Site Assessment Guidelines for Mangrove Rehabilitation in Bac Lieu Province, Vietnam

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Adaptation to Climate Change through the Promotion of Biodiversity in Bac Lieu Province, Vietnam

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1 Introduction

Mangrove afforestation in one form or another has been carried out for at least a century, in the first place as part of sustainable silviculture for timber and wood production in the late 1800s and early 1900s. Since at least the early 1970s, planting mangroves for shoreline stabilisation, coastal protection and general ecoystem restoration has also become increasingly common. Unfortunately, many efforts to restore or rehabilitate mangroves have not been successful, often due to unfavourable hydrology or other site conditions, or a mismatch between the site conditions and the species selected for planting. All too often, however, the particular reasons for success or failure are difficult to determine because of the lack of a sound initial assessment of site conditions and/or a lack of subsequent monitoring of site conditions, survival and growth.

There is always some risk that efforts to restore or rehabilitate mangroves will fail, but this risk of failure can be minimised by adopting 'best-practices', which amongst other things include undertaking a careful site assessment prior to rehabilitation or planting, in order to determine whether or not a site is plantable or restorable, and what kinds of site preparation or modification might be needed to improve the chances of success.

This manual is designed to give practical guidelines for site assessment **BEFORE** formulating a planting or restoration strategy. However, many of the techniques it describes are also useful for monitoring the site after planting. The primary focus of the manual is on Bac Lieu Province in the Mekong Delta, but it should also have wider application throughout the delta. It does not cover questions of how to formulate a site-specific planting or restoration strategy, what site preparation or modification might be needed for particular conditions, or which species should be planted. These questions with case studies will be considered elsewhere.

Broadly, the purpose of a site assessment **before** formulating a planting strategy is to:

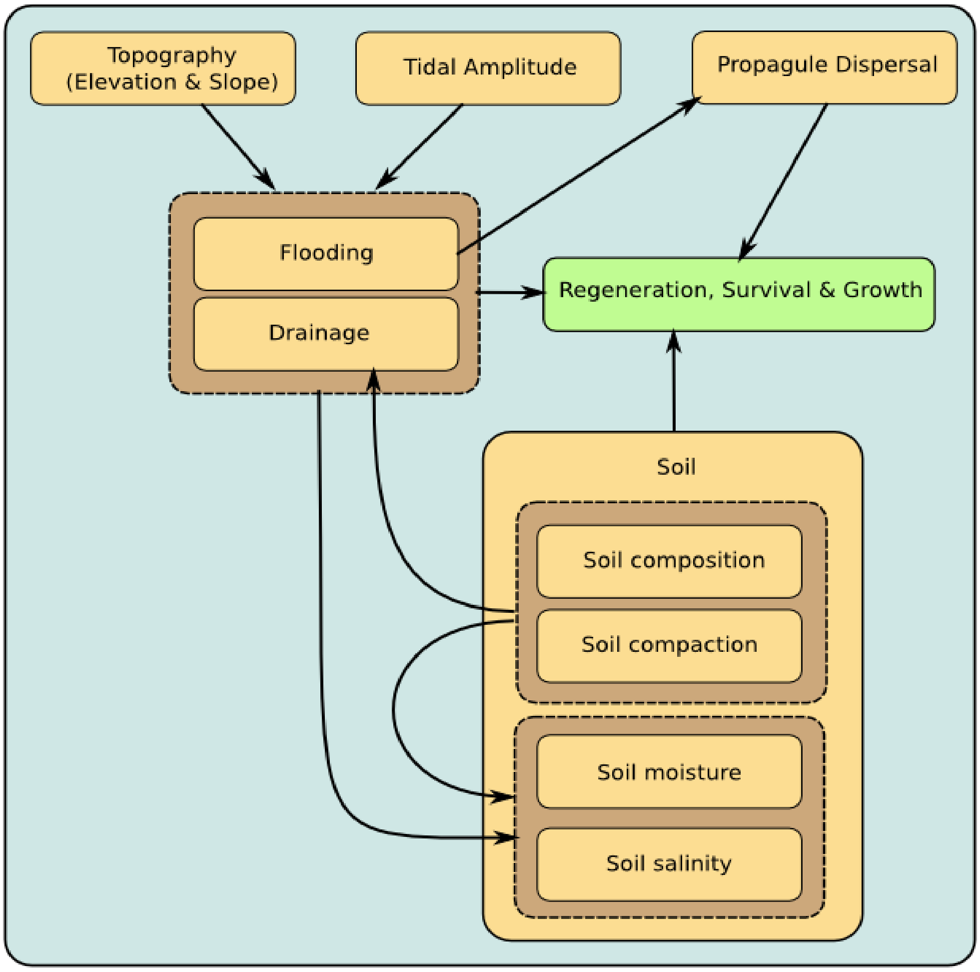
- Provide a sound technical basis for developing an effective site rehabilitation strategy;
- Provide baseline information against which to monitor and evaluate the success or failure of site rehabilitation. Without this it is impossible to learn from mistakes and successes;
- Demonstrate that rehabilitation has been carried out in a robust and technically competent way (best practices).

The term elevation will be used in these guidelines to refer to the height of a site or another object above mean sea level.

2 Site Assessment

Mangroves are usually restricted to intertidal areas that range in elevation from about mean sea level up to the point reached by the highest spring tides. Some mangrove species are better adapted to growing in areas that are frequently flooded by tides (and are perhaps less well-drained), whereas others are better adapted to areas that are flooded less frequently and are better drained. This often leads to a clear zonation of species in areas with different elevations (for a general synthesis see Giesen et al., 2007; and Clough, 2013). Thus, the frequency of tidal flooding and the drainage characteristics of a site are two of the most important factors that need to be considered in assessing a site for rehabilitation and in selecting the most appropriate species to plant.

With this in mind, the diagram on the next page shows the key site factors that need to be considered in a site assessment, and broadly how they interact to influence mangrove



The main site factors that need to be considered in site assessment

regeneration, survival and growth. Site topography (elevation and slope) and the tidal amplitude (difference between high and low tide) mainly determine the flooding and surface drainage characteristics of a site, whereas the physical properties of the soil mainly influence water infiltration, subsurface drainage and root penetration. All these factors also influence soil salinity (see Section 3).

Although not shown in the diagram, the presence and height of a water table can also play a role in the survival and growth of mangroves. The importance of a water table within the rooting depth of mangroves, and the lateral and upward transport of water in areas not flooded by the tide is illustrated by their growth on rarely flooded embankments inside shrimp ponds in Ca Mau and elsewhere. In this case the water requirements of mangroves are presumably met by water that moves laterally from the pond into and through the subsurface soil of the embankments to maintain a water table at about the same level as the water in the pond.

While the importance of tidal flooding and good surface drainage are widely appreciated, the effects of soil structure and degree of compaction on the establishment and growth of mangroves are often neglected. The roots of most plants cannot easily penetrate heavy, compacted, clay soils. This is a serious problem for mangroves as their roots are thicker and softer than those of many other trees because of their outer spongy tissue

layers that are needed to supply oxygen in anaerobic soils. Hard, dry, compacted clay soils present a problem for root development in all mangroves, but particularly for *Rhizophora*, which has very soft, spongy underground roots that are relatively fragile. Furthermore, soil salinity increases as a mangrove soil dries out and becomes compacted, in much the same way that saltwater becomes more saline when water evaporates from a salt pond.

2.1 Assessing the Site Visually

Check a recent satellite image or aerial photograph if one is available. This will give an overview of the site. If necessary, record the coordinates of special features such as visible embankments, drainage lines, isolated trees or patches of trees in an otherwise barren landscape, sand ridges, areas of standing water. This will be helpful when you carry out the on-site inspection. A summary check list for visual assessment of high intertidal sites is given in Annex 1 .

2.1.1 On-Site Inspection

For this you should have:

- A GPS to record the coordinates of features of special interest.
- A camera to provide a photographic record of features of particular interest.
- A paper copy of a recent satellite image or aerial photograph.
- One or two 50m or 100m fibreglass surveyors tapes to measure distances between key features.

Indicators of irregular tidal flooding

- A hard, dry (and often cracked), compacted soil surface in the mid to late dry season.

Two examples of more elevated areas with irregular tidal flooding, showing the cracked relatively hard surface typical of such areas. The area shown in the photo on the right has has a wetter sticky surface, indicating that it has been flooded recently.

- The absence of crab holes - crabs do no usually dig burrows in hard, dry or compacted soil. They prefer to dig burrows in softer, wet soil. Generally, soil aeration and drainage increase with the number of crab burrows.

- The absence of significant mangrove canopy cover.

A satellite image of a barren former shrimp pond with mangroves mainly restricted to old canals

- Poor survival and growth of any survivors from previous plantings. This can be due to a number of factors, including poor root development, a lack of soil moisture, high salinity (salinity increases as the soil dries out), and high soil surface temperatures (often 5-10°C higher than a wet soil) that can stress or kill the roots.

Indicators of poor drainage

- Standing water or undrained areas after tidal flooding or heavy rain.

Lumnitzera racemosa on a poorly drained site (left) and on a better drained site (right). Note the low spreading canopy and swollen, corky stems of trees on the poorly drained site, compared with the more typical growth form on the better drained site.

- Very low, spreading tree canopy (illustrated above for *Lumnitzera* and below for *Rhizophora*).

- More numerous and thicker, spongy stilt roots in *Rhizophora* (illustrated below).

Rhizophora in a more or less permanently flooded pond showing the low spreading canopy and extensive development of thicker, spongier stilt roots, both typical of poorly drained areas. These plants are 4 years old.

- More numerous pneumatophores in *Avicennia*.
- Swollen, corky lower stems with large lenticels in *Ceriops*, *Lumnitzera* and other species without stilt roots or pneumatopores (illustrated below – on the left, *Ceriops*; on the right, *Lumnitzera*).

Examples of the thickened, corky lower stems of *Ceriops* (left) and *Lumnitzera* (right) in poorly drained areas. The photograph of *Ceriops* clearly shows the fissures and large lenticels that are characteristic of oxygen deficient, waterlogged soils and poor drainage. These would also be evident in a closer photograph of the *Lumnitzera* stems.

Other indicators

- **Lumpy, pitted or channelled soil surface** - these are fairly common features of low intertidal and some mid intertidal areas with persistent erosion or alternating seasonal cycles of accretion and erosion.
- **Absence of pneumatophores** - the absence of visible pneumatophores in *Avicennia* communities, together with soft mud, suggests that the pneumatophores might have been buried recently by sediment. If the trees have not already died, then they are likely to do so soon. However, pneumatophores also tend to decompose rapidly, so some caution needs to be exercised when interpreting a lack of pneumatophores.

- **Tree lines** - tree lines, often of *Rhizophora*, usually indicate areas where the soil is softer and wetter. They are common along abandoned canals from old shrimp ponds. In many cases, these abandoned canals have been infilled with sediment, but they remain wet because the soil is less compacted and water can move through it more easily. Tree lines in abandoned canals across a site suggest that the site can be planted after modification of the hydrology to improve flooding and drainage.
- ***Sesuvium*** - the saltmarsh species *Sesuvium* is common on more elevated sites that are not often flooded. Thicker, more succulent leaves generally indicate higher salinity and drier soil; flatter, less succulent leaves generally indicate lower salinity and wetter soil. *Sesuvium* does not grow well when soil pH is less than 6, so its absence from more elevated sites could indicate low soil pH, although other factors could also be responsible for its absence.

The saltmarsh plant *Sesuvium*, showing the thicker, more succulent leaves often associated with soils of higher salinity and lower moisture content (left) and the thinner, less succulent leaves often associated with soils of lower salinity and higher moisture content (right)

Other things to check for

- Surrounding embankments or higher land that could limit site drainage or tidal flooding. It is common for the land to be a little higher where mangroves, and particularly *Rhizophora*, grow along the edge of a canal or along the seaward margin.
- Obvious drainage lines or other lower areas leading to the edge of the site, which could be widened or deepened to improve flooding and drainage.
- Evidence for natural regeneration. For high sites signs of natural regeneration should be obvious along the edge of any mangrove forest present. Widespread natural regeneration away from parent trees is uncommon on high sites because there is little or no tidal flooding to disperse the propagules. For low intertidal sites, daily flooding by the tide may prevent propagules of *Avicennia* and other

pioneering species from settling on the soil surface for long enough to take root.

- The presence of visible mudbanks and sandbanks offshore from seaward low intertidal sites. On the one hand, they often provide some protection from waves and strong currents but, on the other hand, they could impair drainage, particularly if they are composed of clays and fine silt, which have a much lower permeability to water compared to sandy sediments.
- A ridged or stepped shoreline, which generally indicates an eroding coastline. Low intertidal sites undergoing active erosion are difficult to rehabilitate without some form of physical protection against waves and currents, and interventions to promote sediment deposition.

2.1.2 Overall Visual Assessment

No one indicator described above can tell you for sure whether the site is poorly drained or how often it is flooded. However, when all indicators are considered together they usually provide a reasonably good broad assessment of site conditions.

