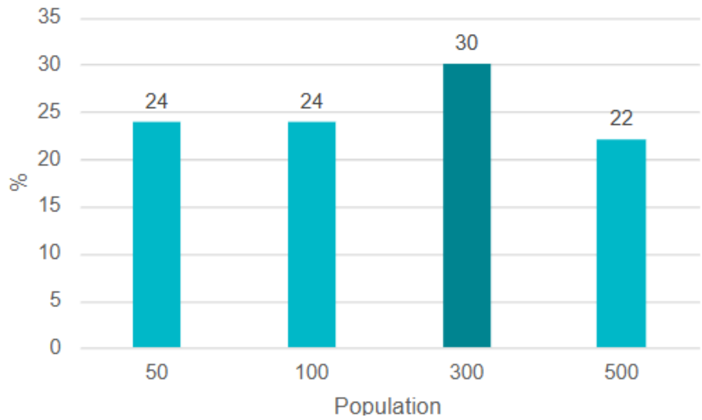


Figure 7.1: Optimal population size MCA results - Equal weighting

In order to ensure the robustness of the results obtained , a sensitivity analysis is performed and can be found in Annex B.4. The sensitivity analysis confirms the small fluctuation of results supporting the final percentages of distribution.

7.5 Population distribution MCA

Insights from the market study identified diverse demographic categories, each with unique accommodation preferences. Based on these demographics, this chapter will further define the distribution of population across different accommodation types, considering both tourists and permanent inhabitants, according to stakeholder preferences. The different options considered for the MCA are a campsite/hostel, cottages, luxury hotel and permanent plots.

7.5.1 Factors

As done with the stakeholder preference, also the criteria for the optimal population size are rated following the larger scale as explained in Chapter 7.1. The scores, based on interviews (see Annex C) and the project philosophy (Chapter 6), are summarised as follows:

For the campsite/hostel, the environmental impact is relatively low, as minimal infrastructure is needed, however, the required facilities still contribute to some impact. The price is very low, making this the most affordable option, ideal for budget travelers. Business growth is hence relatively low due to the minimal revenue generated from this sort of accommodation. The technical difficulty is moderate since although only a few structures are required, the campsite still requires land leveling. User comfort is on the lower side of the scale since only basic facilities are provided.

For cottages, the environmental impact is moderate since more land and resources are required compared to the first option as each unit requires separate facilities. This also results in not affordable options. Business growth is moderate, as this option appeals to middle-range tourists who seek a balance between cost and comfort. Technical difficulty lies in the middle of the scale since more technical construction is required, however, a lot of local materials are planned to be used, reducing the complexity. The cottages offer increased comfort and privacy receiving a moderately high score.

The luxury rooms have the highest environmental impact since they require the most material importation, as well as offer more exclusive amenities that may be harmful to the environment. This also results in increased costs as well as business growth, being the most expensive option that targets high-end tourists willing to pay for premium experiences. With these complexities, the technical difficulty is relatively high, but alongside this increase, user comfort is maximised, offering guests the highest level of luxury.

For permanent house plots, the environmental impact is moderate since the plots will be sold undeveloped, and regulations will be in place to limit the environmental footprint. The price is relatively high, as purchasing and maintaining a house involves significant upfront and long-term costs. Business growth is moderate as although this option produces large initial influx, there is no significant ongoing revenue. The technical difficulty is low since only land preparation is required. In terms of comfort, eventually owning a house provides significant comfort however the user is required to maintain their property, hence slightly reducing the overall rating.

Criteria	Campsite/Hostel	Cottages	Luxury Rooms	Permanent House Plot
Environmental impact	8	6	2	6
Affordability	9	4	1	4
Business growth	2.5	7	10	6
Technical difficulty	7.5	5	2	8
User comfort	2.5	7	9	7

Table 7.2: Population Distribution Criteria Ratings

7.5.2 Results

The results obtained from the MCA are represented as a pie chart, illustrating the distribution of the population across various accommodation types. This visual format highlights the proportions allocated to each accommodation type. More detailed results can be found in Appendix B.3.

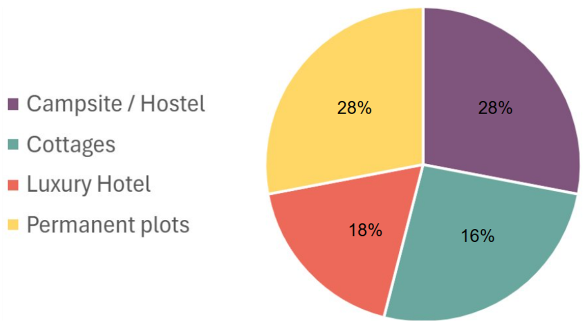


Figure 7.2: Population distribution MCA results - Equal weighting

Based on the results, the Campsite/Hostel and the Permanent plots should accommodate the majority part of the population considering their percentages of around 28%. On the other hand, Luxury Rooms score the lowest allocating around 18%. This shows a tendency towards more affordable accommodation typologies that also have lower environmental impact. To ensure the robustness of the results obtained, a sensitivity analysis is performed and can be found in Annex B. The sensitivity analysis confirms the small fluctuation of results supporting the final percentages of distribution.

Based on the results of the multi-criteria analysis, a general allocation of the 300 occupants across the various accommodation typologies within the village has been determined. The analysis indicates that 28% of the housing will be designated for permanent house plots, which corresponds to 84 permanent residents. The remaining 72% will accommodate tourists; however, this figure also includes the necessary workers to support the tourism sector. According to Chapter 4, the average number of workers required is estimated to be 40% of the total tourist population. Consequently, this results in 154 tourists and 62 workers, completing the total of 300 occupants. These numbers were then used to establish the precise housing requirements, outlined in the table below.

Category	Accommodation Type	Details	People
Tourists	Hostel / Campsite	5 x 6-person rooms	30
		7 x 4-person plots	28
	Cottages	14 x 2-person rooms	28
		7 x 4-person rooms	28
	Luxury Rooms	10 x 2-person rooms	20
		5 x 4-person rooms	20
Workers	Hostel / Campsite	1 x 6-person staff room	6
	Cottages	2 x 13-person staff house	26
	Luxury Rooms	3 x 10-person staff house	30
Residents	Permanent House Plots	28 x 3-person plots	84
Total			300

Table 7.3: Accommodation breakdown for 300 people

7.6 Conclusion

The multi-criteria analyses performed have provided a comprehensive breakdown of the accommodation distribution for the eco-tourism village, reflecting the stakeholders' preferences. This insight will serve as a foundational basis for the preliminary masterplan design and the stages of development in the coming sections.

8 | Requirements and constraints

This chapter defines the fundamental elements that guided the design and development of the preliminary masterplan. The functional requirements establish the essential features and objectives that the project must meet to achieve its intended purpose. Meanwhile, the constraints define the boundaries that were considered in terms of the development of the village. Together, they form the framework for sustainable and feasible project implementation.

8.1 Functional requirements

The functional requirements of this preliminary masterplan were identified as the essential points, or features, that this project must fulfill to meet its purpose and objectives and to align with regulations. The Research phase explained in previous chapters of this report helped identify these requirements, which are here divided according to where they were previously discussed in the report.

8.1.1 Functional requirements from site analysis

The requirements that follow were found while investigating the site analysis. Accessibility was found to be a crucial and complex aspect of the project (Chapter 2.1.1), therefore improving it became an essential functional requirement. When considering accessibility design options for the village, it must be taken into account the changes in water level of Lake San Martín, which can go up to 3m, according to Section 2.2.2. Measurements for wind mitigation are essential as the region is exposed to strong wind year round as mentioned in Chapter 2.2.3. It was found in the site analysis that in the past landslides occurred in the ranch area, therefore safety measurements to prevent them are necessary for the safety of the village as explained in Chapter 2.2.4. Also requirements regarding the need of a sustainable water management and safe drinking water were identified. The requirements are listed below:

- Improve accessibility for people and cargo;
- Take into account the water level change, which varies for a total of 3 metres, while developing options to improve accessibility;
- Measurements for wind mitigation and landslides deterrent;
- A sustainable water management plan for sourcing water needs to be provided, following quality standards;
- Safe drinking water and an effective sewage treatment must be endured according to the environmental standards.

8.1.2 Functional requirements from stakeholder analysis

These requirements come from the interviews that were held with the potential investors, hence stakeholders of the project. The comprehensive version of the interviews can be found in Annex C. The requirements are listed below:

- The land of Estancia La Josefina must be purchased;
- The border with Chile should be opened to allow boats to legally cross and establish a new maritime route from Villa O'Higgins and Estancia La Josefina.
- Plots of land must be designated for private ownership of the investors.

8.1.3 Functional requirements from market study

The following requirements were identified in the market study, where the potential population of the eco-tourism village was analysed. The interviews were held helped define the services possible workers and residents consider essential in the village (Annex C). The requirements are listed below:

- Reliable internet connection must be established on-site;
- Plots of land must be designated for private ownership for the permanent residents;
- Employee accommodations must be sufficient to house 40% of the total amount of tourists.

8.1.4 Functional requirements from case study: Los Huemules

In Chapter 2, the case study of Los Huemules present a number of requirements for their development that also apply for the potential development at La Josefina. These requirements are listed below:

- Water storage tanks for drinking water need to be present in the village;
- Fire safety measures need to be implemented;

8.1.5 Functional requirements from philosophy

In Chapter 6 the philosophy of the project is discussed. Chapter 6.1 emphasizes the importance of creating an open educational community, Chapter 6.3 highlights the importance of balancing the economic sustainability of the project with the morals socially and environmentally. Lastly, Chapter 6.2 addresses the urgency to preserve the environment and to include circularity in the design. The requirements are listed below:

- The design should be socially sustainable
- The design should be environmentally sustainable
- The design should be economically sustainable

8.1.6 Functional requirements from population size and distribution

The optimal numbers of population and population distribution were found respectively in Chapter 7.4 and Chapter 7.5, where the approaches used to perform both the multi-criteria analyses are also explained. These capacities are considered as ideal for the preliminary masterplan. They are listed below:

- An optimal population of the village of 300 people should be respected;
- The distribution of the different types of accommodation should follow the pattern that was found to be the ideal population distribution

8.2 Constraints

The term constraints refers to the restrictions that must be followed during the project design. These limitations regard not only the type of development deemed appropriate for the site, but also to physical boundaries where the development can be located, based on regulatory requirements and implementation feasibility. Some constraints are legal obligations, while others are precautionary measures that were adopted to promote sustainable practices and protect the natural environment.

8.2.1 Constraints from site analysis

During the site analysis laws and regulations were identified in terms of land use (Chapter 2.4). Also constraints in terms of where it is possible to build were assessed during this study. A portion of the property is a part of a Provincial Reserve and part of it isn't buildable due to environment's preservation.

- A portion of the land is within the Provincial Natural Reserve Tucu Tucu, where construction is prohibited. The boundaries of the reserve are shown in Figure 2.10;
- Some areas of the site have been marked as buildable and others as unbuildable as is discussed in Chapter 2.5;

8.2.2 Constraints from case study: Los Huemules

From this case study the constraints that were identified regarding where it is possible to build considering the location of water sources, a regulation regarding the pipes, and fire safety measures, essentials while developing settlements. Also a constraint in terms of development of the land was identified. The constraints identified are the following:

- All homes must be built at least 30 m from the nearest water source to prevent pollution;
- Buildings cannot be constructed upstream of water sources to prevent contamination;
- A maximum of 5% of the total land area may be developed in order to preserve the natural environment;

8.3 Conclusion

The functional requirements address critical needs like accessibility, stakeholders' interests, and service provisions to enable the eco-village to operate in a way that is at the same time efficient and sustainable. The constraints, on the other hand, establish boundaries that respect environmental preservation, laws, regulations and safety standards. The functional requirements and the constraints shown above are considered as guidelines for the proposed preliminary masterplan and for the technical solutions that will be later discussed.

9 | Preliminary masterplan

This chapter presents the proposed preliminary masterplan for the eco-tourism village, highlighting its alignment with functional requirements, stakeholder preferences, and sustainability principles. The purpose of this chapter is to illustrate how the preliminary masterplan effectively addresses the unique challenges posed by the remote site. By focusing on the integration of various functional areas, this chapter demonstrates the thoughtful planning behind the preliminary masterplan, which prioritises environmental preservation while meeting the aspirations and comfort of future residents and tourists.

9.1 Design approach

The preliminary masterplan design was developed through an iterative process, incorporating feedback from potential investors to refine the concept and ensure it met both the functional requirements and constraints of the project. Due to the project's large scale, the decision was made to focus on one cohesive design option, guided by the project's core requirements to ensure feasibility and stay within the scope of the project. Once these fundamental elements were addressed, the decisions left to be made were preference-based decisions. These choices were made collaboratively with potential investors who were actively involved in discussions, allowing their input to shape a design proposal that aligns with their vision for the project.

In order to address the needs of other important stakeholders involved, the results from the Multi-Criteria Analysis (MCA) in Chapter 7 used to guide important design decisions. The MCA provided the population size for the village and the distribution across different accommodation types. For the masterplan design, these accommodation types were organized into four key zones:

- Zone 1: Campsite & hostel
- Zone 2: Cottages
- Zone 3: Permanent plots
- Zone 4: Luxury hotel

The development of the masterplan involved strategically positioning these zones along the buildable area identified in the site analysis, once again ensuring the alignment with the functional requirements and constraints. This placement allows for efficient land use, promotes accessibility, enhances the overall flow of the site, and fosters a sense of community among residents and visitors. Additionally, each zone was designed in more detail, taking into account the specific functional requirements and constraints necessary in each area.

9.2 Masterplan design

9.2.1 Overview

As discussed in the project philosophy (Chapter 6), a main priority of the development of this eco-tourism village is creating minimal environmental impact. The masterplan proposed seeks to achieve a balance between preservation and development by utilising only a small fraction of the land for infrastructure. This ensures that the natural ecosystem remains largely undisturbed, while allowing for the sustainable growth of eco-tourism in the region.

In Figure 9.1 the entire site area is outlined in red, giving a clear visual of the property's boundaries. The Tucu Tucu reserve, which occupies a significant portion of the land, is clearly marked within this boundary, and is preserved to protect its ecological value. The proposed development zones, confined to previously identified buildable areas from the site analysis, can be seen at the bottom of the property, occupying only a small part of the whole plot.

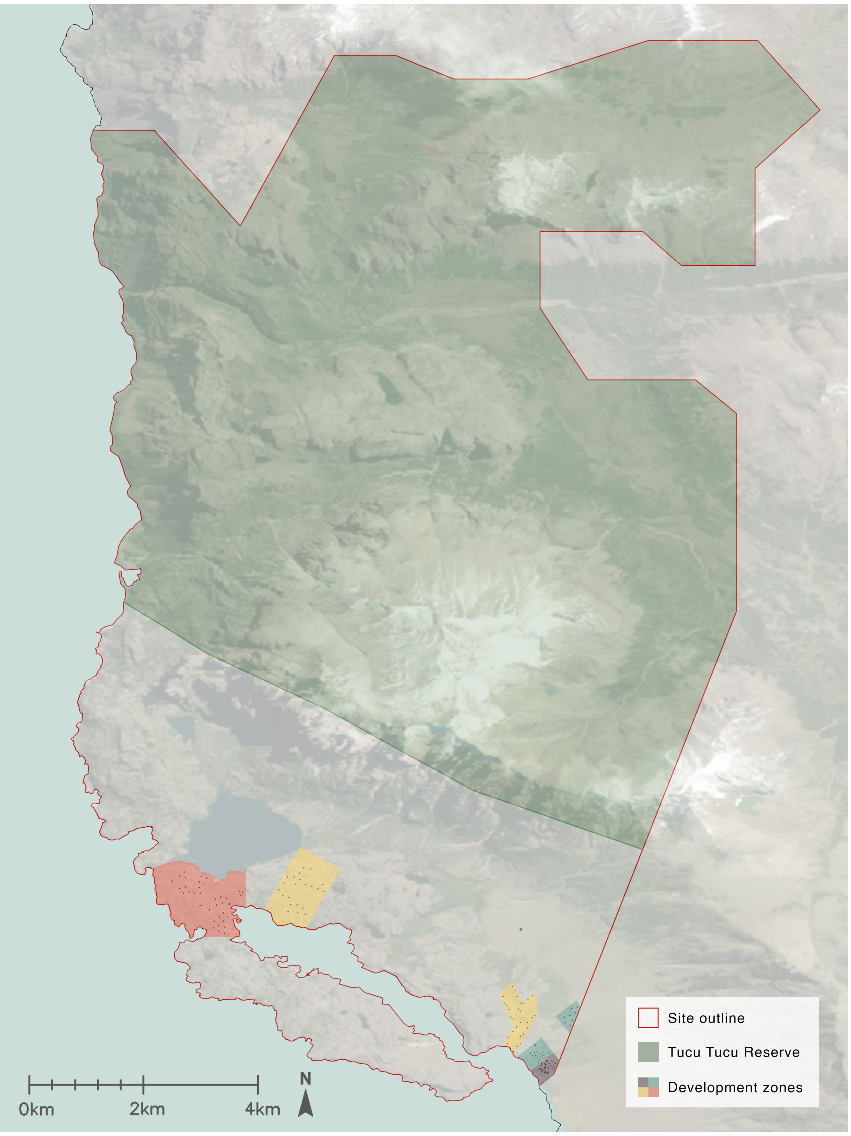


Figure 9.1: Site Development Overview

Table 9.1 provides a quantitative breakdown of the designated areas within the masterplan, highlighting the limited extent of land proposed for development relative to the total property size. The table differentiates between several key areas: the overall size of the site, the Tucu Tucu reserve, the development zone areas, including circulation spaces, and the cumulative building footprints, which account for the overall area occupied by structures. This breakdown highlights the commitment to sustainable land use and the preservation of the natural environment.

Masterplan areas	**Area**	% of total Area
Total site area	16,000 hectares	100
Tucu Tucu reserve	11,700 hectares	73.13
Zone areas	348 hectares	2.2
Building footprints	1.5 hectares	0.01

Table 9.1: Areas of the masterplan

To gain a deeper understanding of the proposed development, attention will now be directed to the lower section of the property, where the designated development zones are highlighted on the map (refer to Figure 9.2). This detailed view illustrates the specific areas allocated for different types of accommodations, consistent with the population distribution findings from the MCA conducted in Chapter 7.

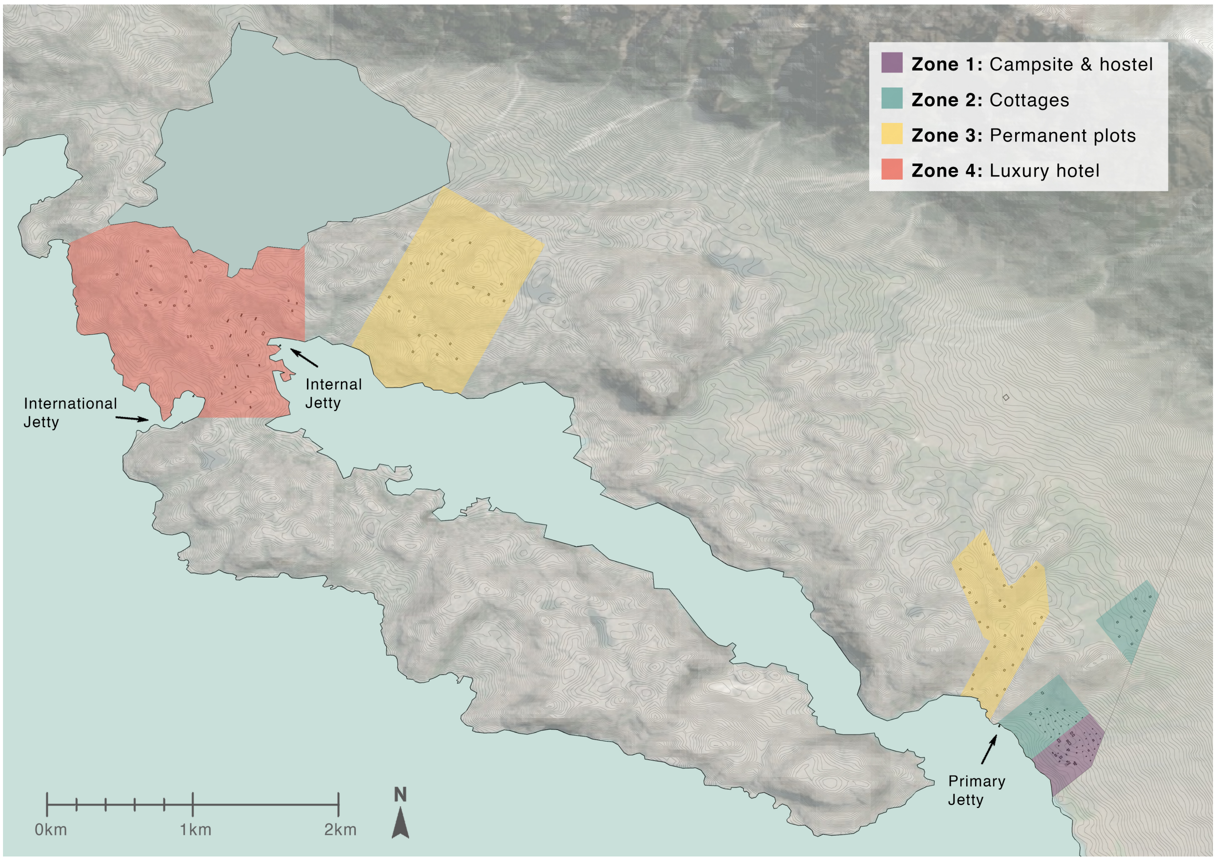


Figure 9.2: Zoning of buildable area

The strategic positioning of these zones within the identified buildable areas has been carefully considered to align with both the functional requirements and the project constraints outlined earlier, as demonstrated in the upcoming design verification chapter (Chapter 9.4).

In addition to practical considerations, the arrangement of these zones aims to create a sense of community among residents and visitors. By thoughtfully separating accommodations for high-class tourists from those for budget travellers, the design enables tailored experiences that align with varying preferences and expectations. To enhance accessibility and guarantee the availability of essential amenities, the development is organised into two main clusters within the designated area. This approach addresses the remote nature of the site while facilitating convenient access to services and facilities. In the figure, the placement of the jetties for water access to the zones is also visible, providing essential connections to the site. These proposed jetties will be discussed in more detail in the improvement of accessibility chapter (Chapter 10).

In the following sub-chapters, a further exploration of each development zone will be provided, starting with an examination of the eastern side, followed by a closer look at the western side. In the appendix, a schematic 3D model illustrating the proposed structures within each zone is included in order to enhance visualization of the site's layout. This model offers a clear perspective on the spatial arrangement and visual impact of the proposed development within the area (see Appendix SD.3).

9.2.2 East side development

The East side development is organised to offer a range of accommodations and amenities that cater to various types of visitors, including budget-conscious travellers, families, and permanent residents. The area encompasses Zone 1 (campsite and hostel), Zone 2 (cottages), and part of Zone 3 (permanent plots), with all zones accessed through the Primary Jetty, which serves as the main point of entry to the east side and supports seamless access across different zones.

In Figure 9.3, the overall map of the east side can be seen, highlighting each zone within this area. To provide a more comprehensive view, in Figure 9.4 a photograph with highlighted zone boundaries accompanies the map. This visual reference allows better understanding of the physical context by seeing how the development is situated within the landscape.

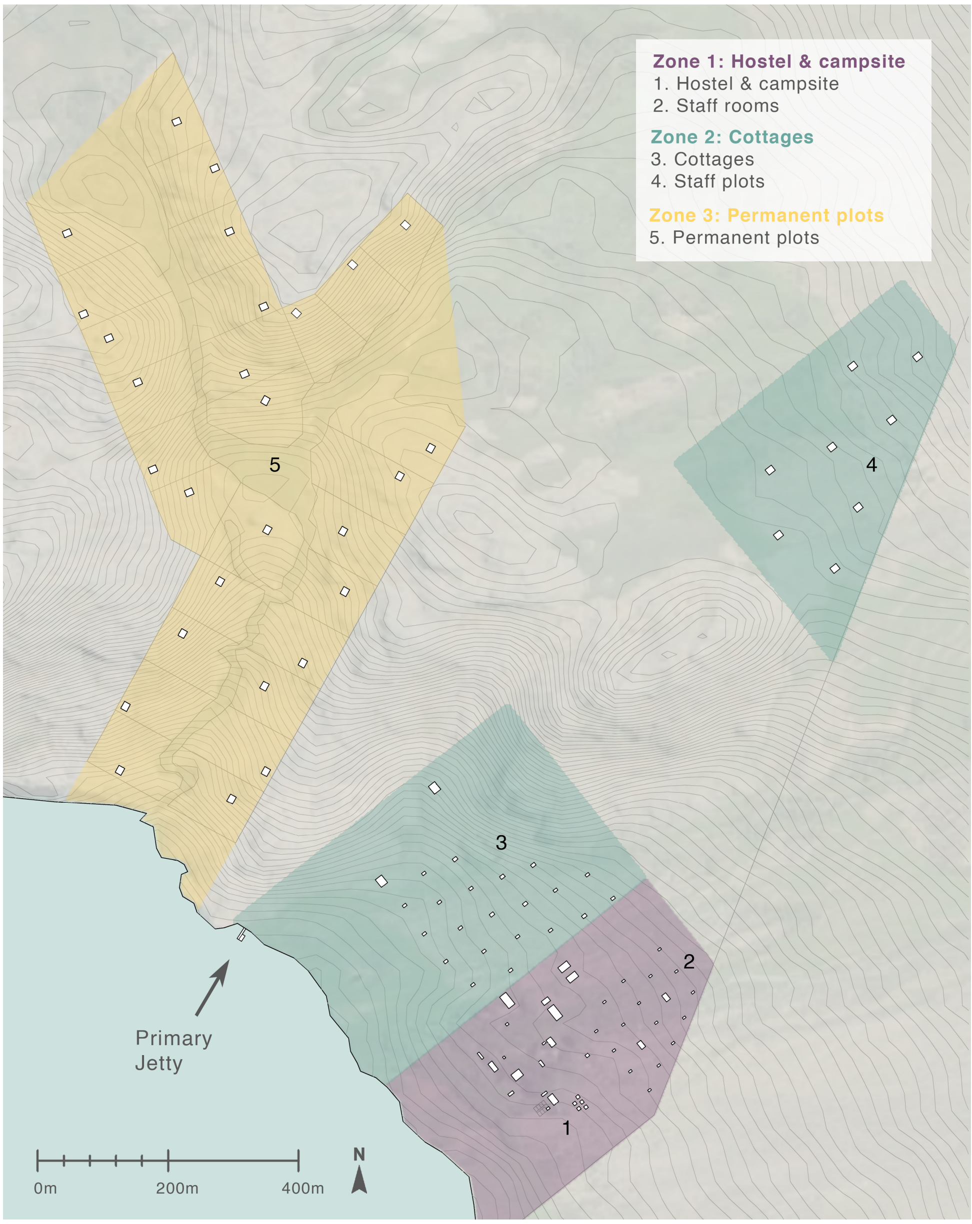


Figure 9.3: East side development

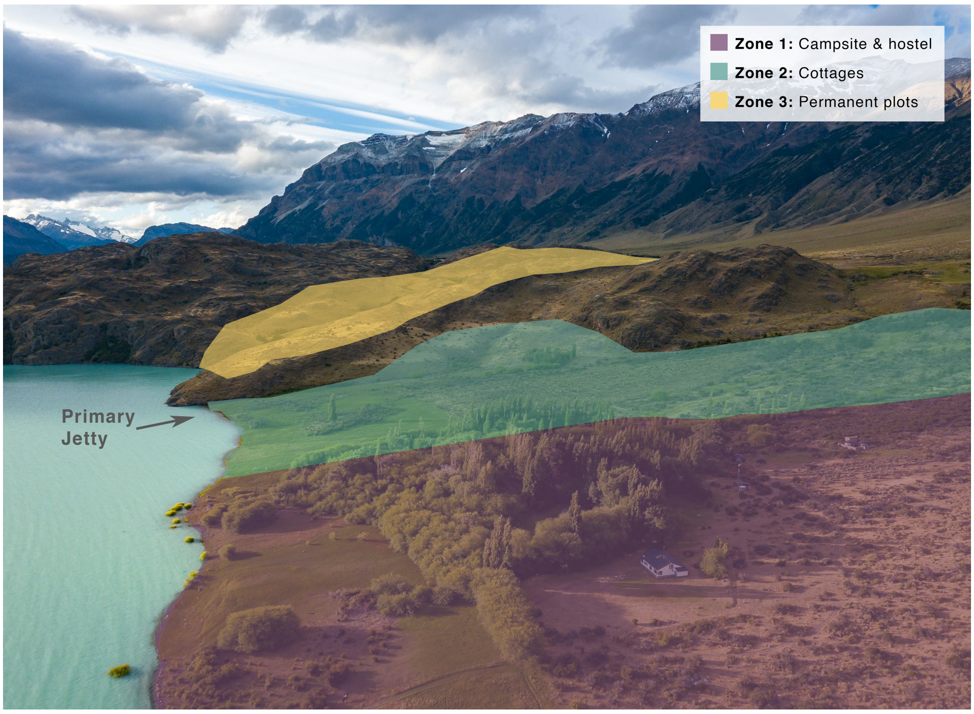


Figure 9.4: Visualisation of east side development zones

A closer look at the map of Zones 1 and 2 (9.5) reveals the proximity of these areas to existing structures from the original estancia. This location is strategic, allowing for the repurposing of current buildings to reduce environmental impact and resource use. Additionally, Zones 1 and 2 share several common amenities, supporting interaction between visitors while maintaining accessibility to essential services.

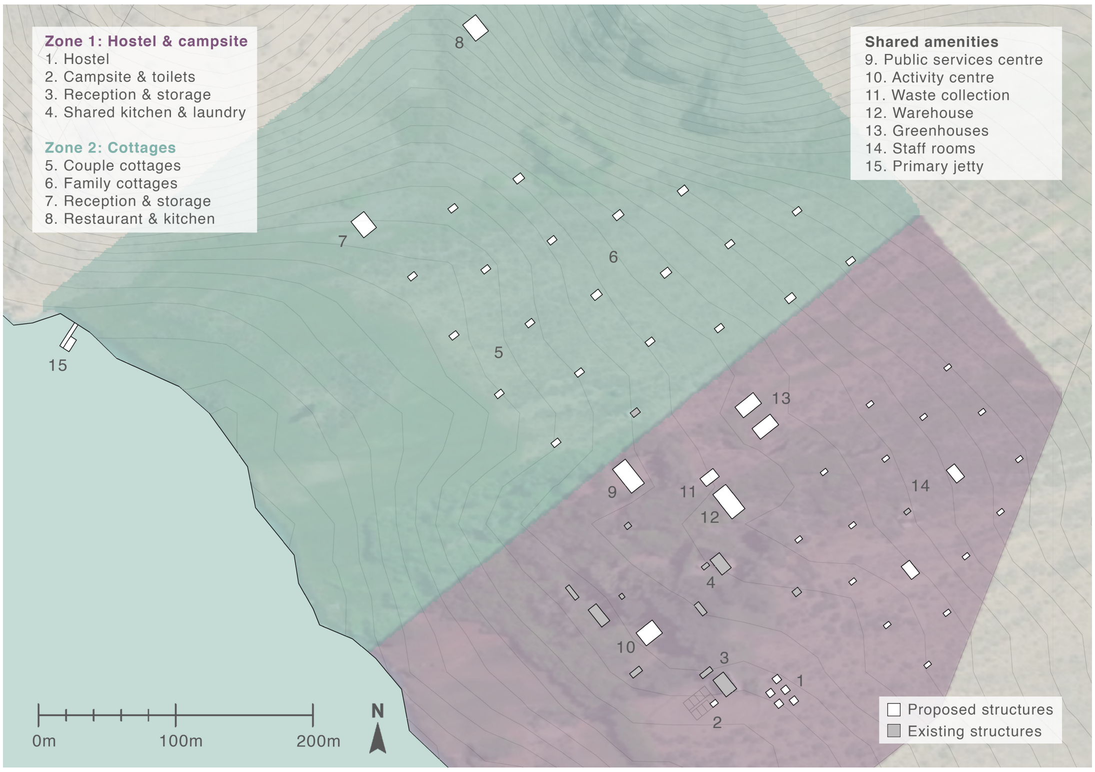


Figure 9.5: Zone 1: Campsite & hostel and Zone 2: Cottages

Zone 1 contains a hostel and campsite targeting low-budget travellers that share similar amenities. It is located where the existing structures on the property are, in order to repurpose the existing structures for this zone. The footprint of Zone 1 is displayed in Map 9.5, and it contains five hostel units, seven campsites, a campsite bathroom, and a common room. Table 9.2 below details the dimensions of each structure. The common rooms will be placed in two existing structures on the property that already include most of the needed amenities. The hostel units each sleep up to six people and the campsite plots sleep up to four people. The common rooms will contain the reception, laundry, and a shared kitchen.

Structure Type	**Dimension** (m^2)	**Quantity**
Hostel unit	25	5
Campsite	35	7
Common rooms	270	1
Campsite bathroom	17.5	1

Table 9.2: Structures in Zone 1

Zone 2 contains several cottages targeting the existing middle class and family tourist category, the location of which can be seen in Figure 9.5. Within Zone 2 there will be seven family cottages housing four people, fourteen couple cottages housing two people, a restaurant, and an administration building. The dimensions of each structure are listed in Table 9.3 below. The administration building will consist of the reception, lobby, and storage. One of the fourteen couple cottages will repurpose the existing sleeping hut currently located on site. Each of the cottages are placed 50 metres apart from one another to provide privacy, and their staggered positions allow all rooms to have a lake view.

Structure Type	**Dimension** (m^2)	**Quantity**
Family cottages	35	7
Couple cottages	25	14
Restaurant	180	1
Administration building	180	1

Table 9.3: Structures in Zone 2

In addition to the structures in Zones 1 and 2, shared facilities, including staff accommodations, are provided to meet the functional requirements and support daily activities across the eco-village. The shared spaces will consist of an activity building, waste collection facility, a warehouse for storage, a public services centre, and a greenhouse. The public services structure will include a small post office, fire safety room, cafe, tourist information desk, small grocery store, medical clinic and garden. Figure 9.5 shows the location of each of these structures. The same staff will be working to support both zones, and there are two different proposed staff accommodations. The first is intended for temporary single staff, such as Workaways, that are not intending to make the estancia their permanent residence. There are sixteen rooms located 40 metres apart to provide privacy for this type of staff and two shared common spaces, visible in Figure 9.5. One of the rooms will repurpose the existing bathroom structure for the domes. The second type of staff housing is intended for workers that would like to move to the estancia. There are eight of these staffing properties that consist of a home with space for a maximum of three people on a 0.75 hectare plot, visible in Figure 9.3. Table 9.4 below states the dimensions of each of the previously mentioned structures.

Structure Type	Dimension (m^2)	Quantity
Activity building	180	1
Waste collection	90	1
Warehouse	270	1
Public service centre	270	1
Greenhouse	170	2
Staff studio rooms	15	16
Staff common spaces	90	2
Staff houses	120	8

Table 9.4: Dimensions of the structures

Zone 3 consists of one-hectare plots intended for permanent residents of the estancia, including plots designated for sale to the public as well as those reserved specifically for project investors. Since a functional requirement of the project stipulates that investors receive their own plot upon investing, the originally established 28 plots, as discussed in Chapter 7, were increased to 50. This adjustment ensures that there are sufficient plots available both for public sale and for investor allocation.

The first 28 plots are situated within the east side development, as shown in Figure 9.3. While the specified lot locations within this region are generally outlined, the precise placement of individual plots will be determined by the residents themselves. Upon sale, each plot will be levelled to prepare for construction; however, the construction of the homes will remain the responsibility of the purchasers. When a plot is purchased, a strict mandate with construction guidelines will be provided to the buyer, detailing the types of structures permitted within Zone 3. In addition to these building guidelines, buyers are required to begin construction on their plot within the first five years of purchase. This requirement is intended to foster a vibrant community on the property and to discourage buyers from acquiring plots solely as speculative investments for resale once the area is more developed.

9.2.3 West side development

The West side development provides luxurious accommodations and essential amenities designed to meet the needs of high-end visitors and long-term residents. This area includes the remaining portion of Zone 3 (permanent plots) and Zone 4 (luxury hotel), all of which are easily accessible via the Internal Jetty and the International Jetty. This location ensures smooth transportation for both guests and staff, and facilitating easy movement both within the property and to and from external destinations.

In Figure 9.6, the overall layout of the West side is presented, showcasing each designated zone within this area. Accompanying this map, Figure 9.7 features a photograph that highlights the locations of the zones in this area. This development area has been strategically located next to Lagoon Estella, a beautiful natural feature that enhances the appeal of the development, making it an ideal location for high-end tourist accommodations and permanent plots, allowing residents and visitors to fully enjoy the scenic surroundings.

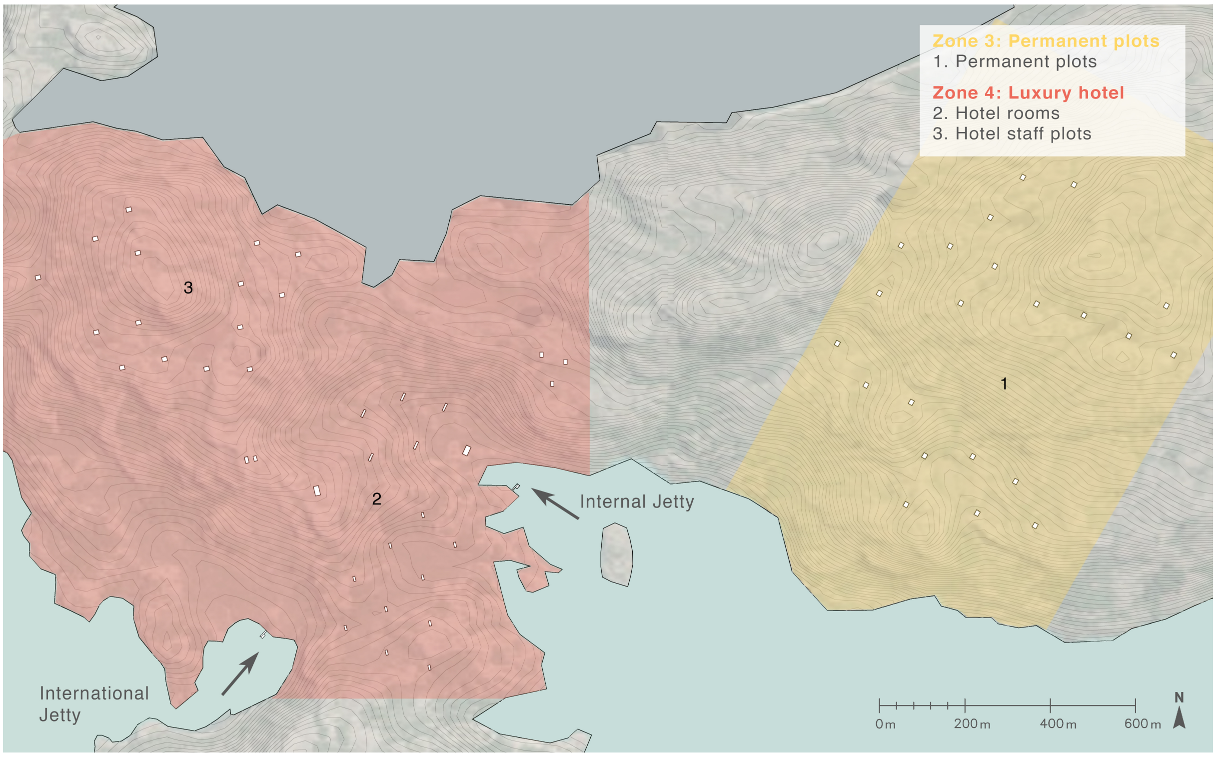


Figure 9.6: West side development

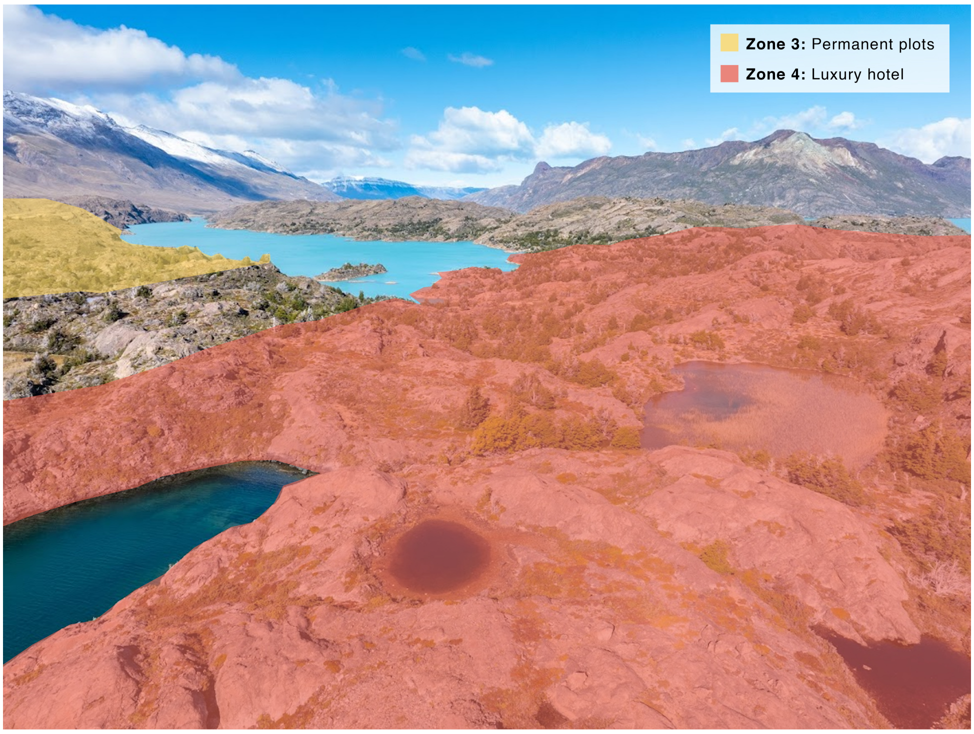


Figure 9.7: Visualisation of west side development zones

Figure 9.8 provides a closer look at the layout of Zone 4, highlighting the intentional positioning of a luxury hotel aimed at high-class tourists. This area is distinguished by its generous accommodations and a selection of premium amenities, all designed to offer an exclusive experience that emphasises privacy.

Figure 9.8: Zone 4: Luxury hotel

The development in Zone 4 comprises five spacious family rooms, each accommodating up to four guests, and ten couple rooms which provide ample space for luxury amenities. In addition, there are 15 staff residences, designed according to the second option of worker housing described, situated on 0.75-hectare plots to ensure generous living space for employees. Complementing these accommodations, the zone also features necessary amenities such as a reception, restaurant, greenhouse and waste collection facility, as well and a variety of luxury amenities, including a gym, activity centre, and spa. The dimensions of the structures planned for Zone 4 are detailed in Table 9.5.

Structure Type	**Dimension (m^2)**	**Quantity**
Family room	95	5
Couple room	60	10
Staff homes	120	15
Greenhouse	120	1
Gym	90	1
Activity centre	90	1
Sauna and spa	90	1
Waste collection	90	1

Table 9.5: Structures in Zone 4

After placing the development zones, the connections between them should be carefully considered to enhance accessibility and safety across the site. A water connection facilitates movement between the Primary Jetty and the Internal Jetty, providing an easy travel route among all the zones. Walking between the two main development areas is also possible, taking approximately four hours on foot. Additionally, for emergencies, the presence of all-terrain-vehicles on-site is proposed to enable rapid transportation between the areas. Also positioned between the zones is a 900 m^2 helipad, enabling helicopter access in case of emergencies. These features ensure that people on site can navigate the area efficiently while prioritizing safety.
A more comprehensive description of each proposed structure, including specific features and amenities, is available in Appendix D. Additionally, preliminary internal layouts for several key structures are provided to verify that the proposed dimensions align with design specifications.

9.3 Construction stages

Given the remote location of the eco-tourism village, careful planning of the construction phases is essential to the project's success. The site's isolation presents considerable logistical challenges in transporting materials, equipment, and personnel, making efficient planning crucial to optimize both time and resources. Each construction stage is strategically phased to ensure that initial setups such as key infrastructure and accommodation units are completed promptly to support early occupancy and income generation.

The phased construction approach aligns with the project's financial study (Chapter 14), allowing for a gradual increase in revenue from the initial investment, which will then support subsequent phases. This ensures the economic feasibility of the proposed preliminary masterplan by distributing costs and resources across manageable intervals while integrating sustainable construction practices. Each construction stage covers a five-year period, forming part of a 20-year development plan as outlined below.

