DESIGN RECOMMENDATIONS FOR CLIMATE RESILIENCY IN AGONDA

PROGRAMS for SUSTAINABLE PLANNING and DEVELOPMENT

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INTRODUCTION

CLIMATE CHANGE AND AGONDA

The focus of the recommendations described in the following sections is climate resilience and design.

By climate resilience, we are referring to Agonda's ability to respond to the climatic changes and extreme weather events that are becoming more frequent worldwide.

Climate affects every aspect of life in Agonda, and directly shapes its architecture and design. In the following sections, potential design solutions that can increase Agonda's ability to respond to these climatic changes. are described in detail.

There are a number of climate change impacts that could potentially effect Agonda, including more extreme and variable temperatures and extreme weather events, more intense flooding during the monsoon season, and erosion of coastal areas as storms result in stronger waves. It is important to prepare for the changes because climate-related events have implications for agriculture, fisheries, health and local tourism.

Although Agonda already successfully responds to its climate in many ways, it is important to note that climate change ensures that these impacts will because more extreme and unpredictable in the coming years.

As flooding events become more frequent and extreme, potential impacts include damage to agriculture and agricultural lands, infrastructure, and property. In addition, public health impacts can result as people come into contact with floodwaters. Water and food security are directly related to temperature and precipitation. Changing weather patterns make temperature and precipitation more variable and can compromise Agonda's water and food supply. These changing weather patterns can cause increased beach erosion with changing wind and ocean currents.

The following sections contain potential design solutions that may act as buffers in protecting Agonda from climate change impacts.

DEFINING CLIMATE RESILIENCE: WORKSHOP SYNOPSIS & SCOPE OF REPORT

On Jan 8 2013, Agondan residents and business owners gathered at St. Anne's Church to discuss how sustainable design decisions can allow Agonda to prepare for climate change. Participants engaged in a series of participatory design and mapping activities focused on climate change in Agonda.

Some of the key issues that were raised during these conversations concerned water shortages throughout the tourist and rainy season, flooding, coastal erosion, and an increasingly unreliable energy supply. With these challenges in mind, participants utilized visual aids to express how some of these issues might be addressed through design measures. A number of the design solutions featured in this document were discussed in terms of their benefits, limitations, and contextual feasibility.

The issues and potential design measures discussed in the 2013 workshop framed the content of this report, and the concerns raised by workshop participants were integrated into a set of design recommendations. While the recommendations in the following sections are not the only strategies for increasing climate resiliency, they are intended to provide a sampling of design strategies that fit into Agonda's existing cultural, architectural, and environmental landscape of while mitigating the effects of global climate change.

1.0 SITE PLANNING

Site planning is the organization and layout of a building in relationship to its landscape and site. Designers and developers must analyze the best techniques and applications in construction that create the least amount of impact on the environment, whether it be in the hills or along the coast. This relationship between the structure and the land are integral to sustainable design. Site planning also takes into account information regarding slopes, soil content, hydrology, existing and planned vegetation and orientation, before having a structure built. Through the process of site analysis, development can be made more sustainably and longer lasting.

RECOMMENDATION: Appropriate Hillside Construction

Objective: When constructing on hillsides, there are many considerations to take into account in order to reduce the risk of damage to the structure and most importantly to people. By following these guidelines, many of the risks associated with hillside construction may be mitigated.

Issue

Hillside areas cover many parts of Agonda, especially Wards 1 and 7, and may be used as new construction areas when the more level areas of Agonda are fully built out. Living on slopes in Agonda can lead to greater possibilities of landslides, and increased property damage due to runnoff.

Description

Landslides are caused by rapid slope instability due to heavy rain, erosion, surface runoff and heavy excavation. These actions can be mitigated through proper site planning and design.
As seen in the figures, knowing how to build with the hillside allows for structural integrity and support such that water flows are controlled and sent away from the structural members of a home. Keeping the existing vegetation, while providing flood mitigation, also locks in the surface soil structures, providing resistance to land flows and slips. Making sure that the structure is anchored in bedrock, as well as having well designed retaining walls and water retention basins can provide for a safer, more stable home on the hillside.

Benefits

One of the biggest benefits is having a soundly designed structure to ensure quality of life for residents. Many of the earthworks that go into ensuring a stable structure also provides with many means of mitigating stormwater and flooding.

Limitations

The best practice for building in Agonda is to avoid hillsides greater than a 15% grade so that there is less of a risk of landslide. Encouraging development on these slopes can cause of more clearing of vegetation, allowing for faster water infiltration and increased surface runoff, often associated with new paving. In order to ensure that the site chosen for a building is proper, there should be a geological survey done to see the soil composition before building.

See Also: Flood Mitigation: Mangrove Preservation, Planting Native Vegetation; Potable Water: Rainwater Collection

References:

"Practice note guidelines for landslide risk management 2007."Journal and News of the Australian Geomechanics Society 42.1 (2007): Web. 5 Mar. 2013.

HILLSIDE CONSTRUCTION

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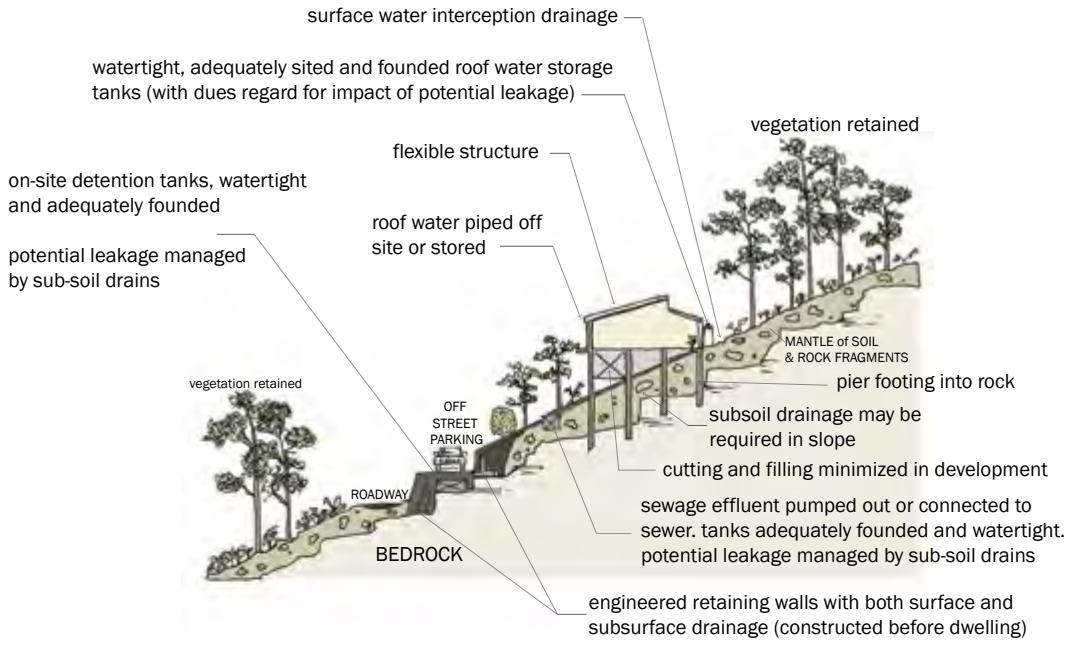

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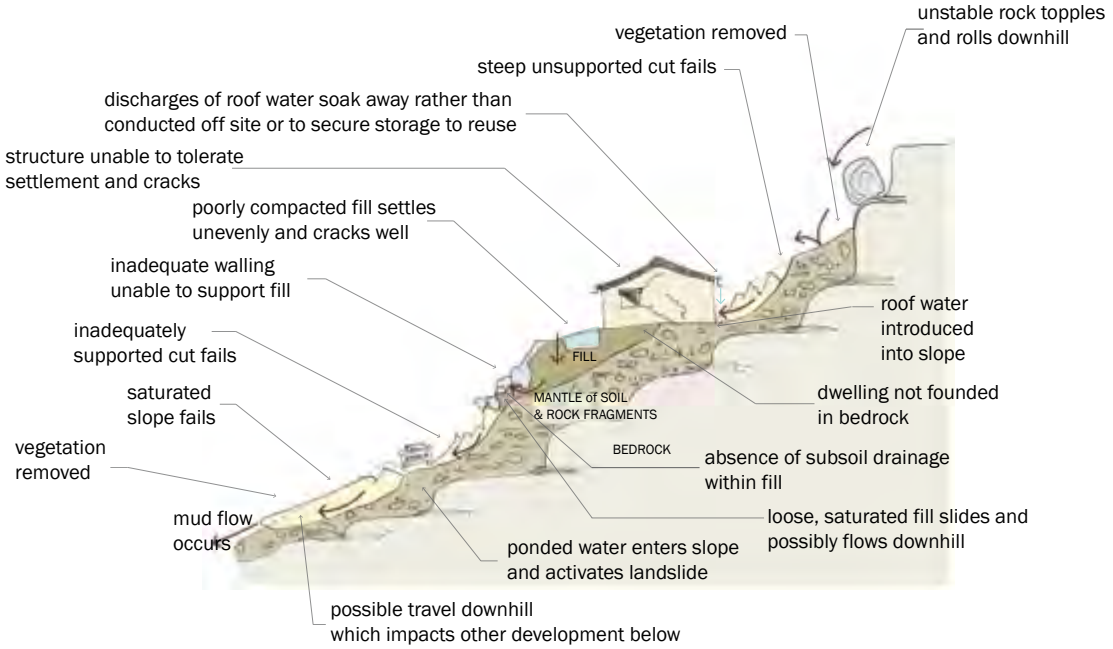

Tags: Safety, Structural Integrity, Flood Mitigation

RECOMMENDATION: Site Planning for climatically resilient coastal developement

Objective: Mitigate climate change impacts of unsafe and unsustainable coastal development

Issue

Agonda is already experiencing the impacts of global climate change. Development and construction decisions should be made with sea level rise and the potential for more unpredictable and intense flooding in mind.

Description

Coastal development (especially in the flood plain) should be avoided at all coasts. If construction in this region is unavoidable, a number of precautions should be taken to protect life, property, and Agonda's natural systems including safe storage of chemicals and materials. Chemicals, essential electrical equipment and potable water supply should be stored further inland or elevated above the high water mark.

Application

If possible, maintain a supply of safe drinking water where it cannot be washed away or polluted during a flood. This can be accomplished by placing a water tank above flood level and keeping it full of water during the flood season.

The **high water mark s**hould be painted or carved as a line on a concrete or stone structure, to record the maximum height of the flood.

Construction methods should be employed in order to mitigate flood damage (See Also: Section 2.0 Materials + Construction, Section 5.0 Flood Mitigation)

New houses and other buildings can be constructed with flood risk in mind. This could include:

- Constructing buildings on raised ground (See 5.1 Plinth)
- Constructing buildings on stilts (with non-essential storage underneath)
- Using flood resistant materials
- Constructing buildings away from areas that are subject to erosion, such as riverbanks and beaches.

Important community buildings should be constructed on raised ground to reduce the risk of flooding, and serve as community meeting spaces

See Also: Flood Mitigation: Mangrove Preservation, Planting Native Vegetation; Potable Water: Rainwater Collection

Info and Image Source "Practice note guidelines for landslide risk management 2007."Journal and News of the Australian Geomechanics Society 42.1 (2007): Web. 5 Mar. 2013.

Tags: Safety, Structural Integrity, Flood Mitigation

2.0

MATERIALS + CONSTRUCTION

Material selection and construction techniques can increase the structural integrity of Agonda's built environment while protecting human health and saftey. Stronger, more resilient buildings will need less repairs after the monsoon season. The design strategies in this section range from proper wall and roof construction to simple paint choices and will simultaneously support a more sustainable and resilient Agonda.

RECOMMENDATION: Consider Length, Height, and Thickness in Wall Construction

Issue: When flooding occurs, poorly constructed walls are susceptible to damages such as severe cracking scouring of the wall base and wall erosion. The damages will weaken the structural integrity of the wall which can lead to the wall collapsing. If the wall is a load bearing (carries the load of the roof) then the building will collapse.

