Barrio de las Lechuzas

Un Studio de Diseño para un Barrio Sostenible en Galápagos
A Design Study for a Sustainable Neighborhood in the Galapagos

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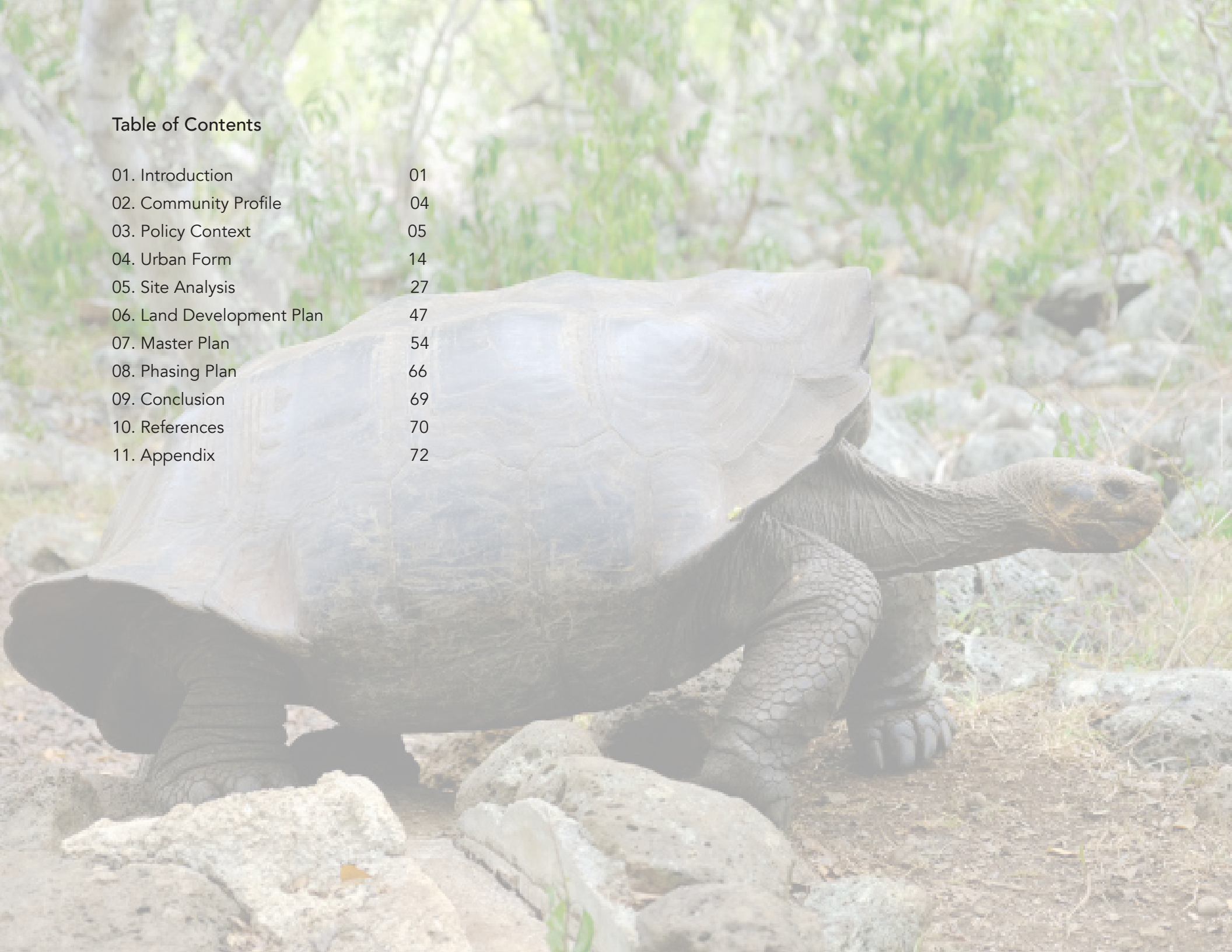

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01. INTRODUCTION

The Galapagos archipelago, a province of Ecuador, is world renowned for its intact ecology, diversity of endemic plants and animals, and its role as the natural laboratory that inspired Charles Darwin and the theory of evolution. The government of Ecuador took action to protect the Galapagos in 1959 by establishing the Galapagos National Park. The park encompasses 7,880 km^2 out of the archipelago's total land mass of 7,995 km^2, leaving just under two percent of the land for human use. With an annual tourist population of nearly 300,000 visitors, the islands' population of just 33,000 is often left in the shadows.

Those 33,000 residents are spread among four islands: Floreana, Isabella, San Cristobal, and Santa Cruze. San Cristobal is home to the provincial capitol and has the second largest population with about 9,000 permanent residents. The town of Puerto Baquerizo Moreno is home to most of San Cristobal's population while a small number of people live in the agricultural highlands.

Galapağuenos, like people everywhere, aspire to the benefits and comforts of modern life yet the Galapagos are very much not like everywhere else. The islands have very limited capacity to support human life at a subsistence level, let alone at a more advanced level. San Cristobal is the only island in the archipelago with a reliable source of water, but the existing infrastructure is inadequate to supply drinking water to the residents or to properly treat and dispose of wastewater. There is no stormwater infrastructure and the town experiences seasonal urban flooding. The local agricultural sector cannot produce the diversity of food demanded by the population nor in sufficient quantity. The island lacks the raw material needed for construction. The consequence is that food, construction material, clothing, fuel, and almost any finished goods from televisions to tractors are shipped by boat from the mainland.

The Ecuadorian government, the Galapagueños provincial government, and the residents themselves understand that current practices are yielding an outsized carbon footprint, threatening the quality of their island home, and are ultimately unsustainable.

The government responded by developing Galapagos 2030: Galapagos Islands Strategic Plan. The strategic plan begins with a set of 10 vision statements. The first reads "By 2030, there will be a high quality of life in friendly, inclusive and safe neighborhoods that are connected to their natural environment" (Galapagos Government Council, p. 6).

Livable, high quality, inclusive neighborhoods that are connected to nature do not happen by accident. They are planned. A planned town is one in which a town's population, boundaries, location, and facilities such as roads, markets, and housing, as well as how these elements are physically organized in two dimensional space, are determined in advance of settlement. In the Western tradition, examples of town planning can be found in Greek, Roman, and Medieval history through to the current period.

Today, town planning is particularly important to ensure that there is sufficient infrastructure (transportation, drinking water, wastewater, stormwater, electricity, telecommunications, and solid waste disposal) to meet the residents' needs. Towns also need to provide educational facilities, public spaces, including natural spaces, and often dedicated areas for more intense manufacturing and production use. A well planned town is livable, sustainable, and resilient.

Planned towns are not the tradition on the Galapagos. Towns grew organically, without planning for basic services,

preserving sensitive lands, or considering the long-term costs of their development pattern. The towns' organic pattern of growth has led to some serious consequences today, particularly in terms of drinking water, wastewater, and long-term sustainability. On the other hand, several elements of the towns' urban form lend themselves to livability and sustainability.

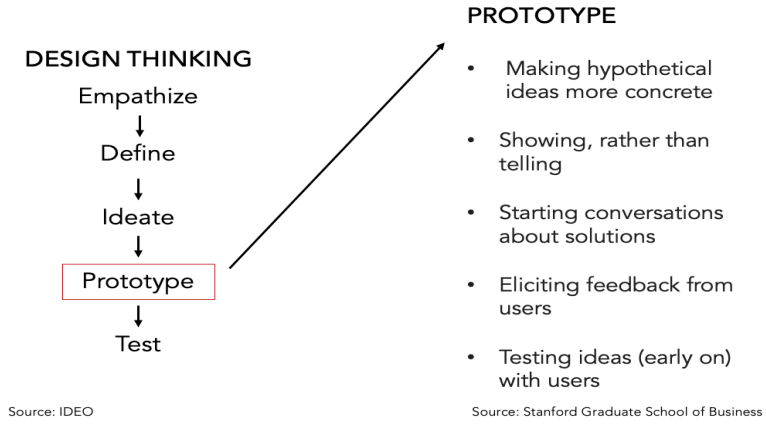
This project presents a design for a new neighborhood for Puerto Baquerizo Moreno, which I have named Barrio de las Lechuzas after the endemic Galapagueño short-eared owl. It provides one answer to the question "what do our policies look like." Planning policies are unique in that they are written down on paper in two dimensions but are realized in three dimensions. Yet very few people can visualize what the future looks like when they are discussing policies. What does "better connectivity" mean? Does it mean a new highway or dedicated bike lanes. Both? What does "connected with nature" mean? Is it a regional new park, a community garden, or better landscaping at the nearby school.

Architects, landscape architects, and other designers know the importance of visualization. They include maps, diagrams, and representative images to help their customers and other stakeholders visualize the final project. Planners tend not to include representative visual elements during policy development. I serve on my community's planning commission, and we recently completed updating our city's comprehensive plan. The revised plan made significant changes to our land use policy to increase density and reduce car use but did not include any material that helped residents understand what the city would look like as the built environment shifted in response to the new policies.

Barrio de las Lechuzas provides the residents of Puerto Baquerizo Moreno just that, an opportunity to visualize how their current policies might appear when built out on a specific site. In this sense, the master plan presents a design prototype or model. It allows residents to react to something specific rather than abstract and to use their everyday, practical knowledge of the local community to participate in planning for their future.

The master plan is set on undeveloped land immediately east of the town's current extent, bounded by Avenido Jaime Roldos Aguilera. This land has been designated to accommodate the town's future growth. It is a logical place on which to develop a prototype future neighborhood. It is unlikely, however, that the town will need to expand in the near future. The town has a significant amount of undeveloped land within its

Figure 01.01: Prototyping as Part of Design Thinking



current street system. Moreover, many buildings outside the central business district are one floor when the building code allows for four floors. It is much more sustainable, both financially and ecologically, to fill in the vacant lots and expand vertically than to expand horizontally. Nonetheless, planning is future-oriented.

Barrio de las Lechuzas is a design response to three sets of input. The first is the policy context, which is set out in the Galapagos 2030 plan. I explore this in section three and identify a set of policies related to the built environment that will be the primary driver of the master plan. The second element is the town's current urban form, which I examine in section four. I want the new neighborhood to integrate well into the existing town's urban fabric. The final element is the site context, which I analyze in section five. I present my conclusion in section six, seven, and eight.

This project includes a few assumptions and omissions that are worth noting. The project's primary omission is a public engagement component. A credible master plan would include a stakeholders' committee to provide ongoing input into the design and a series of discrete activities and events to measure the public's needs and

Figure 01.02 Project Process

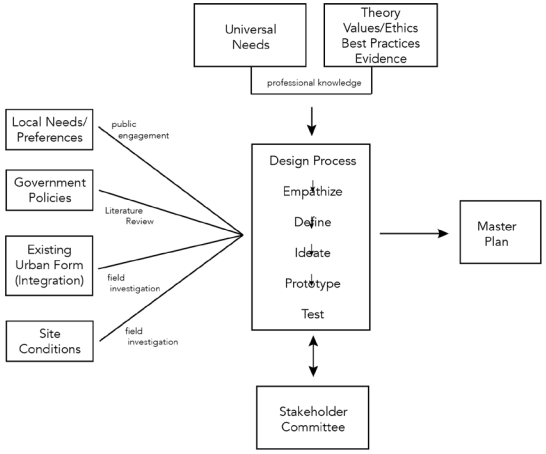


Figure 01 shows the design process. Local needs developed through a public engagement process and a stakeholder committee were omitted.

preferences. These activities would likely include community surveys, focus groups with specific constituencies, walking tours, and design charettes. The Galapagos 2030 plan included a public engagement program and, in the case of Barrio de las Lechuzas, the strategic plan provides both the policy context and stands in for a public engagement process. Figure 02 provides a diagram of the recommended process.

This project assumes that government has the capacity to obtain the capital for basic infrastructure, including drinking water and wastewater, as well as the annual revenue to maintain these systems. It also assumes that the government has enough regulatory authority to control the pace of development. It is critical that residential and commercial development are aligned with infrastructure development.

While Barrio de las Lechuzas is a neighborhood prototype rather than an actionable construction program, my hope is that it contributes to discussions today about what the Galapagos' urban environment looks like tomorrow.

02. COMMUNITY PROFILE

Puerto Baquerizo Moreno (population 7,290) is the larger of two settlements on the Isla de San Cristobal in the Galapagos archipelago. It is one of four inhabited islands of the 19 primary islands that compose the Galapagos.

The Galapagos is world famous as a hot spot of animal species diversity. UNESCO declared the islands and its surrounding marine reserve a world heritage site. The government of Ecuador set aside 97% of the islands' total land mass as a national park in 1958. To protect the island ecosystem, the government has set strict limits on migration to the islands. Despite these limits, Ecuadorians continue to find ways to relocate to the Galapagos, attracted by the islands' relatively prosperous, tourist-driven economy.

Table 02.01 Galapagos Population: 1990-2021

Year	Population
2021	33,042
2010	25,124
2001	18,640
1990	9,758

Source: Galapagos 2030, p. 17.

Tourists, although temporary, significantly increase the islands' population on any given day. Over one-quarter of a million tourists visited the islands in 2019 (Galapagos 2030, p. 17). They are responsible for 80% of the islands' income ((Galapagos 2030, p. 17).

The entire archipelago, including Puerto Baquerizo Moreno, faces severe challenges to create and maintain a human population that meets the UN sustainable development goals and the provincial Galapagos 2030 plan. The government reports that 51% of the population have unmet basic needs (Galapagos 2030, p. 29). Because the islands' natural resources are themselves limited, and because most of the islands' land mass is protected from human use by park regulations, the islands' population is almost entirely dependent on the mainland for food and supplies, including building materials. Each year, about 70,000 tons of cargo are carried by ship to the Galapagos (Galapagos 2030, p.31) This fact, together with use of diesel and gasoline for transportation and energy production, creates an outsized carbon footprint.

One consequence of constraints on the island's development is that water-related utilities are undersized. The potable water system delivers water to each customer for two hours a day. As a result, people store water in tanks to have a regular supply. This solution has created its own problem. Storage tanks become contaminated, and the water becomes unsafe to drink without boiling. For a more detailed discussion, see Grube et al, 2020.

The wastewater treatment plant discharges inadequately treated effluent directly into the bay, a marine ecological reserve that also provides fish for food and recreational activities. The minimal stormwater system does not prevent urban flooding during the island's rainy season. The degradation of the channels and riparian areas of the two urban streams contributes to flooding.

The cost to install below ground utilities is high because of the island's basalt (volcanic) rock. Moreover, equipment and parts need to be shipped from the mainland. In some cases, skilled workers also need to come to the islands from the mainland (personal communication). The island's electricity is supplied mostly by diesel generators. The fuel is shipped in from the mainland. There are two renewable energy facilities. The first is a a recently-installed 1 MW solar farm and battery storage system housed alongside the airport. The second is a 2.4 MW wind farm installed in 2006, which together provides 30% of the island's electricity.

03. POLICY CONTEXT

Two documents set policy for the built environment on San Cristobal. The first is the provincial comprehensive plan, Galapagos 2030: Galapagos Islands Strategic Plan (Galapagos 2030), which is published in English and Spanish. The second is Plan de Desarrollo y Ordenamiento Territorial Del Canton San Cristobal 2020-2024 (Territorial Development and Planning Plan of the Canton San Cristobal 2020-2024), published in Spanish.

03.01 Galapagos 20230

Galapagos 2030 is an 84-page document divided into five sections: Introduction, Galapagos Reactivation Plan (responding to the archipelago's Covid-19 shut-down), Galapagos Today, Looking to the Future, and Achieving the Galapagos 2030 Vision. The opening pages make 10 aspirational vision statements about the future. Throughout the following pages, these aspirational statements are refined through six increasingly specific levels of policy development and programmatic actions. Figure 01 provides a visual representation of the policy framework.

Two of the Galapagos 2030 vision statements have implications for the built environment. The first, which I quoted in the introduction, is: "By 2030, there will be a high quality of life in friendly, inclusive and safe neighborhoods that are connected to their natural environment" (p. 6). The plan defines this vision as including "basic services," a "close relationship with nature," and "complete neighborhoods within a 15-minute walk or bike ride" (p.5).

The second relevant vision statement is: "By 2030, the population will be more responsible towards the environment," which is defined as "the responsible use and consumption of resources, goods and services" by the community (p. 5).

Galapagos 2030 then identifies five strategic domains, or "axes." These are the conceptual space in which policies and actions play out. They are Government, Economy, Environment, Habitat, and Community. Each axis has its own goal. Three of these are most relevant for the project.

- Community, which has a goal of "Increas[ing] the well-being of the island inhabitants in accordance with the heritage value of Galápagos" (p. 46).

- Habitat, which has a goal of "Creat[ing] safe, inclusive and sustainable territories that promote equal opportunities, and are connected to each other as well as to their natural environment" (p. 46).

- Environment, which has goal of "Strengthen[ing] the resilience and sustainability of the Galápagos" (p. 46).

The next two levels are policies and then strategies. Strategies provide the most specific information about how the provincial government expects to achieve their vision and goals. There are eight policies and 11 strategies that relate to the built environment, in addition to three vision statements. Table 01 displays this information. I have summarized this material into eight objectives for the built environment. They are:

- Help residents identify with, appreciate, and care for the Galapagos' unique environment

- Preserve and restore ecosystem processes and biodiversity

- Mitigate adverse impacts from human activities

- Use renewable energy

- Reduce consumption, including land

Table 03. 01. Galapagos 2030 Plan Policy Goals Related to the Built Environment

Axes +Goals	Policies	Strategies
Environment [E] Protecting the human and natural heritage values Of Galápagos Strengthen the resilience and sustainability of the Galápagos.	[E1] Increase the generative and regenerative capacity of ecosystem services and flows by strengthening strategies for the sustainable management and conservation of ecosystems and biodiversity in Galápagos.	[E1.3] Monitor the status and resilience of ecosystem services and the sustainability of their flows
	[E2] Expand the areas that are managed and increase mitigation of impacts and/or pressures on the archipelago.	[E2.1] Reduce the internal and external pressure generated by the exploitation of resources and conserve the habitat for emblematic species.
	[E3] Promote the transition of human settlements toward sustainability and care of their ecosystems.	[E3.1]Promote decarbonization and reduction ecological footprint of settlements and human activities
Community [C] Improving well-being and quality of life. Increase the well-being of the island inhabitants in accordance with the heritage value of Galápagos.	[C1]Improve health, quality of life, and ensure the provision of efficient public services with coverage throughout the archipelago.	[C1.1] Monitor and further projects for the provision of drinking water and sewerage, environmental sanitation and comprehensive waste management, undertaken by the decentralized autonomous governments and executive institutions.
	[C3] Affirm and strengthen the island identity in the Galápagos population based on the natural environment.	[C3.1] Develop training, experiential and recreational activities, so that the population of the islands knows and appreciates the natural environment of Galápagos.
		[C3.2] Promote a culture of responsible consumption.

Table 03.01. Galapagos 2030 Plan Policy Goals Related to the Built Environment (continued)

Axes +Goals	Policies	Strategies
Habitat [H] Maintaining inclusive and sustainable territories. Create safe, inclusive and sustainable territories that promote equal opportunities, and are connected to each other as well as to their natural environment.	[H1] Work to achieve the consolidation of urban areas and the protection of rural areas, with principles of high quality of life, inclusion, peace, sustainability, and resilience.	[H1.1]With a focus on sustainability, promote the occupation of vacant lots and vertical residential growth in urban areas and protect productive rural character.
		[H1.2} Identify and address the limitations for the provision and access to decent, safe and affordable housing within the urban perimeter.
	[H2] Promote a sustainable mobility model that guarantees equal access to opportunities for people of all ages and abilities	[H2.1] Strengthen sustainable mobility and accessibility and reduce the use of, and dependence, on motorized vehicles.
	[H3] Promote sustainable generation of energy and its efficient and responsible consumption, and promote the transition towards a zero fossil fuel energy model.	[H1.3] Reduce the negative impacts and risks that extractive, industrial and artisanal activities present for the ecosystem and the quality of life of the inhabitants.
		[H3.2] Replace the use of fossil fuels with renewable energy.

- Improve mobility and connectivity (without expanding automobile use)
- Ensure adequate housing
- Provide basic services

These eight objectives will help guide the design study of a new, sustainable neighborhood for Puerto Baquerizo Moreno.

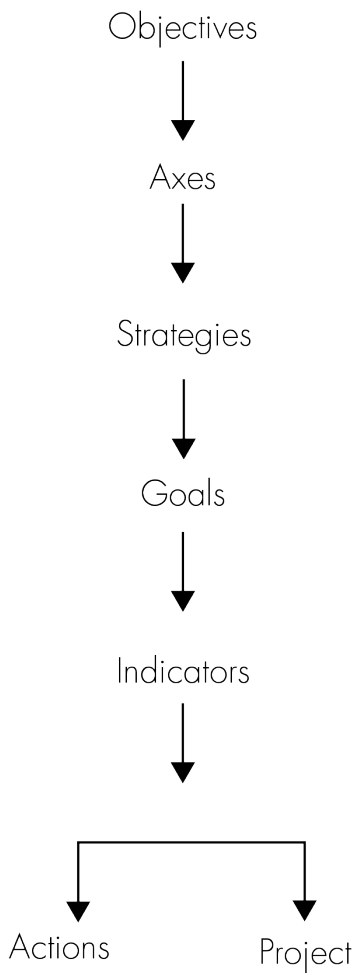
03.02 Territorial Plan

The second policy document is Plan de Desarrollo y Ordenamiento Territorial Del Canton San Cristobal 2020-2024 (Territorial Plan). It is only available in Spanish. I used Google's Spanish to English translation engine.

The Territorial Plan is a lengthy document subdivided into three broad sections. The first several sections describe the natural environment, and the canton's social, political, and economic organization in detail. The second section addresses hazards. The third section, which is the most relevant to this project, proposes goals, strategies, projects and programs for the canton's development.

The Territorial Plan sets out five development objectives. All of the first objective and parts of the second and third objectives are relevant to the built environment. The first reads "Conserve natural resources and biodiversity, controlling, recovering and restricting the activities of predatory, destructive and polluting human settlements in the canton, as well as developing effective actions that help minimize climate change" (p. 209). The second reads, in part, "... strengthening cultural identity through the conservation of tangible and intangible cultural heritage" (p. 209). The third reads, in part, "Improve the provision of public services..." (p.209).