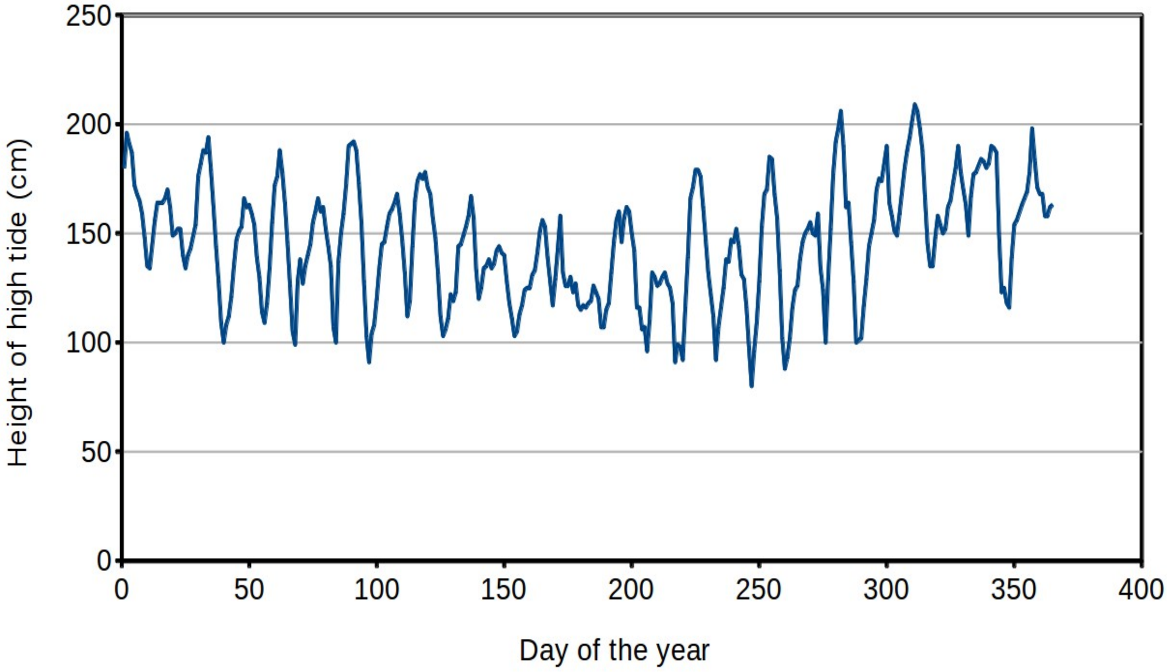
For sites with higher elevations it may be necessary to carry out two separate visual assessments, one in the mid to late dry season when tidal peaks are lower and the site is likely to be dry, and one in the wet season when the site is likely to be wet. The wet season assessment is most useful for evaluating the drainage characteristics of the site it is not flooded regularly by the tide.

A summary check list for visual assessment of high intertidal sties is given in Annex 1.

2.2 Assessing a Site Quantitatively

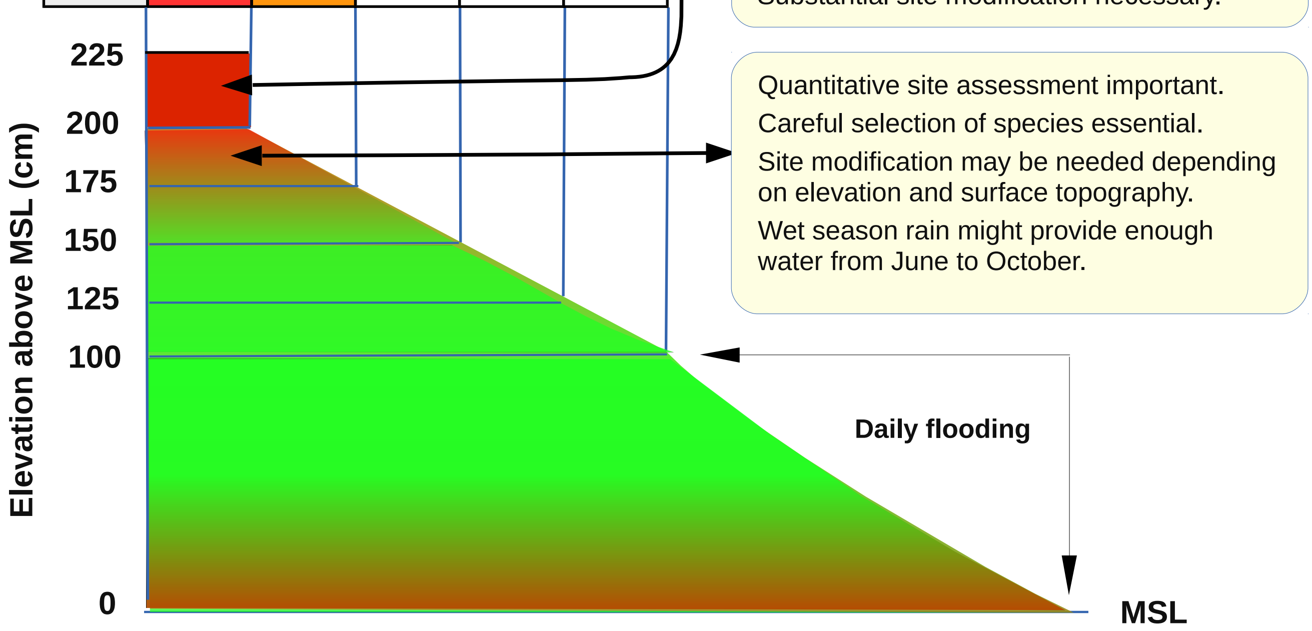
2.2.1 Site Elevation and Tidal Flooding

The maximum tidal range in Bac Lieu is about 4.3 m from low to high tide, with tidal peaks of up to about 2.1 m above mean sea level. High tides vary considerably in height throughout the year, as shown by the record from the Hydrological Station at Ganh Hao for 2010 below.



Although peak tidal heights vary from year to year, the approximate number of days per month that a site at a particular elevation in Bac Lieu will be flooded are shown below.

Month	Days flooded per month				
1	0	5	21	30	31
2	0	5	14	23	28
3	0	4	15	25	30
4	0	4	12	21	28
5	0	0	7	19	31
6	0	0	4	17	29
7	0	0	5	20	30
8	0	1	7	19	27
9	0	3	11	19	26
10	4	9	18	27	31
11	3	13	24	30	30
12	3	9	26	30	31



Relationship between site elevation (cm above mean sea level) and flooding frequency (days per month) for each month of the year. Green colour coding shows elevations that are optimal for planting, and red indicates areas where careful site assessment is needed before deciding to plant. The brighter the red, the greater the need for site assessment. Elevations above 200 cm (2 m) and below mean sea level may be unsuitable for planting mangroves. Flooding frequency (days flooded per month) is based on tidal records from Ganh Hao tide station for the period 2010 to 2013. Note that the flooding frequency refers to the lower end (marked) of each elevation range, and the number of days flooded decreases with increasing elevation within each elevation band.

The red and orange columns of the table above indicate elevations where the lack of tidal flooding could be a problem for mangroves. Many abandoned shrimp ponds and other barren or degraded mangrove areas in Bac Lieu appear to have elevations of 1.5 m or more above mean sea level.

It is probably unnecessary to measure flooding frequency at low to mid intertidal sites that are flooded regularly. However, a lack of tidal flooding is likely to be a problem for high intertidal sites, so it is important to assess their elevation and flooding frequency quantitatively, in order to formulate the most appropriate design for land preparation and planting, and to select the most appropriate species to plant.

There are a number of ways to measure the elevation and topography of a site. The conventional way is to use a theodolite or other surveying equipment to map the surface elevation. However, for mangrove areas this has some disadvantages, which include:

- It requires expensive equipment, and it is time-consuming.
- It has to be done carefully because errors in step-by-step measurements propagate from one to the next, and they are usually cumulative.
- Elevations have to be referenced to mean sea level in order to determine the flooding characteristics of the site.

A detailed discussion of standard surveying techniques is beyond the scope of these guidelines, but some simple techniques can be found at

ftp://ftp.fao.org/fi/cdrom/fao_training/FAO_Training/General/x6707e/Index.htm

It is also possible to use satellite and laser altimetry to measure elevation, but conventional GPS instruments do not have sufficient accuracy for elevation measurements, and the cost of buying satellite data of the necessary quality is prohibitive.

An alternative for areas that are tidally flooded for more than two or three times a year is to use simple tide gauges which record water levels at various positions on the site over a least one tidal cycle. This approach has the following advantages:

- It can be done easily by one person.
- The equipment is inexpensive and can usually be made from readily available local materials.
- It measures site elevation directly in relation to the local tidal and hydrological regime, thereby giving a realistic and practical measure of elevation and topography that can be used to estimate flooding frequency for any month of the year.

For this approach to work, it is important to use observations from the visual assessment to check for elevated areas and embankments around the site that might impede tidal flooding. If embankments or higher land around the site are likely to impede tidal flooding, then it is important that channels be dug at several places around the site to ensure that these are not barriers to tidal flooding. In general, it is best to cut through embankments or higher land as near as possible to the sea or main canal that is most likely to supply water to the site. It is not clear whether or not it is wise to cut a channel through embankments or higher land directly facing the sea, since this could accelerate coastal erosion. However, this is a site-specific judgement that needs to be made based on the the presence or absence of mangroves on lower land seaward of the site and the perceived risk that direct exposure of the site to the sea will accelerate erosion.

2.2.1.1 Simple Tide Gauges

There are probably many ways to make simple tide gauges that will record the highest water level over a tidal cycle. Two inexpensive and easy-to-make examples are shown on pages 11 and 12. Based on the effort involved in construction and the logistics of deployment, the dye-type tide gauge is probably best suited to topographic surveys of relatively large areas. This type of gauge has been used by the author for broad

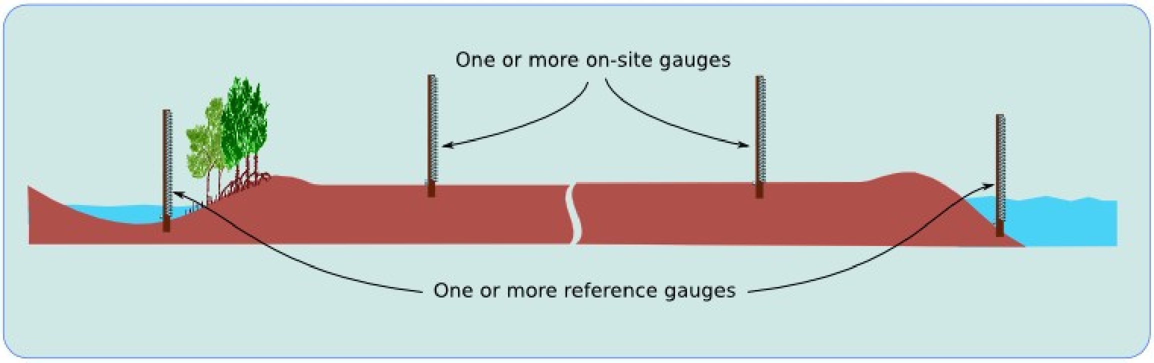
topographic surveys in areas of up to 100 ha. The tube-type gauge, on the other hand, is probably better suited to smaller areas of less than about 5 ha.

2.2.1.2 Using Tide Gauges

Of the two types of tide gauges described below, the tube-based one in Example 1 will probably give more robust measurements than the dye-based one in Example 2.

For sites with high elevation, tide gauges should be deployed around the time of the expected highest spring tides from the calendar month of September to the calendar month of February. These can be obtained from tidal predictions for Ganh Hao. Tidal predictions for Cua Batak (Dinh Anh?) or Vung Tau can also be used to decide which day to do the measurements, but the tide heights and the time of day that they occur will differ from Ganh Hao. For this reason it is probably better to use tidal predictions for Ganh Hao if they are available (but see the cautionary note at the end of Appendix 2).

The number of tide gauges that should be deployed varies with the area of the site and any special topographic features identified in the visual site assessment. As a general rule, it is wise to deploy at least 10 tide gauges on a 1 - 2 ha site, with additional reference tide gauges low in the seaward intertidal area and any canals that might supply water to the site, as shown in the diagram below. A minimum of two reference tide gauges are recommended.



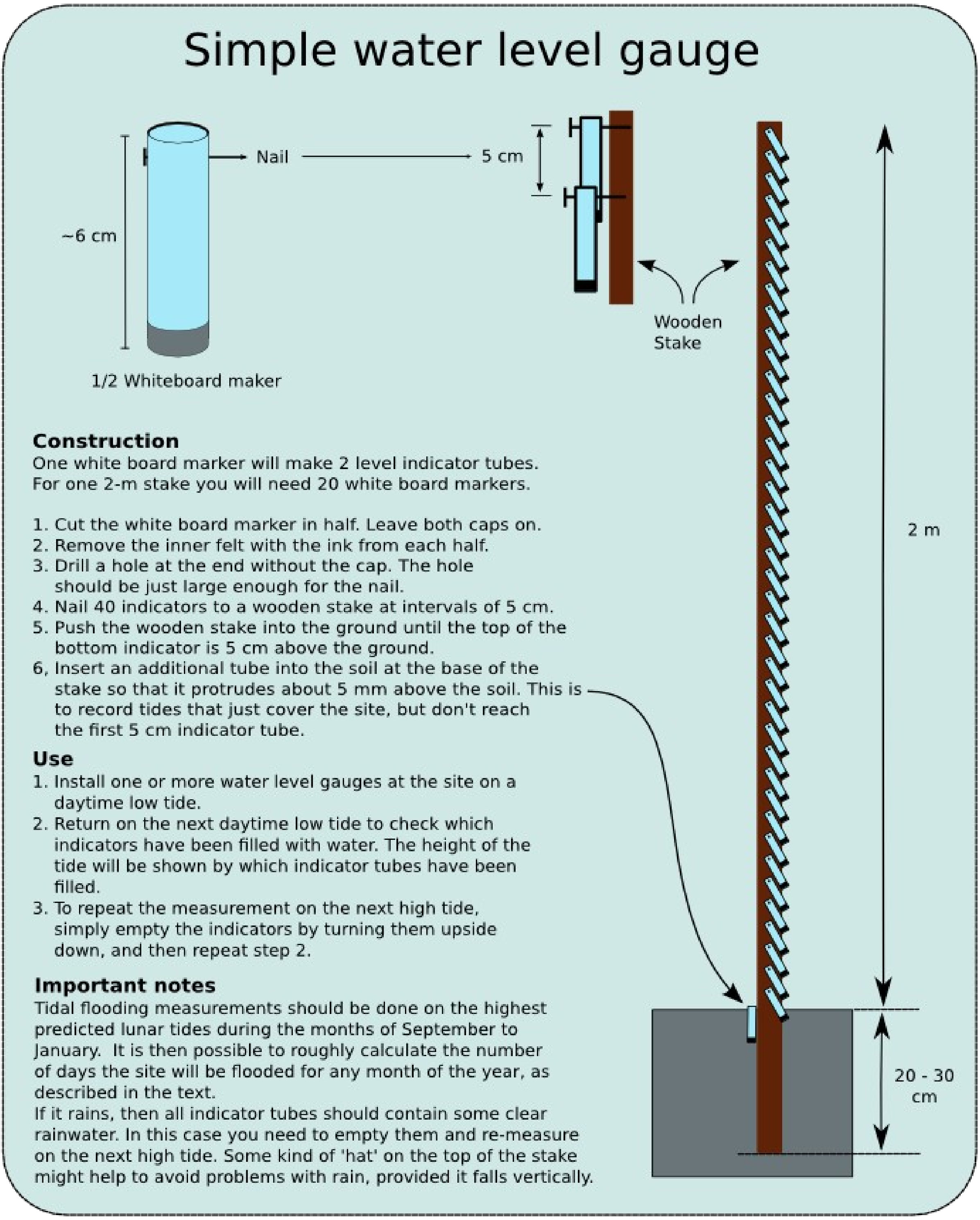
Procedure

- Label each tide gauge permanently with a unique identifier
- Install the tide gauges on the low tide immediately before the tide to be measured.
- Install at least one reference gauge at the sea front, and where possible one reference gauge in each potential supply canal near the site. Without a sea front reference gauge it will be impossible to calculate flooding frequency and site elevation relative to mean sea level.
- Record the water level in each tide gauge on the first low tide after the tide that was measured.
- Enter your recordings into the Microsoft Access database designed for this purpose. This will enable you to calculate the flooding frequency as described later.