Objective: Build better (stronger) walls considering length, height and thickness.

Description

The main function of the wall is to support the roof and ceiling (load bearing walls) and secondly as a divider also known as the partition wall (non- load bearing). A well-constructed wall must consider the relationship between length, height and thickness. Longer walls (more than 7 meters) are susceptible to collapse and easily damaged. As well as walls that are tall and thin.

Application

- Avoid constructing houses with wall length 3 times the width. If you must then construct a **cross interior wall** to connect the parallel long walls. The cross will help maintain the structural integrity of the building.

- Or add **buttresses** for additional supports

- To prevent cracks, a buttress used at the corners will help strengthen the wall.

- Thicker walls are better suited to withstand impact (bending and diagonal tension) and better as load bearing walls than thinner walls.

Benefits

A well-constructed wall is a stable wall which can withstand wind impact, flooding and constant rain. Secondly, it will not collapse nor lead to additional issues such as loss of a home (generating homeless), displacement of community members and deaths.

Limitations

A wall is only one component to whole system known as a building envelope which consists of the foundation, roof, doors and windows. A well-constructed wall may collapse if it does not correlate to the other components and attached properly by using the appropriate joints and frames.

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Brown, G. Z., and Mark DeKay. *Sun, Wind & Light: Architectural Design Strategies.* New York: John Wiley & Sons, 2001. Part 2: Design Strategies. Print

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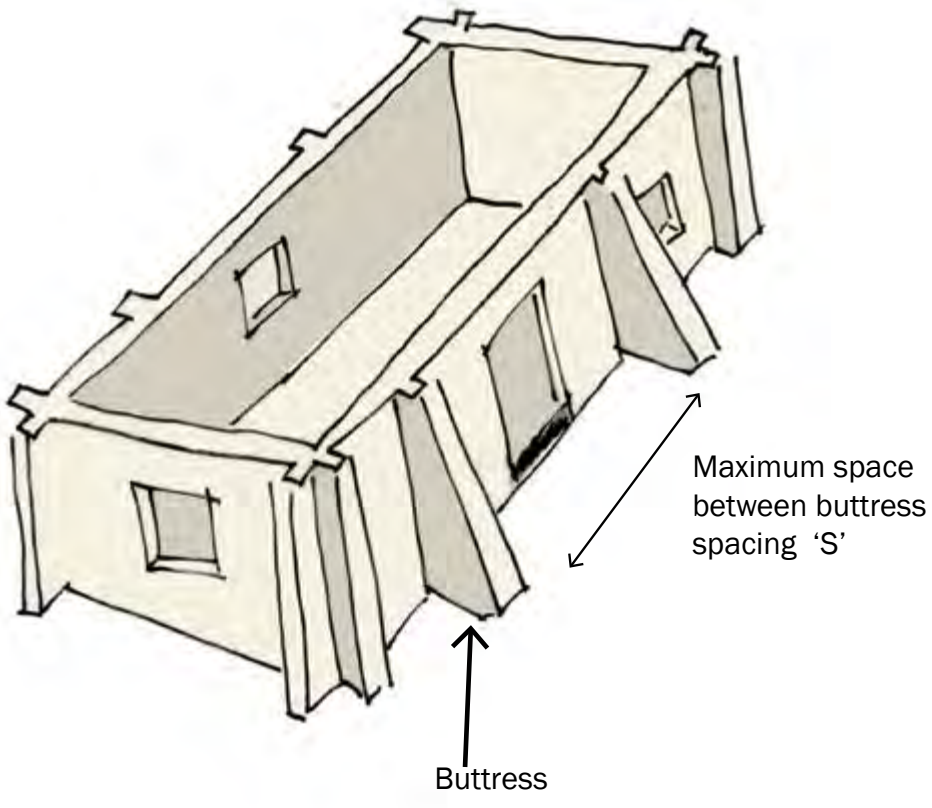
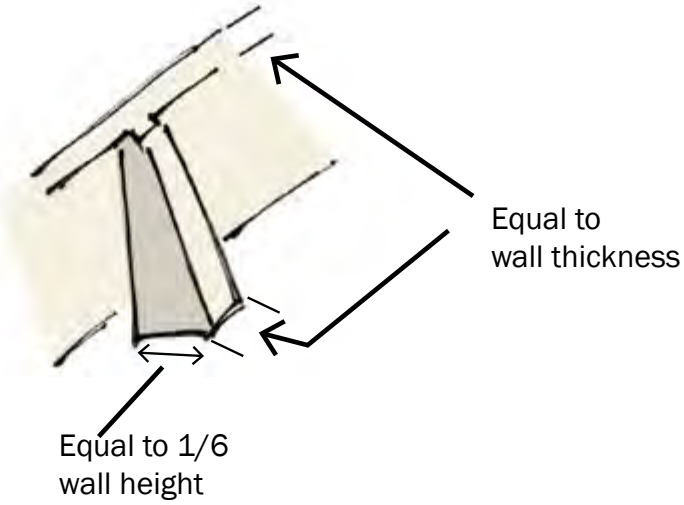
Tags: Construction Methods, Building Materials

WALLS:
LENGTH, HEIGHT, THICKNESS AND WINDOW OPENINGS





RECOMMENDATION: Build Stronger Roofs

Objective: To construct a roof with the capacity to withstand high wind pressure.

Issue

The monsoon season is accompanied by rain and wind. Damages to the roof are caused by uplift when the air pressure below the roofing assembly is greater than the air pressure above the building's roof. As result, the upward force on the roofing system is increased and the roof is lifted from the walls.

Description

The primary function of the roof is to provide a shelter from the environmental elements. Therefore it must span across the desired space and carry its own weight, as well as the weight of placed equipment (such as solar panels).

Application

• A building with a four-sided sloping roof is stronger than one with a two-sided sloping roof. Gable walls in two-sided sloping roof collapse easily.

• Houses should be ideally square or round, for structural stability. The pyramid shaped roof is ideally suited.

• A stable and secured roof will withstand high wind pressure however a steeply pitched roof deflects wind higher which is best.

• For pitched roof the roof slope should be between 22 to 30 degrees.

• Roof overhang must be no more than 500mm. This does not apply to veranda length and overhang.

• Secure roofing to roof frame and wall. Fasten at the connection between roof frame elements: purlins, rafters and beams.

• For sloping roof with span greater than 6 meters use trusses instead of rafters.

• Place rafters and trusses on wall-plate (instead directly on the wall) to reduce concentrated loads, and for anchor. The wall-plate is a timber member of the wall that exists to connect the roof to the wall.

• Existing roofs capable of being damaged during the next monsoon season should consider **retrofitting** and maintainence.

Benefits

A stable roof will not uplift during high wind velocity. Additionally, an attached roof will not leak water into the interior space. Any roof aside from the flat roof will be an asset to discharging rainwater off the edges and assist in keeping moisture away from the interiors.

Limitations

Existing roofs that are not retrofitted are problematic. A well-constructed roof is only a part of the system. The type of materials used plays an equally essential part of the roofing system.

ROOF TYPE AND HEIGHT

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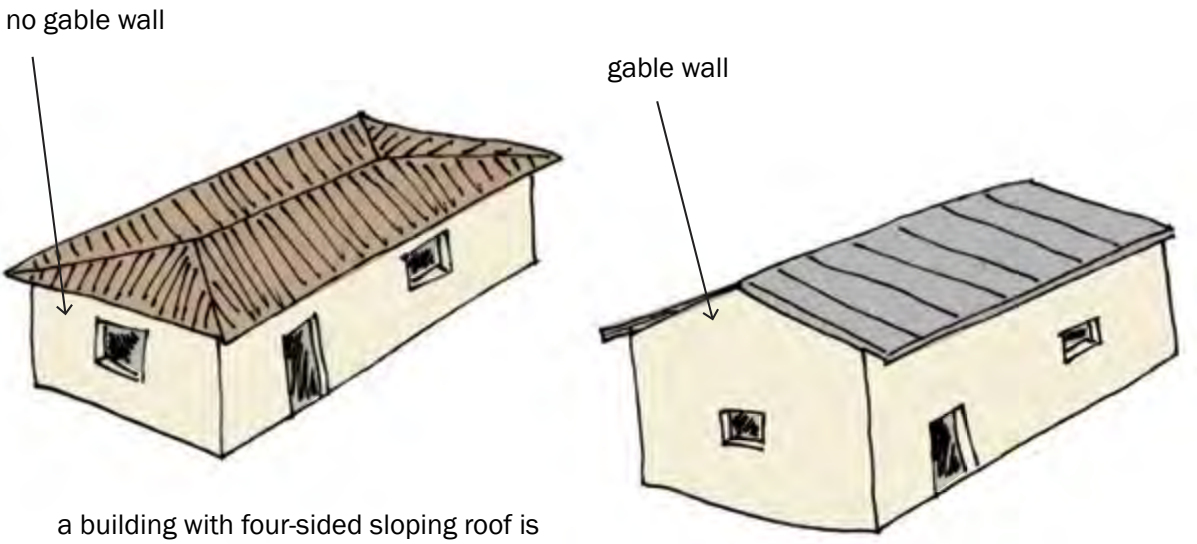

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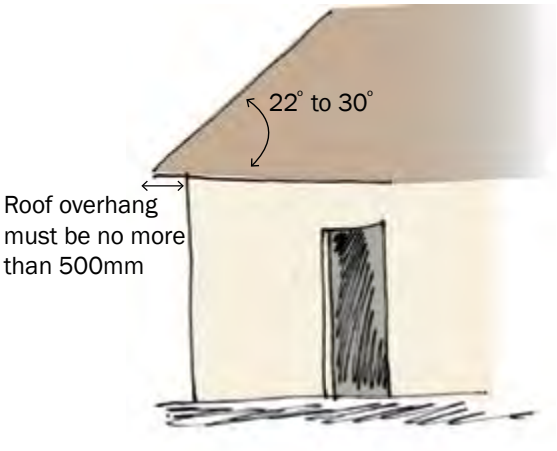

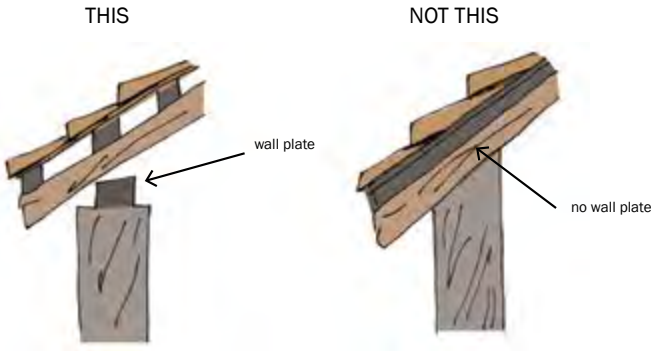

RECOMMENDATION: Consider the Size and Number of Openings in Wall Construction

Issue: When flooding occurs, poorly constructed walls are susceptible to damage, such as severe cracking, scouring of the wall base and wall erosion. The damage will weaken the structural integrity of the wall, which can lead to the wall collapsing. If it is a load-bearing wall (carries the load of the roof) then the building could collapse.

Objective: Consider restricting openings (windows and doors) to smaller sizes, few in numbers and symmetrical.

Issue & Description

A window is basically an opening within a wall or door. Too many and non-strategically placed windows can also weaken the strength of the wall which can attribute to the wall collapsing.

Application

- Houses with asymmetrically arranged wall openings can suffer more damage. For symmetry place identical openings in opposite walls. This also provides opportunities for cross-ventilation

- Consider maintaining same lintel level for all openings and the same size for all the windows.

- For smaller rooms, minimize the number of openings on each wall. eg: one opening per wall.

Benefits

When placed (constructed) properly, a window can increase ventilation, and exposure to daylight.

Limitations

Non- strategically placed openings (window) will weaken the structurally integrity of the wall which may result in the wall collapsing.