Figure 03.01 Territorial Plan Policy Hierarchy



The overall development objectives are then divided in axes, or domains, similar to the Galapagos 2030 plan. Figure 01 shows the policy hierarchy for the Territorial plan. The axes are biophysical, economic, and socio-cultural. The biophysical axis is the most relevant to the built environment. Of the eight goals listed in the biophysical axis, five are most relevant to the design of the urban environment:

- Promote the sustainable management of hydrographic basins.
- Improve the liquid and solid waste management system throughout the territory of the canton through the implementation of improvement mechanisms and constant monitoring

of the system.

- Improve the solid waste collection and treatment system throughout.
- Generate environmental awareness in the population to live in harmony with it.
- Promote actions for adaptation and mitigation to climate change.

The Territorial Plan has two more levels in its policy hierarchy, a strategy level and a goals level. The strategy level has one statement, "Promote environmental sustainability by establishing public, private and community co-responsibility in the management of natural resources as a principle" (p. 211). This is somewhat similar to the Galapagos 2030 Plan Environment policy of "Promote the transition of human settlements toward sustainability and care of their ecosystems" (p.47). The subsequent levels (goals, indicators, actions and project) are more oriented toward implementation and therefore are less relevant for guiding design decisions.

03.03. Policy Comparison

The Galapagos strategic plan and the San Cristobal territorial plan are well aligned, although the strategic plan sets

Table 02. Comparison of Strategic Plan to Territorial Plan

Galapagos Strategic Plan		San Cristobal Territorial Plan
Help residents identify with, appreciate, and care for the Galapagos' unique environment		Generate environmental awareness in the population to live in harmony with it.
Provide basic services		Improve the liquid and solid waste management system throughout the territory of the canton through the implementation of improvement mechanisms and constant monitoring of the system.
		Improve the solid waste collection and treatment system throughout.
Preserve and restore ecosystem processes and biodiversity		Promote the sustainable management of hydrographic basins.
Mitigate adverse impacts from human activities		Promote actions for adaptation and mitigation to climate change.
Use renewable energy		
Reduce consumption, including land		
Improve mobility and connectivity (without expanding automobile use)		
Ensure adequate housing		

out a more expansive vision with eight goals compared to the five goals in the territorial plan. Table 02 compares the two documents. The territorial plan reflects the strategic plan's goal to provide basic services but focuses specifically on the solid and liquid waste system rather than all basic services. While the territorial plan focuses on the area's hydrologic basin, the Galapagos strategic plan includes the broader goal of protecting and restoring ecological process. Goals related to climate change and helping residents connect with the local environment are similar in both plans.

The strategic plan has four goals not addressed by the territorial plan. They are adequate housing, transportation connectivity, using renewable energy, and reducing consumption. However, the territorial plan's goal of mitigating climate change is consistent with the strategic plan's goal to use renewable energy and reduce consumption.

03.04. Implementation

Galapagueños have many well-researched tools and strategies they can employ to achieve their goals. Some goals are well-supported by existing practices while other goals face significant obstacles. In the next several paragraphs, I will explore some evidence-based strategies and practices that can help Galapagueños achieve their policy goals.

There are a few tools that may "help residents identify with, appreciate, and care for the Galapagos' unique environment" or as the territorial plan has it, "generate environmental awareness in the population to live in harmony with it." The first is to create opportunities to interact with the natural environment in different ways and at different scales. A regional park allows people to be immersed in a natural environment, while a community garden allows people to interact with soil and plants, and a landscaped setback provides a small bit of visual relief in an urban environment made primarily of concrete. It is the responsibility of the planner to ensure these spaces exist at a level that serves the population.

A second tool is education. Education can take the form of formal schooling, such as teaching children about the environment as part of the curriculum or as part of school field trips, adult education to demonstrate gardening skills or supporting hobbies such as bird watching, or even signage on park trails and in town. Finally, opportunities to help maintain the built environment, such as weeding, planting, or constructing habitat create strong bonds between people and place. Education and volunteerism are programs that are outside the realm of design, but planning sets the table.

Setting aside sensitive land is an important method to meet the goal to "preserve and restore ecosystem processes and biodiversity." It is much easier and less expensive to set aside land than it is to restore land after it has been developed. Sensitive lands are typically sensitive because important ecological processes take place there, such as groundwater recharge and animal nesting or foraging. Groundwater is a specific concern raised in the territorial plan, which set a goal to "promote the sustainable management of hydrographic basins." This may have several meanings but likely refers to preventing pollution from contaminating groundwater, ensuring that aquifers are being replenished at the same rate or higher than they are being drawn down, or both. Mapping, inventorying, and process analysis are important steps in determining what land should be set aside from development. Regular monitoring is an important part of managing hydrographic basins.

The provision of basic services, especially

wastewater management, which is a strategic plan goal, is an important aspect of managing the hydrological basin. Human sewage poses a significant risk to groundwater supplies. The territorial plan recognizes this when it set a goal of "Improve the liquid and solid waste management system …through the implementation of improvement mechanisms and constant monitoring of the system." I address basic services at several points in this paper.

Compact development is a second method to preserve ecosystem processes and biodiversity. Human development is inevitably accompanied by covering over natural surfaces. This destroys primary production habitat, nesting and foraging habitat, alters hydrological and soil-building processes, and retains excessive solar radiation, among other things. Compact development strategies reduce the overall amount of land that is dedicated to human use. Strategies include reducing or eliminating setbacks between buildings and between buildings and streets, reducing street widths, and building up.

As the name implies, compact development seeks out space-saving approaches to the design of the built environment. Approaches can include small or no setbacks between buildings, which brings buildings closer together. It may include "skinny" streets with narrower lanes and public utility right of way. It includes a focus on building up. It also includes mixed-use development so that people are not forced to drive to work to meet their daily needs. Compact development also means using less materials overall, which reduces the consumption of non-renewable resources and the production of greenhouse gases that result from the manufacturing process. Fortunately, the Galapagos' approach to the built environment includes compact development and mixed use.

The strategic plan has a goal to "reduce consumption, including land." Compact development is an important strategy to reduce land consumption, energy consumption (for travel), and material consumption (by reducing the extent of roads and utility lines).

There is a clear pathway for solar and wind energy in the Galapagos, which meets the strategic plan goal to "use renewable energy." Not only are both solar radiation and wind abundant on the islands, but they also have experience installing and maintaining them. San Cristobal has an existing wind farm with three 800kW turbines and a set of solar panels near the airport that together provides 40% of the island's power. Additional wind and solar facilities, combined with battery storage, can lead to a fossil fuel-free community. This aligns with the territorial goal to "Promote actions for adaptation and mitigation to climate change."

The strategic plan seeks to "improve mobility and connectivity without increasing automobile use." It also judges its existing urban environment harshly, noting that "The roads, including the local streets of the populated centers, are mostly designed for motorized traffic and do not have facilities for sustainable mobility or the transit of people with physical limitations (Galapagos 2030, p. 30).

I have a more charitable take. Puerto Baquerizo Moreno's street grid provides good connectivity and its street design does not favor automobile transportation more than other methods. Streets are narrow, blocks are short (which means more intersections and therefore, slower speeds), buildings are close to the street, there are few on-street parking areas and no off-street parking lots. Bicycles, motor scooters and cars share the travel lane. As a result, speeds are often low, which improves safety. I believe the town's main challenge is to resist any effort to make changes that favor more automobile

use, such as building wider streets or adding more on-street parking. The town could choose to improve the pedestrian experience by widening the sidewalks, which are about 1 meter. Since the sidewalk zone also contains furnishings such as signs and light posts, two people cannot walk together or easily pass one another without stepping on the street. The strategic plan is correct that the street system is not very accessible for people with physical limitations.

The town does not have dedicated bike lanes. For many streets, it is not a problem for bikes and slow-moving cars to share a travel lane in an urban environment. Bikes on travel lanes typically result is slower vehicles. There are some streets, however, that may benefit from a dedicated bike lane. This is the case for a few primary streets that provide connectivity across town, such Avenida 12 de Febrero, Avenida Jaime Roldo Agiuilera, Avenida Alsacio Northia, and stretches of Avenida de Quito. People drive faster when they have further to go and when they are outside of their own neighborhood.

Government has a wide range of tools to manage the affordability of housing, which is a strategic plan goal. These include land tenure laws, land supply, financing, and regulations, most of which are outside the scope of town planning and design. Town planning is responsible for land use. This policy domain determines the overall amount of land available for housing, plot maximum and minimum sizes, neighborhood density requirements, the mix of public amenities, and the dimensions of public spaces. Depending on the town's legal status, it may also set environmental and other standards that influence cost. This paper consistently advocates for compact development by encouraging small lots and four-story buildings to keep housing costs down while contributing to environmental and fiscal sustainability.

The final strategic plan goal is to "provide basic services," which is aligned with the territorial plan to "improve the liquid and solid waste management system throughout the territory." I define basic services as electricity, telecommunications, drinking water, wastewater, stormwater, solid waste management, and the transportation network. Basic services could also include healthcare, education, and child/senior care.

Puerto Baquerizo Moreno, and the Galapagos as a whole, have significant challenges providing basic services. Some challenges are shared by communities around the globe, such as the inability to control the pace of development or collect sufficient revenue to finance or repair infrastructure. Some are more specific to the Galapagos. For example, the Galapagos is so geologically young, there is little soil. As a result, excavation for underground utilities takes place directly in bedrock, an incredibly expensive activity. Many challenges do not have a clear path to a solution. Currently, the most significant challenges in basic service provision are wastewater and drinking water. The solid waste management system is also under pressure, but this system does not require underground infrastructure. I discuss an approach to managing wastewater and drinking water in sections seven and eight.

03.05 Conclusion

The provincial and canton goals are rational and well-grounded in evidence. For many of the goals, there are evidence-based strategies and clear pathways that the town can follow to achieve them. Costs to implement each goal vary considerably, with the goal of providing basic services the most expensive to realize. Other goals require changes in behavior and values to be successful, such as reducing consumption and identifying with the Galapagos' unique environment. The government's

ability to partner with citizens of Puerto Baquerizo Moreno, and inspire confidence in international lending and technical assistance providers, will determine the success of the Galapagos 2030 plan and the Plan de Desarrollo y Ordenamiento Territorial Del Canton San Cristobal 2020-2024.

04: URBAN FORM

This section continues our fact-finding investigation by exploring Puerto Baquerizo Moreno's urban form. My intention is to identify critical elements of urban form that provide insight into the town's current livability, functionality, and sustainability, as well as elements that we may to include or exclude in the master plan for Barrio de las Lechuzas.

Urban theorists have proposed a variety of different elements and frameworks to describe urban form but have not reached consensus (Lynch & Rodwin, 1958; Kropf, 2009; Dempsey, et al.; 2009, Oliveira, 2013; Angel et al., 2020). Given the lack of consensus, I have selected a set of eleven spatial and human-made elements that I believe are most helpful to understand Puerto Baquerizo Moreno's urban form. The spatial elements are shape, extent, mass, and density. The human elements are land use, transportation networks, urban grain (streets, blocks, and parcels), and urban fabric (building, facades, and public spaces).

Urban form applies to all human settlements, not just cities. Topography and land cover influence urban form but are not themselves elements of urban form.

04.01.01 Shape

Dempsey et al. did not include shape in their proposed elements of urban form, neither did Lynch. Urban morphologists, who have a strong quantitative orientation, suggest that urban shape is an important element of urban form. In this case, shape refers to the external form of a city that is created by its administrative boundary line. In contrast to Dempsey et al., Duque et al. identifies shape, internal urban structures, and land use patterns as the key elements of urban form (Duque, 2021,137). They are particularly interested in compactness, which they suggest results in positive social, environmental, and economic outcomes.

Angel et al. share this view of compactness. They note that a circle is the most efficient shape for a city (Angel, 2020). Cities that evolve different shapes do so in response to one or more of six variables. They are: physical barriers; merging of adjacent settlements; intercity roads and rail lines; land use restrictions; beach front preferences; and, land market distortions (Angel, 2020).

In the case of Puerto Baquerizo Moreno, physical restrictions (the ocean) and land use restrictions are driving its form. Market distortions may be coming into play as land speculators hold on to individual lots, forcing prospective buyers towards the periphery even though lots closer to the central area remain vacant.

Puerto Baquerizo Moreno is developing in the shape of an irregular east-west rectangle. It is limited by the ocean to the west and the national park to the north and south. The City's only option is to grow east along the inter-town road towards the smaller town of El Progresso. These boundaries represents the current limits of urban growth on the island of San Cristobal. Puerto Baquerizo Moreno's terminal form will likely be a linear city approximately 3.6 miles east to west by about 0.6 miles north-south. This pattern lends itself towards transit-oriented development.

This shape constrains the town's ability to maximize its sustainability and social capital. On the other hand, the overall extent of the City is modest and the limitations from its shape are likely to be modest as well.

Figure 04.01. The shape of Puerto Baquerizo Moreno

Puerto Baquerizo Moreno's shape as defined by its municipal boundary. The City is expanding east along a main road that connects to the much smaller rural town of El Progresso. The City's shape is driven by physical barriers and land use restrictions. Source: Author.

04.01.02 Extent

I measured the town's extent using Arc Pro to be 3.1 km2, excluding the airport. While this is the overall extent based on the town's administrative boundary, it can be misleading. There is a significant amount of undeveloped land set aside as an urban reserve to accommodate future growth. The built-up extent is 1.9km2.

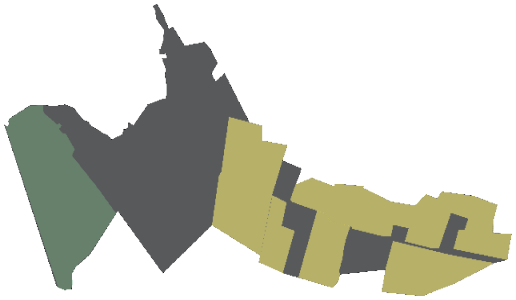
04.01.03 Mass

Whereas shape and extent are two dimensional spaces or planar space (X and Y in a coordinate system), mass is three dimensional space or volumetric space (X, Y, and Z-elevation- in a coordinate system). The formula is simple: building footprint x number of floors. Mass captures vertical development and vertical development more than any other factor drives density. The problem is that collecting data on mass requires information on the lot size, building footprint, and number of floors for each building. GIS information on lot and building footprint tend to be available but floors per building are not as readily available. Information on floors per building is not available for Puerto Baquerizo Moreno.

04.01.04 Density

Density (population ÷ area) has a profound impact on cities. Cities with higher densities use non-renewable resources more efficiently. Multifamily buildings use less resources to heat and cool, as do homes with party walls. Buildings that are closer together reduce transportation costs and shorten the extent of utility lines (e.g. sewer lines). Density allows for mass transit options that further reduce the demand for

Figure 04.02 Built Up Areas



Puerto Baquerizo Moreno's municipal extent covers about 3.1 km^2. Only 61% is developed. The remaining space is divided between the airport and undeveloped areas held as reserves for future growth. Source: Author.

non-renewable resources. Density also increases opportunities for people to interact with a wide range of residents. This, in turn, creates opportunities for friendship, collaboration, and networking (i.e. social capital). High levels of social capital support economic development, innovation, and resiliency.

Puerto Baquerizo Moreno has a 2022 population of 7,290. The towns current extent is 3.1 km2, excluding the airport. This results in a population density of 2,351/km2. This is misleading; however, since it includes 1.2 km2 that is undeveloped and held in reserve. A more accurate population density is

3,836/km2. For comparison, the City of Eugene, home to the University of Oregon, has a population density of 1,542/km2 (2020). Oslo, Norway, has an urban population density of 3,300/km2. Oslo is well-known not only for its walkability but also for its environmental stewardship.

04.01.05 Land Use

Functionally, the island of San Cristobal has two broad classes of land: national park and human use. The boundary between the two were established when Ecuador's national government created the Galapagos National Park in 1959. There have been some adjustments since. The municipal government has not adopted zoning. In the absence of zoning, the entire urban extent is essentially mixed use. Mixed-use is an important element of urban sustainability because it reduces travel distance to access goods, services, and employment. Only uses that produce harmful or disruptive by-products, or pose serious risks to neighbors, should be segregated from other uses.

The prevalence of mixed use varies on a gradient from the central business district, near the pier, radially outwards to the periphery. Density follows a similarly gradient and is driven by two variables: whether or not a lot is developed and the number of floors per developed lot.

04.01.06 Transportation Network

The City's transportation system is relatively simple. It consists of three major components: a road system, a pier, and an airport.

The road system has three elements. The primary element is a strong, comprehensive grid of streets. The street grid, supported by short blocks and small lots, creates a positive pedestrian environment and reduces greenhouse gas emissions for trips in motorized vehicles. The second element is s a ring road that establishes the town's urban edge. The third is an inter-town road that starts at the pier, runs east through the center of the Town, and connects to the rural town of El Progresso in the highlands. This arterial road serves as the primary connection between urban and rural areas, with a bus service operating along its route. Due to its critical role in regional mobility, the corridor presents significant opportunities for urban expansion—particularly through Transit-Oriented Development (TOD) strategies that leverage accessibility and efficient land use. This development strategy aligns well with some of the goals and objectives in the regional and local policy frameworks." There is also one street that functions as a north-south arterial. North-south connectivity is not quite as continuous as east-west connectivity.

The pier provides access to the town for charter and tourist vessels, a point of departure for travel to and from the nearby island of Santa Cruz, and home base for a small fishing fleet. San Cristóbal airport lies within the town's borders on its southeastern edge. It receives daily flights from the Ecuadorian cities of Quito and Guayaquil. Just over 76,000 visitors entered the Galapagos via San Cristóbal airport in 2022.

Urban Grain

Urban grain is the physical dimension of neighborhoods, blocks, and plots. Smaller blocks and plots create a finer grain, and larger blocks and plots create a courser grain. A finer grain is typically better because it often leads to greater building heterogeneity, which results in greater visual richness and consumer options. A fine grain also supports walkability and greater interaction between residents. Greater interaction between residents, facilitates social networks and social capital. Human networks and social capital play a critical role in innovation, problem-solving, and resilience.

Figure 04.03 Puerto Baquerizo Moreno Street Front

A representation of the visual diversity within the confines of a relatively narrow range of building types in the central (and historically earlier) part of Puerto Baquerizo Moreno. Source: Author

Zhao et al. identify five variables that can be used to assess urban grain. They are: road network density, building density, age of housing structure, façade length along street, number of entrances along street, and functional mixture (Zhao, 2023). Number of entrances on streets is a proxy for the number of individual businesses on a street and building density captures the distance between building envelopes. Age of building is correlated with fine grain since older buildings have had longer opportunities to sub-divide.

Puerto Baquerizo Moreno has, in general, a fine grain. It has short blocks, small lots, and mixed use buildings set within a grid-style street pattern. Buildings tend to span the entire length of the frontage without front or side setbacks. This pattern is not consistent across the whole city. Some areas have patches of larger lots with single family detached housing, although block size tends to remain smaller. The city's urban grain, however, suffers from undeveloped parcels. This occurs more frequently further away from the City's center. And, like all cities, there are some uses that require larger lots that then interrupt the fine grain pattern. These exceptions include facilities such as schools, hospitals, and industrial campuses.

04.01.07 Block Structure

We can assess blocks across two dimensions: shape and size. Size is the more important dimension and consists of length and width. Urban theorists maintain that short blocks are better because they facilitate more efficient movement across a city, incentivize walking by providing a more visually engaging street front, and provide more opportunities to support a diverse range of commercial and retail business owners (Zhao, 2013). A diversity of businesses, in turn, reduces the distance residents may need to travel to meet their daily needs, which improves efficiency. The second dimension is shape. Denis identifies three types of block shape: rectangular, square(ish), and irregular (Denis, 2022).

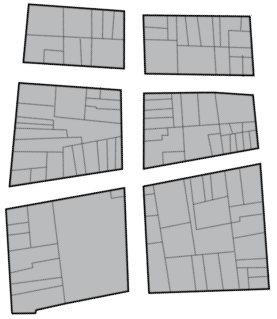
Figures 04.05 show an image of a six-block section of Puerto Baquerizo Moreno's commercial district, while Figure 04.06 illustrates the plot division within the block structures. The overall area is 1.3ha. The largest block is only 68m in length while the shortest block is 31m. There are a total of 101 plots in this space.

Figure 04.07 shows an 11-block section towards the periphery of the town's 1982 border. It is approximately 3ha. Each block is approximately 60m long and

Figure 04.04 A Six-Block Section of the Commercial District

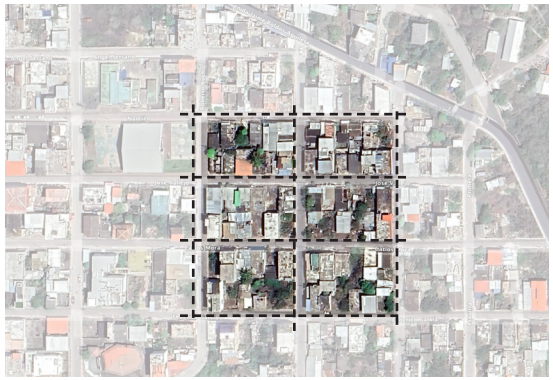
A six-block section of the central building district, the oldest part of the town.
Source: Author.

Figure 04.05 Lot Divisions of the Commercial District



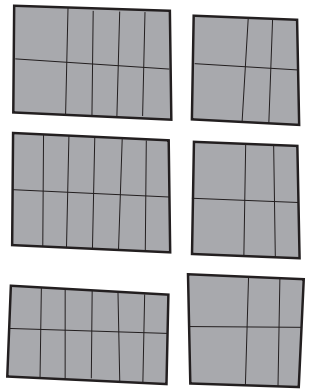
This six-block parcel in the central business district has been divided into 101 lots.
Source: Author.

Figure 04.06 An 11-Block Parcel on the Urban Periphery



This parcel is located at the town's periphery. The parcel's dimesions are 281 m top to bottom and 128 meters aross the center. Source Author.

