Evaluating Soils for Warm Climate Sites

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Above: Haitians building a dormitory of alternative straw wattle on earthbag materials, 2012

This information was first developed in 2008 as in-house training materials for Wycliffe Associates Construction Services, Orlando, FL, USA. Thanks to all the WA staff and volunteers for their labor of love in training novices how to deal with other places and cultures.

Contents

Chapter 1: Looking for Land

All land is not equal. You are looking for inexpensive land that is close to utilities and transportation. It must be big enough for the buildings you need. How do you choose between different building lots?

Steep or soggy land can increase building costs dramatically, or may not fit safe wells with septics. Large proportions of the wrong kinds of clay in a soil (common in damp areas) or landfill may require expensive foundations. Other land may settle if groundwater levels are lowered by wells, or under the weight of buildings.

Get as much local advice as you can.

This booklet has been developed for those who have difficulty finding local advisors in subtropical and tropical regions. Aid workers for many organizations have similar needs. We hope this resource will make planning less costly and more productive by giving non-engineers some tips about what to look for.

REGIONAL INFORMATION

Regional maps like those in the appendix will help us to check for earthquake risk levels, the presence of limestone geology, and some other limiting factors for development.

Get local opinions on these hazard levels for your project site. Information may be available from local builders, city building departments, and regional universities or research centers. Important topics you must be aware of:

What problems with water and power supply are common?

What kind of rocks and bedrock are in the area?

Are there any caves or mines in the area?

Have there been any landslides, mudslides, or areas of collapsing soil in the region?

What kind of damage happens to buildings, roads, or bridges in the area?

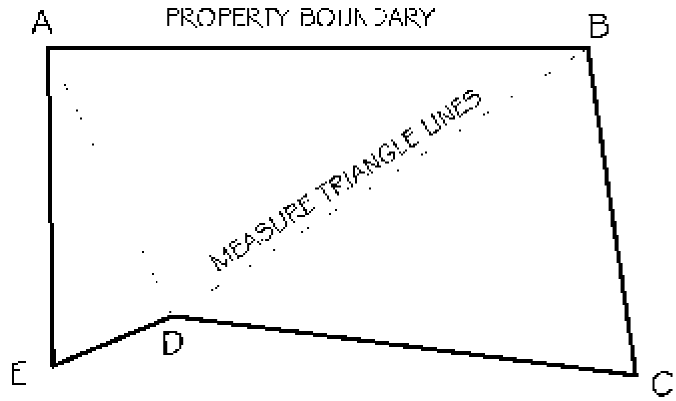
SITE WARNING SIGNS:

Think very carefully and get a lot of information before you buy land with any of these characteristics:

- Large wet areas
- Very soft or sandy soil in earthquake-prone regions
- Very sticky clay soil
- Dry, cracked soil areas, gullies, bare gravel or soil
- A general hummocky appearance
- Surface water that disappears underground
- Leaning trees or posts on slopes

BOUNDARY INFORMATION

If you are purchasing land from a future neighbor, they can show you the limits of the property. There should be some obvious locators like fences, walls, ditches, or rows of trees. If not, ask them to stack some rocks or place some stakes near the corners. People will need to visit the site several times to evaluate it, and everyone must be looking at the same piece of property. A legal survey will have measurements and compass directions.



Before paying for a survey you can find out the approximate lot size and shape. Use multiple roles of colored string if you have to. Mark each distance with a permanent marker and a strong loop of tape next to it.

Rectangles need angle measurement, which is hard to do. To be accurate without expensive equipment, break a lot up into triangle shapes. Stake all these corners and draw a small sketch. Measure all 3 sides of each triangle, and a designer can sketch out the size of the lot.

Make sure you clearly show if your piece of string is the A-B property line or the A-D interior measurement. Then measure the string later with shorter tape measures.

SITE PHOTOGRAPHS

Digital photographs of the land can remind you where trees and buildings in the distance are.

Left: Panorama photograph of land in Cameroon

Use a camera that takes panoramas automatically, or take separate pictures carefully, each photo overlapping the previous photo so that it is clear how they connect. Two separate series from each boundary line, one looking in and one looking out is very helpful. Take careful notes in a notebook so you can label them later (like: 'northwest boundary, looking outward, garden at the left', etc.). Additional closer photos should show any existing structures, landforms (cliffs, ditches), special plants, surface water, as well as the kind of buildings in the neighborhood.

Left: A hillside in Cameroon

If plants block the view of the site, try a ladder or climbing a tree to get better views before you remove all the plants to do a survey or take photos. Leaving trees can reduce problems like soil erosion and give needed shade.

ABOUT SLOPE

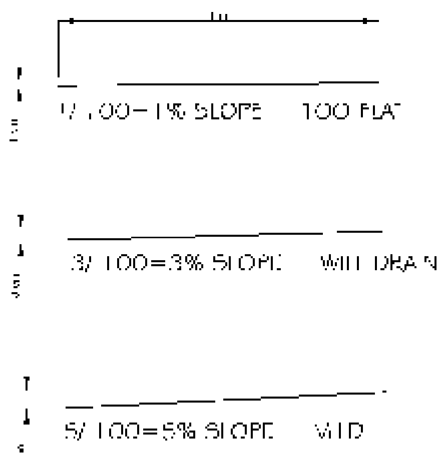
Land that is too flat may be soggy in damp climates. Land that is too steep will require expensive retaining walls or higher building foundation walls. Remember, buildings are flat, and they need flat space around them. Room for cars to drive and park should be 5% slope or less.

Retaining walls with land sloping up above them have to be even stronger than normal walls.

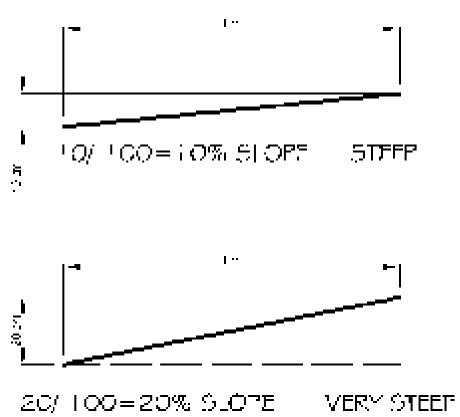
You don't need to know the exact 3-D shape of the land before purchasing it. But you need to know about how steep it is. The amount of slope is called the grade or gradient.

Use a 1 m long level stick and a tape measure to measure the grade. Hold the level so one end touches the ground. Aim it straight down the hill. Measure how high the other end is above the ground.

$$\text{Slope (also called grade)} = \frac{\text{Vertical drop}}{\text{Horizontal distance}}$$

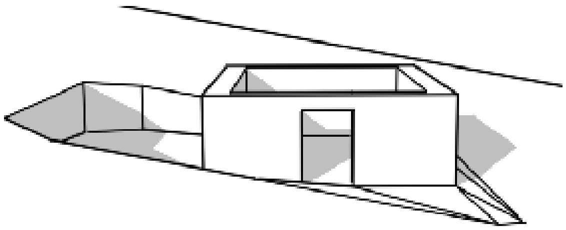


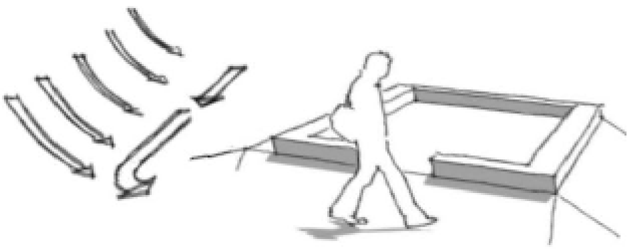
Above right: Site walls around a building on a hillside



How Slope Affects Land Use

Grade	Vertical drop in horizontal distance	Effects
1%	1 cm in 1 m 1/2 inch in 4'	Very flat, may be hard to drain. Rainwater will puddle. Spots of different color in the subsoil show the soil is often wet- bad for wastewater, probably bad for building
3- 5%	3- 5 cm in 1 m 1.5- 2.5 inches in 4'	Water runs off. Is easy to develop. Good for roads.
10%	10 cm in 1 m 5 inches in 4'	Hill. Some retaining walls for larger buildings or parking. A little steep for roads with any freezing weather.
15%	15 cm in 1 m 7.25 inches in 4'	Steep hill. More retaining walls. Erosion likely. Longer streets curve up hill. Septics must be on level.
20%	20 cm in 1 m 9.5 inches in 4'	Very steep. Higher building costs. Lots of retaining walls. Hard to fit buildings in. Special wastewater treatment to prevent leaking out of hillsides.





Rain will need to run around and away from building walls. Rain always flows downhill, so on the uphill side a building needs a small swale or ditch that will direct the water away.

Have the land slope down away from the building on all sides. On the uphill side it might only slope down 10 cm in 3 m (4” in 10’). In humid climates locate the swale at least 3- 6 m (10- 20’) from the building.

Left top: Retaining walls needed above the building
Left: Water should run away from your building

CLEAN WATER

Harvesting rainwater is one way to provide clean drinking water. You will need a cistern large enough to store water from the rainy season through the entire dry season. And you will need large enough roofs and hard surfaced areas to collect enough water.

A well seems much simpler. But think about how the people in your area find and use water. Will your neighbors all expect you to share your water with them? Will they want to bring cattle to drink at your well?

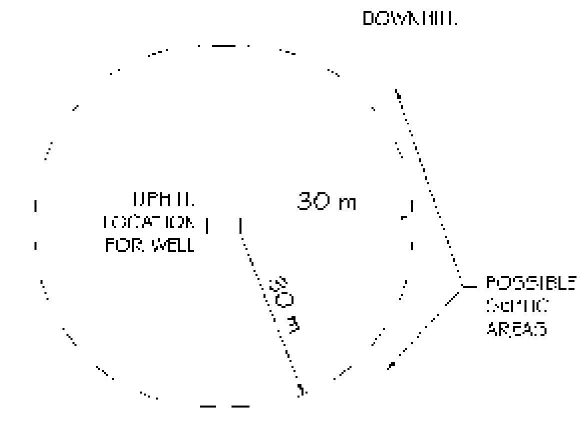
Wells in dry agricultural regions often cause environmental problems because farmers intensify their land use. In many places new wells for aid have caused serious land overuse and soil erosion. Talk this issue over with local people that you respect.

If you choose a well, make it a safe and healthy one. Wells are easily contaminated by pit toilets or septic systems that are too close. There may be no regulations at your location to prevent a neighbor from building one of these right next to your property line. Plan to have enough room so your well will be far enough from all property boundaries. 30 meters is a good separation distance for level ground.

How much land do you need to have a well and waste and wastewater handling? That depends on the shape and slope of your land, and on what your neighbors have.

If your neighbors don’t have any wells near their property boundary, you will need at least 0.4 hectare (1 acre) and must save the center of your site for your well.