Sea swells and waves will affect the maximum tide heights recorded by both types of tide gauge described above. Waves are not likely to be a problem with on-site gauges at highly elevated, rarely flooded sites, but they are very likely to be a problem with reference gauges at the sea front, in canals with boat traffic, and in other positions exposed to waves and swells. To minimise the risk of wildly erroneous readings it is

Example 1

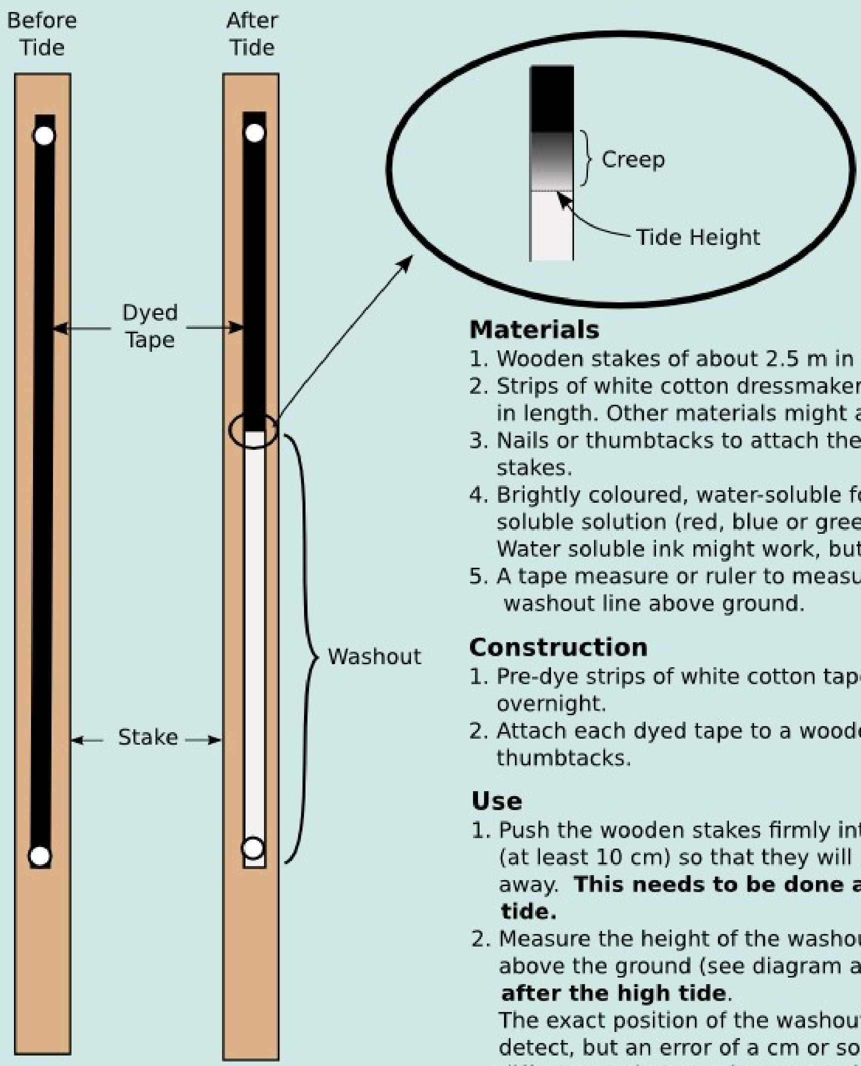
This example uses tubes, sealed at the bottom, which are attached to a stake. It uses tubes made from inexpensive and widely available whiteboard markers, but other types of tubes could also be used. Its construction and use are shown in the illustration below.



Example 2

The second example uses cotton tape soaked in a water soluble dye, which is attached to a stake. Water soluble food dyes are recommended, but if these are not available then other materials that dissolve readily in water or change colour when exposed to water could also be used. Its construction and use are described in the illustration below.

Dye-type tide gauge



Materials

1. Wooden stakes of about 2.5 m in length
2. Strips of white cotton dressmakers' tape of about 2 m in length. Other materials might also work.
3. Nails or thumbtacks to attach the tape to the wooden stakes.
4. Brightly coloured, water-soluble food dye or other water soluble solution (red, blue or green colours are best). Water soluble ink might work, but has not been tested.
5. A tape measure or ruler to measure the height of the washout line above ground.

Construction

1. Pre-dye strips of white cotton tape and allow them to dry overnight.
2. Attach each dyed tape to a wooden stake with a nail or thumbtacks.

Use

1. Push the wooden stakes firmly into the soil (at least 10 cm) so that they will not wash away. **This needs to be done at low tide.**
2. Measure the height of the washout line above the ground (see diagram above) **after the high tide**.
   The exact position of the washout line can be difficult to detect, but an error of a cm or so will not make much difference. The most important thing is to use the same criteria for reading the washout line for all gauges.

Important Notes

This type of tide gauge is not so suitable for situations where there is a swell or surface waves, since these will wash the dye out of the tape at a higher level than mean water level and they will widen the 'creep' band, making it difficult to determine exactly where the water level should be. It should not be used along the sea front or in canals where surface swell or waves will lead to erroneous estimates of tide height. If you want to use it at the sea front or along canals then you need to enclose it in a hollow plastic tube with a small hole drilled in the bottom. This will dampen the waves and give more reliable readings.

advisable to protect the reference tide gauges with 10 – 20 cm diameter plastic water pipe. This should have one or two small 4 – 6 mm holes drilled in the side just above the sediment surface. The tube should also extend for at least a meter above the wooden stake to prevent waves overtopping it and filling the tubes from above. Sealing the top of cylinder with a cap will elimate errors due to rain, but in this case it is also important to drill a small hole on the side of the tube cloas to the top to allow air to escape and re-enter as the tide rises and falls. The plastic cylinder acts like a capacitor in an electrical circuit and dampens wave-induced fluctuations in water level.

The outer plastic tubes are likely to be stolen by local people, so it would be wise to inform the local community of their purpose and request that the tide gauges not be stolen or tampered with.

It is possible that the site is not flooded at all on the day of measurement and so no on-site tide gauges register any water. This could be due to any one of the following causes, or a combination of several of them:

- The day selected for measurement was poorly chosen and the tide was not actually a very high spring tide.
- The site is surrounded by embankments or other higher land that prevented tidal flooding.
- The site really is too high to be flooded by any tides.

However, if the reference gauges have been correctly positioned they should all record a tide height. In such cases, it is useful compare the tide height in the reference gauges with the elevation of nearby embankments and on-site gauges. This can be done with a standard water tube leveler which is used widely throughout Vietnam for leveling at building and other construction sites, and which should be familiar to most Vietanamese.

A comparison of the relative heights recorded by the reference gauges with the height of any surrounding embankments or higher land, and with the ground level at one or two on-site gauges, should show whether embankments or higher land prevented flooding. It should also show whether breaking embankments or cutting a channel through any higher land would be enough to provide tidal flooding, and how much higher the tide would need to be in order to flood at least part of the site. With this information it is then possible to examine other dates with higher predicted tides and decide whether or not it is worth repeating the measurements on a day with tides that are predicted to be high enough to flood the site. If it turns out that the site is presently above all high tides then the information gained from the water level technique will indicate how much higher it is above the highest tides. This will provide valuable input into decisions on whether or not the site can be rehabilitated, and if it is to be rehablitated, what kind of site modification would be needed to make it suitable for mangroves.

Converting Tide Gauge Readings to Flooding Frequency

There is no way to predict exactly how many days each month a more elevated site might be flooded. This will vary from year to year depending amongst other things on the lunar calendar, offshore winds and, in the future, sea level rise. However, it is possible to use tide gauge readings, together with tidal records from Ganh Hao tide station, to calculate an approximate flooding frequency for each month with an accuracy of about ± 2-3 days per month, which in most cases is sufficient to develop an effective site rehabilitation strategy.

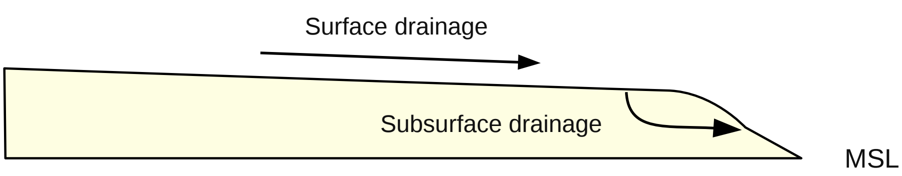
The elevation of a site and the number of days it is likely to be flooded each month is calculated using the MS Access database into which the data was entered. The method of computation and some assumptions underlying it are shown in Annex 2.

2.2.2 Drainage

The surface drainage characteristics of a site depend mainly on its slope, local variations in topography, and its elevation above local mean sea level. Subsurface drainage is also important for flat sites, particularly when surrounded by dikes or higher land. Subsurface drainage is determined mainly by soil porosity which, in turn, is influenced by soil texture and structure, the degree of soil compaction, and the presence or absence of crab burrows. Examples of the drainage characteristics of typical elevated sites in Bac Lieu are shown in the illustration below.

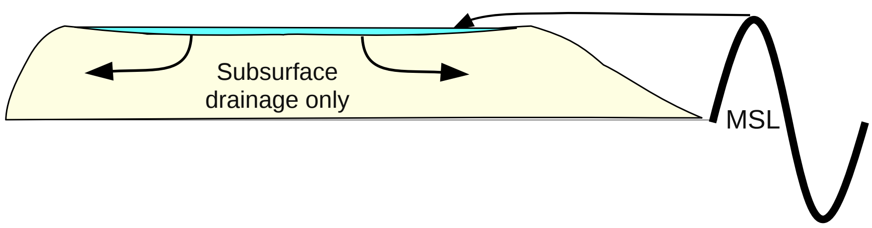
Examples of drainage at typical more elevated sites in Bac Lieu.

Sloping site



Surface drainage predominates on sloping sites, unless there is a barrier at the lower end of the slope.

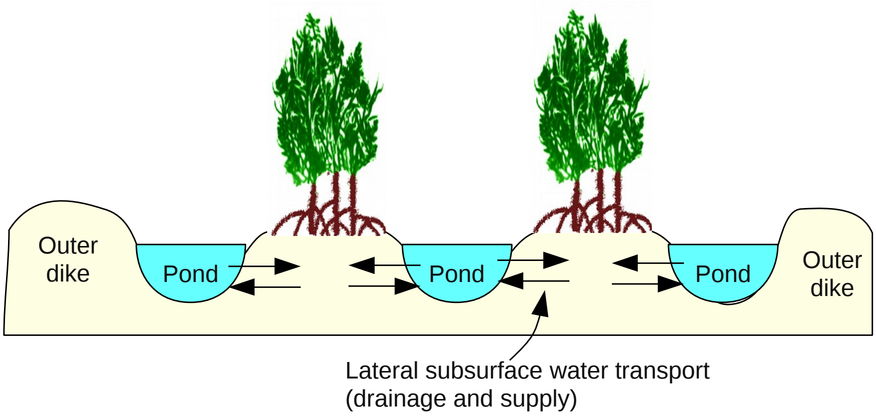
Relatively flat site surrounded by higher land or dike



Subsurface drainage predominates on more elevated sites surrounded by dikes or higher land.

Subsurface drainage can be fast in sandy soils, but it is usually very slow in the clay soils typical of Bac Lieu, usually resulting in ponding after heavy rain or tidal flooding.

Mixed shrimp pond-mangrove forest site



Embankments with mangroves are usually higher than the water level of the pond.

Surface drainage can occur after heavy rain.

Lateral subsurface water transport between pond and embankments maintains a water table at about the same level as the pond.

Subsurface drainage predominates when the pond is drained.

For this reason, a quantitative assessment of drainage characteristics requires a detailed

topographic survey to determine its contour. Detailed topographic surveys can be carried out with a range of commercial survey instruments, but they are time-consuming and often expensive.

2.2.3 Soil Characteristics

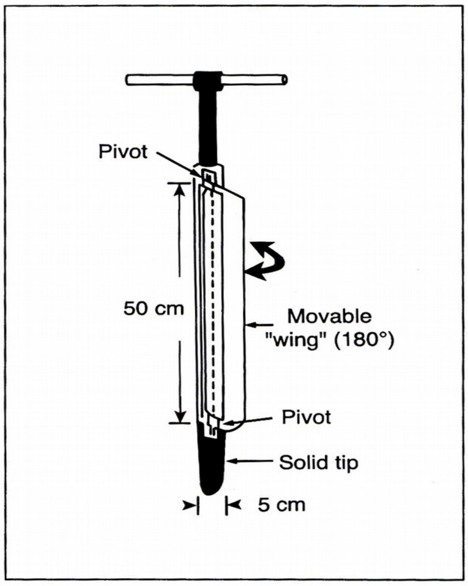
Key soil properties that are likely to influence flooding and drainage characteristics, and/or the early survival and subsequent growth of mangroves include:

- Soil hardness, compaction and texture
- Soil moisture (water) content
- Soil salinity
- The presence or absence of an underground water table within the top 2-3 metres of the soil surface at elevated sites that are rarely flooded.