Figure 04.07 Plot Configuration of Section Near the Urban Periphery



This 11-block parcel has been divided into 114 lots. Source: Author.

about 40m wide, with an area 0.25ha. Figure 04.08 illustrates the lot divisions within the block. This 11-block parcel holds 114 plots.

These two parcels are representative of much of Puerto Baquerizo Moreno, which has small lots on small blocks set into a gridded street system. They differ in the total number of lots per block. This is mostly likely a result of age. Older parcels become sub-divided over time to accommodate the commercial opportunities that arise with urban density. The peripheral parcel has not had time to be sub-divided. In this case, the plots have not all been occupied yet.

The City's fine grain is aided by its lack of front and side setbacks. Side setbacks create space between buildings that (typically) reduce the visual interest and rhythm of street while they increase travel time. Front setbacks diffuse the urban edge and decrease pedestrians' engagement with their immediate environment. The absence of setbacks does create some trade-offs. Setbacks allow for access to light and air circulation, which has human health impacts. It also increases storm water runoff. Setbacks can be used to slow and absorb storm water. In general, setbacks should be limited to specific situations where they are needed and treated as an exception.

04.01.08 Plot Sizes

In general, plots are narrow and have a rectangular shape. This pattern is more consistent towards the town periphery and is likely the result of town planning. This echoes the block pattern. The lots in the central business district are more irregular, again similar to the blocks. Figure 07 shows the lot shape in a newer, peripheral area of town. The plot dimensions are a consistent 18m by 10m

04.01.09 Housing & Building Type

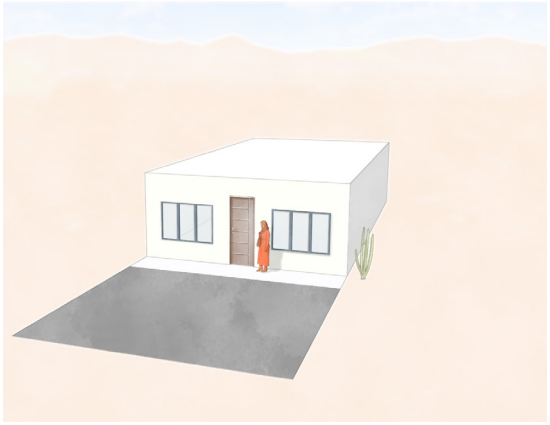
The basic building unit in Puerto Baquerizo Moreno is a rectangular or square cube made of concrete blocks. They can be stacked up to four floors in height. Architects are typically not involved. Local laborers construct the buildings based on their knowledge and experience. Often, buildings are constructed one floor at a time, with a gap of potentially years before another floor is added. Karakiewicz provides a more comprehensive discussion of building typologies in "Towards Urban Self Sufficiency in the Galapagos." Because the availability of building material varies, each floor of an individual building may have material and stylistic (windows, balconies, paint colors, etc.)

variations. Larger buildings and tourist-oriented buildings (i.e. luxury hotels) do not necessarily follow this pattern. These facilities may require an architect and specialty contractors that are sourced from the mainland.

The structural form of most building facades takes on one of four variations as illustrated below. The first is a building whose facade directly fronts the sidewalk. The second type also directly fronts the sidewalk but has a cantilevered second floor that projects over the sidewalk. Although this cantilever is an unpermitted type, it provides a useful benefit to the pedestrian by providing sun and rain protection. The third type has a wall fronting the sidewalk and the building set back. This type allows for an entry plaza or garden. The final type is building that is setback from the street and the resulting open space is used to provide seating for restaurants or display merchandise for retail stores. The result is that there is a uniform, continuous urban edge for pedestrians that also provides variety and visual interest.

No discussion of urban form in Puerto Baquerizo Moreno would be complete without including one of its most iconic features: the incomplete building. In the Galapagos, each building is typically built by its owner as finances allow. This

Figure 04.08. Basic Building Form



The basic building form is one-story rectangular or square cube made of concrete blocks. Source: Author.

Figure 04.09. Building with Cantilever

The second facade type is a 2-story basic building with the second floor cantilevered over the sidewalk. Source: Author.

Figure 04.10. Building with Garden Entrance

The third facade type places a wall at the sidewalk edge to create a more private entry plaza into the building. Source: Author.

Figure 04.11. Building with Customer Space

In the fourth type, the building is setback to create retail space for consumers. Floor material awnings, and furnishing establish a clear edge to the sidewalk. Source: Author.

results in buildings being constructed in phases, often floor-by-floor. It is common, therefore, to see buildings with re-bar, pillars, and other structural components protruding from the roof while waiting for the owner to fund the subsequent floor. Kennedy notes a potential reason other than aspirations exceeding available funds: "The unique shapes of these pseudo-informal constructions are the product of a tax loophole found in many South American and even Southern European countries that allows residents and landlords to defer property taxes on buildings in the process of construction" (Kennedy, 2017). He provides no support, however, for this interpretation.

Figure 04.12 Unfinished House

Source: Kennedy, 2017

Figure 04.13. Inti Raymi Summer Solstice Festival

Residents parade down Avenido Quito to celebrate the Incan new year.

The idea of building in stages to accommodate financial necessity is easily defensible since it is in the public interest to grow vertically. If this practice creates a tax loophole, the government should address that problem without discouraging people from building in stages.

04.01.10 Streets

Streets are not often considered public spaces, especially in the post-World War II era, where the multi-purpose use of streets gave way to the primacy of the automobile. This is not the case, fortunately, in the Galapagos where cars are rare. Streets tend to be narrow, between 5km and 8km wide. (Narrow streets are an urban form that is shared by many islands where land and materials are scare.) They are used by bicycles, motor-scooters, automobiles, small trucks, and minibuses. Many streets are

not wide enough to accommodate on-street parking. The streets are narrower in the older section of the town, but do not increase significantly as the city grew towards its periphery. Most streets have narrow (1m) sidewalks. Sidewalks are interrupted by fixtures such as light posts and utility poles. They are not very accessible to those with mobility challenges, although there is some evidence that accessibility is starting to receive some attention.

One important street is Avenido Quito, which runs along the waterfront. The central business district borders the east side of the street and the pier, beaches, and a promenade (malecón) borders the west side. Avenido Quito provides spaces for tourist and leisure businesses as well as public spaces for important civic and cultural activities. The promenade (malecón) varies in width. Wider areas provide green spaces and seating areas, cafés, gathering spaces, and public toilets. There are also commemorative markers and public art that reflect the island's history. Avenido Quito is likely the most important public space on the island.

I observed three public events that took place on the streets during the three weeks I stayed in Puerto Baquerizo Moreno. Two of them were on Avenido Quito. The first was a political protest over a proposed increase in tourist fees. The second was a cultural festival and the third was street party in honor of the navy.

04.01.11 Public Spaces

Puerto Baquerizo Moreno has several other public spaces in addition to Avenido Quito. They include a public plaza and park located two blocks east of Avenido Quito, which has an area of approximately 0.5ha. There are also three football (soccer) fields distributed north-to-south across the eastern edge of the city, and one large football field and track facility at the southern end of the City, adjacent to the airport. Finally, there are two beaches within the town boundary. They flank the north and south end of the central business district. There are accessible beaches outside the town's boundary as well.

Figure 04.14 Public Spaces Adjacent to Central Business District

Several public spaces located immediately adjacent to the central business district, including: Avenido Quito, which hosts civic and cultural events; a beach; the malecon, which supports green spaces, seatings, cafes, public art, and interpretive installations; and, a park, which includes a plaza, stage, public bathrooms, and a small space with trees and greenery. Source: Author.

It is worth noting that the City has numerous street-level "third spaces." Third places, as described by Ray Oldenburg and Karen Christianson, are places that are not home, not work, but places where we can escape from both; to relax, engage our neighbors, build relationships, and otherwise connect with the community (Oldenburg, 1989). Third spaces contribute to social capital. Puerto Baquerizo Moreno's third paces are primarily cafés and bars across a range of typologies.

04.02. Alignment of Policy with Current Urban Form

Puerto Baquerizo Moreno's current urban form has a mixed relationship with the Galapagos 2030 strategic plan goals. Several elements of urban form support one or more of the strategic plan goals, a few are unrelated, and a few are contrary. I discuss each goal and its relationship to the elements of urban form below.

Help residents identify with, appreciate, and care for the Galapagos' unique environment.

The integration of the natural environment and analogues of the natural environment are not a prominent feature of the current built environment, which mostly features concrete and asphalt. Some natural stone is integrated into the built environment. (I noticed the use of stone was more prevalent in Puerto Ayoro on Santa Cruz.) Landscape elements such as trees, shrubs and groundcover appear sporadically on individual plots as either maintained gardens or as a mix of native and exotic species on unmanaged properties. The promenade along the waterfront (Avenido de Quito) features planting strips and planter boxes with small trees and ornamental shrubs. The nearby park was mostly pavement with some natural landscape elements along one edge. There are few street trees. (I discuss street trees in greater detail in section seven.) There are two seasonal streams that run through the town and into the bay, but they are degraded. Buildings line the streams' edges and invasive grasses and other plants have taken over the rocky channels. Two public beaches in the town help connect residents with the ocean.

I discuss several strategies to better connect residents with nature in section seven. While those strategies are discussed in the context of a greenfield development, they can also be integrated into Puerto Baquerizo Moreno's existing built environment. In addition to the suggestion in section seven, residents may want to consider restoring the existing seasonal streams and identifying opportunities for pocket parks along major streets or places where people gather. The government or an NGO may want to encourage residents to plant climate adapted trees and shrubs on property they own and provide training.

Preserve and restore ecosystem processes and biodiversity

Human development alters ecosystem processes and is incompatible with the spatial and ecological needs of many species. This is why we are in an era of mass extinction. Compact development that supports medium (<3,000) or high (<10,000) density residential populations is one of the best strategies to preserve ecosystem process and biodiversity. Puerto Baquerizo Moreno is an example of compact urban development that has achieved a medium residential density and has an urban form that can accommodate much greater densities. It is important that the town enforce its existing boundaries until it has been fully built out, which means that all privately-owned plots are occupied and most plots contain four-story buildings. The suggestion above to restore urban

streams is one method to restore ecosystem processes.

Mitigate adverse impacts from human activities.

Mitigating adverse impacts from human activities is closely aligned with "preserve and restore ecosystem processes and biodiversity." In this context, mitigate means offsetting the negative consequences of development rather than avoiding (preserve) or repairing (restore) damage. Mitigation includes things such as switching from fossil fuels to renewable energy sources, using green roofs or high albedo surfaces to reduce the heat island effect, and implementing compact development strategies. Mitigation also includes effective wastewater and stormwater management, careful use of freshwater resources, and limiting the spread of invasive species. The current built environment falls short in mitigating pollution, including pollutants from non-point surface, sewage, and heat. Strategies to reduce pollution from the construction and maintenance of the built environment needs to be a priority in retrofitting the existing urban environment and designing the future urban environment.

Use renewable energy

Puerto Baquerizo Moreno is well positioned to transition from diesel to solar and wind sources for electricity. Its current urban form is neither a help nor a hindrance to this transition.

Reduce consumption, including land

The consumption of land, materials to construct and maintain the built environment, and resources for transportation, such as fuel, are driven in large part by policies regulating urban form. In this respect, Puerto Baquerizo Moreno existing practices are aligned with the Galapagos 2030 strategic plan goal. As I have noted elsewhere, the town has a compact, dense form that reduces land consumption and travel distances. The consumption challenge is related to building materials (cement), consumer goods, fuel choice (diesel and gasoline), and food. These goods are imported and some of the materials, particularly cement block, are not optimized for the environment. Improving food self-sufficiency and finding alternative building materials will make an important contribution to reducing consumption.

Improve mobility and connectivity (without expanding automobile use)

Puerto Baquerizo Moreno has a street grid that provides good internal connectivity. It is connected to the highlands by a well maintained road. The airport provides daily flights to the Ecuadorian mainland and the pier provides daily ferry service to Santa Cruz. The quality of the street infrastructure could benefit from improvement. Sidewalks are narrow and often obstructed by street furnishing, facilities to support people with mobility impairments are inadequate, bike lanes are absent, and shade and other street amenities are missing. New street design standards should be developed. These new standards should be implemented for new development and on strategic retrofits for existing streets with high use.

Ensure adequate housing

The town has the capacity to double or even triple in density if current building owners choose to build to the town's four-story limit. If vertical development does not happen organically, the town should develop policies that create incentives for vertical development.

Provide basic services

The town did not develop with a focus on ensuring that all buildings had access to basic services, particularly services

related to water: wastewater, drinking water, and stormwater. It will need to develop a comprehensive, phased program of infrastructure retrofitting and a method to finance the program. Retrofitting is often more expensive. When the town expands beyond its existing boundaries, I suggest that it adopts a decentralized approach, which I discuss in section seven.

04.03 Conclusion

This section examined Puerto Baquerizo urban form through a discussion of 11 elements and how they related to the province's strategic goals. The purpose of this discussion was to identify elements of urban form that could be incorporated into the master plan for a sustainable new neighborhood. The following provides a summary of the discussion.

Shape, extent and mass

The town is an irregular square of 3.1km2, excluding the airport. Of this, 1.2km2 are undeveloped. The town is evolving along the road that connects Puerto Baquerizo Moreno to the small rural town of El Progresso, which will result in a linear shape. This shape is driven by land use restrictions that prohibit development on national parkland. A linear city is less efficient than one with a circular shape; however, the limited extent of the Puerto Baquerizo Moreno means that its shape will have only a modest impact on sustainability and perhaps a slightly larger impact on social capital formation. The town's evolving shape creates opportunities for transit oriented design.

Density

The town has a built up density of 3,836/km2 and overall density 2,351/km2 including the undeveloped area. This is slightly denser than Oslo, Norway, a famously green and walkable city. Puerto Baquerizo Moreno has an opportunity to increase density by building up to a maximum number of four floors. Building up to four floors could double or triple the town's density and help meet provincial goals. Vertical development creates opportunities to capture revenue to invest in needed infrastructure and better public spaces.

Land use

The town's current approach of compact development makes a significant contribution to sustainability and the province's strategic goals. The town does not have a zoning code. The result is a mixed-use pattern across the town's extent, although commercial and retail is concentrated in the town's oldest area near the pier. Mixed use complements the town's compact development. On the other hand, some uses merit some spatial segregation, such as those that produce noise, polluting emissions, or pose health risks. The town would benefit from a simple zoning code that protects a majority of mixed uses while separating out truly incompatible uses. A code that integrates form and use would help maintain the town's walkable form.

Block, lot, and street structure.

Puerto Baquerizo Moreno is characterized by short blocks, narrow lots, and a strong street grid. These are key features of compact, walkable cities that use less resources and have higher social capital than cities with a more disbursed form. The town should maintain this pattern as it expands.

Building and facades.

The town has very limited building typology: square to rectangular volumes made of concrete blocks with a maximum height of four floors. Building are typically self-built by their owners and additional floors are added over time.

Facade forms have a few basic types. Facade features and fixtures vary widely, creating an engaging street scene. The central business district provides a greater diversity of building types, such as hotels. Most buildings do not have front or side setbacks. The island's primary building material, concrete blocks, is not sustainable. The province should research and experiment with different building materials. Aside from the building materials, the is no compelling reason to change the current building types and facades.

05. SITE DESCRIPTION & ANALYSIS

In section three, I explore the project site to develop a set of facts about the site's physical, ecological, and social characteristics. I conclude the section by identifying some opportunities and constraints that will inform the master plan.

05.01 Site Context

The site (figure 05.01) is located on the eastern edge of Puerto Baquerizo Moreno. It contains approximately 37 hectares in the shape of an irregular rectangle. The town's main pier and commercial center is located approximately 1.1km from the center of the site. The airport is 2.3km from the center of the site and the hospital 0.6km from the center of the site

A road that connects Puerto Baquerizo Moreno to the rural town of El Progresso divides the site into a northern and a southern section. The southern section has been added into the town's administrative boundaries while the northern section is part of the island's urban reserve. The distance between the center of the site and the El Progresso is 5.3km.

Figure 05.01 Context

05.02 Land Use History

Figure 05.02 shows the development history of Puerto Baquerizo Moreno at five moments in time, starting with just a handful of structures on the waterfront to a more complex town in 2022. Note the change from a tightly nucleated settlement to a more linear pattern as the town spreads out along the inter-urban road towards El Progresso. The town's north-south expansion is limited by the Galapagos National Park and westward expansion by the Pacific ocean.

While it is not apparent with the resolution of these diagrams, there is a significant amount of undeveloped land that could be used for homes and services. A portion of that undeveloped land is locked up by speculative owners. In addition, the Galapagos 2030 plans encourages vertical development. This policy coincides with local practice, which is to add floors over time as individual owners access financing.

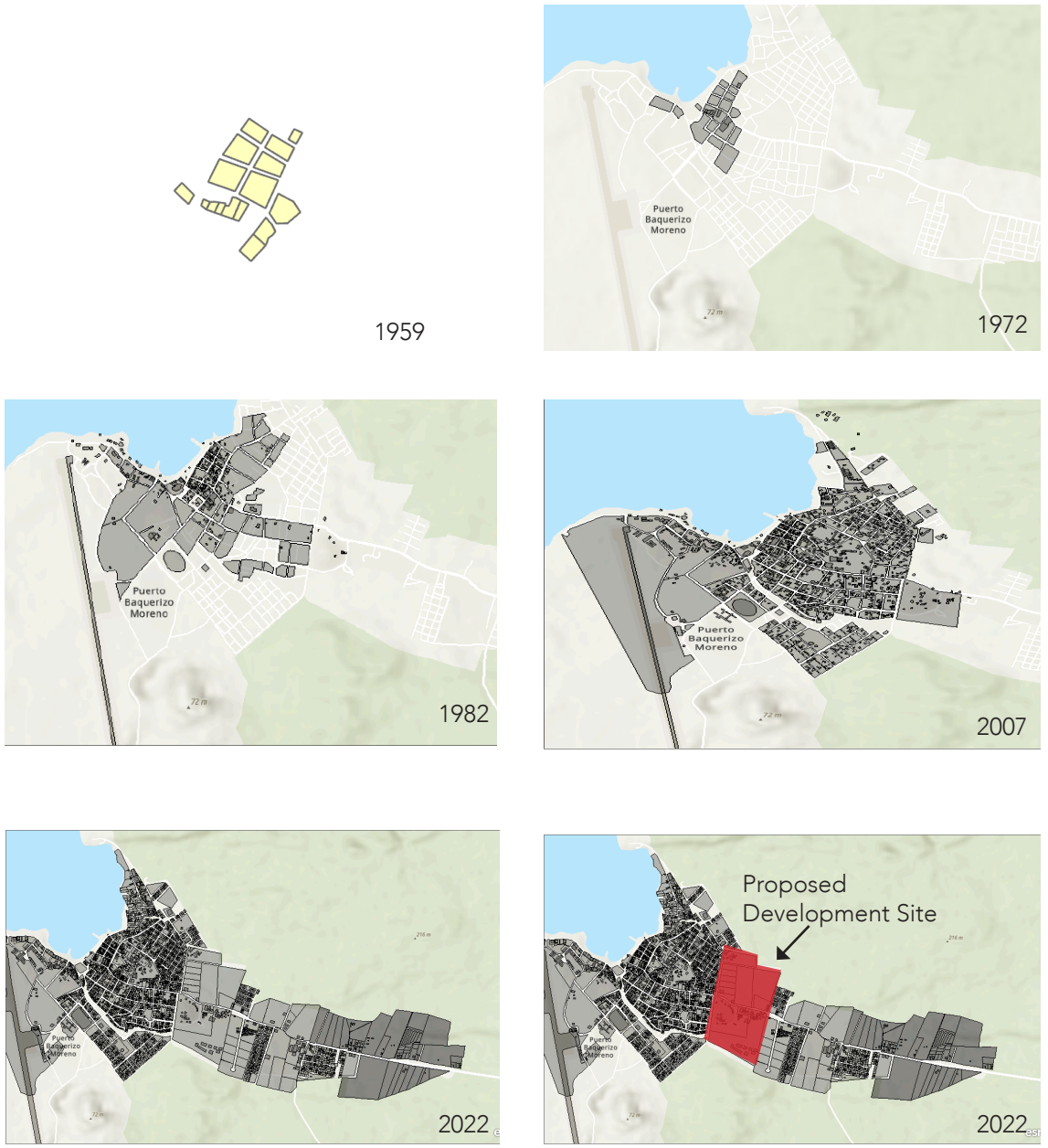


Figure 05.02
Town Development History

05.03 Figure & Ground

Figure 03 is a figure/ground diagram of the site. Figure and ground diagrams show the relationship between buildings, which create a site's overall grain. This diagram shows that the site has a disbursed settlement pattern that is more characteristic of a rural form than an urban form. To the extent there is a coherent pattern, it is the relationship between a set of clusters and the main inter-town road. The buildings on the site's western exterior are more characteristic of an urban form. We can anticipate the site will develop along the lines of the existing urban area, although the existing urban area shows large sections of undeveloped lots.