9.3.1 Stage overview

- **Stage 1 (Years 1-5)**:
  - Site preparation, infrastructure setup (jetties, water reservoir, emergency helicopter pad), initial accommodations (hostels, campsite), and essential services.
- **Stage 2 (Years 6-10)**:
  - Expansion of accommodations, completion of infrastructure, beginning of hotel concessions, and development of renewable energy systems.
- **Stage 3 (Years 11-15)**:
  - Continued development of permanent huts, finalizing family and couple cottages, and ongoing expansion of energy systems.
- **Stage 4 (Years 16-20)**:
  - Final touches, completion of all accommodations, full deployment of energy systems, and final sales of plots.

A more detailed breakdown of the construction phases can be found in Appendix D.4.

9.4 Design verification

This section provides a detailed verification of the preliminary masterplan, demonstrating how each previously defined functional requirement and constraint has been addressed within the design. Each item listed has been carefully integrated to ensure the design meets the established objectives and respects all boundaries.

Functional Requirement	Design Verification
Improve Accessibility	Inclusion of three jetties in the preliminary masterplan ensures good accessibility by water (Chapter 10).
Water Level Change Considerations	A floating jetty is considered, allowing it to fluctuate with the water level (Chapter 10).
Wind Mitigation	Areas with limited wind exposure were considered for zoning.
Landslide Deterrence	Distance is kept from most susceptible landslide zones, and reforestation is proposed to minimize damage in case of occurrence.
Water Management Plan	A sustainable water management plan, and sources for water and water tanks are integrated.
Wastewater Treatment	A wastewater treatment plan, alongside water conservation measures, are proposed.
Land Purchase	The purchase of Estancia La Josefina land is included in the financial considerations (Chapter 14).
Border with Chile	Provisions for an International Jetty are included to facilitate a new maritime route, pending legal agreements (Chapter 10).
Private Land Ownership for Investors	Designated plots for private ownership by investors are included in the preliminary masterplan.
Permanent Resident Plots	Designated plots for permanent residents are incorporated into the site plan.
Employee Accommodation	Accommodation for employees to house 40% of the total tourist capacity is integrated.
Fire Safety Measures	Fire safety rooms are planned on site.
Social Sustainability	The design emphasizes social sustainability through community-focused spaces and structures.
Environmental Sustainability	Measures for environmental sustainability, including conservation and circular design, are incorporated.
Economic Sustainability	Ensured through the financial evaluation performed to assess the economic feasibility and long-term viability of the project (Chapter 14).
Optimal Population	The optimal population amount is used as guideline in the MCA to ensure a sustainable and manageable community.
Accommodation Distribution	The design was based on the accommodation types identified in the MCA.

Constraints	Design Verification
Tucu Tucu Reserve	Construction is prohibited within the Tucu Tucu Provincial Natural Reserve.
Non-buildable Areas	No construction is planned the areas defined as non-buildable.
Distance from Water Sources	All structures are proposed at least 30 metres away from the lake.
Building Downstream	Water will be sourced further upstream from the houses to ensure no contamination.
Max Development Area 5%	2.2% of the total area is within proposed development zones, which respects the maximum allowable development area.

9.5 Conclusion

In conclusion, the proposed masterplan design for the eco-tourism village at Lago San Martín aligns with the stakeholders' aspirations and the investors' vision for sustainable development in this remote area. By respecting the functional requirements and constraints established during the research phase, the design effectively meets the needs of future residents and visitors while safeguarding the natural environment. Additionally, the masterplan enhances accessibility and caters to the diverse demographic of tourists who will visit the site, offering a variety of accommodation options and essential services.

10 | Improvement of accessibility

Estancia La Josefina's remote location is both a unique feature and a critical challenge. To ensure the project's success, as discussed in Chapter 8, improved accessibility is essential. This chapter explores potential solutions to enhance access via navigational routes, specifically by identifying new embarkation and disembarkation points on Lago San Martín. Additionally, a preliminary design proposal for one of these points in Estancia La Josefina is presented.

10.1 Identified mooring locations for vessel navigation

In the following section, the proposed jetty locations are established, and potential routes for vessels to and from the site are explored. In Figure 10.1, the locations of the proposed jetties within the property, as well as the existing neighbouring jetties considered for departures, are illustrated, along with the potential routes connecting these points. This overview provides a comprehensive perspective on the accessibility framework outlined, highlighting how these jetties facilitate travel to and from Estancia La Josefina.

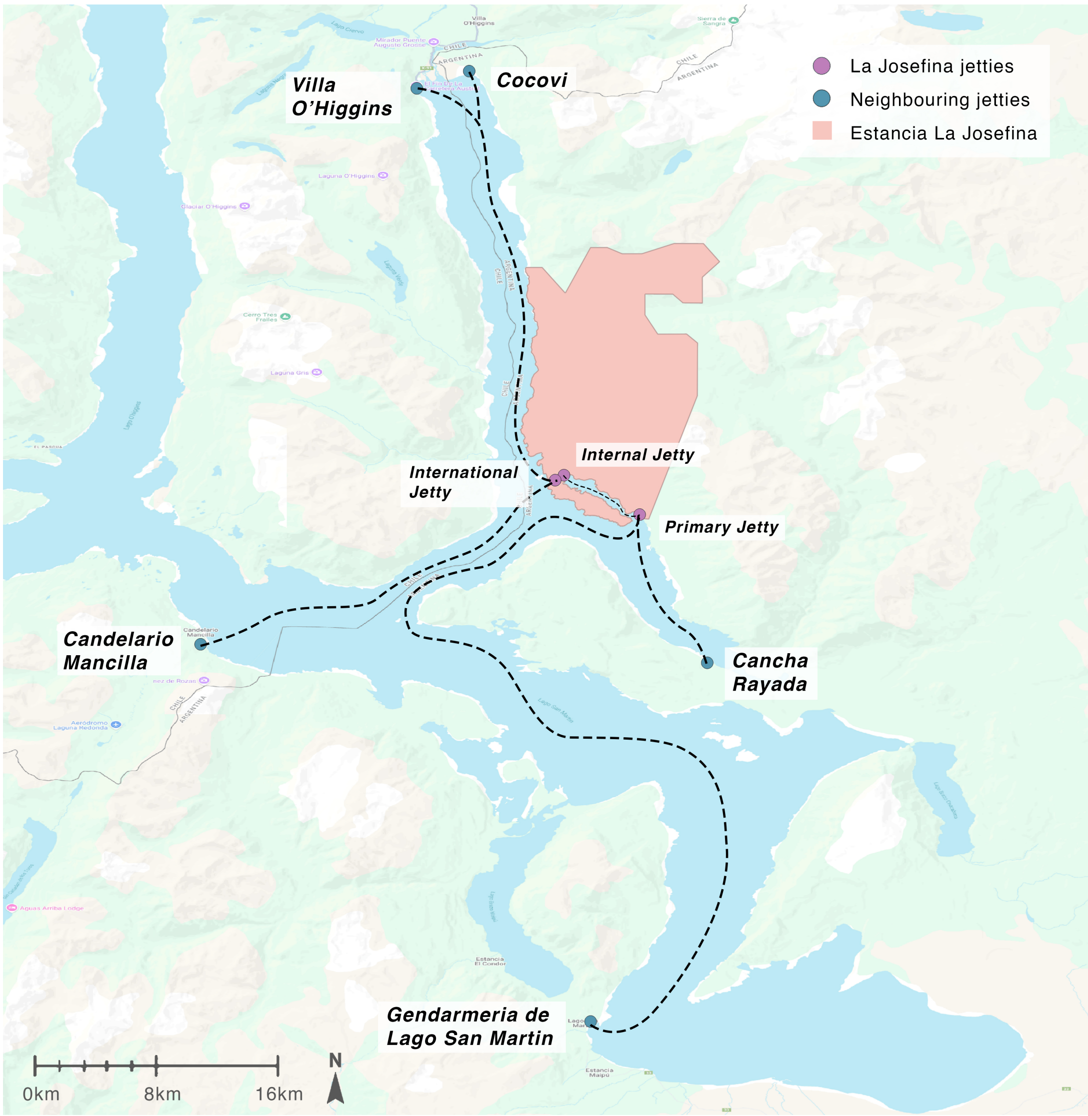


Figure 10.1: Accessibility map

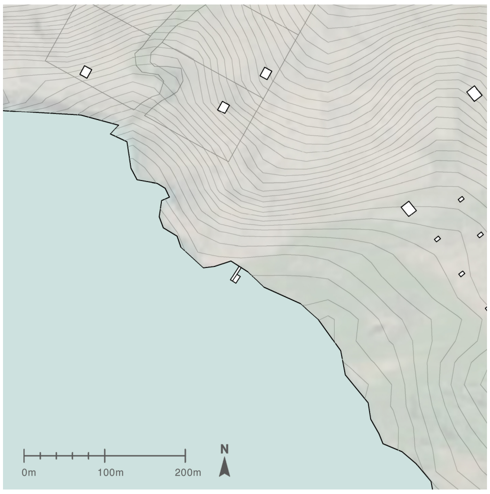
10.1.1 Proposed on-site jetties

The preliminary masterplan design proposes two jetties constructed in the initial phases (see Appendix D.4), with a third jetty planned once an agreement with Chile is reached to facilitate border crossing. The main criteria for selecting these jetty locations were proximity to buildable land, protection from wind and waves, and accessibility via boat transport routes that minimize overall travel distance.

In selecting the locations for the jetties, existing structures were prioritized for reuse wherever possible to reduce environmental disruption. Additionally, the natural morphology of the bays was carefully considered to ensure that minimal construction work would be required, thus preserving the local landscape.

- Primary jetty

  The primary jetty is proposed at the east end of the property near one of the development areas discussed in detail in Chapter 9.2.2, and will serve as the main docking point within the site. This location is close to the current drop-off point and will also serve as the home berth for the motorboat. It was selected due to its proximity to a sheltered bay, which reduces wave action from the north-west. Additionally, a ramp will be built near the jetty for transporting construction materials. The primary disadvantage is its proximity to a swamp area, which will require soil preparation. In extreme weather conditions, the boat can be hauled out of the water using the nearby ramp.



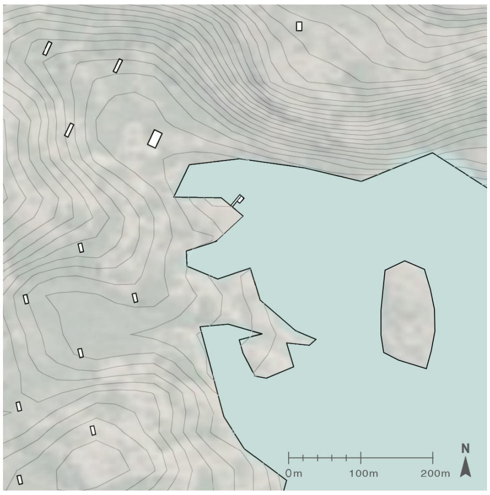
(a) Location and orientation

(b) Proposed site

Figure 10.2: Primary jetty

- Internal jetty

  The internal jetty is proposed at the internal end of the peninsula and is designed to facilitate access between the two proposed development areas discussed in Chapter 9. It will be constructed in an area with a naturally formed ramp, which can be utilized to transport construction materials for the development in the proximity, requiring minimal effort for construction, and less environmental impact. The adjacent low cliff ensures a stable location for the jetty, accommodating tidal fluctuations.



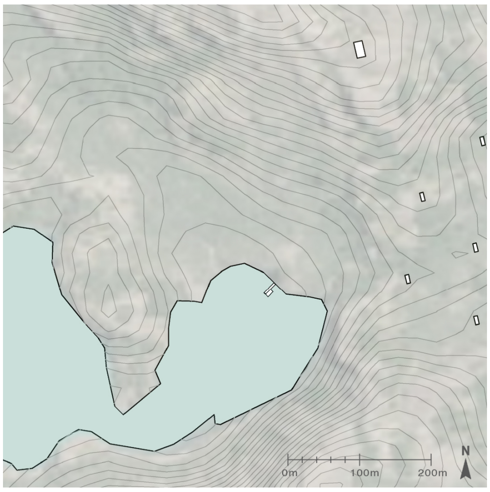
(a) Location and orientation

(b) Proposed site

Figure 10.3: Internal jetty

- International jetty

  The international jetty is proposed on the other side of the width of the peninsula, providing access to the same development area as the internal jetty, but from the outer side of the peninsula. This jetty would provide a connection with Villa O'Higgins in Chile if the border-crossing is made easier, and would support connections from Chile's Carretera Austral or Villa O'Higgins public-use airport, offering a stopping point before continuing to El Chaltén or El Calafate. While a ramp is not immediately necessary since construction materials are planned to be transported through the internal jetty, future construction could streamline material transport from Villa O'Higgins.



(a) Location and orientation

(b) Proposed site

Figure 10.4: International jetty

10.1.2 Proposed orientation of on-site jetties

The orientation of the jetties is crucial to ensure safe and efficient docking, particularly considering the environmental conditions of Lago San Martín. As discussed in Chapter 2.2.2, the lake experiences significant wave formation and fluctuating water levels, both of which can affect docking conditions. To mitigate the impact of wind, waves, and currents on docked vessels, the jetties will be oriented to minimize the forces acting on them. This alignment ensures that the natural elements exert the least pressure on the vessels' surfaces, enhancing safety and reducing wear on both the jetty and the boats.

Since the prevailing winds come from the north-west, the optimal orientation for the boats is to have the bow point away from this direction, allowing the wind and waves to hit the vessel's longitudinal axis. This positioning reduces the strain on the vessel and minimises the force on the boat's surface.

10.1.3 Off-site departure points

After discussions with the ranch manager and evaluating maps of the area, several options were considered for launching boats to and from La Josefina. These locations serve as departure points for guests and inhabitants:

- Cancha Rayada jetty

  Cancha Rayada is the current launch site for visitors to La Josefina. However, the jetty requires repairs, and a ramp needs to be constructed to improve logistics. The proximity to La Josefina, only about a one-hour boat ride, and the existing structure that could be refurbished, make this a cost-effective option. The main drawback is the challenging access by truck via an unmarked gravel road, which necessitates dedicated transportation for guests. Additionally, Cancha Rayada is located on private land, requiring an agreement with the landowners and limiting control over this access point. From interviews with the neighbouring property owners (see Annex C), it was clear that, although they are willing to assist with access, they do not wish for their property to serve as a public pier, due to concerns about increased traffic and daily tourist passage. Consequently, relying on Cancha Rayada as a primary launch site is not a feasible long-term option.

- Helipuerto de Lago San Martín - Gendarmeria Lago San Martín

  The existing pier near the helipad at Lago San Martín offers an attractive alternative. Located near Estancia Maipú on the southern part of the lake, this site benefits from its connection to Route 33, marked on maps, allowing easier and potentially independent access for visitors. The existing pier could be refurbished, saving costs, and the helipad could support air arrivals. Since Cancha Rayada is not a feasible long-term option due to its private land restrictions, this pier stands out as the best candidate for future use. However, given the four-and-a-half-hour boat journey over rough waters from this site to La Josefina, a large and comfortable ferry is recommended to ensure visitor comfort.

- Villa O'Higgins - Puerto Bahamondes

  Establishing a departure point from Puerto Bahamondes could significantly enhance the project's appeal, positioning Estancia La Josefina as a strategic stop for tourists travelling along the Carretera Austral, crossing from Chile into Argentina. However, current restrictions prevent border crossings via the lake's international waters, making this option challenging without an agreement between the two countries. If an arrangement is reached in the future, the existing jetty at Villa O'Higgins could serve as a link, allowing boats which currently connect the Puerto Bahamondes to Candelario Mancilla to potentially stop at Estancia La Josefina along this route.

- Cocovi

  Cocovi, located just across from Villa O'Higgins on the Argentinian side, presents a possibly more feasible option since land border crossings are permitted here. However, this route requires additional infrastructure as to connect Cocovi with the O'Higgins border, a bridge would need to be constructed over the river currently separating the two points. Furthermore, there is no existing jetty at Cocovi, therefore establishing this departure point would also require building a pier from scratch, which would increase both time and budget considerations for this option.

(a) Cancha Rayada jetty

(b) Puerto Bahamondes jetty

Figure 10.5: Neighbouring jetties

10.2 Preliminary design of primary jetty

From Chapter 2.1.1, it is evident that improving boat access and docking infrastructure is essential for providing a more comfortable, efficient, and safe arrival experience at La Josefina. This can be achieved through the introduction of a well-designed jetty and a suitable ramp for launching and docking boats.
This section presents a potential solution by detailing the preliminary design of the Primary Jetty for La Josefina. The design is analysed using both static and dynamic approaches to ensure a stable and durable structure that can accommodate the safe loading and unloading of people and goods, while also withstanding the forces generated by wind, waves, and fluctuating water levels.
Due to time constraints, this project focuses only on the Primary Jetty in detail. The design of the ramp, although essential for the overall functionality of the jetty, will not be addressed here but is suggested as a key area for further research in future developments of the masterplan.

10.2.1 Jetty structure typology selection

Two different structure typologies for the design of a jetty were researched, with the possibility of using a combination of both to create the most suitable design for the site's conditions.

- **Fixed structure**: This type of structure provides a stable platform and remains stationary as it is anchored directly to the lakebed using piles which provide a solid foundation. It is typically used for water depths of less than 6 metres, water level changes of less than 1 metre, and is suitable for high exposure levels (PIANC, 2020a).
- **Floating structure**: This type of structure is composed of a buoyant platform anchored in place with guide posts, allowing the structure to rise and fall with water levels, ensuring flexibility and stability in varying conditions. It may be used for unlimited depths and large water level changes, however is less tolerant to high exposure levels (PIANC, 2020a).

For the use of a hybrid system consisting of both a fixed and floating structure, a connecting structure referred to as a gangway may be used. Two types of connecting structures were considered:

- **Stair connection**: A fixed stair with several levels to accommodate visitors, regardless of water level changes. This option is simple to implement, with minimal chances of malfunction. However, it requires frequent maintenance due to constant contact with water and is not suitable for all visitors (e.g. those with mobility impairments) (see Figure 10.5 in Puerto Bahamondes).

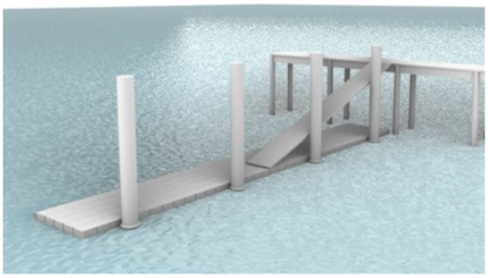
- **Ramp connection**: The ramp, either rigid or flexible, is hinged at the fixed structure, allowing it to adjust its gradient according to the lake's water level. This option is more user-friendly, especially for visitors with different mobility needs, and can be easily moved in the case of harsh weather conditions. However, the hinge mechanism requires maintenance and can be prone to issues.

Based on the characteristics of the chosen location for the Primary Jetty, a combination of a fixed structure and a floating dock with a ramp gangway was selected.

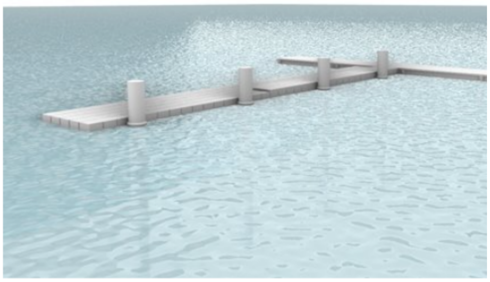
The fixed structure provides resistance to the harsh weather conditions described in Chapter 2.2.3, ensuring a stable and reliable docking point. Anchored directly to the lakebed, this structure remains functional and accessible throughout the year, even with fluctuations in water depth or shoreline position. Given the prevailing strong winds from the North-West, additional bracing would need to be incorporated along this direction to reinforce the frame of the fixed structure.

The floating dock, composed of interconnected blocks adjacent to the pier, is designed to automatically adjust to water level fluctuations, which in Lago San Martín can vary by up to 3 metres (see Chapter 2.2.2). The floating structure requires minimal maintenance, is easily transportable, and can accommodate moderate wave amplitudes. Anchored by piles and rings that permit only vertical movement, it provides a stable docking platform, ensuring efficient disembarking regardless of water level changes. This makes it both a flexible and durable solution for fluctuating environmental conditions.

These two structures are connected by a ramp gangway, facilitating smooth access between the pier and the floating dock. The ramp adjusts to the vertical movement of the dock, guaranteeing easy access to land under varying water levels. Unlike stairs, which remain in constant contact with the water, the ramp requires minimal maintenance and offers an efficient means for transporting goods. A conceptual 3D model (Figure 10.6) helps to visualize how this structure typology, combining fixed and floating jetties with a connecting structure, effectively adapts to changing water levels.



(a) Primary jetty at low tide



(b) Primary jetty at high tide

Figure 10.6: Conceptual model of Primary jetty

10.2.2 Construction materials selection

Timber, concrete, or steel are commonly used for the construction of fixed piers. Among these options, timber is the most affordable and has the lowest environmental impact. Specifically, as discussed in Chapter 2.3.2, the availability of quality construction material, such as Lenga wood, on-site makes timber the best choice. This is because it eliminates the need for transportation, simplifying logistics.

The floating structure of interconnected blocks is generally made of high-density polyethylene (HDPE) following the study by PiEmme Srl, a company specialized in floating devices. The blocks proposed by this comapany are 50x100 cm in width and 40 cm in height, offering a buoyancy capacity of 350 kg per square meter in a single layer (Srls, 2022). Further specifications can be found in the Appendix E.1.

For both the fixed structure piles and the piles required to anchor the floating deck, timber was also selected. One drawback of timber piles is their exposure to water, which necessitates the careful selection of a protective layer. Thus, timber with a protective coating is chosen for the design of all timber members.

For gangways, aluminium is often used since it is durable, lightweight and can be easily assembled.

A summary of the material properties to be used for the structural analysis of the jetty is provided in the table below.

Material	**Density (kg/m³)**	**Young's Modulus (Pa)**	**Poisson's Ratio**
Lenga Wood	330	8.0×10^9	0.3
Aluminum	2700	68.3×10^9	0.34
HDPE	950	1.0×10^9	0.4

Table 10.1: Jetty material properties (see Appendices E.1, E.2, G.1)

10.2.3 Dimensioning of vessels

The dimensioning of the preliminary jetty design is based on the maximum dimensions of vessels allowed to dock and will comply with the PIANC guidelines PIANC (2016a, 2016b, 2017, 2020b).

After analysing the navigation services between Candelario Mancilla and Villa O'Higgins, as well as exploring alternatives to the current motorboat for both construction and tourism activities at La Josefina (see Appendix E.3), the Primary Jetty is designed to accommodate a passenger vessel capable of carrying approximately 45 people or a ferry for transporting materials and goods. The largest vessel that the jetty will accommodate has the following key dimensions:

- **Length**: 15 metres, based on the size of a passenger carrier for around 45 people.
- **Maximum beam**: $B_{\max} = 0.13L + 2.7$ for vessels between 10 and 60 metres in length. Applying this formula, the beam for a 15-metre vessel results in 4.65 metres, which aligns with the dimensional graph provided by PIANC (see Figure E.7).
- **Draught**: The draught of the hull is given by $D = 0.05L + 0.38$ for vessels between 10 and 60 metres in length. For a 15-metre vessel, this results in a draught of 1.13 metres, consistent with PIANC's recommendations (see Figure E.7).

These values provide a robust foundation for the design of the jetty, ensuring that it can accommodate the future demands of passenger transport to and from La Josefina, while also meeting safety and performance criteria as outlined in the relevant PIANC documentation.

10.2.4 Technical design proposal

The dimensional and structural requirements for the technical design of the jetty are outlined below, following the recommendations of PIANC guidelines (PIANC, 2016a, 2016b, 2017, 2020b) and the Australian Standards for Maritime Structures (Global, 2010). Additionally, the design will undergo verification through static and dynamic analyses in the next sections, ensuring the structural integrity necessary for the Primary Jetty.

Docking length

Parallel docking was chosen over perpendicular docking due to the harsh atmospheric conditions in the area, as parallel docking offers greater stability and safety. According to PIANC, the minimum docking length for parallel docking is calculated as:

$$L_b = L_s \times 1.15$$

where L_s represents the maximum length of the vessels docking at the jetty. For La Josefina, the maximum vessel length is set to 15 metres, yielding:

$$L_b = 15 \times 1.15 = 17.25 \text{ metres}$$

Since the floating structure is composed of interlocking blocks with fixed dimensions, the final docking length is adjusted to $L_b = 17.5$ metres.

Water depth

The depth at berths must ensure that even at the lowest tidal level, the draught of the deepest vessel does not come into contact with the lakebed. To achieve ideal depth, the minimum depth should accommodate:

- at least half of the significant wave height, and
- a clearance of 300 mm or 10% of the draught below the keel for soft lakebed material.

Given the maximum draught of 1.13 metres (as previously calculated) and the lakebed characteristics, the fixed structure will extend 28 metres into the lake to reach a depth of 2.15 metres, which meets these requirements.

Width and slope

Walkways on the jetty should have a minimum width of 1.5 metres. For gangways, the recommended clear width is at least 1.2 metres, with a maximum slope of 1:3.

For La Josefina the following dimensions were chosen:

- **Fixed structure width**: 1.7 metres, accommodating adventure tourism equipment.
- **Gangway width**: 1.2 metres with a slope of 1:3, allowing a 10-meter gangway length for a lake height variation of up to 3 metres.
- **Floating structure width**: 2.5 metres, allowing space for passenger disembarkation alongside the gangway.

Piles

According to PIANC, the piles which allow the floating structure to adjust to changes in water levels are recommended to be of diameter 300–500 mm, depending on water depth and bottom conditions (PIANC, 2020b).

- **Floating structure piles**: A diameter of 500 mm is chosen for stability in the harsh conditions of Lago San Martín and to account for the unknown lake bed conditions.
- **Fixed structure piles**: A minimum diameter of 300 mm was selected for the piles in the fixed structure. This diameter provides adequate stiffness over the 4-metre spans in the frame. Since the frame is fixed and constructed with lenga wood, which is already a robust material, the shorter span does not require a larger diameter, allowing the use of the minimum diameter for structural efficiency.

Beams

Given that the specific dimensions of the locally-sourced lenga wood are not readily available for this preliminary design phase, the timber sizes offered by Aserradero Silvio (Silvio, 2008) have been selected as a reference for the structural elements. Each timber beam used in the fixed structure has been specified to measure 355.6 mm by 127 mm (Figure 10.7). This standardisation of beam dimensions helps simplify construction logistics and ensures consistency in structural strength across the jetty.

Primary beams, each 4 meters in length, connect the columns along the jetty, providing the main structural support. Secondary beams were placed perpendicular to the primary beams at 2-meter intervals, adding additional stability and load distribution across the structure.

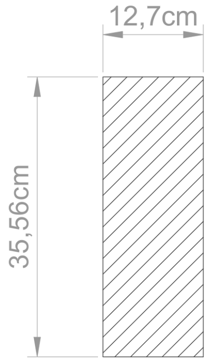


Figure 10.7: Cross-section of beams

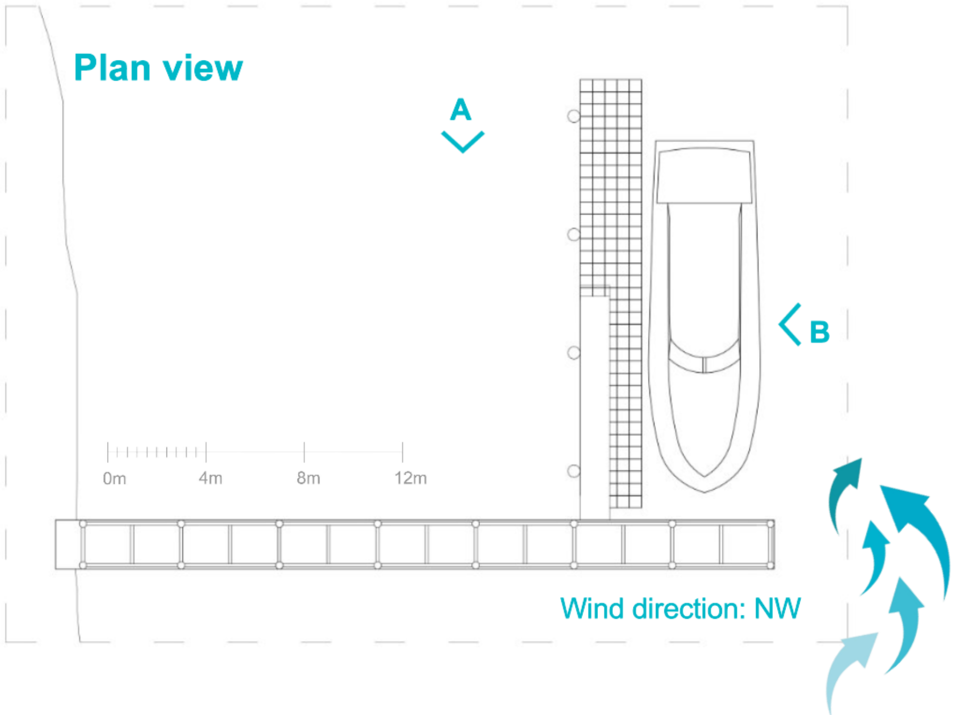


Figure 10.8: Plan of proposed Primary Jetty

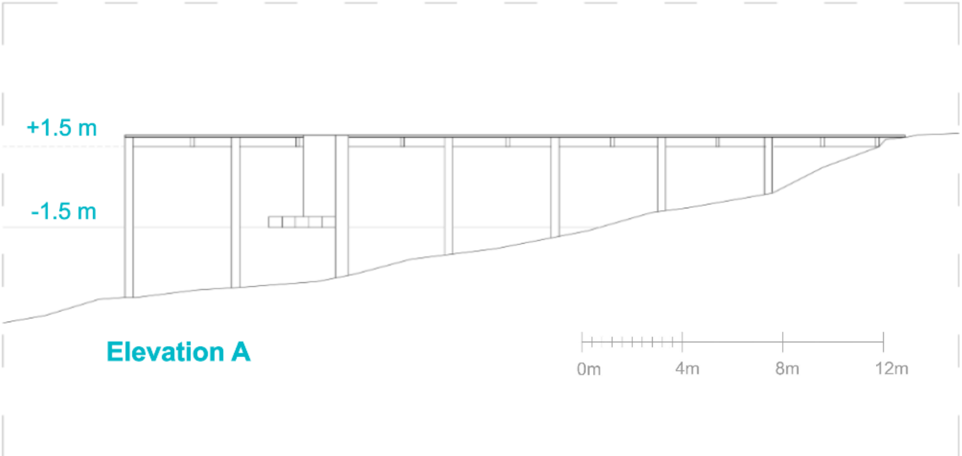


Figure 10.9: Elevation A of proposed Primary Jetty

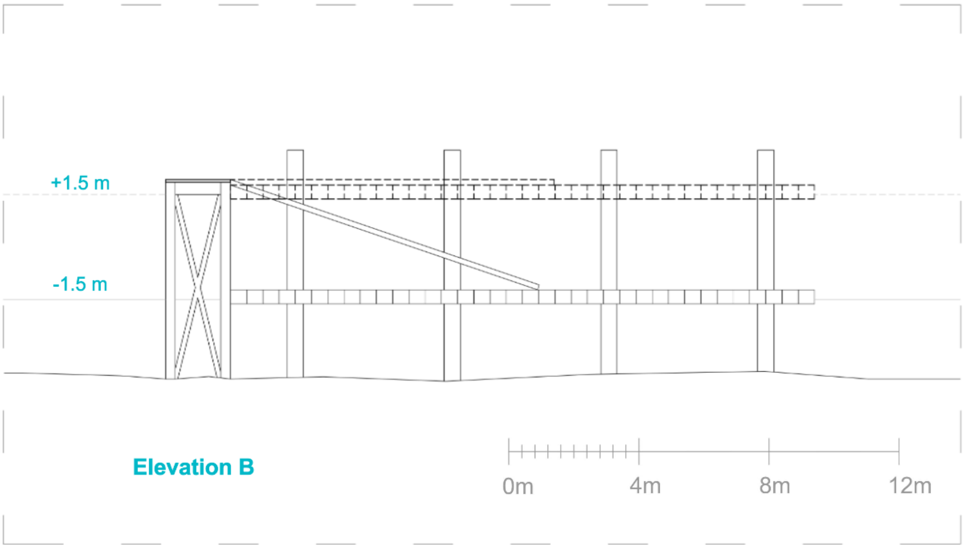


Figure 10.10: Elevation B of proposed Primary Jetty

10.2.5 Static analysis verification

This section outlines the static analysis conducted to verify the structural integrity of the Primary Jetty's fixed structure. Due to time constraints, only the fixed structure is analysed here; however, substantial research on the stability and performance of the floating structure has already been conducted by the company Srls (2022). Consequently, no additional stability analysis of the floating structure is required for this preliminary design.

Loading considerations

In designing a jetty, it is essential to account for various load types: dead loads, live loads, environmental loads, vessel wash loads, and berthing and mooring loads. The following subsections summarize these loading considerations based on guidelines from the Maritime Structures Standards Australia Committee (Global, 2010). For this preliminary design, vessel wash loads, berthing loads, and mooring loads are excluded due to time limitations.

Dead loads

Dead loads primarily include the self-weight of the jetty's structural components and any permanent installations, such as electrical cables. These loads are critical as they contribute to the overall stability and foundation requirements of the structure.

Live loads

Live loads are crucial to consider for jetty design, given their usage by passengers and operational activities. The table below summarises the live loads applied to the different jetty structures. Due to the jetty's anticipated high usage, unrestricted access loads are considered in the calculations.

Structure	**Uniformly Distributed Load**	**Concentrated Load**
Fixed Structure	5 kPa	4.5 kN
Gangway	4 kPa	4.5 kN
Floating Structure	3 kPa	4.5 kN

Table 10.2: Structural live loads for fixed, gangway, and floating structures

Environmental loads

Jetty structures are exposed to various environmental forces, primarily wave loads, wind loads, and current loads. Each of these forces is critical in the preliminary design process, though current loads are excluded here due to time constraints. The influence of wave loads and wind loads on the structure is discussed below.

Wave loads:

Wave loads are typically cyclical, alternating in direction as the wave progresses. This underlines a dynamic nature of wave loads, therefore, their effects are discussed in the subsequent dynamic analysis section.

Wind loads:

The design wind pressure on the jetty's fixed structure is calculated using a steady-state wind model, in line with Australian standards. Steady-state wind loads provide a consistent horizontal force on the structure, simplifying the analysis and ensuring reliable load estimates.

Following the Australian Code's guidelines for wind loads on maritime structures, the horizontal wind force acting on the structure is calculated in Appendix E.4:

$$F_D = 0.0855\,\text{kN}$$

Given the jetty piles' substantial diameter and the comparatively minor impact of horizontal wind forces versus the primary vertical loads, the calculated wind load F_D is neglected in this preliminary design phase.

3D finite element model (FEM) analysis

For verification of the technical design, a 3D FEM model of the fixed structure was developed using Abaqus. This model, which combines wireframe elements for the piles and beams and shell elements for the walkway, was analysed to determine maximum deformation and stress.
The FEM model included the following assumptions:

- **Boundary conditions:** Fixed boundary conditions were applied at both the shore and the lake bed attachment points.
- **Material properties:** Lenga wood was approximated as an isotropic material due to limited data on its anisotropic properties.
- **Structural approximations:** Piles and beams were represented as wire elements, while the walkway was represented as a shell surface due to its thin cross-section.

- **Unified frame:** The fixed structure frame was considered as a single integrated part for simplicity.

The results of the finite element model indicate a maximum deformation of approximately 7.5 mm.

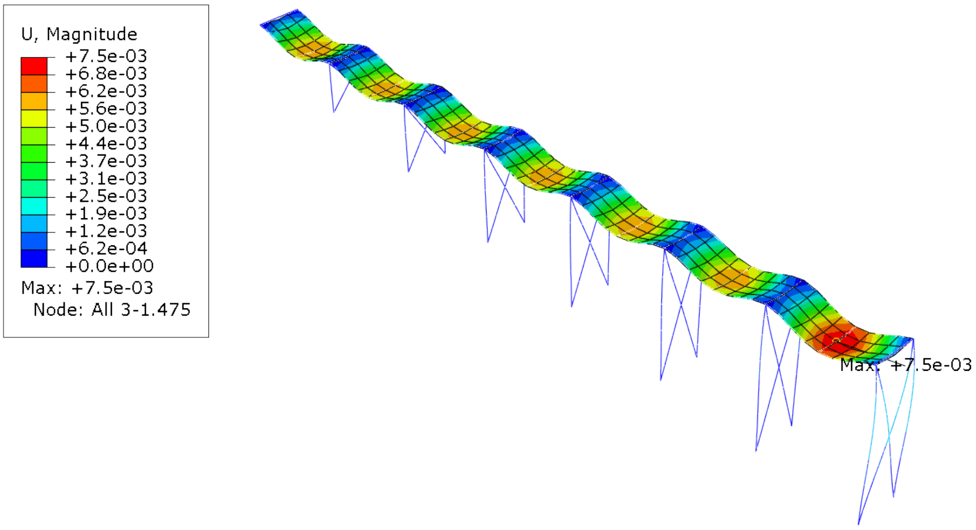


Figure 10.11: FEM amplified results - Max Deformation

Additionally, the model shows a maximum stress of 3.9 MPa.

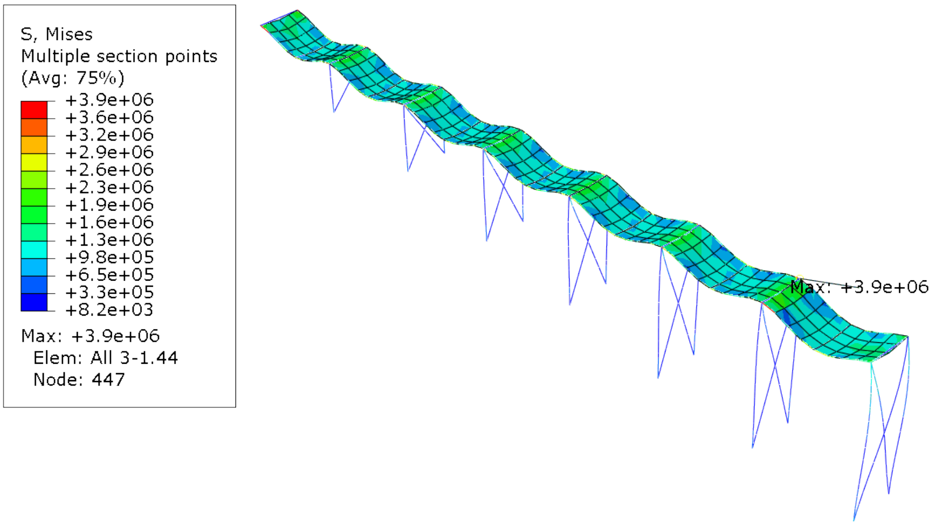


Figure 10.12: FEM amplified results - Max Stress

Verification checks

To ensure the FEM results for the Primary Jetty meets structural requirements, several verifications were conducted:

- **Buckling of piles:** The longest pile, at a length of 6 metres, was analysed for buckling.
- **Beam stress analysis:** The stress on the longest beams was checked to ensure that it remains below the yield stress of lenga wood.
- **Maximum deflection:** The maximum deflection on the longest beams was checked to ensure that it remains below the yield stress of lenga wood.

These calculations are detailed in Appendix E.5.

10.2.6 Dynamic analysis verification

In this section, loading that varies over time is considered. As mentioned in the previous section, wave loads fall under this category since they are cyclic. For this analysis, only loads generated by waves are considered. As per the guidelines in (Global, 2010), the wave loads should be calculated for a return period of 50 years.

Wave loading

The first consideration for wave loads is designing for a limitation on wave height, which can be achieved naturally by positioning the jetty in sheltered waters.
To determine an optimal wave climate for small harbours, the wave period T_p and wind direction need to be assessed, as these factors define the acceptable wave heights and periods for safe harbor conditions. For this analysis, the JONSWAP spectrum is utilised. The full calculations are presented in Appendix E.7.

The results of the analysis indicate the following:

- Reference wind speed: $U_{10} = 10.786\,\text{m/s}$ (Appendix refsection: EVA)
- Fetch: $F = 5000\,\text{m}$ (Appendix E.6)
- Peak wave frequency: $f_p = 0.425\,\text{Hz}$
- Peak wave period: $T_p = 2.356\,\text{s}$
- Significant wave height: $H_s = 0.398\,\text{m}$

According to Australian standards for head conditions with a peak period greater than 2 seconds:

- **1-in-50-year event**: Expected wave heights should remain below 0.6 metres under these conditions, ensuring manageable seas for small craft.
- **Once-a-year event**: Expected wave heights should remain below 0.3 metres under annual conditions, ensuring calm and manageable seas for small craft.

In these calculations, the significant wave height $H_s = 0.398\,\text{m}$ is comfortably below the 0.6 m threshold, indicating a favourable wave climate for small craft operations.

From the data above, the cyclic load induced by irregular waves is calculated using the JONSWAP spectrum. The detailed calculations are provided in Appendix E.7.

The results show that the cyclic load produced by waves with $H_s = 0.398\,\text{m}$ is very low and can be neglected, as the maximum forces reach only 600 N. However, for the dynamic analysis of the piles that keep the floating structure docked, forces of up to 1.5 kN can occur, which could compromise the safety of the structure.