Water seeping through the upper soil usually runs from higher areas towards lower areas. If your land is higher than your neighbors, good for you. Any contaminated water from you neighbors traveling through the soil will flow away from your land.

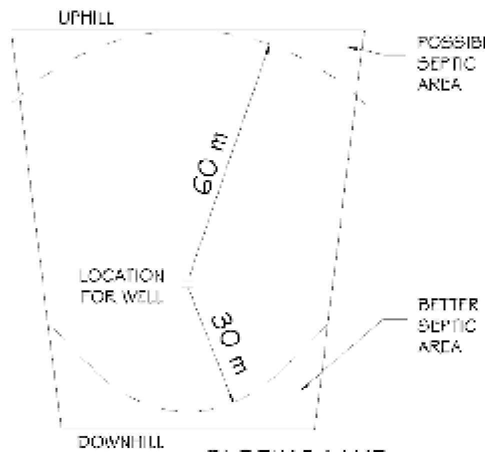


HILLTOP WELL OR LEVEL LAND
0.4 HECTARE/ 1 ACRE

Right: Minimum lot size for a gentle hilltop

Locate a well further from neighbors who are uphill.

On sloping land you need at least 0.7 hectare/ 1.7 acres. Probably since your land will be a less than perfect shape, you will need more than this. This is why you want a survey or sketch of how big your land is. It is easier to find out how wells and roads fit in when you can draw them.



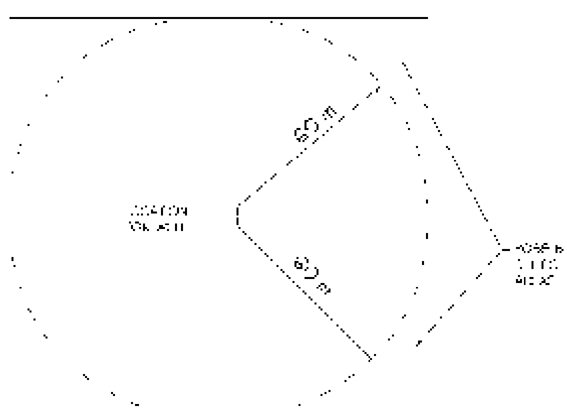
SLOPING LAND
0.7 HECTARE/ 1.8 ACRES

Right: Minimum lot size for well and wastewater on a hillside
Below: Large lot needed to protect a well in a low spot

60 meters is a safer distance to separate a well from pit toilets or septic systems that are uphill. This means that if your land slopes down in one direction, your well should be located 60 m from the uphill side and 30 m from the downhill and all level sides.

If your land is the lowest in the area, you will need a very large lot. A long valley will need more distance between well and septics on some sides. If the center of your land is a low spot, you need almost 2 hectares/ 5 acres.

But these sizes are not considering whether your wastewater treatment couldl contaminate your neighbor's well. In the developed world, new sites have to prove that there will be enough distance between a new septic field and any existing wells.



WELL IN A HOLLOW OR VALLEY
1.8 HECTARE/ 4.4 ACRES

If your soil is very sandy, you could need even more distance between wastewater and water supplies.

Waterless or low-water treatment for human waste can reduce the strain on the environment and local health significantly if they are maintained properly.

HUMAN WASTE

Remember, for any waste system to be successful it must be accepted by local people. They have to feel it is worth the effort to keep it working well. Some cultures cleanse after defecating with water. Others use scraps of bark or sticks. In many places toilet paper may not be very common. Cleaning hands afterwards may not be considered, or it might involve ashes or soap and water.

Discuss preferences and ask for suggestions before introducing something new. Always offer real choices, so people feel ownership of change.

In many parts of the developing world pit toilets are standard. Pits are often 2.4 m/ 8’ deep and 1.5 m/ 5’ or wider. If the platform is old, there is real danger of it collapsing. A small child may feel vulnerable to falling in. In many parts of the world small children refuse to use pit toilets and contribute to polluting their area.

Flies and smells can be overcome by the use of ventilating latrines that have a vent pipe rising from the tank. But to prevent insects transmitting diseases, this type of latrine must be kept dark inside.

Some civil engineers think that soakaways (deep infiltration tanks) and long drop toilets (pit toilets) pollute groundwater because they bring the septic liquids too deep underground. Is this part of the reason why Haitians now have cholera bacteria in all their groundwater?

A septic leachfield is a more complicated and expensive system, using a sealed tank (that must be emptied) and a series of perforated pipes that distribute the liquid just under the ground. These usually work with flush toilets.

Pour-flush Toilet

Flush toilets use too much water for many areas. Simpler slab or squat toilets can be manufactured porcelain or made by local craftsmen with tile. This simple pour-flush system uses 1- 3 liters/ quarts for each flush (Brikke 114). These latrines can be flushed with a bucket without plumbing, or access graywater from a pipe. The slab toilet is attached to a small s-shaped water ‘trap’ in the drain that stops both smells and flies.

Right: Pour-flush toilet

A squat toilet can stay much cleaner than a western seat toilet if the users are accustomed to them. Many people used to latrines and slab toilets will squat on top of a western type toilet seat, dirtying or breaking it. The squatting position is also healthier than a sitting position and keeps legs strong.

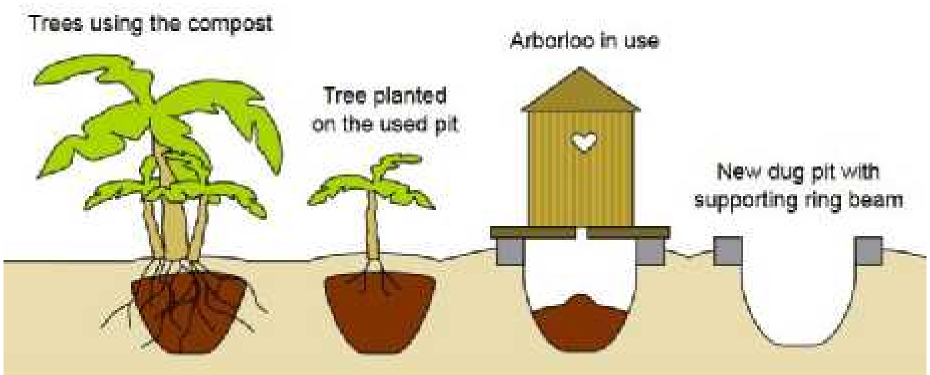
A pour-flush system needs a leaching pit into soil that absorbs wastewater. To keep wastewater higher in the soil layers, a tank can be used for solids, with wastewater flowing to a shallower leaching system. Because of the small flows associated with pour-flush systems, neighbors or communities sometimes connect their wastewater piping and use a small-bore sewerage system leading to a shared leach field (Brikke 127).

Human solid waste will lose its disease organisms with time. In a sealed, damp (but not liquid) environment, 18-24 months are adequate. Pour-flush systems can be built with two alternate tanks. The full tank is left untouched for 18 months until safe to empty and re-use for agriculture. Then the flow is switched to the empty tank while the full tank rests.

Simpler alternatives don't need septic systems. In the developing world, simpler is usually best.

Arbor-Loo

The simplest way to handle human waste on a small scale is the 'fill and cover' arbor-loo. (Sustainable Soil and Water Management). This shallow pit- 1 m deep and 1 m wide is the right size for one or two families.



Left: The arborloo process

The arborloo's cast concrete platform is slightly larger than a slab toilet. A supply of leaves or straw or sawdust or ash sits by the hole. Each person adds enough to cover the waste. When the pit is full, then dig a new one. A single mother can accomplish this herself. She then plants a vine or tree in the old pit. The family has less disease and the plant grows better from the fertilizer.

Composting Toilets

Composting waste systems don't need water either. The double-vault compost latrine is built over a divided solid walled chamber. The two floor openings each access a different side. When one side is filled, the other hole is opened. The waste is not removed until it has been left alone long enough to become safe to use for fertilizer.

These are most effective when they divert urine so that the solid waste is drier and composts quickly (Brikke 111). Solid-wall latrine chambers are too damp, prevent composting and smell terrible. To divert urine, a squat toilet top is shaped to catch urine and lead it away. Even toilet seats can be used that have a special diverter like a funnel added under the front of the seat. Urine (germ-free among healthy people) is used for fertilizer.

The Eco-san system promoted by UNICEF has refined this double-vault system for rural family use (India Water Portal). The slab contains a urine collection bowl that connects to a pipe leading to a small leaching tank. Behind this bowl is a drop-hole for excreta with a wooden lid. A bowl of ash or sawdust is kept near the hole so that dry organic matter can be added after each use. Behind the drop-hole is a second basin for anal cleansing. A water container nearby allows rinsing instead of using leaves or paper to cleanse the body. The rinse water runs through a second pipe into a small filter bed of well-draining soil where salt-tolerant plants are grown.

Less expensive composting toilet systems or those for urban areas require more active handling of waste. SOIL is an NPO working in Haiti that has overcome cultural prejudices against handling waste to develop large composting waste treatment facilities. They use the Eco-san system but empty chambers frequently. In their composting facility a week at 122° F renders waste material safe to handle. They sell both toilets and compost, as well as training, but also rely on donor funding for this high quality service that is overwhelmingly run by local Haitians.

PeePoo Bags

If you are working with slum tenants or refugees, some places don't have enough room for any toilet. It may be possible to fund a system of sanitary waste bags. PeePoo bags are biodegradable and have a liner with enough ammonia to neutralize germs in human waste (Sustainable Sanitation and Water Management). They can be picked up within 24 hours (before beginning to smell) and placed in a sealed barrel.

Right: Pee poo bag collector

After only a month the PeePoo barrel can be opened and used to grow plants. An organizer must collect and compost the waste, but in one Kenyan slum women earn a living selling the bags for 3 cents each. They refund 1 cent when returned for composting.

Hand Cleansing without Plumbing

For best health, near toilets without running water, add a tippy tap (www.tippytap.org). This simple handwashing station is made out of a used plastic container and some string for a foot control. Germs aren't passed on when feet work the 'tap'.

Left: A Tippy tap made out of an old bottle or tin

Handwashing (scrubbing well) with either soap or ash can reduce deaths from diarrheal diseases by almost half.

GRAYWATER

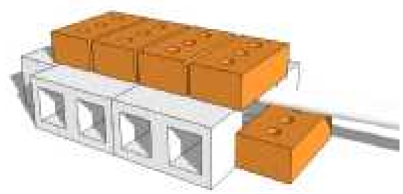
Much waste water from a household can be re-used. Handwashing, bathing, showers, and clothes washing all produce slightly dirty water, called graywater. Usually graywater does not contain many germs.

This may be left to run down streets. Where graywater from several families joins up on the ground it causes erosion, and leaves some sludge behind.