Many of the soil parameters are also likely to change from season to season depending on the site elevation (low, mid, or high intertidal). For sites at low to mid intertidal elevations that are flooded on at least 10-15 days each month, soil measurements can be made at any time of the year, since tidal flooding is usually the main factor affecting surface hardness, soil water content and soil salinity. However, for sites at high elevations which are only rarely flooded, soil measurements should be carried out in the mid to late dry season (i.e. from March to May), when the soil is likely to be drier or more saline because of lack of rain. This is the time of greatest stress (and risk) for seedlings, saplings and young trees on more elevated sites.

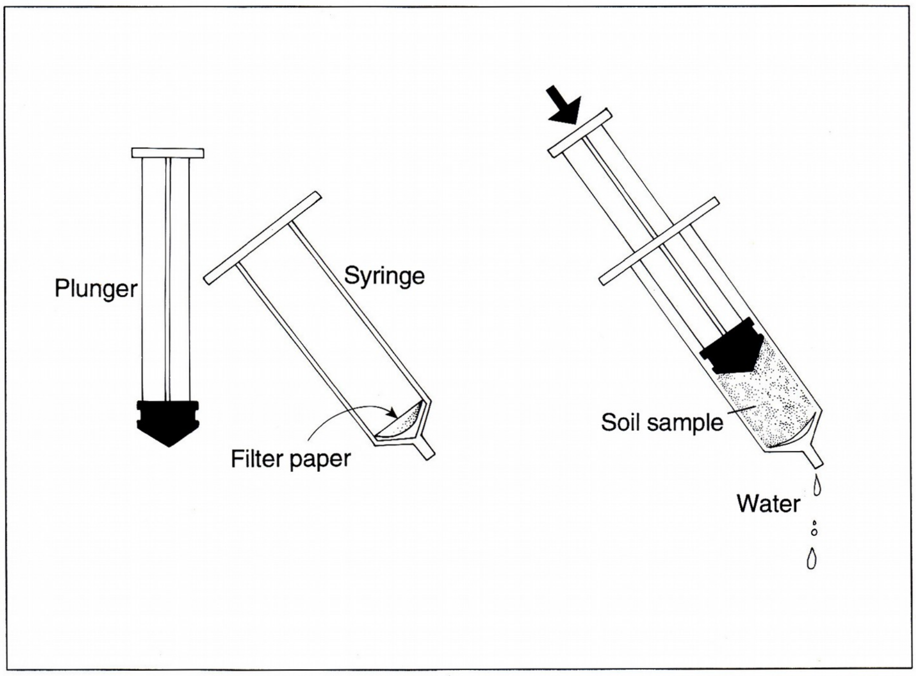
As with all field sampling, the number of samples and where they are taken represents a compromise between a representative broad site coverage on the one hand, and the labour and time involved in collecting them and processing them on the other hand. Sampling theory is beyond the scope of this manual, but as a general guideline, at least three or four samples should be collected from different parts of a site, more if the site is large.

Unfortunately, apart from soil salinity in very wet soils, most soil properties are difficult to measure quantitatively and reliably without a good laboratory balance, an oven, and

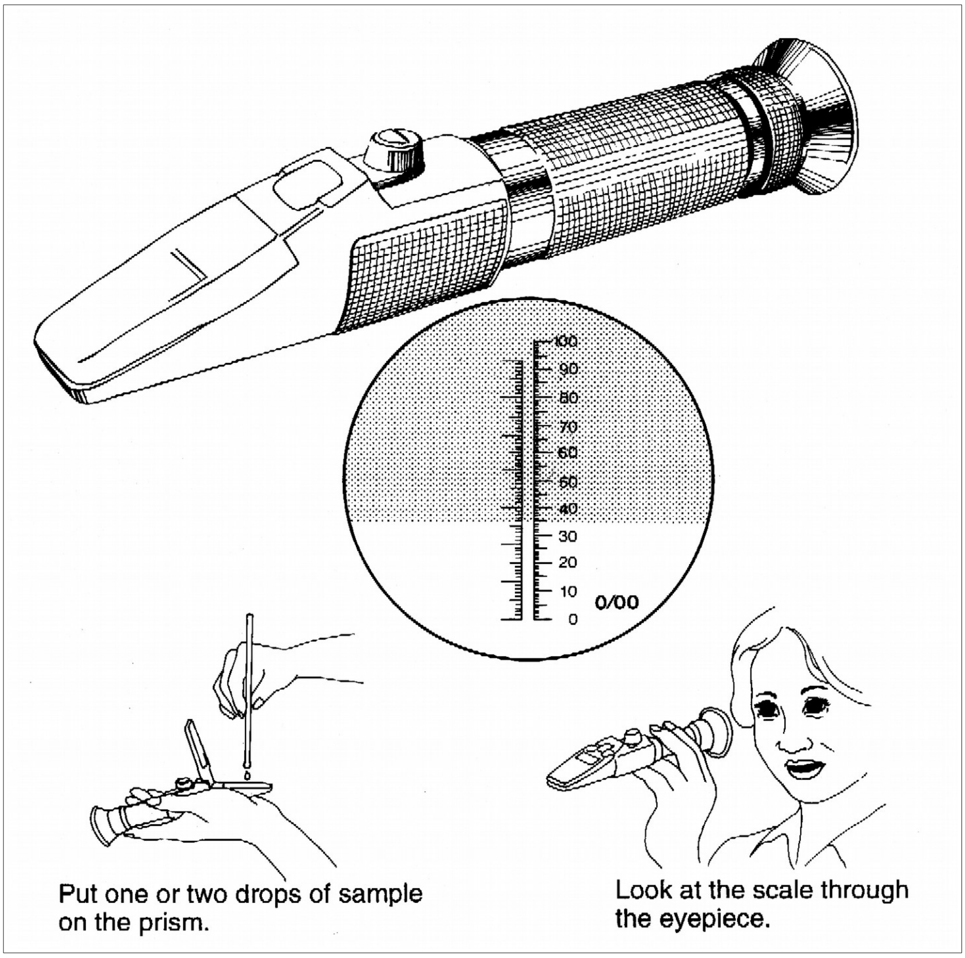


'D'-Corer

(From English et al., 1997)



Using a syringe to squeeze water from a wet soil (from English et al., 1997)



Using a refractometer to measure the salinity of soil water (from English et al., 1997)

other standard laboratory equipment. Moreover, their measurement takes time and requires a reasonable level of technical skill. Without all of these, the accuracy of such measurements are likely to be so poor that they are probably not useful and a waste of time.

2.2.3.1 Soil Sampling

Single soil samples from the top 5-10 of the soil profile can be taken easily by simply digging up a representative sample with a spade, shovel or other implement. However, where possible it is better to take a soil core to a depth of at least 40 cm, and then divide it into sections on which a representative range of analyses are carried out. Softer, wet and muddy sediment cores are best sampled with a 'D'-corer, which is shown on the right.

A 'D'-corer provides a relatively undisturbed soil sample and is therefore suitable for even demanding analyses such as redox potential. Both the Wetlands Forest Research Center of SFFI in Ca Mau and the College of Environment & Natural Resources at Can Tho University have 'D'-corers. Other tubular soil corers are also suitable for wetter, clayey soils that hold together when the core is extracted, but not very soft muds. Loose and sandy soils are difficult to sample with any kind of corer, and neither the 'D'-corer nor other tubular coring devices work well with them. However, loose sandy soils are rare in Bac Lieu and Ca Mau, although more common in Soc Trang and Tra Vinh.

While the 'D'-corer and other types of corers work well in softer soils that are flooded regularly, they do not work at all in the hard, compacted soils typical of elevated claypans and saltpans, which represent a significant part of the coastal area in Bac Lieu. In fact conventional hand-operated soil augers of the type usually found in Vietnam also do not work on these soils, so the best option seems to be to dig a hole of about 1-2 m in diameter by hand and then sample the soil from different depths down one side of the hole. This is labour-intensive and time-consuming, but there seems no other way without a mechanically-powered corer.

Sample storage and processing

Since we are mainly concerned with soil water and soil salinity, the most important thing is to make sure that the soil samples do not dry out or come in contact with salt. Soil samples should be put into a pre-labelled sealable plastic bag. Before sealing the bag, try to evacuate the bag to squeeze as much air as possible. This will reduce moisture loss. Transport the samples to the laboratory or building where processing will take place, making sure that they are in a dark, cool place during transport, again to minimise water loss. If possible process samples the day they were collected, or within two days of collection. If they are not processed on the day of collection, store them in a cool, dark place.

Procedure for soft, wet soils

- Use a 'D'-corer or other tubular corer to take a soil profile from the surface to about 40-50 cm.
- The corer should be pushed into the soil with the wing or flange open (as shown in the illustration on the previous page).
- When the corer has been pushed down to the full depth of the tubular part, twist the handles half a turn (180) anticlockwise to close the tubular part.
- Gently extract the corer and its core.
- Open the corer to expose the core. Soil pH (and Eh if you have an Eh electrode) can be measured directly by inserting a pH electrode gently into the soil.
- Take samples of about 5 cm in length from the top and bottom of the core and seal them in plastic bags or tubes, excluding as much air as possible (see the

section on sample storage and processing on the previous page).

- If the soil is wet enough, extract some soil water with a syringe (see illustration next page) and measure the soil salinity directly on site with a refractometer (see illustration next page).

Procedure for harder and drier soils.

- Dig a hole to 50 cm in depth. It will probably need to be at least 1 m in diameter or width to allow you access.
- Take a sample from the bottom of the hole and at about 5 cm from the top of the hole.
- The soil will be too hard and dry to measure salinity and pH on-site.
- Seal the samples in labelled plastic bags (using the precautions described in Sample Storage and Processing on the previous page) and take them back to the laboratory for further analysis.

2.2.3.2 Measuring Soil Water Content and Salinity in the Laboratory

The salinity of drier soils will need to be measured in the laboratory. For this you will need:

- A balance to weigh soil samples. If a laboratory balance is unavailable, you can use an inexpensive digital (electronic) kitchen balance with a minimum resolution of 0.1 g or better.
- An oven to dry the soil samples. If a laboratory oven is unavailable you could use a small electric domestic oven, <u>provided</u> that its temperature can be regulated reliably to 80°C.
- Small glass, ceramic or aluminium dishes or trays to hold the samples while drying and for mixing the dried sample with distilled or de-ionised water. If necessary, you can use ceramic or glass kitchenware like saucers and cups.
- A refractometer to measure salinity.
- A source of distilled water (good quality commercial pre-bottled water produced by reverse osmosis is probably good enough – but not mineral waters from natural springs or to which minerals have been added).

Procedure

The size of the soil sample depends on the quality of the balance you use. For a laboratory balance you will need 2 – 5 g of soil; for a digital kitchen balance with a resolution of <= 10 mg, you will need at least 20 g of soil.

- Dry the soil sample in glass or ceramic containers for a least 48h in an oven at 80°C.
- Reweigh the oven dry sample to obtain a dry weightt.
- Grind the sample to a fine or coarse powder in a mortar and pestle .
- Transfer the sample from the mortar to a **pre-weighed** glass or ceramic container (e.g. glass, cup or saucer). Then weigh the dry powdered sample and the container together.
- Add just enough distilled or de-ionized water to mix the soil into a slurry with a consistency of sticky mud. Don't add too much water as this could make it difficult to read the salinity reliably with a refractomer.
- Re-weigh the wet sample and its container so you know how much water you

added.

- Use a syringe to squeeze a few drops of water from the slurry onto the refractometer prism and measure the salinity, as describe above.

Calculations

At the end of the steps above, you should have four (4) weights for the sample, all in grams:

- Fresh weight of the original soil sample (FWo)
- Dry weight of the original soil sample (DWo)
- Dry weight of the powdered sample before adding water to it (DWs)
- Wet weight of the powdered sample after adding water to it (FWs)

Then,

Soil water content (%) = 100 x (FWo - DWo)

and soil salinity is calculated as,

$$So(‰) = \underbrace{Ss(‰)}_{①} \times \underbrace{(DWo / DWs)}_{②} \times \underbrace{((FWs - DWs) / (FWo - DWo))}_{③}$$

where

So(‰) = salinity of the original soil sample in parts per thousand,

Ss(‰) = salinity of the extract from the re-wetted soil sample in parts per thousand,

FWo = fresh weight of the original soil sample,

DWo = dry weight of the original soil sample,

DWs = the weight of the powdered soil sample after it has been transfered to the dish for mixing with water, but before the water is added,

FWs = the weight of the soil slurry after the soil has been mixed with water.

If no soil is lost during grinding, and all the powdered original sample is transfered to the dish used to mix the soil and water into a slurry, then item ② in the formula above would equate to 1 (i.e. DWo = DWs), and it could be left out of the calculation. However, it is possible, perhaps even likely, that some of the original soil sample will be lost when it is ground to a powder and transfered to the dish for mixing with water. For this reason, and for the sake of accuracy, the full form of the formula above should be used for calculating soil salinity.

If carried out with care, this method should give an estimate of the original soil salinity with an accuracy of ± 2‰, which is sufficient for site assessment.

2.2.3.3 Other Soil Properties

Soil hardness and compaction in agricultural soils are normally measured with a penetrometer. However, penetrometers are relatively expensive and are unlikely to work well in the very dry, compacted soils typical of more elevated mangrove sites in the Mekong Delta.

The assessment of nutrient status and other soil chemical properties is beyond the scope of a simple site assessment, and would normally be carried out only in a research setting.