To ensure that no resonance occurs due to the dynamic loading of waves, the eigenmodes and eigenfrequencies of the fixed structure were determined through a FEM model. The first five modes are calculated and presented below:

- Eigenfrequency 1: $f_1 = 14.2\,\text{Hz}$

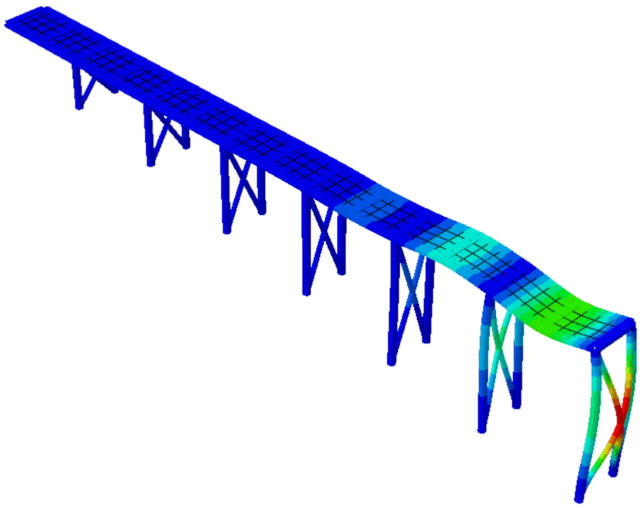


Figure 10.13: FEM amplified results - Eigenmode 1

- Eigenfrequency 2: $f_2 = 14.7\,\mathrm{Hz}$

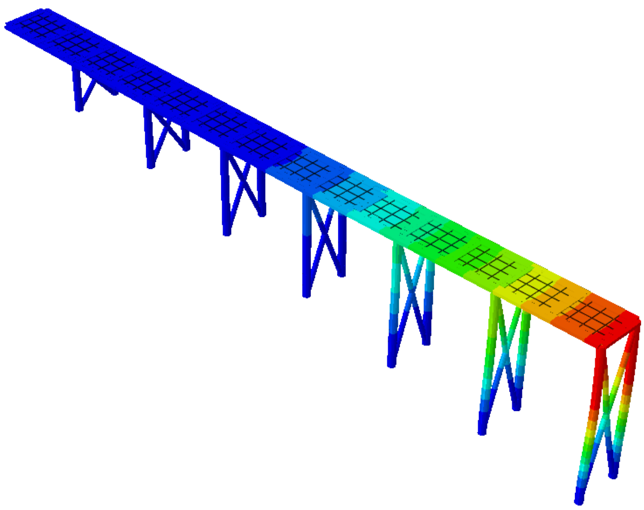


Figure 10.14: FEM amplified results - Eigenmode 2

- Eigenfrequency 3: $f_3 = 15.5\,\mathrm{Hz}$

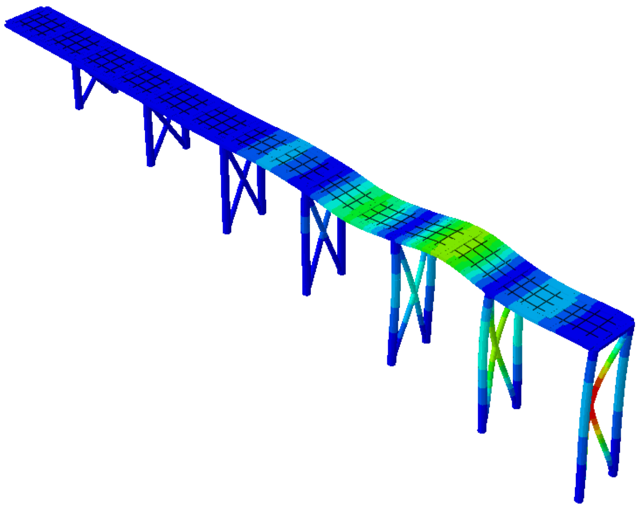


Figure 10.15: FEM amplified results - Eigenmode 3

- Eigenfrequency 4: $f_4 = 16.6\,\text{Hz}$

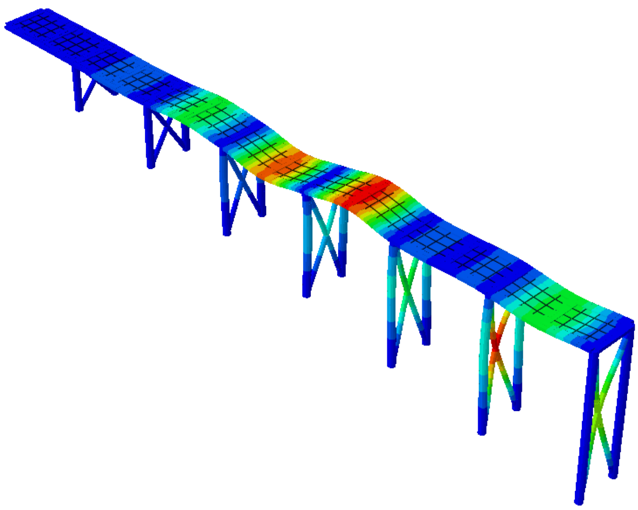


Figure 10.16: FEM amplified results - Eigenmode 4

- Eigenfrequency 5: $f_5 = 17.5\,\text{Hz}$

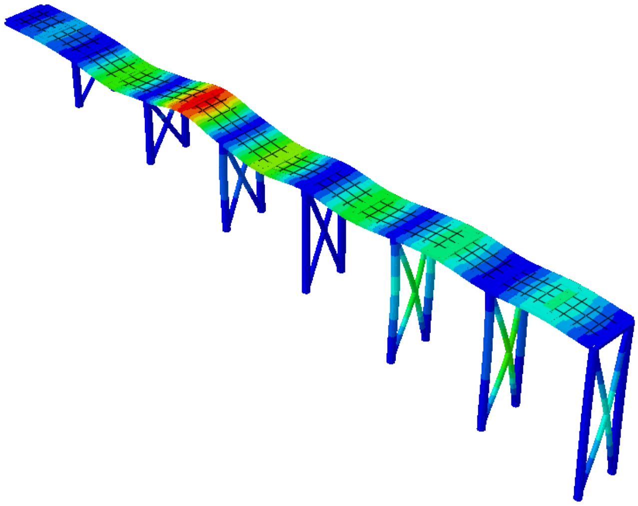


Figure 10.17: FEM amplified results - Eigenmode 5

By comparing the peak wave frequency $f_p = 0.425\,\mathrm{Hz}$ with the first natural frequency of the structure $f_1 = 14.2\,\mathrm{Hz}$, we can confidently conclude that wave-induced loading will not influence the design or cause resonance. The significant difference between these frequencies indicates that the structure's dynamic response is well outside the range of typical wave forces. The structure's high natural frequency suggests a strong, stiff frame, consistent with the assumption that it behaves as a rigid body. Therefore, resonance is not a concern for this design.

10.3 Conclusion

By proposing new routes and creating additional jetties at Estancia La Josefina, an improvement in accessibility is not only feasible but highly beneficial. The analysis explored potential solutions that could enhance connectivity to the estancia, boosting its significance within Lago San Martín/Lago O'Higgins. These solutions also provides a more efficient access for visitors and future inhabitants.

The preliminary design of the jetty, utilising locally sourced materials, has been thoroughly evaluated for both static and dynamic stability. The static and dynamic verifications confirm that the Primary Jetty is structurally sound and capable of supporting its intended use. The detailed analysis, including FEM modeling and wave load calculations, assures that the jetty will function safely and efficiently under the expected environmental conditions. In addition, the design demonstrates no risk of resonance or failure, reinforcing the durability and reliability of the jetty.

11 | Energy plan for the village

In this section, the renewable energy options suitable for powering the village are explored. Given its isolation, the village requires a self-sufficient energy system. The discussion will focus on the feasibility and integration of solar, wind, and hydroelectric energy sources, examining each option's potential and limitations. Data on solar irradiation, wind speeds, and hydraulic systems will be provided to assess their suitability for energy generation in the village. Case studies, such as the Patagonia National Park's energy system, will also be referenced.

11.1 Renewable energy research

Energy accessibility is essential for the development of the village. The village is located in a remote area, and therefore it needs to rely on its own energy production. Considering all the variables of the village, especially its remoteness, it is opted from the start to focus the research on a hybrid renewable energy system. Given the variable weather conditions in Patagonia, the hybrid system allows for year-round energy production. The system is more reliable if it depends on more than one energy source. To expand even more the system reliability also storage batteries were considered in the design. The research will centre on renewable energy off-grid energy systems, which are systems that are not connected to the main electricity grid.

The area where the village is located is known for its strong winds as well as for the glaciers with their rivers, as it was previously discussed in the site analysis (Chapter 2). For this reason, both the options of wind energy and hydroelectric energy will be explored and discussed within this section. Solar energy will be discussed as well.

Currently the energy at the ranch is provided mainly by photovoltaic panels for electricity and wood for heating. There is also a small wind turbine but it is not used as much as the solar energy. The energy system is enough for the current population.

Patagonia National Park, which is located in both Argentina and Chile, provides a case study, chosen for its similar nature and for the closeness to the project's site. According to Ingram (2020), the park uses a hybrid energy system with run-of-river hydroelectric, solar panels, and battery storage. Initially the park was powered by diesel generators, then it shifted to renewable energy systems to minimize environmental damage and improve energy efficiency. The park utilizes two micro-turbines to take energy from the rivers during the rainy season, while solar panels provide power during summer. Excess energy is stored in lithium-ion batteries, ensuring uninterrupted power supply year-round.

11.1.1 Solar energy

To investigate the solar energy availability, Irradiation had to be analysed. The data that are collected and analysed in the following paragraph are taken from Ministerio de Energía (2024).Data are collected and divided by month in Table F.1. The variation of DHI per month is shown in Figure F.1a.

The DHI per month graph shows clearly that the amount of Diffuse Horizontal Irradiation reaches its peak in summer (from October to February) and its minimum in winter (from May to August), suggesting a better performance of solar panels in the summer period.

For the Global Horizontal Irradiation, data are collected and divided by month in Table F.2. Figure F.1b shows how the GHI varies per month. The GHI per month graph shows that the amount of Global Horizontal Irradiation reaches its peak in summer (from October to February) and its minimum in winter (from May to August), suggesting a better performance of solar panels in the first one.

The Irradiation TILT in the village area's data are collected and divided by month in the Table F.2. In Figure F.3, there is a graph that shows how the TILT Irradiation varies per month. The TILT Irradiation per month graph shows similar results to the GHI, suggesting a better performance of solar panels in summertime. The TILT angle can be assumed to be the latitude of the village, which is 48°.

11.1.2 Hydroelectric energy

The area where the village is located is optimal for hydroelectric energy systems since there are glaciers which guarantee a continuous and constant flow to rivers. There are some perennial rivers in the area of the village, as it is mentioned in the Site Analysis (Chapter 2.2.2). In the same area, according to Ministerio de Energía (2024), other hydroelectric systems exist, as showed in Figure F.4.

A closer look is done on Run-of-the-river hydroelectric systems, which is the system used in the Patagonia National Park. Run-of-the-river hydroelectric systems generate electricity by harnessing the natural flow of rivers without the need for large dams or reservoirs. Instead of relying on water stored in a reservoir, these systems use the natural flow rate of the river, often with a small dam (weir) to direct water into a penstock. The water flows through the penstock to a turbine, which spins and powers a generator, converting the kinetic energy of the moving water into electricity. After generating power, the water is returned to the river downstream.

There are two main advantages to run-of-the-river systems. First, they require less land and have a smaller environmental footprint compared to traditional dams, which often flood large areas and disrupt ecosystems. Second, they can be scaled to meet the needs of remote communities with lower energy demands, providing a cleaner, more sustainable alternative to diesel generators.

However, there are also limitations. Without a major reservoir, run-of-the-river systems are more vulnerable to seasonal fluctuations in water flow, which can significantly reduce energy output. Additionally, the absence of a reservoir limits the size of the plant, making this technology most feasible for rivers with large year-round flow rates. It is important to notice that there are some environmental risks in using this system, such as interruption of fish migration.

11.1.3 Wind energy

Patagonia is well-known for its strong winds, therefore wind energy will be explored further.
To investigate the Wind Energy potential in the area of the village, an analysis on the wind speed in the area in essential. The analysis can be found in Chapter 2.2.3 and it shows a good wind energy potential.

11.1.4 Ion-Lithium storage batteries

Storage batteries are essential when evaluating renewable energy technologies. There are some things that need constant energy throughout the days and the hour of the day (e.g. particular medical appliances, fridges), and therefore a minimum constant energy must be provided always. Lithium-ion batteries are chosen due to their high efficiency, long lifespan, and low maintenance needs, which is particularly important in a remote area where accessibility for repairs is limited. Therefore, ion-lithium storage batteries are included in the design.

11.1.5 Final reflections

In conclusion, the hybrid solar-wind energy system with lithium-ion storage was chosen as the most reliable and sustainable solution for the village. This solution was selected among the other alternatives because it is the one with less environmental impact on the area from the one studied, and the easiest to realize. The integration of lithium-ion batteries further guarantees energy availability during low-generation periods by storing excess energy.
Other options, such as hydroelectric and biogas systems (refer to Appendix F.3), were carefully evaluated but deemed less practical given the specific conditions of the site. Hydroelectric systems are sensitive to seasonal fluctuations in river flow and involve environmental risks. Moreover, during the site visit, it was more clear that it is not a reliable option due to the great variation of stream flow. Biogas, while promising, requires continuous maintenance and stable temperatures, which is challenging for this specific site.

11.2 Energy plan

Given the remote location of the estancia, an off-grid energy system is essential to meet its energy requirements. Based on the research stage's findings, the design of a hybrid solar-wind off-grid energy system is selected. The design process will follow the flowchart outlined in Figure 11.1. The design process starts with an energy demand analysis, which involves identifying user profiles to determine the total energy consumption. Once the demand is established, the next step is an energy system planning, focusing on the logistics and energy distribution. The last step is the technical design, in which wind turbines and photovoltaic panels will be dimensioned to meet the energy needs.

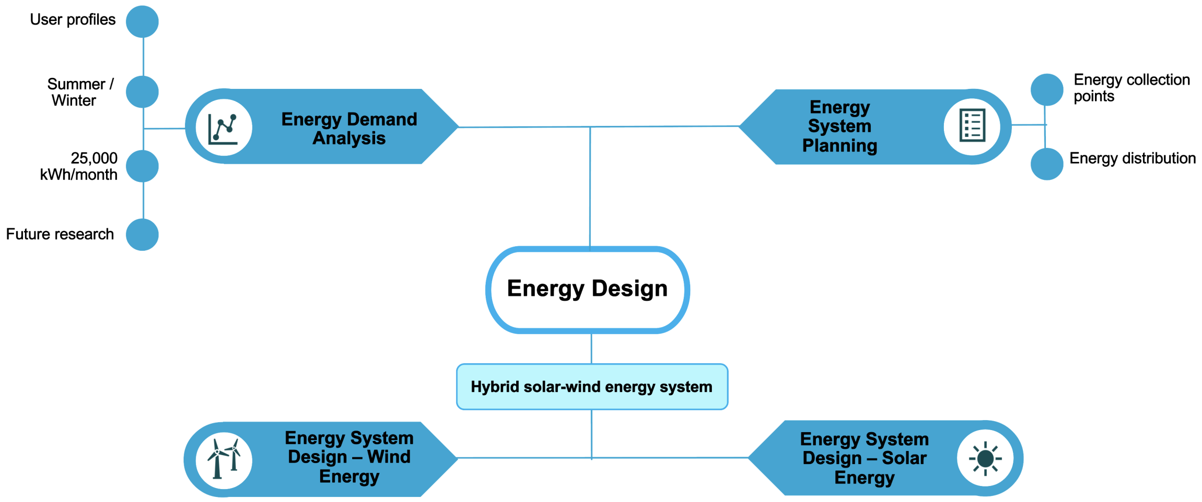


Figure 11.1: Energy Design Flowchart

11.2.1 Energy demand

An energy demand study was conducted to determine the average monthly energy demand. The results of the latter study are shown in Figure F.9 and Figure F.10. Two different calculations were performed: one for summer demand and one for winter demand. Winter presents the harshest climate conditions (temperatures can drop as low as -16°C), but during winter, the population is at its lowest. In summer the climate conditions are more favorable but the population is at its highest. To perform this calculation, electrical appliances were considered as loads and categorized based on the services they provide, ranging from very low power to very high power equipment. Figure F.5 distinguishes typical household appliances according to International Renewable Energy Agency (IRENA), 2023. A conservative power value (in Watts) was assigned to every category. For each population group, appliance usage and estimated daily operating hours were assessed, allowing the calculation of total kWh/day for every category. The energy consumption of the common areas was also included. By summing up all the values, the total energy demands were calculated in kWh/day for both summer and winter. The energy demand for the two conditions is approximately the same and can be rounded up to 25000 kWh/month. This happens because even if the population is three times smaller in winter, electric heating is heavily used due to the extreme winter conditions. For future research, it is recommended to investigate more sustainable alternatives for heating, such as solar thermal energy, which is already used at the estancia. The energy demand was determined to be 25000 kWh/month. It is important to note that the calculations are based on the average annual wind and solar energy, without accounting for specific monthly variations, due to lack of time. While these estimates are useful for assessing system feasibility, they may be too broad and potentially underestimated for detailed design purposes. Future research should address this distinction and incorporate seasonal variability into the design process. To compensate for this uncertainty, a correction factor of 1.3 was applied.

11.2.2 Energy system planning

The energy system will be organized as follows: there will be two energy collection points: one in the north-west, serving the luxury hotel and permanent residents, and another in the south-east, serving the permanent residents. The area of the cottages, hostels, and campsite will rely on stand-alone solar energy. This decision was made because tourism in this area does not require constant and high-efficiency energy, with peak capacity concentrated in summer. Installing a wind turbine in this area would be inefficient since it is uninhabited in winter. Both the collection points will use hybrid wind-solar energy systems. The village's total energy demand will be met with 60% from wind energy and 40% from solar energy. This distribution was chosen to account for the seasonal variability, as both wind and solar energy are less available during winter. Relying on both sources ensures a more balanced and reliable energy supply. The specific 60/40 split was determined based on the simplicity of system dimensioning, as detailed in the following sections.

11.2.3 Energy system dimensioning

The wind energy design is done considering E-10 HAWT turbines from Energy (n.d.) (data sheet available in Figure F.7), which are 10kW small wind turbines intended for off-grid power systems. The calculations are based on an annual mean wind speed of 8m/s following the research and data processing outlined in the Wind - Research and Requirements section. According to the Power Curve of this specific turbine model (F.6), the estimated annual output is 64 kWh, which means an estimated monthly output of around 5 kWh.

Given the total monthly energy demand of 25000 kWh, three turbines of this type are sufficient to cover the 60% of it (15000 kWh). two in the north-west area and one for the south-east area. The remaining energy demand will be supplied through solar energy. Ion-lithium storage batteries are essential in the design to provide the minimum constant energy that is always required, also in winter night time (e.g. fridges, medical tools which need constant energy source). The solar energy design is based on the following data: TILT Irradiation (yearly), Yield (equivalent hours), and standard test conditions Irradiation. The solar energy system has to cover a monthly energy demand of 10000 kWh/month. The calculations indicate a rate power of around 1000 kW. This number allows to find out the precise number of solar panels, once one typology is chosen. Considering, for example, monocrystalline solar panels from Solar (n.d.) (data sheet available in Figure F.8), 320 photovoltaic panels cover the entire demand. The energy construction plan develops at the same pace of the village development, since for simplicity every house/common area will have its own solar panel for localized energy production. However, a reliable energy system must be provided for the permanent residents, therefore the houses will not be stand-alone, but they will form an energy community, enabling shared resources.

12 | Sustainable building solutions

One of the main parts of the development of the project consists of building new structures at the estancia. As it was mentioned before, the development of the area is particularly complex due to its remoteness and difficult accessibility. These factors represent a challenge for the development, especially considering construction logistics. The key criteria that were chosen to determine the building typologies were: low carbon footprint, quick construction time and sustainability, as shown in Figure 12.1.

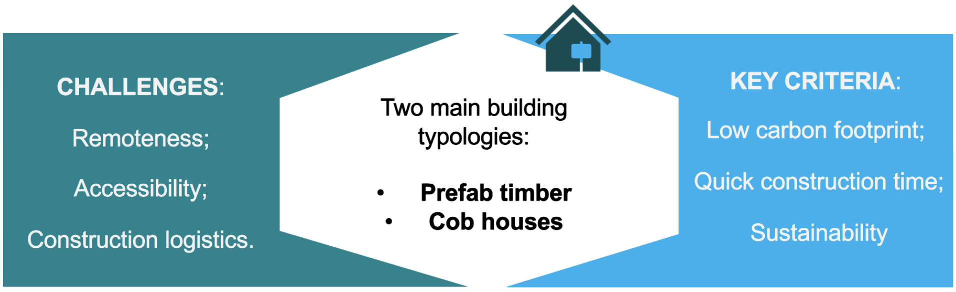


Figure 12.1: Challenges and Key Criteria

Following the key criteria, two different building typologies are selected: prefabricated timber buildings and cob houses. Prefabricated timber buildings are chosen as the best option because it is possible to transport on-site via boat, and they guarantee a small construction time since it is difficult to arrange a large number of workers in such a remote area. Cob houses are chosen as an option for the cottages and hostels and could be investigated for the permanent houses, because of their low carbon footprint and their reflection of the client's vision of the development. In the estancia, there is already a cob house built in 2023. Firstly, a look into this case study on-site is presented, followed by investigations into cob house regulations in Argentina.

12.0.1 Case studies

Two main case studies were investigated for this part of the project. The first one is the existing cob house on site, which was built in 2023 using mainly cob and plastic bottles, while the second one is a Dutch Company, called Huys Advies, that is successfully using Polyethylene terephthalate (PET) as insulation material for their houses.

Existing cob house on site

The cob house was built in 2023 by the ranch manager and his family. This house, is 26 square meters, and consists of an open space area. The layout has a bedroom, a kitchen, and a bathroom where a sink, a toilet and a shower are placed.

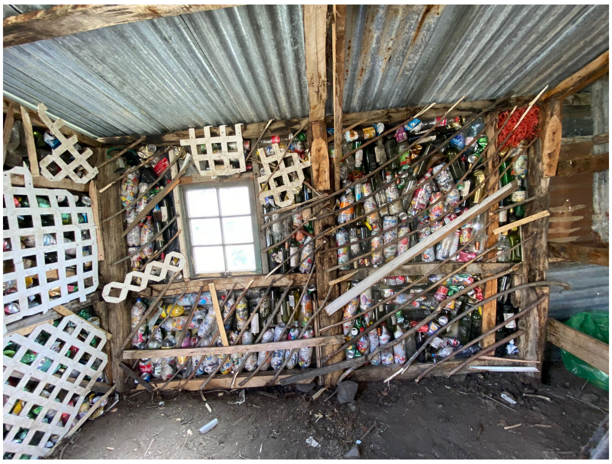
The main structure of the house is made of structural timber found on site from old abandoned houses, while the walls were built in this way: two layers of cob separated by an inner layer of PET recycled plastic. The cob mixture was prepared by using straw, water, and clay (taken from Lake San Martin), while the layer of plastic was realized by repurposing used plastic bottles filled with more plastic waste. In this way, the walls constructed have not only good insulation properties, but since the waste management is quite crucial on-site, due to its remoteness and difficult accessibility, the waste was repurposed in a circular way and didn't need to be disposed of.

For the roof, corrugated steel panels from old gauchos' abandoned houses were reused. More of these panels were also used for the walls as the external layer, to prevent atmospherical damage to the cob layers.

The glass used for the windows was recovered as well from abandoned Gaucho's houses. Pictures of the existing cob house can be found below.

(a) Detail of the interior of the Case Study house (1)

(b) Detail of the interior of the Case Study house (2)



(c) Detail of the plastic bottles insulation

(d) Detail of the exterior of the Case Study house

Figure 12.2: Existing cob house on site

Huys Advies

Huys Advies is a Dutch company that reuses plastic waste, in particular PET bottles, for thermal insulation purposes, especially in mountainous regions in Asia. For insulation purposes the bottles of PET are added into fiber sacks with the caps off, whose thickness varies on the temperature outside, and it ranges from 5 to 15 cm. These sacks can be used for insulation of roofs, walls and floors.
The most thermal heat is lost through the ceiling because of the heat rising so to minimize the amount of energy needed for heat a lot of insulation is needed in the ceiling.

According to CENN (2024) it is essential that the plastic is completely washed and dried because if it is not completely dry, moisture will remain in the wall and cause condensation issues.

12.0.2 Regulation of cob houses in Argentina

Before starting to design houses in cob, it is essential to confirm their legal feasibility. According to the analysis conducted by Red Proterra (2020), at the moment there is not a national regulation for earth construction. To address this situation, regulatory modifications, ordinances, decrees, and laws are being enacted in provinces and municipalities. "The regulation of earth-based construction at the national level in Argentina is an unresolved issue. Currently, most municipal ordinances and building codes do not consider earth construction, or simply prohibit it. The lack of national regulation presents two major problems: the absence of seismic resistance regulation and the lack of tools that facilitate and allow its technological development. Earth construction has been stigmatized since the 19th century by various state agencies, but in recent decades, the prohibition of 'adobe' construction has proven to be an unproductive path."

In the annex of the report from Red Proterra (2020) it is mentioned, in particular for the region of Santa Cruz, that earth houses "are not regulated, it recommends gathering information to incorporate into the Building Code". As a description of the regulation just mentioned, it continues: "Authorize, within the jurisdiction of El Calafate, the use of sustainable construction techniques and materials through methods of raw earth construction, as long as current National regulations (CIRSOC Regulations and others) are complied with". In Figure G.3 the annex of the Red Proterra (2020) report is shown.

12.1 Innovative insulation solutions

Once the feasibility of cob houses is confirmed, another critical aspect is investigated: is the insulation provided by natural and repurposed materials enough? Will there be condensation problems?

According to Haddad et al. (2024), using a natural material for walls, as cob, has been found out to reduce the energy footprints of heating and cooling by up to 5% and 30% respectively. However, cob has low insulation capacity: depending on the mixture proportions and fiber content, the thermal conductivity of cob range from 0.47 W/mK to 0.93 W/mK. Is therefore necessary to add insulation to cob walls.

Usually to enhance cob's properties, fibers are added. The fiber content facilitates the mixing of cob, assists handling, accelerates the drying process, works on distributing shrinkage cracks throughout the wall mass, enhances cohesion and shear-resistance of the wall, and helps improve weathering resistance. According to Keefe (2012) the impact of fibers on thermal conductivity would be noticeable when the content of fibers in the fabric is about 25% by mass, so it can be neglected.

To improve cob houses' insulation, the possibility of adding a cavity filled with insulation materials is analysed. For the insulation two possible materials are researched: straw bales and PET recycled plastic. These two materials are selected for their availability on-site. According to Haddad et al. (2024) incorporating straw bales into a cavity results in enhancing insulation. A wall with a cavity filled with straw results in a thermal conductivity of 0.32 W/m.K in comparison with 0.48 W/m.K for a solid wall section. Walls with lower conductivity and lower density are more advisable due to their higher insulation value and lighter weight.

Straw is a byproduct of cereal cultivation, usually the ones used in construction come from wheat cultivation. In most countries there is a great availability of it and at a low cost. It is one of the first materials that was investigated for earth constructions, therefore there are plenty of buildings constructed with it all over the world. Several researchers investigated the possibility of using straw as an insulation material. The report from Asdrubali et al. (2015), which details the state of the art of unconventional building insulation products, outlines in Figure G.4 the thermal conductivity of straw bales, highlighting its good insulation potential. According to Goodhew and Griffiths (2005) straw has a thermal conductivity of 0.067 W/mK and a specific heat capacity of 600 J/kgK for a 60 kg/m3 dense sample. Additionally, the study conducted by Munch-Andersen and Andersen (2004) reported that straw has better insulation properties when the stalks of straw are perpendicular to heat flow. There is a distinction between these two situations in literature regarding thermal properties: straw fibers perpendicular to the heat flow, and straw fibers parallel to the heat flow. McCabe (1993) calculated the following thermal conductivities' values :

- $\lambda = 0.048$ W/mK when the heat flow is perpendicular to the fibers;
- $\lambda = 0.061$ W/mK when the heat flow is parallel to the fibers.

For this project the value of $\lambda = 0.048$ W/mK will be used since the straw fibers will be positioned perpendicular to the heat flow in order to have a more efficient insulation material.
Polyethylene terephthalate (PET) is one of the most produced plastic materials, used in particular in the industry of packaging and bottle production. An innovative method to reuse PET, HDPE (High Density Polyethylene) and PVC (Polyvinyl chloride) wastes to repurpose them as insulation materials is reported in Nienhuys (2004): the authors explained how plastic was repurposed in the areas of the mountains of the Himalayas in Nepal, a popular trekking area for tourists. This area faced similar issues to the ones that La Josefina faces when it is peak season and there is a peak in tourism: plastic is brought into the area both from the tourists and from the local community. Since the area is really remote, there is a critical situation in waste management. This result is an accumulation of non-degradable waste which pollutes the environment. Recycling is not an option because it would mean bringing the plastic back to recycling plants which are too far away. Therefore the best solution is direct re-use or re-purpose.

A distinction needs to be made between usable and non-usable waste materials. In order to use a waste material for thermal insulation, it must be non-conductive and it must contain air. Additionally, they should be non-degradable and non-water absorbing. The following chart lists some materials and their possible application:

Can be used under floors in PP or PVC bags	Can be used in ceilings, cavity walls and under dry roofs	Cannot be used for thermal insulation
Plastic bottles (empty/closed).	Plastic bottles (empty).	Metal cans and containers.
Plastic foil, bags (crumpled).	Plastic foil, bags (crumpled).	Aluminium cans, containers.
Plastic foam, PP, EPS (waterproof and shredded).	Plastic foam, PP, EPS (waterproof and shredded).	Hard and brittle PVC (as this may cut the container bags).
Rubber goods (shredded).	Rubber foam mattress (shredded).	Glass bottles (any size).
Cleaned battery containers.	Fleece and nylon (shredded).	Earthenware.
Chip bags, candy wrappers	Wood shavings, curls, saw dust.	Dirty or soiled materials.
Wax paper, shopping bags.	Glass wool, rock wool [2], air bubble plastic.	Paper or cardboard waste. Leather, animal skin.
Clay mixed with straw (1:1) volume and 5% lime/cement	Straw in PP bags with 2%-3% lime dust against mice.	

Figure 12.3: Chart on plastic materials

The report also recommends thicknesses of the plastic insulation layer considering different temperatures:

Minimum Average Winter Temperature	Approximate Altitude	Recommended Thickness of Insulation Layer with $\lambda = < 0.06$ W/m.K	Heat Resistance of the Insulation R_c in m^2K/W
0 degrees C.	1200 m	5 cm	$R_c = 1.3$
-5 degrees C.	1500 m	7.5 cm	$R_c = 2.0$
-10 degrees C.	1800 m	10 cm	$R_c = 2.6$
-15 degrees C.	2100 m	12.5 cm	$R_c = 3.3$
Colder than -15 degrees C.	2400 m	15 cm	$R_c = 3.9$

Figure 12.4: Insulation thicknesses

It is crucial, and widely mentioned in the report, the necessity of the plastic to be clean before starting any assembly to use it as insulation. The report from Asdrubali et al. (2015) outlines in Figure G.5 the thermal conductivity of PET, highlighting its good insulation properties. According to the latter report, a value of $\lambda = 0.0355$ W/mK will be used for this project.

12.2 Design

Based on the research conducted, this section outlines the proposed wall layers designed to enhance the thermal performance of cob houses. The walls will be made with cob, with a cavity filled with the insulation. From the research, both straw bales and PET presented great insulation properties. PET recycled plastic bottles are filled with other plastic inside, compressed as much as possible and then closed with their cap. The plastic bottles will be in between two straw layers so that all the space between one bottle and the others is filled with straw. This avoids air circulating freely between the plastic bottles and prevents the creation of convection currents, which would compromise the insulation. The fibres of the straw will be perpendicular to the heat flow for the reasons previously explained. The layers, with their respective thicknesses, are shown in Figure 12.5.

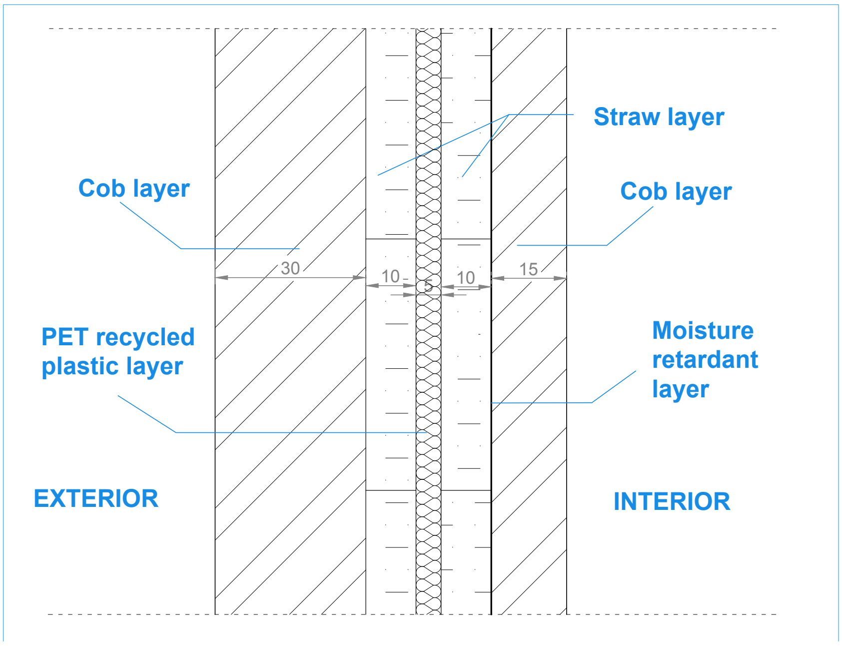


Figure 12.5: Cob wall layers

A steady-state heat and moisture transfer analysis is performed with this layer configuration and the result is shown in Figure G.6. In order to have a configuration that does not allow condensation a moisture retardant layer is needed. It is positioned between the insulation and the cob through the inside. The following Table (12.1) summarizes the layers of the wall with their relevant properties.

Table 12.1: Properties of Construction Layers

Construction Layer	**Thickness (m)**	**Thermal Conductivity (W/m·K)**	**Vapour Resistance Factor (μ)**
Cob	0.3	0.6	19
Straw	0.1	0.048	3.1
PET	0.05	0.0355	8.6
Straw	0.1	0.048	3.1
Moisture Retardant Layer	0.001	0.2	50,000
Cob	0.15	0.6	19

The steady state heat and moisture analysis is done using the values for the thermal conductivity and vapour resistance factor summarized in Table 12.1. The result of the analysis is shown in Figure 12.6, where the green line indicates the saturation vapour pressure and the red one the partial vapour pressure. The analysis shows that the partial vapour pressure remains below the saturation vapour pressure throughout the construction layers. This means that there is no risk of condensation within the layers, ensuring that moisture accumulation is avoided.

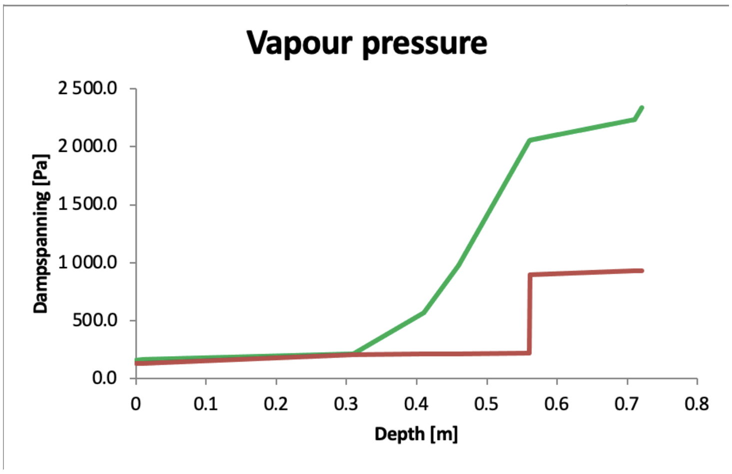


Figure 12.6: Condensation graph

13 | Water and wastewater systems

When developing a remote village, a detailed water and wastewater plan is needed to prevent cross contamination and ensure there will be sufficient water for all inhabitants. The following section will first introduce multiple water reduction methods considered for the design, and then detail a proposed water management plan for the development. The design will be divided into potable water and wastewater systems. Each part will first detail existing systems, and then propose a final design solution.

13.1 Preliminary water research

Water availability is a critical factor considered for any development currently as water scarcity is becoming a global issue. Reducing water consumption is a goal for many sustainable villages across the globe solved through two different methods. The first method targets water reduction at the source, by using new technologies that require less water than conventional methods. The second method reuses slightly dirty water or grey water for tasks where potable water is not needed. Prior to presenting water consumption alternatives, a differentiation of water types must be made.

The different types of water are referred to as:

- Blue water - potable water
- Grey water - relatively clean water previously used in bathroom sinks, showers, and laundry.
- Black water - water contaminated with faeces and diluted with toilet water.
- Yellow water - urine that has not been contaminated by black water or grey water.

13.1.1 Water reduction practices in sustainable villages

Many sustainable villages reuse collected grey water for flushing the toilets and crop irrigation, decreasing overall water consumption Hanæu (1997). Another common practice is the implementation of dry toilets. As the name suggests, these toilets do not have to be flushed, reducing the amount of water used. Dry composting toilets utilize the moist environment for microorganisms to decompose solid waste, only requiring the addition of a bulking agent to allow aeration of the compost. Composting toilets are a double faceted sustainable practice: minimizing water use and converting waste into fertilizer. There are several types of dry toilets, the most common being:

- **Composting toilets:** utilize biological processes to break down waste into a nutrient-rich compost that can be used as a fertilizer;
- **Vacuum toilets:** use a venturi system to create a vacuum that draws waste into a holding tank;
- **Chemical toilets:** use chemicals to break down waste and neutralize odours.

Advantages of dry composting toilets (Anand, 2013):

- Sustainable: decrease water consumption and wastewater production
- Compact: dry toilets store the collected waste underneath the toilet basin requiring more frequent emptying.
- Easy to maintain: minimal upkeep and do not require use of chemicals or electricity.

These sustainable methods were found in two case studies in Latin America, Gaia Eco-Village and the EPSAS project in La Paz. The two projects have both successfully implemented water reducing toilets that have been accepted by the community.

Gaia Eco-Village is an ecological community in the Buenos Aires Province of Argentina that is based on the principles of permaculture. Permaculture is defined as "the development of agricultural ecosystems intended to be sustainable and self-sufficient" Insitute (2023). Gaia village utilizes the urine diverting vermicomposting toilets from the Argentinian brand Permapreta, that will be further explained in the following section. In this community permaculture is a large aspect of the community, so the collected fertilizer is used for this practice (Gaia Association, n.d.).

The EPSAS project in La Paz, Bolivia implements urine diverting toilets in an impoverished farming neighbourhood. Where the waste collection process is standardized for the community to contribute to the nearby farm fields, and the system collects all the urine tanks and sends them to a plant that converts the urine into dehydrated fertilizer. Here the urine follows a process where the urine first remains in tanks for six months. Then compounds are added and mixed for 30 minutes until struvite precipitation forms. Next the mixture is sent through sieves to separate the precipitate from the liquid. Lastly, the urine is dried by the sun for several days to turn the fertilizer into a dried powder that is much easier to store and maintain (Valenzuela, 2023).

13.1.2 Urine diverting toilets

The implementation of urine-diverting toilets for the purpose of producing fertilizer is increasing its popularity. Prime examples of the implementation of these toilets on a commercial scale are the Swedish beer company Wisby Kloster, that collects their fertilizer from toilets in the offices of VA Syd in Malmo (Prof Mariska Ronteltap, 2024) and the Swiss company Aurin that creates concentrated fertilizer (Ronteltap, 2024).

13.1.3 Waste recovery

Under most circumstances urine and faeces are considered to be waste products. However, when they are separated, valuable sources of nutrients become available that can be used as fertilizers.

Adults excrete about 0.8-1.5 L of urine per day and about 30% of total water consumption is used to flush toilets (Zadeh, 2013). Urine contains the following macronutrients:

- Nitrogen (N)
- Phosphorus (P)
- Potassium (K)
- Sulphur (S)
- Calcium (Ca)
- Magnesium (Mg)

A fertilizer is considered a "complete fertilizer" when it contains the first three elements, hence the importance of urine recovery (Prof Merle de Kreuk, 2023).

The composition of urine can be observed in the graph below:

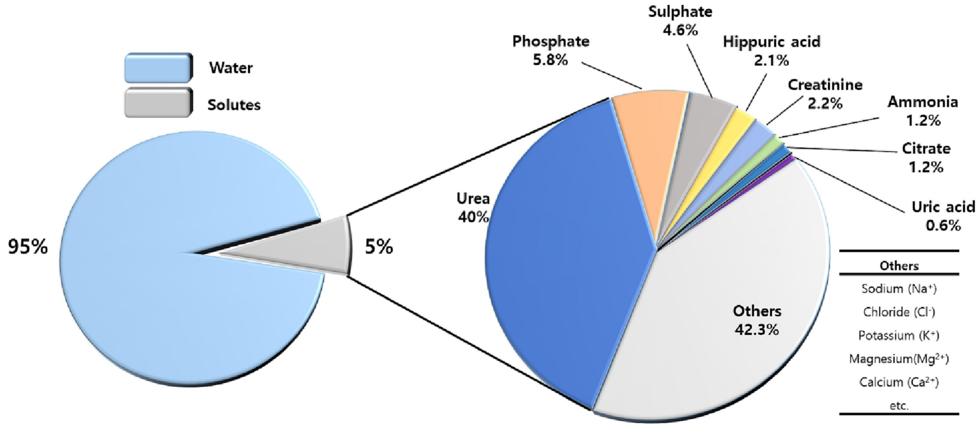


Figure 13.1: Composition of urine (Sohn et al., 2023)

Faeces is useful for compost because it is rich in organic matter and nutrients such as nitrogen, phosphorous, and potassium. Similar to urine, these elements are critical for plant growth. Faeces, with the appropriate treatments, can be turned into compost that improves soil fertility.

The recovery of urine and faeces also reduces the need for chemical fertilizers, that can be harmful to the environment. Additionally, due to the remote location of the project chemical fertilizer must be imported, while this alternative provides and on-site solution.

The incorporation of resource reuse creates a closed nutrient cycle, reducing waste, minimizing environmental impact, and promoting a more sustainable approach to agriculture and resource management.

For these reasons, along with the ones mentioned in the previous section, the use of dry toilets are investigated for the final design.

13.2 Proposed water and wastewater design

13.2.1 Potable water

Currently, all drinking water is provided by a stream sourced from the glacier above the mountains on the property. There are numerous streams of varying flow rates throughout the ranch that can provide potable water to many locations around the property. The existing system receives water from the stream roughly 100m from each of the structures and is immediately sent through a small filter as seen in Figure 13.2a. This also adheres to the national regulation mandating all structures must be at least 30m away from bodies of water (Martinez, 2001). The water from this intake point is then sent downstream through a gravity flow system to tanks for each structure as shown in Figures 13.2b and **??**. These tanks serve as hot water tanks, while also complying with the law requiring homes to have a water storage capacity to provide a water supply for 12 hours (Martinez, 2001).

The water quality of the stream is currently unknown, as the economics and practicality of testing made it infeasible. To fully recommend the following design for the development, a full lab test panel must be done for each of the water sources. Los Huemules, a nearby ranch have had water quality issues due to large amounts of wild cattle on the property. They reduced high E. coli levels by removing the livestock from the property, and now only use a filter for treatment. It is safe to assume that the water is relatively clean, given locals, tourists and infants have drank the water for years without treatment with no illness reported. This being said, water testing is still crucial prior to implementation.

(a) Current water filter

(b) Solar heated current water tanks

(c) Wood burning current water tank

Figure 13.2: Water system solutions

The proposed potable water design for the ranch will be similar to the existing system on the property, with glacial streams serving as the water source. Each of the streams intake points will have a filter similar to the existing system to lower turbidity and remove any floating particles in the water. Due to the lack of water quality knowledge of these streams further treatment methods cannot be proposed. A contributor to the previously mentioned zone selection of the property was the proximity to streams on the property. Sites downstream at lower elevations of streams were prioritized to allow water to be gravity-fed rather than pumped.

The second aspect of the potable water design is water storage. As mentioned previously, homes in remote areas must have water tanks to supply water for 12 hours if disconnected from the source. The following section details the dimensions needed for each tank. When determining the tank sizes needed, a conservative daily average consumption per capita was assumed to be 100 L. This assumption was made by the average urban consumption in Argentina being 299 L per person with losses of 45% on average (OECD, 2019). Water on the estancia will be transported in new pipes for a shorter distance, so there will be lower losses than in urban areas. As a result, a value of 10 was taken into account for losses. In addition to accounting for losses, the dry flush toilets detailed below will reduce daily water consumption by 30% (Zadeh, 2013), rounding this value down to 100 L per person. This value also does not account for greywater reuse, as it has little impact on everyday human use and varies greatly. This assumption is conservative, and it is proposed to conduct a water consumption assessment on the property to make a better decision for tank sizing.

Each accommodation will be equipped with water tanks designed to supply water for 12 hours, assuming a daily average consumption of 100 L per person (equivalent to 50 L per person for 12 hours). The planned water tank capacities are shown in Table 13.1.

Water tanks	People	m3 needed	m3 design	Quantity
Hostel+campsite	58	2.9	3.0	1
Cottages	2/4	0.1/0.2	1	28
Luxury rooms	2/4	0.1/0.2	0.5	15

Table 13.1: Dimensions of Water tanks

13.2.2 Wastewater

The wastewater section will address the disposal of the different types of wastewater, grey water, yellow water, and black water. The importance of waste management was emphasized by numerous stakeholders and current employees. The proposed waste management solutions prioritize environmental protection to prevent the development from causing damage. As previously mentioned in the research, a variety of options were considered, and the most optimal choice was reusing waste to create a circular society. This section will focus on reuse of grey water, final toilet proposal, and uses for yellow and black water.

Greywater from bathroom sinks, showers, and washing machines will be collected and reused for irrigating areas for reforestation. Greywater will also be used as an irrigation source for the indoor gardens that will serve as decoration and air purification in luxury rooms and in common spaces of the cottages and the hotel. Lastly, greywater will be also be utilized to dilute concentrated urine prior to use as a fertilizer. Dilution of the urine is essential right before usage to prevent the high ammonia concentrations from harming the environment.

Proposed toilet design
After analysing different alternatives for sustainable toilets during the research phase, two main urine-diverting toilets were being considered: composting or biogas. Both create a fertilizer rich in nutrients that can be used on-site in the gardens while also having minimal environmental impact. Once on-site, discussions with the ranch manager, stakeholders, and other eco-tourist estancias it became clear the best solution for the project is a composting toilet. The composting toilets require a significantly smaller initial investment and can be implemented in phases individually as more structures are built Seadi (2008). The biogas solution required a significant initial investment to create an on-site anaerobic digester, a specialist to manage the digester, and significant amounts of energy produced would be used to heat the digester Seadi (2008). These challenges presented the urine-diverting composting toilets as a clear option for the preliminary masterplan.

The specific brand selected for zones 1 2 and 3 (refer for the zoning in Chapter 9) is the Permapreta dry toilet, as seen in Figure 13.3a. This design is currently being used effectively in the Gaia Ecovillage near Buenos Aires Gaia Association, n.d. These toilets are non-flush and separate urine and feces to minimize water usage and concentrate the nutrients in both while preventing foul smells. Urine and feces will be collected in separate tanks and will be used for different fertilizing purposes. The toilet proposed for zone 4 is the one from the brand Ecodomeo. The toilet has the same functional system of vermicomposting toilets but has a much more elevated design for the luxury rooms. The Ecodomeo toilet can be seen in Figure 13.3. Further explanation on the general function of Permapreta toilets is found below.