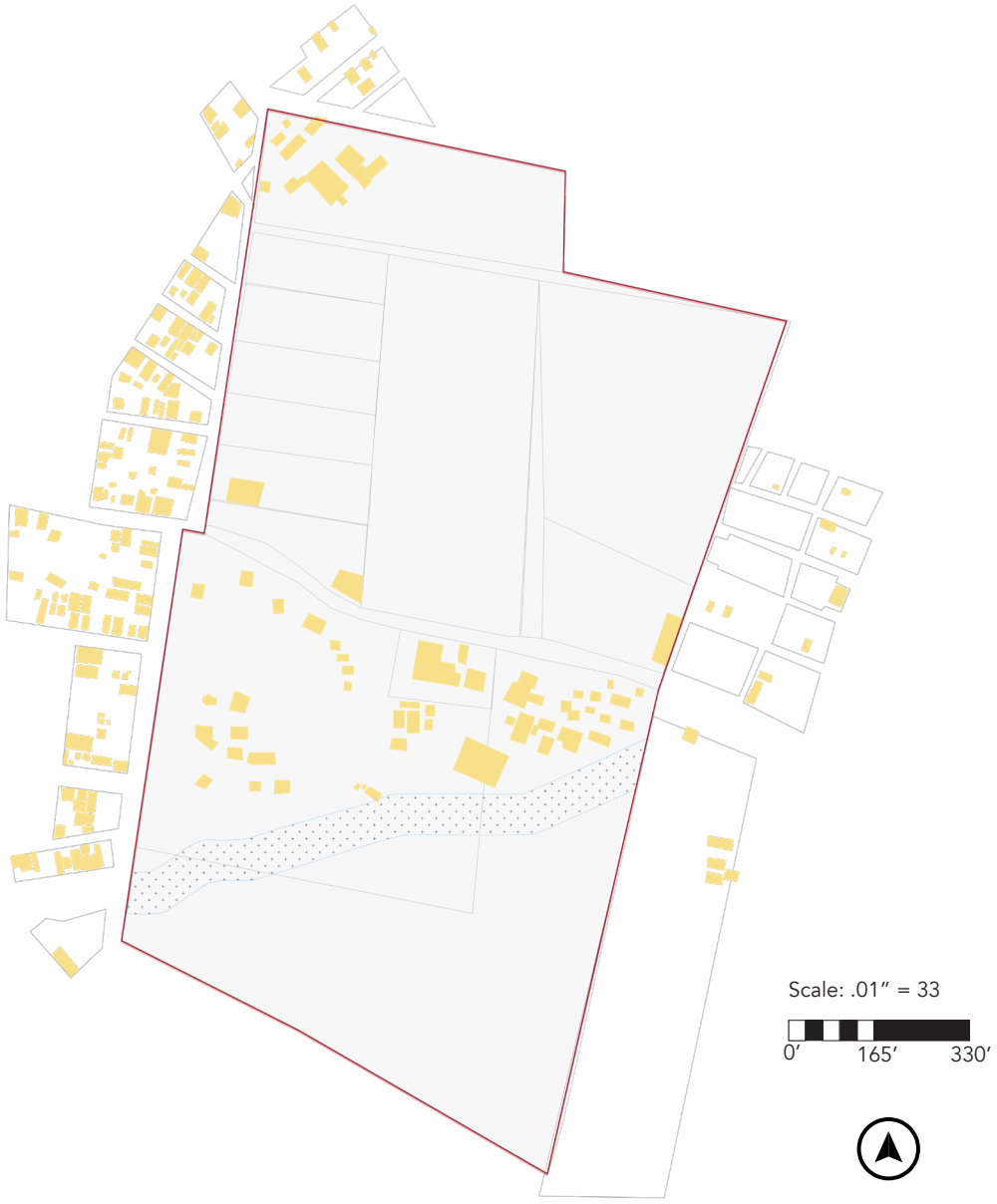


Figure 05.03 Figure Ground

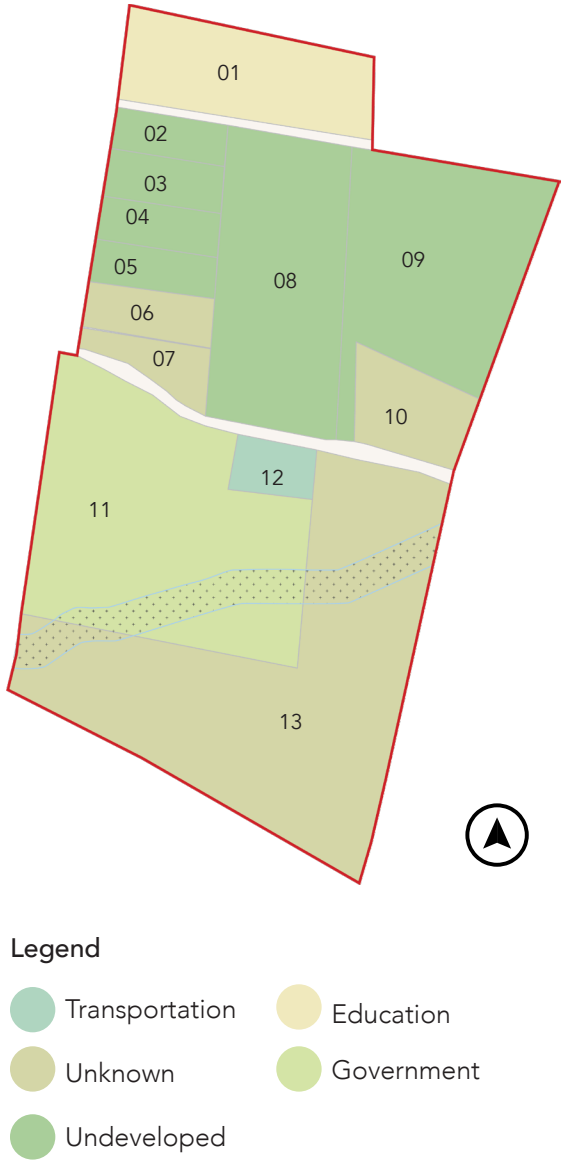
05.04 Current Land Use

Based on satellite images and digital maps, I can identify four facilities on the site (figure 4): a school, a gas station, a water treatment plant, a soccer field. A fifth facility, a police station, is just outside the southeastern border of the site. With this information, I assigned land uses to each plat as a heuristic device (figure 06). They are: education (a school), government, transportation (the island's only gas station), undeveloped, and unknown. The unknown category is likely a mix of residential and commercial/retail functions. Table 05.01 shows the existing plat sizes and whether or not there are structures on the plat.

Table 05.01
Plat Area and Presence of Structures

No.	Area (sq m)	Structure (y/n)
1	31,185	Yes
2	6,026	No
3	7,295	No
4	7,288	No
5	7,377	No
6	8,874	Yes
7	6,899	Yes
8	52,824	No
9	54,188	No
10	13,686	Yes
11	84,068	Yes
12	5,935	Yes
13	110,214	Yes

Figure 05.04. Current Land Use



05.05 Existing Facilities

Figure 05 shows four existing, identifiable structures on the site. They are (A) a school, (B) the island's only gas station, (C) a water treatment center, and (D) a soccer field. These are important assets to the new neighborhood and I anticipate that they will be retained and integrated into the design.

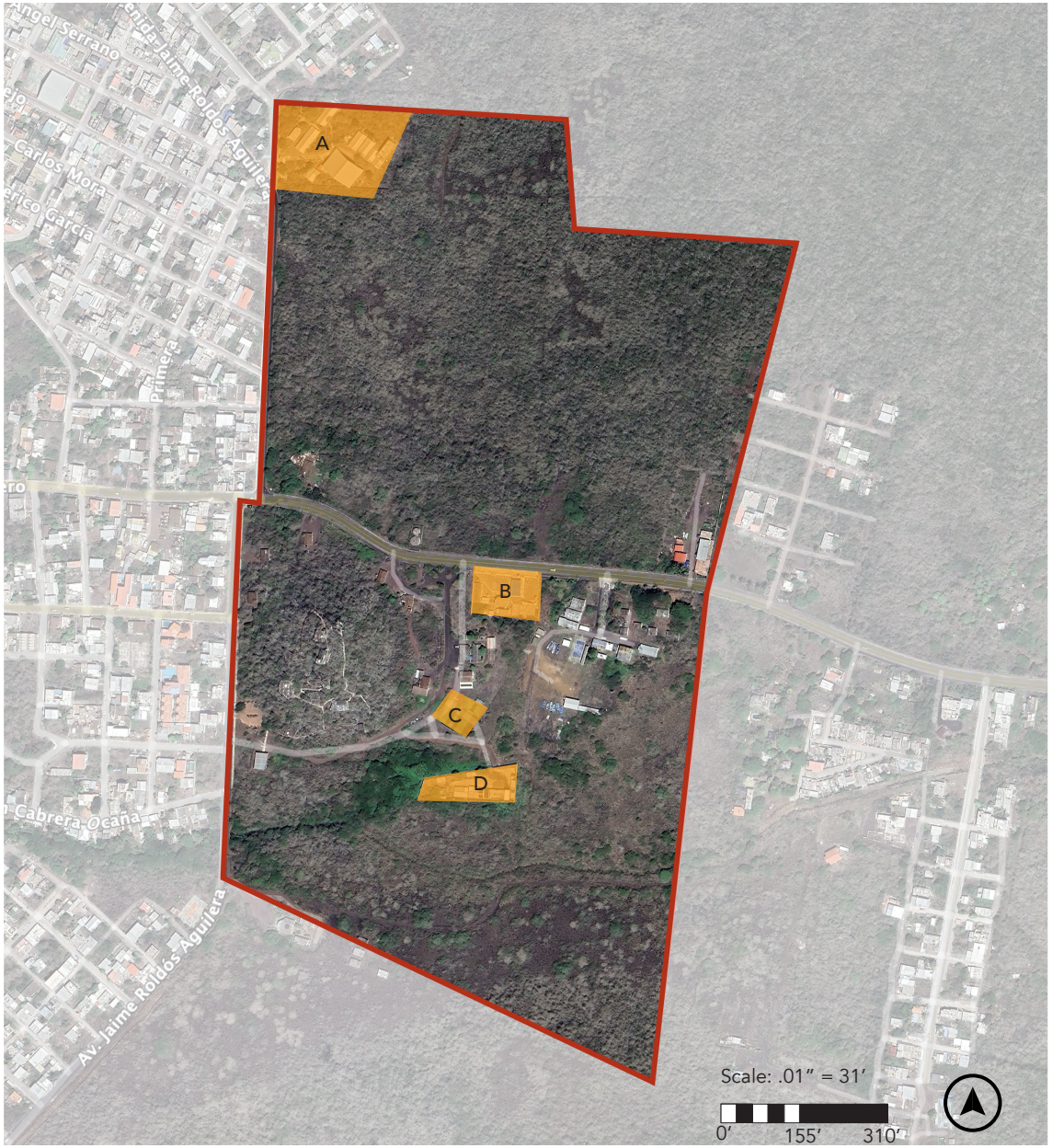


Figure 05.05 Existing Facilities

05.06 Transportation

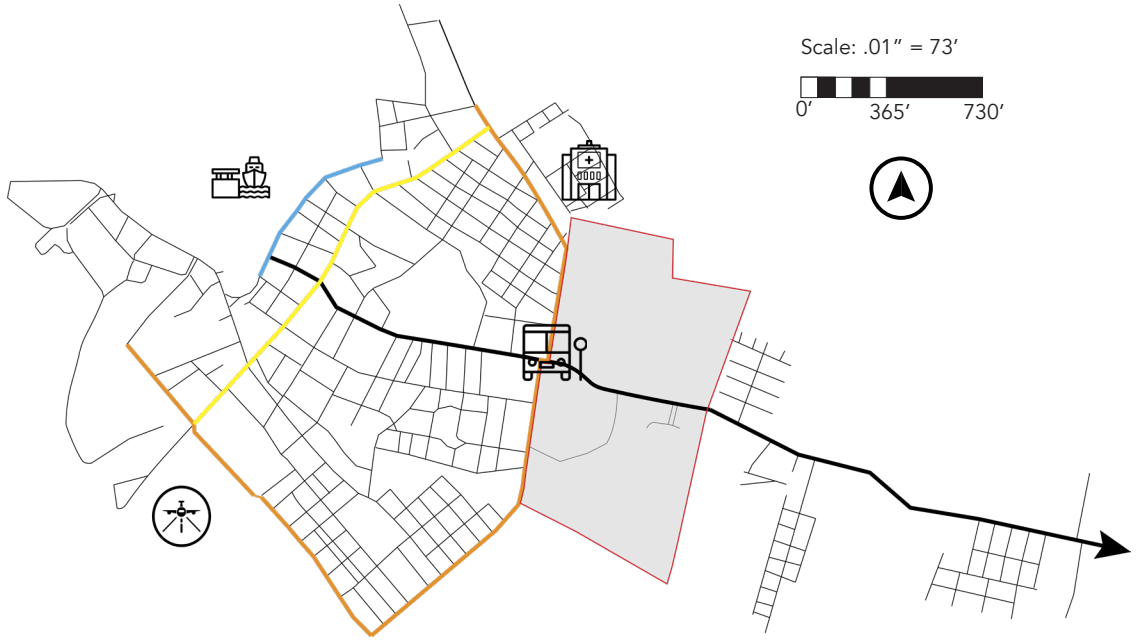
Figure 06 shows that the site's road system is limited, which is in keeping with its mostly undeveloped status. The area's main inter-city road runs through the site and provides access to the main pier and urban core and to the rural town of El Progresso. The inter-city road that connects Puerto Baquerizo Moreno to El Progresso provides a buffered multi-use path for pedestrians and bicyclists.

The City has a ring road that runs along the City's north, east, and south perimeter. This road serves as the west edge for the site. It provides site residents with access to the airport (south) and the hospital (north). There is a north-south through street that connects to either side of the ring road on the town's western edge.

There is also a bus stop at the west edge of the site on the main road. The route begins at Puerto Baquerizo Moreno's main pier, travels through the city, stops at the western edge of the City before traveling on to El Progresso.

There are few local streets on the site.

Figure 05.06 Transportation Network



Legend

- Airport
- Pier
- Hospital
- Bus Stop
- Site Boundary
- Inter-Town Road
- Ring Road
- Main North-South Road
- Local Street
- Malecon

05.07 Climate

Although located on the equator, the climate on San Cristobal is moderate due to a combination of ocean currents, ocean upwelling, and prevailing winds. Temperatures range from a high of 27° to a low of 20°. There are two seasons on San Cristobal, a rainy season between January and May, and a dry season between June and December. On average, there are only 13 days of measurable precipitation. Higher temperatures occur during the rainy season. The prevailing winds are from the south and southeast, with stronger winds blowing in the dry season.

Figure 05.07 shows the position of the sun over the site at four points throughout the year, as well as prevailing wind direction.

Figure 05.07. Sun and Wind

Table 05.02 . Monthly Average for Precip., High and Low Temp., Wind Speed, and Wind Direction

MONTH	PRECIPITATION (Milliliters)	HIGH TEMP. (Celsius)	LOW TEMP (Celsius)	RAIN DAYS	WIND SPEED (Kph)	WIND DIRECTION
January	15	26	23	1	19	SSE
February	46.5	27	25	4	14.5	SSE
March	39.4	27	25	3	11	E
April	48	26	25	4	14.5	SSE
May	22.8	25	24	1	21	SSE
June	2.6	24	22	0	21	SSE
July	1.2	23	21	0	22.5	SSE
August	1.1	22	20	0	22.5	SSE
September	1.8	21	20	0	22.5	SSE
October	1.2	22	20	0	22.5	SSE
November	1.4	23	21	0	22.5	SSE
December	2.7	24	22	0	21	SSE

Temperature and precipitation data: www.worldweatheronline.com

Wind Information data: Windfinder accessed at https://www.windfinder.com/windstatistics/san_cristobal_galapagos

05.08 Land Formation

The majority of San Cristobal is a shield volcano, similar to the Hawaiian Islands. A shield volcano "produces low viscosity, runny lava, it spreads far from the source and forms a volcano with gentle slopes... Most shield volcanoes are formed from fluid, basaltic lava flows"(British Geological Survey).

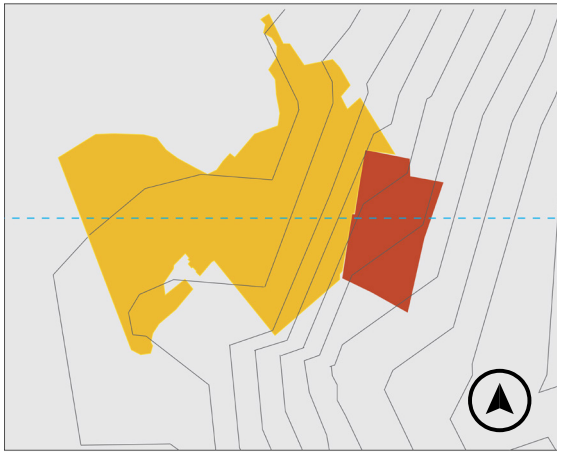
Kelley et al. tells us that "The typical morphology of a shield volcano has the steepest slopes where the flanks rise to the summit crater. Moving outward down the flanks, the grade of the landscape lessens. In Galapagos, the flank typically can be divided roughly into 3 sections, with 15–30° slopes near the summit, the majority of the intermediate slopes at around 5°, and with only the most distal slopes having a pitch of 1–2° (2018, p. 2).

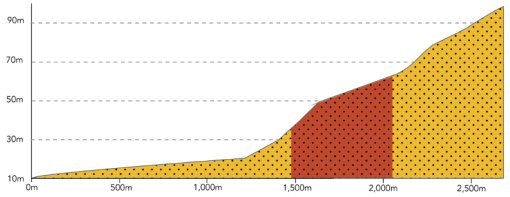
Our proposed site (figure 05.09 in red) has an overall slope of 2.7%, which is consistent with Kelley's description of a Galapagos shield volcano. The site slopes moderately from a high point of approximately 70m above sea level in the southeast corner to a low point of about 40m above sea level in the northwest corner. As noted later, the site is divided north-south into two drainage basins, so the site's topography is more complex than this diagram's 10m contour line scale indicates.

San Cristobal distributes drinking water and collects waste water using gravity-fed systems. These systems typically require a minimum of a 2% slope. The site has a 2.7% slope overall, which supports gravity-fed systems.

The gentle slope, combined with low rainfall (see Climate) and hard basalt bedrock, reduce the challenges of erosion on the site.

Figure 05.08. Land Form





05.09 Drainage & Hydrology

The site is divided into two drainage basins. The northern drainage basin flows to a stream off-site while the southern basin flows to a stream on site. Both streams are seasonal. Both streams also flow through Puerto Baquerizo and directly into the bay, which is a part of the Galapagos marine reserve. Developing the area will require protecting the southern stream and mitigating pollution from surface water runoff before it enters either stream.

The basin divide is relevant for siting water-related utilities. If the drinking water distribution and waste water collection systems are gravity fed, then each basin will need its own drinking water and wastewater system. Similarly, the site will need storm water facilities in each basin at the lowest points on the site.

There is no information available on the presence or absence of aquifers on the site or the elevation and quality of the water table. Ideally, hydrologic testing should occur prior to development.

Key questions include:

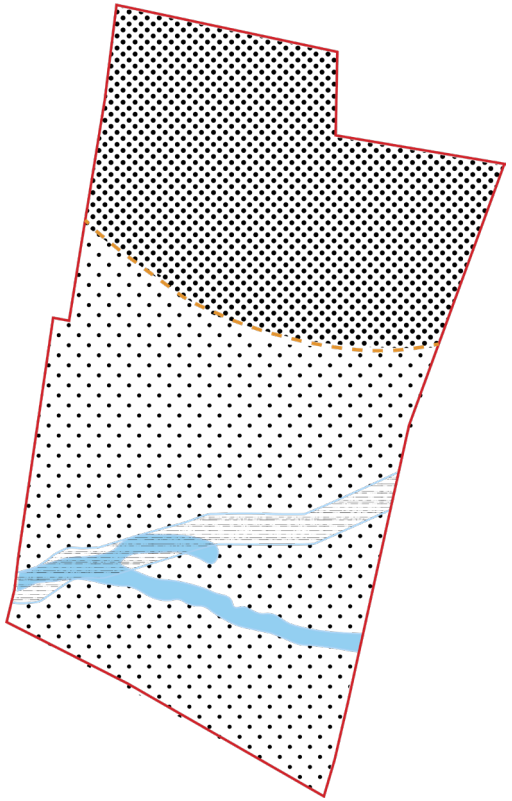
- Is there an aquifer present on the site? If so, what is its extent and capacity? Is it exploitable for drinking water? What is its recharge rate?
- How does ground water flow through the site?
- How much precipitation percolates into the ground versus running off into existing channels.
- What is the relationship between ground water and the southern stream?
- Does the groundwater have any connection to ocean?

The resulting information should be incorporated into the final design of the site.

Legend

- North Watershed Basin
- South Watershed Basin
- Protected Area
- Stream
- Basin Divide

Figure 05.09 Hydrology



05.10 Geomorphology & Soils

A volcanic hotspot, located at about -°0.20" latitude and -91°30", is responsible for the creation of the Galapagos islands. As the Nazca tectonic plate passes over the hotspot on its way east towards the coast of South America, the hotspot generates new islands. (The subduction of the Nazca plate under the South American plate is responsible for the Andes.) The oldest, and therefore easternmost island, is San Cristobal, which is about 2.4 to 4 million years old.

The parent material for the majority of San Cristobal, including our site, is basalt. Basalt is a hard, heavy material that is often porous and fragmented. It is also associated with aquifers. As a consequence, managing non-point source runoff pollution will be important. It is slow to weather, which results in slower soil development.

Basalt readily supports structures and infrastructure, such as roads, without deforming. It can be cut into blocks for construction or sliced into tiles for building surface treatments. Puerto Baquerizo Moreno provides examples of both uses. It is, however, hard to excavate. This increases the cost of subsurface infrastructure such as sewerage.

Figure 12 shows the underlying geomorphology of the site, which is divided into six discrete sections. The characteristics of these sections are described in Table 03.

There is not detailed soil profile information for the Galapagos in general, as noted by Stoops (2015), or for our site specifically. Fortunately, the San Cristobal canton development plan has a course-grain map of soils for areas outside the park. Map 8 (not shown) indicates that the soils on the site are entisols (Plan de Desarrollo Y Ordenemiento Territorial del canton San Cristobal 2020-2030, p. 38).

The Encyclopedia of Solis in the Environment says that "Entisols show little or no evidence of soil formation. They are most extensive on recent alluvial plains and valleys or on steep slopes where erosion is rapid. The rate of soil formation is reduced for several reasons. Generally time has not elapsed since deposition of the material for soil-forming processes to act" (Eswaran & Reich, 2005).