Sources

Brown, G. Z., and Mark DeKay. *Sun, Wind & Light: Architectural Design Strategies.* New York: John Wiley & Sons, 2001. Part 2: Design Strategies. Print

Ching, Francis. *Building Structures Illustrated: Patterns, Systems, and Design.* New York: John Wiley & Sons, 2009. Chapter 4: Vertical Dimensions. Print

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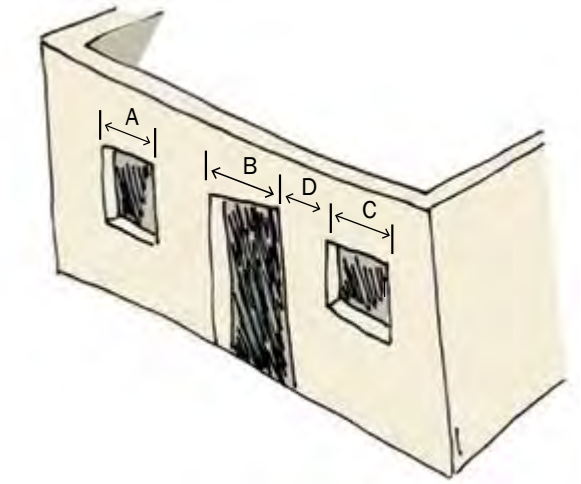
Tags: Construction Methods, Building Materials

SIZE AND AMOUNT OF OPENINGS



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Tags: Construction Methods, Building Materials

RECOMMENDATION: Roof Building Materials

Objective: Using proper roofing materials in order to ensure cooler interiors.

Issue: Current trends in concrete and Portuguese style home construction are leading to a hotter Agonda, both indoors and out. With erratic season lengths and hotter, drier Agondan summers, building material needs to be taken into account to provide cooler conditions.

Description

Knowing what materials should be used can provide many levels of comfort and stability to homes. Materials like stone, clay and concrete tend to slowly absorb heat throughout the day, and reemit it throughout the night, both outwards into the streets, and inwards to interiors, creating **heat island effect** and hotter interiors. The historic use of stone and clay throughout Goa utilizes these materials. Alternative construction use of cement and concrete (See 2.5 Concrete Guidelines) coupled with other roofing materials can provide marked drops in interior temperature.

Mangalore tile or Red Clay, has a Solar Reflectance Index of 41, which is not very good at diverting heat from incoming sunlight. A solar Reflective Index of at least 75 is necessary for reduction of interior heat (See Appendix A).

Application

See Appendix B for a detailed table that expresses how different roofing materials reflect the sunlight, how much heat it stores and emits, and the degree change that this heat means. A material and coating combination with a solar reflectance index of 75 or greater would provide the home with a cooler interior, and the surrounding air will be cooler as well.

Agonda uses Red Clay (mangalore) tile for the most part. This roofing material has been successful in the past, providing airy interiors, but other materials and coatings can provide for greater heat drop offs, see 2.7 Colors.

Benefits

Utilizing many of the more traditional home construction styles of wooden framed houses and mangalore roof tiles, many Agondans can have a cool home. Combined with light colors reflecting sunlight, the heat island effect would be lessened, and the reradiated heat over the course of a day would be diminished hugely.

Limitations

Many of the materials that have very high solar reflectance for roofing tend to be very expensive, or are processed elsewhere, requiring a huge transportation cost to bring it to Agonda. Tin and aluminum roofing, which is also found in Goa can provide for metal roofing, but require a lot of upkeep, and are much harder to patch, repair and maintain when there is smaller levels of damage.

Sources

Brown, G. Z., and Mark DeKay. Sun, Wind & Light: Architectural Design Strategies. New York.: John Wiley & Sons, 2001. Print.
Lauber, W. Tropical architecture. London, England: Prestel Publishing, 2005. Print.

See Also: Flood Mitigation: Mangrove Preservation, Planting Native Vegetation; Potable Water: Rainwater Collection

Tags: Construction, Heat, Walls, Roofs, Color

RECOMMENDATION: Hillside Construction Practice

Objective: When constructing on hillsides, there are many considerations to take into account in order to reduce the risk of damage to the structure and most importantly to people. By following these guidelines, many of the risks associated with hillside construction can be mitigated.

Issue

Hillside areas cover many parts of Agonda, especially Wards 1 and 7, and may be used as new construction areas when the more level areas of Agonda are fully built out. Living on slopes in Agonda can lead to increased flooding damage and potential for landslides.

Description

Landslides are caused by rapid slope instability due to heavy rain, erosion, surface runoff and heavy excavation. These actions can be mitigated through proper site planning and design.
As seen in the figures, knowing how to build with the hillside allows for structural integrity and support such that water flows are controlled and sent away from the structural members of a home. Keeping the existing vegetation, while providing flood mitigation, also locks in the surface soil structures, providing resistance to land flows and slips. Making sure that the structure is anchored in bedrock, as well as having well designed retaining walls and water retention basins can provide for a safer, more stable home on the hillside.

Benefits

One of the biggest benefits is having a soundly designed structure to ensure quality of life for residents. Many of the earthworks that go into ensuring a stable structure also provides with many means of mitigating stormwater and flooding.

Limitations

The best practice for building in Agonda is to avoid hillsides, so that there is less of a risk of landslide. Encouraging development on these slopes can cause of more clearing of vegetation, allowing for faster water infiltration and increased surface runoff, often associated with new pavings.

See Also: Site Planning - Slopes

References:

Brown, G. Z., and Mark DeKay. Sun, Wind & Light: Architectural Design Strategies. New York.: John Wiley & Sons, 2001. Print

Tags: Construction, Heat, Roof

RECOMMENDATION: Repurpose materials and structures

Objective: To reduce cost, cut down on construction waste by reusing materials.

Issue:

In construction projects, existing buildings, closer to the central commercial area, are being overlooked in favor of land further from the center of town. As development projects increase in Agonda, more and more land could be lost to new construction as natural resources become limited and solid waste increases due to construction and demolition.

Description

In any construction project, it is recommended that existing available buildings be considered first to help cut down on cost of building and reduce the use of already limited resources. of existing materials should also be considered when beginning a project.

Benefits

By incorporating **adaptive reuse** into construction methods Agondans will conserve land, reduce environmental impacts, and save costs on new construction. Most existing buildings are already in central locations, by reusing these buildings Agondans will maintain **central density**. In addition, by reusing existing older buildings, Portuguese architectural character will be better preserved. Many of these older buildings rely more heavily on passive cooling techniques, which also save costs on energy consumption.

Limitations

Not all buildings or materials will be viable options for projects. Buildings may be too structurally unsound or unusable. Sometimes the cost to repair damage may be higher than new construction.

Tags: Building materials, Adaptive Reuse , Waste Management

RECOMMENDATION: Building Structures with Concrete Bricks

Objective: The types of materials used for constructing housing can reduce damage to housing and provide passive ways to reduce energy use.

Issue

Concrete and cement have become more and more popular as a building material in Agonda in recent years. However, current concrete mixing techniques can lead to structures that can degrade quickly, and do not have the structural integrity to withstand years of heavy flooding. Similarly, thick, solid concrete bricks can cause increased interior heat, as well as warmer evenings and nights due to heat island effects.

Description

Knowing what materials should be used can provide many levels of comfort and stability to homes. By using lighter color coating and better material for walls and structures, Agondans can live a cooler lifestyle. **Heat island effect** is caused when latent heat that is absorbed during the hottest parts of the day is rereleased and heats the surrounding area. Some materials, such as concrete and stone can hold onto a lot of heat, and release it throughout the night, creating even warmer nights in dense areas. The proper use of color and materials can reduce the heating effects of the concrete used in so many structures in Agonda.

Application

Mixing sand and cement is often the technique to make concrete in Agonda. As suggested by the International Building Code, concrete mixes should be about 1 part cement to 4 parts sand. Using sand that is low in salt content can provide for stable concrete materials. Concrete with high salt content ends up disintegrating easily, and is susceptible to massive damage during rainy seasons, causing need for repair and replacement. Using other aggregates, such as crushed laterite gravel and pebbles, can provide concrete that can be structurally stronger, and withstand more damage from water. This kind of concrete would be ideal for making plinths and hollow blocks.

A specialized technique of making cement cavity blocks, or hollow cinder blocks, and using them as wall material can provide better thermal insulation, and inevitably a cooler interior. These hollow blocks can be made the same way as solid blocks, just utilizing a different mold in order to create the extra spacing. These spaces provide air pockets within the structure's walls that create greater insulation than solid concrete or laterite bricks.

Benefits

The proper utilization of concrete, such as hollow core concrete bricks, and properly mixed concrete can provide further cooling of households, and provide structural longevity for houses built with locally made concrete. Using hollow cement blocks as wall members can provide added thermal insulation to houses made of concrete, by trapping air within the wall, causing the stone to heat up much slower.

Limitations

Concrete blocks made in low cement to sand ratios, (less than 1 in 4) can lead to premature decay, or disintegration of the blocks. This is a common practice in Agonda, using beach sand, which has a great salt content in it, in order to mix for concrete. This type of concrete is not very good structurally, as they do not support buildings of greater than two structures. Using other types of aggregate that is mixed into the cement can provide stronger structural materials.

Concrete blocks that are at least 10 cm thick end up trapping more heat and contributing heavily to heat island effect. Solid body concrete blocks are easiest to make, and can create thick walls that trap and transmit heat to the interiors of buildings.

Sources

Brown, G. Z., and Mark DeKay. *Sun, Wind & Light: Architectural Design Strategies*. New York.: John Wiley & Sons, 2001. Print.

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Lauber, W. *Tropical architecture*. London, England: Prestel Publishing, 2005. Print.

Tags: Construction, Heat, Concrete, Walls

RECOMMENDATION: Reduce heat through exterior pain selection

Objective: To provide cooler conditions in structures, using paint.

Issue: Extreme heat and extended sunlight hours can create hotter interiors within Agondan buildings.

Description

By utilizing lighter color options, Agondans can deflect a lot of heat, reducing the heat island effect. Heat island effect is caused when latent heat that is absorbed during the hottest parts of the day is rereleased and heats the surrounding area.

Using lighter color coats of paint also increase the albedo of a structure. **Albedo** is how well a material or color reflects light and heat. Colors like white and light yellow have great albedo, as they reflect sunlight more than they absorb, so the heat does not get into the building materials and is not re-radiated out throughout the day. Dark colors, like blues and blacks have very low albedo, and absorbs heat steadily.

These materials, when the air becomes cooler reradiates the heat and causes heat to emanate throughout the night.

Application

The type of coatings mentioned below can give an idea of the spectrum of heating induced by darker colors (Gray, Dark Blue). When using color, Agondans should keep in mind that the lighter and brighter colors have higher solar reflectance, and lower temperature rise. These colors are often found through tropical communities, and already exist in Agonda.

Limitations

Many of the most efficient heat reflecting paints and colors are expensive to produce (polymer based paints may need to be imported). The other main thing is ensuring that the color is pretty uniform throughout the shell of the structure, and that areas that wear away are painted over in ensure the most effective use of color reflectivity.

Benefits

Usage of light and bright colors, like yellows, pinks and oranges can provide huge reflectance of the sun and its heat. Many of the materials used in Agondan construction can be coated with light colored paints, or light colored tiles can be pressed at time of manufacture. These lighter colored homes can have extensive cooling effects for more comfortable houses and homes.

Sources

Brown, G. Z., and Mark DeKay. *Sun, Wind & Light: Architectural Design Strategies.* New York.: John Wiley & Sons, 2001. Print.

Lauber, W. *Tropical architecture*. London, England: Prestel Publishing, 2005. Print.

Tags: Construction, Heat, Walls, Roofs, Color

3.0 WATER

Countries around the world are faced with the growing problem of providing safe, drinkable water to its people. With climate change, more frequent natural disasters, and dwindling resources it is more important than ever that Agonda adopts a more sustainable water management system. Agondans need to take advantage of strategies that provide a more reliable source of potable water. Having a supply of dependable water will be invaluable during tourist and monsoon seasons, when water supplies are scarce.

RECOMMENDATION: Rainwater Harvesting

Objective : To collect and store rainwater as an additional supply of **potable water.**

Issue

In Agonda, water scarcity is a major concern, especially during the tourist season (from November to early March). The scarcity of water is also worsened during the rainiest months of the monsoon season. Rainwater harvesting offers a sustainable and low cost alternative to reliance on the scarce and unreliable city water supply that will only become more unreliable as precipitation levels vary.