(a) Toilet selected for zones 1-3

(b) Ecodomeo toilet for Zone 4

Figure 13.3: Proposed toilet design

There are currently very few dry toilets being used within Argentina, most of which are from the same brand. The Argentinian company, Permapreta, creates a composting dry toilet. The toilet uses biological processes to convert human waste into humus, a fertilizer that can be used for crops and trees, while also reducing water consumption from flushing.

Permapreta is quickly installed and can fit through the door of any bathroom. To install the system it is first buried below ground and then the flooring is laid on top. A hybrid wind-electric ventilation system developed by Permapreta to avoid foul odors. This system has built-in wind sensors enabling it to determine when the extractor fan is powered by wind or electric energy. Human manure falls into the chamber and then it is transformed into humus. Microorganisms, worms, straws, and wind are all utilized to facilitate the transformation process. Toilet paper and wood residues from chopping firewood are also thrown into the toilet chamber to provide a carbon source and aid in the composting process. Organic kitchen waste is also added to the composting chamber monthly to be composted as well (Permapreta, n.d.).
A schematic design of the dry toilet developed by Permapreta can be found in Figure 13.4.

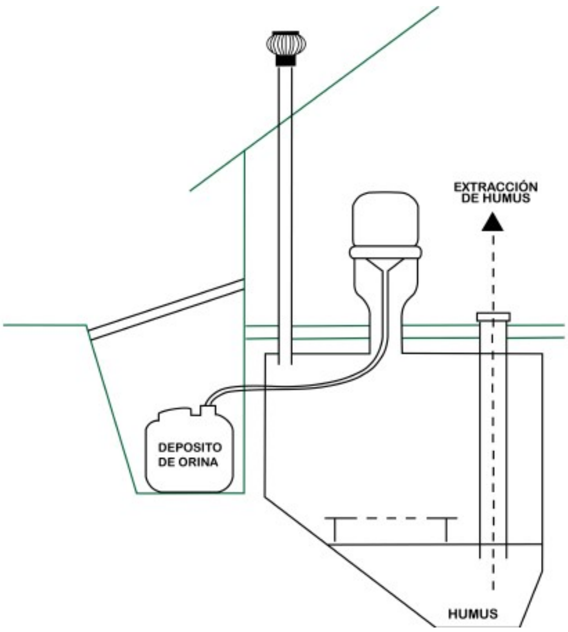


Figure 13.4: Permapreta's dry toilet system (**permapetra**)

Each toilet will consist of one urine collection tank and a compost bin for faecal waste. Each individual toilet in the cottages and luxury rooms will have smaller tanks for the urine of 1 m^3, while communal toilets, serving the hostel and the campsite, will use larger shared tanks of 4 m^3. Communal areas will have tanks of 15 m^3, and toilets in the restaurant and common areas of the luxury hotel will have tanks of 10 m^3. In addition, to the tank in use, there will be space below each accommodation for a second tank to remain as it rests for six months. Once the urine is left to rest for six months it is stabilized and can be used as fertilizer when diluting with greywater directly before use. After the six months are over the tanks can be swapped allowing the second tank to now be left for six months continuing the cycle. If the project were continued, a dehydrating system similar to that used in the EPSAS Valenzuela (2023) project should also be considered, however with the lack of vehicles at the moment to transport the tanks this would be difficult to implement with the current design. Compost in the feacal tank must be left to compost for the first two years and can be used after that point, after the first use compost must be left for one year. The faecal compost will also serve as a general compost mixed with toilet paper and kitchen organic waste.

13.3 Conclusion

The sections above detailed specific proposals for the final design of an ecovillage in Estancia La Josefina. These designs are each targeted to solve a few of the previously listed requirements for the success of the village. Many additional technical studies will be needed to implement the overall design, however, the ones detailed above are the most crucial to beginning the project. The designs target accessibility, energy, shelter, and water. Additional specialty studies needed for the project will be detailed in Chapter 17.

14 | Financial study: feasibility of the preliminary design

In this chapter, the proposed designs are evaluated on their financial feasibility. This is done considering the capital expenditures (CapEx) only. In Chapter 14.1 an explanation can be found of why only CapEx is considered. In Chapter 14.2 the general setup of the financial study is explained. In Chapter 14.3, the expected project expenses are explained, followed by the calculation of the expected revenue in Chapter 14.4. At last, the needed investment will be explained in Chapter 14.5, after which a conclusion will be drawn in Chapter 14.6.

14.1 Capital expenditure (CapEx): A strategic financial decision

Different choices can be made when evaluating the financial feasibility of a project. It is chosen to only consider the capital expenditures (CapEx). Capital Expenditures are the payments to purchase long-term physical or fixed assets used in a business's operations (Vipond, 2023). This means that operational expenditures (OpEx) are not included in the financial evaluation. There are several reasons why only CapEx is considered:

- **Simplifying early-stage financial overview**: The project is a preliminary design of a masterplan that has a very conceptual nature. Since operation costs vary based on management approaches and ongoing adjustments during the project, projecting OpEx accurately in this stage is challenging and speculative;
- **Investor focus**: Since this project will be made possible by investors, it is important to understand the initial financial commitment and potential for return of investment over time. CapEx gives an initial overview of what is needed to get the project started, which is more relevant for decision-making at an early stage than a detailed OpEx projection;
- **Focus on project scope and design**: Analysing CapEx allows stakeholders to concentrate on the scope and design of the project. This is crucial for both making design decisions and making a fast evaluation of the financial feasibility.

14.2 Setup of the financial model

The financial model is based on 4 business stages of 5 years, resulting in a total duration of the model of 20 years. This total duration is chosen because of sustainable construction considerations. As clarified in Chapter 9.3, slow development of infrastructure is better for the environment and allows local materials to be used as construction materials. Since the development of the project is assumed most critical in the first business stage, this stage will be split up into 5 years in the model. An assessment of the revenue and expenses will thus be made at the end of years 1, 2, 3, 4, 5, 10, 15, and 20. These years will hereafter be called assessment years. Note that the expenses are not accumulated. This means that in year 10, only the expenses of years 6-10 will be evaluated. The same principle holds for year 15 and 20.

14.3 Expected project expenses

The expected expenses of the project are divided into five categories: purchasing the property, general infrastructure, marine infrastructure, utility infrastructure, and accommodations. For each of these categories, the total expenses until the end of the project will be calculated. Thereafter the total costs are assigned to the assessment years using a percentage. This percentage is based on the construction stages and represents the staged development, and thus the staged capital expenditures. Due to the remoteness of the property, a factor is included to account for the extra transportation costs that have to be made in order to build the infrastructure. This factor is called the 'remoteness factor' and is abbreviated with 'RF'. After the total expenses are calculated, 10% will be added to each assessment year to account for unforeseen expenses. The calculations of the expected expenses per category are explained in the following five chapters.

14.3.1 Purchasing the property

In order to be able to develop the project, the property of Estancia La Josefina needs to be bought. This investment is $4,500,000 USD. After interviewing the current ranch manager, who has done similar projects before, it is usual that the property is bought in stages. He proposed the following payment plan: 50% of the property in the first year, followed by 10% per year afterward until the payment of the total value of the property is completed. This is $2,250,000 USD in the first year followed by $450,000 USD in the years after, resulting in the completion of the payment within 6 years.

14.3.2 General infrastructure

The following buildings and facilities are considered in this category: Entrance building, Activity building, Warehouse, and Waste facility. Each of these buildings/facilities has a certain area which is based on case studies and assumptions. To calculate the price of each building, a standard price to build a house in a nearby city called El Calafate is assumed to be $\$1,500 USD/m^2$. This price is based on an interview with the current ranch manager of the Estancia (see Appendix C). The expenses of each assessment year are calculated by multiplying (1) the price per square meter to build a house, (2) the area of the building, (3) the remoteness factor (RF) and (4) the percentage of construction completion per assessment year. The calculations are elaborated in Table 14.1.

Assessment year				**1**	**2**	**3**	**4**	**5**	**6-10**	**11-15**	**16-20**	
Building	**[#]**	**Area of building** $[m^2]$	**RF**	**Construction completion [%]**								**Total expenses** ($*10^3$ **USD)**
Entrance building	1	270	1.4	0	20	40	60	80	100	100	100	$567
Activity building	1	180	1.4	0	20	40	60	80	100	100	100	$378
Warehouse	1	270	1.4	0	20	40	60	80	100	100	100	$567
Waste facility	2	90	1.2	0	20	40	60	80	100	100	100	$324
Staged expenses ($*10^3$ **USD)**				$0	$367	$367	$367	$367	$367	$0	$0	$1,836

Table 14.1: Results of general infrastructure expenses calculation. RF is the Remoteness Factor.

14.3.3 Marine infrastructure

The marine infrastructure contains the three jetties and ramps that will be built on-site. The calculation is based on (1) the length of the jetty in meters and (2) the costs per meter of a jetty. The latter one is assumed to be $5,000 USD/m. Within this price, the construction costs for the boat ramp are included. The lengths of the jetties are based on the jetty design in Chapter 10.2.4. The primary jetty and internal jetty will be built in the first year. They are needed for the transportation of construction materials to the site. The international jetty will be built in year 6-10. In Table 14.2 the results of the calculation of the marine infrastructure expenses are elaborated.

Assessment year				1	2	3	4	5	6-10	11-15	16-20	
Jetty location	**[#]**	**Length of jetty [m]**	**RF**	**Construction completion [%]**								**Total expenses ($*10^3$ USD)**
Primary jetty	1	28	1.4	100	100	100	100	100	100	100	100	$196
Internal jetty	1	20	1.4	100	100	100	100	100	100	100	100	$140
International jetty	1	28	1.4	0	0	0	0	0	100	100	100	$196
Staged expenses ($*10^3$ USD)				$336	$0	$0	$0	$0	$196	$0	$0	$532

Table 14.2: Results of marine infrastructure expenses calculation.

14.3.4 Utility infrastructure

As explained in Chapter 11.2, there will be a hybrid wind/solar energy system consisting of wind turbines, solar panels and an energy storage system. Additionally, there will be water storage tanks as explained in Chapter 13.2.1. The costs will be split in two parts: material costs and installation costs. In contradiction to the material costs, the remoteness factor will not be used for the installation costs. This is because installation does not bring extra costs due to the remoteness of the area. In Table 14.3 the material and installation costs are elaborated. Afterwards, in Table 14.4 the total expenses of the utility infrastructure during the staged construction are elaborated.

Type	**Material costs per unit (USD)**	**Installation costs**
Wind turbine*	$80,000	25%
Solar panel**	$300	15%
Battery costs per kWh	$500	12%
Water tank ($10m^3$)***	$2,500	50%

Table 14.3: Material and installation costs per unit. Note that the prices are assumptions based on the current market prices in the world. These might differ from the prices in Argentina. The costs of battery costs per kWh is based on an assumption The installation costs are an assumption as well. *("Ryse Energy Wind Turbine", n.d.); **(Bailey, 2023);; ***("Tanque de agua Waterplast", n.d.).

Assessment year			1	2	3	4	5	6-10	11-15	16-20	
Type	**[#]**	**RF**	**Construction completion [%]**								**Total expenses ($*10^3$ USD)**
Wind turbines	3	1.4	0	20	40	60	80	100	100	100	$336
Installation costs wind turbines	1	1.0	0	20	40	60	80	100	100	100	$60
Solar panels	320	1.4	0	20	40	60	80	100	100	100	$134
Installation costs solar panels	1	1.0	0	20	40	60	80	100	100	100	$14
Energy storage system (per kWh)	833	1.4	0	20	40	60	80	100	100	100	$583
installation costs batteries	1	1.0	0	20	40	60	80	100	100	100	$62
Water storage tank	1	1.4	100	100	100	100	100	100	100	100	$4
Installation costs water tank	1	1.0	100	100	100	100	100	100	100	100	$2
Staged expenses ($*10^3$ USD)			$5	$238	$238	$238	$238	$238	$0	$0	$1,195

Table 14.4: Results of the utility infrastructure expenses calculation.

14.3.5 Accommodations

The accommodation types in the design are a camping, a hostel, cottages and staff housing. For these buildings, the same calculation method as mentioned in Chapter 14.3.2 apply here. Each of these buildings/facilities have a certain area which is based on case studies and assumptions. The same price of $\$1,500 USD/m^2$ is used. The expenses of each assessment year is calculated by multiplying (1) the price per square meter to build a house, (2) the area of the building, (3) the remoteness factor (RF) and (4) the percentage of construction completion per assessment year. For the camping, a different calculation method holds, since only levelling of the ground is needed. For this, \$50 USD/m^2 is assumed. The numbers and calculations are elaborated in Table 14.5.

Assessment year				**1**	**2**	**3**	**4**	**5**	**6-10**	**11-15**	**16-20**	
Building	**[#]**	**Area** $[m^2]$	**RF**	**Construction completion [%]**								**Total expenses** ($*10^3$ **USD)**
Campsite	7	35	1	0	100	100	100	100	100	100	100	\$12
Campsite bathroom house	1	20	1.2	0	100	100	100	100	100	100	100	\$36
Hostel	5	25	1.4	20	20	40	60	60	100	100	100	\$263
Cottage family	7	35	1.4	0	0	0	0	20	50	90	100	\$441
Cottage couple	14	25	1.4	10	10	10	10	10	70	90	100	\$630
Common area camping & hostel	1	270	1.4	0	50	100	100	100	100	100	100	\$567
Common area cottages	1	360	1.4	0	20	40	80	100	100	100	100	\$648
Staff accommodations	1	660	1.4	20	60	80	100	100	100	100	100	\$1,188
Staged expenses ($*10^3$ **USD)**				\$353	\$937	\$703	\$549	\$218	\$615	\$302	\$107	\$3,784

Table 14.5: Results of accommodation expenses calculation. RF is the Remoteness Factor.

14.4 Expected project revenue

The expected project revenue is divided into four categories: accommodation profits, luxury hotel concession, passenger boat concession, and selling of plots. For each of these categories, the revenue per assessment year will be calculated. However, the calculation method differs per above listed category. In the following chapters, each of the listed categories will be elaborated.

14.4.1 Accommodation profits

The calculation of the accommodation profits at each assessment year is calculated by multiplying:

1. **Nr. of people**: Max number of people that each accommodation type allows. This amount is based on Chapter 7.5;

2. **Nr. of nights / year**: Number of nights a year that the accommodation is open for tourists. During winter, most of the accommodation types will be closed. During the case study in Los Huemules, it was found that the park was open from October until June. For the camping, it is assumed that only half of the year there will be demand for camping because of the weather;

3. **Exp. ocp. [%]**: The expected occupancy. It is not expected that the accommodations are fully occupied each night. A conservative approach is assumed reasonable and therefore a percentage of 50% is used;

4. **Price / night (USD)**: The price per night for the hostel and campsite are based on an assumption. The low price per night is chosen to keep this accommodation attractive to backpackers and hikers.

5. **Profit margin [%]**: A profit margin, to account for operational costs of running the accommodations. This percentage is based on an assumption and is different per accommodation type. The profit margin is assumed to be higher for the campsite and hostel than for the cottages since the assumption is made that the camping and hostel both need less maintenance and have lower maintenance costs.

6. **Maximum occupancy**: A percentage representing the maximum occupancy that each accommodation type allows. Due to the staged development of the village, accommodations become available over the years. This percentage is based on, but lower than, the construction stages in Chapter 9.3. The maximum occupancy is assumed low during the first five years. This is because of several reasons: (1) the Estancia is not well known in the first five years of the project, so a lot of marketing needs to be done in order to attract people, (2) the basic and marine infrastructure is being built, so the site is not fully ready yet before the 5-year mark, (3) there may be delays in the project, which could delay revenue being made.

Since there will be a concession for the luxury hotel plot, the revenue and the way the concession is built up will be elaborated in Chapter 14.4.2. In Table 14.6 the expected profits of the accommodations are elaborated.

Assessment year						1	2	3	4	5	6-10	11-15	16-20	
Type	**Nr. of people**	**Nr. of nights/ year**	**Exp. ocp.* [%]**	**Price/ night (USD)**	**Profit margin [%]**	**Maximum occupancy [%]**								**Total revenue ($*10^3$ USD)**
Hostel	30	240	50	$40	90	10	10	10	10	10	40	100	100	$1,620
Campsite	28	180	50	$40	90	0	10	10	10	10	40	100	100	$1,125
Cottages family	28	240	50	$250	70	5	5	5	5	5	30	70	100	$6,027
Cottages couple	28	240	50	$250	70	5	5	5	5	5	30	70	100	$6,027
Staged expenses ($*10^3$ USD)						$72	$81	$81	$81	$81	$2,205	$5,218	$6,982	$14,798

Table 14.6: Results of the calculation of profit per accommodation type. *Exp. ocp. is Expected occupancy.

14.4.2 Luxury hotel concession

It is chosen to have a concession for the luxury hotel. Running a luxury hotel is complicated and a lot of knowledge is needed in order to run it successfully. There are companies in the region that run concessions for luxury hotels successfully such as Explora (Explora, 2024) and Eolo (Patagonia, 2024). It is beneficial for both the village and the concessionaire to grow as partners together. It is chosen to start with the hotel concession after 5 years, because the marine infrastructure needs to be built before the construction of the hotel can start. Besides, starting a concession if the area is hardly accessible or not at all, is not appealing for companies. The concession consists of the following components:

1. **The estimated value of the plot**: In the preliminary masterplan, a significant part of the property is selected where the luxury hotel accommodations can be built. The total value of this plot is, after interviewing the current ranch manager, assumed to be around $2,000,000 USD.

2. **Inflation percentage**: Since the business plan will have a duration of twenty years, the inflation percentage will be taken into account. This percentage is assumed to be 4%.

3. **Annual ground rent**: To be able to build and operate the hotel on the plot, an annual ground rent of 7.5% per year is used.

4. **Revenue share**: it is chosen to include a revenue share in the concession after 10 years of the concession duration and only if the revenue of the hotel is more than $400,000 USD per year. This revenue share is assumed to be 10%. To be able to calculate the revenue share, the revenue of the luxury hotel is determined. This is done in the same way as in Chapter 14.6. The results of the revenue calculation is shown in Table 14.7.

Assessment year						1	2	3	4	5	6-10	11-15	16-20	
Type	**Nr. of people**	**Nr. of nights/ year**	**Exp. ocp.* [%]**	**Price/ night (USD)**	**Profit margin [%]**	**Maximum occupancy [%]**								**Total revenue ($*10^3$ USD)**
Luxury rooms family	20	240	50	$2,000	70	0	0	0	0	0	10	40	100	$3,600
Luxury rooms couple	20	240	50	$1,500	70	0	0	0	0	0	0	40	100	$5,040
Staged revenue ($*10^3$ USD)						$0	$0	$0	$0	$0	$240	$2,400	$6,000	$8,640

Table 14.7: Results of the hotel revenue calculations. *Exp. ocp. is Expected occupancy.

Assessment year	1	2	3	4	5	6-10	11-15	16-20	Total revenue
Annual ground rent	0	0	0	0	150	912	1,110	1,351	3,523
Revenue share (10%)	0	0	0	0	0	0	240	600	840
Staged revenue	0	0	0	0	150	912	1,350	1,951	4,363

Table 14.8: Results of the calculations of the hotel concession. In 10^3 USD [$].

14.4.3 Passenger boat concession

In order to cater for all the tourists, passenger boats are needed. It is chosen to have a concession for the passenger boats because there is a lot of knowledge about operating ferry services on the other glacier lakes near Lago San Martín/O'Higgins. The concession will start in year 6 and will have a total duration of 15 years. From the sixth year onwards, the amount of tourists that enter the ranch is expected to increase. The concession consists of the following components:

1. **Upfront concession fee**: To start the concession, there will be an upfront concession fee of $50,000 USD. This value is based on an assumption and is verified with the current ranch manager.

2. **Annual operating fee**: It is chosen to have an annual operating fee of $10,000 USD. Since the property is not very accessible yet, it will be highly dependent on a ferry service. The price to enter the ranch should stay low to also cater for low-budget tourists. Therefore it chosen to keep the annual operating fee low. In Table 14.9 the total revenue of the concession is shown.

Assessment year	1	2	3	4	5	6-10	11-15	16-20	Total revenue
Upfront concession fee	0	0	0	0	0	50	0	0	50
Annual operating fee	0	0	0	0	0	56	68	83	207
Staged revenue	0	0	0	0	0	106	68	83	257

Table 14.9: Calculation of the total revenue of the passenger boat concession. In 10^3 USD [$].

14.4.4 Selling of plots

In the preliminary masterplan, 28 plots are included that are meant to sell to future inhabitants. These will be sold in stages. Since the value of the property is expected to increase when new infrastructure is built, the value of the plots to be sold should also increase. This is an incentive for future inhabitants to buy a property in an early stage, which causes revenue in an early stage of the project. In Table 14.10 the revenue of selling the plots is elaborated.

Assessment year	1	2	3	4	5	6-10	11-15	16-20	Total revenue
Amount of plots	2	2	2	2	2	8	5	5	
Price per plot	40	40	40	40	40	50	75	150	
Staged revenue	80	80	80	80	80	400	375	750	1,925

Table 14.10: Revenue of selling plots. In 10^3 USD [$].

14.5 Financial results: total needed investment

In this chapter, the total expenses and revenues are shown in Table 14.11 and 14.12 respectively. Table 14.11 shows, that the total expenses of the project during the 20 years is thirteen million USD.

Assessment year	**1**	**2**	**3**	**4**	**5**	**6-10**	**11-15**	**16-20**	**Total expenses**
Purchasing the property	2,250	450	450	450	450	450	0	0	4,500
General infrastructure	0	367	367	367	367	367	0	0	1,836
Marine infrastructure	336	0	0	0	0	196	0	0	532
Utility infrastructure	5	238	238	238	238	238	0	0	1,195
Accommodations	353	937	703	549	218	615	302	107	3,784
Staged expenses	2,944	1,992	1,758	1,605	1,273	1,867	302	107	11,848
Unforeseen expenses	294	199	176	160	127	187	30	11	1,185
Total staged expenses	3,238	2,191	1,934	1,765	1,400	2,053	332	118	13,033
Accumulative expenses	3,238	5,429	7,364	9,129	10,529	12,582	12,915	13,033	

Table 14.11: Total staged expenses and accumulated expenses of the project. In 10^3 USD [$].

Assessment year	**1**	**2**	**3**	**4**	**5**	**6-10**	**11-15**	**16-20**	**Total Revenue**
Accommodations	72	81	81	81	81	2,205	5,218	6,982	14,799
Hotel concession	0	0	0	0	150	912	1,350	1,951	4,363
Passenger boat concession	0	0	0	0	0	106	68	83	258
Selling of plots	80	80	80	80	80	400	375	750	1,925
Total staged revenue	152	161	161	161	311	3,623	7,011	9,766	21,346
Accumulated revenue	152	313	473	634	945	4,569	11,580	21,346	

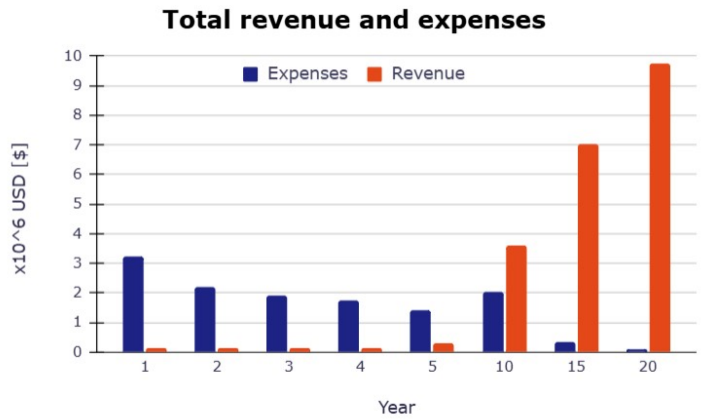
Table 14.12: Total staged revenue and accumulated revenue of the project. In 10^3 USD [$].

In Table 14.13, the total expenses, revenues and needed investment is shown. The negative numbers indicate profit, as there is more revenue than expenses. It also shows the amount of needed investors if an investment option is $175,000 USD. This option and the total of 55 investors is considered reasonable by the ranch manager.

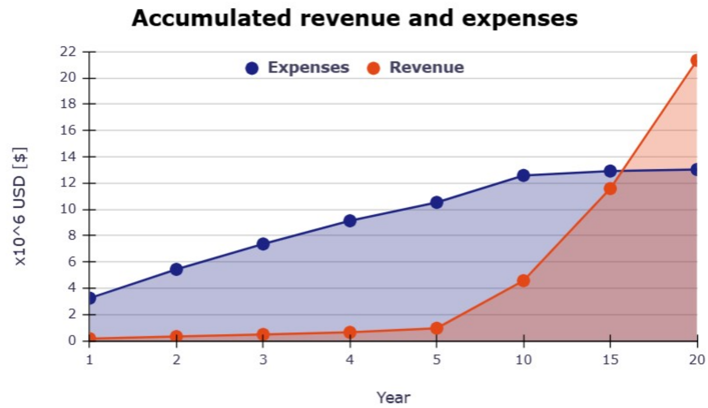
Assessment year	**1**	**2**	**3**	**4**	**5**	**6-10**	**11-15**	**16-20**	**Total**
Total expenses ($*10^3$ USD [$])	3,238	2,191	1,934	1,765	1,400	2,053	332	118	
Total revenue ($*10^3$ USD [$])	152	161	161	161	311	3,623	7,011	9,766	
Needed investment ($*10^3$ USD [$])	3,086	2,030	1,773	1,604	1,089	-1,570	-6,679	-9,648	
Needed investors	18	12	10	9	6	0	0	0	55

Table 14.13: Total staged revenue and expenses and amount of investors needed considering an investment option of $175,000 USD. Negative values indicate profit.

In Figure 14.1a and 14.1b the total and accumulated revenue and expenses are shown respectively. Figure 14.1b shows that after approximately 16 years, the accumulated revenue is higher than the accumulated expenses. Only after the operational expenditures are added to the financial study, it is possible to calculate the expected year of return of investment. However, also some 'operational revenue' is not considered (such as income from tourist activities) and a percentage of profit margin (for the camping, hostel and cottages) is used to account for operating costs of these accommodations. It is assumed that these operational costs and revenues cancel each other out. This shows the potential for a return of investment and an indication that the preliminary design is financially sustainable.



(a) Bar graph of total revenue and expenses



(b) Line graph of accumulated revenue and expenses

Figure 14.1: Results of the financial study

14.6 Conclusion

In this financial study, the preliminary design's feasibility was assessed by evaluating its capital expenditures (CapEx) and projected revenues over 20 years. With a total expected expense of approximately $13 million USD and a total projected revenue of around $21 million USD by the end of 20 years, profit is expected to be made. Although the operational expenditures were not taken into consideration due to the conceptual nature of the preliminary masterplan, the design still shows potential to be financially sustainable. The return of investment is expected to be around 16 years. This is however not completely accurate, because the operational expenditures were not taken into considerations. However, some revenue such as the revenue from tourist activities, were not taken into consideration. Moreover, in the model, conservative choices were made. The return of investment is therefore expected to be around the same year as it is now. Further research of the OpEx should be done to prove whether this hypothesis is correct.

15 | Discussions

The discussion addresses both the strengths and limitations of the project, reflecting on how the design choices align with the project's objectives while acknowledging areas that could have been improved and tackled differently.

The project faced some limitations that shaped the final design. First of all, due to the large scope and the limited time, one cohesive preliminary masterplan was developed, without exploring alternative options in detail. Having multiple proposals to compare could have provided additional insights. Moreover, although the design was verified, it was just evaluated by a single client presentation, which, while encouraging, does not confirm its effective applicability.

Creating a sense of community was a key consideration, especially after our visit to Los Huemules. However, due to the proposed division of the permanent residential plots between the Northwest and Southeast zones, the layout might unintentionally create a physical separation. This division, driven by the site's (in)accessibility and the constraint in buildability of some parts of the property, could challenge the cohesion of the village and influence social dynamics. The resulting spatial separation may impact interaction and engagement among residents, potentially affecting the overall unity of the community of zone 1, 2 and 3 and zone 4.

Furthermore, only four potential investors were consulted, a small sample that may have led to a biased outcome, as the preliminary masterplan primarily reflects their needs. Data limitations also impacted the project: water quality testing and soil analysis were unfeasible due to the site's remoteness, lack of nearby facilities, and high costs. Full land exploration also was not possible due to time constraints, and bathymetric data for the area weren't available. In terms of the technical design, the cob house present on site, that was taken as case study, represents has been on-site for only a year, making it insufficient for evaluating long-term performance.

A current limitation for the proposed project at Estancia La Josefina is the border crossing between Chile and Argentina. Although improving this border crossing is outside the scope of our project, if made more accessible, it could significantly increase the flow of tourists not only from Argentina but also from Villa O'Higgins in Chile. This would create a stronger regional connection and boost the potential for tourism in the area. Hence, whether or not this improvement occurs, it will greatly influence the success of the proposed development.

Along with these limitations, the strengths of this project are discussed. One of the primary strengths of this project is the collaborative approach that was adopted while developing the preliminary masterplan, since it was discussed with the main interested parties, such as the manager of the ranch and some of the possible investors. This ensured that the design proposed directly addressed challenges considered of key importance, such as accessibility and sustainability. Despite the broad scope of the project, essential components of the preliminary masterplan were thoroughly covered, ensuring a comprehensive approach. The proposed zoning aligns closely with the natural characteristics of the ranch, a design choice that was verified during the two-week on-site visit. This visit offered a first-hand understanding of the area's unique challenges and beauty, allowing us to identify certain issues that had not been considered in preliminary assessments.

Several aspects of the project could have been approached differently to improve its effectiveness and efficiency. Given the vast scope of the project, a narrower focus with more specific goals might have been advisable. While covering multiple aspects provided a comprehensive understanding of the development, concentrating on key priorities could have allowed for a deeper exploration of critical components. Additionally, visiting the case study at Los Huemules before visiting the ranch would have offered valuable insights that could have informed the planning of the project; however, this was not feasible due to scheduling conflicts with the Los Huemules team. Arranging the site visit to the ranch earlier in the project timeline would have also allowed more time to refine and adjust the preliminary masterplan based on observations during the visit. Improved communication with the client prior to the site visit could have clarified project expectations, though logistical challenges between different regions of Argentina complicated this process. A clearer initial understanding of the requirements would have been helpful, as the project's financial aspects, particularly the need to include land acquisition within the budget, only became apparent later on. This shift led to a greater focus on economic sustainability, with tourism emerging as a crucial element of the financial plan.

16 | Conclusions

In conclusion, this project successfully developed a preliminary masterplan for a sustainable village that accommodates both ecotourism and permanent residents. The preliminary masterplan addresses essential elements, such as energy, accessibility, and water management, to create a self-sustaining community with a limited environmental impact. By meeting the project's goals, this plan offers a balanced foundation for sustainable development in this remote area. The design choices across each area of the project contribute to sustainability by addressing environmental, social, and economic aspects, reflecting the philosophy of the project.

Environmental sustainability is prioritised through building designs that use low-impact materials and circular construction methods, such as repurposed insulation, which help minimise waste. Similarly, the hybrid solar-wind energy system reduces fossil fuel dependency and adapts to seasonal changes, ensuring a renewable energy supply throughout the year. Water and waste management also promote environmental sustainability by reducing water use and embracing a circular model that repurposes waste. The jetty design, which relies on local materials, reduces environmental impact and streamlines transportation logistics, aligning with sustainability goals.

Social sustainability is supported by accessibility improvements, such as the jetty and enhanced navigation routes, which make the village more accessible and integrated with the surrounding region. Investors emphasised that improved accessibility is essential for the village's long-term social success, and considering the environment as a key stakeholder reinforces a commitment to environmental stewardship that benefits the community. Additionally, the proposed planning in the preliminary masterplan was carefully designed to promote community engagement by creating spaces and infrastructure that encourage interaction among residents.

Lastly, economic sustainability is achieved through a financial plan that demonstrates the potential for return on investment. If developed further, it could provide a sustainable economic model for the population of the village. This project holds significant relevance not only for Estancia La Josefina but also as a potential model for sustainable development in remote and challenging environments. The outcomes could offer valuable guidelines and inspiration for similar initiatives, contributing to the advancement of sustainable living practices and the development of eco-friendly communities.

In summary, the previously discussed results highlight potential for the sustainable village's development, with specific design choices suited to the region's needs. However, the project's success will depend on critical factors such as reliable border access from Chile and sufficient investment support and interest. By addressing these challenges, the project can transform this vision into a sustainable community-centred village that sets an example for similar developments across the region.

17 | Future research

This chapter outlines the key aspects for future research to support the continued development of the project. Each of these areas reflect critical aspects of the preliminary masterplan and the ongoing refinement needed.

A comprehensive site analysis is essential to understand the multiple characteristics of the location. A more detailed site survey and bathymetric analysis should be conducted to map water bodies and seasonal streams accurately. This will aid in understanding the impact of seasonal changes on water levels and site accessibility. Additionally, further investigation of unexplored potentially buildable areas is recommended, along with testing of ground conditions to assess soil stability and suitability for construction.

To enhance the versatility and effectiveness of the preliminary masterplan, exploring alternative zoning configurations is recommended. Research into different placement options for structures within designated zones could further optimise land use and site functionality. Additionally, further study is needed on connections between proposed structures, particularly circulation zones and pathways, to improve accessibility and integration across the site.

Further investigation is required to validate and improve building materials and techniques. The proposed insulation composite material requires testing to ensure effectiveness and compatibility with local environmental conditions. Testing for fire resistance of wall layers and structural stability of cob houses is also essential for compliance and safety. Lastly, a feasibility study should evaluate the logistics of transporting construction materials to this remote area, ensuring that all chosen materials can be sustainably sourced and delivered.

For a more sustainable energy supply, more advanced heating options should be explored, with a particular focus on solar thermal energy. Since the proposed energy calculations relied on annual mean values, detailed monthly energy calculations are recommended to reflect seasonal variations more accurately and optimise energy system efficiency. To further promote the sense of community in the village, the option of creating energy communities could be explored.

Further research on accessibility is needed to refine the design of the primary jetty and related structures. This includes designing the floating components and assessing structural loads (such as berthing, wash, mooring, and current loads) for the fixed jetty. Additionally, it is essential to explore the feasibility of a water border crossing between Argentina and Chile, as this could significantly improve site accessibility. Research should also consider the suitability of proposed departure points and potential issues in developing neighbouring properties. Ramp design will also require further consideration to meet accessibility standards.

Further research on water and wastewater is necessary before implementing the proposed designs. Water quality tests must be done to determine the safety of the water, and if treatment measures are needed. The second aspect of water management that would need further investigation is the daily water consumption, or in similar eco-villages. It was estimated a water consumption of 100 L per person daily, but local data may reveal lower needs, potentially reducing tank sizes and costs. Finally, switching from liquid to dehydrated urine fertilizer could simplify storage, though it presents logistical challenges. While all research areas would add value, only the first two are essential for project development.

To ensure the project's financial sustainability, it is recommended to include a study of operational expenses (OpEx), which was not considered. This research would provide a clearer understanding of ongoing costs, facilitating more accurate budget planning and investment decisions.

Finally, a comprehensive feasibility study should be undertaken to assess the practicality of all proposed elements in the preliminary masterplan, alongside the development of a waste collection plan and fire safety plan. These measures will ensure the project aligns with best practices for sustainability, safety, and environmental impact.

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A | Site analysis

A.1 Existing on-site structures

This section presents images of the existing on-site structures, corresponding to those shown on the map in the site analysis chapter (Figure 2.3). These images are provided to offer a clearer visualization of the current conditions on-site, allowing for a better understanding of the layout and status of the structures within the context of the overall site.

(a) Sleeping dome: exterior

(b) Sleeping dome: interior

Figure A.1: Sleeping dome

(a) Sleeping hut: exterior

(b) Sleeping hut: interior

Figure A.2: Sleeping hut

(a) Sleeping domes

(b) Toilet hut

Figure A.3: Domes and toilets

(a) Manager's house

(b) Owner's house

Figure A.4: Houses

(a) Waste collection

(b) Electricity shed

Figure A.5: Waste collection and electricity shed

(a) First gaucho house

(b) Second gaucho house

Figure A.6: Gaucho houses

A.2 Topography

Figure A.7: 3d model of site topography

A.3 Lake Level Rise

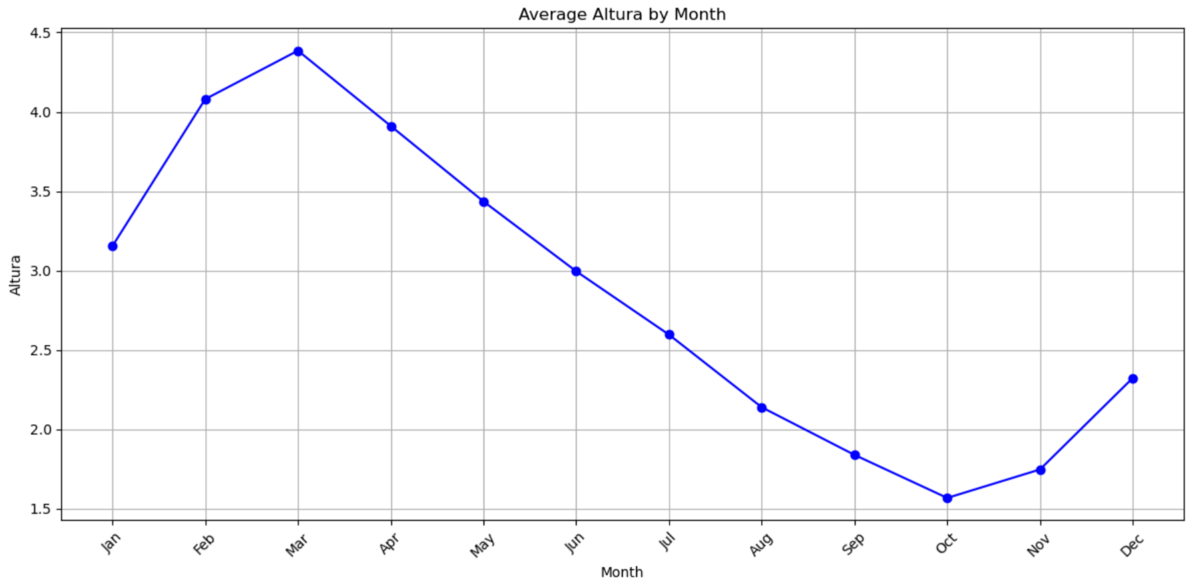


Figure A.8: Monthly lake level rise

A.4 Atmospheric conditions

A.4.1 Climate

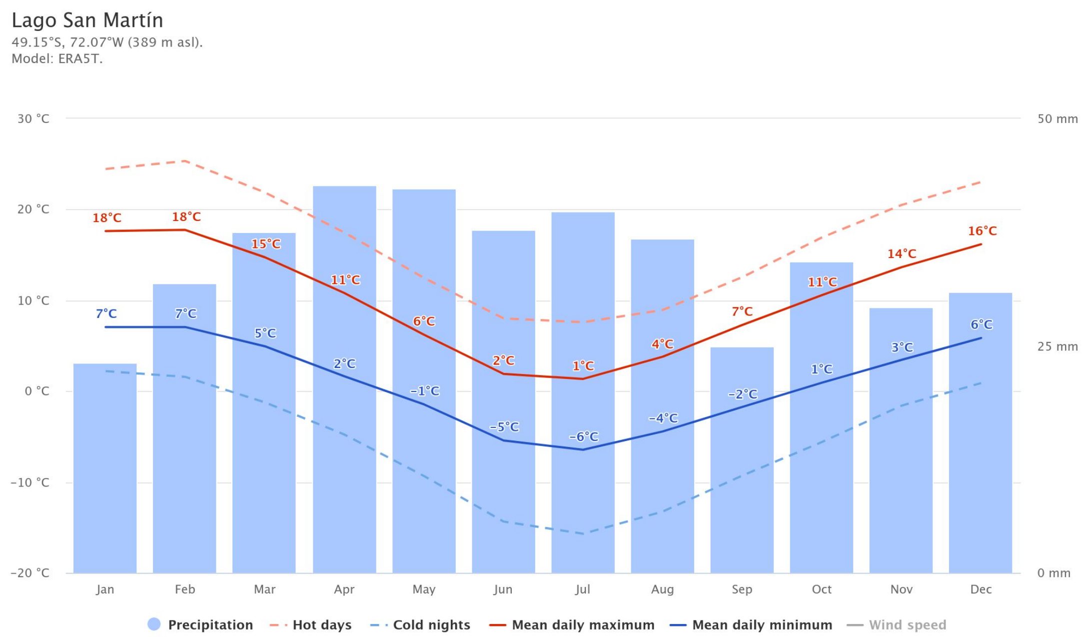


Figure A.9: Average temperatures at Lago San Martin (MeteoBlue, 2024)

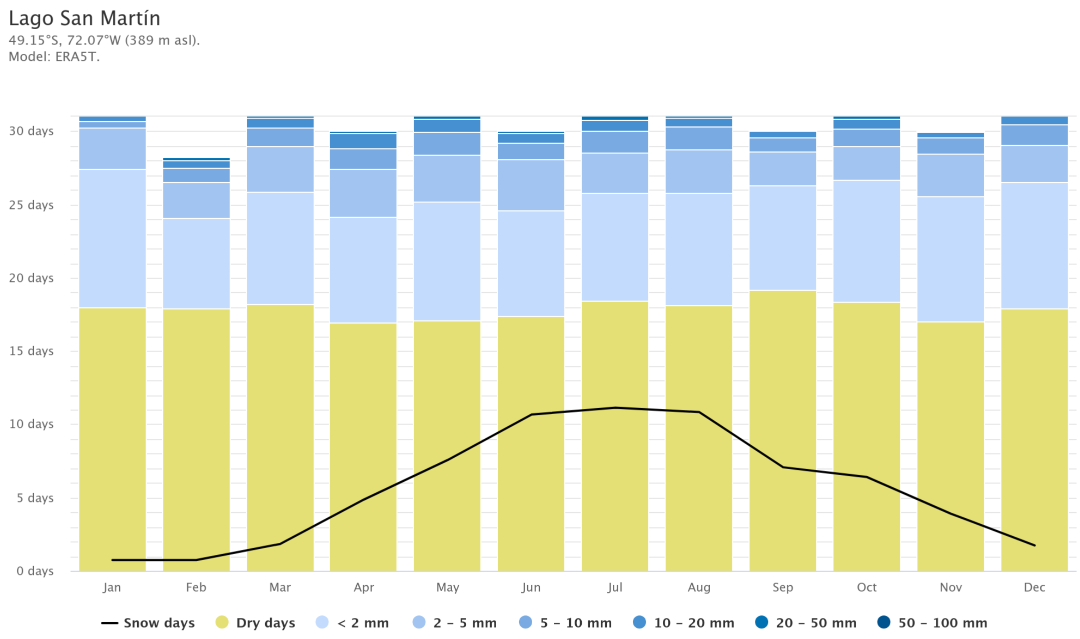


Figure A.10: Average precipitation at Lago San Martin (MeteoBlue, 2024)

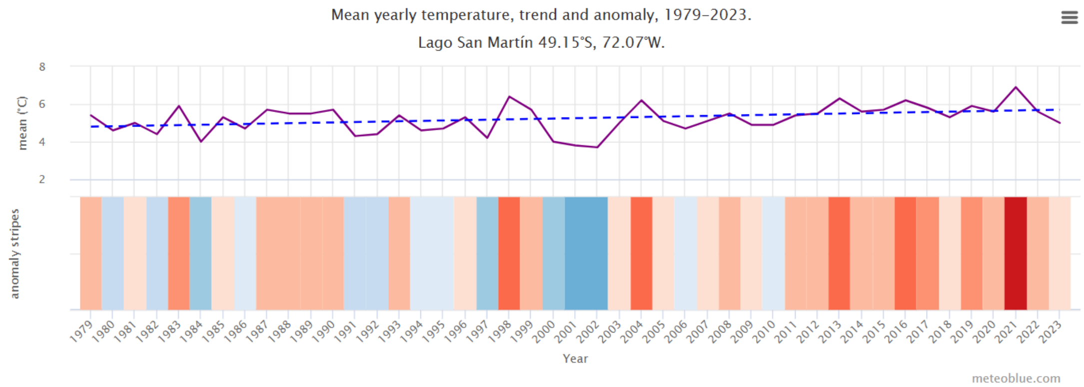


Figure A.11: Yearly temperature change at Lago San Martin (MeteoBlue, 2024)