Right: Graywater running on the ground

A better system is to throw it onto a plant bed with vines or other plants that tolerate the soap residue. If sinks and showers are built with drains, the pipes can be run directly to feed plants.

Drains from kitchen sinks should never run to plant beds if the family treats food and drinking water with chlorine. Also, kitchen sink water has much more grease than water from other sources. A settling bucket with a lid running into a small soakpit underground is the safest for kitchen water.



Any graywater stored for a full day can become contaminated as nutrients and bacteria multiply. Don't store it. It is also better if graywater doesn't run on the surface of the ground.

In the developing world shower stalls are often used for washing clothes. Staff at a school may bring their laundry to wash at work. If they have small children, they will include diapers to wash, which add dangerous germs to the water. If you can, keep graywater underground. Do not let it 'daylight'.

Above: Underground graywater outlets
Right: Testing a perforated pipe outlet

Drains from showers can run underground to a shallow leachfield- a perforated pipe set in gravel. Wrap this with landscape fabric and pour gravel or small stones around it. Then cover, and plant vines or trees or vegetables. For best health, don't grow root vegetables like carrots or yams in this area.

A cheaper system is to make underground water outlets from plastic buckets, clay flower pots, stones, bricks or blocks. Always try out your graywater system before you cover it up. The space in the pipe or buckets or under the blocks has to be big enough to hold all the water used until it soaks into the ground.

STORMWATER

Builders always made roads with curbs and used gutters to trap and collect stormwater. Special pipes had to direct it away from buildings. Often during heavy rains, it washed soil away and caused problems.

Right: Rain garden below lawns and roads, Maryland, US

Newer low impact development (LID) ideas work better to prevent soil erosion even in the developing world.

- Don't collect water
- Don't speed it up
- Let water soak in near where it lands
- Less pavement, more porous surfaces
- Plants hold the soil and clean the water

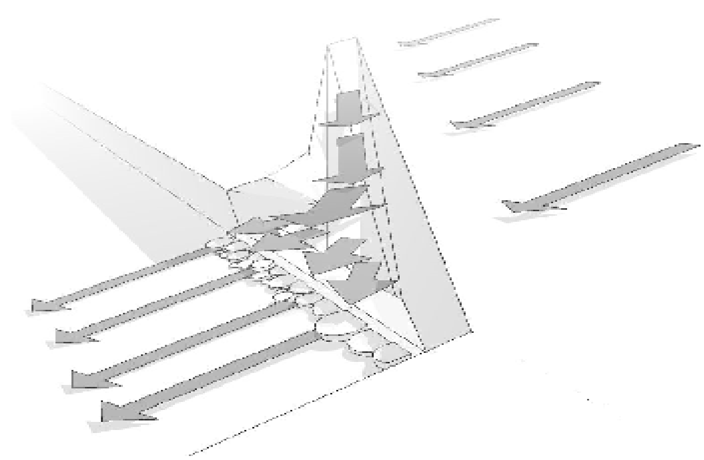
Find out how water travels on your land before you build. Help it continue to flow without disturbing buildings.

Locate hard surfaces above green parts of your land. Slope them so the water runs down to help plants. Provide good soil and start plants that your site users want. Vines or vegetables, or special herbs will get their attention if they are planted at the downhill side of the house. In dry regions, make a ditch and lead the rainwater to feed special plants. The more water that soaks into your land, the more reliable your well will be.

Above: Tropical plants catch runoff after the level pavement spreads it out.

Keep plants growing on slopes so rain can soak in and soil stays in place. Strong grasses like vetiver can grow even in drainage areas. They can be planted in soil held in poly rice bags through holes in the fabric. Then the plants won't be washed away before the roots are strong enough to resist the flowing water.

Don't concentrate rainwater. Avoid solid, raised curbs. Don't run gutters together, but let them pour out at many places. Where rain runs off of roofs or paved areas, make a level area that will spread the flow out.



Right: Spread water over a rough surface at the end of a swale.

On sloping land, you will need swales above buildings or roads. But at the end of a swale, spread the water out again.

Because roofs increase how quickly rain runs off, lead roof water to special drainage areas. Ditches that slope gently can be rain gardens, where water can soak in slowly and plants that need moisture can flourish.

Or even better, use your rainwater. Place drums or cisterns to save stormwater for use later. Keep it covered to prevent mosquito growth. Rainwater is much healthier than surface water from streams. Where groundwater is also polluted, saving and using rainwater carefully will improve health.

Above left: Round cistern in Kenya
Below left: Graywater and rainwater for a Kenyan fish pond

Where water is scarce, captured rainwater may allow more food plants or animals.

The concrete tanks shown at left combine graywater used by 100 people with captured roofwater. This flows into a covered tank to settle for 2 days. It then flows through two slightly sloped beds that will grow a water-tolerant vetiver grass. As water takes 3 days to pass through the grass tank it loses nutrients and becomes cleaner. The deeper tank at the downhill side is for raising edible fish in the cleaned water.

There are many ways to use water. Keep in mind where water will be flowing and keep your options open.

Below: Vetiver grass planting in Kenya to stabilize a drainage channel

Chapter 2: Preliminary Soil Evaluation in Warm Climates

INTRODUCTION

To choose a good building site someone must know a little bit about its soil.

Soils with too much clay or silt can make wastewater treatment difficult or expensive and building foundations large or expensive. Sometimes sandy soil drains too quickly for ordinary wastewater systems. Water close to the surface of the soil or running onto your site from hills above can also make it a more difficult place to build.

Good soil can also be used as a building material To check soil for earth building, please see the Field Tests for Soil Building Strength booklets online at www.BuildSimple.org.

The soil tests that follow will tell you how the soil will work for buildings and wastewater. They may confirm what your contractor or local people already know about the site. Or they might tell you to ask for help from a professional like an engineer.

FIELD SOIL TESTS

Equipment you might need:

- shovel, pick-axe
- hand soil core tool or auger or a post-hole digger
- your site survey or location description
- a notebook, pens, a contractor's tape measure
- plastic bags, plastic containers
- a small bottle of water
- masking tape or labels

Right: A hand soil auger with a shovel.

Sketch where the soil samples are dug from on a plan of your land. Call them A, B, etc. Label the bags you fill with samples.

With water, you may be able to finish most of the tests at the property. If it has been raining recently, the land is in a low-lying area, or near a lake or stream, you may need to dry some of the soil samples out to test them well.

First check if the soil is very different in the higher or lower parts of the site. In places where you will want buildings or pavement use the auger or post-hole digger to get one or two samples of each kind of soil from at least 500 mm below the surface. In stony soil holes can be dug with a shovel. If there are small areas of different soil in a corner or along an edge of your land, don't worry about them.

These tests are to check for obvious problems with the upper layer of soils. Different soil layers below affect buildings. If you have an auger, dig deeper and find out if the soil changes below, and where the water level is.

If you find standing water in any hole, measure how deep the top of it is and note the location and date. A sucking noise when you pull the augur out does not mean you have high water unless you can see the water.

Scrape debris and topsoil away from each testing site. The top 400 mm (16 inches) of soil usually contains plant matter and humus. Topsoil is darker and smells musty, especially if damp. It is also a little springy when you squeeze it, and may have a slightly fibrous appearance. Topsoil is valuable for growing things. It should not be left under buildings or used for building.

Find out how deep the topsoil is. Dig until the color changes. Then cover a handful of soil with water in a bowl and stir.

Organic material floats. Topsoil leaves dark stuff all over the top of the water.

Above: Topsoil on the left has floating debris, subsoil on the right leaves water almost clean

Sometimes there is no topsoil or very little.

If the soil is in a low-lying flat area (or one that used to be low) it may have very deep organic matter. Deep topsoil won't hold heavy buildings well, and may keep slowly settling lower. New Orleans had so much flooding from hurricane Katrina because large areas were built on deep organic soil that keeps slowly settling.

Dig a couple of holes where you hope to build. Is it easy to dig?

It is good if the soil is firm and requires some effort to dig. Loose soils are more expensive or dangerous places for buildings. If soil can be dug by a shovel without using your feet, it is a very soft soil. When you need to use a pick to dig, the soil will probably have high bearing strength.

If it is very hard to dig, but not rocky, check whether it might be lateritic soil that forms a hard layer at the surface up to several meters thick. Ask for local advice. Are there are any colored or white levels in the soil?

If you are considering building with your soil, mix a couple of clumps or shovelfuls from each different area together to get an average sample. Take out any rocks, gravel, or debris. Put some of the subsoil in a labeled bag and note which part of the site it came from.

If you find soft soil, topsoil deeper than 40 cm, some unusual colors, or very porous, light soil use Table 1.

Table 1: Unusual First Observations

Observation	Find out		Meaning
A very light-weight texture	Is this a dry or desert region?	Clumps seem porous, crush easily	!!! Read about hydro-compacting soil p.
Very easy to dig, don't need to use your foot on the shovel	Different soil less than 1 m below?	Test the deeper soil for strength	?
	Same soil is very deep	Do a strength test p	?
Thick topsoil	Dry location	400 mm deep or less?	!!! Dig deep and remove the topsoil under the building
		More than 400 mm deep	!!! Read about organic compacting soil p
	Flooded sometimes, damp all the time, or near damp areas?	Very dark or black soil AND damp, in or near tidal saltwater area?	!!! Soil may become acid/ toxic if you drain it. Read about acid sulfate soil p
Light colored soil	Below the surface, in a dry region AND is this layer hard to dig?	Caliche or mineral layer will be difficult to dig, but strong soil.	? Do a perc test p 21
	Surface soil or along ditches	May be alkaline or other mineral	!!! May be too saline for good buildings. !!! May be too saline for plants to grow.

ü Should be ok

? May cause some trouble

!!! Find out more about this serious issue

For more ordinary soils start here, using a handful or two of the soil.

PINCH TEST:

Take a pinch of soil. Add water until wet and mix it. Rub it between your fingers.

1. Does it feel very gritty and fall off your fingers? It is a sandy LIGHT SOIL. Go to Table 2 below.
2. Some soils stick a little but more to your lower finger. When they dry they brush off clean. The 2nd picture is silt, a LIGHT SOIL. Go to Table 2 also.
3. If your pinch doesn't look like this, go to the next page.

Table 2: Light Soils

Observation	Find out			Meaning
Low Earthquake Risk Region (white to light green on GSHAP map)	Will make a weak ball Silty texture like flour	Sometimes high water level		!!! Look for signs of subsidence
		Groundwater is deep		? Strength test p 23
Medium to High Quake Risk Region	Crumbly Silty texture or fine round sand	It is near a stream or beach. It has high groundwater. Or it floods sometimes		!!! Read about quake liquifaction p
		Groundwater is deep	Jar test p 21	? If not well-graded do strength test p 23
				ü Ok if well-graded
Very grainy sand feels angular	Crumbly Do a perc test p 21	Water takes 1 minute or less to drop 1 inch/ 25 mm		!!! Ask engineer for wastewater advice
		Water takes 2- 60 minutes do drop one inch/ 25 mm		ü Ok

ü Should be ok

? May cause some trouble

!!! Find out more about this serious issue

If your soil is more sticky than crumbly, check it against these pictures and use Table 3 below.