Figure 05.10 Soils & Geomorphology

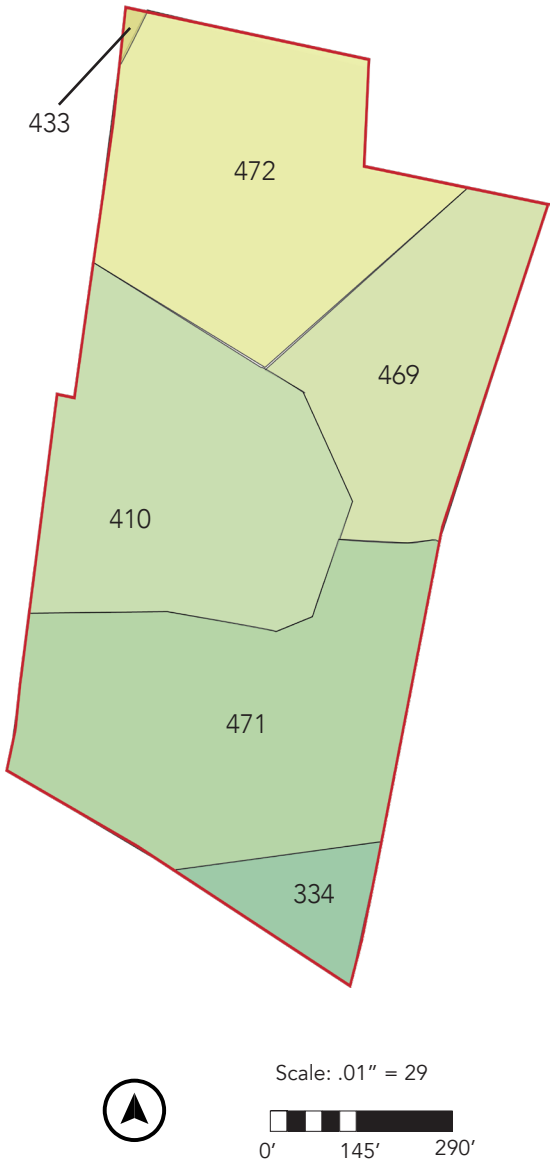


Table 05.03 Site Geomorphology

ID NO	433	472	469	471	334	410
Relief	basalt part; very smooth; first generation lava flows	Soft lower flanks: second generation lava flows.	Soft lower flanks: second generation lava flows	Soft lower flanks: second generation lava flows.	Small isolated volcanic cones.	NA
Description	casting surfaces; horizontal to very slightly inclined not dissected to slightly undulating	Moderate to strong abruptness at the limit of the terminal spill fronts	Flow surfaces horizontal to slightly inclined, gently undulating to slightly dissected, presence of small abrupt faces of the flow.	Moderate to strong abruptness at the limit of the terminal spill fronts.	Latest generation volcanic cones.	NA
Lithography	Solid lava flows with little vesicular basalt, weak and very discontinuous reddish clay alterations, rocky and stony outcrops; chaotic surfaces in solid broken blocks.	Solid lava flows, poorly vesicular basalts, discontinuous and shallow reddish clay alterations, rocky and stony outcrops; chaotic blocks	Solid lava flows, poorly vesicular basalts, discontinuous and shallow reddish clay alterations, rocky and stony outcrops; chaotic surfaces in broken solid blocks.	Solid lava flows, poorly vesicular basalts, discontinuous and shallow reddish clay alterations, rocky and stony outcrops; chaotic blocks	Interspersed with lavas, clay-silty alterations, more powerful in the upper part.	NA
Evolution	Diffuse and highly concentrated runoff in the rainy season, accumulations in depressed areas.	Very localized diffuse and concentrated runoff from the rainy season, accumulations in depressed areas	Very localized diffuse and concentrated runoff from the rainy season, accumulations in depressed areas.	Very localized diffuse and concentrated runoff from the rainy season, accumulations in depressed areas.	Very localized diffuse runoff from the rainy season, gravity movements inside the craters	NA

Source: Universidad San Francisco de Quito, "Geomorphology" layer. Translation by Google.

05.11 Ecosystem

The terrestrial ecosystems in the Galapagos archipelago is primarily the result of elevation. As the elevation increases from sea level, the air holds more moisture and generates more precipitation. Kelley writes "Crucially this zonation from relatively moist highland areas, often with seasonal mists, to more arid and sparsely vegetated lowland areas, is a major ecological control and many species and subspecies, including most notable tortoises, have adaptations for different climactic zones" (Kelley, et al, 2019, p. 22).

Classification systems do not all agree on how to categorize Galapagos's varied ecosystems. In this project, we recognize four. They are:

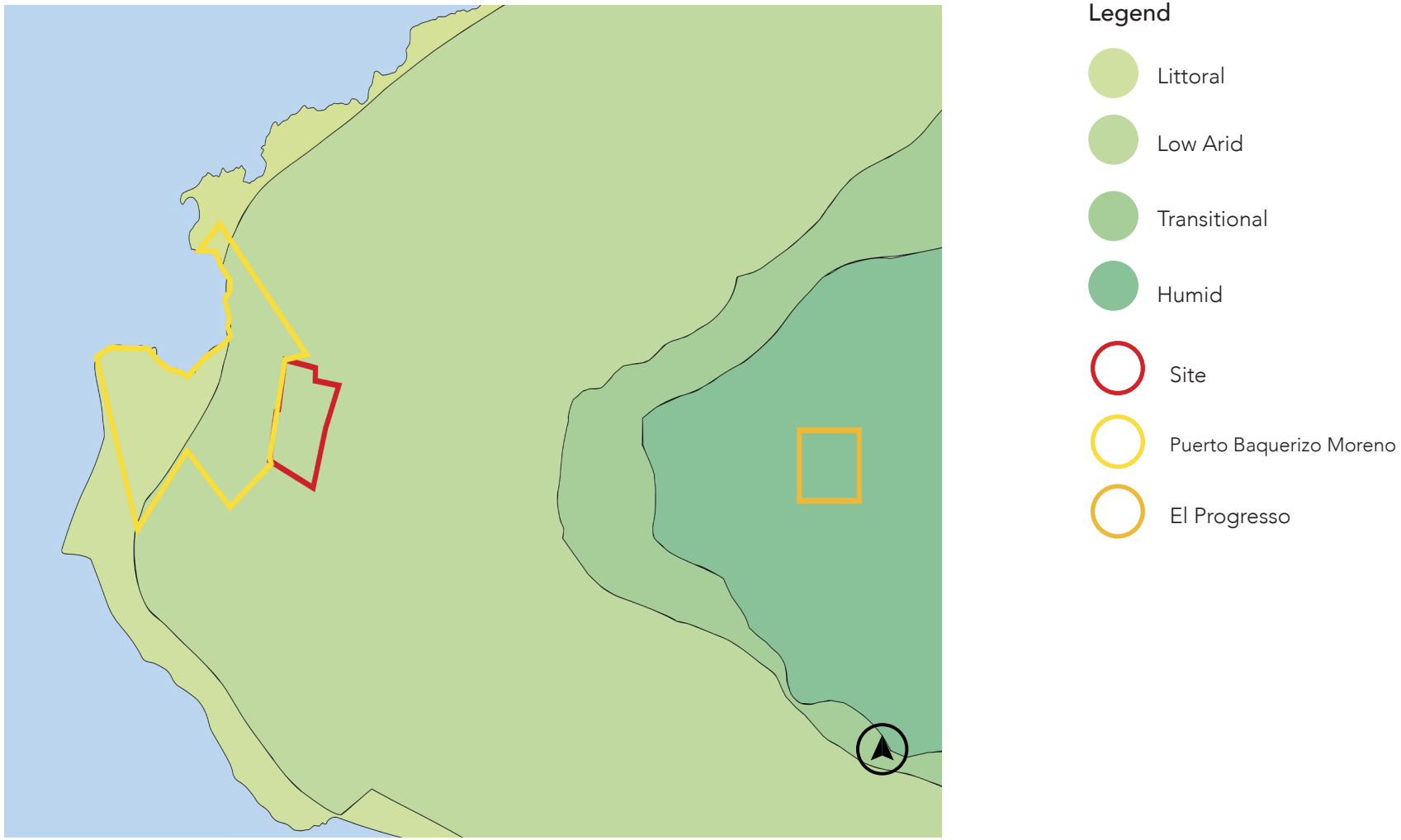
- Littoral (or coastal)
- Arid
- Transitional
- Humid

Some classification systems do not include the littoral zone while others lump the transitional zone into the arid zone. Some scholars divide the humid zone into two sections, a humid zone and a very humid zone. These two zones are also labeled the Salesia (a type of native tree) zone and the pampas zone. Figure 13 does not show a two-part humid zone.

Figure 11 shows that the site is in the arid ecosystem. It is characterized by scrub and cactus, mostly Opuntia species. This is the most common ecosystem in the Galapagos. Unlike the humid zone, it is not considered threatened in the Galapagos. Watson et al. sstimate that less than 1% of the arid zone has been lost to human activity across the archipelago, although this information is now dated (Watson et al, 2009, p. 81). Opuntia is a keystone species for the arid ecosystem. The arid ecosystem is also home to the largest percentage of endemic Galapagos species (Johnson & Raven, 1973, p. 895).

Other researchers have classified this arid zone as a "dry forest," which is a rare and declining ecosystem worldwide (Gillespie, et al., 2020).

Figure 05.11. Ecosystem



05.12 Arid Zone Food Web

A food web is a graphical representation of the feeding relationship between species in an ecosystem. The Galapagos food web, and Pacific island food webs more generally, tend to be different from continental food webs. This is the result of islands' limited range of species. For example, San Cristobal and other Galapagos island lack large mammalian carnivores. As a result, species fill niches in island ecology that they may not fill on the mainland.

A food web shares some similarities with a trophic pyramid. A trophic pyramid displays the movement of energy through the ecosystem from primary producers (plants), who capture their energy from sun, through subsequent levels of consumption. The further a species is removed from consuming plants, the higher that species is on th trophic pyramid. Trophic pyramids typically shows primary producers (plants), primary consumers (herbivores) and one or more levels of secondary consumers (omnivores and carnivores). Decomposers, including bacteria, fungi, and some animals, break down dead tissue and fecal matter and make the chemicals available for re-use. It is a flow rather than a cycle because the initial energy comes from the sun.

Figure 13 (next page) shows a simplified portion of the arid ecosystem food web. The core actors are cactus, arthropods, reptiles, and birds. Figure 15 provides an example of an arid zone trophic pyramid.

Designers need to understand a site's food web and trophic pyramid in order to minimize or compensate for the inevitable disruption of the existing relationships that development will cause on the site. Thoughtless development may drive local populations to extinction. Where development overlaps with the habitat of critical species, designers must be even more thoughtful.

Figure 05.12 Trophic Pyramid Example

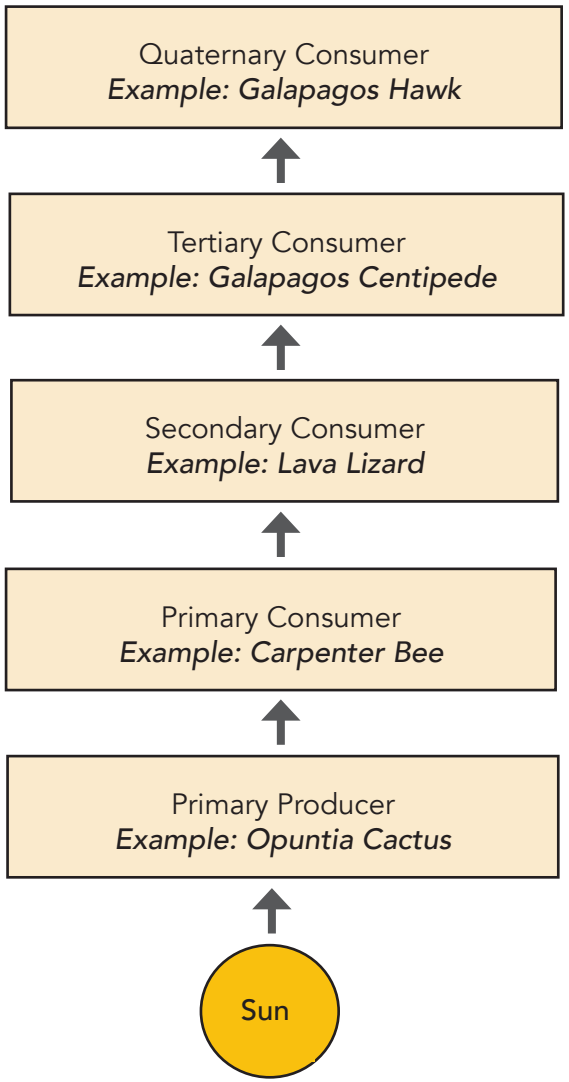
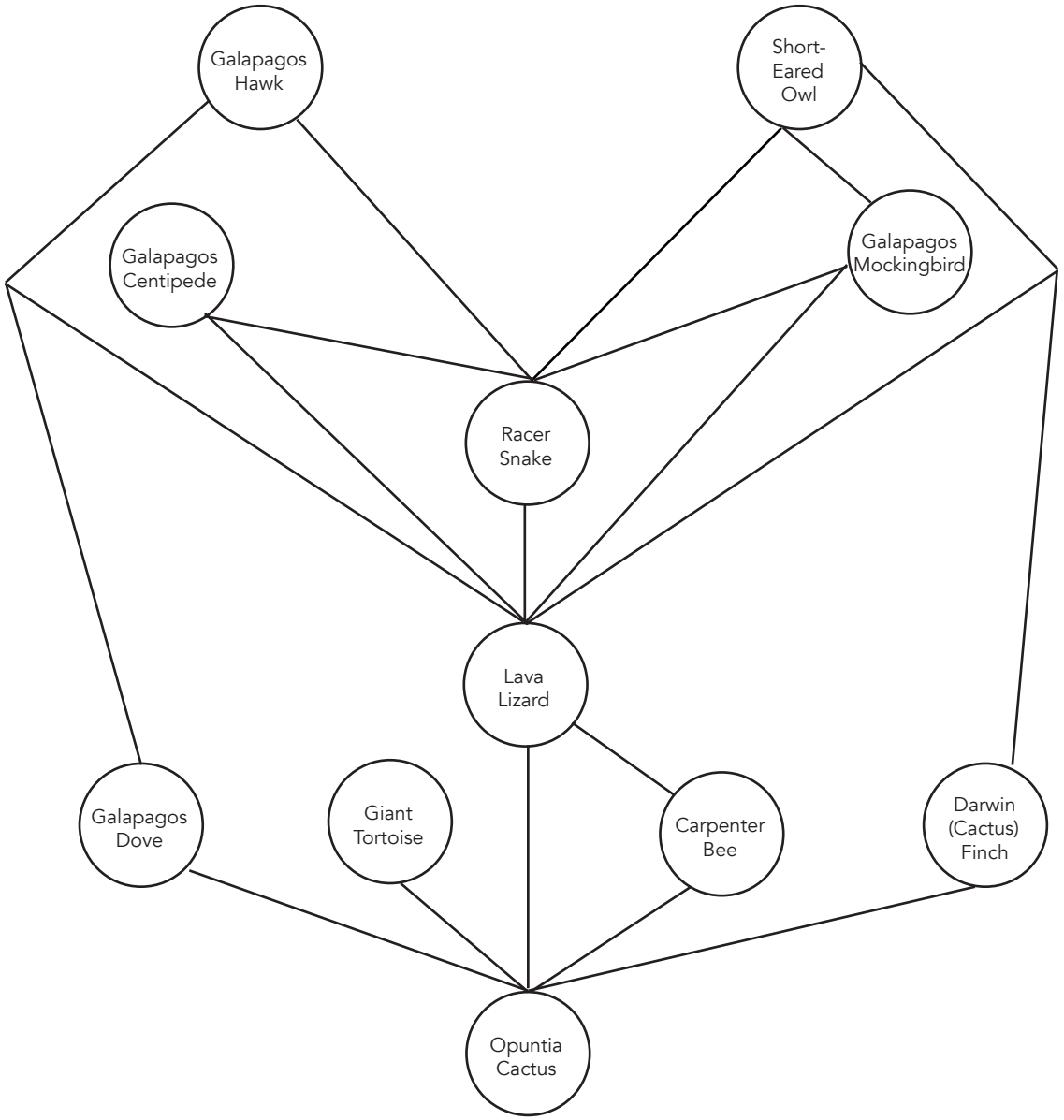


Figure 05.13 Arid Zone Food Web Example (Decomposers Omitted)



Arid Zone Species Examples


Galapagos Hawk


Galapagos Short-eared Owl


Darwin Finch (Cactus Finch)


Galapagos Dove


Lava Lizard


Racer Snake


Carpenter Bee


Galapagos Blue


Opuntia Cactus


Palo Santo Tree

05.14 Opportunities & Constraints

This page identifies the site's unique opportunities and constraints. Opportunities are primarily land form and transportation. Constraints are primarily ecological and existing land uses. Sensitive ecological areas are both opportunities and constraints.

OPPORTUNITIES

1 Developable Land

Housing + Economic. The area north of the inter-town road is level, mostly undeveloped, and without sensitive ecological features. It is within the urban growth reserve/

2 Inter-Town Road

Transportation + Economic. The island's main road runs through the site. This creates good transportation connects to a range of resources. It also provides economic opportunities that facilitate higher density mixed-use structures.

3 Connecting Streets

Transportation. The site affords access to streets on the town's west edge, which creates opportunities for east-west integration.

4 Government Property

Amenity: The government owns a large piece of property on the site, This can be converted into a public amenity with no property acquisition cost.

5 Stream and Flood Channel

Contact with Nature. Streams and flood channels are ecologically rich areas and provide opportunities to connect residents with their environment and educate them on local ecological functions.

6 Soccer Field

Amenity. There is an existing soccer field on the site.

7 Bus Stop

Transportation + Economic. There is an existing bus stop on the main inter-town road on the site's west side. This provides access to the central town and El Progresso. It also creates an economic opportunity for nearby stores.

CONSTRAINTS

A Stream and Flood Channel

Ecological. Streams and flood channels are ecologically rich areas. They also convey materials down hill and eventually to the ocean. They need to be protected from pollution and habit-destroying land uses.

B Low Areas

Ecological. The west and northwest perimeter are the points at which storm water exits the site. This area should be limited to green storm water infrastructure to prevent urban pollutants from contaminating streams and reaching the ocean.

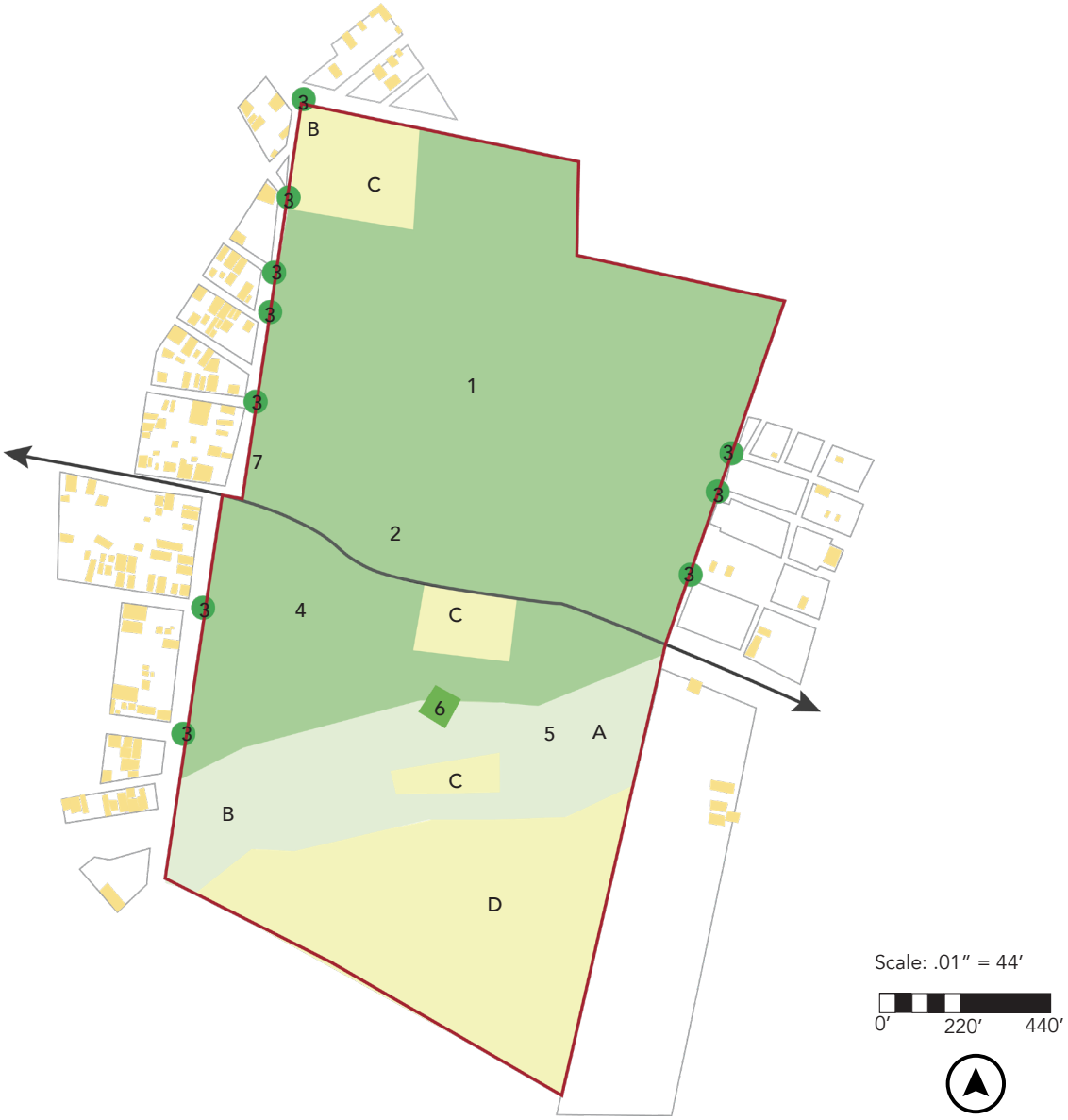
C Existing Land Use

Legacy. Several lots on the site have buildings that will likely remain, including the island's only gas station, a school, and a water treatment facility. Development will need to integrate these facilities into the overall plan.

D Connectivity

Ecological. The presence of a sensitive ecological area immediately north of the site precludes connecting this area to the street system without significant expense to mitigate the ecological risk.