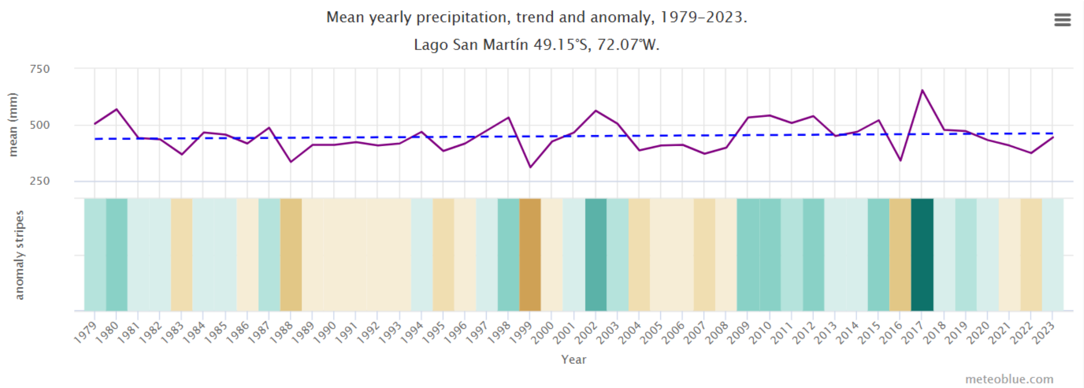


Figure A.12: Yearly precipitation change at Lago San Martin (MeteoBlue, 2024)

A.5 Seismic activity

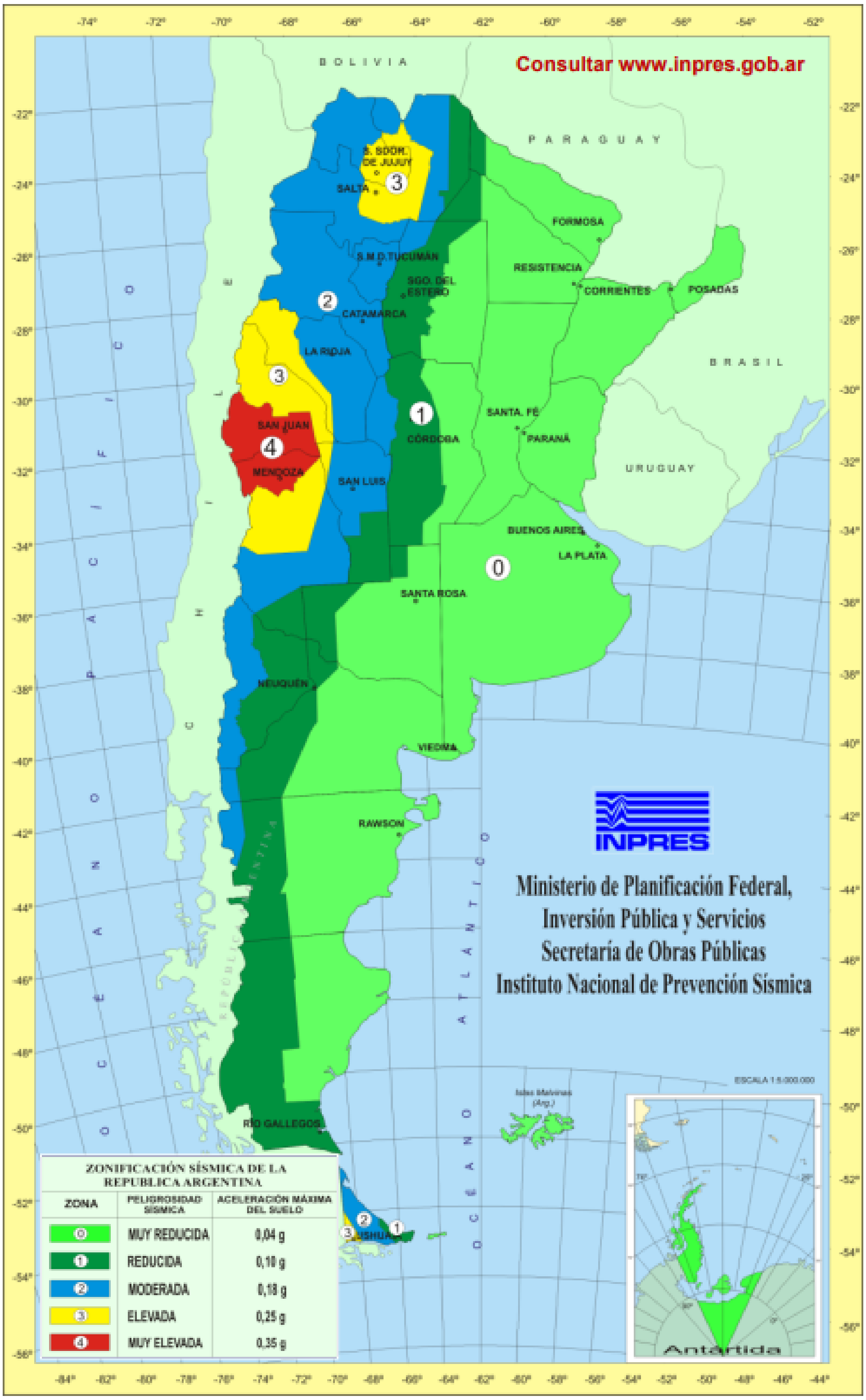
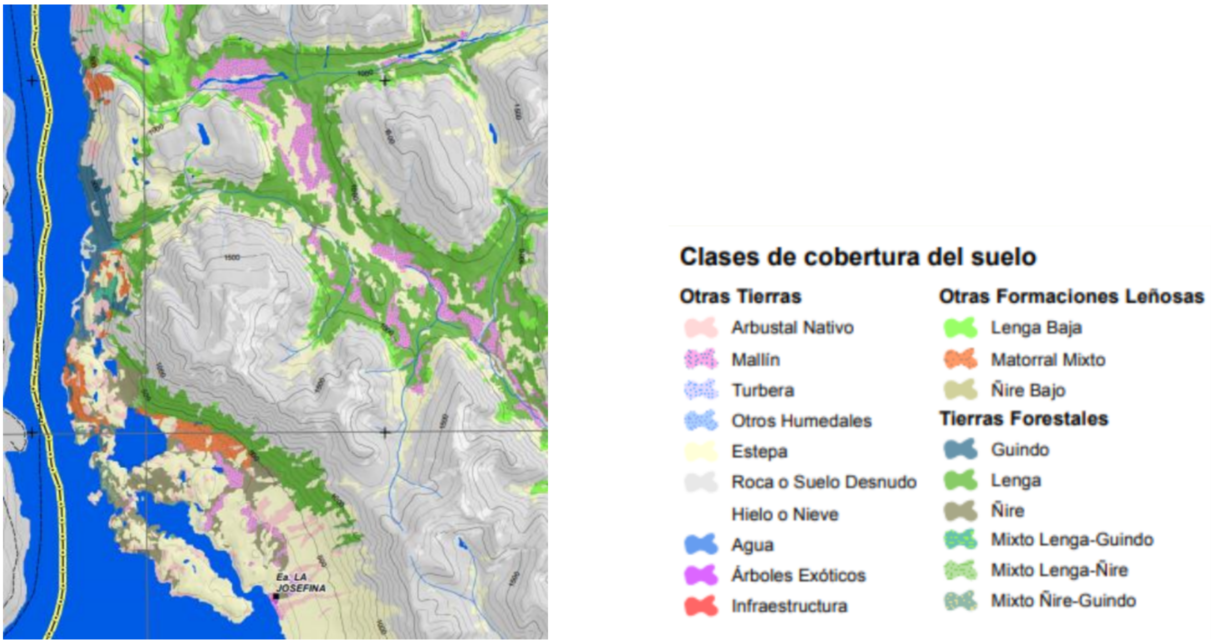


Figure A.13: Seismic zoning of the Republic of Argentina (Instituto Nacional de Prevención Sísmica (INPRES), 2018)

A.6 Flora



(a) Map of flora

(b) Legend of flora

Figure A.14: Flora at Estancia la Josefina (Secretaría de Ambiente y Desarrollo Sustentable de la Nación, 2016)

A.7 Wind direction

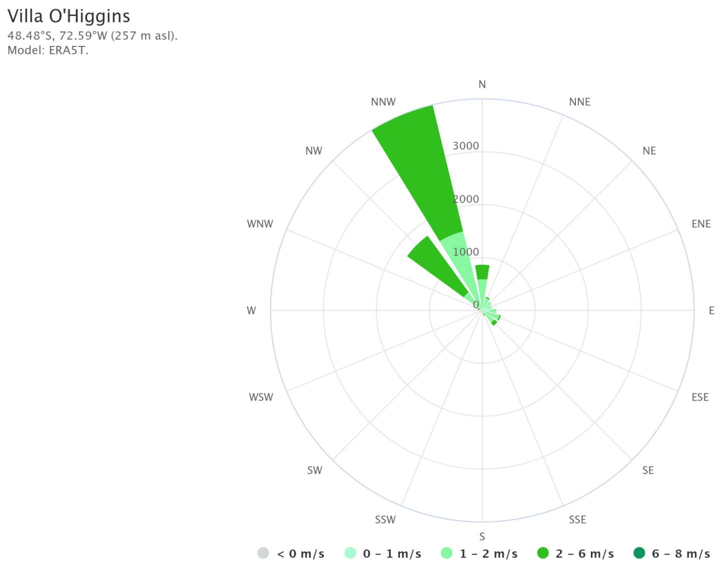


Figure A.15: Wind rose - Villa O'Higgins (MeteoBlue, 2024)

A.8 Wind Seasonality

This section presents a monthly wind speed graph derived from data analyzed from NASA (n.d.), illustrating the seasonal variation in wind strength. The analysis highlights that wind speeds are notably higher during the summer months compared to the winter, reflecting seasonal patterns.

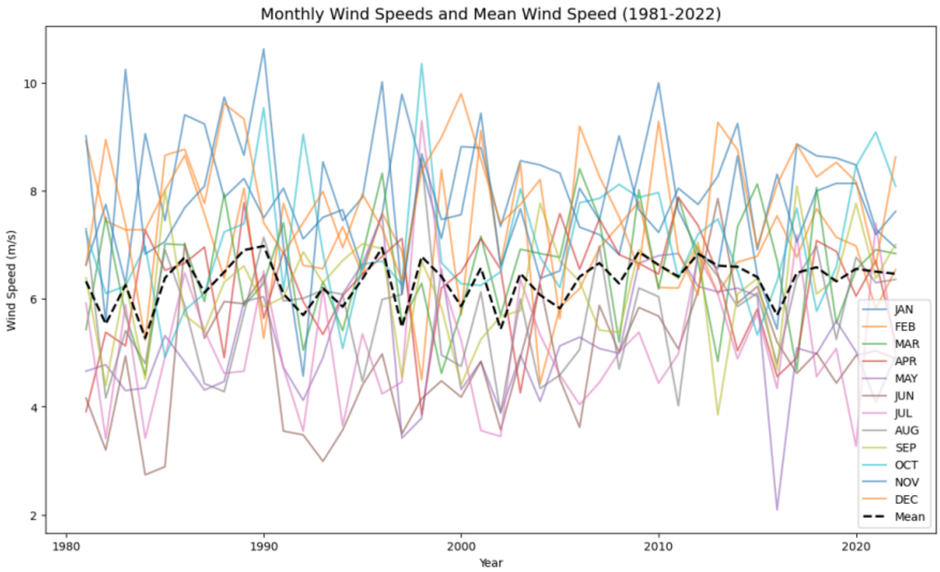


Figure A.16: Wind seasonality

A.9 Extreme Value Analysis of the Mean Wind Speed

In this section, the design mean wind speed at 10 meters above ground level (U_{10}) for Estancia La Josefina is determined through an Extreme Value Analysis (EVA) of historical wind speed data obtained from NASA's Prediction of Worldwide Energy Resources (POWER) Data Access Viewer (NASA, n.d.). The EVA utilizes the **block maxima method** and the **Generalized Extreme Value (GEV)** distribution, which helps ensure that sampled extremes are independently and identically distributed.

A.9.1 Data Preparation and Initial Analysis

The wind speed data was initially organized into a time series (as shown in Figure A.17) with monthly average wind speeds, including calculated mean and standard deviation limits. Given the monthly data, we selected a block size of one year, resulting in 42 annual maxima across the dataset.

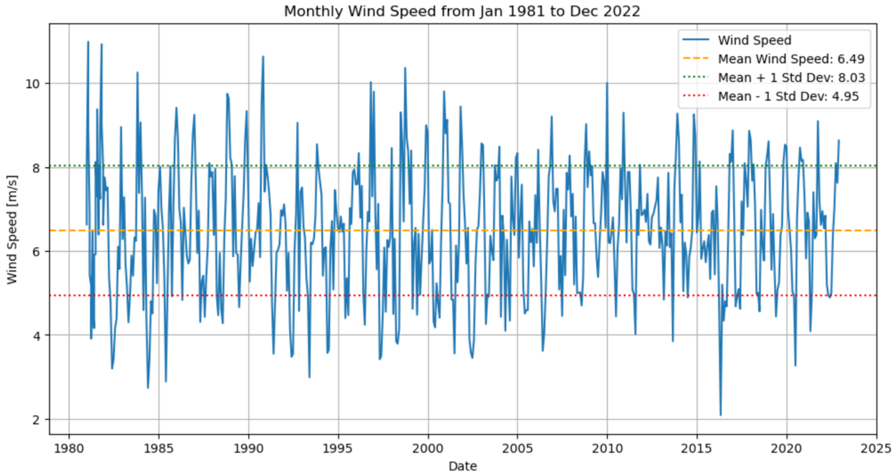


Figure A.17: Time Series of Monthly Wind Speed at 10 Meters - Estancia La Josefina.

A.9.2 Choice of Extreme Value Method

The block maxima method was chosen over the peaks-over-threshold (POT) method due to the monthly data, which would complicate threshold selection in POT. Although block maxima captures only one extreme per block (and may miss other significant events in the same period), it remains effective for long-term data. For more localized extreme wind events, however, higher-frequency data would be ideal.

It's worth noting that this wind data is derived from satellite estimates, which may not fully capture localized wind characteristics specific to Estancia La Josefina, but it serves as a solid approximation for design.

A.9.3 GEV Distribution Fitting

The GEV distribution is commonly used for block maxima, and it was fitted to the annual maxima data using the Maximum Likelihood Estimation (MLE) method. The GEV distribution is expressed as

$$G(x) = \exp\left(-\left[1 + \xi \frac{x - \mu}{\sigma}\right]^{-1/\xi}\right)$$

where μ, σ, and ξ are the location, scale, and shape parameters, respectively. The fitted parameters for this dataset are:

- Location parameter $\mu = 8.639$
- Scale parameter $\sigma = 0.736$
- Shape parameter $\xi = 0.157$

Since the shape parameter ξ is positive, this indicates a Type II (Reverse Weibull) distribution, suggesting an upper bound on extreme values. The estimated upper bound is 13.325 m/s, calculated as $8.639 - \frac{0.736}{0.157}$, providing a conservative limit for wind extremes.

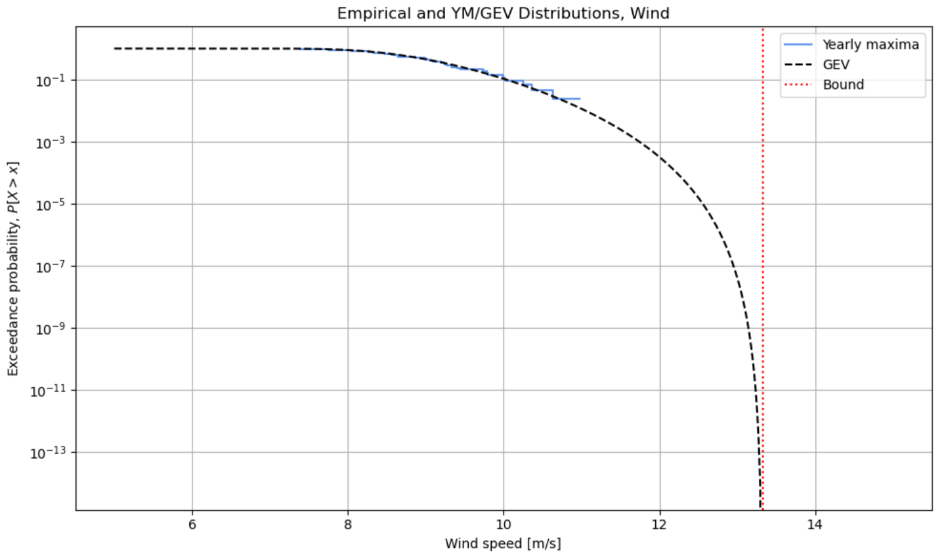


Figure A.18: Empirical Distribution and GEV Fit for Annual Maxima of Wind Speed.

A.9.4 Design Wind Speed for a 50-Year Return Period

Per the Australian Maritime Structures Standard (Global, 2010), structures in harsh environments are typically designed for a 50-year return period. Using the fitted GEV model, the wind speed for a 50-year return period was calculated to be 10.786 m/s, providing a conservative estimate for structural design considerations at the site.

$U_{10} = 10.786$

A.9.5 Model Verification and Goodness-of-Fit

The accuracy of the GEV model was checked using a Quantile-Quantile (QQ) plot, comparing the quantiles of observed maxima with the fitted GEV distribution. The alignment of quantiles along the 1:1 line indicates a good fit.

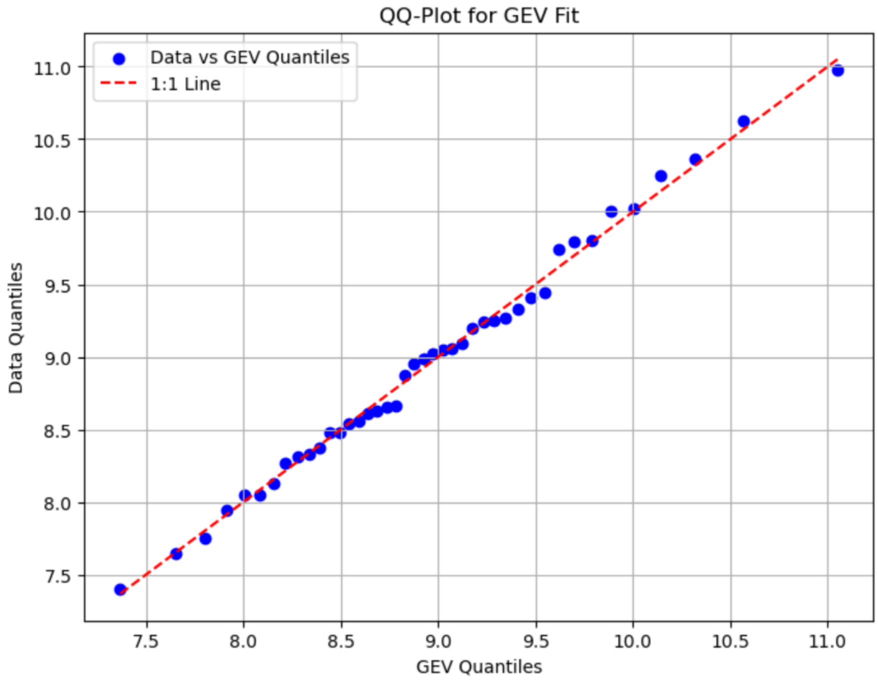


Figure A.19: Quantile-Quantile Plot for GEV Fit.

A Kolmogorov-Smirnov (KS) test further assessed the fit, yielding a KS statistic of 0.074 and a p-value of 0.964 ($p > 0.05$), supporting the adequacy of the GEV distribution for modeling extreme wind data at the site.

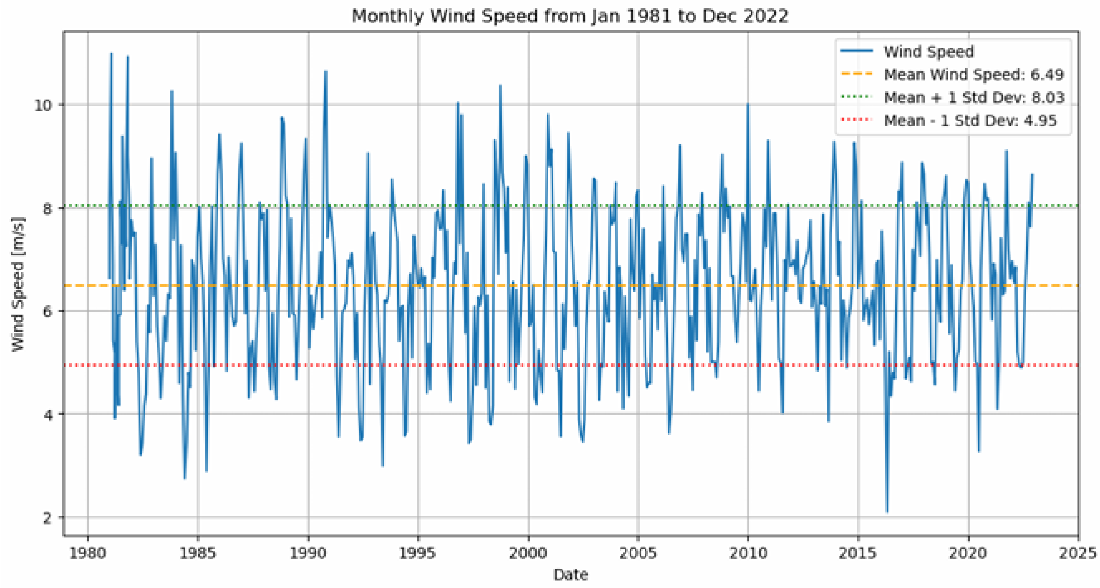
In summary, the GEV model provides a reliable estimate of the design wind speed for Estancia La Josefina, validated by goodness-of-fit tests. This distribution serves as a useful tool for anticipating rare high-wind events in the area.

A.9.6 Code documentation

In [1]:
```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
from scipy import stats
from scipy.signal import find_peaks
```

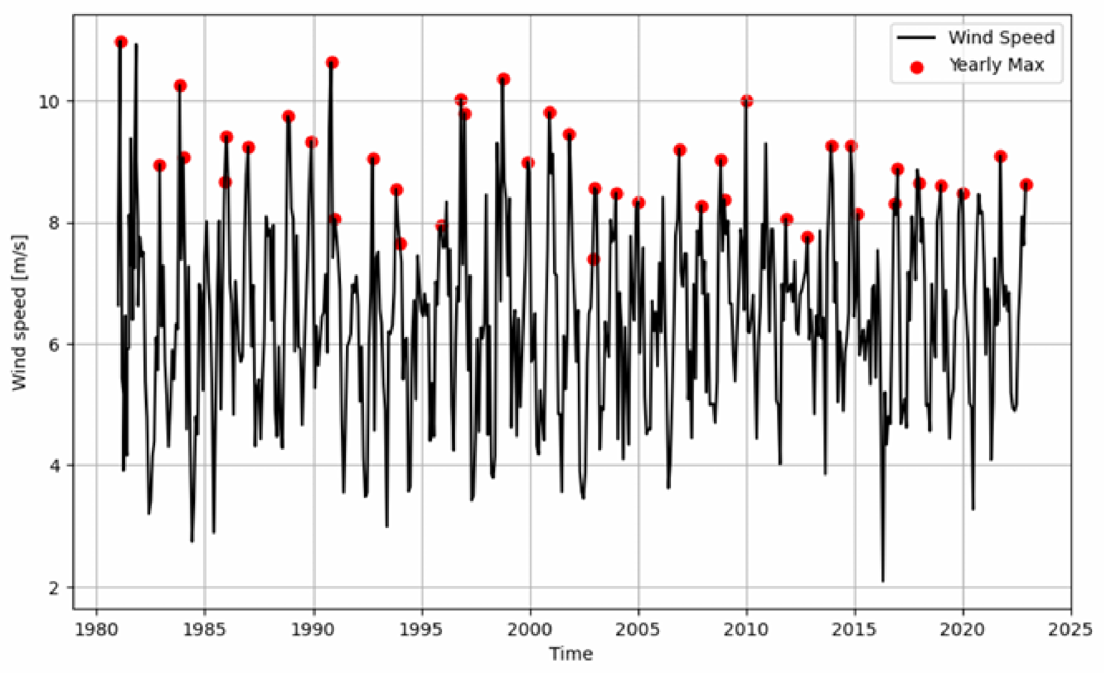
In [2]:
```
# Load the CSV file, skipping the first 4 rows and first column
file_path = 'POWER_Point_Monthly_19810101_20221231_048d79S_072d46W_UTC.csv'  # R
df = pd.read_csv(file_path, skiprows=102, nrows=43, usecols=range(1, 14))

# Rename columns: assume the first column is 'Year' and others are months
df.columns = ['Year', 'Jan', 'Feb', 'Mar', 'Apr', 'May', 'Jun', 'Jul', 'Aug', 'S

# Convert the DataFrame to long format
df_long = df.melt(id_vars='Year', var_name='Month', value_name='Wind Speed')

# Convert 'Year' and 'Month' into a datetime format
df_long['Date'] = pd.to_datetime(df_long['Year'].astype(str) + '-' + df_long['Mo

# Sort by date to ensure correct order
df_long.sort_values('Date', inplace=True)

# Print the first and last wind speed values
first_wind_speed = df_long['Wind Speed'].iloc[0]
last_wind_speed = df_long['Wind Speed'].iloc[-1]
print(f"First Wind Speed: {first_wind_speed}")
print(f"Last Wind Speed: {last_wind_speed}")

# Calculate the mean wind speed
mean_wind_speed = df_long['Wind Speed'].mean()
variance_wind_speed = df_long['Wind Speed'].var()
std_dev_wind_speed = df_long['Wind Speed'].std()  # Calculate standard deviation

print(f"Mean Wind Speed: {mean_wind_speed}")
print(f"Variance of Wind Speed: {variance_wind_speed}")
print(f"Standard Deviation of Wind Speed: {std_dev_wind_speed}")

# Plot the data
plt.figure(figsize=(12, 6))
plt.plot(df_long['Date'], df_long['Wind Speed'], label='Wind Speed')
plt.axhline(y=mean_wind_speed, color='orange', linestyle='--', label=f'Mean Wind
plt.axhline(y=mean_wind_speed + std_dev_wind_speed, color='green', linestyle=':'
plt.axhline(y=mean_wind_speed - std_dev_wind_speed, color='red', linestyle=':',
plt.title('Monthly Wind Speed from Jan 1981 to Dec 2022')
plt.xlabel('Date')
plt.ylabel('Wind Speed [m/s]')
plt.legend()
plt.grid()
plt.show()
```

```
First Wind Speed: 6.63
Last Wind Speed: 8.63
Mean Wind Speed: 6.486647286821705
Variance of Wind Speed: 2.3741147569052443
Standard Deviation of Wind Speed: 1.5408162631881988
```



In [3]:
```
# Find the index of the maximum wind speed per year in the `df_long` DataFrame
idx_max = df_long.groupby(df_long['Date'].dt.year)['Wind Speed'].idxmax()

# Select the rows with the yearly maximum wind speed
YM = df_long.loc[idx_max]

# Print the shape of the sampled extremes to check it
print('The shape of the sampled extremes is:', YM.shape)

# Plot the time series with highlighted yearly maximum wind speeds
plt.figure(figsize=(10, 6))
plt.plot(df_long['Date'], df_long['Wind Speed'], 'k', label='Wind Speed')
plt.scatter(YM['Date'], YM['Wind Speed'], color='red', s=40, label='Yearly Max')
plt.xlabel('Time')
plt.ylabel('Wind speed [m/s]')
plt.grid()
plt.legend()
plt.show()
```

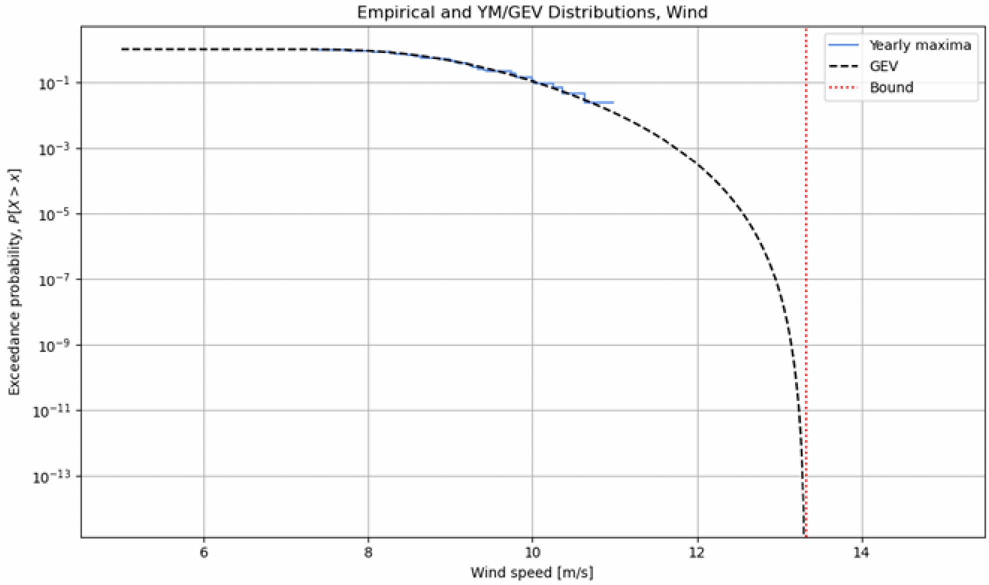
```
The shape of the sampled extremes is: (42, 4)
```



In [4]:

```
def ecdf(var):
    x = np.sort(var)
    n = x.size
    y = np.arange(1, n + 1)/(n + 1)
    return [y, x]

params_YM = stats.genextreme.fit(YM['Wind Speed'])
print('GEV parameters are: {:.3f}, {:.3f}, {:.3f}'.format(*params_YM))

x_range = np.linspace(5, 15, 500)
plt.figure(figsize=(10, 6))
plt.step(ecdf(YM['Wind Speed'])[1],
         1 - ecdf(YM['Wind Speed'])[0],
         'cornflowerblue',
         label = 'Yearly maxima')
plt.plot(x_range,
         1 - stats.genextreme.cdf(x_range, *params_YM),
         '--k', label='GEV')
if params_YM[0]>0:
    bound_YM = params_YM[1] - params_YM[2]/(-params_YM[0])
    plt.axvline(x = bound_YM, color = 'red',
                linestyle = ':',
                label='Bound')
plt.xlabel('Wind speed [m/s]')
plt.ylabel('Exceedance probability, $P[X > x]$')
plt.yscale('log')
plt.grid()
plt.legend()
plt.title('Empirical and YM/GEV Distributions, Wind')
plt.tight_layout()
```

```
GEV parameters are: 0.157, 8.639, 0.736
```




```
In [5]: # for Markdown report
print('GEV parameters are: {0:.3f} | {3:.3f} | {1:.3f} | {2:.3f}\n'.format(*para

if params_YM[0]>0:
    print(f'Shape parameter from scipy.stats is {params_YM[0]:.3f}\n'
          '  - scipy.stats shape greater than 0\n'
          '  - Tail type is Reverse Weibull --> there is a bound!\n'
          '  - bound = '
          f'{params_YM[1]:.3f} - {params_YM[2]:.3f}/(-{params_YM[0]:.3f}) = {bou
elif params_YM[0]<0:
    print(f'Shape parameter from scipy.stats is {params_YM[0]:.3f}\n'
          '  - scipy.stats shape less than 0\n'
          '  - Tail type is Frechet --> unbounded\n')
else:
     print(f'Shape parameter from scipy.stats is {params_YM[0]:.3f}\n'
          '  - Tail type is Gumbel\n')
```

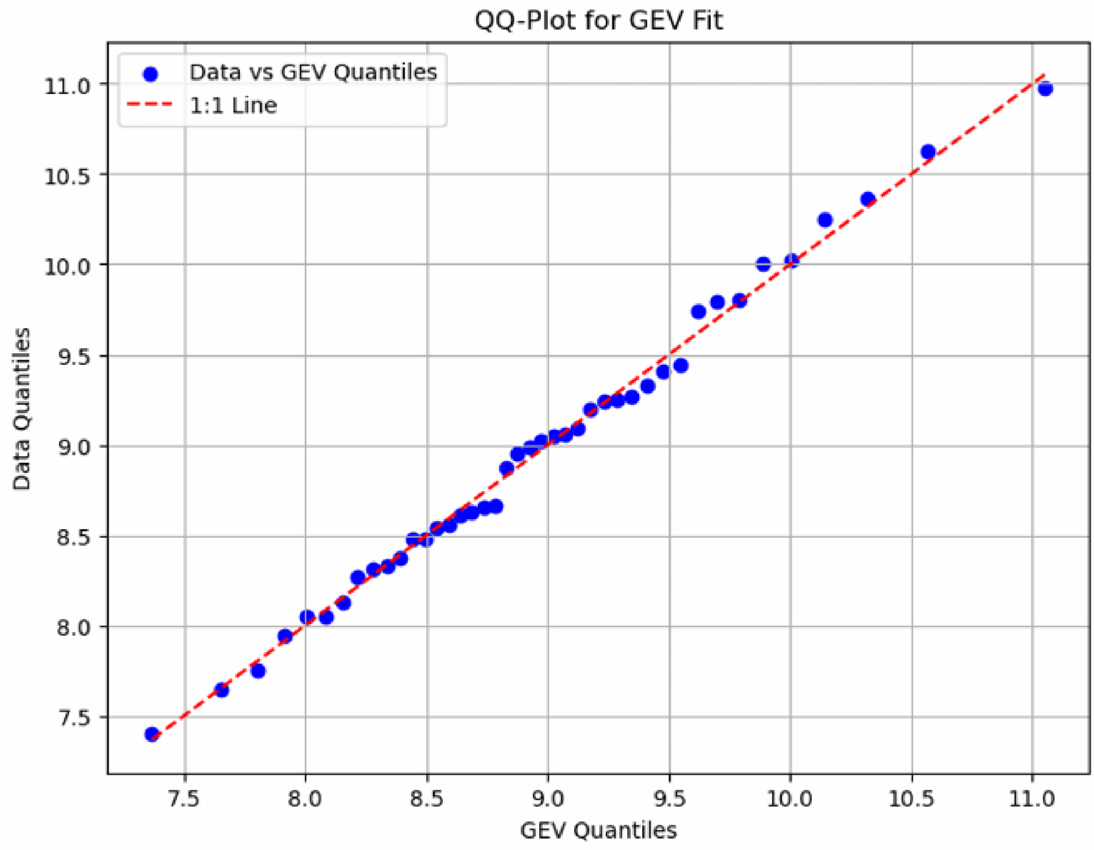
```
GEV parameters are: 0.157 | -0.157 | 8.639 | 0.736

Shape parameter from scipy.stats is 0.157
  - scipy.stats shape greater than 0
  - Tail type is Reverse Weibull --> there is a bound!
  - bound = 8.639 - 0.736/(-0.157) = 13.325
```

```
In [6]: # YM & GEV
YM_design_value = stats.genextreme.ppf(1 - 1/50, *params_YM)

print('The design value for a RT = 50 years computed using',
      'BM and GEV is:', np.round(YM_design_value, 3), 'm/s')
```

```
The design value for a RT = 50 years computed using BM and GEV is: 10.786 m/s
```

```
In [7]: # Generate quantiles from the fitted GEV distribution
shape, loc, scale = params_YM

gev_quantiles = stats.genextreme.ppf(np.linspace(0.01, 0.99, len(YM['Wind Speed'
data_quantiles = np.sort(YM['Wind Speed'])

# Plot the QQ-plot
```

```
plt.figure(figsize=(8, 6))
plt.scatter(gev_quantiles, data_quantiles, color='blue', label='Data vs GEV Quan
plt.plot([gev_quantiles.min(), gev_quantiles.max()],
         [gev_quantiles.min(), gev_quantiles.max()],
         'r--', label='1:1 Line')
plt.xlabel('GEV Quantiles')
plt.ylabel('Data Quantiles')
plt.legend()
plt.title("QQ-Plot for GEV Fit")
plt.grid()
plt.show()
```



In [8]:
```
# Perform KS test with the fitted GEV distribution
ks_stat, p_value = stats.kstest(YM['Wind Speed'], 'genextreme', args=(shape, loc
print(f"KS Statistic: {ks_stat:.3f}, p-value: {p_value:.3f}")

# Interpretation
if p_value > 0.05:
    print("The KS test suggests the GEV distribution is a good fit (p > 0.05).")
else:
    print("The KS test suggests the GEV distribution may not be a good fit (p <=
```

```
KS Statistic: 0.074, p-value: 0.964
The KS test suggests the GEV distribution is a good fit (p > 0.05).
```

Figure A.20: EVA Code Documentation

B | Multi-criteria analysis

Further details of the multi-criteria analysis are presented in this Appendix. From a detailed explanations of the scoring system to the results of the analysis.

B.1 MCA Scoring

The tables below explain the two scoring used for the different criteria.

Scale	Environmental impact	Affordability	Business growth	Technical difficulty	User comfort
0	very high impact	very low affordability	very low growth	very high difficulty	very low comfort
1	high impact	low affordability	low growth	high difficulty	low comfort
2	low impact	high affordability	high growth	low difficulty	high comfort
3	very low impact	very high affordability	very high growth	very low difficulty	very high comfort

Table B.1: Rating Description - Optimal Population Size MCA

Scale	Environmental impact	Affordability	Business growth	Technical difficulty	User comfort
0	extremely high impact	extremely low affordability	extremely low growth	extremely high difficulty	extremely low comfort
1	very high impact	very low affordability	very low growth	very high difficulty	very low comfort
2	high impact	low affordability	low growth	high difficulty	low comfort
3	moderately high impact	moderately low affordability	moderately low growth	moderately high difficulty	moderately low comfort
4	slightly high impact	slightly low affordability	slightly low growth	slightly high difficulty	slightly low comfort
5	neutral impact	neutral affordability	neutral growth	neutral difficulty	neutral comfort
6	slightly low impact	slightly high affordability	slightly high growth	slightly low difficulty	slightly high comfort
7	moderately low impact	moderately high affordability	moderately high growth	moderately low difficulty	moderately high comfort
8	low impact	high affordability	high growth	low difficulty	high comfort
9	very low impact	very high affordability	very high growth	very low difficulty	very high comfort
10	extremely low impact	extremely high affordability	extremely high growth	extremely low difficulty	extremely high comfort

Table B.2: Rating Description - Population Distribution MCA

B.2 Stakeholder Preferences

This section presents and discusses stakeholder preferences regarding the importance of each MCA criterion. The scores, based on survey results (see Annex C) and the project philosophy (see Chapter 6), are summarized as follows:

For investors, environmental impact is rated as neutral as while sustainability is not their main focus, it can attract eco-tourists who are a key demographic of the development. Affordability is given low importance, as investors are more concerned with generating income rather than specific cost of staying. Therefore, economic growth is a top priority for this stakeholder in order to ensure long-term revenue. Technical difficulty is also rated highly, as they want to minimise construction time and maintenance requirements, as well as ensure the project's feasibility, given their financial investment. User comfort is rated lower, since it primarily impacts tourists, however is still relevant since a satisfied customer base directly influences income.

For tourists, environmental impact is rated fairly high, as the primary visitors are eco-tourists and backpackers who prioritise sustainability, however they still expect certain amenities, even if these may have some environmental impact. Affordability is a key concern, with most tourists preferring affordability through lower costs for their stay. Economic growth holds no significance for this stakeholder, as they are not directly affected by the project's financial outcomes. Technical difficulty is also of minimal importance to tourists, however they recognize that higher complexity often leads to better-quality facilities. Finally, user comfort is rated the highest, as tourists are one of the main users of the village's amenities, and their satisfaction depends on the quality of their experience.

For the environment, environmental impact is naturally rated extremely high, reflecting the primary interest in preserving nature. Affordability receives a neutral rating, as on the one hand, higher costs can be seen positively since they enable better quality materials and sustainable methods, however on the other hand they could also result in larger facilities, bringing negative implications. Economic growth is viewed negatively, as larger projects lead to further environmental degradation, however it is acknowledged that economic initiatives might also facilitate positive outcomes, such as reforestation. Technical difficulty is given a relatively lower score, as higher difficulty often translates to more sustainable practices which are preferred by this stakeholder. Lastly, comfort receives no importance as this stakeholder has no interest in user amenities.

For inhabitants environmental impact is a relatively high priority as they reside in the area and wish to preserve the natural ecosystem surrounding them as much as possible. Affordability is a crucial criteria, as residents seek to minimise their cost of living. Economic growth receives a moderately low rating as while workers favour increasing job opportunities, other permanent residents may not see this as a priority. Technical difficulty is given a middle rating, reflecting their preference for ease of maintenance and efficient construction. Finally, user comfort is rated highest as inhabitants want to maximise their comfort and quality of life within the village.

Criteria	**Investors**	**Tourists**	**Environment**	**Inhabitants**
Environmental impact	5	7	10	7
Affordability	2	8	0	9
Business growth	10	0	-5	3
Technical difficulty	8	3	4	5
User comfort	4	10	0	10

Table B.3: Stakeholder Preferences - Population Distribution MCA

The motivation of the scoring for the stakeholders in the population sizing MCA is consistent with the previous analysis. Initially, a score from 0 to 10 was assigned as explained earlier. Subsequently, the scoring is changed to use a more compact scale from 0 to 3 by using the following conversion system:

$$0; 1 \rightarrow 0$$

$$2; 3; 4 \rightarrow 1$$

$$5; 6; 7 \rightarrow 2$$

$$8; 9; 10 \rightarrow 3$$

The reason of the different scoring systems is further explained in Chapter 7.1.

Criteria	Investors	Tourists	Environment	Inhabitants
Environmental impact	2	2	3	2
Affordability	1	3	0	3
Business growth	3	0	0	1
Technical difficulty	3	1	2	2
User comfort	1	3	0	3

Table B.4: Stakeholder Preferences - Optimal Population Size MCA

B.3 MCA results

In this section, the detailed, non-rounded results of the two multi-criteria analyses (MCAs) are presented in tabular format. These tables provide a precise breakdown of outcomes, capturing stakeholder preferences as calculated in each analysis.

Optimal Population Size MCA

Population	Ranking	Percentage
50	2	23.97%
100	4	24.38%
300	1	29.34%
500	3	22.31%

Table B.5: Optimal population size MCA results - Equal weighting

Population Distribution MCA

Population Distribution	Ranking	Percentage (%)
Campsite/Hostel	2	28.18
Cottages	3	25.56
Luxury Rooms	4	18.39
Permanent Plots	1	27.87

Table B.6: Population distribution MCA results - Equal weighting

B.4 Sensitivity analysis

In this section the sensitivity analysis performed for the two multi-criteria analysis are discussed. This allows to verify the robustness of the obtained outcomes. More in detail, the analysis are conducted by considering different weighting of the stakeholders and by looking for the most critical criteria.

Optimal Population Size MCA

In the initial multi-criteria analysis (MCA), option 300 emerges as the preferred choice for most stakeholders, achieving the highest total score and accounting for 29.34% of the overall score. The only stakeholder group for which option 300 does not rank as the best choice is the Environment, where it performs poorly due to its potential environmental impact. This finding underscores a common trade-off in development projects between economic growth and environmental preservation.

Stakeholders	**Investors**				**Tourists**				**Environment**				**Inhabitants**			
Criteria	50	100	300	500	50	100	300	500	50	100	300	500	50	100	300	500
Environmental impact	1.5	1	0.5	0	1.5	1	0.5	0	2.25	1.5	0.75	0	1.5	1	0.5	0
Affordability	0	0.25	0.75	0.75	0	0.75	2.25	2.25	0	0	0	0	0	0.75	2.25	2.25
Business growth	0	0.75	2.25	2.25	0	0	0	0	0	0	0	0	0	0.25	0.75	0.75
Technical difficulty	2.25	1.5	0.75	0	0.75	0.5	0.25	0	1.5	1	0.5	0	1.5	1	0.5	0
User comfort	0.25	0.5	0.75	0.75	0.75	1.5	2.25	2.25	0	0	0	0	0.75	1.5	2.25	2.25
Sum	**4**	**4**	**5**	**3.75**	**3**	**3.75**	**5.25**	**4.5**	**3.75**	**2.5**	**1.25**	**0**	**3.75**	**4.5**	**6.25**	**5.25**

Table B.7: Sensitivity Analysis of Optimal Population Size Across Stakeholders and Criteria

Further analysis shows that option 50 becomes the leading choice if the Environment is assigned a weight of 45% or higher, leveraging its superior performance in environmental impact.

Option	Total Score	Ranking	Percentage
50	14.6	1	27.94
100	13.5	3	25.75
300	14.3	2	27.40
500	9.9	4	18.91

Table B.8: Optimal Population Size MCA - Environment 45%

Similarly, increasing the overall weight for Investors to 40%—a common adjustment that emphasizes the business aspects of a project—yields only minor deviations from results obtained with equal weighting, as shown in the table below.