PINCH TEST: Continued

1. Does it stick to your upper finger and make your hand dirty? It is a clay or HEAVY SOIL. Use Table 3.

2. Soil is a mix of clay, sand and silt if it is gritty but also sticks on your upper finger. It is a clay loam. Use Table 3.

3. If your soil is not gritty, and holds together very well but is not sticky, it might be a tropical clay. Squeeze a ball of it, and use a table knife to cut a piece off. Is the cut piece shiny? Then it is clay. Use Table 3.

Table 3: Loam and Heavy Soils

Observation	Find out		Meaning
Clay makes your hand dirty and does not brush off when it is dry.	Do a handful drop test, next page	It does not crack, it flattens	!!! Ribbon test p 20
		It cracks a little	!!! Do a perc test p 21
		It splits into 2 or 3 pieces	ü Loam
		It shatters	? Test for strength p 22

ü Should be ok

? May cause some trouble

!!! Find out more about this serious issue

HANDFUL DROP TEST:

Take a damp handful and squeeze it into a small ball, about 25 mm/ an inch across.

(If it doesn't form a firm ball that you can roll in your hands, go back to the light soil information on Table 1!)

Hold the ball at 1.5 m/ 5' above a hard surface. Drop it. What did the ball do?

Flatten?

Pick it up and look underneath.

Did it leave a wet spot? Then your handful was too wet. Mix some drier and try again.

Crack but stay in one piece

Split into 2 or 3 pieces

Shatter into more than 3 pieces

Repeat this test a few times to see how the soil performs most of the time.

RIBBON TEST:

The stronger and more bendable a clay is, the more problems it can give you when you build. This test shows how plastic clay is (Schoeneberger 2-53)

Knead moist soil well. Remove grit. Roll it on a flat surface into a 6 mm, a 4 mm, and a 2 mm diameter roll. Cut all the rolls off at 40 mm long.

1. Does the 6 mm roll stay together if you hold it by one end?

   No- if it falls into pieces, it is not a plastic clay. Good!

   Yes- if it stays in one piece, it's a little plastic. Probably safe to build on. Do the perc test.

2. Does the 4 mm diameter roll stay together when you hold it by one end?

   Yes- the soil is plastic. Do the perc test.
   Do the shrink test to see how expansive it is (see p).

3. Does the 2 mm diameter roll stay together when you hold it by one end?

   Yes- this is a very plastic soil.
   This soil is very likely to have expansion problems. It probably will not soak water in well at all, unless there is a less plastic layer of soil below.

   Do the shrink test to see how expansive it is. (Read about Expansive clays page).

PERC TEST:

Percolation tests show if a heavy clay soil will soak up water well. Slow perc rates mean that wastewater disposal costs more. Perc rates that are too fast may mean that your soil won't cleanse wastewater before it gets into the groundwater. This can be a problem also.

You need a lot of water for this. Bring a truck with a large water container, or do it after a well is working on-site. The goal of this test is to see what the maximum continual rate is at which water can drain through the soil.

Dig a 30 x 30 cm (12" x 12") hole 60- 75 cm (24- 30") deep (or to the level of the bottom of soakaways or latrine pits that you plan to use). Place pebbles covering the bottom of the hole. Fill the hole up with water. Every time the water drops to 15 cm (6") from the bottom, refill it. Keep this going for at least 4 hours.

Then measure how many minutes it takes for the water level to drop 25 mm (1 inch). Keep refilling and writing down the time, until the water drops at the same rate twice in a row. This is the percolation rate of the soil.

If the soil is a very fast draining sand or gravel, the percolation rate may not slow down. The hole should be filled several times.

A perc rate of 30 minutes to an hour is long, and will require large wastewater treatment structures. In the US soil with perc rates of more than an hour are not used for wastewater.

Perc rates that are too fast are also considered problems. A very permeable sand or gravel may drain in less than 1 minute, and cannot treat wastewater without contaminating the groundwater below.

JAR TEST:

This test is good to see if light soils are well-graded or not. Well-graded means they contain a full range of particle sizes. Well-graded soils are stronger for holding up foundations than poorly-graded soils.

Heavy soils will cloud the material with clay and a jar test will not show you much. Clay particles are so small you need a microscope to see them. You can see silt particles with a magnifying glass.

Put two handfuls of soil in a clear jar. Add water to cover and a little more. Stir until it is all softened.

Shake it well. Then set the jar somewhere and don't touch it for 24 hours. The soil will settle in layers, the largest particles first.

If you see pebbles, small pebbles, grains the size of rock salt, and smaller grains, with 20% or less of material that is too fine to see the particles, this is a well-graded light soil.

Right: Poorly graded sandy soil has no coarse sand or aggregate.

SOIL BEARING STRENGTH

Standard bearing capacities of average soils range from 2.5- 4 ksf/ 17- 30 psi (Underwood, Chiuini 589). Many soils are not average.

Soils of low strength cause problems and expense for construction. Buildings that settle unevenly crack walls and foundations.

For one or two-story construction soils do not need to have very high bearing capacity, unless they are built in thick walls of heavy earthen or stone materials.

The soils that are most likely to require over-sized footings are poorly graded silts or sands or clays. Light and heavy soils are evaluated in different ways.

Sometimes soil footing problems result from a seasonal high water table, or weak or unstable layers buried beneath soil layers of adequate strength. Is there damage to structures in similar areas? Dig a little deeper.

24- 48 hours after a rain is a good time to test soil bearing strength. In a dry season, soils could be watered well once or twice and examined the next day.

Engineering tests of soil bearing strength are expensive. The alternative tests that follow may take some effort, but will be much cheaper than tests using fancy equipment.

STRENGTH TEST 1: Thumb or Fist Penetration in Clay or Silt Soils

Weak clays or silts are often easy to dig. If undisturbed and moist clay or silt soil can be penetrated by a fist or thumb, its bearing capacity is probably very low.

Dig a hole to test how hard it is to push into the side of the hole. Dig carefully- don't loosen or compact the edges of the hole. You probably should repeat the test at several locations to be sure that this problem soil is everywhere you need to work.

This chart shows about how strong (with a safety factor of 3) many ordinary claylike soils usually are if not compacted and without other unusual shapes (Gaylord 5-5).

Table 4: Approximate Bearing Strength for Heavy Soils

Consistency	Compressive strength		Characteristics	SPT N: # blows/ 30 cm
	Ksf	psi		
Very soft	<0.5	<3.5	Easily penetrated several inches by fist	<2
Soft	0.5- 1	3.5- 7	Easily penetrated several inches by thumb	2- 4
Medium	1- 2	7- 14	Can be penetrated several inches by thumb with moderate effort	5- 8
Stiff	2- 4	14- 28	Readily indented by thumb but penetrated only with great effort	9- 15
Very stiff	4- 8	28- 56	Readily indented by thumbnail	16- 30
Hard	>8	>56	Indented by thumbnail with difficulty	>3

Note: SPT values refer to Standard Penetration Test described on the next page.

Weak clays under normal footings may only start to settle after construction is finished, and 'significant settlement can continue for years' (Lindeberg 36-2).

Clays do not drain easily, and weight added to a weak clay will over time slowly squeeze moisture out from the soil pores, reducing the soil volume. A soft or very soft soil will need extra-large footings to hold a building up.

STRENGTH TEST 2: Pipe Penetration into Light or Sandy Soils

Sandy soil is most accurately tested on the site. If a promising site has sandy soil that seems to be fine or not very dense, do a simple approximate penetration test with a pipe and a hand-held sledge hammer.

Use a 50 mm/ 2 inch outside diameter pipe.

Drive it 300 mm/ 12" into the subsoil with a 15- 30 kg/ 33- 66 pound sledge hammer. Count the blows needed.

Table 5: Approximate Penetration Test for Bearing Strength of Sandy Soil

	Approximate Bearing Strength
10 blows or less	Very weak
11- 20 blows	Weak
More than 20 blows	Medium to strong

Since sandy soils aren't squeezed smaller with less water, if sand settles, it is more likely to settle immediately under the weight of the footing and wall. If this is slight or equal on all sides, little or no damage happens.

Sand gets weaker when wet with flooding or seasonal high water levels. With no flooding, dense sands that are coarse or well-graded are often strong. Densely packed grains and angular grains are stronger. A densely packed sand with clay or gravel probably has a good bearing capacity. Gravel and coarse sand in natural thick beds can have a safe bearing capacity of between 8 and 10 ksf/ 56- 70 psi (Avallone Baumeister 12-26).

Additional Tests

If these field tests or any surface conditions show there might be serious problems, call an engineer.

Right: Soldiers doing a cone penetrometer test

They may know the area already to compare the site in the local geology, or take soil cores from deeper levels to discover where and how serious soil problems are. Often they need a backhoe to dig 2 m/ 7' or more down to look for groundwater and changing soil layers. An engineer's fee will be cheaper than a ruined building.

Contractors can make a standard penetration test (SPT) with a 65 cm (25.5”) long piece of pipe and a 63.5 kg (140 lb) slide hammer. It evaluates deeper soil layers well. The SPT is best for sandy soils. It may be less accurate for clay and gravelly soils, but can assess them if laboratory tests are not available.

The pipe must have an outside diameter of 50mm (2”) and an inside diameter of 35mm (1-3/8”). The slide hammer should fall a distance of 76 cm (30”). Drive the pipe 15 cm (6”) into the ground. Then write down the number of blows needed to drive it in each successive 15 cm (6”). The number of blows is called the 'standard penetration resistance' or N-value (Wikipedia Standard Penetration Test).

If more accurate soil evaluations are needed when an engineer is not available, a dynamic cone tester can be made out of steel rod with a cone shaped tip according to standard specifications (Illinois Department of Transportation).

Chapter 3: Watch Out for Problem Soils

This chapter gives a quick introduction to unusual problems. Glance through the dry climate or humid climate sections. You are in a dry climate if there is an extended dry season, or precipitation is less than 40 cm (16") each year. Humid climates have more rainy than dry season, and receive more precipitation than 40 cm (16")

Problem Soils for Footings or Walls

Soils high on hillsides can be very stony, and areas with boulders or rock ledge may be hard to dig or re-grade. Exposed rock areas may complicate foundations. Most rocks have high bearing strength, but rock may need to be chipped to level surfaces. And footings may need to be fastened to the exposed rock ledge.