Figure 05.15. Opportunities & Constraints Analysis



05.14 Programmatic Analysis

We can identify a series of critical features and phenomena that will help shape the design of the site.

Transportation: The island's main road passes through the middle of the site. This feature creates (1) an organizing principle for urban development and (2) easy access to both downtown Puerto Baquerizo Moreno and the highland's gateway town of El Progresso. It also creates opportunities for commercial and retail development. Puerto Baquerizo Moreno's ring road serves as the western boundary of the site, which creates a clear edge to the new community, affords easy integration with the existing urban development, and provides access to the hospital and the airport. A bus stop is located at the intersection of the inter-urban road and the ring road at the western edge of the site. Access to public transportation is consistent with the Habitat policy goal to: "Promote a sustainable mobility model that guarantees equal access to opportunities for people of all ages and abilities (Galapagos 2030, 2020, p. 46).

Climate: The site is characterized by overhead equatorial sun, very low precipitation, few cloudy days, and a consistent south-southeast prevailing wind. The high solar radiation from the equatorial sun combined with clear days creates an opportunity for clean solar energy. The consistent direction of the prevailing wind provides an opportunity for natural cooling. The opportunity to generate solar power and use prevailing winds for cooling is consistent with two Galapagos 2030 objectives. The first is Environment policy three, which is to "Promote the transition of human settlements toward sustainability and care of their ecosystems" (Galapagos 2030, 2020, p.47). The second is Habitat policy three, which is to "Promote sustainable generation of energy and its efficient and responsible consumption, and promote the transition towards an zero fossil fuel energy model (Galapagos 2030, 2020, p.47).

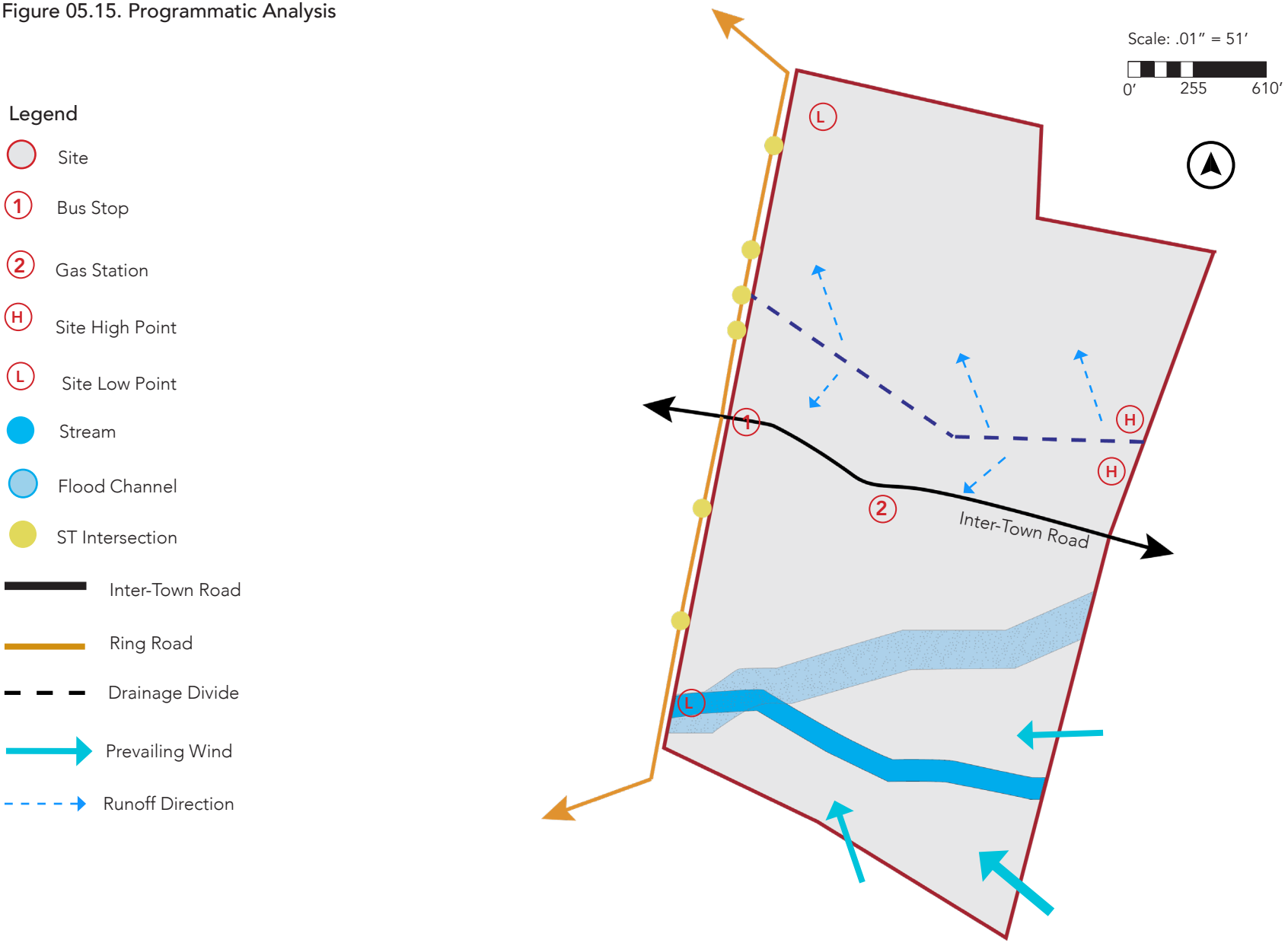
The low precipitation and xerophytic plant community necessitates the careful use of any landscape irrigation. This is consistent with Galapagos 2030 Community strategy two: "Promote a culture of responsible consumption" (Galapagos 2030, 2020, p.49).

Drainage. The site falls in two drainage basins. Designers will need to address surface runoff for both basins. The southern portion of the site contains a stream. The stream and its riparian area will need to be protected from development. The stream also creates the opportunity for a community amenity.

Slope. The site's modest three percent north-northwest slow facilitates the use of gravity for the distribution of drinking water and the collection of storm water and wastewater. Designers will need to site water-related utilities carefully to minimize costs by taking full advantage of the site's topography.

Flora & Fauna. The site is home to Opuntia cactus species, which is a keystone species in the Galapagos' arid zone. Opuntia cactus provide food and nesting habitat for the area's endemic bird and insect population. Planners and designers should maximize the retention of existing Opuntia cactus and related plants on the site and, if available, include them in any new landscape that is installed. This approach is consistent with Community policy three of the Galapagos 2030 Plan: "Affirm and strengthen the island identity in the Galapagos population based on the natural environment" (Galapagos 2030, 2020, 47).

Figure 05.15. Programmatic Analysis



06. LAND DEVELOPMENT CODE

06.01 Introduction

Puerto Baquerizo Moreno grew organically from a small set of blocks immediately adjacent to the pier. It grew without a formal zoning code that regulates land use, which is different from much of the United States and Europe. While there is evidence that some aspects of the town's growth are now planned, the town is still without a zoning code.

Typically, zoning is the process of assigning a particular set of uses to a parcel of land, which also results in a prohibition on non-listed uses. Ideally, zoning is separating incompatible uses, such as factories and homes, to different areas of a city. The concept's application, however, has led to bad outcomes throughout the United States. Zoning has been used to enforce racial and economic segregation, steer resources to the more powerful members of the community, and limit the housing supply. It has also separated where people live from where they work, shop, and play. This physical separation requires people to drive to many of their daily destinations, increasing green-house gas emissions, household costs, and poor health outcomes. It also contributes to loneliness, isolation, and poor social capital formation, especially among more vulnerable citizens.

Puerto Baquerizo Moreno does not have a zoning code, a fact that has largely been to its benefit. Its mixed-use development pattern has kept travel distance low and limited the related health, economic, and social consequences of strict land use segregation. The absence of a zoning code has been made easier by the lack of heavy industry or economic activities that create nuisances and hazards for neighbors, which provided impetus for the development of zoning.

There are, however, some challenges facing residents of the town that a zoning code may help address. For example, restaurants on blocks with mostly residential uses have caused complaints with their late hours. Small manufactures, such as carpentry workshops, create noise from equipment and odors from chemicals that are out of scale with their neighbors. As the town grows and diversifies economically, a zoning code may become more important. But there is an alternative.

Form-based codes focus not on land use but instead on the shape and physical characteristics of buildings. The underlying theory is that (a) compatible uses share similar forms and conversely incompatible forms have incompatible uses, and that (b) similar forms (coherence) across a neighborhood or district is desirable. One reason this is true is that coherence often improves legibility and a sense of place, which most people find desirable. The second reason is that it makes it easier to design a public realm that is tailored to a form's specific characteristics. For example, the infrastructure, street dimension, area coverage, façade details, and public spaces should be different in an area that supports one building on each block with loading docks and few windows than from a neighborhood with ten buildings a block and balconies overlooking the street.

In the United States, some cities have adopted a hybrid code that combines elements of traditional zoning with form-based codes. In this paper, I suggest that the canton (municipality) of Puerto Barquerizo Moreno adapt a hybrid development code that combines a minimal number of land use categories with regulations that specify the physical characteristics of those land uses. This code should be carefully developed to align with the town's context with respect to population, culture, economic

activities, and existing urban form.

The purpose of a development code is to provide for the public health, safety, and well-being of the City's residents and guests; specifically, (1) to ensure the provision of basic services, (2) to ensure good urban form, (3) to protect sensitive areas, and (4) to facilitate analysis of the built environment.

06.02 Zones & Form

06.02.01. Blocks and Plots

Blocks are created in the land division process. Each block is a contiguous space that is defined by some form of boundary, typically a street. Figure 06.01 illustrates a standard block. Each block is 64 m wide by 40 m deep set into an orthogonal street grid. There is a 4 m easement that separates the rear of buildings on each block for stormwater conveyance and above-ground electrical utility placement. This easement also serves to capture any excess land that may result from the lot partition process. The easement is established at the time of land division and is not reflected in the lot dimensions. Figure 06.02 provides a three dimensional perspective of a standard block.

From an urban design perspective,

Figure 06.01. Basic Block

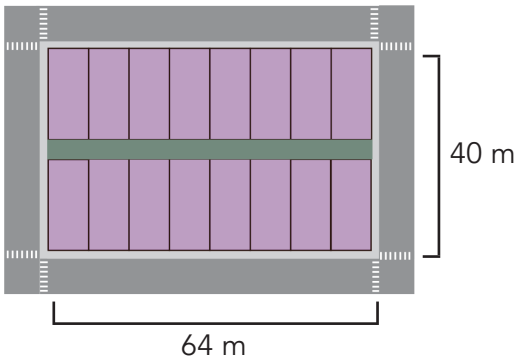
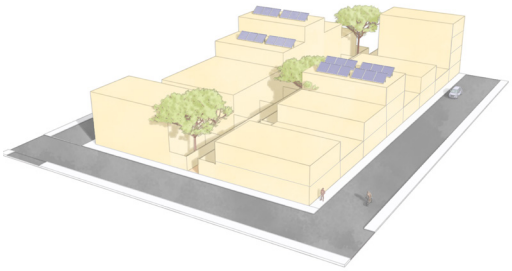


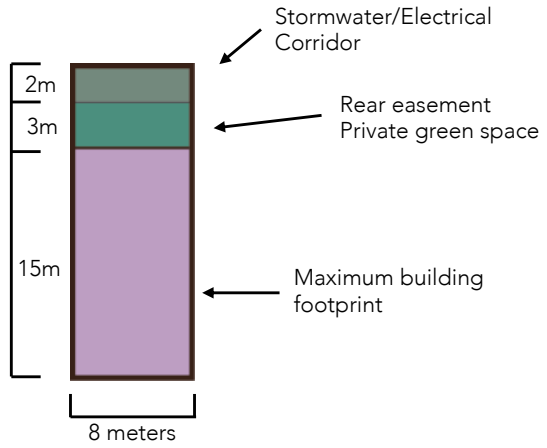
Figure 06.02. Basic Block, Perspective



blocks mean something different than from a planning perspective. Urban design blocks are based on street segments and consist of the buildings facing one another across from the street. Urban design blocks, in general, should share the same zoning or, at least, compatible form.

The standard building plot is 8 m wide by 20 m deep. It may vary by four meters in

Figure 06.03. Basic Plot



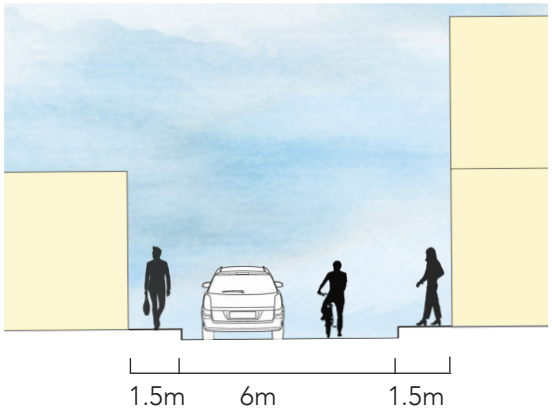
width and 2 meters in depth (14 m x 22 m) to accommodate street placement. Narrow but deep lot sizes facilitate a fine urban grain. Two lots may be joined to allow for a larger building. Owners who need a larger building should apply to create a Campus I or Campus II zone.

06.02.02 Streets-Neighborhood

Neighborhood streets are the most common street type. They are narrow (6 m wide), lack striping, and have frequent intersections. These three characteristics, in turn, reduce speed and thereby make it safer for bicycles, motor scooters, cars, and trucks to share the same travel lanes. Elevated sidewalks flank the street on both sides. Neighborhood streets do

not contain street trees. The omission of street trees is a trade-off between comfort and cost. Additional research on street tree maintenance may find cost-

Figure 06.04 Neighborhood Street Cross Section

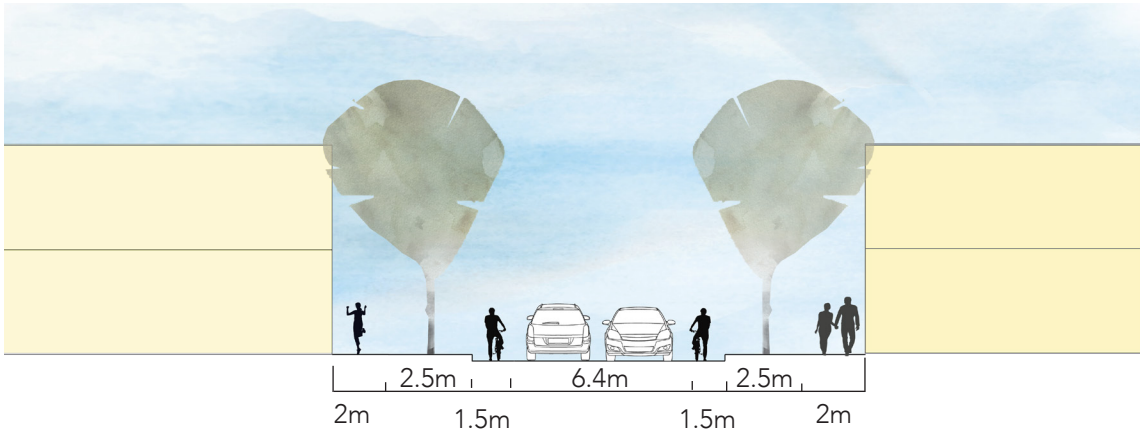


effective methods to support trees and shift the equation towards including trees in the neighborhood street type.

06.02.03 Streets-Arterial

The arterial street facilitates the expeditious movement of people and goods across the community rather than within a neighborhood. Equally as important, is serves as the armature for more intensive mixed use areas and also as a boundary marker between districts and neighborhoods. Arterial streets

Figure 06.05 Arterial Street Cross Section



(Figure 06.08) have a 6.4m bidirectional travel lane, flanked by 1.5m bike lanes, a 2.5m planting strip, and 2m sidewalks. This allows for dedicated bike lanes on either side and better accommodates larger vehicles (e.g. trucks and buses). The 2.5m planting strip creates a better environment for walking and biking, which can contribute to increased economic activity. The planting strips also serve as a bioswales to help manage stormwater. The 2 meter sidewalk is .5m wider than the neighborhood sidewalk.

06.02.04 Streets-Special

Special streets are created by application and are meant to service a building or zone that needs alternative street standards.

06.02.05 Infrastructure

Infrastructure includes facilities that: manage or convey stormwater; manage or convey drinking water; manage or convey wastewater; generate, store, or convey electricity; receive, transmit or convey telecommunication signals; or manage ecological processes or hazards. Design standards for infrastructure shall follow the professional standards associated with the specific facility.

06.02.06 Sensitive Areas

Sensitive areas are one that have a unique value because they (1) support an important ecological process or resource, (2) provide critical habitat to a species

of concern, or (3) pose a risk to human health and safety. These areas should not be developed for housing or economic use. They may be developed in a limited fashion to provide access for the purpose of education, research, recreation, or maintenance. Trails, parking facilities, bathrooms, equipment enclosures, and signage are examples of appropriate development within a sensitive area. Not every sensitive area is appropriate for even limited development.

06.02.07 Public Purpose-General

This land use category includes parks, plazas, schools and other facilities that provide services and amenities to the general public and do not excessively limit access. PP-G should be located adjacent to MU-I and MU-II zones.

06.02.08 Public Purpose-Restricted (PP-R)

Public Use-Restricted provides for land uses that serves the public good but are not generally accessible to the general public. These include military, law enforcement, and corrections facilities. PP-R facilities should be located towards the periphery of the town when possible and not intermingle with MU or CI areas.

06.02.09 Mixed Use I

Mixed Use includes a broad range of commercial, retail, medical, educational, and residential uses. It also includes light manufacturing, repair services, and warehousing when those uses do not produce high levels of pollutants. Mixed Use I has a standard block and lot size. It requires the facade to meet the sidewalk in order to create a pedestrian edge.

Figure 06.06 illustrates three possible approaches to complying with this requirement. The first approach (A) is for the building envelope to directly abut the sidewalk. The second approach (B) permits a setback of up to 3 meters but requires fixed structures, such as planters, along at least 60% of the sidewalk, contrasting pavement from the sidewalk, and an awning that covers the space. Furnishings, such as tables and chairs, or

Figure 06.06 Mixed Use I, Three Facade Variations

retail goods may occupy the space. The third approach (C) is a setback of up to 4 meters with a wall abutting the sidewalk. The wall may not exceed 2.5 meters in height and must include an entry gate and 25% additional fenestrations to provide visual interest for pedestrians.

Mixed Use I prohibits residential use on the first floor. It also requires two finished floors at the time of occupancy. Two additional floors may be added at any point in the future, for a total of four floors.

06.02.10 Mixed Use II

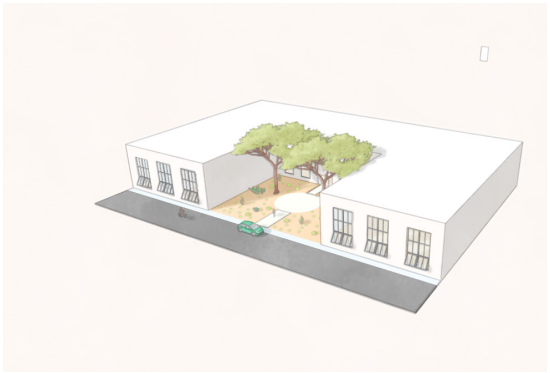
Mixed Use-II favors residential use over other uses. It differs from MU-I in the following ways:

- Limits operating hours to provide nighttime quiet,
- Allows first-floor residential use,
- Allows a limited side setback of up to 1-meter
- Requires a 3-meter rear setback to provide from green space.
- Can be occupied with only a first floor built.

06.02.11 Campus I

The Campus I zone allows property owners an opportunity for a larger building footprint than what is typically

Figure 06.07 Three examples of a C-I Form



permitted, up to one full block (64m x 40m), while conserving some elements of good urban form. The three examples below illustrate the priority of (1) maintaining a good pedestrian edge, either through the building envelop or through a modest, landscaped setback, (2) providing amenities such as shaded courtyards and furnishings that provide pedestrians some visual interest and protection from the elements, and (3) a high ratio of entrances and glazing to break up the mass and provide visual interests.

06.02.12 Campus II

Campus II zone provides for building types or uses that are not compatible with other zones. Campus II is established with a land use application. It is limited to the town's periphery.

06.02.14 Transportation Center

Transportation centers include facilities such as airports and marinas. These facilities require more than one block, need a building form that may not compatible with their neighbors, and may need spatial separation due to risk, noise, chemical emissions, or security concerns.

06.02.15 Cemetery

Cemeteries are for the burial of deceased individuals or storage of their remains.