Population	Ranking	Percentage
50	2	23.95%
100	4	24.27%
300	1	29.45%
500	3	22.33%

Table B.9: Optimal Population Size MCA - Investors 45%

Additionally, sensitivity analysis reveals that option 50 ranks highest when weights for **technical difficulty** and **environmental impact** are increased, capitalizing on its advantages in these areas. Conversely, option 500 performs best when greater emphasis is placed on **affordability** and **user comfort**, where it excels relative to other options. This sensitivity analysis provides insights into how prioritizing different criteria can influence optimal population size decisions based on stakeholder preferences and project goals.

Population Distribution MCA

The initial multi-criteria analysis for the distribution of population across various accommodation typologies identifies the Campsite/Hostel as the optimal choice, achieving a total score that constitutes 28.18% of the overall score while Luxury Rooms score the lowest at 18.39%.

This ranking indicates a preference for more affordable, lower-impact accommodations, such as the Campsite/Hostel and Permanent House Plot, likely due to their lower technical difficulty, cost, and moderate environmental impact.
When considering investor priorities, increasing the weight of their influence to 40% results in minimal fluctuations in the overall rankings that still favour more affordable accommodations, as detailed in the table below.

Population Distribution	Ranking	Percentage (%)
Campsite/Hostel	2	26.84
Cottages	3	25.61
Luxury Rooms	4	19.70
Permanent House Plot	1	27.86

Table B.10: Population Distribution MCA Results - Different Weighting

The analysis further reveals how adjustments in criteria weights can shift the rankings of options.

- Luxury Rooms would ascend to the top by placing greater emphasis on **user comfort** and **economic growth**.
- Huts/Domes could be prioritized by enhancing the weight of **economic growth** and **environmental impact**.
- Permanent House Plots could secure a winning position by emphasizing **technical difficulty** and **user comfort**.
- Campsite/Hostel would maintain its leading status by prioritizing **environmental impact**.

This sensitivity analysis illustrates how modifying the weight of specific criteria influences the accommodation rankings, providing valuable insights for aligning decision-making with stakeholder priorities regarding population distribution across different accommodation types.

C | Market study: interviews and data

C.1 Population: Inhabitants

C.1.1 Temporary residents: Workawayers

Two people who had experience with that type of project were interviewed to gain a better insight into the Workaway experience. Both of them were asked the same questions. These two people are Flavia Visca and Michela Mascia. The first one had three Workaway experiences, two in the Canary Islands and one in the south of Italy, while the second had one Workaway experience in the Canary Islands and works currently there, managing her own Workaway.

The questions that were proposed to them were chosen to identify which are the essential facilities that need to be present in a Workaway experience, what is the typical arrangement between host and volunteer, and have an opinion from both points of view, both the host of the Workaway and the volunteer.
Here follow the two interviews that were held.

1. Can you describe your typical living arrangements during your Workaway experiences?

Flavia Visca: "I've had various living arrangements during my Workaway experiences. In one case, when I did a WorkAway in the South of Italy, I stayed at a bed and breakfast, where I had a private room and all meals included. In exchange, I did different tasks such as gardening, preparing meals for the family, and helping the owner restore furniture.
My second WorkAway experience was in Tenerife. I stayed in a tipi and worked throughout the whole week, even though typically the work schedule is Monday to Friday. Another time, I lived in a lady's house that was part of a nonprofit organization. I received accommodation and meals and worked 4-5 hours a day, with weekends off. My tasks included helping in the garden, doing cleaning, and assisting with event organization for the nonprofit. The most important aspect of these volunteer experiences is having accommodation and meals included, as well as free weekends to explore the area, meet new people, and learn new skills. I typically stayed for at least one month, as it takes time to adjust and build a relationship with the hosts."

Michela Mascia: "I had only one WorkAway experience, which was where I currently work. I manage a project where the living arrangements for volunteers consist of yurts, shared between two people. These spaces are simple but comfortable. One of the main challenges is that some hosts expect volunteers to work without proper contracts and provide only the bare minimum. It's important to remember that volunteers are not workers—they are not paid and should not be treated as such. Their role is to contribute to the project, and in return, they should receive appropriate accommodation and meals.
The living spaces for volunteers should be well-equipped, allowing them to feel part of the project. Clear communication is another very important aspect; volunteers need to fully understand the situation and living conditions before they arrive, so they can decide if it's a good fit for them. Privacy is also important, so having separate spaces for volunteers is ideal. Providing accommodations specifically for volunteers helps them feel more comfortable and supported in their role."

2. What facilities and amenities did you find essential during your stays? Were there any facilities or services that were consistently missing or inadequate?

Flavia Visca: "In Tenerife, there was no Wi-Fi, which posed a challenge. It's important to have a backup plan in case something happens with the room or other facilities provided to volunteers. For example, once during a retreat, I had to sleep in a children's tent due to limited space. A key improvement would be to have a dedicated house or space solely for volunteers, ensuring they always have a comfortable, reliable place to stay, even during special events or busy times."

Michela Mascia: "Essential facilities during my stay included a private space to sleep, access to a kitchen, and a private bathroom, with a shower and hot water at least for the shower. Laundry facilities are also important, like a washing machine or a simple way to hand wash clothes with space to hang them.

The kitchen situation needs to be specified prior the arrival—whether volunteers will prepare their meals in the same kitchen where food for guests is made, or if they have a separate area. This can greatly impact the overall experience.
As for practical matters, we had Wi-Fi, though it wasn't always stable, but it's something volunteers typically ask for. It's helpful to inform them in advance. We are also planning on installing satellite Wi-Fi. Regarding the energy aspect, we have two systems; one for the house and one for the irrigation of the crops. We also have lead-acid batteries. To conserve energy, activities like laundry were done during the day using solar power. This system was well-suited for a place without too much sun or water, though occasional maintenance is important."

3. What kind of community or social environment made the experience better for you?

Flavia Visca: "A strong sense of community, built through sharing experiences with both fellow volunteers and locals, greatly enhances the experience. Learning to share and work as a team creates a deeper connection, and teamwork becomes a vital part of the stay."

Michela Mascia: "Creating a welcoming and cohesive group is essential. It's important to consider the existing dynamics among those already present, not just the type of work people do or their professions, but factors like age and whether they are couples or not. Organizing group meals is essential, both for efficient management and to build a sense of community and togetherness. Social activities such as shared dinners, game nights, or group events help strengthen the bond and ensure a more enjoyable experience for everyone."

4. What were the peak seasons during your Workaway experiences, and how did they affect your work or living conditions?

Flavia Visca: "During the peak season at the retreat in Tenerife, there was a sudden influx of people, and the hosts were not fully prepared. This highlighted the importance of proper organization under aspects such as understanding how many people are needed and ensuring that tasks are clearly divided. Volunteers are happier when they have plenty to do, as long as their responsibilities are well-structured and they know what needs to be achieved during that period."

Michela Mascia: "It's essential to respect the agreed-upon working hours, giving volunteers their free time unless there's an urgent situation. If they work extra hours one day, it's important to compensate with time off later. Flexibility on both sides is key. Ensuring there's enough staff to handle the increased workload is crucial so that the experience remains enjoyable for everyone. Proper planning and a balanced workload help maintain morale and prevent burnout during busy times."

5. How much flexibility did you typically have in your daily work schedule, and what kind of work did you prefer?

Flavia Visca: "There was a lot of flexibility compared to a regular job, which is expected since it's volunteer work. By communicating your needs with the host, a solution can always be found to adjust the schedule or tasks.
The types of work I enjoyed the most included participating in retreats, organizing events for nonprofit organizations, and working closely with nature, such as gardening and learning about permaculture. These activities allowed me to grow personally and professionally while contributing to the projects in a meaningful way."

6. Did you ever encounter difficulties adapting to the lifestyle or local community during your stays? If so, what could have helped?

Flavia Visca: "It's important that the host makes the volunteers feel comfortable, explaining clearly what tasks need to be done and being present to provide support when needed."

Michela Mascia: "A key thing is explaining in advance the type of volunteer work volunteers will be doing.

If expectations aren't set clearly, they may arrive with different ideas, which can lead to misunderstandings and issues. Clear communication about the role and responsibilities can prevent these problems and create a more positive experience for everyone."

7. What motivated you to choose specific Workaway destinations over others?

Flavia Visca:"My first Workaway experience happened because I was contacted during the pandemic, which made it an easy choice. In Tenerife, I had initially been a customer, so I was already familiar with the place and decided to become a volunteer while I was there. In other cases, I chose locations based on cultural interests or because they were well-known for something I was passionate about."

Michela Mascia: "Often, people choose their destination first, and then find a Workaway opportunity in that location. That's why it's important for hosts to have a clear and detailed profile page. While some places don't require specific skills, others choose their volunteers based on the type of work needed, which also influences decision-making."

8. What do you value more between cultural exchange, work experience, or other aspects of the Workaway experience?

Flavia Visca: "Work experience is my top priority, as the primary goal of volunteering is to contribute and learn through the tasks I'm involved in. However, cultural exchange is also very valuable, especially when shared with people who have similar interests. Additionally, outdoor experiences play an important role in making the stay more enriching and enjoyable, offering opportunities to connect with nature while working."

9. How did you usually spend your free time during your stays?

Flavia Visca: "Even though I had weekends off, I often stayed with the host family and participated in activities that I couldn't do during the workweek. There was a nice exchange with other volunteers as well, for example those who taught yoga or other skills would often share these with the group during the weekends. I didn't mind spending my weekends with the same people, and I valued the time spent with the family that was hosting me."

Michela Mascia: "During the free time volunteers usually hang out together, go for walks, but also enjoy time by themselves. The host would also provide materials for creative activities, such as woodworking, making mosaics, or soap-making, things that aligned with volunteers' hobbies. Yoga was also a common activity. "

10. What types of training or guidance did you receive, and how important was it to your overall experience?

Flavia Visca: "I didn't receive any formal training and sometimes found myself in situations without clear directions. It would have been helpful to have proper guidance and I would've appreciated if the host had asked me what I enjoyed doing. Having that kind of input would have made the experience more engaging and aligned with my interests."

11. Would you recommend Workaway experiences to others, and why?

Flavia Visca: "Yes, I would recommend Workaway experiences because it's a unique way to work and engage in cultural exchange. There's a greater openness and flexibility in the tasks, which makes the experience more rewarding. It's important to guide volunteers, but equally important to listen to them and allow them to focus on tasks they are most interested in or best suited for. This balance helps create a more fulfilling experience for both the volunteer and the host."

12. Were there any environmental or sustainability practices you found particularly inspiring or lacking during your experiences?

Flavia Visca: "I found the permaculture practices implemented by the nonprofit host very interesting. The WorkAways where I volunteered also also organized workshops on ceramics, tiling, and eco-construction techniques, which I really enjoyed. Recycling played also an important role, especially in building useful structures with reclaimed materials.

Michela Mascia: "In the village where I work sustainability is enhanced through self-production, recycling for construction (which requires knowledge in the field), and eating seasonal, locally sourced food to avoid waste. It's crucial to create an initial plan that identifies the necessary activities and recruits the right volunteers to match those needs."

13. Would you consider our option, and if so, what kind of work do you think would be needed during peak seasons?

Flavia Visca: "There would be a variety of activities needed during the peak season. Offering nature-based sports, using available materials for construction, and engaging in local traditions like ceramics or textile work would be great. It could also be tailored to attract younger tourists with smaller budgets.
Some specific activities could include horseback riding, kayaking, sustainable fishing, ceramic workshops using clay from the lake, or even something related to textiles, inspired by the communities in the Argentine mountains who work with traditional fabrics."

C.1.2 Digital nomads

1. How old are you?

Sierra Mendosa:"27"
Leny Buzzelli:"21"
Bautista Saint Antonin:"24"

2. How long have you been a digital nomad?

Sierra Mendosa: "Almost one 1 year."
Leny Buzzelli: "Not much, I started a few months ago."
Bautista Saint Antonin: "Less than 6 months."

3. Where have you settled before as a digital nomad?

Sierra Mendosa: "Thailand/SE Asia"
Leny Buzzelli: "Buenos Aires"
Bautista Saint Antonin: "Bienos Aires and Patagonia"

4. How do you typically choose your destination as a digital nomad?

Sierra Mendosa: "Usually I consider the cost of living there, the language spoken and if a visa is needed to go there. Other stuff that I take into consideration are the wifi, the things to do and the weather."
Leny Buzzelli: "When I choose the destination I consider if I am interested in traveling the country, the culture, the food, the weather."
Bautista Saint Antonin: "Usually I chose according to the site. I like outodoor activities, so it would be very important for me to be in contact with nature."

5. Would you consider living in a remote area like our village in Patagonia? Why or why not?

Sierra Mendosa: "Maybe for a little bit, could be a unique experience. Patagonia is definitely a place I'd love to check out. The only thing that makes me nervous is the 5-hours hike carrying all my stuff."
Leny Buzzelli: "Yes, because I think it would be great for my mental health and it'd help me unplug my

brain."
Bautista Saint Antonin: "Because it is a unique place in nature, and also because there are lot of job opportunities related with the development of the project."

6. If yes, for how long do you think you would stay in a remote area like ours?

Sierra Mendosa: "One month."
Leny Buzzelli: "A month and a half maybe."
Bautista Saint Antonin: "At least 3 months. For the summer/spring season."

7. What essential facilities or amenities would you need in a remote area to consider living there?

Sierra Mendosa: "Wifi/cellular service, heating since I think it gets pretty cold, hot water, a few cafes/restaurants."
Leny Buzzelli: "WiFi, laundry, gas station, parilla, backyard, a pet-friendly environment."
Bautista Saint Antonin: "Good Wifi service."

8. Would you be okay in sharing common areas such as libing room and kitchen with other digital nomads?

Sierra Mendosa: "Yes."
Leny Buzzelli: "Yes."
Bautista Saint Antonin: "Yes."

9. Are there specific social or community aspects you would expect when living in a remote village?

Sierra Mendosa: "I would expect, since it would be a small village, that you get to know the locals. I'd hope that there were organized hikes or activities you could join to explore different parts of Patagonia. I'd also probably expect there to be more local produce I guess, maybe 1 or 2 small markets/convenience stores. I'd hope there was something like a bowling alley or a few bars, or something late at night that everyone goes to."
Leny Buzzelli: "To have neighbors."
Bautista Saint Antonin: "It would be great to have a community".

10. What types of people would you like to meet or connect with while living in a remote village? (e.g. : other digital nomads, local people, tourists ...)

Sierra Mendosa:"I guess I'm open to all, but I'd gravitate to locals and other digital nomads."
Leny Buzzelli: "Tourists, other digital nomads."
Bautista Saint Antonin: "Mostly people of my age you are in the same situation as me. I'm still studying at the moment."

11. What kind of work setup do you require to be productive in a remote area (e.g., co-working spaces, quiet zones, fast internet)?

Sierra Mendosa:"Fast internet, and coworking spaces are great but I tend to just find a cafe or work at home."
Leny Buzzelli: "Desk, WiFi, comfortable chair, air conditionier, and espresso machine."
Bautista Saint Antonin: "Fast internet for sure, and also a coworking place could help."

12. How important is access to nature and outdoor activities when choosing where to live and work remotely?

Sierra Mendosa: "Very important."

Leny Buzzelli: "Important but not essential."
Bautista Saint Antonin: "Very important."

13. Would you be open to contributing to the community (e.g., sharing skills, participating in local projects) during your stay?

Sierra Mendosa: "Probably, especially if there were programs for discounted/free living, or free food, free tours/activities, etc. ."
Leny Buzzelli: "It depends on the amount of work."
Bautista Saint Antonin: "Yes."

14. What challenges do you foresee in living in a remote area, and how could we address those?

Sierra Mendosa: "The 5 hour hike. I don't mind a hike after I'm there, but getting all my stuff to the village, especially if I'm only there for a short period of time does not seem fun. Depending on how big the village is, it may feel a little lonely if there aren't others in my similar age range to hang out and do activities with. Fresh produce/food, I bet the water is delicious so that probably wouldn't be a problem haha, just making sure that there's a store that has the essentials I would need so I don't have to trek all the way back to BA for shampoo or something."
Leny Buzzelli: "A health issue maybe would be my concern!"
Bautista Saint Antonin: "I think the greatest challenge is to survive here by yourself during all the season. But if there is a community it gets much easier."

15. What would encourage you to return to a place like this after your initial stay?

Sierra Mendosa: "Sense of community, ease of working, realizing how big Patagonia is and wanting to see more of it. Comfort levels."
Leny Buzzelli: "That I feel comfortable and well rested after the experience."
Bautista Saint Antonin: "The sense of tranquility after leaving the ranch."

16. How would the remote and difficult access to and from the village impact your decision to live and work here? Would limited ease of travel be a major concern for you, and if so, how often would you need to leave the area?

Sierra Mendosa: "Yes, ease of travel could be a concern. Leaving the area would depend on if they have essentials. If they have things like food, cleaning supplies, some clothing, dishware, personal hygiene, pet supplies, I could probably stay for a while. Especially if the houses were already stocked. I would only stay there if there were homes available to rent that were fully furnished and stocked with kitchen essentials."
Leny Buzzelli: "My mine concert would be social interaction, but if there are fun activities planed I would consider a longer stay."
Bautista Saint Antonin: "The main problem that its so far away its the cost. I dont mind doing such a long trip, but if its too expensive then it would be difficult for me to say yes."

C.1.3 Permanent residents: Investors

In the following section the full interviews with some possible stakeholders that were found to be interested in the project as potential investors can be found. These are: Pablo Arecco, Mathias Goyeneche, Andres Cucci, Juan Cazenave, and Jaime Smart, the current manager of the ranch.

Here are the interviews that were held.
1. Are you interested in investing in the project? And if yes, why?

Pablo Arecco: "Yes, for some reasons. First of all because the way we are living now in most of the cities is not sustainable and it doesn't provide a good quality of life. There is not enough connection with nature. Another reason regards how kids grow and how we impact the surroundings. This is one of the most pristine areas of the world, there are some issues with the wind but it's a liveable area."

Mathias Goyeneche: "Yes, I am interested in investing in the project. Mainly because it is a unique place and since I have friends already involved, there would be a sense of community. I would be willing to invest around 50 thousand dollars."

Andres Cucci : "Maybe, the place is amazing. Unique nature. Nature-oriented motivation."

Jaime Smart: "Yes, of course. Because I like the place and enjoy the project, and think that it is the future for many young people. I'm old, but it's a project for 15/20 years. When I was 40 they made Sierra Patagonicos, now he is 63. I think the project is for people that are 30/40. My challenge is to make something for the new generations with nature, forests, glaciers, lakes, and pure water."

Juan Cazenave: "Yes, I am a possible investor."

2. What is your vision of the development of the area (e.g. population number, type of amenities, type of tourism involved, comfort and accessibility)?

Pablo Arecco: "In my opinion 90/95 % part of the ranch should remain a reserve, a natural park. Should be accessible but only for activities like hiking. Some natural areas are impacted by cattle and forests should be recovered. The area shouldn't be heavily densely populated. For example, there can be plots of 1-1,5 hectares with one family living in it, and in this area like 200-250 square meters of building. The rest should be left to nature. In my opinion any subdivision of plots shouldn't be allowed, plots should remain of the size they are at the beginning. I don't see more than 1000/1500 people living here. The only village near this zone is Villa O'Higgins. In the future you can think about three or four villages spread in the areas where estancias like Condor and Maipu are now, and they can be connected by lake. Is important that the acquisition of the lands is by an argentine, by law. In this specific case, the majority of stakeholders should be an Argentine (maybe research).
I also think that there should be greenhouses for growing vegetables, so that won't be necessary anymore to buy them from El Calafate.
Also outdoors activities that you can now find in El Chalten could be extended here to maintain the areas connected. Activities like cross country skiing and ice trekking, but not in a massive way. Another idea could be puma sightseeing. You need a good relationship with your neighbours, also for like food and vegetable, green houses."

Mathias Goyeneche: "I agree with the development you made. I understand that you don't want to do things really big. I think that this development is necessary in this area, it's a positive thing that tourism and economic growth comes to this area."

Andres Cucci: "There should be a duality between a return in investment and preserving the nature, a minimum development to guarantee a return"

Jaime Smart: "At the moment I don't really know how many people could live here. I imagine an area where the people can live from the Earth and bring products and services to tourists. Creating a tourism opportunity without a large environmental impact and without a large city. I don't believe in a new city here so the number has to be balanced between nature, humans, and tourists. I don't believe in a town or city like Calafate here. It has to be a new type of development. The challenge is to make a development with environmental conservation, and make it a business. The emphasis must be on a balance between business, development, and conservation."

Juan Cazenave: "I would not imagine a lot of people to live in the village, that would require the need to expand facilities. I would imagine 100 people living here. With this number of people, you would need a hospital or at least a good connection to El Calafate. You can imagine using a helicopter but the wind is an issue for landing and tit is also an expensive option. I would imagine the accessibility to be by boat and the road that connects Lake San Martin to Tres Lagos needs more maintenance, "

3. What would be the goal of your investment? (e.g. moving here, having a second house, tourism business)

Pablo Arecco: "It depends. To move here you would need facilities, also considering that I have kids. Argentina has plans to increase the number of people working in the rural areas. You can ask the Ministry of Education to open an elementary school, but you need a minimum of 7 kids per education. In the first period I see this place as a holiday location, for summer and winter holidays, also for working away. I would also consider moving 50% of the staff here for some periods. They would have a house and a working space. You would also need some shops in the area. Maybe in one plot there could be an area where to work. In Los Huemules there is an interpretation center, I think that is a good idea. There could also be an area for start up companies where they can work, for example for IT companies. Maybe there could be a connection with starlink."

Mathias Goyeneche: "I wouldn't come here to live permanently because it would be very harsh. I see this as a place where I can come with family and friends, also for a work and holiday combination, to escape the city for a while."

Andres Cucci: "Living here when it is more developed. Winter is a concern, so maybe living here for part of the year, like spring and summer."

Jaime Smart: "The goal is, of course, to live here, and to make something for my family, for my children and grandchildren."

Juan Cazenave: "The goal of my investment would be to live here and in a second moment to develop a touristic business".

4. How important is to you the environmental impact for the development of La Josefina?

Pablo Arecco: "It is very important. In my opinion one of the most valuable aspects of the area is that there is a boat access instead of a road one, it is very valuable. I don't see this as a problem. I would like to have a regular house here, as much sustainable as possible. Not made with mud but could be made with timber and stones, and should have a proper roof."

Mathias Goyeneche: "It is really important, the development shouldn't have a negative impact on the environment. The less resources you waste the better. Energy and waste management are essentials. Is also important not to impact on water resources, wild fauna and flora.

Andres Cucci: "The environmental impact is more important than the economic return."

Jaime Smart: "It's everything."

Juan Cazenave: "For me the environmental impact of the development is the most important aspect that needs to be considered."

5. After how many years do you want to break even?

Pablo Arecco: "For now it's important that the project starts. I don't have the goal of becoming richer and I don't need to have a revenue. I want to build my house and have a nice place tpo stay. I would like to recover some money, but only the part of the ones used for investing, not for buying the plot."

Mathias Goyeneche: "I am not interested in revenue, the value is the property. It would be more real estate."

Andres Cucci: "It is not important to break even."

Jaime Smart: "Between 6-10 years. In tourism, to make a new destination you need 6 years. In 6 years you can develop the tourism business. During these 6 years, you have to prepare the land and have young people come and work to build the houses and start their families here."

Juan Cazenave: "I do not care, I would expect my land to be reevaluated after the investment and that would be my return. I would consider a tourism business within my own property."

6. How many investors do you think would be appropriate for the project? and why that number?

Pablo Arecco: "The company that invested in Los Huemules was made by 300 people. They acquired 25 properties in Patagonia. For Phase one a minimum investment of 8-10 million dollars is needed. Is important that the stakeholders that invest are trustful people that share values. If you have trustworthy people, having many investors is not a problem."

Mathias Goyeneche:"The least possible, around 50 and 100 is a good number."

Andres Cucci: "Around 100 investors."

Jaime Smart: "I think that a good number would be 50 investors. With different levels of investment. One level would be investing only money, and another would be investing money and working here, and the last would be someone coming to work here without making or investing money but works in exchange for a house here over a certain period of time."

Juan Cazenave:" Fifty is ideal."

7. How much land would you expect to be yours?

Pablo Arecco: "One hectare of land would be good. I think that it is very important that a large part of the land remains to nature, for the population that comes. it can be possible to go there for things like hikes and activities in nature but it shouldn't be possible to build there. I also think that it is important to promote reforestation."

Mathias Goyeneche: "I would like to stay in a dome, and it should be far from the next one. I think 1 hectare is good, but better is already developed, not to build on it."

Andres Cucci: "One hectare."

Jaime Smart: " I don't want just a piece of land. The plots must be the size necessary to make the plots productive. For someone that just wants to build a garden, 1 hectare is ok. But a person who wants horses for horseback riding needs more space. The average should be 5 hectares. This depends on the type of investment."

8. What aspects may concern you about this project? And that could prevent you from investing in it? (e.g.accessibility)

Pablo Arecco: "There should always be a plan B for healthcare and accessibility, for how people are gonna reach the area. In my vision I don't see cars in the area, but service vessels are needed. Also fire mitigation measurements, maybe an airplane that can land on water, water access area a plan b is needed, health care and emergencies. These measurements can be discussed with gendarmerie because they have helicopters in the area for rescuing trekkers. Development shouldn't be only for rich people, but for people that want to have a better quality of life. It's important that there is a distance between the houses. "

Mathias Goyeneche: "Accessibility is a concern, might become a burden to come here in the future if it is not improved."

Andres Cucci: "Accessibility, winter extreme conditions, energy reliable sources, medical services, education for the kids."

Jaime Smart:"I think that one thing is that it is difficult to explain the project to the people of the cities. To invest in a building in a big city is easy. Here it's not. It will be difficult to explain to new investors to come here and invest to understand the project and the idea."

9. As a shareholder, what responsibilities would you be interested in having or would you prefer to give them to someone else? Such as managing and hiring staff, or do you expect someone to be hired to manage the whole property

Pablo Arecco: "I'm interested in the project, in its preparation and development."

Mathias Goyeneche: "I could help in the technical part of the project, in the development of the infrastructure. Regarding the management of tourism I would give it to someone else, but it should remain in the hands of stakeholders.

Andres Cucci: "Would be interested in having responsibilities but it's not really important.

Jaime Smart: "I don't want to manage and hire the staff. I can meet people and show them the place and share my experience."

10. Would you like to keep the existing structures yours? Or would you be okay in using the existing structures for different purposes or all/some of them you want to keep?

Jaime Smart: "He thinks that the houses can be for other people. Probably would be fine with other people living here. The domes he doesn't want to keep. Maybe in the first step we can use the domes until we construct enough of the other questions."

11. If we were to sell the hotel what companies could be interested?

Jaime Smart: "Explora in Condor. Awacsi for competence. I don't know we have to look at other hotels in these remote places. Maybe in Calafate Eolos would be a good example."

C.2 Population: tourists

C.2.1 El Chaltén

In the following section the full interview with Rolando Garibotti can be found.
Rolando Garibotti is an alpine guide that worked in the region for many years and knows the area very well. Here is the interview that was held.

1. What do you know about tourism and its development in the area between El Calafate, El Chaltén and Lago San Martín?

Rolando Garibotti: "Nestor Kirchner and his wife, had been respectively presidents of Argentina between 2003 and 2015. They lived in the Santa Cruz region and for this reason a lot of money was sent to this province, which currently has only around 300 thousand inhabitants. A lot of money was invested to improve infrastructures and streets in the Patagonia region, such as the airport in El Calafate. One of the projects consisted of building a connection between Chile and Argentina, more specifically between Candelario Mancilla and El Chalten, but this project was never concluded. Outside national parks, in the part of the Laguna del Desierto the paths are private. A law that regulates the accessibility is needed, because at the moment it's up to the owners to decide if tourists can go there or not. Chile under Allende and Pinochet witnessed a redistribution of the land. Argentina has never redistributed land since the time of the landowners who exterminated the Native Americans. In Argentina apart from the National Parks the land is mostly private."

2. What do you think are the main environmental threats that unregulated tourism could cause in this area?

Rolando Garibotti: "Erosion Problem and insufficient number of workers: The land in the El Chaltén area is experiencing severe erosion due to high tourist traffic. The most famous trail, Laguna de Los Tres, is poorly maintained, with visible erosion lines. Currently, the trail crew consists of only 8 people, which is insufficient for managing the volume of visitors. There should be better measures in place to prevent soil erosion and protect the environment. Inadequate Sanitation: El Chaltén receives around 150,000 tourists annually, many of whom use the trails where there are no proper toilets. Feces are often left untreated, buried in an anaerobic environment that lacks the necessary organic activity for proper degradation and pathogen removal. This creates an urgent need for appropriate waste management solutions along the trails. There have been developments like an airport and streets but not basics like feces treatments."

3. Have you ever witnessed a negative impact of tourism on nature or the local community? What do you think could have been done differently?

Rolando Garibotti: "The negative impact in this region is not directly caused by tourism, but rather by poor management practices in farming. The mismanagement of cows, sheep, and their manure, as well as energy usage, have caused harm to the environment. While tourists tend to stick to designated paths, overgrazing from livestock has severely degraded the land, reducing the organic layer to just a mineral one. Sustainable tourism, if well-managed, wouldn't have the same destructive consequences as farming and cuttle."

4. How do you think a sustainable village can integrate into the tourism dynamic of this region without harming the ecosystem?

Rolando Garibotti: "A sustainable village could fit well into the region without damaging the environment. The real harm has come from farming, particularly overgrazing, which destroys ecosystems. Tourism has a more localized impact, usually limited to certain paths and areas. Farming, on the other hand, causes widespread destruction as animals move freely and graze on everything. From an environmental standpoint, I don't see any opposition to the idea of a sustainable village."

5. What services or infrastructure do you believe are necessary to support sustainable tourism in the long term without overburdening local resources?

Rolando Garibotti: "As I said before proper paths in order to avoid the problems of erosion are essentials, as well as proper toilets along the path. Urine-diverting toilets are ideal in this case. Some innovative designs are the ones from the companies:

- Ecodomeo (France): This system uses a pedal to move feces uphill on a belt, preventing them from being visible to the next user, thus maintaining hygiene and comfort.
- Toilet Tech (Canada): A North American company distributing sustainable toilet products, including urine-diverting systems.
- Clivus Multrum (Sweden): A well-known composting toilet system that efficiently manages waste.

Also an interesting Case Study is the Switzerland Mönchsjochhütte in Switzerland. This mountain hut uses innovative sanitation systems in a high-altitude environment, showcasing sustainable waste management in remote locations."

6. How could a sustainable village collaborate with the local community and promote environmentally friendly tourism?

Rolando Garibotti: "We have to imagine a connection by ferry with both the Chilean side and the Argentine one. Make a connection with El Chalten. The tourists there are normal tourists, there are not anymore backpackers and trekkers. We have to create new paths that attract that type of more adventurous tourists. The current path isn't in good condition on the Argentine side, it is a wetland. An education for the tourists is needed, along with a control and maintenance of the path. Also a national regulation to support the owners of the paths. National parks in the Chilean and Argentine part are positive but the most positive thing would be provincial laws that help to regulate lands and give rights of accessibility to the lands. This would give wide territorial accessibility and not be punctual as a national park. Individuals need help to do this, at the moment the discharge of responsibility is on them."

7. Do you think the area of El Chaltén can become an example of sustainable tourism for other regions? If so, how?

Rolando Garibotti: "The tourism changed in that region, it isn't anymore the same that it was before. Now there is overtourism. If you go to La laguna de Los Tres there are more or less 2000/2500 people every day. They go to Parco Patagonia and in the Chilean part. They also go to Vuelta al Huemul, is a trekking path in El Chalten. Touristic routes are missing for the adventure seeker type of tourists. El Chalten isn't a favorable destination anymore. There has been a massification of tourism. Now 90/95% of the tourists that go to El Chalten have some walks in the valley but they don't go further. They don't move around backpacking, they just stay there and have walks. They also do the W Circuit in Torres del Paine in 3-4 days. A more adventurous type of tourist is the one that goes to Villa O'Higgins. El Chalten has many natural attractions that attract tourists. Villa O'Higgins put things to offer to tourists. To bring tourism you need subjectivity. In addition to the natural beauties of the city, it is an imaginary vision that attracts tourists. There is a nice example in Sardinia: they created a trekking path called 'Sentiero Blu', the name is catchy, you have to sell an identity, a brand. Tourists in Torre del Paine used to do two paths: the W and another one, but they can't do this anymore because it has become too expensive, there are too many people and you have to book it in advance."

8. If you could change one thing in the current management of tourism in this area, what would it be?

Rolando Garibotti: "In my opinion there are three main problems: 1- Environmental problems: in Los Glaciares it is about the animals. They were abandoned 50-60 years ago in the park, and now they destroy the wood because they are not controlled. 2- In El Chalten the electrical energy is still provided by a diesel engine, and this pollutes a lot. There are two big rivers that could be used. 3- The wastewater treatment plant was planned to be able to serve 5 thousand people. Wastewater instead of staying there for 36 hours, is treated for only 4 hours. Water was contaminated with E.Coli and Salmonella. This water goes to the lake Voerma and leaves the village. This is a problem that the government has to tackle. Along with tourism also basic services needs to be developed."

C.2.2 El Calafate

The following tables were constructed using the data that were found on Turismo Santa Cruz, 2018. The passengers arriving at the airport of El Calafate were interviewed regarding their nationality, the accommodation they booked and the length of their stay.

C.2.3 Villa O'Higgins

The data regarding the tourists travelling to Villa O'Higgins were gathered by contacting the Municipality of the town. They provided the data they collected during the years 2023 and 2024, where they noted down the nationality, the transportation mode and the date of arrival in the town. Data prior year 2023 weren't accessible since they hadn't been recorded in a digital form.

Passengers	**Summer 2022**	**Winter 2022**	**Summer 2023**	**Winter 2023**	**Summer 2024**	**Winter 2024**
Total passengers embarked		18,324	45,289	21,118	52,448	21,018
National travelers (%)	84	74	59	66	51	42,5
Foreign travelers (%)	16	26	41	34	49	57,5
Average lenght of stay (nights)	4,16	4,7	3,9	4,1	3,5	3,6

Table C.1: Tourists' overview in El Calafate from 2022 to 2024

Accomodation	**Summer 2022**	**Winter 2022**	**Summer 2023**	**Winter 2023**	**Summer 2024**	**Winter 2024**
4-5 star hotels (%)	32	36	30	39	29	37
1-3 star hotels (%)	23	22	27	23	32	25
Hostel/Second house/Hosteria (%)	31	28	28	20	15	10
Cottage/Airbnb (%)	11	13	14	18	14	20

Table C.2: Accomodation's preferences of tourists in El Calafate from 2022 to 2024

The total number of tourists in the year 2023 was 6772, while in 2024 was 5859. Information regarded the amount of people interested in crossing the border was asked and it was discovered that about 3,000 people every year cross the border between Chile and Argentina in the town of Villa O'Higgins. This border, as the one in Candelario Mancilla, located as well along Lago San Martin, is open only between the months of October and April.

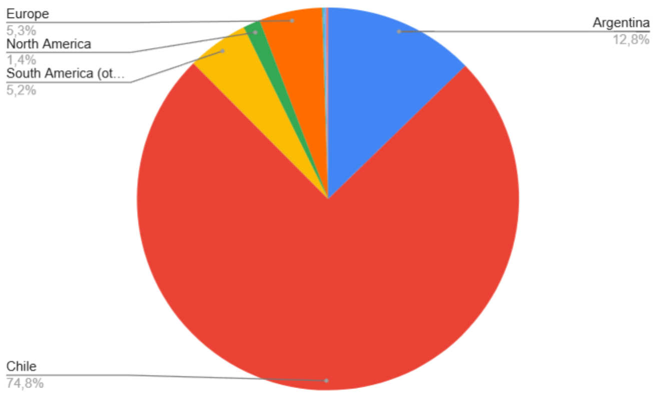


Figure C.1: Nationality of the tourists between 2023 and 2024

Figure C.1 shows the nationality of the tourists that travelled to Villa O'Higgins in the years 2023 and 2024. As expected, the vast majority of the travellers are from Chile, followed by Argentina. The type of transport that was used to reach the town was mainly cars and buses. A small part of them used bikes or got there by hiking and walking.

C.3 Neighbouring Properties

In the following section the full interview with the owners of Cancha Rayada can be found. Cancha Rayada is a direct neighbour of Estancia La Josefina. Here is the interview that was held.

1. What is your vision for the development of the area?

Cancha Rayada's owners: "It would be an interesting development if it include a well designed sustainable development."

2. How do you see La Josefina's development impacting the surrounding area and community?

Cancha Rayada's owners: "For sure the development will impact the surrounding areas. The level of the impact will depend on the design itself. The development of La Josefina could reflect a positive impact on the surrounding estancias for example by implementing medical care and first aid in the area, or by improving maintenance on the road that connects Tres Lagos to the estancias. Also some negative impacts could occur such as the environmental impact."

3. Do you see opportunities for collaboration between your estancia and the proposed project?

Cancha Rayada's owners: "Yes. It is important to have good relationship between neighbouring estancias. If the project is well structured, I will be interested in a collaboration."

4. How important is the environmental impact for you in the development of La Josefina?

Cancha Rayada's owners: "Really important. It should be the main aspect to keep in mind during the development."

5. Do you have preferences between low-impact, luxury, or adventure tourism? How do you think these preferences would blend with the environment of Lake San Martin?

Cancha Rayada's owners: "Adventure tourism is the one to prefer because it suits better the area of Lago San Martin. I do not think that luxury tourism in this area is possible right now."

6. What are your main concerns regarding this project? For instance, are you worried about issues like accessibility challenges, potential environmental impacts, or a high volume of visitors?

Cancha Rayada's owners: "The only way to make the project sustainable is having the right investors who aligns with the vision of it. I would prefer to avoid frequent traffic through my property and would recommend considering alternative routes, such as the one near gendarmeria Lago San Martin, adjacent to Estancia Maipu. In the past in the estancia we encountered problems with wind and solar energy so a solid plan and maintenance is needed."

7. Would you consider the development of a similar project on your estancia? If no, why not?

Cancha Rayada's owners: "Probably not because the wildness of these areas has an unique beauty. If the development of tourism is compatible with preserving the wildness I could maybe consider it."

8. Are you interested in investing in the project? If yes, why? If not, what would make this project attractive to you as an investment opportunity?

Cancha Rayada's owners: "I am interested, given that Estancia La Josefina is near our own estancia. If I would ever invest in this project it would be only if it is promising and the objective of it would not only be a return of investment but a sustainable development of the area. However, I am concerned about the level of government support, as the Argentine side of the lake is considerably less developed than the Chilean side, particularly in terms of infrastructure like first aid services and airports, which suggests a limited government interest in supporting such developments."

D | Preliminary masterplan

D.1 Descriptions of Buildings in the Preliminary Masterplan

This section provides detailed descriptions of the main buildings and facilities included in the preliminary masterplan for the eco-tourism village. Each structure has been designed with specific functions in mind to meet the needs of visitors and residents while promoting sustainable practices.

Public service centre

The entrance building serves as the main reception area, hosting the front desk and information point for tourists. It includes a post office, fire safety room, cafe, grocery room, medical clinic, and essential storage for items like medicine and gas. The structure consists of three prefab timber blocks, each 90 m^2. The building also contains a small bathroom and features an indoor garden that uses greywater from the sink for irrigation.

Hostel

The hostel features multiple rooms, each accommodating up to 6 guests. Each room includes a shared bathroom. This design prioritizes communal lodging for budget-friendly eco-tourism.

Campsite

The campsite provides 7 individual spots for tents, available for rent on a per-person basis, with camping equipment available for rental. A shared facility includes two bathrooms (one for men and one for women), each equipped with 2 toilets, 2 showers, and 2 sinks.

Family cottages

Constructed from structural timber and cob, each family cottage includes a private bathroom. Notable imported components include windows, structural timber, and sanitary facilities.

Couple cottages

Similar to family cottages, the couple cottages are made of structural timber and cob and feature private bathrooms. Imported components include windows, structural timber, and sanitary fixtures.

Family luxury lodges

These family luxury lodges are modular timber and glass lodges offering luxury amenities such as jacuzzis and terraces. Each lodge accommodates up to four people.

Couple luxury lodges

The couple luxury lodges, made from timber and glass, feature luxury facilities such as jacuzzis and terraces. Each lodge accommodates up to two people within 60 m^2.

Permanent plots

Each plot covers 1 hectare of land, prepared for custom construction by plot owners, who must adhere to village construction guidelines.

Jetties

The jetties are designed to facilitate access to the lake, supporting eco-tourism activities and improving site accessibility by water.

Emergency helicopter pad

A dedicated helicopter pad is planned for emergency use, ensuring rapid response capabilities.

Warehouse

This large storage space, built from two prefab timber blocks (90 m^2 each), is intended to store food and other essentials for the community.

Waste collection room

This facility includes separate sections for recycling and organic compost.

Common rooms for hostel and campsite

The shared common areas for hostel and campsite guests are located in previously existing structures and include a kitchen and lobby space, laundry and storage.

Administration building + restaurant for luxury lodges

These common areas for luxury guests include six 90 m^2 prefab timber blocks. A 270 m^2 area serves as the luxury restaurant (dining area, kitchen, and storage), and a 270 m^2 space serves as the lobby and lounge.

Administration building + restaurant for cottages

Designed for cottage guests, these common areas includes four 90 m^2 prefab timber blocks. The restaurant and kitchen cover 180 m^2, with an additional 180 m^2 for the lobby, common area, and storage.

Staff rooms

The staff rooms are designed for individual staff members, featuring single beds and private toilets, and are built from sustainable cob material.

Staff common rooms

The common area for staff is constructed using one prefabricated timber block. This shared space includes a kitchen, a living area, and laundry facilities.

Staff plots

Similar to the permanent plots provided for residents, these staff plots are slightly smaller, covering 0.75 hectares each. Long-term staff members have the opportunity to construct their own homes on these plots, adhering to village construction guidelines.

Greenhouses

The greenhouses are designed and sized based on the agricultural population demand within each zone.

D.2 Verification of accommodation areas

In this section, preliminary internal layouts for the various accommodation types used in the preliminary masterplan are presented. These layouts were developed to assess the adequacy of the space allocated for each accommodation type within the proposed design. The goal was to verify that the footprints of these structures on-site are sufficient to meet the functional and spatial requirements.

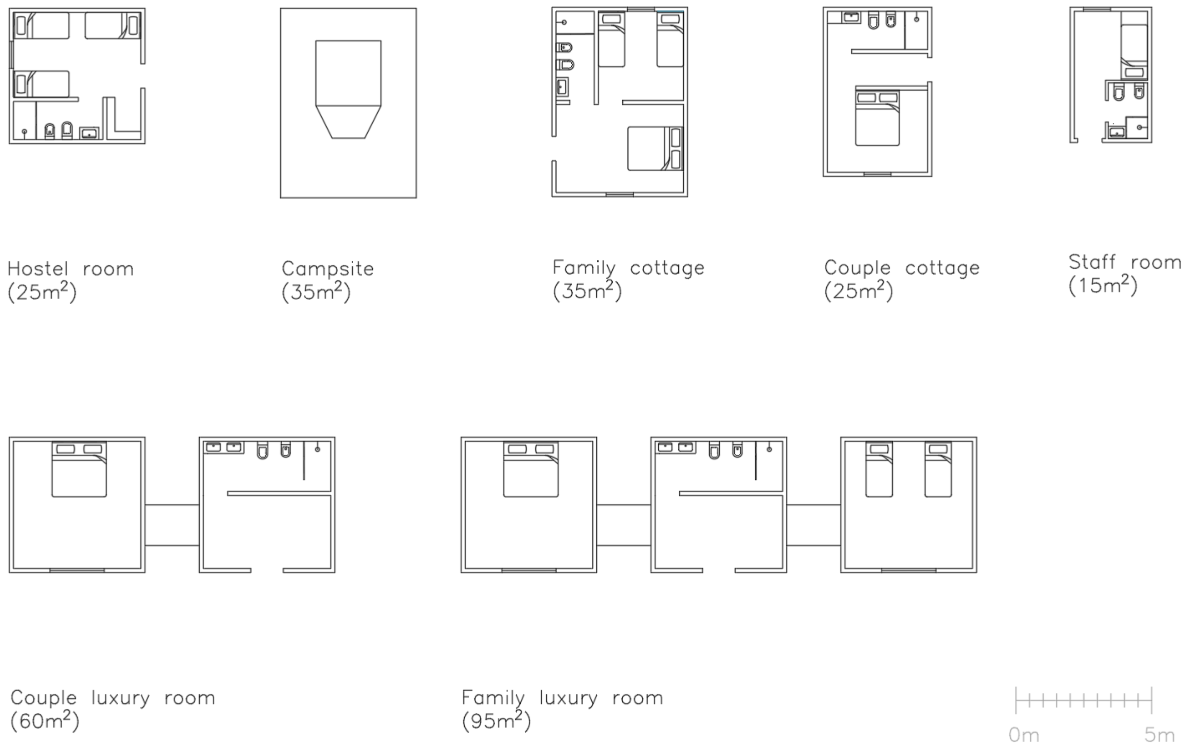


Figure D.1: Preliminary accommodation internal layouts

D.3 Model of proposed development

To better understand and visualise the potential visual impact of the proposed structures on the site, a 3D digital model was created. This model incorporates the site terrain, providing a conceptual representation of how the massing of the buildings will look within the existing landscape.