Sandy or silty soils of uniform particle size may also 'liquefy' during an earthquake. Other types of deep soft soils can also 'amplify' the effects of earthquakes.

Some poorly compacted materials do not provide a good base for buildings. This includes flood, landslide, and volcanic deposits as well as human debris.

Some low-lying soils that contain large proportions of plant material begin to compact when drained. Some low-lying soils of tidal areas can become highly acidic when drained, damaging structures and destroying plant life.

The stickiness of heavy clay soils make them harder to dig and re-grade. Construction in clay areas may be delayed by rainy periods, and plants may have difficulty growing. Some clays shrink and swell with moisture changes and cause serious building damage.

Hopefully your land will not have any of these issues. If some of the pictures look like your land, then read carefully and follow the links to find out more.

Low Bearing Strength Soils

In addition to problems from weak soils, any type of soil or rock that has been moved will settle after you build. Volcanic ash, and material deposited recently by floods or mudslides is often poorly compacted. Areas that have buried trash or agricultural wastes will settle as the materials decompose. Either re-grade these areas and methodically compact them little by little, or have footings that go through them to undisturbed soil layers (Underwood and Chiuini 577).

Landslides and Soil Creep

Land and mud slides happen on hillsides, but also damage sites below. They are often caused by adding or removing soil or structures on the toe of a slope, or by the wetting of a weak layer.

Sites prone to landslides: areas underlain by shale and other soft sedimentary rocks
steep areas of clay soil

Regions with many seeps, springs, and small bogs are often subject to landslides or soil creep because a deep layer of impermeable clay prevents water drainage, and this increased soil water reduces friction between the soil layers above the clay (Muckel 67).

Right: Lumpy hill shapes from repeated soil creep

Tree roots hold soil on steep slopes, and reduce soil moisture levels. Trees and vegetation should be untouched and grading kept to a minimum on slopes in areas known for landslides. Slopes where fire or drought has removed vegetation may also become subject to landslide.

Disturbing the base, or toe, of a slope can destabilize large amounts of soil and rock above. Sometimes small amounts of erosion at the base of a slope can begin much larger landslides.

Signs of landslide activity:
- Hummocky, dissected topography
- Abrupt changes in slope
- Trees or posts that lean
- Debris in valleys and stream channels
- Crescent shaped slopes seen on large aerial photos
- Crescent shaped changes in plant growth

Stabilization measures may include replanting, redirecting runoff and/or providing drainage (Harris and Dine 253-2). Many slides are too large for restraining structures of concrete. Bio-stabilization measures like brush layering have become standard practice using vegetation, natural materials like logs and brush, and geo-textiles.

The International Consortium on Landslides provides a world database of landslides at http://landslide-db.dpri.kyoto-u.ac.jp/landslide/simple.php which may give some indication of their frequency in different regions. More warning signs of landslides are available at http://landslides.usgs.gov/learning/prepare/.

PROBLEM SOILS OF DRY REGIONS:

Expansive Soils (Harris and Dine 255-2)

Soils high in plastic clays, and those located over some types of shale rock cause serious construction damage when their moisture levels change. Damage to buildings from expansive clay is common around the world.

Shales are layered rocks that weather and contain clay. They are commonly found in plains and on the sides of valleys, often on the best building locations in hilly or mountainous regions (Colorado Geological Survey).

Right: Cracked clay soil, New Mexico

Pure montmorillonite may swell up to 15 times its dry volume. Natural expansive clay soils seldom increase more than 50% of their volume, but any increase of 3% is damaging, and 10% causes severe damage to foundations, retaining walls, and other confining structures.

Buildings constructed during dry periods may become cupped as the soils around the building swell and force walls to tip inward during the next wet season. Construction during wet seasons may later experience down-warping as the exterior walls slant down and out after the surrounding soil becomes more dry than the soil beneath the building. Point leaks from water pipes can cause one-sided swelling.

Existing structures in the vicinity of a new building site should be inspected for signs of damage which could indicate expansive soils, like crack lines running diagonally upward from the tops of windows and doors. Cracks in buildings and bridges, and 'rollercoaster' roads and heaved or broken utility pipes are also indicators.

Several of these soil warning signs would indicate a serious problem with expansive soils:

Soft, puffy, popcorn appearance of dry clay soil
Very sticky wet soil
Substantial open cracks in dry clay soil
Lack of vegetation due to heavy, clay soils.
Soil that is very highly plastic when wet, but rock hard when dry

The problems of expansive soils are greater the higher the proportions are of expansive materials, the thicker the layers of expansive material, and the more fluctuation experienced in moisture levels. Soils that are 12% or more clay, and that have a high plasticity will be expansive.

Areas that have obvious dry and wet seasons receive more damage than areas where moisture levels stay constant. Sometimes even shade cast by buildings or soil drying from plants causes heaving because of differing moisture levels.

Construction can be done safely on expansive soils, but it will usually be more expensive. Buildings on expansive clays may need expensive spread footings, or grade beams on drilled pier footings. Floor slabs are often disconnected from footings to allow vertical motion and are placed over void forms that allow the soil beneath to swell without raising the floor.

Foundations of loose rock may allow clay to expand into the spaces between rocks with less damage than a solid concrete foundation. Gravel can be used in strong plastic mesh tubes, or larger rock can be wrapped with plastic mesh fencing.

Buildings without basements are easier to modify for expansive soils than structures with sub-grade sections. Retaining walls are especially susceptible to damage. Retaining walls can be built if the expansive soil is covered with a waterproof layer, has extra drainage above, and the wall is completely backfilled with a different non-expansive soil.

Stabilization plantings growing through fascines, brush layering, coir logs, and/or other bio-engineering techniques may be a more economical choice than retaining walls, although they require more ground area.

Another approach seeks to keep moisture levels consistent. Solid pavement one meter wide that pitches down from the building it surrounds may reduce fluctuation of soil moisture levels under the exterior walls. Consistent irrigation has also been used. But with these strategies underground utilities may require flexible connections to allow the pipes further from the house to be raised and lowered with the seasonal soil changes.

Plants should be kept 1.7 m (5’ 6”) from a building wall, and trees at least 5 m (16’) away. Very careful treatment of surface runoff is also necessary to prevent water soaking into different areas during severe storms (Colorado Geological Survey).

Subsidence: Hydro-compacting Soils

These difficult soils are located in deserts or dry plains at the base of hills or mountains.

Material deposited by short but intense flash floods can dry quickly without settling. These collapsible soils occur in fan-shaped layers where narrow valleys widen out. They are very porous and may be 40 – 60% empty voids. Often they form thick deposits located below more ordinary soil.

When buildings are placed above collapsible soils, or the soil moisture level is increased, significant settlement can occur. Any very low density soils are cause for concern, or these signs in undeveloped plains below steeper regions:

- Small depressions in areas of fan deposits not associated with grading
- Sinks where rainwater is gathered or retained (in areas without soluble soil or bedrock like limestone)

In developed parts of plains below steeper regions these signs should be investigated:

- Ponding and poor surface drainage.
- Curving cracks in soil or asphalt
- Misaligned or separated joints in concrete slabs and curbs.
- Tilted structures
- Evidence that cracks in structures or roads have been repaired.

Building footings cannot rest on these kinds of layers, and septic systems must be located far from buildings. Piles or posts must extend below the un-compacted soils to an undisturbed layer that has a good bearing strength.

One construction strategy is to pond or inject water or place an excessive load of fill to induce collapsing before construction begins.

If the collapsible layer is not too deep, another option is to excavate and repack the material (Muckel 62).

Radon Gas

This naturally occurring radioactive gas associated with uranium and radium occurs in glacial till and granitic rocks, and can be transmitted in groundwater.

In tightly sealed buildings it can build up to levels that may cause lung cancer. Radon gas is higher in basements or where showering with contaminated groundwater introduces the gas.

Although sealed buildings and basements are uncommon in hot regions, buildings in rocky areas that include sub-grade construction could be tested for radon content, especially if the building will be closed sometimes for air conditioning.

Chemical Residues: Salt, Anhydrous Salts, and Gypsum

Some bedrock in dry regions contains chemicals which are soluble. If groundwater is highly mineralized, or there is any record of caves in the region, sinkholes may be a possibility (see under *Subsidence: Sinkholes* in the *Problem Soils of Humid Regions* section below). Soils of bedrock areas that contain gypsum, table salt, or anhydrous salts may also contain these chemicals, which can prevent or limit plant growth and damage structures.

Right: Salty soil with white surface deposits and discolored runoff

Some agricultural regions are also developing areas of salty soil. This has been caused by modern agricultural practices that may not be common in developing areas, including using plant-killers to remove weed plants. This allows more water to penetrate past the root zones, concentrating natural salts in field runoff. In some areas where field runoff collects or subsurface drainage emerges, salt concentrations have become high enough that white residue can be seen, and standard crops cannot grow.

Salty soils can cause damage to structures as well as limit agricultural use. Saline seepage can only be limited by reducing water flowing into the soil above or using salt-tolerant plantings that capture soil moisture and reduce seepage (Muckel 83).

Soil heaving and property damage has also been linked to the presence of special salts in the soils of mildly saline lakebeds in arid inland regions. When the temperature drops past a certain level, soils that contain anhydrous salts increase suddenly in size. They seem to require water to enable the chemical process that causes expansion, and damage can be prevented by avoiding irrigation, treating wastewater and storm runoff at some distance from structures, and monitoring for utility leaks (Muckel 11).

If as much as 10% gypsum is naturally present in a soil, it can dissolve and cause the soil to collapse. Gypsum can resemble white sand, but reduces the available soil fertility for plants, and deprives them of soil moisture as well. It is also caustic to structures. Abundant gypsum can cause a barren 'badlands' appearance (Muckel 58).

Vegetation is important to provide shade, reduce wind and wind-blown dust, and to moderate humidity and soil moisture in warm regions.

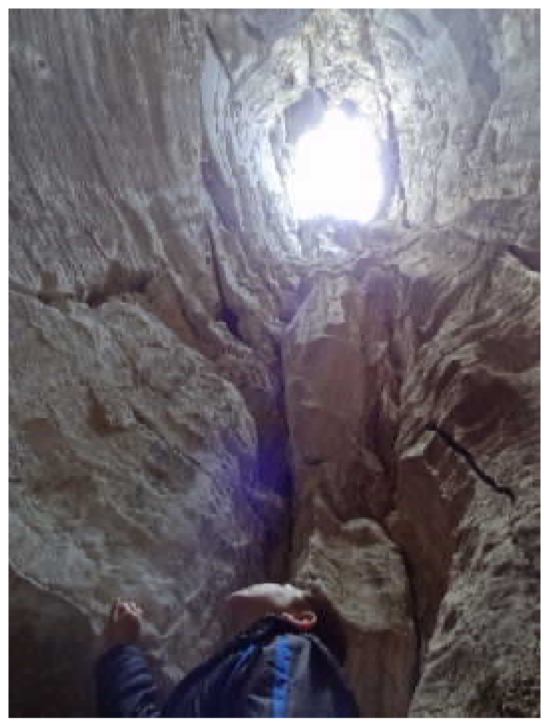
If site soils do not already support a wide variety of plants, use a simple growing test with the soil. Plant one or two quick-sprouting types of seed like radishes in soil samples, to evaluate how difficult it may be grow plants there after development.