06.04 Barrio de Las Lechuzas Land Use & Rationale

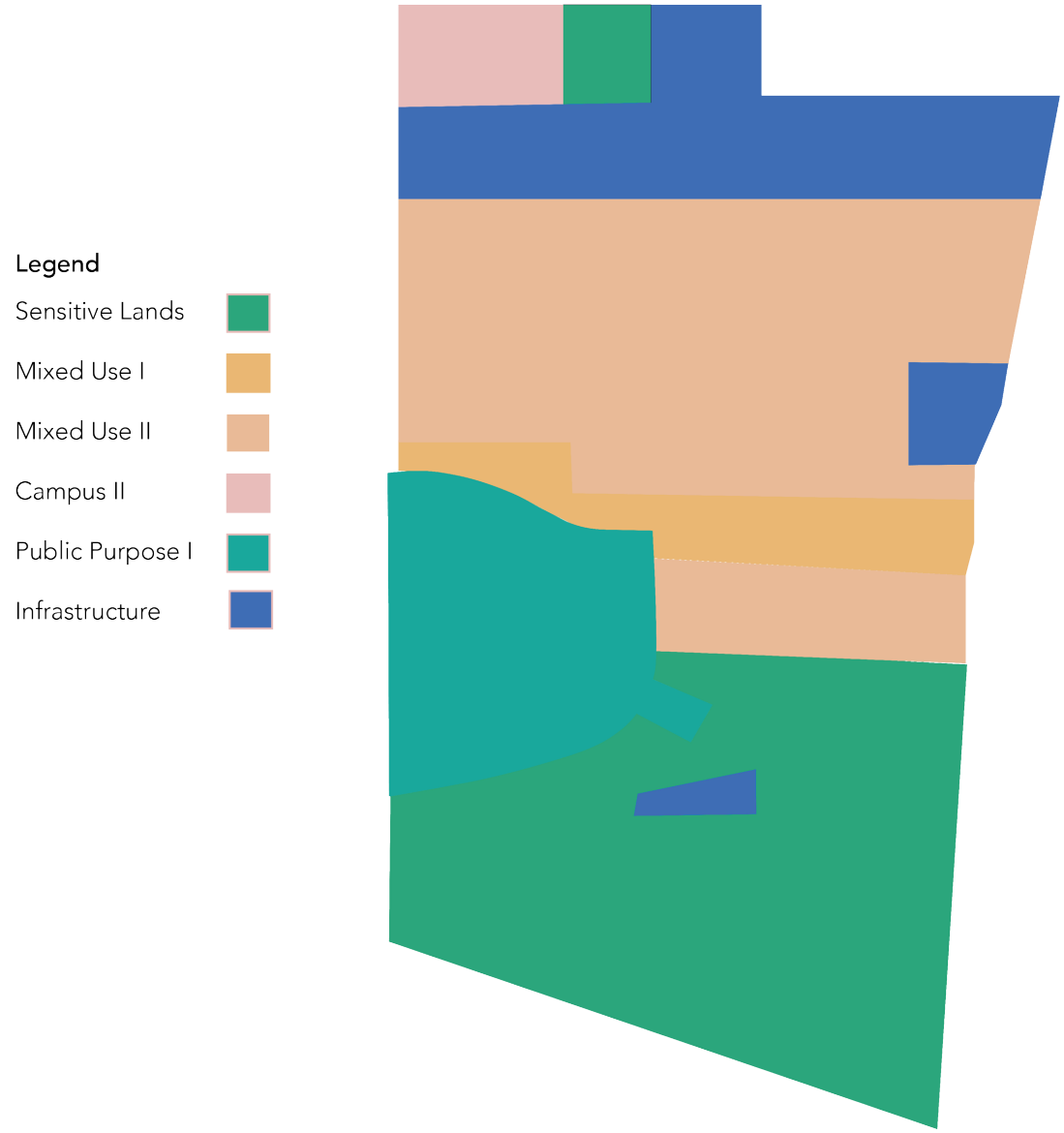
Figure 06.08 shows a proposed land use map of the Barrio, with seven of our proposed land use categories applied.

The first land use assignment was to sensitive lands. I selected two areas based on the site analysis. Both areas contain varied topography and seasonal streams that drain the Barrio. Seasonal streams tend to have more biological diversity than adjacent areas because of the availability of water. Moreover, the streams flow into the bay, which is a marine preserve, Protecting it from human use will help limit pollutants from entering the stream and then the ocean.

The second land use assignment (infrastructure) was to the existing wastewater treatment plant, while the third assignment was to an existing school (campus II).

The fourth assignment was to set aside a section of land on the west edge of the Barrio, immediately south of the main road, as a future municipal park. This area

Figure 06.08: Land Use Map



is neatly bounded by existing roads and is home to a set of unused government buildings and a maintained soccer (football) field. It abuts the larger of the two sensitive areas and thus serves as buffer. It is readily accessible to all town members.

The next assignment was to establish the plots lining either side of the main road as MU-I. This use requires two floors and commercial-retail use of the ground floor. The purpose is to establish an active main street for the emerging neighborhood that also continued the existing use pattern for that street.

The fifth assignment was to establish a large portion of the northern area immediately north of the MU-I land to MU-II use. This assignment is based on both the availability of remaining land but also the logical extension of the existing neighborhood streets to the east.

The final assignment was to set aside land for infrastructure, this included drinking water, a second wastewater treatment plant, and an area for agrivoltaics. The first two determinations were based on the land's slope and hydrographic basins that we identified during the site analysis. The location of the agrivoltaic facility is used to provide some buffering between the national park north of the Barrio and the active use of the MU-II area.

06.05 Conclusion

This section suggested a land development code for Barrio de las Lechuzas, a proposed planned neighborhood of Puerto Baquerizo Moreno. The code is simple, which reflects the current planning and development practices of the town. There are eight zones: Environmentally Sensitive Lands, Public Spaces, Mixed Use, Public Infrastructure, Campus I, Campus II, Transportation Center, and Cemetery.

Zones are based on both use and form. The goal of the zoning program is both to separate truly incompatible uses and to preserve good urban form, including the town's current fine urban grain.

Key elements of the zoning code include:

- Municipal government is responsible for new land division
- Sensitive land is set aside and protected at the outset of land use planning
- The appropriate amount of land for solar generation and wastewater treatment is set aside at the beginning of land use planning
- Short blocks set within a street grid
- Narrow and deep lots
- Little to no setbacks
- A strong building edge on the sidewalk
- Green infrastructure alleys on each block to manage water and provide green space.
- Design requirements for uses requiring larger lot sizes
- Uses requiring larger block sizes are assigned to the periphery to protect the town's existing urban grain
- Minimal street widths to reduce expense and support low-speed multi-modal use
- The use of arterial streets to anchor higher intensity mixed use, create a public transit corridor, and create urban legibility.

SECTION 07: MASTER PLAN

Barrio de las Lechuzas has been designed to create a livable, dynamic neighborhood that models sustainable growth for the Galapagos. The master plan, figure 07.01 (following page) implements eight of the provincial government's policy goals, integrates into the town's existing urban form, and adapts to the site's unique context. Situated at the east end of the town, the Barrio creates an opportunity to bridge the short but seemingly intractable distance between the ocean and the highlands or the town and the country.

07.01 Housing, Economic Activities, and Land Efficiency

Two of the provincial government's policy goals that we identified in section three are closely related: (1) ensure adequate housing and (2) reduce consumption, including land. The way to achieve both goals is through spatially compact, mixed use development. The strategy behind compact, mixed use development is to bring people physically closer to their everyday needs. In practice, this means that a neighborhood includes not just housing but stores, employment opportunities, government services, and public amenities. Some scholars use the phrase 15-minute neighborhoods to describe a neighborhood where a family can find employment and most of the goods and services they need for daily life within a 15-minute walk or bike ride from their home.

Compact, mixed use neighborhoods tend to have certain physical characteristics. They grow vertically, whether as low-rise buildings (1-4 floors), mid-rise (5-9), or high-rise (over 10). The buildings are typically attached (although not necessarily structurally), so they appear as a continuous edge to pedestrians. The street prioritizes walking, and increasingly, biking. The emphasis on walking and biking may result in wider sidewalks and amenities such as street trees, lighting, and benches. The plots tend to be narrow to maximize access to the street by different business.

In compact development, there is an overall ethos that land is valuable and it needs to deliver services and benefits, ideally more than one. This approach tends to reduce open or "blank" space. Street travel lanes may be narrower than elsewhere, setbacks between buildings may be smaller or absent, and space for cars may be limited.

Compact, mixed use communities provide higher tax returns per square foot than those developments with a horizontal, low-rise approach, such as single family detached neighborhoods. Higher revenue supports public transportation and higher quality public amenities. They also require less material for infrastructure, such as roads and pipes, which leads to long-term cost savings. Compact development are more cost-efficient to heat and cool as well. These advantages result in considerable GHG emissions saving, installation cost savings, and operational cost savings.

For compact, mixed use communities to be livable, rather than just crowded, the quality of the streets as well as the quantity and quality of public spaces need attention.

Fortunately, the idea of compactness is already embedded in Puerto Baquerizo Moreno's urban form. As we saw in section 4, the town's existing urban grain is short blocks, narrow parcels fronting the street, and buildings without front or side setbacks. Buildings can be up to four stories. This is a very efficient use of land and contrasts strongly with the American practice of detached buildings and setbacks. Puerto Baquerizo Moreno does not have zoning, so it essentially all mixed use. (In section six, I suggested the town adopt a simple zoning system to prevent possible conflicts between

Figure 07.01 Master Plan

Legend

A. Wastewater Facility (north basin)
B. Agrivoltaics Cooperative
C. Mixed-Use II Zone
D. Water Storage Facility
E. Nature Reserve
F. Interpretive Trail
G. Existing Arroyos
H. Existing Wastewater Treatment Facility (south basin)
I. Existing Soccer Fields
J. Town Park
K. Neighborhood School
L. Town Plaza
M. Native Plant Demonstration Garden
N. Mixed-Use I
O. Green Belt
P. Neighborhood Park
Q. Neighborhood Plaza
R. Green Infrastructure
S. Existing School
T. Drainage Field

truly incompatible uses.)

In recognition of the sustainable nature of the town's existing block and parcel form, the master plan continues that pattern. Section six, which proposes a set of land development policies, calls for blocks that measure 64 meters by 40 meters and parcels that measure 8 meters by 20 meters. This allows for 16 ground floor units per block or 64 units per block if the parcels are developed to a maximum of four floors. If each unit housed 2.5 individuals, a standard block would provide housing for 120 people.

The blocks are formed by the street grid. In order to connect the Barrio's street grid to the existing street grid on the west, there is some variation in block dimensions. All total, the Barrio has 40 standard mixed-use blocks and 535 parcels. If each parcel is built to four floors and each floor is one unit, this produces 2,140 units with 120 meters^2 of indoor habitable space. Seventy-two parcels are Mixed Use I, which requires ground floor retail or commercial use. All other parcels allow but do not require ground floor commercial-retail. In the maximum built-out scenario, the Barrio could house 5,120 people (assuming 2.5 people per household).

Housing and commercial activities are distributed mostly in a rectangular band 440 meters east to west and 230 meters north to south, totaling approximately 11 hectares. The band follows along the northern edge of main inter-town road. This location was selected based on the findings from the site analysis in section five.

The selection criteria for housing and retail-commercial uses included: generally flat ground, avoiding sensitive lands, connectivity to the street system, taking advantage of the main inter-town road, and buffering human use from national park lands. The economic and residential district's current placement in the master plan fit these criteria.

07.02 Transportation and Connectivity

A third provincial policy goal is to "improve mobility and connectivity without expanding automobile use." This goal, in conjunction with several other strategic goals, speaks to the desire of developing a sustainable transportation system. An urban sustainable transportation system maximizes residents' preference for active transportation (walking and biking) and public transportation while discouraging personal automobiles.
There are a number of strategies to achieve a sustainable transportation system. One important strategy is mixed use, compact development, which I discussed in the preceding paragraphs.

Other strategies include:

- Quality street facilities—these include lighting, benches, buffered bike lanes, bike parking, shaded bus stops, street trees, and garbage bins.

- Transit service—frequent (15 minute or less) service, real-time information on arrival/departure times (dedicated bus lanes, which are not yet necessary in the Galapagos), and discounted transit passes.

- Discouraging cars—high registration fees, limited licensing of personal automobiles, limited on-street car parking, low design speeds, and narrow lanes.

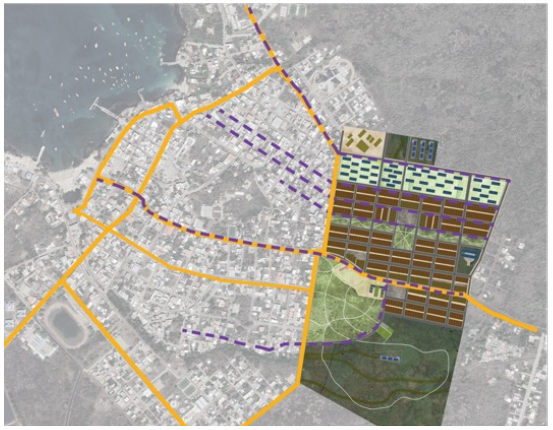
Puerto Baquerizo Moreno is fortunate that it developed without much pressure to accommodate vehicles, which is evident in narrow streets, few places for cars or other vehicles to park, a good street grid, and a compact urban form. Today, personal cars are still rare, although taxis and buses are in evidence. Despite a good street grid and a compact form that makes most

destinations readily accessible, there are some mobility challenges. The most significant is the poor quality of the sidewalk. Sidewalks in Puerto Baquerizo Moreno are very narrow, perhaps a meter, often uneven, and often interrupted by electrical poles and other street facilities. These barriers can push people into the streets and make it much more challenging for people with physical challenges to walk. There are no dedicated bike facilities.

The Galapagos 2030 identifies a set of connectivity and mobility improvements that address some of these shortcomings. These improvements include dedicated bike lanes and bike parking, ADA ramps and audio crosswalk signals, and better road speed management devices (p. 61).

In terms of the connectivity and mobility aspects of proposed master plan for Barrio de las Lechuzas, the plan largely follows the town's existing street pattern of a gridded street system. This system provides for quick and easy travel within the Barrio. The main commercial and residential heart of the Barrio includes six east-west streets, four of which connect to the town's existing street grid on the west. The main inter-town road is a seventh east-west connection that directly connects the Barrio with the urban core and the highlands. When the town expands again, the Barrio's strict grid can be extended east to the new neighborhood. There are eight north-south roads that connect residents to the main inter-town road, which provides quick access to the town's urban core or the smaller town of E Progresso, gateway to the agricultural highlands.
I have suggested changes to the street design in order to address some of the town's transportation shortcomings. The master plan provides for two street types, an arterial street type and a neighborhood street type. (I have provided detailed information and cross-sections in section six.)

07.02 Street Connectivity



This diagram shows major streets (orange) in the town's existing street network and the connecting streets (purple) in the Barrio.

Both street types are relatively narrow (compared to their U.S. counterparts) and provide separated sidewalks. The neighborhood streets call for a 1.5 meter wide sidewalk, which allows two people to walk alongside one another and for people to pass street fixtures. The arterial street calls for a two meter sidewalk. Neighborhood streets are shared streets so the travel lanes are meant for vehicles, motor scooters and bikes. Arterial streets have slightly wider travel lanes and separate bikes and vehicles. They also have planted stormwater channels. The inter-town road and the western ring road are both arterial streets. The remaining streets are neighborhood streets. Narrow streets are less expensive, reduce vehicle speeds, and retain less solar radiation than wider streets. Due to the area's dry environment, limited tree selection options, and cost of maintenance, the master plan omits street trees for neighborhood streets. This difficult decision is partially mitigated by the use of trees and other vegetation in the stormwater infrastructure running through the middle of most blocks.

07.03 Public Spaces

I divide public spaces into two broad categories. The first category is public space meant primarily for people to interact with one another, such as a plaza, and the second for people to interact with nature, such as a park. The Barrio's master plan provides a range of public spaces totaling 14 hectares, three hectares more than the core housing and commercial-retail district. This equals 30m^2 per person based on the maximum built-out scenario.

07.03.01 Plazas

The master plan provides for two plazas. The first is in the more developed north half. It offers 3,800m^2 for leisure, unstructured social interaction, or programmed activities developed by the residents. Land development policy requires first floor commercial-retail use along three of the plaza's perimeter. A neighborhood park occupies the block immediately south of the plaza and continues as a set of linear park blocks to the eastern and western edges of the Barrio.

The second, larger, plaza abuts the main inter-town road. It provides a connecting point between the central business

07.03 Plaza in Guayaquil, Ecuador

This plaza in new, mixed-use neighborhood in Guayaquil, Ecuador, provides an excellent example of what is possible for Puerto Baquerizo Moreno. Source: CNU.org

district at the pier and the highland town of El Progresso. The plaza provides 0.4ha of space. It serves multiple purposes: as a gateway to Barrio de las Lechuzas, as a meeting point for the community, a town-wide market space, and as an entry to the park, demonstration garden and nature reserve. The plaza has one fixed building—a community center—that consists of a large kitchen, bathrooms, and a dividable hall that can open to the outdoors. Rooftop solar panels support the center's operation, and a demonstration graywater system educates the public on an important water-saving opportunity. The community center creates a venue for new public activities that can include a public market, educational activities around food preparation and health, and to celebrate important civic and religious holidays.

07.03.03 Parks

The Barrio has three very different parks. Each park provides a different experience that meets the provincial government goal to connect residence with the Galapagos' unique environment."

The first is a large 5 hectare park that serves the whole town. It is on the corner of Avenido 12 de Febrero and Avenido Jaime Roldos Aguilera. The larger plaza and native plant demonstration garden are integrated into the park and add another hectare of public use. The landscape is an idealized arid zone ecosystem with an extensive trail system that allows for walking, running and wheeled activities such as biking and skateboarding. A network of small solar-covered patios provide shade for resting or outdoor picnics. Visitors are not limited to the trails. A small and large soccer field are immediately east of the park. A small solar-covered parking lot

accommodates bikes, motor scooters, and cars. It is the only off-street parking in the Barrio.

The second park is a neighborhood park centrally located in the heart of the mixed use district and next to the plaza. It makes use of select native groundcover and other plants to provides a true green space in an otherwise arid environment. This park allows residents to relax under the shade of the overhead tree canopy, an experience that is rarely available for town residents. It contrasts with the open plaza and offers residents two very different experiences.

The third park is a linear park, approximately 22 meters that runs from the neighborhood park through the middle of the town to the east and west edges. It provides a canopied walking or running trail and creates a cool, engaging route between the town's edges and the center. While both parks use trees, the linear park showcases native blooming perennial plants whereas the neighborhood park uses groundcovers.

The stormwater channels that run through the community are another opportunity to view nature, but they do not provide walking paths.

Figure 07.04 A Desert Demonstration Garden in Scottsdale, AZ.

Source: AZPlantLady.com

07.03.03 Demonstration Garden

The native plant demonstration garden is located in the larger urban park that is intended for the whole town. The garden displays rows of native plants with name tags to help residents become familiar with local flora as well as several garden beds of mixed plants that offer ideas for home landscapes. The demonstration garden also creates opportunities for residents school children to engage the natural environment through planting and maintenance activities. The garden and community center can be integrated to provide education programs, including hands-on horticultural activities.

07.03.04 Nature Preserve

Figure 07.05 A Desert Ecology Trail

This desert interpretive trail at Saguaro National Park, AZ, provides an example for an interpretative trail in Barrio de las Lechuzas. Source.utahsadventurefamily.com

At 8.1 hectares, the nature preserve is the largest natural space in the town. It is only a ten-minute walk from the farthest edge of the Barrio's mixed use area and a short bus or bike trip from the town's pier and urban core. The preserve is in the arid zone and consists of an uneven topography of arroyos. The site analysis discovered that the arroyos merge into a stream that runs through town and empties into the bay at a sea lion pup nursing area. To protect the bay's water quality and the sea lion habitat, the master plan designated this space as sensitive lands to be protected from development. Fortunately, protecting the stream and habitat does not preclude human use.

The master plan envisions an interpretative trail that loops through the nature preserve. Low signs are distributed throughout the trail to educate residents and visitors on the special features of the Galapagos' unique environment.

The intent of the nature preserve is to provide an accurate, educational portrayal of island's arid zone ecosystem for residents and tourists without the need for a permit, fee, or guide. Moreover, it creates opportunities for residents and tourist to engage directly in the environment by helping to remove invasive plants, install appropriate native plants, or conduct citizen science under the direction of an approved NGO.

The nature preserve differs from the park in that the nature preserve focuses on ecological authenticity and asks visitors to stay on the trail unless they are part of a program while the urban park focuses on aesthetics and unlimited access.

07.03.05 Public School

There is land set aside by the demonstration garden for a public school.

07.04 Basic Services

One of the advantages of a planned town is the ability to correctly size and place infrastructure for the expected demands. Puerto Baquerizo Moreno grew organically from just a few buildings. It also faced challenges accessing materials, skilled labor, and financing needed to install and maintain infrastructure. As a result, some basic services such as drinking water and sanitary sewers are not up to standards. The government has responded by setting a policy goal for 2030 of providing basic services. The Barrio's master plan provides for appropriately placed infrastructure facilities, including electricity, drinking water, wastewater, and stormwater. The island has an effective solid waste and recycling program.

07.04.01 Electricity & Microgrid

The master plan dedicates 4.7 hectares of land for a community agrivoltaics farm. Agrivoltaics combines farming with raised solar arrays. Typically, solar panels cover 50% of the land and produce can be raised in both sun and shade. Researchers have found that co-locating solar and agriculture "provides multiple additive and synergistic benefits, including reduced plant drought stress,

07.06 Agrivoltaics Facility in Pennsylvania

Source: USLightEnergy.com

07.07 Agrivoltaics Research Facility Outside of Tuscon, AZ.

A desert agrivoltaics research facility outside of Tuscon, operated by the University of Arizona. Source: College of Social & Behavioral Sciences, University of Arizona.

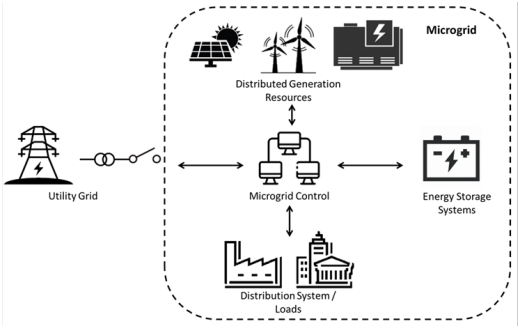
greater food production and reduced PV panel heat stress" (Barron-Gafford, et al, 2019). Figures 07.05 and 07.06 provide examples of agrivoltaics facilities.

The agrivoltaics farm offers several community advantages. First, it produces enough electricity to support 2,000 residents, or about 45% of the population in the built-out scenario. Second, it can be organized in a variety of ways: as a community cooperative to generate income from the sales of the produce, as individual garden plots assigned to residents, or as an educational and research facility. In fact, all three organizational approaches could be used simultaneously. Finally, an agrivoltaics farm that involves neighborhood residents helps meet several government policy goals: Help residents identify with, appreciate, and care for the Galapagos' unique environment; preserve and restore ecosystem processes and biodiversity; mitigate adverse impacts from human activities; use renewable energy, and reduce consumption, including land.

The opportunity for Barrio residents to garden individually or collectively has physical and mental health benefits and contributes to stronger social connections, which in turn contributes to greater community resilience (Smith, G., 2024).