Description

Rain water harvesting is a system of collection and storage of rain water that runs off from roof tops, parks, roads, open grounds, etc. This water run off can be either stored or recharged into the below ground aquifers and used for agriculture etc. A rainwater harvesting systems consists of the following components.

1. catchment from where water is captured and stored or recharged,
2. conveyance system that carries the water harvested from the catchment to the storage/recharge zone,
3. first flush that is used to flush out the first spell of rain,
4. filter used to remove pollutants,
5. storage tanks and/or various recharge structure

Application

In order to determine the amount of rain that you will be able to collect, information about the area of the catchments and rainfall patterns will have to be collected.

The amount of rainfall that will be collected will depend directly on the area of the catchment-the larger the area, the more the water.

- The annual average rainfall: Provides an overall view of how much rainfall can be collected

- The pattern of rainfall over different months: Will tell you when the rainfall is available – is it available most of the year or only during a certain part of the year.

- Number of rainy days: Will give an indication to decide whether to store the rainwater or to recharge it. If most of the rainfall comes only in a short span of time, then it is better to recharge the aquifer.

- The peak rainfall intensity: Will give an indication to design the size of the storage or recharge structure. The sizing will be based on how much water will need to be stored or recharged during the most intense spell of rain.

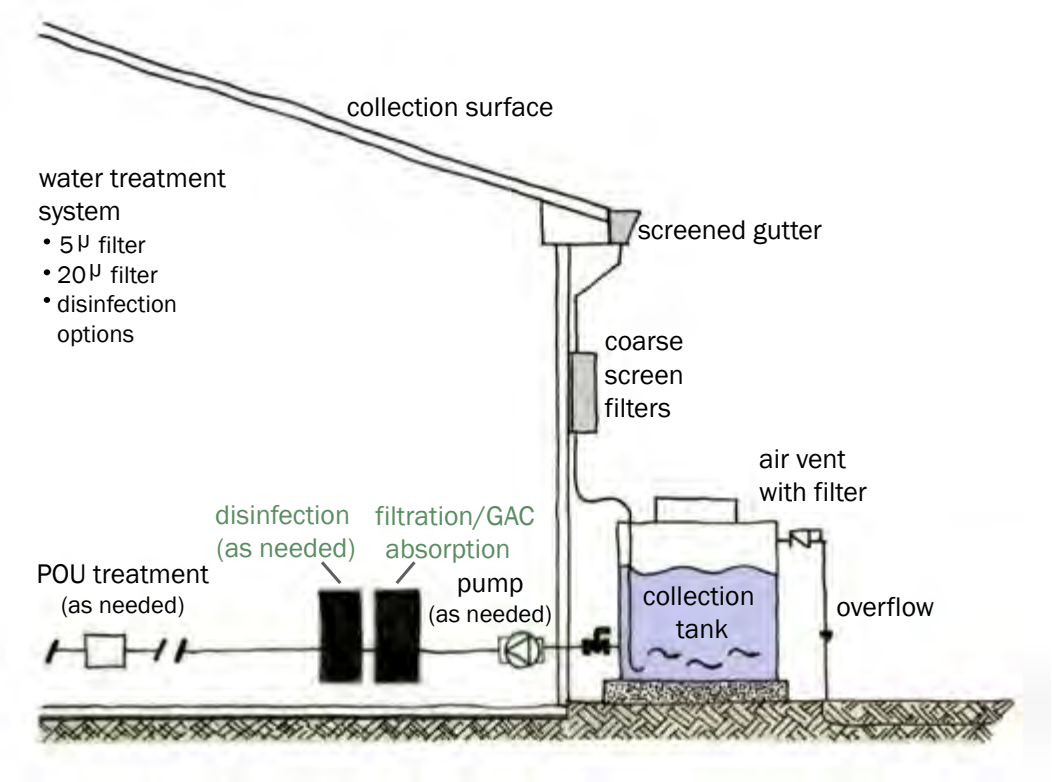
The following equation can be used to calculate water harvesting potential:

Water harvesting potential (Total volume of water) = Area x runoff coefficient x rainfall

Filtration and treatment: Filtration types vary depending on the use of the rainwater. For example, minimal filtration (sand, gravel) can be used for harvested rainwater that will be used for toilets and irrigation. Higher levels of filtration are needed in cases where harvested rainwater will be used for drinking.

Several factors affect how much rainfall can be collected from a particular catchment. Different catchments have different levels of efficiency depending on its material. In addition, the area of the catchment and the annual rainfall also influence the amount of rainfall that will be collected.

RAIN WATER HARVESTING



Benefits

Rainwater Harvesting is an extremely sustainable and cost effective strategy of meeting the demand for water. In addition, it improves the quality and quantity of groundwater and can have the added benefit of reducing flooding (See also: Section 5.0: Flood Mitigation).

Limitations

Rainwater harvesting is preferred, more sustainable, and less expensive when used to collect non potable water.

Sources:

Centre for Science and the environment, “Rainwater Harvesting”, <http://www.cseindia.org/node/1162>

See Also: 5.0 Flood Mitiation

Tags: Potable Water, Rainwater Harvesting, Green Infrastructure, Flood Mitigation

RECOMMENDATION: Well Boring Practices

Objective : To utilize properly designed water wells to ensure household potable water security.

Issue

Potable water supply is often at issue in Agonda. Between water shortages during the tourist season, to an outright lack of water during the rainy season, Agondans are on their own for drinking water supply. Climate change can only exacerbate these supply issues, along with saltwater intrusion into the aquifers of Agonda from the Arabian Sea.

Description

Well water is a highly localized source of potable water, which can provide for one or a few households, depending on depletion rates of the wells, and what extent the area has been contaminated by salt water. Having a properly bored well can provide water security for many years, until municipal supplies catch up.

Appplication

Well Siting – A new well should be dug under the following conditions:

Distance Away from ...	Source of Pollution
3m (10ft)	Areas of stagnant water
20m (50ft)	Pump pits
	Septic Tanks
30m (100ft)	Septic Tank Drainfields

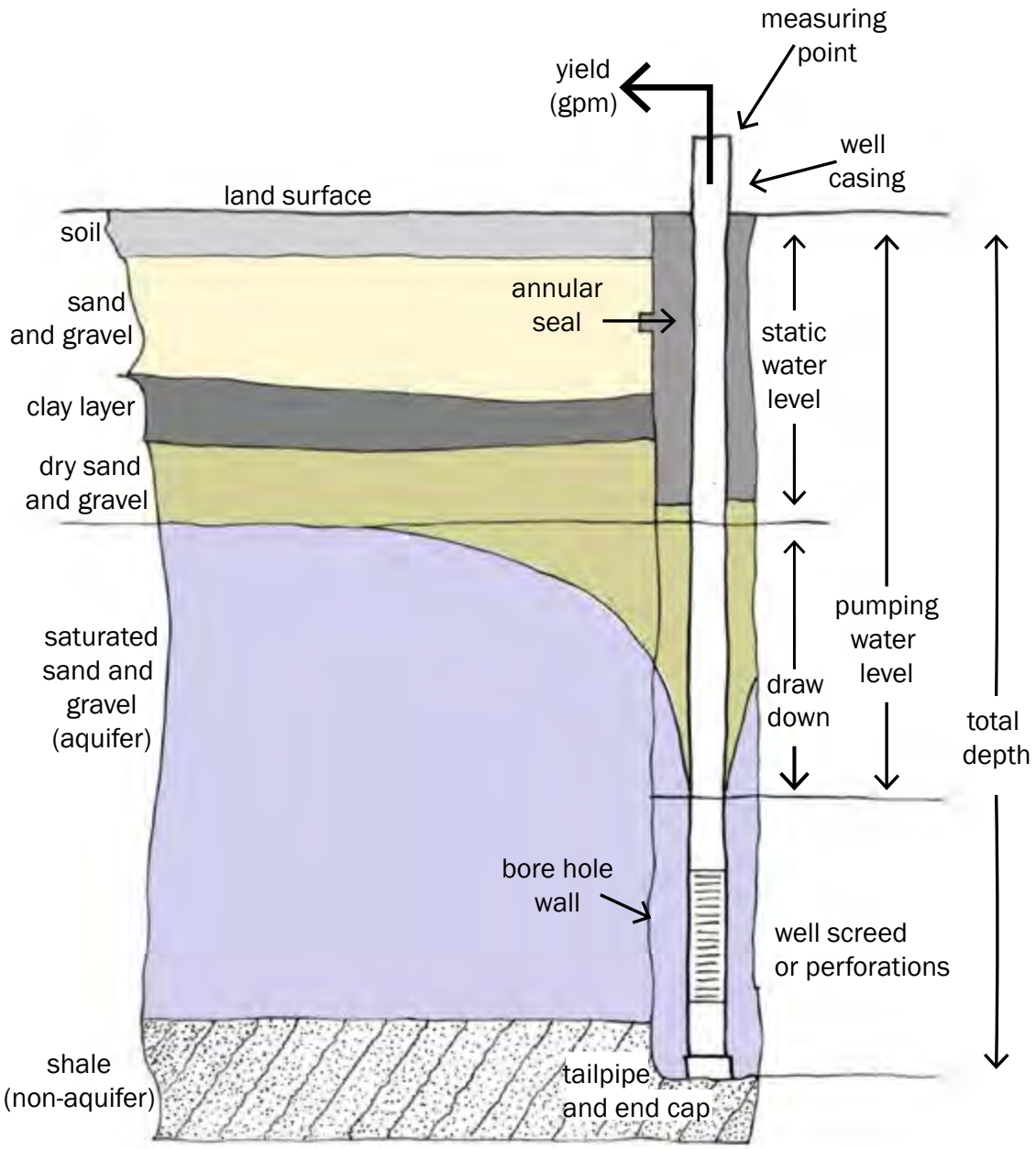
Limitations

Wells should be used in concert with other dis¬tributed water collection systems, as the limiting factors of having to deal with saltwater intrusion can severely damper the effectiveness of these wells. The water should only be used as drinking water, or for cooking. It is important to have a well monitoring program in place, as aquifer recharge can be heavily impacted with seasonal rains and water usage. Because of these needs, rainwater harvesting should be tried and practiced first, before boring more wells. The well water usage should be done to complement rainwater and municipal use. Usage programs can be based on the table shown in 3.1 Rainwater Harvesting.

Benefits

Wells are very local, and each household has complete autonomy over the water supply. Each home can care for these wells, and ensure water quality for the family unit. Providing this autonomy can allow for homes to store water for rainy seasons, and would be on a separate system from the municipal supply that ends up being depleted during tourist season. A proper well can also be sealed against untreated water entering from above during rainy seasons.

WELL CROSS SECTION



See Also: 3.1 Rainwater Harvesting

Tags: flooding, greywater system, solid waste, composting for agriculture

RECOMMENDATION: Grey Water Recycling System

Objective

To conserve the supply of clean drinking water by recycling used water or greywater for other uses.

Issue

Water shortages during monsoon season, peak tourist season, and overall in government supply.

Description

Greywater gets its name from its cloudy appearance and from its status as being between fresh, potable water (known as “white water”) and sewage water (“black water”). In a household context, greywater is the leftover water from baths, showers, hand basins and washing machines only. Some definitions of greywater include water from the kitchen sink. Any water containing human fecal waste is considered black water.

Application

Recycled water is most commonly used for nonpotable (not for drinking) purposes, such as irrigation of plants, toilet flushing, dust control, construction activities, and concrete mixing. Use of greywater instead of potable water is recommended for these activities mentioned. This saves clean water for more urgent needs like drinking and cooking.

Toilet & Sink System:
Clean water is commonly used to flush toilets, which is unnecessary. Save this water to use when you require clean water.

1. Turn off the water being supplied to your toilet tank.

2. Collect the used water from your shower or sink to fill up your toilet tank. Or connect a pipe from your sink pipe to feed into your toilet tank.