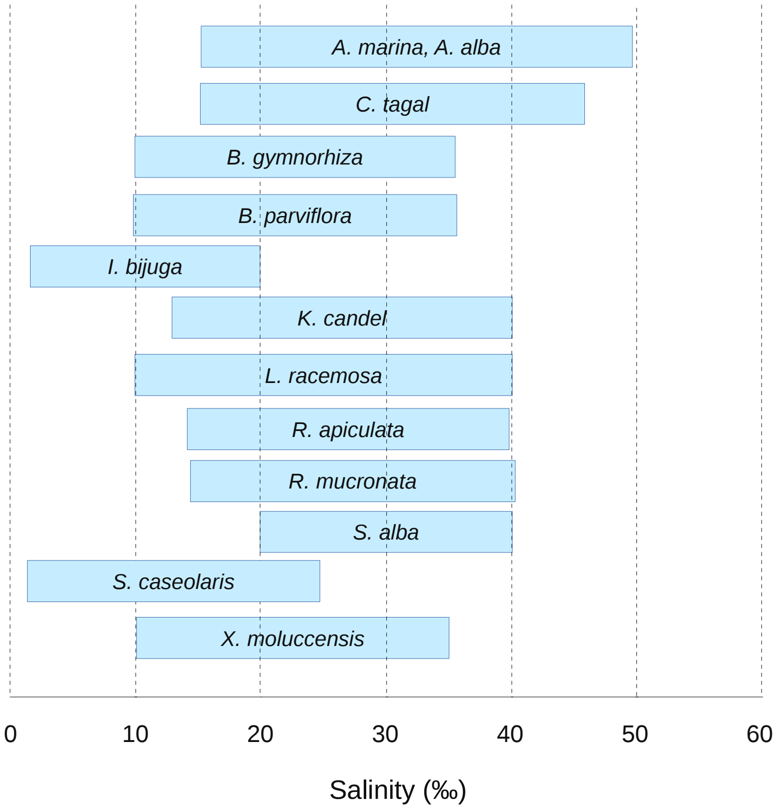
2.2.3.4 Measurement of the Water Table

Determining whether or not there is a more or less permanent water table and its depth is not easy in a simple site assessment. In general, soil moisture content increases with depth, but it is highly dependent on soil structure and site hydrology. Since the rooting depth of mangroves seldom exceeds 1 m, the simplest method to assess the presence of a water table is to dig a hole to a depth of 1 – 1.2m and note whether or not water is present at the bottom, or measure the soil water content at the bottom of the hole using the techniques described earlier in Section 2.2.3.2.

3 Species Salinity Preferences

Most mangrove species can grow over a range of salinities. However, some species cope with high soil salnities better than others, and some species do not usually grow well at very low salinities. Defining the salinity tolerance of any species exactly is difficult because it also depends on physical factors like soil water content, the physical structure and composition of the soil, flooding frequency and climate, as well as on the morphological and physiological characteristics of a given species. A general overview of the role of these various factors can be found in Clough (2013).

For practical purposes, it is probably best to consider the usual patterns of species distribution and growth in relation to salinity locally. This is illustrated very approximately for Bac Lieu in the figure below:



Approximate salinity range for mangroves in Bac Lieu

These ranges are based on Project experience in Bac Lieu Province. Optimal salinities probably fall in a band somewhere around the middle of the ranges shown. Survival and growth could be lower than expected or less than desirable towards the ends of the

range shown for each species, due to the nature of the soil, and/or flooding and drainage characteristics of the site. In fact, most species will probably also grow outside the ranges shown above if other site conditions are favourable, but survival and growth are likely to be poor. This highlights the importance of monitoring survival and growth over a time frame of at least five years. Without monitoring, the reasons for failure, success or something in-between are difficult to explain, and we do not learn any lessons to help to do better next time.

4 Concluding Remarks

Best practices in rehabilitating or restoring mangroves for coastal stabilisation, for coastal protection, and to provide other coastal ecosystem services require a thorough site assessment before formulating a rehabilitation strategy in order reduce the risk of failure and provide the best possible outcome. The simple guidelines and techniques described in this manual should provide a fairly robust site assessment that can be used to determine whether or not a site is plantable or restorable, and to help with the formulation of an appropriate plan for rehabilitation that will greatly improve the chances of success.

It is important to understand that, by itself, no one indicator described in these guidelines can provide a reliable assessment of particular site conditions. However, in most cases, all the indicators considered together do provide a reliable assessment of site conditions.

Finally, there is considerable variation in the site characteristics of degraded mangrove areas throughout the Mekong Delta. No two sites are exactly the same. For this reason, it is important to take a practical, open-minded and objective approach to site assessment, and to make sure that it is well-documented.

5 References

Clough, B. (2013). *Continuing the Journey Amongst Mangroves*. ISME Educational Book Series No.1, International Society for Mangrove Ecosystems, Okinawa, Japan, and International Tropical Timber Organization, Yokohama, Japan. 86 pp. PDF available from http://www.mangrove.or.jp/isme/english/books/educational-series.book1.pdf

English, S., Wilkinson, C. And Baker, V. (1997). *Survey Manual for Tropical Marine Resources, 2nd Edition*. Australian Institute of Marine Science, Townsville, Australia. 389 pp.

Giesen, W., Wulffraat, S., Zieren, M. and Scholten, L. (2007). *Mangrove Guidebook for Southeast Asia*. FAO, Bangkok and Wetlands International, Wageningen. PDF available from http://www.fao.org/docrep/010/ag132e/ag132e00.htm

Annex 1 - Visual Site Assessment Check List

Visual Site Assessment of High Intertidal Sites – Check list		
Feature	**Indicators**	**Follow-up**
General (from satellite image)	• Presence / absence of mangrove tree lines around site. • Presence / absence of probable mangrove tree lines across site. • Presence / absence of tree canopies. • Presence / absence of obvious drainage lines. • Location of nearby canals • Proximity to sea	
Poor surface drainage	• Undrained surface water after heavy rain or tidal flooding. • Low, spreading, poorly developed mangrove canopy. • Unusually thick and knotted stilt roots, or larg-e lenticels surrounded by flaky bark on lower stem in species without stilt roots. • Very dense pneumatophores. • Hard, sticky surface after rain or tidal flooding (not softer mud at least ankle deep).	• Check for surrounding dikes or more elevated land that might impede drainage. • Check for natural drainage lines or channels that could be deepened or redirected to facilitate drainage.
Poor subsurface drainage	• Hard, compacted, cracked soil surface in the dry season. • Hard, sticky surface after rain or tidal flooding (not softer mud at least ankle deep). • Absence of crab burrows. • Absence of sand and shell fragments.	• Check soil profile to a depth of 1 m for the presence of a more porous layer of sand or shell fragments. • Check soil salinity in soil profile to a depth of 1 m.
Infrequent tidal flooding	• Hard, dry soil, especially in the dry season. • Poorly developed mangroves. • Presence of *Sesuvium*. • Absence of crab burrows.	• Check for surrounding dikes or more elevated land that might hinder flooding. • Check for a water table in the top 1 m (in dry season). • Check soil water content and salinity in the soil profile to a depth of 1 m. • Measure tidal flooding quantitatively

Visual Site Assessment for Low Intertidal Sites – Check List

The shoreline of Bac Lieu and other coastal provinces n the Mekong Delta is highly unstable, with significant seasonal and year-to-year variability in erosion and sedimentation patterns, which are often quite site specific. Assessing potential planting sites along the shoreline and on coastal mudflats is therefore extremely difficult. Specific indicators are hard to define, and the list below simply summarises some of the features that should be considered in assessing these kinds of sites.

Feature	Indicators	Follow-up
Overall site stability	• Presence / absence of elevated compacted offshore clay banks exposed at low tide.	
Erosion	• Stepped shoreline, in Bac Lieu typically consisting of highly compacted clay material. • Collapse of trees along the coastal fringe. • Sharp drop from the seaward mangrove boundary to the mudflat below. • Absence of natural recruitment on near-shore mudflats. • Eroding channels running from landward to seaward.	
Accretion	• Accumulation of soft mud. • Natural regeneration	

Annex 2 – Tidal Database & Estimating Elevation

6 Introduction

Site topography and elevation with respect to mean sea level are key factors in determining the hydrology of the site, including the frequency of flooding and drainage characteristics. These, in turn, will influence what site modifications might be needed and what species could (or should) be planted to rehabilitate the site successfully.

Conventional surveying techniques can of course be used for assessing toprography and elevation, provided they have a good reference benchmark. However, these techniques can be time consuming to carry out and require a level of expertise that might not always be available.

This annex describes an alternative approach for assessing site topography and elevation that, while perhaps not as accurate as conventional survey techniques, is faster to do and requires less expertise. It is based on the use of simple tide gauges to measure water depths during tidal flooding, and then relating these depths to the average tide heights recorded by the nearest tide station, in this case Ganh Hao (for Bac Lieu Province). The construction and use of the tide gauges is discussed in the main body of this manual. Here we describe the principle and limitations of the method and procedure for calculating elevation and topography from tide gauge measurements.

2 Approach and Computation

The basic idea is to use simple, home-made tide gauges (described in the body of the manual) to measure waters levels at different points on the site and then relate these to:

- The peak tidal height on the day of measurement, which gives an estimate of the elevation of the site with respect to the tidal benchmark for Ganh Hao tide station.
- Tidal records from Ganh Hao for past years, in order to obtain an estimate of the flooding frequency for each month of the year.

This method assumes that the tidal regime offshore from the site is the same as that at Ganh Hao, so that the height of peak tides are the same at both the site and Ganh Hao tide station for each day of the year. This is not likely to be the case. Differences in the shape of the coastline, offshore seabed bathyrmetry, surface currents, winds and waves will all contribute to unknown and unpredictable differences in peak tidal heights between the site and Ganh Hao, and these differences are likely to be greater with increasing distance from Ganh Hao. However, there seems no way to avoid this uncertainty without installing and calibrating a commercial tide gauge offshore at each site.

Estimating Elevation

For estimating elevation we need the water levels recorded by onsite tide gauges, and the peak tidal height for the day of measurement. The error associated with the measurement of water level by both types of simple tides gauges described elsewhere in this manual is about 5 cm, if they have been installed correctly. The greatest uncertainty and largest potential source of error will be in the height of the tidal peak for the day of measurement. We assume that the peak height at the site will be the same as that at

Ganh Hao but, as discussed above, this is unlikely.

For the tidal peak on the day of measurement we have a choice of:

- The predicted tidal peak for the day of measurement. This is not a particularly good choice because tidal predictions are less reliable than tidal measurements.
- The actual tidal peak measured at Ganh Hao for the day of measurement. This should be more reliable than the predicted tidal peak, but it means that elevations cannot be calculated until the measured tidal peak is available from Ganh Hao tide station.

To calculate the elevation of an onsite tide gauge:

Let HS_i = the height of the water recorded by onsite gauge i .

Let HR_n = the height of the water recorded by reference gauge n located to the seaward of the site or in an adjacent canal.

Let HG_p = either the predicted tidal peak or the measured tidal peak for Ganh Hao on the day of measurement. As explained below, it is preferable to use the measured tidal peak rather than the predicted tidal peak.

Then,

$$\text{Elevation of onsite gauge } (ES_i) = HG_p - HSi$$

Strictly speaking, the height of the water recorded by offshore or canal reference gauges is unnecessary to estimate the ground elevation at a particular onsite gauge, but we still record it because it could be useful for cross checking measurements that might be repeated at the same site on different days, at different times of the year, or in different years. In other words, provided the reference gauges are at exactly the same coordinates and pushed into the bottom to the same depth, the water levels they record could be used, if needed, to compare day to day, season to season, or year to year differences between the tidal regime at the site and that at Ganh Hao.

In order to minimise errors in estimating elevation, it is recommended that measurements be replicated on at least three different days, preferably a month apart.

Estimating Flooding Frequency

To calculate the flooding frequency in number of days per month, we need the elevation of the site (or more particularly the ground level at the coordinates of each onsite tide gauge) and tidal records for past years from Ganh Hao tide station. Then, for any given day of the year, if the tidal peak recorded by Ganh Hao is greater than the elevation at the location of a particular tide gauge, that part of the site should be flooded. This can be done for each onsite tide gauge for each day of the year, and averaged over whatever years that tidal records are available from Ganh Hao.

Since the estimate of flooding frequency depends on site elevation, any uncertainties and errors in estimating site elevation will also propagate through to the estimate of flooding frequency. However, there is also another source of possible error in estimating flooding frequency. This is due to inter-annual variability both in tide heights and in their timing. Tidal records from Ganh Hao are supplied for calendar dates, whereas tides follow the lunar cycle. Consequently, there is a phase shift in the tidal cycle between years which, coupled with inter-annual variability in tidal peaks, can lead to a difference in flooding frequency of up to 10 days per month between years. Estimates of flooding frequency for a site based on a single year of tidal records from Ganh Hao, therefore, may not be very reliable.

In order to minimise errors in estimating flooding frequency, it is recommended that monthly flooding frequencies be averaged over all years for which the database (see below) contains a full

year of tidal records.

3 Tidal Database

A Microsoft Access 2000 database (Tidal_Database.mdb) has been developed to store tidal records from different tide stations, and assist with the estimation of site elevation from tide gauge data. Although written in Access 2000, it is known to also work in the versions of MS Access that are included with MS Office 2003, MS Office 2007 and MS Office 2010. It has not been tested with the the version of Access that ships with MS Office 2013.

Microsoft Access was chosen for two primary reasons:

- It is installed on most computers in Vietnam, and as part of the MS Office suite it is likely to be more familiar to users than other database frameworks like sqlite, MySQL, Postgre SQL and Firebird.
- It is much easier to build a simple user interface with Microsoft Access than having to program a completely new user interface for other database frameworks.

This database does three things:

- Stores yearly tidal records and tidal predictions for Ganh Hao and other tide stations. At the present time, the database only contains tidal records from Ganh Hao for the years 2010, 2011 and 2012. However, data for other years and from other tide stations can be added as they become available.
- Stores data on water levels recorded from both the dye-type and tube-type tide gauges.
- Based on 1 and 2, it calculates the elevation of each tide gauge above the reference level for the selected tide station, and estimates the number of days for each month of the year that a site is likely to be flooded by the tide.

The database can thus be used in conjunction with the tide gauges described in the main guidelines to estimate site elevation and flooding frequency. The output from these calculations can be exported and pasted into any spreadsheet program for further analysis.

Tidebase consists of two separate MSAccess databases:

TidebaseApp.mdb – this is the database application, which contains the graphical user interface (GUI), queries and other code needed for data entry and computation. The data are in a separate database, TidebaseData.mdb, described below.

TidebaseData.mdb – this contains the actual tidal data tables that are linked to TidebaseApp.mdb.. These are described in greater detail below.