Figure D.2: 3d model of development zone

Figure D.3: 3d of east side development

Figure D.4: 3d model of west side development

D.4 Detailed Construction Phases

First Construction Stage (Years 1-5): Infrastructure, Preparation, and Basic Services

- **Year 1**:
  - Expenses: Bureaucratic approvals, 1 hostel room, 2 couple cottages, 20% staff housing, marine infrastructure (primary and internal jetty), water storage, purchasing 50% of the property.
  - Revenue: Pre-launch sales (2 plots).
  - Milestones: Land preparation, jetty constructions.

- **Year 2**:
  - Expenses: Completion of campsite and bathroom house, 50% common area (camping + hostel with kitchen), 40% staff housing (60% total), 20% energy systems, entrance facilities.
  - Revenue: Pre-launch sales (2 plots).
  - Milestones: Emergency helicopter path setup, basic services for camping and trekking paths.
- **Year 3**:
  - Expenses: 1 hostel room, 100% common area, 20% restaurant and common area (40% total), 20% staff housing (80% total), 20% energy systems.
  - Revenue: Pre-launch sales (2 plots).
  - Milestones: Completion of camping and hostels.
- **Year 4**:
  - Expenses: 1 hostel room, 40% restaurant and common area (80% total), emergency helicopter path, 20% energy systems (60% total).
  - Revenue: Pre-launch sales (2 plots).
  - Milestones: Completion of key amenities for early occupancy.
- **Year 5**:
  - Expenses: 1 family cottage, 100% restaurant and common area, 20% energy systems (80% total), 10% property purchasing (90% total).
  - Revenue: Pre-launch sales (2 plots).
  - Milestones: Transition to the second stage.

Second Construction Stage (Years 6-10): Expand Accommodation and Activities

- **Year 6**:
  - Expenses: 3 family cottages (50% total), 8 couple cottages (70% total), 20% energy systems (100% total), 10% property purchasing (100% total).
  - Revenue: Start hotel concessions, selling plots (8 sold).
  - Milestones: Completion of primary accommodations.
- **Years 7-10**:
  - Expenses: Continue expansion of accommodations and complete key facilities.
  - Revenue: Ongoing revenue from hotel concessions and plot sales.
  - Milestones: Construction of International jetty and finalization of energy systems.

Third Construction Stage (Years 11-15): Permanent Plots

- **Year 11**:
  - Expenses: 2 family cottages.
  - Revenue: Plot sales (5 plots).
  - Milestones: Continued expansion of eco-friendly accommodations.
- **Year 12**:
  - Expenses: 1 couple cottage.
  - Revenue: Ongoing plot sales.
  - Milestones: Ongoing hut development.
- **Year 13**:

  - Expenses: 1 family cottage.
  - Revenue: Ongoing plot sales.
  - Milestones: Ongoing hut development.

- **Year 14**:
  - Expenses: 1 couple cottage.
  - Revenue: Ongoing plot sales.
  - Milestones: Ongoing hut development.

- **Year 15**:
  - Expenses: 1 couple cottage.
  - Revenue: Ongoing plot sales.
  - Milestones: Ongoing hut development.

Fourth Construction Stage (Years 16-20): Final Touches and Expansion of Services

- **Year 16**:
  - Expenses: 1 family cottage (100% total), final phases of energy systems.
  - Revenue: Plot sales (5 plots).
  - Milestones: Project closeout preparations.

- **Years 17-20**:
  - Expenses: Final adjustments to accommodations.
  - Revenue: Ongoing plot sales.
  - Milestones: Full occupancy readiness and completion of the project.

This phased approach provides a clear pathway for gradual development and income generation, balancing construction costs with revenue from sales and concessions to ensure a sustainable project timeline.

E | Improvement of Accessibility

This annex provides a comprehensive overview of the calculations and parameter definitions essential for conducting the dynamic analysis of the Primary Jetty. Detailed explanations are included to improve the accessibility and understanding of the analytical processes and technical requirements involved in this analysis.

E.1 Floating structure material specifications

In the table below some specifications about the interconnected blocks that form the floating structure of the jetty are given:

Description	Details
Block Dimensions	50x100 cm (side) x 40 cm; 2 cubes = 1 m² 50x50 cm (side) x 40 cm; 4 cubes = 1 m²
Weight	Approx. 11.50 kg per double cube, 6 kg per single cube
Material	High-Density Polyethylene (HDPE)
UV Protection	UV-resistant plastic for weather and UV protection
Colors	Blue, Beige, or Gray
Buoyancy Capacity	350 kg per m² for single layer
Wave Resistance	Modular system, strong yet flexible, tested for installations in open sea, nearshore, lakes, and rivers, up to 150 cm waves (depending on anchorage)
Maintenance	Low maintenance; clean occasionally with a pressure washer
Installation	Easy and quick installation; all components are lightweight and easy to handle
Recyclable	100% recyclable
Temperature Resistance	Resists from -55° to +75° without deformation or alteration
Additional Features	Resistant to saltwater, acids, and sunlight. High impact resistance and elasticity. No sharp edges or corners.

Table E.1: Technical Specifications of CubeDocks

E.2 Gangway material specifications

In the table below some specifications about the aluminium used for the construction of the gangway of the jetty are given:

Property	**Value**
Density	2.70 kg/m^3
Melting Point	605 °C
Thermal Expansion	24×10^{-6} /K
Modulus of Elasticity	70 GPa
Thermal Conductivity	188 W/m.K
Electrical Resistivity	$0.034 \times 10^{-6}\,\Omega \cdot m$

Table E.2: Aluminium Alloy 6005A - T6 Material Properties (thyssenkrupp Materials (UK) Ltd, 2016)

E.3 Dimensions of vessels

The following section outlines several types of vessels considered to determine the maximum length for the preliminary design of the Primary Jetty. This design will support a range of uses, from tourism to cargo transport. Three vessel types were selected based on similar vessels in use at nearby locations, such as Puerto Bahamondes and Candelario Mancilla, as well as vessels suitable for the needs at La Josefina:

- **Small Cargo Vessel -** for transporting materials and goods.
- **Motorboat -** for internal connectivity between the estancia and logistics.
- **Small Ferry -** for tourism purposes.

For these vessel types, reference was made to both existing boats and suitable models that would offer stability on routes that may be long and encounter challenging conditions, such as the probable future embarking point at Gendarmería Lago San Martín (see Chapter 10.1). Observations from Google Maps provided approximate dimensions for the vessels currently operating between Puerto Bahamondes and Candelario Mancilla.
Dimensions of Example Vessels:

- **Vessels in Use between Puerto Bahamondes and Candelario Mancilla**
  - **Small Cargo Vessel**
    - Length: approximately 15 meters.

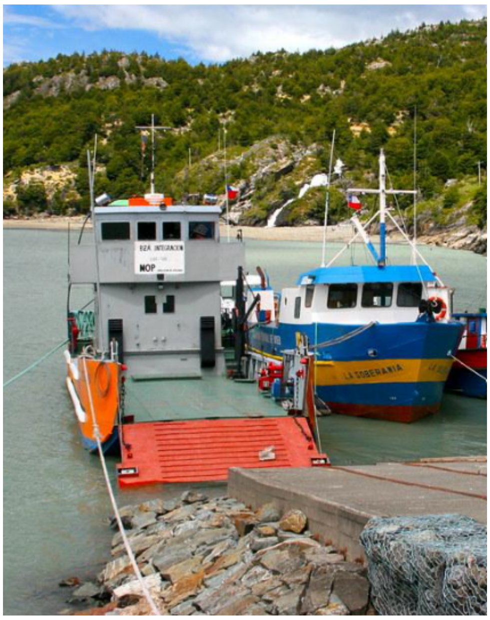


Figure E.1: Small Cargo Vessel

  - **Small Ferry**
    - Length: typically between 13 and 15 meters.

Figure E.2: Small Ferry

- **Similar Vessels in Use at La Josefina**
  - **Track 13 Baader** ("Barco 13.00m Baader Track Pesca Artesanal, Trabajo Especial", n.d.)
    - Length: 13.00 meters
    - Beam: 3.65 meters
    - Draft: 1.40 meters
    - Capacity: 18 people

Figure E.3: Track 13 Baader

  - **Track 7.8** ("Tracker Cabinado 7.80 Baader Track,reforzado, Pesca,trabajo", n.d.)
    - Length: 7.80 meters
    - Beam: 2.25 meters
    - Draft: 0.95 meters
    - Capacity: 10 people

Figure E.4: Track 7.8

- **Vessels Suitable for Tourist Transport**
  - **Lancha de Madeira** ("Lancha De Madera Colectiva", n.d.)
    - Length: 11.8 meters
    - Beam: 2.78 meters
    - Capacity: estimated around 20 people

Figure E.5: Lancha de Madeira

- **Touring 48 Ferry** ("Passenger boat Touring 48 Ferry", n.d.)
  - Length: 14.5 meters
  - Beam: 3.91 meters
  - Draft: 0.8 meters
  - Capacity: 48 people

Figure E.6: Touring 48 Ferry

Based on this analysis, a passenger vessel capable of carrying approximately 45 people, or a ferry for transporting materials, with a length of up to 15 meters, was selected as the maximum vessel size for the design requirements of the Primary Jetty. These specifications ensure that the jetty can accommodate various vessel types while aligning with the operational needs at La Josefina.
From PIANC guidelines also the following tables should be considered for verifying if the draft and the beam of the vessel are within the recommendation of the code.

Vessel type	Typical characteristics [1]		
	Length Overall	Draft	Beam
Day boat (motor)	< 10 m	< 1 m	< 4 m
Day boat (sail)		< 2 m	< 4 m
Small cruising (motor)	10-15 m	< 1.5 m	< 5 m
Small cruising (sail)		< 3 m	< 5 m
Large cruising (motor)	15-20 m	< 2 m	< 6.5 m
Large cruising (sail)		< 3.5 m	< 6 m
Luxury (motor)	20-25 m	< 2 m	< 7 m
Luxury (sail)		< 4 m	< 7 m
Super-yacht [2]	> 25 m	See note 2	

[1] Typical characteristics apply to mono-hull vessels only.
[2] For specific guidance relating to superyacht, megayacht and gigayacht vessel characteristics the designer should refer to PIANC RecCom Report No. 134 – 'Design and Operational Guidelines for Superyacht Facilities' (2013).

Table 4-1: Typical vessels covered by this guidance

Figure E.7: Typical Vessel Dimensioning

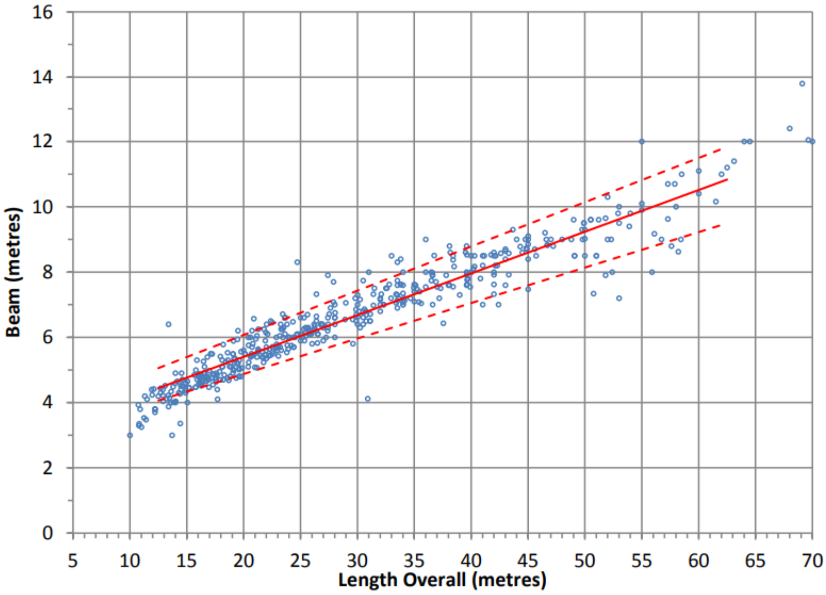


Figure 4-1: Beam to Length Overall Relationship (motorboats)

Figure E.8: Beam to Length Ratio for Motorboats

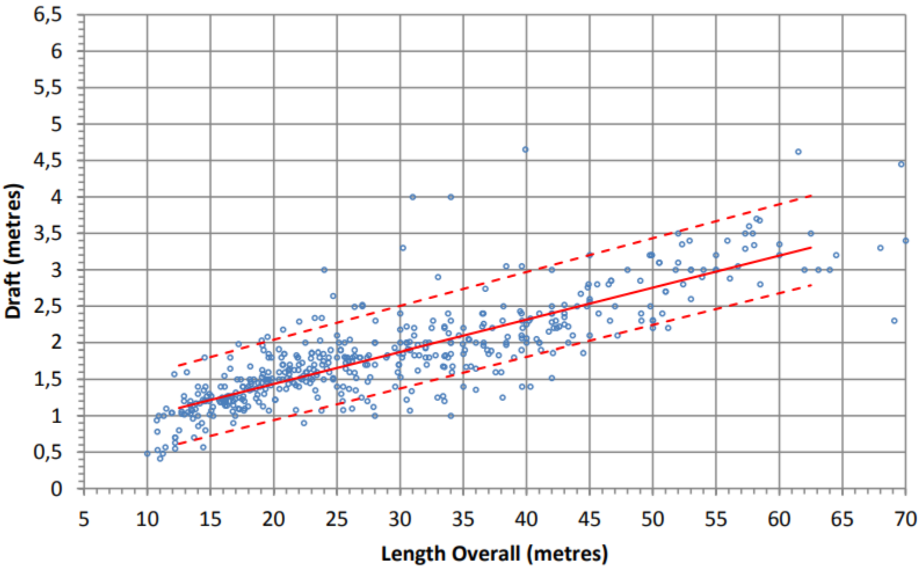


Figure 4-3: Draft to Length Overall Relationship (motorboats)

Figure E.9: Draft to Length Ratio for Motorboats

E.4 Wind load on fixed structure of Primary Jetty

This section follows the Australian Code (Global, 2010) to determine the wind load acting on the fixed structure of the Primary Jetty.
The wind pressure q_z is calculated from the design wind speed U_{10} (in m/s) using the equation:

$$q_z = 0.0006 \times U_{10}^2$$

Given that the design wind speed U_{10} is 10.786 m/s (from Annex A.9), the wind pressure q_z becomes:

$$q_z = 0.0006 \times (10.786)^2 = 0.0699\,\text{kPa}$$

With q_z known, the wind force F_D in the wind direction can be calculated using the drag coefficient C_D, the projected area A, and q_z:

$$F_D = C_D \times A \times q_z$$

For a cylindrical pile, the projected area facing the wind is calculated as:

$$A = D \times L$$

where:

- $D = 0.3\,\text{m}$ - diameter of the pile (see Chapter 10.2.4).
- $L = 3.4\,\text{m}$ - maximum length exposed to wind, based on low tide.

To ensure a conservative estimate, we apply this maximum length to all columns, even though this only represents the maximum exposure possible for the longest columns. This approach results in a higher projected area and, consequently, a higher wind force than might actually act on shorter columns, providing an additional safety margin in the design.
The drag coefficient C_D for a cylindrical shape is taken as 1.2 based on Table E.10.

TABLE 4.3

TYPICAL DRAG COEFFICIENTS

Vessel or structure	Coefficient of drag (C_D)
Vessels —Bow to wind —Stern to wind —Beam to wind	 0.7 to 0.9 0.9 to 1.1 0.9 to 1.1
Tubular piles	1.2
Rectangular members	2.0

Figure E.10: Typical drag coefficients for cylindrical structures

Substituting the values of C_D, A, and q_z:

$$F_D = 1.2 \times 1.02 \times 0.0699 = 0.0855\,\text{kN}$$

Therefore, the calculated wind force acting horizontally on each pile is approximately:

$$F_D = 0.0855\,\text{kN}$$

This force should be applied at the midpoint of the pile's exposed length (i.e., at $\frac{3.4}{2} = 1.7\,\text{m}$ from the base) to represent the wind load distribution accurately.

E.5 Static loading verification

E.5.1 Buckling of piles

Assuming that the pile is fixed at both ends, the effective length factor $k = 1$. Considering the longest pile, the actual length of the pile is $L = 6\,\text{m}$, so the buckling length L_b is:

$$L_b = k \times L = 1 \times 6\,\text{m} = 6\,\text{m}$$

To calculate the critical buckling load P_{cr}, the following formula is used:

$$P_{\text{cr}} = \frac{\pi^2 EI}{L_b^2}$$

Where:

- P_{cr} is the critical buckling load,
- $E = 8.19 \times 10^9\,\text{Pa}$ is the modulus of elasticity for Lenga wood (air-dried),
- I is the moment of inertia of the pile's cross-section (for a circular pile),
- $L_b = 6\,\text{m}$ is the buckling length.

The pile has a circular cross-section with a diameter $d = 0.3\,\text{m}$. The moment of inertia for a circular cross-section is given by:

$$I = \frac{\pi d^4}{64}$$

Substituting $d = 0.3\,\text{m}$:

$$I = \frac{\pi (0.3)^4}{64} = 3.976 \times 10^{-4}\,\text{m}^4$$

Substituting the values into the critical buckling load formula:

$$P_{\text{cr}} = \frac{\pi^2 \times 8.19 \times 10^9 \times 3.976 \times 10^{-4}}{(6)^2}$$

$$P_{\text{cr}} \approx 8.92 \times 10^5\,\text{N} \approx 892\,\text{kN}$$

Thus, the critical buckling load for the pile is approximately 892 kN.

The stress in the pile calculated from Abaqus is $\sigma = 3.9\,\text{MPa}$. To ensure that the stress is less than the critical buckling load, applied load is compared with the pile's critical load.

The stress in the column is given by:

$$\sigma = \frac{P_{\text{applied}}}{A}$$

Where:

- P_{applied} is the applied load on the pile,
- A is the cross-sectional area of the pile.

For a circular pile, the cross-sectional area A is given by:

$$A = \frac{\pi d^2}{4}$$

Substituting $d = 0.3\,\text{m}$:

$$A = \frac{\pi (0.3)^2}{4} = 0.0707\,\text{m}^2$$

Rearranging the stress equation to find the applied load P_{applied}:

$$P_{\text{applied}} = \sigma \times A = 3.9\,\text{MPa} \times 0.0707\,\text{m}^2$$

$$P_{\text{applied}} = 3.9 \times 10^6\,\text{N/m}^2 \times 0.0707\,\text{m}^2 = 275,730\,\text{N} \approx 276\,\text{kN}$$

Now, we compare the applied load P_{applied} with the critical buckling load P_{cr}:

$$P_{\text{applied}} = 276\,\text{kN} < P_{\text{cr}} = 892\,\text{kN}$$

Since the applied load is much less than the critical buckling load, the pile will not fail due to buckling.

E.5.2 Beam stress analysis

The flexural strength σ_f of Lenga wood (air-dried) is given as:

$$\sigma_f = 489\,\text{kg/cm}^2 = 4.89\,\text{MPa}$$

This value represents the maximum bending stress that the material can withstand before failure due to bending.

The maximum bending stress σ_{max} obtained from the Abaqus model under the applied loads is:

$$\sigma_{\text{max}} = 2.96\,\text{MPa}$$

Comparing the calculated maximum bending stress from Abaqus with the flexural strength of the material:

$$\sigma_{\text{max}} = 3.5\,\text{MPa} < \sigma_f = 4.89\,\text{MPa}$$

Since the maximum bending stress is less than the flexural strength of the material, the beam is considered to be safe under the given loading condition. If the maximum bending stress exceeds the flexural strength, the beam would be at risk of failure due to bending, and design modifications may be necessary.

E.5.3 Beam deflection

For a preliminary calculation of the maximum permissible deflection of a beam subjected to a point load, we use the following rule of thumb formula based on the span L:

$$\delta_{\text{max}} = \frac{L}{360}$$

Where:

- $L = 4\,\text{m}$ is the length of the beam,
- δ_{max} is the maximum permissible deflection.

Substituting the values:

$$\delta_{\text{max}} = \frac{4}{360} = 11.1\,\text{mm}$$

This value represents the maximum allowable deflection for the beam when subjected to a point load according to the $\frac{L}{360}$ rule. This was chosen over the equation for a distributed load since point loads on a simply supported beam typically causes the highest deflection because the load is concentrated at a single location. This result is compared with the deflection obtained from the finite element analysis model in Abaqus. The deflection calculated from the model is:

$$\delta_{\text{model}} = 7.5\,\text{mm}$$

The deflection obtained from the Abaqus model is less than the maximum permissible deflection of 11.1 mm. Therefore, the deflection in the model is within the acceptable limits and the beam is considered to perform within the required deflection criteria.

E.6 Fetch

In this section, the worst-case scenario for the North-West fetch is presented:

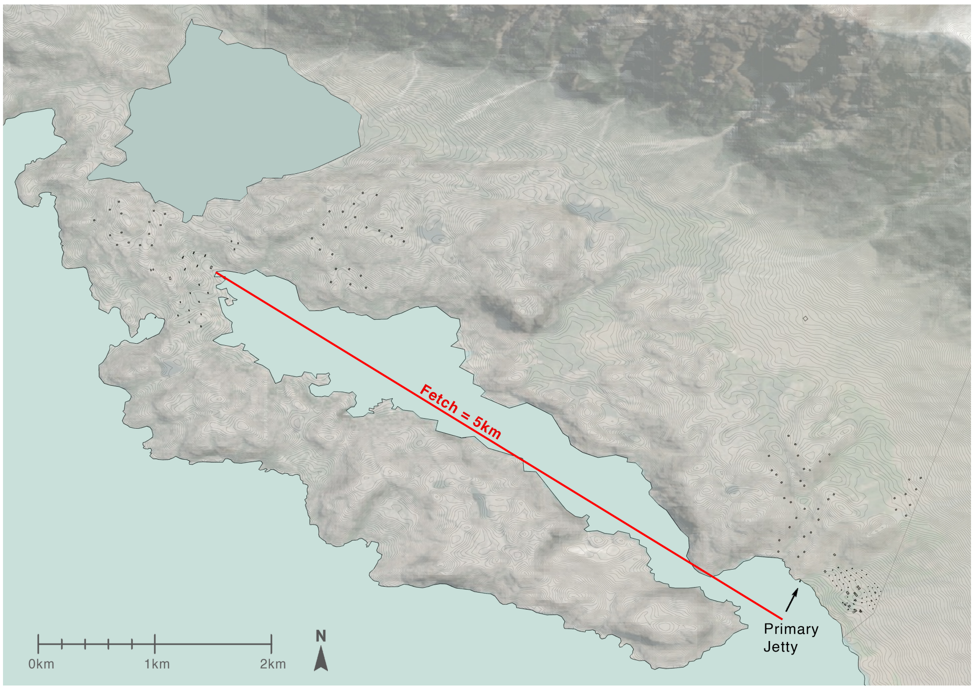


Figure E.11: Calculation of fetch for primary jetty

Although this direction is not perfectly aligned with the prevailing wind, it still represents the most critical fetch due to the diffraction properties of the waves. This is because the jetty is positioned in a bay, which effectively reduces the precise fetch distance. However, the diffraction effect still results in significant wave propagation from this direction, making it the worst-case scenario for wave impact on the jetty.

E.7 Wave Cyclic Load on Fixed Structure of Primary Jetty

Waves exert cyclic loads on structures, influenced by various factors such as wind speed, fetch, and the wave spectrum. This section focuses on the wave loads on the Primary Jetty using the JONSWAP spectrum and the Morison equation, which are widely used to model the forces exerted by waves on submerged or semi-submerged structures. The analysis aims to evaluate the cyclic wave forces that may impact the structural stability and design of the jetty following the theory of P. Meijers (2023).

E.7.1 JONSWAP Spectrum and Wave Characteristics

The JONSWAP (Joint North Sea Wave Project) spectrum is often employed in cases where waves have not yet reached a fully developed state. It takes into account the effect of fetch, which is the distance over which the wind blows, influencing wave growth. This spectrum is especially useful for irregular wave conditions commonly observed in real-life environments.
The following coefficients and non-dimensional parameters are central to the JONSWAP spectrum:

$$\tilde{f}_p = \frac{U_{10} f_p}{g}, \quad \tilde{F} = \frac{gF}{U_{10}^2}, \quad \tilde{f}_p = 3.5\tilde{F}^{-0.33}$$

where:

- U_{10} is the mean wind speed at 10 meters above the surface,
- f_p is the peak wave frequency,
- g is the acceleration due to gravity,
- F is the fetch (the distance the wind blows over the water).

By solving these relations, the peak wave frequency f_p is derived as:

$$f_p = \frac{3.5g}{(gFU_{10})^{\frac{1}{3}}}$$

The fetch F is calculated using wind maps and the prevailing wind direction, as described in Annex E.6. Using the JONSWAP spectrum, the significant wave height H_s, a key parameter in estimating wave forces, is calculated as:

$$H_s = 4\sqrt{1.67 \times 10^{-7}\frac{U_{10}^2}{g}F}$$

For the Primary Jetty scenario, the key parameters obtained are as follows:

- Reference wind speed: $U_{10} = 10.786\,\text{m/s}$,
- Fetch: $F = 5000\,\text{m}$,
- Peak wave frequency: $f_p = 0.425\,\text{Hz}$,
- Peak wave period: $T_p = 2.356\,\text{s}$,
- Significant wave height: $H_s = 0.398\,\text{m}$.

E.7.2 JONSWAP Spectrum Equation

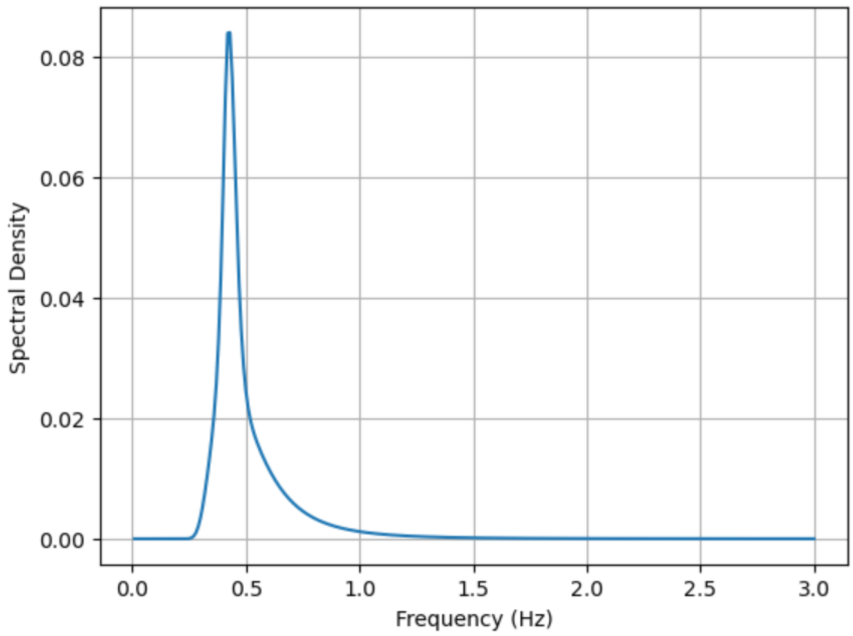
For a more detailed representation of the wave spectrum, the JONSWAP equation is used:

$$S_{JONSWAP}(f) = \alpha g^2 \frac{2\pi^{-4}}{f^5} \exp\left(-\frac{5}{4}\left(\frac{f}{f_p}\right)^{-4}\right) \gamma^{\exp\left(-\frac{1}{2}\left(\frac{\frac{f}{f_p}-1}{\sigma}\right)^2\right)}$$

where:

- $\gamma = 3.3$ is the peak enhancement factor,
- $\alpha = 0.076\tilde{F}^{-0.22}$ is a scaling factor,
- $\sigma = 0.07$ for $f \leq f_p$, and $\sigma = 0.09$ for $f > f_p$.

This equation generates the JONSWAP spectrum, which is then used to model the wave forces acting on the jetty. The following graph shows the JONSWAP spectrum generated for the given parameters:




```
Maximum S_jonswap value: 0.084
```

Figure E.12: JONSWAP Spectrum

E.7.3 Irregular Wave Time Series

Waves are often irregular and consist of a superposition of many sinusoidal waves with varying frequencies. To simulate these irregular waves, the following time series representation is used:

$$x(t) = \sum_{n=0}^{N-1} A_n \cos(2\pi f_n t + \phi_n)$$

where:

- A_n is the amplitude,
- f_n is the frequency, and
- ϕ_n is the phase.

The amplitude A_n is derived from the JONSWAP spectrum as follows:

$$A_n = \sqrt{2 S_{xx}(f_n) \Delta f}$$

This leads to the generation of an irregular wave time series, as shown below:

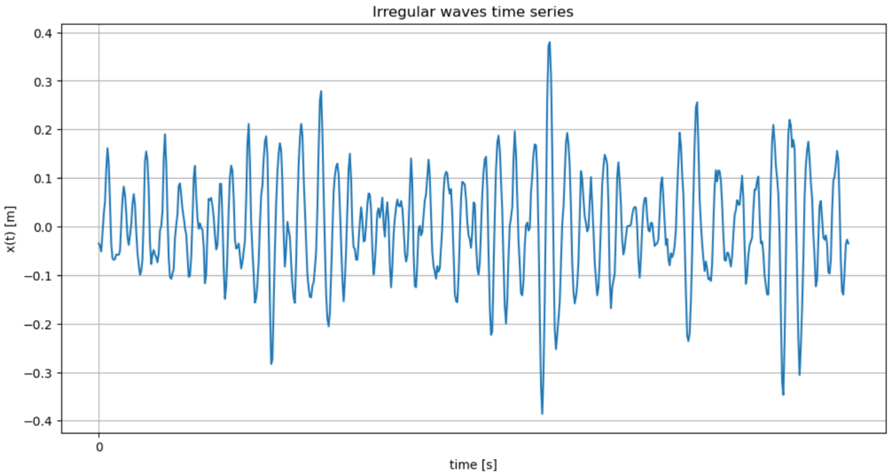


Figure E.13: Irregular Wave Time Series

The time series reflects wave heights up to 0.4 meters, which is consistent with the relatively moderate wind speed in this scenario. This result aligns with the JONSWAP spectra amplitude, where the power of the wave is not particularly high.

E.7.4 Convergence Check

To verify the accuracy of the time series and its representation of the JONSWAP spectrum, a convergence check was performed by comparing the standard deviation of the generated time series to the theoretical standard deviation calculated from the JONSWAP spectrum. The standard deviation σ is computed from the area under the JONSWAP spectrum:

$$\sigma = \sqrt{m_0} = \sqrt{\int_0^\infty S(f)\,df}$$

The significant wave height is also checked using:

$$H_s = 4 \times \sigma$$

The results show that the time series and the spectrum are in good agreement, as detailed in the following table:

Time Series	**Spectrum**	
Hs [m]	0.431	0.398
σ	0.107874	0.107954

Table E.3: Time Series and Spectrum vs Hs and Standard Deviation

E.7.5 Wave Forcing and Morison Equation

To estimate the wave forces acting on the jetty, the Morison equation is used, which is commonly applied in offshore engineering for calculating wave-induced forces on cylindrical structures. The Morison equation includes two components: the drag force and the inertia force. The total wave force is given by:

$$F = \frac{1}{2} C_D \rho D\, u|u| + C_M \rho \frac{\pi D^2}{4}\, \dot{u}$$

where:

- ρ is the density of seawater (1025 kg/m^3),
- C_D and C_M are the drag and inertia coefficients, respectively,

- D is the diameter of the structure,
- u is the particle velocity, and
- $\dot{u}$ is the particle acceleration.

Using the generated irregular wave time series, the drag and inertia forces are computed, resulting in the following force time series:

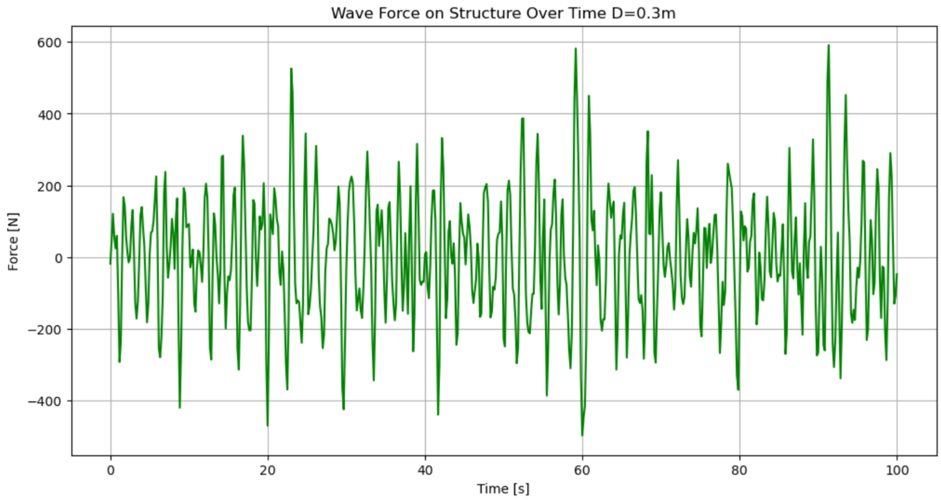


Figure E.14: Irregular Wave Force Time Series for $D = 0.3\,\mathrm{m}$

The results indicate that the cyclic loads generated by waves with a significant wave height of $H_s = 0.398\,\mathrm{m}$ are relatively low and can be considered negligible, as the maximum forces do not exceed 600 N. These forces are unlikely to pose a threat to the stability of the jetty structure.
However, for the dynamic analysis of the piles that secure the floating structure, it is recommended to consider the effects of waves with a larger diameter of $D = 0.5\,\mathrm{m}$. Under these conditions, forces can reach up to 1.5 kN (see Figure E.15), which may potentially compromise the safety of the structure if not properly accounted for.

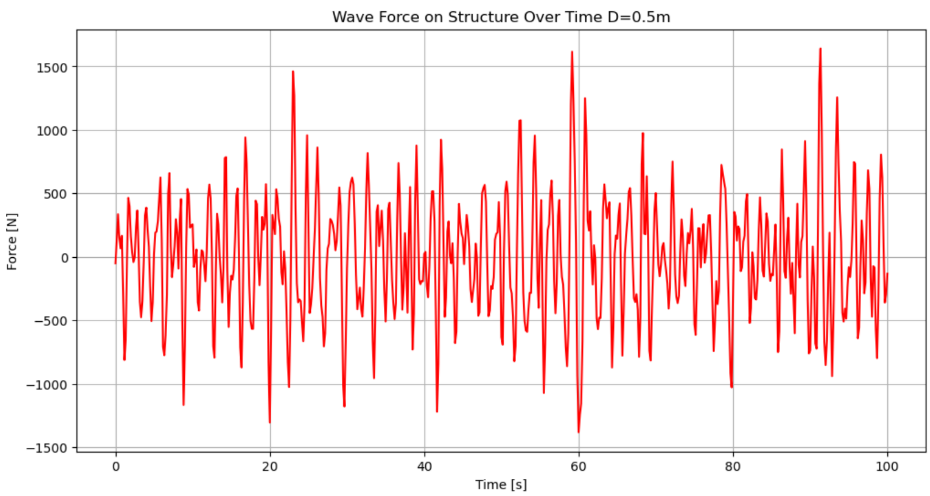


Figure E.15: Irregular wave force time series for $D = 0.5\,\mathrm{m}$

It is important to note that the results obtained in this section should be interpreted with caution, as several assumptions were made to apply the JONSWAP spectrum and the Morison equation. These assumptions include simplifications regarding wind conditions, fetch, and the interaction of waves with the structure. Given the limited fetch and shallow water conditions at the Primary Jetty site, alternative wave spectra or equations might better represent the wave loading in this specific context. Further studies, potentially incorporating more site-specific data and alternative models, would be necessary to refine the analysis and enhance the reliability of the results.

E.7.6 Code documentation

JONSWAP Spectrum

Load Conditions

Relevant JONSWAP coefficients & non-dimensional coefficients:

$$ \begin{cases} \tilde{f_p} = \frac{U_{10} f_p}{g} \\ \tilde{F} = \frac{g F}{U_{10}^2} \\ \tilde{f_p} = 3.5 \tilde{F}^{-0.33} \end{cases} \quad \Longrightarrow \quad \frac{U_{10} f_p}{g} = 3.5 \left(\frac{g F}{U_{10}^2} \right)^{-0.33} $$
Solving for f_p:

$f_p = \frac{3.5g}{\left(gFU_{10}\right)^{\frac{1}{3}}} $

We have U_{10} from EVA of wind data

Calculate the fetch F through maps

To obtain the significant wave height H_s the following formula for JONSWAP spectra is used:

$H_s = 4\sqrt{1.67\times 10^{-7} \frac{U_{10}^2}{g} F}$

In [28]:
```
U_10 =  10.786   #[m/s]                         #Reference wind speed
F = 5000 # [m]

f_p = 3.5*9.81/((9.81*F)**(1/3)*(U_10)**(1/3))
T_p = 1/f_p

Hs =4*np.sqrt(1.67*1e-7*F*U_10**2/9.81) #Significant wave height

print('The reference wind speed is U10 =',"{:.3f}".format(U_10))
print('The wave peak frequency is fp =',"{:.3f}".format(f_p))
```

```
print('The wave peak period is Tp =',"{:.3f}".format(T_p))
print('The significant wave height is Hs =',"{:.3f}".format(Hs))
```

```
The reference wind speed is U10 = 10.786
The wave peak frequency is fp = 0.425
The wave peak period is Tp = 2.356
The significant wave height is Hs = 0.398
```

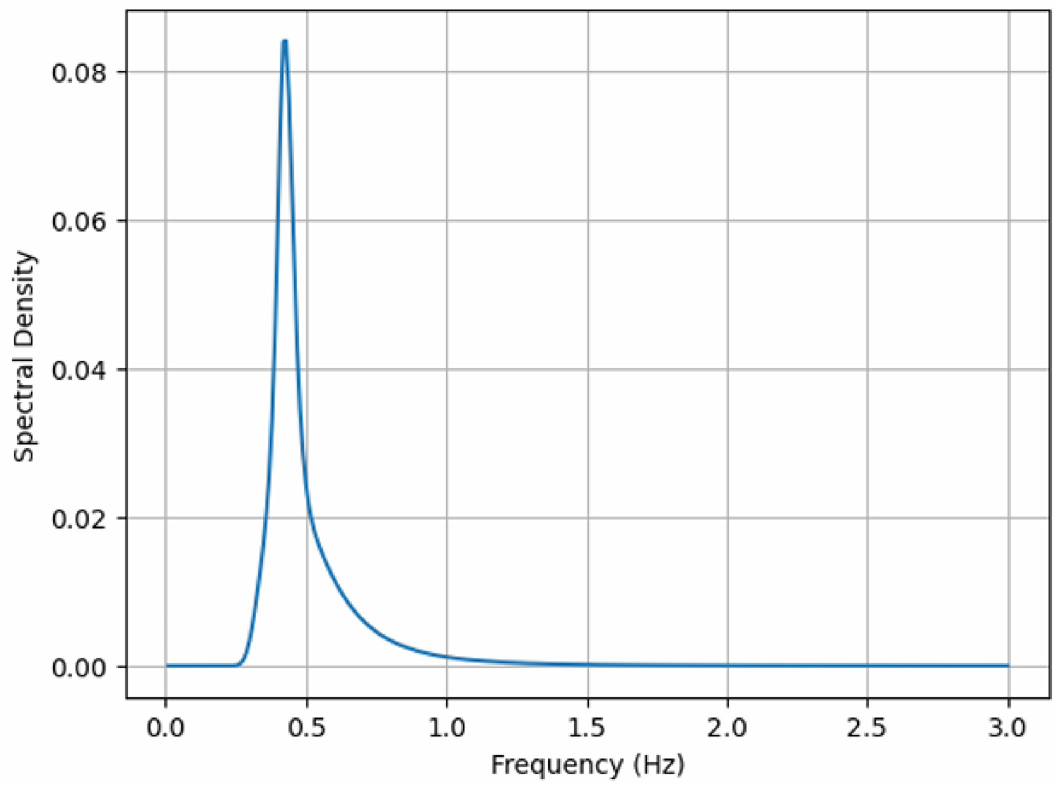
Now here below the JONSWAP spectra for the two load conditions can be found:

$$ S_{JONSWAP} = \alpha g^2 \frac{2\pi^{-4}}{f^5} \exp\left(-\frac{5}{4} \left(\frac{f}{f_p}\right)^{-4}\right) \gamma^{\exp\left(-\frac{1}{2}\left(\frac{\frac{f}{f_p} - 1}{\sigma}\right)^2\right)} $$
where:

$\gamma = 3.3$
$ \alpha = 0.076 \tilde{F}^{-0.22}$

$\begin{cases} \sigma = 0.07 \quad \Longrightarrow \quad f \leq f_p \\ \sigma = 0.09 \quad \Longrightarrow \quad f > f_p \end{cases} $

In [29]:
```
freq_f = np.arange(0.01, 3.01, 0.01)

# Constants
gamma = 3.3
F_nd = 9.81 * F / (U_10)**2
alpha = 0.076 * F_nd**(-0.22)

# Calculate sigma array based on frequency
sigma = np.where(freq_f <= f_p, 0.07, 0.09)

# Compute spectral density S_jonswap for all frequencies in one step
S_jonswap = (alpha * 9.81**2 * (2 * np.pi)**(-4) * freq_f**(-5) *
             np.exp((-5 / 4) * (freq_f / f_p)**(-4)) *
             gamma**(np.exp((-1 / 2) * (((freq_f / f_p) - 1) / sigma)**2)))

# Plotting
plt.plot(freq_f, S_jonswap)
plt.xlabel('Frequency (Hz)')
plt.ylabel('Spectral Density')
plt.grid()

plt.show()

# Print the maximum S_jonswap value
print("Maximum S_jonswap value:", "{:.3f}".format(np.max(S_jonswap)))   #0.3564
```



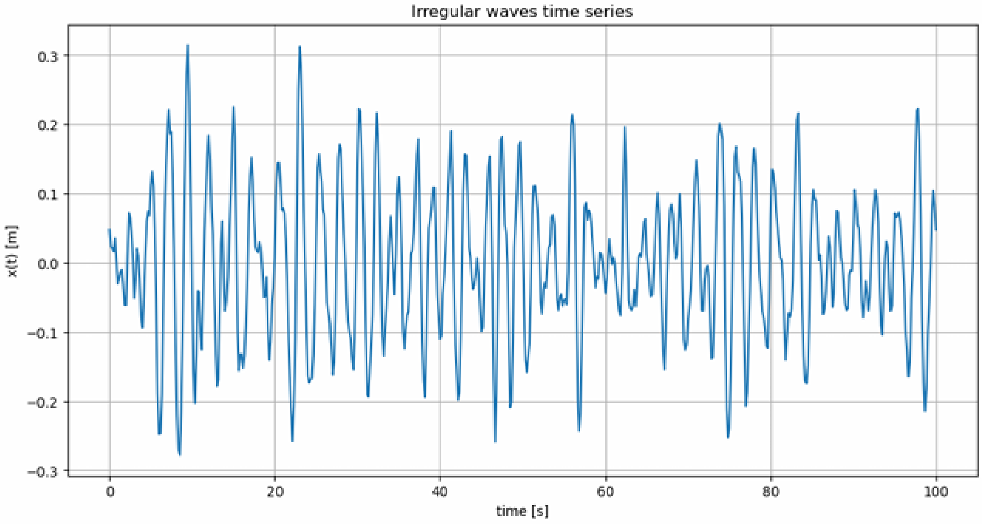

```
Maximum S_jonswap value: 0.084
```

In [30]:
```
def wave_time_series(f, S_jonswap,t):
    An = []

    for i in range(len(f)):
        Sxx = S_jonswap[i]
        df = np.max(f)/len(f)
        A_value = np.sqrt(2*Sxx*df)
        An.append(A_value)

    num_values = len(An)
    phin = np.random.uniform(0, 2*np.pi, num_values)

    xt = 0

    for n in range(len(f)):
        xt = xt + An[n]*np.cos(2*np.pi*f[n]*t+phin[n])

    return xt
```