3. You can now flush the toilet using grey water instead of clean water.

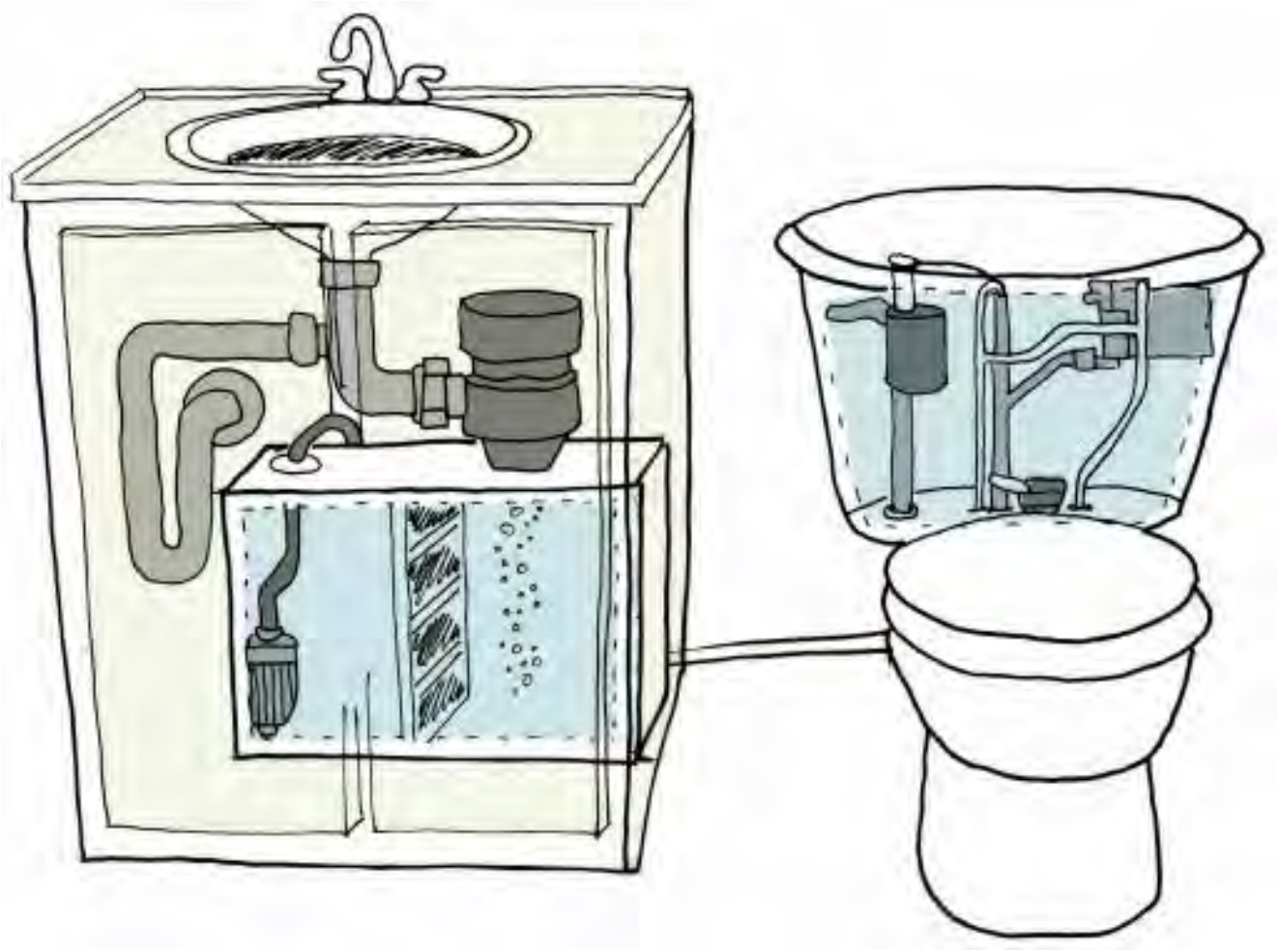
Limitations

Because gray water has not been disinfected, it could be contaminated. A careful, commonsense approach to the use of gray water, however, can virtually eliminate any potential hazard. The following precautions are recommended:

1. Never use gray water for direct consumption.
2. Gray water should not be used directly on anything that may be eaten.
3. Gray water should not be sprayed, allowed to puddle, or run off property.
4. Use only water from clothes washing, bathing or the bathroom sink. Do not use water that has come in contact with soiled diapers, meat or poultry, or anyone with an infectious disease.

Benefits

Recycling waste water can stretch your water budget during the hot summer months by providing an additional source of water. Other benefits include decreasing wastewater discharges and reducing and preventing pollution. Recycled water can also be used to create or enhance wetlands and riparian habitats.



Sources

Jett, John W. “Recycling Grey Water.” West Virginia University Extension Service. September 2008. http://www.wvu.edu/~agexten/hortcult/homegard/graywate.htm

“Water Recycling and Reuse: The Environmental Benefits.” Water Division Region IX - EPA 909-F-98-001. United States Environmental Protection Agency. http://www.epa.gov/region9/water/recycling/#whatis

Tags: Green Infrastructure, construction, ecological conservation

RECOMMENDATION: Composting Toilet System

Objective: To create more sustainable and manageable on-site waste treatment.

Issue

With unsuitable water supply, no local waste treatment facility and a high number of temporary structures, Agonda relies on septic systems to capture waste. These septic systems, particularly tanks associated with commercial buildings, are often overburdened by waste loads from increased tourism and run the risk of overflowing when low-lying areas flood. Additionally, because of the preventative upkeep required to maintain the septic tanks' efficiency, much of Agonda's sewage is dumped directly into the local streams. This has led to increased flooding due clogged waterways.

Description

A composting toilet is a dry toilet that uses little or no water to manage waste. The waste is typically mixed with sawdust, coconut coir or moss to reduce odor, increase airflow and absorb liquids so that the waste can break down further and decompose. This process, known as aerobic processing, is generally faster than the decomposition that takes place in wet sewage treatment such as septic tanks.

Application

1. Waste is collected in a sealed chamber beneath the toilet seat.

2. Extra organic matter such as sawdust, coconut coir, moss or vegetable scraps is added to create composting environment.

3. Organic waste breaks down material with about three quarters of it being converted to carbon dioxide and water vapor.

4. Air* is drawn though veneration pipe and removes gasses and assists in creating ideal living environments for micro-organisms in organic material.

***Helpful to have window in bathroom for more cross ventilation.**

5. Left-over solid material slowly moves down sloping floor as more waste is added to pile.
6. Solid material can then be removed out of chamber door and used as fertilizer for garden.
7. Excess liquid either flows into the greywater stream, which includes all other wastewater generated in the bathroom, kitchen and laundry, or is directed to a separate land application area.

Benefits

Low cost, low maintenance requires little to no water use resulting in water use reduction; less environmental impact.

Limitations

Requires proper airflow to keep odors from seeping into the home; if not properly managed, build-up of bacteria could raise a health issue and threaten the water table below.

COMPOSTING TOILET

Tags: flooding, greywater system, solid waste, composting for agriculture

4.0 ENERGY

Countries around the world are faced with the growing problem Energy use in Agonda has drastically increased as tourism has grown. In some cases the competition for energy has led to illegal theft. This underground consumption further strains an already overworked system, leading to more frequent power shortages. Villagers are faced with no power as tourists enjoy air-conditioned rooms on the beach.

Image: Guardian, UK

Agonda's weak energy system also leaves it susceptible to environmental hazards like soil erosion, falling trees, and flooding which cuts off the village from the electricity supply for indefinite periods of time. The following chapter provides recommendations on more sustainable energy use practices that can be incorporated into current and future building design in Agonda. By installing solar panels or wind turbines to power the village, relying on passive ventilation to cool homes or utilizing existing resources like cow manure to produce biogas, Agonda will be able to meets its energy needs now while not compromising the village's needs in the future.

RECOMMENDATION: Biogas

Objective: To provide a clean allternative to fuel

Description

Biogas is a gas produced by anaerobic digestion (in the absence of oxygen) of organic material, largely comprised of methane (about two-thirds). Basically, it breaks down wet organic matter like animal dung (cow manure), human sewage or food waste into a reusable gas. As a gas, it can be used as fuel for cooking and generating electricity.

Application

- The components of a biogas system are a container to hold the decomposing organic matter and water (slurry), another to collect the biogas, feed in the organic matter (the feedstock), to take the gas to where it will be used, and to remove the residue.

- For a fixed biogas dome (the most common type), the slurry container and gas container are combined, so that the gas collects under a rigid dome over the slurry.

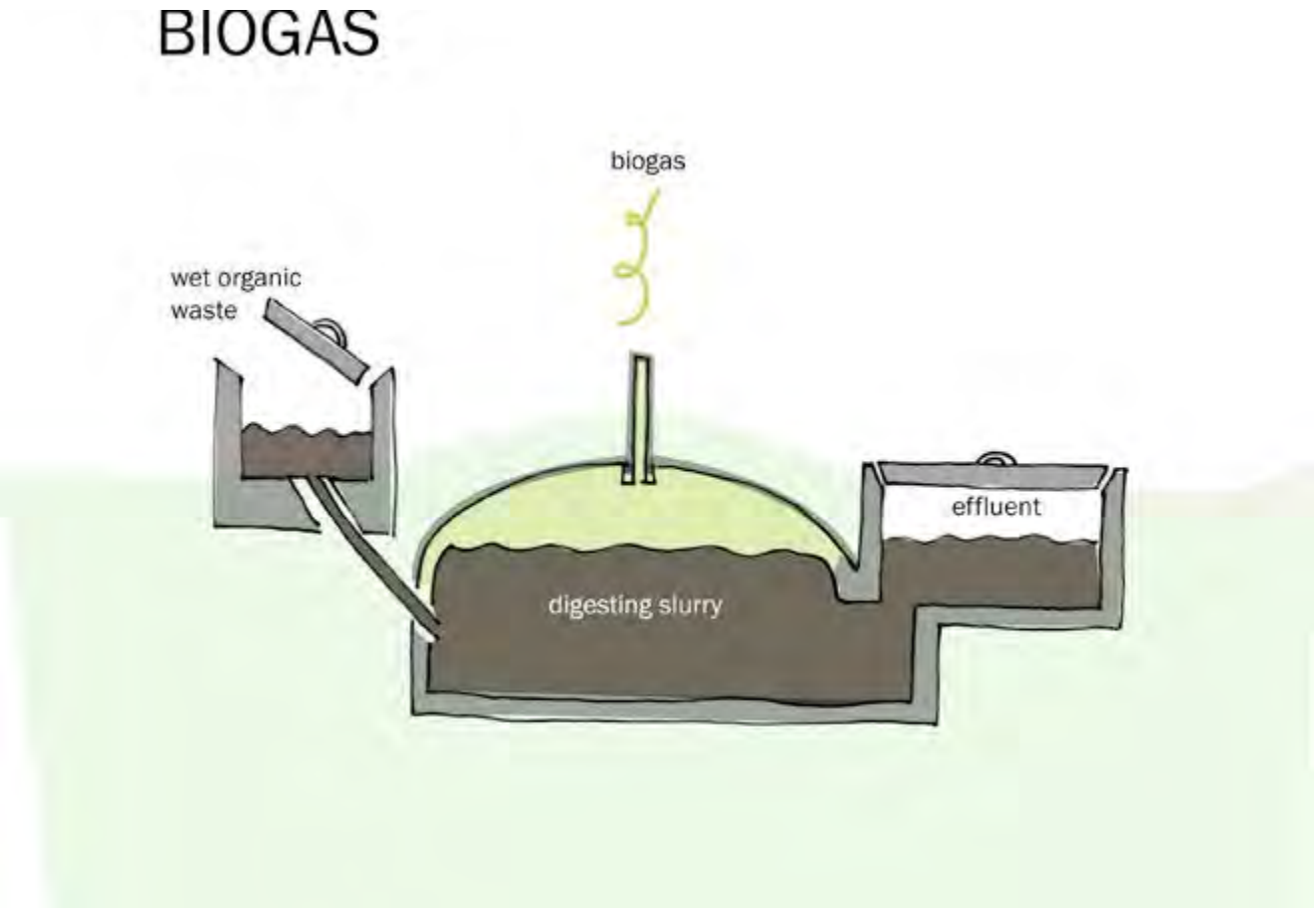
- As the slurry breaks down, the biogas which is produced pushes some of the slurry into a separate reservoir. When the biogas is taken off, the slurry flows back.