Separating the data from the GUI and code in this way enables the data to be stored on a server if desired, and allows multiple users with the GUI installed on their computer to access the same data simultaneously.. It also simplifies adding new tidal records, which only need to be entered once into the master database, and then shared by all users.

3.1 Tables in TidebaseData.mdb

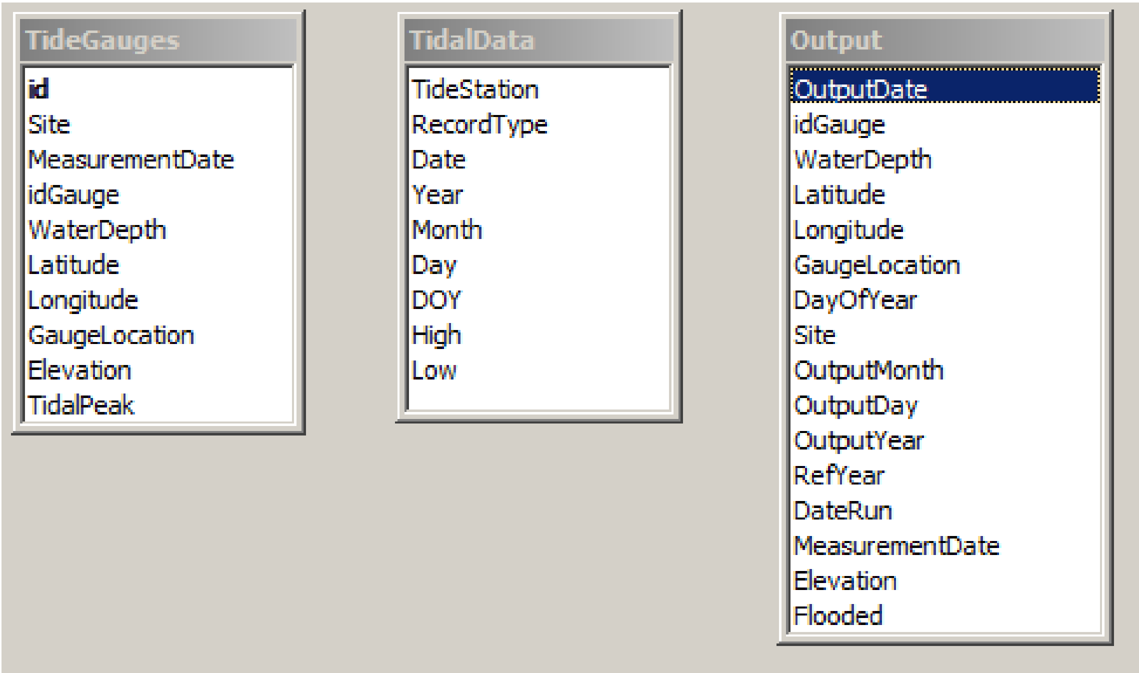
The database is very simple and contains just four tables:

- **TidalData** – this table holds the past tidal records and, if desired, future tidal predictions for any tide station, though it only presently contains tidal records

from Ganh Hao.

- **TidalData-Serial** – this contains the same data as that in the TidalData table, arranged in a different format. It is not used in the current version of Tidebase, but might be used in future versions, as it provides more flexibility in entering and processing tidal data.
- **TideGauges** – this table holds the water levels recorded by the tide gauges, and other relevant information related to the tide gauges. At the time of writing, this table only contains some test tide gauge data, which can be deleted before genuine data is added.
- **Output** – this table holds the output from the calculations of elevation and fooding frequency. It is automatically cleared before each run to avoid duplicating output records. There are some duplicated output fields in this table (with different names) that you can ignore. They will be removed in a future version.

The fields in the tables are illustrated in the diagram below.



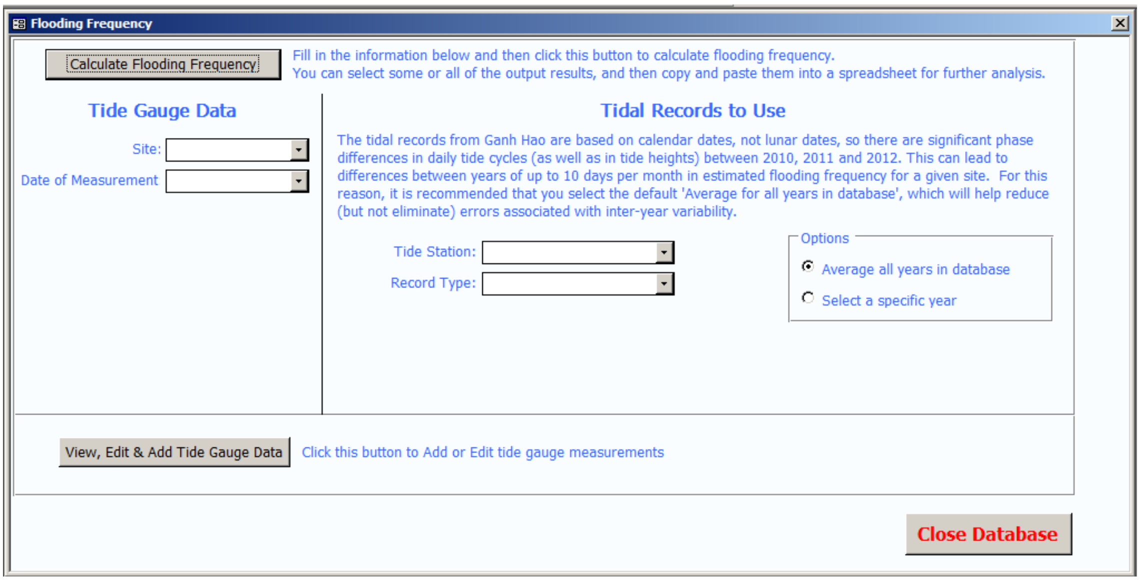
3.2 Forms in TidebaseApp.mdb

The database contains 3 forms:

- **FloodingCalculation** - the main application form, from which flooding frequency can be calculated and from which the TideGauges form can be opened.
- **TideGauges** - a form to display, add and edit tide gauge measurements
- **frmUpdate** – for updating tidal records after they have been imported.

3.3 Using the Database

When you first start the database, you will usually be presented with the Flooding Frequency form shown below. However, after adding new tidal records you may first see a Database Update form which will be described later in Section 3.3.3.2.



This is the main form in the database, and it is used for two purposes

- To estimate gauge elevation and flooding frequency for any set of tide gauge data in the database.
- To open the Tidal Measurements form, where you can add or edit tide gauge data.

3.3.1 Estimating Level and Flooding Frequency

The instructions on the form are more or less self-explanatory. All you have to do is:

- Select an option (as discussed below, it is probably best to leave this on the default setting);
- Select a site;
- Select the Date of Measurement
- Click 'Calculate Flooding Frequency'.

You will be asked if you want to delete the 'Output' table. Click Ok or Yes depending on the prompt of the message box, then click Ok to any further MS Access prompts. This is necessary to avoid duplicating output data for the tide gauges.

The output will be similar to that shown below (where the column 'Flooded' is the number of days flooded in the indicated month).

Click here to select all records, then use Ctrl + C to copy them to the clipboard

Fall3 : Select Query

Site	idGauge	Gauge Type	Latitude	Longitude	Month	Elevation	Flooded
Test Data	id11	Onsite	52367	1237650	1	195	0
Test Data	id11	Onsite	52367	1237650	2	195	0
Test Data	id11	Onsite	52367	1237650	3	195	0
Test Data	id11	Onsite	52367	1237650	4	195	0
Test Data	id11	Onsite	52367	1237650	5	195	0
Test Data	id11	Onsite	52367	1237650	6	195	0
Test Data	id11	Onsite	52367	1237650	7	195	0
Test Data	id11	Onsite	52367	1237650	8	195	0
Test Data	id11	Onsite	52367	1237650	9	195	0
Test Data	id11	Onsite	52367	1237650	10	195	4
Test Data	id11	Onsite	52367	1237650	11	195	4
Test Data	id11	Onsite	52367	1237650	12	195	2
Test Data	id12	Onsite	52387	123666	1	190	1
Test Data	id12	Onsite	52387	123666	2	190	0
Test Data	id12	Onsite	52387	123666	3	190	1
Test Data	id12	Onsite	52387	123666	4	190	0
Test Data	id12	Onsite	52387	123666	5	190	0
Test Data	id12	Onsite	52387	123666	6	190	0
Test Data	id12	Onsite	52387	123666	7	190	0
Test Data	id12	Onsite	52387	123666	8	190	0
Test Data	id12	Onsite	52387	123666	9	190	0
Test Data	id12	Onsite	52387	123666	10	190	4
Test Data	id12	Onsite	52387	123666	11	190	5
Test Data	id12	Onsite	52387	123666	12	190	3
Test Data	id13	Onsite	52167	123777	1	180	2
Test Data	id13	Onsite	52167	123777	2	180	2
Test Data	id13	Onsite	52167	123777	3	180	3
Test Data	id13	Onsite	52167	123777	4	180	1
Test Data	id13	Onsite	52167	123777	5	180	0

Record: 1 of 132

Simply select the whole table, copy it to the clipboard and past it into a spreadsheet, where you can summarise and analyse it further.

It would take only a very simple query to summarise this data for the whole site, but in summarising, differences of elevation across the site will be obscured, which is probably not good for assessing what modifications to the topography might be needed to improve flooding and drainage. Moreover, if you are using QGIS GIS software to map the site, this detailed elevation data can be easily imported (via a spreadsheet) into the GIS to provide a spatial analysis of elevation across the site.

Using tidal records for a single year or an average for all years in the database

Tidal records supplied by Ganh Hao Tide Station are based on calendar dates, not lunar dates. Consequently, there is a phase shift in the tidal peaks from year to year. Furthermore, the heights of the tidal peaks vary from year to year. These two characteristics of the tidal data can lead to a difference in flooding frequency of up to 10 days per month between years for a particular site. Transcribing the tidal records from calendar dates to lunar dates is a difficult and tedious task. For this reason, it is probably best to use the default option 'Average all years in database', which should help to reduce (but not eliminate) errors associated with inter-year variability. However, an option is also provided that allows you to use tidal records for a single year if you wish. This can be run for different years, and is useful if you want to compare differences in estimated flooding frequency between years.

The use of the 'Average all years in database' option should provide an estimate of average flooding frequency to within 3-4 days per month, which is considered to be

adequate for site assessment.

Ultimately, the estimate of elevation and flooding frequency also depends on the reliability of the height of tidal peak on the day of measurement (see the earlier discussion in Section 2 of this annex).

3.3.2 Adding Tide Gauge Data

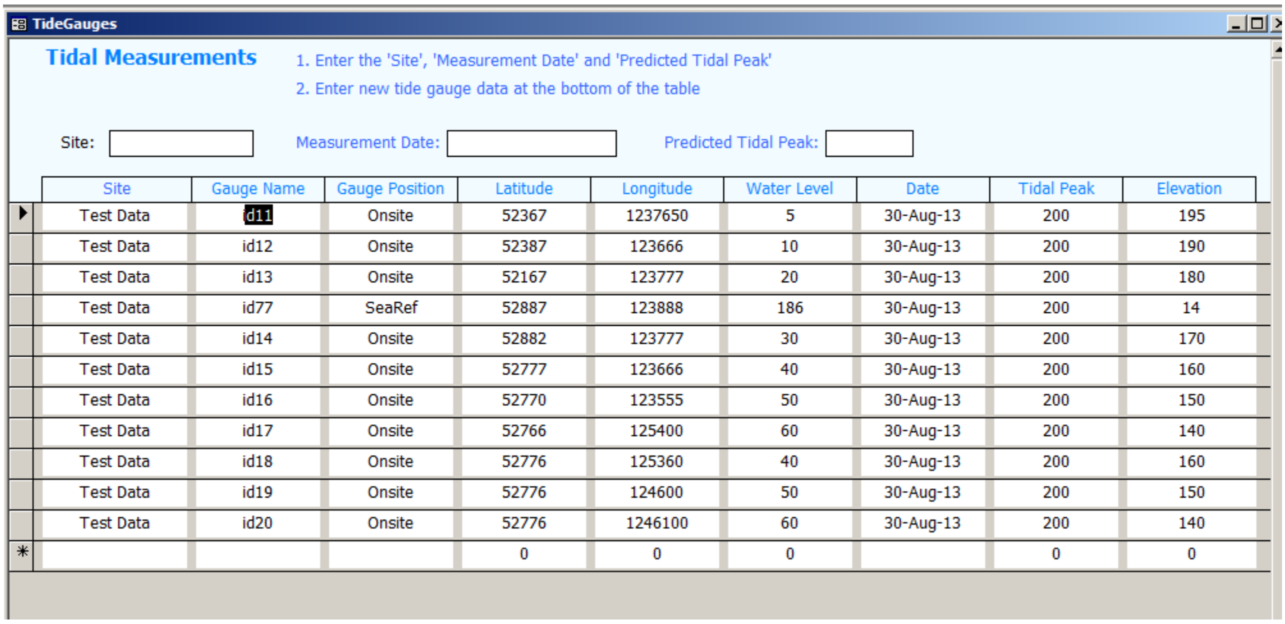
Tide gauge data are added to the database using the 'Tidal Measurements' form, which can be opened from the main form by clicking the appropriate button.

To enter new tide gauge data, follow the instructions on the form, shown in the illustration below.

In order to estimate the elevation and flooding frequency it is necessary to know the peak tidal height for the day of measurement. We have two choices for the height of the tidal peak:

- The predicted peak tidal height (before it actually occurs).
- The actual measured peak tidal height (after it occurs). [PREFERRED]

Both should be available from the Ganh Hao Tidal Station, The actual measured tidal peak is likely to give more reliable estimates of elevation and flooding frequency. This means you might have to wait a few days (or even weeks) before you enter the tide gauge data.