The Barrio's community solar, as well as any individual-scale solar panels, can be connected to a battery storage system

07.08 Islanded Microgrid Diagram



Source: Comodi, G., Iannarelli, A., & Moneti, M. (2022). Experimental Validation of Systems Engineering Resilience Models for Islanded Microgrids.

and an electrical switching facility to create a microgrid. With a microgrid, electricity flows from the main island grid into a central battery storage and switching facility located in the Barrio, where it is then distributed to individual Barrio customers. Similarly, energy produced in the Barrio flows to the same battery storage and switching facility, where it can either be fed into the main grid or redistributed back to the Barrio to meet demands. A microgrid allows the Barrio to both receive and contribute electricity to the main grid. Importantly, a microgrid makes the Barrio "islandable," i.e. the Barrio can disconnect from the main grid and operate autonomously. This is an important resiliency feature in the event of an emergency.

03.04.02 Drinking Water

An island-wide utility is responsible for providing drinking water. The system, however, is outdated and does not provide regular, continuous water service. To address this problem, customers store water in building-scale tanks. These tanks become contaminated, and the water stored in them needs to be boiled or otherwise treated before drinking.

This project replaces individual water storage tanks with a community scale storage tank. This allows for better quality control (maintenance) while providing continuous water service to customers. A final disinfectant step may be necessary depending on the length of storage.

The existing system relies on gravity to distribute drinking water. This is a resilient method that avoids the cost and risks (outages due to equipment or power failure) of pumping water. The challenge, though, is development needs to take topography and slope into account. The site analysis found that Barrio de las Lechuzas has a three

percent slope, which accommodates gravity-fed water distribution, and that the site was divided into two drainage basins, a north basin and a south basin. The master plan locates the water storage facility at the east (uphill) edge of the Barrio on the line dividing the drainage basin. This allows one facility to serve residents in both basins.

07.04.03 Wastewater Treatment

The municipal wastewater system is undersized for the current population. As a result, it is discharging partially treated water into the bay. This effluent does not meet discharge standards and poses health risks to humans and marine life. This project addresses the wastewater problem by establishing a neighborhood-scale wastewater "packet" treatment facility.

A packet facility is custom-made to meet the site' specific context and community needs. It is built off-site, shipped in, and installed. It is "plug and play" modular system. Additional units can be added in parallel to accommodate growth. Packet systems are both compact and can meet high standards for water treatment. The method of treatment varies, but all involve separating organic solid waste (sludge) from liquid waste. Sludge is typically hauled away while liquid waste (effluent) is treated and released into a receiving body of water.

07.09 Packet Waste Water Treatment Facility

A packet waste water treatment facility in South Africa. Source: WEC Water

07.10 Intermediate Scale Biodigester

A biodigester converts sludge to methane and "digestate," an organic fertilizer. Source. PigProgress.net

There is a more recent approach to managing sludge than shipping it to a landfill. A biodigester is a facility that uses anaerobic bacteria to convert sludge into methane, which can be burned to generate electricity, and a substance called "digestate," which can be used as fertilizer. Biodigesters can be simple facilities made of generally available household materials or complex facilities designed by engineers with a dedicated staff. Figure 07.10 shows a small biodigester of intermediate complexity.

A neighborhood wastewater treatment facility has several advantages. First, it prevents stress on the existing system. Second, it takes advantage of current technology rather than having to conform to a legacy system. Third, if it or the main municipal system fails, not everyone is impacted.

The municipality has one wastewater system in the Barrio's southern drainage basin. This facility may meet the need of the area's limited population. If not, there is sufficient space within the facility's existing footprint to install additional equipment to increase capacity.

The vast majority of the community's residents live in the northern drainage basin. This area will need a new facility. The master plan locates the new facility at the southern low point on the property immediately south of the existing school. This is an ideal location not only because it is at a low point, but also because of an existing arroyo that can handle the treatment plant's discharge. The parcel of land has enough space that it can hold several treatment modules. This allows the community to add capacity as the Barrio grows, which reduces upfront costs.

The master plan calls for a dual wastewater plumbing system. The first component is a black water system that conveys toilet water to the treatment facility. Black water requires more intensive treatment before it can be released and results in solid sludge waste that needs to be handled separately. Graywater is water from clothes washers and sinks. It also needs to be treated but much less intensively. By separating gray water and black water, the community can save money in installation, maintenance, and use of their wastewater system (although the dual plumbing that runs from each building will add some cost).

07.04.04 Stormwater Management

Puerto Baquerizo Moreno does not have a complete stormwater system. This leads to urban flooding near the coast and contamination of the harbor when stormwater carries pollutants from urban surfaces into the ocean.

Barrio de las Lechuzas addresses this problem through a series of green infrastructure (GI) facilities. GI is an approach that uses natural analogues (rock-filled, landscaped drainage ditches) to capture, direct, filter, and occasionally store stormwater. This technique avoids the expense of gray infrastructure while simultaneously treating the stormwater (i.e. filtering out pollutants and removing heat).

This project calls for a series of narrow green infrastructure facilities. One set of facilities will run east-west through center of each block. They intersect a north-south channel on the west edge the town's low point in the northwest corner, where it flows into an existing arroyo. These open areas also provide some habitat space and opportunities for residents to interact with local species. The nature preserve on the south and southwest portion of the site will serve the same function as the green infrastructure in the north half of the town.

07.11 Green Infrastructure in Tempe, AZ

This shallow channel directs, slows, and helps filter stormwater runoff. It also contributes to habitat. Source: City of Tempe, AZ.

Green roofs and walls are important components of GI, but we did not include them in the master plan because of installation costs and maintenance demands.

The use of trees, an important part of green infrastructure in temperate and tropical climates, is limited in Barrio de las Lechuzas for several reasons. First, the island is limited to using mostly indigenous tree species, and there are only a few available indigenous tree species. Second, several of the available tree choices provide limited or no urban benefits (e.g. dormant in the summer). Third, urban trees create conflict

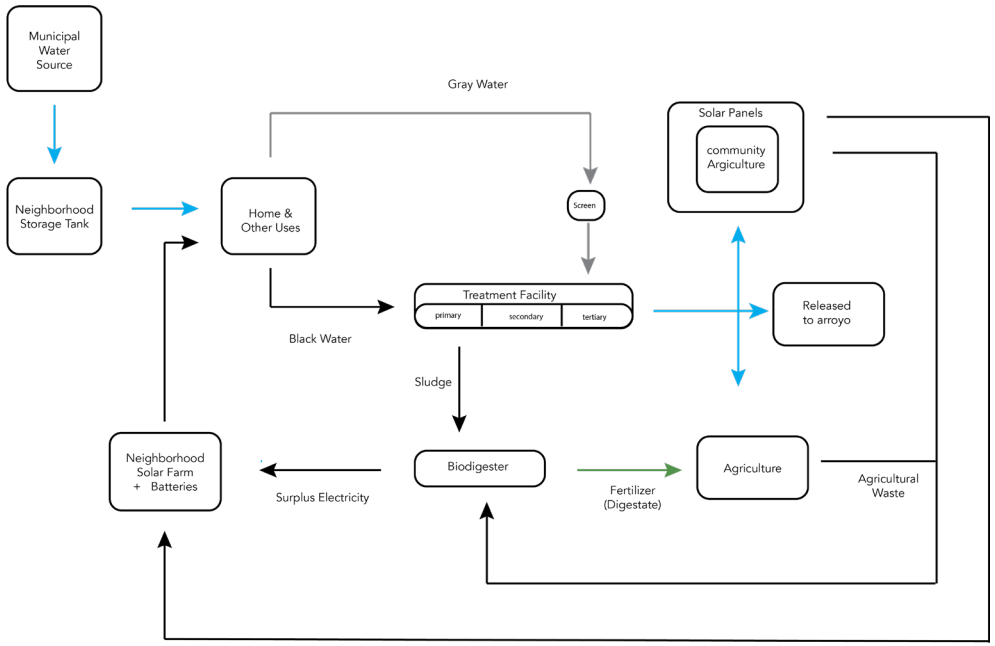
with gray infrastructure and require maintenance. This creates an economic hardship for the community. Finally, many trees, even in arid environments, require supplement irrigation or other interventions to help them establish. Trees are used in the neighborhood park, linear park, arterial streets, stormwater channels, and sporadically in the city park and nature reserve.

07.04.05 Circularity

Several components of the utility system work together to maximize beneficial outcomes while minimizing waste. Figure 07.12 illustrates this process.

The inclusion of a biodigester and microgrid are the critical element in the system. As I discussed earlier, the biodigester converts sludge, a byproduct of the sewage system, into methane gas and a solid called digestate. The methane is then burned to create energy. This energy flows into the microgrid and is either used by the community immediately or stored in batteries for later use. The digestate is used as fertilizer for the community agrivoltaics facility or provided to farmers in the highlands. Agricultural waste is returned and fed back into the biodigester. Effluent from the waste water facility can be used to water the plants grown at the agrivoltaics facility or provided (via tanker truck) to highland farms. The use of properly treated effluent to support food production reduces the pressure on the island's limited supply of freshwater.

07.12 Utility Circularity



07.05 Conclusion

Barrio de las Lechuzas offers a model of the built environment that provides both continuity with town's past and a significant departure from it as it tries to meet residents' desire for "a high quality of life in friendly, inclusive and safe neighborhoods that are connected to their natural environment."

The Barrio's key features include:

- *Compact, mixed use development.* This development strategy consists of short blocks, mixed use low-rise buildings, minimal or no building

setbacks, and a consistent street grid. It is an efficient use of land and other resources, enhances social capital by bringing people together, and is consistent with the town's current fabric.

- *Space for housing and economic activities.* The master plan includes 40 blocks, 535 plots, and a total of 2,140 units for housing, retail, and commercial use. Barrio de las Lechuzas can comfortably accommodate just over 5,100 residents. Public spaces are distributed in and on either site of the residential/economic district.

- *Good connectivity.* The town's existing street system is well integrated into the new neighborhood, allowing residents easy access to the pier and central business district, the hospital, and other destinations. The town's public transit system includes a stop in the Barrio on the main road. Street design promotes walking and biking.

- *Excellent public spaces and access to nature.* The master plan provides for 22 ha of total public space distributed among eight different facilities, including a town park, a neighborhood park, plazas, soccer fields, and a nature preserve.
- *Decentralized basic services.* The barrio has its own water storage facility to provide 24-7 safe drinking water. A community solar farm, batteries and a microgrid to supply reliable carbon-free electricity. A neighborhood-scale waste water treatment facility protects the local environment and water supply from contamination and health risks while creating electricity and water for agricultural use.

- *Residential agriculture*. The agrivoltaics facility provides residents with 4.7 hectares of space for garden plots, equally divided between shaded and sunny plots. The adjacent waste water treatment plant provides water than can be used on agricultural and also accepts garden waste.

08. PHASING & FINANCE

In section six, I offered a land use development code for a sustainable new neighborhood, in section seven I provided a master plan, and in the final section of recommendations, I offer a suggestion on how to best sequence the development into a set of phases and one suggestion on how to fund the infrastructure.

08.01 Phasing

I propose phasing the development of Barrio de las Lechuzas into five stages, as shown in figure 08.01. The primary reason to develop in phases is to match the need for infrastructure services with the financing, instillation, and maintenance of infrastructure facilities. Phasing also keeps the development compact, which better fits the community's policy goals and is more efficient.

The general approach is to develop from west to east, expanding along the lines of the existing street grid.

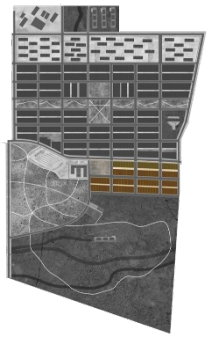
Stage one primarily includes major town amenities, including the park and related facilities, site of a future school, and the nature reserve. These features would benefit not just the neighborhood's

Figure 08.01 Development Phases

01

02

03



04

05

future residents but the town's current residents. Since the government owns most of the land, setting phase one in motion is primarily an administrative action. Development of the land into a public park, demonstration garden, and nature reserve can be phased in to coincide with a financing plan. Making substantial progress on phase one creates a favorable environment for phase two by demonstrating the government's commitment to implement the master plan and by creating a significant amenity for new residents.

Phase two follows. It consists of nine blocks of mixed use, three blocks west to east and three blocks north to south. The blocks on the south edge front the main inter-town road and are MU-I while the remaining six blocks are MU-II. Phase two also includes the first two blocks of a linear park, two blocks of agrivoltaics, the water storage facility, and the first phase of the wastewater treatment plant.

The drinking water and wastewater facilities are a departure from the west to east development pattern in order to accommodate the needs of the new residents. The underground distribution systems, however, would be phased in along with development. Additional modules for the wastewater would be added as the community is developed to keep the cost in line with the use.

Phase three continues to move west to east and adds the Barrio's central plaza and neighborhood park. This brings the residential and economic area to a total of 27 blocks and expands the agrivoltaics area by another two blocks for a total of four blocks.

Phases four completes the mixed use area south of the main road while phase five completes the development of the mixed use areas and adds the last block of agrivoltaics in the northeast corner.

08.02 Financing Proposal

Funding infrastructure installation, maintenance, and repair is challenging for almost every community across the globe. As I noted earlier, it is especially difficult in the Galapagos because there is little soil and subsurface excavation requires digging in basalt bedrock. This challenge is compounded by the expense of shipping equipment, material, and even technical expertise to the islands.

To address the funding challenge, I suggest residents use a community collective model Figure 08.02 provides a diagram of how this process might work.

The first step is an administrative one in which the government agrees to transfer the land to a collective of residents. The transfer agreement would specify what the collective must do in order to maintain title to the land. This would include making property tax payments, installing and maintaining agreed-upon infrastructure, and following agreed-upon governance procedures to ensure all members of the collective participate in decision-making. There may be a range of other agreements, such as cost-sharing for public spaces.

The next step is for residents to come together to incorporate the collective and establish a governing system, pursuant to the provisions of the title transfer agreements. Residents would buy into the collective. In turn, they would receive access to a plot for development and a vote on governance issues.

The collective would use the buy-in funds to finance the drinking water, wastewater, and electrical facilities from an international lender. Annual fees to collective members would pay for both the property tax on the land, the repayment on the infrastructure loan, and any other services collective members agreed to obtain.

The town would continue to

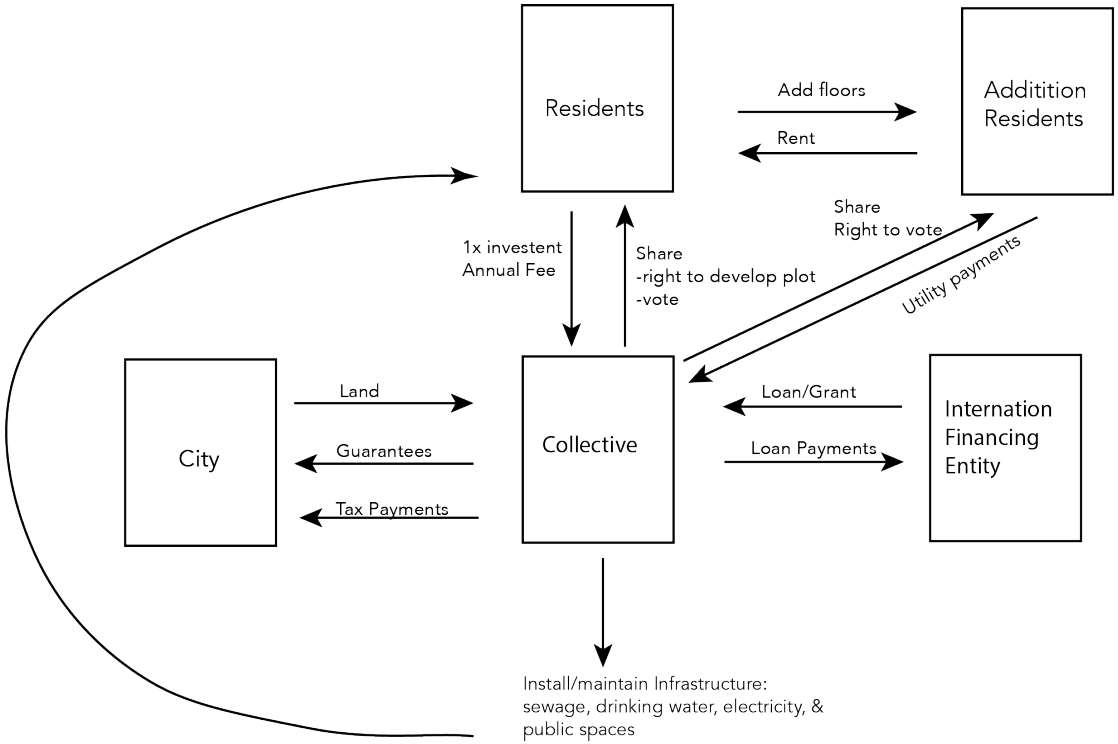
maintain streets, care for public spaces, and provide solid waste and telecommunications services.

This model leaves unclear the tenure status of residents who live on floors two through four. Are they renters who have a different status from those residents who have a right to the plot? Does the right to the plot become sub-divided when the ground floor resident adds additional floors. These are at least two questions that must be addressed for this model to work.

This short overview of a collective model is rooted in a few concepts:

1. Public-private partnership
2. Collective engagement and shared responsibilities of the residents
3. Decentralize (community scale) utilities
4. Pay as you develop
5. Leveraging the Galapagos' unique global status to access grants or low-interest loans

Figure 08.02 Financing Proposal



09. CONCLUSION

This project has provided a design study for a new, sustainable neighborhood for the town of Puerto Baquerizo Moreno in the Galapagos archipelago. The study takes the form of a master plan for a neighborhood of 5,000 residents, as well as supporting material from an analysis of the community's policy framework, existing urban form, and site context.

The project's purpose is to help residents visualize one potential future for their built environment. This, in turn, allows them to participate in shaping that future better than if they were limited to written policies. The project is an intermediate step in a design process that is meant to create the built environment that best fits the needs, aspirations, and circumstances of the community.

To develop this study, I reviewed the community's existing policy documents; specifically, the Galapagos 2030 strategic plan and the town's territorial plan. From those documents, I developed a set of eight policy goals that directed the development of the master plan. These goals also had to stand in for the community's ongoing engagement.

Next, I examined the town's existing urban form, including aspects such as geographic extent and population density, the transportation systems, street, block, and plot patterns; and, public spaces. Finally, I explored the site context and provided a series of tables and diagrams that illustrated features such as slope, hydrology, geology, and flora and fauna.

Based on this set of materials, I proposed a land development process, which combined elements of traditional zoning practices with more contemporary form-based development code. This process resulted in a land use map. I then created a spatially explicit master plan that provided for roads and basic infrastructure, land for housing and economic activities, and public spaces. I concluded with a suggestion for how best to phase development in over time and a potential solution to financing basic infrastructure.

In the course of the design study, I reached a set of conclusions.

1. The town's shape and development pattern lend itself towards transit-oriented development along the main road.
2. The town's current urban form—low-rise (4 story) mixed use building, no front and side setbacks, and narrow plots set in a street grid of short blocks—can accommodate a significant amount of population growth without intruding into national park land.
3. The municipal government should develop a criteria based on density, vertical expansion, and quality of public space that regulates the release of additional land for future development.
4. The town needs more public spaces and public amenities, including green spaces, if it wants to meet its policy goals and accommodate any new growth.
5. The government should set standards for the size and type of public spaces based on population statistics and community preference.
6. Residents, the government, and international stakeholders need to work together to find a funding solution to the installation and maintenance of infrastructure that provides for basic needs.
7. There is sufficient land to meet the community's energy needs with small to medium scale community solar facilities.
8. The government and NGO partners should begin a process of testing local and non-invasive exotic tree species to identify ones capable of serving as street trees.

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11. APPENDIX

Table 11.01. Design Strategies' Alignment with Policy Goals

Design Strategy	Description	Policy
Compact Development	An overall development approach that minimizes space between buildings. See also: setbacks, skinny streets, low-rise development	• Preserve and restore ecosystem processes and biodiversity • Reduce consumption, including land • Improve mobility and connectivity
Mixed Use	A land use regulatory framework that allows residential, commercial, retail and some others to co-exist within the same neighborhood	• Reduce consumption, including land • Ensure adequate housing • Improve mobility and connectivity
Skinny Streets	a street design that uses the narrowest dimensions that meet safety guidelines	• Reduce consumption, including land
Few or no setbacks	Buildings have little or no space between each other or between buildings and the sidewalk	• Reduce consumption, including land
Grid Street System	An orthogonal pattern of streets that repeat at regular intervals.	• Improve mobility and connectivity
Short blocks	Blocks of less than 100 meters	• Improve mobility and connectivity
Narrow Plots	Plots that are deeper than wide to maximize the change of facade as pedestrians pass by (visual interest) and which encourage vertical growth (land efficiency)	• Reduce consumption, including land
Wide sidewalks	Sidewalks that are sized to allow people to easily walk side by side or pass other people without going into the street	• Improve mobility and connectivity

Table 11.01. Design Strategies' Alignment with Policy Goals (continued)

Design Strategy	Description	Policy
Demonstration garden	A garden focused on displaying plants for educational purposes	• Help residents identify with, appreciate, and care for the Galapagos' unique environment
Nature Preserve	A space that it protected from development but still allows passive human use	• Help residents identify with, appreciate, and care for the Galapagos' unique environment • Preserve and restore ecosystem processes and biodiversity • Mitigate impacts from human activities
Form-based Code	An alternative approach to regulating urban land that focuses on building form rather than land use	• Reduce consumption, including land • Mitigate impacts from human activities
Low-rise development	A development approach that favors structures between one and four floors	• Reduce consumption, including land • Ensure adequate housing
Decentralized Utilities	Neighborhood-scale utilities	• Provide basic services • Mitigate impacts from human activities
Agrivoltaics	Land that supports both solar panel arrays and agriculture	• Use renewable energy • Provide basic services • Help residents identify with, appreciate, and care for the Galapagos' unique environment • Mitigate impacts from human activities

Table 11.01. Design Strategies' Alignment with Policy Goals (continued)

Design Strategy	Description	Policy
Green Infrastructure	An approach that relies on vegetation and natural analogues to manage stormwater	• Help residents identify with, appreciate, and care for the Galapagos' unique environment • Preserve and restore ecosystem processes and biodiversity • Provide basic services