PROBLEM SOILS OF HUMID REGIONS:

Subsidence: Organic Soils

These problem soils are usually saturated peat or muck soils found in low-lying areas.

Subsoil does not decay. But organic material found in topsoil and peat gradually decays when exposed to air. Soils with high proportions of organic plant materials begin to slowly subside as the organic matter decays after drainage channels allow damp soils to drain.



Above: Rich peat soils continue to subside, including under the road

Right: Narrow sinkhole through limestone in Kentucky

These soils will compact rapidly during the first few years after draining. Subsidence often continues at between 1 and 3 cm (1/3 to 1 inch) each year. These soils are the reason for much of the vulnerability to flooding in New Orlean and in Holland.

Subsidence rates can be reduced (but not stopped) by allowing the soil to be saturated for longer portions of the year. Buildings require expensive piles or posts that extend below the organic material to a layer that has a good bearing strength. Connections to utility lines must also be flexible (Muckel 87).

Subsidence: Sinkholes

Evidence of hummocky topography, or water flowing underground are cause for concern in areas with subsurface mines, lava tubes, or caves, such as karst regions.

Karst is a type of landform found on limestone or dolostone bedrock, which includes few or sinking streams, caves, bedrock sculpted by solution, and dolines or round depressions. Humid tropical regions also include tower karst, where isolated steep walled hills are surrounded by a low-lying plain, and cockpit karst, where conical hills surround star shaped depressions.

Regions that were covered by glaciers may have soils deposited above these characteristic shapes, but still have these groundwater systems below grade (Worthington Groundwater). See the world map of carbonate rocks in the Appendix.

Regions with highly mineralized groundwater may also be areas of concern because similar sinkhole processes occur in areas with halite, anhydrous and gypsum bedrock, which are more common in drier regions (Hollingsworth).

It is hard to predict where a sinkhole may appear, because they are often the result of very gradual subsurface processes that continue for long periods without visible effects. Subsidence has been caused also by the withdrawal of oil or gas in the past, but current extraction techniques reduce this risk by replacing materials with water (Muckel 65). There is some evidence that heavy clay soils above caves, lava tubes, or bedrock with solution channels may be somewhat more risky places to build than lighter soils.

In some parts of the world areas with shallow soil deposits above soluble bedrock tend to gradually produce shallow and broad 'solution sinkholes'. Areas with deeper sandy soil tend to develop few and small 'cover-subsidence sinkholes', which also develop gradually. In Florida, US, areas with less permeable clay soils do not produce many sinkholes, but 'the ones that occur are deep and wide. These types of sinkholes are referred to as “cover-collapse sinkholes” because cohesive layers of sediment collapse into underground cavities when they form. The abrupt formation of sinkholes may follow extreme rain producing events...' (Florida DEP).

Karst or carbonate bedrock areas are generally difficult to develop well. Wastewater treatment might need to be more carefully planned because bedrock solution channels are common. Karst regions often have generous supplies of groundwater, but they are vulnerable to contamination. In selecting land for development, sites with thinner or lighter soils may be more stable. But thinner soils will definitely provide less wastewater cleansing. Wastewater systems may require deeper soils than needed in areas where solution channels are uncommon.

Karst areas have been targeted worldwide for environmental preservation because their less acidic soils often support rare plants and animals. In addition these soils tend to form slowly and only support a narrow variety of plants. They are easily damaged under the drought and flooding cycles often caused by their subsurface drainage. Badly eroded karst farming areas may not recover even 20 years after damaging factors cease (Daoxian).

Expansive Soils

Expansive clays are also found in humid regions. They will require sturdier foundations and retaining walls, as well as great care with grading for drainage. These soils are not as destructive in areas that have rain all year long as they are in regions with a dry season (Harris and Dine). See below under Problem Soils of Dry Regions.

Expansive soils may be available cheaply in a town under development. Although undesirable under footings or as a wall material alone, they can be used as a construction material with agricultural waste like straw. Light straw clay (LSC) is used as a thermal insulating infill wall material in areas without too high levels of termite activity.

Chemical Residues: Acid Sulfate

Sediments and dredged material from the tidal edges of seacoasts are often high in iron sulfides, a material responsible for much surface water pollution from mining.

Right: Squares of barren acidic sulfate soils near mangrove forests in Guinea Bissau

Soil with this type of chemical is not very common. But the problems it causes when it does occur are very severe.

After this chemical is exposed to oxygen, it changes from neutral to highly acidic within a few months. It is highly toxic to plants and animals. It causes erosion because it kills plants that stabilized streams wherever water runs through it. Aluminum and iron may be released into the environment. The soil can release sulfuric acid in strong enough concentrations to damage metals and concrete in structures. '

Improper drainage of acid sulfate soils can, in effect, create an acid wasteland that is very difficult to reclaim.

Because machines enable larger land shaping operations than in the past, these soils are sometimes deposited on coastal sites. Land reclaimed from the sea may contain significant amounts. Because of the dark color of sulfidic sediments, they are sometimes confused with topsoil and mistakenly spread as a soil amendment on neighboring land.

The soils commonly occur in nearly level, low-lying areas that are attractive sites for drainage and construction (Muckel 7). It is much simpler to avoid disturbing this type of soil than it is to repair the damage it causes.

PROBLEM SOILS OF EARTHQUAKE HAZARD AREAS:

Quake Liquefaction Risk

Earthquakes can cause sand or silt to liquefy if they are saturated with water. Vibration causes the voids in the material to collapse, or the material to behave as a fluid and lose its bearing capabilities. 'Deposits most susceptible to liquefaction are... sands and silts of similar grain-size (well-sorted) in beds at least several feet thick...(Wikipedia Soil Liquefaction).

These kind of soils are common along riverbeds, beaches, dunes, and areas where wind-blown silt (loess) and sand are located.

If this type of soil experiences an earthquake, the bearing strength drops suddenly. Buildings can tilt or sink. Vehicles and site structures will be pulled underground during the vibrations.

The greatest dangers from liquefaction occur in marshes, wetlands or along shorelines where these soils are more than 60cm thick. Some areas may only have high water levels during part of the year, but earthquakes during this time can cause massive damage. Urban areas with dense construction near water bodies, and areas of reclaimed land are particularly liable to liquefaction (ibid).

Other results of quake vibration can include lateral spreads and flow failures. Lateral spreading is most common in soils deposited in flood plains, and can cause movement of 3- 5 m (10- 15') on nearly flat areas. Flow failures can be catastrophic, because large blocks of intact materials are moved on top of a layer of liquefied materials. They may be up to 1.5 square kilometers (0.6 square miles) , and can move at great speed. They usually involve layers of saturated sands or silts on slopes greater than 6 or 7 percent.

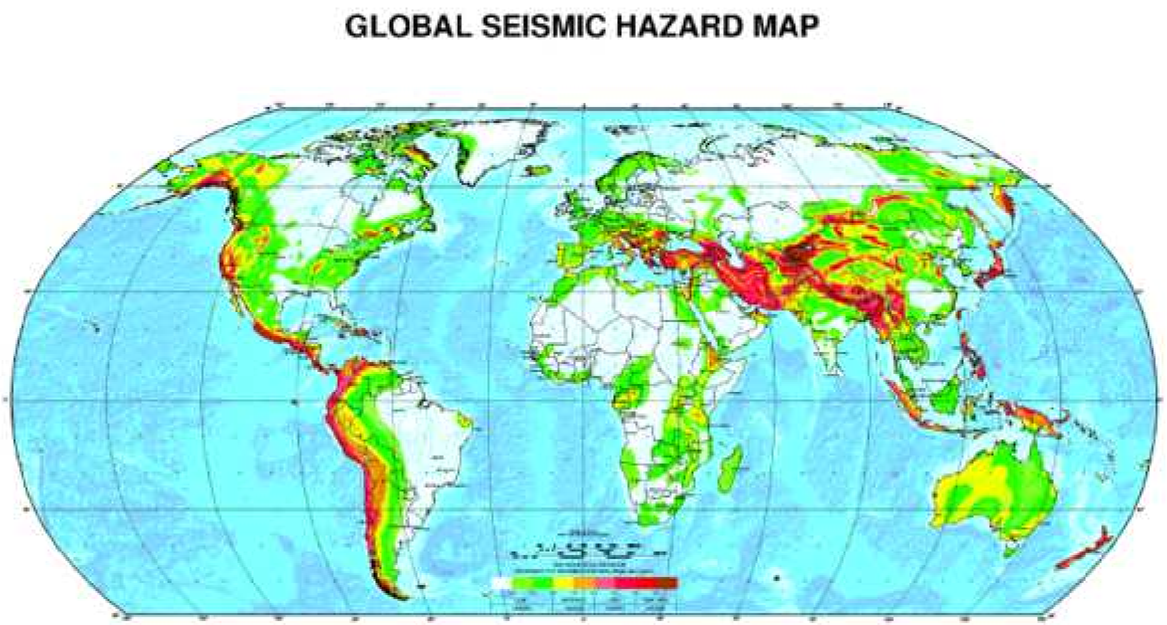
Some types of more expensive construction can be safe in quake hazard regions without saturated soils. These include lighter buildings with more flexible connections or squatter buildings with heavier reinforcement. But because saturated soils can undergo sudden loss of bearing strength and/or lateral movement, it is harder to design safe structures for these areas.

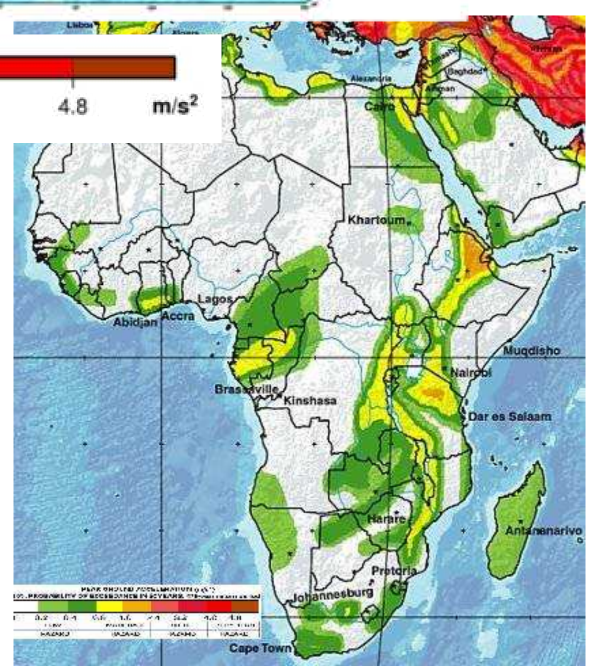
One strategy is to attempt to improve the strength, density, and/ or drainage characteristics of the soil. If the susceptible soil is deep, (some extend as deep as 30 meters) modifying the upper 2 or 3 m (6- 10') of soil may not be adequate (Muckel 71).