Limitations

Potentially high initial costs and investment

Benefits

Converting cow manure into methane biogas can produce gas for cooking and electricity. Food waste is another option to use as a feedstock. It breaks down quicker than the dung and appropriate as a small system for homes. Secondly, it can generate enough to fuel between 25 % and 50 % to use as cooking fuel. The gas burns as a clean flame therefore it reduces indoor air pollution. Every year, an estimated 1.6 million deaths are caused from breathing in wood smoke. The decomposing waste can be sent to a composition system to divert it from the waste stream.



Sources

"Biogas." Ashden: Sustainable solutions, better lives, n.d, n.p. Web. 08 April 2013. < http://www.ashden.org/biogas>.

U.S. Department of Energy Federal Energy Management Program (FEMP). "Biogas." Whole Building Design Guide: A program of the National Institute of Building Sciences, 04 August 2011. Web. 08 April 2013. < http://www.wbdg.org/resources/biogas.php>.

Tags: Flood mitigation, Construction methods, Green Infrastructure, Public health

RECOMMENDATION: Passive Cooling

Objective: To apply natural ventilation strategies to help reduce energy consumption and improve indoor air quality. It is dependent on the sun's energy and simple elements such as a window or an opening and materials to create a comfort zone temperature.

Issue: As energy use in Agonda is increasing, production and availability has not met the demand. In addition not every Agondan can afford the increased price for electricity therefore simple measures should be implemented to help allow for energy independence, and alleviate reliance on carbon based fuels.

Description

Wind driven ventilation depends on wind behavior and it interacts with the openings within the building or home. The location of the fenestration can vary and will produce different results. The cooling effect is produce by certain strategies such as single-sided, cross and passive stack.

Application

• Single sided ventilation is predominantly wind driven ventilation turbulence and can adequately ventilate smaller rooms with average occupancies. Achieves penetration depths of up to 2.5 times the room height.

• Cross ventilation uses the wind pressure to drive air through openings in the building. Air enters on one side of the building, and exits another side. Achieves penetration depths of up to 5 times the room height.

• Cross-ventilation is most effective when the inlets are placed in the higher pressure and the outlets in the lower pressure.

• Passive Stack ventilation is driven by the Wind Effect and can be aided by a "stacking "effect, a difference in heights between two openings. Will achieve up to double the penetration of cross ventilation

• The more the opening area is distributed, the more likely it is that there will be a pressure difference between openings to drive the flow – i.e. many small openings are better than one large opening.

• Consider the use of clerestories. A **clerestory** will provide an opening for stale air to escape in a buoyancy ventilation strategy.

• Naturally ventilated buildings should be narrow if possible. The maximum width that one could expect to ventilate naturally is estimated at 13 meters.

Benefits

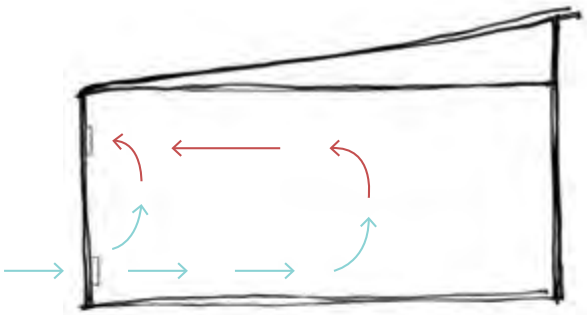
It is low maintenance, cost effective consumes zero energy and provides a cleaner indoor air quality. It is also healthier, connects with the natural environment and has a psychological benefit on the individual.

Limitations

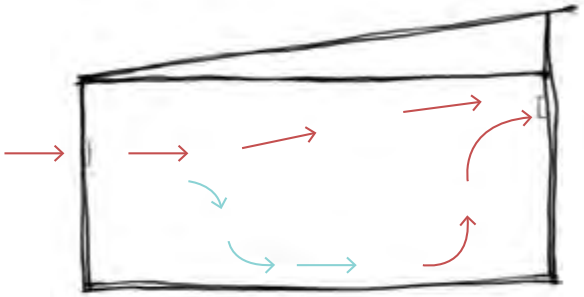
For existing buildings with openings, air will flow through however it will not be as effective. To implement such strategies into an existing building would require the retrofitting the wall. It is entirely based on the velocity of the wind which is unpredictable and varies. If the building is situated adjacent to polluted areas then the quality of the air is problematic.

PASSIVE COOLING

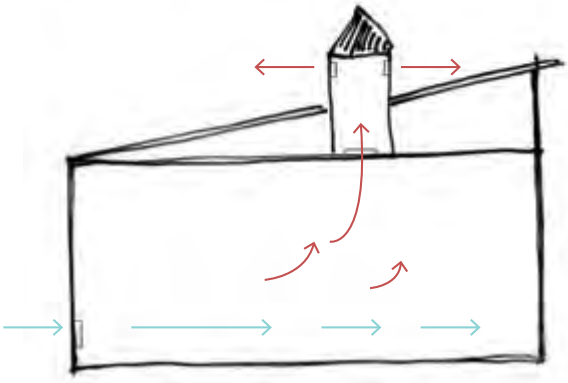
single-sided ventilation



cross ventilation



stacked ventilation



Brown, G. Z., and Mark DeKay. Sun, Wind & Light: Architectural Design Strategies. New York: John Wiley & Sons, 2001. Part 2: Design Strategies. Print

"Strategies – Wind Driven Ventilation." Natural-Vent. Web. 08 April 2013. <http://www.natural-vent.co.uk/stratagies.asp >. Note – also image source

Walker, Andy. "Natural Ventilation." Whole Building Design Guide: A program of the National Institute of Building Sciences, 07 September 2012. Web. 15 June 2010. <http://www.wbdg.org/resources/retro_sustperf.php>.

Reccommendation: Solar Panels

Objective: To provide a reliable source of power

Issue

Electricity in Agonda is scarce on the everyday basis and worsens during the monsoon season. The capacity of the transformers has not increased to accommodate increased usage. Agondans are always left in the "dark" since commercial activities consume a significant amount of electricity; the cost per household has increased and unreliable.

Description

Solar power is an energy source based on the solar cell technology, which converts energy obtained from the Sun into electricity.

Application

- Solar panels are roof or ground mounted and composed of solar cells which generate electric power.
- Each typically ranges from 100 to 320 watts.
- For best results, the solar panels should have direct access to the sun.
- In addition to providing electricity for the home, solar panels can be used for street lighting. Solar powered lights can reduce power consumption by 40- 70% than traditional light sources.
- Lastly provides bright white light which improves color recognition and night visibility from 400 – 1000 % over traditional light sources.

Benefits

For the individual, solar panels provide power without the cost of a grid infrastructure. During power outrage or shortage, solar panels will still generate electricity. The solar energy can be used to power other equipment such as small home appliances, water pumps and heat hot water. Solar street lights benefits the individual and the community. It provides to isolated areas which is certainly a need after natural disasters. The installation process is minimal, convenient and applicable to most street conditions in Agonda. Overall the benefits are limitless.

Limitations

Potentially high initial costs and lower output in cloudy weather

Sources

Brown, G. Z., and Mark DeKay. Sun, Wind & Light: Architectural Design Strategies. New York: John Wiley & Sons, 2001. Part 2: Design Strategies. Print

U.S. Department of Energy Federal Energy Management Program (FEMP). "Photovoltaics." Whole Building Design Guide: A program of the National Institute of Building Sciences, 24 August 2012. Web. 08 April 2013. <http://www.wbdg.org/resources/retro_sustperf.php>.

"Solar panels." 3R Care (India) Private Limited, LIGHT UP LIFE, n.d. Web. 08 April 2013

Image: Think Solar Power, Solar Power in India

Tags: Renewable Energy, Passive Cooling, Green Infrastructure, Public Safety,

Reccommendation: Solar Water Panels

Objective: To provide access to water to use for irrigation or portable drinking water.

Description

Solar water pumps can supply water to locations which are beyond the reach of power lines. The water supplied by the solar water pump can be used to irrigate crops, water livestock or provide potable drinking water. A solar water pump system is essentially an electrical pump system in which the electricity is provided by one or several PhotoVoltaic (PV) panels.

Application

- A typical solar powered pumping system consists of a solar panel array that powers an electric motor, which in turn powers a bore or surface pump.
- The water is often pumped from the ground or stream into a storage tank that provides a gravity feed, so energy storage is not needed for these systems.
- The pump can potential delivers about 140,000 liters of water/day from a total of 10 meters.
- The size of the storage tank can accommodate 3-5 days of water demand.

Benefits

- Low maintenance
- No fuel costs or spills
- Easy to install
- Simple and reliable
- Unattended operation
- System can be made to be mobile

Limitations

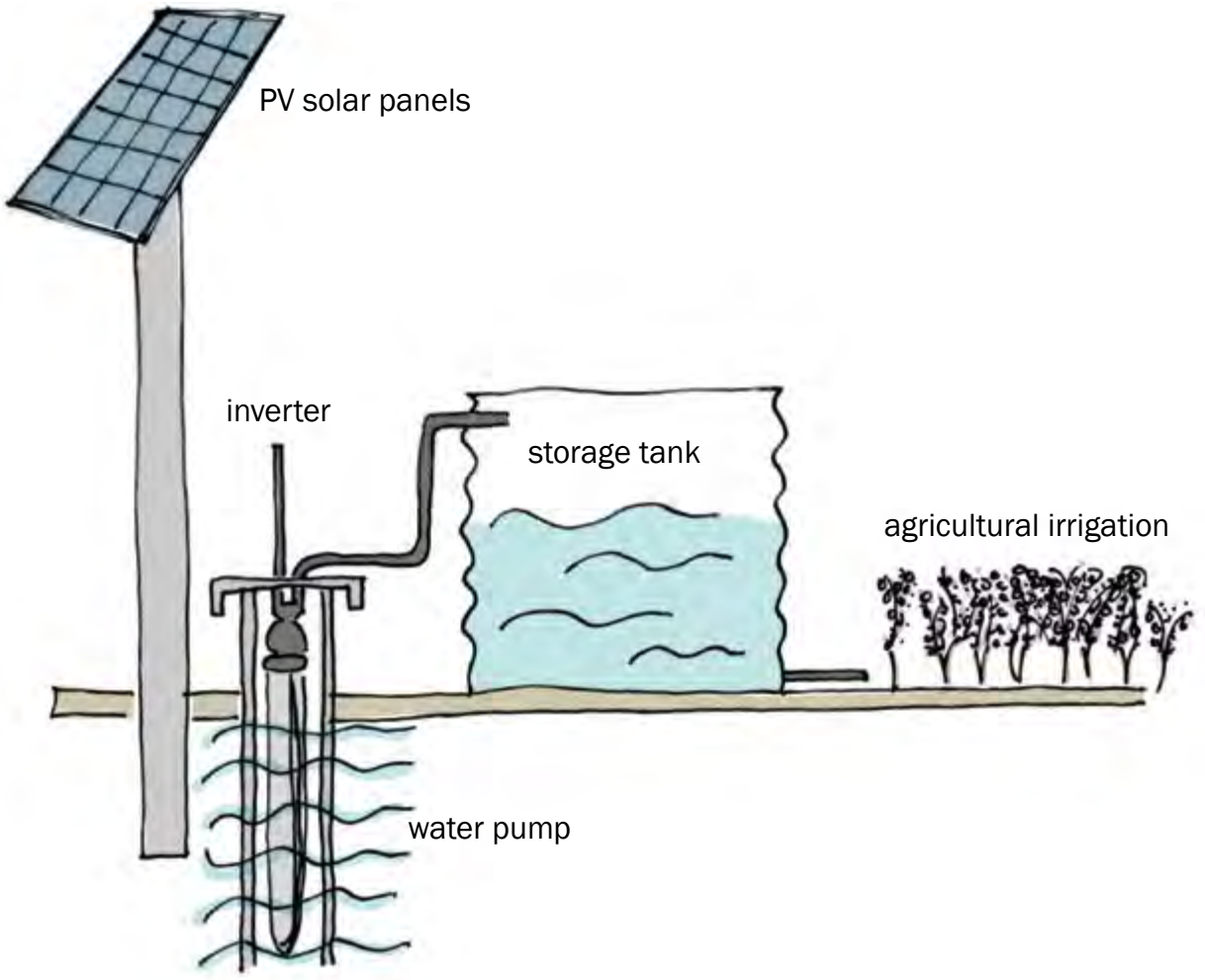
- Potentially high initial costs
- Lower output in cloudy weather
- Must have good sun exposure between 9 AM and 3 PM
- **Repairs often require a skilled technician.**

Sources:

"Solar Water Pumping System." Conergy, n.d, n.p. Web. 08 April 2013. <http://www.suntechnics.in/desktopdefault.aspx/tabid-139/331_read-273/>.