TideGauges

Tidal Measurements

1. Enter the 'Site', 'Measurement Date' and 'Predicted Tidal Peak'
2. Enter new tide gauge data at the bottom of the table

Site: Measurement Date: Predicted Tidal Peak:

Site	Gauge Name	Gauge Position	Latitude	Longitude	Water Level	Date	Tidal Peak	Elevation
Test Data	id11	Onsite	52367	1237650	5	30-Aug-13	200	195
Test Data	id12	Onsite	52387	123666	10	30-Aug-13	200	190
Test Data	id13	Onsite	52167	123777	20	30-Aug-13	200	180
Test Data	id77	SeaRef	52887	123888	186	30-Aug-13	200	14
Test Data	id14	Onsite	52882	123777	30	30-Aug-13	200	170
Test Data	id15	Onsite	52777	123666	40	30-Aug-13	200	160
Test Data	id16	Onsite	52770	123555	50	30-Aug-13	200	150
Test Data	id17	Onsite	52766	125400	60	30-Aug-13	200	140
Test Data	id18	Onsite	52776	125360	40	30-Aug-13	200	160
Test Data	id19	Onsite	52776	124600	50	30-Aug-13	200	150
Test Data	id20	Onsite	52776	1246100	60	30-Aug-13	200	140
			0	0	0		0	0

3.3.3 Adding New Tidal Records from Ganh Hao Tide Station

The database presently contains tidal records from Ganh Hao for the years 2010, 2011, 2012 and 2013, and tidal predictions for the years 2011, 2012, 2013 and 2014. Records for additional years can be added as they become available (typically after the end of each year).

Tidal records and predictions for Ganh Hao are usually made available as a Microsoft Excel spreadsheet. Microsoft Access 2000 (and presumably later versions) can import

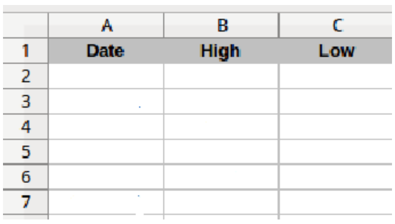
data from an Excel spreadsheet. Unfortunately, the spreadsheet format provided by Ganh Hao Tidal Station is not in a form that can be imported easily into MS Access, so you will have to do some cutting and pasting.

The following instructions for importing an Excel spreadsheet are based on Microsoft Access 2000 and Microsoft Excel 2000. Later versions of Microsoft Office (2003, 2010, 2013) probably use a similar procedure, but I do not have these later versions so I am unable to check that they work the same way.. **BE CAREFUL – SOMETIMES THE DATA ARE SUPPLIED IN A DIFFERENT FORMAT**. **ALWAYS BACK UP THE ORIGINAL EXCEL FILE AND TIDEBASEDATA.MDB BEFORE YOU DO ANYTHING ELSE, IN CASE SOMETHING GOES WRONG**.

3.3.3.1 Creating and Preparing a spreadsheet for import into MS Access

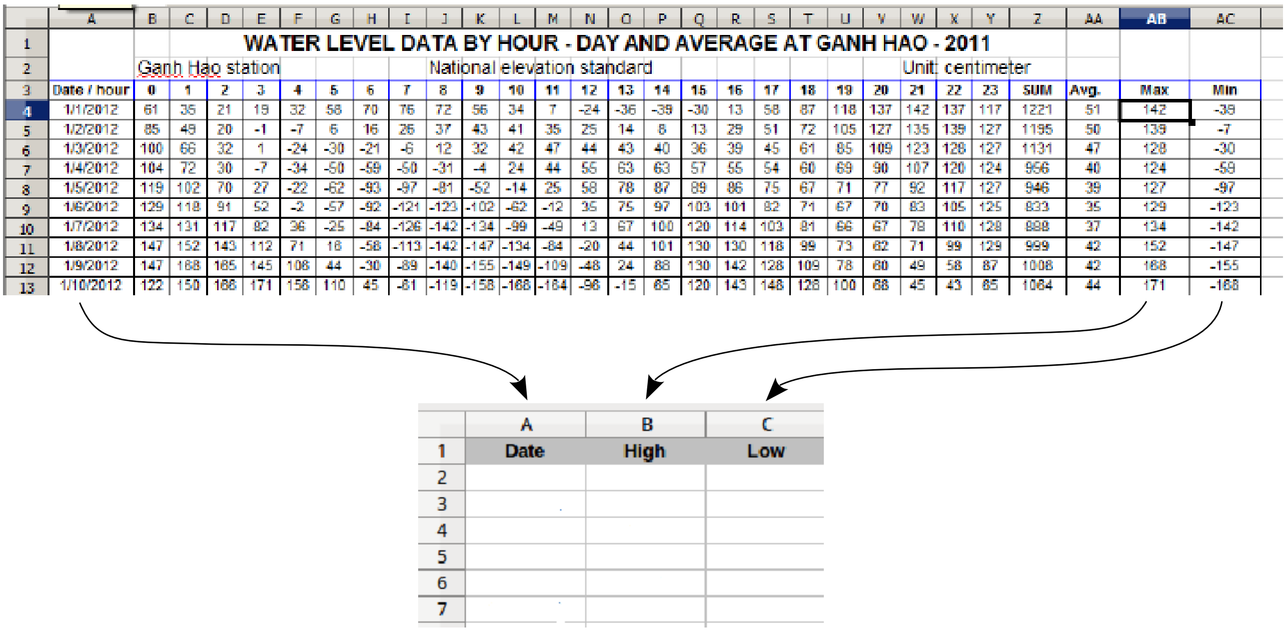
If the Excel spreadsheet is an *.xlsx file, you will have to convert it to an *.xls file. MS Access 2000 and MS Excel 2000 do not recognise *.xlsx files.

1. Create a new *.xls file and name it with the year of the data (in this example we will use tidal records from 2012, so the Excel spreadsheet will be named 2012.xls). You cannot import *.xlsx files into Access 2000 and I am not sure about later versions, so the safest is an *.xls file, which even later versions of MS Access should be able to handle.
2. Set the column headings of columns A to G in Sheet1 as shown below:



	A	B	C
1	Date	High	Low
2			
3			
4			
5			
6			
7			

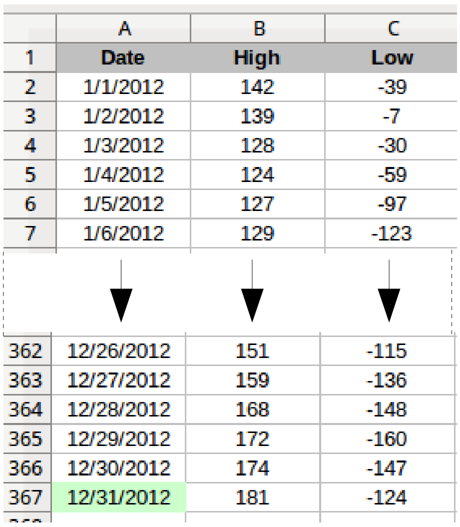
3. Open the source file supplied by the Ganh Hao Tide Station and the new file (in this example, 2012.xls) side by side.
4. Copy only the numeric data in the columns of the source file to the columns of in the new spreadsheet as illustrated below.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC
1			WATER LEVEL DATA BY HOUR - DAY AND AVERAGE AT GANH HAO - 2011																										
2		Ganh Hao station							National elevation standard													Unit: centimeter							
3	Date / hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	SUM	Avg.	Max	Min
4	1/1/2012	61	35	21	19	32	58	70	76	72	56	34	7	-24	-36	-39	-30	13	58	87	118	137	142	137	117	1221	51	142	-39
5	1/2/2012	85	49	20	-1	-7	6	16	26	37	43	41	35	25	14	8	13	29	51	72	105	127	135	139	127	1195	50	139	-7
6	1/3/2012	100	66	32	1	-24	-30	-21	-6	12	32	42	47	44	43	40	36	39	45	61	85	109	123	128	127	1131	47	128	-30
7	1/4/2012	104	72	30	-7	-34	-50	-59	-50	-31	-4	24	44	55	63	63	57	55	54	60	69	90	107	120	124	956	40	124	-59
8	1/5/2012	119	102	70	27	-22	-62	-93	-97	-81	-52	-14	25	58	78	87	89	86	75	67	71	77	92	117	127	946	39	127	-97
9	1/6/2012	129	118	91	52	-2	-57	-92	-121	-123	-102	-62	-12	35	75	97	103	101	82	71	67	70	83	105	125	833	35	129	-123
10	1/7/2012	134	131	117	82	36	-25	-84	-126	-142	-134	-99	-49	13	67	100	120	114	103	81	66	67	78	110	128	888	37	134	-142
11	1/8/2012	147	152	143	112	71	18	-58	-113	-142	-147	-134	-84	-20	44	101	130	130	118	99	73	62	71	99	129	999	42	152	-147
12	1/9/2012	147	168	165	145	108	44	-30	-89	-140	-155	-149	-109	-48	24	88	130	142	128	109	78	60	49	58	87	1008	42	168	-155
13	1/10/2012	122	150	166	171	158	110	45	-61	-119	-158	-168	-164	-96	-15	65	120	143	148	128	100	68	45	43	65	1064	44	171	-168

	A	B	C
1	Date	High	Low
2			
3			
4			
5			
6			
7			

5. The Max and Min columns in the source file are calculated values, so when you paste them into the new spreadsheet you will have to use Paste Special and select only numbers.
6. After pasting into the new spreadsheet you should have something like this:



	A	B	C
1	Date	High	Low
2	1/1/2012	142	-39
3	1/2/2012	139	-7
4	1/3/2012	128	-30
5	1/4/2012	124	-59
6	1/5/2012	127	-97
7	1/6/2012	129	-123
362	12/26/2012	151	-115
363	12/27/2012	159	-136
364	12/28/2012	168	-148
365	12/29/2012	172	-160
366	12/30/2012	174	-147
367	12/31/2012	181	-124

Make sure you save the new spreadsheet, and you have now finished preparing it for importing into MS Access (any version)

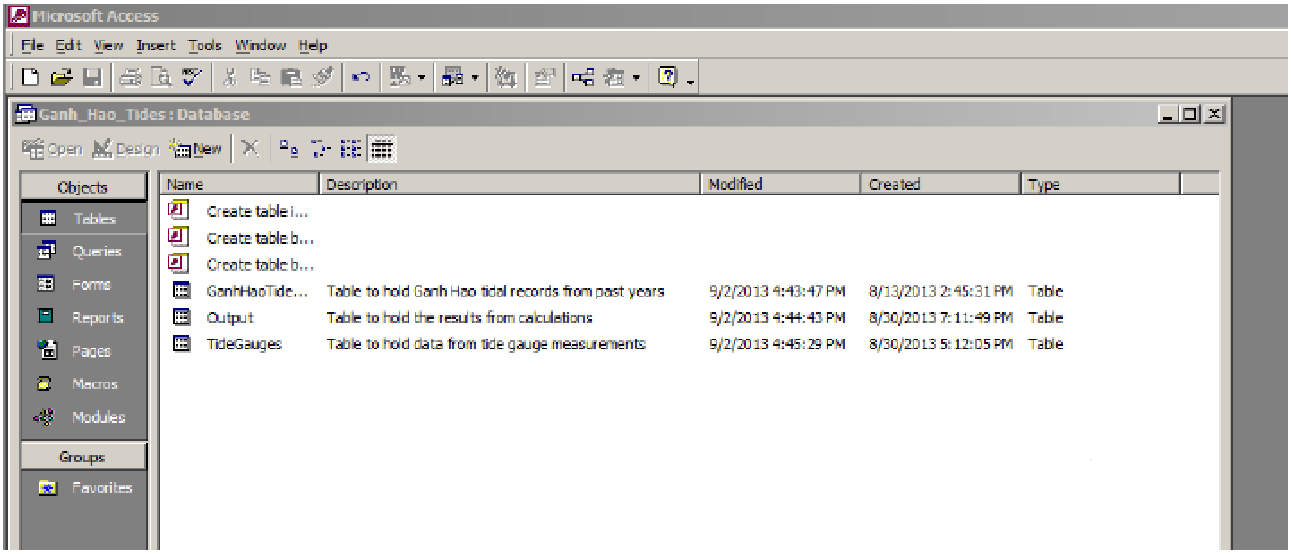
3.3.3.2 Importing the spreadsheet into MS Access 2000

Note: These instructions are for MS Access 2000. If you are using a later version, then you will have to figure out the steps for yourself – they may be the same, or they may be different. I recommend that you create a backup of either the TidalRecords table or the whole database before you carry out the steps below. Then you will be able to recover the database should anything go wrong with the import.

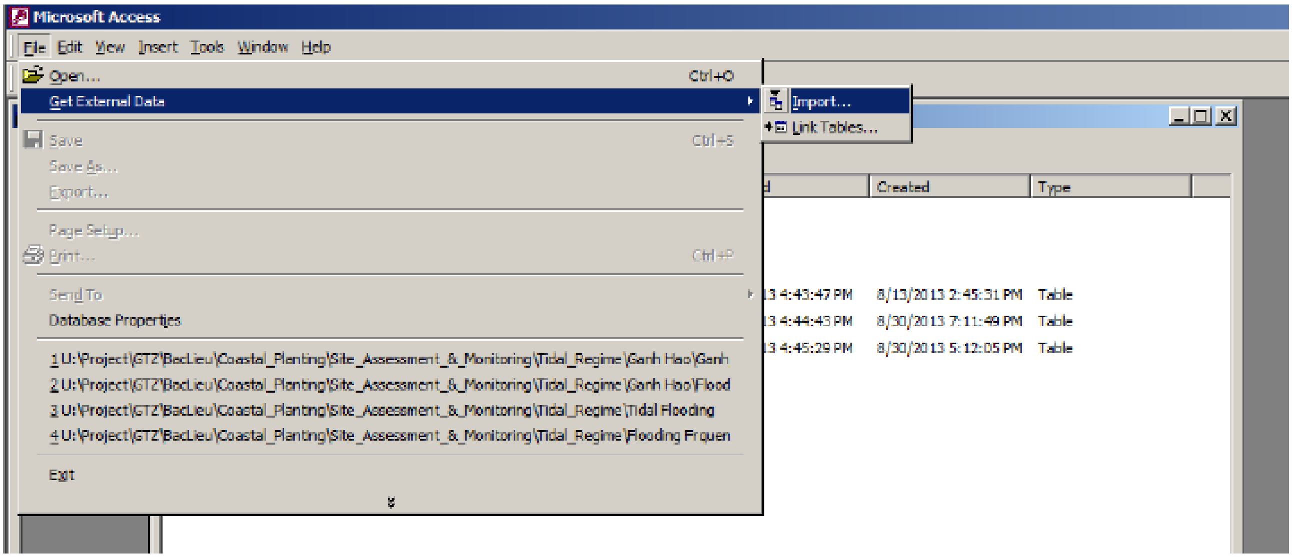
Basically we want to append the data in the Excel spreadsheet to the TidalRecords table,

and then run a query to update the remaining columns in the TidalRecords table. Unfortunately there is no simple way to automate this for all versions of MS Access, so you will have to do it manually.