Appendix: Regional Hazard Maps

Seismic Hazard

The first hazard to check is seismic risk. The US Geological Survey's GSHAP maps (shown below) are somewhat out of date, but a quick glance can tell you whether you need to do further research. White or green denote areas of very low seismic risk. Yellow or orange are moderate risk. Red is high, and brown to black are very high risk.



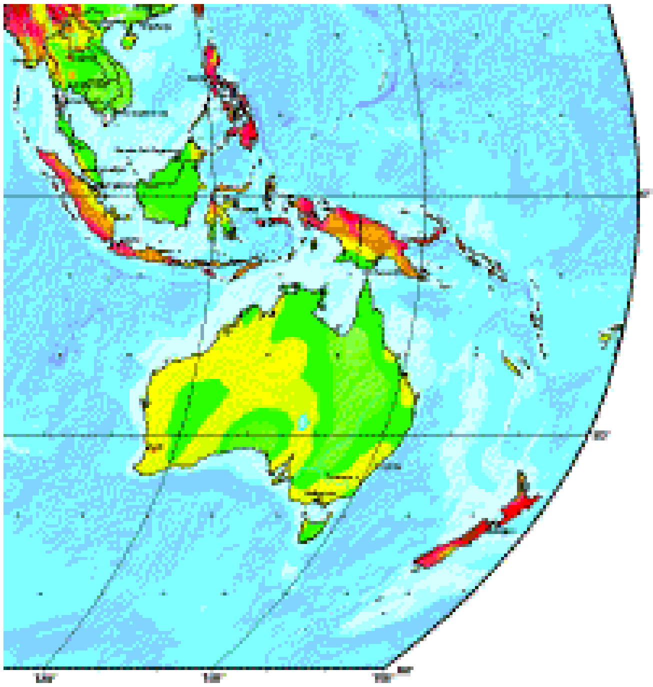


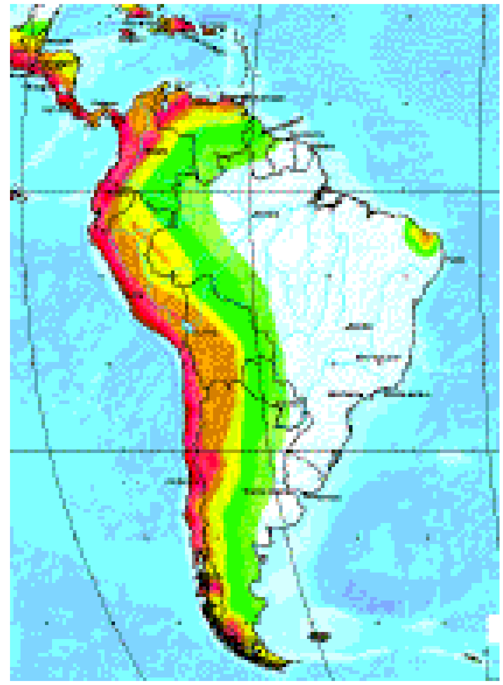
Regional maps can help you to see which level of risk the GSHAP shows for your area. See images at right and on the following page.

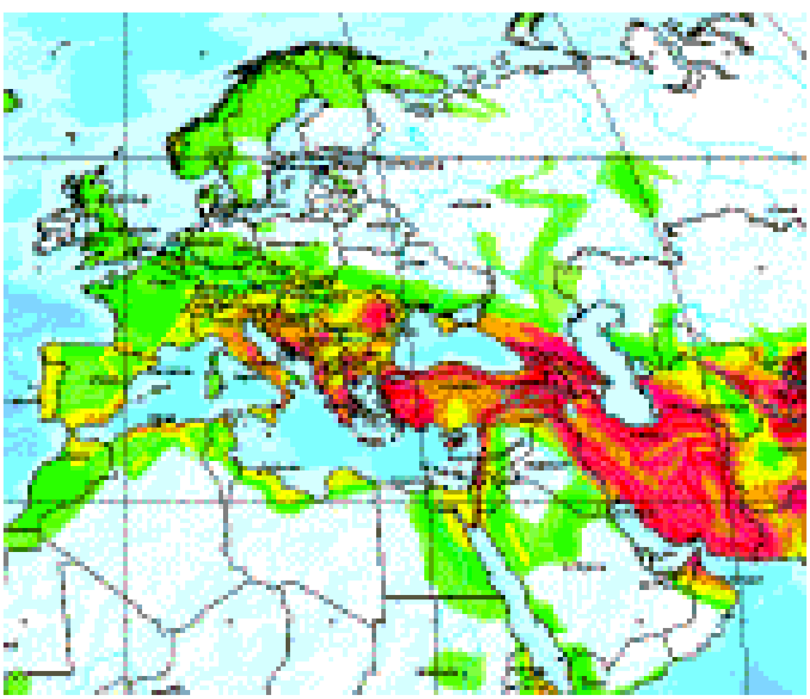
Risk is evaluated as the horizontal force compared to gravity that has a 10% chance of occurring in any 50 year period.

White and light green areas are low risk, although at 0.3 g forces vernacular earthen buildings are often damaged.

Dark green and yellow are moderate risk areas. Orange and red to brown are increasing high and very high risk levels.







Higher risk areas are likely to experience larger earthquakes sooner than low risk areas. Yet the costs to build safely enough to survive any possible event may prohibit building.

Aid planners should try to improve on the currently accepted level of construction quality. Yet often it is important to let local users gain real or assumed ownership of a building. Construction technologies that are so expensive and/ or complex that local clients could never conceive of building tends to prevent this.

People may not have heard that they live in an area with seismic risks. They may have a cultural background that does not plan for future possibilities, and no experience with this way of thinking. Ask whether their area has had problems from earthquakes in the past. Sometimes showing them information about past events in their area can be helpful.

If a project site is located in areas shown on the GSHAP maps as yellow, orange, red or brown, it is critical to know the exact level of risk. Look for hazard maps developed by the national government.

Types of Buildings for Seismic Risk Levels

Engineers can give you much more accurate information than what follows. Also, please realize that the shape and locations of openings can make buildings unsafe or safe for earthquakes.

Any values less than 0.3 indicate that low-strength buildings like local earth and unreinforced brick or stone should be safe.

Values between 0.3 and 0.6 indicate that careful planning and some reinforcement can allow you to build safely with low-strength materials. In New Zealand, some basic plan requirements for two story moderate size buildings have allowed the use unreinforced earth. For this level of risk New Zealand requires a good reinforced concrete footing and a strong wood or concrete bond beam on top of the building. New Zealand is mentioned, because their code has a unique system for designing buildings without engineers. Severe recent earthquakes have also confirmed that their code provisions save buildings.

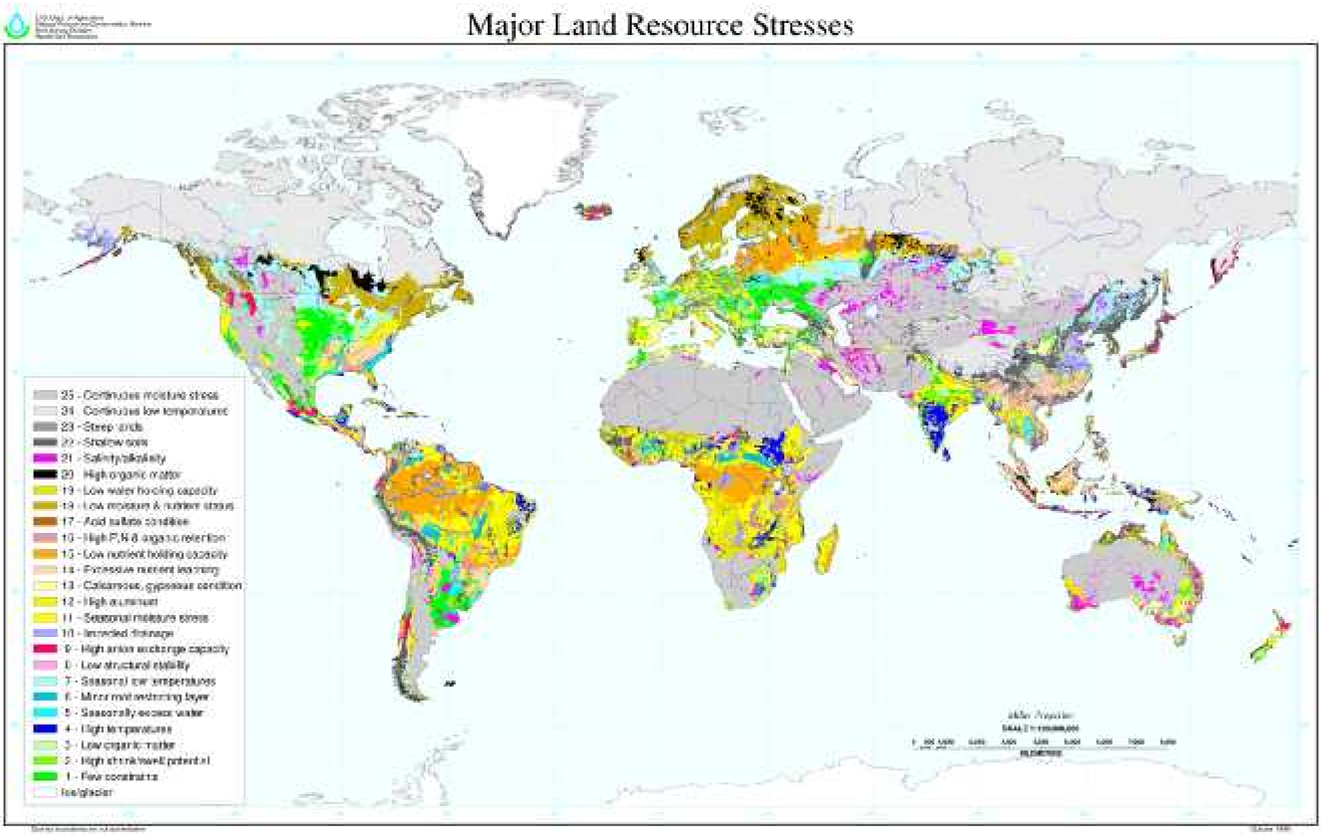
Values greater than 0.6 show that light-weight or stronger reinforced buildings are important. In these areas it's worthwhile to do a little research and get some help.