"Solar Photovoltaic Waterpumping." Pratical Action, n.d,n.p. Web. 08 April 2013. <http://practicalaction.org/solar-photovoltaic-waterpumping-1>.

SOLAR WATER PANELS



Tags: Renewable Energy, Solar Energy, Green Infrastructure, Potable Water

Reccommendation: Wind Turbines

Objective : To provide energy on the community level

Description

A **wind turbine** converts kinetic energy from the wind to produce electricity. A wind turbine works the opposite of a fan. Instead of using electricity to make wind, like a fan, wind turbines use wind to make electricity.

Application

The wind turns the blades, which spin a shaft, which connects to a generator and makes electricity. The amount of watts produced depends on the type and size of the wind turbine. Small wind turbines are capable of up to 100 kilowatts and suitable for the home. Larger turbines are capable of producing much more however requires additional elements such as space.

Limitations

The initial cost is significantly high. It's probably best as a community investment. Larger turbines and longer transmission lines are requires a remote location to operate. Agonda may not the physical space required to place a wind turbine although it varies in size.

Benefits

A clean fuel source equals a clean air. Unlike power plants that rely on combustion of fossil fuels, wind turbines do not therefore improves air quality and one of the cheapest forms of renewable energy. Depending on the average wind speed and amount of kilowatt used within the home, the wind turbine can typically lower the cost of electricity by 50 to 90% for six/ten months of the years.

Sources

"Wind Turbines." 3R Care (India) Private Limited, Light up Life, n.d, n.p. Web. 08 April 2013 < http://www.lightuplife.net/wind-turbines.html>.

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Image: NewsPost India

Tags: Renewable Energy, Green Infrastructure, Clean Source of Energy

5.0 FLOOD MITIGATION

Flood Mitigation is an important prevention and management tool that will greatly alleviate the impacts of flooding especially during times of crisis. Implementing design techniques early on will help residents, commercial owners, and the entire village of Agonda become more prepared and safe. Flooding is an annual occurrence that affects many aspects of daily life. Flooding contaminates your water supply, causes damage to your homes, cuts your supply of power, and aggravates pollution. And, although Agonda has adapted to flooding, with sea-levels rising and more intense storms we can anticipate that flooding will worsen therefore protective measures must be a top priority.

Image: Herald, Goa (2010)

RECOMMENDATION: Plant Native Vegetation

Objective: Ecological conservation is a very important aspect when developing your site. Maintaining the ecological health of your site will help preserve the types of plants that grow, the animals that live and in general benefit the appearance of your site and village. Existing ecologies also help in protection from storms and flooding.

Issue

A decrease in biodiversity due to climate change, new developments, disregard for the environment, and pollution can create a more vulnerable environment during storms and flooding.

Description

Trees, shrubs, and smaller plants have root systems that structurally reinforce and support slopes (similar to rebar reinforcing concrete in building construction), bind soils, and reduce their susceptibility to erosion from wind or rain.

Landowners can mimic nature by planting native coastal plants to protect property from storm damage and flooding.

Application

Native plants found in Goa are best.

Here are some examples:

Sand stabilizing plants that are found along Goa's coastline like: *Spinifex, Ipomea, Acanthus, Clerodendron, Vitex, Spermacosea, Urginea, Dioscorea, Pandnus, Crotolaria, Duranta,* and Leucus.

Herbaceous plants: *Ipomea pes-caprae, Cypreus sp.,* and *Spinifix Littoreus.*

Shrub-like plant: *Duranta*

Benefits

By taking up the water directly from the ground, absorbing it through their leaves, and breaking the impact of raindrops or wave-splash, plants slow down the rate and quantity of water runoff that can lead to erosion.

Using native coastal plants also enhances the visual appeal of coastal property, protects property values, preserves the natural character of the coastal environment, provides habitat for wildlife, and helps to filter pollution.

Limitations

Cost of plants, minimal maintenance and care is required

Sources

Sources: Alvares, Claude Alphonso, Vidyadhar Gadgil. "Fish Rice and Curry, Chapter 5: The Coastal Region" Goa Foundation. 2002. Pg. 39

Landscaping to Protect Your Property from Storm Damage and Flooding." Massachusetts Office of Coastal ZoneManagement (CZM). January 2009. http://www.mass.gov/czm/stormsmart/resources/stormsmart_landscaping.pdf

Tags: biodiversity, flood, construction, public health, ecological conservation

RECOMMENDATION: Wetland Protection

Objective: Preserving and reconstructing coastal marshes to reduce storm damage.

Issue

Wetlands are transition zones between uplands and deeper water. They are unique ecosystems characterized by their hydrology, soil, sand, and vegetation. They function like natural tubs, storing floodwaters that over flow riverbanks and surface water that collects in depression areas.

Description

Wetland Hydrology and Flood Control Wetlands are transition zones between uplands and deeper water, unique ecosystems characterized by their hydrology, soil sand vegetation. They function like natural tubs, storing floodwaters that over flow riverbanks and surface water that collects in depression areas.

Benefits

Wetlands can help protect adjacent and downstream property from flood damage. Preserving wetlands, along with other flood control measures, can offer a degree of protection against flooding that is often more effective and costs less than a system of traditional dikes and levees. If more communities protect existing wetlands and increase the quantity of wetlandsthrough restoration projects, they will be better protected against the consequences of floods.

Coastal wetlands serve as storm surge protectors when hurricanes or tropical storms come ashore. Forested wetlands and other features of the coastal landscape can provide a significant and potentially sustainable buffer from wind wave action and storm surge generated by tropical storms and hurricanes.

Sources

"Wetlands: Protecting Life and Property from Flooding." United States Environmental Protection Agency. May 2006. http://water.epa.gov/type/wetlands/outreach/upload/Flooding.pdf

Tags: Biodiversity, Ecological conservation, Flood, construction, Public Health

RECOMMENDATION: Mangrove Restoration

Objective: Existing ecologies help in protection from storms and flooding.

Issue: **Mangroves** can serve as buffers and mitigate the effects of coastal erosion and flooding.

Description and Benefits

Mangroves grow between land and sea in the intertidal areas and mouths of estuaries. They have **aerial roots** (grow above ground) that filters salt and leaves that excrete salt, which makes them salt tolerant.

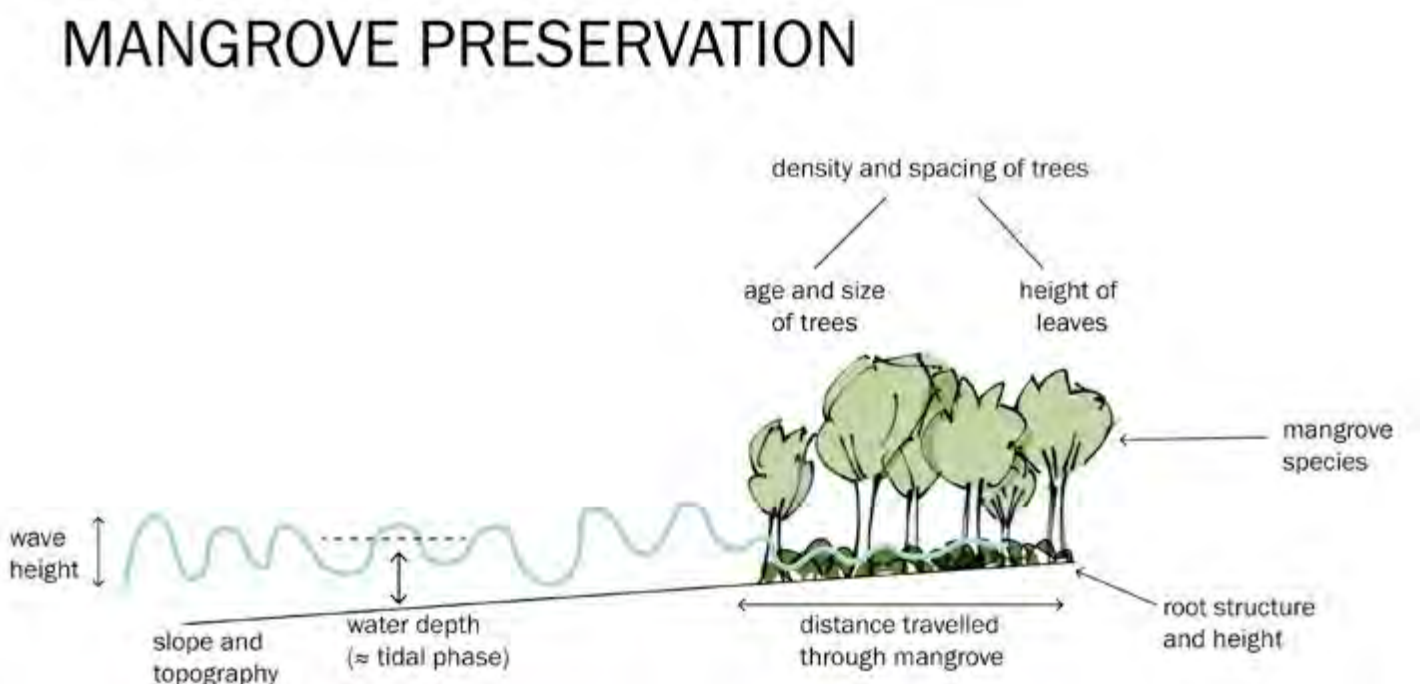
Mangroves can reduce storm surge water levels by slowing the flow of water and reducing surface waves. Therefore mangroves can potentially play a role in coastal defense and disaster risk reduction, either alone or alongside other risk reduction measures such as early warning systems and engineered coastal defense structures (e.g. sea walls).

Application

Measured rates of storm surge reduction through mangroves range from 5 to 50 centimeters water level reduction per kilometer of mangrove width. In addition, surface wind waves are expected to be reduced by more than 75% over one kilometer of mangroves.

Sources

"Reduction of Wind and Swell Waves by Mangroves." Natural Coastal Protection Coastal Ecosystems Reducing Risks From Natural Hazards & Climate Change. August 2012. http://.org/workspaces/naturalcoastalprotection/documents/mangroves/view.html



Tags: biodiversity, public health, ecological conservation

Objective

New channels should be constructed or the capacities of existing channels should be expanded to divert stormwater runoff away from elevated areas and agricultural lands.

Issue

Surface water accumulates during the monsoon season in areas that are lacking natural or man-made drainage systems. As flooding events become more unpredictable and frequent in Agonda, it may become necessary to divert stormwater runoff away from elevated areas that may be subject to erosion and landslides, and away from sensitive flood-prone agricultural land.

Description

An **earthen dike** is a temporary ridge of compacted soil that can be used to divert runoff to a desired location.

Application

Some applications include:

- Diversion of **sheet flows** away from disturbed areas and away from unprotected slopes.
- Diversion of water away from sensitive agricultural lands which are prone to **salinization**.
- Slope drains can also prevent erosion and landslides in elevated areas. Runoff can be diverged away from these areas and then directed towards sediment basins or traps.
- Earthen dikes can also be installed along roadways subject to flooding and along the river to lower the water level.

See Appendix C for suggested dike design criteria.

Benefits

Earthen dikes are a low-impact strategy for diverting runoff and stormwater away from flood prone areas (See also: Ecozones pages XX, 5.5 Bioswale pages XX).