In [31]:
```
df = 0.01
fmax = 3
tmax = 1/df
dt = 1/(2*fmax)
N = tmax/dt
t = np.linspace(0, tmax, int(N+1))

xt = wave_time_series(freq_f, S_jonswap,t)

print (dt)

plt.figure(figsize=(12,6))
plt.title('Irregular waves time series')
```

```
plt.xlabel('time [s]')
plt.ylabel('x(t) [m]')
plt.plot(t,xt)
plt.grid()
```

0.16666666666666666



In [32]:
```
std_S= np.sqrt(np.trapz(S_jonswap, freq_f))

std_xt= np.std(xt)

print('std time series:',"{:.6f}".format(std_xt))
print('std spectrum:',"{:.6f}".format(std_S))
```

std time series: 0.107882
std spectrum: 0.107954

In [33]:
```
# 2. Significant wave height

Hs_xt = 4*std_xt

print('The significant wave height is Hs =', "{:.3f}".format(Hs_xt))
```

The significant wave height is Hs = 0.432

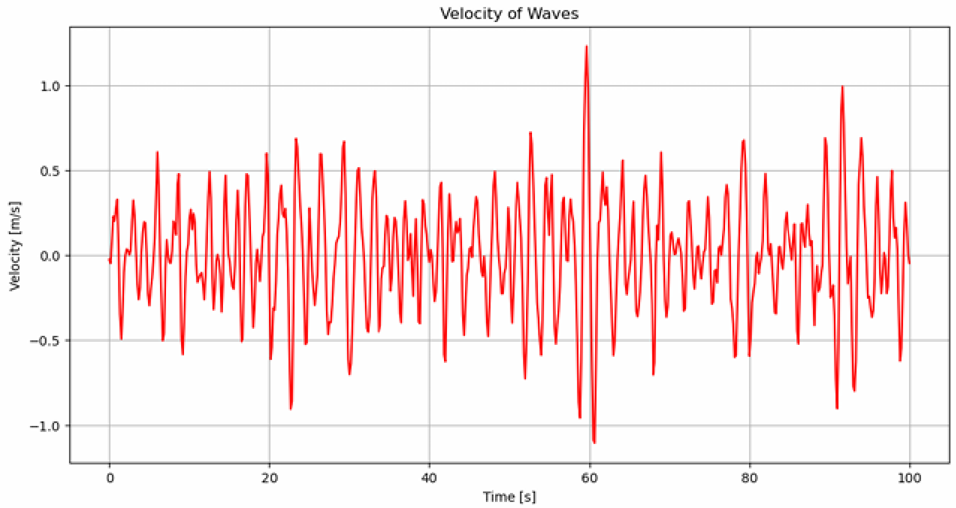
Wave Force

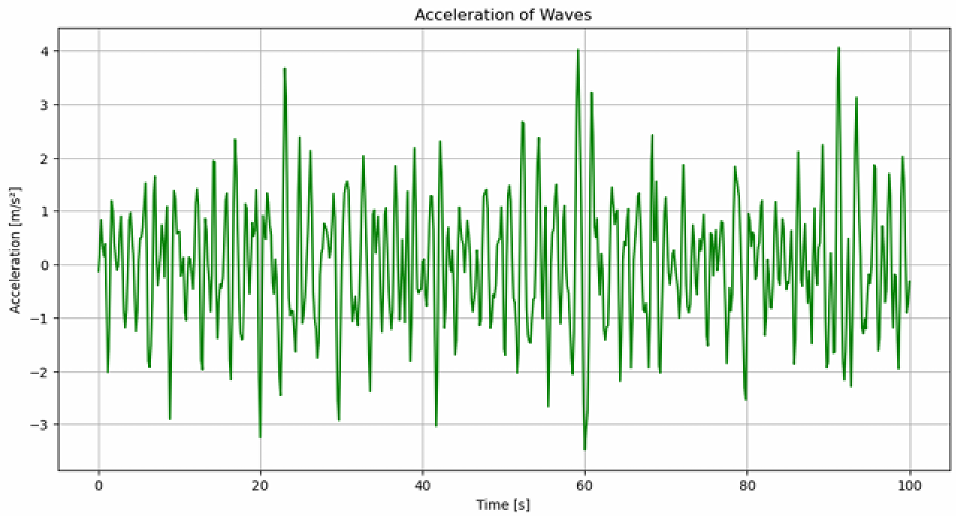
In [35]:
```
D = 0.3
KC = np.pi*Hs/D
print ('The KC number is', KC)
```

The KC number is 4.168288395621922

In [13]:
```
# Calculate the velocity (first derivative)
velocity = np.gradient(xt, t)

# Calculate the acceleration (second derivative)
acceleration = np.gradient(velocity, t)

# Plot the velocity
plt.figure(figsize=(12,6))
```

```
plt.title('Velocity of Waves')
plt.plot(t, velocity, label="Velocity v(t)", color='r')
plt.xlabel('Time [s]')
plt.ylabel('Velocity [m/s]')
plt.grid()

# Plot the acceleration
plt.figure(figsize=(12,6))
plt.title('Acceleration of Waves')
plt.plot(t, acceleration, label="Acceleration a(t)", color='g')
plt.xlabel('Time [s]')
plt.ylabel('Acceleration [m/s²]')
plt.grid()
```

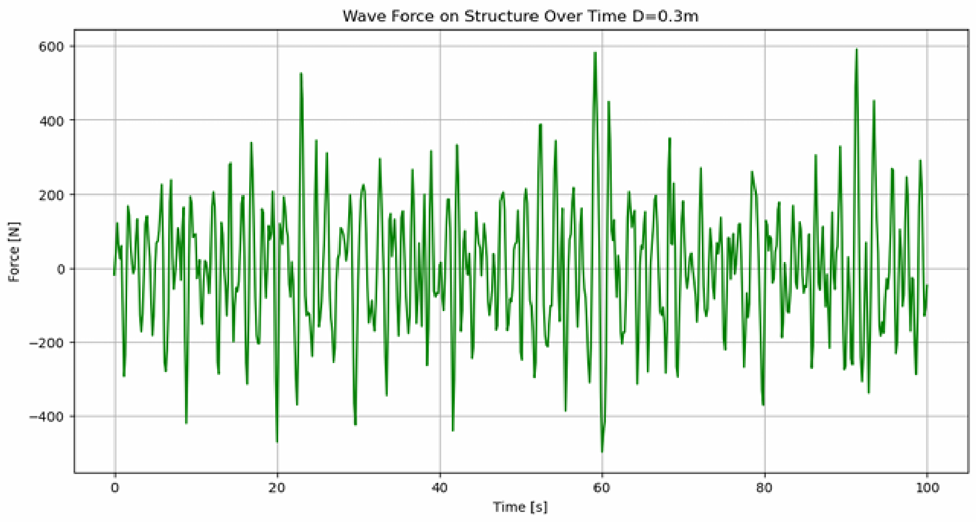




In [21]:

```
# Parameters (example values)
rho = 1025  # density of seawater in kg/m^3
C_d = 1.2   # drag coefficient (example for cylindrical structure)
C_m = 2.0   # inertia coefficient (example)
D = 0.3     # diameter of the structure in meters
A = np.pi * (D**2) / 4  # cross-sectional area of the cylinder (m^2)
```

```
# Assuming `velocity` and `acceleration` are already calculated

# Calculate wave force (Morison equation)
force_drag = 0.5 * rho * C_d * A * np.abs(velocity) * velocity  # drag force com
force_inertia = rho * C_m * A * acceleration  # inertia force component

# Total force (sum of drag and inertia)
total_force = force_drag + force_inertia

# Plotting force over time
import matplotlib.pyplot as plt

plt.figure(figsize=(12,6))
plt.title('Wave Force on Structure Over Time D=0.3m')
plt.plot(t, total_force, color='g')
plt.xlabel('Time [s]')
plt.ylabel('Force [N]')
plt.grid()
plt.show()
```



In [23]:
```
# Parameters (example values)
rho = 1025  # density of seawater in kg/m^3
C_d = 1.2   # drag coefficient (example for cylindrical structure)
C_m = 2.0   # inertia coefficient (example)
D = 0.5     # diameter of the structure in meters
A = np.pi * (D**2) / 4  # cross-sectional area of the cylinder (m^2)

# Assuming `velocity` and `acceleration` are already calculated

# Calculate wave force (Morison equation)
force_drag = 0.5 * rho * C_d * A * np.abs(velocity) * velocity  # drag force com
force_inertia = rho * C_m * A * acceleration  # inertia force component

# Total force (sum of drag and inertia)
total_force = force_drag + force_inertia

# Plotting force over time
import matplotlib.pyplot as plt

plt.figure(figsize=(12,6))
plt.title('Wave Force on Structure Over Time D=0.5m')
```

```
plt.plot(t, total_force, color = 'r')
plt.xlabel('Time [s]')
plt.ylabel('Force [N]')
plt.grid()
plt.show()
```

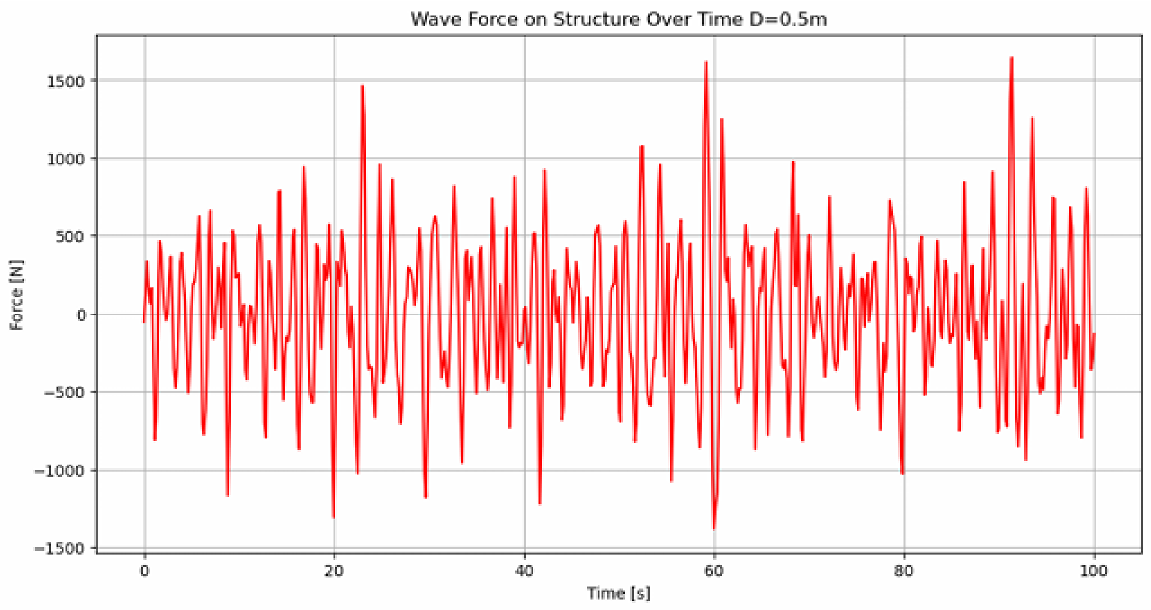


Figure E.16: Wave cyclic loading code documentation

F | Energy plan for the village

Further details of the energy plan for the village are presented in this Appendix.

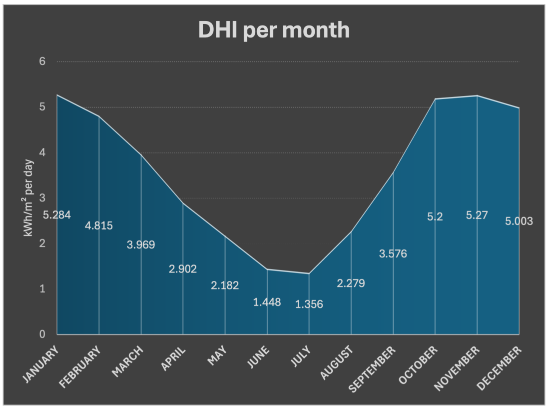
F.1 Solar Energy

Month	DHI Annual Average (kWh/m^2 per day)
January	5.284
February	4.815
March	3.969
April	2.902
May	2.182
June	1.448
July	1.356
August	2.279
September	3.576
October	5.200
November	5.270
December	5.003

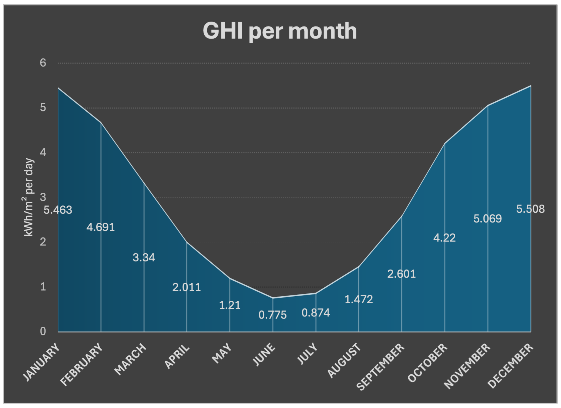
Table F.1: Monthly Diffuse Horizontal Irradiation (DHI) Annual Average

Month	GHI Annual Average (kWh/m^2 per day)
January	5.463
February	4.691
March	3.340
April	2.011
May	1.210
June	0.775
July	0.874
August	1.472
September	2.601
October	4.220
November	5.069
December	5.508

Table F.2: Global Horizontal Irradiation (GHI) Annual Average



(a) DHI per month



(b) GHI per month

Month	Tilt Irradiation Annual Average (kWh/m² per day)
January	5.372
February	5.251
March	4.338
April	3.225
May	2.363
June	1.685
July	1.741
August	2.857
September	3.917
October	5.187
November	5.228
December	5.159

Figure F.2: Tilt Irradiation Annual Average

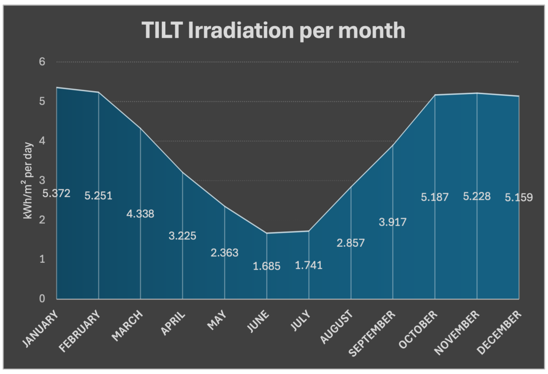


Figure F.3: TILT Irradiation per month

F.2 Hydroelectric Energy

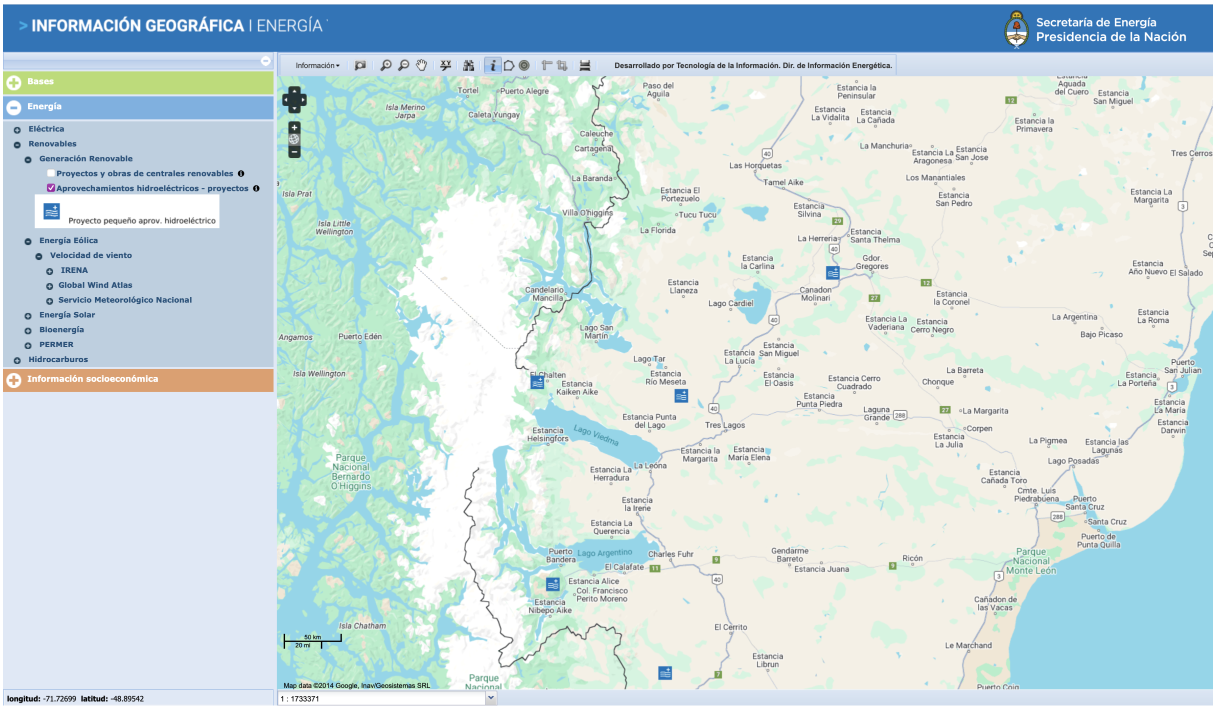


Figure F.4: Hydroelectric systems map

F.3 Final Reflections

Biogas System

While evaluating various energy sources, biogas emerged as a possible supplementary energy option. Due to the quantity of people and cattle on the property, there would be an ample amount of feces available to be converted into electrical and thermal energy. Advantages of using biogas as an energy source are the minimized water consumption, the conversion of waste material into energy, and the creation of energy 24/7 independent of weather conditions. Additionally, this solution provides a use for the excess amount of cattle currently on the property.

The type of anaerobic digest design explored for implementation included urine diverting toilets that sent the fecal waste to a farm scale anaerobic digester. The anaerobic digester produces methane for energy and a nutrient-rich byproduct, high in sulfates and nitrates, making it a good fertilizer. The fertilizing byproduct produced can also be used to make ceramics and bricks. This creates a circular economy selling products back to the clients from waste. The ceramics aspect is particularly interesting with respect to the project, as the ranch manager's wife is a ceramist and encourages the development of this tourism opportunity.

However, further investigation of anaerobic digestion proved that there would be significant issues running the digester in the winter with most of the residents gone. Additionally the digester requires significant maintenance, technical expertise, and energy to maintain temperatures high enough for efficient operation. Ultimately the previously mentioned difficulties led to alternative energy sources and toilets being chosen that are more feasible for population fluctuations. If additional energy is needed in the future and the development reaches a phase with domesticated cattle, further research would be beneficial for the project, and can be seen in Appendix XX.

F.4 Energy Demand

Appliances – power range						
		Very low power	Low power	Medium power	High power	Very high power
Services provided	Lighting	Task lighting	Multi-point lighting			
	Communication and entertainment	Mobile phone (charging), radio	Television, computer, printer			
	Space heating and cooling		Fan	Air cooler		Air conditioner, space heater
	Refrigeration			Refrigerator, freezer		
	Mechanical loads			Food processor, water pump	Washing machine	Vacuum cleaner
	Product heating				Iron, hair dryer	Water heater
	Cooking			Rice cooker	Toaster, microwave	Electric cooker, oven

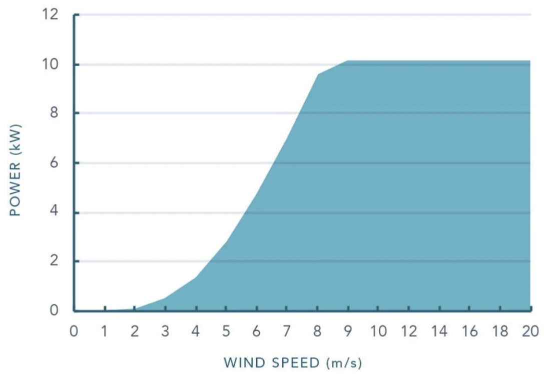
Source: Bhatia and Angelou (2015).

Figure F.5: Operating power range of typical household appliances

F.5 Energy System Dimensioning

PERFORMANCE

POWER CURVE



ENERGY OUTPUT

Annual Mean wind Speed (m/s)	Estimated Annual Output (kWh)
2	3,160
3	8,257
4	16,911
5	28,507
6	41,271
7	53,454
8	63,870
9	71,854
10	71,854

Figure F.6: Power Curve of Energy (n.d.)

DATA SHEET

GENERATOR	Type	Permanent Magnet
	Maximum Power	20 kW
	Rated Power	10 kW (Software Limited)
ROTOR	Configuration	Horizontal Axis
	No. of Blades	3
	Blade Material	Glass fibre
	Blade Length	4.5 m
	Rotor Diameter	9.8 m
	Swept Area	75.4 m2
	Nominal Rotor Speed	120 rpm
	Pitch/Yaw	Downwind active pitch with assisted yaw
WIND	Cut-In Speed	2 m/s
	Rated Wind Speed	9 m/s
	Cut-Out Speed	30 m/s
	Survival Speed	70 m/s
WEIGHTS	Nacelle/Rotor	1,000 kg
TOWERS	Lattice	15 – 36 m
	Monopole	18 – 27 m
	Tilt-Up	18 – 27 m
DESIGN PARAMETERS	Turbine Design Class	IEC 61400-2 Class I
	Temperature Range	-20° to 50°C
	Lifespan & Servicing	20 years, subject to regular maintenance

Figure F.7: Data sheet of Energy (n.d.)

Monocrystalline Solar Panel Datatsheet

Model	Power	Voltage(Pmax)	Current(Imap)	Dimension
PMS30W	30W	18.24V	1.65A	420x404x25mm
PMS40W	40W	18.24V	2.20A	570x400x25mm
PMS50W	50W	18.24V	2.75A	670x400x25mm
PMS60W	60W	18.24V	3.29A	430x760x25mm
PMS80W	80W	18.24V	4.39A	550x760x25mm
PMS100W	100W	18.24V	5.49A	680x760x25mm
PMS120W	120W	18.24V	6.58A	800x760x30mm
PMS160W	160W	18.24V	8.78A	1040x760x30mm
PMS200W	200W	18.24V	10.97A	1290x760x30mm
PMS240W	240W	18.24V	13.16A	1530x760x35mm
PMS300W	300W	34.20V	8.78A	1290x1134x35mm
PMS360W	360W	34.20V	10.53A	1540x1134x35mm

Figure F.8: Data sheet of Solar (n.d.)

Type of accomodation	Max nr. of people [summer]	Min nr. of people [winter]
Hostel	30	0
Campsite	28	0
Huts/domes family	28	0
Huts/domes couple	28	0
Luxury rooms family	20	0
Luxury rooms couple	20	0
permanent plots	84	84
total tourists+inhabitants	238	
workers	62	30
total	300	114

Appliances - power range					
	Very Low Power	Low Power	Medium Power	High Power	Very High Power
Lighting	Task lighting	Multi-point lighting			
Communication and entertainment	Mobile phone (charging), radio	Television, computer, printer			
Space heating and cooling		Fan	Air cooler		Air conditioner, space heater
Refrigeration			Refrigerator, freezer		
Mechanical Loads			Food processor, water pump	Washing machine	Vacuum cleaner
Product heating				Iron, hair dryer	Water heater
Cooking			Rice cooker	Toaster, microwave	Electric cooker, oven

Power Category	Power (Watts)
Very Low Power	1–10 W
Low Power	10–100 W
Medium Power	100–500 W
High Power	500–1500 W
Very High Power	1500–3000+ W

(yellow) = used in every unit

(cyan) = used in common areas

SUMMER (maximum capacity)

Appliances - power range - Hostel users (30)					
	Very Low Power	Low Power	Medium Power	High Power	Very High Power
Lighting	Task lighting	Multi-point lighting			
Communication and entertainment	Mobile phone (charging), radio	Television, computer, printer			
Space heating and cooling		Fan	Air cooler		Air conditioner, space heater
Refrigeration			Refrigerator, freezer		
Mechanical Loads			Food processor, water pump	Washing machine	Vacuum cleaner
Product heating				Iron, hair dryer	Water heater
Cooking			Rice cooker	Toaster, microwave	Electric cooker, oven
Unit Power consumption [W]	10	75	300	1200	3000
Hour per day [h]	6	3	-	-	0,05
Total KWh/day	1,8	6,75	-	-	4,5

Appliances - power range - Hostel and campsite common area (58)					
	Very Low Power	Low Power	Medium Power	High Power	Very High Power
Lighting	Task lighting	Multi-point lighting			
Communication and entertainment	Mobile phone (charging), radio	Television, computer, printer			
Space heating and cooling		Fan	Air cooler		Air conditioner, space heater
Refrigeration			Refrigerator, freezer (3)		
Mechanical Loads			Food processor, water pump	Washing machine	Vacuum cleaner
Product heating				Iron, hair dryer	Water heater
Cooking			Rice cooker	Toaster, microwave	Electric cooker, oven
Power consumption [W]	10	75	300	1200	3000
Hour per day [9]	4	3	24	4	-
KWh/day	1,12	6,3	21,6	4,8	-

Appliances - power range - Campsite users (28)					
	Very Low Power	Low Power	Medium Power	High Power	Very High Power
Lighting	Task lighting	Multi-point lighting			
Communication and entertainment	Mobile phone (charging), radio	Television, computer, printer			
Space heating and cooling		Fan	Air cooler		Air conditioner, space heater
Refrigeration			Refrigerator, freezer		
Mechanical Loads			Food processor, water pump	Washing machine	Vacuum cleaner
Product heating				Iron, hair dryer	Water heater
Cooking			Rice cooker	Toaster, microwave	Electric cooker, oven
Power consumption [W]	10	75	300	1200	3000
Hour per day [9]	0	0	0	0	0
KWh/day	-	-	-	-	-

Appliances - power range - Huts users (56)					
	Very Low Power	Low Power	Medium Power	High Power	Very High Power
Lighting	Task lighting	Multi-point lighting			
Communication and entertainment	Mobile phone (charging), radio	Television, computer, printer			
Space heating and cooling		Fan	Air cooler		Air conditioner, space heater
Refrigeration			Refrigerator, freezer		
Mechanical Loads			Food processor, water pump	Washing machine	Vacuum cleaner
Product heating				Iron, hair dryer	Water heater
Cooking			Rice cooker	Toaster, microwave	Electric cooker, oven
Power consumption [W]	10	75	300	1200	3000
Hour per day [9]	8	5	-	-	0,05
KWh/day	4,48	21	-	-	8,4

Appliances - power range - Huts common area (56)					
	Very Low Power	Low Power	Medium Power	High Power	Very High Power
Lighting	Task lighting	Multi-point lighting			
Communication and entertainment	Mobile phone (charging), radio	Television, computer, printer			
Space heating and cooling		Fan	Air cooler		Air conditioner, space heater
Refrigeration			Refrigerator, freezer (5)		
Mechanical Loads			Food processor, water pump	Washing machine	Vacuum cleaner
Product heating				Iron, hair dryer	Water heater
Cooking			Rice cooker	Toaster, microwave	Electric cooker, oven
Power consumption [W]	10	75	300	1200	3000
Hour per day [9]	-	-	24	3	0,2
KWh/day	-	-	36	3,6	33,6

Figure F.9: Energy Demand Calculations (1)

Appliances - power range - Luxury rooms users (40)					
	Very Low Power	Low Power	Medium Power	High Power	Very High Power
Lighting	Task lighting	Multi-point lighting			
Communication and entertainment	Mobile phone (charging), radio	Television, computer, printer			
Space heating and cooling		Fan	Air cooler		Air conditioner, space heaterr
Refrigeration			Refrigerator, freezer		
Mechanical Loads			Food processor, water pump	Washing machine	Vacuum cleaner
Product heating				Iron, hair dryer	Water heater
Cooking			Rice cooker	Toaster, microwave	Electric cooker, oven
Power consumption [W]	10	75	300	1200	3000
Hour per day [9]	8	5	-	0,2	1
KWh/day	0,08	0,375	-	0,24	3

Appliances - power range - Luxury common area (40)					
	Very Low Power	Low Power	Medium Power	High Power	Very High Power
Lighting	Task lighting	Multi-point lighting			
Communication and entertainment	Mobile phone (charging), radio	Television, computer, printer			
Space heating and cooling		Fan	Air cooler		Air conditioner, space heater
Refrigeration			Refrigerator, freezer (8)		
Mechanical Loads			Food processor, water pump (1)	Washing machine	Vacuum cleaner
Product heating				Iron, hair dryer	Water heater
Cooking			Rice cooker	Toaster, microwave	Electric cooker, oven
Unit Power consumption [W]	10	75	300	1200	3000
Hour per day [9]	8	8	24	15	2
KWh/day	3,2	0,6	64,8	18	6

Appliances - power range - Permanent residents + workers (146)					
	Very Low Power	Low Power	Medium Power	High Power	Very High Power
Lighting	Task lighting	Multi-point lighting			
Communication and entertainment	Mobile phone (charging), radio	Television, computer, printer			
Space heating and cooling		Fan	Air cooler		Air conditioner, space heater
Refrigeration			Refrigerator, freezer		
Mechanical Loads			Food processor, water pump	Washing machine	Vacuum cleaner
Product heating				Iron, hair dryer	Water heater
Cooking			Rice cooker	Toaster, microwave	Electric cooker, oven
Power consumption [W]	10	75	300	1200	3000
Hour per day [9]	8	5	24	10	0,2
KWh/day	11,68	54,75	309,6	12	0,6

monthly energy demand	hostel + campsite + huts		4618,5		
monthly energy demand	permanent		11658,9		
monthly energy demand	luxury		2888,85		
				per persona	
			19166,25	91,26785714	
		correction factor	24916,125	https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://it.bluettipower.eu/blogs/news/10-kwh-al-giorno%23:~:text%3DSecondo%2520dati%2520statistici%252C%2520una'	

WINTER (minimum capacity)

Appliances - power range - Permanent residents (114)					
	Very Low Power	Low Power	Medium Power	High Power	Very High Power
Lighting	Task lighting	Multi-point lighting			
Communication and entertainment	Mobile phone (charging), radio	Television, computer, printer			
Space heating and cooling		Fan	Air cooler	space heater	Air conditioner
Refrigeration			Refrigerator, freezer		
Mechanical Loads			Food processor, water pump	Washing machine	Vacuum cleaner
Product heating				Iron, hair dryer	Water heater
Cooking			Rice cooker	Toaster, microwave	Electric cooker, oven
Power consumption [W]	10	75	300	1200	3000
Hour per day [9]	12	5	24	6	0,5
KWh/day	13,68	42,75	252	252	42

stoccaggio (storage) stabilizza la rete, può dare una frequenza minima costante

*grande costo

trasformatore

Figure F.10: Energy Demand Calculations (2)

wind

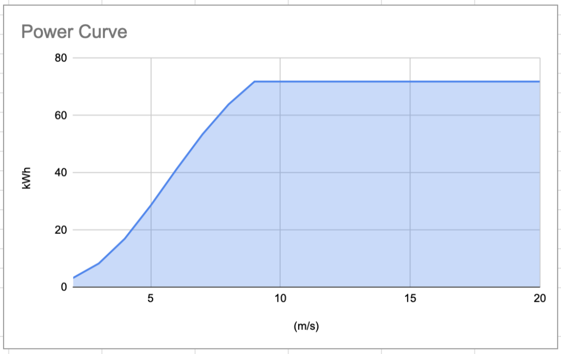
total	E-10
max energy demand	annual mean wind speed
KWh/month	(m/s)
25000	8

https://www.ryse.energy/10kw-wind-turbines/

Annual mean wind speed	Estimated annual output	Estimated monthly output
(m/s)	kWh	
2	3,16	
3	8,257	
4	16,911	
5	28,507	
6	41,271	
7	53,454	
8	63,87	5,3225
9	71,854	
10	71,854	
20	71,854	

60% wind

40% solar



3 turbine totali		
luxury	-->	1 turbina + solar
permanent	-->	2 turbine + solar
cottages + campsite + hostel	-->	solar

Figure F.11: Wind Energy Design

solar

Irradiation (yearly)	Yield	Irradiance	Yield	Efficiency	Energy demand	Nominal Power
Emonth	Ymonth	Gstc	Ymonth	PR	Edem	Pn (unit)
[kWh/month]	[h/month]	[kW/m^2]	[%]	[-]	[kWh/month]	[kW]
115,8075	115,8075	1	16,084375	0,9	10000	95,94465912

Month	Tilt Irradiation Annual Average	
[-]	[kWh/m² per day]	
January	5,372	161,16
February	5,251	157,53
March	4,338	130,14
April	3,225	96,75
May	2,363	70,89
June	1,685	50,55
July	1,741	52,23
August	2,857	85,71
September	3,917	117,51
October	5,187	155,61
November	5,228	156,84
December	5,159	154,77
		0
mean	3,86025	115,8075

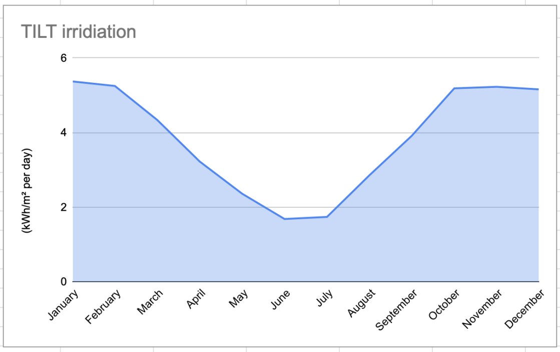


Figure F.12: Solar Energy Design

G | Sustainable building solutions

Further details of the building engineering of the houses of the village are presented in this Appendix.

In an initial phase of the research stage, it was investigate the possibility to build with the local wood. On-Site Research showed that there is not enough timber availability on the property, and since there is an attempt in reforesting the Estancia, the timber that will be used is imported structural timber. However, the research done on it is presented here.

G.1 Argentinian Code for Timber

In a first research stage, the possibility to use local timber as structural timber is considered. The Argentinian code for timber structures is CIRSOC 601 (INTI (2020)). The code does not mention the Nothofagus in particular, which are the tree species that are available on site (reference flora—). The CIRSOC 601 gives some general guide on Timber Constructions based on mechanical properties like modulus of elasticity, rupture, shear, and compressive strength, durability and resistance to environmental factors, density.

The properties of Nothofagus that will be used are found in a report of the Instituto Forestal Instituto Forestal (INFOR) (2021). The material used for this report was found in the province of Aisén, in the following locations: Coyhaique Alto, Ñirehuao, Mañihuales, Puerto lbáñez, Mano.Negra y El Gato. Since these areas are close to the village site, the data can be used for the village design. The properties of Lenga are showed in Figure G.1, where it is displaced a table from the Instituto Forestal (INFOR) (2021) report.

Figure (G.2) shows the Modulus of Elasticity of Lenga compared with other species in the Instituto Forestal (INFOR) (2021) report. The data showed in the previous table will be summarised and re-organized in the Table G.1

TABLA 12. PROPIEDADES MECANICAS Y ASOCIADAS DE LA LENGA. RESUMEN DE LOS VALORES OBTENIDOS PARA LA PROVINCIA DE AISEN

26.

ENSAYO O DETERMINACION		PROPIEDAD		ESTADO VERDE			ESTADO SECO AL AIRE (H≈12 o/o)		
		Símbolo X	Unidad	Número probetas n	Media $\bar{X}$	Desviación estándar s_x	Número probetas n	Media $\bar{X}$	Desviación estándar s_x
Humedad		H	o/o	330	64,6	15,7	329	12,5	0,5
Peso específico	original	D_{oo}	kg/m3	330	779	74,6	329	602	27,1
	básico	D_{so}			474	22,6		535	23,6
	seco	D_{ss}			553	33,7		566	26,0
Flexión		σ_f, lím.prop.	kg/cm2	30	269	52,2	30	489	66,4
		R_f, rotura	kg/cm2		498	61,2		917	110,3
		E_f, mod. elasticid.	ton/cm2		81,9	12,6		104,6	13,6
Compresión paralela		σ_{cp}, lím. prop.	kg/cm2	30	161	41,7	29	259	38,3
		R_{cp}, rotura	kg/cm2		227	28,5	30	432	50,4
		E_{cp}, mod. elasticid.	ton/cm2		90,7	15,9	29	108,9	14,8
Compresión normal		σ_{cn}, lím. prop.	kg/cm2	30	35,3	4,8	30	71,6	8,9
		R_{cn}, rotura			73,7	10,8		139,0	22,7
Tracción normal	tangencial	R_{tnt}	kg/cm2	30	34,0	9,5	30	47,2	13,4
	radial	R_{tnr}			22,6	6,0		31,3	9,3
Cizalle	tangencial	R_{czt}	kg/cm2	30	73,5	8,3	29	119,8	12,1
	radial	R_{czr}			62,7	5,5	30	96,1	10,3
Clivaje	tangencial	R_{cvt}	kg/cm	30	50,3	9,2	30	73,4	14,7
	radial	R_{cvr}			35,7	4,5	29	51,0	14,8
Dureza	normal	R_{dn}	kg	30	268	28,4	30	387	50,0
	paralela	R_{dp}			326	38,2		556	60,6
Extracción clavo	normal	R_{cln}	kg	30	86	9,4	30	131	21,0
	paralela	R_{clp}		29	41	5,4		81	12,0

INFOR

Figure G.1: Mechanical Properties of Lenga for the province of Aisén

TABLA 15. FATIGAS BASICAS * DE LA LENGA Y COMPARACION DE ELLAS CON LAS DE ALGUNAS ESPECIES CHILENAS

ESPECIE	FATIGA BASICA					MODULO DE ELASTIC.	
	Flexión σ_f kg/cm2	Compres. paralela σ_{cp} kg/cm2	Compres. normal σ_{cn} kg/cm2	Tracción paralela σ_{tp} kg/cm2	Cizalle σ_{cz} kg/cm2	Medio E_f ton/cm2	Mínimo E_f mín. ton/cm2
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Pino insigne	115	60	15	115	15	65,5	34,5
Alamo	125	95	13	125	17	50,5	41,5
Eucalipto	215	176	44	215	30	122,5	68,0
Coihue	195	140	60	195	30	83,3	67,0
Ulmo	240	195	32	240	28	104,0	75,5
Lenga	158	115	12	158	24	81,9	52,5

* Valores calculados de acuerdo al método propuesto en Informe Técnico 37 del Instituto Forestal.

29.

Figure G.2: Modulus of Elasticity Lenga for the province of Aisén

Property	**Green State**	**Air-Dried (12% Moisture)**
Moisture Content (H)	64.6%	12.5%
Density (Basic)	779 kg/m^3	602 kg/m^3
Density (Original)	474 kg/m^3	535 kg/m^3
Flexural Strength (σ_f)	269 kg/cm^2	489 kg/cm^2
Flexural Rupture (R_f)	498 kg/cm^2	917 kg/cm^2
Compressive Strength (σ_{cp})	161 kg/cm^2	259 kg/cm^2
Compressive Rupture (R_{cp})	227 kg/cm^2	432 kg/cm^2
Tensile Strength	34.0 kg/cm^2	71.6 kg/cm^2
Shear Strength (Tangential)	73.5 kg/cm^2	119.8 kg/cm^2
Shear Strength (Radial)	62.7 kg/cm^2	96.1 kg/cm^2
Modulus of Elasticity (Medium)	81.9 ton/cm^2	
Modulus of Elasticity (Minimum)	52.5 ton/cm^2	

Table G.1: Mechanical Properties of Nothofagus pumilio (Lenga) for Design, including Modulus of Elasticity (Medium and Minimum)

G.2 Regulation of Cob Houses in Argentina

40	El Calafate	Lago Argentino	Santa Cruz	Ordenanza	Ordenanza Nº 1980/17	Municipal	0	No está reglamentada. Encomienda recopilar información para incorporar al Código de edificación.	AUTORICESE, en el ejido de El Calafate la utilización de técnicas constructivas y materiales sustentables a través de métodos de construcción de tierra cruda, siempre y cuando se cumpla con las reglamentaciones vigentes a Nivel Nacional (Reglamento CIRSOC y otros).

Figure G.3: Regulations in the province of Santa Cruz

G.3 Innovative Insulation Solutions

Table 3
Summary of thermal properties, fire classification and μ-value of natural unconventional insulation materials. Colors indicate qualitatively the thermal insulation performance (green = good, yellow = intermediate, red = poor). NA: not available.

Natural materials	Density (kg/m^3)	Thermal conductivity (W/mK)	Specific heat (kJ/kgK)	Fire classification	Water vapor diffusion resistance factor, μ–value	References
Banana and polypropylene (PP) fiber	980–1040	0.157–0.182	1.3–1.5	NA	NA	[106]
Bagasse	70–350	0.046–0.055	NA	NA	NA	[55], [56], [57]
Corn cob	171–334	0.101	NA	NA	NA	[64], [65]
Cotton (stalks)	150–450	0.0585–0.0815	NA	NA	NA	[66]
Date palm	187–389	0.072–0.085	NA	NA	NA	[67], [68]
Durian	357–907	0.064–0.185	NA	NA	NA	[69]
Oil palm	20–120	0.055–0.091	NA	NA	NA	[56]
Pecan	600–680	0.0884–0.1030	NA	NA	NA	[76]
Pineapple leaves	178–232	0.035–0.042	NA	NA	NA	[74]
Reeds	130–190	0.045–0.056	1.2	E	1–2	[109], [110], [53], [111]
Rice	154–168	0.0464–0.566	NA	NA	NA	[76]
Sansevieria fiber	1410	0.132	1.52	NA	NA	[79]
Sunflower (cake from biorefinery)	500–585	0.0885–0.110	NA	NA	NA	[81]
Sunflower (pitch)	36–152	0.0385–0.0501	NA	NA	NA	[80]
Straw bale	50–150	0.038–0.067	0.6	NA	NA	[83], [84], [85]

Figure G.4: Table 3 from Asdrubali et al. (2015)

Table 4
Summary of thermal properties, fire classification and μ-value of recycled unconventional insulation materials. (green = good, yellow = intermediate, red = poor). NA: not available.

Recycled materials	Density (kg/m^3)	Thermal conductivity (W/mK)	Specific heat (kJ/kgK)	Fire classification	Water vapor diffusion resistance factor, μ–value	References
Cotton (recycled)	25–45	0.039–0.044	1.6	E	1–2	[94]
Cotton (recycled denim)	NA	0.036–0.038	NA	NA	NA	[95]
Recycled glass	450	0.031	0.83	NA (probabily A1)	NA	[88]
Recycled glass (commercialized)	100–165	0.038–0.05	1.0	A1	Very high	[89], [112]
Recycled PET	30	0.0355	NA	NA	NA	[90]
Recycled PET (commercialized)	15–60	0.034–0.039	1.2	B	3.1	[92]
Recycled textile (commercialized)	30–80	0.0358–0.042	1.2–1.6	E, F	2.2	[92], [113], [114], [115]
Recycled textile fibers (polyester and polyurethane)	440	0.044	NA	NA	NA	[103]
Recycled textile fibers (synthetic)	200–500	0.041–0.053	NA	NA	NA	[102]
Recycled textile and paper	433	0.034–0.039	NA	NA	NA	[104]

Figure G.5: Table 4 from Asdrubali et al. (2015)

	construction layer	d	λ	R	ΔT	T	p_{max}	μ	μ.d	φ	Δp_w	p_w
	parameters	m	W/(m.K)	(m2.K)/W	°C	°C	Pa	-	m	%	Pa	Pa
air outside						-15.0	162.7			80		130
	surface resistance R_e			0.04	0.2							
						-14.8	166.0					130
1	cob	0.3	0.6	0.50	2.7			19	5.7		77	
						-12.1	213.3					207
2	straw	0.1	0.048	2.08	11.2			3.1	0.3		4	
						-0.9	568.1					211
3	PET	0.05	0.0355	1.41	7.6			8.6	0.4		6	
						6.7	981.2					217
4	straw	0.1	0.048	2.08	11.2			3.1	0.3		4	
						17.9	2052.4					221
5	moisture retardant layer	0.001	0.2	0.01	0.0			50000	50.0		675	
						18.0	2055.9					896
6	cob	0.15	0.6	0.25	1.3			19	2.9		38	
						19.3	2236.6					934
7		0	1	0.00	0.0			0	0.0		0	
						19.3	2236.6					934
8		0	1	0.00	0.0			0	0.0		0	
						19.3	2236.6					934
9		0	1	0.00	0.0			0	0.0		0	
						19.3	2236.6					934
10		0	1	0.00	0.0			0	0.0		0	
						19.3	2236.6					934
11		0	1	0.00	0.0			0	0.0		0	
						19.3	2236.6					934
12		0	1	0.00	0.0			0	0.0		0	
						19.3	2236.6					934
	surface resistance R_i			0.13	0.7							
air inside						20.0	2336.0			40		934
	Totaal			6.50	35.0				59.6		804	

Figure G.6: Steady State heat and moisture transfer Analysis