Wood buildings with light roofs that are built carefully resist earthquakes well.

Confined masonry is a cheaper way to reinforce bricks or compressed earth blocks (CEB) than the standard western reinforced concrete building. There are many ways to reinforce other materials.

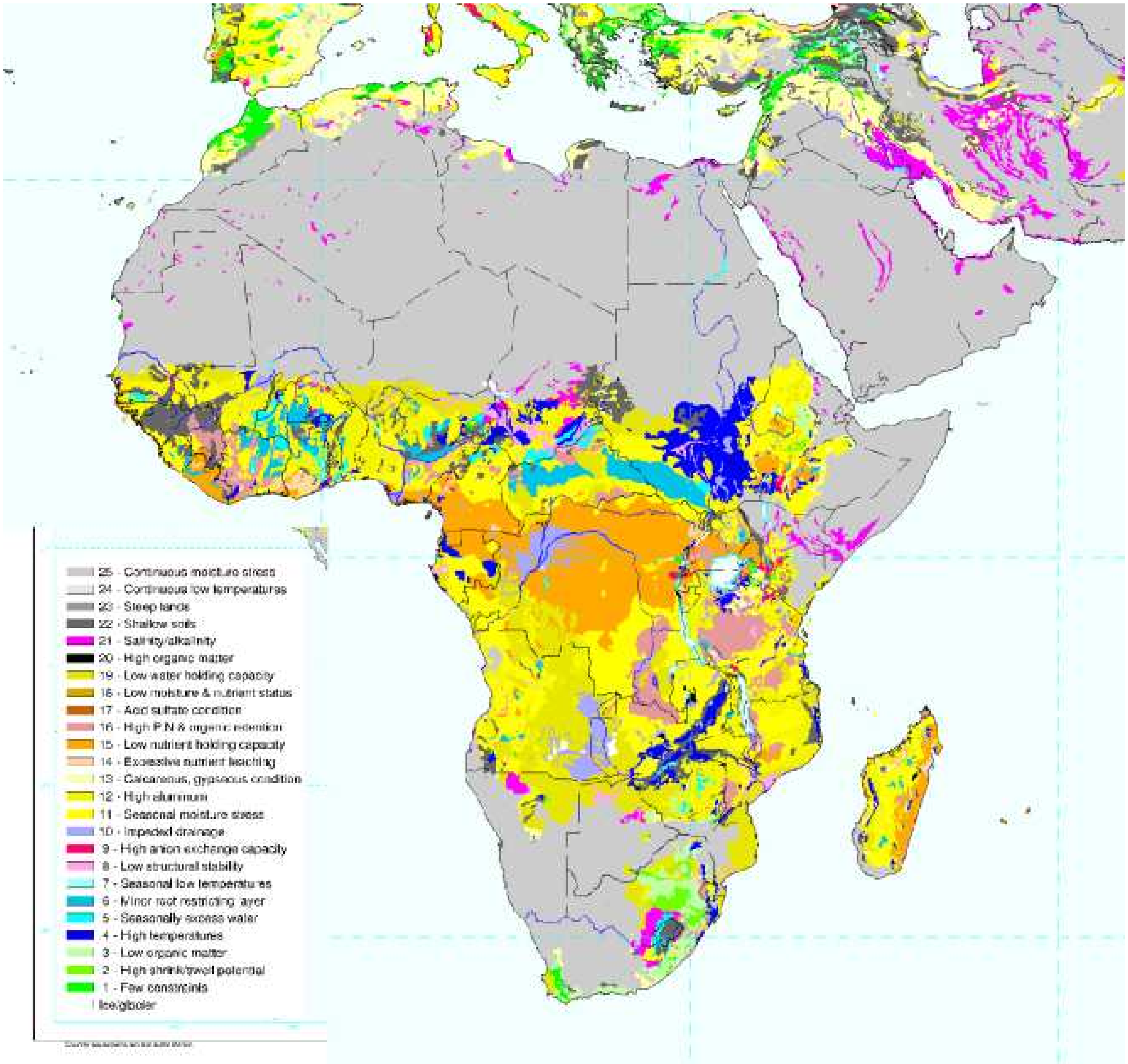
Other Hazards

What is the limiting factor in the area of your project? This information may be so basic to life for local residents that they wouldn't think of mentioning it.

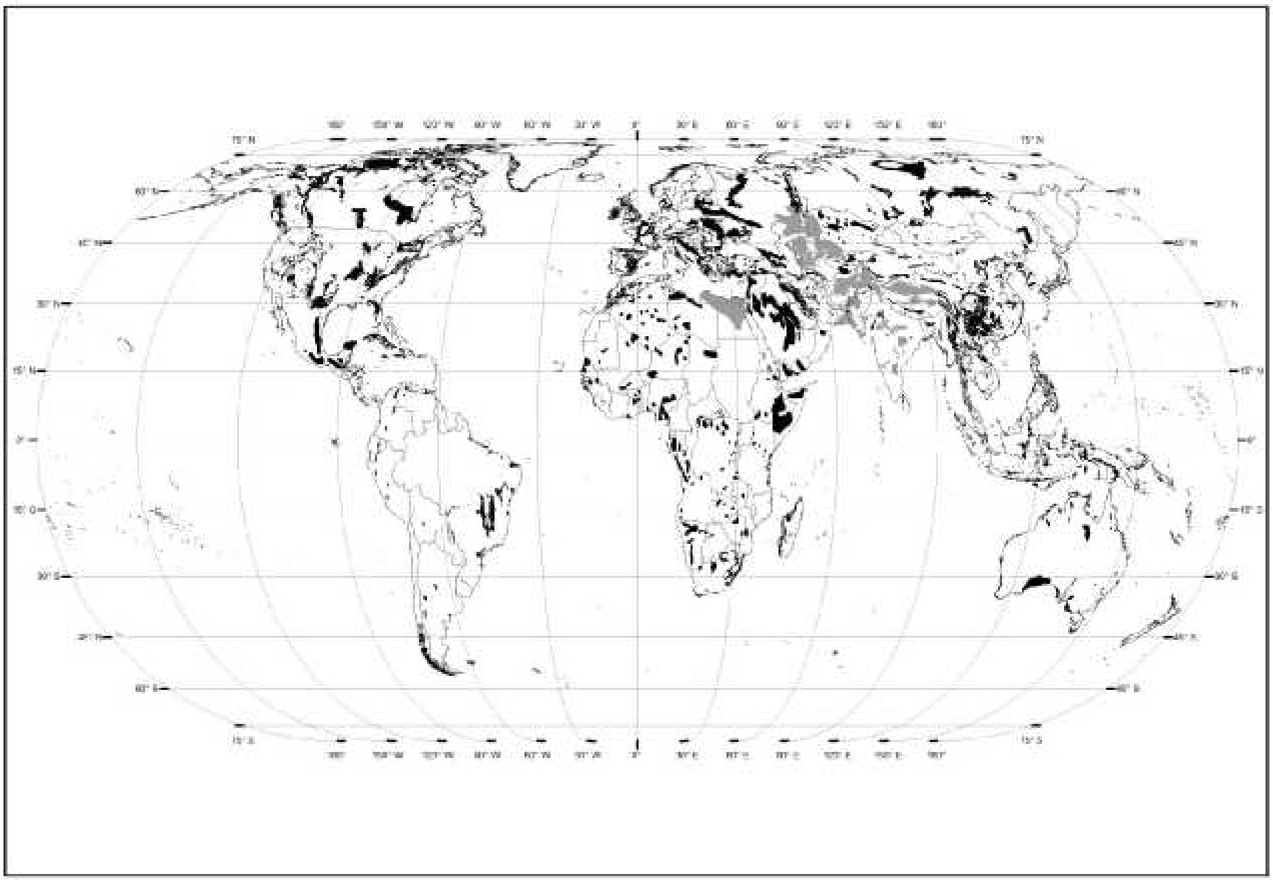


Is there enough rainfall for crops? Is the heat so intense that people stay inside during sunny days? Are rains so heavy that buildings are often damaged? Are soils so hard that they can't be dug?

The map above from the US Natural Resources Conservation Service (NRCS) is available in a large file size online at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/use/worldsoils/?cid=nrcs142p2_054020. Have a glance at this information. More detailed maps of regions may be available online, like the map of Africa on the next page.


25 - Continuous moisture stress
24 - Continuous low temperatures
23 - Steep lands
22 - Shallow soils
21 - Salinity/alkalinity
20 - High organic matter
19 - Low water holding capacity
18 - Low moisture & nutrient status
17 - Acid sulfate condition
16 - High P N & organic retention
15 - Low nutrient holding capacity
14 - Excessive nutrient leaching
13 - Calcareous, gypseous condition
12 - High aluminum
11 - Seasonal moisture stress
10 - Impeded drainage
9 - High anion exchange capacity
8 - Low structural stability
7 - Seasonal low temperatures
6 - Minor root restricting layer
5 - Seasonally excess water
4 - High temperatures
3 - Low organic matter
2 - High shrink/swell potential
1 - Few constraints
Ice/glacier

Limestone-derived bedrock can cause difficult conditions for plant growth, as well as occasional sinkholes. When surface water trickles into underground passageways, once in a while it decays the subsoil and rocks in a large area. You may want to have an idea of whether that might happen in your region. The map of carbonate rock occurrence below may give you a hint of whether to look for a more detailed map for your areas.



Karst maps are available online from the University of Auckland, New Zealand website at www.sges.auckland.ac.nz/sges_research/karst.shtm.

Any large scale map may be helpful if it gives an outsider some clues about life in a region. Climate averages, rainfall intensity, hurricane winds, natural vegetation. Don't forget that simple topography is also important. Do your research before you recommend buildings on a visit to a distant location.

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Catholic Relief Services developed the arborloo- see http://crs-blog.org/world-toilet-day-arbor-loos-do-double-duty/. More Arborloo information is online at http://www.sswm.info/category/implementation-tools/water-use/hardware/toilet-systems/arborloo#reference_book7934

Peepoople.com has simple information on the PeePoo aimed at users. www.peepoople.com

Soil is an NPO that has been working with the ecosan composting toilet in Haiti. See information on https://www.oursoil.org/

Sustainable Soil and Water Management has information about many sanitation issues at www.sswm.info , including the Arborloo, the PeePoo sanitation systems, and more

Tippy Tap.org has a simple how-to pdf for this simple hand-washing station at http://www.tippytap.org/wp-content/uploads/2011/03/How-to-build-a-tippy-tap-manual.pdf.

Engineering Ministries International has many resources under their volunteer links. Their Developing World Design powerpoint is a great place to start. Look through all of their architectural and engineering resources at http://www.emiworld.org/volunteer_resources.php

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