Limitations

- Earth dikes must be stabilized immediately, which adds cost and maintenance concerns.

- Diverted stormwater may cause downstream flood damage.

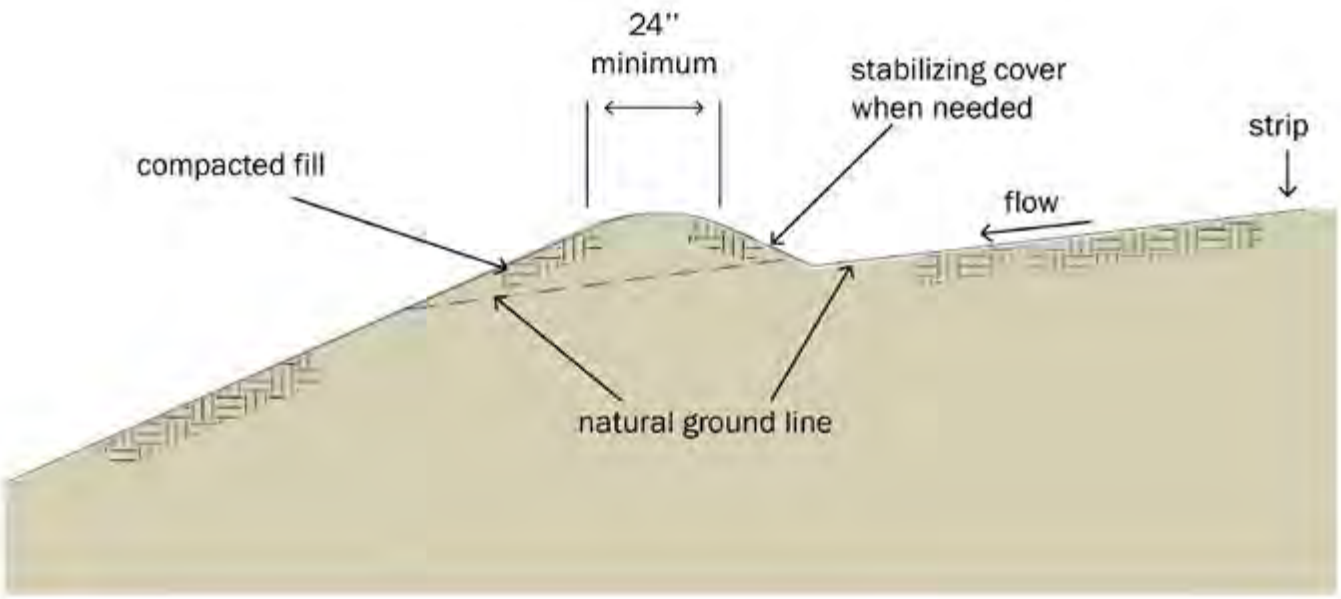
See Also: Bioswale, Rainwater Harvesting

Sources:

IDEQ Storm Water Best Management Practices Catalog, September 2005, http://www.deq.idaho.gov/media/617962-41.pdf

California Stormwater BMP Handbook January 2003, http://www.cabmphandbooks.com/documents/construction/ec-9.pdf

TYPICAL EARTHEN DIKE



Tags: Construction, Flood, Public Health, Green Infrastructure

RECOMMENDATION: BIOSWALE

Objective

Slow, spread, and absorb stormwater runoff to minimize the threats of flooding, increase **groundcharge** for well water supply, and minimally treat water pollution.

Issue

Stormwater runoff happens when a heavy downpour or prolonged rain unleashes more water than the ground can absorb. Then the excess water travels overland until it finds a river, lake or ocean to call home. Along the way, it picks up dirt and debris as well as pesticides, fertilizers and other contaminants, all of which end up in our waterways.

Description

Bioswales are vegetated open channels specifically designed to help treat storm water runoff in defined water volumes. Like open ditches, they move larger stormwater volumes from a source to a discharge point, but unlike ditches, they intentionally promote slowing, cleansing and infiltration along the way. A sloped base to facilitate this water movement distinguishes bioswales from rain gardens.

Application

There are some design variations of the bioswale, including grassed channels, dry swales and wet swales. These designs may also include an underlying rock reservoir, with or without a perforated underdrain. The specific design features and treatment methods differ in each variation, but all are considered improvements on traditional drainage ditches. Each type of swale incorporates modified geometry and other design features to allow it to treat and convey stormwater runoff.

A typical swale bottom is flat in cross section, 600 to 2400 mm wide, with a 1-2% longitudinal slope, or dished between weirs on steeper slopes. Bioswale side slopes are usually no more than 3:1, horizontal to vertical.

Bioswale vegetation is a combination of grasses, perennials, shrubs, groundcover and trees.

Maintenance requirements are similar to those for ditches: inspecting for bank slumping & erosion, replanting any bare patches where vegetation has been unsuccessful or removed, maintaining ideal vegetation heights by mowing, and removing garbage. Additionally, sediment build-up within the bottom of the swale should be removed once it has accumulated to 25% of the original design volume.

Benefits

Even where soils have very poor hydraulic conductivity (around 1 mm/h), a 4 m long swale/trench can reduce the volume of runoff from a typical local road to about 25% of total rainfall. In general, infiltration facilities along roads are more effective than on-lot infiltration facilities because there is typically less concentration of runoff (i.e. the ratio of impervious area to infiltration area tends to be lower).

As stormwater runoff flows through bioswales, pollutants are removed through filtering by vegetation and soils. Above ground plant parts (stems, leaves, and stolons) slow flow and thereby encourage particulates and their associated pollutants to settle. The pollutants are then incorporated into the soil where they may be decomposed. In particular, bacteria within healthy soils can help break down carbon-based pollutants like motor oil.

Grassed channels and dry swales provide some groundwater recharge if a high degree of infiltration is achieved by the practice.

Siting

Grassed swales can be applied in most development situations, including residential areas, office complexes, rooftop runoff, parking and roadway runoff, parks and green spaces. Swales are well-suited to treat highway or residential road runoff because of their linear nature and because they are designed to receive stormwater runoff.

Limitations

If designed improperly, bioswales will have very little pollutant removal. They also do not seem to be effective at reducing bacteria levels in stormwater runoff.

While some sources recommend that bioswales should be used on sites with relatively flat slopes (i.e., less than 4%), others note that the use of properly spaced weirs can allow siting on slopes up to 10%. When slopes become too steep, runoff velocities become fast enough to cause erosion, and prevent adequate infiltration or filtering in the channel.

Sources

"Regulating Stormwater Discharges." Capital Regional District. CRD Watershed Best Practices. Website. Accessed March 2013.

"What is a Bioswale?" Capital Regional District. <http://www.crd.bc.ca/watersheds/lid/swales.htm#. Website. Accessed March 2013.>

Tags: flooding, construction, biodiversity, public health

RECOMMENDATION: Plinth construction

Objective : Construction of more resilient plinths with heights that correspond to zones

Issue

Many of the buildings located by the riverbank and canal are not built high enough to withstand rising flood levels. Often, the present plinths are cracked and damaged which leaves them more vulnerable to weakening over time.

Description

Increase the height of Plinths, use materials that last longer, and apply techniques that protect your construction.

Application

- Plinth height should be determined according to location: flood zone, coastal, flatlands, hillside
- Height and width of plinth should be determined based on height of whole structure and proportionate to weight of the building..

plinth height = height of zone's high water mark + natural occurrences + 1 meter

- Treat exposed concrete plinth surface with water repellant.
- When building plinth, construct cavity wall between plinth and home foundation to protect masonry from moisture
- Grout seams and cracks between plinth and building.

Benefits

Reduces risk of first floor flooding

Limitations

Cement can become weakened over time.

Tags: Construction Methods, Flood Mitigation, Materials, Public Health

APPENDIX

APPENDIX A

Application Roofing Material	Solar Reflectance	Infrared Emmitance	Temperature Rise (C)	Solar Reflectance
Coatings				
White Polymer	0.7-0.85	0.86-0.91	5-13	88-107
Light Yellow	0.79	0.91	9	99
Gray	0.40	0.91	31	47
Dark Blue	0.12	0.91	46	9
Aluminized	0.61	0.25	27	56

APPENDIX B

Roofing Material	**Solar Reflectance**	**Infrared Emmitance**	**Temperature Rise (C)**	**Solar Reflectance Index**
Tiles				
Metal, white	0.67	0.85	16	82
Clay, Red	0.33	0.90	34	41
Concrete, Red	0.18	0.91	43	23
Cement, Unpainted	0.25	0.90	39	31
Concrete, Light Brown	0.42	0.90	29	49
Fiber Cement, earth brown	0.26	0.90	38	28
Coatings				
White Polymer	0.7-0.85	0.86-0.91	5-13	88-107
Light Yellow	0.79	0.91	9	99
Gray	0.40	0.91	31	47
Dark Blue	0.12	0.91	46	9
Aluminized	0.61	0.25	27	56

Suggested Dike Design Criteria		
Criteria	Drainage area < 5 acres	Drainage area between 5 to 10 acres
Dike Height	18 in	3 ft
Dike Width	2 ft	3 ft
Flow Width	4 ft	6 ft
Flow Depth in channel	8 in.	15 in.
Side Slopes	2:1 or flatter	2:1 or flatter
Grade	0.5% - 20%	0.5% - 20%

SUSTAINABILITY AND CLIMATE RESILIENCY ACTION LIST

Instructions: The following actions items are provided to help guide your development and construction practices to include sustainable design and climate preparedness strategies. Use this Action List to help you monitor your development's progress and to ensure that your development is sustainable and prepared for emergencies. Use the comments section to include additional information of what work is still in progress and details explaining alternative applications. Each number corresponds to a recommendation described in detail.

1.0 SITE PLANNING

		YES	NO	COMMENTS/OTHER CONSIDERATIONS
1.2	Did you establish a safe foundation? (i.e. not on steep slopes)			
1.2	On a slope: Are you excavating or filling in land for your structure?			
1.2	Have you sited your structure where it would have the most benefits cooling from shade?			
1.2	Has a soil composition study been done?			
5.2	Have you taken precaution to remove the least amount of existing vegetation?			
5.4	Are you using native plants for landscaping?			

2.0 Materials and Construction

		YES	NO	COMMENTS/OTHER CONSIDERATIONS
2.1	Is your wall stable? Did you consider the relationship between length, height and thickness?			
2.2	Are the door (s) and windows symmetrical?			
2.2	Are the lintel level for all openings and the windows the same size?			
2.3	Did you secure the roof to the frame and wall?			
2.6	Have you considered the best use of the materials you've decided to use?			
2.7	Have you thought of what colors the outer walls / roof are of your building?			
2.8	Have you considered retrofitting?			
	Have you considered which materials for your structure would provide the coolest interior?			
5.1	Is your foundation high enough in preparation for flooding?			

3.0 WATER

		YES	NO	COMMENTS/OTHER CONSIDERATIONS
3.1	Are you havesting rainwater?			
3.2	If you have a well, did you take steps to protect your water from salt water intrusion?			
3.3	Are you taking steps to conserve water?			
3.4	Are you taking steps to treat your own waste water?			
	Do you have a supply of drinking water for emergencies?			

4.0 ENERGY

		YES	NO	COMMENTS/OTHER CONSIDERATIONS
4.1	Are you passively heating and cooling your building?			
4.2	Are you preparing for renewable energy sources in the future?			
4.3	Are you conserving your energy use?			
4.4	Did you use one of the wind driven strategies?			
	Do you have an energy source in case of emergencies?			

5.0 FLOOD MITIGATION

		YES	NO	COMMENTS/OTHER CONSIDERATIONS
1.1	Are you building in CRZ?			
5.1	Are you building on elevated ground or using construction techniques that elevate your foundation?			
5.4	Does vegetation make up at least 20% of your site?			
5.5	Are you using techniques that will help slow, spread, and soak up storm water run off?			
	Are you using flood and mold resistant materials?			
	Have you planned to store water supplies, critical infrastructure, and cleaning supplies above the high water mark?			

Proposed Development / Location

Name

Contact Information

Phone / Fax

Email

Date