1. Open the GanhHaoTidalRecords.mdb database. By default it will open and display a form ready for data processing, but we need to go into the basic design interface which shows tables, queries and forms. In some cases you can go to the design interface by holding down the Shift key as you open the database, but if this doesn't work then you need to close the form and, if necessary, re-open the database from the MS Access interface while holding down the Shift key. This is more or less what you should then see.

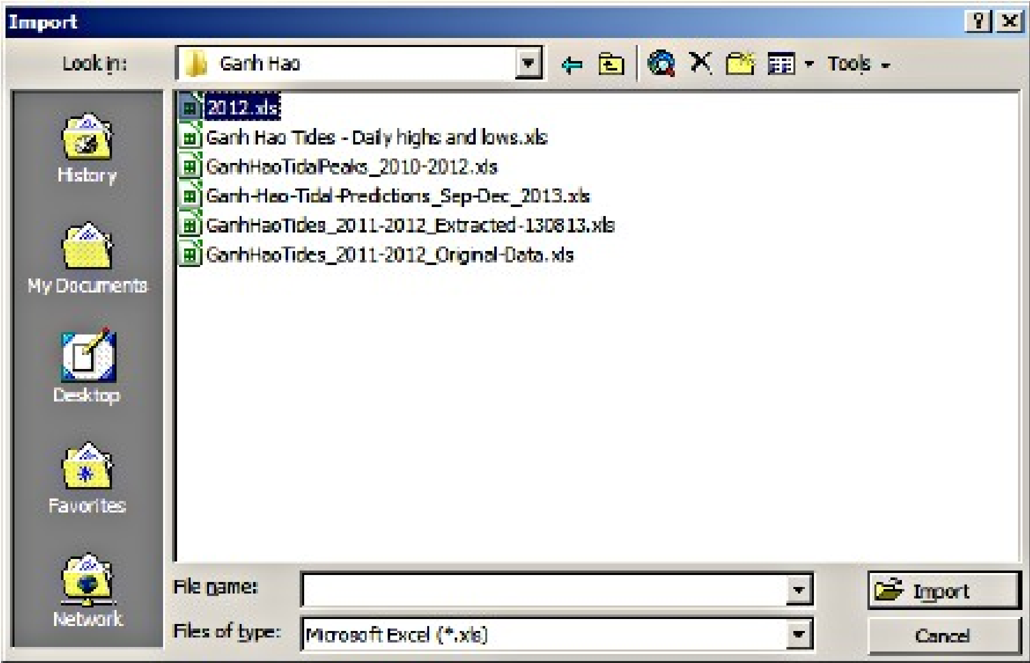


2. Go to File → Get External Data → Import in the menu at the top of the screen.

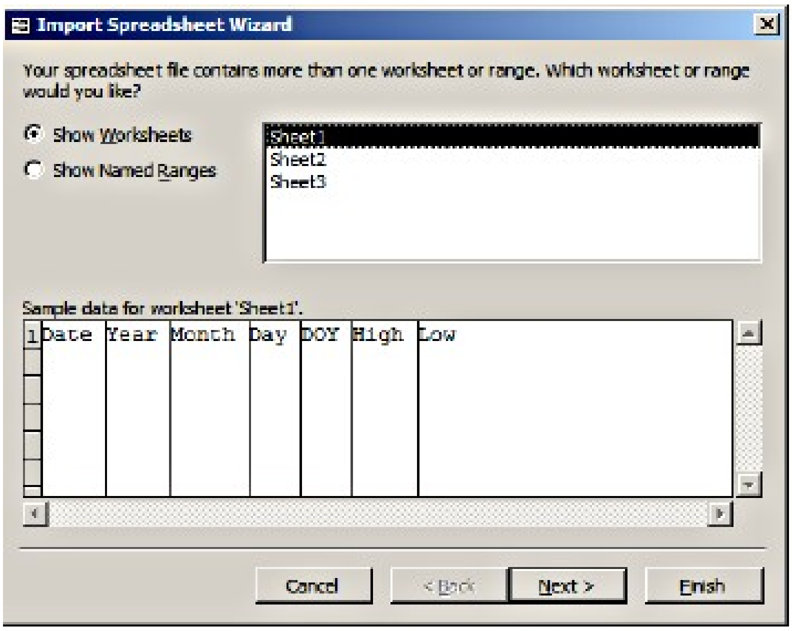


3. Select Microsoft Excel (*.xls) as the File type, then navigate to the xls file you want to import (in our example, 2012.xls), and finally

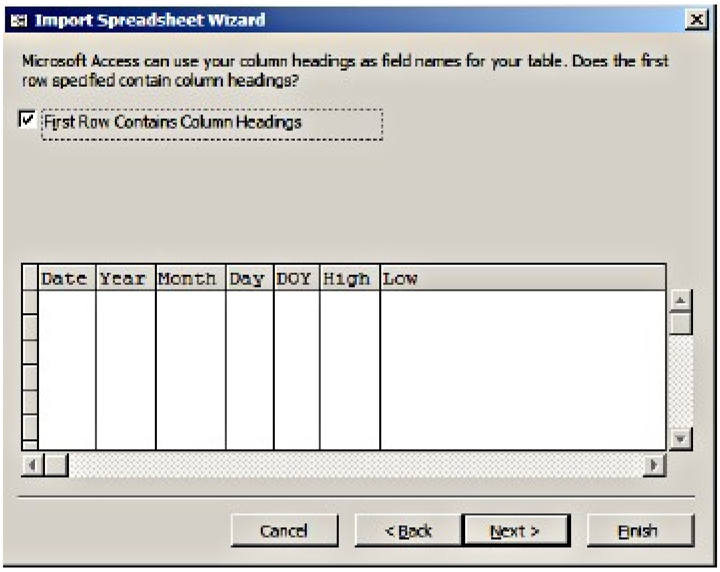
click Import.



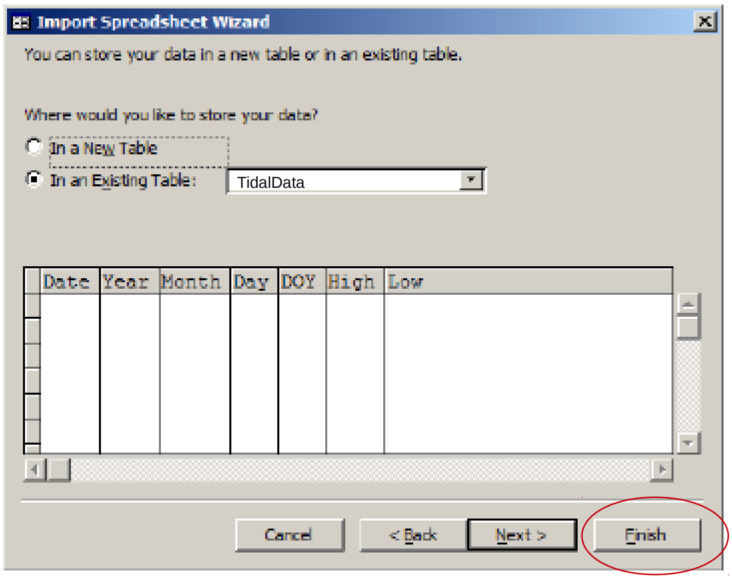
4. Select the sheet with the data you want to import.



5. Make sure First Row Contains Column Headings is checked, then click Next.



6. Select Import into an Exiisting Table, and select TidalData from the drop-down list, then click Finish.



MS Access will give you a message about whether the import was successful. If there was a problem with importing, the most likely cause is that one of the columns, or one or more items in a column of the spreadsheet were not formatted to the right data type. All of Column A in the import spreadsheet must be formatted as a Date, and all records in Columns B and C of the import spreadsheet must be formatted as numbers.

MS Access puts any record that cannot be imported successfully into a special table, usually named 'Import Errors'. You can examine this table to see which records were not imported and why they were not imported.

If the spreadsheet did not import successfully, then follow these steps:

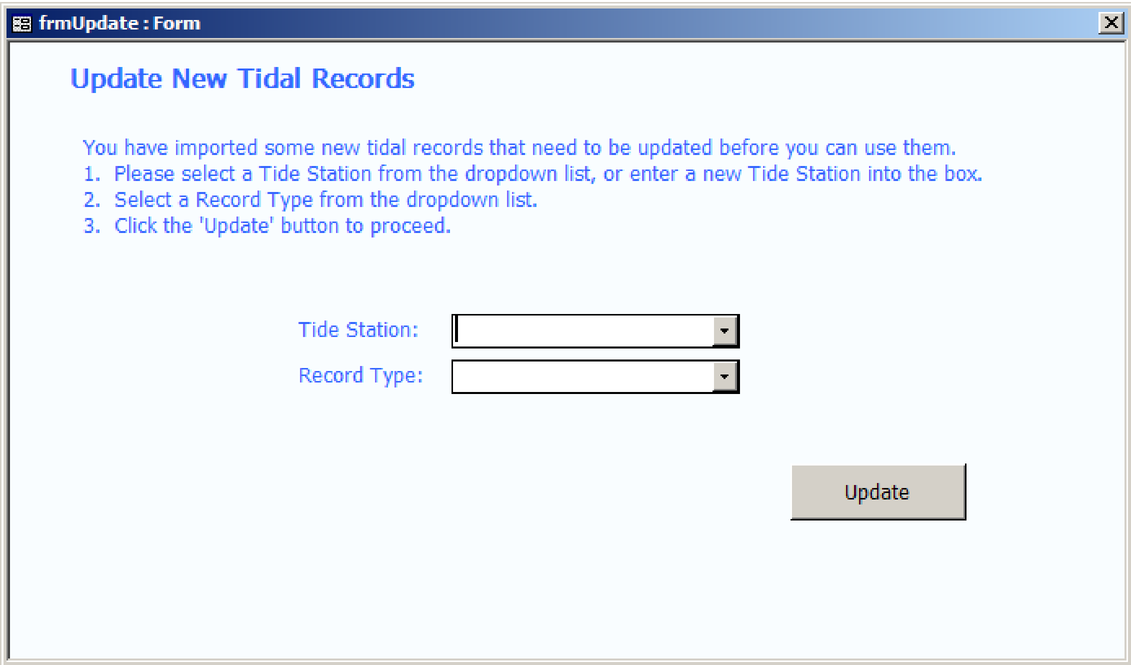
- Open the the TidalData table and delete all the newly added records. These will

be records that contain data only in the Date, High and Low columns; the other columns will be blank.

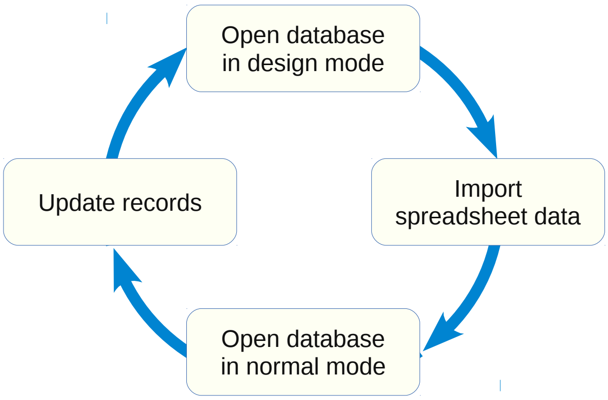
- Delete the 'Import Errors' table.
- Open the spreadsheet in Excel or another spreadsheet program, select the whole of Column A and format it as a Date, then select Columns B and C and format them as Numbers.
- Re-import the spreadsheet into the TidalData table as described in the steps above.

3.3.3.3 Updating the TidalData table

After importing a set of tidal records, the newly imported records in the TidalData table will only contain the three columns you imported from the spreadsheet (Date, High, Low). The other key fields in the table (Tidal Staion, Record Type, Year, Month and Day) will be blank. The next time you open the database in normal mode (i.e. To enter and process tide gauge data, or analyse flooding frequency), the program will check for any records with blanks in these key fields, and will display a form (shown below) prompting you to update the table. Simply enter the name of the Tide Station and the type of record into the two boxes on the form and click 'Update'. The Year, Month and Date fields in the TidalData table will be generated automatically from the Date column.



You can only import tidal data from **ONE** tide station at a time and, although data for more than one year for the <u>same</u> station can be imported as a single batch, it makes sense to limit importing tidal records to one full year at a time for any given tide station. The overall sequence for importing new tidal records is illustrated below.



A final recommendation – MAKE SURE YOU BACK UP THE TiIDALDATA TABLE OR THE WHOLE DATABASE BEFORE YOU IMPORT TIDAL RECORDS. Usually nothing goes wrong, but by backing up you know that you will always be able to return to the former version if something does go wrong. Repairing a corrupted database can be a difficult and painstaking task.

CAUTIONARY NOTE

The two nearest tide stations to Bac Lieu appear to be Cua Batak (9°28.00 N, 106°13.00 E, coordinates from http://www.chronglobal.com/station-list/?regions=12&countries=332) and Ganh Hao (9°1'53.2 N, 105°25'10.2 E, coodinates provided by Ganh Hao tidestation). Unfortunately, the Cua Batak station is located at the mouth of the Hau River, and the Ganh Hao station is located well inside the mouth of the Ganh Hao River. The timing and heights of tides at both stations are likely to be influenced by river flows, especially on a seasonal basis, and tides at both stations are expected to differ significantly from those along more exposed sections of the Bac Lieu or Soc Trang coastlines away from river mouths. Presently, there is no simple way to independently verify the accuracy of estimates of flooding frequency based on tidal records in TideBase.